Source to Sink, Oxnard CA, January 2011

Possible flood events in large shelf crossing troughs on the Southeast Canadian Margin



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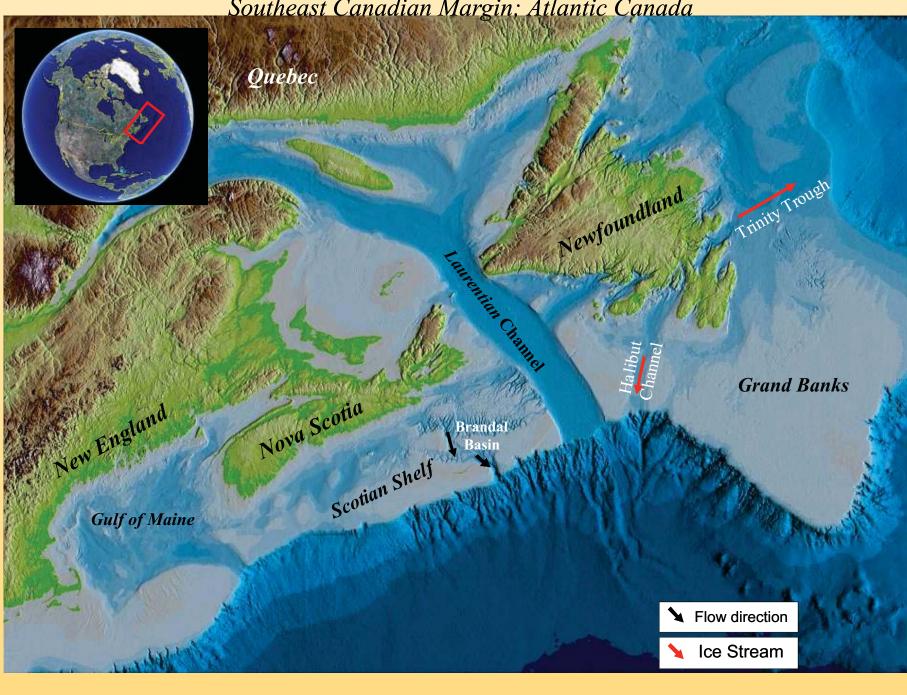
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INTRODUCTION

The continental shelf off southeastern Canada was glaciated numerous times in the mid to Late Pleistocene. The resulting continental shelf morphology consists of banks and glacially over-deepened shelf-crossing troughs.

Over-deepened basins, constructional moraine complexes, till deposits and interbedded glacigenic debris flows with glacimarine sediments are elements common to these troughs. Within this setting a giant moraine breaching, midaxis marginal meltwater channeling in late glacial sediments, ubiquitous late glacial unconformities found in deep water below the Holocene transgression and large sandwave field are observed as possible indicators of flood events. Evidence shows the presence of hyperpycnal deposits in nearby Orphan basin as described by Tripsanas and Piper, 2008. Piper et al., 2006 has also documented flood events on Laurentian Fan which have been dated between 17 and 14 ¹⁴C ka.

We will attempt to show, through interpreted high resolution seismic profiles and core data from Trinity Trough, Halibut Channel and Brandal Basin, how the above indicators can be attributed to flood events that allowed sediment flux to deep ocean basins.

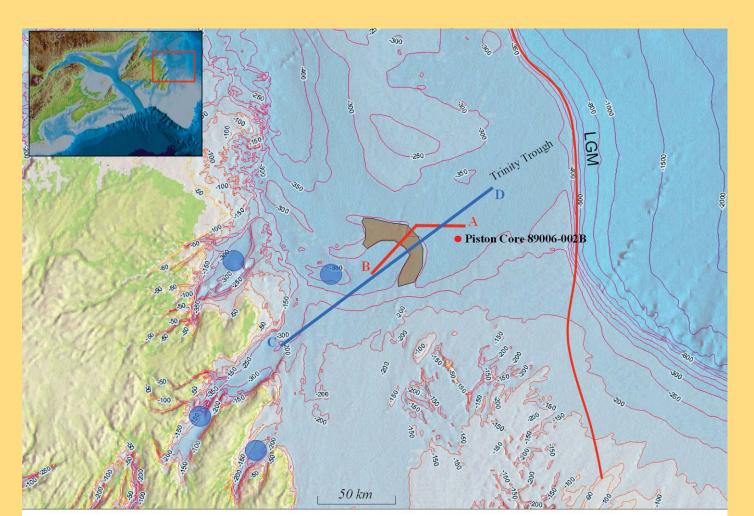


Trinity Trough, Halibut Channel and Brandal Basin, their locations shown on the above map, are shelf crossing troughs and basins featured in this study.

