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RELATIVE TIMING OF SEDIMENT FAILURES WITHIN SLIDE-VALLEY COMPLEXES IN THE KUGMALLIT FAN AREA OF THE CENTRAL BEAUFORT SLOPE, OFFSHORE NORTHWEST TERRITORIES

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Abstract

Hydrocarbon related activities on the Beaufort Slope raise concerns about slope geohazards. Ubiquitous seabed and shallow sub-surface sediment slide complexes have been identified on the Beaufort Slope, from multibeam bathymetry and high-resolution sub-bottom sonar data collected mainly in 2009 and 2010. Multiple shallowly-buried failures indicate a long-term history of periodic failure.

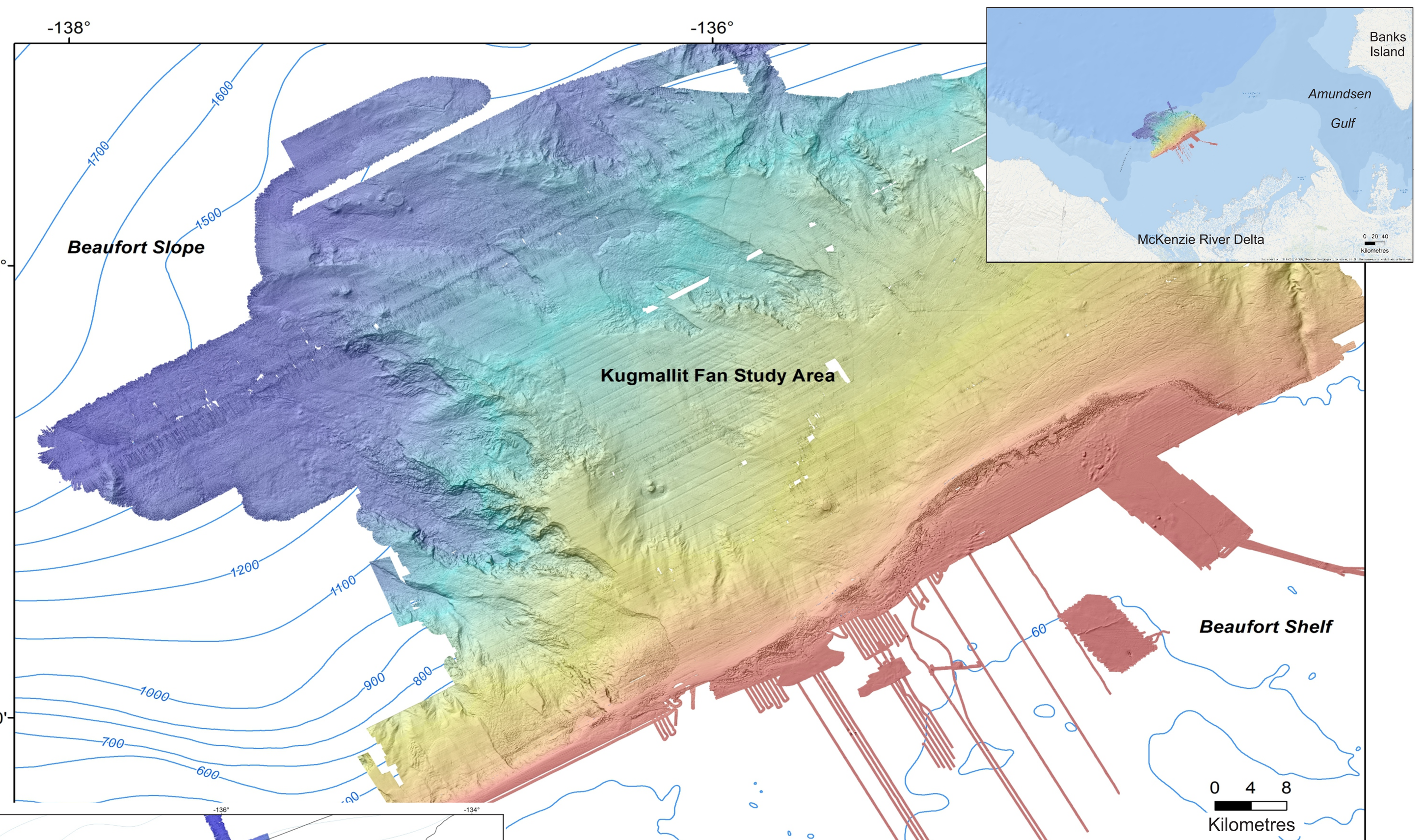
Two geologically recent, large, multiple-event failure complexes have been identified; the Ikit and Kugmallit slide-valley complexes. Neither have appreciable overlying sediment despite continuous Holocene deposition recognized from sonar profiles in nearby parent sediment. The Ikit complex is about 24 km wide, along the shelf break and about 54 km downslope, with undefined total run-out, covering over 1900 sq. km. The Kugmallit complex is narrower at 14 km wide and 68 km long, with undefined total run-out, covering 1550 sq. km.

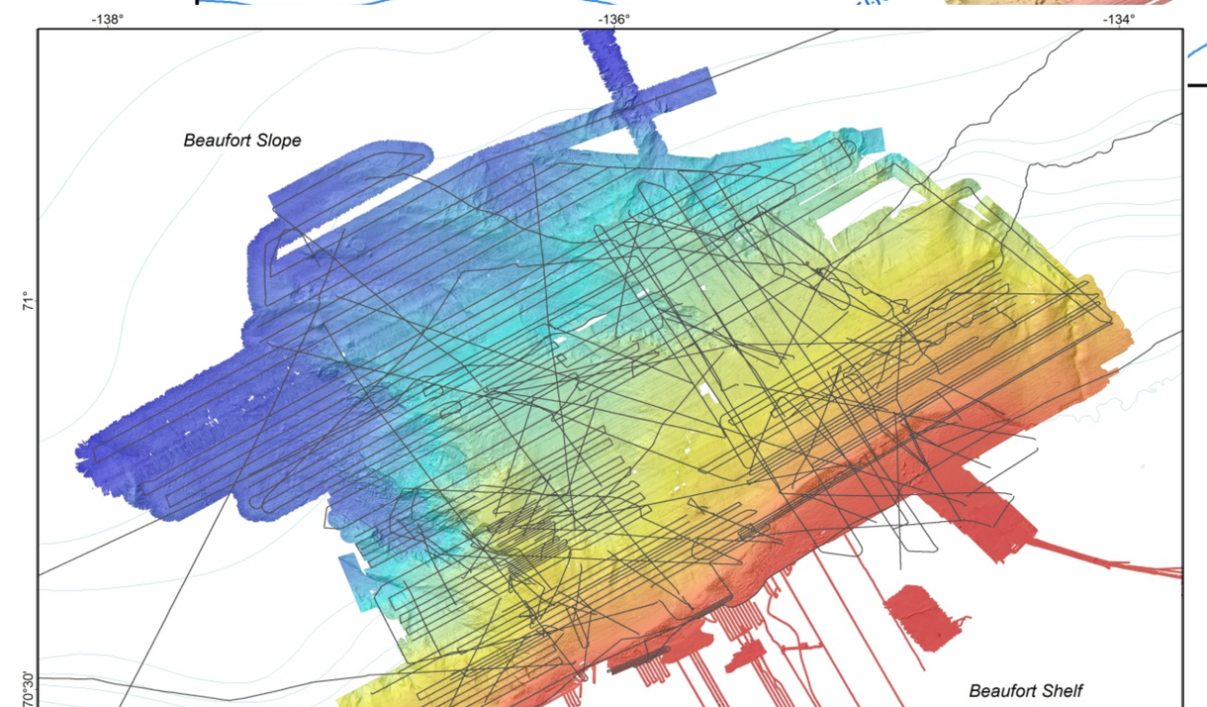
Some failure scarps exceed 100 m relief and evacuated volumes exceed 100 cubic km, placing these amongst Canada's largest surficial failures. Stratified Holocene and largely glacigenic blankets, tens to over 100 m thick including presumably LGM material, have been removed in the deepest valleys. Failures span the entire post-glacial sediment sequence, but an underpinning buried interval appears more prone to collapse.

