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

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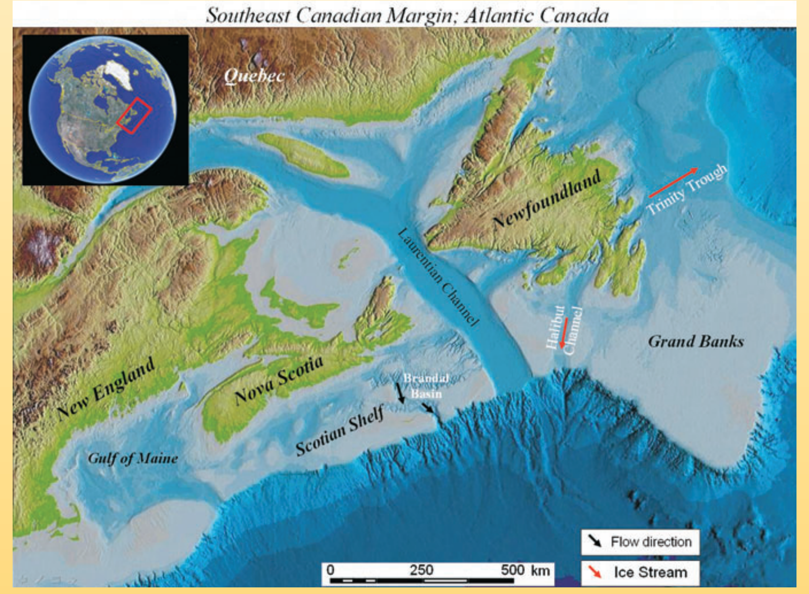
INTRODUCTION

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

Overdeepened 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, mid-axis 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 ^{14}C ka.

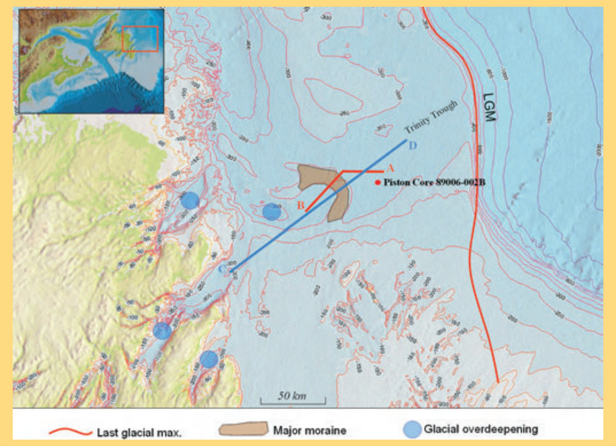
We will attempt to show, through interpreted high resolution seismic profiles and core data from Trinity Trough, Halibut Channel and Brandal Basin, how the above indicators can be attributed to flood events that allowed sediment flux to deep ocean basins .

Southeast Canadian Margin: Atlantic Canada



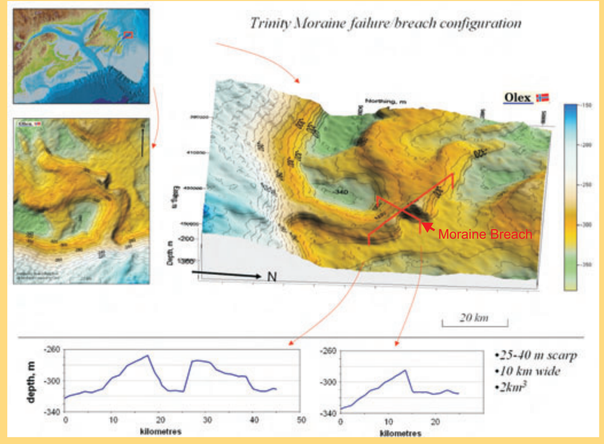
Trinity Trough, Halibut Channel and Brandal Basin, their locations shown on the above map, are shelf crossing troughs and basins featured in this study.

