Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2022 - 2023

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Module 3.6
Continental slope: deposits associated to gravity flows

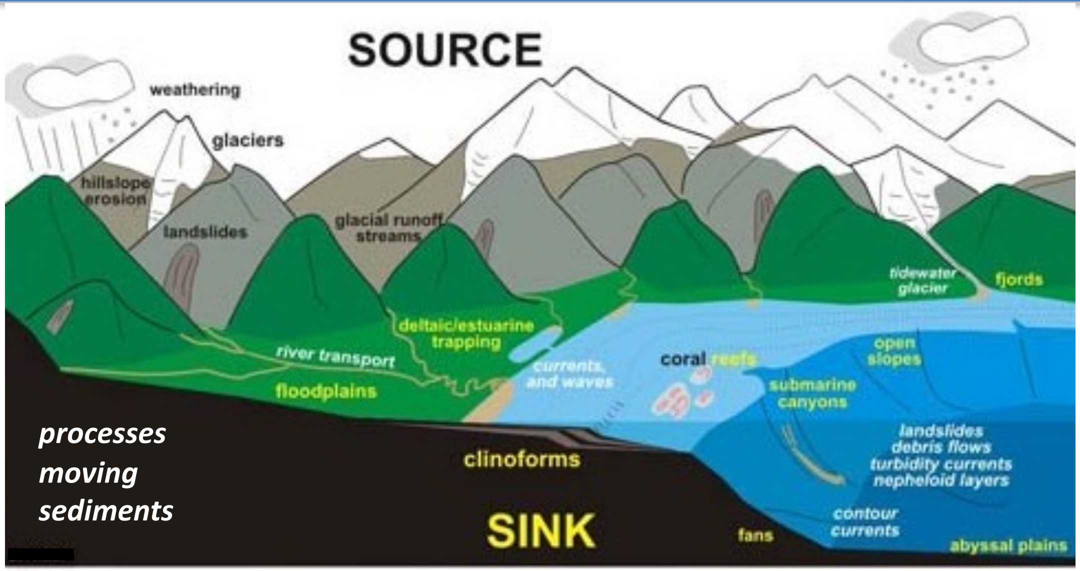
Teacher: **Renata G. Lucchi**

Modulo 3.6 *Continental slope: deposits associated to gravity flows*

Teacher: Renata G. Lucchi

OUTLINE

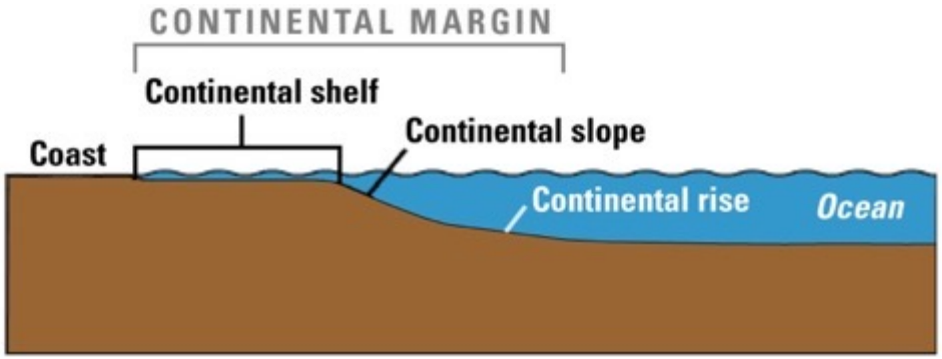
- The source to sink system
- Continental slope types and key features
- Continental slopes at high latitude margins (TMFs, gullies, channels)
- Continental slopes at mid latitude margins (canyon-channel-deep sea fans systems)
- Identifying submarine landslides and debris flows



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)

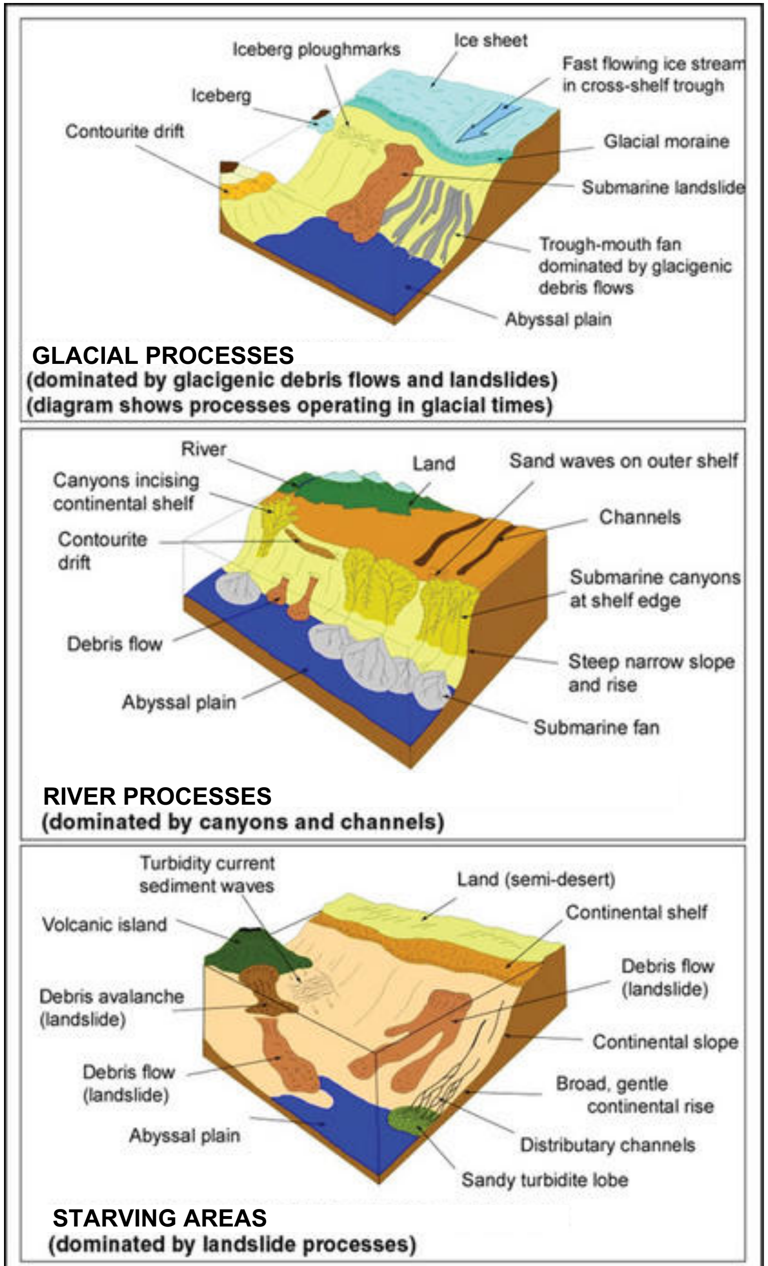


Continental shelf
Preferential area of sediment accumulation
High sediment accumulation
High isostatic subsidence
Continental slope sediment deposition and transfer toward deeper environments
Continental rise: sediment deposition (deep sea fans, sediment drifts)

High latitude

Mid latitude

Low latitude



Continental slope types and related distinctive sedimentary features

GLACIAL INFLUENCES MARGINS

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

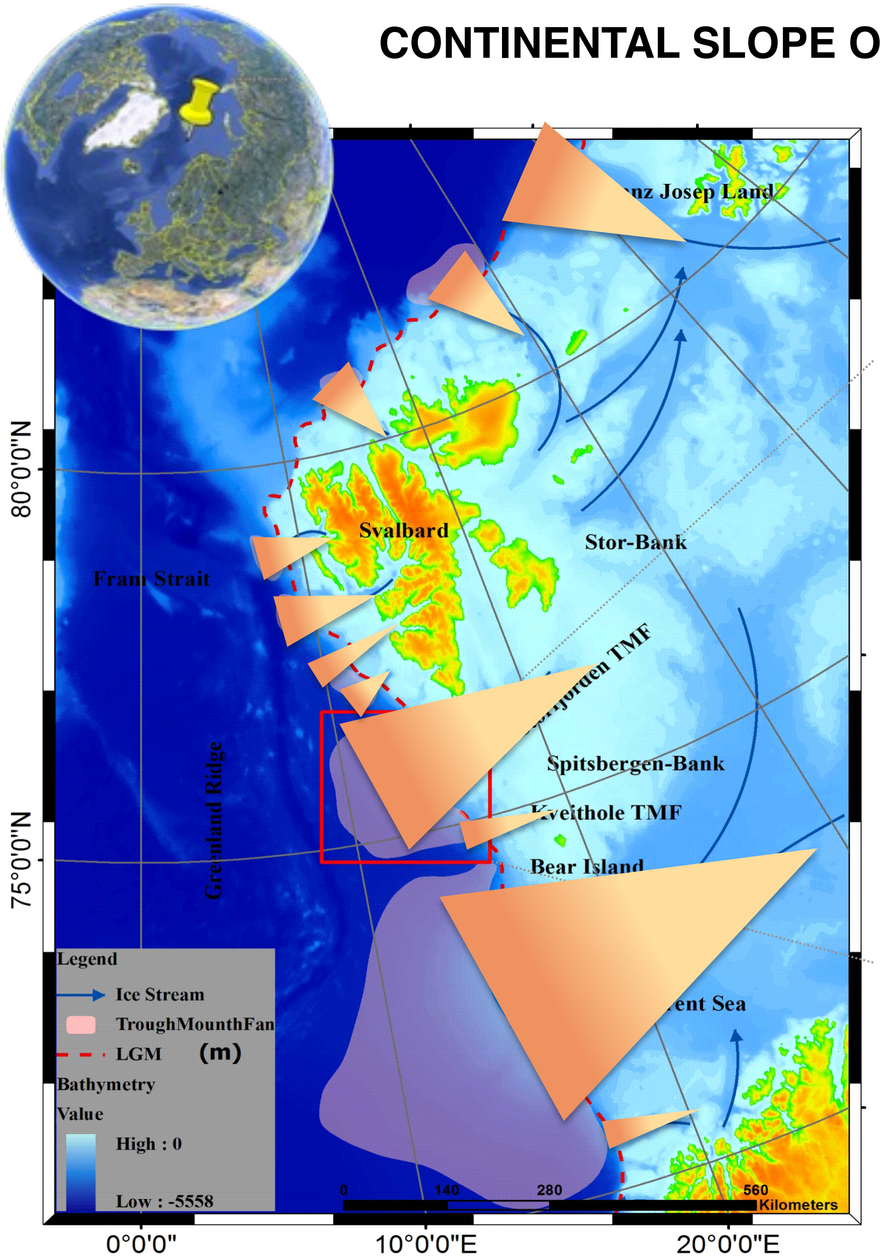
RIVER INFLUENCES MARGINS

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

SEDIMENT STARVING MARGINS

- Submarine landslides
- Mass gravity deposition

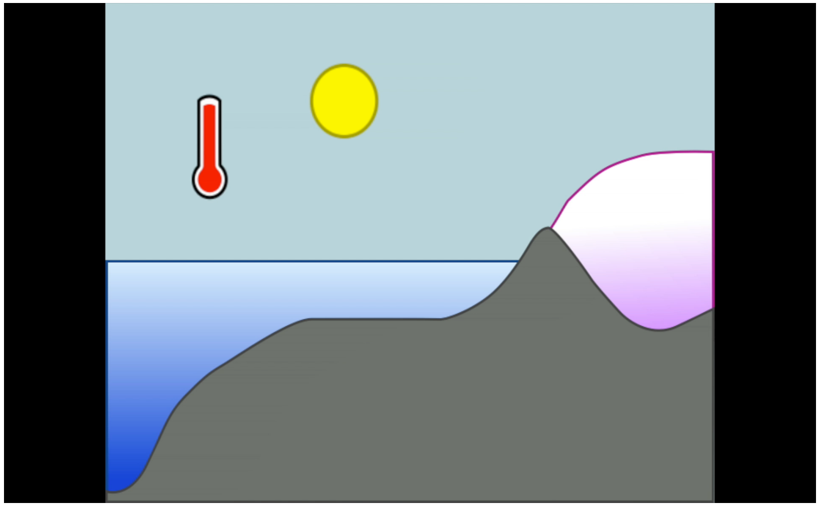
CONTINENTAL SLOPE ON GLACIATED GLACIATED MARGINS