Large and numerous retrogressive failure types are identified within the slide valley complexes. Blocky to disintegrated rotational slumps have been identified and occur near the top of the valleys. Numerous and thick (10s to 50m) debris flow deposits have been identified with cross-cutting lobes and tongues which have runouts from 100s of m to 100 km. Relative timing of as many as five failure areas are recognized, based on cross-cutting relationships. Maximum failure event age is constrained locally by recognition of translated parent blocks as young as 1300 cal yrs BP. in shallow cores. Minimum Pb 210 ages for failures in Ikit Valley can be as young at 230 yrs BP.

Removal of confining sediments presents opportunity for continued retrogressive failure. Failure-prone unit behavior suggests sediment preconditioning in the subsurface. The state of in-situ or introduced excess pore pressures in the region is not known. Proximity to an earthquake cluster suggests a trigger mechanism for episodic and widespread failure, but temporal and causal relationships are not yet established.

Location

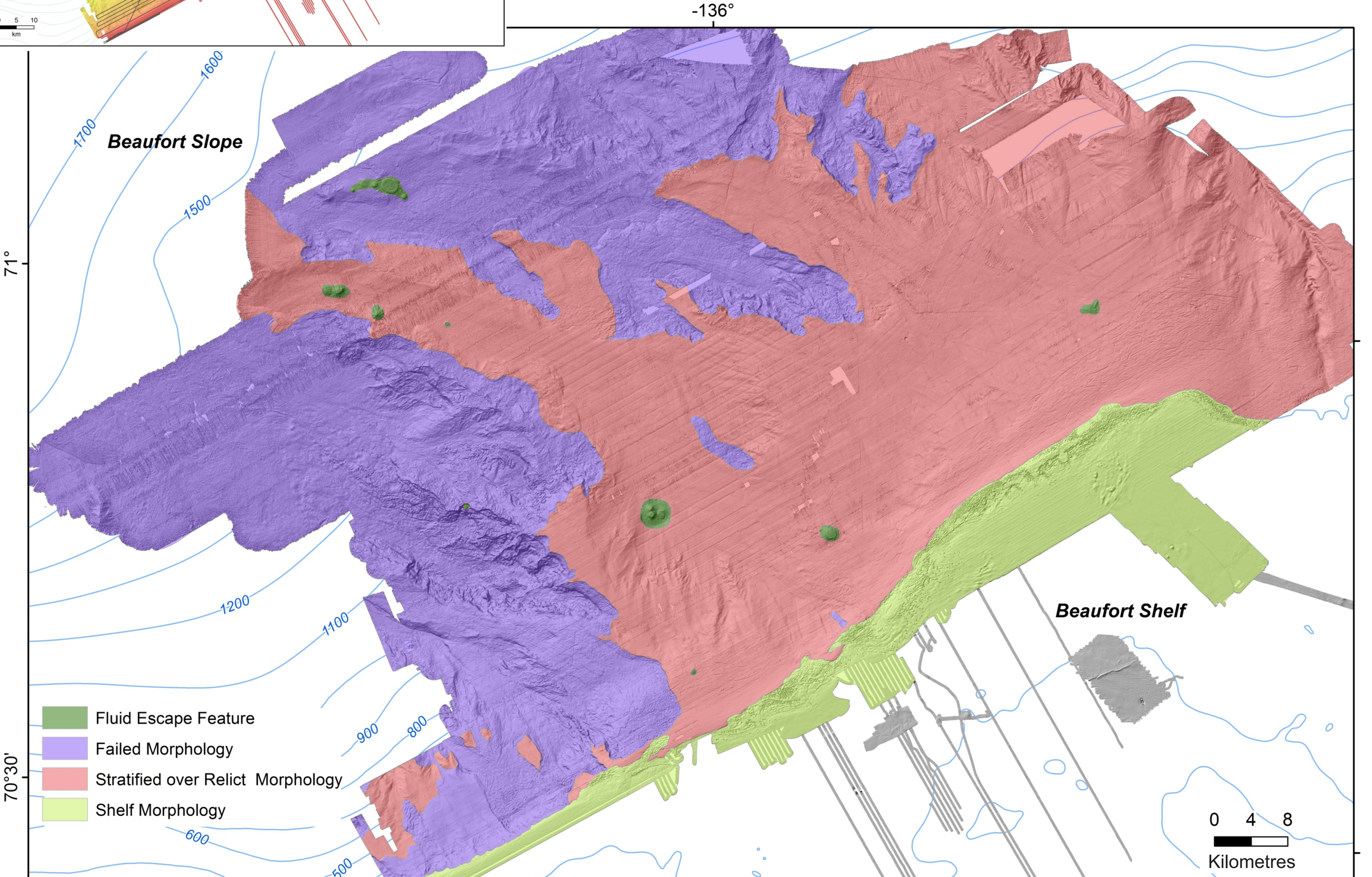




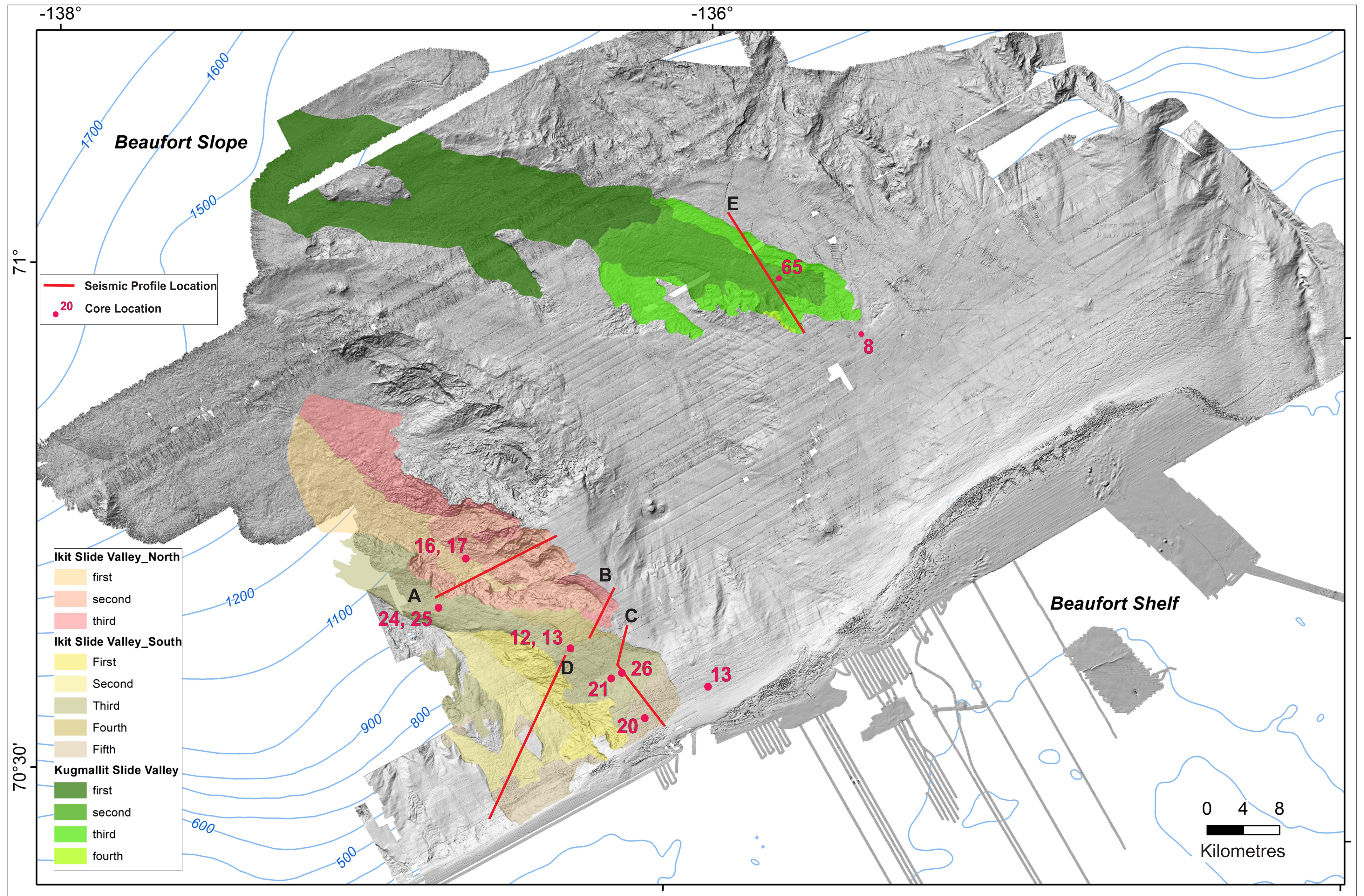
Kugmallit Fan study area is approximately 8000 sq. kilometres and is located on the upper continental slope in the Canadian Beaufort Sea, between 100 and 1500 m water depth, see maps above. The combination of multibeam bathymetry and high-resolution seismic has shown that there are large, complex, mud rich sediment failures in the study area.

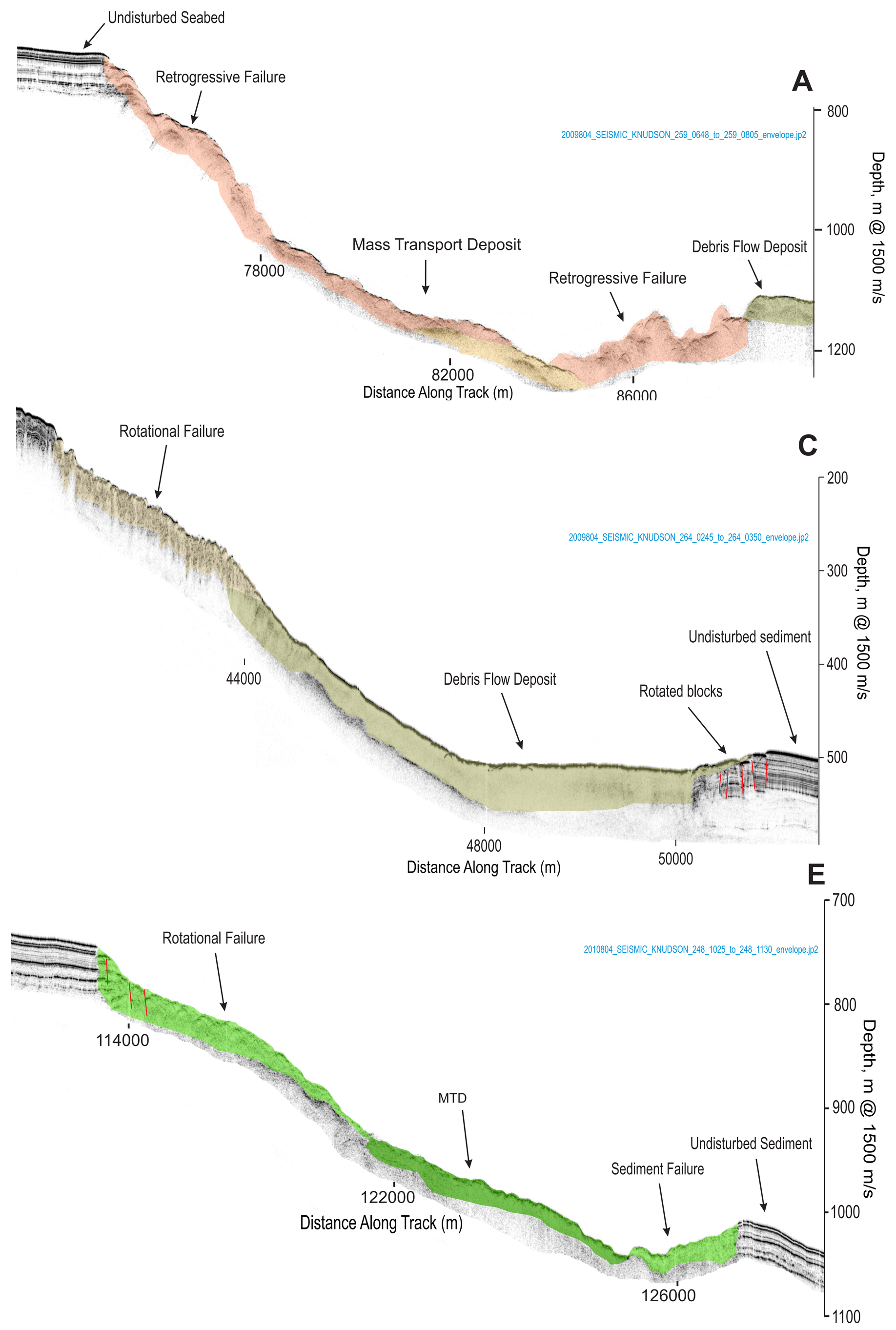
Map at left shows the distribution of 3.5 kHz seismic lines (grey lines) used in this study, which were collected, along with multibeam, during Amundsen cruises 2009804, 2010804, 2011804 and 2014804. The estimated coverage exceeds 4000 line kilometres.