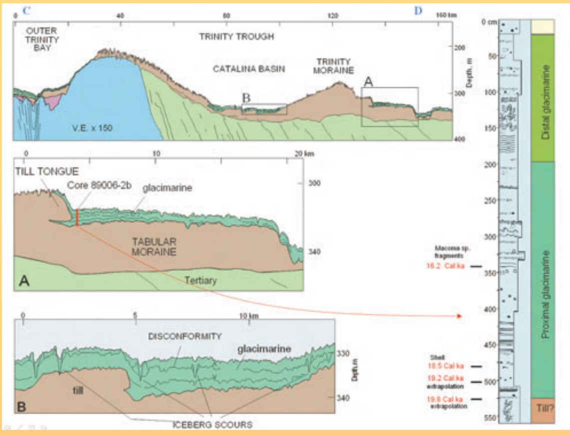
HAS A CATASTROPHIC FLOOD OCCURRED IN TRINITY TROUGH/FAN?



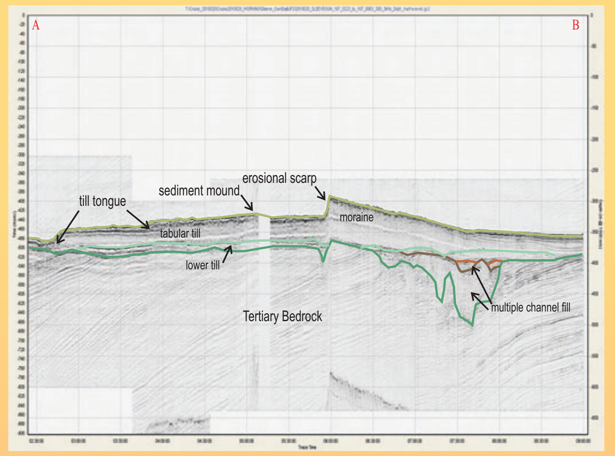
Map of Trinity Trough located on the Northeast Newfoundland Shelf, shows the location of Trinity Moraine, over-deepened basins and core and seismic cross-sections along with the position of the last glacial maximum. Orphan Basin is location seaward of this line.

A giant moraine breaching, located in Trinity Trough may have been from a rapid outburst flood release of a sub-glacial lake found in Catalina basin, an over-deepened basin within the trough. This sudden release of sub-glacial water occurred when the moraine collapsed removing ca 2 km^2 of sediment (see diagram at left). This collapse created a slope of 7 degrees on a 25-40 km scarp face.

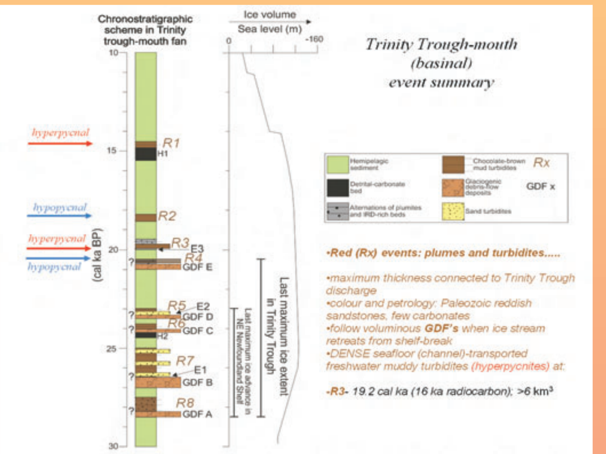




A disconformity and limited iceberg scoured sediment behind Trinity Moraine may be related to this flood event (see diagram at left). A piston core collected in 1989 in glacimarine sediment in front of the moraine has been radiocarbon dated and suggests a date of 16.0 ka ^{14}C (19.2 ka Cal) at the base 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 ^{14}C (19.3 ka Cal). The ice stream would have retreated to the edge of Catalina Basin (or further) allowing the deposition of glacimarine sediment.

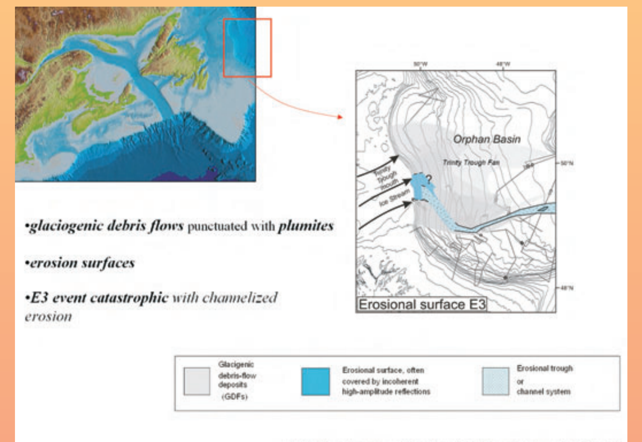


Sleeve gun profile collected in 2010 cross Trinity Moraine through the breach shows multiple channel fill in tertiary bedrock below the moraine, evidence of previous floods. Till tongues seaward of the moraine show where previous glacial ice positions occurred. The Trinity moraine is construction features that aggraded over time.