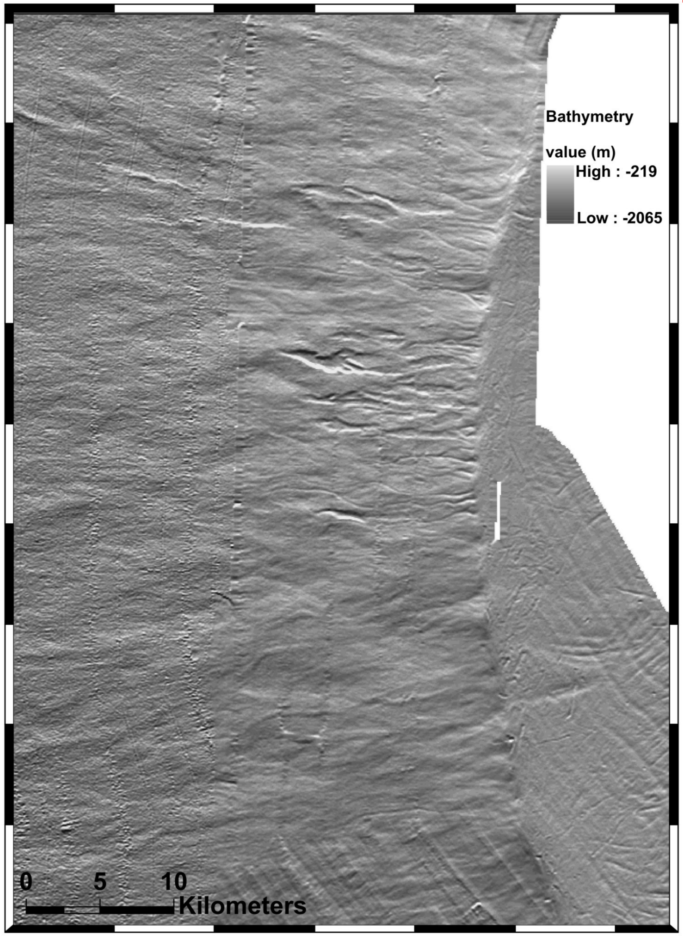


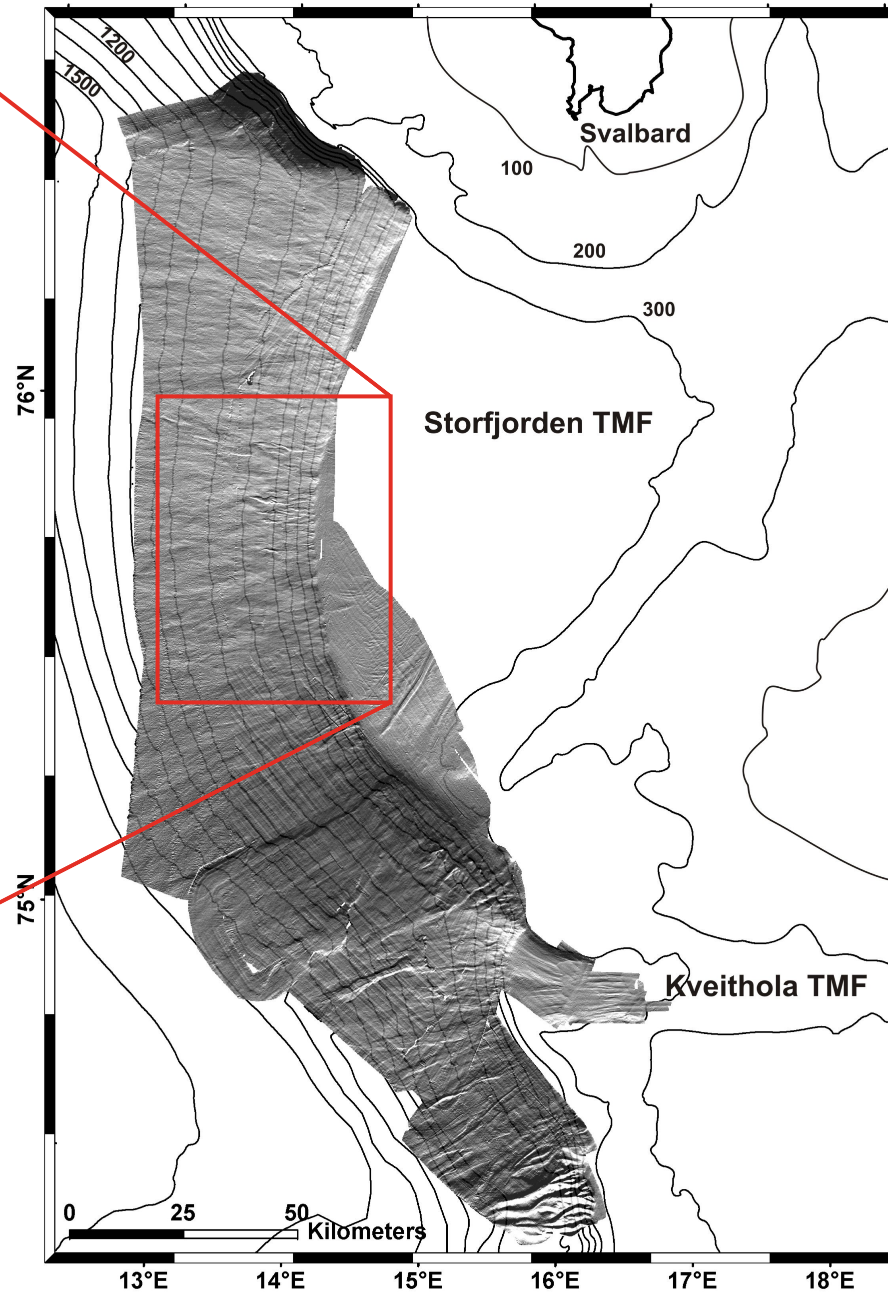
Ice Streams= Correnti di ghiaccio

Glacial trough= Fosse glaciali

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

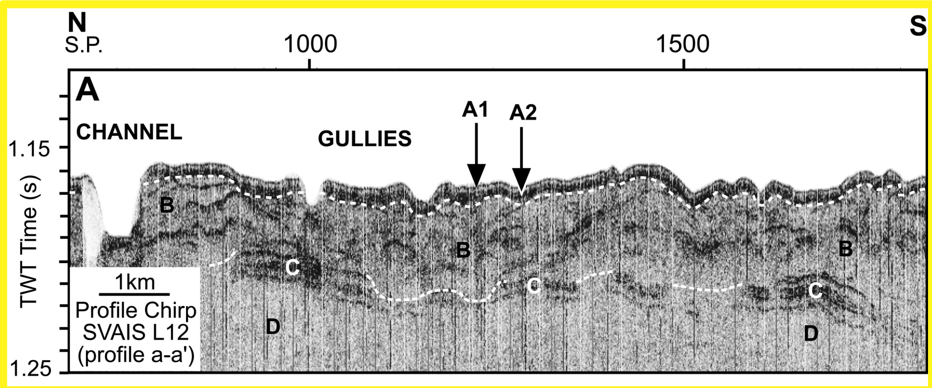


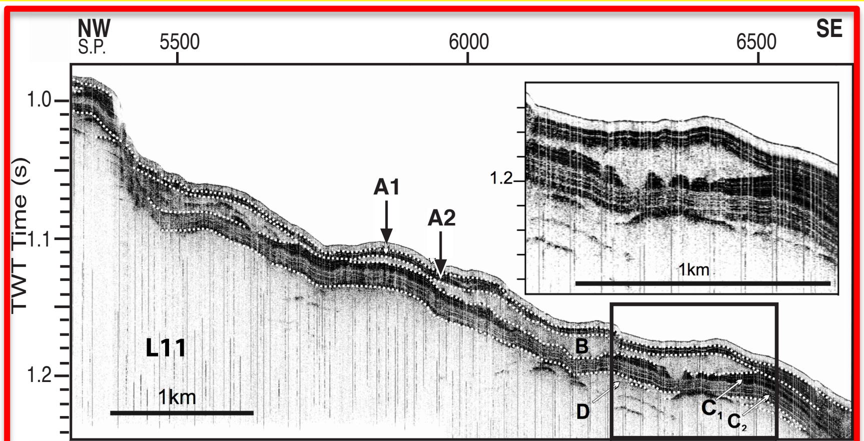


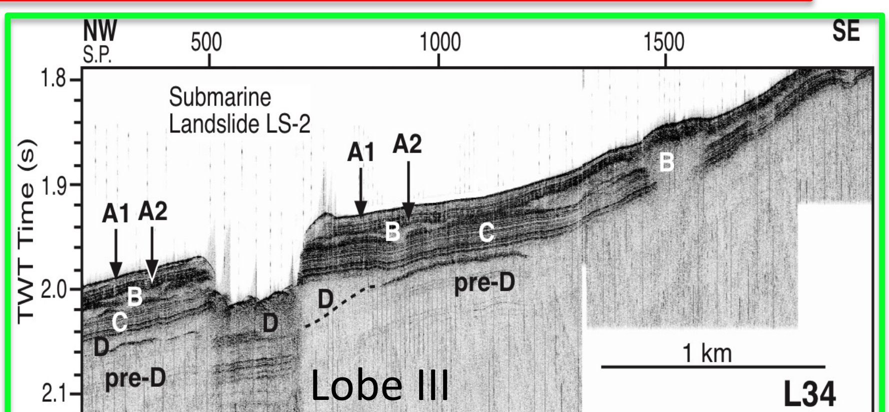


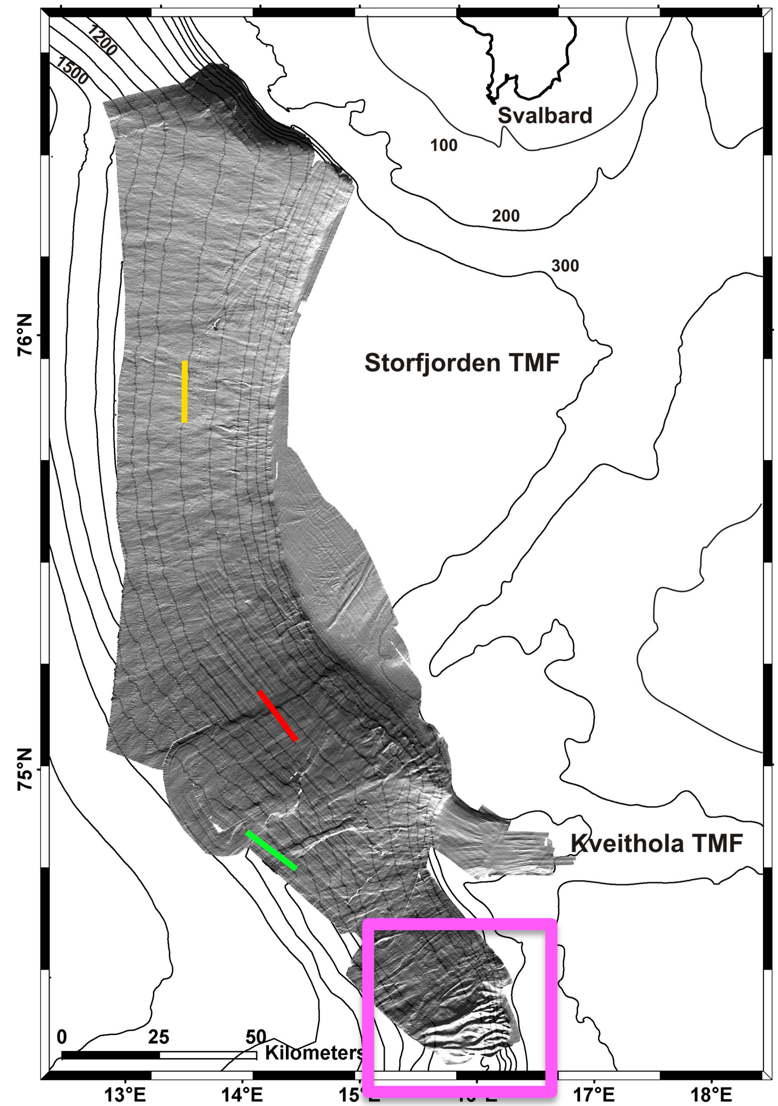
- Gullies (a few 10s m deep, a few 10s m large a few km long)
- Channels deriving from coalescent gullies
- Debris mounds
- Landslides

Continental slope architecture

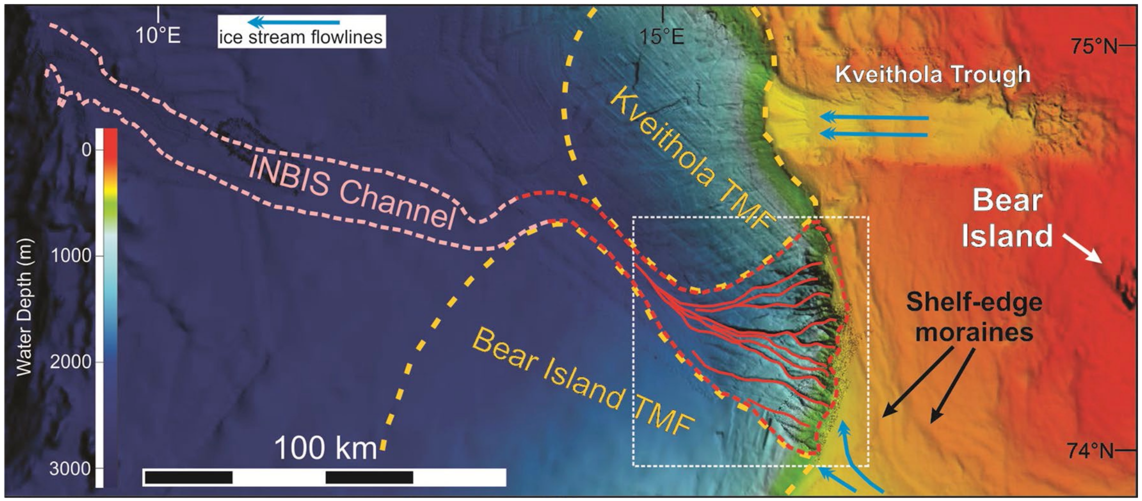


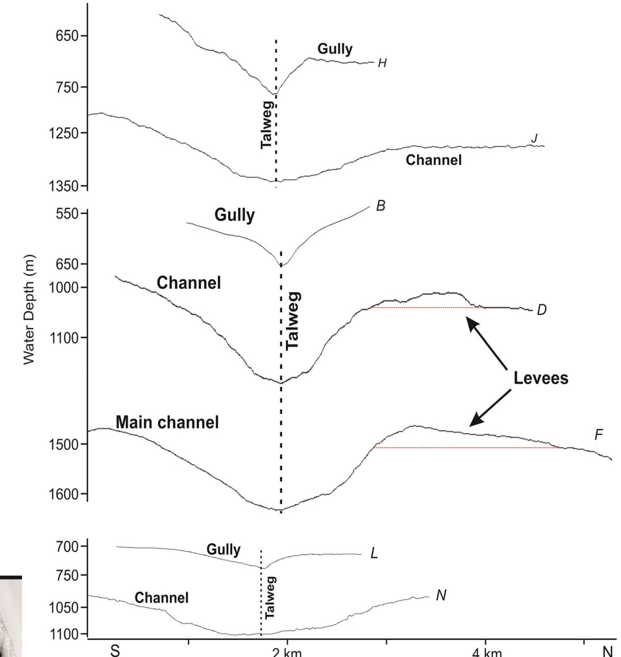


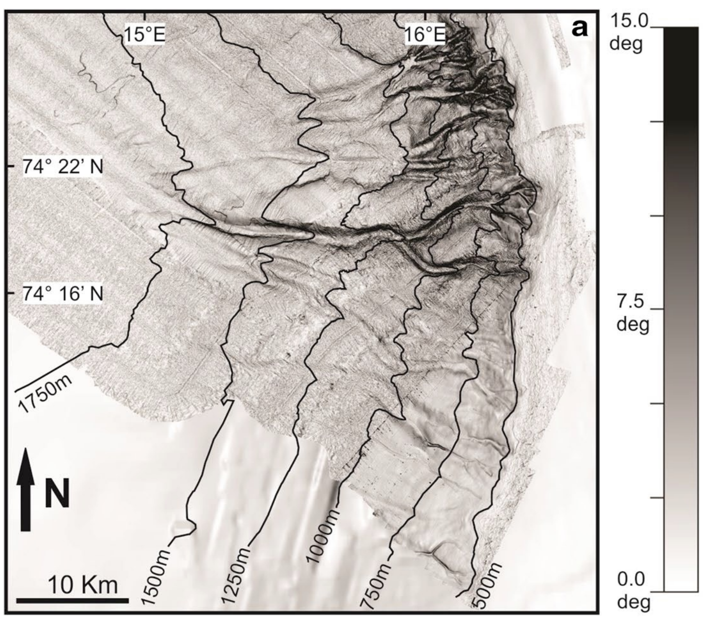


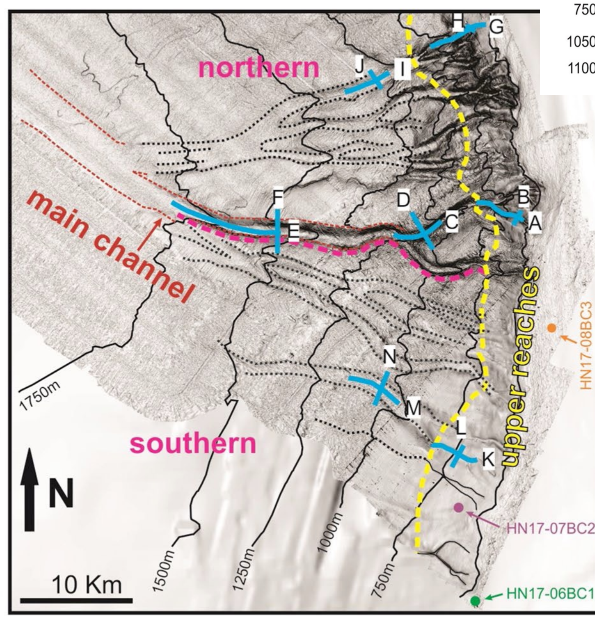


IN-Between-Ice Seets (INBIS) Channel



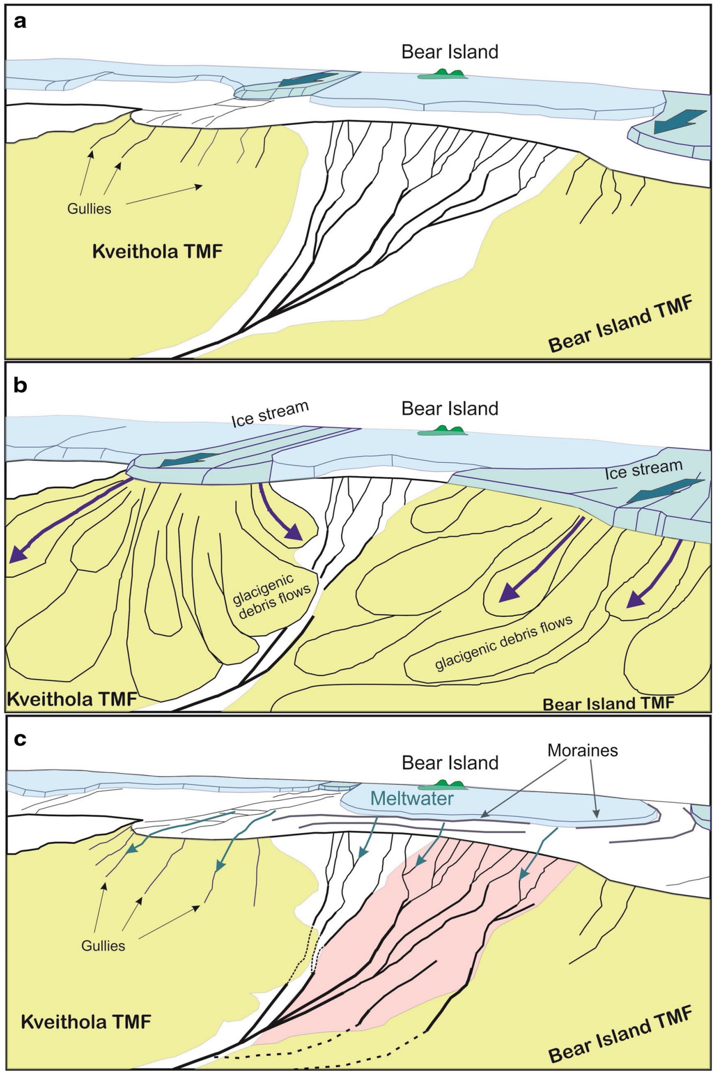






Gullies and Channels
down-slope
cross profiles

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



Rui et al., 2019_Arktos

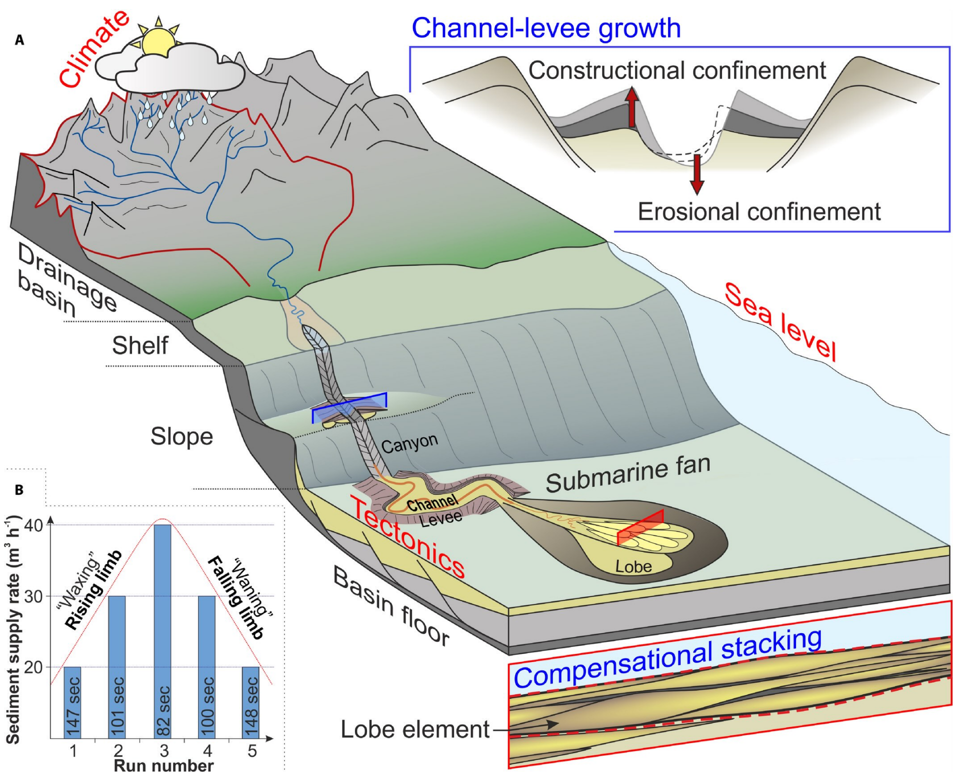
(a) pre-Last Glacial Maximum (LGM), slope sedimentation derived by pelagic settling and contour bottom currents

(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.

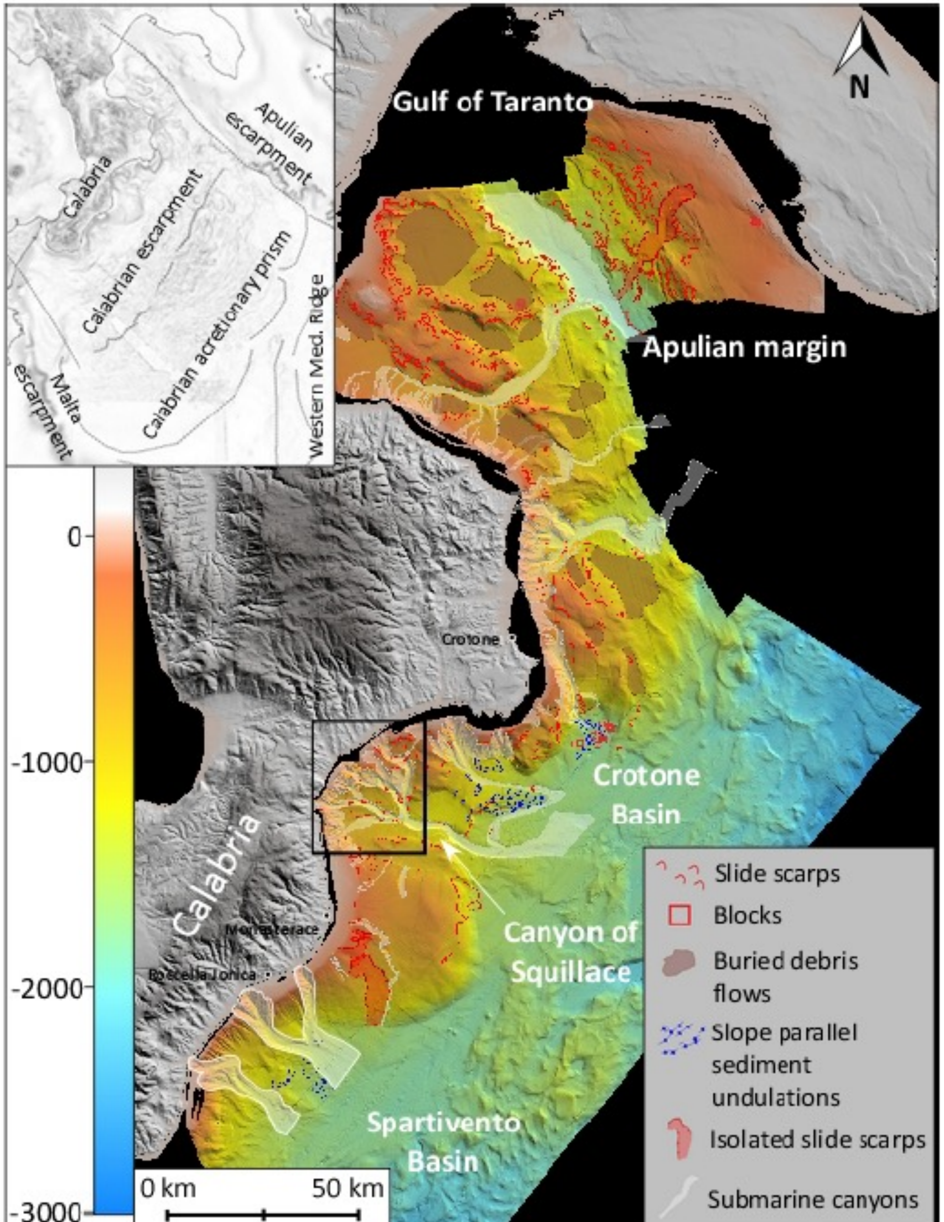
SLOPE SEDIMENTARY CONDUITS ON MID-LATITUDE MARGINS: CANYONS - CHANNELS - GULLIES

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).



