

# BULK AND TRACE SEDIMENT GEOCHEMISTRY OF HOLOCENE LAKE CORES, WESTERN IRELAND: HIGH RESOLUTION ANALYSIS OF THE YOUNGER DRYAS

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## INTRODUCTION

While medium-term (1,000 to 100,000 years) climate variability is known to be caused by Milankovich (orbital) cycles, shorter scale variations and their forcings are less well understood [McDermott et al., 2001]. High-resolution analysis of Holocene lake cores should improve our knowledge of these less substantial changes. Western Ireland (Figure 1) was selected for our research because it is in a prime location for studying eastern Atlantic climate change because its distance from mainland Europe means it is only minimally affected by continental processes. In addition, comparison of our results with previous work from eastern North America will give us a better understanding of jet stream and Atlantic Ocean current variability over the northern Atlantic Ocean through the Holocene [Kirby, 2001].

This project focuses on a specific interval of post-glacial Holocene climate change known as the Younger Dryas (YD). During this event (~13,000 to 11,700 yr BP) climatic conditions rapidly deteriorated, probably due to a change in Atlantic Ocean current circulation. From pollen and other analyses, it appears that average temperatures dropped 6 - 10° C in Europe and North America within the first 100 years of the event [Broecker, 1990]. The frigid climate of the YD caused the forests that grew in North America and Europe after the retreat of the glaciers to be replaced by shrubs and grasses. Because of decreased vegetation cover, more soil was exposed, and it was held less firmly in place. Cold periods are



Figure 1. Ordnance Survey Geologic map of western Ireland showing location of coring sites (LINC-1 was taken at Site 3).

generally associated with high wind speeds, causing loose soil to be eroded and transported, so that cold periods have higher soil dust deposition rates than warm periods. This difference should be reflected in the sediment record [Shotyk, 2002], therefore it is expected that the YD is represented by silt and clay in the sediment cores from western Ireland.

Bulk and trace sediment geochemistry was analyzed from the YD interval, plus the sediment immediately preceding and following it. Results show the warming and cooling trends associated with the YD, as well as other smaller climatic shifts.

## Geologic Setting

Three Holocene lake sites were selected for coring (Figure 1). These were chosen based on their potential for producing a detailed continuous climate record: The selected lakes have existed for most of the Holocene and sedimentation/carbonate precipitation was continuous over this period. The core selected for high-resolution analysis (LINC-1) came from Inchiquin Lough, County Clare (Site 3 - Figure 1). This core was chosen for detailed sub-sampling because it had the thickest section of lake sediment (late-Glacial and Holocene), and also because it was more sedimentologically variable.

The lake sediment from all sites is primarily biologically-mediated, fine-grained calcite precipitate (marl). However, there are some interbedded clays. The thickest of these clay units occurs between 6.30 m and 6.90 m in the LINC-1 core, and is interpreted to represent the YD. Another clay layer, at 7.50 m, was probably deposited at the end of the last glaciation (~15,000 yr BP).

## Methods

**Field:** The lake sediment cores were taken with a square-rod piston (Livingstone) corer, which enabled us to take the cores in one-meter segments. Each core segment was placed in a half-PVC tube, wrapped in plastic, and sent back to the lab for analysis.

**Laboratory:** After the cores had been split, they were ready for sampling. Marks were made every centimeter along the LINC-1 core length, and then centimeter-wide sample chunks were taken with a razor blade. I took samples every centimeter from the base of the peat to the base of the core. These 670

samples were wrapped in foil for later use.

From these samples a smaller subset was selected to be run on the ICP and AA (Table 1). These samples were chosen because they were from an interval encompassing the YD, and thus they were expected to show significant geochemical variability related to climate change.

Because the AA and ICP can only analyze liquid solutions, the sediments had to first be digested in acid. The samples were first dried at 50° C for 24 hours. Then 0.1000 g of sediment from each sample was weighed out. For ICP analysis, the sediment was dissolved in H<sub>2</sub>O<sub>2</sub>, HNO<sub>3</sub>, HCL, and HF, digested in the microwave, and left to cool overnight. The samples were then evaporated down to .5 ml and diluted for ICP analysis. For the AA, the sediment was placed in tubes where it underwent a weak acid digest in H<sub>2</sub>O<sub>2</sub> and HNO<sub>3</sub>. The samples were then placed on a revolving wheel for mixing overnight. After mixing, the undigested sediment was separated with a centrifuge, and the liquid solution was poured into a separate tube and diluted for AA analysis.

## RESULTS

Twelve samples were analyzed with the ICP. Measurements of nine major elements and fifteen trace elements were made on the samples. 57 samples were analyzed using the AA, including three duplicates of samples that had already been run on the ICP. Seven elements were measured in these samples (six major - Ca, Fe, K, Mg, Mn, and Na, and two minor - Cu and Sr). The data from both sets of samples were converted to grams of the element per 100 grams of sediment (weight percent element) in the case of the major

**Table 1. Description of core selected for detailed analysis.**

Core Name	Site Location	Length	Sampling Method for Geochemical Analysis
LINC-1	Inchiquin Lough shore (20 km south of Galway Bay)-County Clare	7.60 m	5.80 m to 6.20 m – every 2cm 6.20 m to 6.40 m – every 1cm 6.40 m to 6.50 m – every 2cm 6.50 m to 6.70 m – every 1cm 6.70 m to 6.90 m – every 2cm

elements, and to ppm for the trace elements (Figure 2).

