Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2021 - 2022

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Modulo 3.2
Scarpata continentale: strutture associate a flussi gravitativi

Docente: **Renata G. Lucchi**

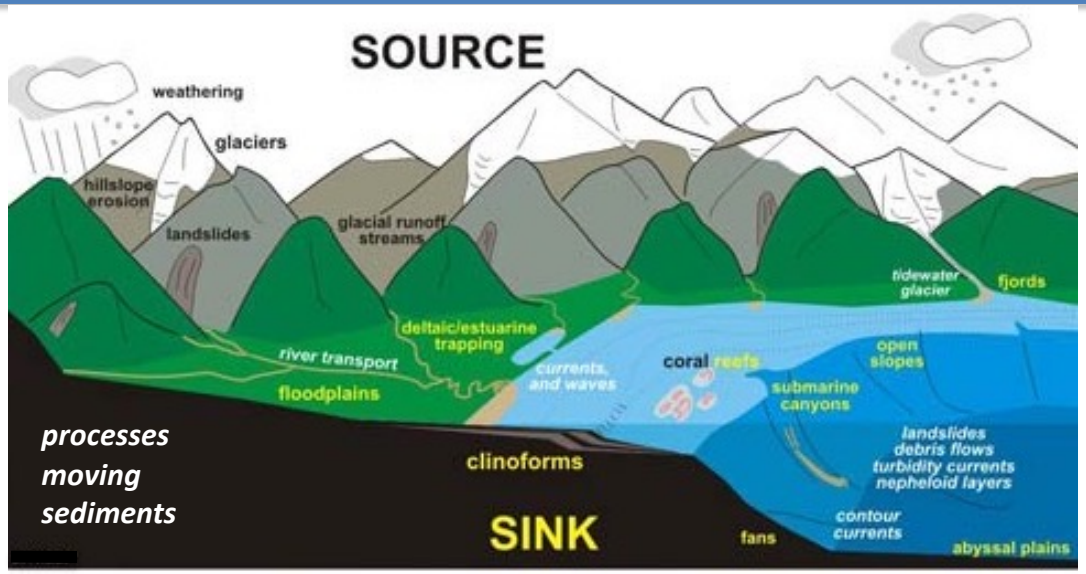
Modulo 2.3a Scarpata continentale: strutture associate a flussi gravitativi

Docente: Renata G. Lucchi

OUTLINE

- The source to sink system
- Continental slope and rise sedimentary features and processes
- Continental slope types and key features
- Continental slopes at high latitude margins (TMFs, gullies)
- Continental slopes at mid latitude margins (canyon-channel-deep sea fans systems)
- Identifying submarine landslides and debris flows

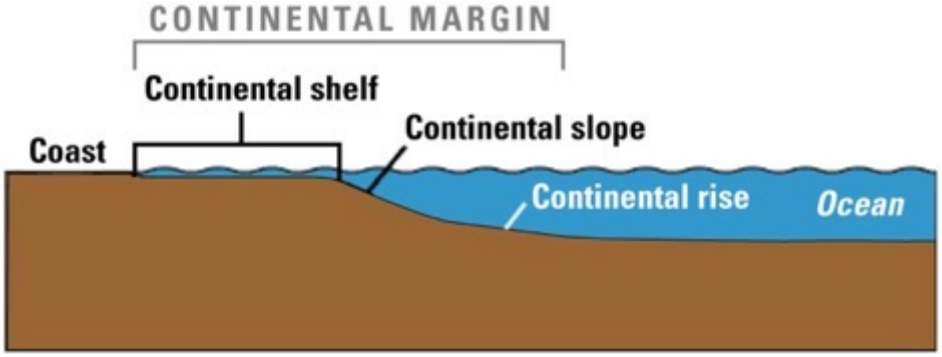
the Source to Sink System



Sedimentary Processes on Continental Margins

down-slope: driven by gravity forces

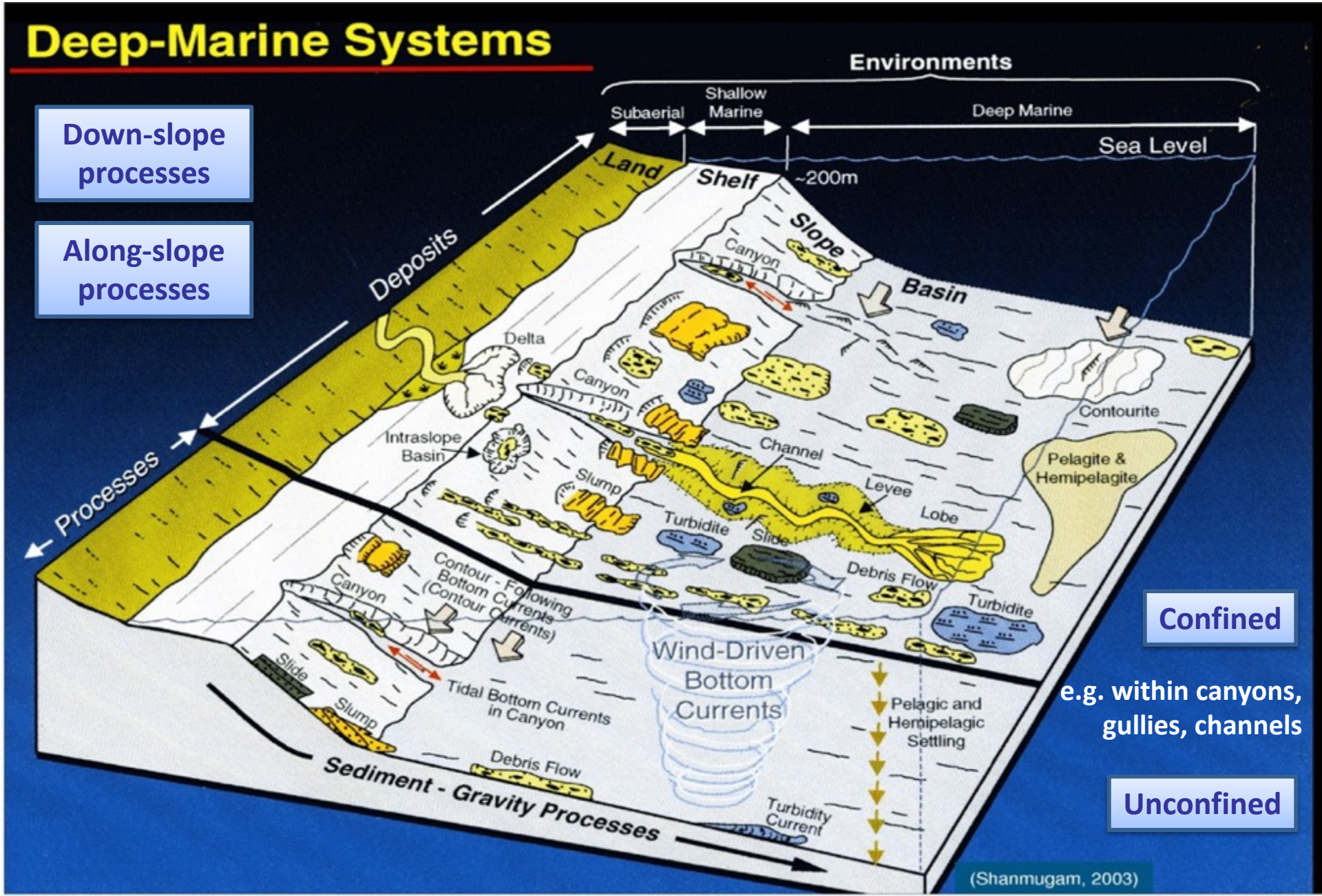
along-slope: driven by density forces (thermo-haline or water mass accumulation)



Continental shelf
Preferential area of sediment accumulation
High sediment accumulation
High isostatic subsidence

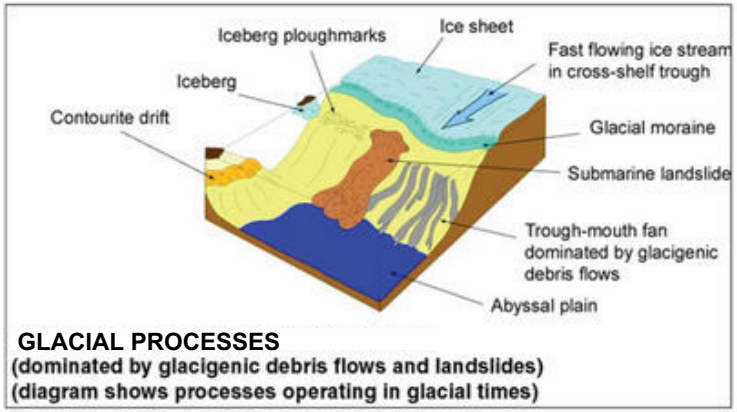
Continental slope sediment deposition and transfer toward deeper environments

Continental rise: sediment deposition (deep sea fans, sediment drifts)


Deep-Marine Systems
Down-slope processes
Along-slope processes
Environments
Subaerial
Shallow Marine
Deep Marine
Sea Level
Land
Shelf
~200m
Slope
Basin
Deposits
Processes
Canyon
Delta
Intraslope Basin
Slump
Channel
Levee
Lobe
Turbidite
Slide
Debris Flow
Contourite
Pelagite & Hemipelagite
Contour - Following Bottom Currents (Contour Currents)
Tidal Bottom Currents in Canyon
Wind-Driven Bottom Currents
Pelagic and Hemipelagic Settling
Turbidity Current
Sediment - Gravity Processes
Confined
e.g. within canyons, gullies, channels
Unconfined
(Shanmugam, 2003)

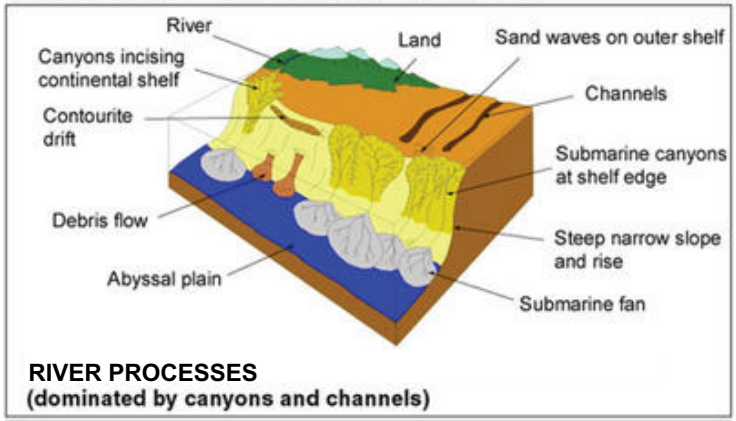
Continental slope types and related distinctive sedimentary features

High latitude



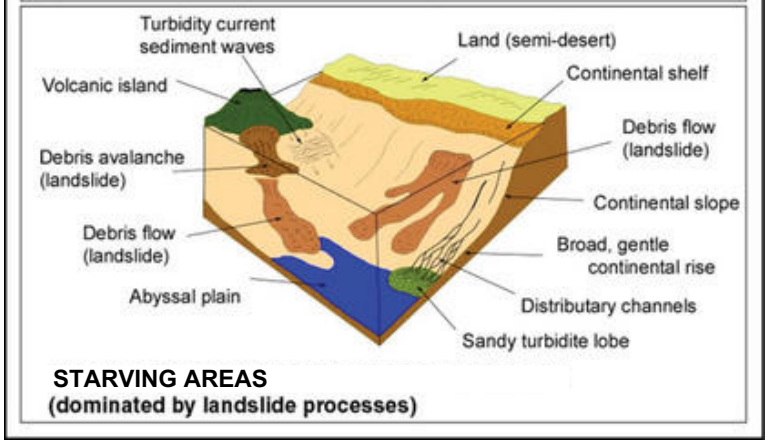
GLACIAL PROCESSES
(dominated by glacigenic debris flows and landslides)
(diagram shows processes operating in glacial times)

Mid latitude



RIVER PROCESSES
(dominated by canyons and channels)

Low latitude



STARVING AREAS
(dominated by landslide processes)

GLACIAL INFLUENCES MARGINS

- Gullies (rare canyons)
- Trough Mouth Fans (TMF)
- Submarine landslides

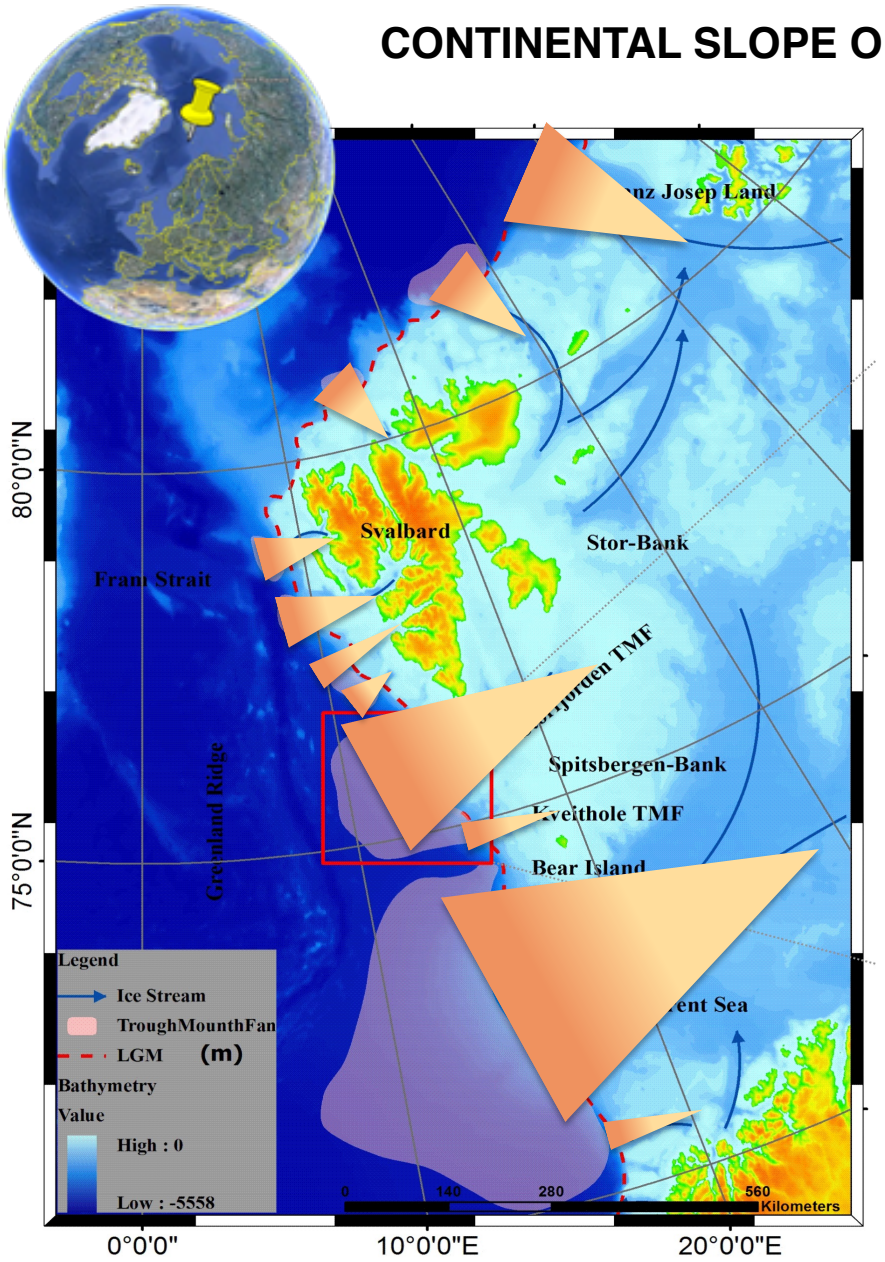
RIVER INFLUENCES MARGINS

- Well developed canyon-channel-deep sea fan systems
- Submarine landslides

SEDIMENT STARVING MARGINS

- Submarine landslides
- Mass gravity deposition

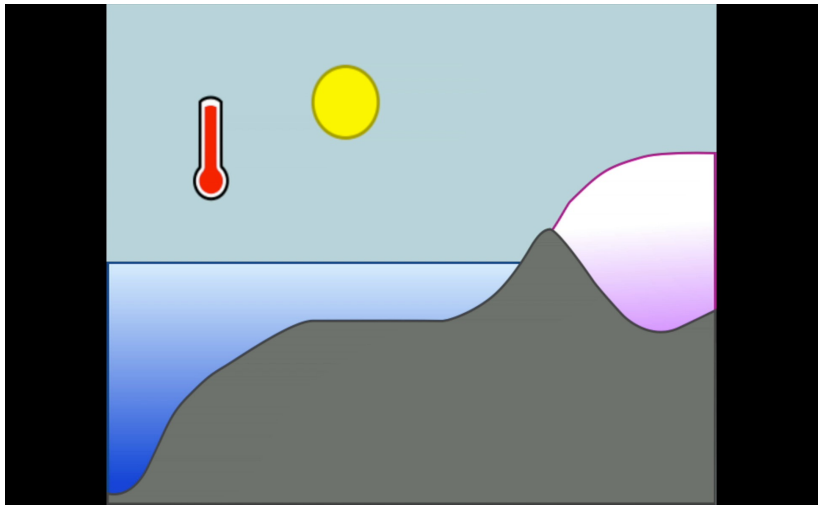
CONTINENTAL SLOPE ON GLACIATED GLACIATED MARGINS