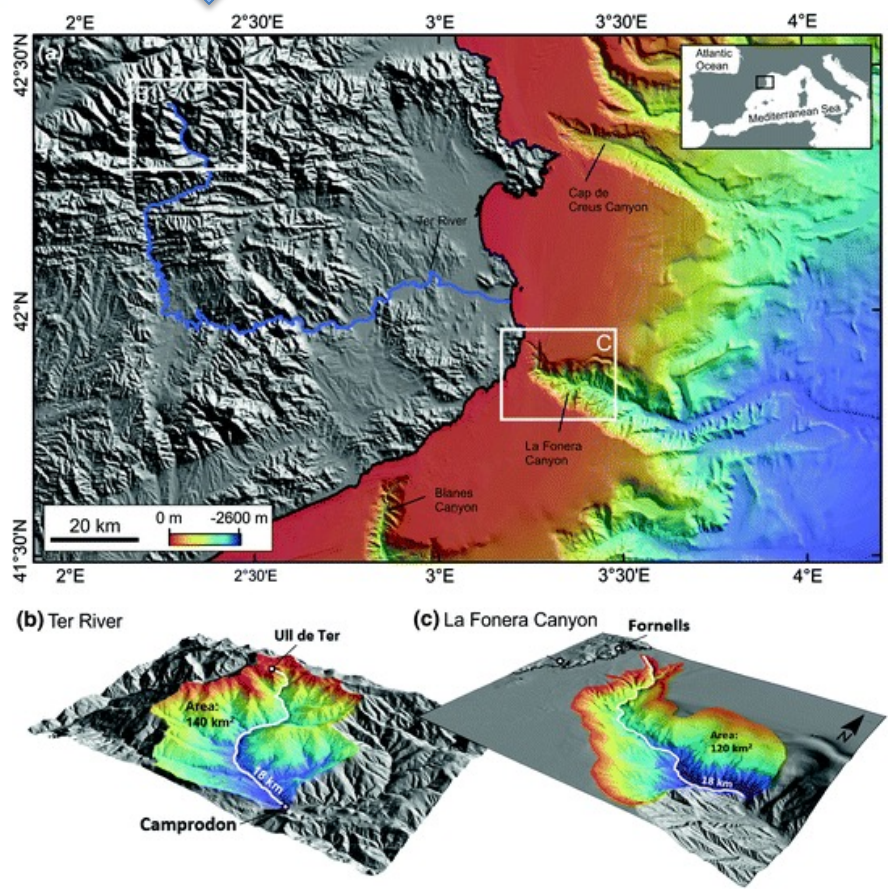
Submarine canyon: narrow steep-sided valleys cutting into continental slopes and rises. They can originate either within continental slopes or on continental shelves.

- 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

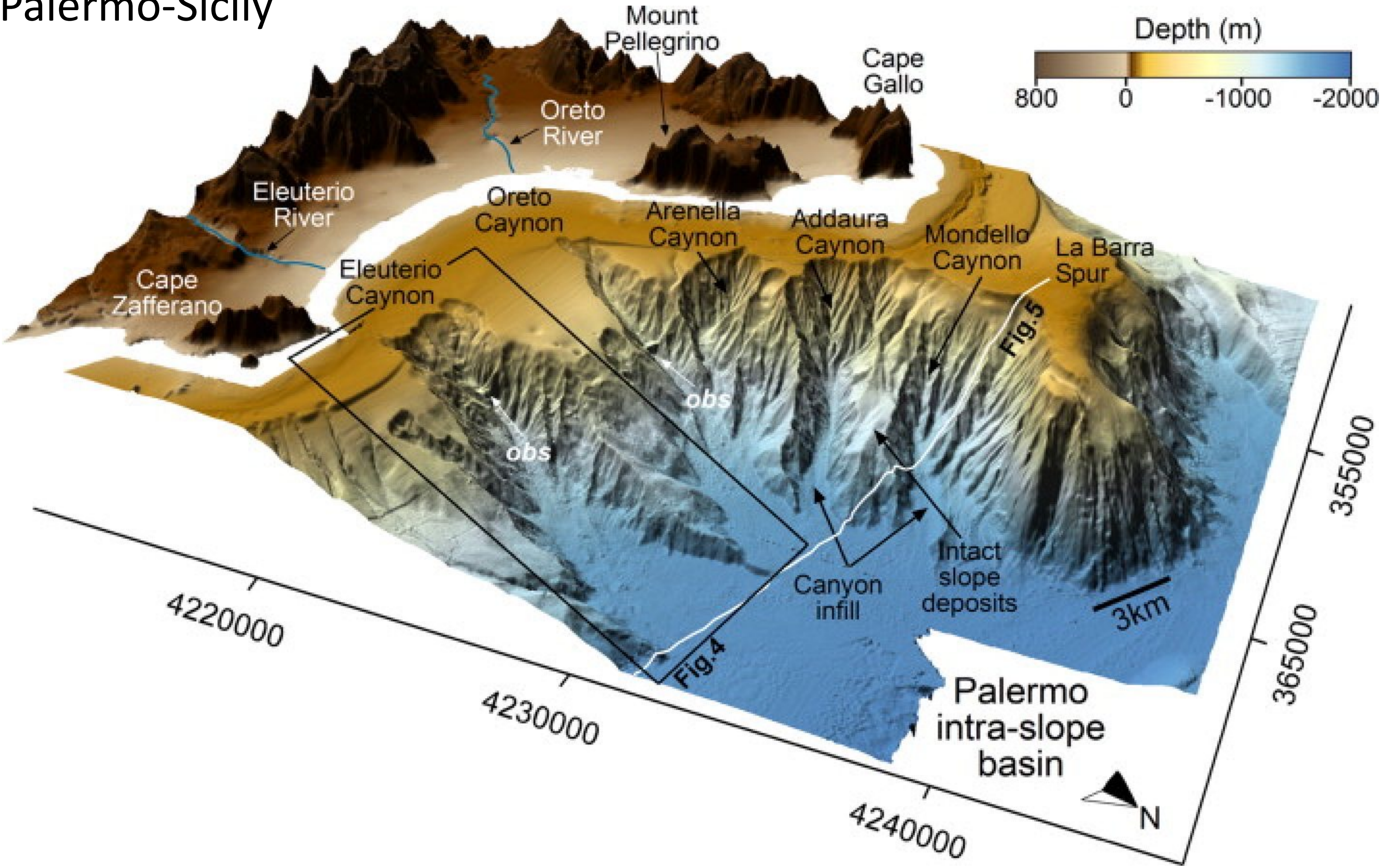


Calabrian Ionic Margin

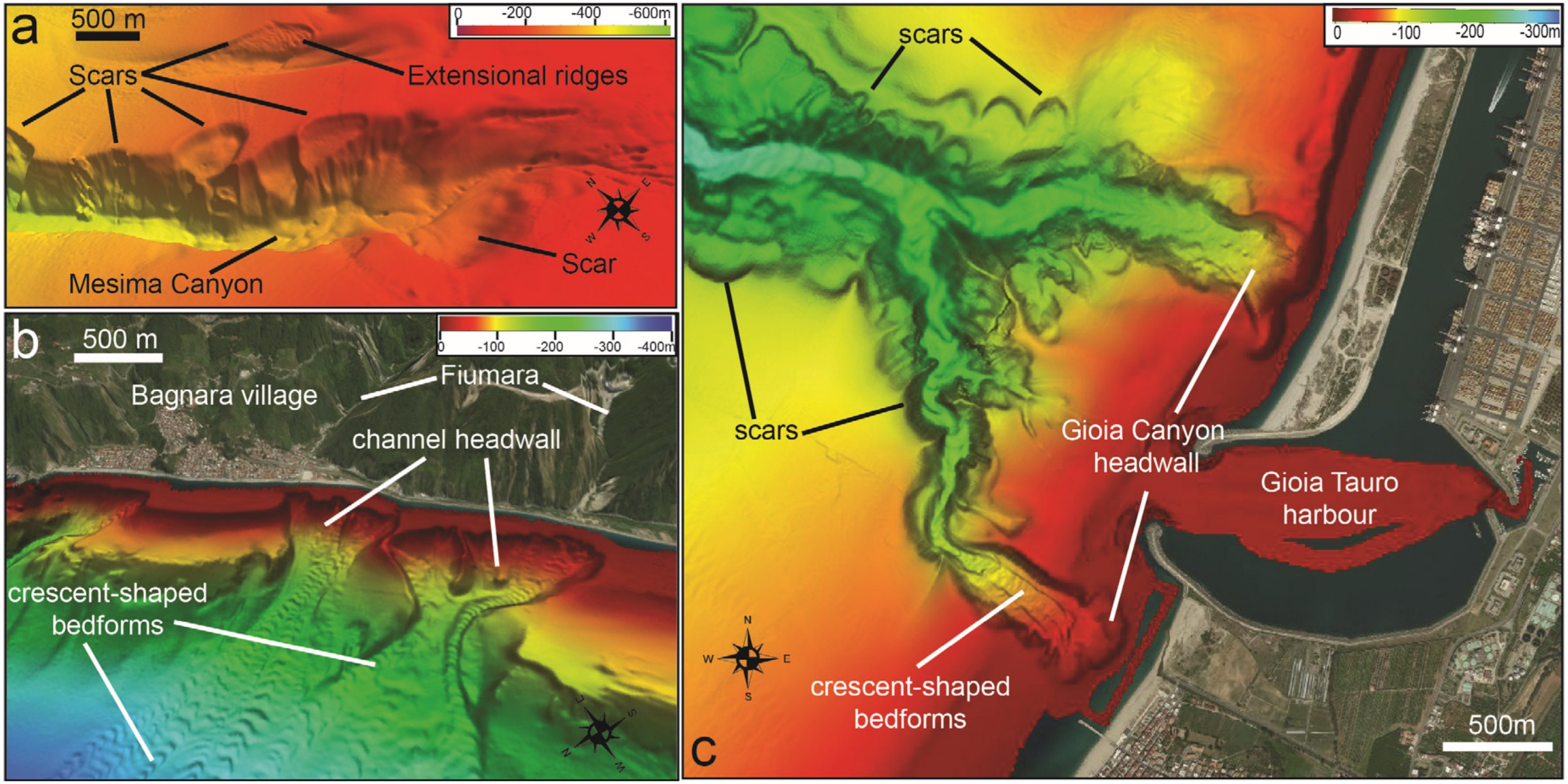
Catalan Margin

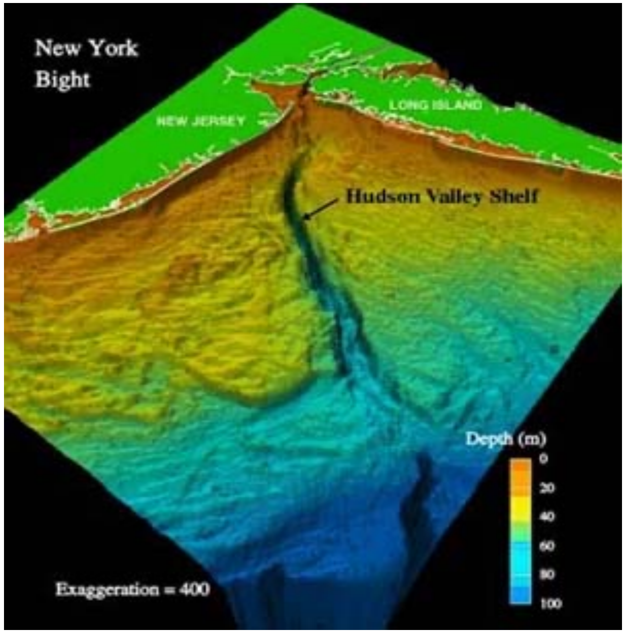


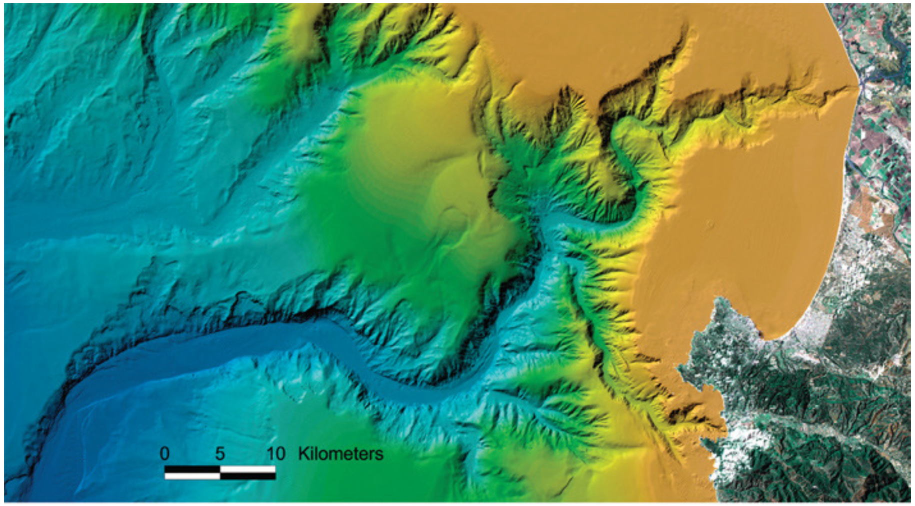
Palermo-Sicily



Calabrian Thyrrhenian Margin







Hudson Canyon

Monterey Canyon

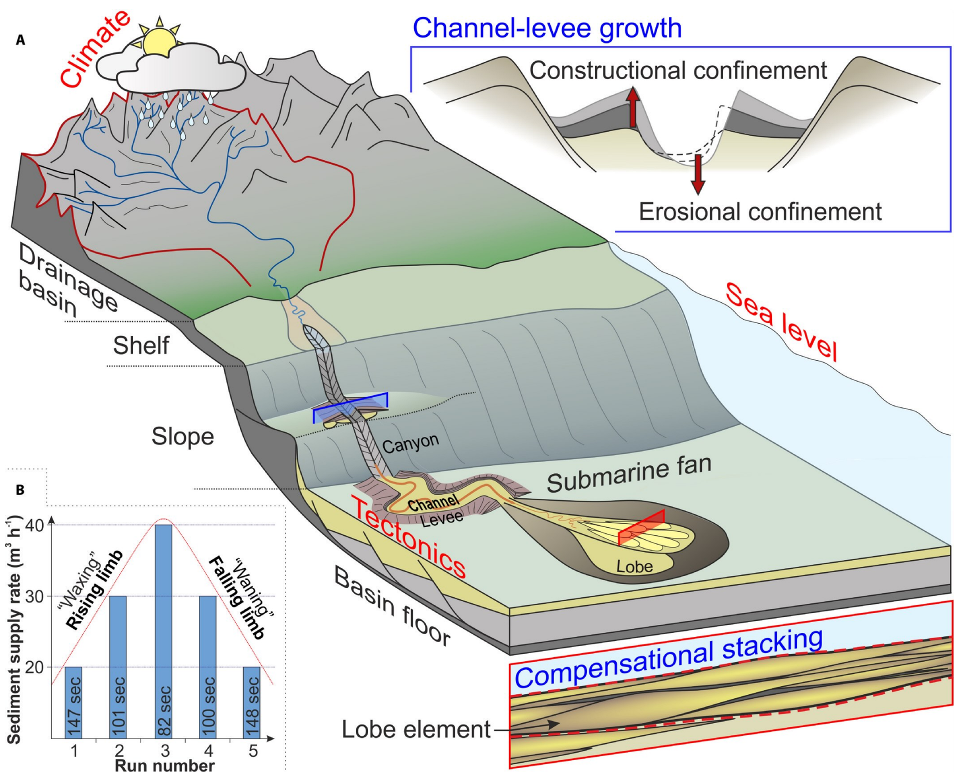
About 3% of submarine canyons include **shelf valleys** cutting across continental shelves, having upstream ends in alignment with, and sometimes within, the mouths of large rivers, such as the Hudson Canyon.

