Deep-water Sedimentation Patterns Seaward of Shelf-crossing Glaciations, Eastern Canadian Margin*

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Abstract

Studies of the Late Quaternary of the eastern Canadian continental margin show a distinctive style of deep-water sedimentation that is directly related to inputs of sediment and water from shelf-crossing glaciation. Principal sediment input was through transverse troughs occupied by ice streams. This study proposes a synthesis of sediment depositional facies and architecture resulting from proglacial sediment supply through transverse troughs. Coarse sediment is principally transferred across the slope, but a high proportion of fine-grained sediment is transported along slope in meltwater plumes. The high rates of deposition from such plumes favour sediment instability on the down-current side of transverse troughs. Three end-member processes are recognised on submarine fans seaward of transverse troughs: (1) glacigenic debris flows; (2) turbidity current deposition of channel-levee complexes; and (3) blocky mass-transport deposits resulting from debris avalanches. High meltwater discharge appears responsible for increased supply of fluid glacial diamict (till) that on gentler slopes (<2.5 degrees) creates glacigenic debris flows but on steeper slopes breaks up, entrains water, and transforms to create erosive turbidity currents. The relative importance of hyperpycnal meltwater appears greater at lower than at higher latitudes. Meltwater cuts broad flat-floored valleys and sculpts residual buttes. Based on erosional morphology, a wide range of scales of deposition from meltwater discharge may take place. Discharge of abundant hyperpycnal and hypopycnal muds leads to prominent asymmetric leveed channels in some systems. Basin-floor turbidites are principally the result of hyperpycnal meltwater flows producing sheet like deposits with a braided morphology. Some slump-generated turbidites deposit on the basin floor, but others deposit most of the load near the base of slope.

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Objective and outline

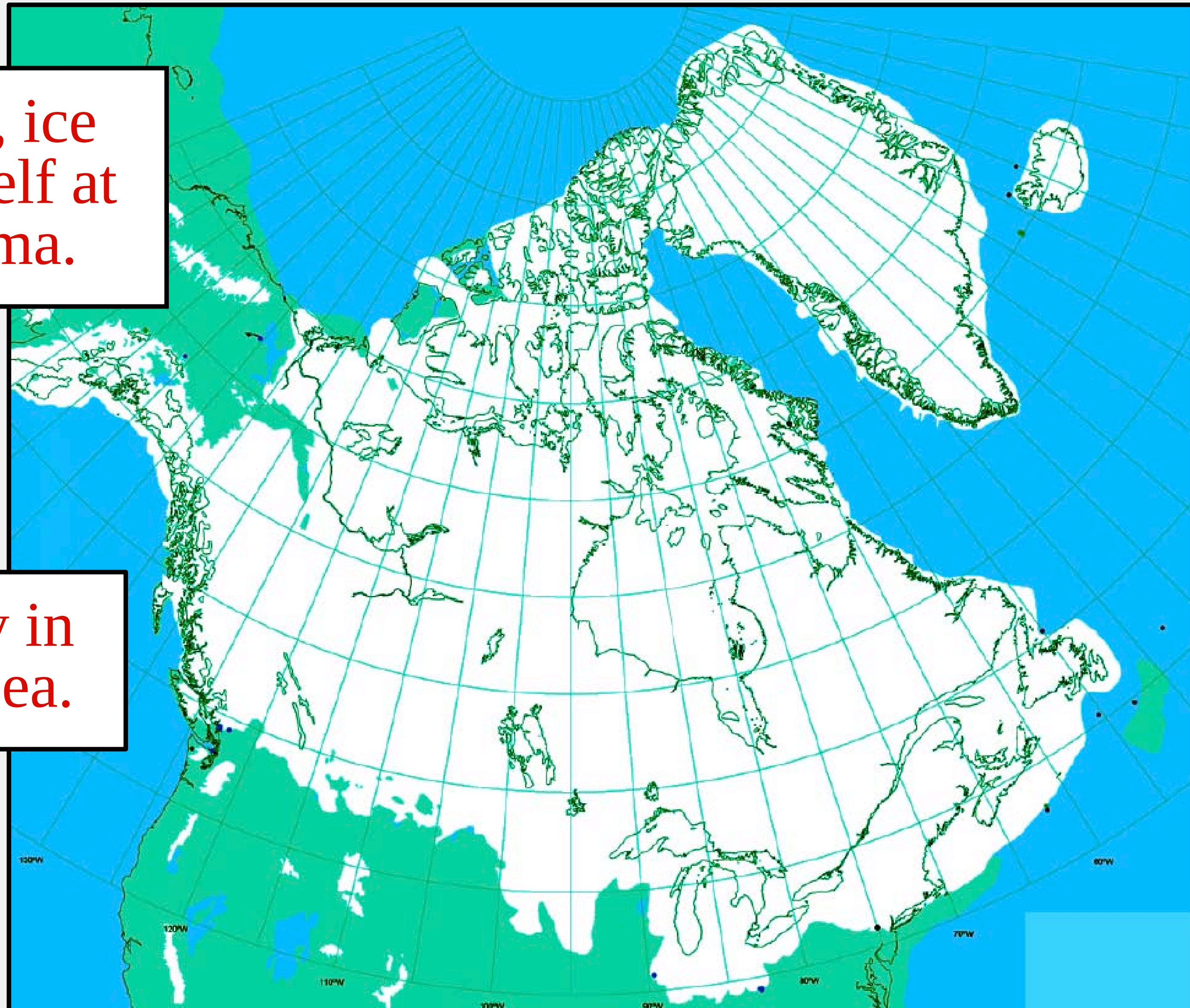
To develop a depositional facies model from studies of Late Quaternary deep-water sediments

- The regional context
- The importance of ice streams
- End-member processes on submarine fans
- Deposits on the basin floors
- Latitudinal variation

Ice-margin facies distribution

- Deposition of glacial till on the upper slope and the formation of glacigenic debris flows where low slopes seaward of ice streams
- Hyperpycnal subglacial meltwater discharges erode canyons, transport coarse sediment to the basin floor, likely a complex “braided” depositional pattern. Only minor over-bank sands.
- Sediment failure
  - large scale MTDs
  - small scale failures of proglacial sediment producing turbidity currents
- Sediment plumes giving draped sediments at several metres/ka.

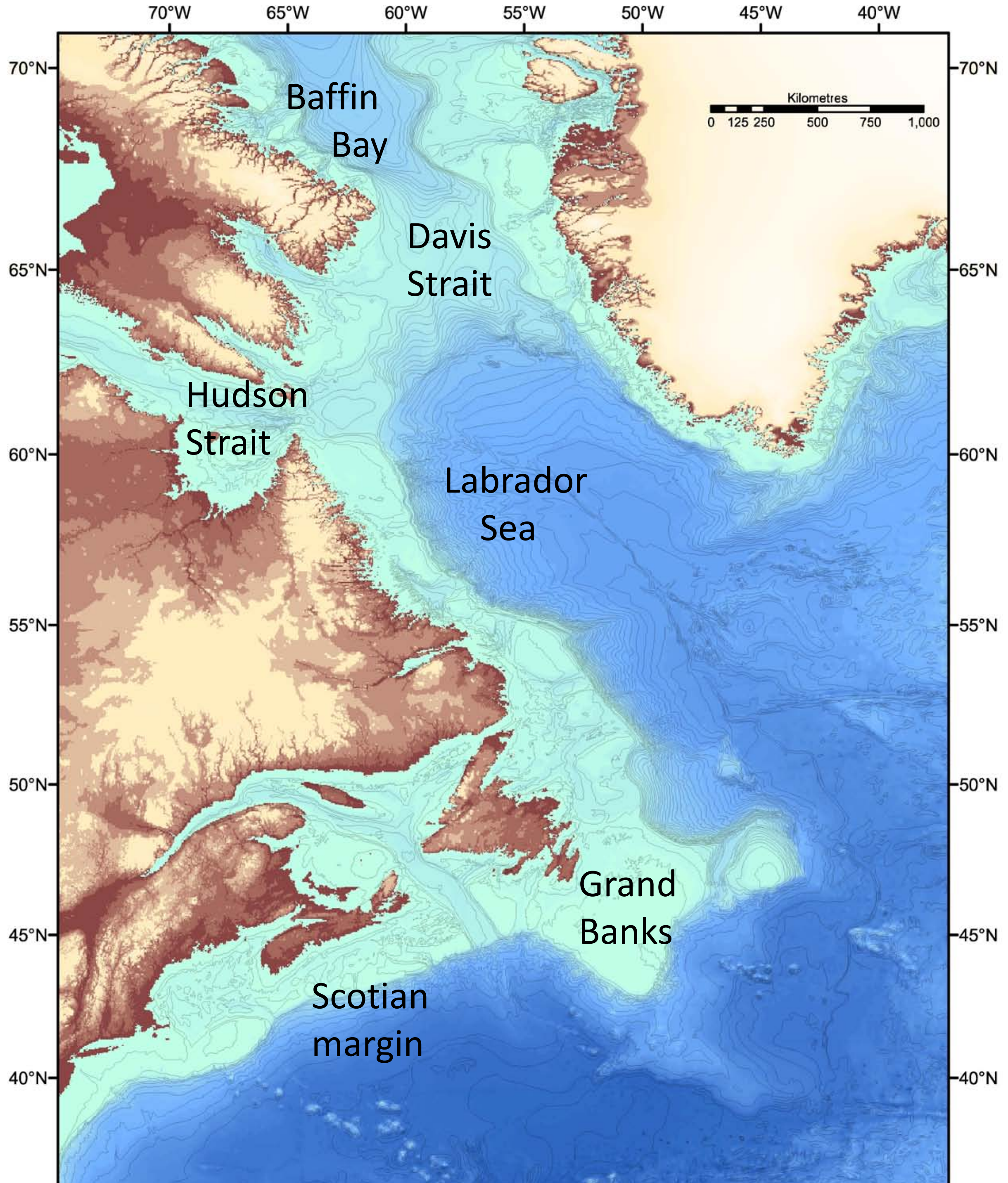
The regional context:
Glaciated Canadian margins



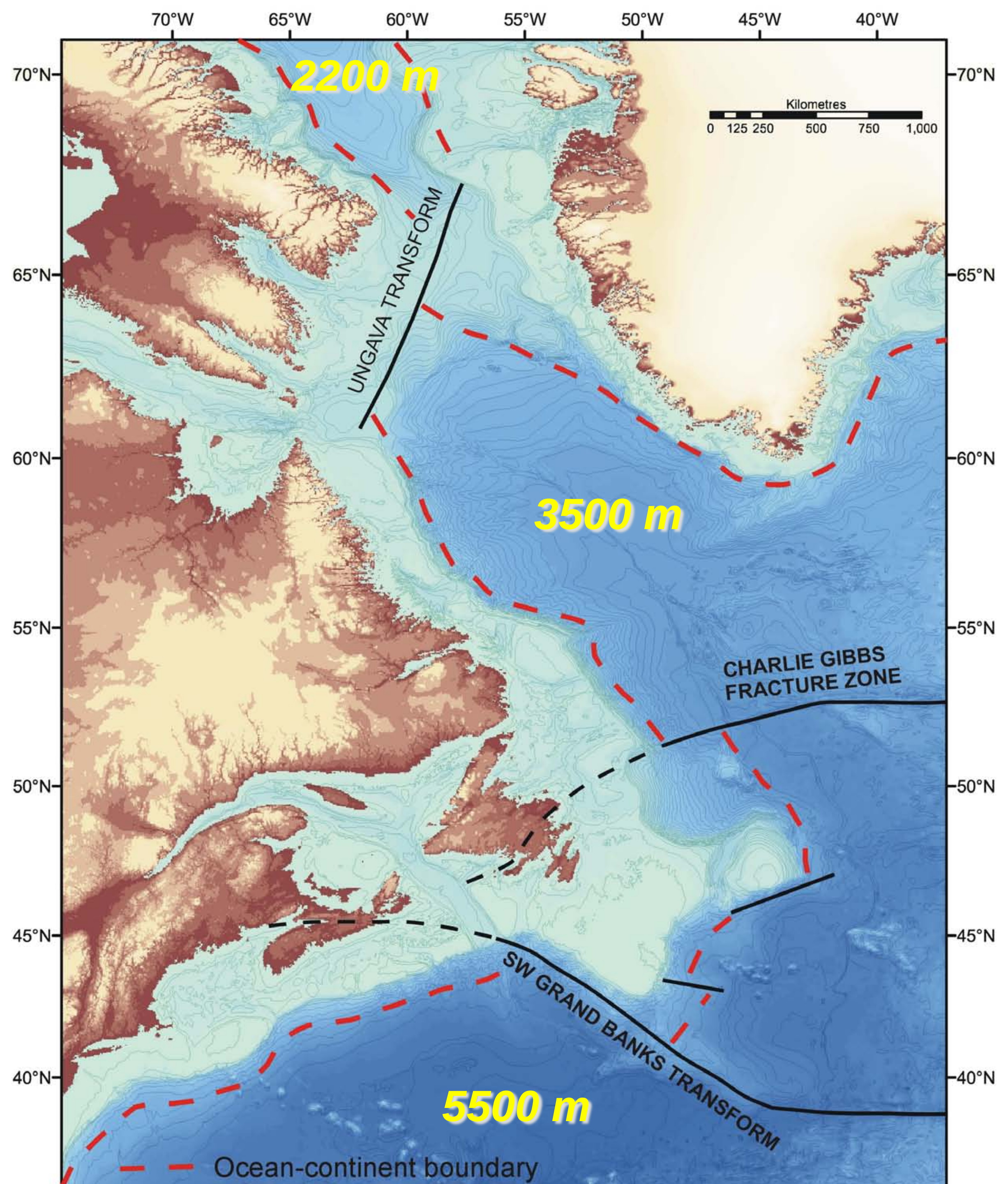
In most areas, ice crossed the shelf at glacial maxima.

Different story in the Beaufort Sea.