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

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 ^{14}C (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 right).



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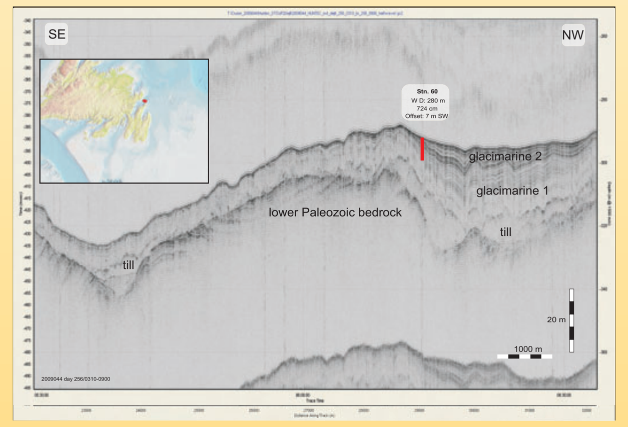
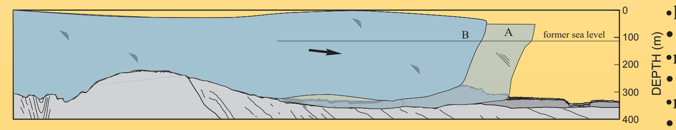
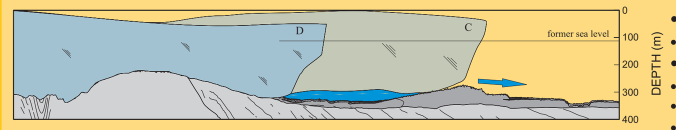


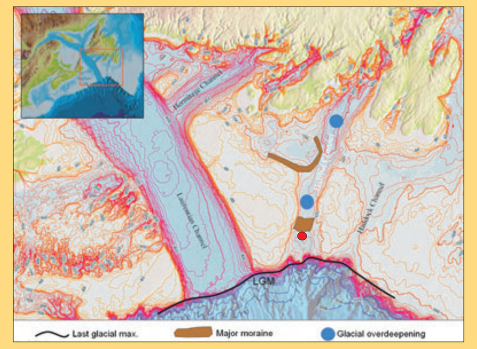
Location of piston core 20010 020 PC0060 on Huntec boomer seismic traverse. The glacimarine section and unconformity were subsampled for radiocarbon dates. A radiocarbon age at 12.3 ka ^{14}C (13.7 ka Cal) was assigned for the upper limit of the unconformity in Trinity Bay. This suggests that a second 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.



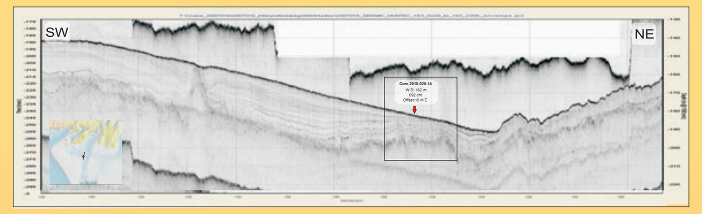


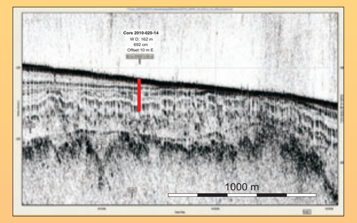
- •large volume semi-continuous glacigenic debris flows in Orphan Basin when ice stream was at shelf-break
- •retreat from shelf-break to still-stand at tabular tills deposited with loss of dilatency, glacimarine deposited
- •retreat to Trinity moraine position with build-up; created a sub-glacial basin (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 ^{14}C (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 ^{14}C (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 ^{14}C (19.5 ka Cal)

IS THERE EVIDENCE OF A FLOOD IN HALIBUT CHANNEL?