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

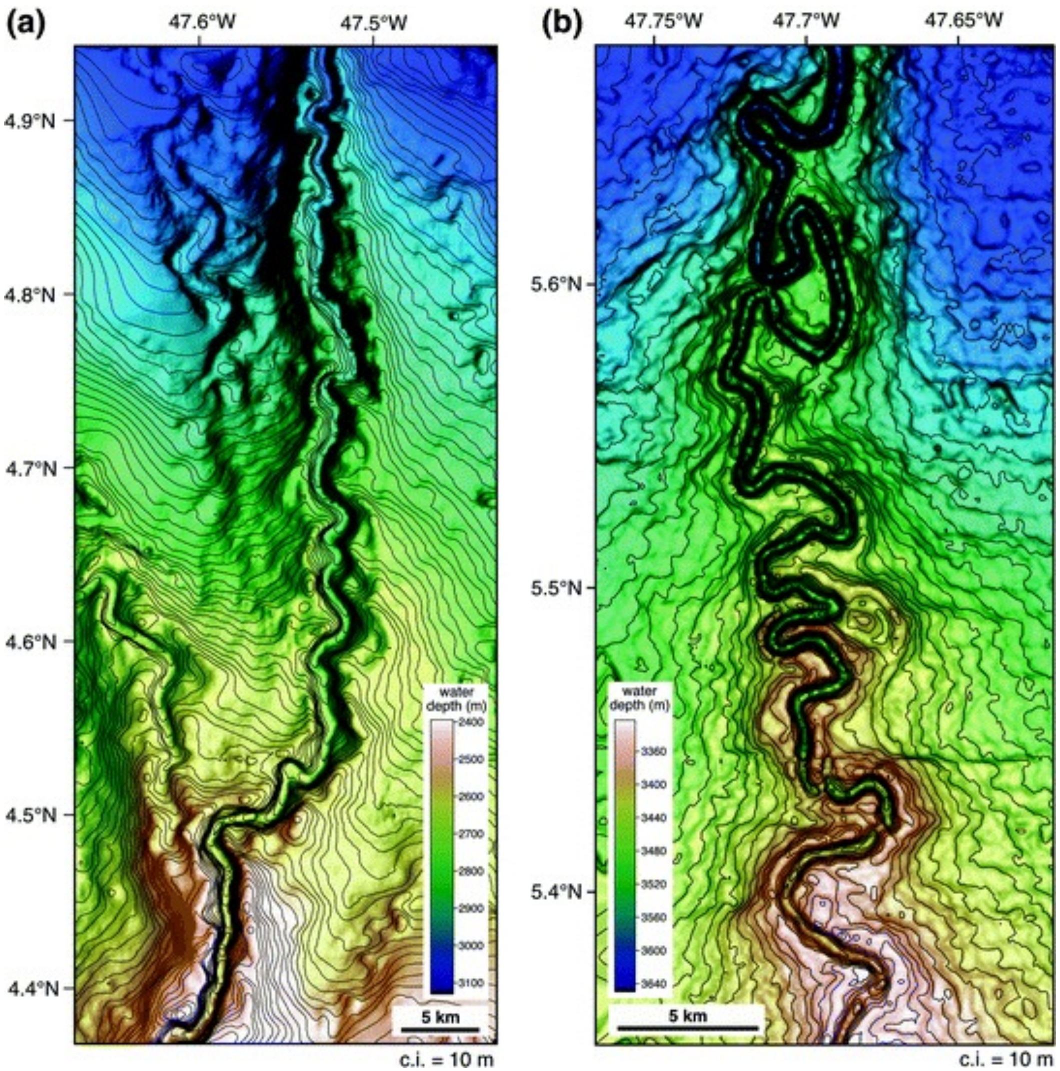
SLOPE SEDIMENTARY CONDUITS ON MID-LATITUDE MARGINS: CANYONS - CHANNELS - GULLIES

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).



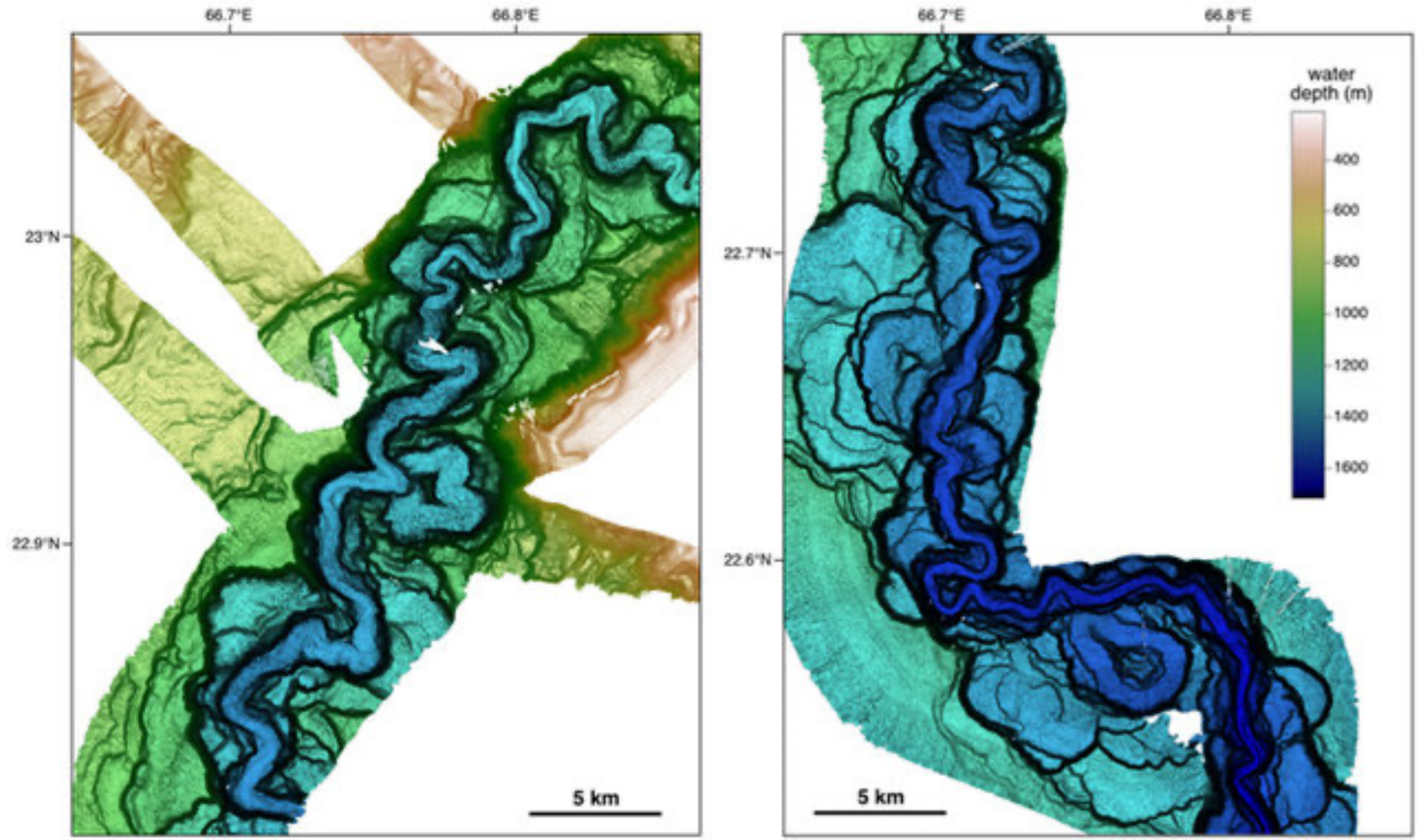
Submarine channels: wide flat valley flanked by depositional channel's levees They originate at the base of continental slopes or on continental rises.

- 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

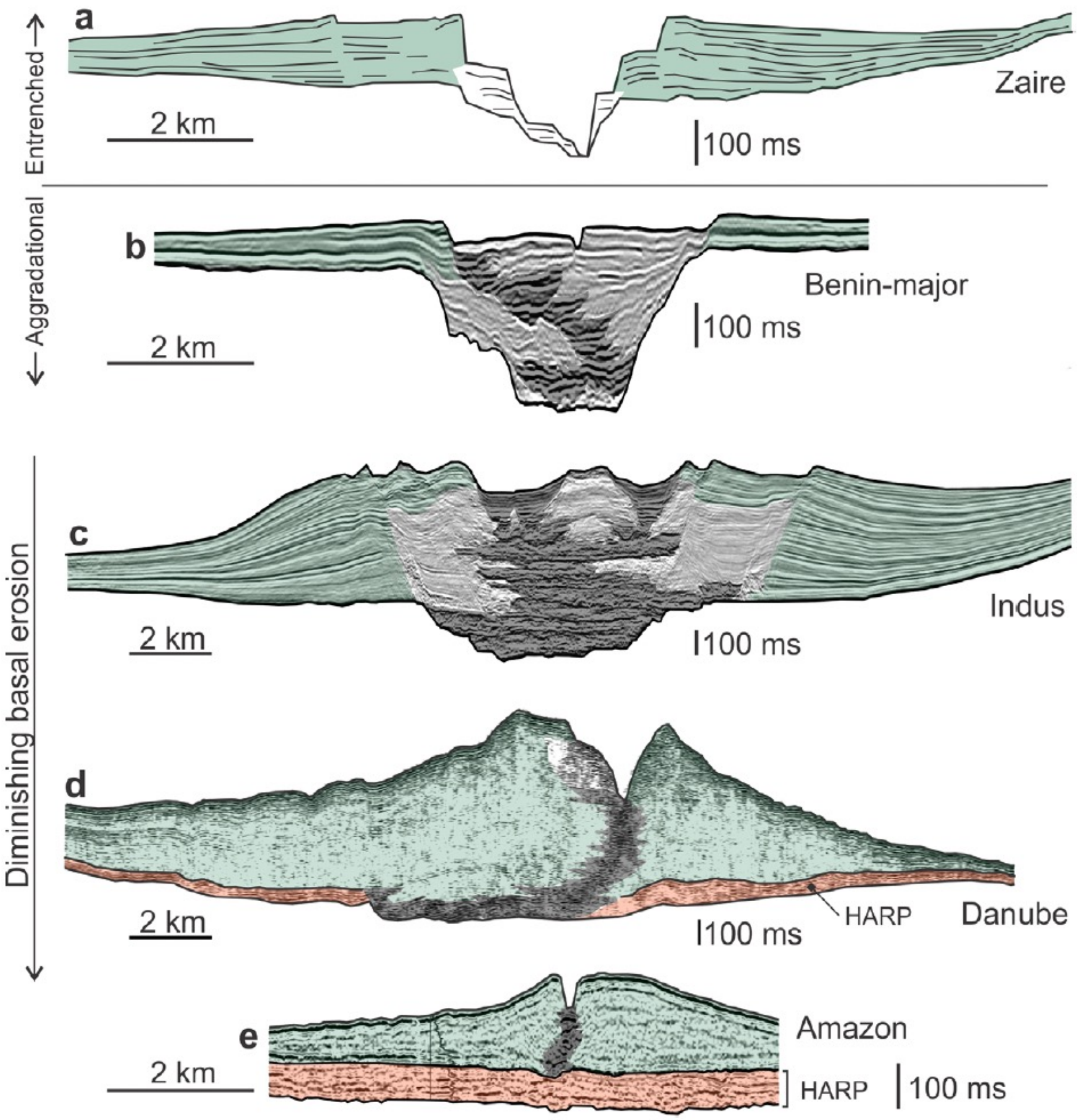


Sinuous submarine channels on the **Amazon Fan**.

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



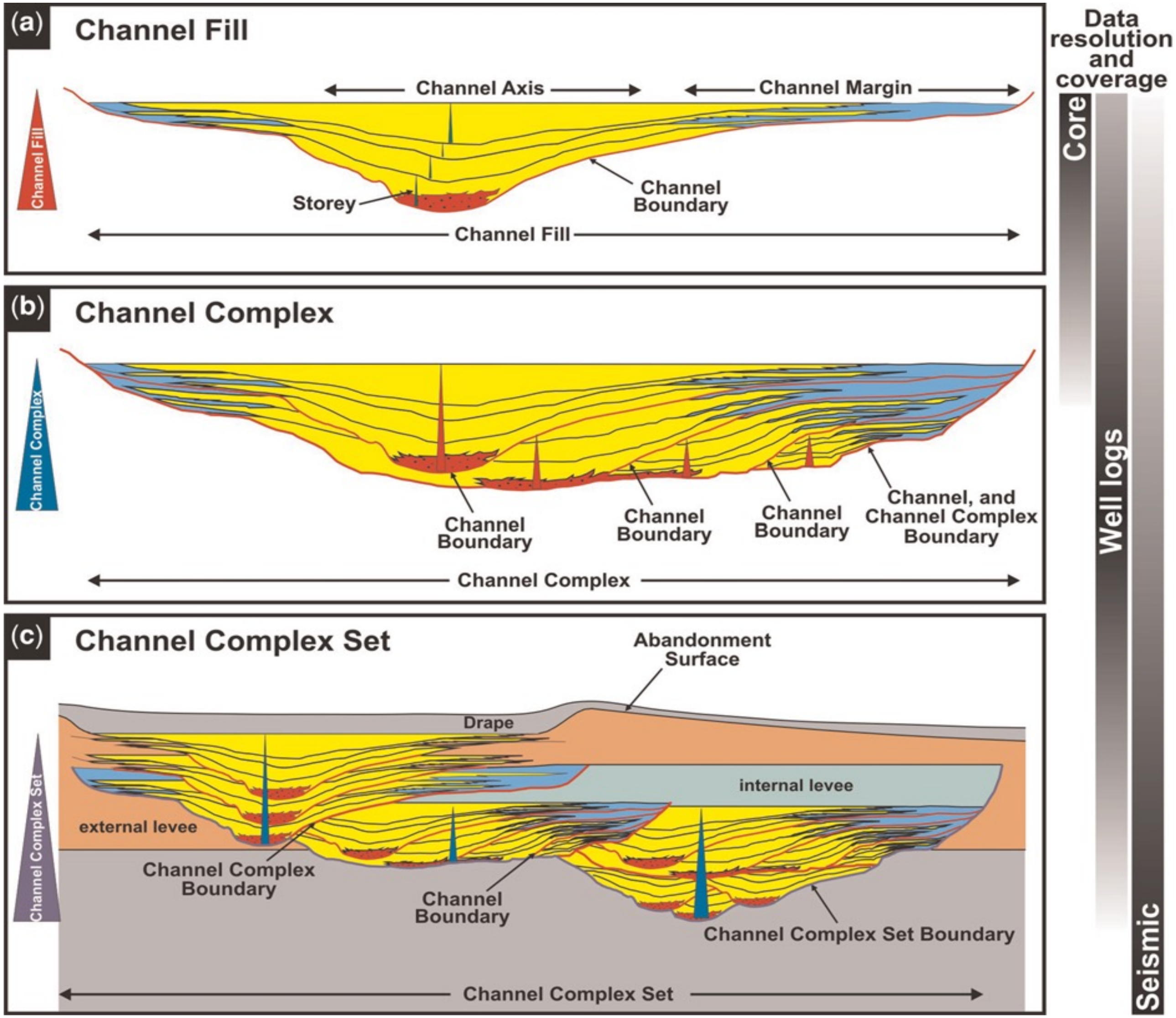
Morphology of large channel-levee systems: the canyon-channel transition zone on the upper part of the **Indus Fan**, with terraces and cutoffs. Data from Clift and Henstock (2015).



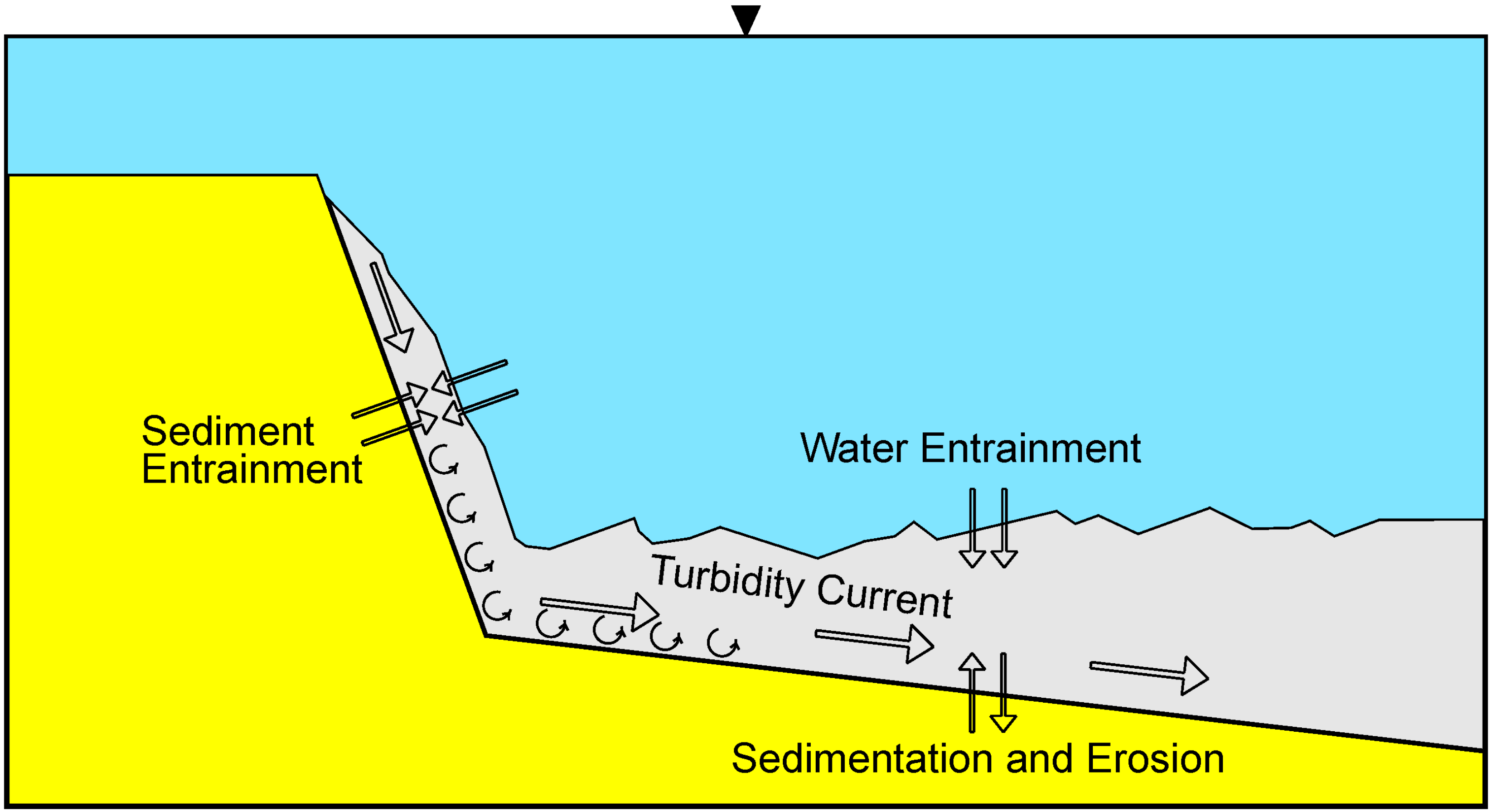
Deptuck & Sylvester, 2018 Submarine Fans and their channels, levees, and lobes. *In*: Submarine Geomorphology, Springer.

Architectural variations in long-lived channel-levee systems (CLS).