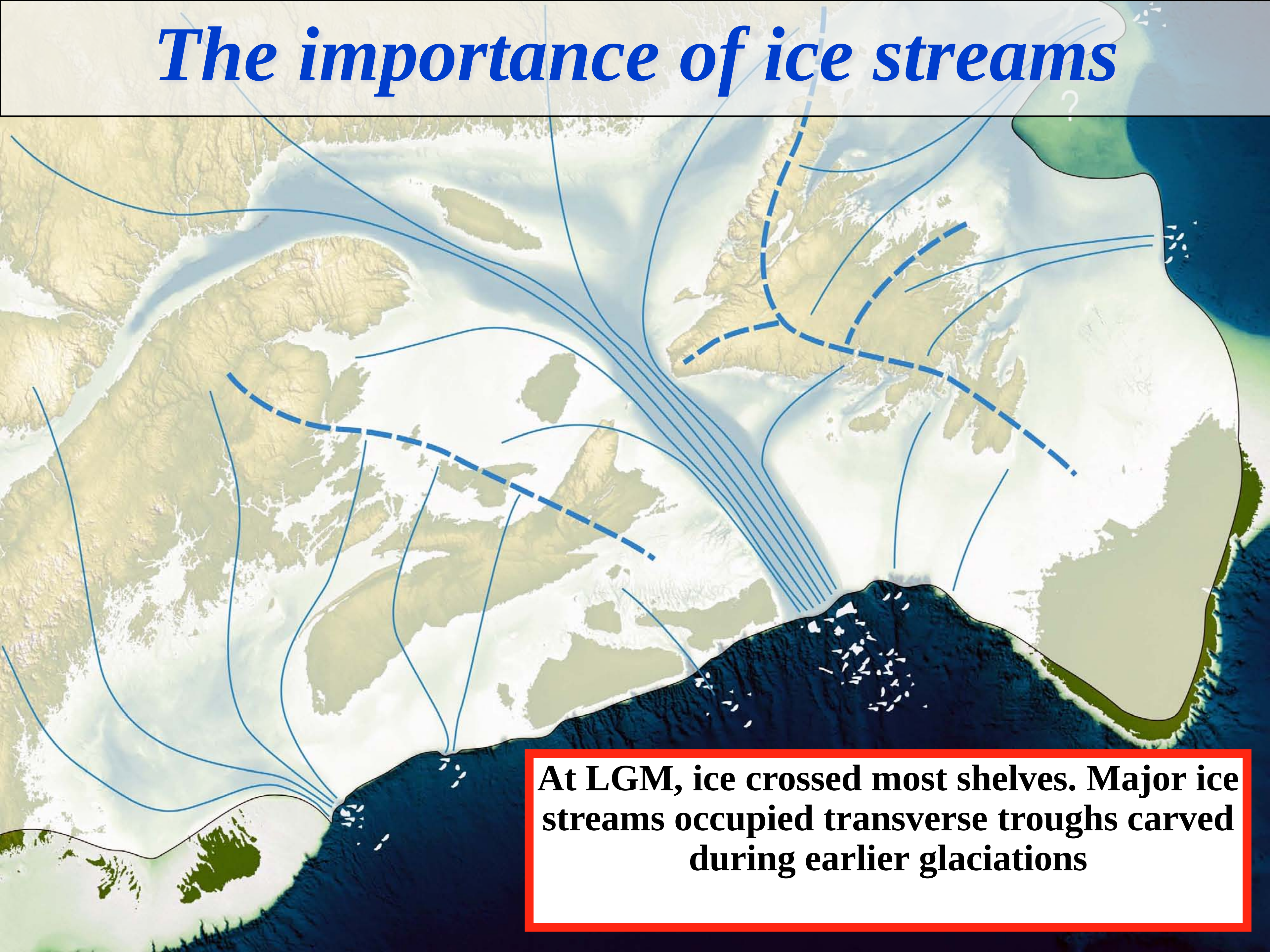
- Entire eastern Canadian margin was glaciated



- Entire eastern Canadian margin was glaciated
- Basin floors shallow from south to north as a result of progressively younger sea-floor spreading

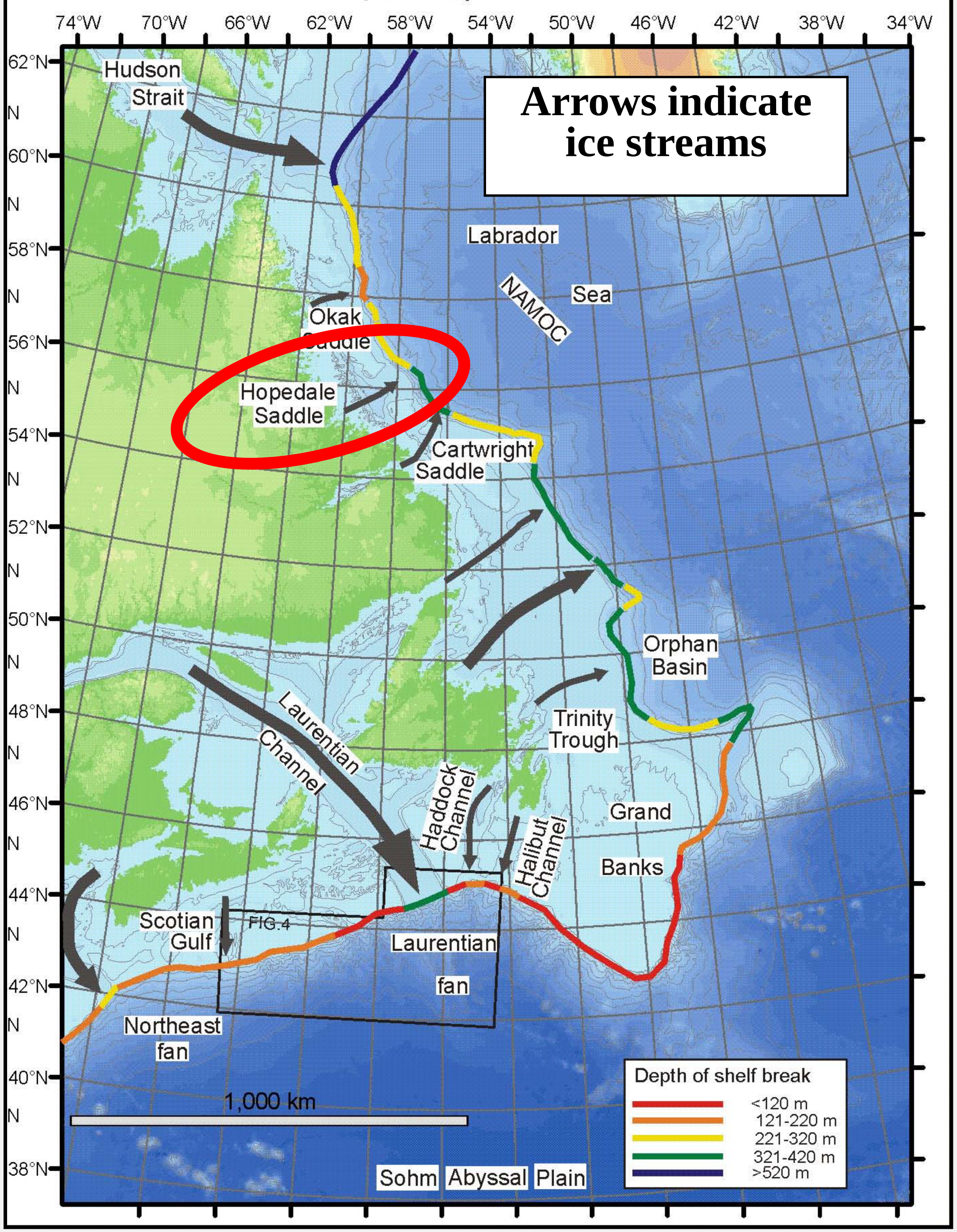


The importance of ice streams



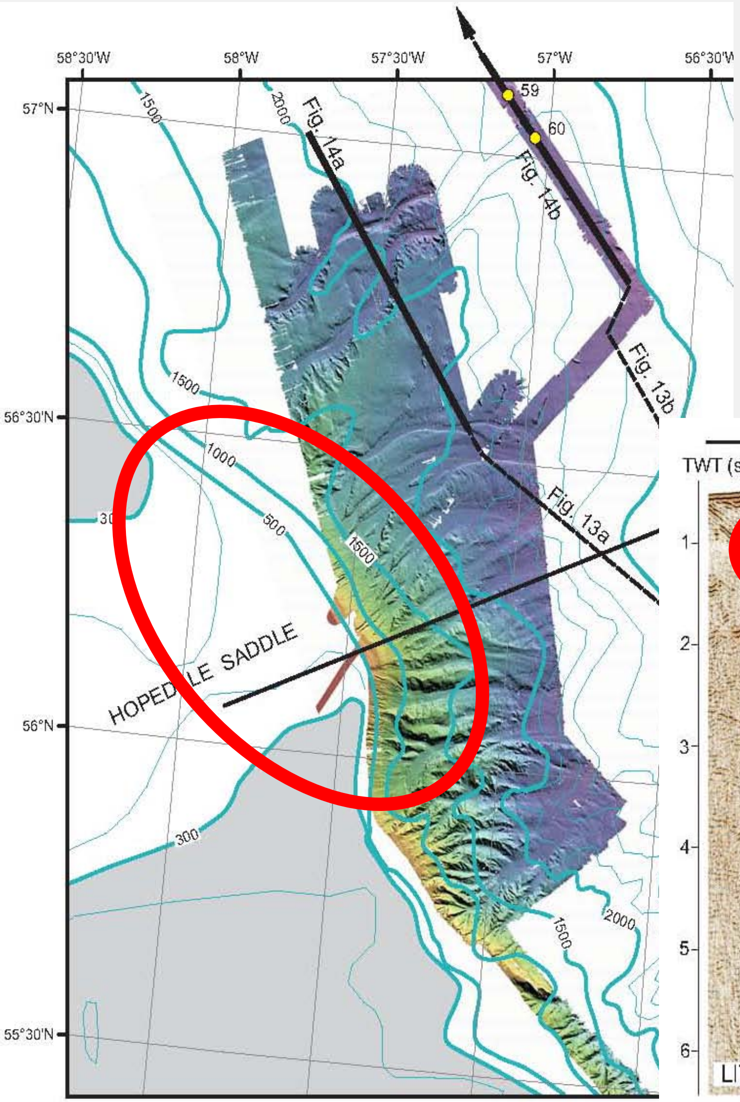
At LGM, ice crossed most shelves. Major ice streams occupied transverse troughs carved during earlier glaciations

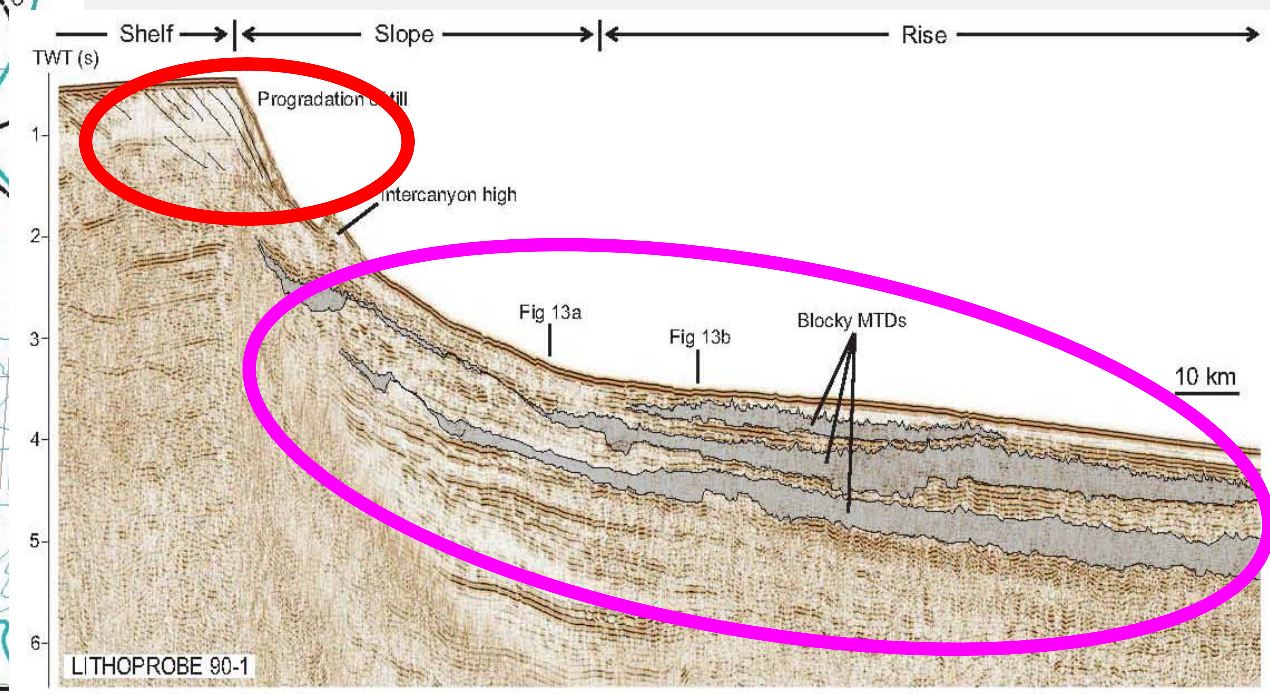
Shelf crossing ice delivered sediment and water to the upper slope



Major depocentres seaward of former ice stream positions

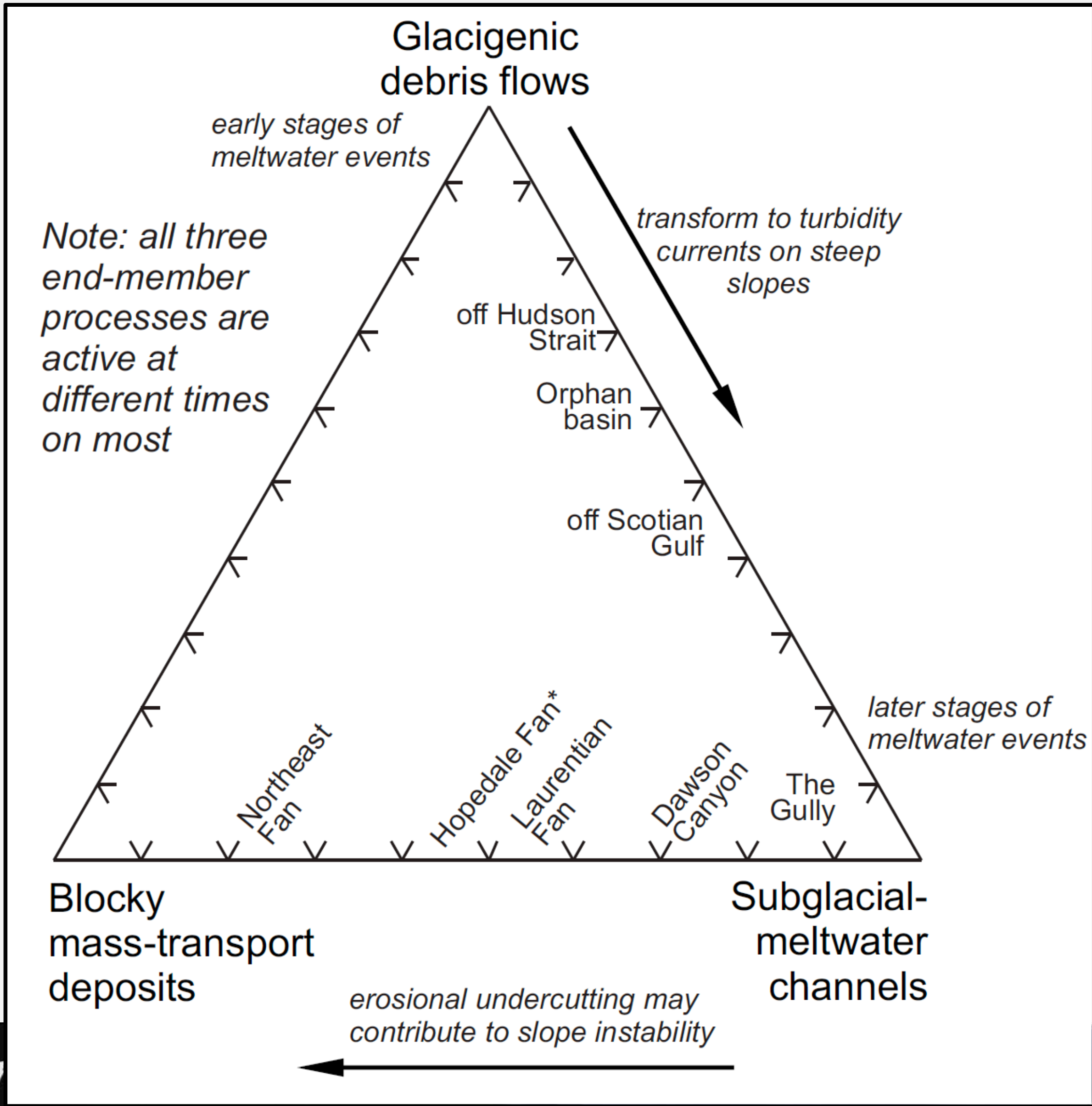
- bulge in contours at shelf edge due to progradation of till
- complex fan-like deposit seaward of the former ice stream





End-member processes on submarine fans

- Deposition of glacial till on the upper slope and formation of glacigenic debris flows seaward of some ice streams
- Erosion of canyons by hyperpycnal subglacial meltwater discharges
- Sediment failure
    - large scale MTDs
    - small scale failures of proglacial sediment producing turbidity currents
- Sediment plumes giving draped sediments at several metres/ka.