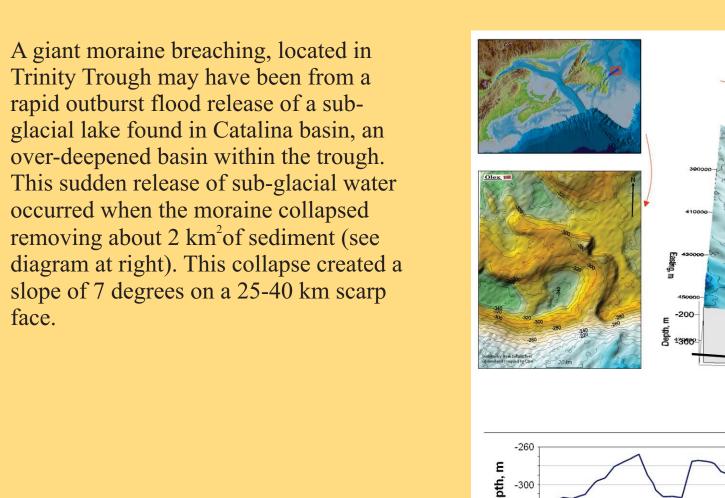
A 3-D view of Trinity Moraine, based on Olex data.

Trinity Moraine failure/breach configuration

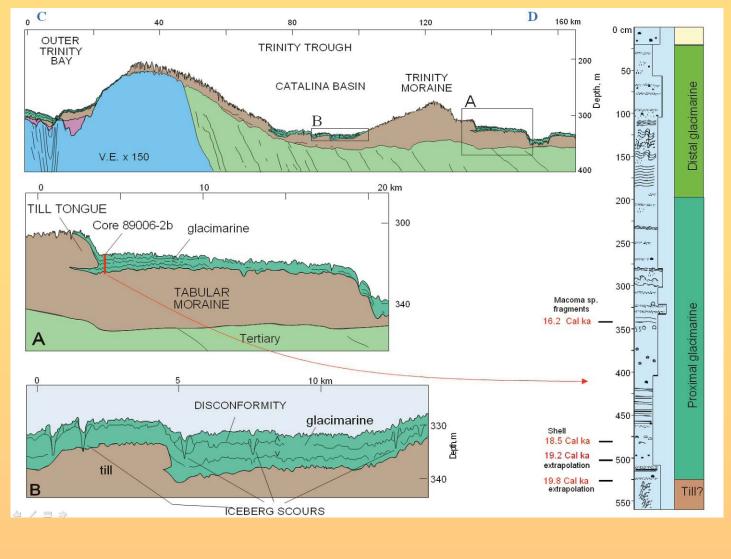
A CATASTROPHIC FLOOD OCCURRED IN TRINITY TROUGH/FAN



Last glacial max. Major moraine Glacial overdeepening Map of Trinity Trough located on the Northeast Newfoundland Shelf, showing the location of Trinity Moraine, over-deepened basins and core and seismic cross-sections along with the



position of the last glacial maximum. Orphan Basin is location seaward of this line.



