HOLOCENE CLIMATE CHANGE IN WESTERN IRELAND: EVIDENCE FROM THE OSTRACOD POPULATIONS OF LOUGH INCHIQUIN

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INTRODUCTION

In the context of growing concerns about the effects of increasing levels of anthropogenic greenhouse gases on the global climate, the need for better understanding of the nature and causes of the rapid climatic changes of the earth's past has led to aggressive efforts to collect, date, and correlate oceanic, atmospheric (ice core), and continental climate records from diverse locations (Cronin, 1999). The continental record of Western Ireland, with its key position in the Atlantic Ocean and its relatively uniform climate, has the potential to harbor a wealth of information about past changes in North Atlantic atmospheric circulation and, when combined with existing data from elsewhere in North America and Europe, would play an integral part in establishing a regional picture of Holocene climatic variation.

Lough Inchiquin is a small lake located near the town of Corrofin on the Burren of Western Ireland, the karstic Carboniferous limestone region of northwest County Clare. The lacustrine deposits of Lough Inchiquin are of great interest to this study because they predate the Younger Dryas cooling event, the last advance of continental glaciation that roughly marks the boundary between the Pleistocene and Holocene epochs (~10-11 ka), and potentially contain a record of the climate changes surrounding the Mid-Holocene Thermal Maximum (~6-7 ka). The causes of these and other centennial to millennial scale climate fluctuations such as volcanism, solar variability, and/or internal ocean circulation dynamics are currently not well understood. According to Broecker et al (1988), the Younger Dryas cold episode may have been caused by the diversion of meltwater from the Mississippi River drainage to the North Atlantic during the deglaciation of North America. The resulting reduction in surface water salinity would have caused a significant weakening in the formation of the North Atlantic Deep Water, thereby stopping the import of warm South Atlantic surface waters by the Gulf Stream.

Lough Inchiquin is an ideal site for studying these Holocene climate changes because it is a marl lake similar to those described by Murphy & Wilkinson (1980) and Treese & Wilkinson (1982), thus allowing for the construction of a _^{18}O history of the lake from both biogenic and authigenic calcite. Marl lakes are typically temperate, low-salinity, hard-water bodies with little clastic input. Broad, shallow benches of carbonate-rich sediment form around lake margins and prograde basinward with time. The growth of these benches is primarily due to the actions of the lake algae, *Chara*, which during photosynthesis removes bicarbonate from the water column in the vicinity of its stems, creating a zone of higher pH and causing a shift in the carbonate equilibrium that results in the precipitation of calcium carbonate encrustations on its stems (Treese & Wilkinson, 1982) and gyrogonites, the calcified fertilized female gametangia (Garcia, 1994). Selective lakeward transport of this authigenic carbonate from the nearshore region results in a coarsening upward sequence in the sediment record, with the finest carbonate fractions being deposited in the basin center.

According to Murphy & Wilkinson (1980) these authigenic calcites are formed during the warm summer months, so the _^{18}O signal of a given sample will be determined by the summer temperature at which it was formed and by the _^{18}O value of the ambient lake water, which varies with the _^{18}O composition of the former atmospheric precipitation and the water balance of the lake. Under steady state conditions the _^{18}O value in a lake should show little variation with time, and therefore shifts in the _^{18}O should be a reflection of changes in climate or catchment hydrology (Lister, 1988).

Aaron Diefendorf of the University of Saskatchewan is currently examining the _^{18}O record of Lough Inchiquin based on the analysis of authigenic calcite. However, bulk sampling of the authigenic calcite record is subject to confounding by the presence of multiple sources of carbonate. Lacustrine carbonate is not limited to calcite of biologically-mediated origin, but can also include carbonates of biogenic, clastic, and physiochemical origins (Talbot, 1990). Even if a bulk carbonate sample comprised solely of biologically-mediated calcite were successfully isolated, there are additional unavoidable complications that could influence the authigenic carbonate _^{18}O signal. As Garcia (1994) points out, *Chara* gyrogonites calcify at different intervals within the same plant, and it is also not uncommon for them to be exposed to the atmosphere during times of lower base level. Therefore, there is a need for the use of multiple proxies in interpreting lacustrine climate records, and this study seeks to complement that of Aaron Diefendorf by examining the variation in the _^{18}O shell chemistry and faunal assemblages of the microfossils of Lough Inchiquin. An emphasis is placed on ostracod distribution and stable isotope chemistry because these tiny bivalved crustaceans, sometimes known as “seed shrimps,” are highly responsive to environmental perturbations and their occurrence is controlled primarily by the chemical and thermal parameters of a water body. Ostracodes live a benthic or weakly nektonic lifestyle and molt up to nine times before reaching maturity (Hutton et al, 1995). The calcification of their new carapace occurs in a matter of hours or days and is thought to occur in thermal and chemical equilibrium with the host water, although differences in microhabitat and molt period lead to differences in the _^{18}O and _^{13}C signals recorded by separate species for the same time period (Hutton et al, 1995). As Hutton et al (1995) pointed out, because temporal and spatial variations are common in lakes, a single ostracod carapace records conditions over a limited time and space, but a general paleoclimate record can be derived from the simultaneous analysis of several valves over the same section of sediment core.

