Long-term water balance variability in Lake A, northern Ellesmere Island

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Introduction: With increasing concern about changing environmental conditions in the Canadian Arctic, understanding the past variability in arctic processes is needed in order to place recent changes into context and identify possible future scenarios. Variability in water resources are an important issue as little is known about long term changes. Given that changing climate conditions in the High Arctic are leading to events such as the fracture of the largest remaining arctic ice shelf (Ward Hunt Ice Shelf; Mueller et al., 2003), it is likely that surface waters are changing as well. High-resolution proxy records of hydrological processes are potentially available from arctic lake sediment records, allowing for a detailed examination of changes in sediment and, thus, water input to lakes to establish likely forcing factors and the range of natural variability.

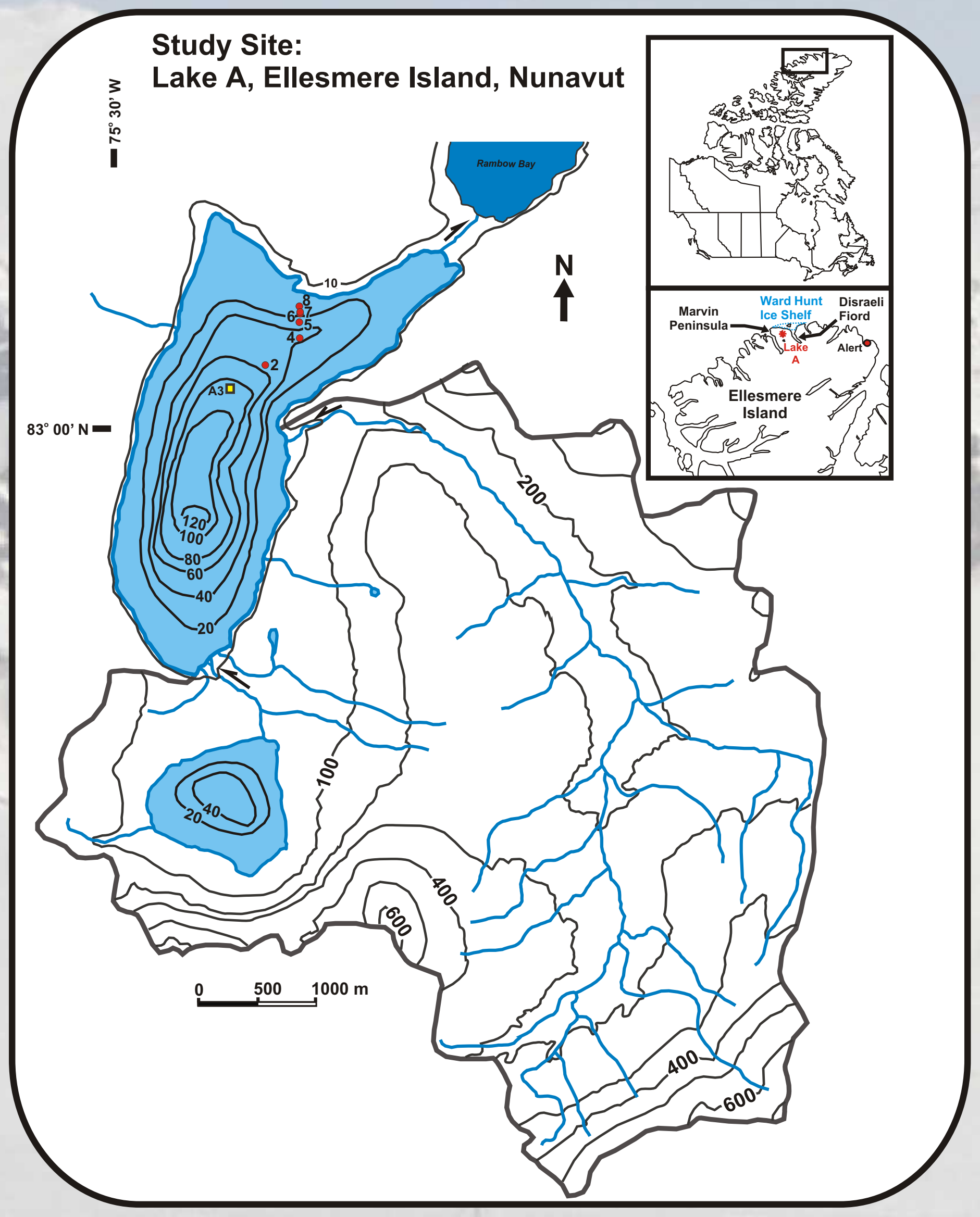

Figure 1: Lake A catchment and bathymetric map, including coring sites from 1993 (yellow square) and 2005 (red dots). All measures are in metres.