## DISCUSSION

Most of the AA data show a sharp change between about 6.30 m and 6.60 m (Figure 2). This result is expected, since this section of the core represents the YD and exhibits a visible difference in lithology. The relative rapidity with which the elements shift at the beginning and end of this interval also comes as no surprise, as the YD is known to have started and come to a close abruptly [Broecker, 1990]. Fe, K, Mg, and Na concentrations can indicate the amount of inwash of unweathered silicate minerals [O'Connell, 1999]: High concentrations indicate high levels of inwash, high erosion rates, and thus colder climatic conditions. Evidence of this should be seen especially

well in the YD [Andrieu, 1993].

Geochemistry confirms that marl is replaced by clays at the onset of the YD: Ca, Mn, and Sr all decrease, while Cu, Fe, and Mg increase over this interval (Figure 2).

The high-resolution AA data reveal variation within the YD itself. Ca shows a small increase between 6.54 m and 6.50 m, suggesting a slight warming at the beginning of the YD (Figure 2), followed by a return to colder conditions. This trend can also be seen in the Cu, Mn, Na, and Sr plots. The climate over the rest of the YD seems to have been relatively stable, which is why this one small jump in temperature is so noteworthy.

Fe and Mg both show a general increase over the YD because of their association with clay minerals [Andrieu, 1993], but they show a

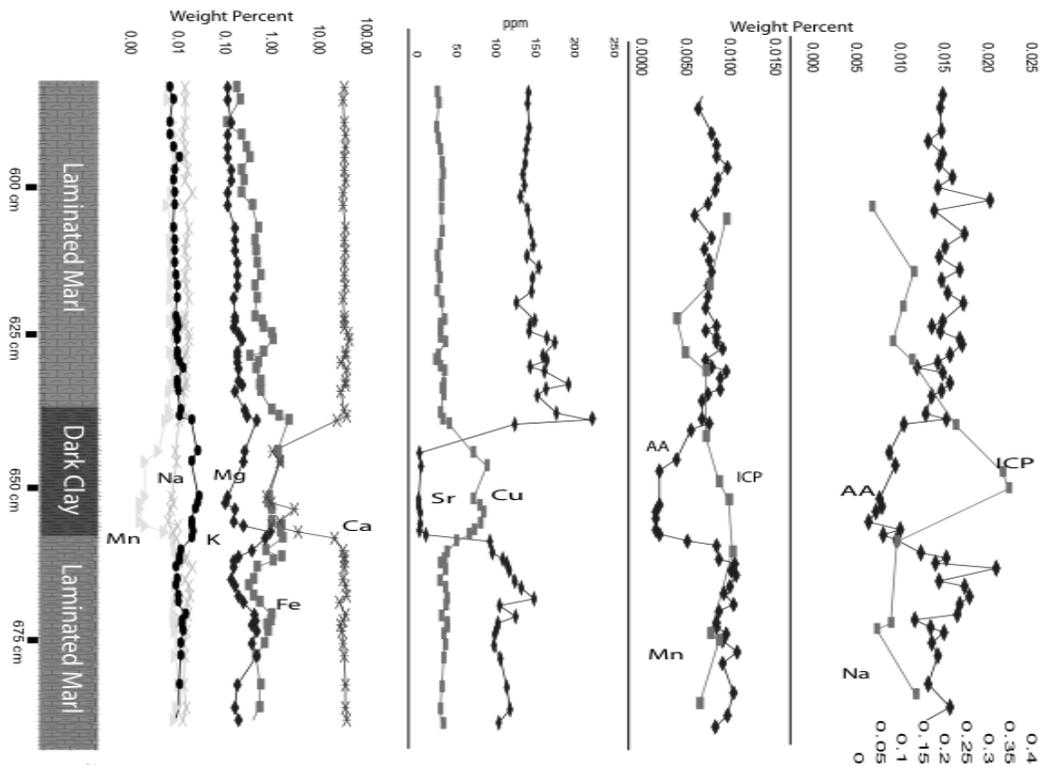


Figure 2. Variation of 6 major (far left) and 2 trace (second from left) elements (from AA data), and comparison of AA and ICP data for Mn and Na (right), over interval of 5.80m to 6.90m in LINC-1

slightly different pattern than the other elements (Figure 2). They each have multiple peaks (at about 6.40 m, 6.60 m, and 6.80 m) and troughs (at 6.52 m and 6.65 m). Increases in Fe may also be related to its increased mobility in reducing conditions (which would also increase its likelihood of being found in lake-bottom sediments) [Andrieu, 1993]. However, the reason for the extreme variation of these two elements over the YD is not yet clear.

Divergent trends in the ICP and AA data suggest mineralogical differences between the marl and clay intervals. For most elements, the trends follow the same general pattern on both machines. In the cases of Na and Mn, however, the ICP-generated values rise or stay relatively steady over this interval, indicating that the total amount of both of these elements increases throughout the YD. In contrast, the AA-generated values drop (Figure 2). This suggests that during the YD, Na and Mn resided in insoluble silicate minerals rather than in soluble carbonate minerals.

## CONCLUSIONS

Bulk and trace sediment geochemistry allows us to look at the abrupt climatic shift, known as the YD, in high detail and to see minor (but still important) climate changes within this interval.

Understanding the natural climatic variations of the past is important for predicting future climate (especially when considering the possible implications of global warming on the planet). It will be useful to compare the Holocene climate change of western Ireland with that of eastern North America, as this will give us the opportunity to look at changes in the size and shape of the jet stream over the North Atlantic Ocean.

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