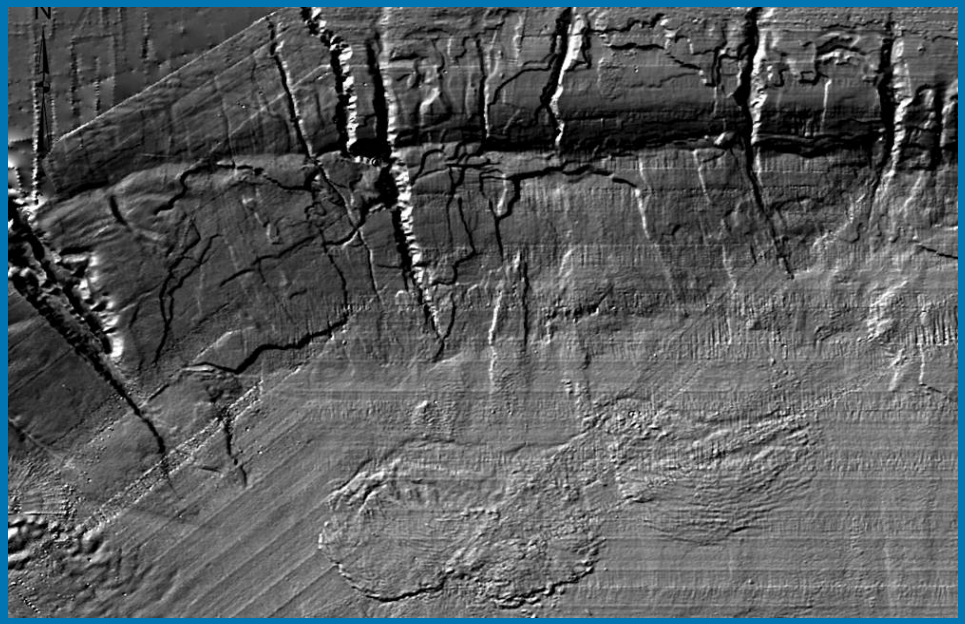
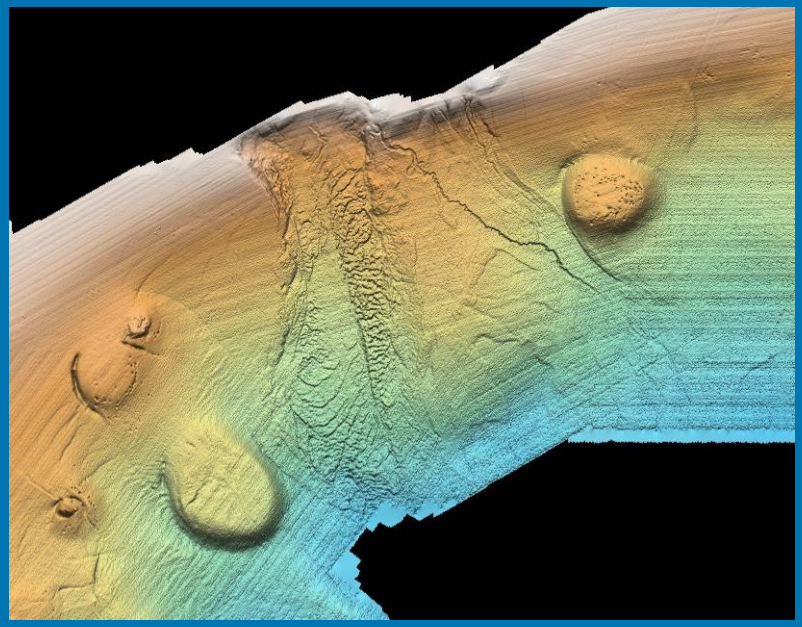
Overview of Landslide Mapping of the Atlantic and Gulf of Mexico Margins

David Twichell, Jason Chaytor, Uri ten Brink

Multibeam bathymetry, long-range sidescan sonar imagery, and high-resolution seismic-reflection data have been used to map the size and distribution of recent landslide scars and deposits along the US Atlantic and Gulf of Mexico margins. These data provide some of the basic information needed for predictive models addressing tsunami wave height and frequency. The US Atlantic margin is divided into three provinces that affect the size and distribution of landslides differently. Landslides are most extensive off the glaciated part of the margin, which lies south of Georges Bank and southern New England, and less extensive off both the fluvially dominated middle Atlantic margin (Hudson Canyon to Cape Hatteras) and the Carolina margin (Cape Hatteras to the Blake Spur) which is dominated by recent salt movement. The largest failures occur in open slope settings rather than in canyons, and the largest excavation generated by a single landslide was on the Carolina margin downslope of a salt diapir. The headwall scarp is in approximately 2500 m water depth, the volume of material removed was 179 km^3, and the failure occurred before 9000 yr BP. The US Gulf of Mexico margin is also divided into three distinct geologic provinces: the northwestern Gulf underlain by mobile salt, the northeastern Gulf characterized by thick siliciclastic deposits carved by canyons and deep-sea fans, and the carbonate province in the eastern Gulf. The greatest number of landslides occurs in the salt province but most are much smaller than those found in the other two provinces. The smallest number of landslides, but the one with the largest excavation volume, was found in the siliciclastic northeastern Gulf. The largest excavation (425 km^3) was in the head of the Mississippi Canyon, the headwall scarp was in 200-300 m water depth, and sedimentation suggests the failure occurred prior to 7500 yr BP. The largest failures on the US Atlantic margin and those that have the potential to generate the largest tsunamis are the open-slope sourced landslides, while in the Gulf of Mexico the largest failure is in the head of the Mississippi Canyon

Overview of Landslide Mapping of the Atlantic and Gulf of Mexico Margins





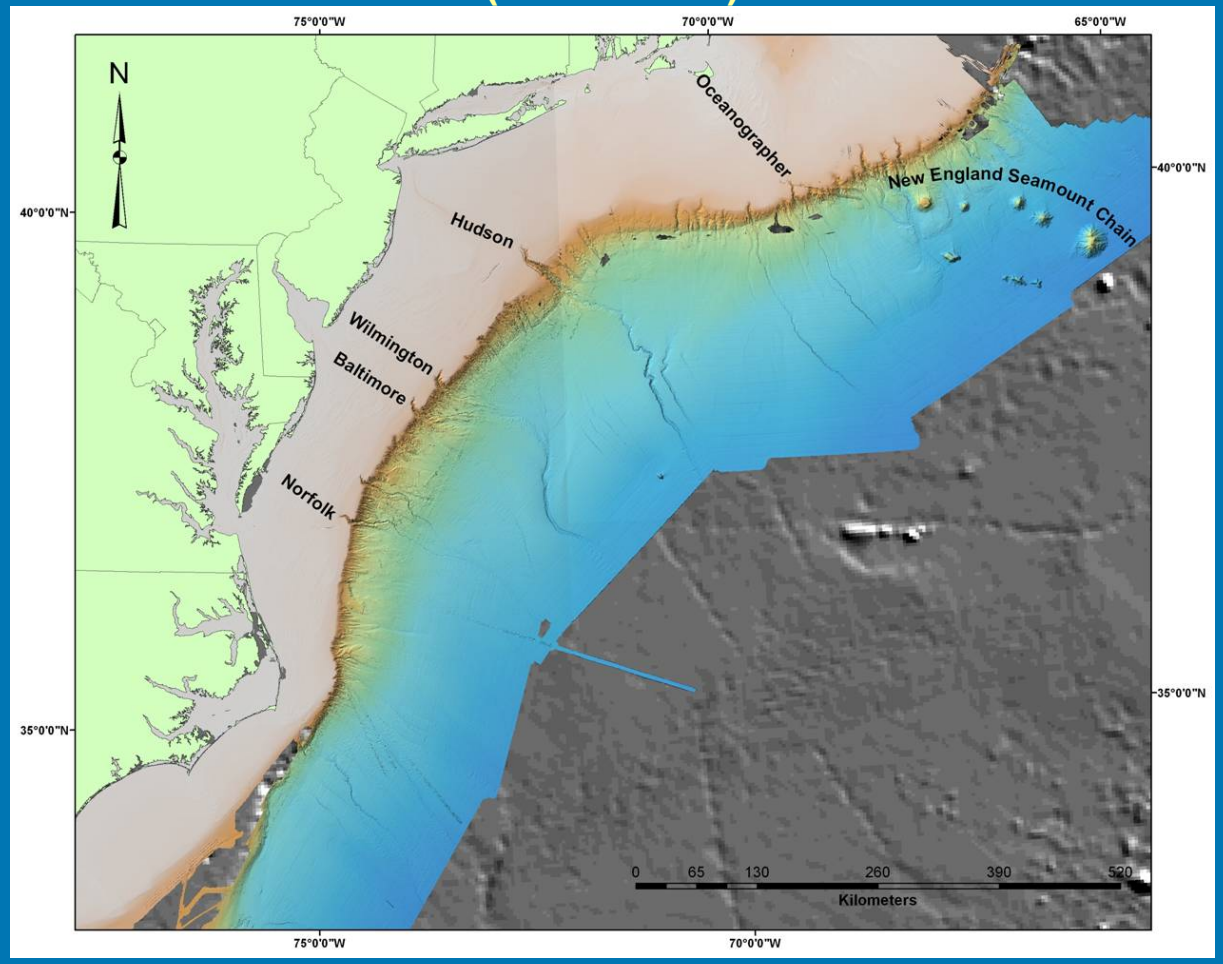
U.S. Department of the Interior
U.S. Geological Survey

By Dr. David Twichell, USGS-Woods Hole

Reexamination with New Dataset

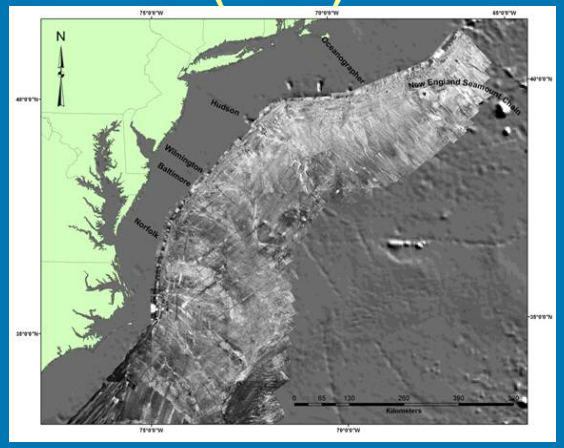
Multibeam Bathymetry

(2004-2010)



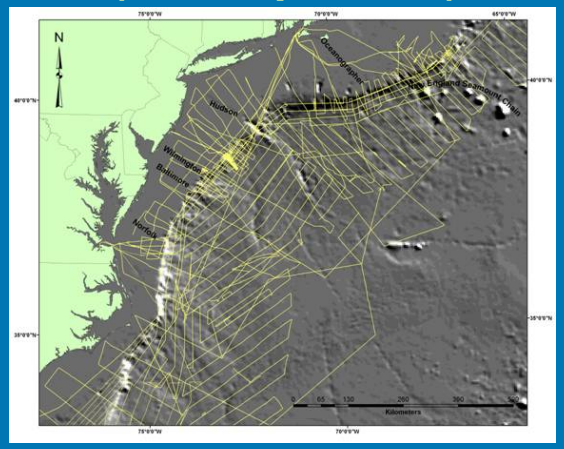
Sidescan sonar

(1987)