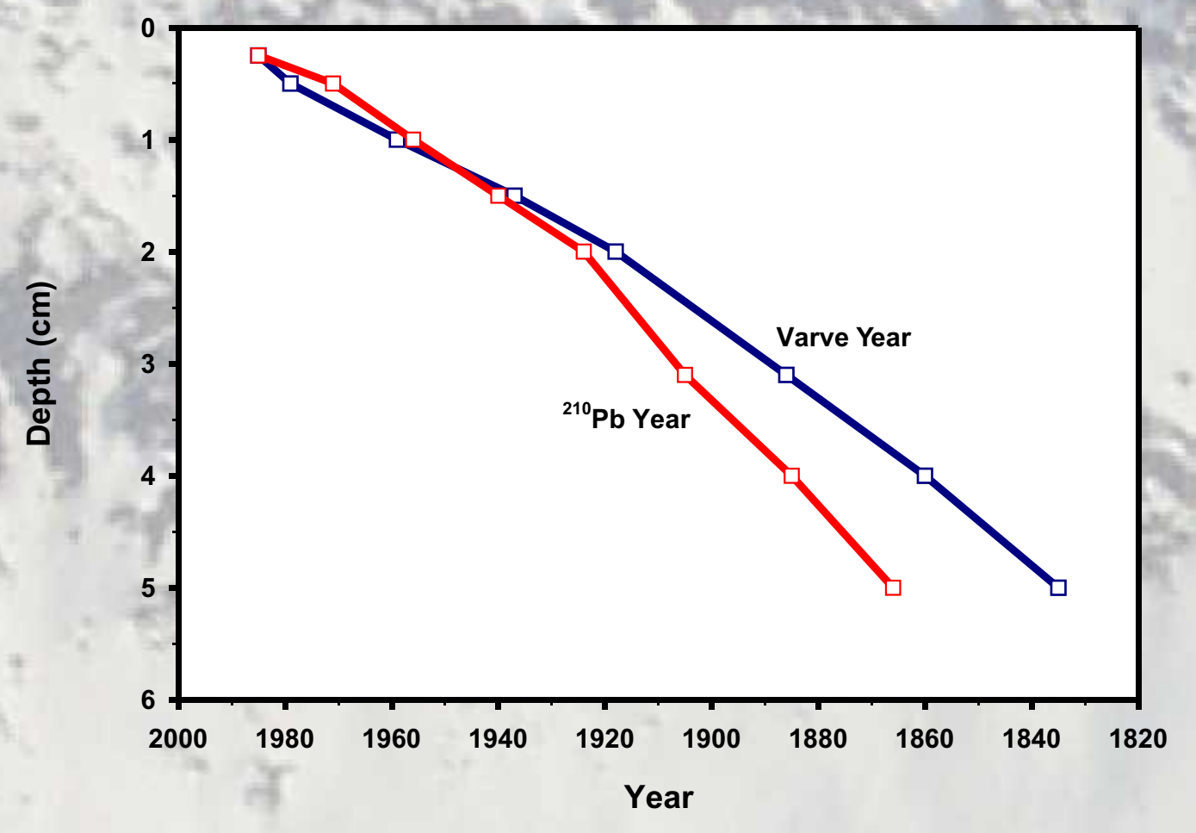

Figure 2: Age-depth curve demonstrating similarity between dates estimated using ^{210}Pb levels from the upper 7 cm of Core A3 (obtained in 1993) and dates determined through varve counting on Core 2 (obtained in 2005).