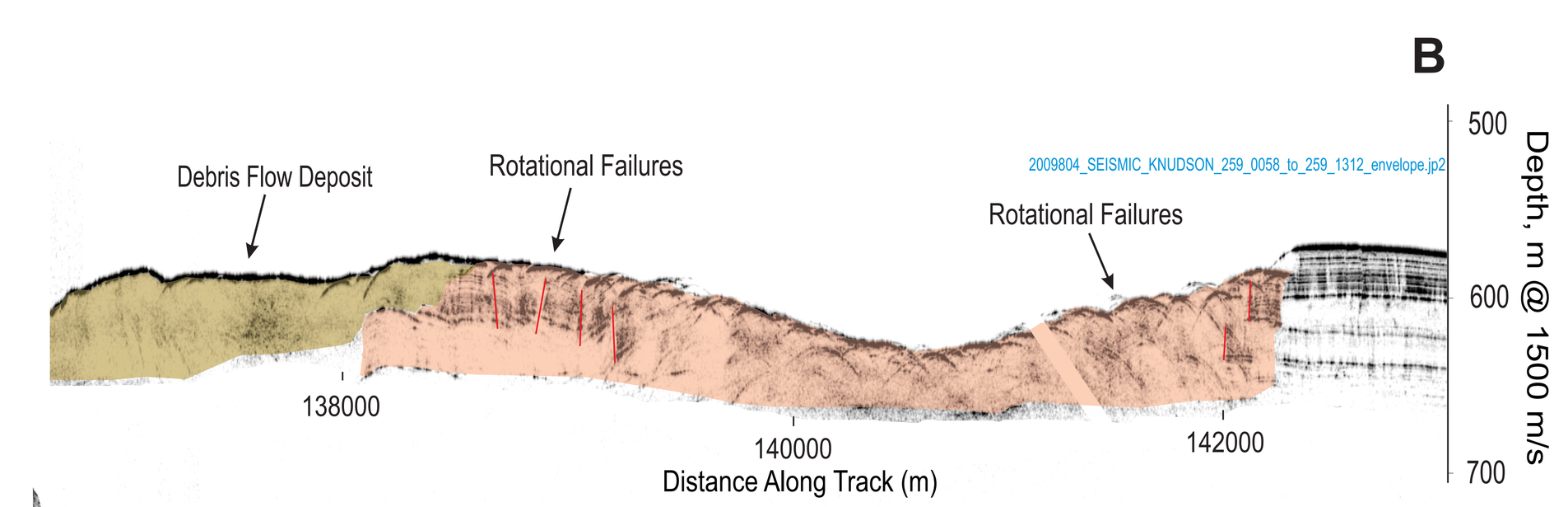
The seafloor has been subdivided mostly into areas of failed (purple) and relict morphology (red), see map below. Well stratified glacial and post-glacial sediments, up to 50 m thick, overly areas of relict morphology. Failed areas consist of complexes tens of kilometres wide and more than 60 km long, which join downslope into large regions of accumulated failed sediment. Thin recent sediments, only 10's of cm thick, overlie these areas.

