A STABLE ISOTOPE PALEOCLIMATE RECORD OF THE LATE-GLACIAL/INTERGLACIAL TRANSITION FROM LOUGH INCHIQUIN, WESTERN IRELAND

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INTRODUCTION

The shift from the Last Glacial Maximum to the current Interglacial period is characterized by several oscillations. Most prominent in Western European and ice core records, the B∅lling-Aller∅d/Younger Dryas/Preboreal sequence of climate shifts is widely recognized. However even the most dramatic and extensively studied of these climate swings, the Younger Dryas, has not been adequately characterized.

The wide distribution of sites that indicate climate fluctuation is significant because these climate shifts are thought to be closely tied to global ocean and atmospheric circulation (Broecker, 2000). A greater understanding of these abrupt perturbations gained by better documentation of their magnitude and distribution can improve predictions of the impact human activities may be having on global climate (Alley, 2000). New high-resolution studies of continental paleoclimate in Europe, where the events are most clearly defined, contribute to developing an overall picture of the conditions that produced climate instability.

The purpose of this study is to develop a paleoclimate record that will help to illuminate the nature of the glacial-interglacial transition in western Ireland.

METHODS

An eight-meter piston core was recovered from the shore of Lough Inchiquin, western

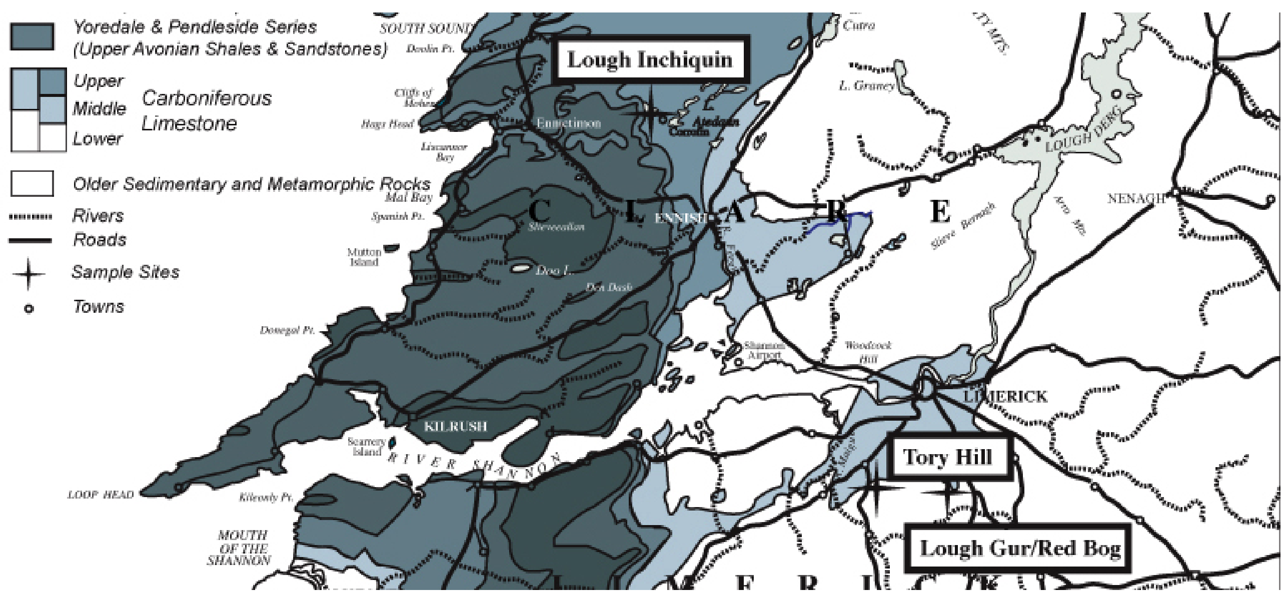

Figure 1: Map showing locations of Lough Inchiquin, Tory Hill, Lough Gur, and Red Bog. Modified from (O'Brian, 1962)

Ireland (Fig.1). In this study the bottom 1.5 m of the core were analyzed (LINC 1-7 and 1-8). The Younger Dryas event, marked by a distinctive clay-rich section, is present in the part of the core that was analyzed. Sediments were sampled at ten cm intervals for loss on ignition and two mm intervals for isotope analysis.