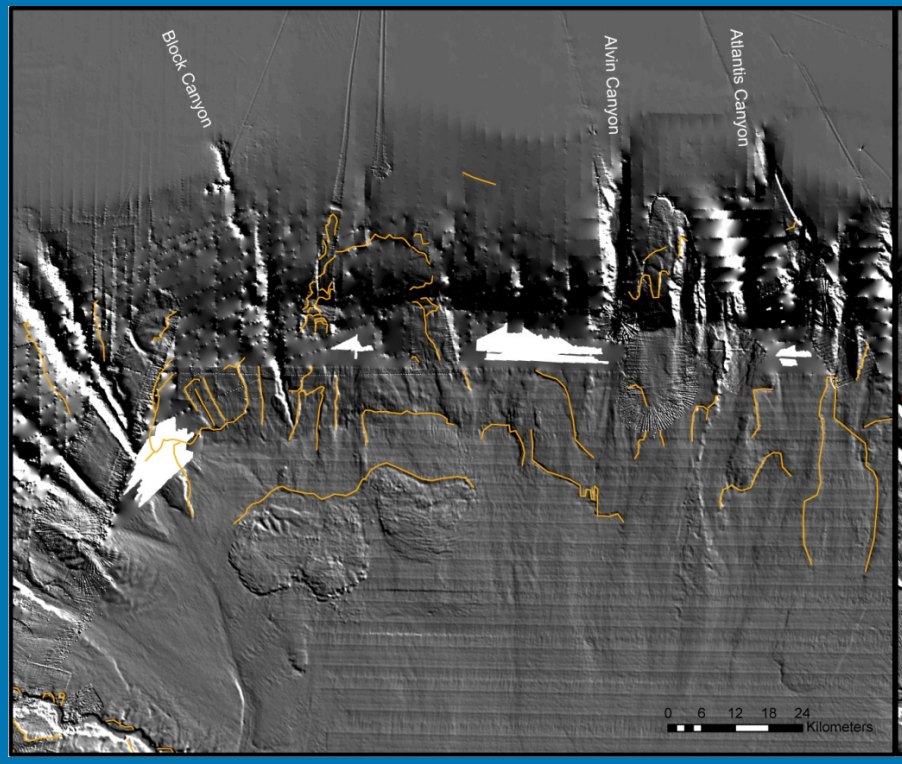


Seismic

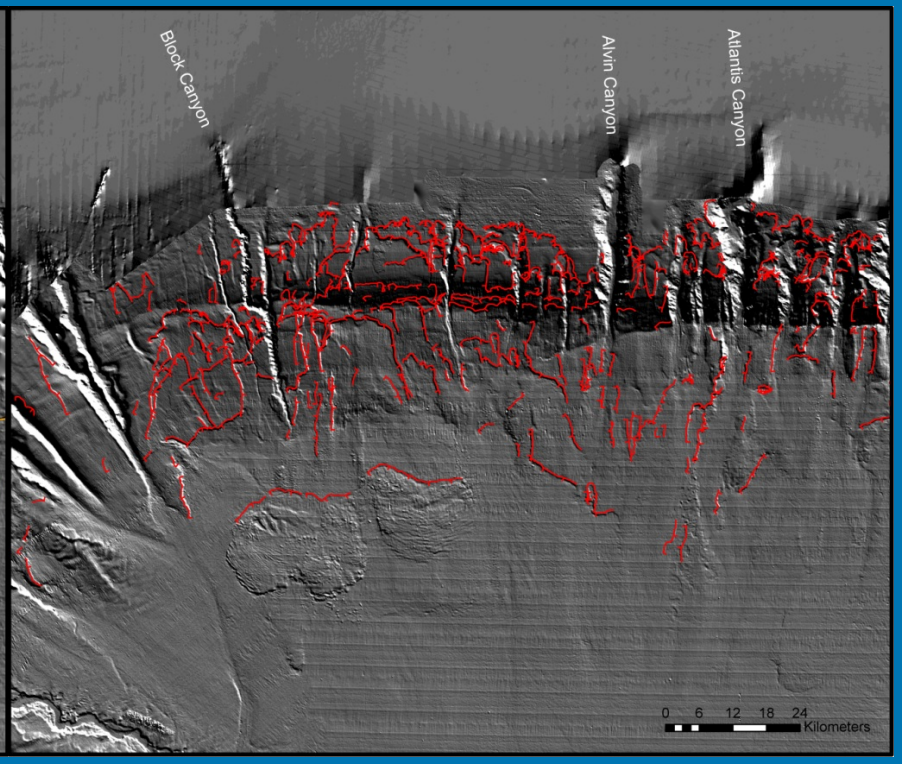
(1970s-present)



