Quaternary Science Reviews 129 (2015) 57–67

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

The deglaciation over Laurentian Fan: History of diatoms, IRD, ice and fresh water

Isabelle M. Gil [a, b, *], Lloyd D. Keigwin [c], Fatima Abrantes [a, b]

[a] IPMA – Portuguese Institute for the Ocean and Atmosphere, Marine Geology and Geo-resources Division; Rua Alfredo Magalhães Ramalho, 6, 1495-006 Lisboa, Portugal
[b] CCMAR – Centre of Marine Sciences, Campus de Gambelas, 8005-139 Faro, Portugal
[c] WHOI - Woods Hole Oceanographic Institution, Geology & Geophysics, 266 Woods Hole Rd. - MS# 08, Woods Hole, MA 02543-1050, USA

ARTICLE INFO

Article history:
Received 29 April 2015
Received in revised form
23 July 2015
Accepted 1 October 2015
Available online 24 October 2015

Keywords:
Deglaciation
Sea-ice
North atlantic
Diatom
Heinrich event 1
Younger Dryas
Bølling-Allerød
Older Dryas
Preboreal

ABSTRACT

A high-resolution diatom census coupled with other proxy data from Laurentian Fan (LF) provides a detailed description of the last deglaciation, bringing new insight to that period by revealing directly the timing of sea-ice formation and melting. Cold events Heinrich Event 1 (H1) and the Younger Dryas (YD) were multiphase events. H1 (~16.8–15.7 cal kyr BP) was defined by a two-pulse release of icebergs promoting sea-ice formation. Melting of sea-ice after H1 corresponds to a cold and fresh anomaly that may have kept the Bølling colder than the Allerød. At ~13.6 cal kyr BP, a cooling trend culminated with sea-ice formation, marking the YD onset (~12.8 cal kyr BP). The decrease in sea-ice (~12.2 cal kyr BP) led to a YD second phase characterized by very cold winters. However, the contribution of warm water diatoms tends to increase at the same time and the YD gradual end (~11.6 cal kyr BP) contrasts with its abrupt end in Greenland ice cores. The YD cannot be regarded as an event triggered by a fresh water input through the Laurentian Channel since only one weak brief input nearly 1000 yrs after its onset is recorded. Very cold and cool conditions without ice mark the following Preboreal. A northward heat flux between 10.8 and 10.2 cal kyr BP was interrupted by the increased influence of coastal waters likely fed by inland melting. There was no further development of sea-ice or ice-drift then.

1. Introduction

The North Atlantic exerts a strong influence on present day climate, with its oceanographic changes affecting directly the climate of both sides of the basin (Dickson et al., 1996; Visbeck, 2002). Fresh water input and the presence of ice in the North Atlantic are assumed to have played a major role during abrupt climate changes through their impact on the thermohaline circulation - THC (Broecker et al., 1989; Rahmstorf, 2002), in particular during the deglaciation. However, there is no direct tracer for fresh water. Past fresh water input is inferred from oxygen isotope measurements on planktonic and benthic foraminifera, and the presence of melting icebergs is inferred from Ice Rafted Debris (IRD) in the sediments (Bond et al., 1992; Heinrich, 1988; Hemming, 2004). Furthermore, the absence of IRD does not necessarily mean the absence of ice, especially sea-ice. Regarding modeling experiments, the massive discharge of icebergs during Heinrich events (HE) is often simulated by a fresh water hosing (Flückiger et al., 2006; Liu et al., 2009; Prange et al., 2004), but those simulations do not accurately reflect fresh water pathways in the ocean (Condron and Winsor, 2011). Few studies have attempted to simulate an iceberg discharge with progressive melting and transport (Jongma et al., 2012; Levine and Bigg, 2008; Roche et al., 2014).

Diatoms are siliceous microscopic algae with the ability to colonize diverse environments (including ice and fresh water) with diverse species. The diatoms preserved in marine sediments therefore reflect directly the properties of the surface water (photic zone), e.g. salinity, temperature and nutrients. They are also a major component of the phytoplankton community in polar environments associated with ice (Medlin and Priddle, 1990). Diatom assemblages can therefore offer an original description of the main climatic events of the last deglaciation over our study area, the Laurentian Fan (LF).

* Corresponding author. IPMA – Portuguese Institute for the Ocean and Atmosphere, Marine Geology and Geo-resources Division, Rua Alfredo Magalhães Ramalho, 6, 1495-006 Lisboa, Portugal.
E-mail address: isabelle.gil@ipma.pt (I.M. Gil).

http://dx.doi.org/10.1016/j.quascirev.2015.10.006

The few diatom records from the North Atlantic for the deglaciation are mainly from its equatorial and subtropical eastern margin (Romero et al., 2008; Stabell, 1986) or from the subpolar North Atlantic and Nordic Seas (Andersen et al., 2004; Knudsen et al., 2004; Koç Karpuz and Jansen, 1992; Koç et al., 1993). The only detailed deglacial marine record from the western side of the North Atlantic, on Bermuda Rise, is unfortunately limited in time because the diatoms are not preserved in the sediments after Heinrich Event 1 - H1 (Gil et al., 2009). For this part of the North Atlantic, only one study from the Gulf of St Lawrence (Lapointe, 2000a) is available. Here, we provide a detailed description of the deglaciation in the north western Atlantic with the aim of tracing directly the major forcings of the climate system that are assumed to have played an important role: ice cover and the fresh water input.