hyperpycnal

event summary

Alternations of plumites and IRD-rich beds

colour and petrology: Paleozoic reddish

DENSE seafloor (channel)-transported

-R3- 19.2 cal ka (16 ka radiocarbon); >6 km3

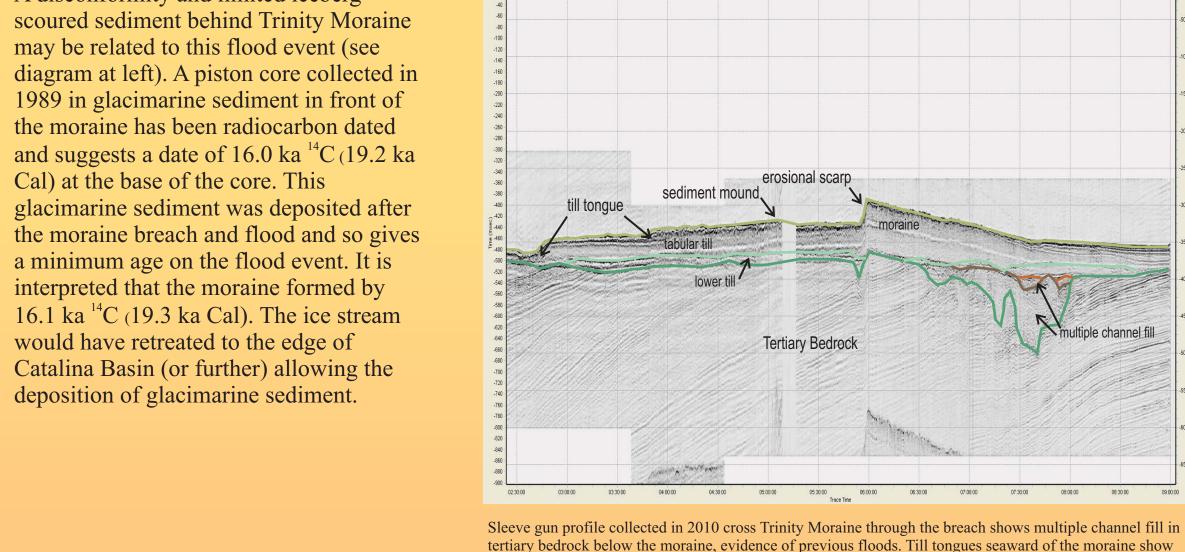
sandstones, few carbonates

retreats from shelf-break

Modified from Tripsanas and Piper Journal of Sedimentary Research, 2008, v. 78

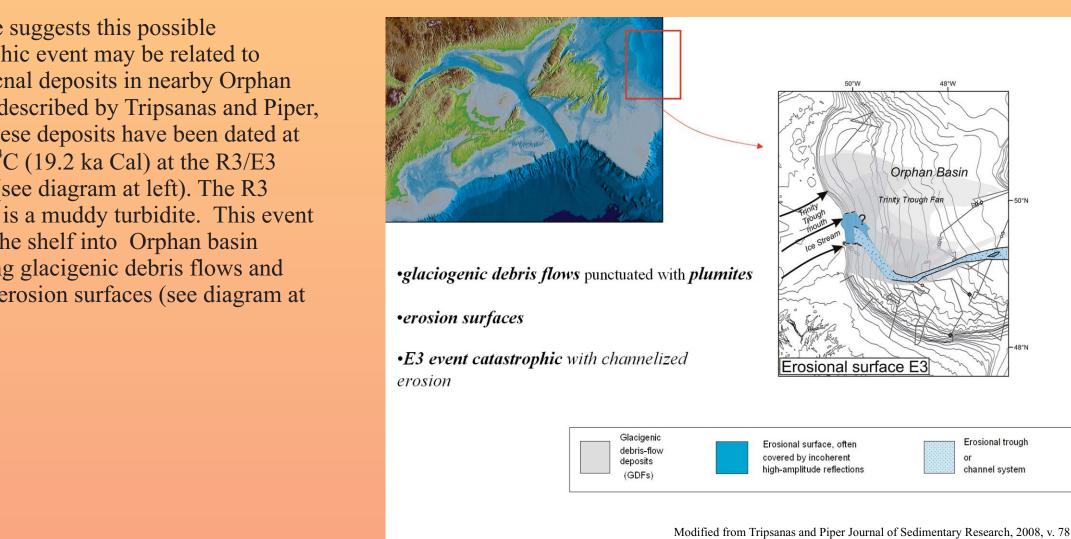
diagram at left). A piston core collected in 1989 in glacimarine sediment in front of and suggests a date of 16.0 ka ¹⁴C (19.2 ka Cal) at the base of the core. This glacimarine sediment was deposited after the moraine breach and flood and so gives a minimum age on the flood event. It is interpreted that the moraine formed by 16.1 ka ¹⁴C (19.3 ka Cal). The ice stream would have retreated to the edge of Catalina Basin (or further) allowing the deposition of glacimarine sediment.

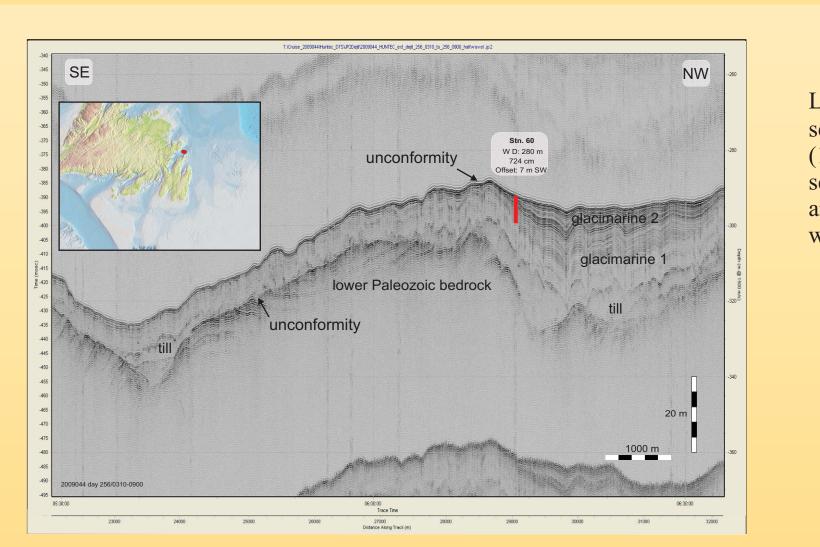
A disconformity and limited iceberg



where previous glacial ice positions occurred. Trinity moraine is a constructional feature that aggraded over

Evidence suggests this possible catastrophic event may be related to hyperpycnal deposits in nearby Orphan basin as described by Tripsanas and Piper, 2008. These deposits have been dated at 16.0 ka ¹⁴C (19.2 ka Cal) at the R3/E3 horizon (see diagram at left). The R3 horizons is a muddy turbidite. This event crossed the shelf into Orphan basin depositing glacigenic debris flows and creating erosion surfaces (see diagram at •Red (Rx) events: plumes and turbidites..... •maximum thickness connected to Trinity Trough follow voluminous GDF's when ice stream freshwater muddy turbidites (hyperpycnites) at:





Proposed ice positions at Trinity Moraine during flood event

Location of piston core 20010 020 PC0060 on Huntec boomer seismic traverse. The glacimarine section and unconformity were subsampled for radiocarbon dates. A radiocarbon age of 12.3 ka ¹⁴C (13.7 ka Cal) was assigned for the upper limit of the unconformity in Trinity Bay. This suggests that a second erosive event occurred in Trinity Trough after the retreat of the ice stream further into the Bay and may have been another flood event. This unconformity is identified in water depths of 280 m, well below the marine low stand.