Preliminary results: Based on a ^{137}Cs profile (developed in 2005) and a ^{210}Pb profile (developed in 1993), the sedimentary record of Lake A appears to be annually-laminated (varved)(Figure 2). A high-resolution analysis of thin sections (Figure 3) was possible, allowing for an annual chronology of sedimentation to be developed. In the two surface cores analysed from water depths below 43 m (Cores 2 and 4), varves were present throughout the sedimentary record. However, shallower cores (5, 6, 7 and 8) clearly demonstrated massive sedimentation at depth (Figure 4).

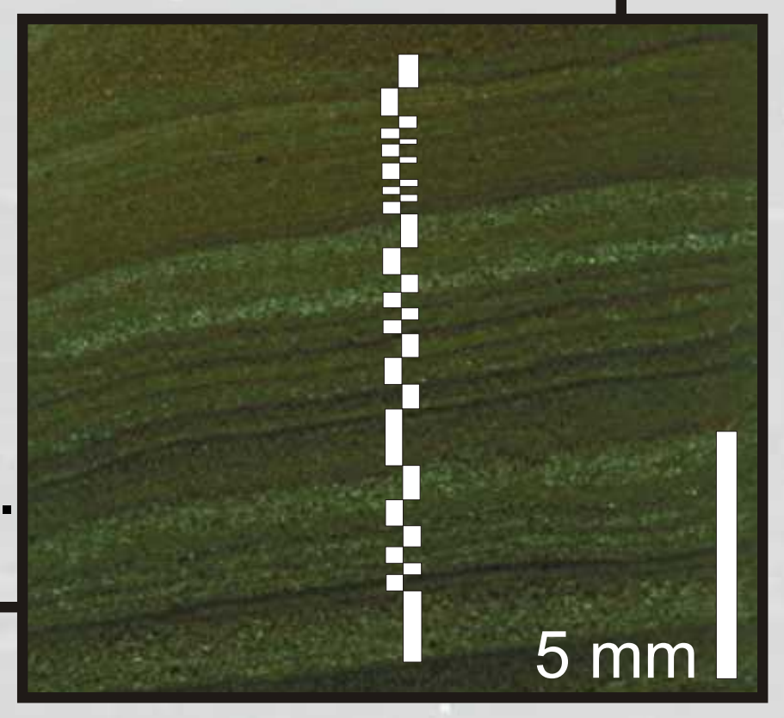

Figure 3: Lake A varves (white boxes) from 10 to 11.5 cm depth in Core 2 (Figure 1).

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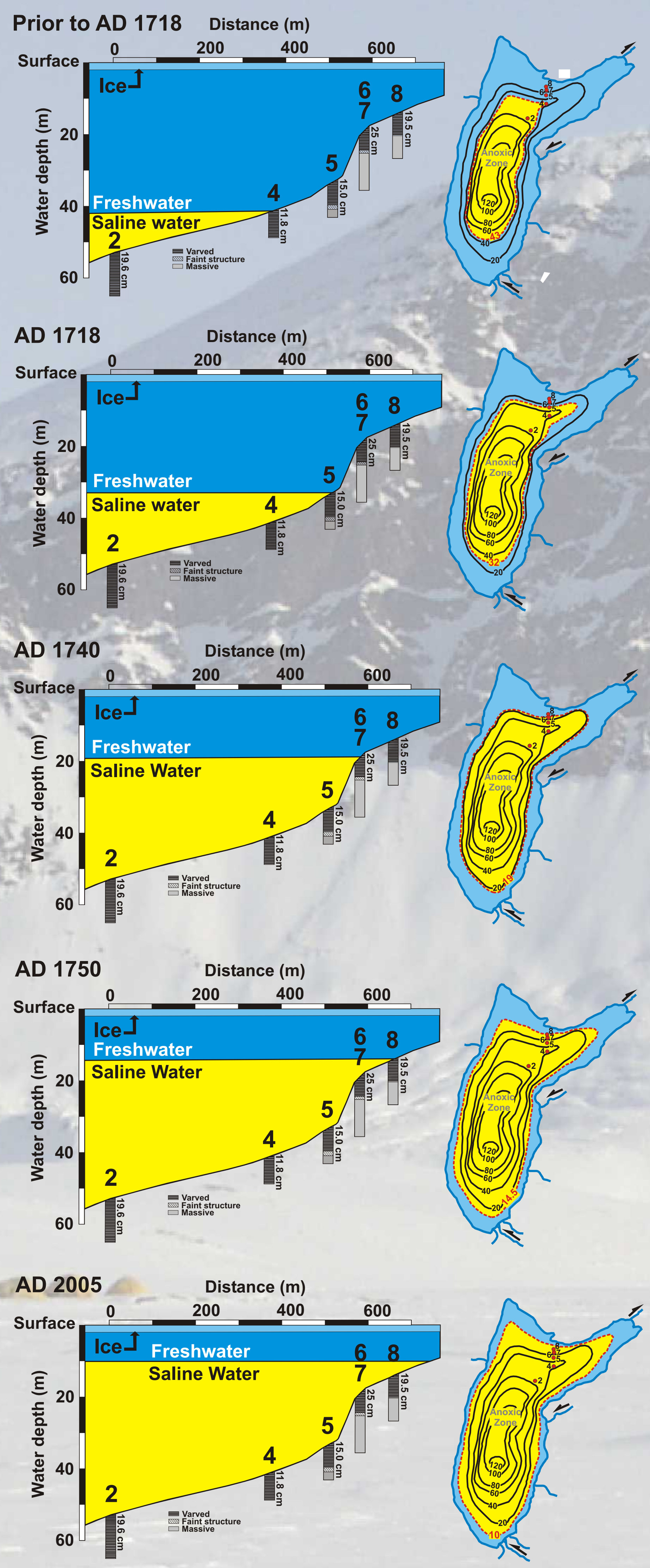
Figure 5: Water column profile and aerial view schematics of the rising of the oxycline of chemically-stratified (meromictic) Lake A from AD 1718 to 2005. As Cores 6 and 7 were from the same location, their depth and length values were averaged.



