A MULTIPROXY PALEOLIMNOLOGIC INVESTIGATION OF LOUGH CARRA IN COUNTY MAYO, IRELAND.

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INTRODUCTION

The nature and consequences of climate change are an increasingly important and urgent area of study. As a continuation of the 2002 Ireland Keck Project, this study seeks to reconstruct a detailed record of Holocene climate variability from carbonate lake sediments in Western Ireland. The current project focuses on Lough Carra in County Mayo, Ireland and the most recent portion of the lake's climate record (approximately 2,000 to 4,000 years before present).

Lough Carra provides an excellent study site for the reconstruction of Holocene climate. Its location at the edge of western Ireland allows for study of climate variability through stable oxygen isotopes with a minimum of continental rainout fractionation effects. Lough Carra is part of an extensive system of carbonate drainage lakes in western Ireland with continuous sediment records extending beyond the Younger Dryas, approximately 10,500 years BP (Mitchell, 1981). The proximity of these lakes to the North Atlantic Ocean make their stable isotope records ideal for the study of changes in the thermohaline circulation, which is thought to be a major control on global climate patterns (Bianchi and McCave, 1999; Nyberg and others, 2002). Changes in the North Atlantic Oscillation (NAO), a decadal scale oscillation of wet and dry winter precipitation levels in eastern North America and western Europe, can also be studied using data obtained from isotope records from western Ireland. The NAO is the result of periodic shifts in the path of the jet stream over North America and the North Atlantic; however, the underlying cause of this shift is unclear (Hurrell, 1995). A better understanding of how these phenomena change in the Holocene will allow for a stronger understanding of the mechanisms of climate change.

The project aims to create detailed records of lake conditions over the past 2,000 to 4,000 years using multiple complimentary proxies including stable oxygen and carbon isotopes, elemental and trace element proxies, and zoological indicators such as gastropod and ostracode population studies. These records may be correlated with the records of the past 10,000 years reconstructed from the Lough Inchiquin (approximately 80 km south of Lough Carra) core of the 2002 Ireland Project. Additionally, the current project seeks to understand the influence of early diagenetic processes, especially microbiological processes, on the stable isotope record of carbonate sediments.

Setting

Lough Carra in County Mayo, western Ireland, is approximately 9.6 km at its longest extent and 2.5 km at its widest. The lake's mean depth is 1.75 m and its greatest depth is 18 m. Lough Carra has a surface area of 14.38 km^2 and its catchment area is 104 km^2. The lake is comprised of three distinct basins: the Castleburke, Castlecarra, and Twin Islands basins. (King and Champ, 2000).

Lough Carra and its catchment lie on Carboniferous limestone bedrock. The soils in the catchment are predominantly composed of limestone glacial till or blanket peat. The topography surrounding the lake is generally flat and low lying, and land use in the catchment area is primarily devoted to sheep grazing (King and Champ, 2000).

The sediment of Lough Carra is composed of nearly pure calcium carbonate, as much as 95% calcite. The endogenic precipitation of marl in temperate carbonate lakes such as Lough Carra is primarily biologically induced as a result of photosynthesis in aquatic plants (Drummond and others, 1995; Ito, 2001). The sediment also has a relatively high organic content, as much as 5% organic carbon.