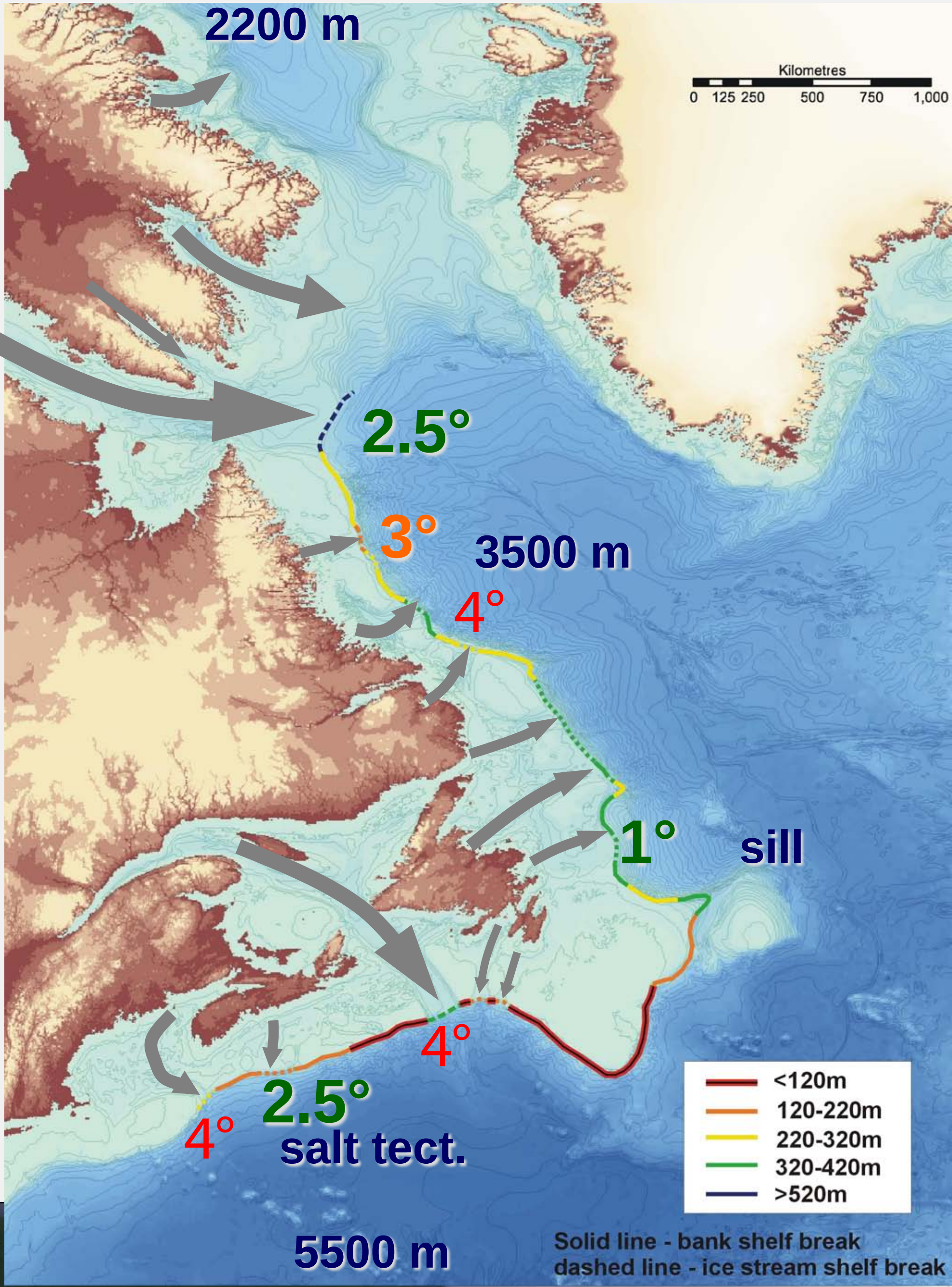


Glacigenic debris flows seaward of ice streams

Gradient of upper 1000 m of slopein degrees

Glacigenic debris flows only on gradients of < 3.5°

On steeper gradients, presumably convert to a turbulent turbidity current



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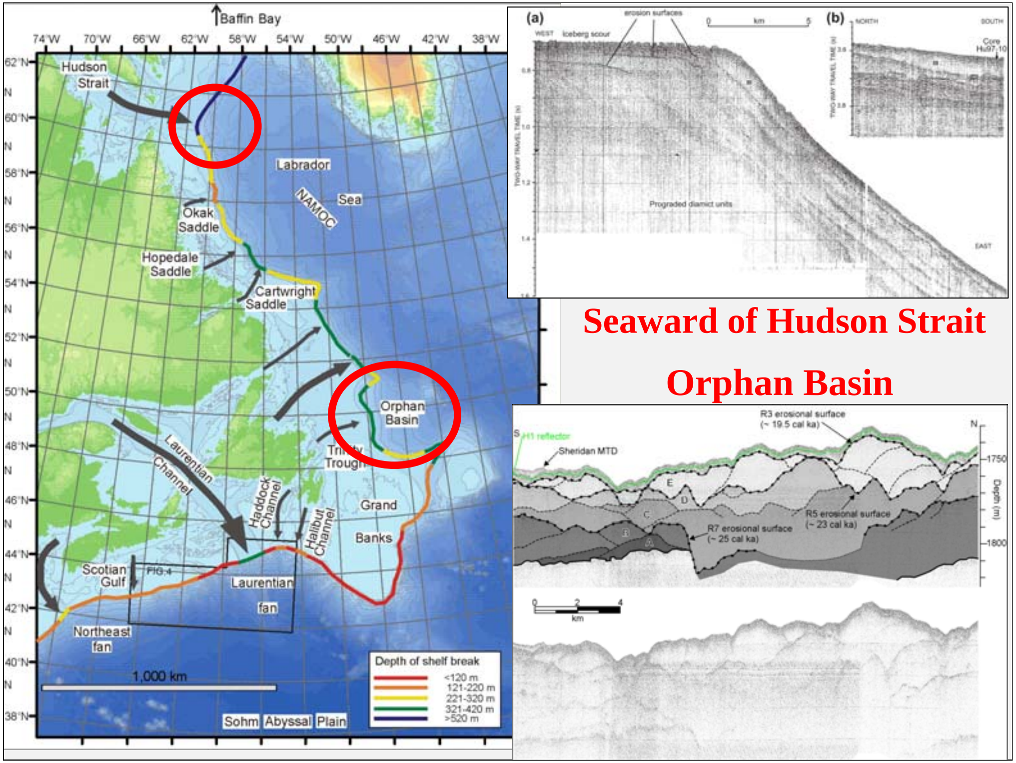
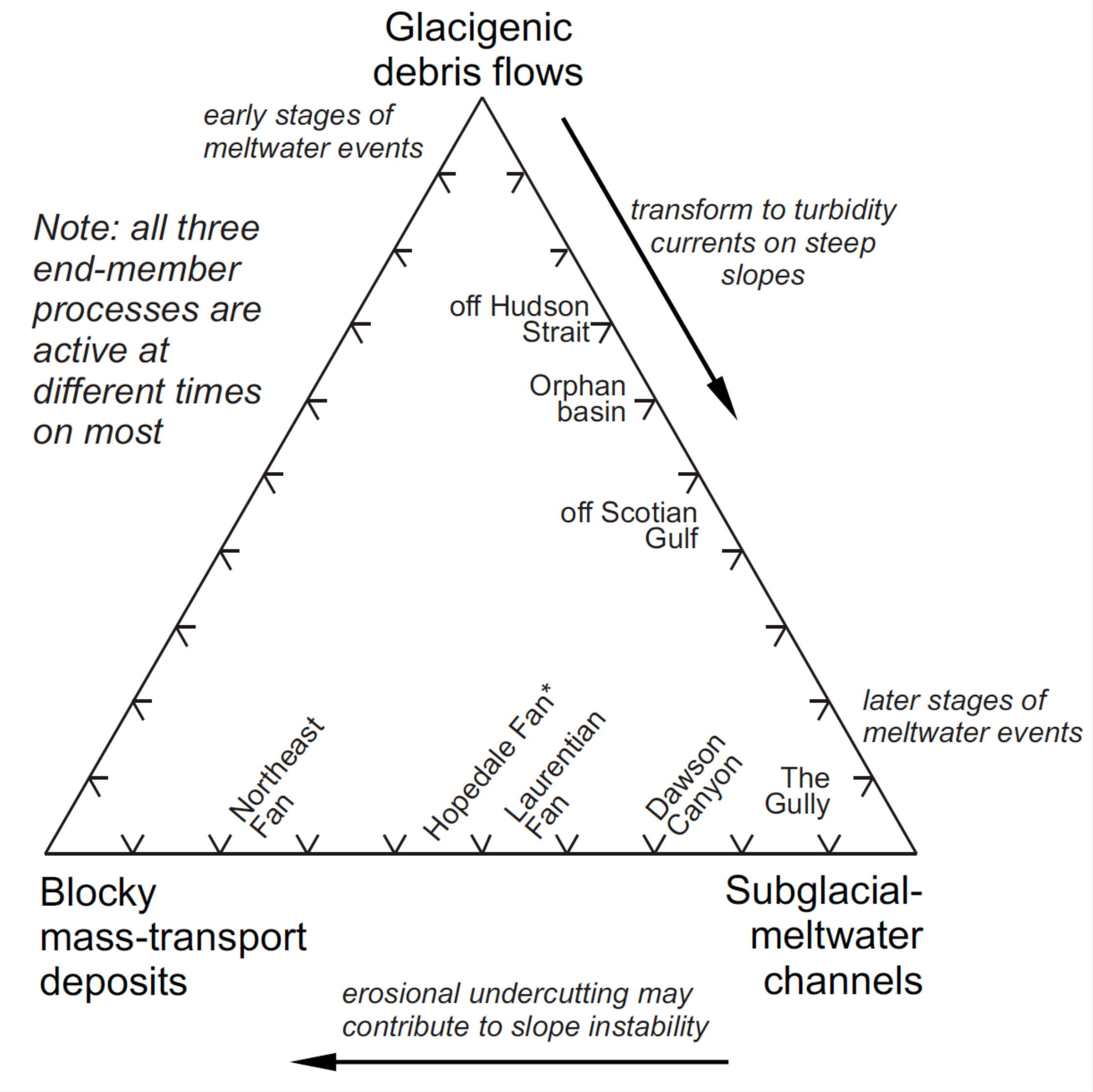
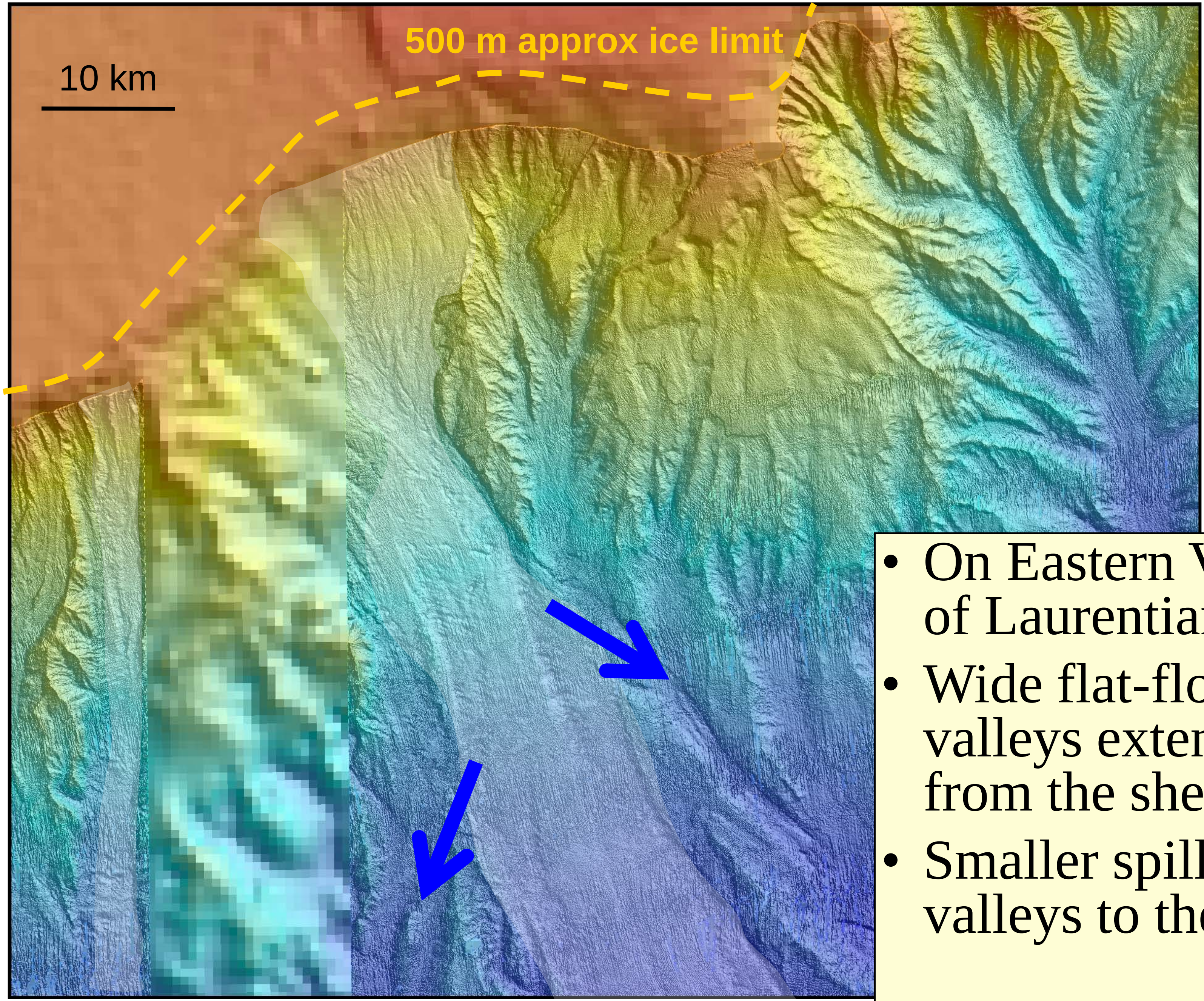


Presenter's Notes: Progradation of till and stacking of glacigenic debris flows

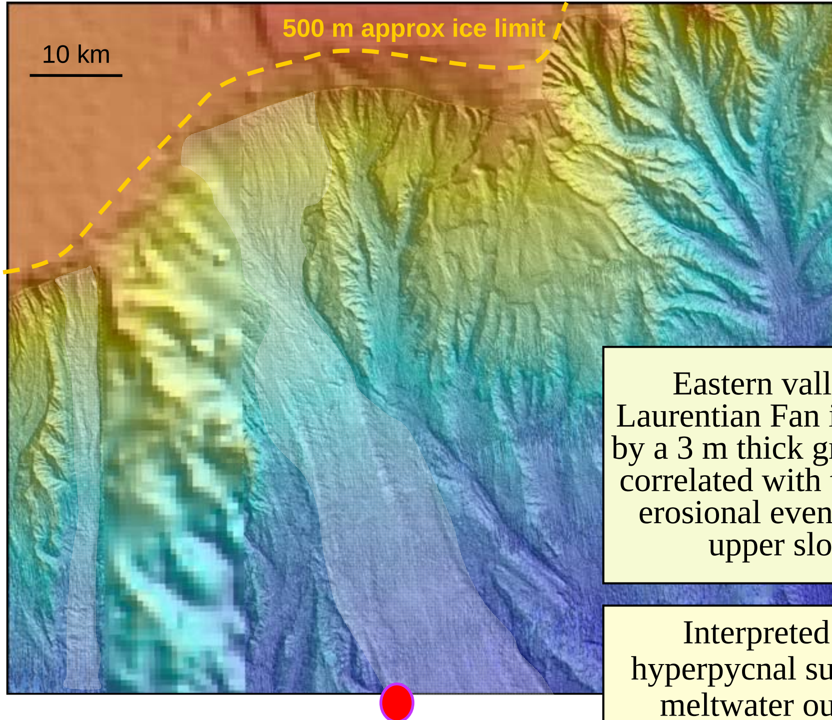
Three types of turbidity currents

- On steeper gradients, glacigenic debris flows transform to turbidity currents
- Small failures in other ice-proximal deposits may transform to turbidity currents
- Hyperpycnal meltwater events erode flat-floored valleys