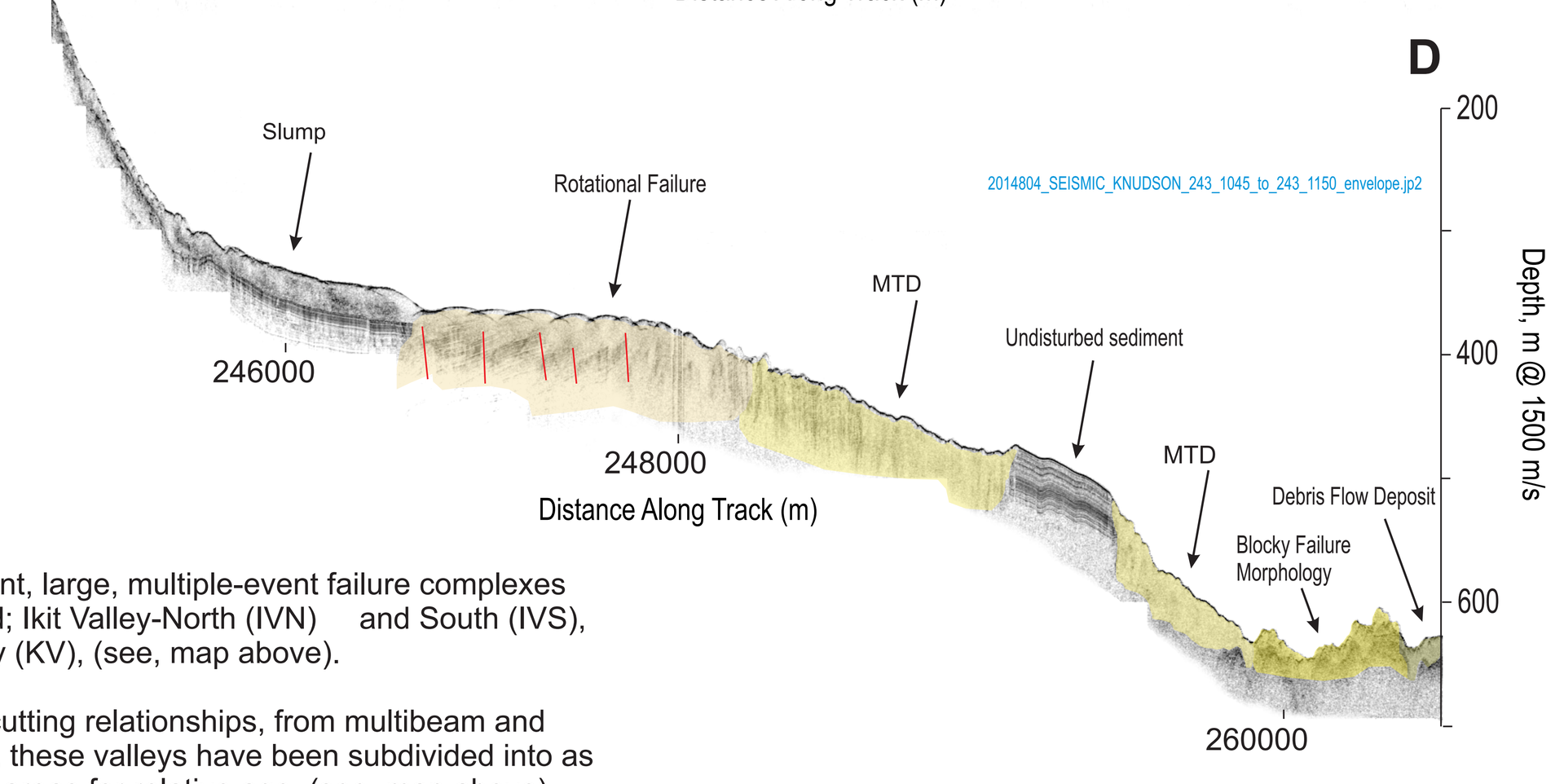


Relative Failure Timing



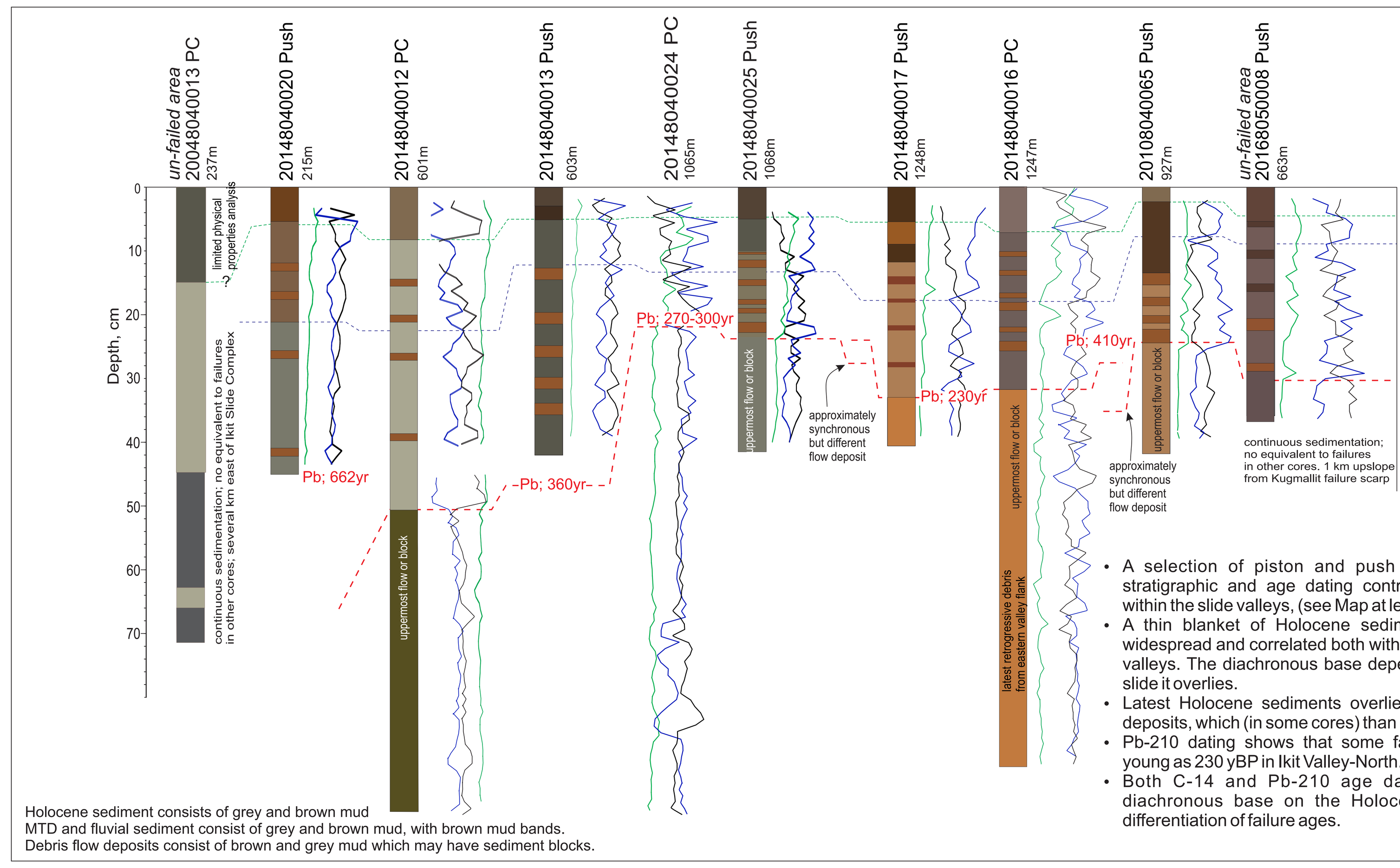






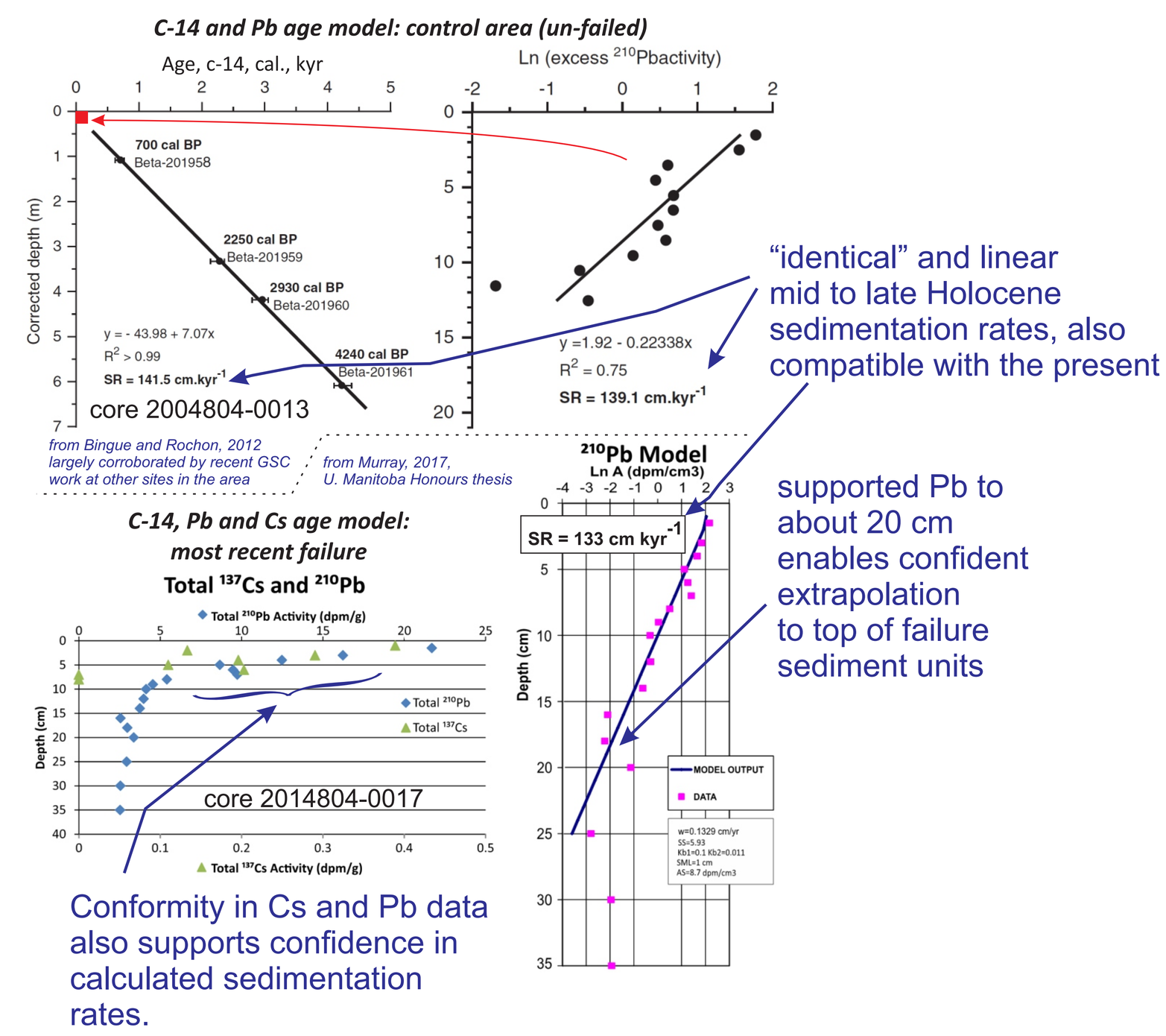
- Geologically recent, large, multiple-event failure complexes have been identified; Ikit Valley-North (IVN) and South (IVS), and Kugmallit Valley (KV), (see, map above).
- Based on cross-cutting relationships, from multibeam and seismic profile data, these valleys have been subdivided into as many as five failure areas for relative age, (see, map above). Numerous failures occur within each area.
- The Ikit slide-valley is about 24 km wide, along the shelf break and about 54 km downslope, with undefined total run-out, covering over 1900 sq. km.
- The Kugmallit slide-valley is narrower at 14 km wide and 68 km long, with undefined total run-out, covering 1550 sq. km.
- Stratified Holocene and largely glacigenic blankets, tens to over 100 m thick, have been removed in the deepest valleys.
- Some failure scarps exceed 100 m relief and evacuated volumes exceed 100 cubic km, placing these amongst Canada's largest surficial failures.
- Large and numerous retrogressive failure types are identified within the slide valleys.
- Blocky to disintegrated rotational slumps have been identified and occur near the top of the valleys.
- Undisturbed sediment and older blocky failure morphology are identified in profile D and is some of the first failed sediment in this complex, (see, map above).
- Debris flow sediment in IVS has refailed retrogressively along the southern flank of IVS. Making most failures In IVN younger than much of IVS, (see profile A and map above).
- Areas with rotational failures (see profiles C, B, D and E) in the third and fifth areas in IVN, IVS and KV may be similar in age and amongst the younger failure areas, (see map above).