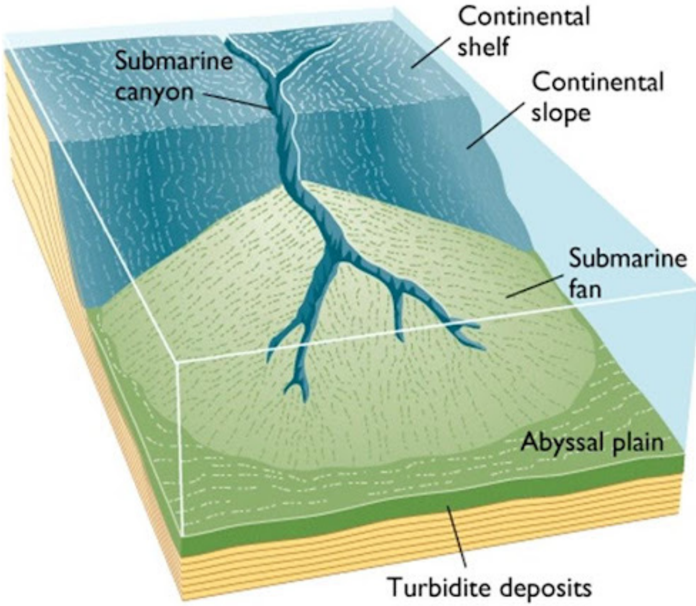
- **Light grey** = Inner levees
- **Green** = outer levee
- **Dark grey** = channel
- **Orange** = avulsion-related lobe deposits


(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 Set
Channel Complex Boundary
Channel Boundary
Channel Complex Set Boundary
Channel Complex Set
Data resolution and coverage
Core
Well logs
Seismic

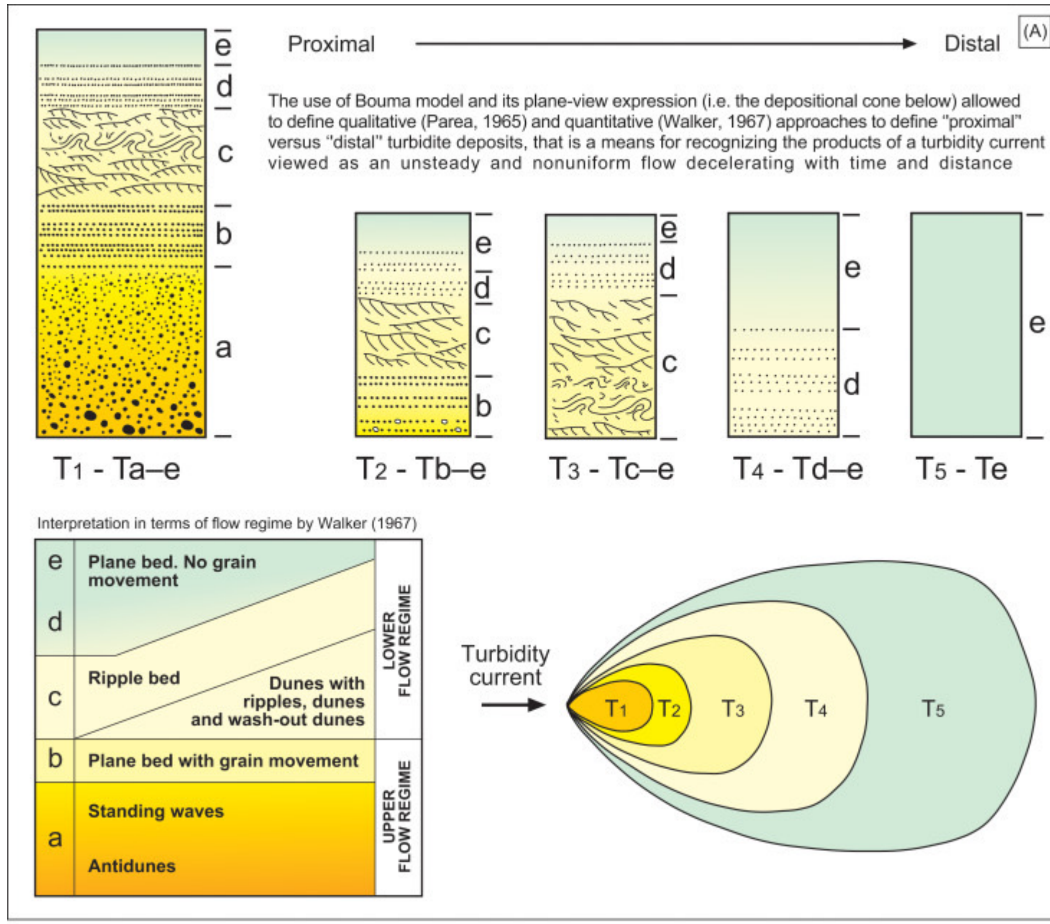
HYDRAULIC JUMP



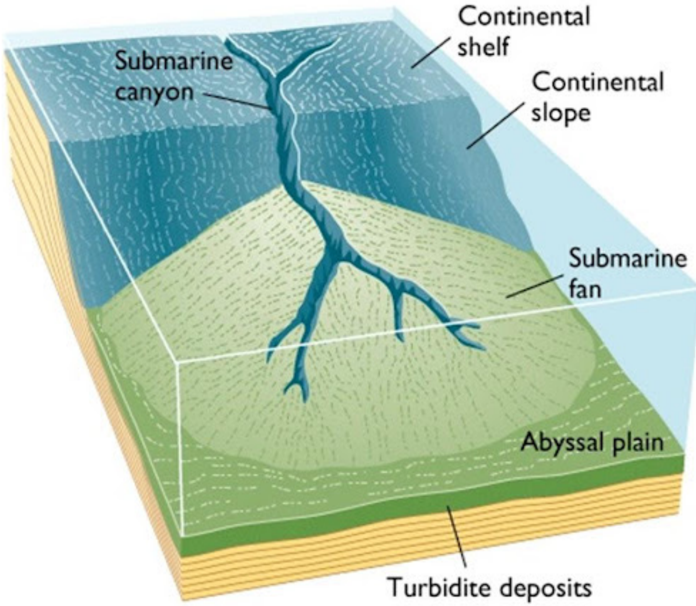
Turbidite-fan link proposed by Bouma (1962)

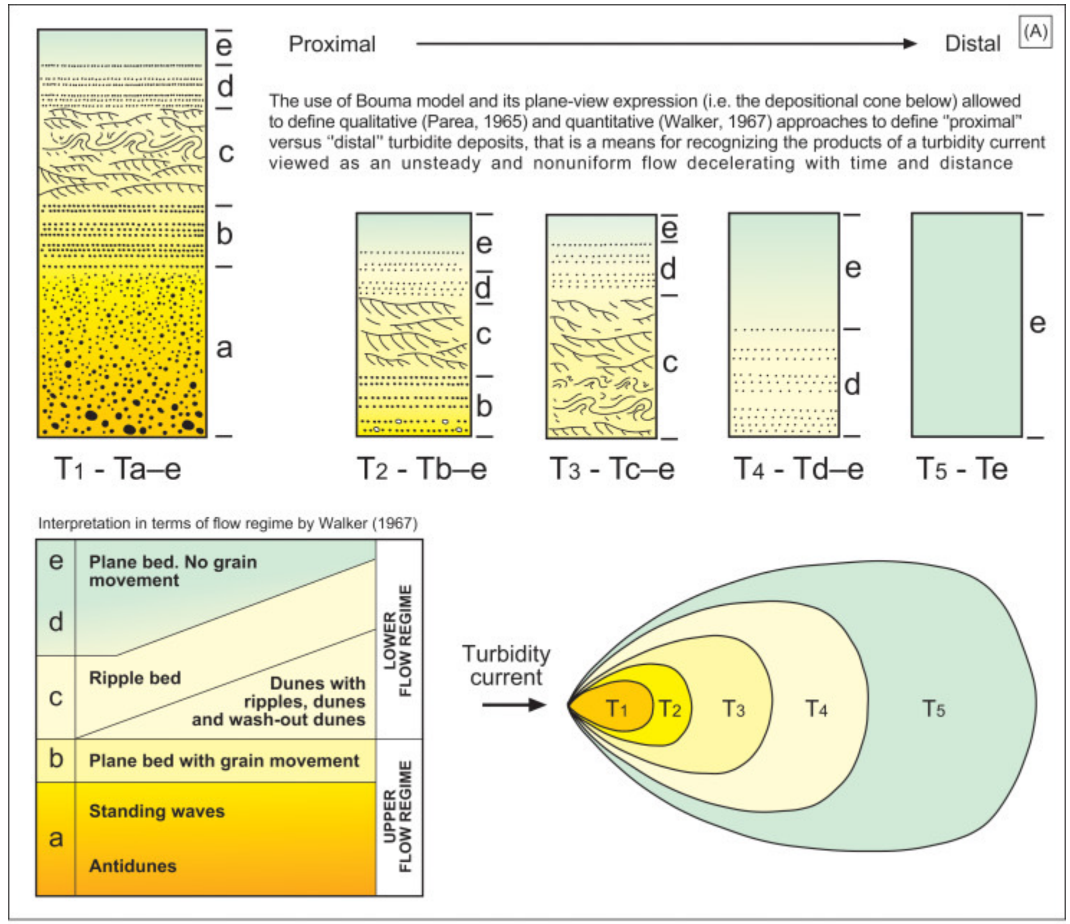


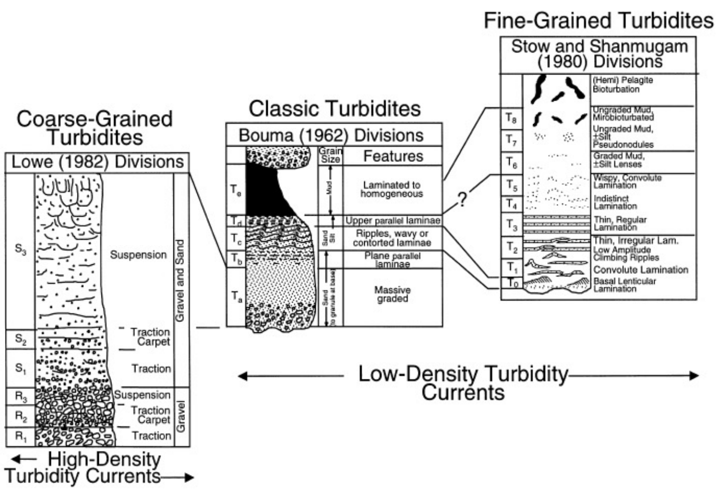
Depositional cone

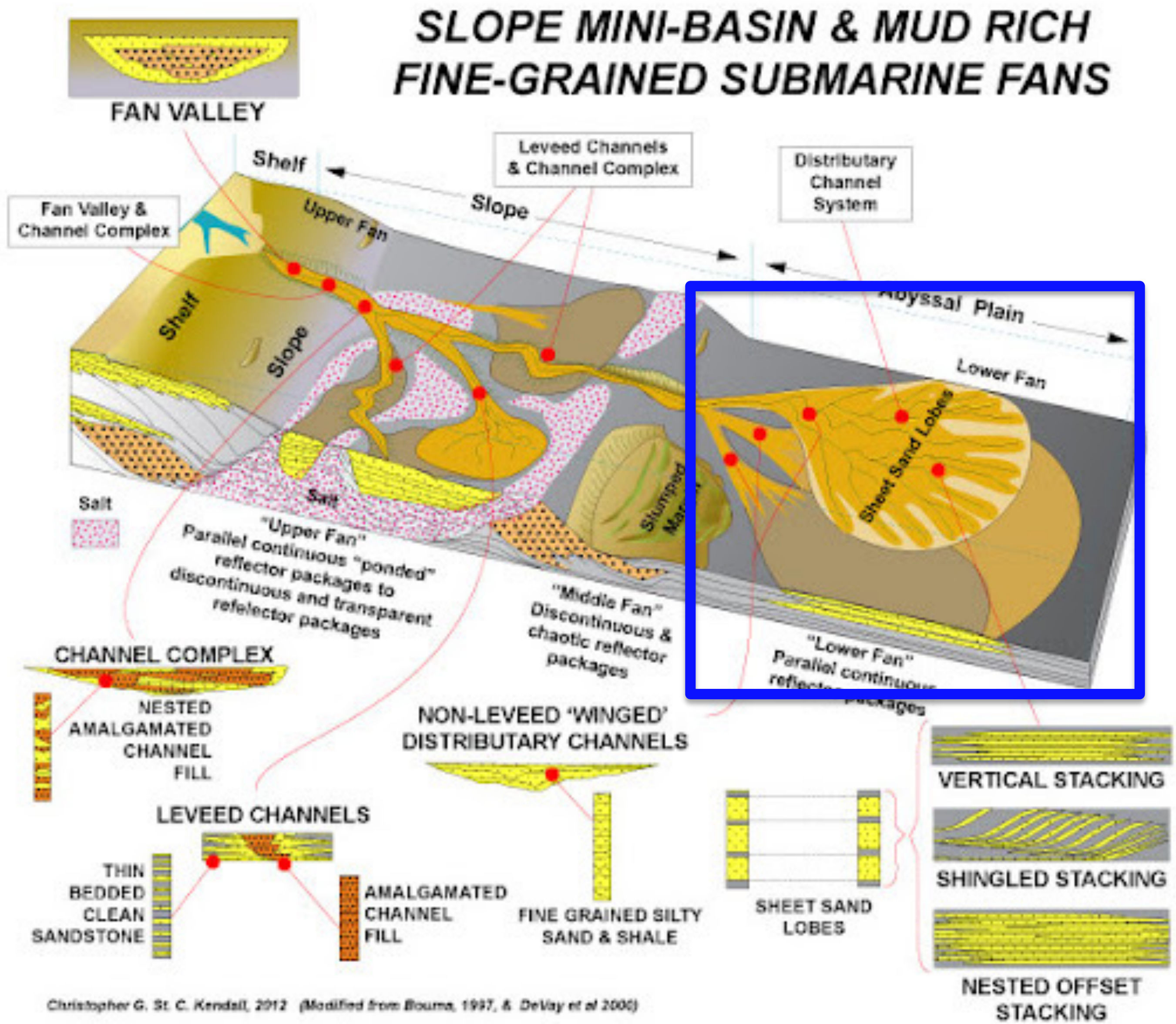


Turbidite-fan link proposed by Bouma (1962)

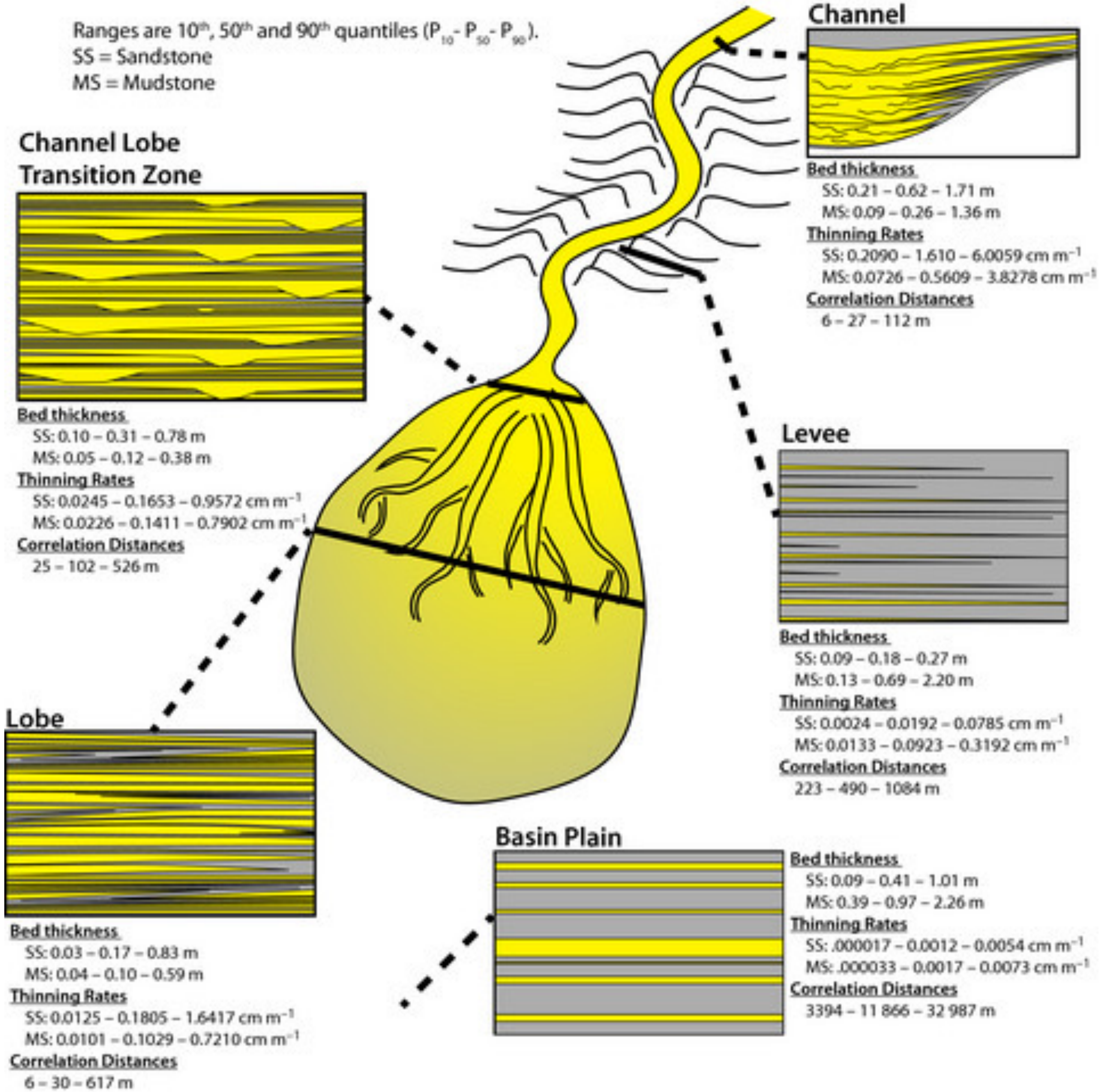




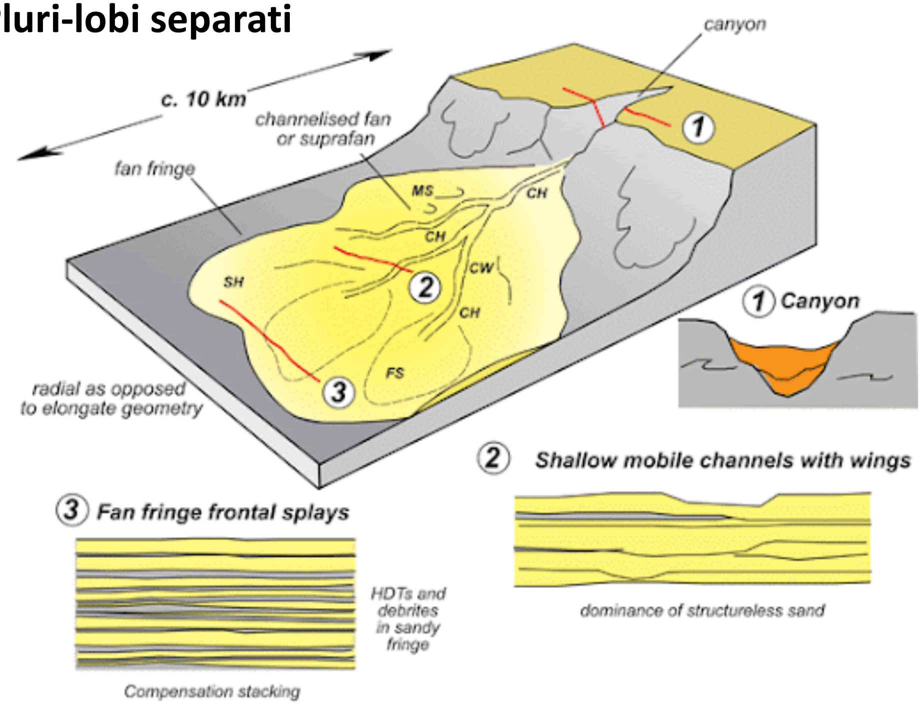



SLOPE MINI-BASIN & MUD RICH FINE-GRAINED SUBMARINE FANS
FAN VALLEY
Shelf
Slope
Leveed Channels & Channel Complex
Distributary Channel System
Fan Valley & Channel Complex
Upper Fan
Abyssal Plain
Lower Fan
Shelf
Slope
Sheet Sand Lobes
Salt
Salt
"Upper Fan" Parallel continuous "ponded" reflector packages to discontinuous and transparent refelector packages
"Middle Fan" Discontinuous & chaotic reflector packages
"Lower Fan" Parallel continuous reflector packages
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 2000)