2. Regional setting

Laurentian Fan underlies part of the Slope Water System, where waters from subpolar and subtropical origin meet. Gatien (1976) described two distinct water zones of opposite characteristics: the Warm Slope Water Current, a bifurcation of the Gulf Stream and a well-mixed water found between 0 and 400 m depth, flowing primarily eastward; and the cold poorly mixed Labrador Slope Water flowing deeper and westward (Fig. 1). These water masses are juxtaposed and their borders and flows vary in response to changes in intensity of the Gulf Stream and of the Labrador Current (Pickart et al., 1999). A strong temperature and salinity front results therefore from the competing influence of these water masses along the North wall of the Gulf Stream. In addition, brackish and fresh water from the Gulf of St Lawrence potentially overflows LF (Ohashi and Sheng, 2013). Finally, the site was located near the Laurentide Ice Sheet (LIS) margin during the Last Glacial Maximum (LGM) according to Dyke's reconstruction (2004). Diatoms (when preserved) appear therefore as an appropriate proxy to describe the contrasted environments of the Slope Water System.

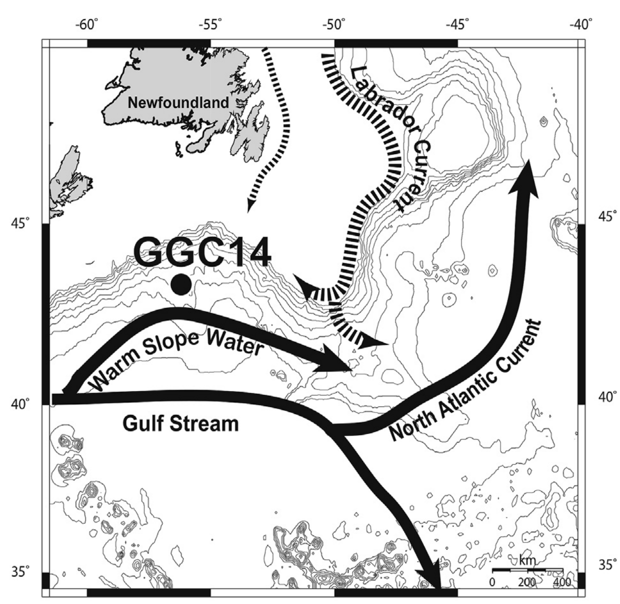

Fig. 1. Location of core GGC14 and modern surface water distribution in the region of the Grand Banks of Newfoundland after Pickart et al. (1999) and Petrie and Anderson (1983). Cold and warm currents are represented by dashed and plain arrows respectively.

3. Material and methods

3.1. Material and age model

Gravity core OCE326 GGC14 (GGC14 – 43°03.959′N; 55°49.992′W; 3525 m depth) was retrieved from LF (Fig. 1) in July 1998 on board the R/V Oceanus from the western valley of LF (Keigwin et al., 2005).

GGC14 age model is based on seven AMS ^{14}C dates on planktonic foraminifera (Keigwin et al., 2005). One additional ^{14}C date at 189 cm (^{14}C 10 800 ± 70 years) was obtained from the National Ocean Sciences Accelerator Mass Spectrometer (NOSAMS) facility at Woods Hole Oceanographic Institution to better define the Younger Dryas (YD) in this study. ^{14}C ages were calibrated using the INTCAL13 curve (Reimer et al., 2013) with a standard marine correction of 400 years. Age-depth modeling was elaborated using Clam 2.2 (Blaauw, 2010) R package. Ages were linearly interpolated at 95% confidence ranges using Monte Carlo sampling (Fig. 2). The ages below the last dated level were extrapolated.

3.2. Diatom analyses and ecology

The core was sampled every 4 cm for diatom analyses. The samples were treated and counted following the method described in Gil et al. (2009). The total diatom abundances are reported as the median, minimum and maximum values (Fig. 3G). Diatom abundances were calculated in 89 samples and 63 had diatoms abundant enough to determine the assemblages. Three hundred diatom specimens (on a *Chaetoceros* free basis, as they are common) were identified to calculate the contribution of each diatom species. The minimum amount of 300 is required to assume that a contribution of 2% is significant with a confidence level of 95.4% (Galehouse, 1971). The diatom flora consists of 260 species (cf. Supplementary data including references for taxonomy) and a main environmental preference other than marine (e. g fresh water, brackish, ice, cold and warm) was attributed to several species.

The first step of diatom analysis was to compare the GGC14 record with the modern surface distribution of diatoms in the Gulf

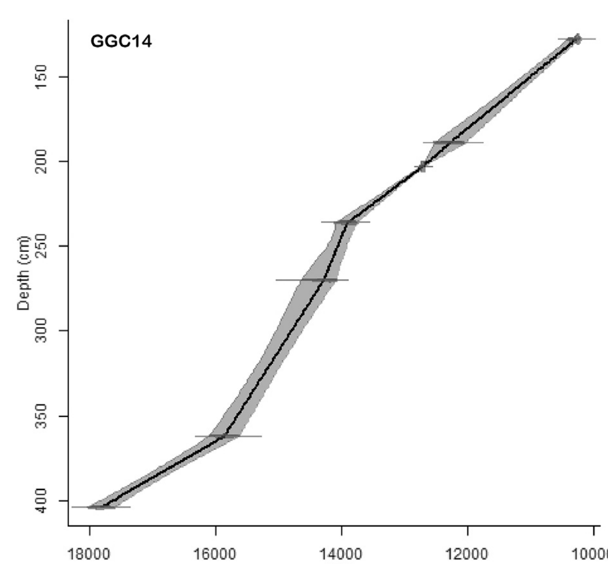

Fig. 2. GGC14 age-depth modeling obtained with CLAM 2.2 R package (Blaauw, 2010). Points on the curve and error bars represent AMS dates on planktonic foraminifera calibrated to calendar years assuming the standard 400 year reservoir effect and calibration probability. Grey area illustrates the 95% probability range.