- On Eastern Valley of Laurentian Fan
- Wide flat-floored valleys extending from the shelf break
- Smaller spill over valleys to the sides

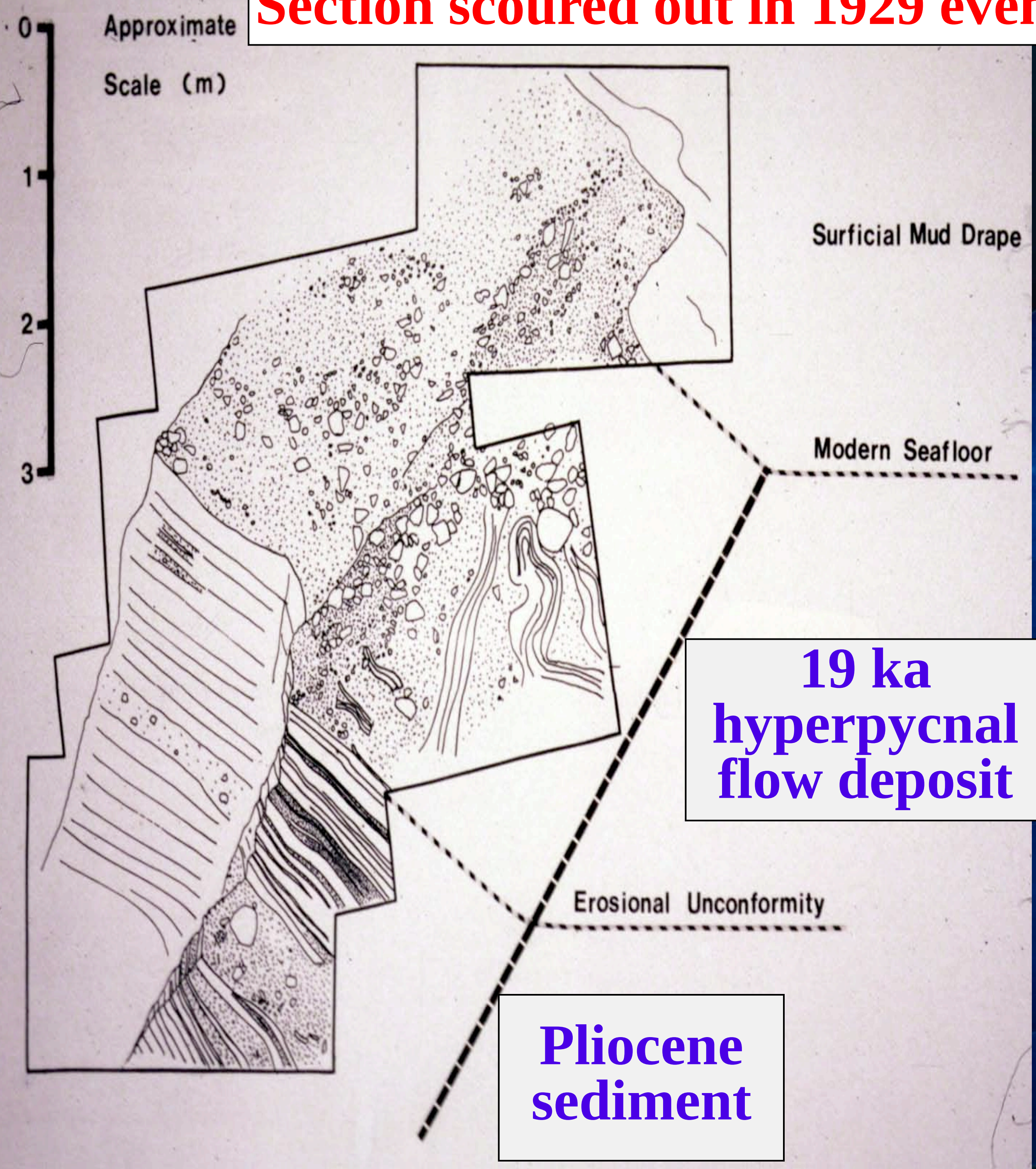


Eastern valley of Laurentian Fan is floored by a 3 m thick gravel bed, correlated with the 19 ka erosional event on the upper slope

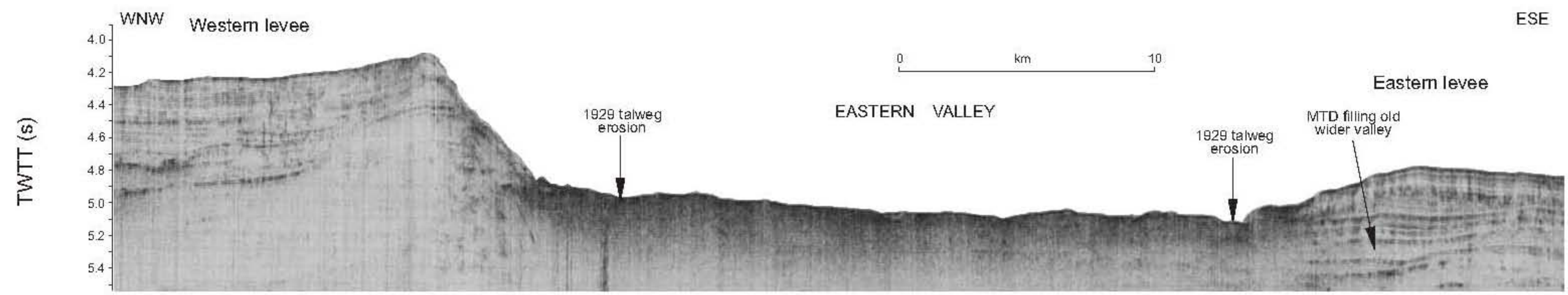
Interpreted as a hyperpycnal subglacial meltwater outburst

Presenter's Notes: red dot shows section seen in valley floor

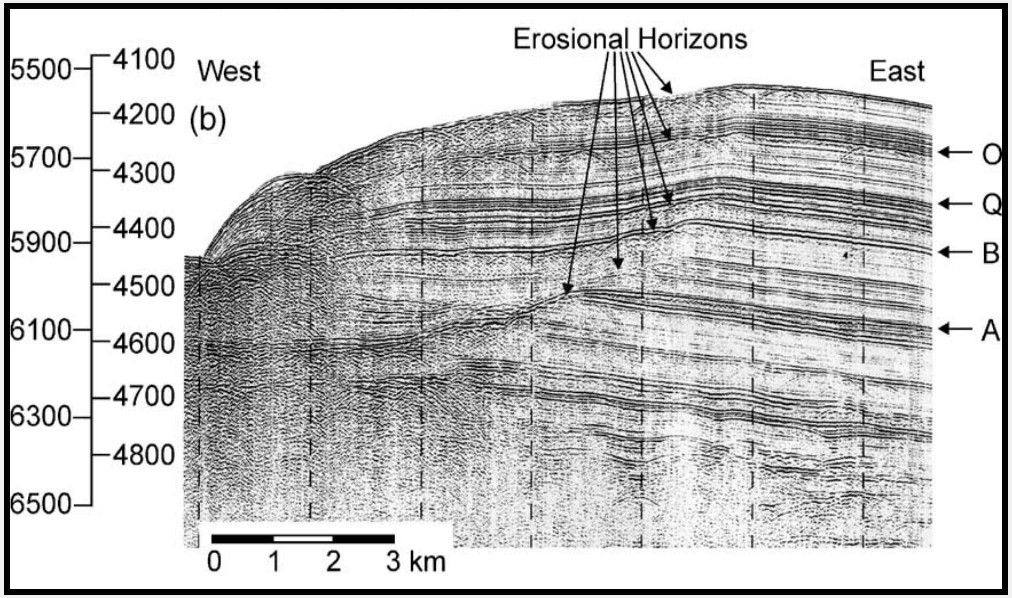
Section scoured out in 1929 event



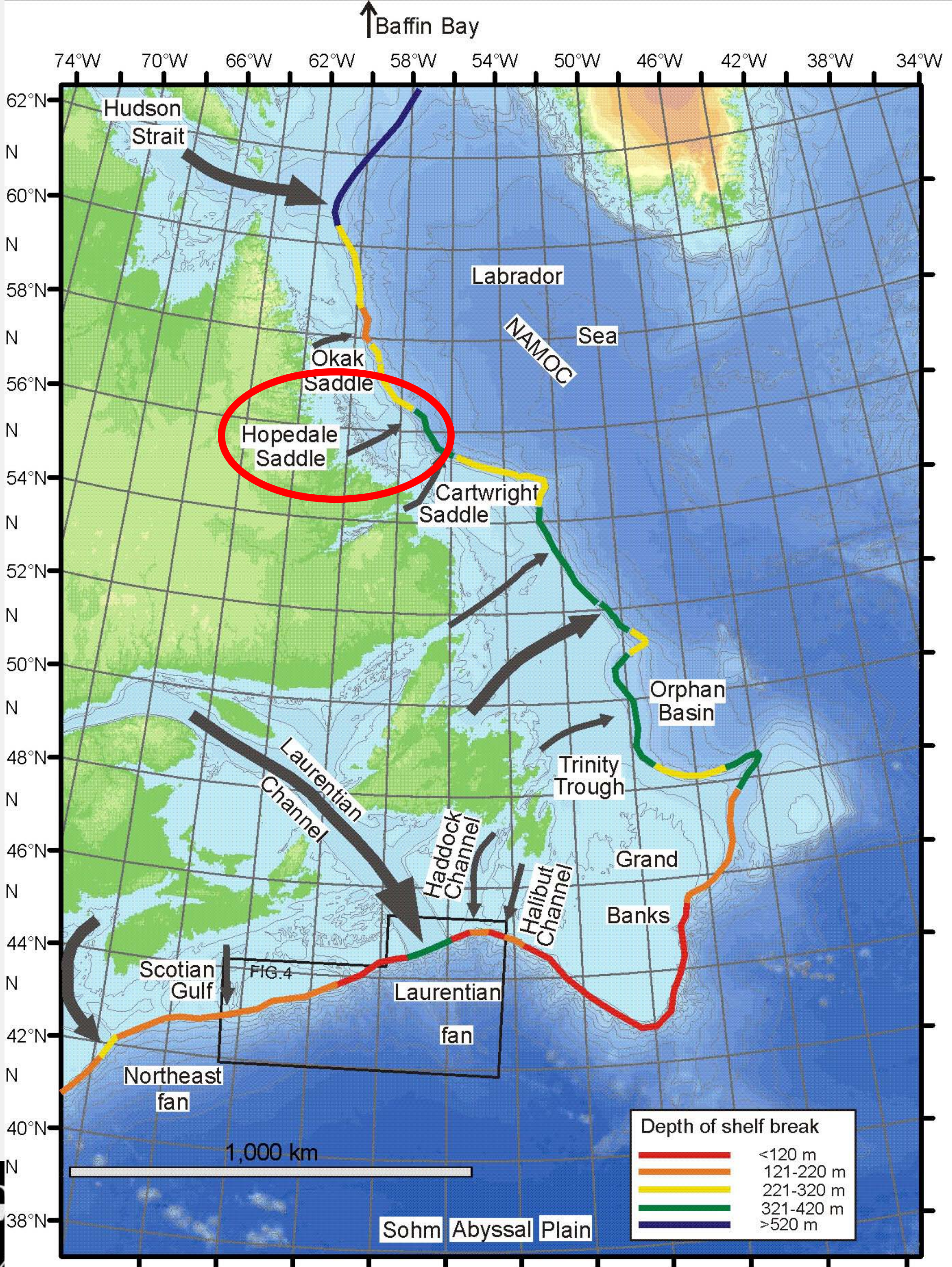
Prominently asymmetric valleys with high right-hand levees maintained by muddy hyperpycnal flows



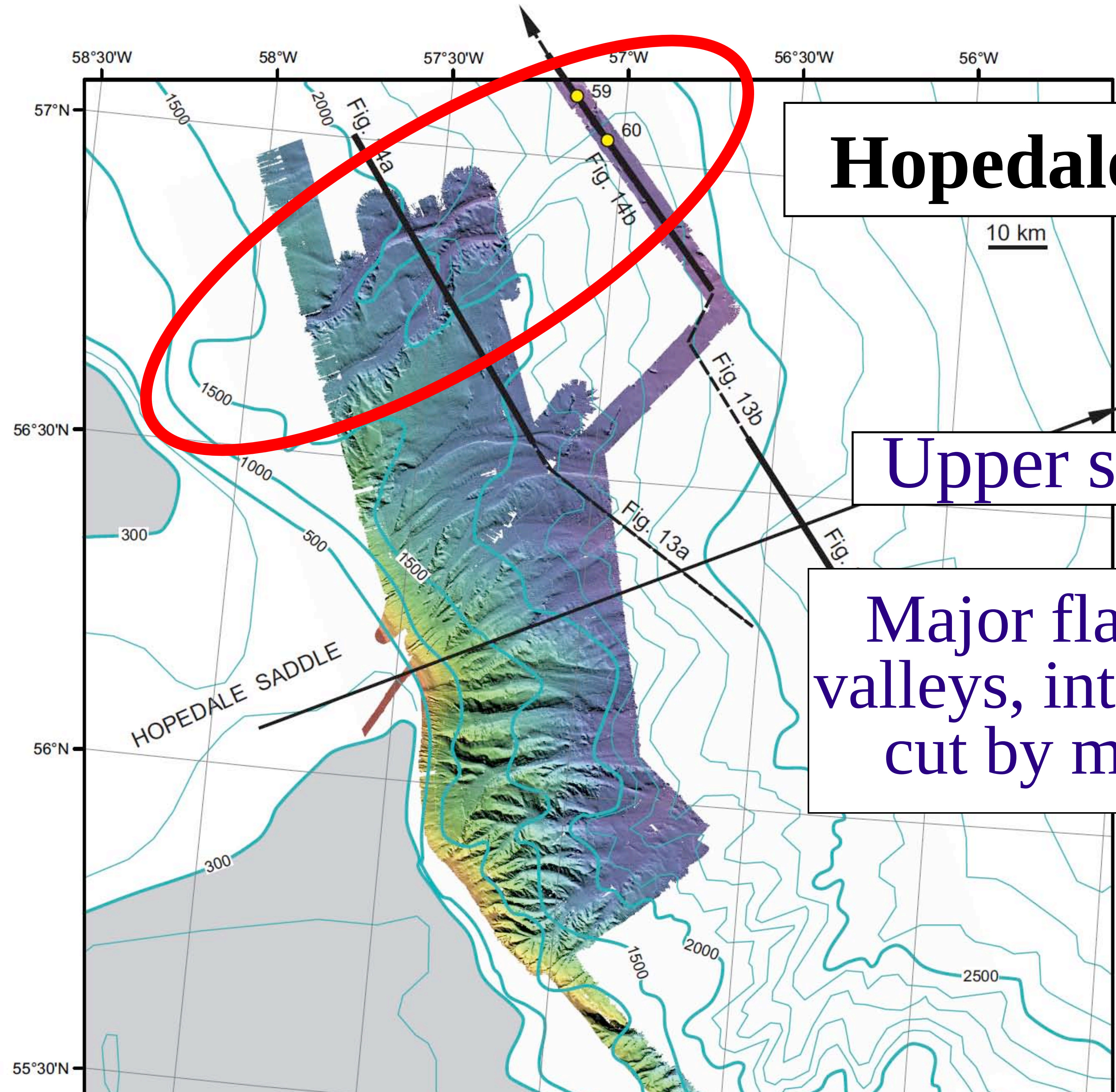
Valleys widened by major gravelly hyperpycnal flows and then are narrowed by muddy hyperpycnal deposition and slump-generated turbidity currents.