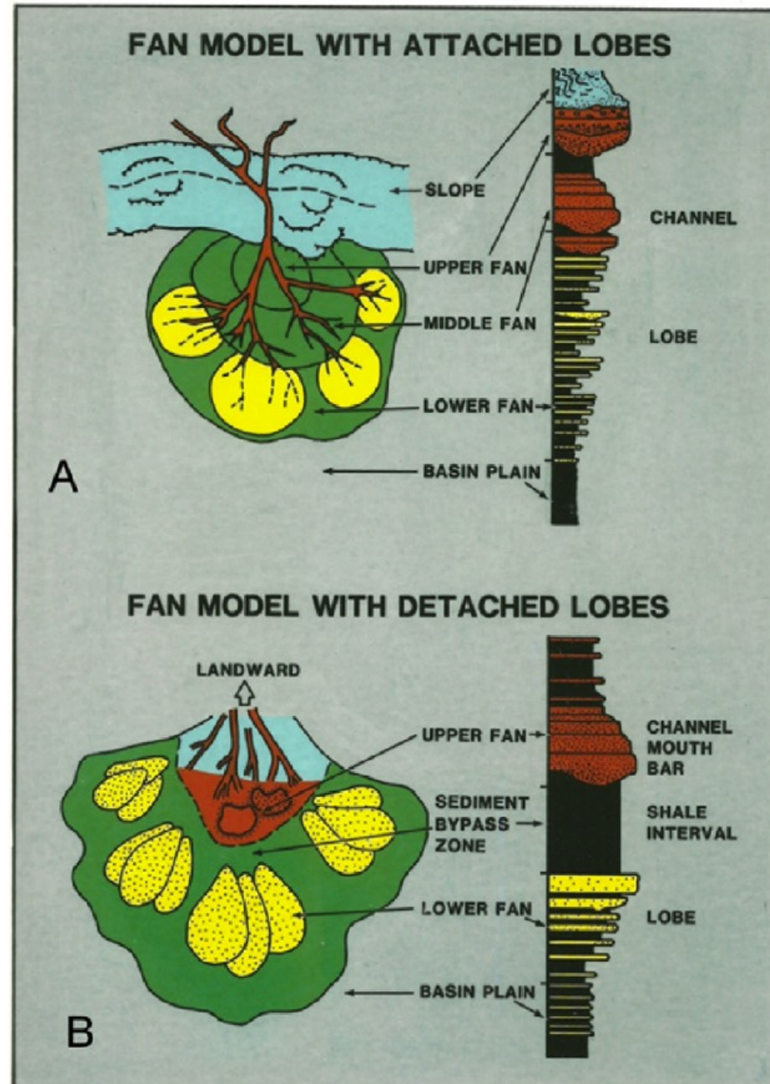
SEDIMENT FACIES in channel-deep sea fan



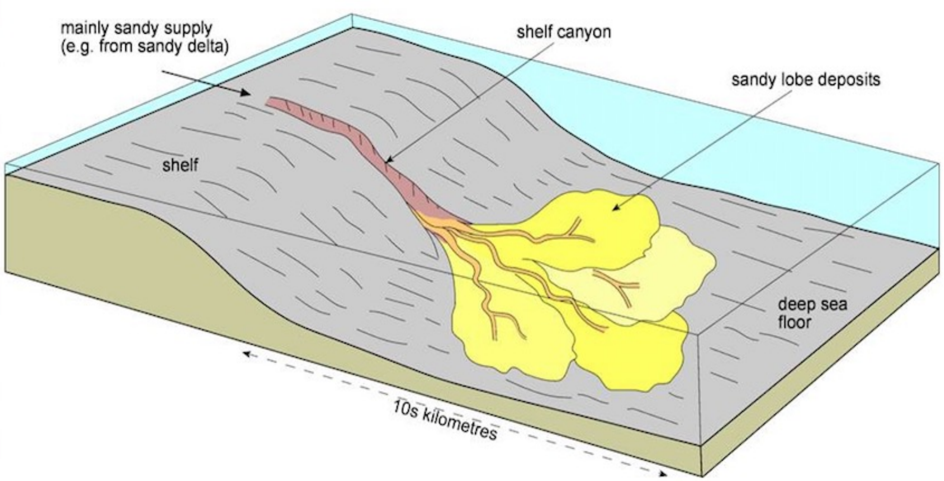
Pluri-lobi separati



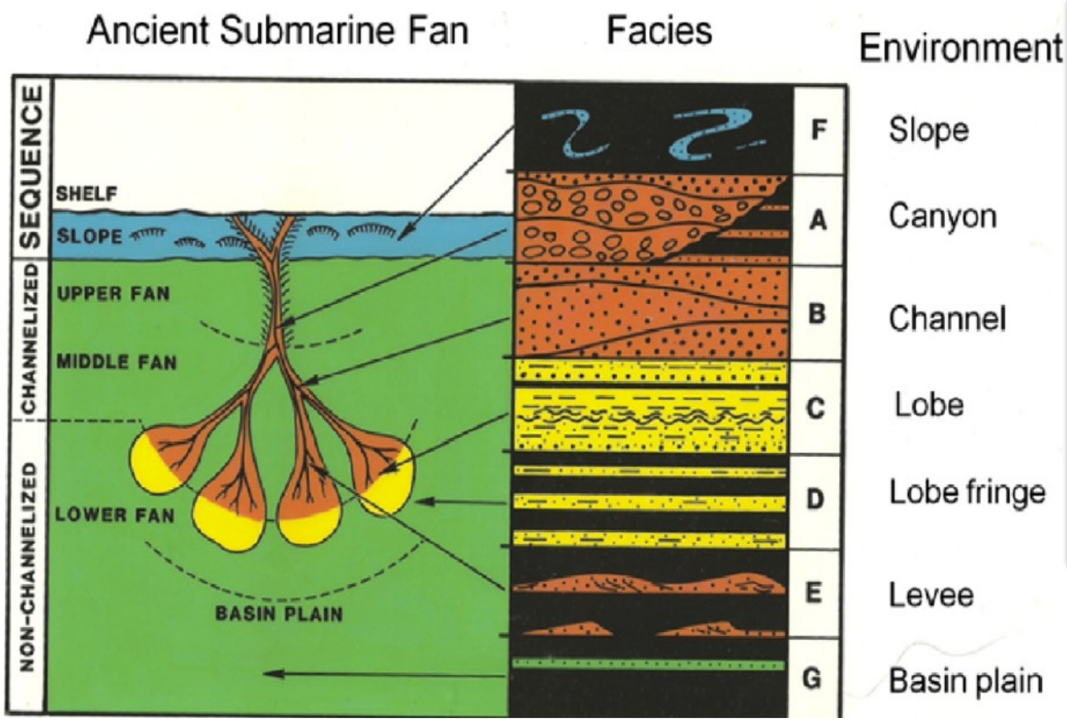
NUMBER and LOCATION of lobes forming deep sea fans

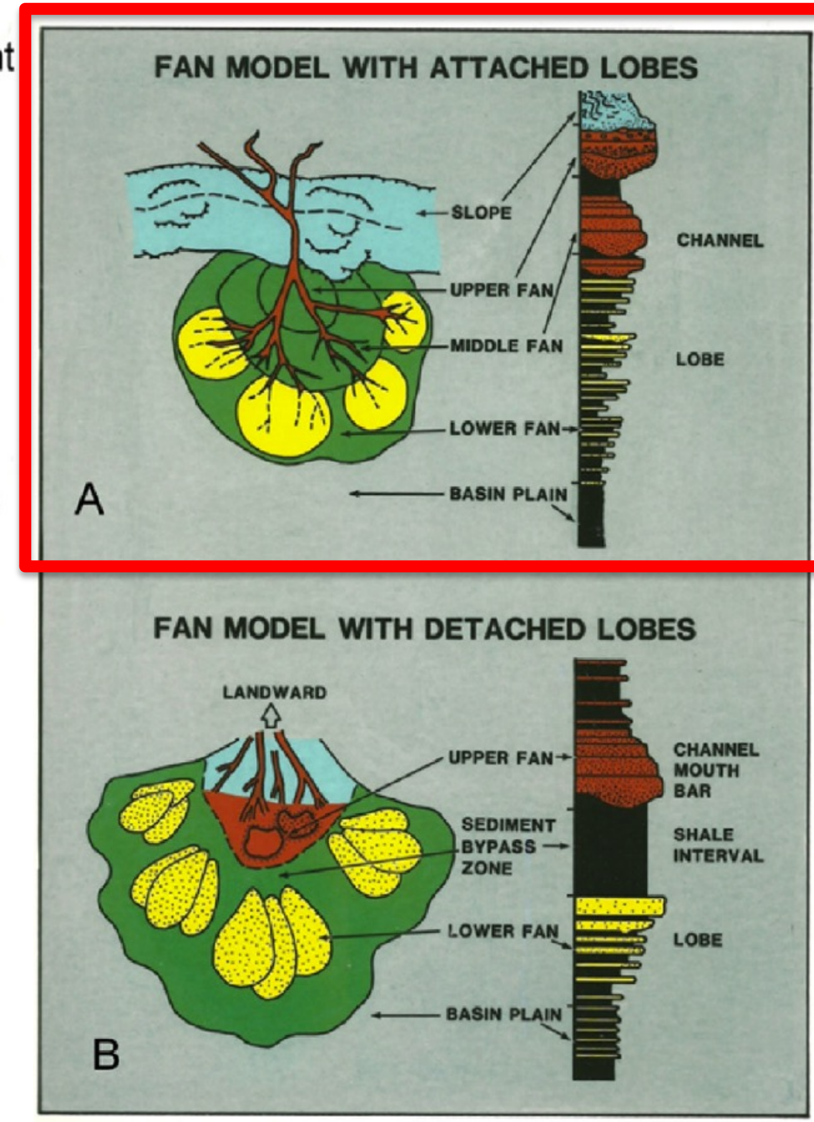


Pluri-lobi coalescenti



Components of a classic, ancient submarine fan with a canyon, distributary channels, and lobes

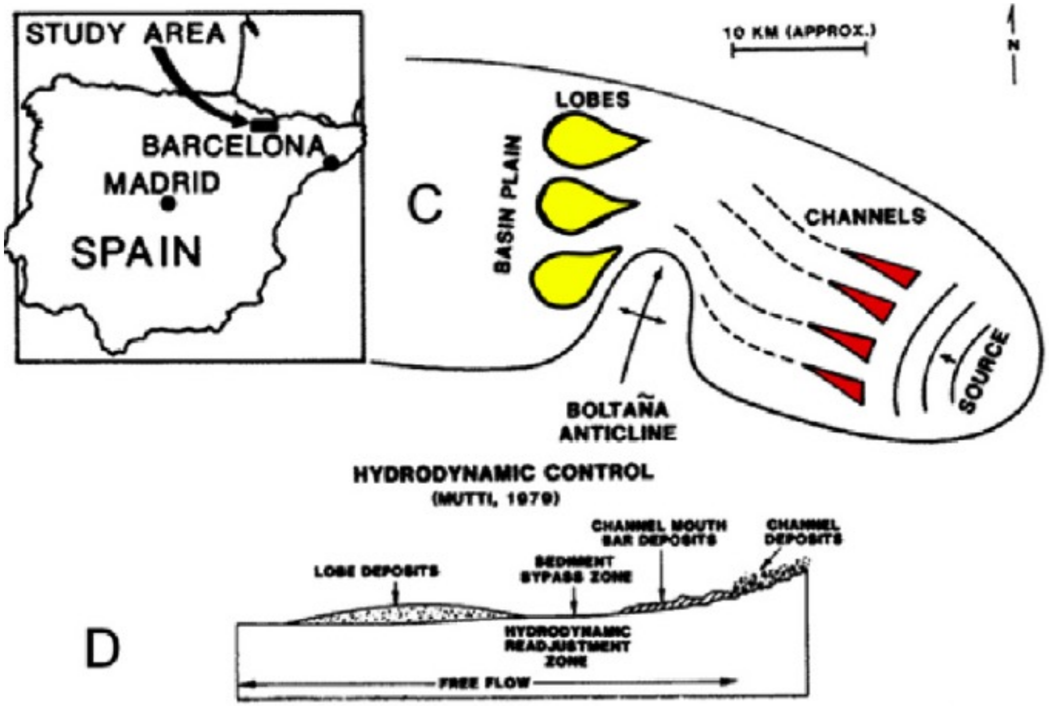


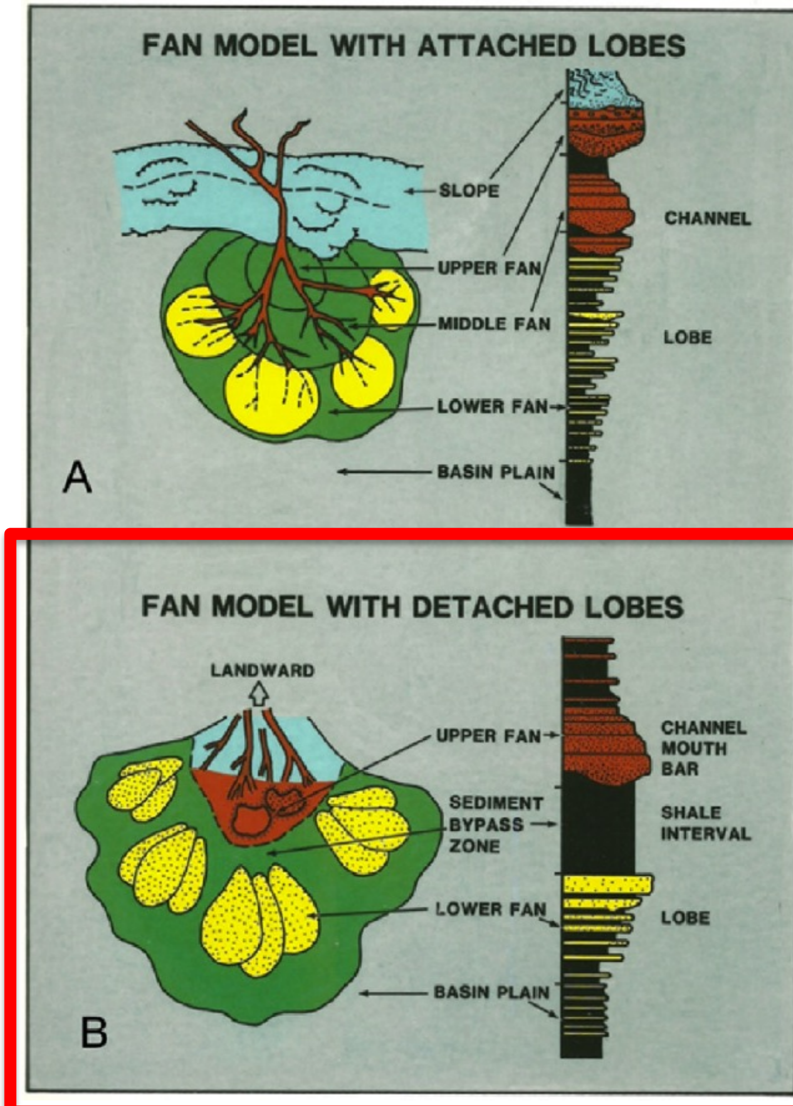


The original turbidite facies scheme (A, B, C, D, E, F, and G), proposed by Mutti and Ricci Lucchi (1972), is applied to a classic submarine fan.

Note each environment is characterized by a turbidite facies (e.g., channel with Facies B and lobe with Facies C)

Depositional lobes detached from feeder channels



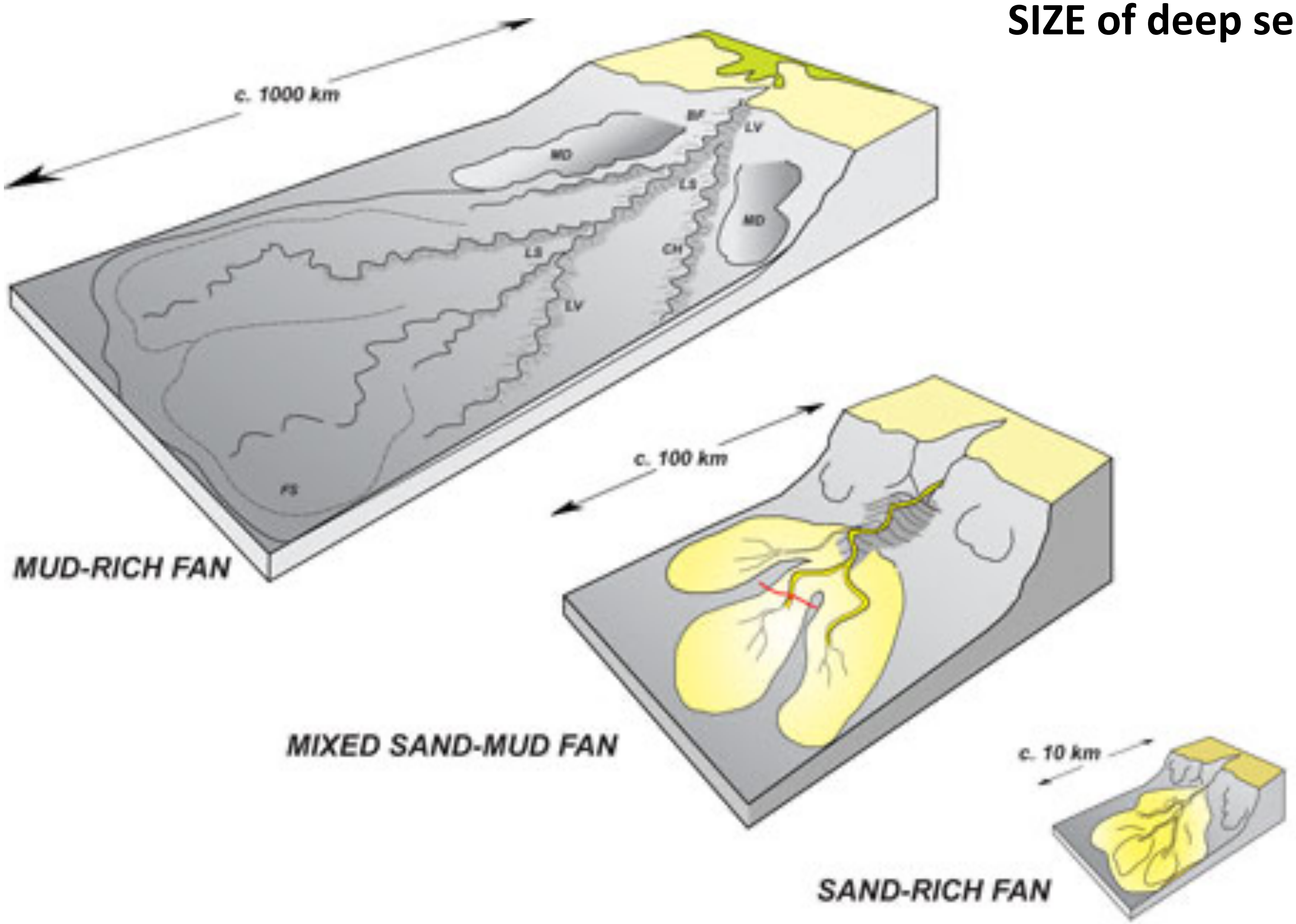


B- Fan model, in which depositional lobes are detached from feeder channels, proposed by Mutti and Ricci Lucchi (1975)