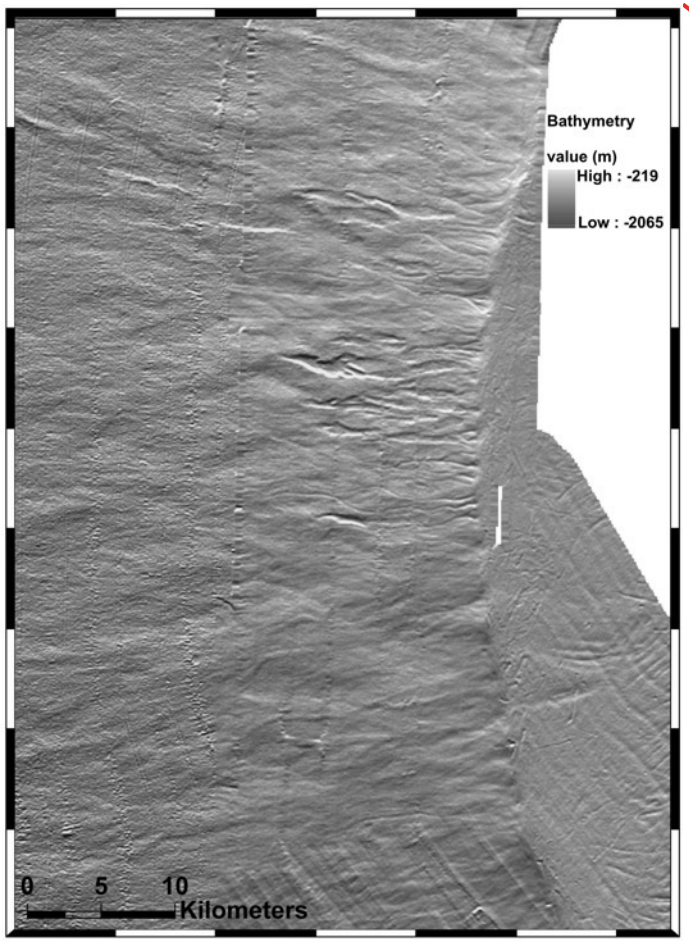


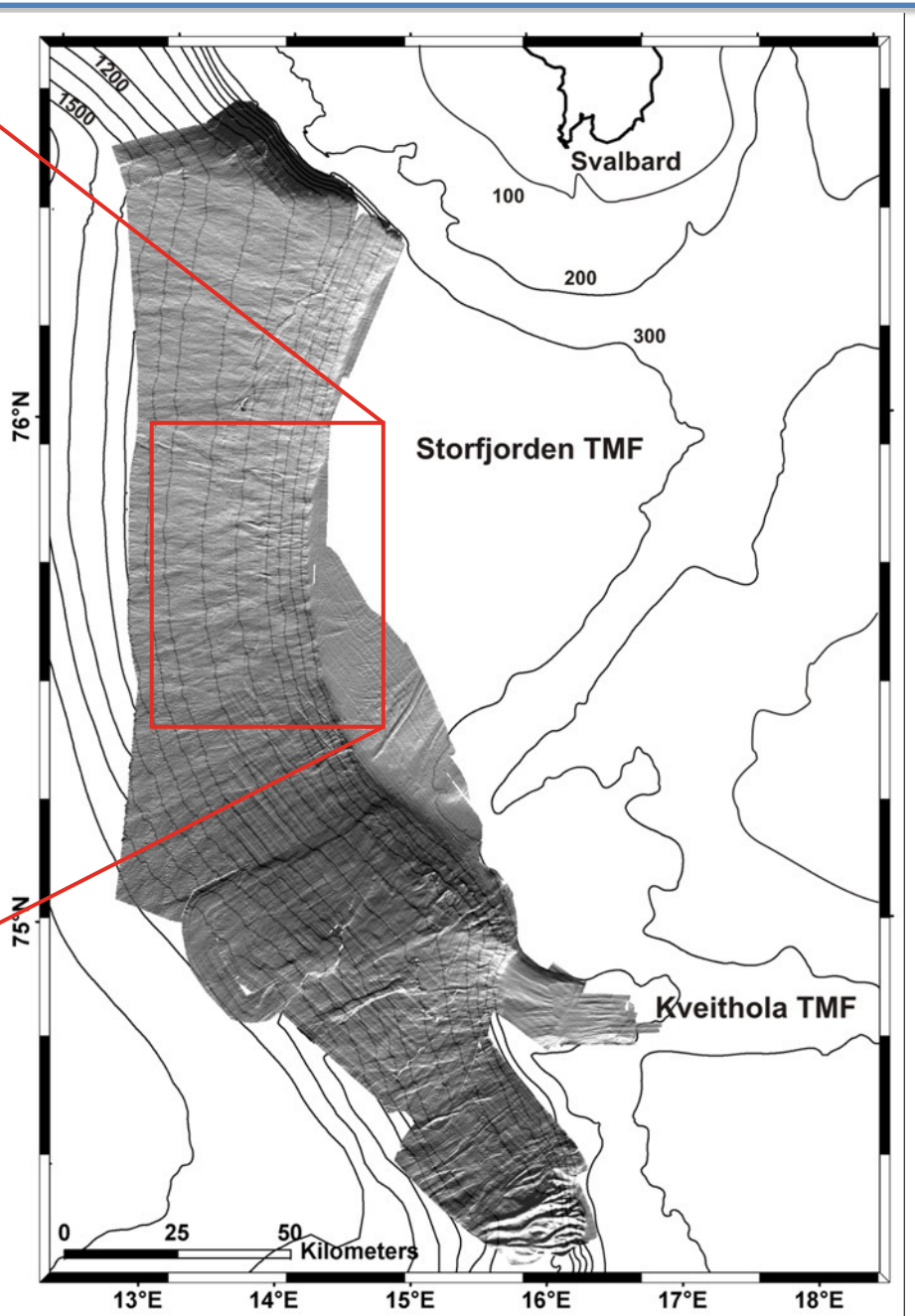
Ice Streams= Correnti di ghiaccio

Glacial trough= Fosse glaciali

Trough Mouth Fans (TMFs)= Conoidi alla bocca della fossa glaciale

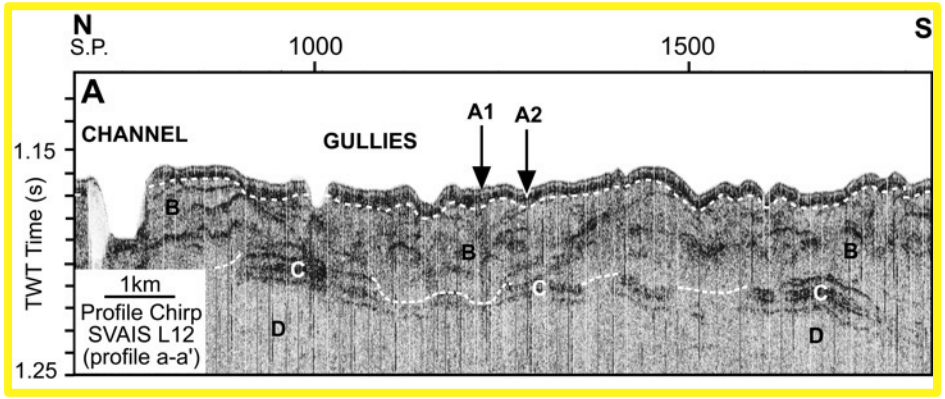


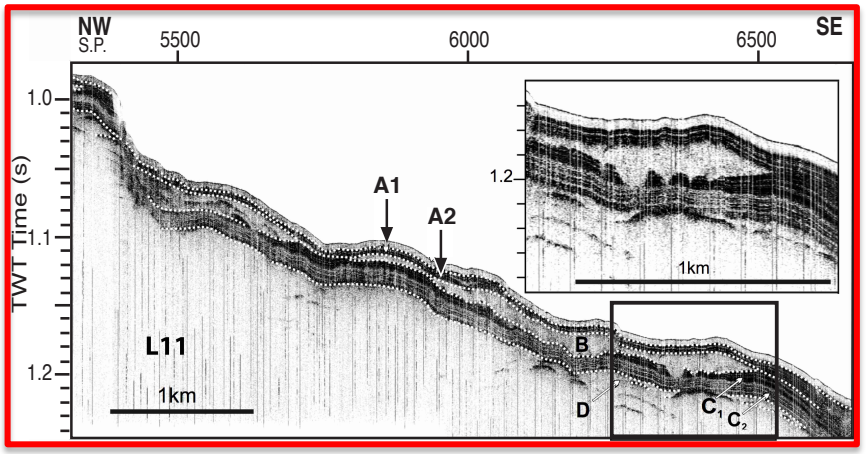


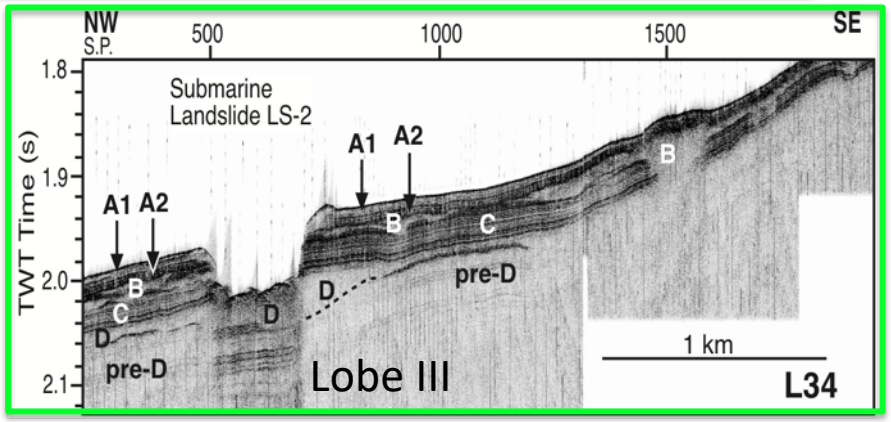


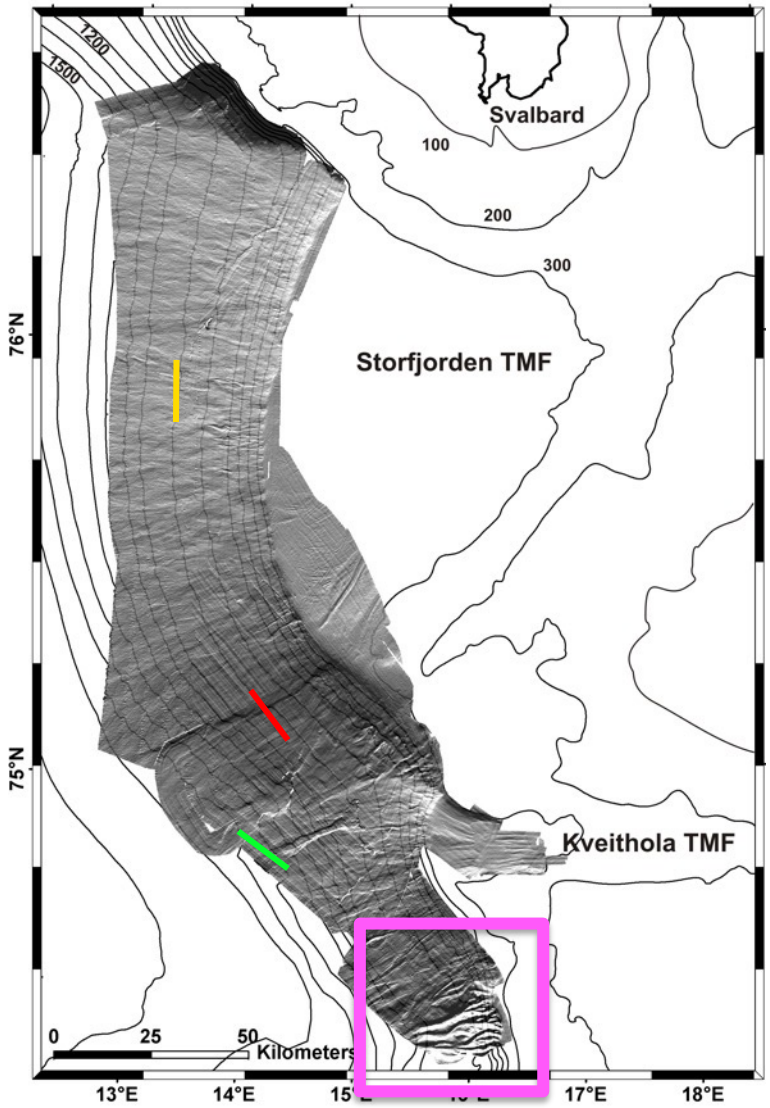
- Gullies (a few 10s m deep, a few 10s m large a few km long)
- Channels deriving from coalescent gullies
- Debris mounds
- Landslides

Continental slope architecture

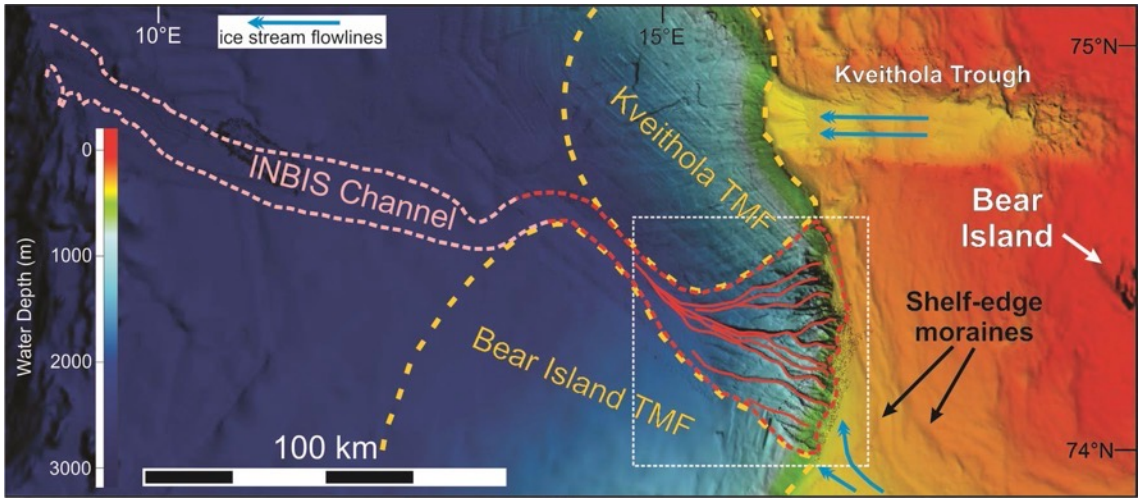


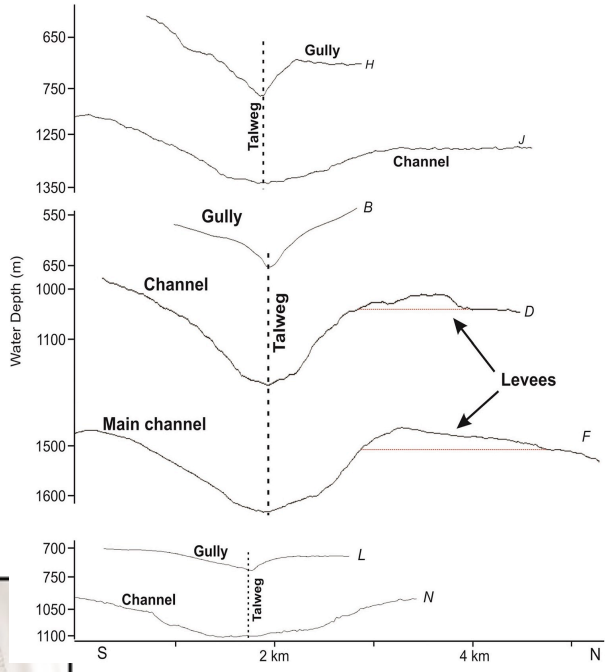


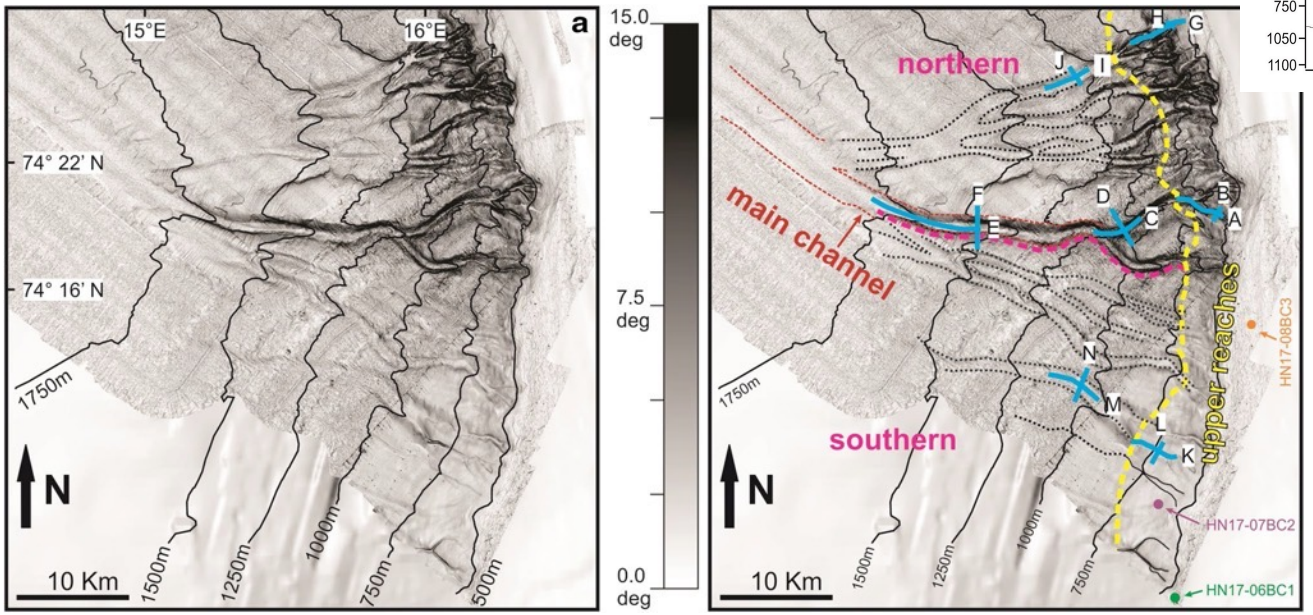




IN-Between-Ice Seets (INBIS) Channel

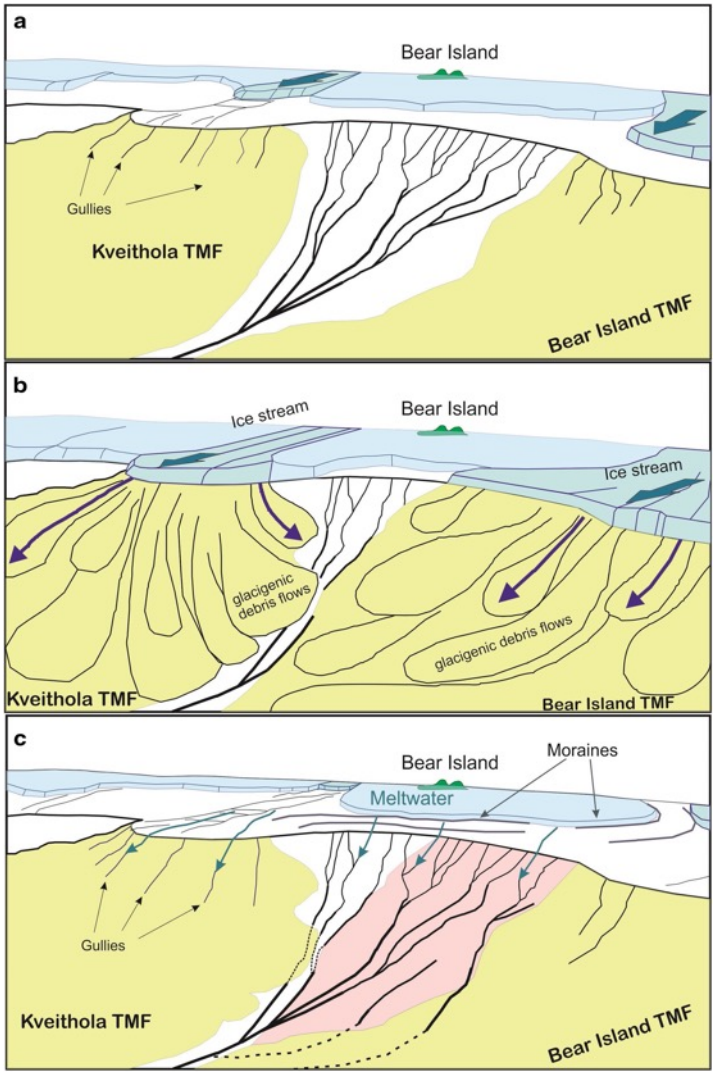






Gullies and Channels down-slope cross profiles

IN-Between-Ice Seets (INBIS) Channel temporal evolution

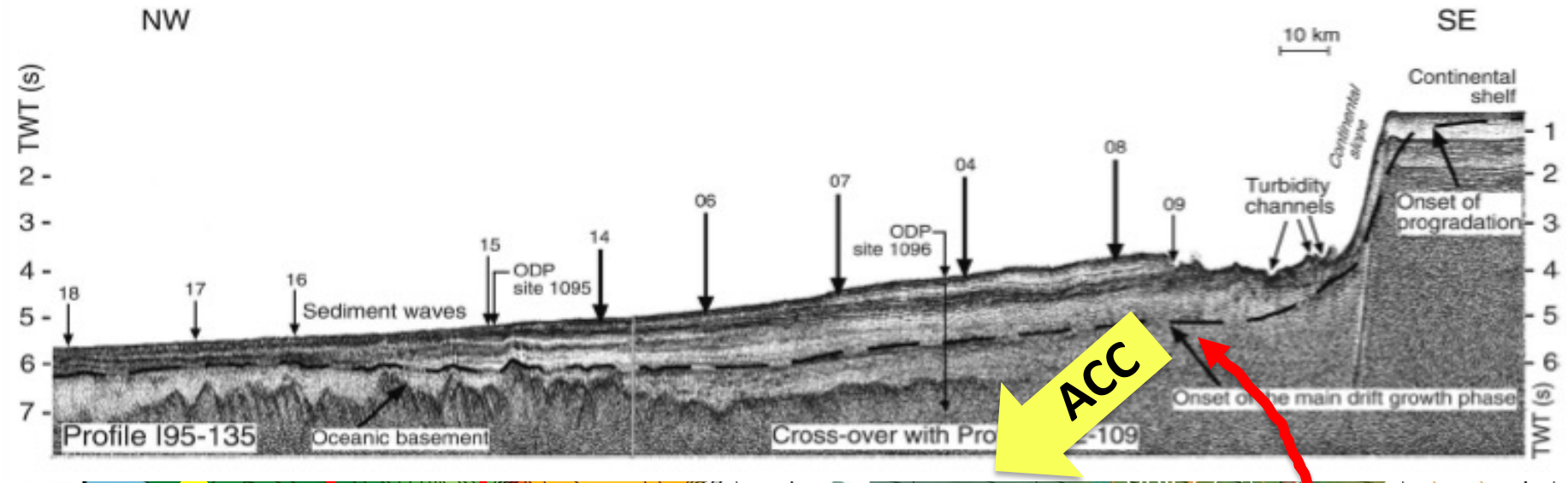


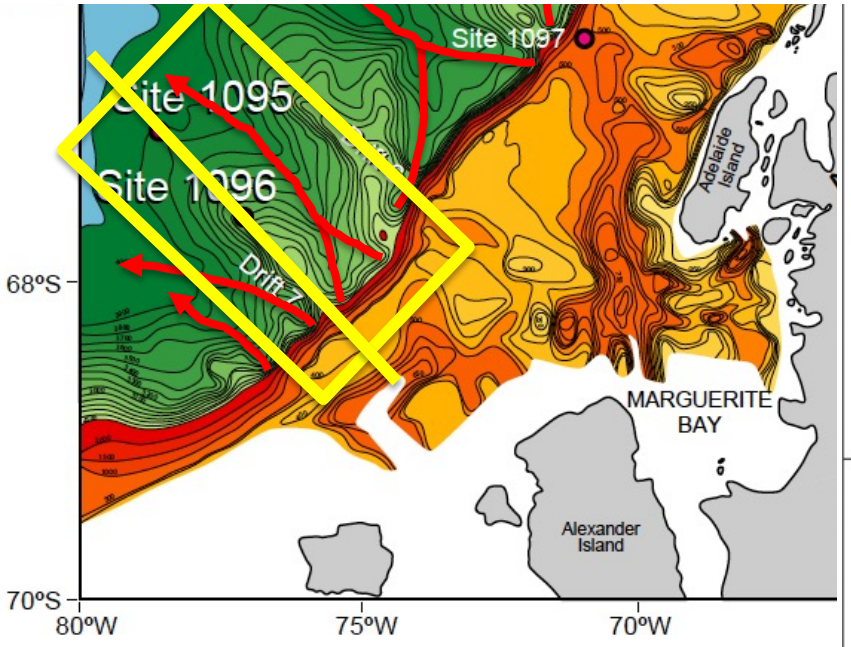
Rui et al., 2019_Arktos

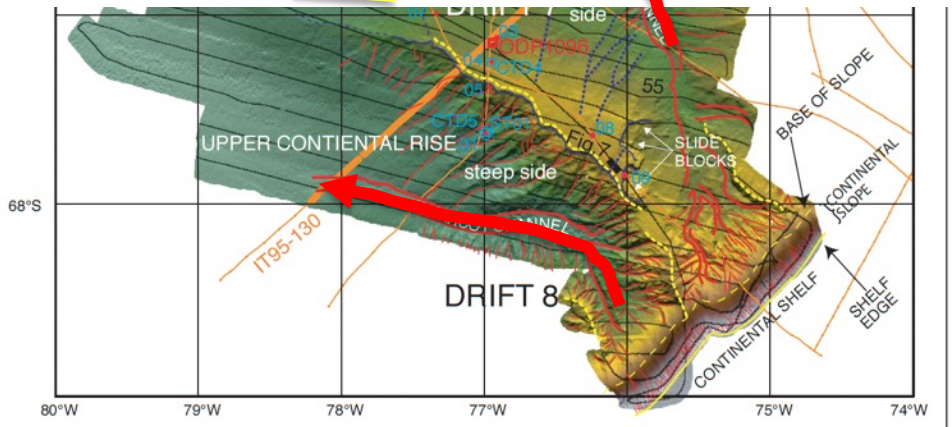
(a) pre-Last Glacial Maximum (LGM), slope sedimentation derived by pelagic settling and contour bottom currents