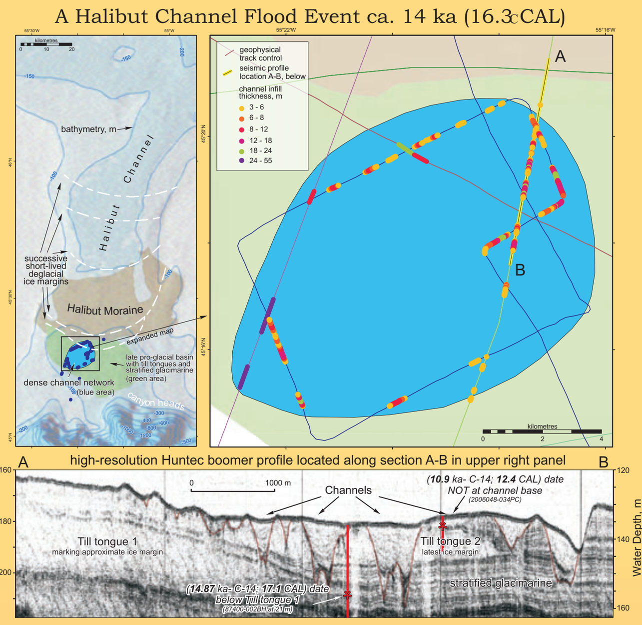
Map (at left) of Halibut Channel area located on the Southwest Grand Banks, shows the location of two moraines and over-deepened basins and core and seismic cross-sections along with the position of the last glacial maximum. The approximate positions of the borehole and piston cores (red dot) in front 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 found fringing Halibut Channel.





This Huntec seismic profile shows a thick stratified glacimarine mud section over till. The glacial section has been eroded at the seabed. The unconformity is found below 190 water depth, well below the marine low stand. The sediment age just below the unconformity is dated at 14774 +/-82 Cal. Yr (13080 C14) in core 2010-020-14, limiting the unconformity to within this age.

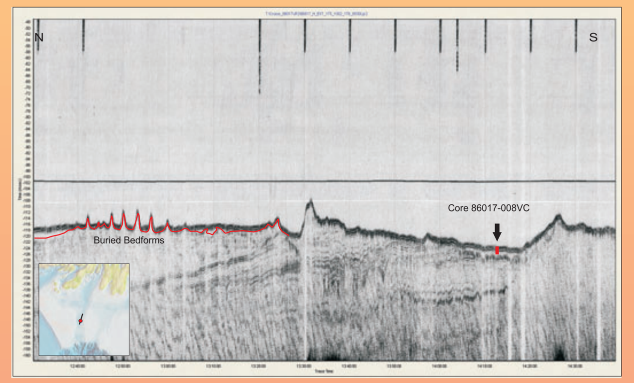
A Halibut Channel Flood Event ca. 14 ka (16.3 CAL)



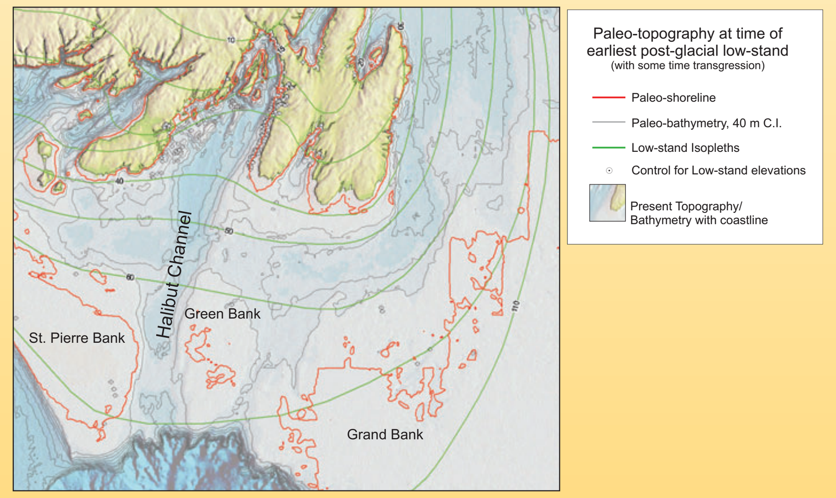
Evidence for a latest-glacial stage flood event in outer Halibut Channel. Here a channel constrained ice stream built the Halibut Moraine followed by a re-advance represented by till tongue 2 in profile above, which was then cut by a multiple-channel network. These are 3 to 55 m relief channels, both fully and partially infilled, cut into the stratified glacimarine and uppermost till. Limited geophysical tracks preclude thalweg mapping but their density and distribution, restricted in distribution to the blue polygon, suggests an anastomizing pattern. These are overdeepened, with no connection to the shelf break. Infill is dated to 10.9ka ^{14}C (12.0 or 11.3 ka CAL), which represents a minimum date (base of channel infill is older, according to seismic profile). All dates are reservoir corrected 400 yr. The penultimate ice margin fluctuation (till tongue 1) here was at 14.8 ka (17.1 ka CAL). 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. Deglaciation was rapid; the margin was ringing the innermost shelf by 13.8 ka (15.9 ka CAL) so the flood event timing is suggested at ca. ***14*** ka (***16.3*** ka CAL). As with Laurentian and Trinity ice stream collapse, the lasted recorded glacial event was a flood.

