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Little Ice Age recorded in summer temperature reconstruction from varved sediments of Donard Lake, Baffin Island, Canada

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Abstract

Clastic varved sediments from Donard Lake, in the Cape Dyer region of Baffin Island, provide a 1250 yr record of decadal-to-centennial scale climate variability. Donard Lake experiences strong seasonal fluctuations in runoff and sediment fluxes due to the summer melting of the Caribou Glacier, which presently dominates its catchment. The seasonal variation in sediment supply results in the annual deposition of laminae couplets. A radiocarbon date measured on moss fragments, with a calibrated age of 860 ± 80 yrs before present (BP), is in close agreement with the age based on paired-layer counts. Together with the fabric of the laminae determined from microscope analysis, the age agreement demonstrates that the laminae couplets are annually deposited varves. Comparisons of varve thickness and average summer temperature from nearby Cape Dyer show a significant positive correlation (r = 0.57 for annual records, r = 0.82 for 3-yr averages), indicating that varve thickness reflects changes in average summer temperature. Varve thickness was used to reconstruct average summer temperatures for the past 1250 yrs, and shows abrupt shifts and large amplitude decadal-to-centennial scale variability throughout the record. The most prominent feature of the record is a period of elevated summer temperatures from 1200–1375 AD, followed by cooler conditions from 1375–1820 AD, coincident with the Little Ice Age.

Introduction

Previous research has shown that Baffin Island, in the eastern Canadian Arctic, is sensitive to climatic fluctuations on regional-to-hemispheric scales (Andrews et al. 1972; Bradley & Miller, 1972; Barry et al., 1977). The location of Baffin Island beneath a major trough in the northern hemisphere upper Westerlies contributes to local climatic sensitivity to global-scale changes in atmospheric circulation (Keen, 1980). Warming or cooling causes shifts in the hemispheric temperature gradient and the east-west position of the trough, directly affecting surface winds and the advection of southerly vs. northerly air masses over the Baffin Island region (Brinkman & Barry, 1972; Keen, 1980). Bradley & Miller (1972) showed that the mass balance of alpine glaciers and perennial snowbanks on Baffin Island responds rapidly to abrupt changes in climate. Varved glacial lakes associated with alpine glaciers are ideal places to investigate high-resolution climate change in the eastern Canadian Arctic.

Climate change takes place on a variety of time scales, but perhaps the least understood of these is the decadal-to-centennial scale (Overpeck, 1991). It is important to gain an understanding of the patterns of natural variability on this time scale in order to measure the human impact on the Earth's climate system, as well as to successfully predict climatic changes in the future.

Most instrumental records are too short for the study of decade-to-century scale climate variability, particularly in the Arctic (Bradley, 1973). Obtaining high-resolution paleoclimate records is therefore necessary to study the record of these rapid fluctuations. Annually laminated (varved) lake sediments record seasonal changes in sediment deposition and are capable of preserving a history of abrupt climatic changes (Overpeck, 1996). Lakes containing varved sediments exist throughout the Arctic, and provide an important paleoclimatic proxy in regions north of treeline (Bradley et al., 1996; Overpeck et al., 1997). Varved records may provide a broad network of sites with which to decipher temporal and spatial patterns of climate change. Here we present a new paleotemperature record from varved sediments of Donard Lake, a glacierized meltwater-dominated lake on Baffin Island in the eastern Canadian Arctic. Calibration of the varve thickness record using instrumental temperature data allowed the reconstruction of average summer temperature variability for the past 1250 yrs.