•large volume semi-continuous glacigenic debris flows in Orphan Basin when ice stream was at shelf-break

•retreat from shelf-break to still-stand at tabular tills deposited with loss of dilatency, glacimarine deposited •retreat to Trinity moraine position with build-up; created a sub-glacial basin (Catalina Basin) • Ice thickens at moraine increasing sub-glacial pressure, sub-glacial lake forms

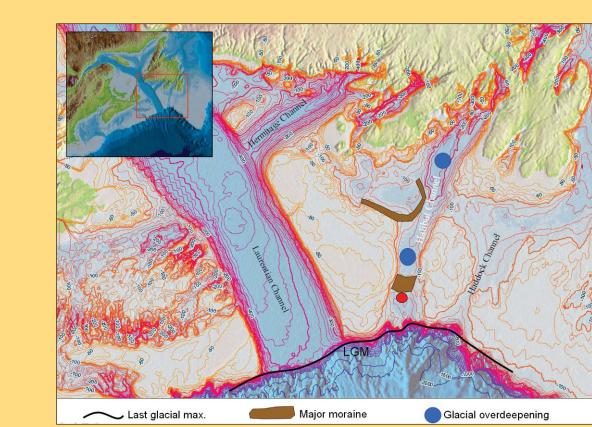
•Sub-glacial lake catastrophic discharge/jokulhaup and moraine breach at 16.0 ka ¹⁴C (19.2 ka Cal) •E3 erosion and channelization followed by R3 chocolate red mud turbidite in Orphan Basin

•Flushing/bypass or thin shelf deposits distal to moraine, some deposition near breach •Ice stream retreat to edge of Catalina Basin (or further)

•Correlative with debrites, iceberg scouring and unconformities in inner shelf basins •Younger unconformity at 12.3 ka ¹⁴C (13.7 ka Cal) may be due to another erosional flood

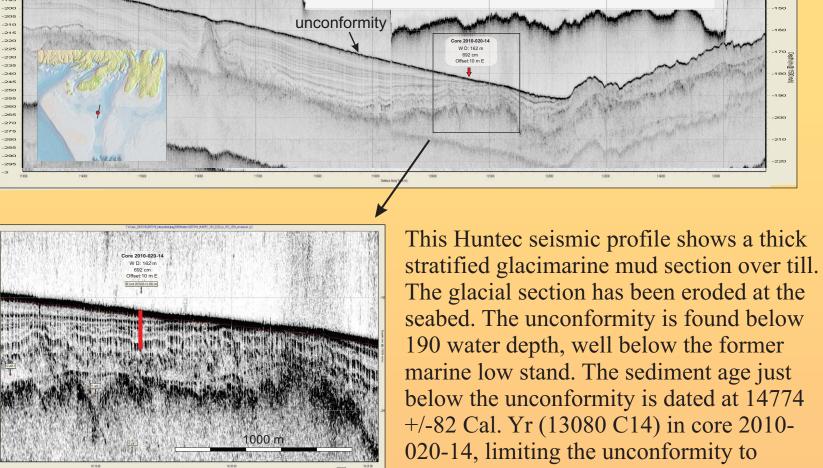
•Piper et al., 2006 described a large scale erosional flood event on Laurentian Fan, dated 16.5 ka ¹⁴C (19.5 ka

EVIDENCE OF A FLOOD IN HALIBUT CHANNEL



located on the Southwest Grand Banks, shows the location of two moraines and over-deepened basins and core and seismic cross-sections along with the position of the last glacial maximum. The approximate positions of the borehole and piston cores (red dot) in front of Halibut Moraine are also shown. Halibut Moraine is a constructional retreat moraine crossing Halibut Channel between St. Pierre Bank and Green Bank. St. Pierre moraine is a younger horseshoe shaped retreat moraine ound fringing Halibut Channel.