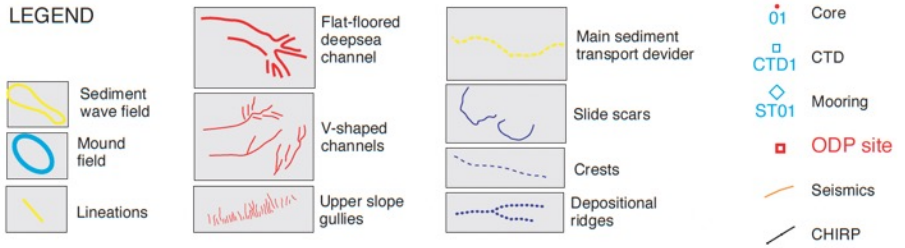
(b) LGM state with emplacement of glacigenic debrites forming depositional mounds (or lobes)

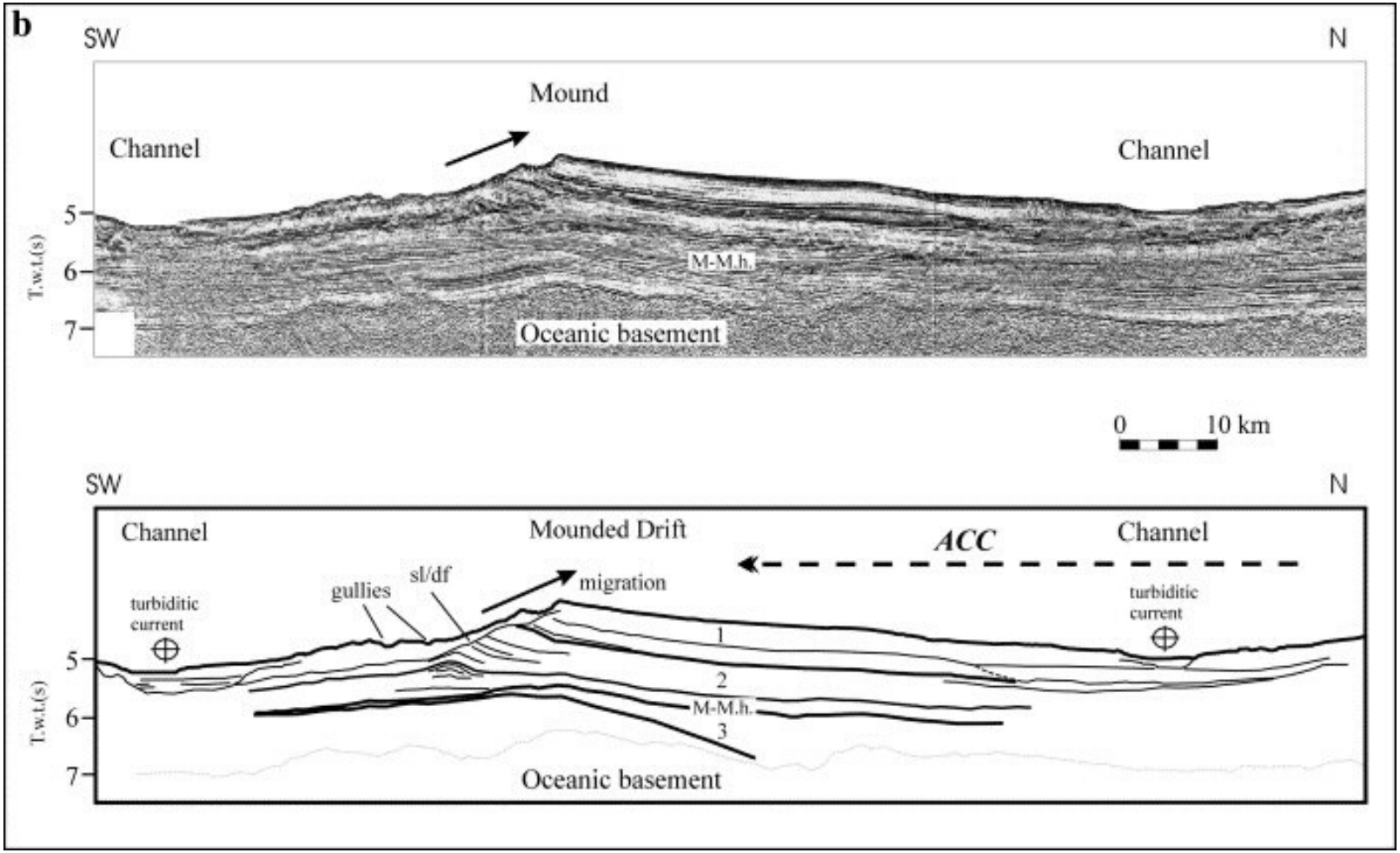
(c) post-LGM state with high-energy jet flows derived from ice sheet melting caving new gullies at the shelf break and uppercontinental slope.


NW
SE
10 km
TWT (s)
Continental shelf
Turbidity channels
Onset of progradation
Continental slope
ODP site 1095
ODP site 1096
Sediment waves
18
17
16
15
14
06
07
04
08
09
Profile I95-135
Oceanic basement
Cross-over with Pro
-109
Onset of the main drift growth phase
ACC


Site 1097
Site 1095
Site 1096
Drift 7
Adelaide Island
MARGUERITE BAY
Alexander Island
68°S
70°S
80°W
75°W
70°W

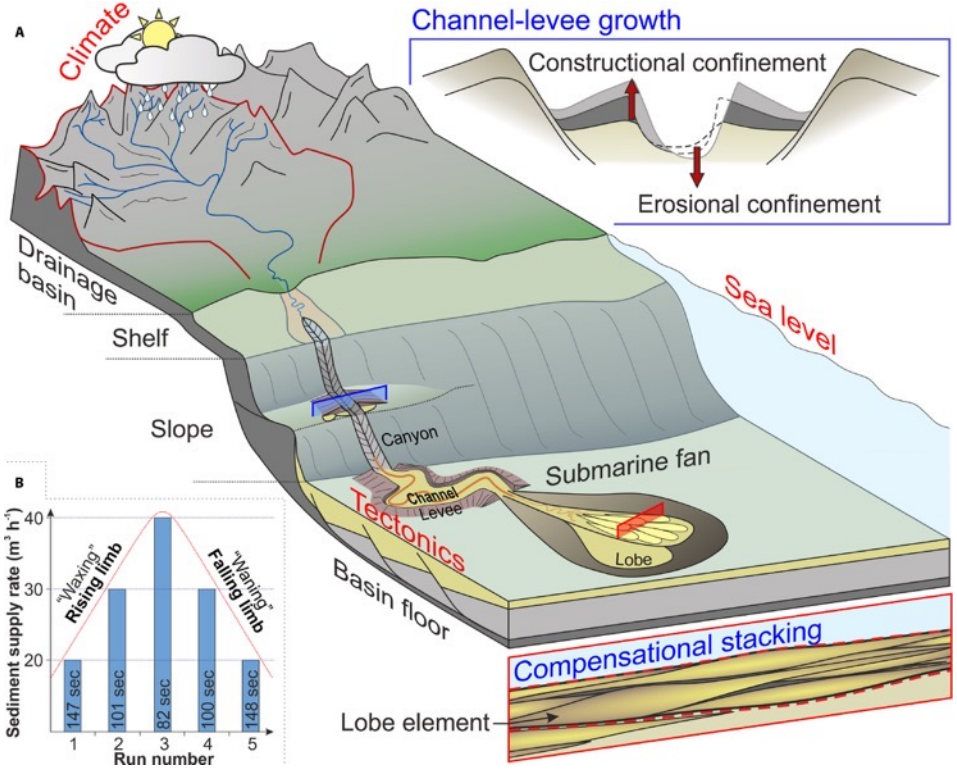

UPPER CONTIENTAL RISE
steep side
SLIDE BLOCKS
BASE OF SLOPE
CONTINENTAL SLOPE
CONTINENTAL SHELF
SHELF EDGE
IT95-130
DRIFT 8
68°S
80°W
79°W
78°W
77°W
75°W
74°W


LEGEND
Sediment wave field
Mound field
Lineations
Flat-floored deepsea channel
V-shaped channels
Upper slope gullies
Main sediment transport devider
Slide scars
Crests
Depositional ridges
Core
CTD
Mooring
ODP site
Seismics
CHIRP


b
SW
N
Mound
Channel
Channel
M-M.h.
Oceanic basement
T.w.t.(s)
5
6
7
0
10 km
SW
N
Channel
Mounded Drift
ACC
Channel
turbiditic current
gullies
sl/df
migration
turbiditic current
1
2
M-M.h.
3
Oceanic basement
T.w.t.(s)
5
6
7

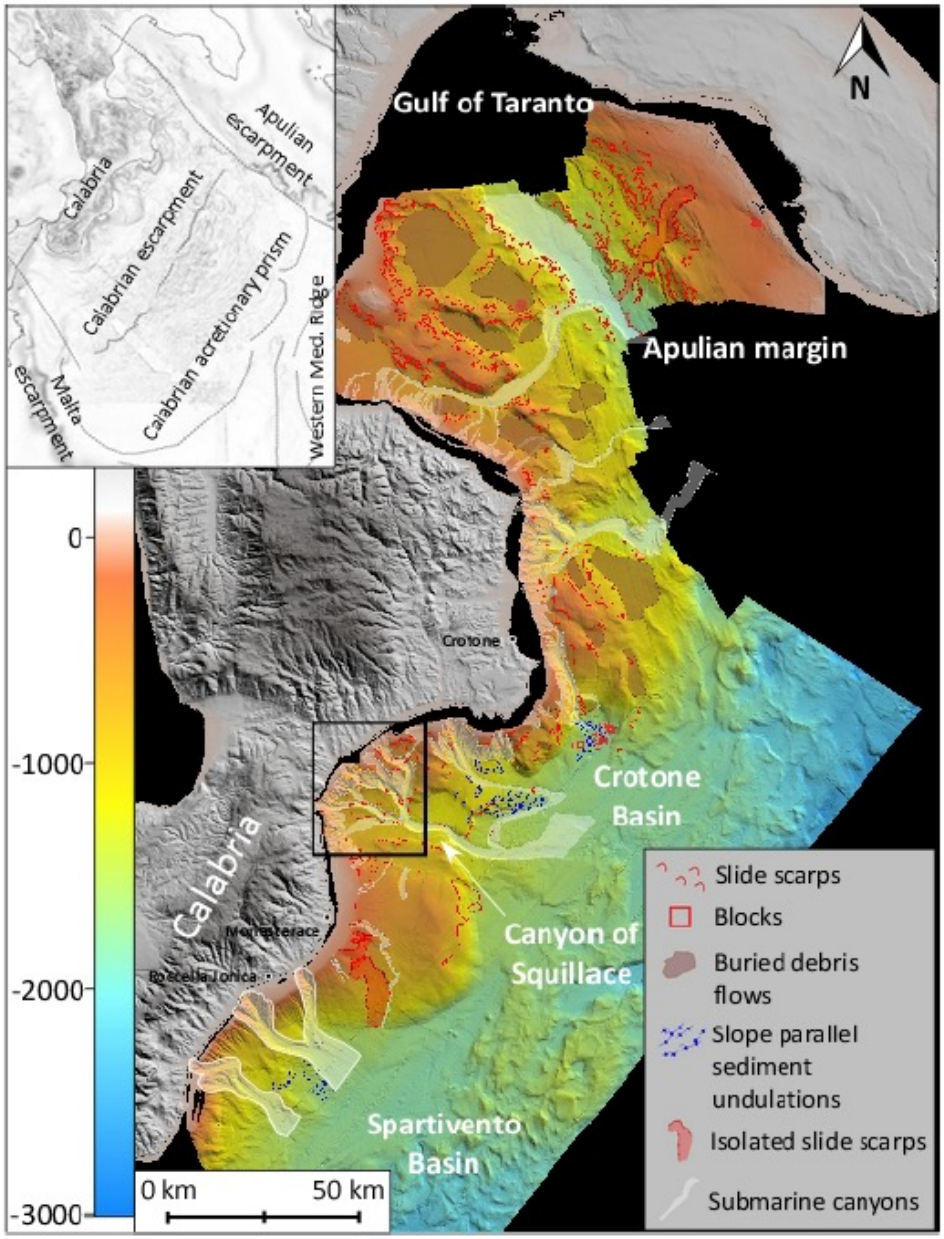
SLOPE SEDIMENTARY CONDUITS ON MID-LATITUDE MARGINS: CANYONS - CHANNELS - GULLIES

Submarine canyons and channels are **conduits** through which **sediments** are **transported across continental margins to deep-sea basins** by sediment gravity flows and other mass movements (Shepard, 1948, 1981; Menard, 1955).



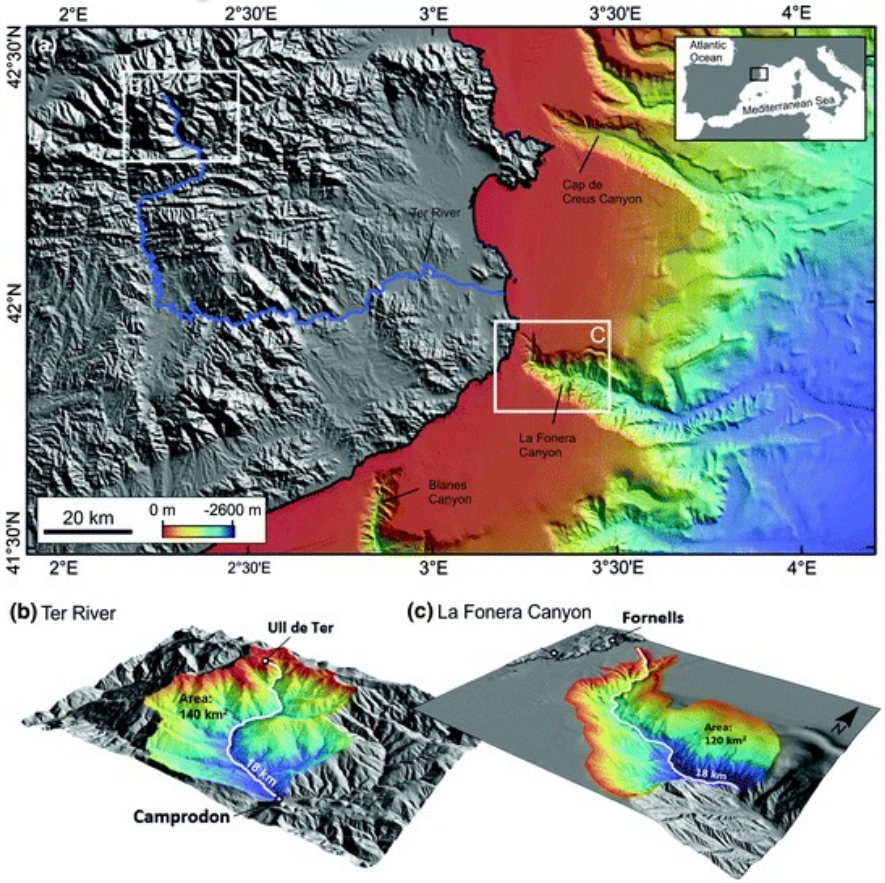
Submarine canyon: narrow steep-sided valleys cutting into continental slopes and rises. They can originate either within continental slopes or on continental shelves.

- Erosive or by-pass areas
- High gradient, strait conduict
- V-shaped cross profile with
- steep, rocky side walls 1000s m high (Grand Bahama Canyon 5 km)
- Side walls often intersected by erosive gullies
- 10s km wide
- 10s-100s km long