Background

Cape Dyer, on Cumberland Peninsula, is the easternmost point on Baffin Island (Figure 1). Sharp glacially carved peaks (maximum elevation of 1800 m) dominate the landscape from the Penny Ice Cap, which covers most of Cumberland Peninsula, eastward to Cape Dyer. The combination of rugged topography and a network of deep, fault-controlled valleys may have helped to isolate Cape Dyer from all but local ice for much of its recent Quaternary history (Miller, 1973; Miller & Dyke, 1974; Hawkins, 1980; Dyke et al., 1982; Locke, 1987). Most of the bedrock in the field area consists of Precambrian gneiss, granite, and quartz monzonite (Clarke & Upton, 1971). Carbonate bedrock is entirely absent from eastern Cumberland Peninsula. Donard Lake, a small glacially fed lake at an elevation of approximately 450 m, lies 19 km west of the Distant Early Warning (DEW) Line site at Cape Dyer and 2 km north of Sunneshine Fjord (Figure 2). Donard Lake is 0.9 km long, 0.4 km wide, and 22 m deep at its deepest point (Figure 3), and is surrounded on its elongate sides by steep walls that rise to elevations in excess of 1000 m. The lake completely freezes over beginning in October, with ice usually melting in June. During cold summers, an ice pan surrounded by an ice-free moat will persist throughout the summer.

A bedrock saddle separates the Donard Lake basin from an adjacent, deeply excavated glacial valley

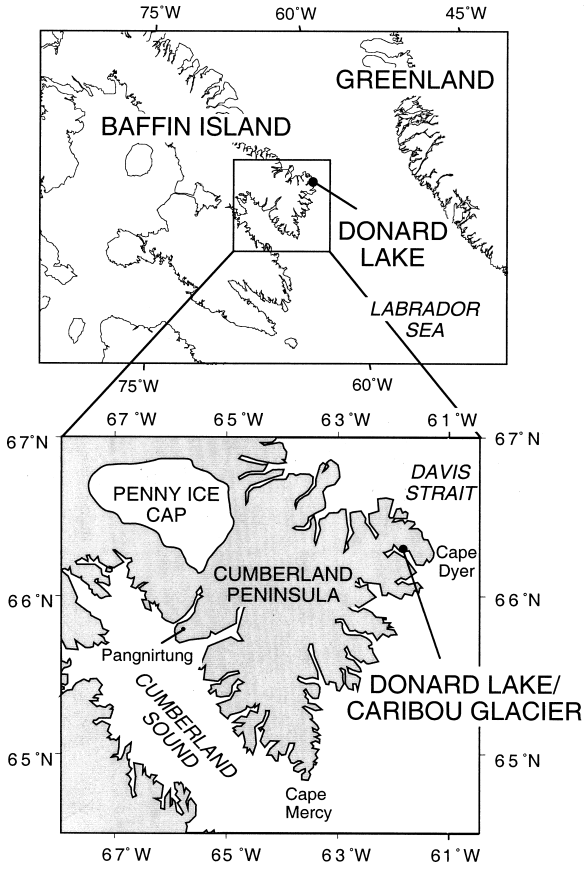

Figure 1. Location of Donard Lake and the Caribou Glacier system on eastern Cumberland Peninsula, Baffin Island.

containing the Caribou Glacier (Figure 2). The Caribou Glacier is approximately 7.5 km long and 1 km wide at its widest point, and originates from icefields in the mountains 6 km north of Donard Lake. As the glacier leaves these headlands it flows south-southwest past Donard Lake, terminating 1 km north of Sunneshine Fjord. A small sub-lobe of the glacier currently extends over the bedrock saddle and terminates 0.75 km from the west end of Donard Lake (Figure 2). The Neoglacial end moraine for the Caribou Glacier in the Donard Lake drainage lies approximately 0.25 km from the lake. Caribou Glacier input into Donard Lake operates around a threshold ice volume. When the Caribou Glacier possesses enough ice to crest the lip of the bedrock saddle, the drainage along the southern margin of the glacier is diverted from the Caribou valley and flows into Donard Lake. During these periods the drainage basin reaches a maximum of 7.8 km^2 and delivery of glacial sediment facilitates the formation and preservation of organic-poor clastic laminae. When the volume of ice