Southern New England Scarps



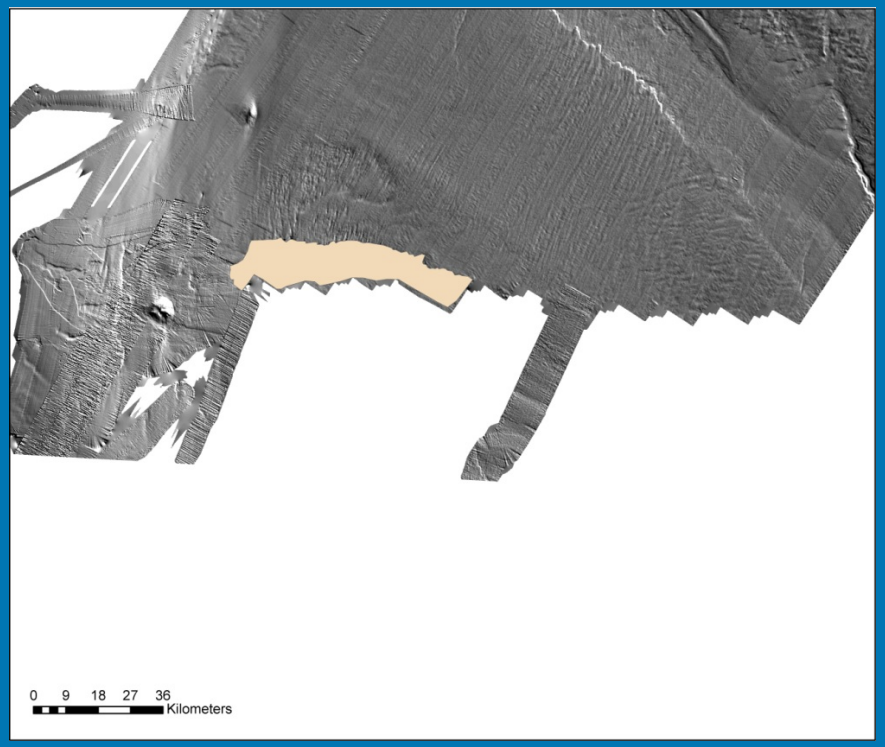
Pre-May 2009



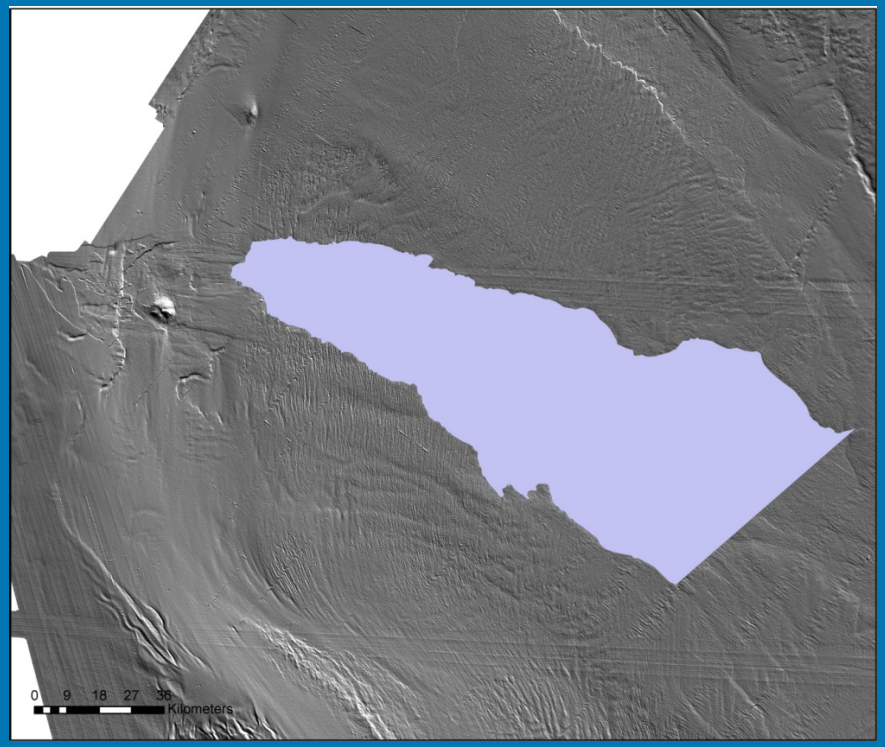
Post-May 2009

USGS

Cape Fear



Volume: 25 km^3

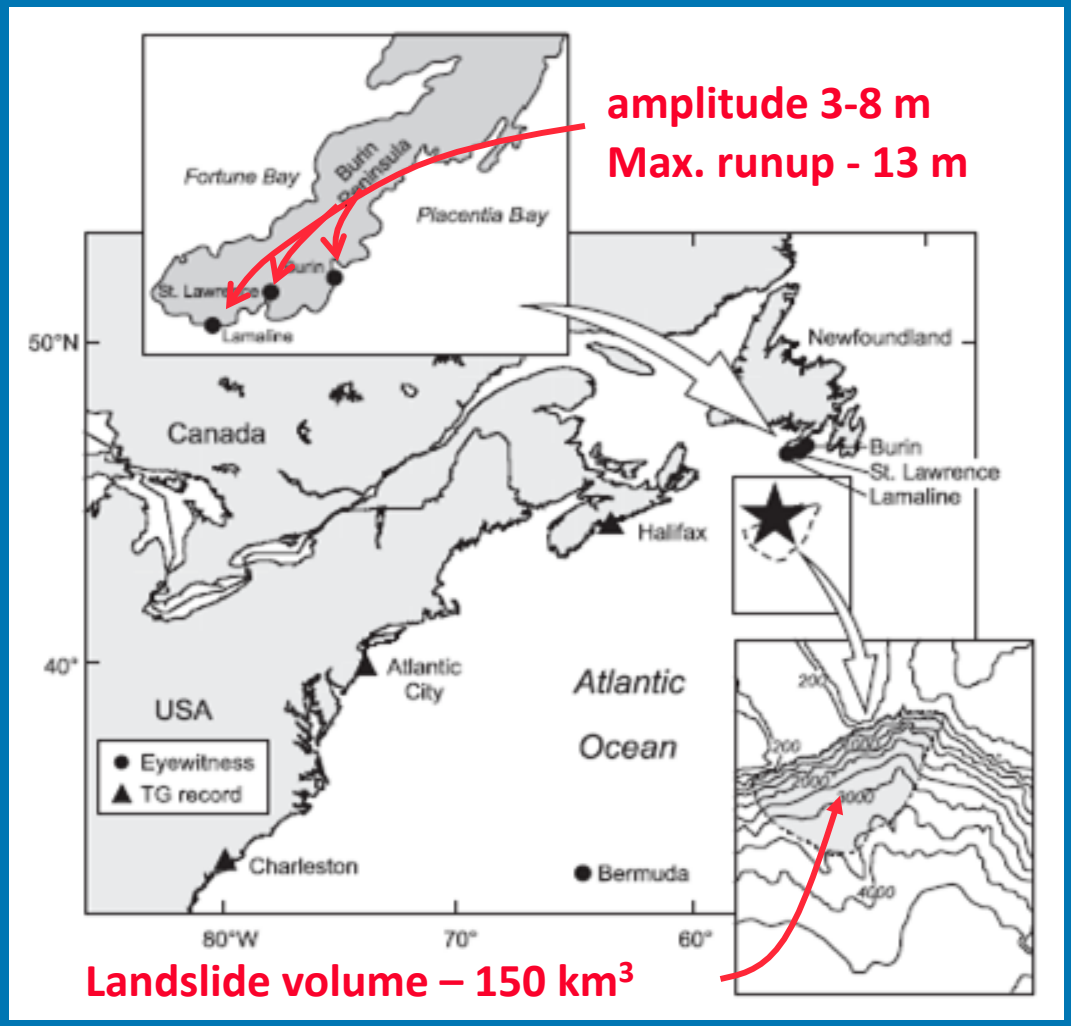


Volume: 342 km^3

USGS

Landslide tsunami

Landslide tsunamis have locally caused significant damage and loss of life



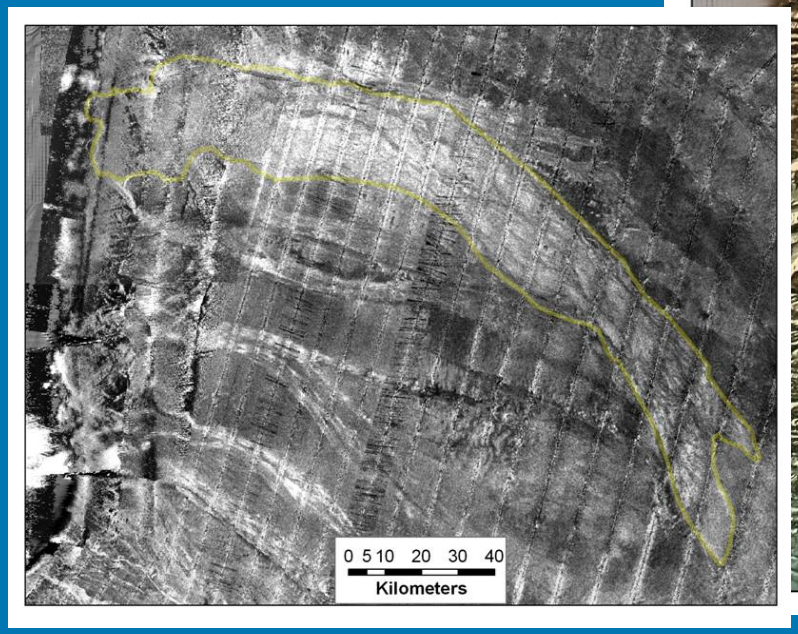
Grand Banks, 1929

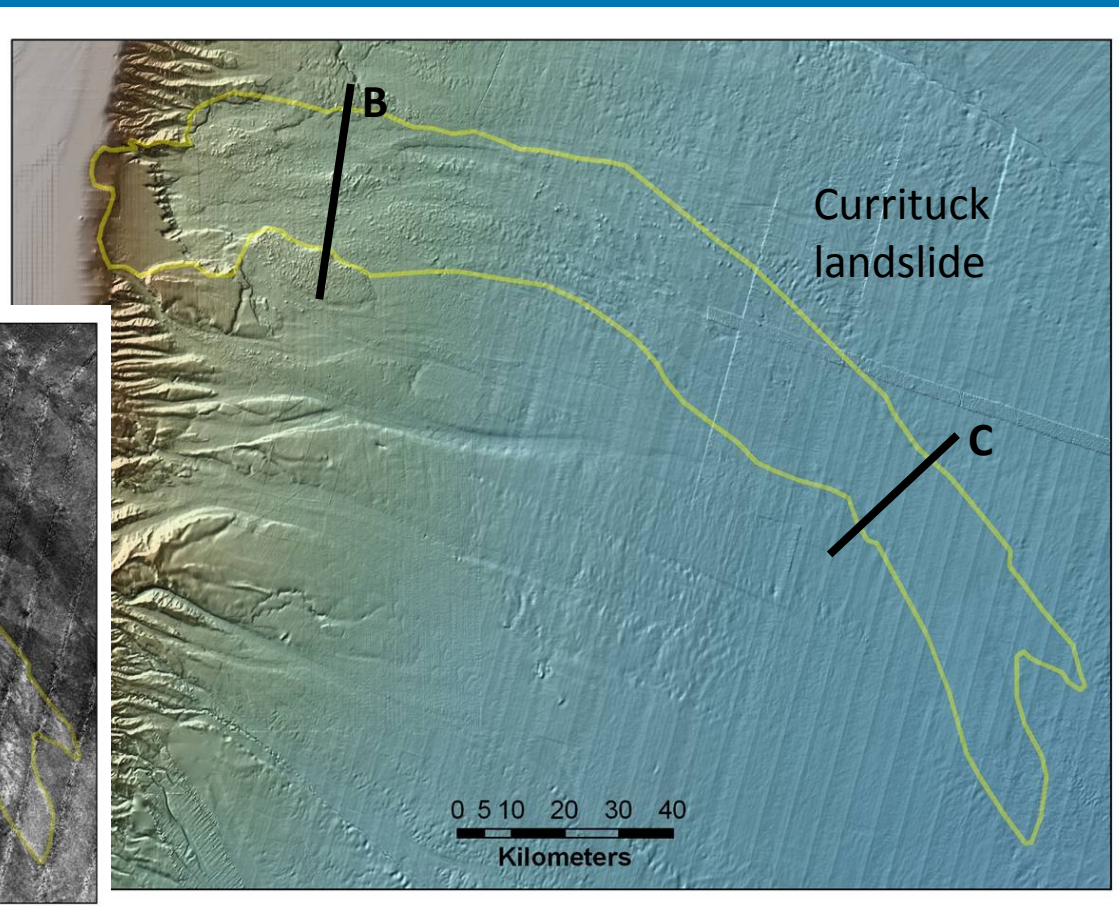
Fine et al., 2005

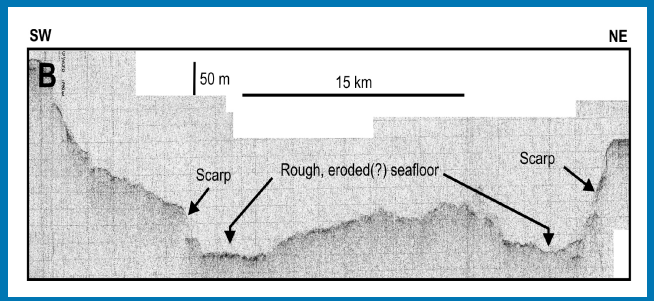
Approach used to map submarine landslides

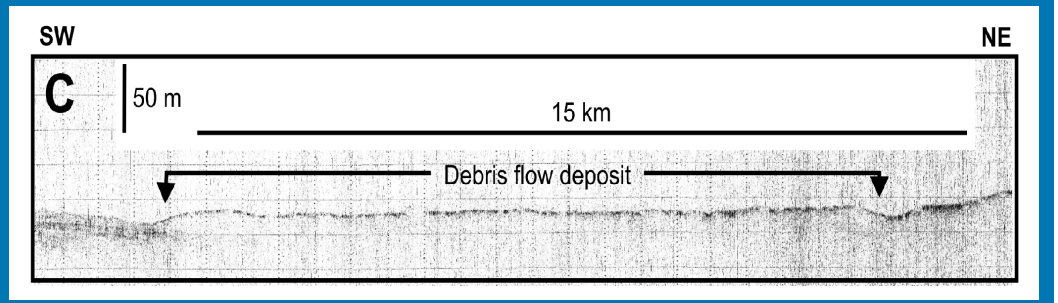
Sidescan sonar data is better at defining depositional area

