Continental Shelf Research 96 (2015) 45–55

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Research papers

Sediment flux and recent paleoclimate in JordanBasin, Gulf of Maine

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ARTICLE INFO

Article history:
Received 3 April 2014
Received in revised form
6 January 2015
Accepted 19 January 2015
Available online 22 January 2015

Keywords:
Holocene
Deglaciation
Sediment trap
Foraminifera
Radiocarbon
Oxygen isotope

ABSTRACT

We report planktonic foraminiferal fluxes (accumulation rates) and oxygen isotopes ($\delta^{18}O$) from a nine-month sediment trap deployment, and $\delta^{18}O$ from three sediment cores in Jordan Basin, Gulf of Maine. The sediment trap was deployed at 150 m, about halfway to the basin floor, and samples were collected every three weeks between August 2010 and May 2011. The planktonic foraminiferal fauna in the trap is dominated by *Neogloboquadrina incompta* that reached a maximum flux in the second half of October. Oxygen isotope ratios on that species indicate that on average during the collecting period it lived in the surface mixed layer, when compared to predicted values based on data from a nearby hydrographic buoy from the same period. New large diameter piston cores from Jordan Basin are 25 and 28 m long. Marine hemipelagic sediments are 25 m thick, and the sharp contact with underlying red deglacial sediments is bracketed by two radiocarbon dates on bivalves that indicate ice-free conditions began 16,900 calibrated years ago. Radiocarbon dating of foraminifera indicates that the basin floor sediments (270–290 m) accumulated at >3 m/kyr during the Holocene, whereas rates were about one tenth that on the basin slope (230 m). In principle, Jordan Basin sediments have the potential to provide time series with interannual resolution. Our results indicate the Holocene is marked by $\sim$2°C variability in SST, and the coldest events of the 20th century, during the mid 1960s and mid 1920s, appear to be recorded in the uppermost 50 cm of the seafloor.

1. Introduction

Basins on continental shelves are common where the margin was glaciated. In the northwest Atlantic Ocean, the Gulf of Maine is the southernmost occurrence of these basins (Fig. 1) and it is also close to Canadian and New England centers of oceanography. Because of its rich fisheries, investigations of the marine biology began in the 1870s by the U.S. Fisheries Commission and the world's first purpose-built oceanographic ship, *Albatross*, after 1881. Academic investigators began studying the Gulf's circulation in the 1920s (Bigelow, 1927), and hydrographic data for Jordan Basin, in the northeastern Gulf, are available for the sea surface since 1870, and for deep water every year since 1965 (http://www.bio.gc.ca/science/data-donnees/base/data-donnees/climate-climat-eng.php; Brian Petrie, pers. comm. 2013). It was recognized long ago that major deep hydrologic changes result from intrusion of cold slope waters into shelf basins (Colton, 1968; Petrie and Drinkwater, 1993), forced by the North Atlantic Oscillation (NAO) (Petrie, 2007; Mountain, 2012). These data show substantially colder and fresher surface and deep waters in the mid 1960s than later years, and echo the changes observed at the same time in nearby Emerald Basin on the Scotian Shelf (Petrie and Drinkwater, 1993). Surface waters over Jordan Basin circulate cyclonically, and are cool and fresh, reflecting their Arctic source (Pettigrew et al., 2005) with additional contributions from local rivers and especially the Gulf of St. Lawrence (Houghton and Fairbanks, 2001). The strength of these surface flows, especially the Nova Scotia Current and the Eastern Maine Coastal Current, should affect upwelling in Jordan Basin as they define the Jordan Basin Gyre (Fig. 1). Recent hydrographic studies have documented increased freshening in the coastal waters that flow southward past Nova Scotia and into the Gulf, and that such changes affect the entire ecosystem (Townsend et al., 2010). Over decades these are related to the NAO because when nutrient-rich warm slope waters flood the basins during the NAO positive phase, the productivity is higher (Drinkwater et al., 2003, Durbin et al., 2003). However recent freshening at high latitudes coupled with intense regional warming, has led to an overall decrease in phytoplankton and zooplankton abundance over the past decade despite the prevalence of positive NAO conditions (Pershing et al., 2005; Townsend et al., 2010; Mills et al., 2013).

Studies of particle flux from the surface ocean using sediment traps are a main source of information about the seasonal flux (mass accumulation rate) of particles, their transport, their

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http://dx.doi.org/10.1016/j.csr.2015.01.008
0278-4343/