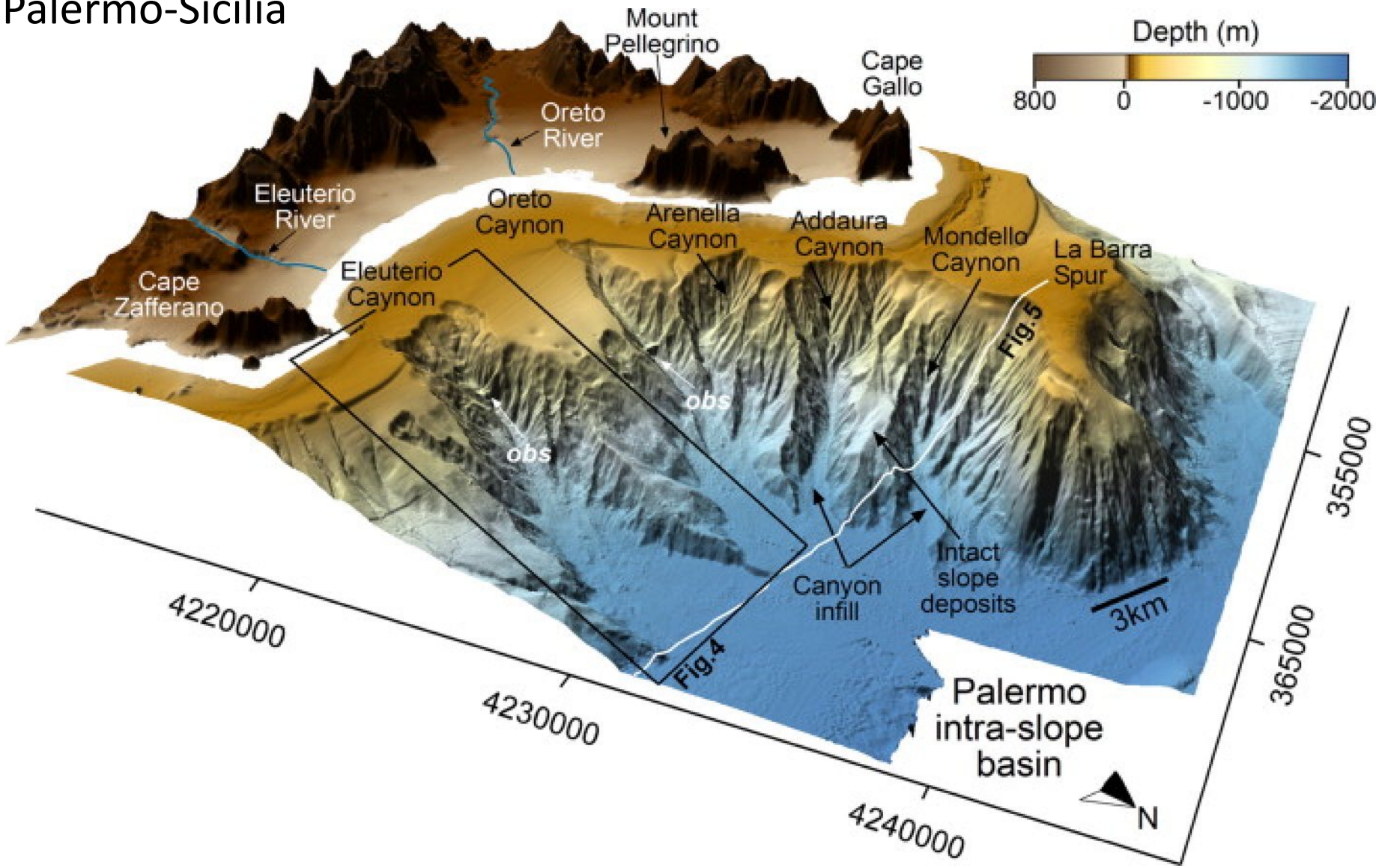


Margine ionico della Calabria

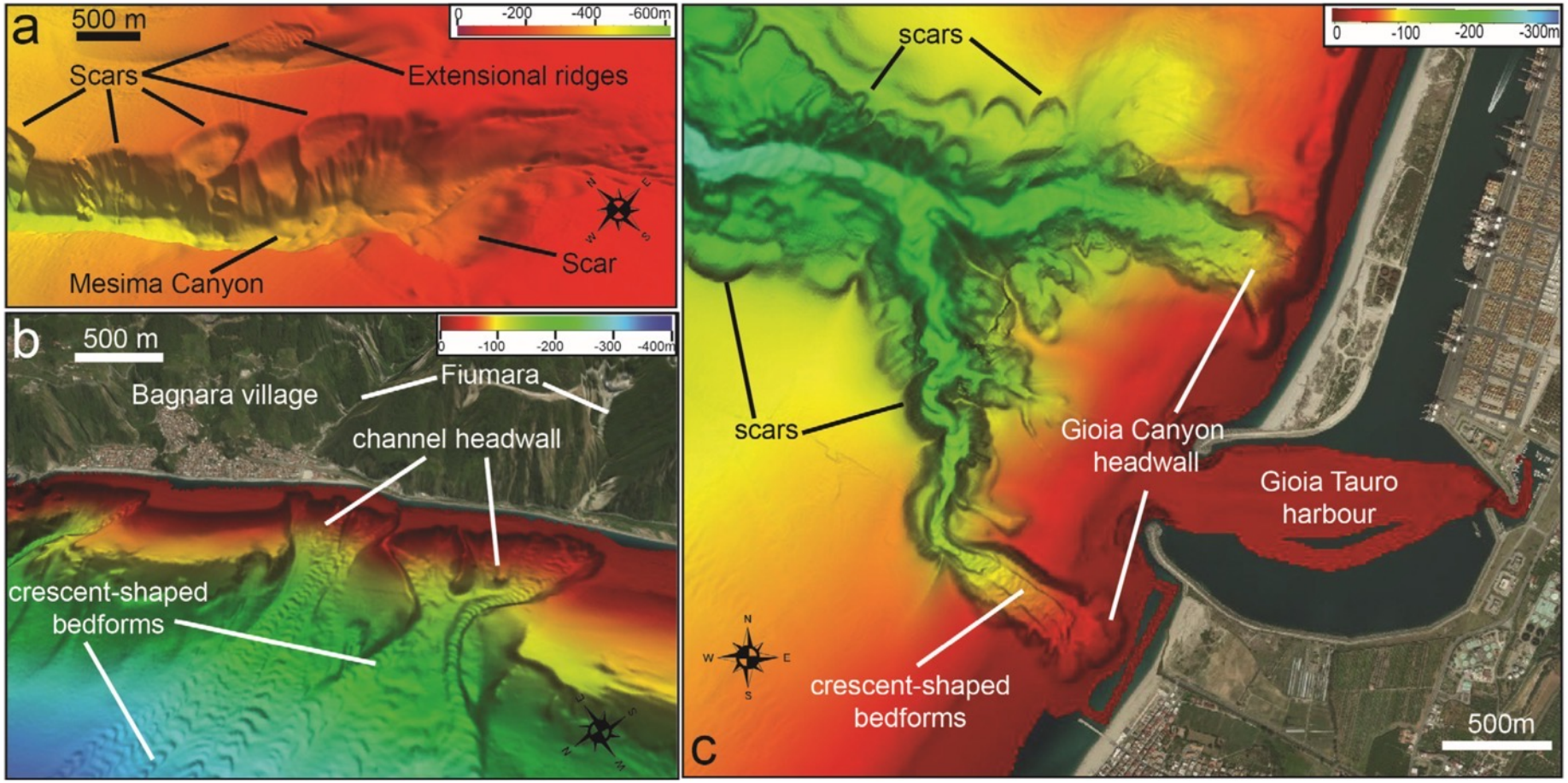
Margine Catalano



Palermo-Sicilia



Margine Tirreno Calabrese



Stromboli Canyon, SE Tyrrhenian Sea

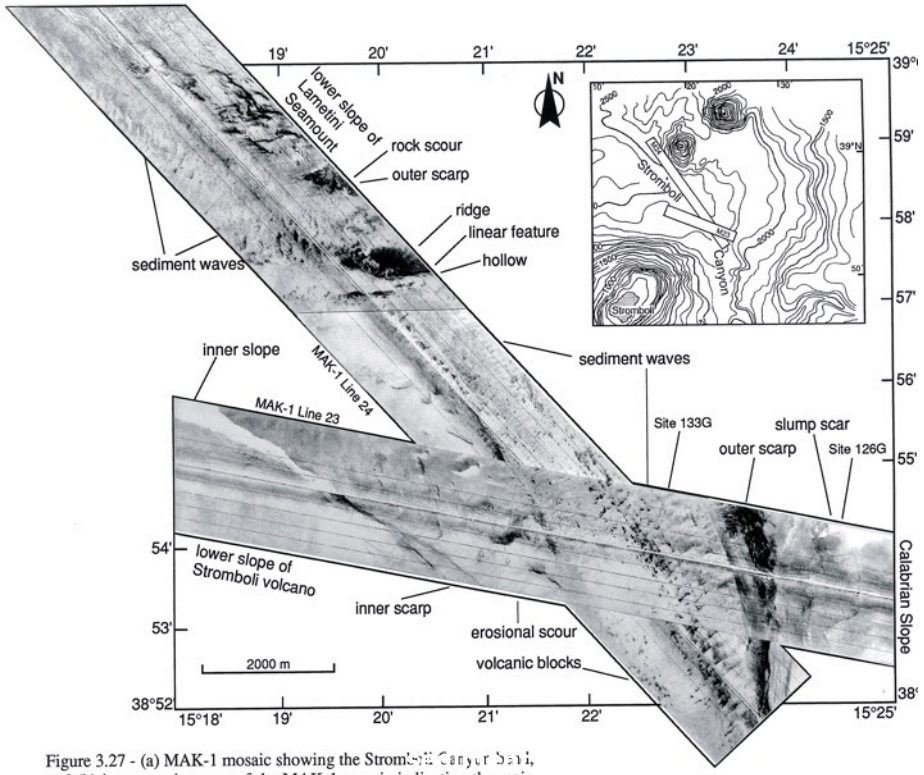
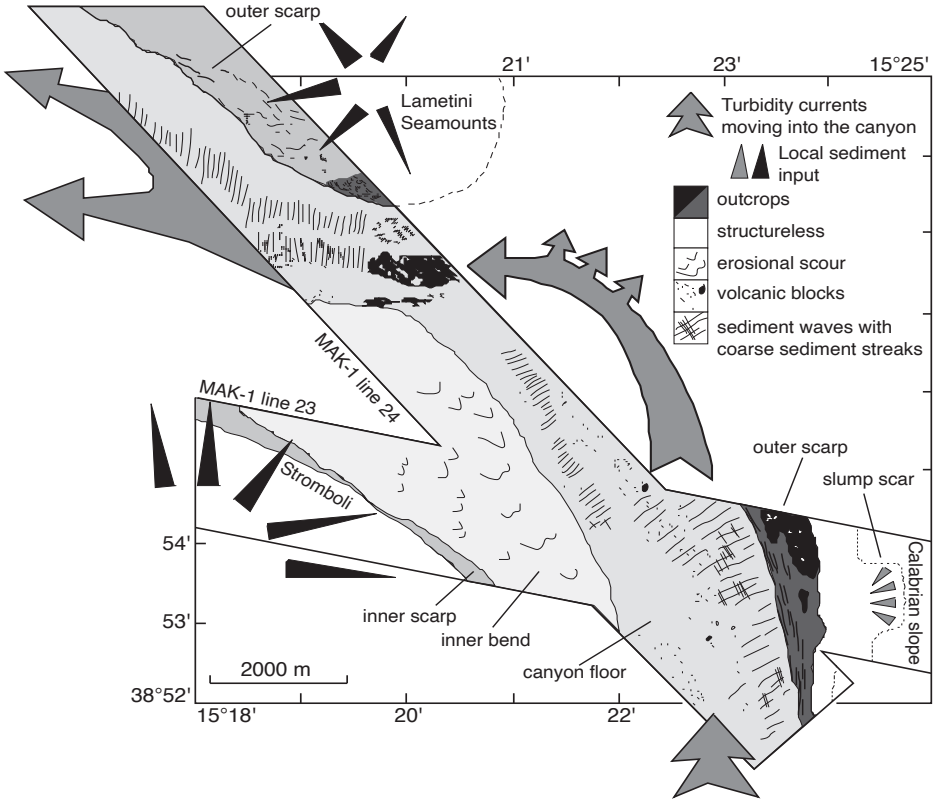
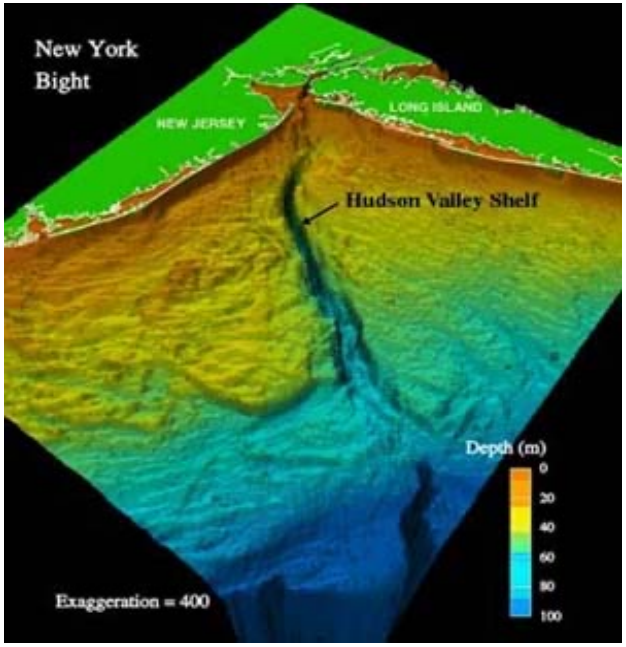
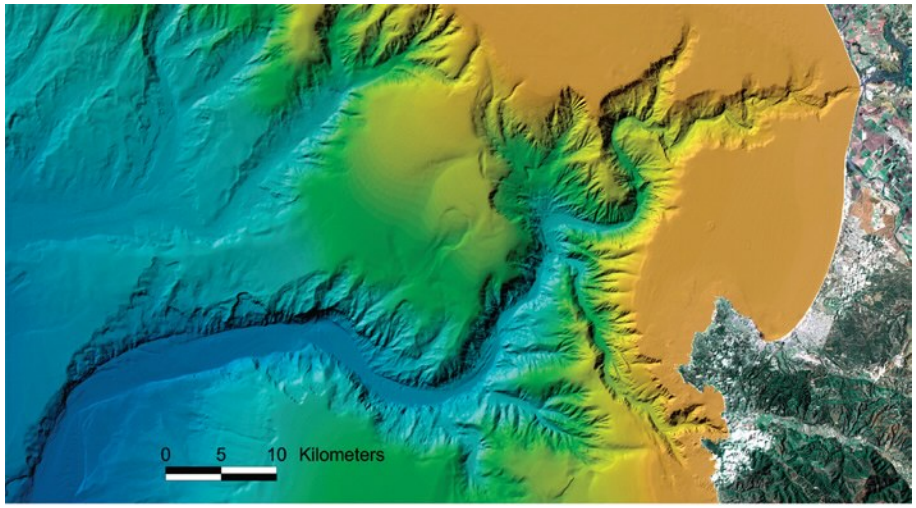


Figure 3.27 - (a) MAK-1 mosaic showing the Stromboli Canyon area, and (b) interpretation map of the MAK-1 mosaic indicating the main morphological and structural features (see text for discussion).







Hudson Canyon

Monterey Canyon

About 3% of submarine canyons include **shelf valleys** cutting across continental shelves, having upstream ends in alignment with, and sometimes within, the mouths of large rivers, such as the Hudson Canyon.

About 28.5% of submarine canyons **cut** into the continental shelf edge, whereas the majority (**about 68.5%**) have their upstream heading on the continental slope.

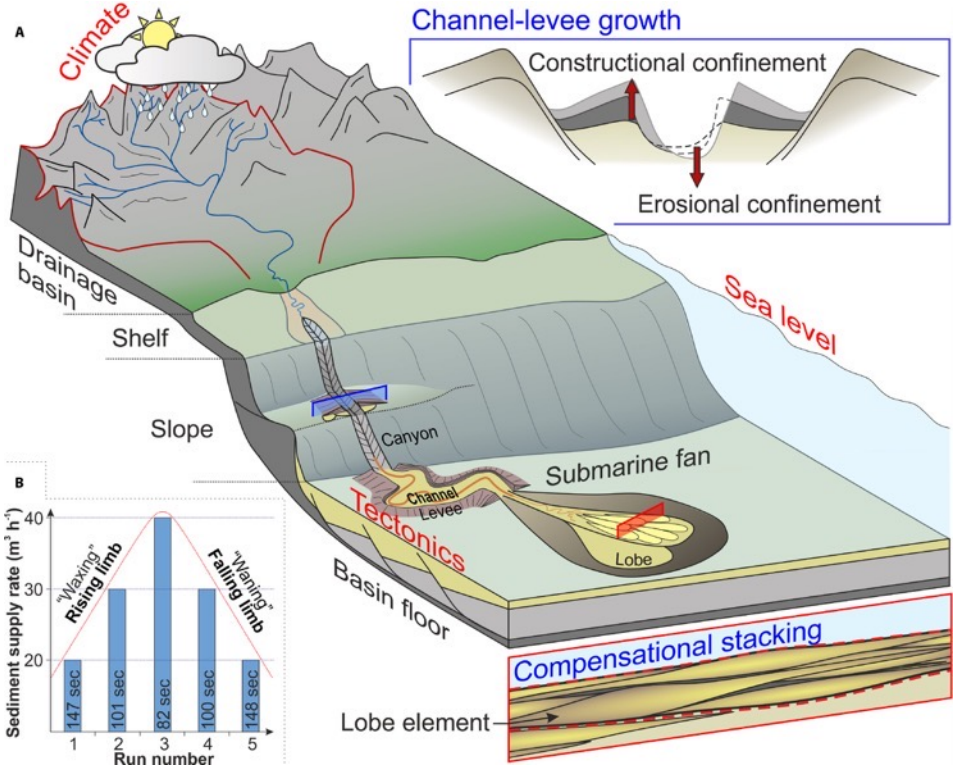
ORIGIN: **a)** Low-standing sea level (e.g. during LGM or the Messinian Salt Crisis in the Mediterranean *ca.* 5.5 Ma ago)

b) Mass-gravity failure

c) Tectonic initiation

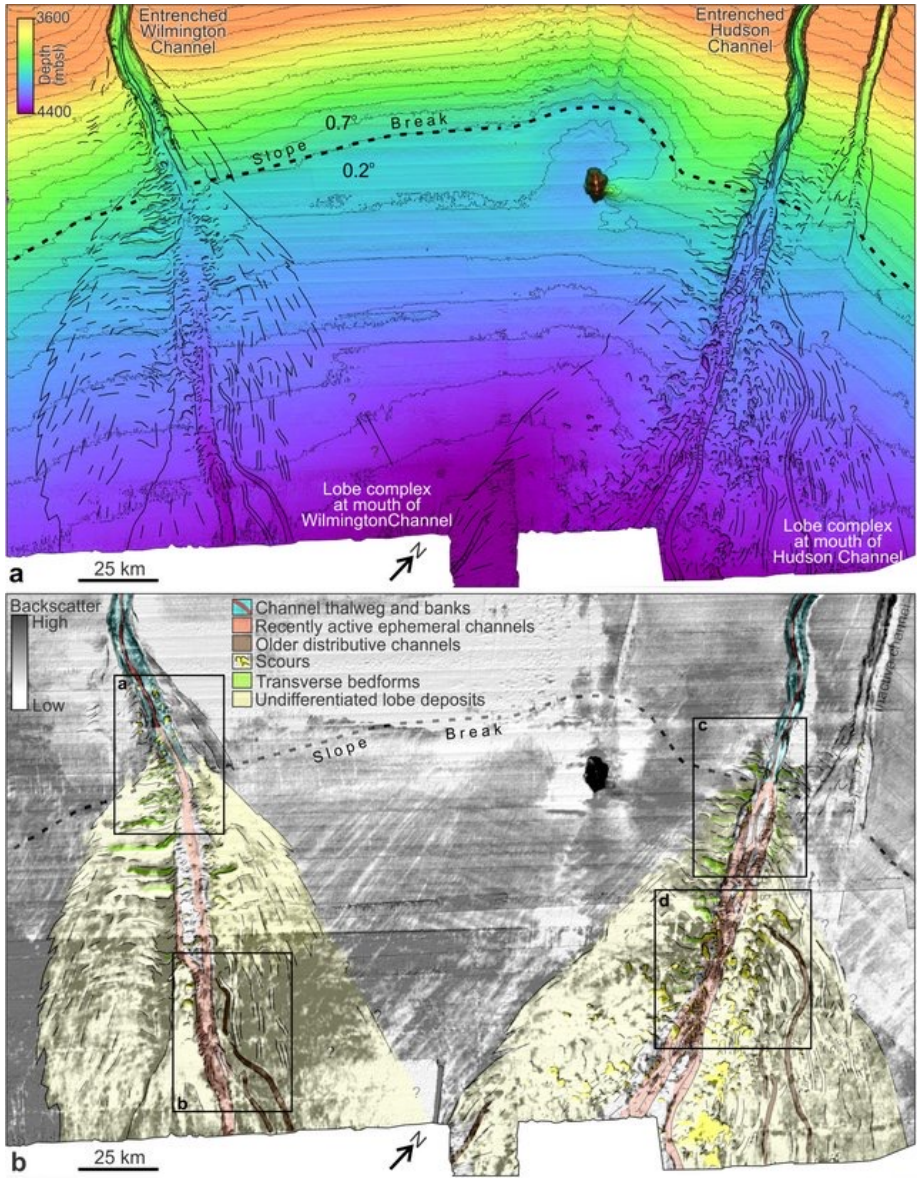
SLOPE SEDIMENTARY CONDUITS ON MID-LATITUDE MARGINS: CANYONS - CHANNELS - GULLIES

Submarine canyons and channels are **conduits** through which **sediments** are **transported across continental margins to deep-sea basins** by sediment gravity flows and other mass movements (Shepard, 1948, 1981; Menard, 1955).

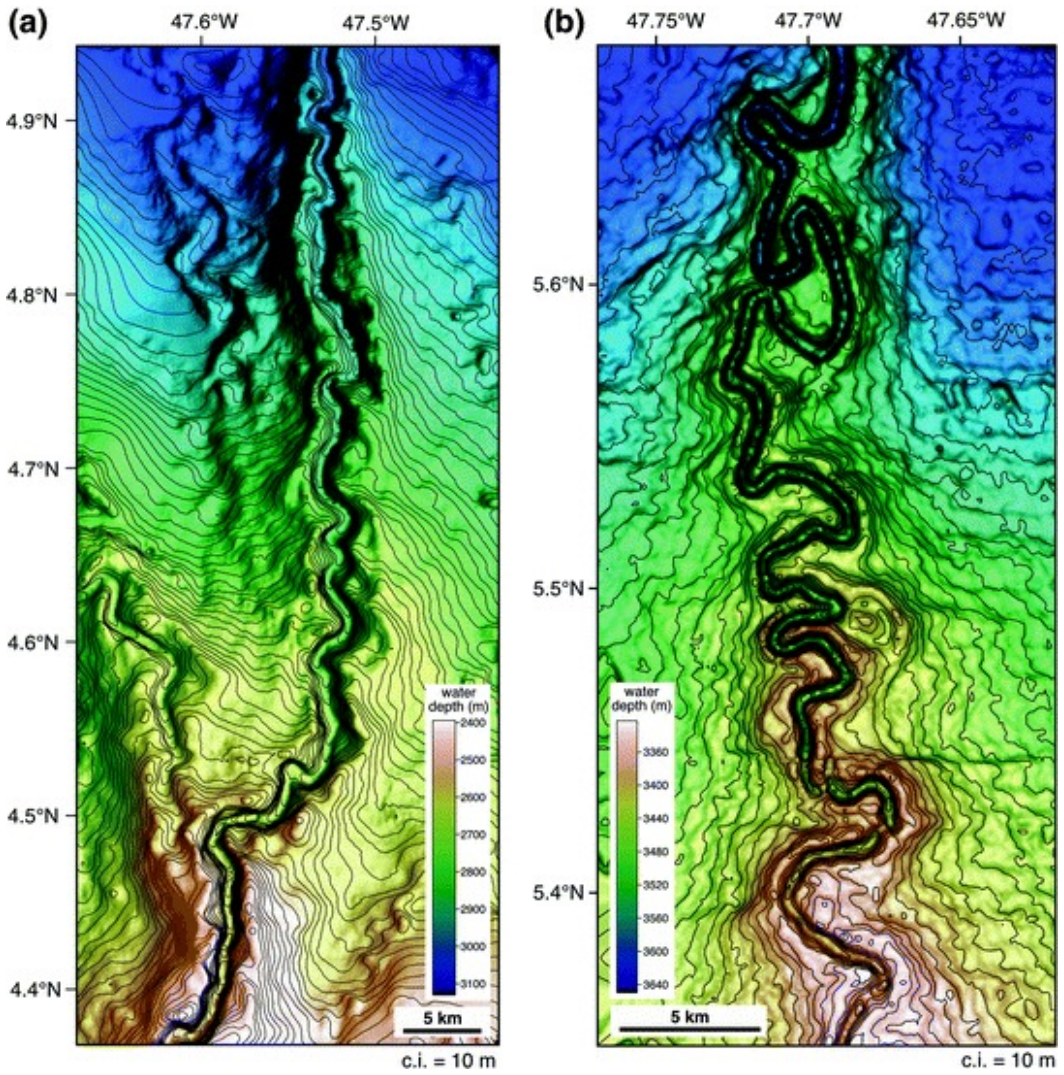


Submarine channels: wide flat valley flanked by depositional channel's levees They originate at the base of continental slopes or on continental rises.

