Millennial and Centennial-Scale Hydrological Change in the Central Interior of BC, Canada: A Multi-Proxy Reconstruction of Holocene Climate From Felker Lake

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Introduction

Paleoclimate records from the North Atlantic region suggest that the abrupt climate changes that characterized the last deglaciation have persisted into the Holocene Epoch as lower amplitude and less severe events (e.g., the ~1500-year Bond Cycle; Bond et al. 2001). Recent paleoecological evidence raises the possibility that Holocene millennial-to-centennial scale climate cycles observed in the North Atlantic are also pervasive in North America where they are manifested as hydrological changes (Springer et al. 2008). For example, the ca. 1,470 ± 500-year Bond Cycle of ice drift in the North Atlantic is recognized as changes in stable isotopes and strontium in a 7000-year stalagmite record from West Virginia (Springer et al. 2008), and may be a harmonic of the ca. 2440-year drought cycle recognized at Big Lake, central British Columbia (BC; Cumming et al. 2002). Centennial-scale cycles, such as the ca. 400 to 650-year quasi-cycle of sea-ice formation and storminess along the shelf of the Barents Sea (Sarnthein et al. 2003) is similar to the ca. 400-year cycle of aridity and windiness documented in the Great Plains of North America (Dean 1997; Yu and Ito 1996).

Low-frequency climate dynamics cannot be recognized in the relatively brief instrumental dataset and therefore, proxies of climate change must be used to reconstruct past environmental change. Diatoms are particularly useful indicators of past hydrological conditions because they are sensitive to the concentration or dilution of dissolved salts that are controlled by effective moisture (the balance between precipitation and evaporation) in lakes in arid or semi-arid regions, such as the central interior of BC (Fritz et al. 1991). This study presents a post-glacial history of hydrological change inferred from diatom and pollen preserved in a ~11.6 m sedimentary record recovered from Felker Lake, located in the Upper Chimney Creek Basin of the central interior of BC, Canada (Figure 1). Felker Lake is a relatively closed basin (<5% total water budget) that receives low annual runoff (~32 mm), so water availability is expected to have a large influence on the hydrological budget of the lake (Hart 2000). Felker Lake was targeted for

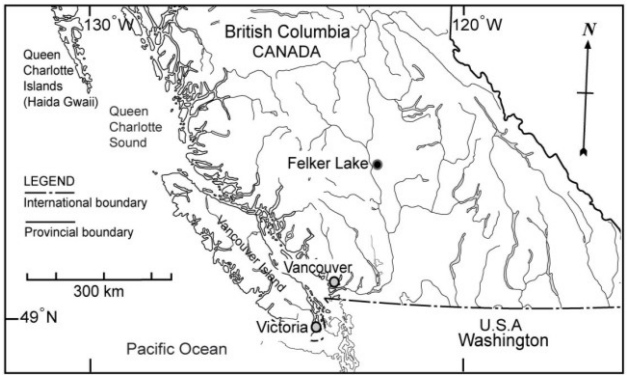

Figure 1: Map of BC showing the location of Felker Lake

detailed study because a recent decrease in water quality associated with increased human activity in the Upper Chimney Creek Basin led the Chimney Felker Water Quality Committee and the BC Ministry of the Environment to suggest that a historical perspective of water quality and quantity for Felker Lake was necessary to develop recommendations for future land-use.

Methods

Quantitative diatom-based inferences of post-glacial lake level and salinity at Felker Lake are based on weighted-averaging regression using a calibration data set of 219 lakes in British Columbia and the northern Great Plains (Wilson et al. 1996) and an age depth model generated by linear interpolation of four AMS radiocarbon dates and two volcanic tephras. Inferences of past terrestrial climate change are based on the relative abundance and pollen accumulation rates (PARs) of 14 pollen types.