Loss on Ignition (LOI) for the sediments was run at the National University of Ireland, Galway. Samples were burned at 500° C to combust organic plant matter (organics) and at 1000° C to combust carbonate.

Stable isotopes of carbon and oxygen were analyzed at the University of Saskatchewan in Saskatoon, Canada. Prior to analysis samples were heated *in vacuo* to 200 º C to remove volatiles. Samples were reacted with 103% phosphoric acid at 70 º C by a Kiel III carbonate preparation device coupled to a Thermo Finnigan MAT 253 gas ratio mass spectrometer. The results have been corrected for ^{17}O contribution, and have a 0.1 per mil or better standard deviation. Both $\delta^{13}C$ and $\delta^{18}O$ have been calculated relative to the Vienna Peedee Belemnite (VPDB) international standard.

RESULTS

Dates

AMS dates are not yet available from the Lough Inchiquin (LINC 1) core. However, lithological correlation of LINC 1 to a core from Tory Hill (Fig.1) taken by O'Connell et al. (1999) indicates an age of 15 ka cal BP at the core's base. The Younger Dryas period is correlated to an age of 12 ka cal. BP (Fig. 2).

Loss on Ignition (LOI)

Between 7.53 m and 7.45 m and subsequently between 7.15 m and 7.05 m clay percentages decrease and carbonate increases. A large increase in clays and a dramatic drop in carbonate takes place between 6.49 m and 6.30 m. This shift, the most significant variation in the loss on ignition results, marks the Younger Dryas interval. The Younger Dryas interval is also the location of the most dramatic increase in organic values.

Carbon Isotopes (Fig. 2)

The most prominent trend in my carbon isotopes is 6.6 ‰ overall shift towards more negative values.