- Initially by-pass, evolve as depositional areas
- U-shaped cross profile flanked by
- Well developed channel's levees (overbank deposits)
- Often sinuous conduit
- 10s-100s km wide
- 10s-1000s km long
- Internal and outer levee sides often hosting slumps/failure



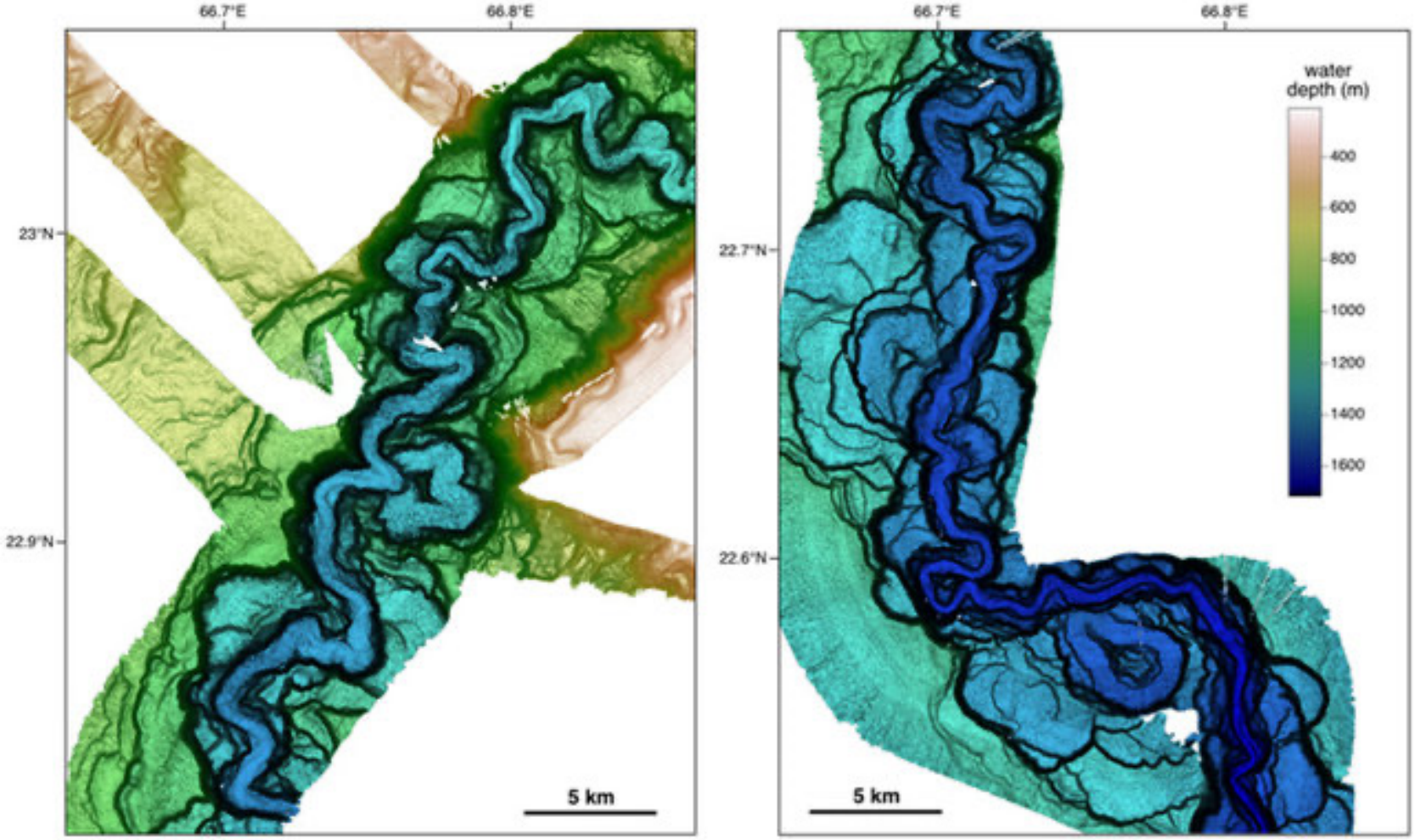
Gardner, 2004: Interpretation of geomorphic features near the channel-lobe transition seaward of Wilmington and **Hudson channels**. a bathymetry; b backscatter.



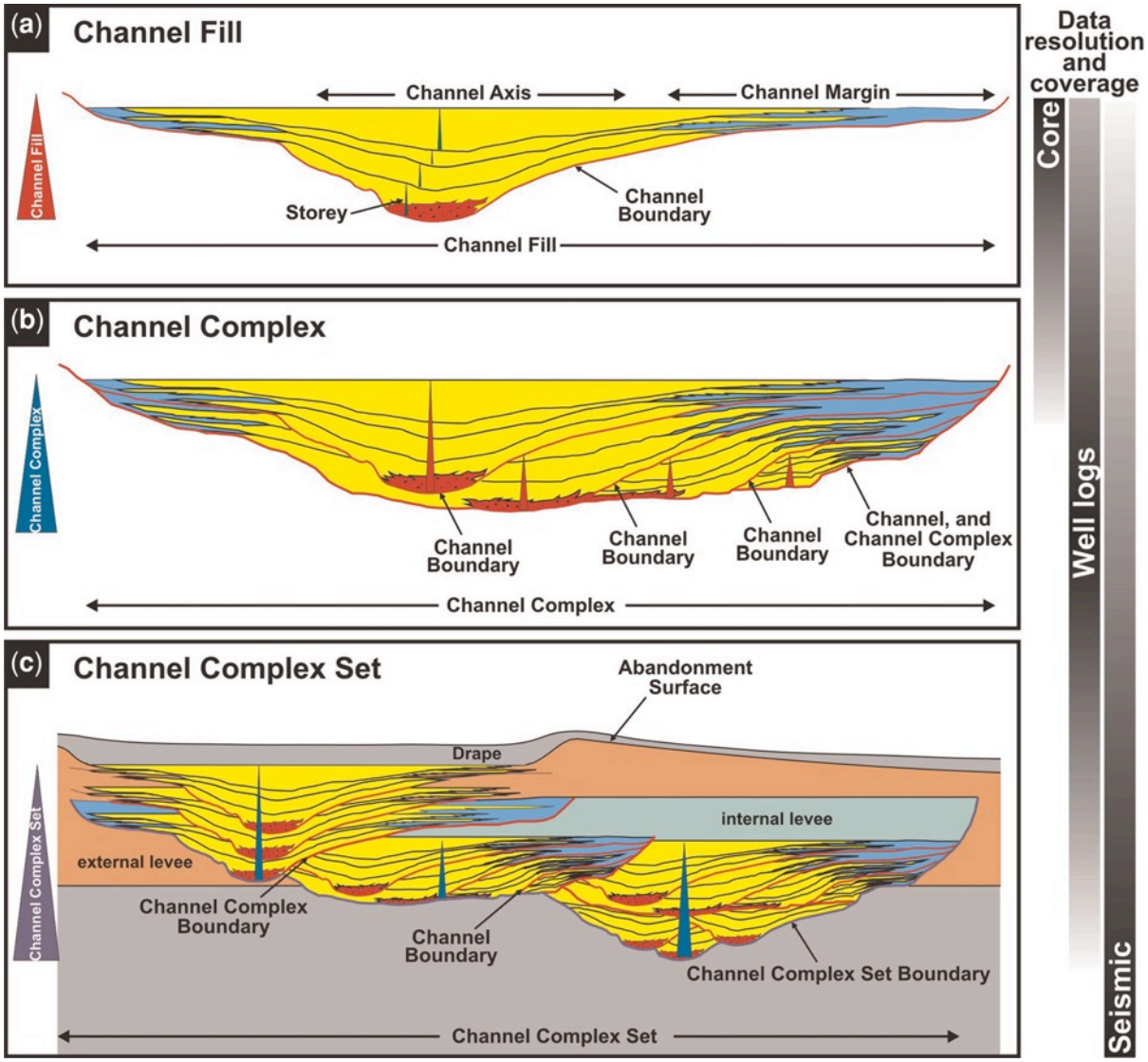
Sinuous submarine channels on the **Amazon Fan**.

(a) Avulsion on the upper fan,

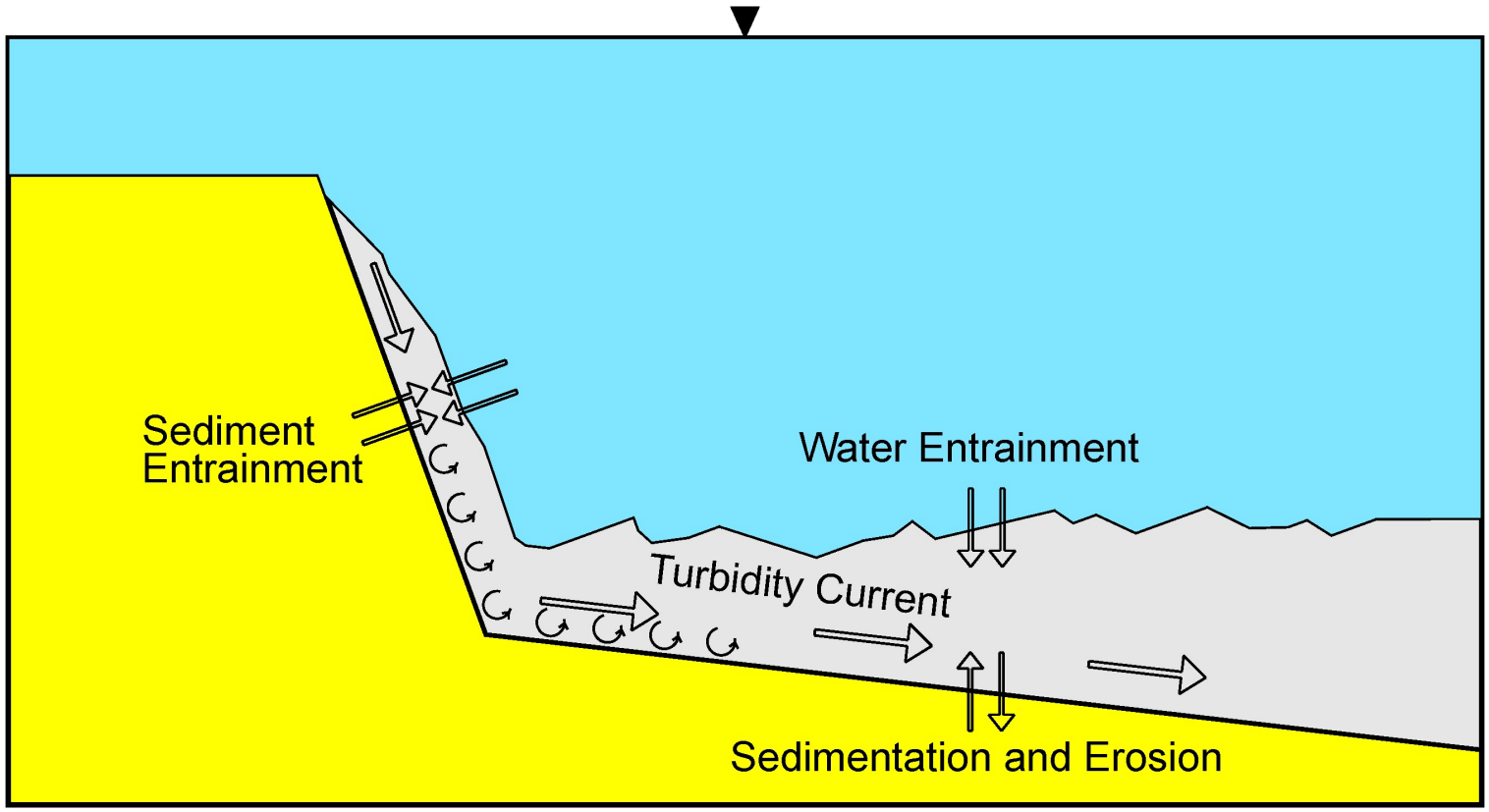
(b) Higher sinuosity and recent and incipient cutoffs on the middle fan. Bathymetry data from NOAA

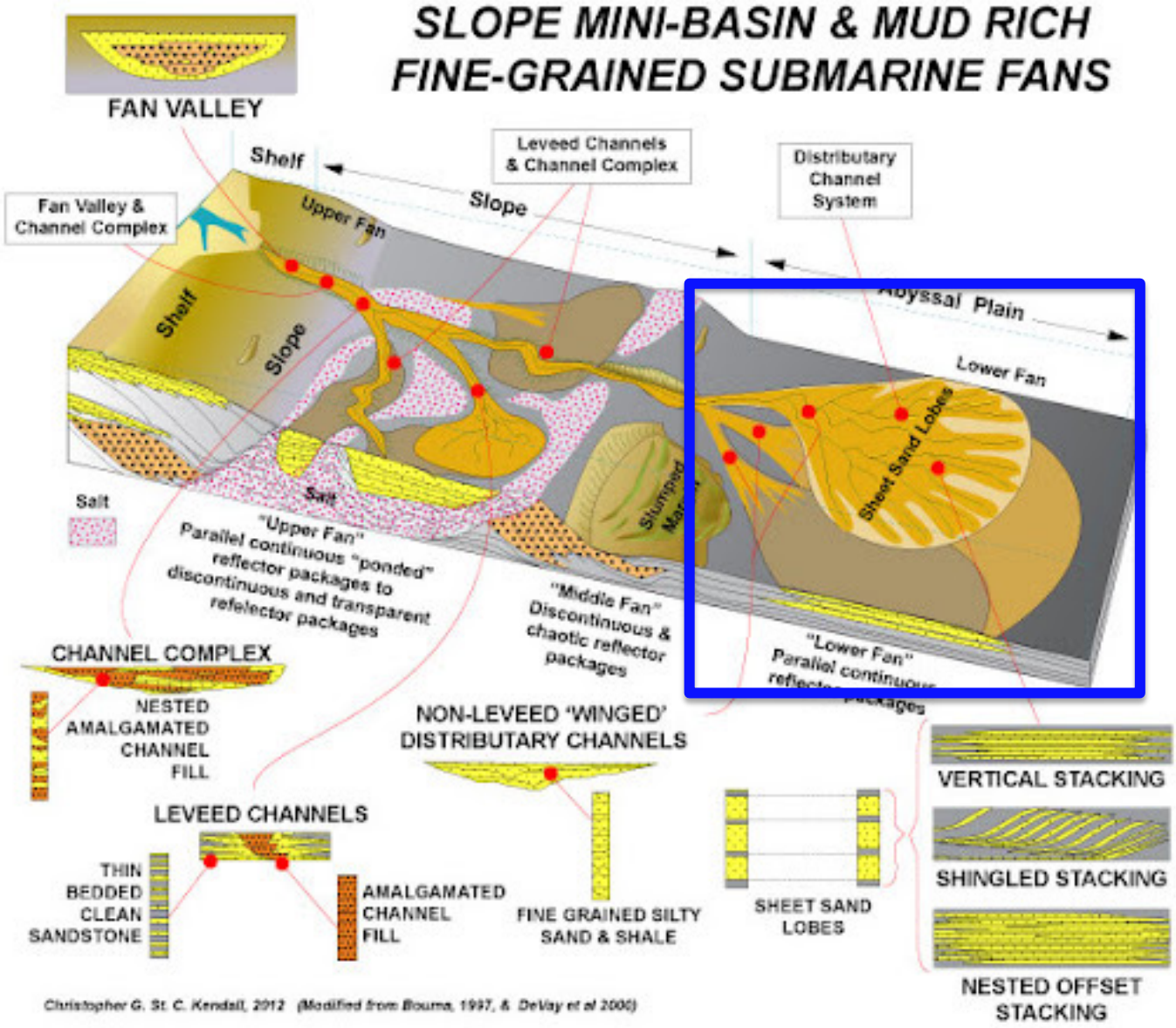


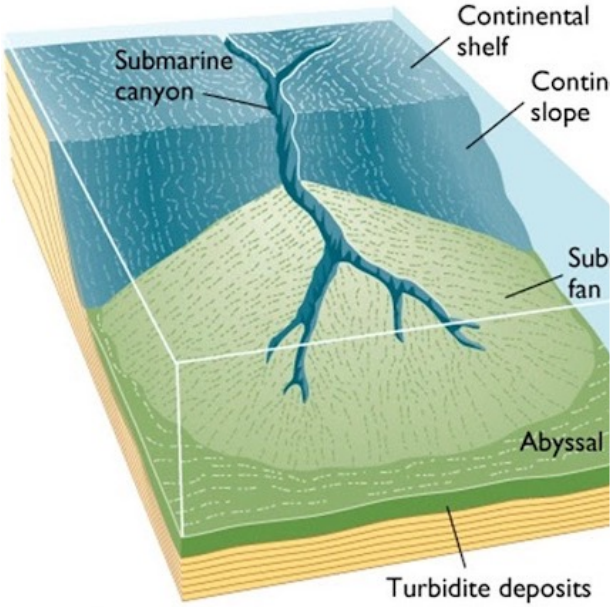
Morphology of large channel-levee systems: the canyon-channel transition zone on the upper part of the **Indus Fan**, with terraces and cutoffs. Data from Clift and Henstock (2015).


(a)
Channel Fill
Channel Axis
Channel Margin
Channel Fill
Storey
Channel Boundary
Channel Fill
(b)
Channel Complex
Channel Complex
Channel Boundary
Channel Boundary
Channel Boundary
Channel, and Channel Complex Boundary
Channel Complex
(c)
Channel Complex Set
Abandonment Surface
Drape
internal levee
external levee
Channel Complex Boundary
Channel Boundary
Channel Complex Set Boundary
Channel Complex Set
Data resolution and coverage
Core
Well logs
Seismic