Multibeam data is better at defining excavated area



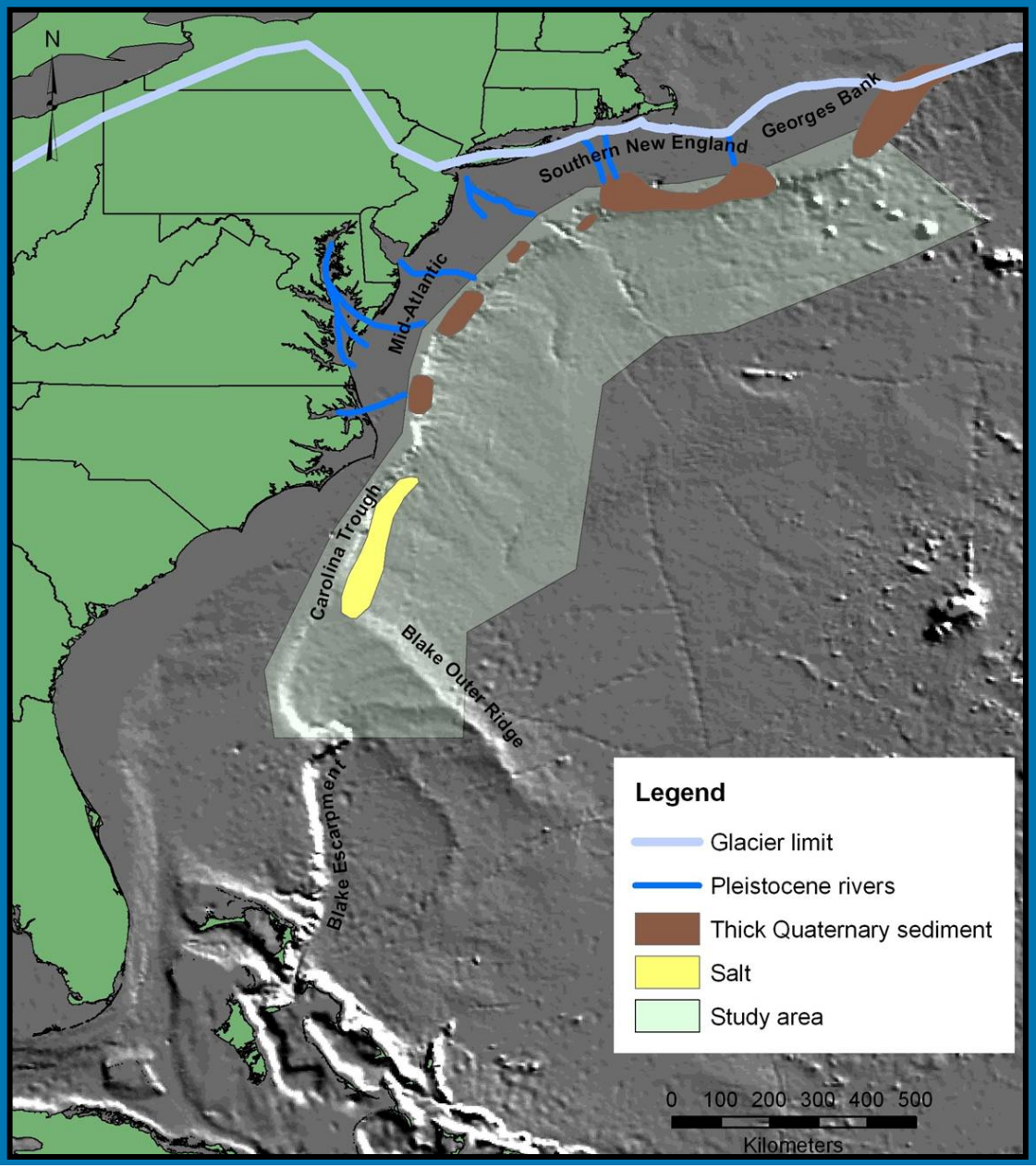




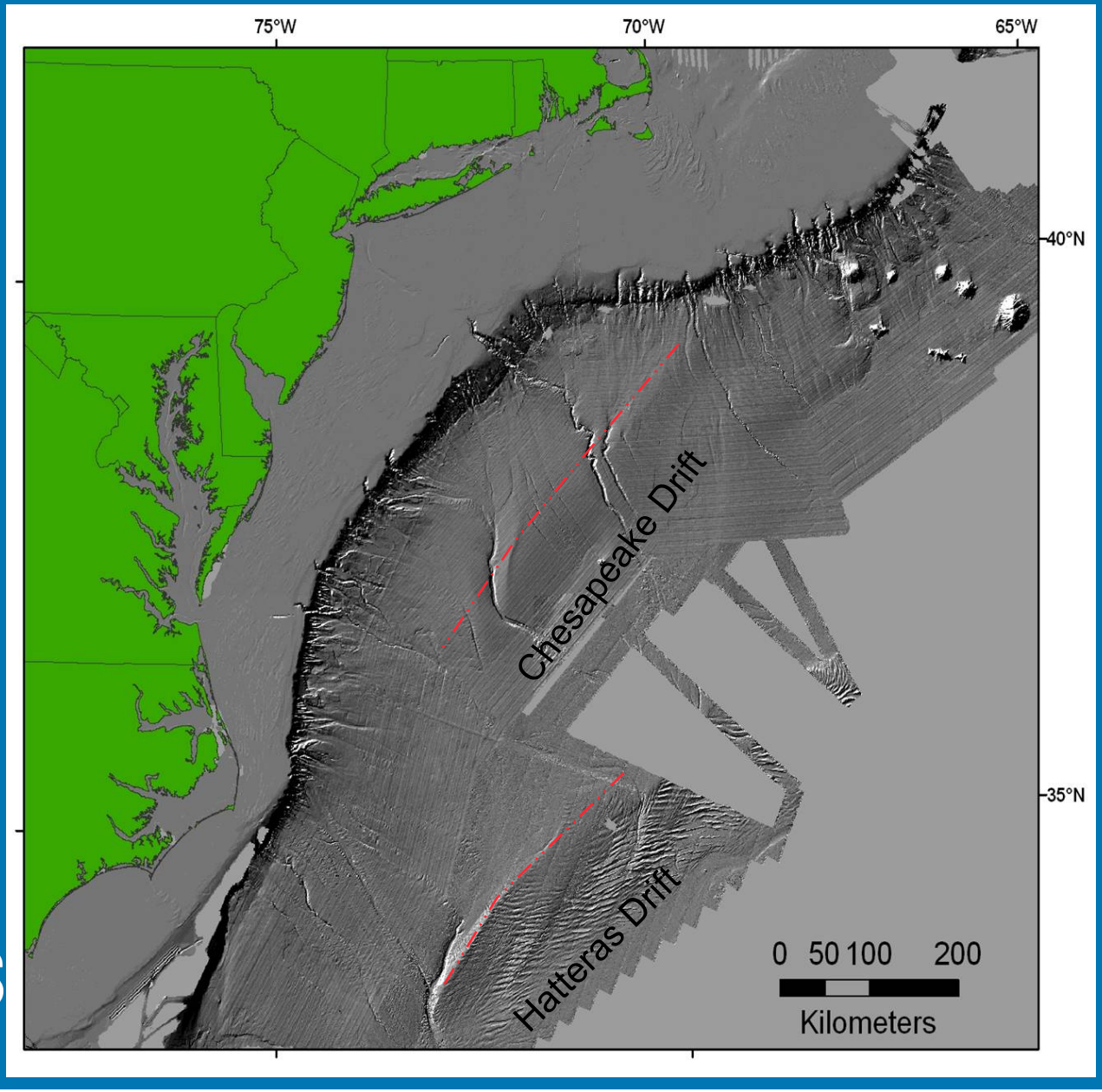


High-resolution seismics verifies and determines thickness of landslide deposits

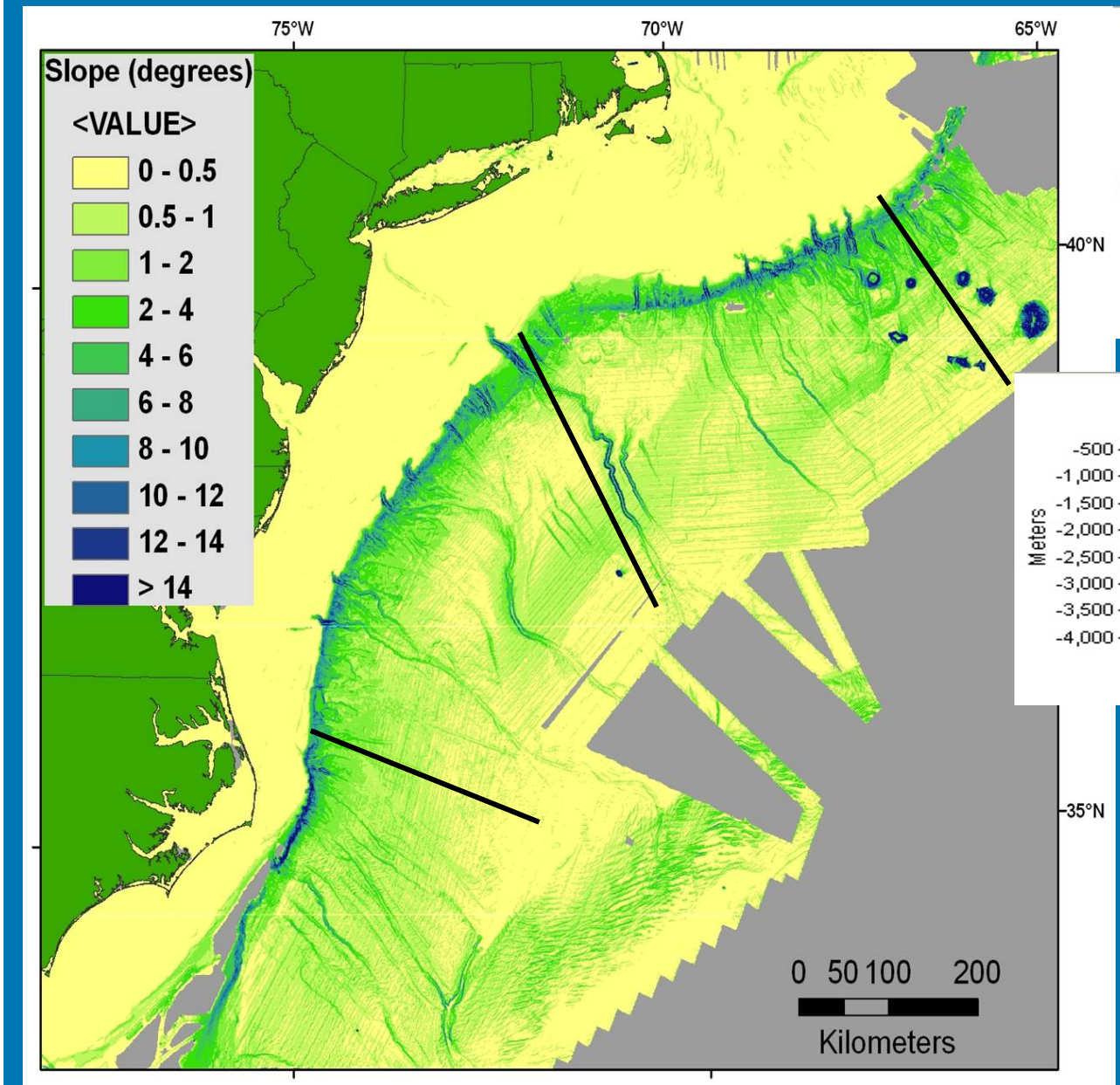
Background Geology

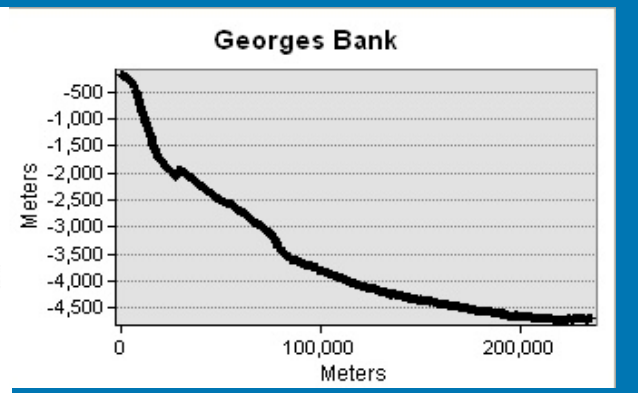


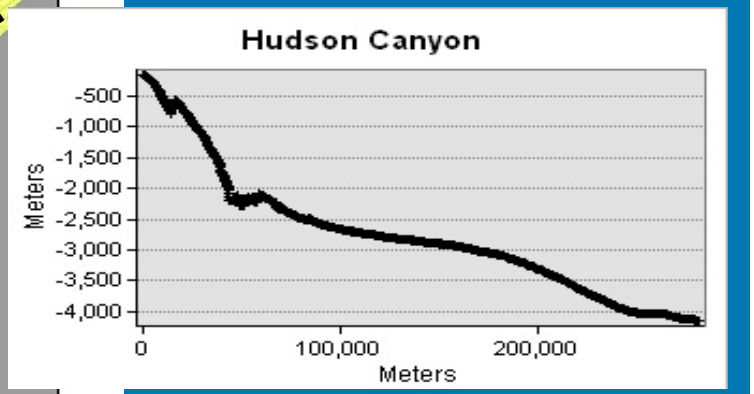
Margin Geomorphology

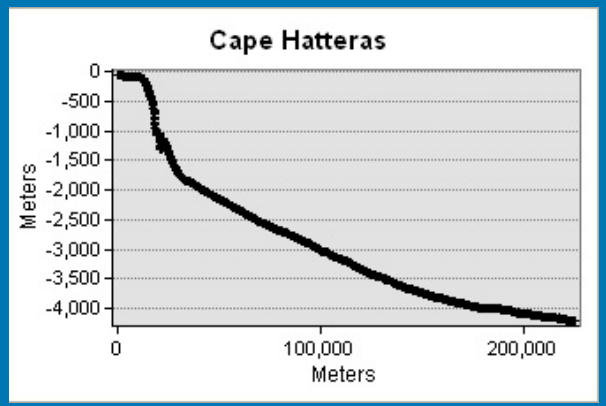


Seafloor Gradient

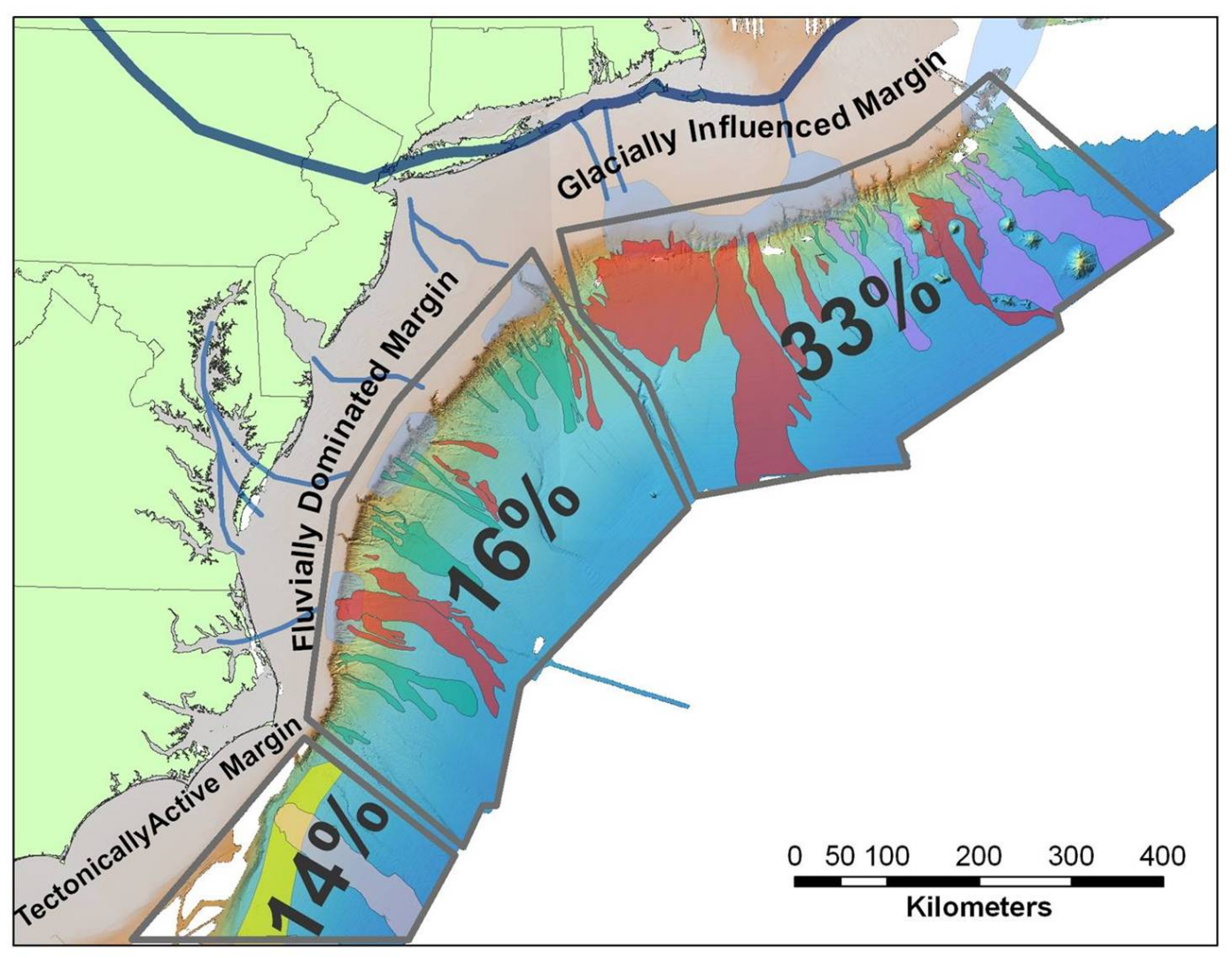








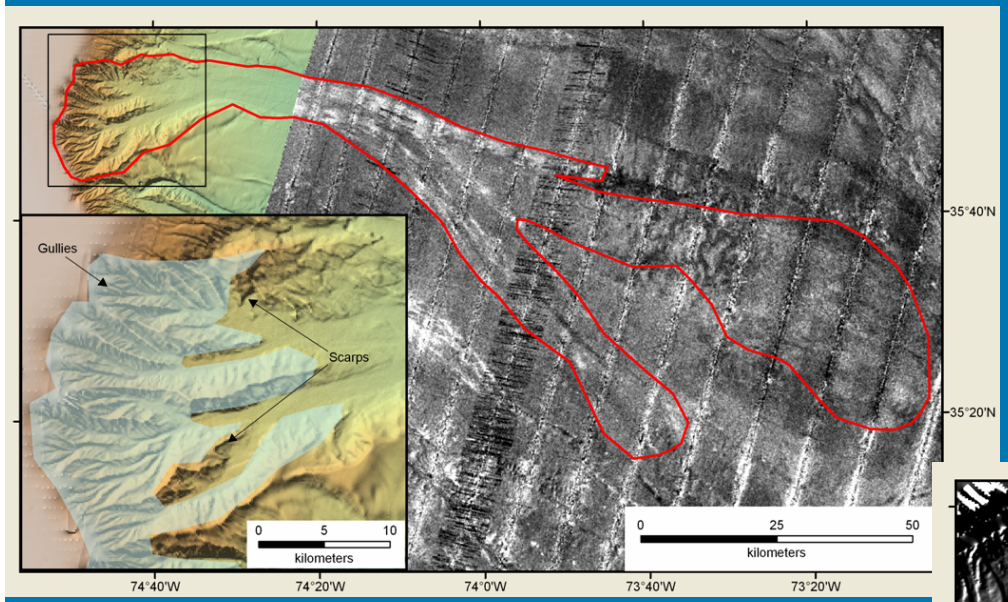
Landslide Distribution



USGS

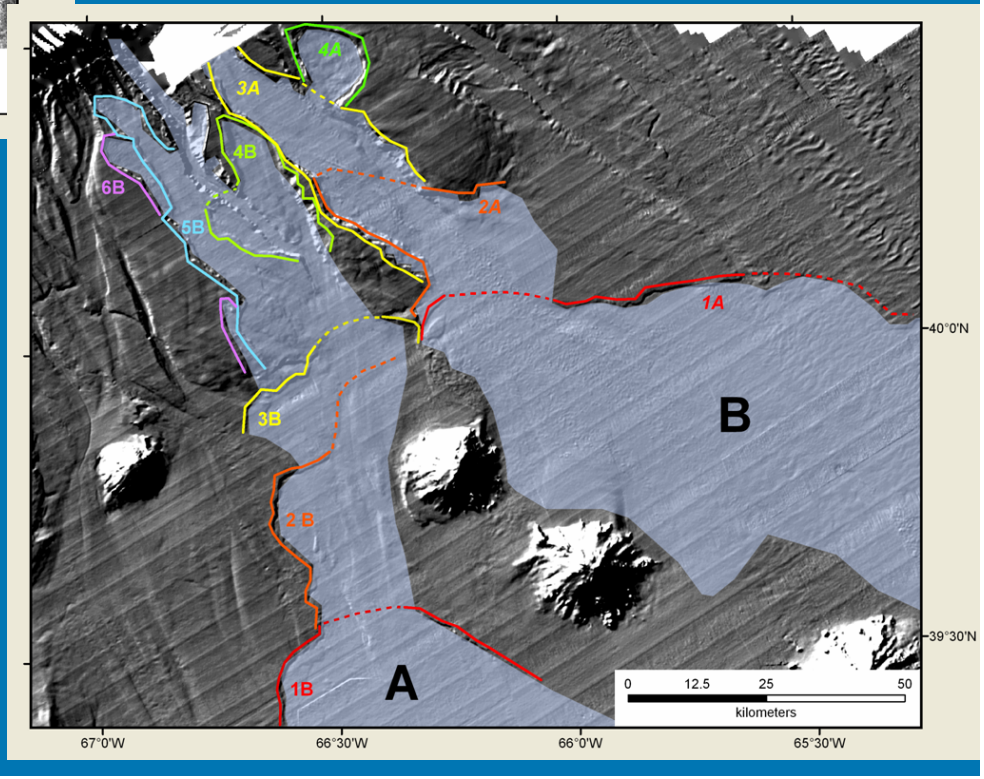
Area of source + deposit

Landslide source-area types



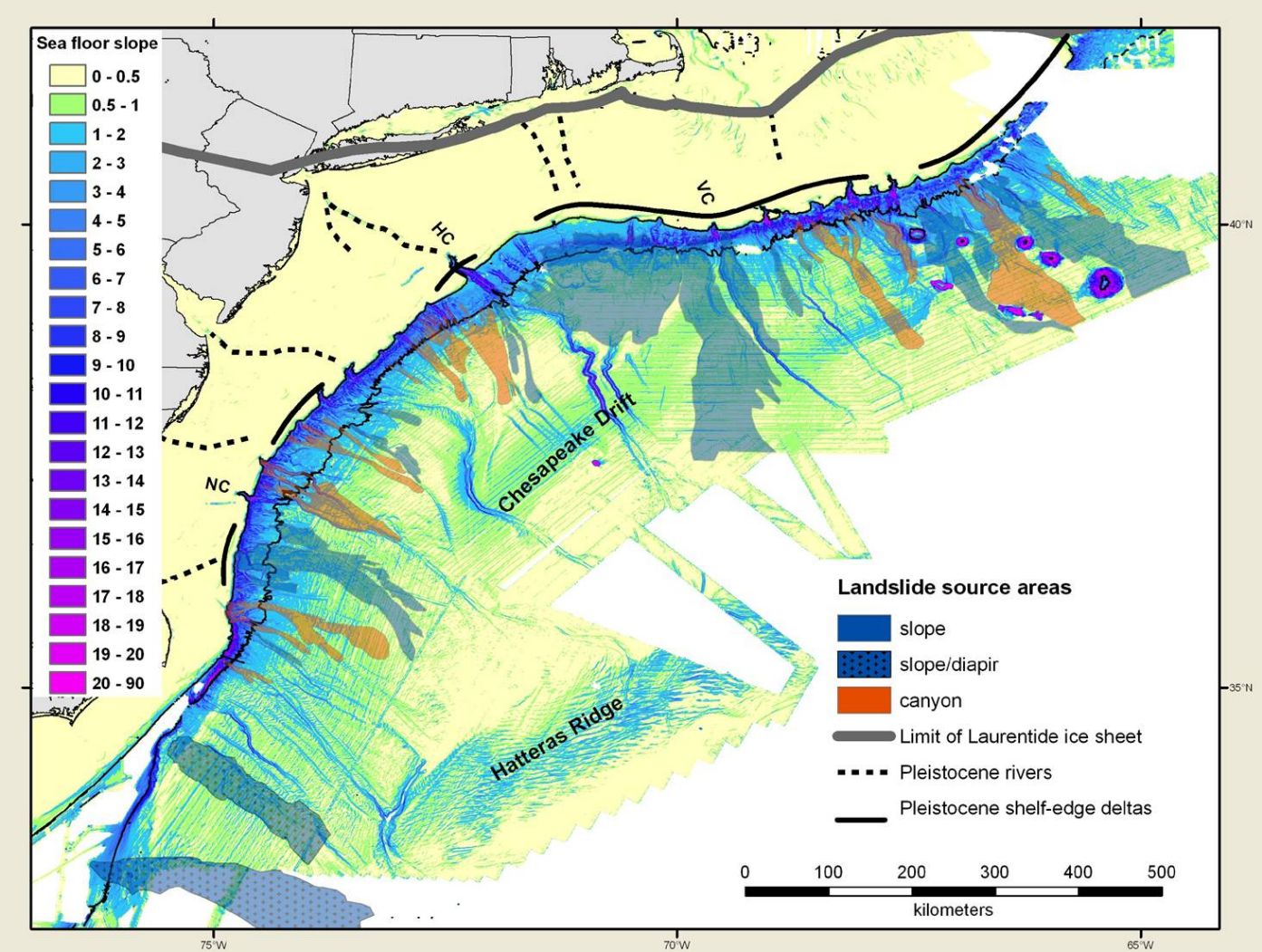
Canyon-sourced landslides