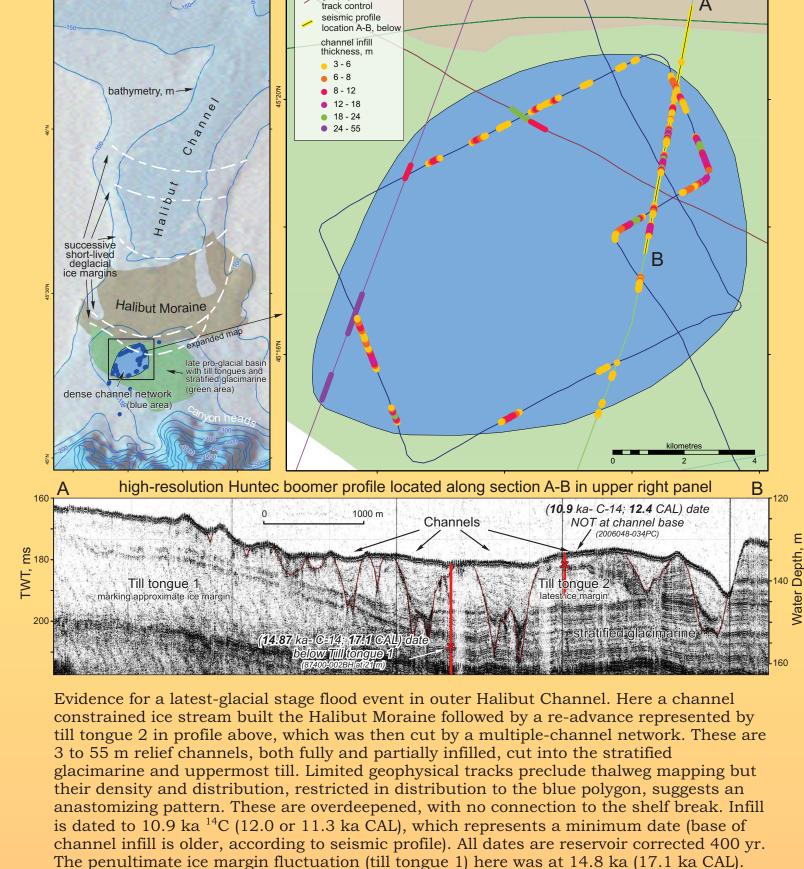
Map (at left) of Halibut Channel area



The glacial section has been eroded at the eabed. The unconformity is found below 90 water depth, well below the former narine low stand. The sediment age just below the unconformity is dated at 14774 -/-82 Cal. Yr (13080 C14) in core 2010-20-14, limiting the unconformity to within this age. See inset map for location of seismic sections.

Constricted subglacial waters cut channels in glacimarine and till tongue sediments seaward of the moraine complex found in Halibut Channel, after 14.0 ka ¹⁴C (16.3 ka Cal). This flood event is similar in age to flood deposits described by Piper et al., 2006, which they dated at 14.2 ka ¹⁴C (16.1 ka Cal) and is likely the same regional event. Glacial ice quickly retreated from Halibut channel by 13.8 ka ¹⁴C (15.9 ka Cal) depositing the inner St. Pierre Moraine and depositing glacimarine sediment above portions of it. A late glacial unconformity, dated 13.1 ka ¹⁴C (14.8 ka Cal) in glacimarine sediments, in inner Halibut Channel may have been created by constrained sheet erosion as glacial ice withdrew from the area. This erosion event may also have created a large sandwave field in inner Halibut channel, dated in overlying sediments at 12.1 ka ¹⁴C (13.6 ka Cal). This possible flood event would be constrained between these time periods and likely is the same flood event seen in Trinity Trough, which is

constrained at 12.3 ka ¹⁴C (13.7 ka Cal). These events would have contributed sediments to the



The channels have always remained sub-aqueous. These are interpreted to have formed

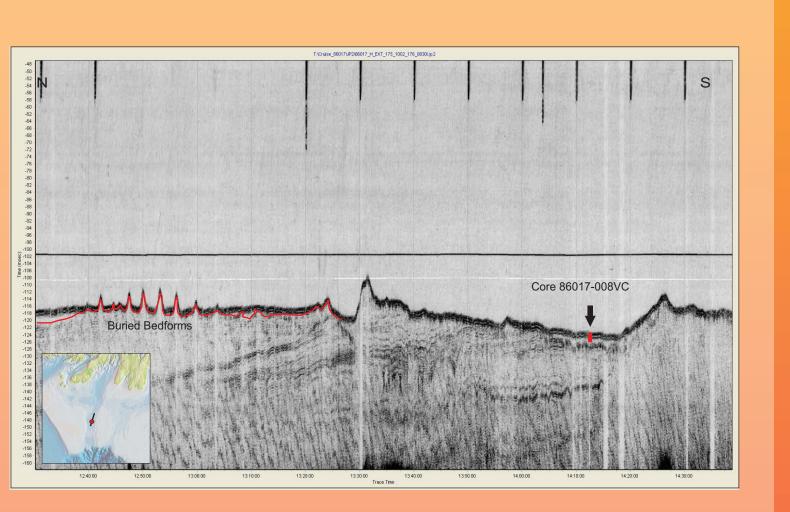
from a *catastrophic flood* either sub-glacially or as an immediately pro-glacial plunge-pool.

