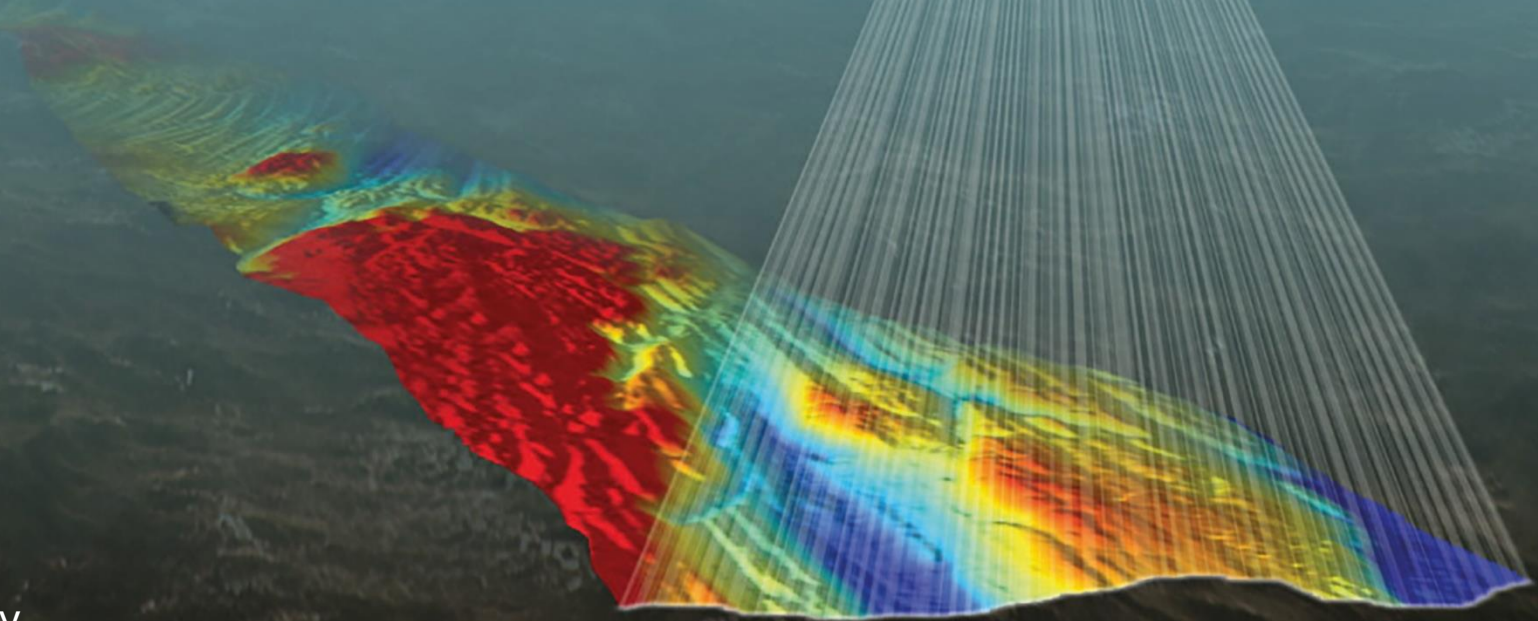




Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David



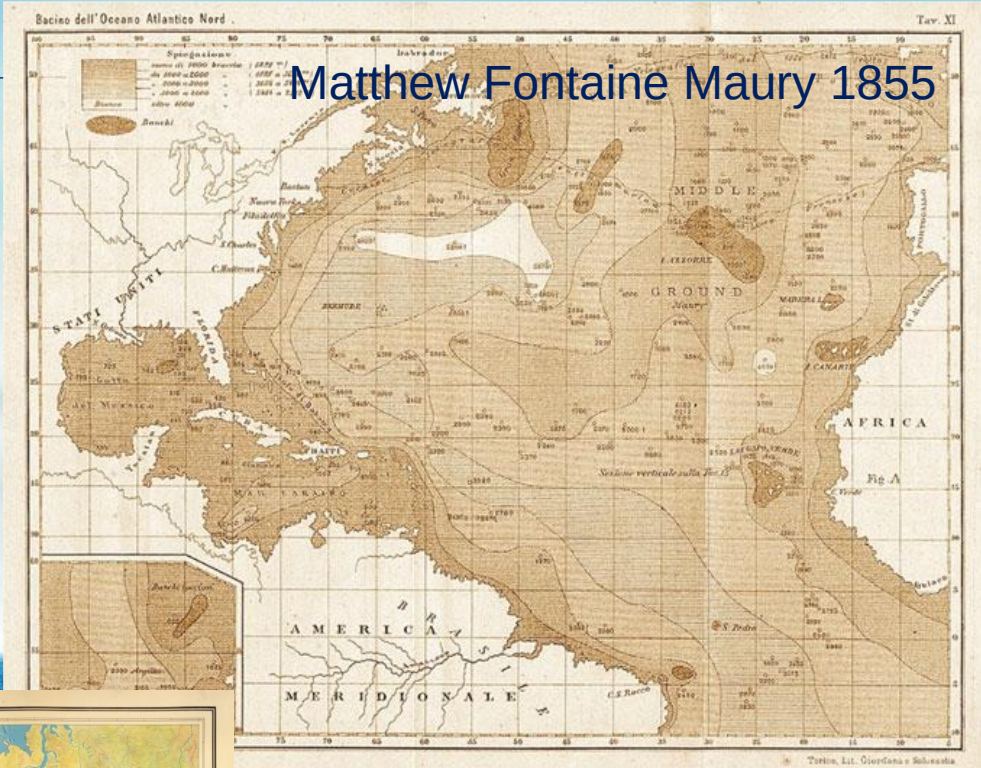
Beyond the horizon Submarine Landscapes



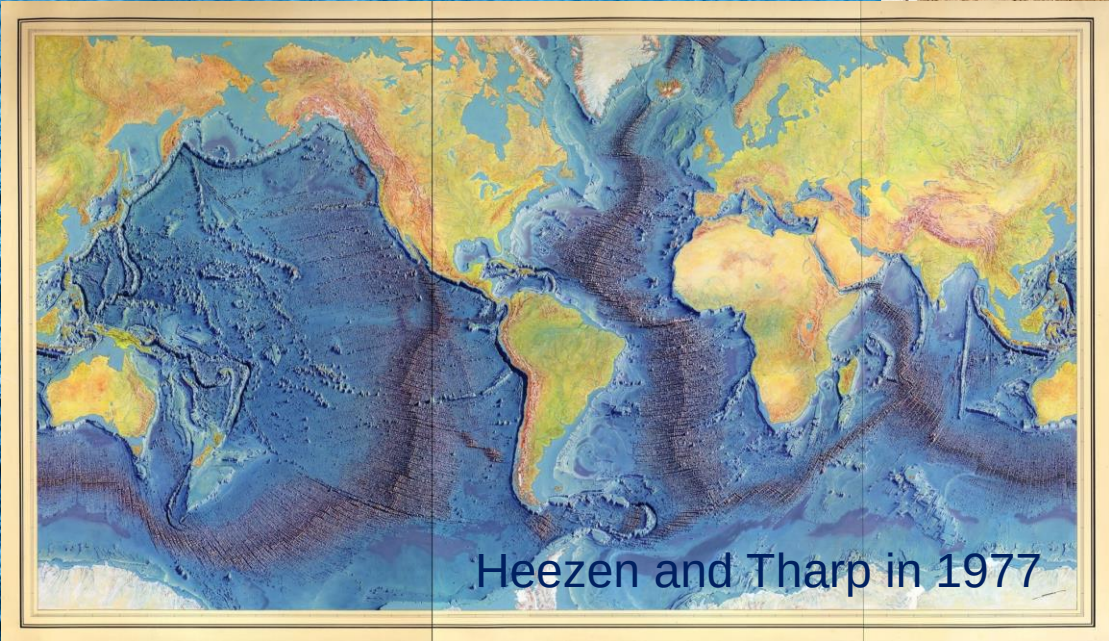
Dr Alissa Flatley
ACNA4007 – Physical Landscape and the Geosphere

The Oceans...

- The big unknown – but 70% of Earth surface
- Terrestrial vs marine observations
- Topography vs bathymetry
- 1860s – dredges, first soundings...