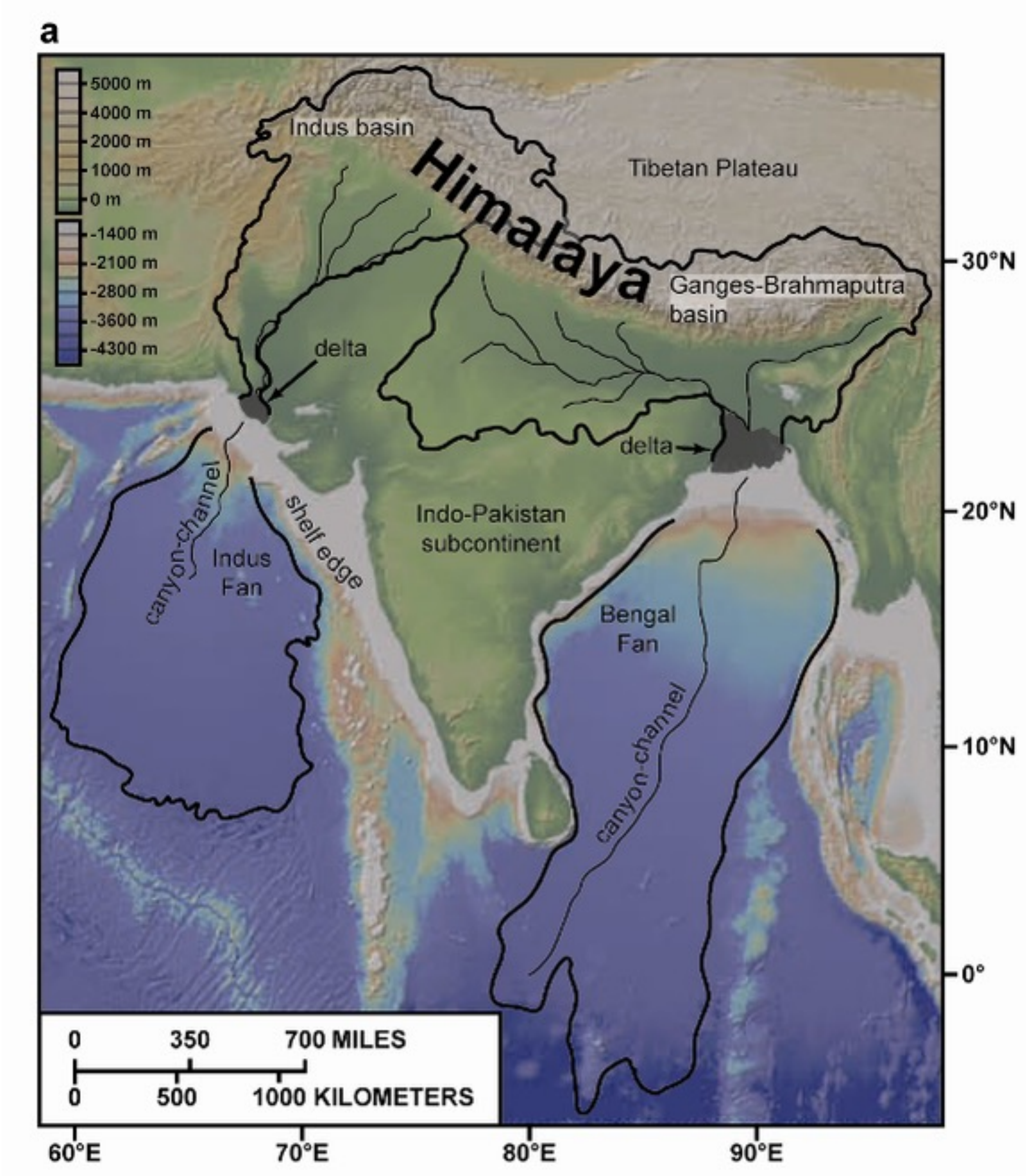
C- Hecho Basin with Boltaña anticline separating lobes from channels

D- Longitudinal section showing hydrodynamic control by sediment bypass zone;

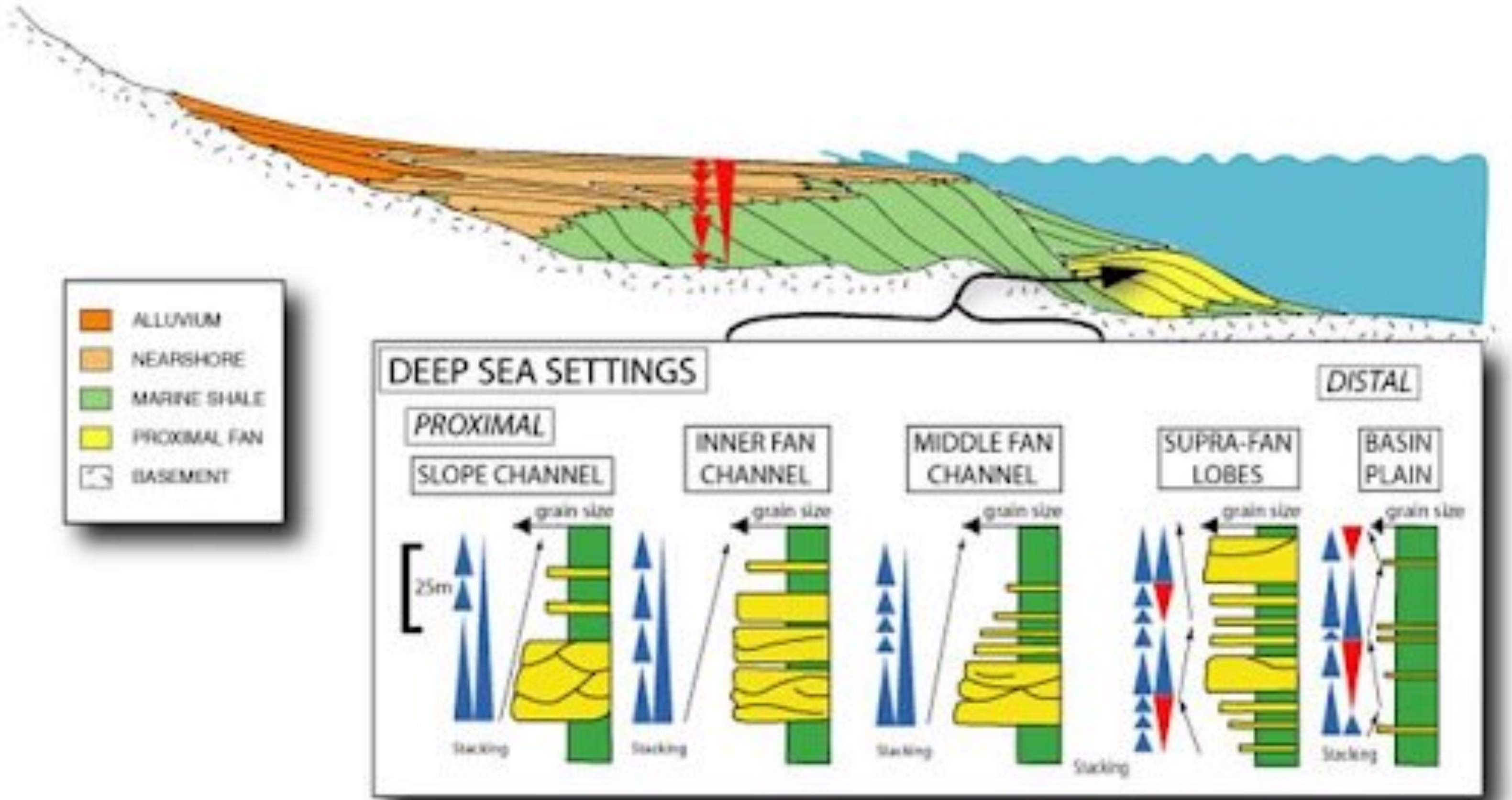
SIZE of deep sea fans



SIZE of deep sea fans

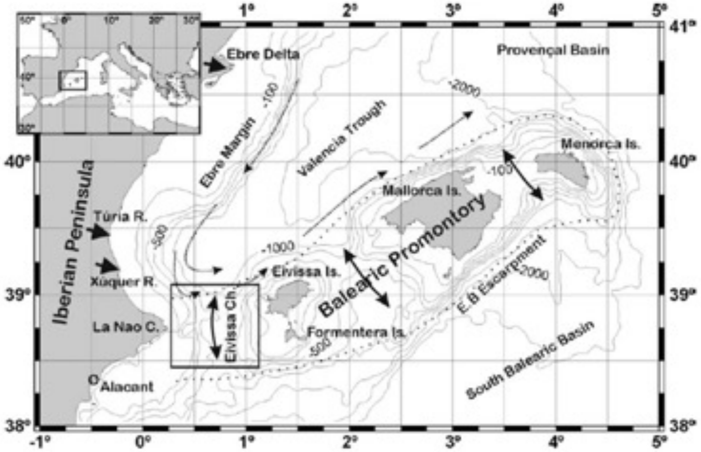


The **triggering mechanism for gravity flows initiation** can influences the volume and duration of individual flows (Piper and Normark 2001). The **flow behaviour** controls how coarse- and fine-grained material is partitioned into different fan settings, and is strongly influenced by the **overall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

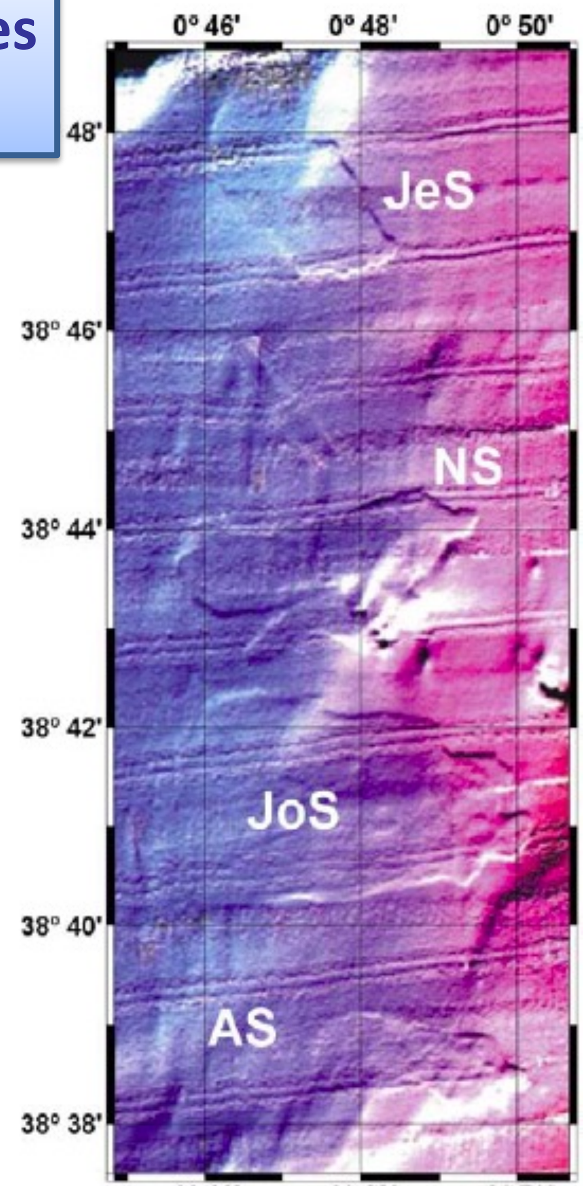


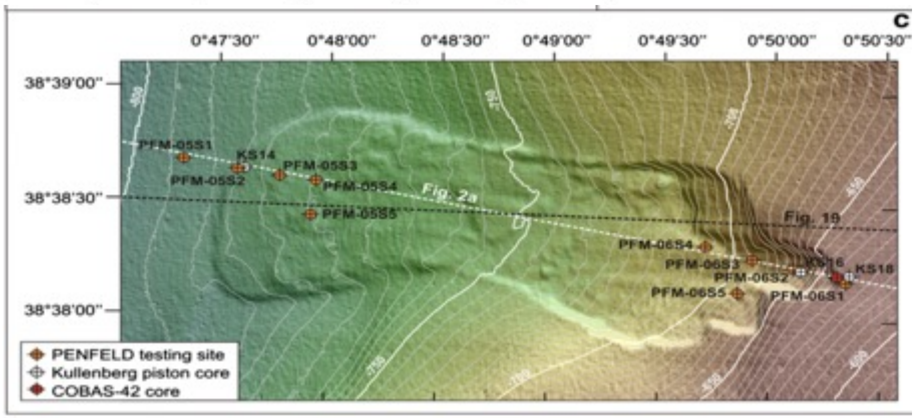
C.G. St. C. Kendall 2004 (based on Malcolm Rider 1999 & Jerry Baum x-section)