CAL) so the flood event timing is suggested at ca. 14 ka (16.3 ka CAL). As with Laurentian

Deglaciation was rapid; the margin was ringing the innermost shelf by 13.8 ka (15.9 ka

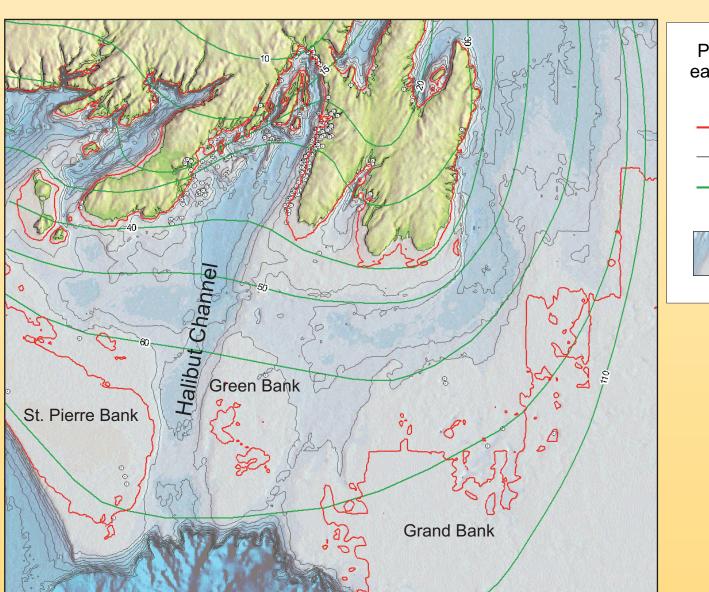
and Trinity ice stream collapse, the lasted recorded glacial event was a flood.

A Halibut Channel Flood Event ca. 14 ka (16.3 CAL)



Huntec boomer profile showing core 86017-008VC location and buried bedforms. Age of the overlying sediment burying the bedforms has been dated at 12125 ¹⁴C. These bedforms are likely similar in age and

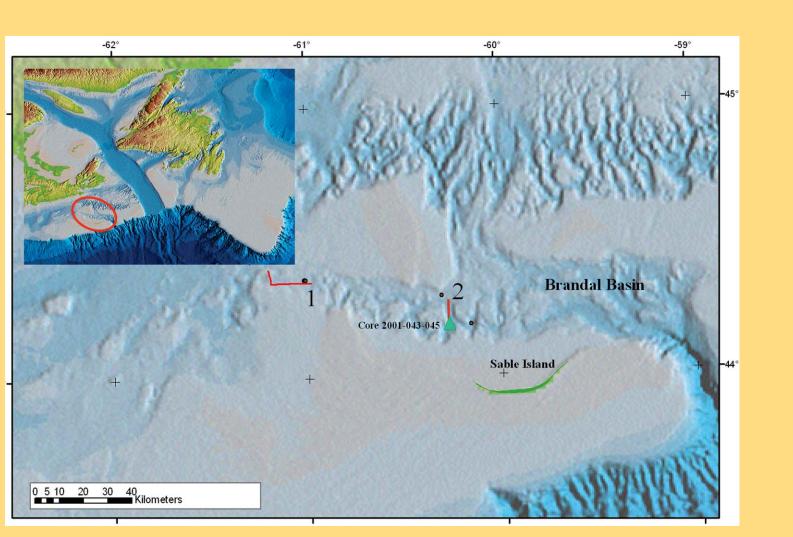
origin to the unconformity found in inner Halibut Channel. See inset map for location of seismic profile.



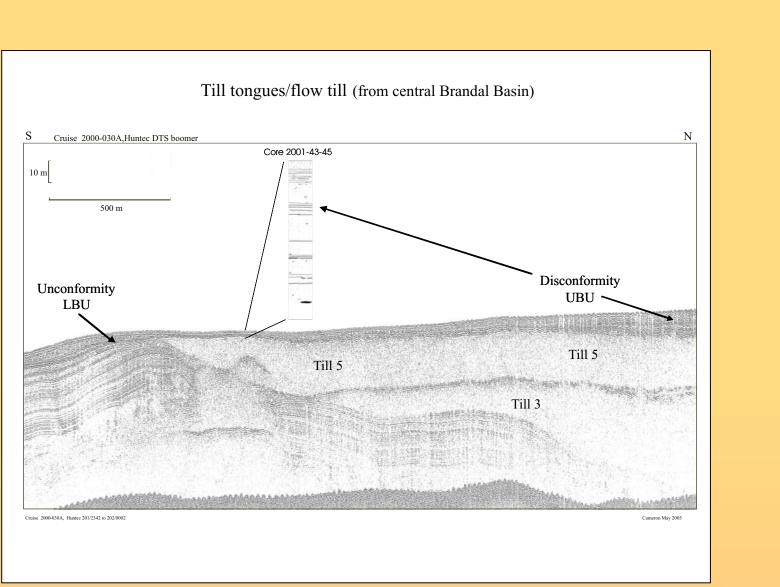
Paleo-topography at time of earliest post-glacial low-stand (with some time transgression) Paleo-shoreline Paleo-bathymetry, 40 m C.I. Low-stand Isopleths Control for Low-stand elevations Present Topography/

Paleo-topographic reconstruction of the southeast Grand Banks centered on Halibut Channel. This reconstruction was derived from low water elevation indicators such as submerged shorelines, beaches, delta and shallow unconformities. Low-stand opleths represent earliest post-glacial crustal elevation. All elevations inside the red paleoshoreline would have been above sea-level. Much of the Grand Banks, St. Pierre Bank and some of Green Banks would have been islands. This paleotopographic reconstruction suggests that bottom currents may not have solely accounted for the development of the sea floor unconformity in Halibut channel and is more likely due to glacial sheet

FLOOD EVENTS IN BRANDAL BASIN



Map of Brandal Basin located on the Scotian Shelf near Sable Island, shows a glacially enhanced basin with numerous topographically constraining channels and highs. Brandal Basin is connected to The Gully, a deep sea canyon which is a direct route to the continental slope and deep-sea. The location of two seismic cross-sections along with the position of piston core 2001-043-45 is also shown.