Hopedale Saddle



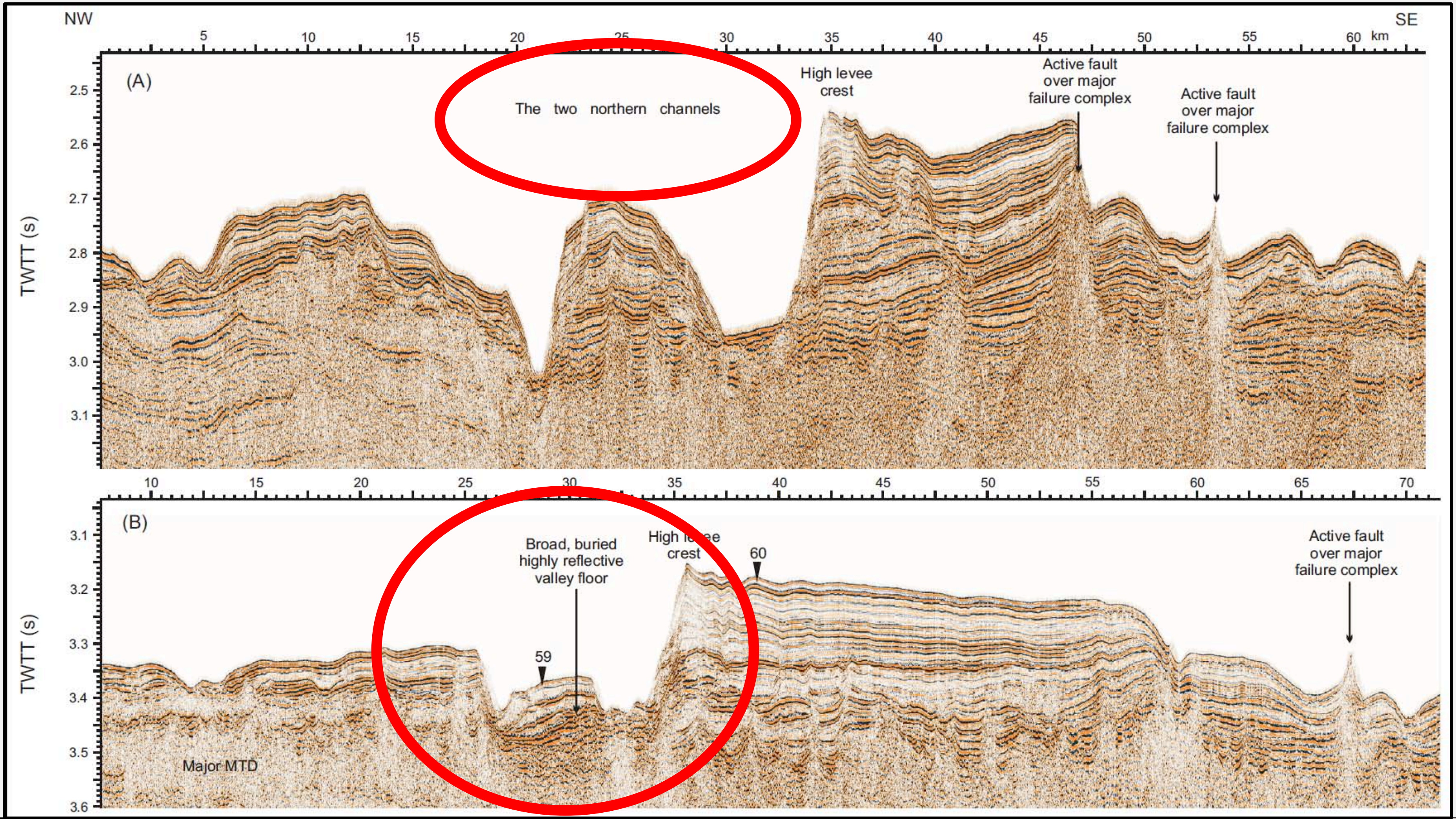
Hopedale Saddle



Upper slope till

Major flat-floored valleys, interpreted as cut by meltwater

Gravelly floor like Laurentian Fan; asymmetric main levee then muddy inner levee progradation down system



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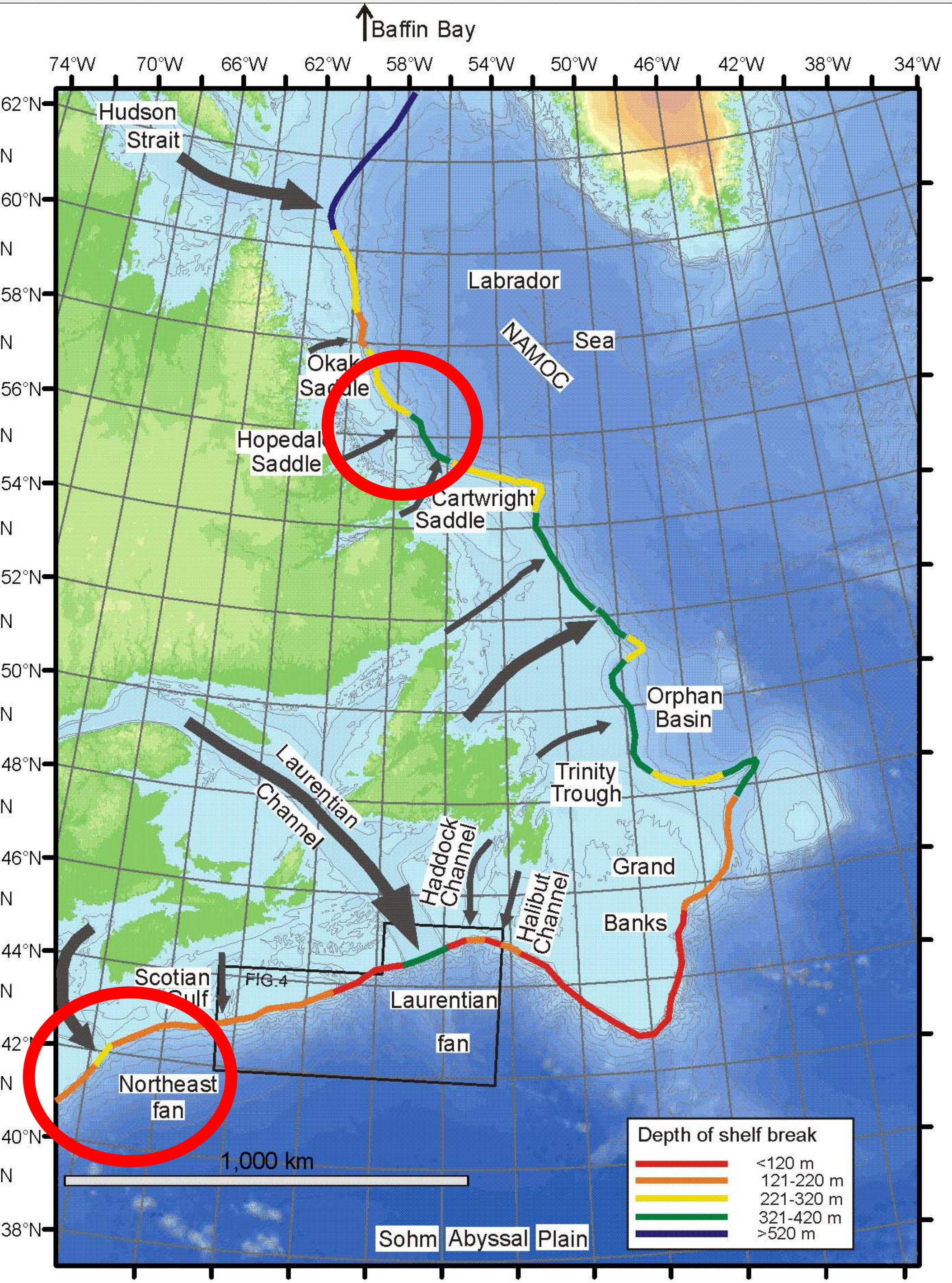
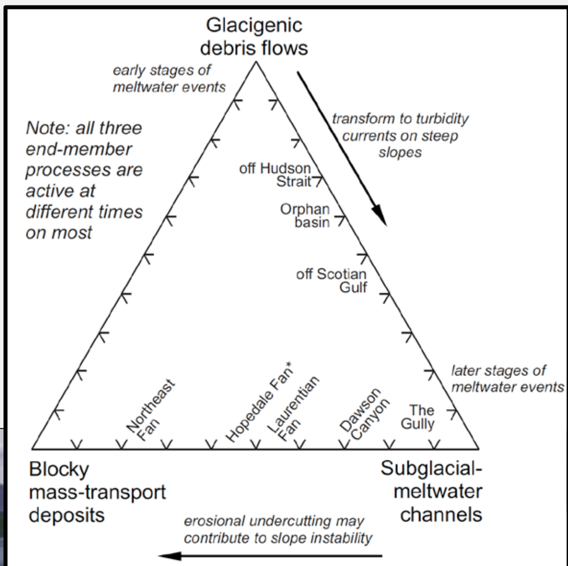
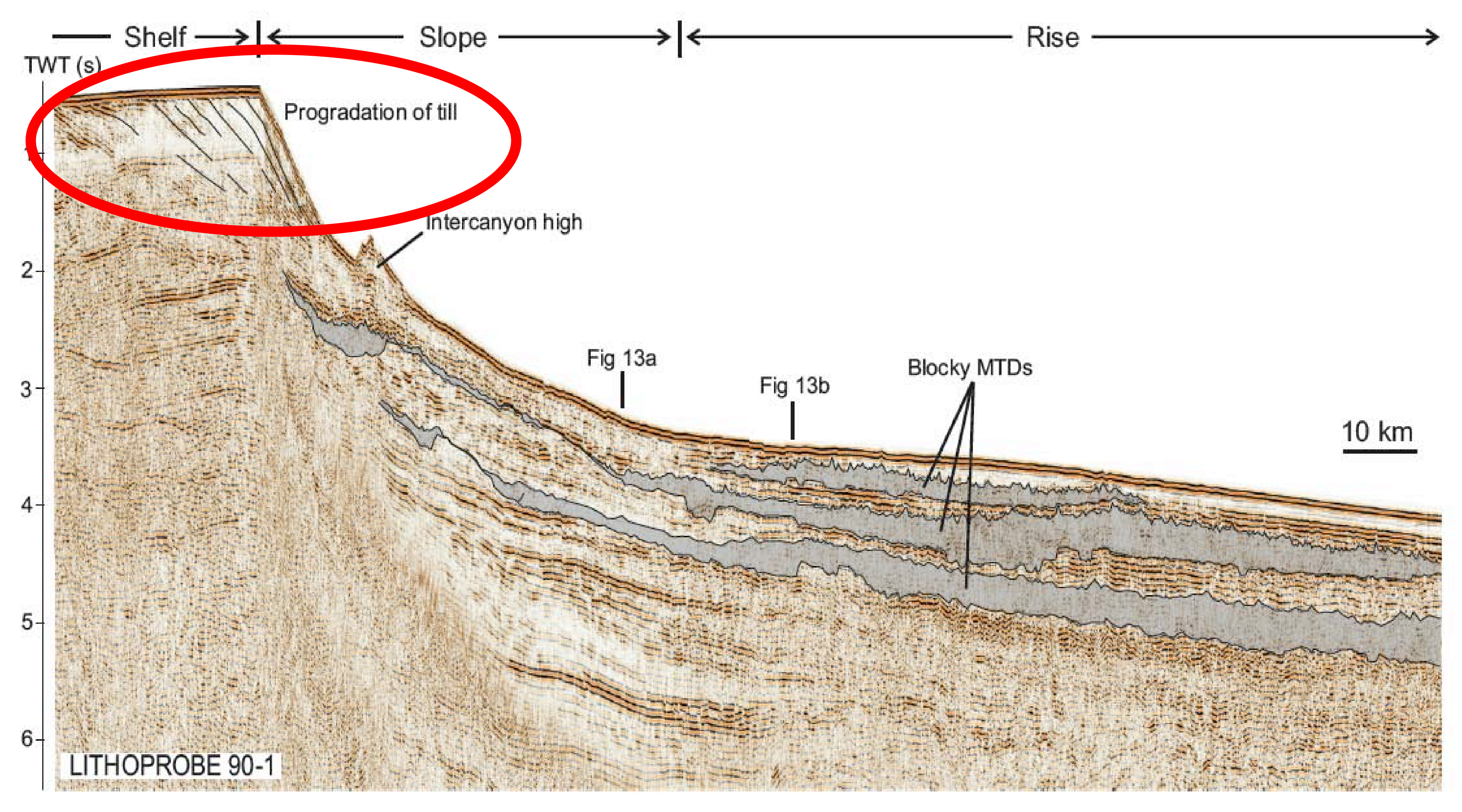


Blocky mass-transport deposits

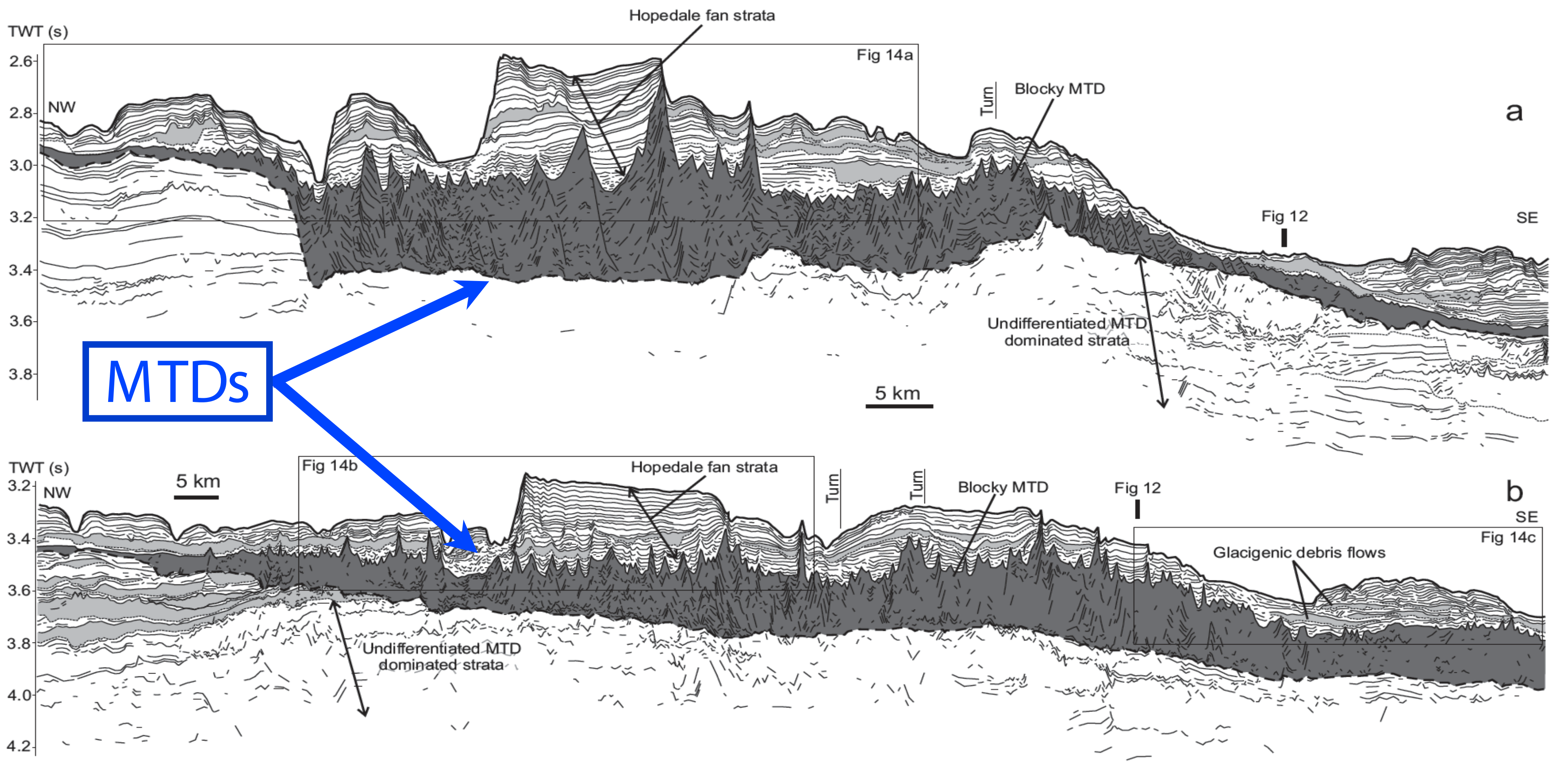
- Hopedale Saddle
- bank edge collapse from till progradation
- Northeast Channel
- deep incision of meltwater channels