- The youngest failures likely occur in IVN, (see profile A) as retrogressive failures burying older MTDs, (see map above).

Core Correlation



- A selection of piston and push cores was used for stratigraphic and age dating control on failure deposits within the slide valleys, (see Map at left for core locations).
- A thin blanket of Holocene sediments (~20-40 cm) is widespread and correlated both within and beyond the slide valleys. The diachronous base depends on the age of the slide it overlies.
- Latest Holocene sediments overlie fluvial and thin MTD deposits, which (in some cores) than overlies debris flows.
- Pb-210 dating shows that some failure deposits are as young as 230 yBP in Ikit Valley-North.
- Both C-14 and Pb-210 age dating demonstrate a diachronous base on the Holocene blanket allowing differentiation of failure ages.

Towards a Slide Chronology



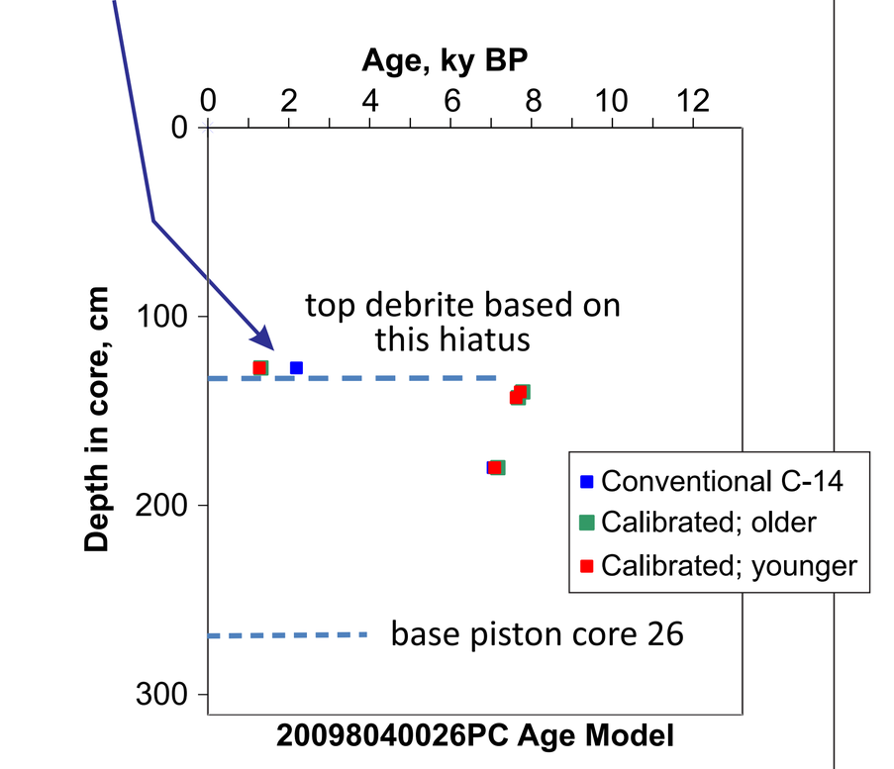
Towards a slide failure complex chronology and periodicity:

Due to the recent age of the failures, development of a late Holocene sedimentation framework is necessary for failure age-dating and periodicity.

Radiocarbon, lead and cesium dating techniques yield consistently complementary results on the Beaufort Slope with good correlation of ages and sedimentation rates from all three techniques.

- Cs and Pb results confirm decadal and century-scale linear sedimentation rates at each sample site, but ranging amoung sites, from 0.06 to 0.14 cm/yr (seven core-sites)
- ~30 C-14 ages in numerous cores, most in the 5 to 9 ka cal range, are tied to a seismo- stratigraphic framework (early results in King et al. 2017). This further demonstrates spatially systematic sedimentation patterns for the entire Holocene epoch. However, sedimentation rates decrease exponential through time in deeper water (>500m).