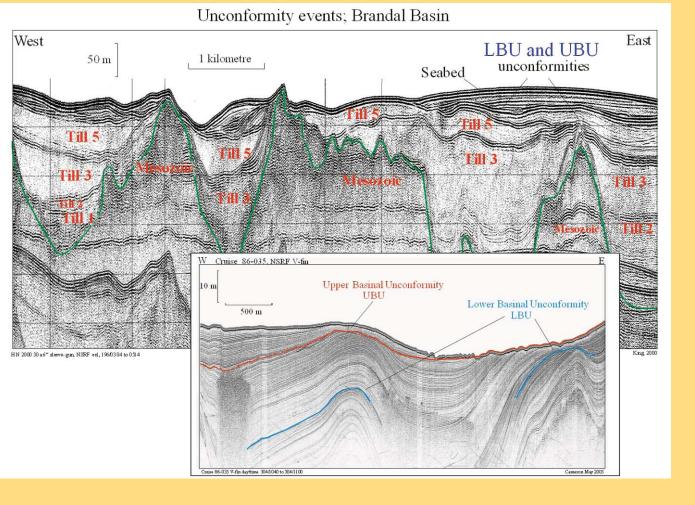
Huntec seismic north-south cross-section (see map cross-section 2 for location) shows a well stratified glacimarine sequence with two till-tongues inter-stratified in the section. One lower unconformity (LBU) and one disconformity (UBU, equal to upper unconformity found else where in the basin) are identified in the section. The LBU is related to the timing of till tongue deposition.

•Two Brandal Basin basinal unconformities, LBU and UBU •Short-lived rigorous basin-wide erosional event for UBU Both are strong current-related immediately followed by quiescence sedimentation

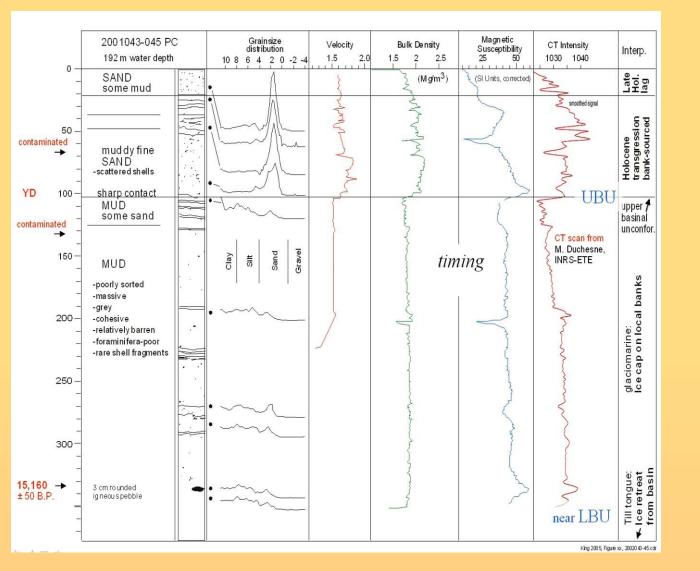
•Within a topographically constrained corridor (island and hydraulic constriction point) • Catastrophic glacial outburst would explain episodic nature of unconformities

Pene-synchronous with ice-regime reorganization •Evidence from nearby Emerald Basin suggests oceanographic bottom currents and

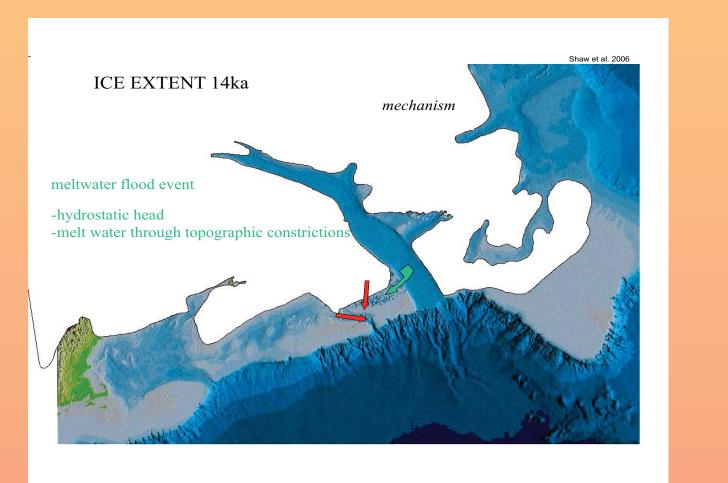
topographic constraints may not have played a role in creating unconformities. •Basin is swept clean of eroded sediment, which was delivered to the slope through The Gully (a deep-sea canyon)



Airgun seismic cross-section (see map section 1 for location) shows numerous small basins cut into Mesozoic bedrock. These basins have been infilled by a succession of glacially derived till and stratified glacimarine sediment. Two unconformities are identified in the section which has eroded into glacimarine sediment. The lower unconformity is discontinuous while the upper unconformity is continuous and may be found at the seafloor (see inset above of Huntec seismic profile from the same section). These unconformities may have occurred from glacial floods.