Progradation of till at the shelf edge, over less strong proglacial sediments

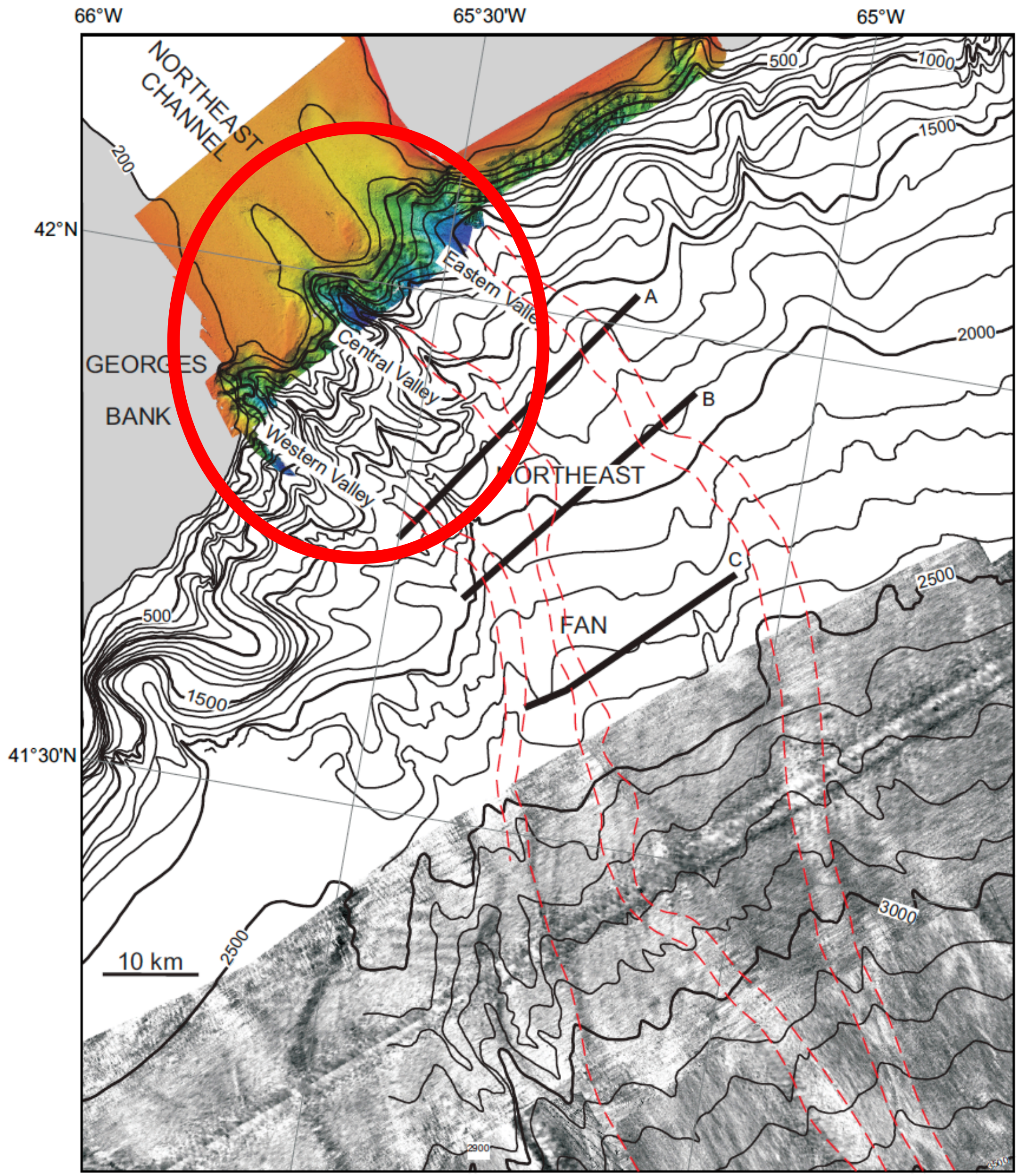


Hopedale: example of large MTDs seaward of an ice stream

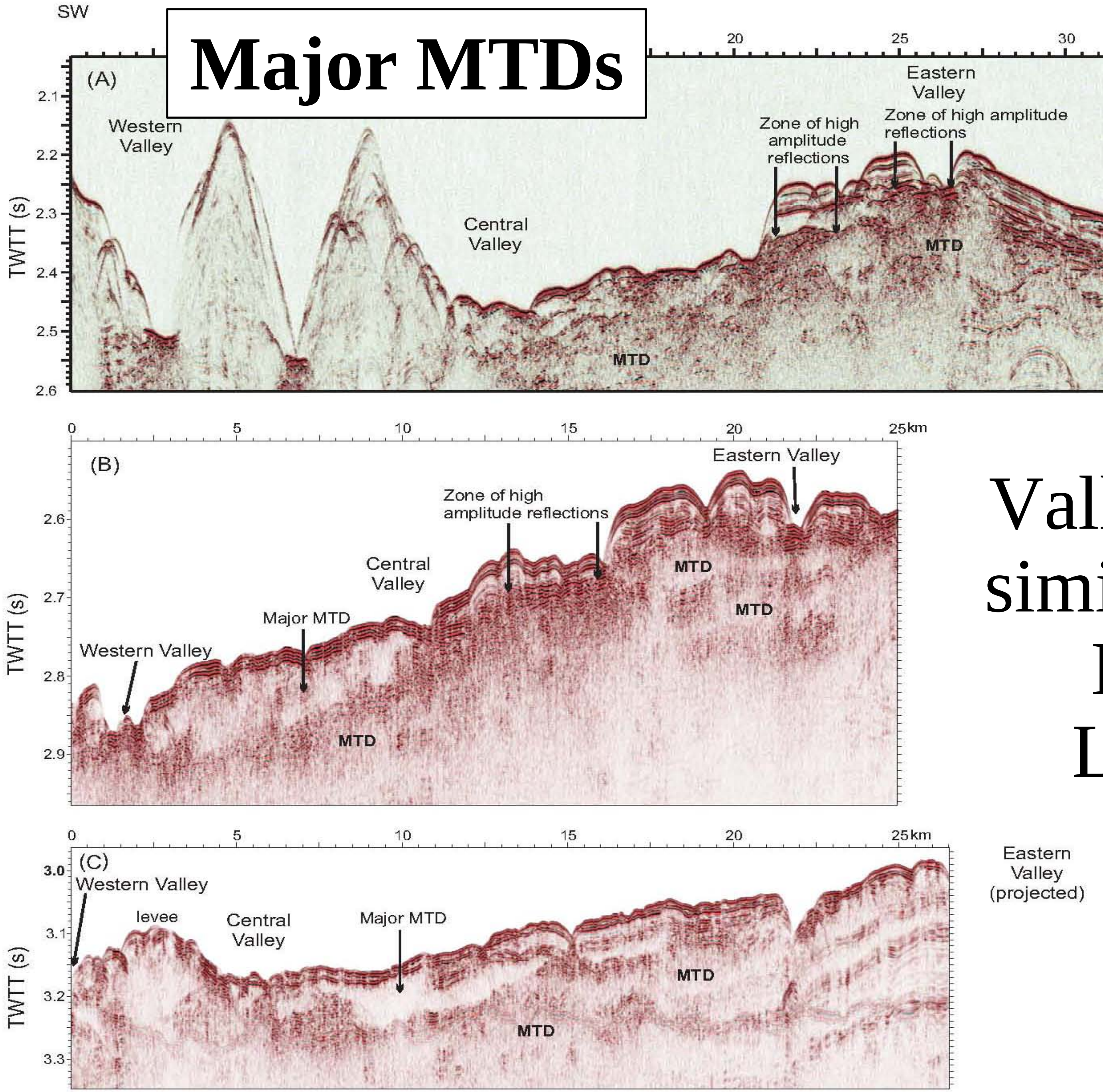


Northeast Channel

- Deep incision of slope valleys by hyperpycnal flows leads to over-steepening valley walls and large failures



Major MTDs



Valleys show similarities to Hopedale, Laurentian

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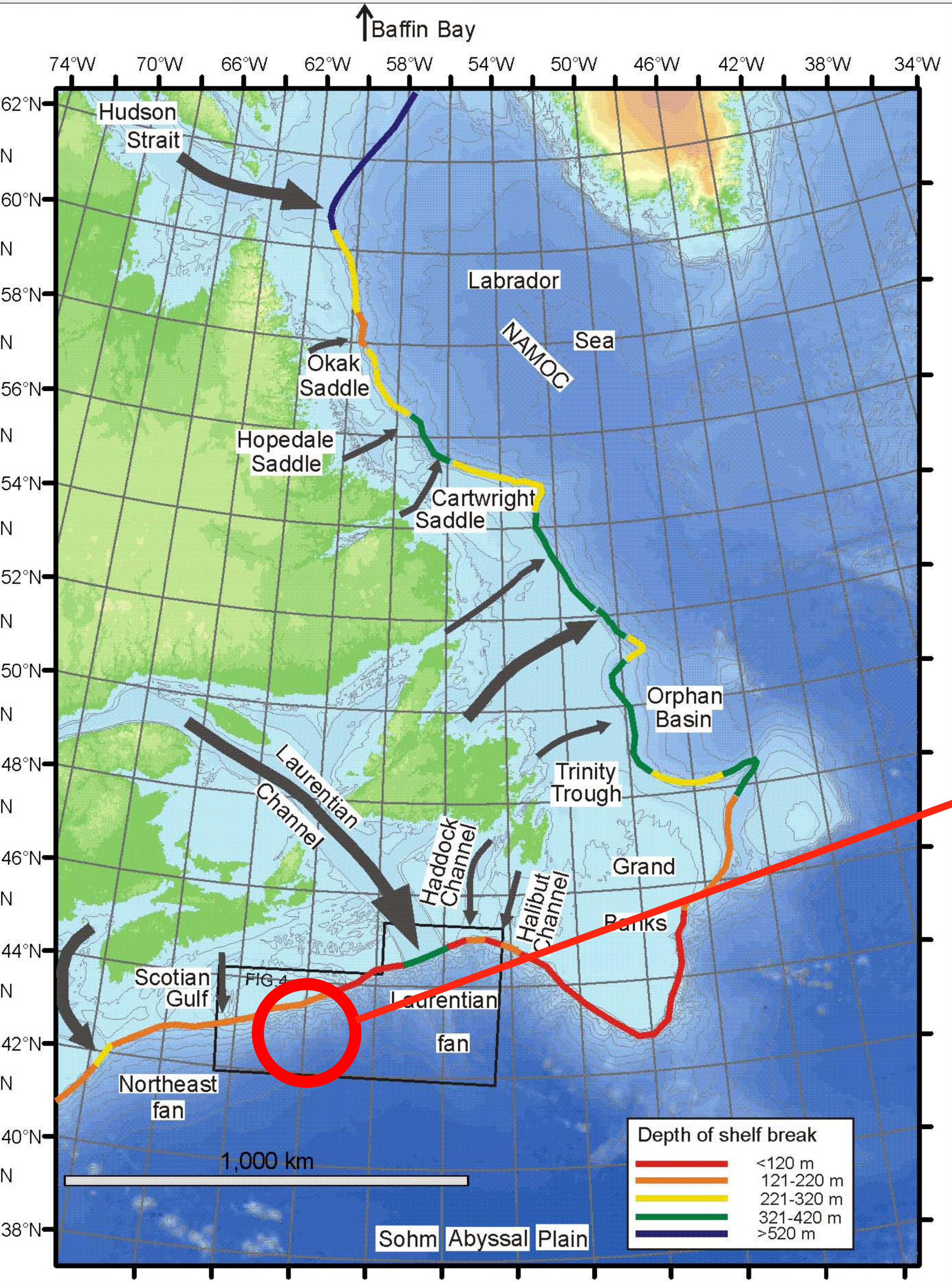


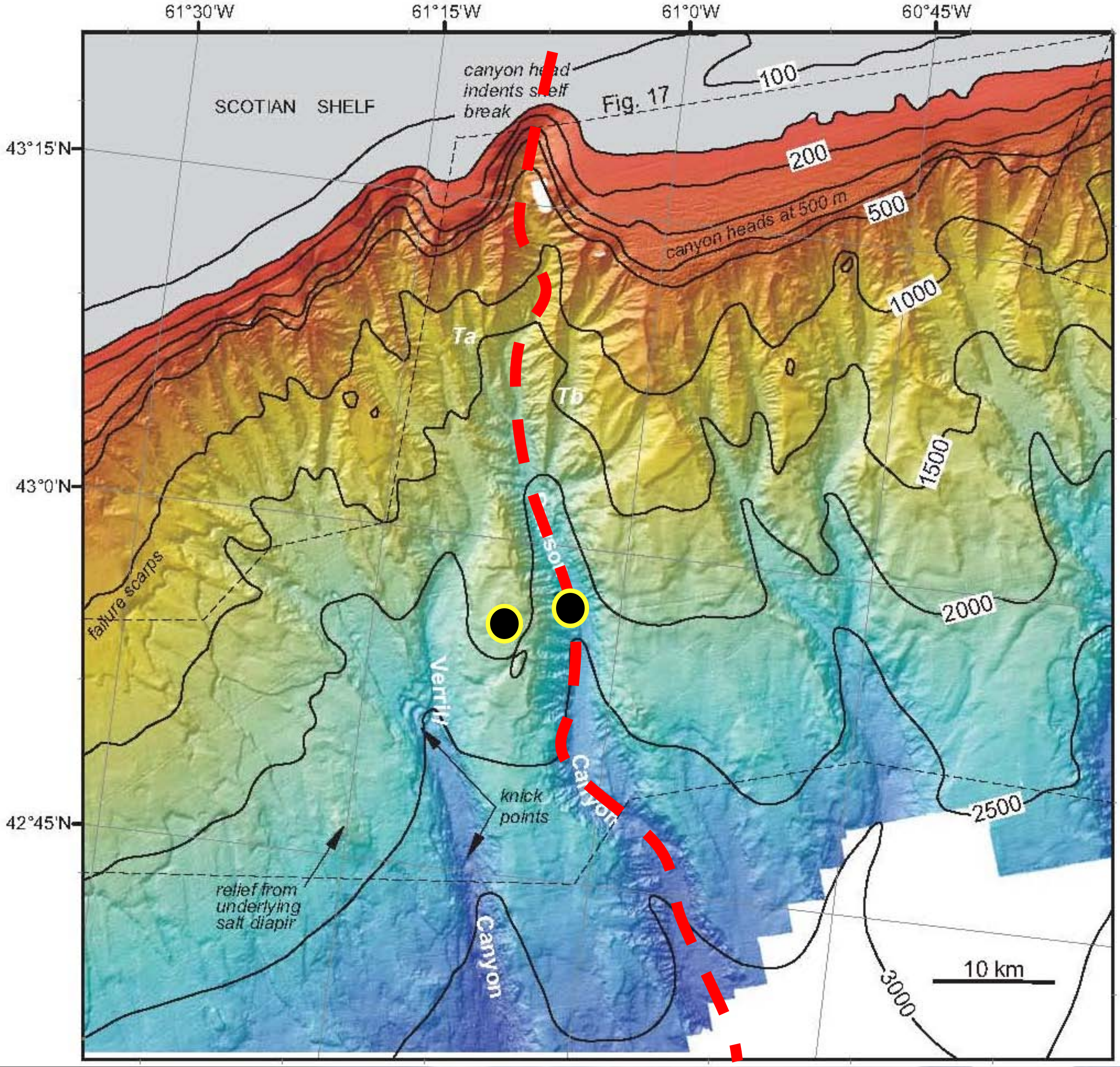
Small-scale sediment failure at ice margins also important