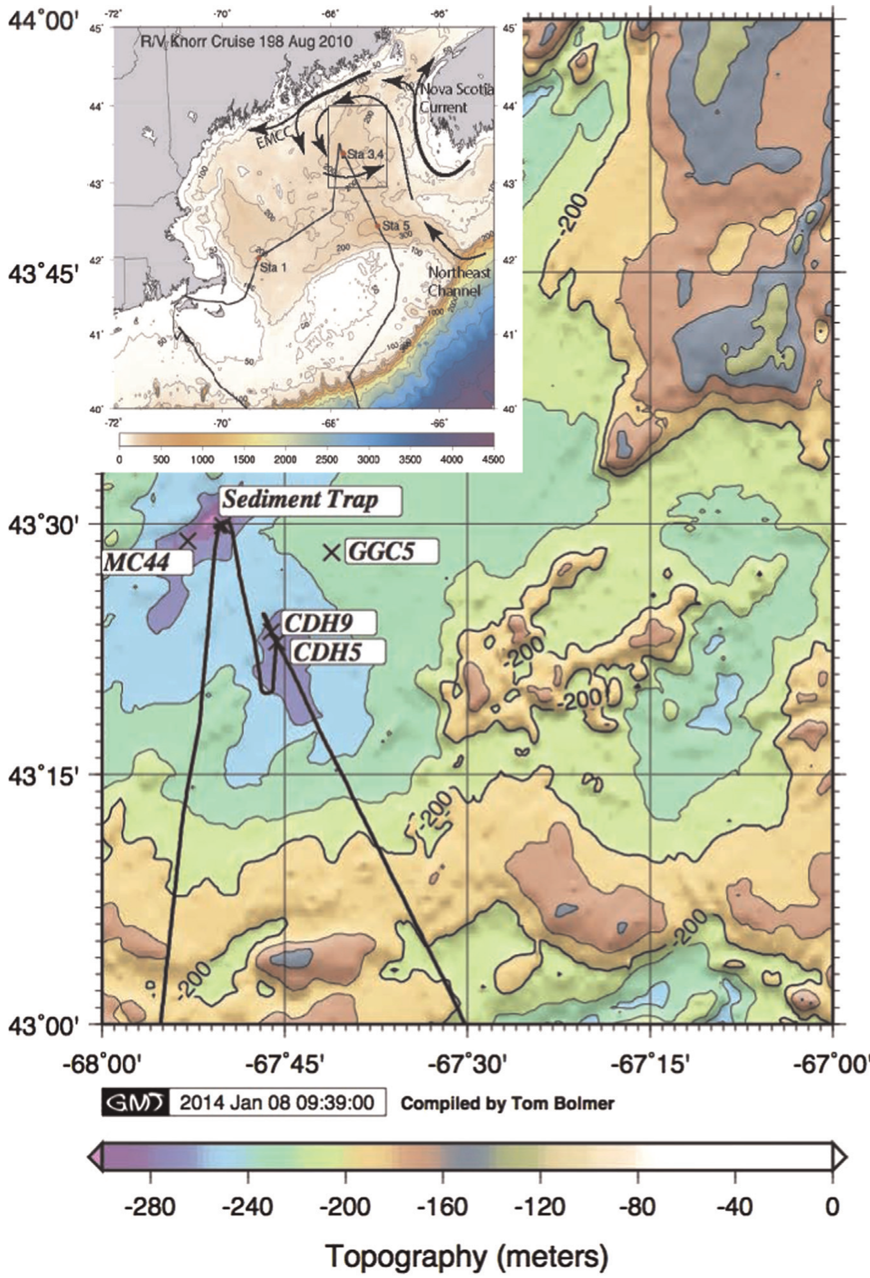

Fig. 1. Locations discussed in this paper. Box in inset shows part of Jordan Basin in blow-up, with arrows illustrating surface currents relevant to Jordan Basin (the Eastern Maine Coastal Current, EMCC; the Nova Scotia Current; and flow through Northeast Channel). Additional cores in the study area are described by Schnitker et al. (2001).

chemical composition, and their role in chemical mass balance in the ocean. Sediment trapping is the only method to determine short-term accumulation rates of sediment. At most open ocean locations, the shells of pelagic micro-organisms such as foraminifera, coccolithophores, radiolaria and diatoms are an important part of the mass flux from the surface, and their study in sediment trap samples provides an important opportunity for paleoceanographers to ground truth or calibrate bio-geo-chemical proxies to surface ocean conditions. Surprisingly, there are few locations in the North Atlantic where both sediment trapping and sediment coring for long paleo records have occurred together. We are aware of only two examples: Cariaco Basin (Black et al., 1999) and the Sargasso Sea. At Sargasso Sea Station S (now known as the Bermuda Atlantic Time Series (BATS) (Deuser and Ross, 1989; Conte et al., 2001), trap data have been especially useful in in calibrating proxy measurements such as Mg/Ca (Anand et al. 2003) and in enabling a late Holocene time series of SST (Keigwin, 1996).

Here we discuss a new sediment trap time series, and accompanying sediment cores, from Jordan Basin in the Gulf of Maine (Fig. 1). The trap location was chosen specifically to complement sediment cores taken nearby, and to benefit from a nearby hydrographic station. The trap was about 2 km east of hydrographic buoy M that is a component of the Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS; http://www.neracoos.org/realtime_map), formerly the Gulf of Maine Ocean Observing System (GoMOOS). Sediment coring in the Gulf of Maine has occurred for decades, with the goal of revealing the history of glacial retreat (Tucholke and Hollister, 1973; for an overview, see Schnitker et al. 2001).

We focus on the recent climate history of Jordan Basin, based on changes in the stable isotope ratios in planktonic foraminifera. This would not have been possible without the synergy of both sediment trapping and sediment coring at the same location. We find that Jordan Basin is a remarkable archive of paleoclimate