Piston Core 2001-43-45 sampled stratified glacimarine sediment to the top of the upper till tongue. The lower unconformity has been dated at 15.2 ¹⁴C ka (18.2 ka Cal). The upper unconformity was dated by King, et al., 1994 in nearby Emerald Basin at 10.6 ¹⁴C ka (12.5 ka Cal), a late glacial erosional event.



A possible model modified from Shaw, et al., 2006 that suggests how flood waters developed from retreating ice events and are driven through topographic pinch-

points. Which is a likely scenario for flood waters through Brandal Basin.

DISCUSSION

Time ka Radiocarbon	Brandal Basin	Laurentian Channel/Fan	Halibut Channel	Trinity Trough/Fan
10	• 10.6 ¹⁴ C ka (12.5 ka Cal) upper unconformity King et al., 1994		• 10.9 ¹⁴ C ka (12.4 ka Cal) within channel fill Unconformity Flood	
13			12.1 ¹⁴ C ka (13.6 ka Cal) top of buried bedforms 13.1 ¹⁴ C ka (14.8 ka Cal) unconformity	12.3 ¹⁴ C ka (13.7 ka Cal) unconformity, inner trough
14		Outburst Flood 14.2 ¹⁴ C ka (16.1 ka Cal) Laurentian Fan, Piper et al., 2006	13.8 ¹⁴ C ka (15.9 ka Cal) inner shelf, Shaw et al., 2006 14.0 ¹⁴ C ka (16.3 ka Cal) estimated age of moraine flood	
15	15.2 ¹⁴ C ka (18.2 ka Cal) lower unconformity	1 tper et at., 2000	14.8 ¹⁴ C ka (17.1 ka Cal) below till tongue	Catastrophic Flood(s
16		Catastrophic Flood(s) 16.5 ¹⁴ C ka (19.5 ka Cal) Laurentian Fan, Piper et al., 2006		16.0 ¹⁴ C ka (19.2 ka Cal) moraine breach and mud turbidite, Orphan Basin, <i>Tripsanas and Piper, 2008</i>
1,				

Unconformity flood events are similar in age with an estimated age between 12.1 ¹⁴C ka (13.6 ka Cal) and 13.1 ¹⁴C ka (14.8 ka Cal) in Halibut channel and 12.3 ¹⁴C ka (13.7 ka Cal) in Trinity Trough (see table). This implies similar timing for a regional flood event, suggesting a broad based change in ice conditions possibly due to change in climate conditions. The derived sediments partially or completely by passed the shelf and were delivered to the slope.

The Outburst flood event in Halibut Channel, with an estimated age of 14.0 ¹⁴C ka (16.3 ka Cal) is similar in age to a flood event described by Piper et al., 2006 in Laurentian Fan dated at 14.2 ka ¹⁴C (16.1 ka Cal) (see table). This implies similar timing for regionally base events. This flood event carved channels into glacial sediments in front of the Halibut Moraine and delivered sediments to the slope. This occurred during an overall retreat of the ice stream in Halibut channel and likely Laurentian Channel.

The catastrophic moraine breaching flood event in Trinity Trough dated at 16.0 ¹⁴C ka (19.2 ka Cal) is similar in age to muddy turbidite deposits described by Tripsanas and Piper, 2008 in Orphan Basin (see table). This connection between this catastrophic flood and hyperpycnal flows, confirms that these types of flood events deliver significant volumes of sediment to the slope. The timing of this flood is more broadly similar in age to another flood event on the Laurentian fan described by Piper et al., 2006 which was dated at 16.5 ¹⁴C ka (19.5 ka Cal). This would suggest regional flood events and changes in ice conditions and likely climate.

Two unconformities dated at 10.0 ¹⁴C ka (12.5 ka Cal) and 15.2 ¹⁴C ka (18.2 ka Cal) are interpreted as evidence of melt water erosion of glacimarine sediments in Brandal Basin. The older unconformity is associated with till tongue deposited by glacial ice and is localized to highs in section. The younger basin wide unconformity is usually found at the sea floor and formed by sheet erosion during a basin wide flood event. Most of the eroded material was delivered to the slope since little is found within the basin.

CONCLUSIONS

• Erosional and depositional elements in large shelf crossing troughs can be attributed to constrained, channelized and episodic floods.

• Floods are important mechanisms in delivering sediment across the shelf and into ocean basins

• Shelf crossing troughs are important as sediment transport conduits, delivering large volumes of sediment to ocean basins

Ice stream retreat is punctuated by catastrophic flood and erosional events

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