Another significant trend is associated with

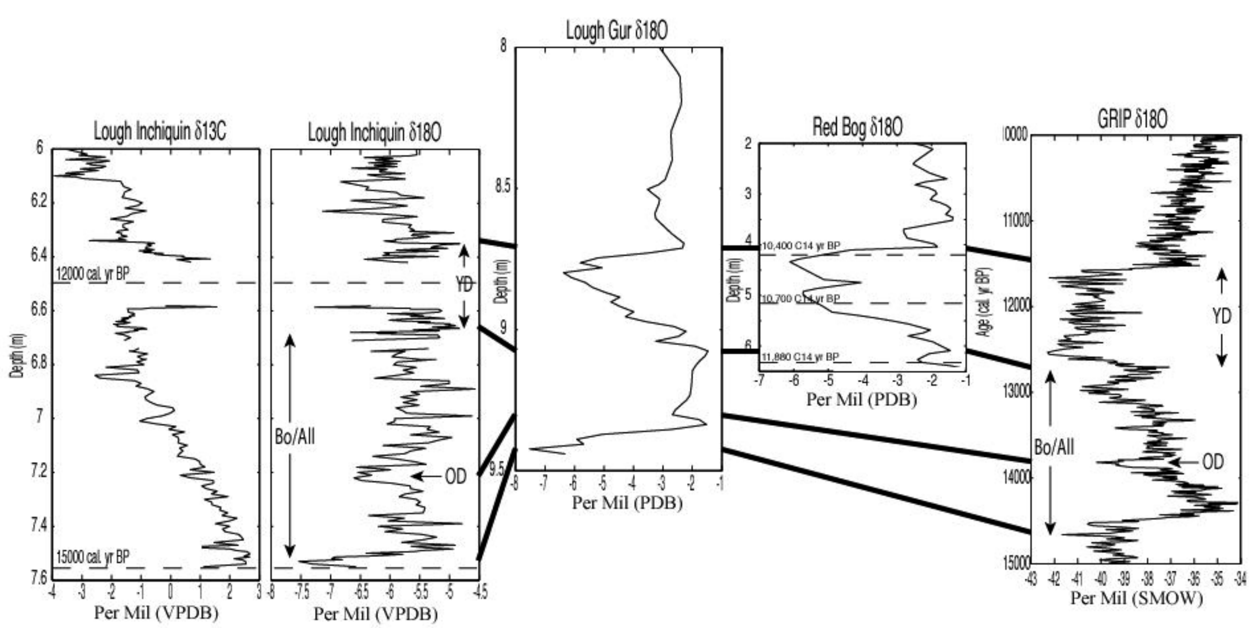

Figure 2: Stable isotope results from Lough Inchiquin. Tie lines correlate LINC 1 $\delta^{18}O$ nearby Lough Gur and Red Bog (Ahlberg et al., 1996) as well as the GRIP ice core $\delta^{18}O$ (Dansgaard et al., 1993) based on age and curve similarities. The BØlling-AllerØd (Bo/All), Younger Dryas (YD), and Older Dryas (OD) are marked on the GRIP and LINC 1 $\delta^{18}O$ records.

the Younger Dryas period between 6.61 m and 6.34 m. Although no data was obtained between 6.58 m and 6.43 m due to lack of carbonate, values leading into the data gap make it clear that a positive shift in $\delta^{13}C$ of at least 2.06 ‰ takes place.

Oxygen Isotopes (Fig. 2)

Between 6.60 m and 6.35 m, a negative shift is indicated by the values leading in and out of Younger Dryas section of the core. The change in $\delta^{18}O$ associated with this period was a minimum of 2.55 ‰. Most of this change is abrupt (between 6.60 m and 6.59 m) leading into the Younger Dryas, but was more gradual coming out of it.

The base of the core, between 7.55 m and 7.48 m, shows a dramatic negative peak. The minimum $\delta^{18}O$ value of this peak (-7.53 ‰ at 7.53 m) is the lowest value in the core. A rapid shift leads out of this peak, raising values by 2.59 ‰ by 7.48 m. Negative departures from the normal values take place between 7.27-7.09 and 6.29-6.11 m. Throughout the course of my core section, $\delta^{18}O$ shows frequent oscillations of about 1 ‰.

DISCUSSION

Interpretation of Paleoclimate Proxies

Clay in lacustrine sediments is generally an indicator of dry climate. During cold, dry periods sparse vegetation allows clay to be easily washed or blown into the lake from nearby. During dry periods windblown loess can also bring clay-size particles from a considerable distance.

Lacustrine carbon isotope records are often considered a measure of organic matter productivity in the lake. Productivity changes may be influenced by changes in aridity, among other factors. Kirby et al. (2002) have hypothesized that when cloud cover is high (low aridity), productivity is reduced causing wet periods to result in low $\delta^{13}C$.

Because plants preferentially use C^{12}, $\delta^{13}C$ values are also affected by the amount of vegetation in the environment. Increases in dissolved organic carbon (DOC) supplied by decomposing organic matter could decrease $\delta^{13}C$. C3 plants contribute more C^{12} to DOC than C4 plants. A shift from wet, warm conditions to cold, dry conditions could force a change in vegetation from C3 to C4 plants. This adaptation would increase $\delta^{13}C$. However, high $\delta^{13}C$ in the LINC 1 core implies that at Lough Inchiquin the proportion of C3 to C4 plants is less significant than the total vegetation around the lake.

The bedrock underlying Lough Inchiquin is also important to consider in interpretation of my isotopic record. Groundwater that enters the lake may acquire carbon from carbonate bedrock. Given that the $\delta^{13}C$ values of this record are high, it is likely that the bedrock has influenced $\delta^{13}C$ especially at the base of the core.