Slope-sourced landslides



USGS

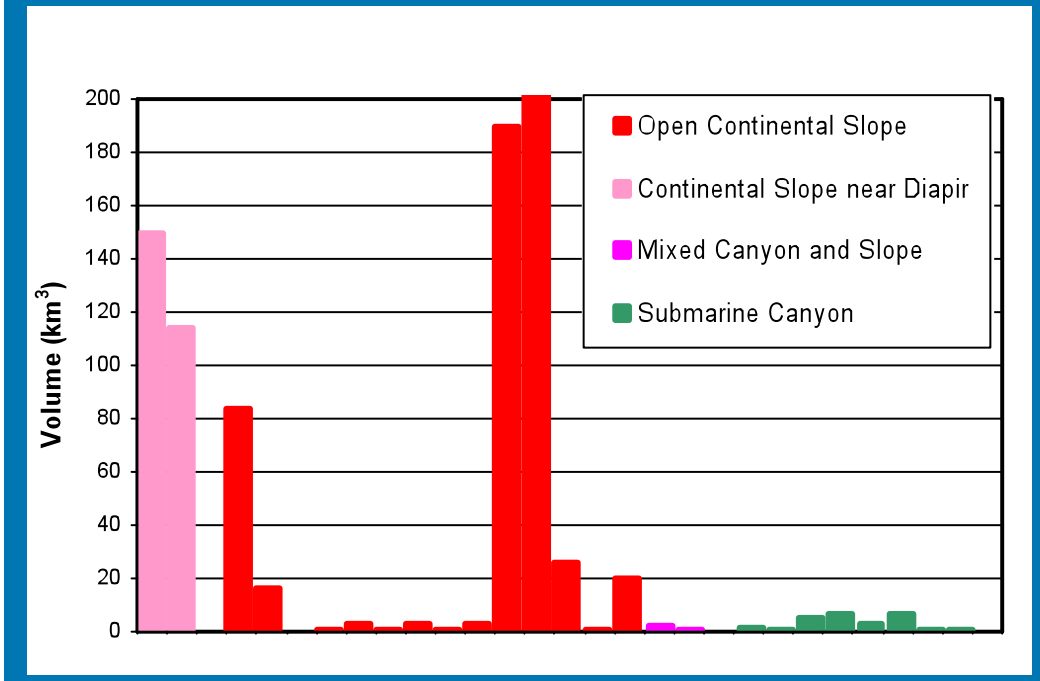
Distribution of Landslide Types

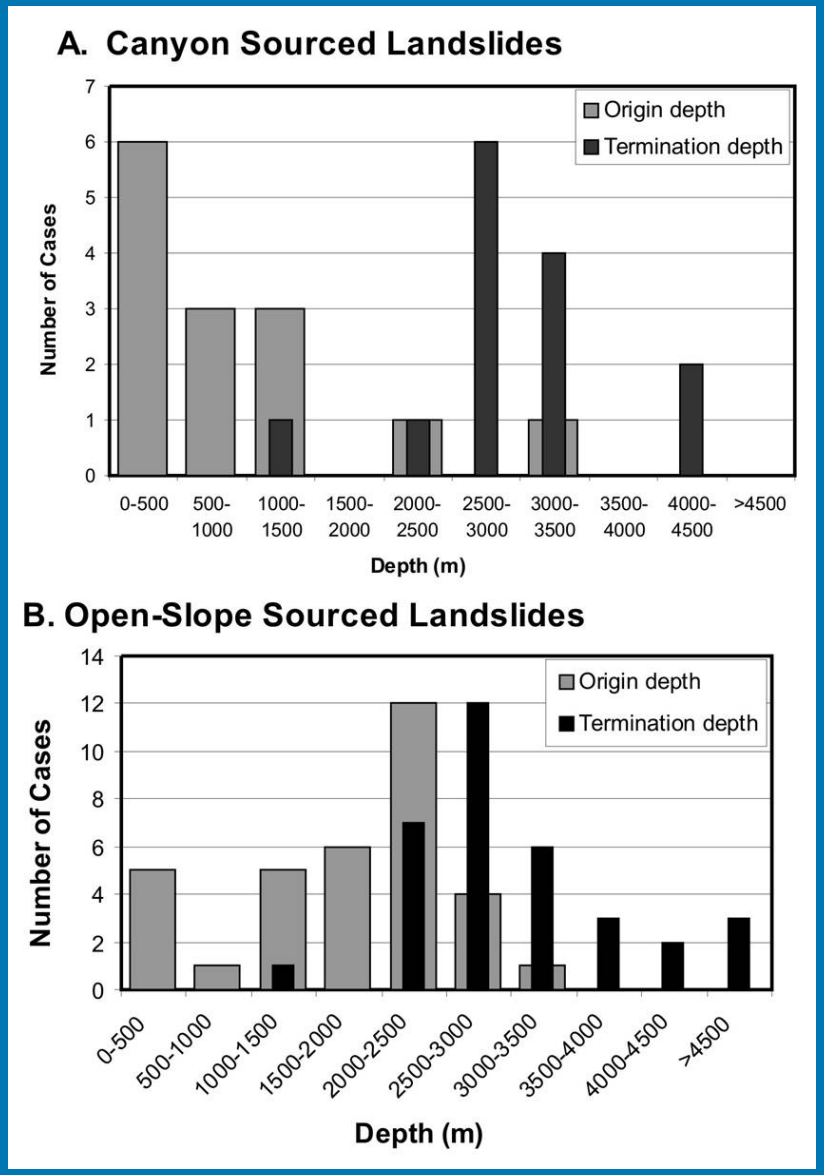


Runout distance partly controlled by existing rise morphology

Landslide Characteristics

Volume of landslide deposits as a function of landslide type

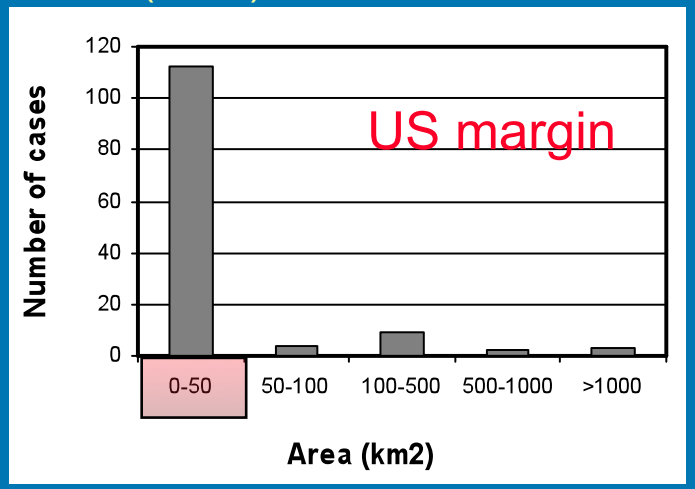




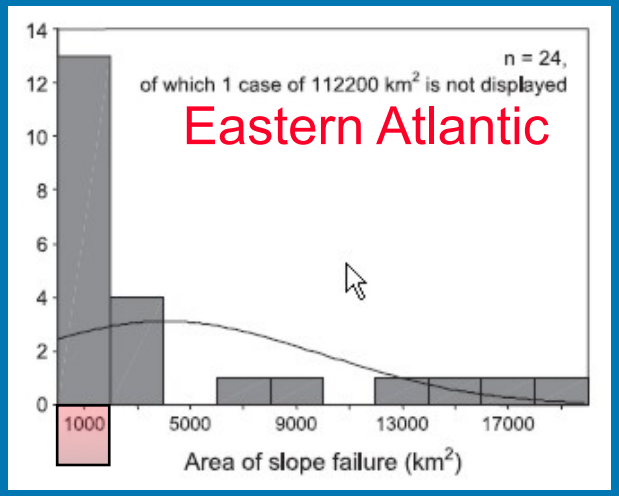
USGS

Comparison to other studies

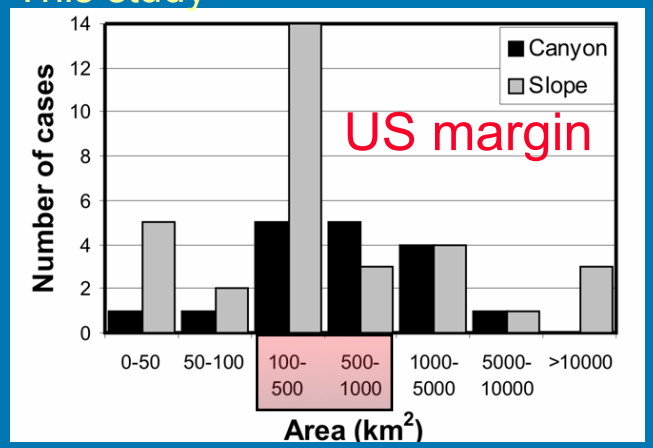
Booth (1993)



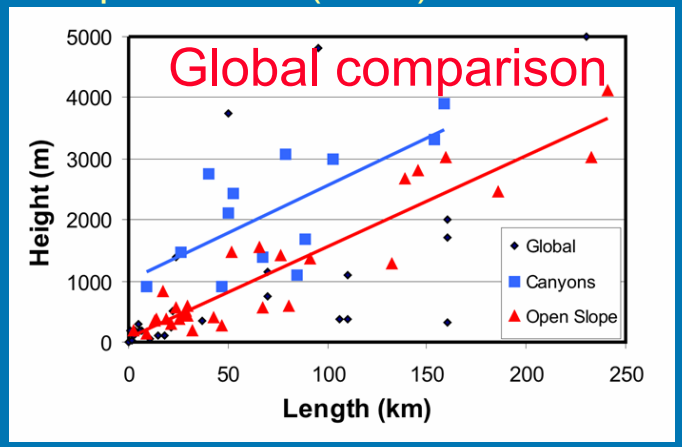
Huhnerbach (2004)



This study



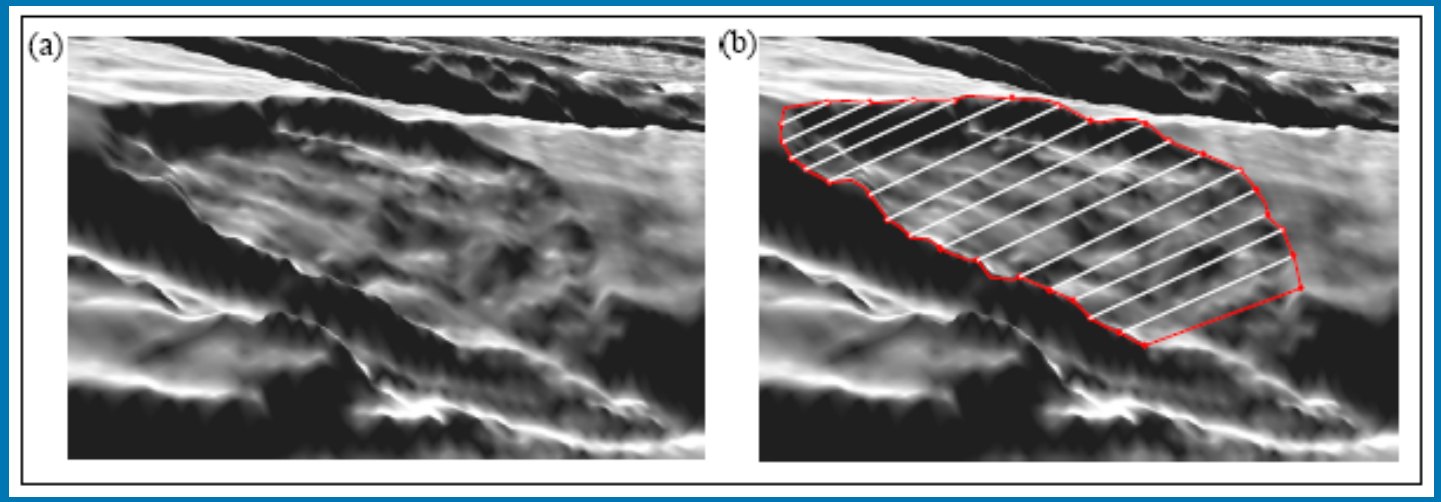
Hampton et al. (1996)



New data indicates landslides from US Atlantic margin have similar dimensions to those on other margins.