Contribution to the Theme 2 Integrated Regional Impact Study (IRIS): The future of arctic water resources is uncertain, with projected changes to permafrost stability and runoff and substantial precipitation increases, especially in coastal areas (ACIA, 2005). These conditions could influence arctic water resources in a different but similarly dramatic way as Lake A's inflow was likely influenced by climate conditions during the 1700s. Further analysis of the Lake A sedimentary record will determine the processes that caused the anoxic zone of the lake to rise, while also identifying hydrological changes in the lake during periods of high and low runoff. This analysis will indicate whether the inferred change in oxycline depth was a unique event in the history of the lake.

This research contributes to the Theme 2 IRIS by investigating the variability of fresh water input over time in nival stream environments. Understanding the causes of this variability and the response of river and lake systems to different environmental conditions over time will benefit current understanding of how these systems may respond to future climate conditions and, thus, their potential influences on local to regional water resources.

Discussion: Lake A is a chemically-stratified (meromictic) lake whose water column contains a transitional zone (oxycline) between overlying aerobic freshwater and underlying anoxic saline water. As we hypothesize that anoxia aids in the preservation of varves through the stabilization of the water column, the presence or absence of varves within a sedimentary record can be an indicator of the depth of the anoxic zone. This study suggests that the aerobic zone of Lake A was much deeper than at present prior to the early 1700s but rapidly became shallower between AD 1718 and 1750.

As the oxycline rose, varve sedimentation migrated to shallower areas of the lake (Figure 5). We infer this to have resulted from a substantial change to the freshwater/saline water balance of Lake A, likely due to a period of decreased snowmelt and runoff to the lake. The resulting thinner freshwater layer, in turn, may have caused the oxycline to rise through salt diffusion.

A period of below-average temperatures in the eastern Canadian Arctic (Overpeck et al., 1997) occurred during the early 1700s, possibly contributing to reduced runoff to this snowmelt-dominated system. The presence of continuous varves after AD 1750 in cores from all water depths studied suggests that the oxycline has remained near is current depth (10 to 13 m) since this time.