Interpretation of lacustrine oxygen isotopes involves two primary sources of variation: temperature and the oxygen isotope value of the lake water. Dansgaard (1964) first demonstrated that there is a positive linear correlation of precipitation $\delta^{18}O$ values with air temperature. A 0.33 ‰ /°C rate of change, as discussed by Ahlberg et al. (1996) is used to quantify temperature-based relationships at Lough Inchiquin.

Near Ireland's western coast, precipitation from westerly air masses has always dominated (Ahlberg et al., 1996). Consequently, variations in the precipitation/evaporation ratio at Lough Inchiquin and ocean salinity changes are the sources of water value variation significant to this study. These effects, which correlate negatively with $\delta^{18}O$, are considered subordinate influences at Lough Inchiquin with respect to larger trends. Any effect they have serves to dampen temperature oscillations recorded.

Paleoclimate at Lough Inchiquin

Low $\delta^{18}O$ values at the base of the LINC 1 core suggest that climate was still cold when sedimentation began in Lough Inchiquin. The high clay content and $\delta^{13}C$ values in this basal section support an interpretation of cold, dry climate.

B⌀lling/Aller⌀d warming is shown to be rapid, recorded in less than 4.6 cm. The $\delta^{18}O$

indicates that temperatures increased by up to 7.8° C. A brief negative $\delta^{18}O$ shift, possibly the Older Dryas, suggests that there was a short return to cold and/or dry conditions (Fig.2). A decrease in clays following this interruption implies that the climate became more humid after the inferred Older Dryas.

$\delta^{18}O$ leading into and out of the Younger Dryas imply cooling of 7.7°C associated with the event. Interpretation of $\delta^{13}C$ in the same section implies a dry, low vegetation environment around the lake. High clay content and relatively high levels of preserved organics in this portion of the core imply a cold, dry climate as well.

Although an abrupt $\delta^{18}O$ increase marks the end of the Younger Dryas in this core, the $\delta^{18}O$ values do not maintain the peak values reached at 6.35 m. Decreasing $\delta^{13}C$ values at the top of the core imply that humidity increased after the Younger Dryas. A brief cold period indicated by the oxygen isotopes at 6.2 m corresponds to a slight increase in $\delta^{13}C$. This excursion hints that a minor cold, dry period followed after the Younger Dryas, most likely the Preboreal Oscillation.

The frequent $\delta^{18}O$ shifts of 1 ‰ or greater magnitude present the possibility of recurrent minor events. Local temperature variation may have taken place, but at this small scale precipitation patterns may play a role as well. Comparison to $\delta^{18}O$ curves from nearby Lough Gur and Red Bog (Ahlberg et al., 1996) shows that significant local variation does take place, even when larger trends are preserved. LINC 1 shows remarkable similarity to the GRIP ice core $\delta^{18}O$ record, illustrating that large shifts are broadly regional (Fig. 2).

Consideration of the overall shift in $\delta^{13}C$ as a proxy for the amount of plant life nearby indicates a gradual increase in the vegetation surrounding the lake. Using $\delta^{13}C$ as a proxy for aridity, it is inferred that climate at Lough Inchiquin has gradually become wetter since the last glacial period.

CONCLUSIONS

The well-documented Late-glacial/Interglacial transition sequence is evident in the stable isotope and LOI results from the LINC 1 core. The sequence obtained by looking at isotope and loss on ignition results is validated by the dates linked to the core.

The presence of a dominant overall shift in $\delta^{13}C$, a feature not present in $\delta^{13}C$ records from nearby areas, implies a strong and highly localized environmental change was also taking place between the end of the last glacial maximum and the beginning of the Holocene. This may represent the development of extensive vegetation from a barren landscape left when the glaciers retreated. Increasing total vegetation in the area around the lake caused by wetter conditions and warmer temperatures is the most plausible explanation for the change in $\delta^{13}C$ observed in my record.

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