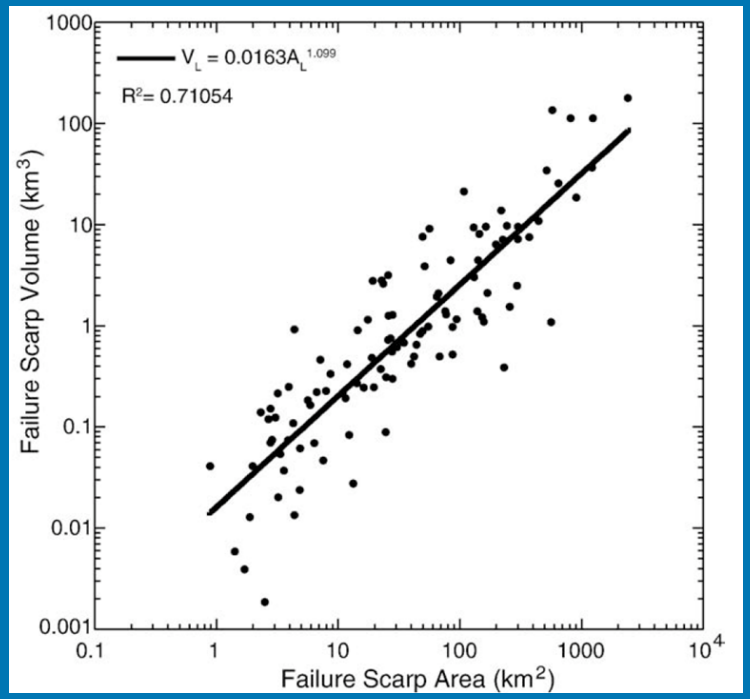
Source-area volumes

Calculating landslide source area volume



10x vertical exag.

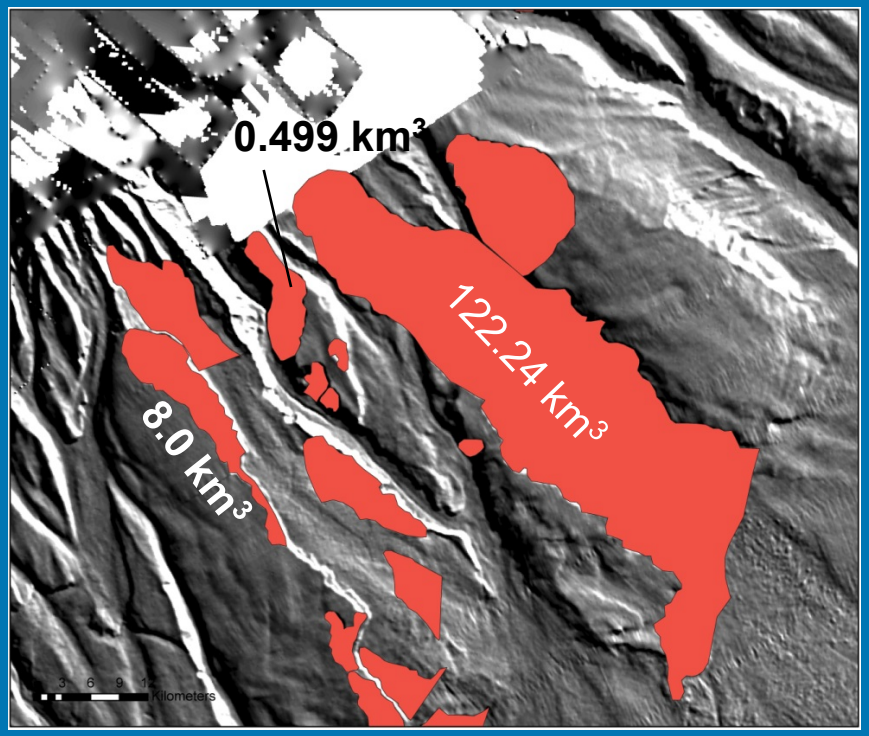
Area-volume relationship

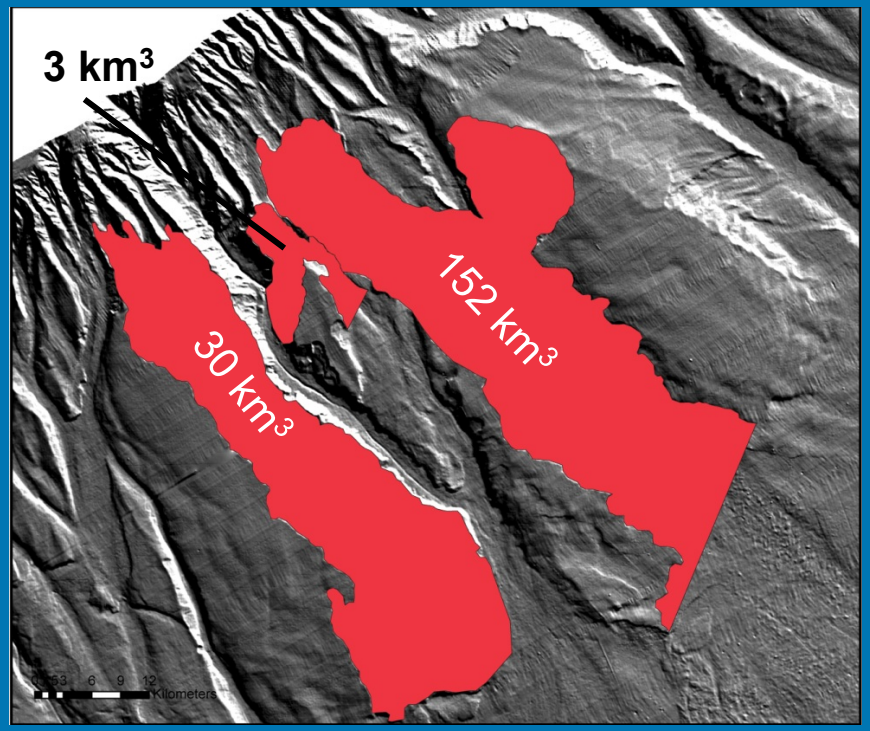


~1:1 area-volume relationship means that submarine landslides along the Atlantic margin have roughly constant thickness

Chaytor et al., 2009

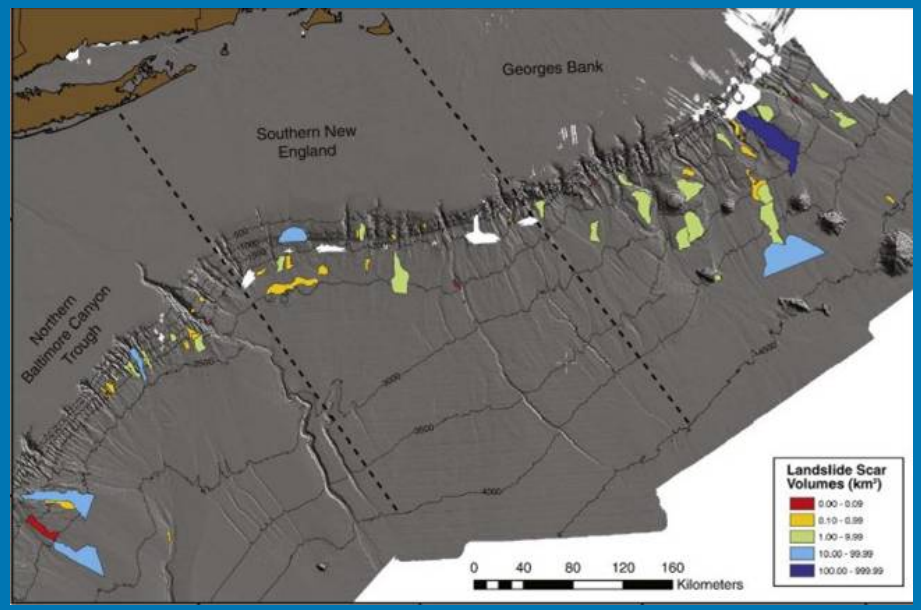
Munson-Nygren-Retriever (Georges Bank)

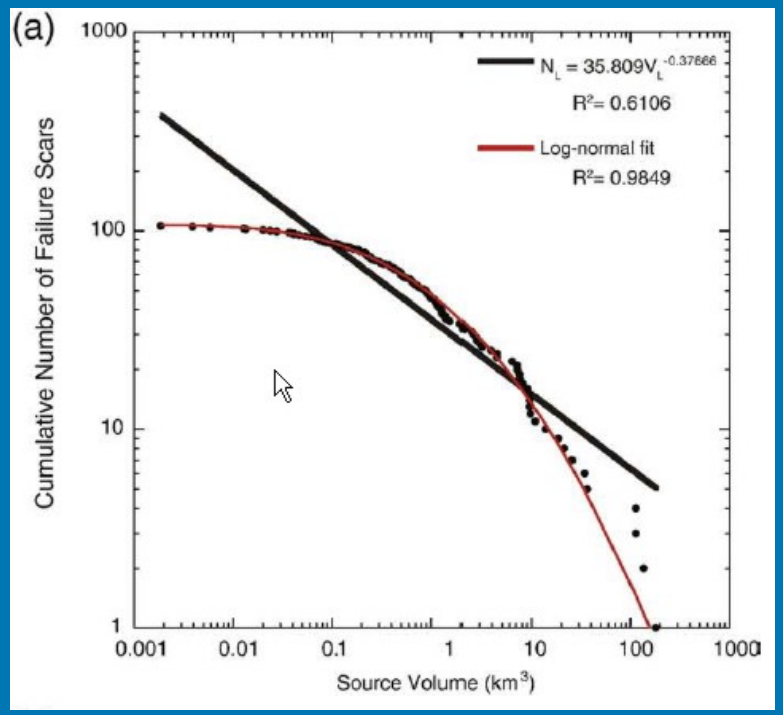


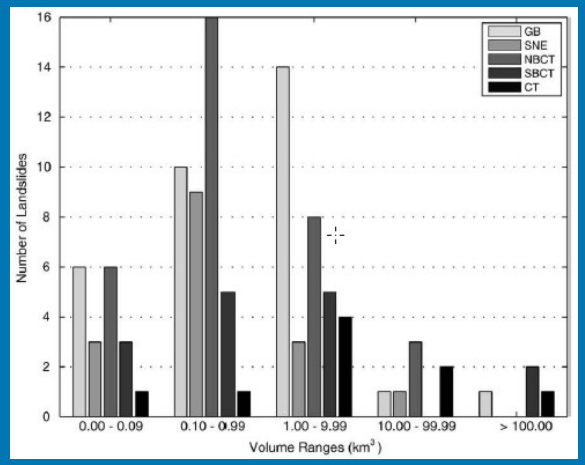


USGS

Source-area volumes







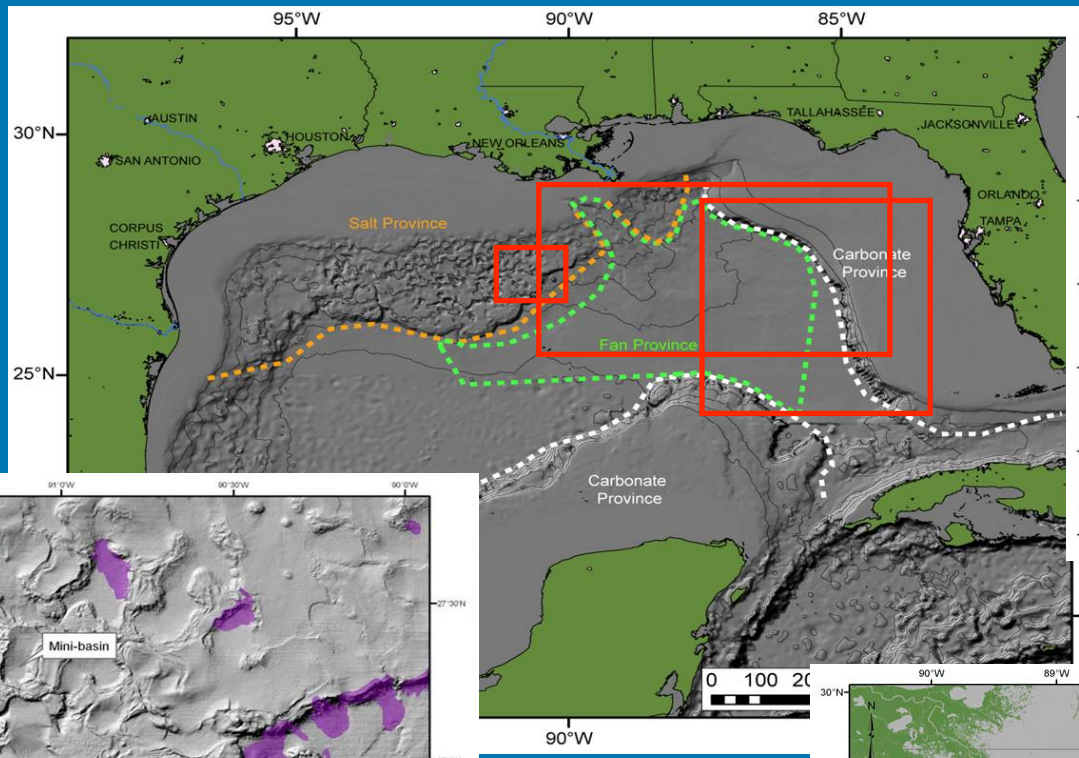
Size distribution of landslides on the Atlantic margin is log-normal rather than inverse power-law.

