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Sedimentary and rock magnetic signatures and event scenarios of deglacial outburst floods from the Laurentian Channel Ice Stream

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A B S T R A C T

Eastern Canadian margin sediments bear testimony to several catastrophic deglacial meltwater discharges from the retreating Laurentide Ice Sheet. The reddish-brown plumite layers deposited on the levees of the Laurentian Fan valleys have been recognized as indications of multiple outburst floods between Heinrich events 2 and 1. Five event layers have been consistently recorded in three new gravity cores retrieved on the SW Grand Banks slope and comply with the previously published Laurentian Fan core MD95-2029. The apparently huge extent of these outburst plumes around the Laurentian Fan as well as their causes and consequences are investigated in this study using physical properties, rock magnetic and grain-size analyses, together with seismoacoustic profiling. We provide the first detailed ^{14}C ages of the outburst event sequence and discuss their recurrence intervals in the context of regional ice retreat. Compared to the hemipelagic interlayers, event layers have overall uniform and systematic changes of rock-magnetic properties. Hematite contents increase over time and proximally while magnetite grain sizes fine upwards and spatially away from the fan. Based on the sediment composition and load, we argue that these plumites were formed by recurrent erosion of glacial mud deposits in the Laurentian Channel by meltwater outbursts. Three alternative glaciological scenarios are evaluated: in each case, the provenance of the transported sediment is not an indicator of the precise source of the meltwater.

1. Introduction

Subglacial meltwater discharge was an important feature of the North American Laurentide Ice Sheet (Dyke, 2004; Lewis and Teller, 2007) and occurred most frequently around the Last Glacial Maximum (LGM) when continental ice sheets and their ice streams reached the edge of the continental shelf. Meltwater release was commonly episodic, as short-lived outburst floods (Shoemaker, 1992; Johnson and Lauritzen, 1995), and accompanied by gigantic iceberg releases, the so-called Heinrich events (Andrews and Tedesco, 1992; Hemming, 2004; Andrews et al., 2012), that are documented as ice-rafted detritus (IRD) layers across the northern North Atlantic Ocean. The accompanying temporary freshwater cap hindered deep -water formation in the northern North Atlantic Ocean, reduced the strength of the Atlantic meridional overturning circulation (Bond and Lotti, 1995; McManus et al., 2004), and provoked climate changes even in temperate and tropical regions (e.g., Broecker, 1994; Mulitza et al., 2008, 2017). Flood-like deglacial meltwater pulses from the retreating Laurentide Ice Sheet also impacted Late Pleistocene and Early Holocene climates, but their marine records are more localized. The most documented outburst flood event is the early Holocene final drainage of the ice-dammed Lake Agassiz-Ojibway through Hudson Bay and Strait at 8.2 cal ka (Hillaire-Marcel et al., 2007; Lajeunesse and St-Onge, 2008; Jennings et al., 2015), which has been linked with a pronounced northern hemisphere cold spell.

Late Pleistocene meltwater pulses have been documented from Heinrich events off Hudson Strait (Rashid et al., 2003), where non-fossiliferous, homogenous, typically fine-grained and finely

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laminated siliciclastic beds with thicknesses of several meters near outflow channels down to a few centimeters in the distal fringes of the affected area have been observed. Such proximal irregularly stratified muds with some IRD are identified as suspension fall-out from surface plumes. They are therefore termed plumites and differentiated from mud turbidites, which feature distinct silt laminae and lack ice-rafted detritus (Hesse et al., 1997, 2004). More frequent outburst floods are recognized around the LGM in Orphan Basin off Newfoundland (Tripsanas and Piper, 2008) and at the outlet of Laurentian Channel, the major ice stream that drained the southeastern Laurentide Ice Sheet (Skene and Piper, 2003).

The foremost evidence for major deglacial meltwater pulses through Laurentian Channel, the so-called ‘red plumes’, are reddish-brown muddy overbank deposits of the Laurentian Fan. These sediments were sourced from Permo-Carboniferous redbeds of Appalachian Canada (Alam and Piper, 1977) that stretch from northern Nova Scotia and New Brunswick across the Gulf of St. Lawrence up to the western coast of Newfoundland (Fig. 1). Five reddish-brown mud beds up to a few meters thick between Heinrich events 2 (H2) and 1 (H1) are intercalated by cm-thick hemipelagic layers (Skene and Piper, 2003). The outburst flood theory (Piper et al., 2007, 2012) is now widely accepted, but event scenarios and chronologies are still uncertain. Also unknown are the origin and trajectory of Laurentian outburst floods and their relationship to Laurentide Ice Sheet retreat. Here we ask the following research questions:

1. How do event layer thickness and composition vary with water depth and distance from channels, and in which ways does this constrain the extent of the plume, the sediment dispersal process and its paleoceanographic significance?
2. What information on sediment transport and deposition processes can we draw from grain-size and rock-magnetic properties, as well as structures of the event layers?
3. How were the postulated outburst flood events preconditioned and timed with respect to deglacial retreat of the Laurentide Ice Sheet in the Gulf of St. Lawrence region?