Evidence from a terrace core in Dawson Canyon on the Scotian margin

Dawson Canyon

Small flat-floored valley that heads back to the shelf

Appears linked to tunnel valley on shelf

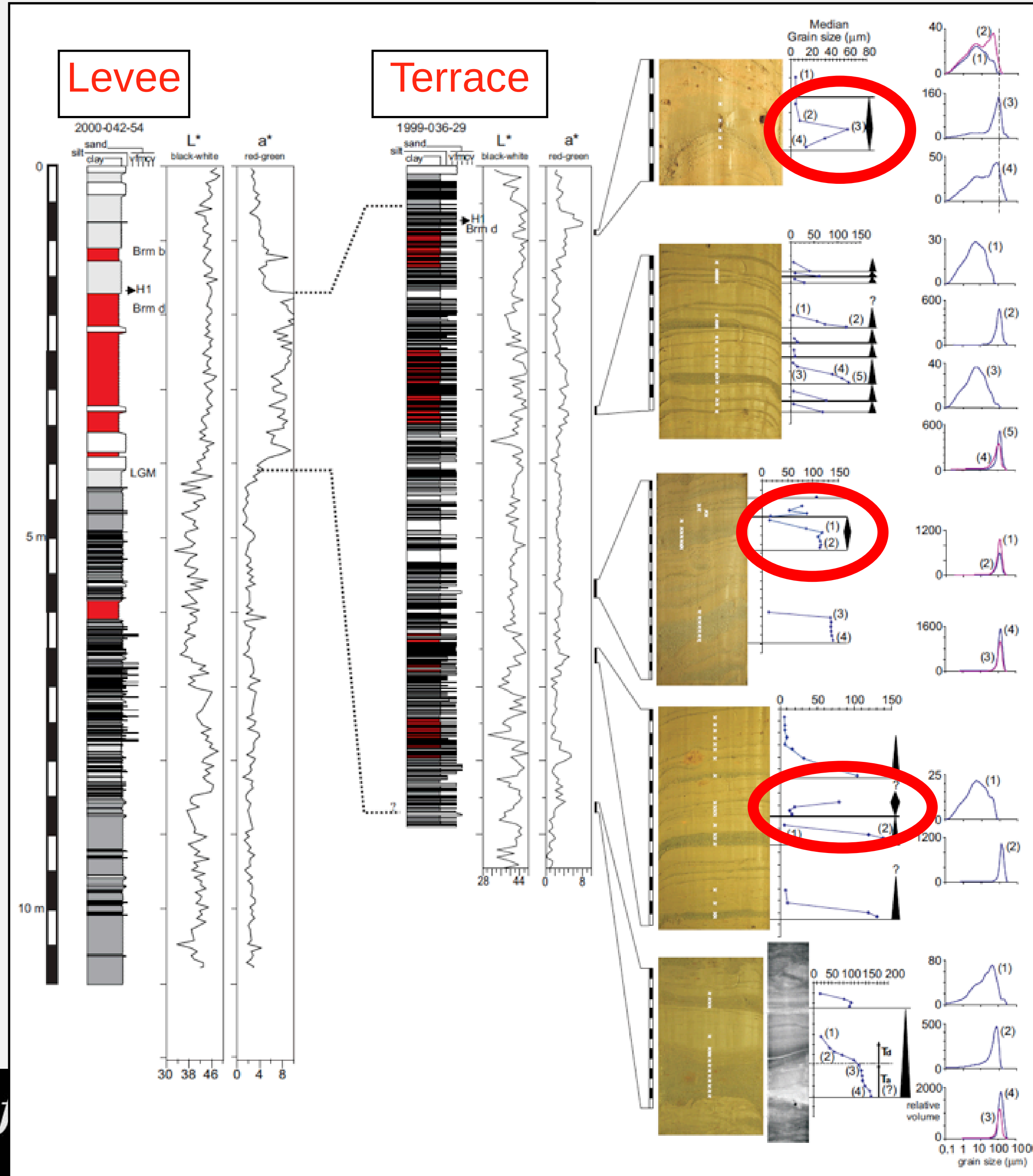


Sandy core on terrace 75 m above valley floor

Levee core 500 m above valley floor gives chronology

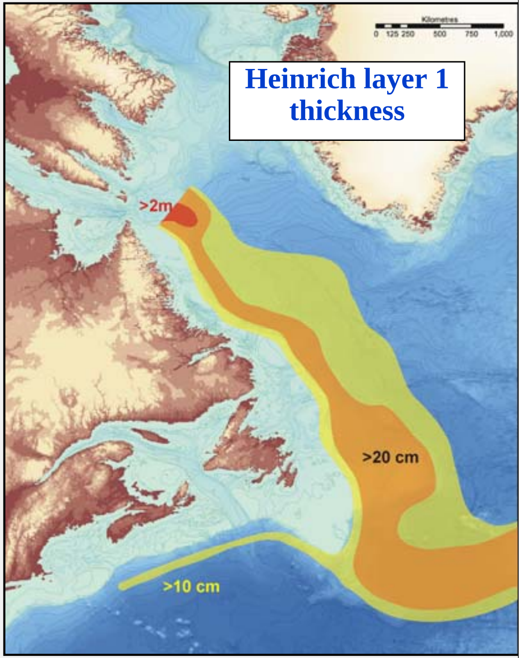
Only a few beds on terrace show hyperpycnal reverse grading

Most flows have normal grading, probably from ice-margin slumping



Plumes and IRD on slopes

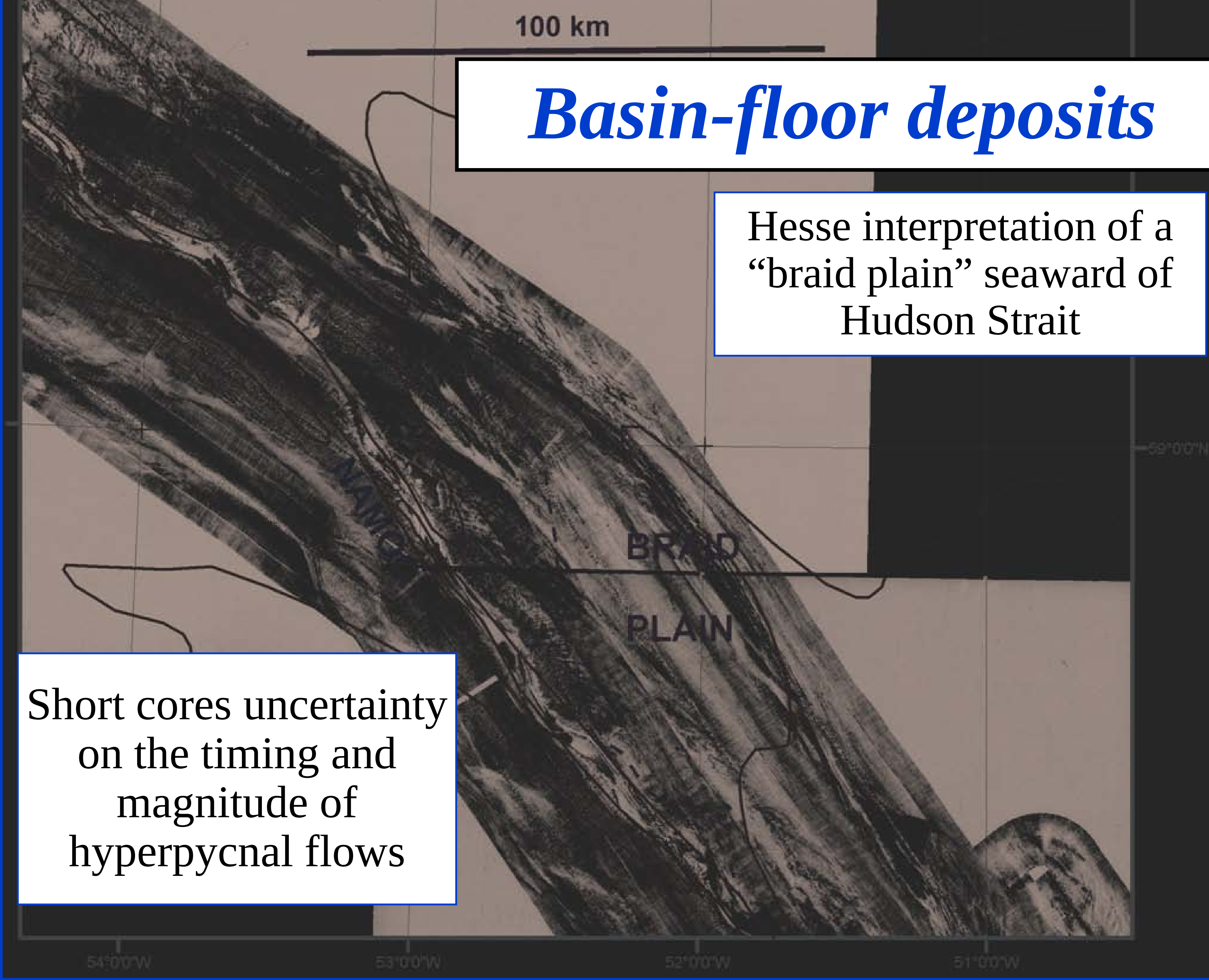
- “background” sedimentation between ice outlets
- long distance transport known from Heinrich layers
- sedimentation rates up to 5 m/ka proximal to ice outlets



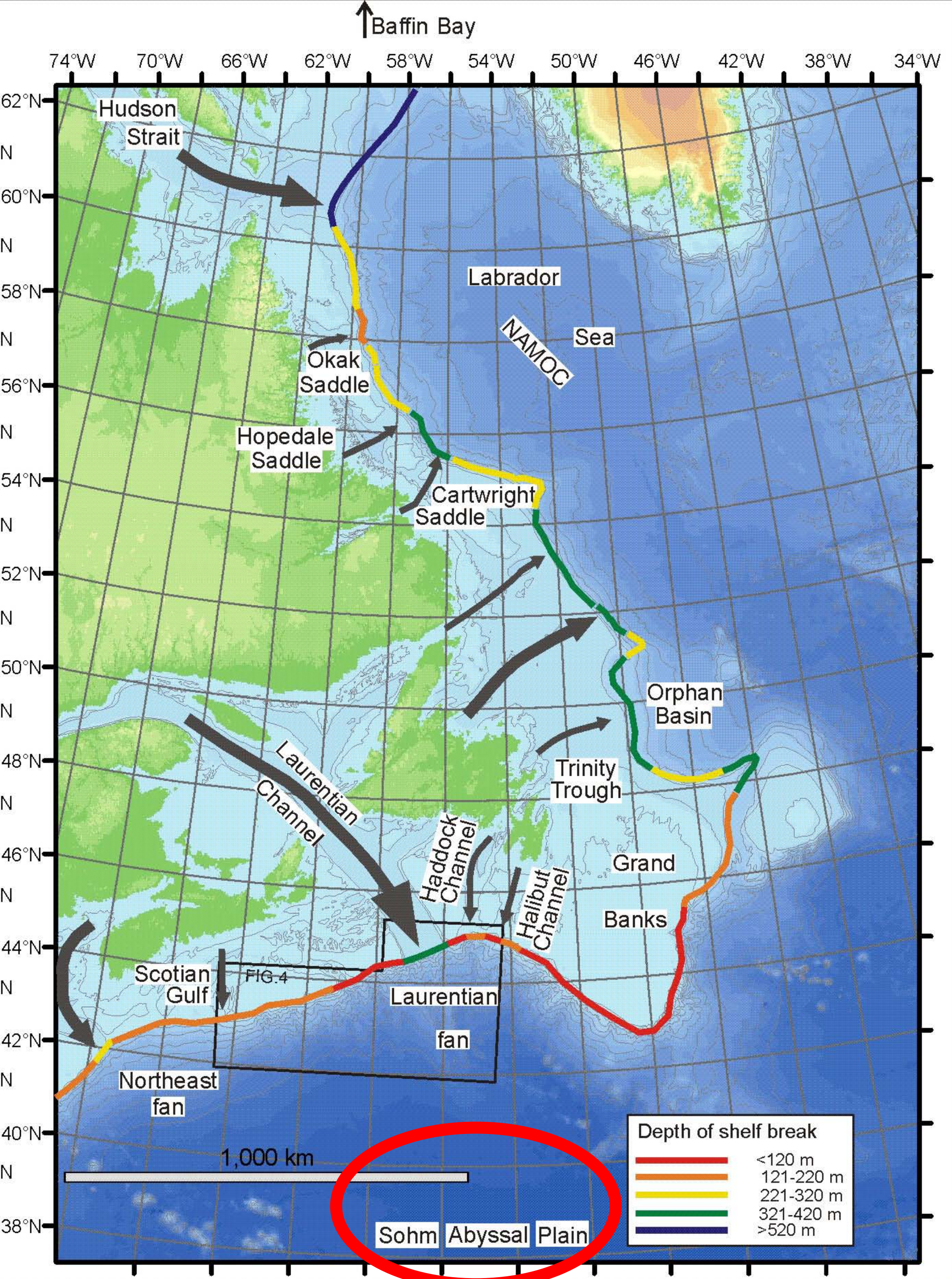
Presenter’s Notes: Make the point that nothing has been said previously about plume sedimentation