Methods

The core examined in this study, LINC1, was obtained by use of a piston coring apparatus in the summer of 2002 along the western shore of Lough Inchiquin (UTM 29 499426.7 m E, 5867015 m N). The core recovered was 7.6 meters in length. It was split and subsampled by other members of 2002 Keck Ireland team, and one quarter of the core was shipped back from Ireland in 10 cm sections for use in this study. Upon arrival at Smith College, the core was reassembled and sampled in 5 or 10 cm intervals, depending upon the condition of the sediment.

Each sample was processed by washing through a 250 _m and 60 _m sieve. The 60 _m fraction was archived, and the 250 _m fraction was oven-dried at 100ºC for picking. After drying, each sample was passed through a second set of sieves, and all microfossils greater than 250 _m were counted and/or picked. Charophyte gyrogonites, bivalves, and gastropods were counted in bulk, and ostracodes were differentiated according to genus. Exceptional ostracod specimens were photographed using the SEM to aid in classification, and where present, specimens of charophyte gyrogonites, juvenile bivalves, and two types of ostracodes, *Candona* and

Limnocythere, were selected from each sample for stable isotope analysis.

Stable isotope analysis (_^{18}O and _^{13}C) was performed at the University of Saskatchewan using a Finnigan-MAT Model 251 mass spectrometer coupled to a Kiel carbonate preparation device, which allowed for the accurate analysis of samples as small as 20 _g. Prior to analysis, samples were roasted under vacuum at 250˚C for one hour to remove volatile orgainics. The number of specimens analyzed simultaneously from a single sample consisted of 3 to 10 *Candona*, 3 to 8 *Limnocythere*, 3 to 10 *Chara*, or 1 to 4 bivalves, depending upon availability.

Loss on ignition (LOI) data, was generated during the field portion of the project by heating sediment samples first to 100ºC to remove any water. Heating to 500ºC allowed for the determination of the weight percent organic material in the sample, and by subsequent heating to 1000ºC, the percent carbonate and inorganic material was determined. Results of radiocarbon dating of organic material from the LINC1 by AMS are expected soon and will provide a depositional time frame for the core, the upper limit of which is currently unconstrained.

RESULTS

The preliminary results of this study are shown in Figure 1. The ostracodes identified in LINC1 include *Heterocypris*, *Limnocythere sancti-patricii* BRADY AND ROBERTSON, *Metacypris*, *Eucypris*, multiple species of *Candona* and an isolated occurrence of *Ilyocypris* in the uppermost extent of the core.

At a depth of 6.6-6.4 meters, a grey clay layer interrupts a period of marl deposition, marking the Younger Dryas cooling event. Prior to this interval microfossil counts are generally low, and bivalves, *Candona*, and *L. sancti-patricii* are predominant. However, at 6.6 meters, all fauna disappear with the exception of the brief appearance of a stout, uncalcified variety of charophyte gyrogonite, and there is a decrease in the _^{18}O value of *Candona* and bivalves analyzed from upper portion of Younger Dryas clay. However, _^{18}O values quickly recover with the return of marl-producing conditions at 6.4 meters, and *Limnocythere* counts peak before total ostracodes, *Chara*, bivalves, and gastropods undergo a dramatic increase in relative abundance at 5.8 meters. At this time, the ostracod assemblage is predominately *Candona* and *Heterocypris*. By approximately 4.8 meters, total ostracod numbers drop off, possibly due to progradation of the carbonate bench, and by 2.8 meters, the sediment has a common medium sand component dominated by the calcified stems of *Chara*, a typical feature of carbonate bench platform deposits (Treese & Wilkinson, 1982). The sediment becomes increasingly organic-rich with increasing height in the core until approximately 1.6 meters where peat deposition begins and microfossils become exceedingly rare with the exception of gastropods and occasional intervals rich in bivalves. Interestingly, approximately 0.1 meters below the surface of the present day shoreline there is a sudden increase in carbonate content, a significant increase in the relative abundance of *Limnocythere*, and a positive excursion in _^{18}O of *Candona*, *Limnocythere*, and bivalves, a trend most likely indicative of a flooding event possibly coincident with that observed by Caseldine et al. (1998).