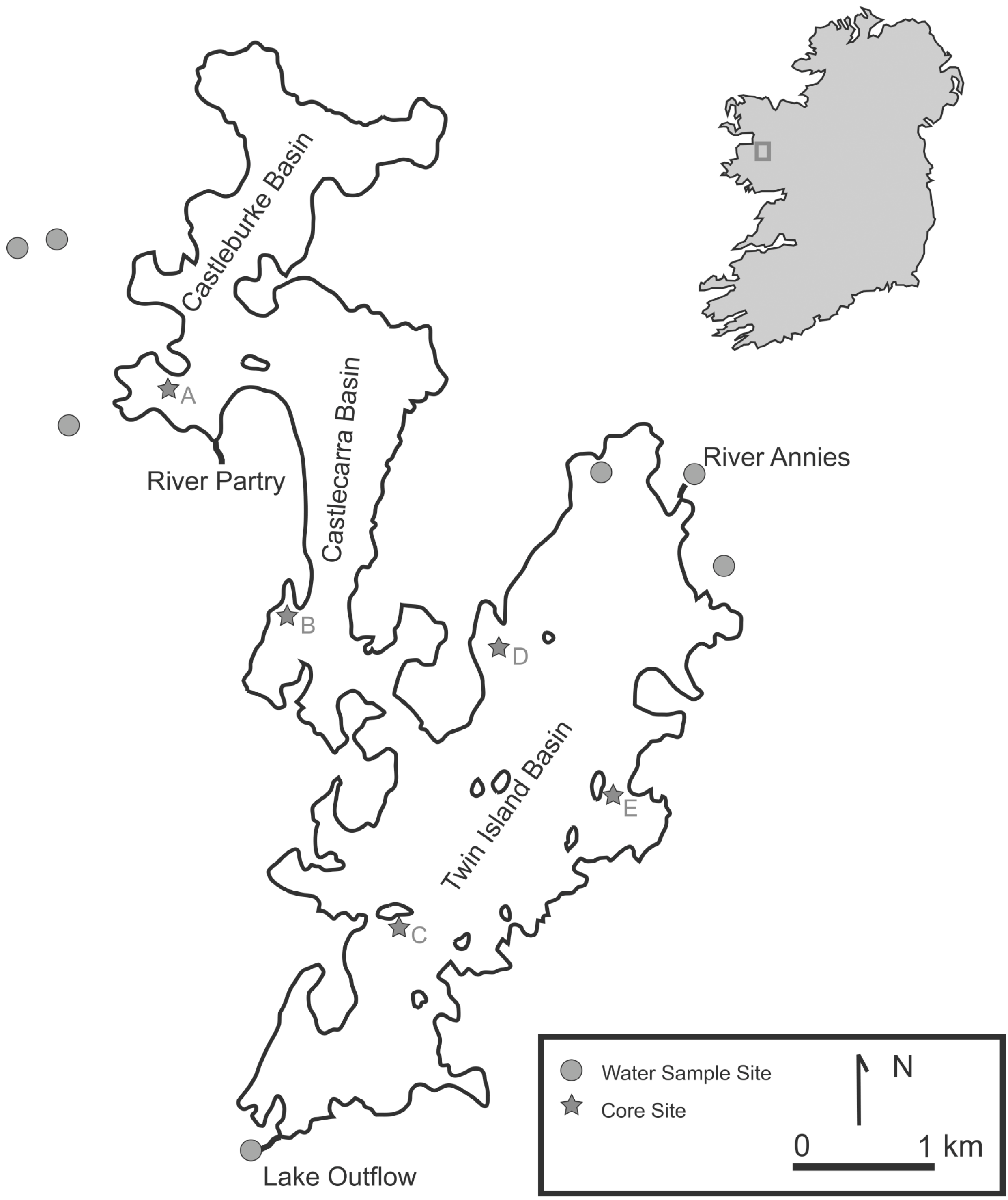

Figure 1. Lough Carra and site locations. Modified from Ordinance Survey Ireland, sheet 38, 1:50,000 and King and Champ, 2000.

Methods

Field Methods

The students worked together to collect sediment core and water samples from several sites in Lough Carra and its surrounding catchment. Two types of coring devices were used to retrieve continuous sediment samples: push cores using 60 cm long polycarbonate tubes and a modified 2.5 m steel hand-coring apparatus. The cores were taken from five sites in Lough Carra (Fig. 1, Table 1). The hand cores were pre-processed in the field laboratory; the cores were described, logged, and photographed, and then cut, sub-sampled, and packaged for transport to Amherst College. The push core sediments were centrifuged to separate the porewater for elemental analysis. Additional water samples for elemental analysis were taken from several lake sites, including all coring sites, as well as from rivers and lakes within the lake's catchment. Temperature and pH were recorded from each site and all water samples were titrated for alkalinity in the field laboratory.

Laboratory Analysis

Sediment composition was determined at the Luce Environmental Analytical Geochemistry Laboratory at Amherst College. These analyses included dry bulk density, porosity, and loss-on-ignition (LOI). Former Ireland Keck scholars Aaron Diefendorf and Justin Dodd conducted stable isotope analyses at the Saskatchewan Isotope Laboratory at the University of Saskatchewan, Saskatoon. Stable isotope analyses included □^{18}O and □^{13}C of the bulk sediment, porewaters, and selected gastropod samples. Elemental analysis of lake, river, and porewaters were conducted at Amherst College, while the elemental composition of the cored lake sediments were performed at Whitman College by Samantha Saalfield. Ryan Phelps at Trinity University performed population analyses of macro biota. Helen Dole used gene sequencing to identify microbial communities at the Nuesslein

Figure 2. [SO_4^{2-}] based sedimentation rates. The initial slope of a sulfate concentration profile can be used to calculate a sedimentation rate via the equation: log □ = log □(dc/dx) □(Berner, 1977).

Microbiology Lab at the University of Massachusetts, Amherst.

Summary

Correlating cores and proxies has proven troublesome due to difficulties in obtaining concrete dates within the cores. ^{14}C dating has suffered from a lack of terrestrial organic matter within the cores to use as datable material. Rough dates have been obtained through the correlation of cesium peaks and by estimating sedimentation rates. Berner (1977) has shown that in sulfate concentration profiles with concave-down asymptotic trends resulting from sulfate reduction, the initial slope of the sulfate concentration vs. depth profile is directly proportional to the sedimentation rate. The initial sulfate gradient is related to the sedimentation rate by the equation:

log □ = log □(dc/dx)□

where □ is the sedimentation rate (cm/yr), and (dc/dx) is the initial slope of the sulfate concentration profile (mM/cm). Figure 2 shows the initial slopes from four push cores and the calculated sedimentation rates.

Student Projects

Samantha Saalfield studied the elemental and trace element chemistry of the carbonate sediments.

Ryan Phelps characterized population trends in gastropods and ostracodes and compared the trace element chemistry of gastropods with that of the surrounding sediment.

Helen Dole investigated the microbiological controls on carbonate precipitation and its potential effects on the stable isotope records within these sediments.

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