Results and Discussion

Diatom-based inferences of past hydrological change at Felker Lake show that millennial-scale pacing of water availability occurred during the past ca. 11,300 cal. years with changes in lake level and salinity centered at ca. 7800 cal. yr BP, ca. 6850 cal. yr BP, ca. 5750 cal. yr BP, and ca. 2550 cal. yr BP. After ca. 2550 cal. yr BP centennial-scale change in lake depth and salinity and terrestrial vegetation is inferred (Figure 2). Early postglacial diatom assemblages are dominated by Fragilaroid taxa, suggesting that cool and moist climate conditions and relatively high lake levels prevailed at this time. Early Holocene warming near ca. 7800 cal. yr BP reduced lake depth in Felker Lake and promoted *Cylotella bodanica* var. *lemanica*, a fall bloomer competitive in limnological conditions associated with warm air temperatures. Warmer early Holocene temperatures were experienced on at least a hemispherical scale, indicated for example, by prolonged periods of aridity in the northern Great Plains and a increase in subpolar

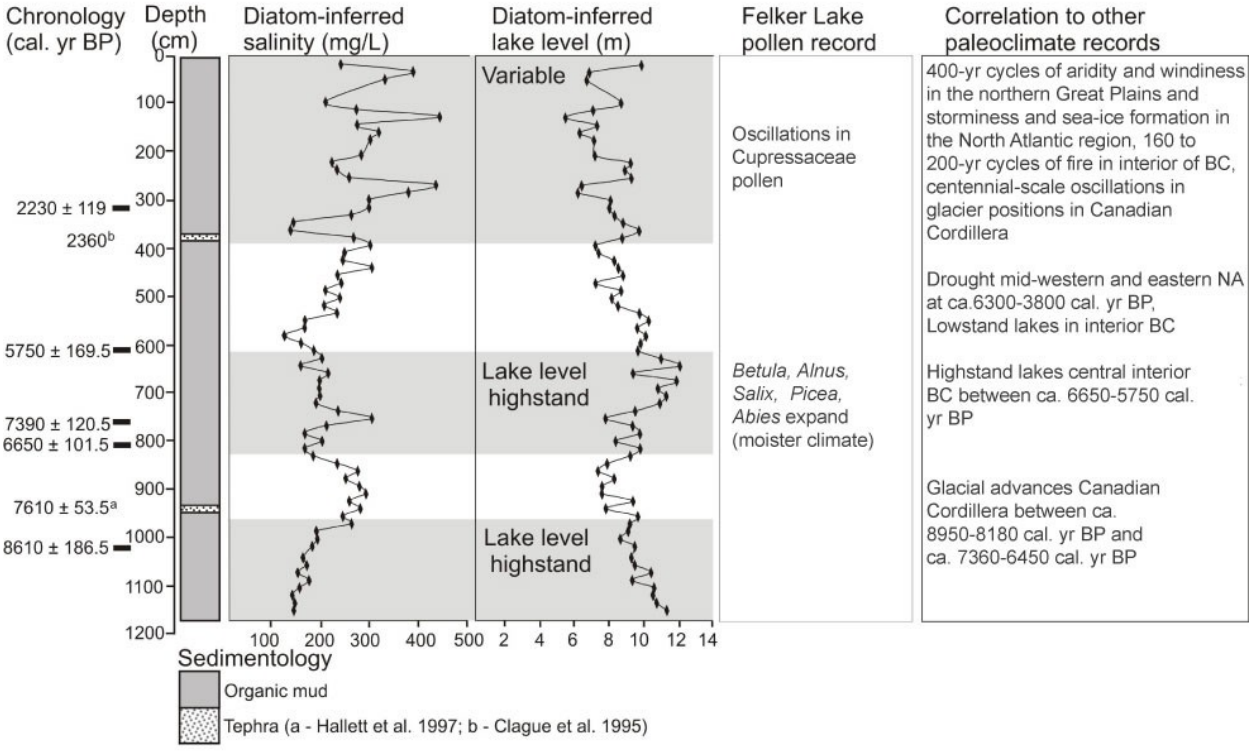

Figure 2: Summary of paleoclimate interpretations from Felker Lake and comparison to other records. Chronology is based on calibration of AMS radiocarbon dates using CALIB6.0 and the IntCa09 dataset (± 2 sigma; Stuiver and Reimer 1993; Reimer et al. 2009) and two volcanic tephras identified as Mazama (Hallett et al. 1997) and Bridge River (Clague et al. 1995). The age at 777 cm (7390 cal. yr BP, bulk sediment sample) was excluded from the age-depth model