2. Geological setting and deglacial history of the study area

2.1. SW Grand Banks Slope

The Grand Banks are the now submerged eastern extension of the Newfoundland terrane complex in the northern Appalachians. They were exposed and partly (Dyke, 2004) or fully (Shaw et al., 2006) land-ice covered during glacial periods. The SW Grand Banks Slope was an ocean-continent transform fault during the early opening of the Atlantic Ocean (Tucholke and Whitmarsh, 2012) (Fig. 1). The upper slope consists of thick, progradational Tertiary successions overlain by mainly glaciomarine Quaternary sediments (Piper and Normark, 1989).

The submarine canyon systems of the SW Grand Banks Slope

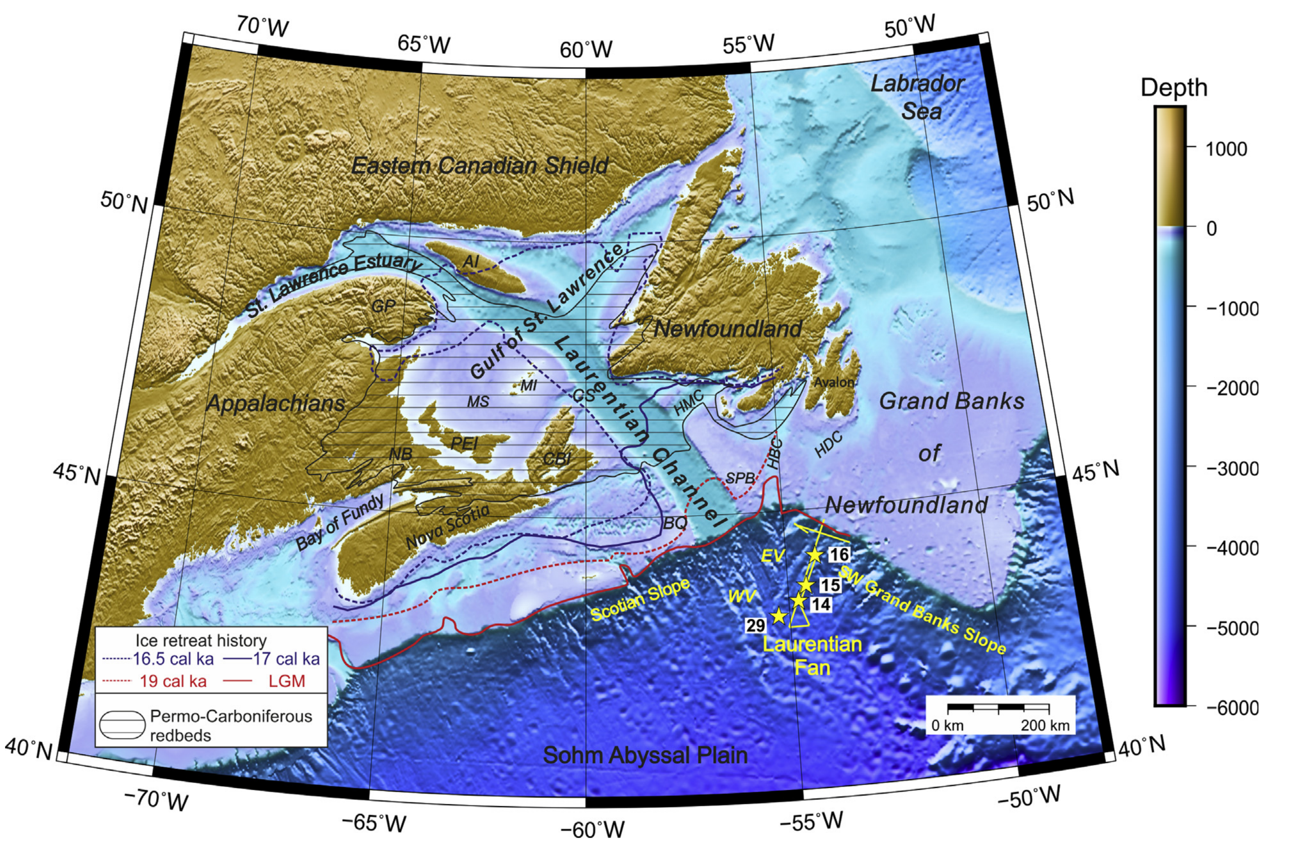

Fig. 1. Topographic map of eastern Canada. Yellow stars shows locations of cores 14 (GeoB18514-2), 15 (GeoB18515-1), 16 (GeoB18516-2) and 29 (MD95-2029) on the eastern levee of the Laurentian Fan (Skene and Piper, 2003; Piper et al., 2007). The yellow line marks echosounding profile connecting cores 14–16. Bedrock types simplified from Williams and Grant (1998). Ice margins at 16.5 cal ka (13.7 ^{14}C ka) and 17 cal ka (14.3 ^{14}C ka) according to Josenhans and Lehman (1999) as revised by Piper and Macdonald (2001); at 19 cal ka (16.5 ^{14}C ka) from Dyke (2004); and at the Last Glacial Maximum (LGM) from Shaw et al. (2006) and Shaw and Longva (2017). AI = Anticosti Island, CBI=Cape Breton Island, BQ=Banquereau, CS=Cabot Strait, EV = Eastern Valley, GP = Gaspé Peninsula, HBC=Halibut Channel, HDC=Haddock Channel, HMC=Hermitage Channel, MI = Magdalen Island, MS = Magdalen Shelf, NB= New Brunswick, PEI=Prince Edward Island, SPB= St. Pierre Bank, WV= Western Valley. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)