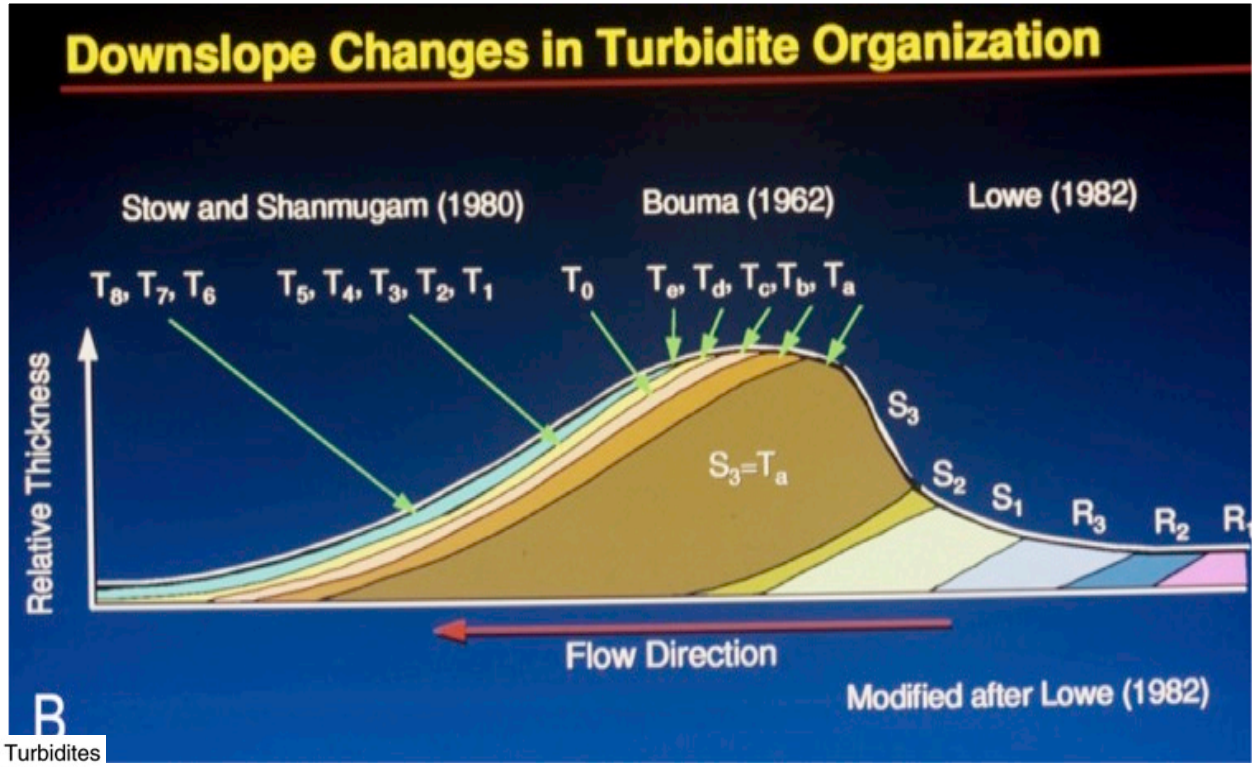
HYDRAULIC JUMP

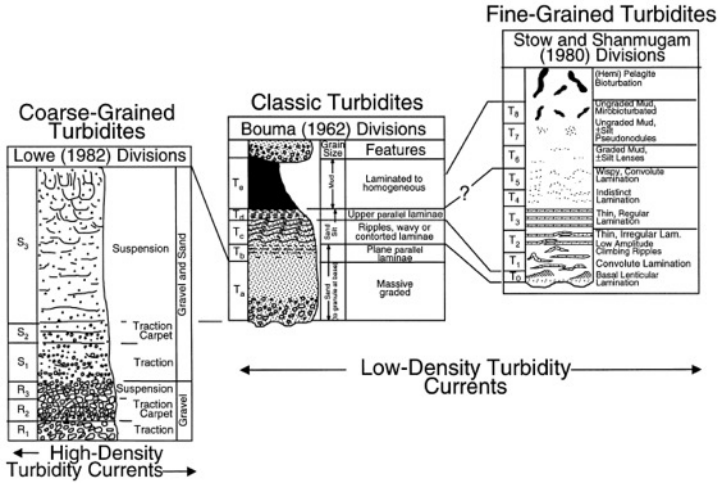


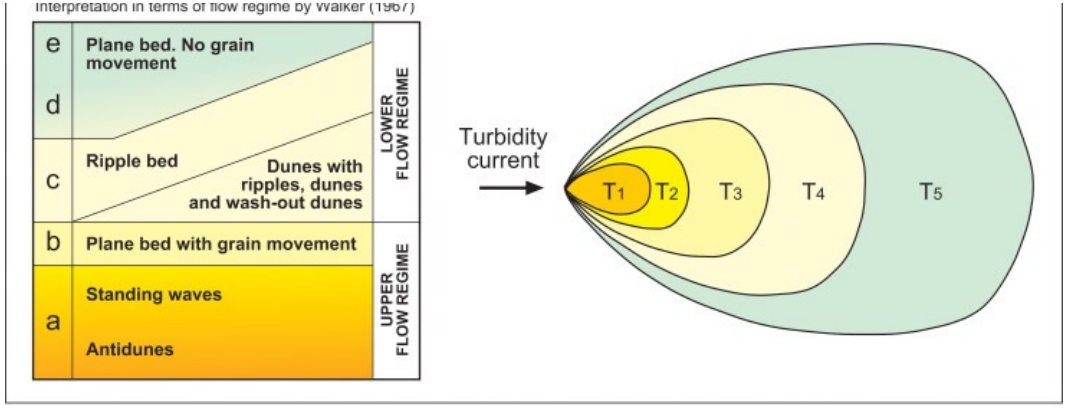

SLOPE MINI-BASIN & MUD RICH FINE-GRAINED SUBMARINE FANS
FAN VALLEY
Shelf
Slope
Leveed Channels & Channel Complex
Distributary Channel System
Fan Valley & Channel Complex
Upper Fan
Abyssal Plain
Lower Fan
Sheet Sand Lobes
Salt
"Upper Fan" Parallel continuous "ponded" reflector packages to discontinuous and transparent refelector packages
"Middle Fan" Discontinuous & chaotic reflector packages
"Lower Fan" Parallel continuous
CHANNEL COMPLEX
NESTED AMALGAMATED CHANNEL FILL
NON-LEVEED 'WINGED' DISTRIBUTARY CHANNELS
LEVEED CHANNELS
THIN BEDDED CLEAN SANDSTONE
AMALGAMATED CHANNEL FILL
FINE GRAINED SILTY SAND & SHALE
SHEET SAND LOBES
VERTICAL STACKING
SHINGLED STACKING
NESTED OFFSET STACKING
Christopher G. St. C. Kendall, 2012 (Modified from Bouma, 1997, & DeVay et al 2006)



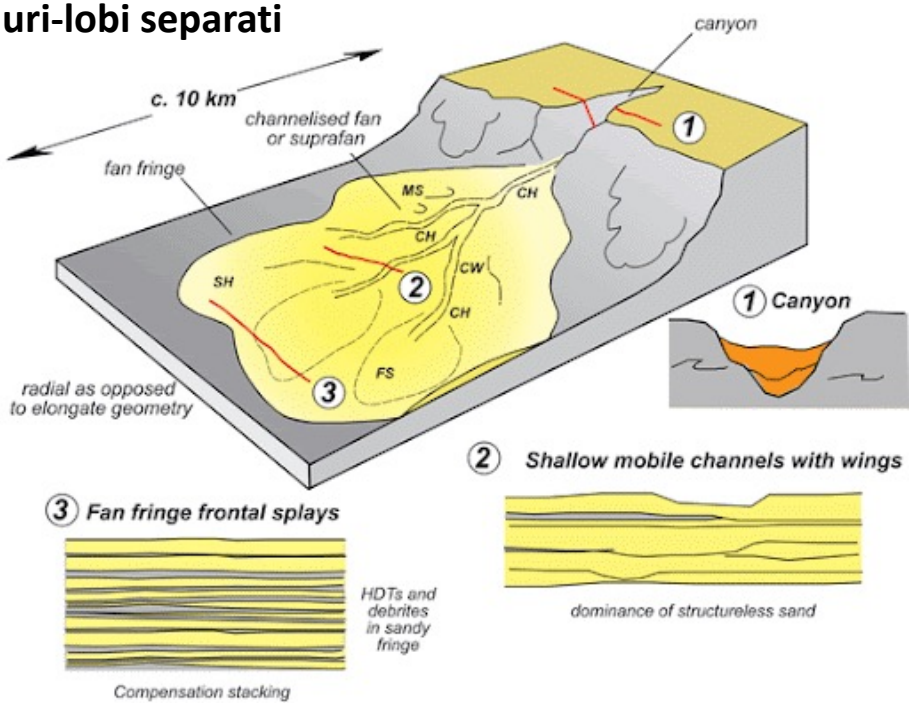
Depositional cone



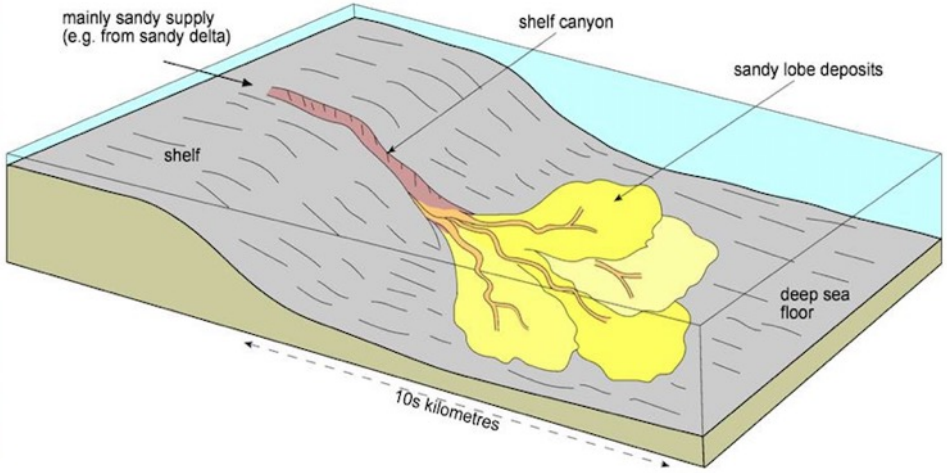




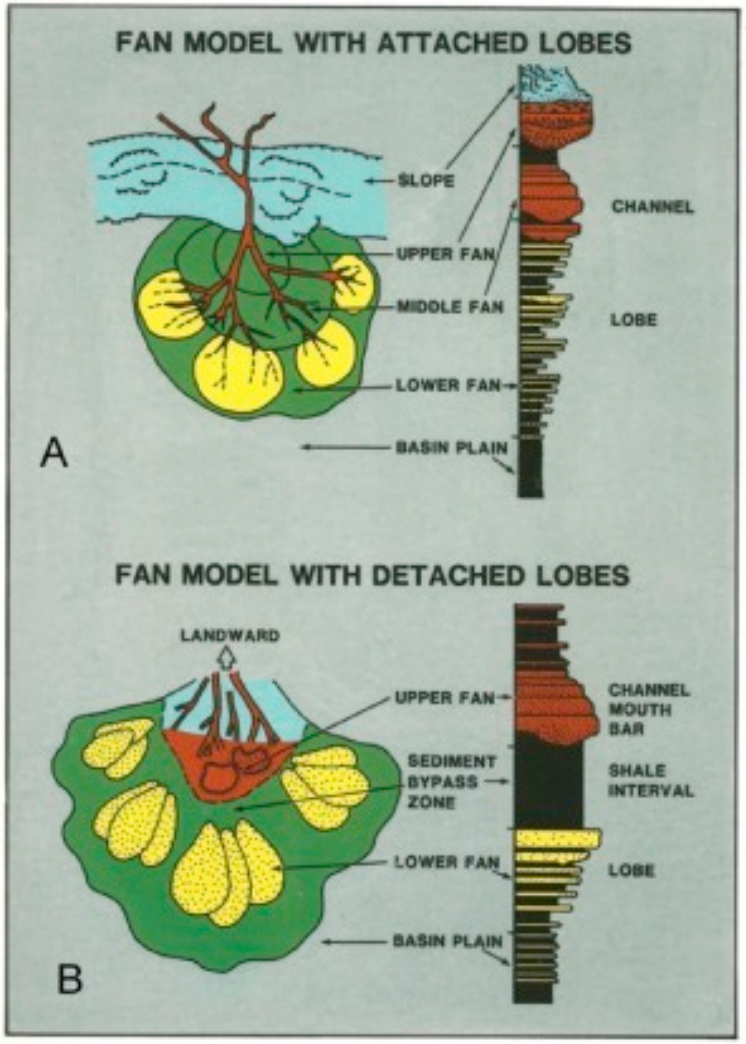
Pluri-lobi separati



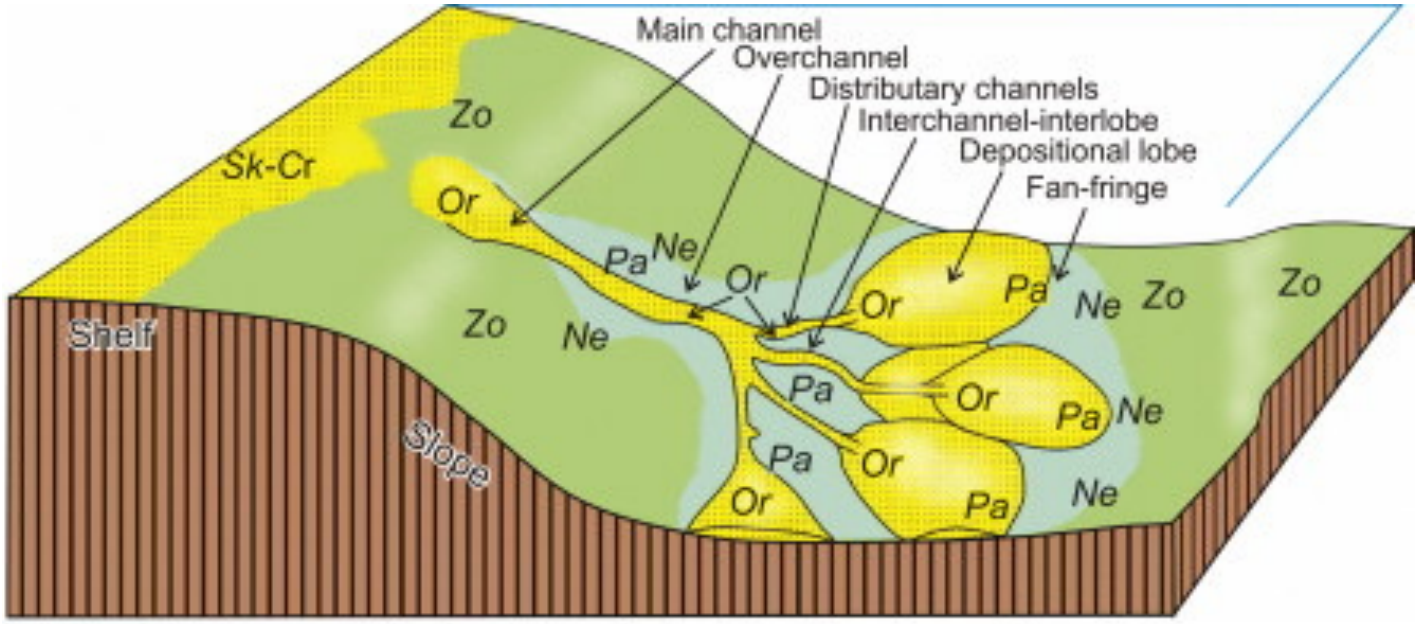
Pluri-lobi coalescenti



NUMBER and LOCATION of lobes forming deep sea fans

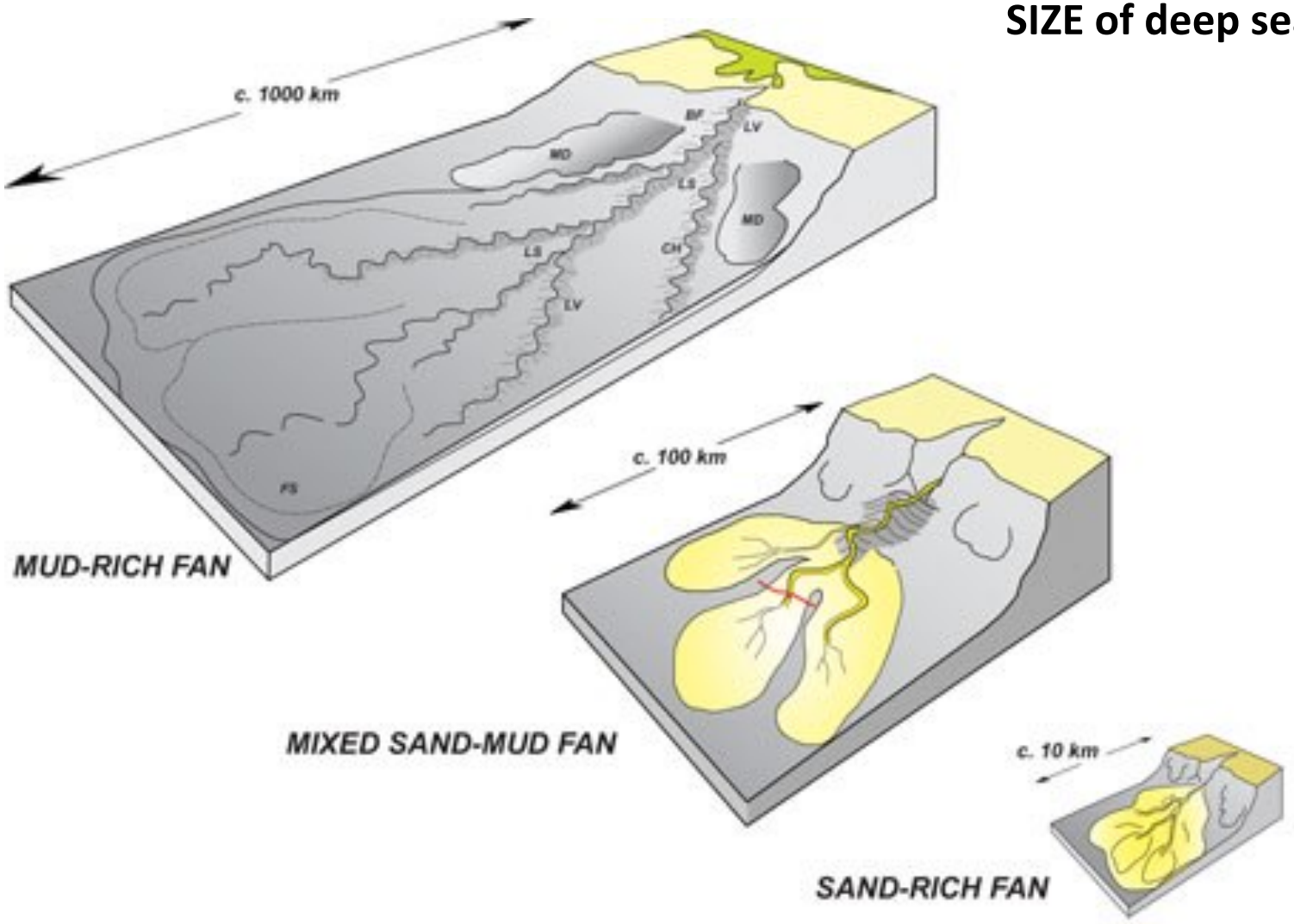


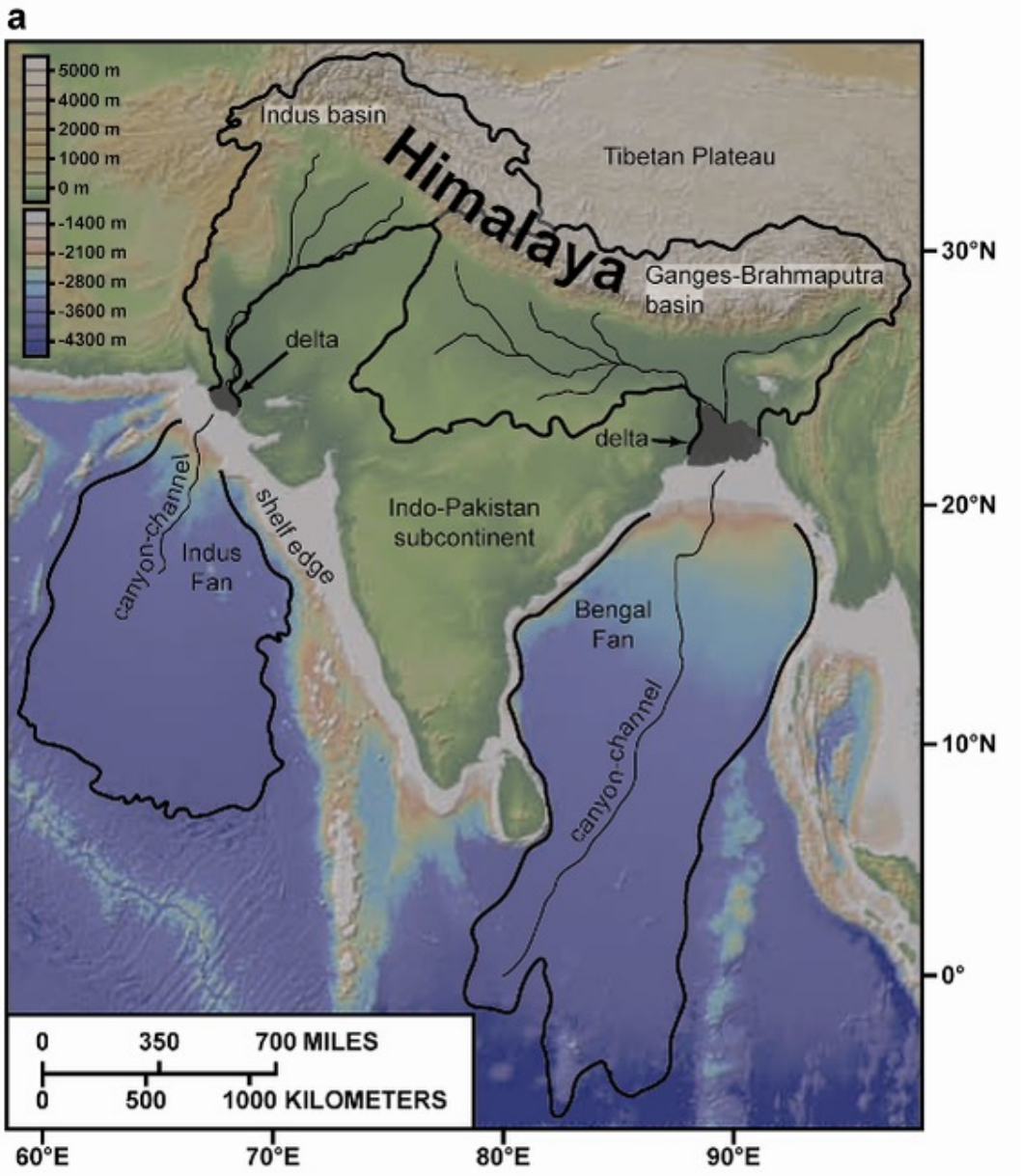
GEOMORPHOLOGY of channel-deep sea fan systems



Sk-Cr - *Skolithos* and *Cruziana* ichnofacies, *Zo* - *Zoophycos* Ichnofacies
Nereites Ichnofacies: *Or* - *Ophiomorpha rudis* subichnofacies,
Pa - *Paleodictyon* subichnofacies, *Ne* - *Nereites* subichnofacies