Basin-floor deposits

Hesse interpretation of a "braid plain" seaward of Hudson Strait

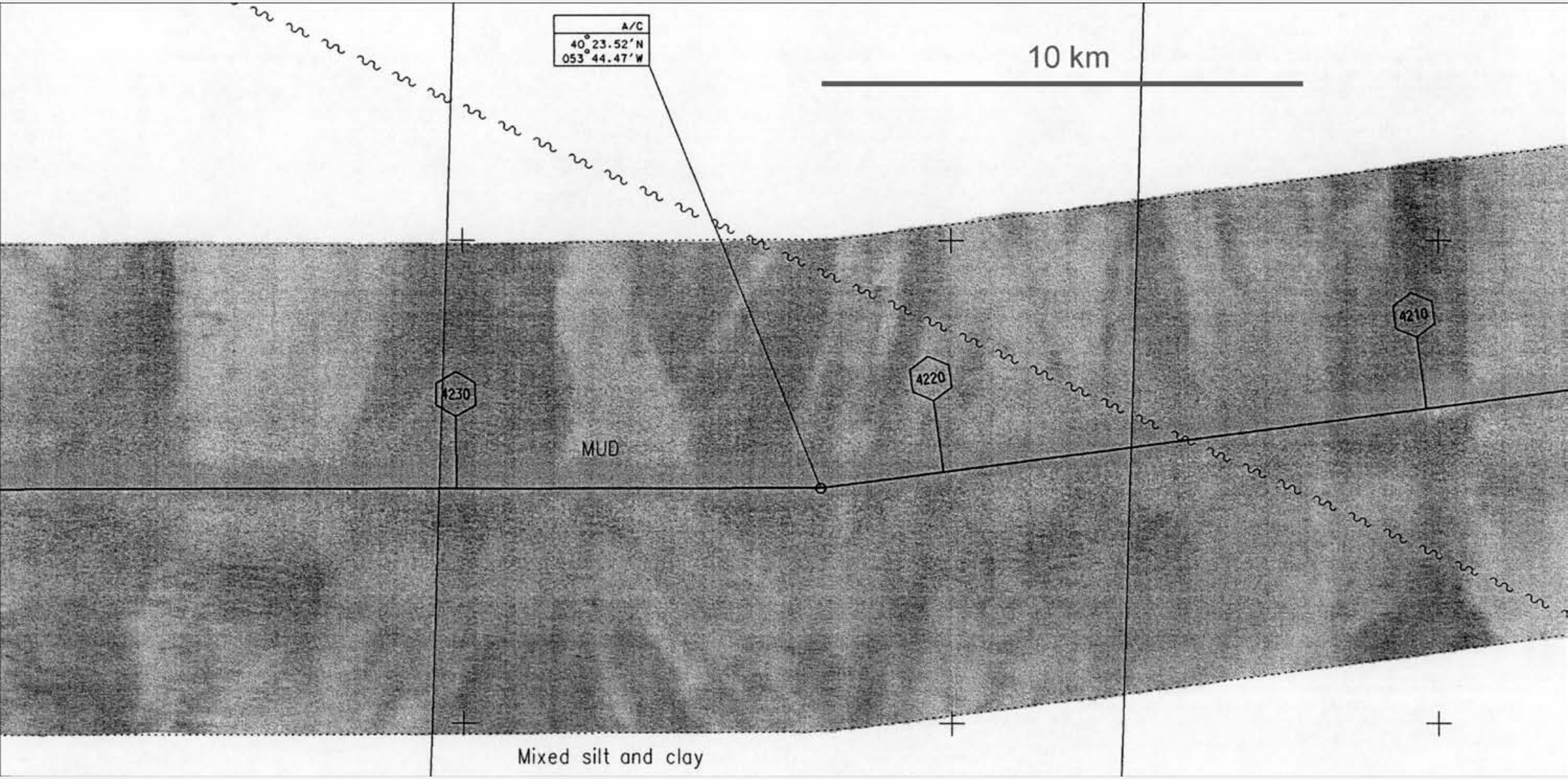


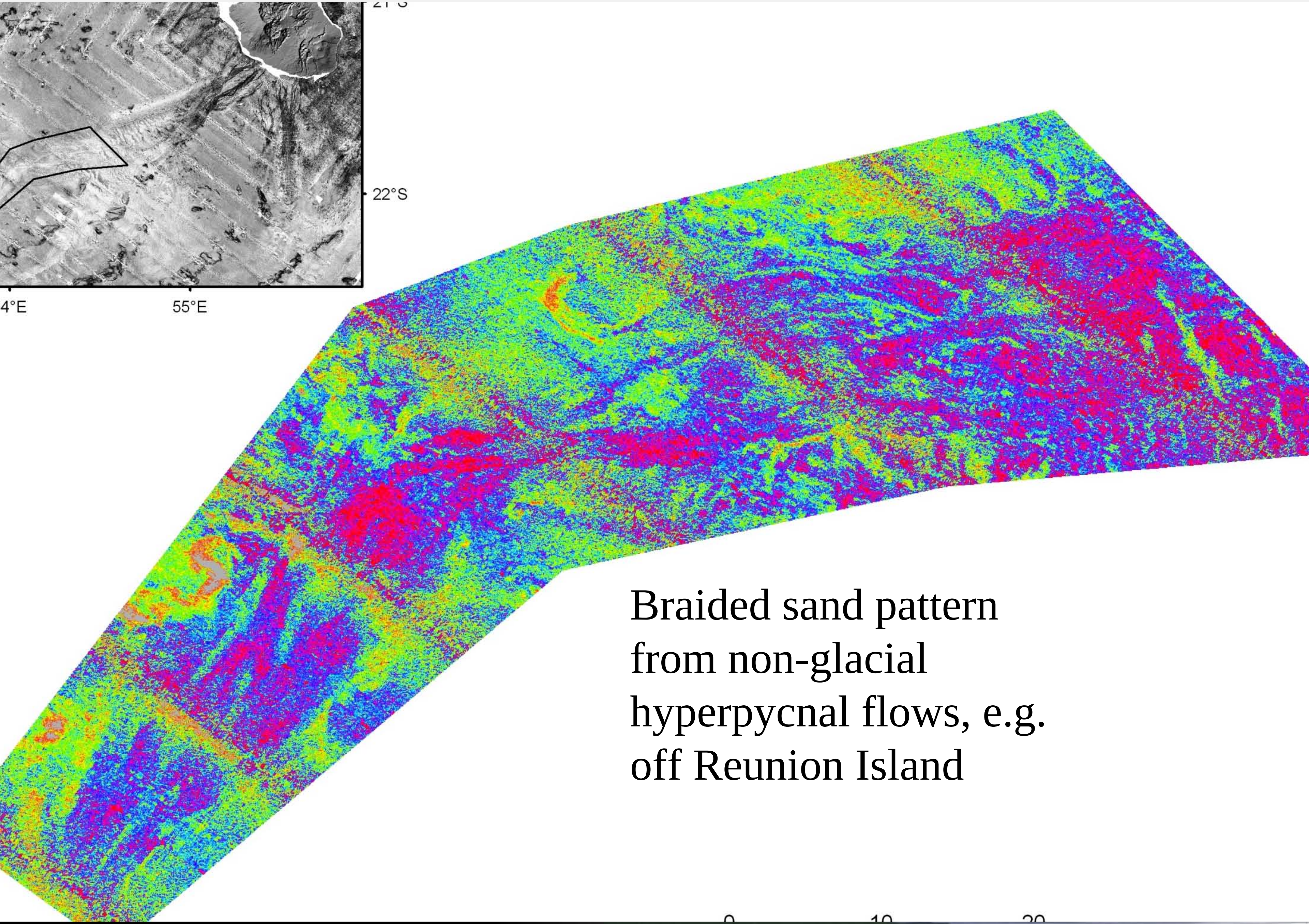
Short cores uncertainty on the timing and magnitude of hyperpycnal flows



- Sparse supporting evidence
  – cable-route sidescan from Sohm Abyssal Plain

Sohm Abyssal Plain at 5200 m





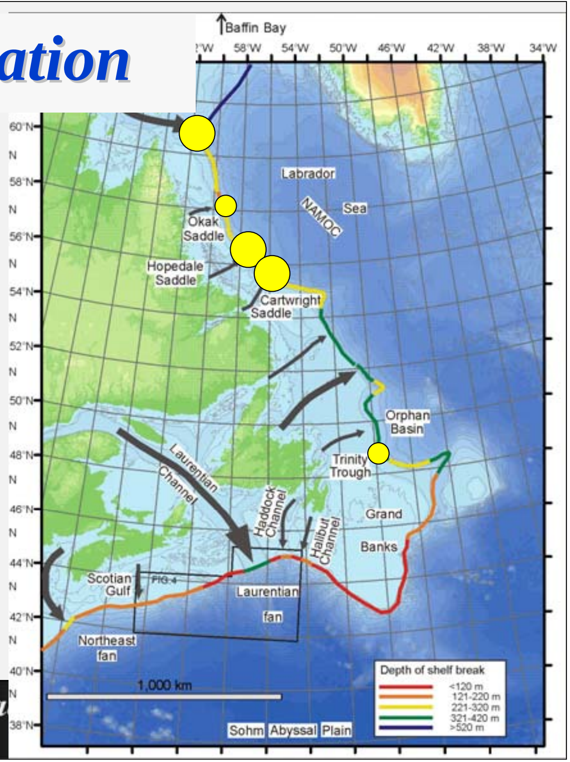
Braided sand pattern from non-glacial hyperpycnal flows, e.g. off Reunion Island

Latitudinal variation

- more progradation of till at higher latitudes

  > 10 km shelf edge progradation of till

- wider flat-floored slope valleys at lower latitudes



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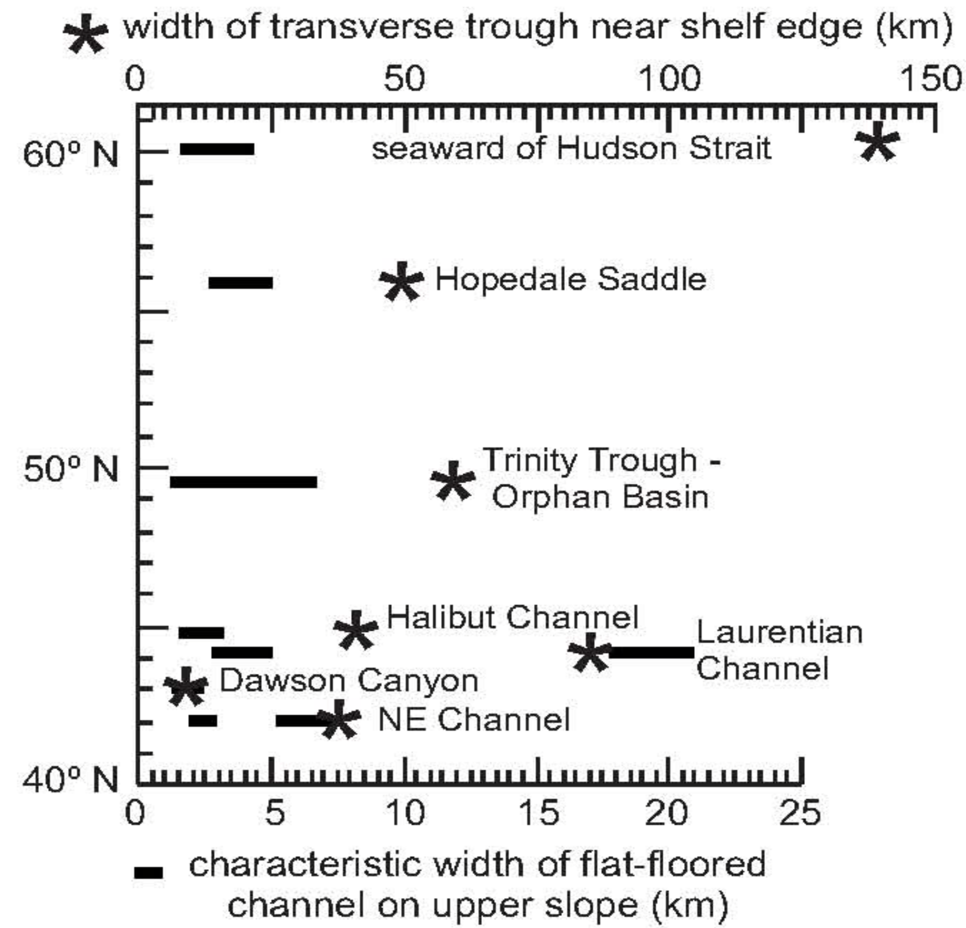
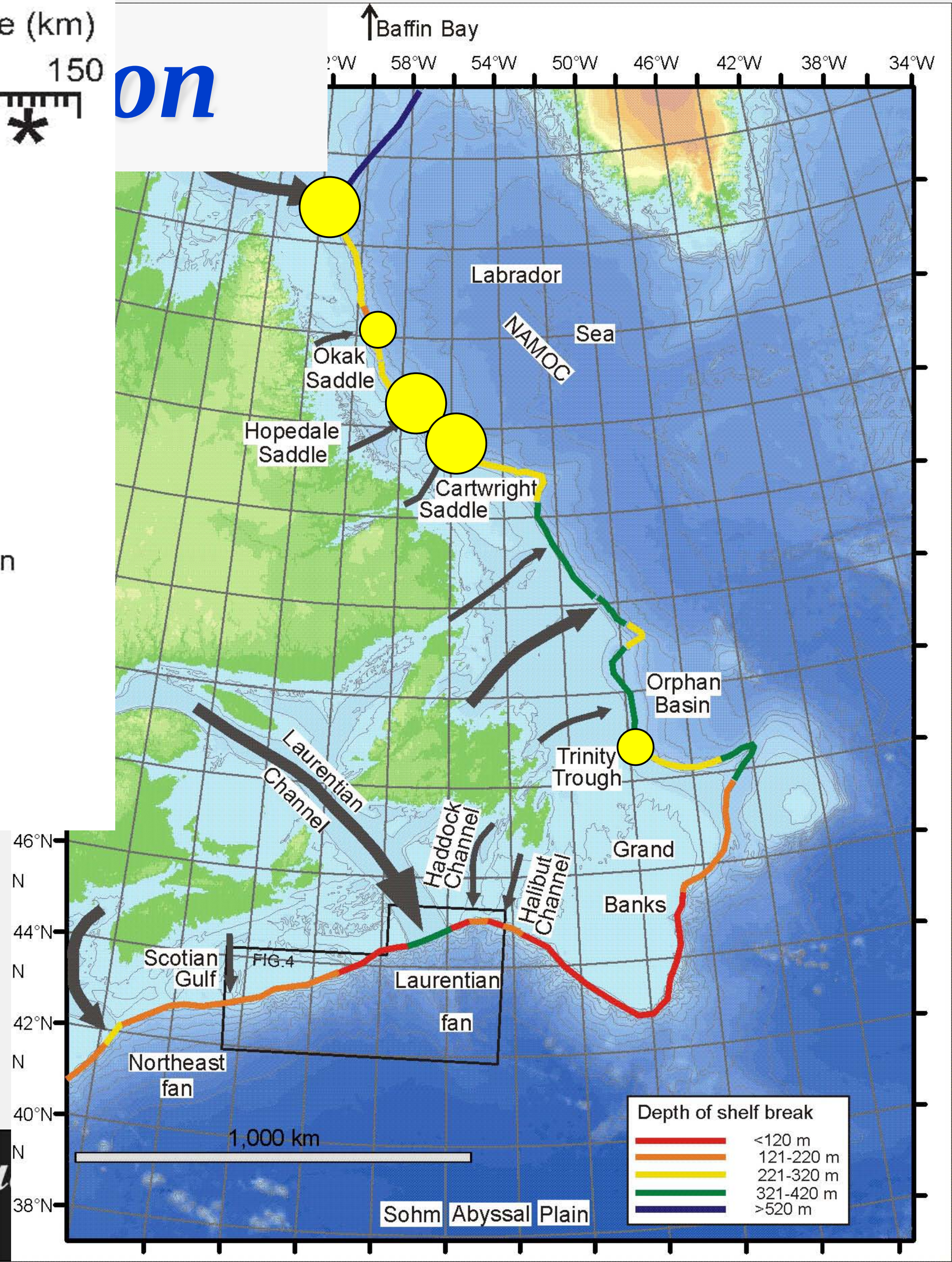
Presenter's Notes: e.g. NE Channel and Laurentian Channel valleys bigger than off Hudson Strait, despite greater width of the transverse trough at Hudson Strait.

on





- wider flat-floored slope valleys at lower latitudes

Conclusions

- Ice-stream outlets result in three linked processes
  - till progradation and glacigenic debris flows
  - release of meltwater, erosive hyperpycnal meltwater flows, small scale failures, regional plume deposits
  - blocky MTDs from ice and till loading or erosion of canyons
- With increasing latitude, the role of meltwater diminishes and the role of progradation of till increases

Conclusions

- Shelf edge facies: prograding till, erosion by hyperpycnal flows, perhaps transient sorted grounding line deposits
- Slope and upper rise: thick mud sections from plume fall-out, thin over-bank sands on levees (?), hyperpycnal flows of muds.
- Lower rise, basin floor: braid-plain sands from hyperpycnal flow, interbedded with slump-generated turbidites; *EXCEPT* where cold dry ice prevails.

Thank you

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