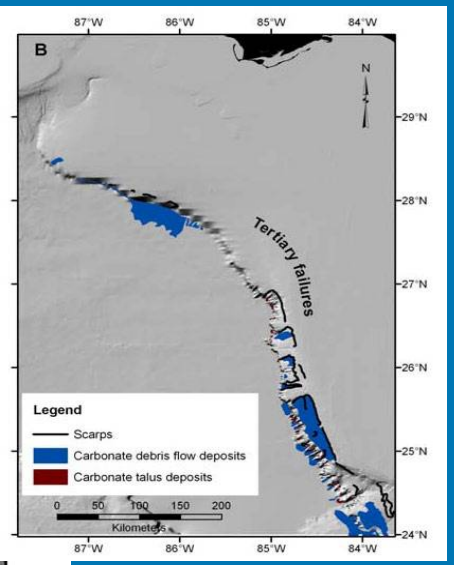
Average source volume ~1 km^3, fewer larger and smaller landslides

Most source-area volumes <10 km^3

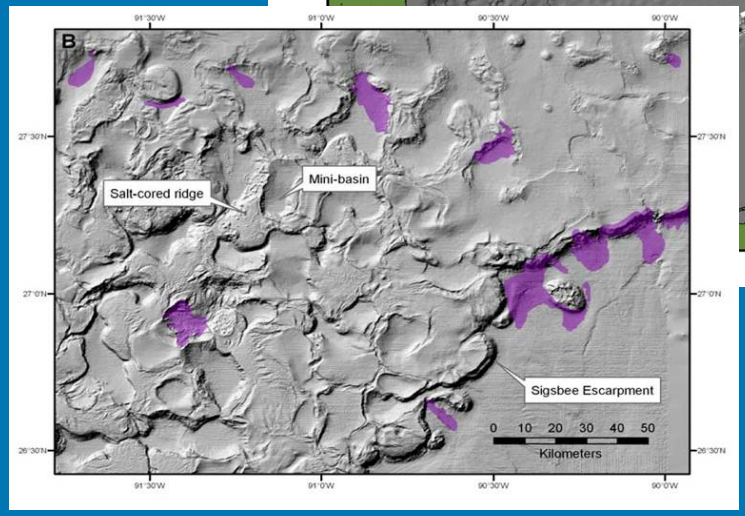
Chaytor et al. (2009)