Constricted subglacial waters cut channels glacimarine and till tongue sediments seaward of the moraine complex found in Halibut Channel , after 14.0 ka ^{14}C (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 ^{14}C (16.1 ka Cal) and is likely the same regional event.

Glacial ice quickly retreated from Halibut channel by 13.8 ka ^{14}C (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 ^{14}C (14.8 ka Cal) in glacimarine sediments, in inner Halibut Channel and 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 ^{14}C (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 ^{14}C (13.7 ka Cal). These events would have contributed sediments to the slope.

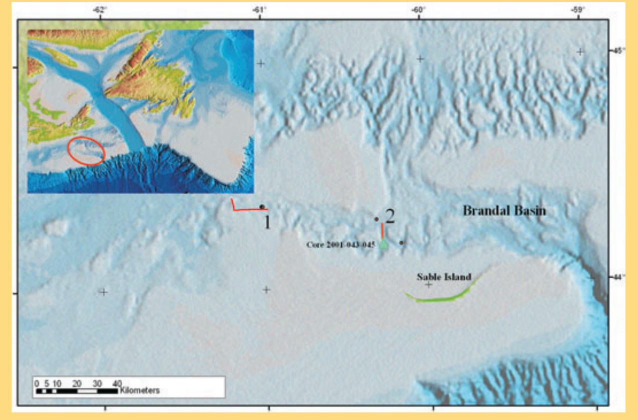


Huntec boomer profile showing core 86017-008VC location and buried bedforms. Age of the overlying sediment burying the bedforms has been dated at 12125 C14. These bedforms are likely similar in age and origin to the unconformity found in inner Halibut Channel.

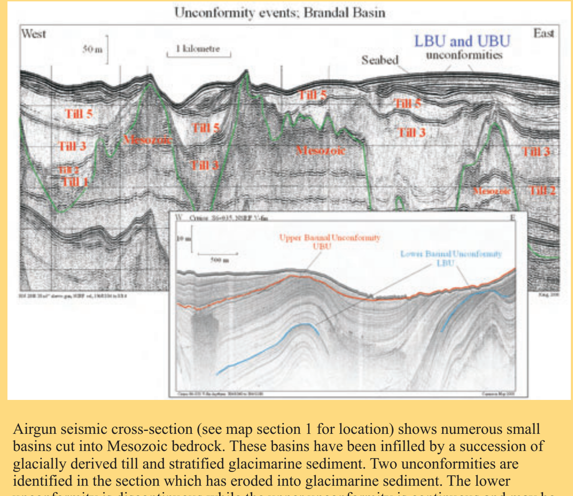


Paleo-topographic reconstructions of the southeast Grand Banks centered on Halibut Channel. This reconstruction was derived from low water elevation indicators such as submerged shorelines, beaches, delta and shallow unconformities. Low-stand isopleths represent earliest post-glacial crustal elevation. All elevations inside the red paleo-shoreline would have been above sea-level. Much of the Grand Banks, St. Pierre Bank and some of Green Banks would have been islands. This paleo-topographic 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 flooding.