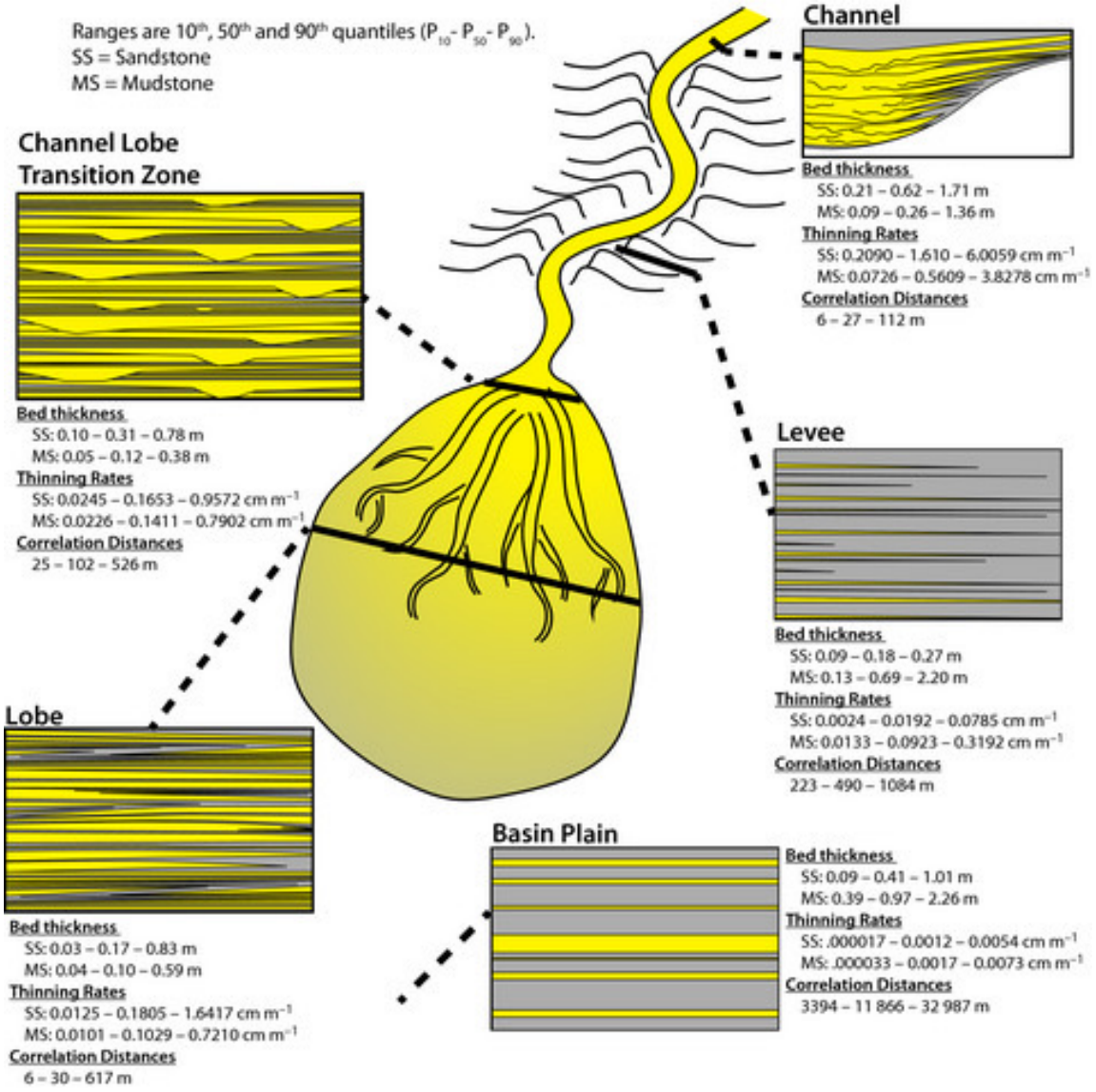
SIZE of deep sea fans



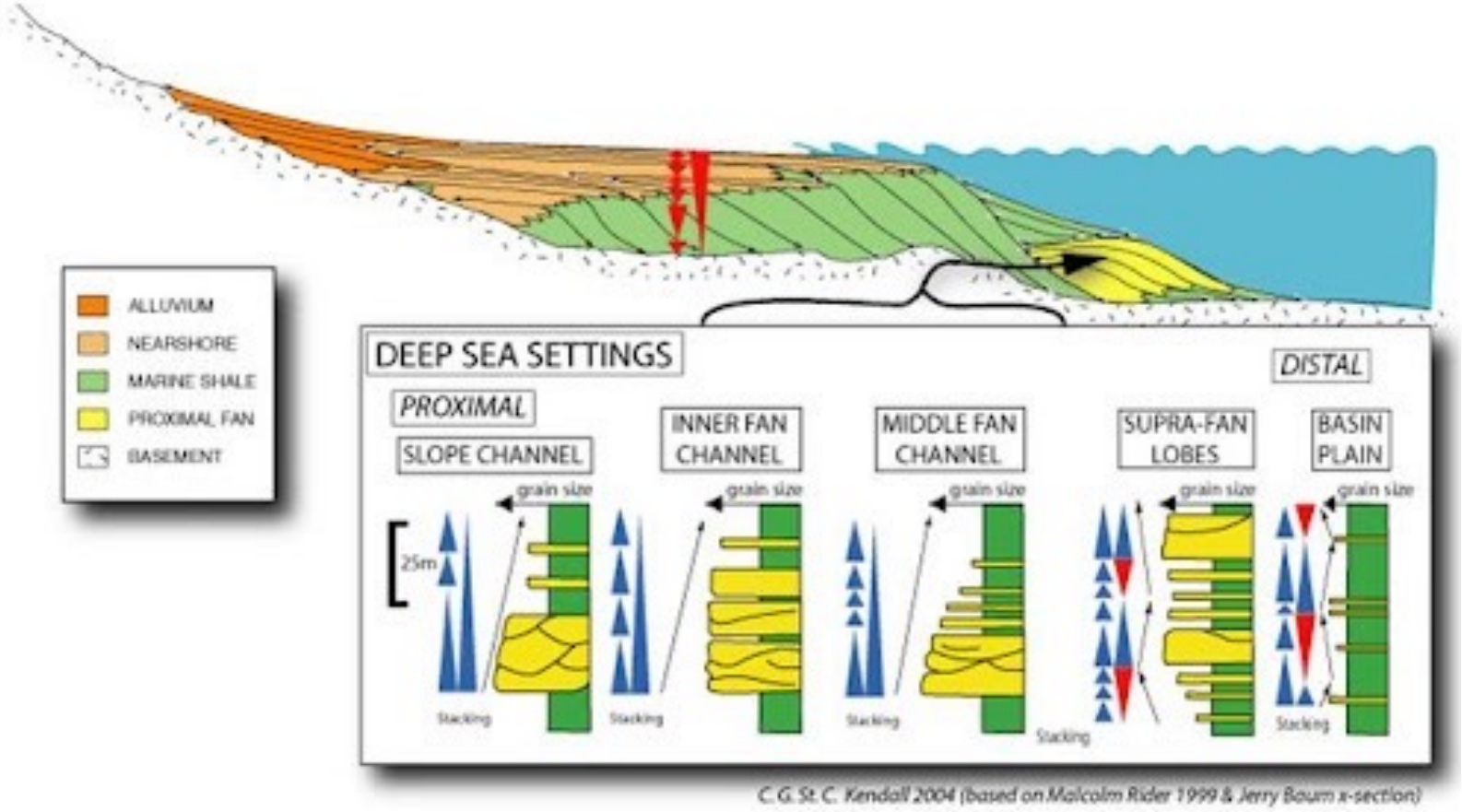


SIZE of deep sea fans

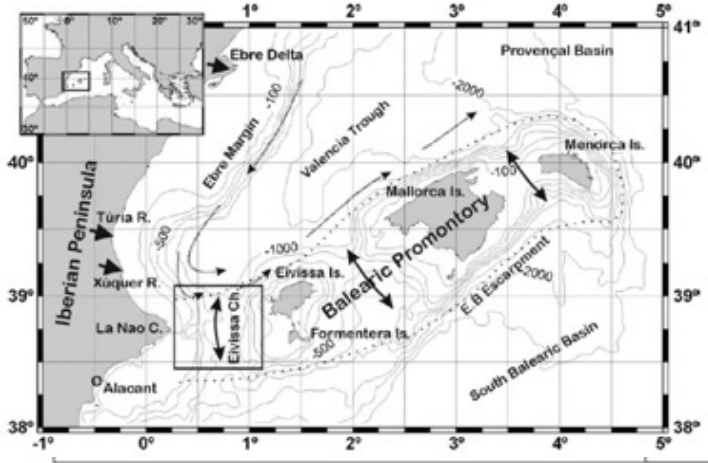
SEDIMENT FACIES in channel-deep sea fan



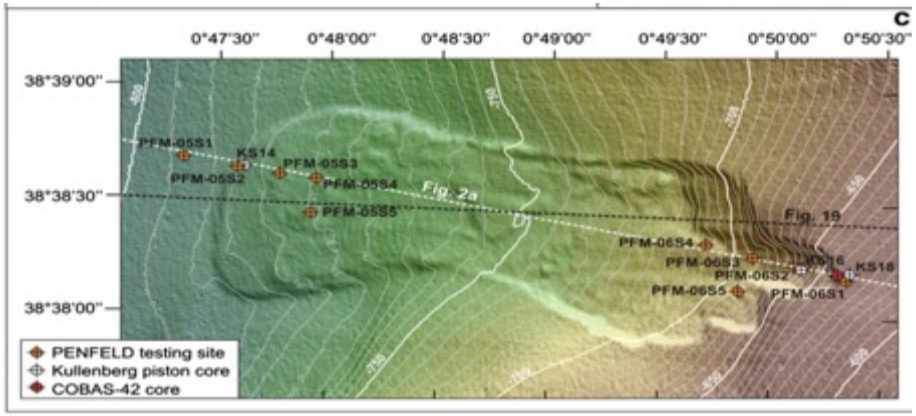
The **triggering mechanism for gravity flows initiation** can influences the volume and duration of individual flows (Piper and Normark 2001). The **flow behaviour** controls how coarse- and fine-grained material is partitioned into different fan settings, and is strongly influenced by the **overall gradient** (Normark and Piper 1991) **and seabed morphology** (Mulder and Alexander 2001). **Sea level changes can remodulate the deep sea fan configuration.**



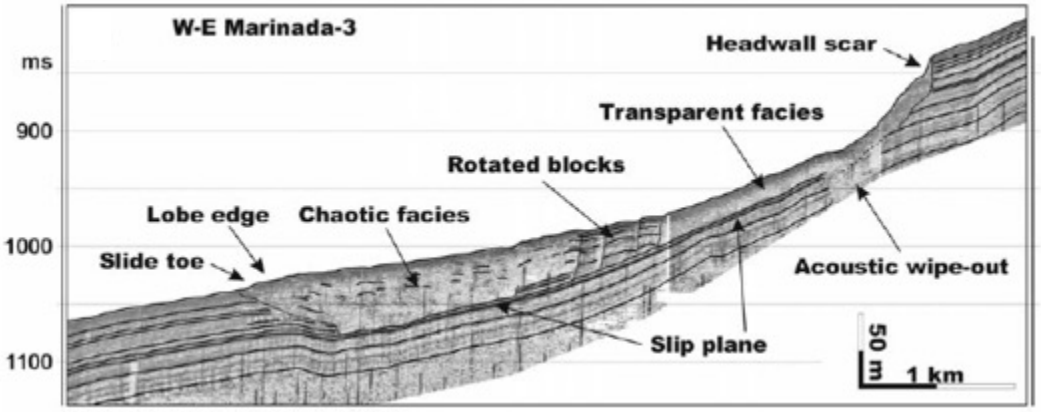
Submarine Landslides and debris flows



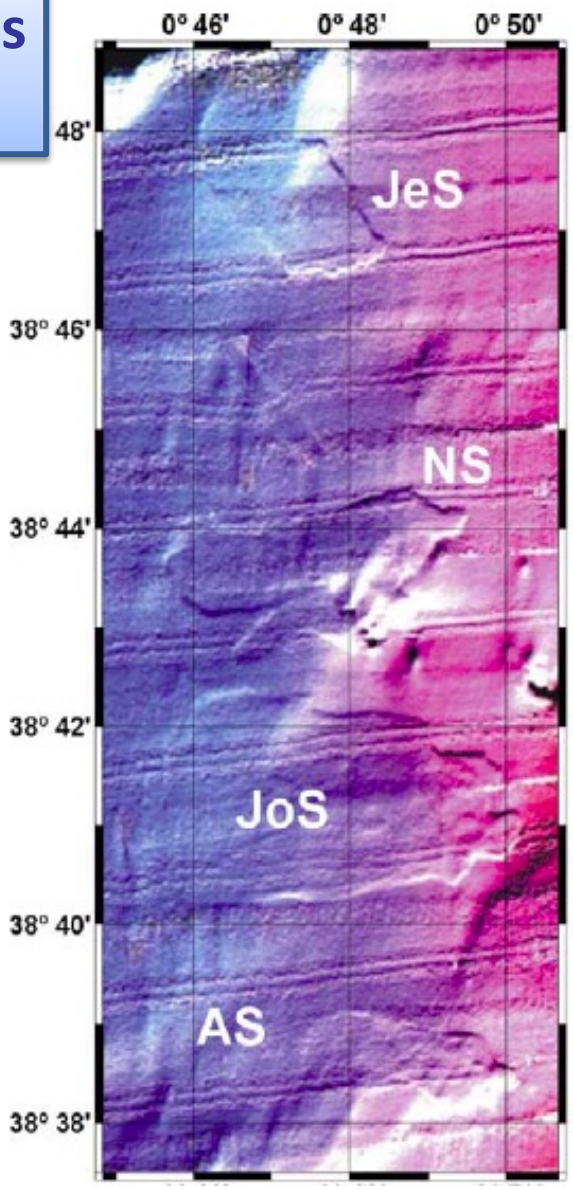
Ana submarine landslide
Ibiza Channel
Western Mediterranean