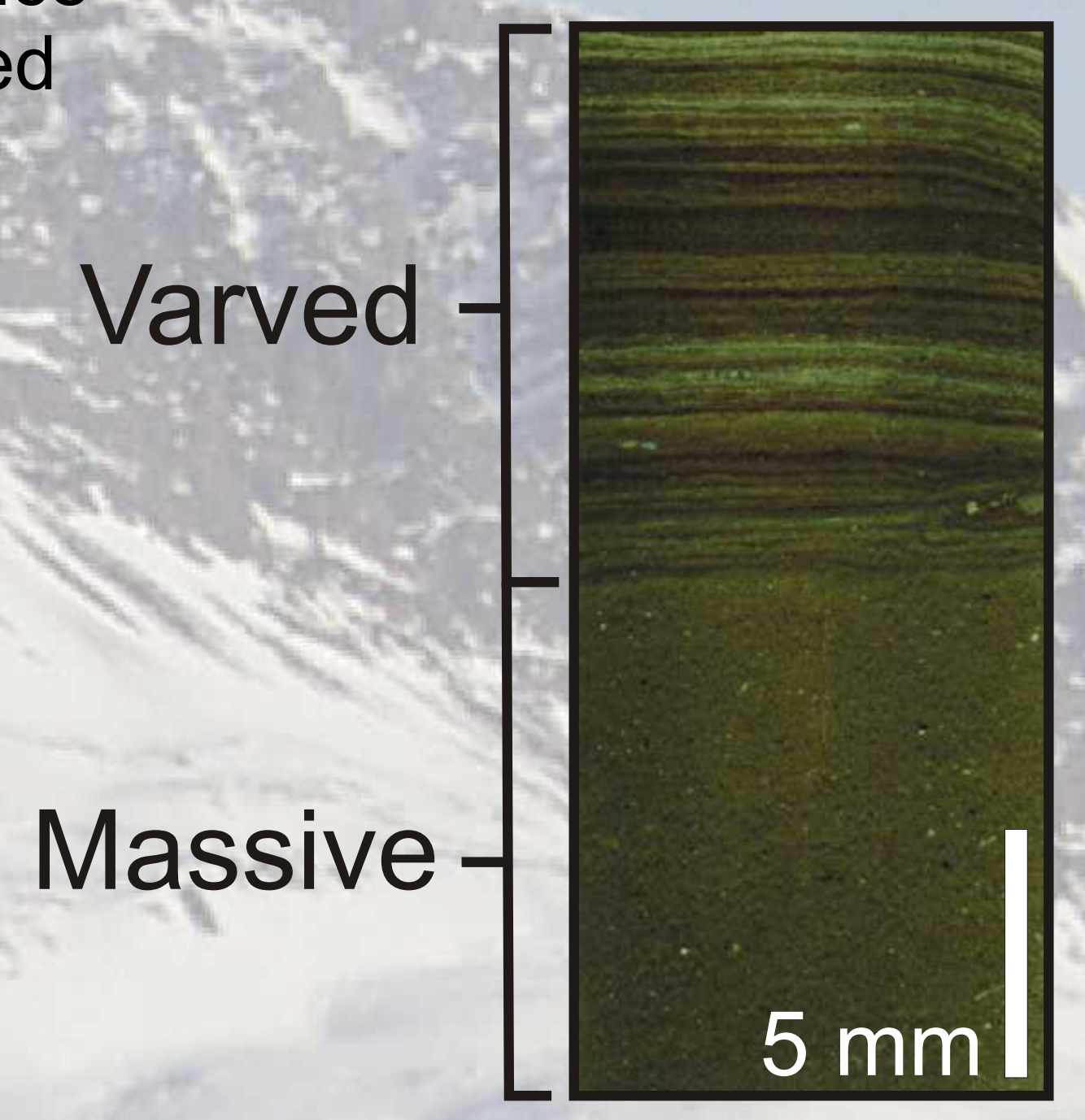


Figure 4: The abrupt change from massive to varved sedimentation in the sedimentary record from a water depth of 14.5 m (Core 8).

Long-term regional comparison: Lamoureux and Bradley (1996) developed a 3300-year record of oxycline changes in Lake C2, located 35 km west of Lake A (Figure 6). Unlike Lake A, Lake C2 shows a progressively deepening oxycline during the past 3300 years, which is hypothesized to be due to gradual removal of salt water and expansion of the aerobic zone. The most rapid rate of oxycline deepening occurred during a period of increased inferred inflow. However, they also note short-lived reversals of the oxycline deepening, similar to the results from Lake A. As we develop the long record from Lake A, we will be able to closely compare with Lake C2 and determine the water inflow/saltwater balance in nival (Lake A) and glacial (Lake C2) environments.