North Atlantic sea surface temperatures (Dean et al. 1996; Anderson et al. 2004). Short lived peaks of *Stephanodiscus parvus/minutulus* between ca. 6800 cal. yr BP and ca. 5900 cal. yr BP indicate periodic increases in nutrient availability in Felker Lake likely associated with long cool and windy springs that promoted and prolonged seasonal in-lake turbulence. Increases in PARs of *Betula, Salix, Alnus, Picea*, and *Abies* suggest that these taxa expanded at this time in response to higher moisture, also evident by the record highstand at inferred at Felker Lake at ca. 5900 cal. yr BP. Glacial advances in the Canadian Cordillera between ca. 7360 cal. yr BP and ca. 6450 cal. yr BP provide further evidence for a regional cool and moist climate in western Canada at this time (Menounos et al. 2009). Diatom-inferred lake depth decreases after ca. 5750 cal. yr BP, suggesting a return to lower effective moisture. Mid-Holocene drought appears to have been pervasive in mid-western and eastern North America, possibly influenced by a period of weak solar activity that affected the strength and position of westerly winds and the jet stream (Dean et al. 1996; Springer et al. 2008).

High amplitude centennial-scale fluctuations in diatom-inferred lake depth and salinity occurred after ca. 2550 cal. yr BP at Felker Lake. Three diatom-inferred low lake level and high salinity events are reconstructed for Felker Lake at ca. 1925-1825 cal. yr BP, ca. 1350-700 cal. yr BP, and ca. 250-125 cal. yr BP. The ca. 1350- 700 cal. yr BP diatom-inferred lowstand event is the most extreme episode at Felker Lake in the past ca. 11,300 years and overlaps temporally with the Medieval Warm Period (ca. 1000-600 cal. yr BP). High amplitude late Holocene fluctuations in Cupressaceae pollen relative abundance and PARs at Felker Lake probably reflect oscillations in terrestrial moisture availability. Late Holocene centennial-scale oscillations in effective moisture are also documented at nearby Mahoney Lake (Lowe et al. 1997) when, similar to Felker Lake, the greatest variation in lake salinity occurred relative to any other time in the post-glacial history of the lake (Heinrichs et al. 1997). Similarly, centennial-scale changes in effective moisture are also a feature of late Holocene climate in the northern Great Plains where they appear to be linked to variations in solar irradiance (Yu and Ito 1999). Changes in solar irradiance may affect North American climate through modulation of the relative position and intensity of atmospheric pressure cells, such as the Aleutian Low pressure system (AL), that can in turn influence the location of the jet stream and moisture bearing westerly winds and storms across the continent (Christoforou and Hameed 1997). During periods of solar maxima, the centre of action of the AL is displaced westward, which could result in a more seasonally persistent North Pacific high-pressure system that would generate dry and warm summer weather in the central interior of BC (Christoforou and Hameed 1997). Indeed, more rapid and frequent shifts in the AL are inferred to have occurred after ca. 1200 cal. yr BP relative to the past 7500 cal. years (Anderson et al. 2005). Dynamics in the position and intensity of this air mass, that can be linked to variations in solar irradiance, may therefore be an important control of moisture availability in the central interior of BC.

Conclusions

In summary, post-glacial hydrological change at Felker Lake is coherent with regional, hemispherical, and global paleoclimate events, suggesting that millennial and centennial-scale shifts in water availability are a persistent feature of western North American climate.

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