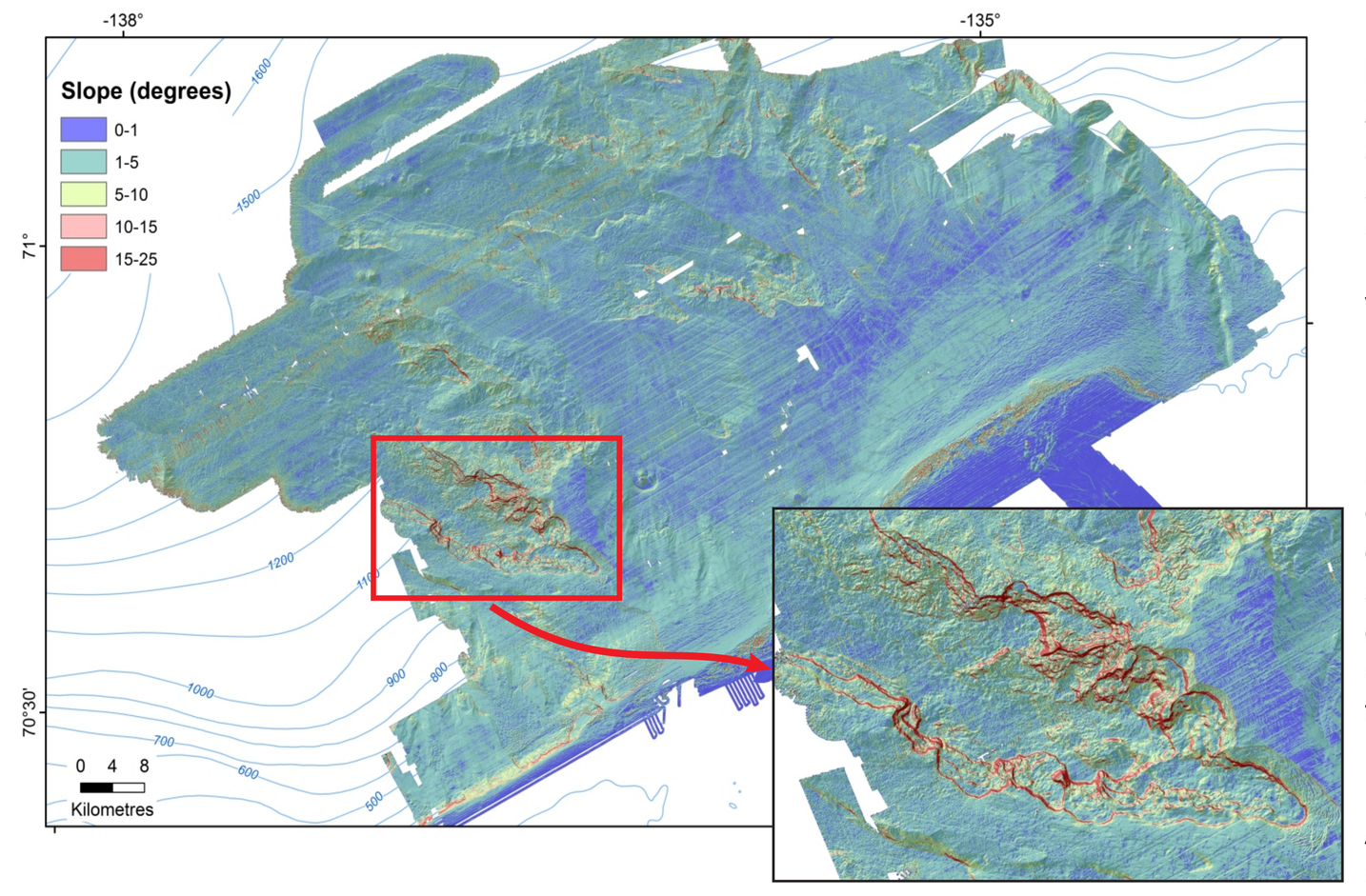
hiatus defined by C-14 dates provide maximum 1.35 ka age on failure