Gulf of Mexico Geologic Provinces

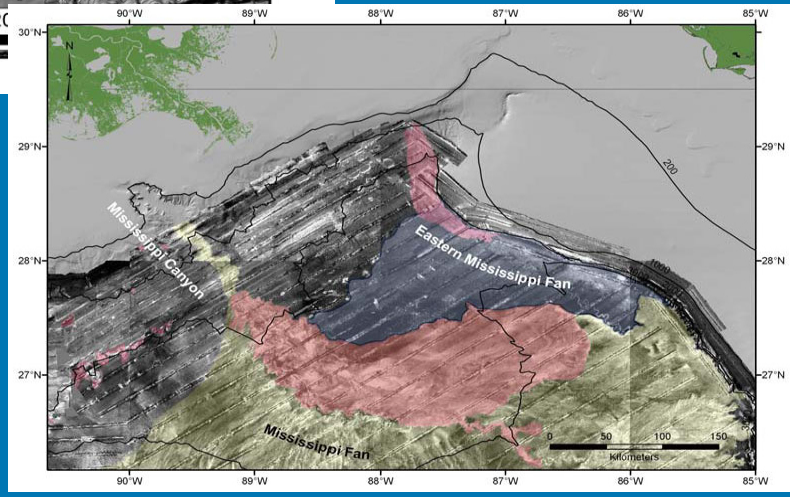




Carbonate Province



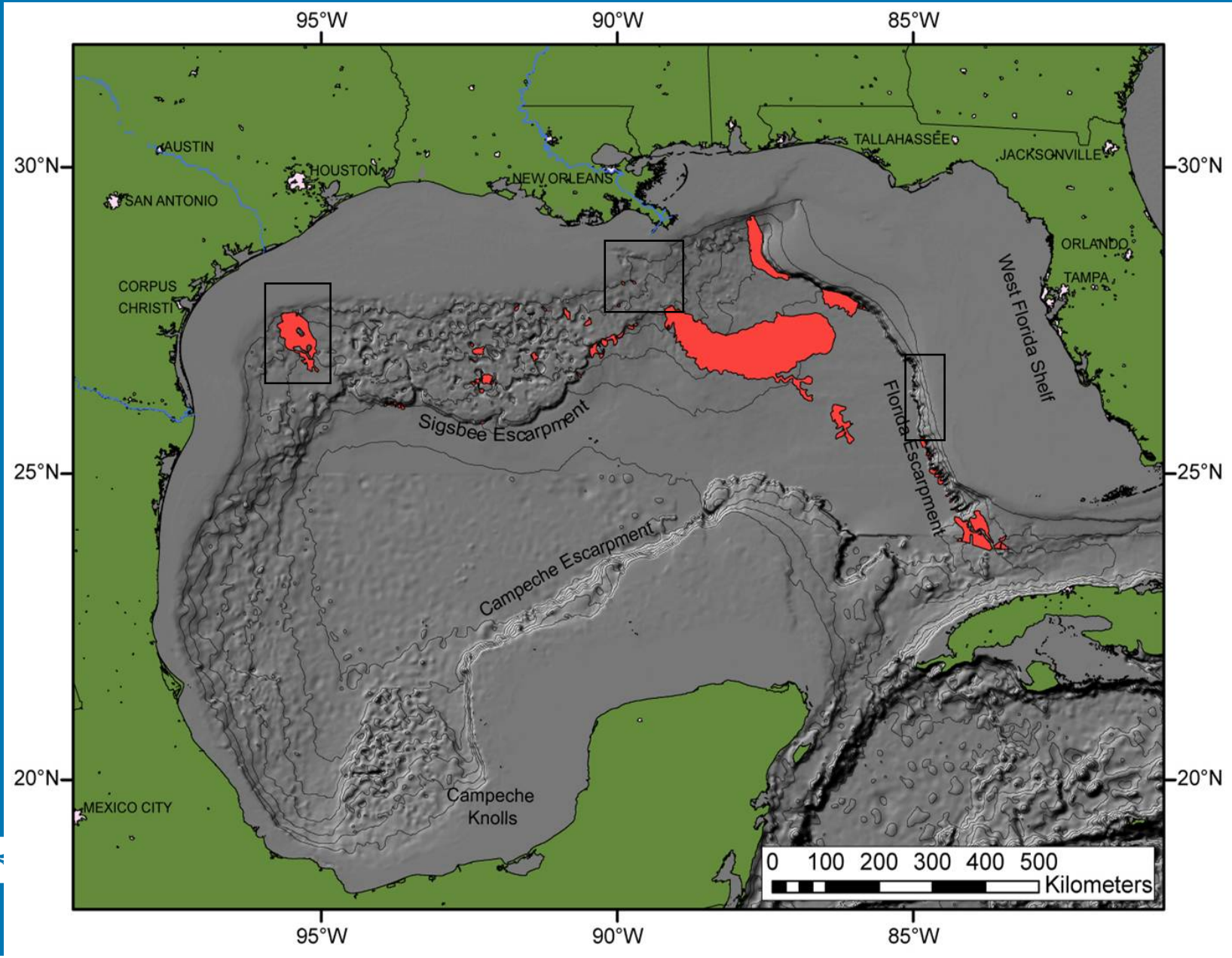
Salt Province



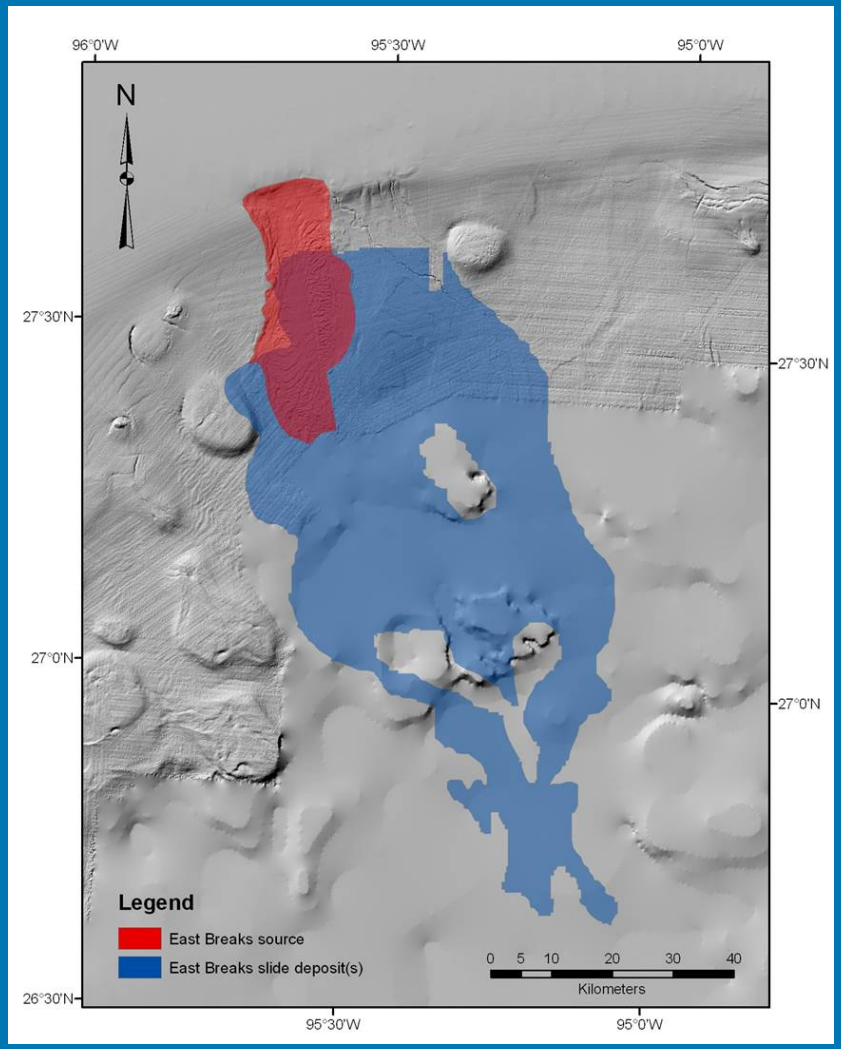
Fan Province

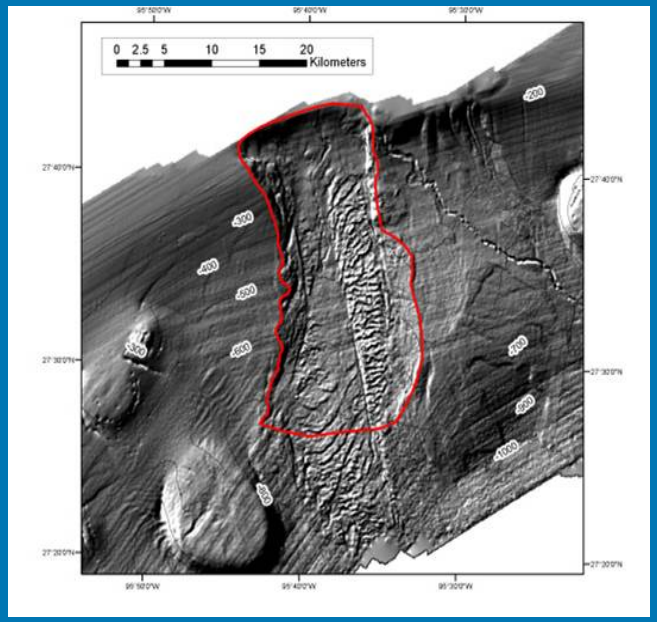
USGS

Landslide Distribution



Largest salt province landslide

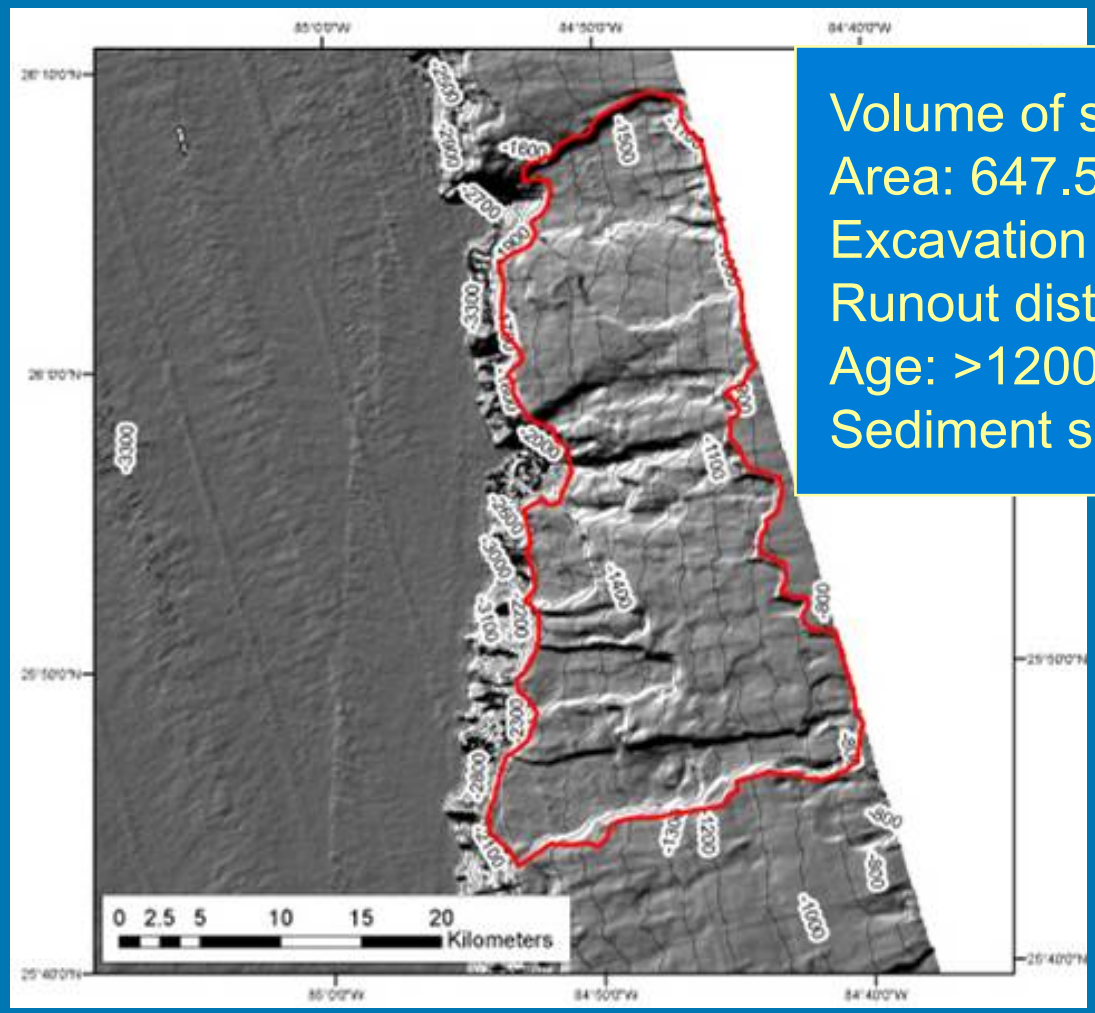




Volume of source area: 21.95 km^3
Area: 520 km^2
Width: ~ 12 km
Length: ~ 50 km
Excavation depth: ~160 m
Run out distance: 91 from toe of excavation
Age: 10000-25000 yr B.P.
Sediment source: Rio Grande River

USGS

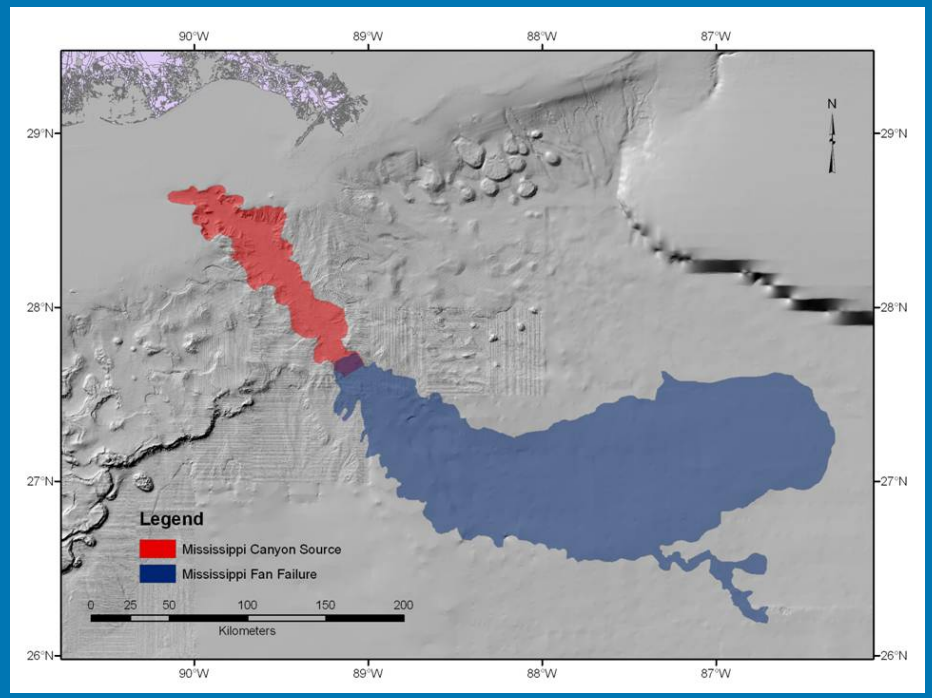
Large carbonate province landslide

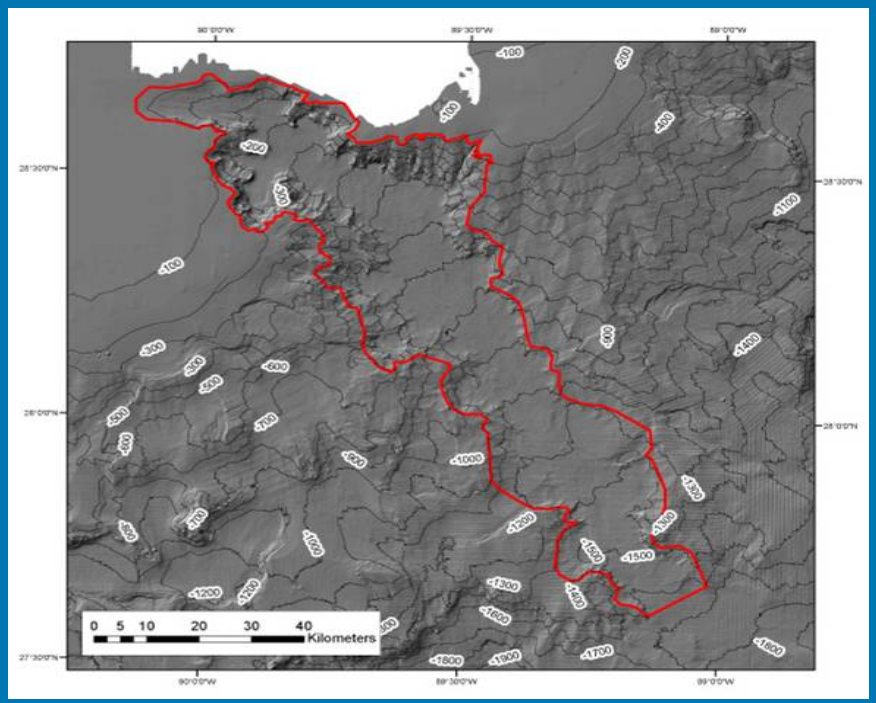


Volume of source area: 16.2 km^3
Area: 647.57 km^2
Excavation depth: ~150 m
Runout distance: Unknown
Age: >12000 yr B.P.(?)
Sediment source:carbonate sedimentation

USGS

Largest canyon/fan sourced landslide



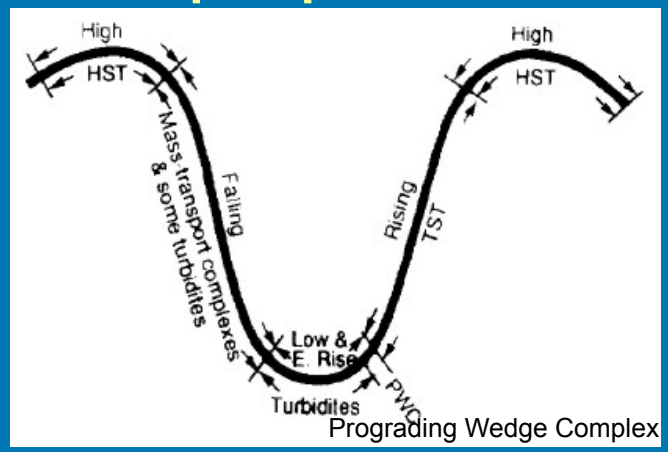


Volume of source area: 425.54 km^3
Area: 3687.26 km^2
Excavation depth: ~300 m (in the upper canyon)
Runout distance: 297 km from toe of excavation
Age: 7500-11000 yr B.P.
Sediment source: Mississippi River

USGS

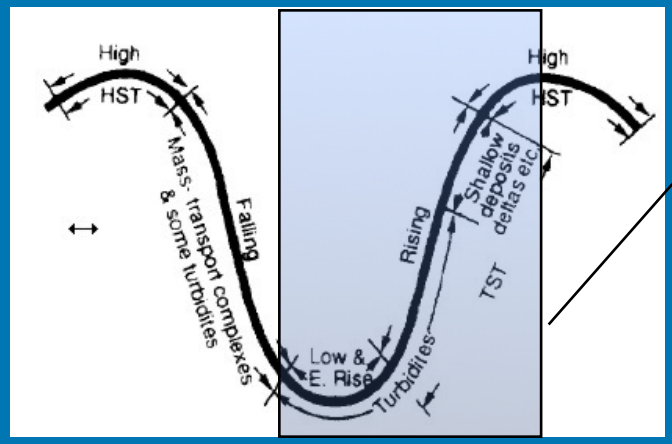
Timing of Mississippi Canyon/Fan Sedimentation

General deep-sea fan perspective



Vail et al. (1991)

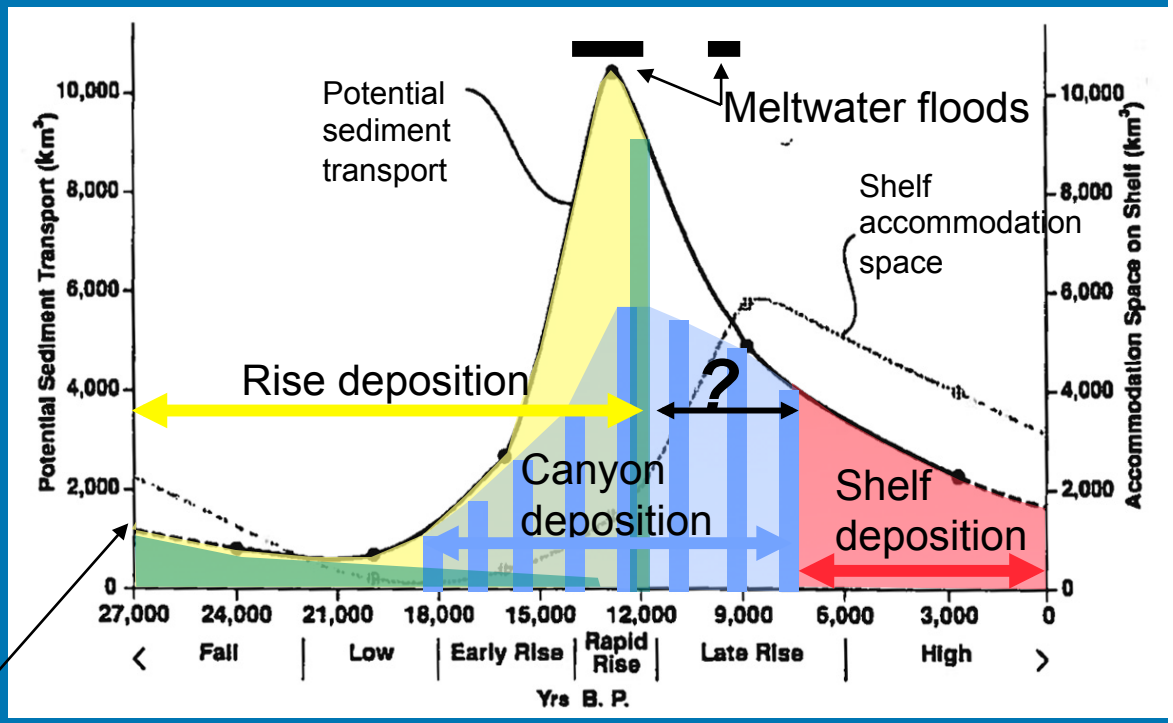
Mississippi perspective



Kolla et al. (1993)

Mississippi perspective

Where sediment is deposited



- Landslide deposits on rise
- Turbidites on rise
- Canyon deposition and failure
- Delta formation on shelf

Comparison of Atlantic and Gulf of Mexico Landslides

Atlantic	Gulf of Mexico
General distribution Source: most on glaciated margin Ave. source volume: ~1 km^3 Headwall depth: Canyon: <500 m Open slope: >2500 m Run out distance: 85 km	***General distribution*** Source: most in salt province Ave. source volume: small Headwall depth: Canyon: <500 m Open slope: 500-3000 m Run out distance: most < 25 km
Largest landslide Source area: salt province Source volume: 179 km^3 Headwall depth: ~2500 m	***Largest landslide*** Source area: canyon (point source) Source volume: 425 km^3 Headwall depth: ~200 m

USGS

Some remaining questions

- Dimensions and nature of failures on the Campeche margin
- Age of landslides sourced in carbonate sediment
- Refined age of landslides sourced in terrigenous sediment
- Triggering mechanisms

USGS