Submarine Landslides and debris flows

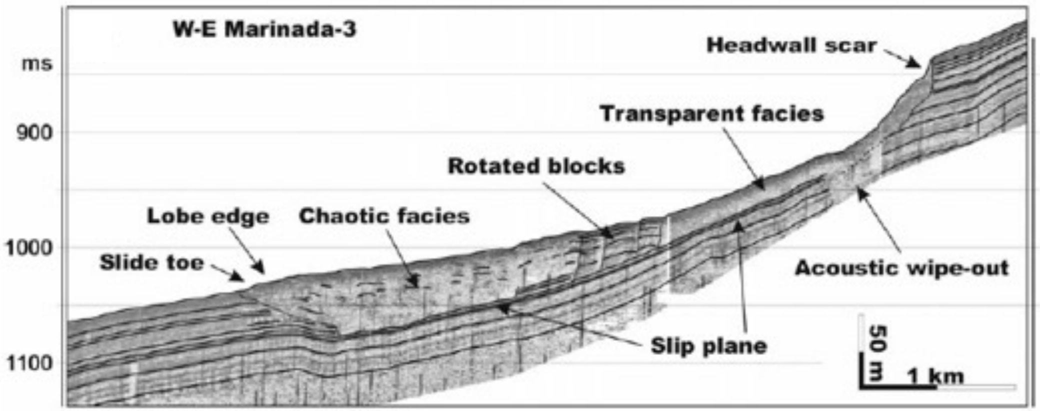


Ana submarine landslide
Ibiza Channel
Western Mediterranean





Multibeam

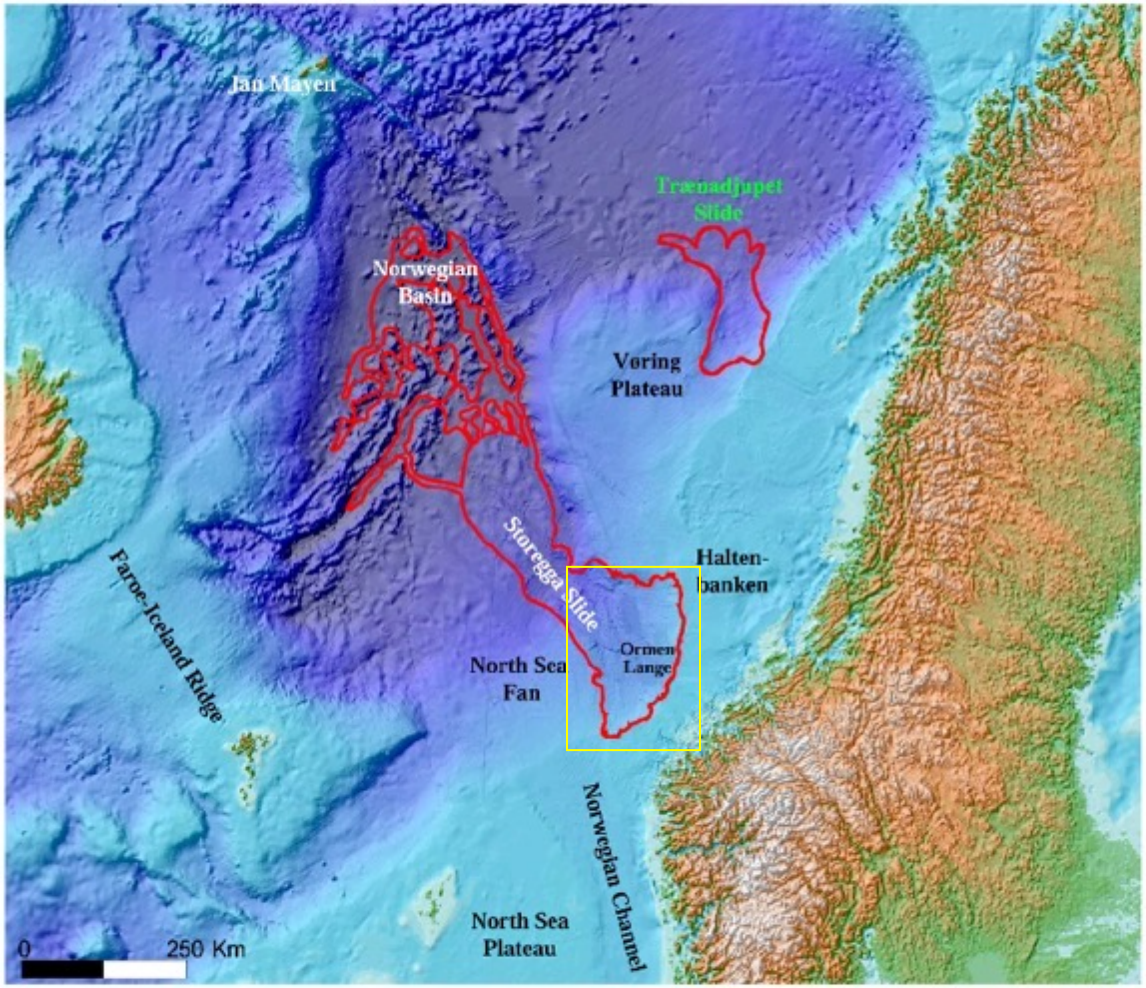


Sub-bottom

Lastras et al., 2004 Sedimentology

STOREGGA SUBMARINE LANDSLIDE, NORWAY

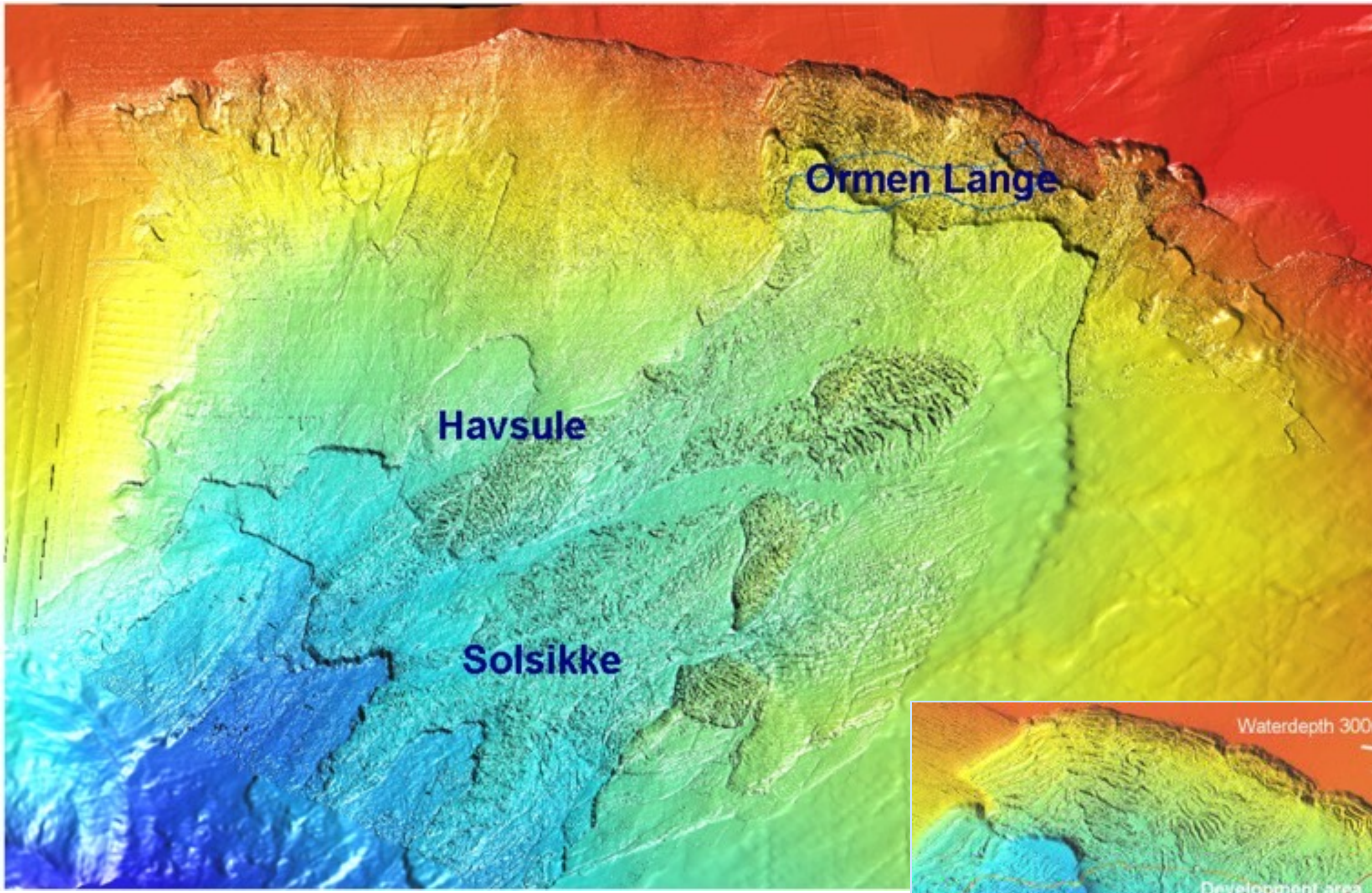
8000 y BP
3500 km^3 of debris

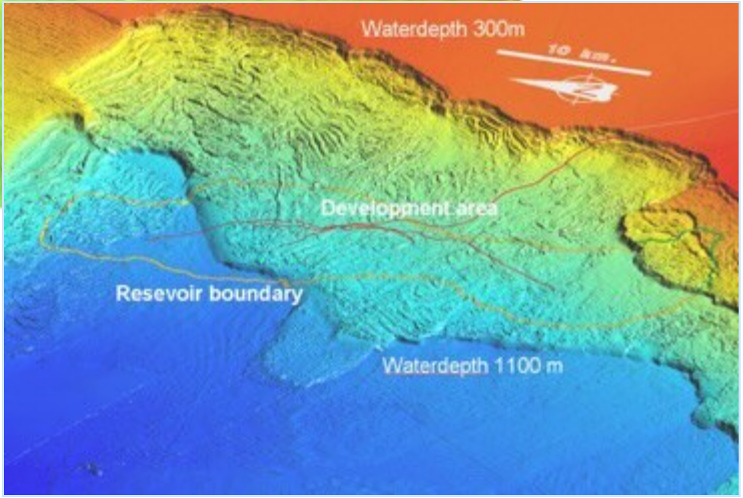


Courtesy Petter Bryn

Norsk Hydro E&D Norway

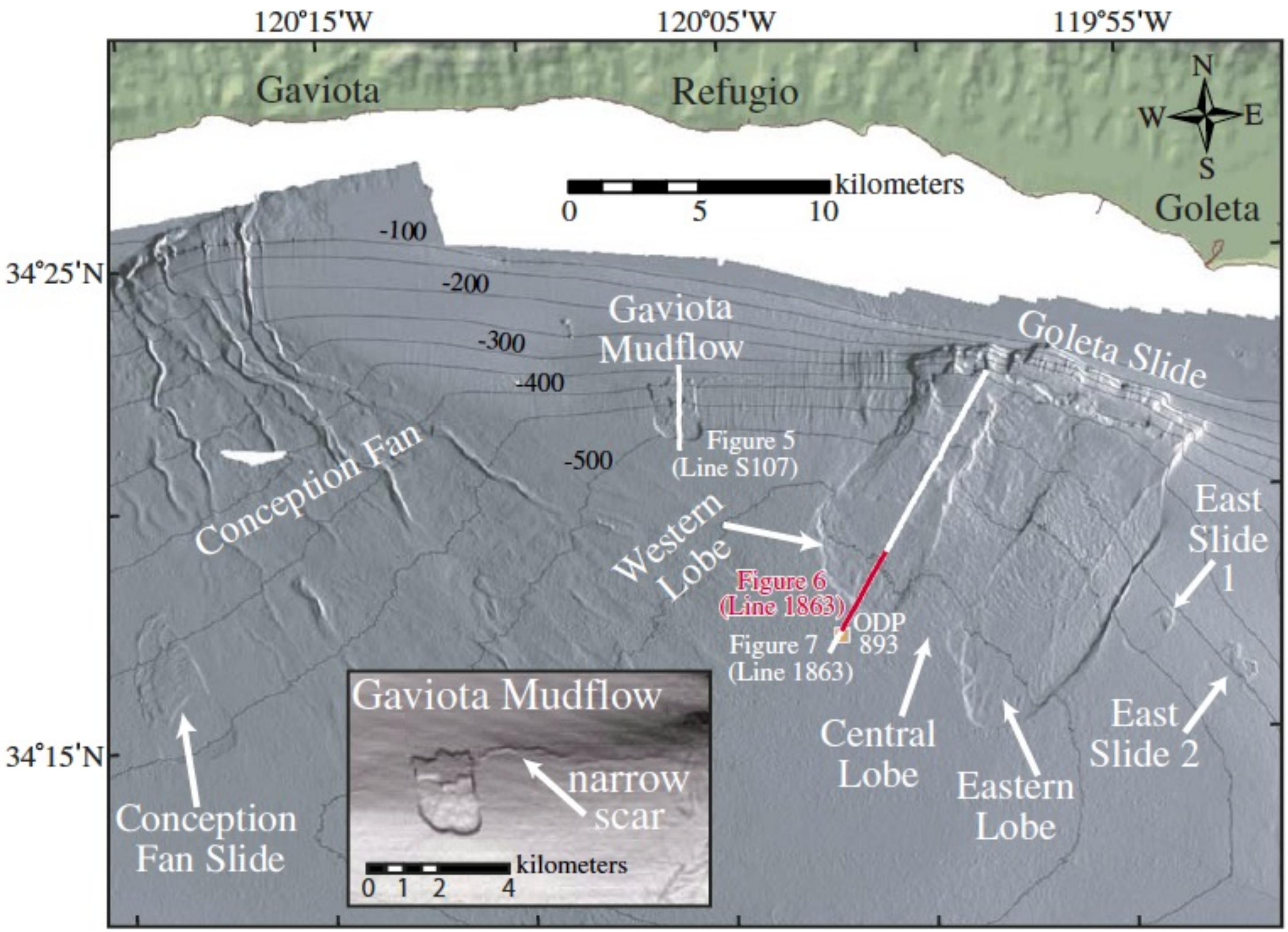
Geophysical Operations





STOREGGA SUBMARINE LANDSLIDE

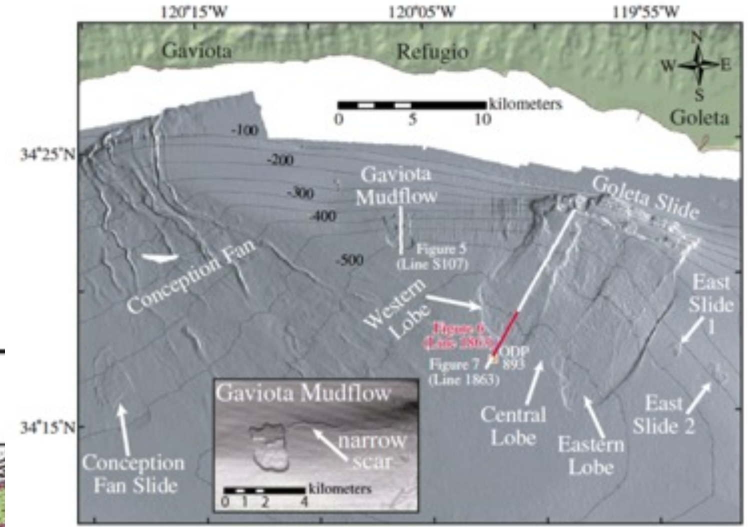
GOLETA LANDSLIDE (CALIFORNIA)

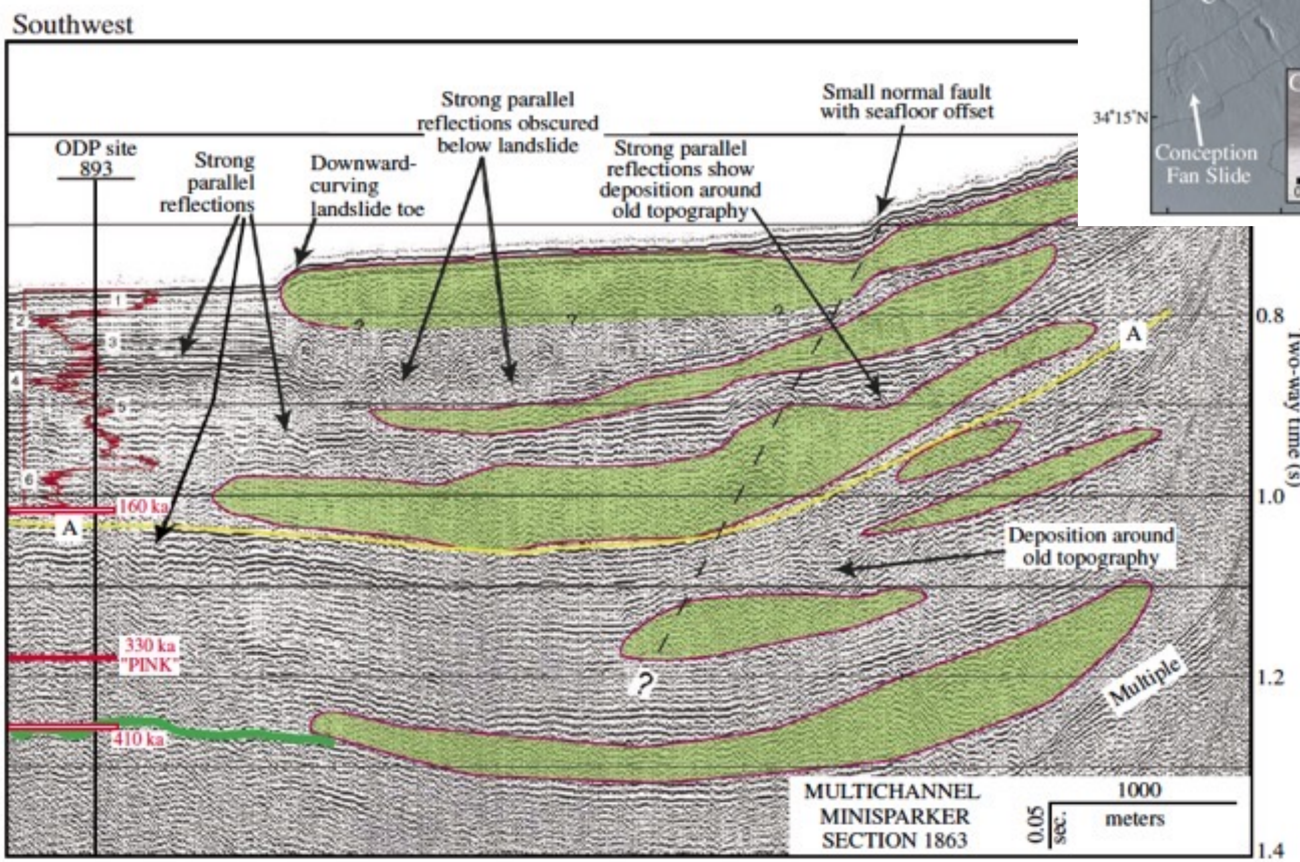


Multibeam echosounder

Lee et al., 2009. GSA Special Issue

GOLETA LANDSLIDE (CALIFORNIA)

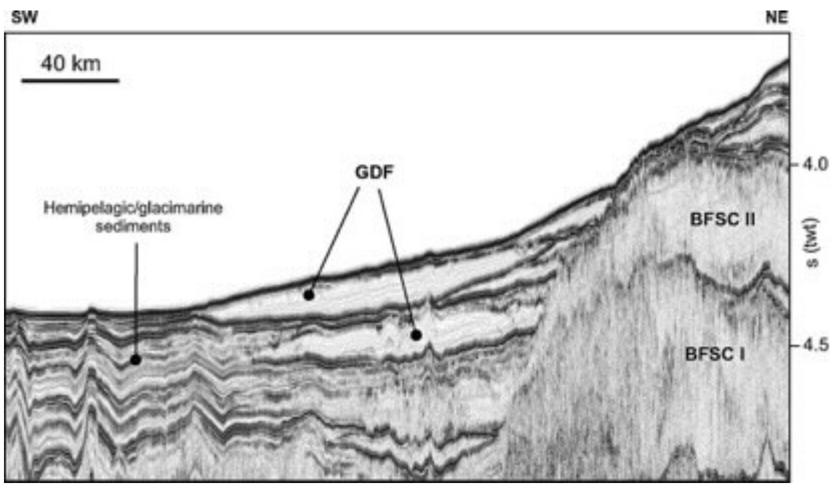


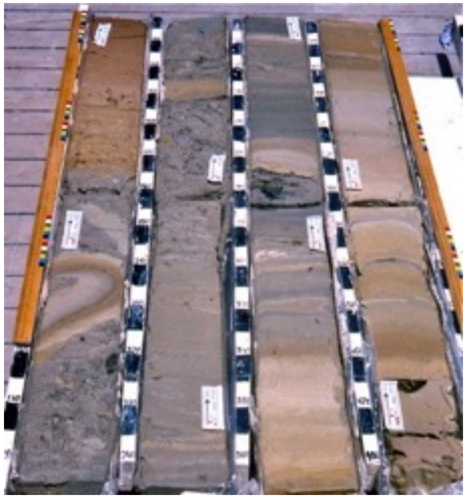


Deep penetration seismic 2D Sparker

Lee et al., 2009. GSA Special Issue

Debris flows





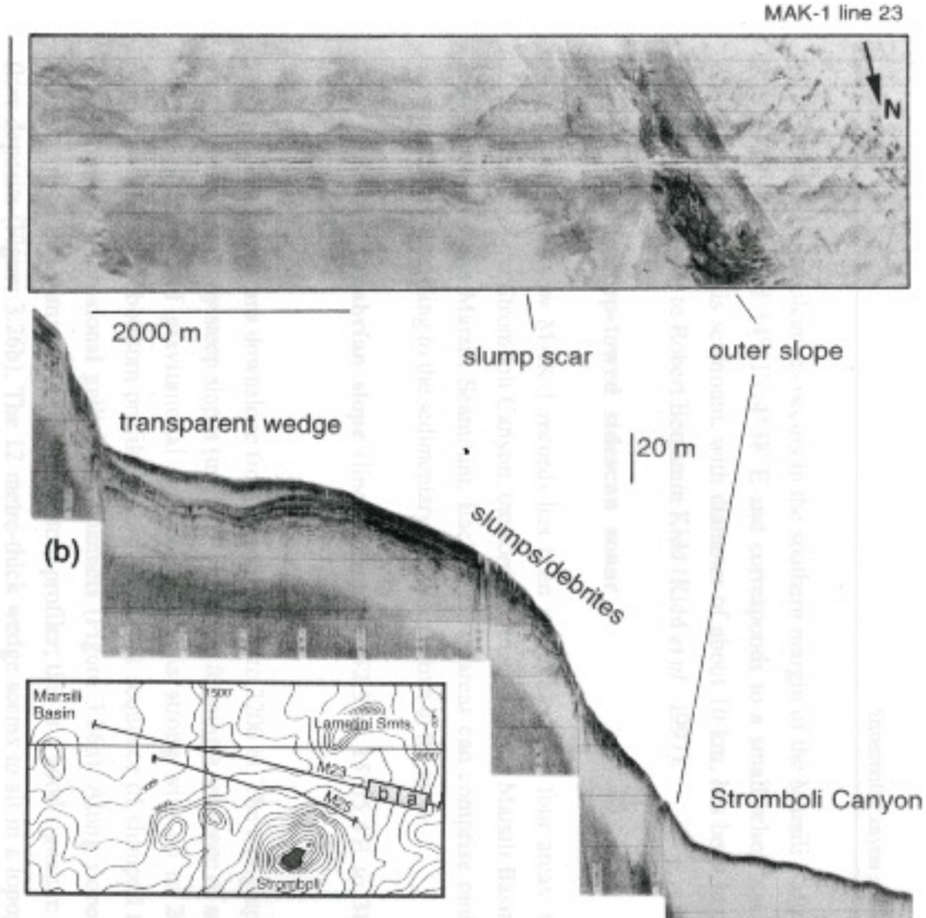


Figure 3.26 - Two images of the MAK-1 Line 23 along the Calabrian slope give evidence of slope instability (see text for discussion).