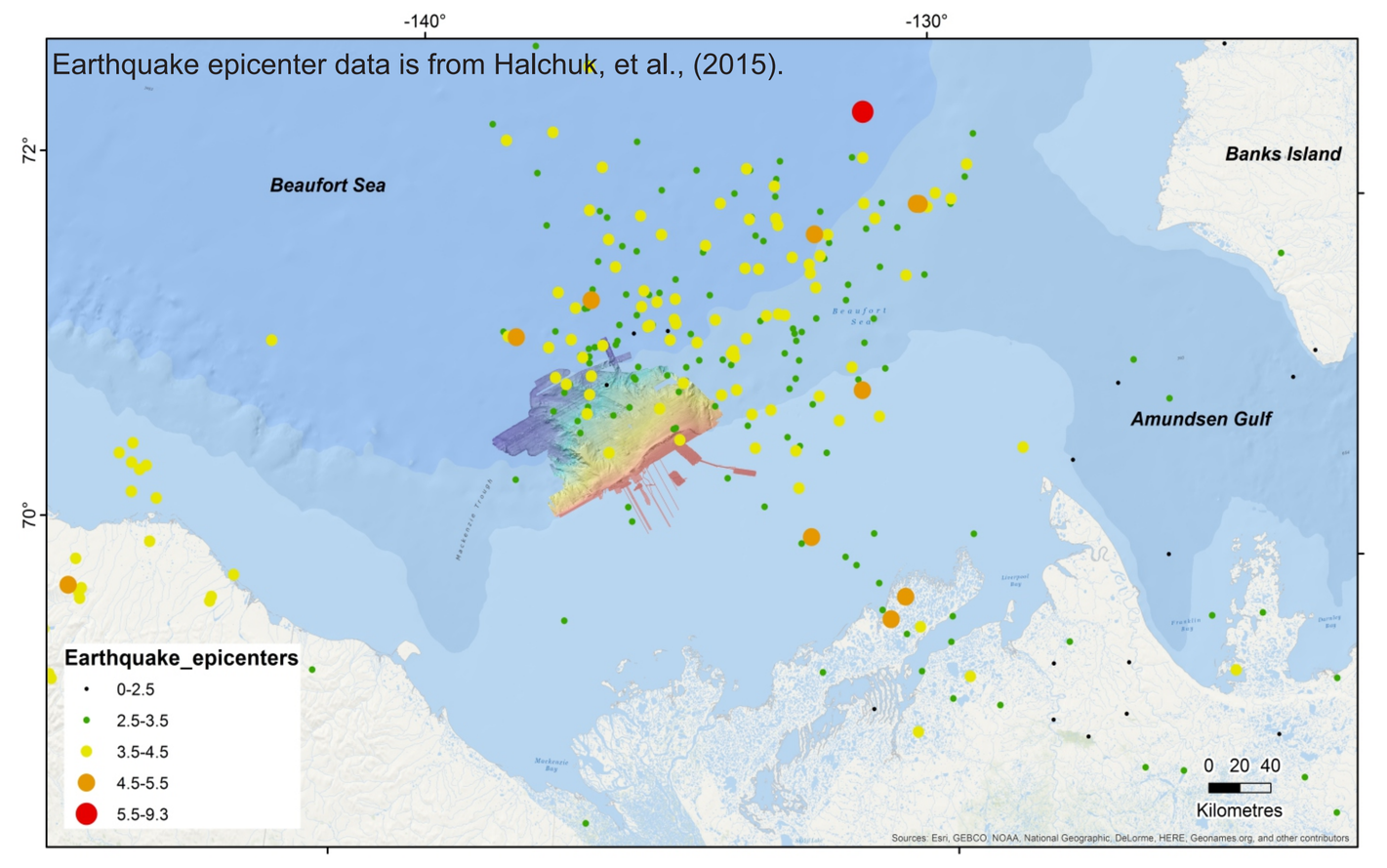


20098040026PC Age Model

Offset in ages defines a clear depositional hiatus, constraining the failure event age to 1.35 ka.

Conclusions





Ipik Valley_North has the youngest slide dated at 230 yrs BP in core 17, (see, Time/Space Diagram, at right and timing map upper left). Steep slopes, scarps greater than 100 m and removal of confining sediments have allowed for continued retrogressive sediment failure, in Ipik Valley_North, (see, Slope Map at left). This area likely has the highest failure rate and is the most recently active.

Multiple failures in Ipik Valley_South have been dated, with younger failures found further downslope in core 25 at 270 yrs BP and core 13 at 360 yrs BP (see, Time/Space Diagram). An older failure was dated deeper in the section in core 26 at 1314 +/-43 cal yrs BP. This suggests that downslope areas are actively receiving more recently failed sediment.

An unconformity within the fifth failure area (rotational failure), in Ipik Valley_South has been dated at 1600 +/-250 cal yrs BP in core 20, (see, Time/Space Diagram and timing map upper left). Timing of the rotational failure within this area has not been dated and are likely much younger than the unconformity.

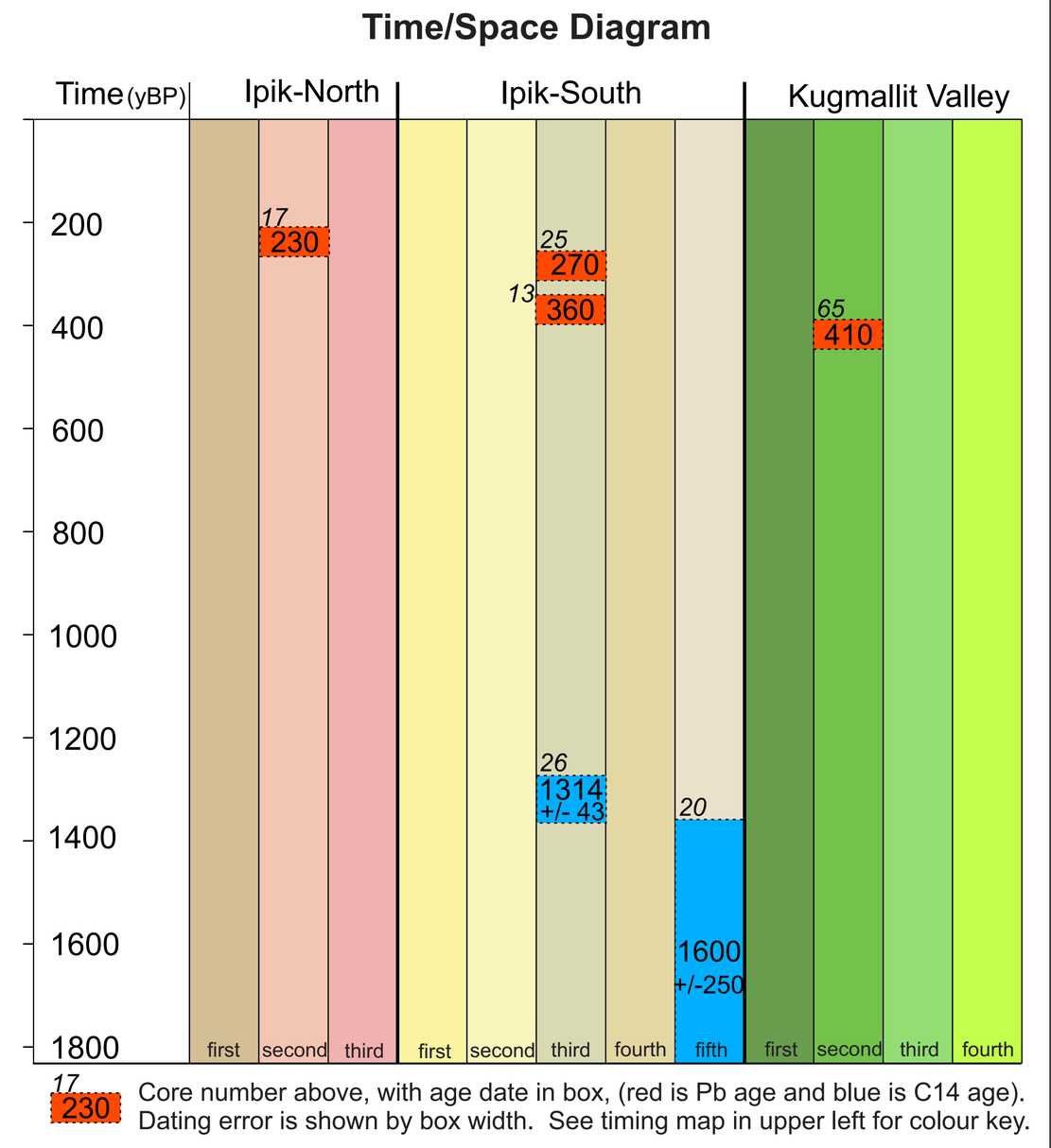
An age in sediment core 65 of 410 yrs BP, in Kugmallit Valley, has a similar age range to those in Ikit Valley, suggesting that these wide spread failures may be related to seismic activity.

Historical earthquake epicentre distribution shows high seismic activity between 1926 and 2010 in the southern Beaufort Sea and within the study area, (see, Epicenter Map at left).

At least two seismically triggered events are suggested by the circa one millennium time span.

Among the four dated youngest failure events, a seismic trigger versus oversteepened retrogressive mechanism is uncertain.

Time/Space Diagram



17 230 Core number above, with age date in box, (red is Pb age and blue is C14 age). Dating error is shown by box width. See timing map in upper left for colour key.

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