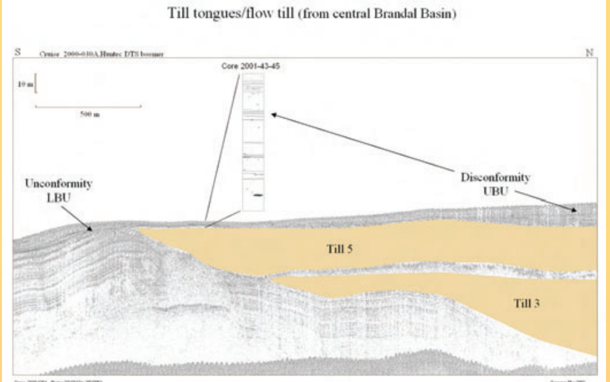
FLOOD EVENTS IN BRANDAL BASIN ?



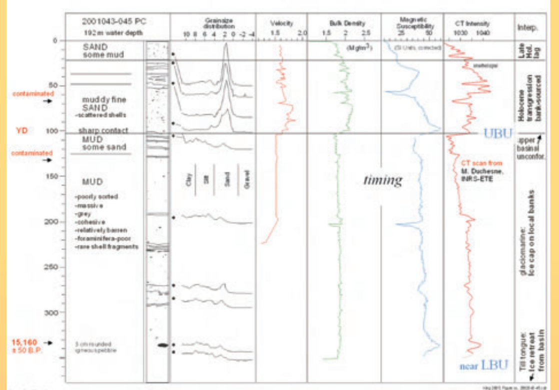
Map of Brandal Basin located on the Scotian Shelf near Sable Island, shows a glacially enhanced basin with numerous topographically constraining channels and highs. Brandal Basin is connected to The Gully, a deep sea canyon which is a direct route to the continental slope and deep-sea. The location of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



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.

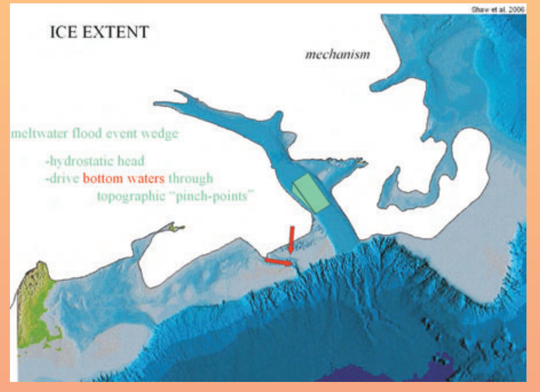


Huntec seismic north-south cross-section (see map cross-section 2 for location) shows a well stratified glacimarine sequence with two till-tongue inter-stratified in the section. One lower unconformity (LBU) and one disconformity (UBU, equal to upper unconformity found else where in the basin) are identified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



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 ^{14}C ka (18.2 ka Cal). The upper unconformity was dated by King, et al., 1994 in nearby Emerald Basin at 10.6 ^{14}C ka (12.5 ka Cal), a late glacial erosional event.

- ●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)



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/Distance

Time ka Radiocarbon	Brandal Basin	Laurentian Channel/Fan	Halibut Channel	Trinity Trough/Fan
10				
11	**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	
12			***Unconformity Flood*** **12.1 ^{14}C ka (13.6 ka Cal)** top of buried bedforms	**12.3 ^{14}C ka (13.7 ka Cal)** unconformity, inner trough
13			**13.1 ^{14}C ka (14.8 ka Cal)** unconformity; **13.8 ^{14}C ka (15.9 ka Cal)** inner shelf, *Shaw et al., 2006*	
14		***Outburst Flood*** **14.2 ^{14}C ka (16.1 ka Cal)** Laurentian Fan, *Piper 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		**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, *Tripsanas and Piper, 2008*
17				

Unconformity flood events are similar in age with an estimated age between 12.1 ^{14}C ka (13.6 ka Cal) and 13.1 ^{14}C ka (14.8 ka Cal) in Halibut channel and 12.3 ^{14}C 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 ^{14}C 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 ^{14}C (16.1 ka Cal) (see table). This implies similar timing for regionally base events. This flood event carved channel 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 ^{14}C ka (19.2 ka Cal) is similar in age to muddy turbidite deposit 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 at16.5 ^{14}C 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

- ●We suggest that erosional and depositional elements in large shelf crossing troughs can be attributed to constrained, channelized and episodic floods that may have contributed to slope and rise deposits during the late glacial
- 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 events

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Acknowledgments

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