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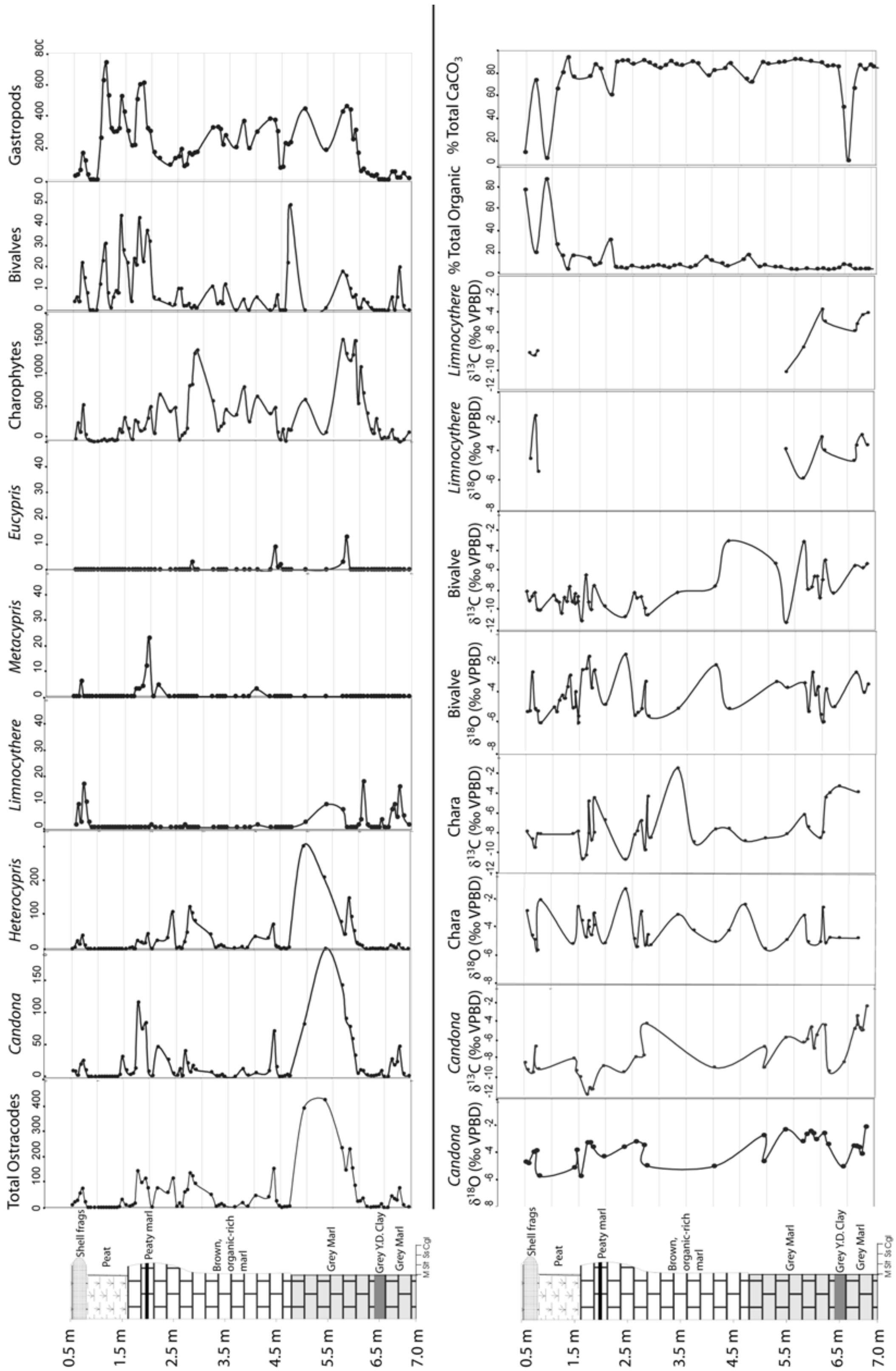

Figure 1: Top: Microfossil abundances in Lough Inchiquin by depth. Bottom: Stable isotope compositions of the microfossil species *Limnocythere*, *Candona*, charophytes, and juvenile bivalves, where available. Also shown are the percentages of carbonate and organics in the lake sediments by depth, as determined by loss on ignition.