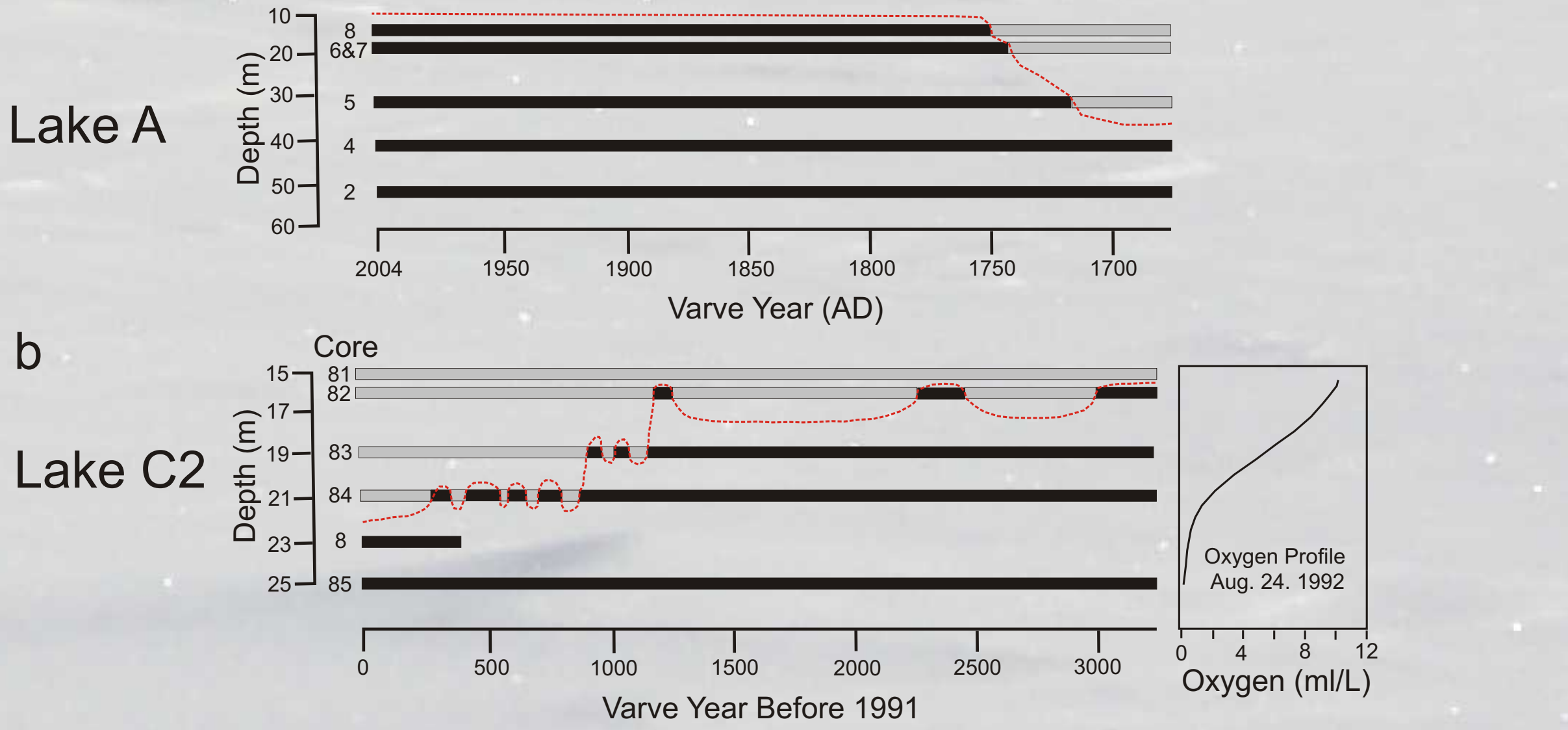


Figure 6: Schematic diagram of changes in oxycline depth in (a) Lake A and (b) Lake C2. Black bars in both diagrams represent periods of varve sedimentation. Grey bars in (a) represent massive sedimentation and grey bars in (b) represent diffuse varve structure. In (b), an oxygen profile from Lake C2 in late summer of 1992 shows core depths along the oxycline. Note the different time scale for each lake record (modified from Lamoureux and Bradley, 1996).

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