Multibeam



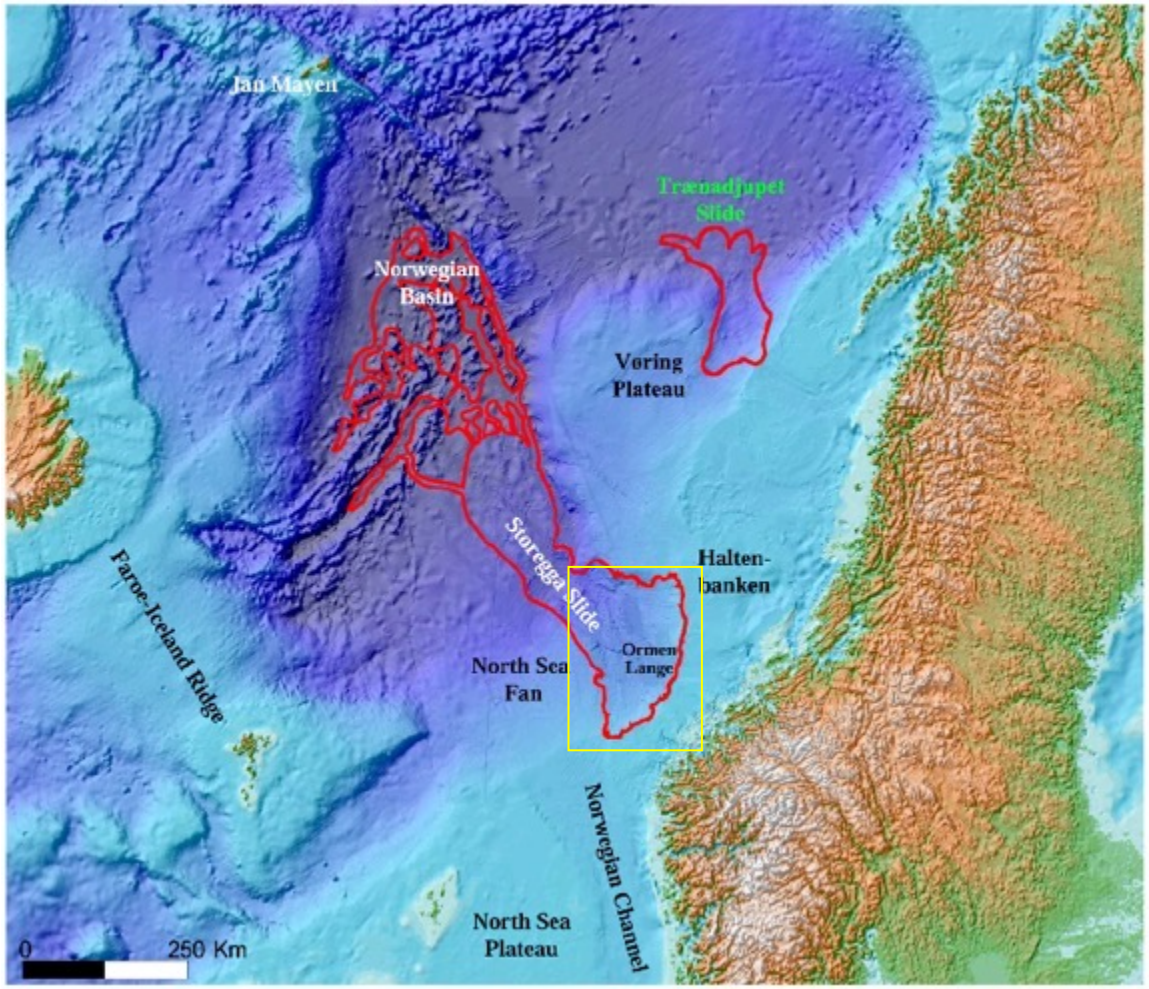
Sub-bottom



Lastras et al., 2004 Sedimentology

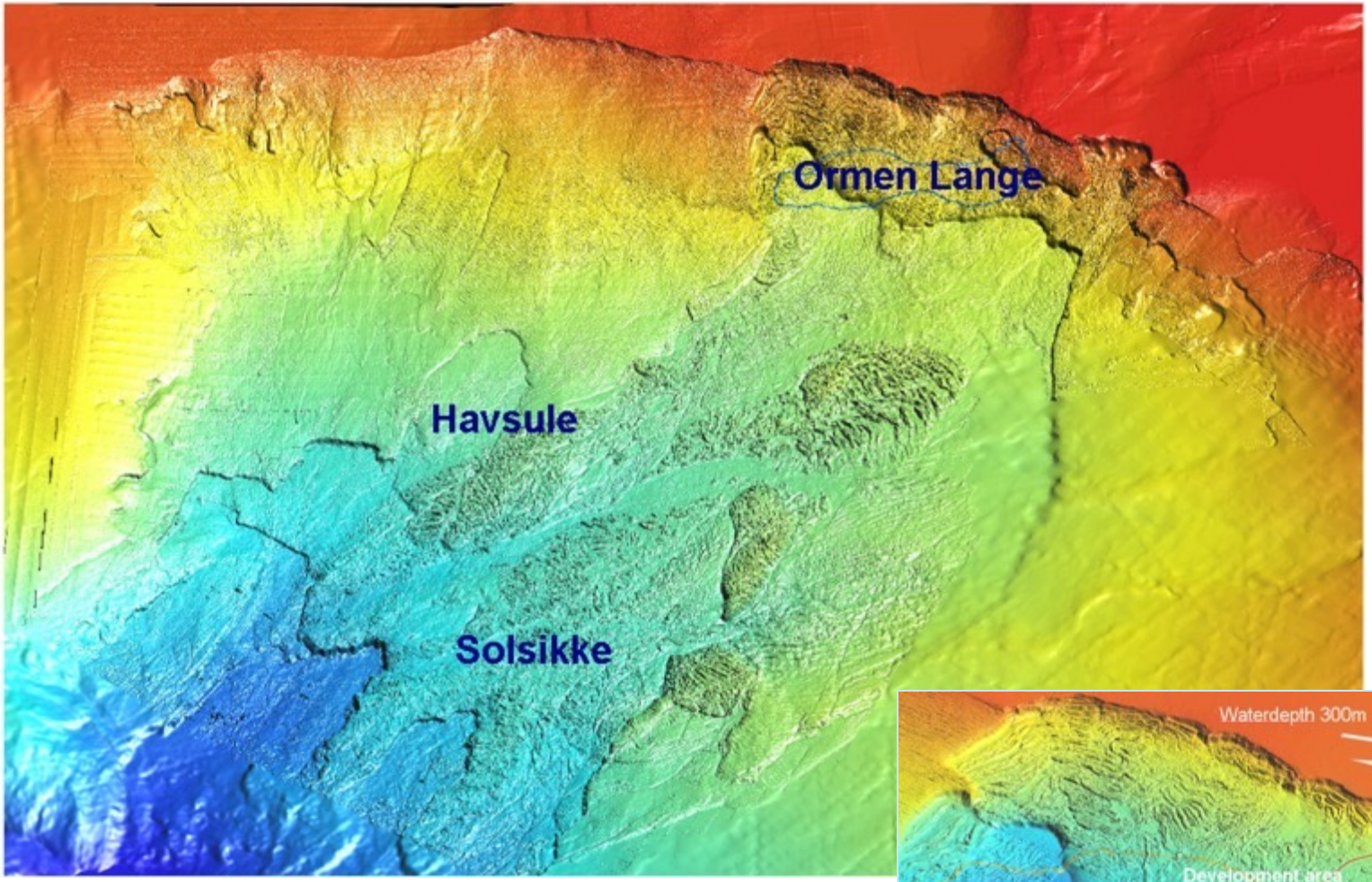
STOREGGA SUBMARINE LANDSLIDE, NORWAY

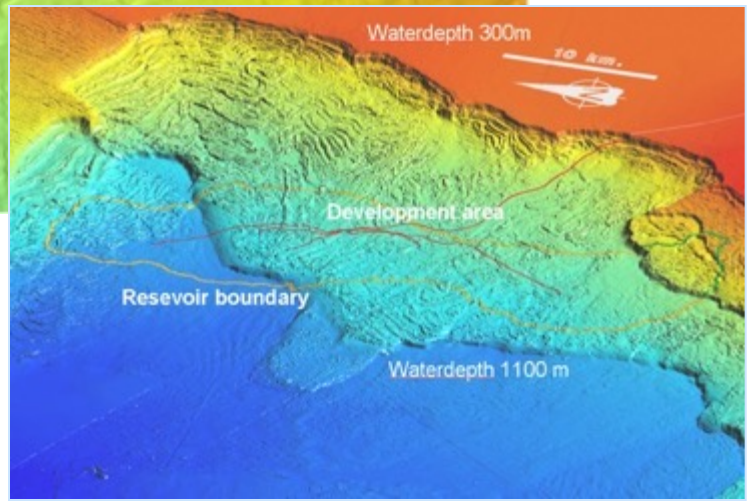
8000 y BP
3500 km³ of debris



Courtesy Petter Bryn

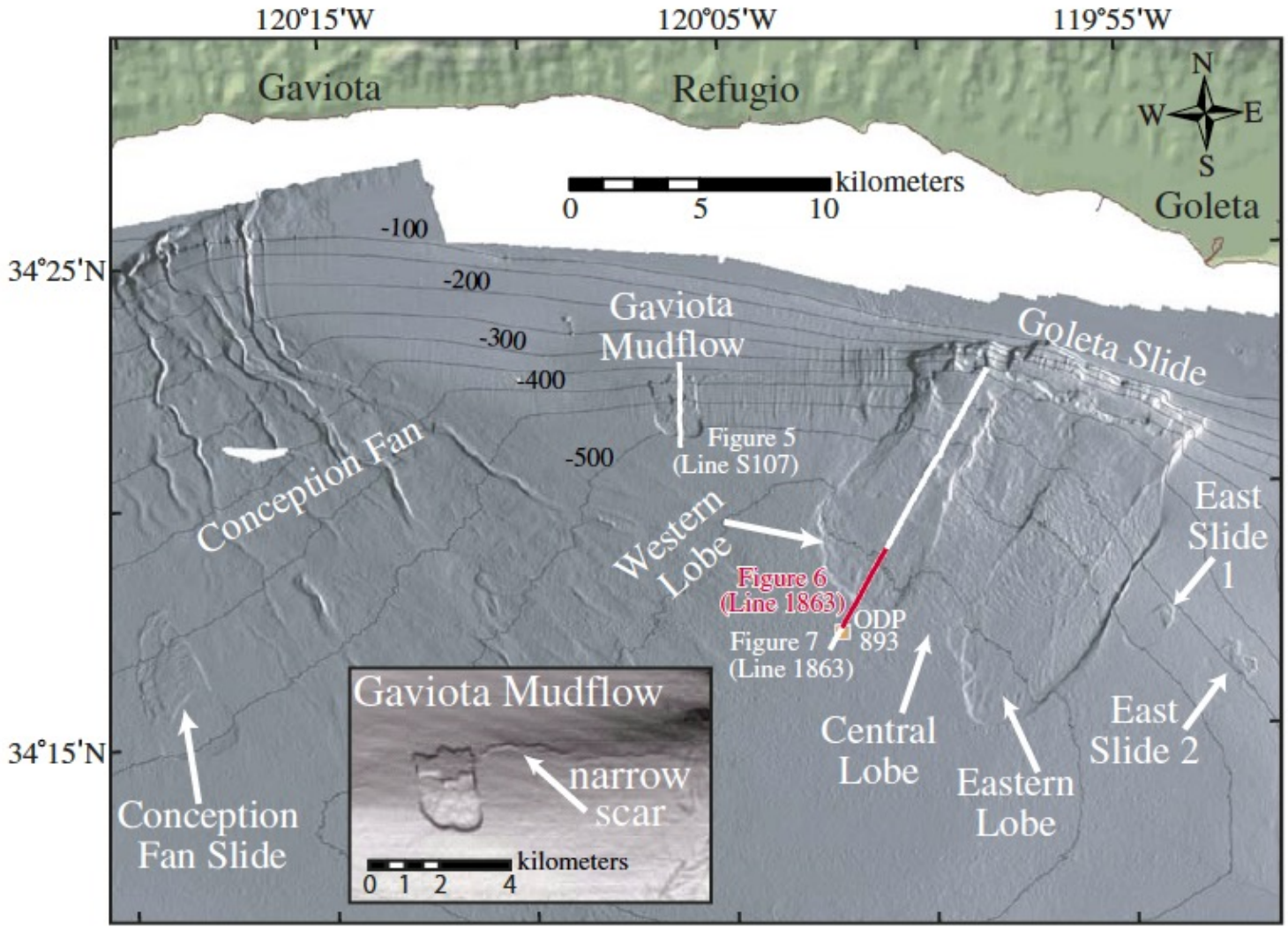
Norsk Hydro E&D Norway
Geophysical Operations





STOREGGA SUBMARINE LANDSLIDE

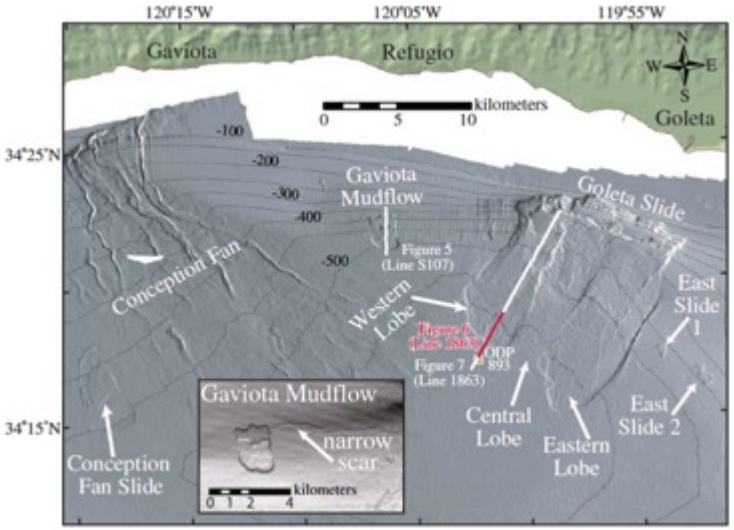
GOLETA LANDSLIDE (CALIFORNIA)

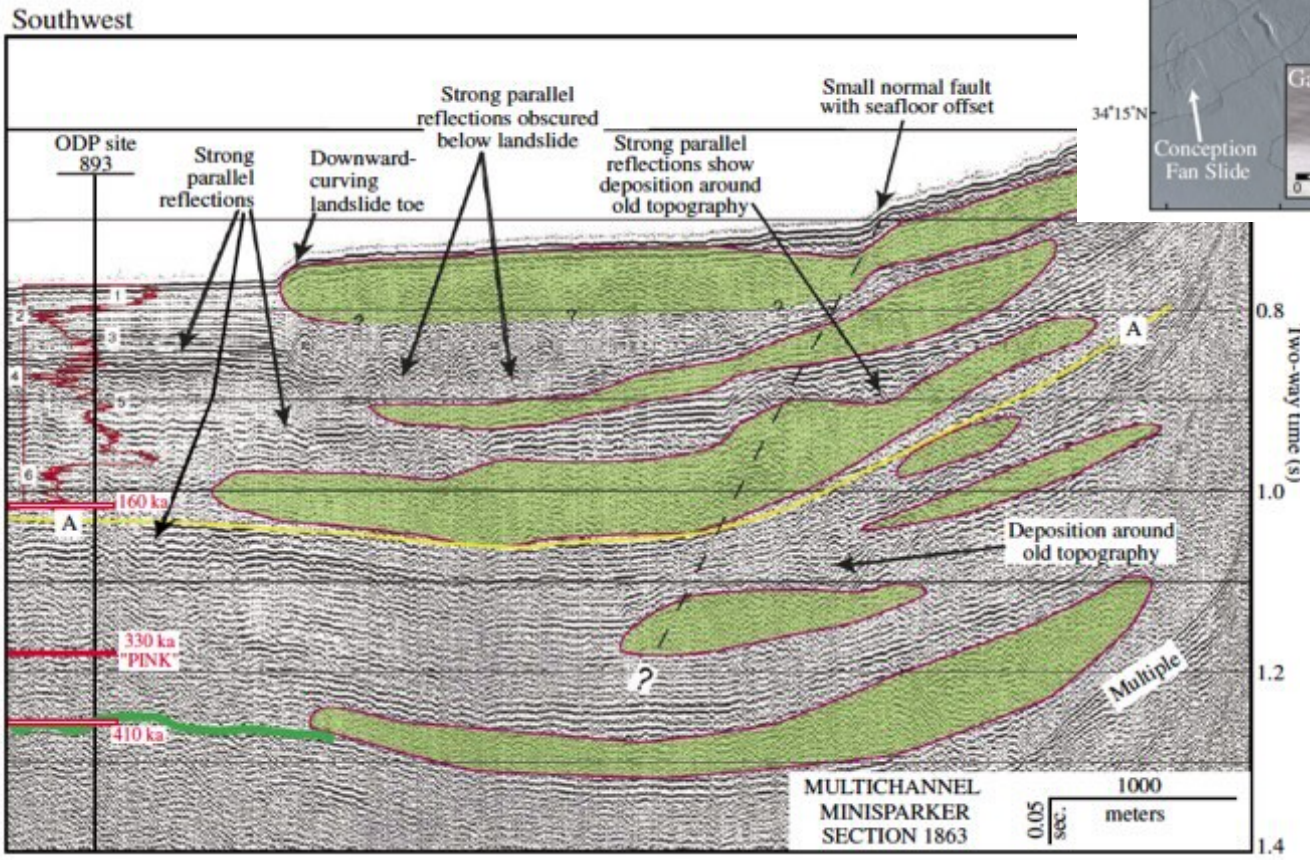


Multibeam echosounder

Lee et al., 2009. GSA Special Issue

GOLETA LANDSLIDE (CALIFORNIA)

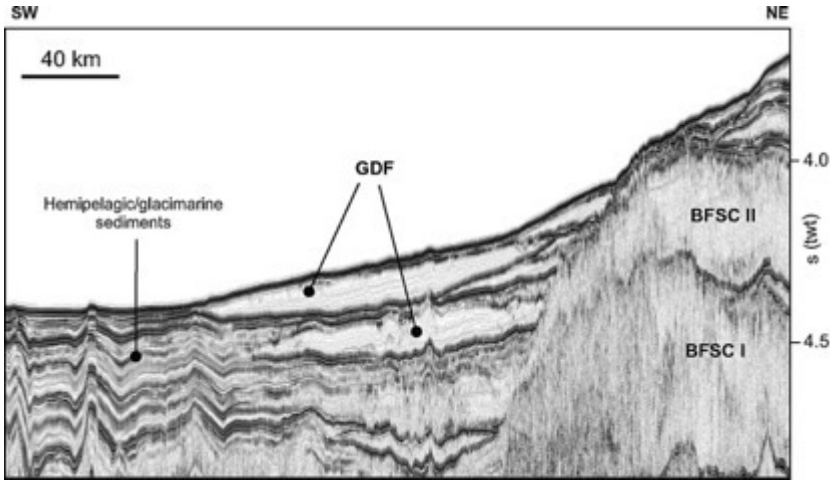


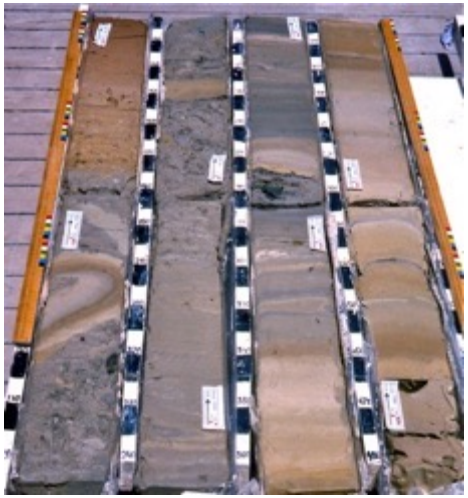


Deep penetration seismic 2D Sparker

Lee et al., 2009. GSA Special Issue

Debris flows





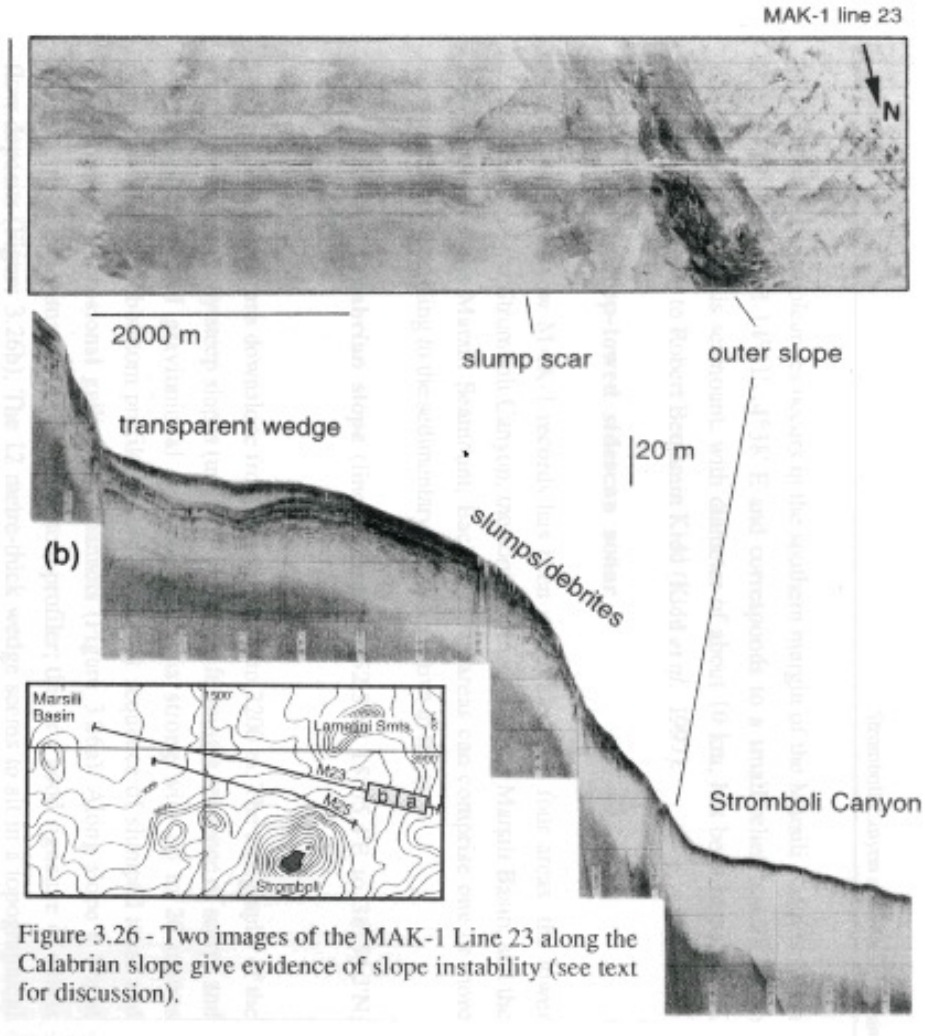
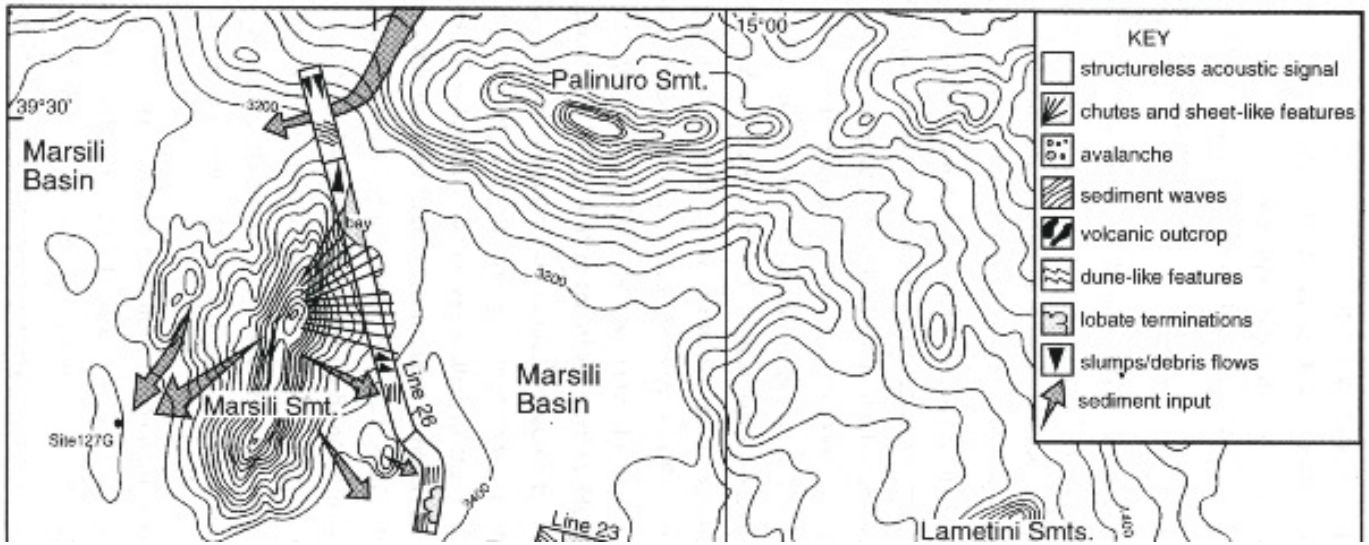


Figure 3.26 - Two images of the MAK-1 Line 23 along the Calabrian slope give evidence of slope instability (see text for discussion).



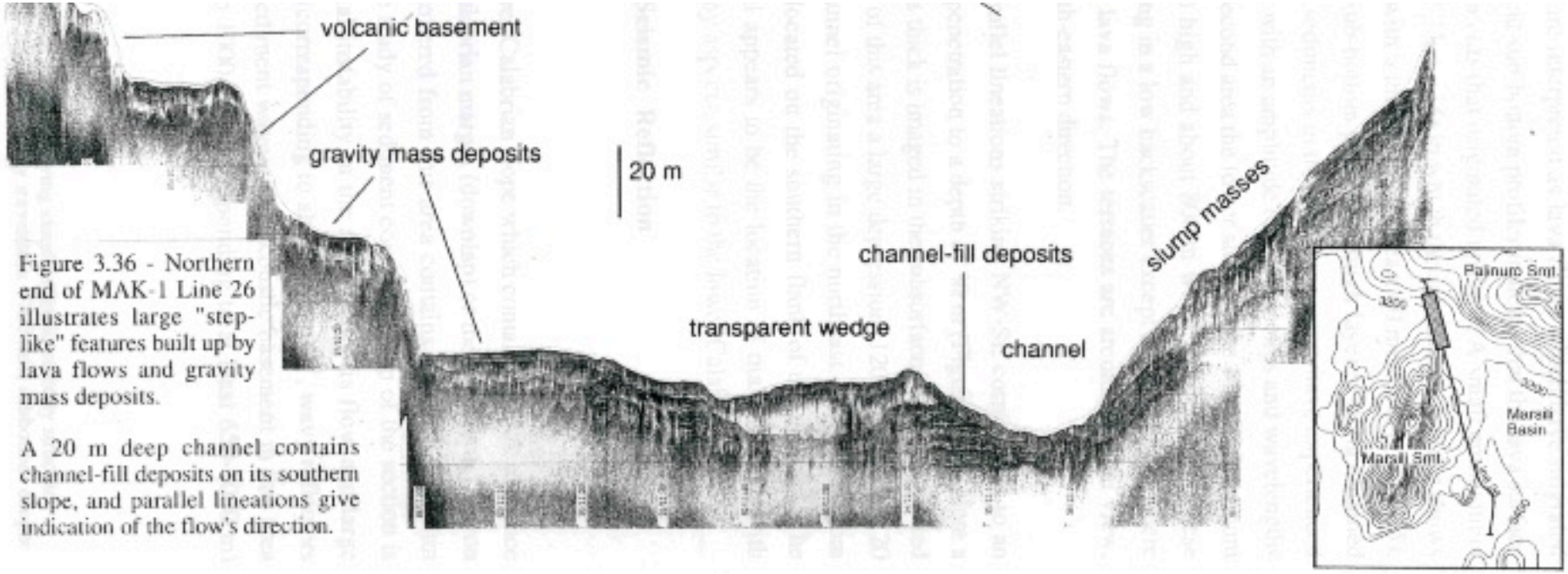


Figure 3.36 - Northern end of MAK-1 Line 26 illustrates large "step-like" features built up by lava flows and gravity mass deposits.

A 20 m deep channel contains channel-fill deposits on its southern slope, and parallel lineations give indication of the flow's direction.