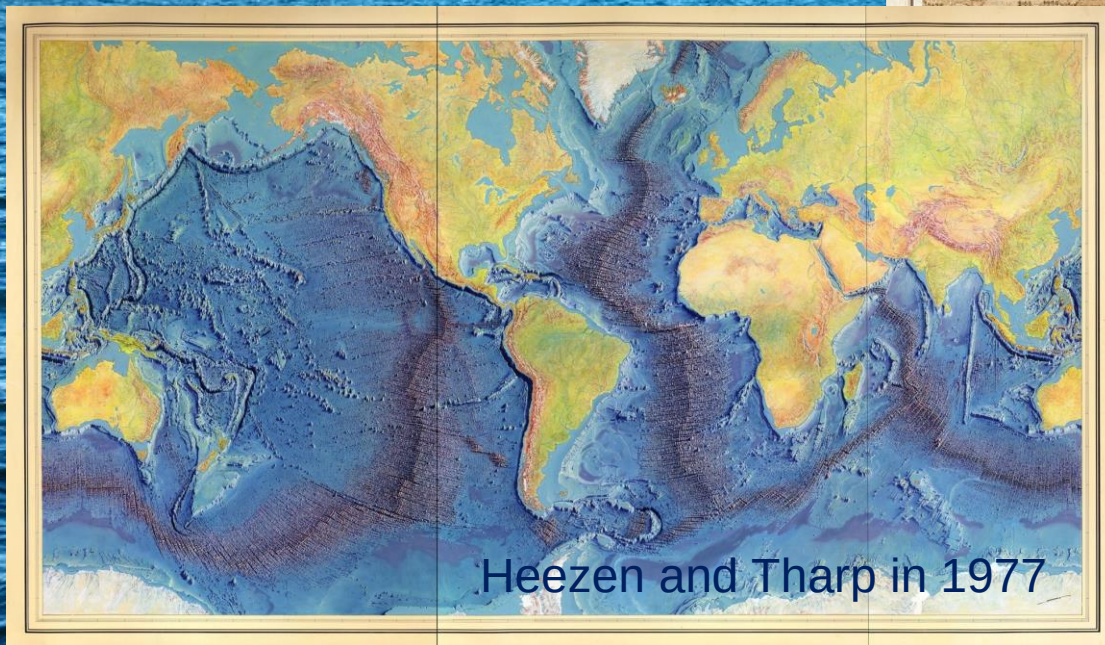
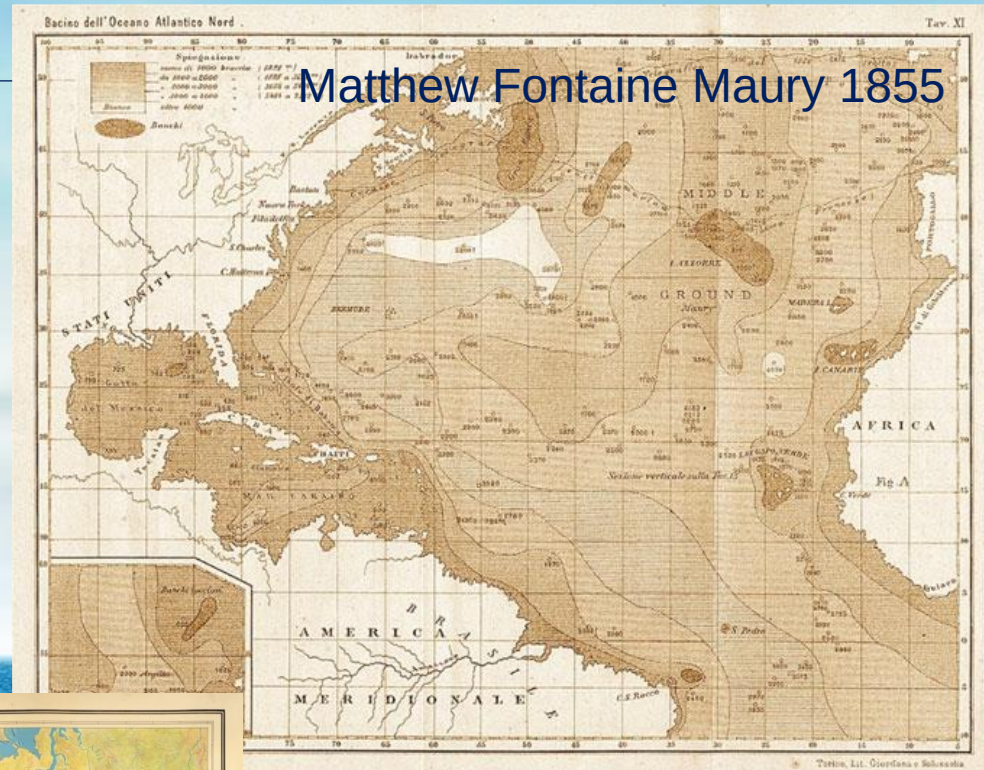
Matthew Fontaine Maury 1855



Heezen and Tharp in 1977

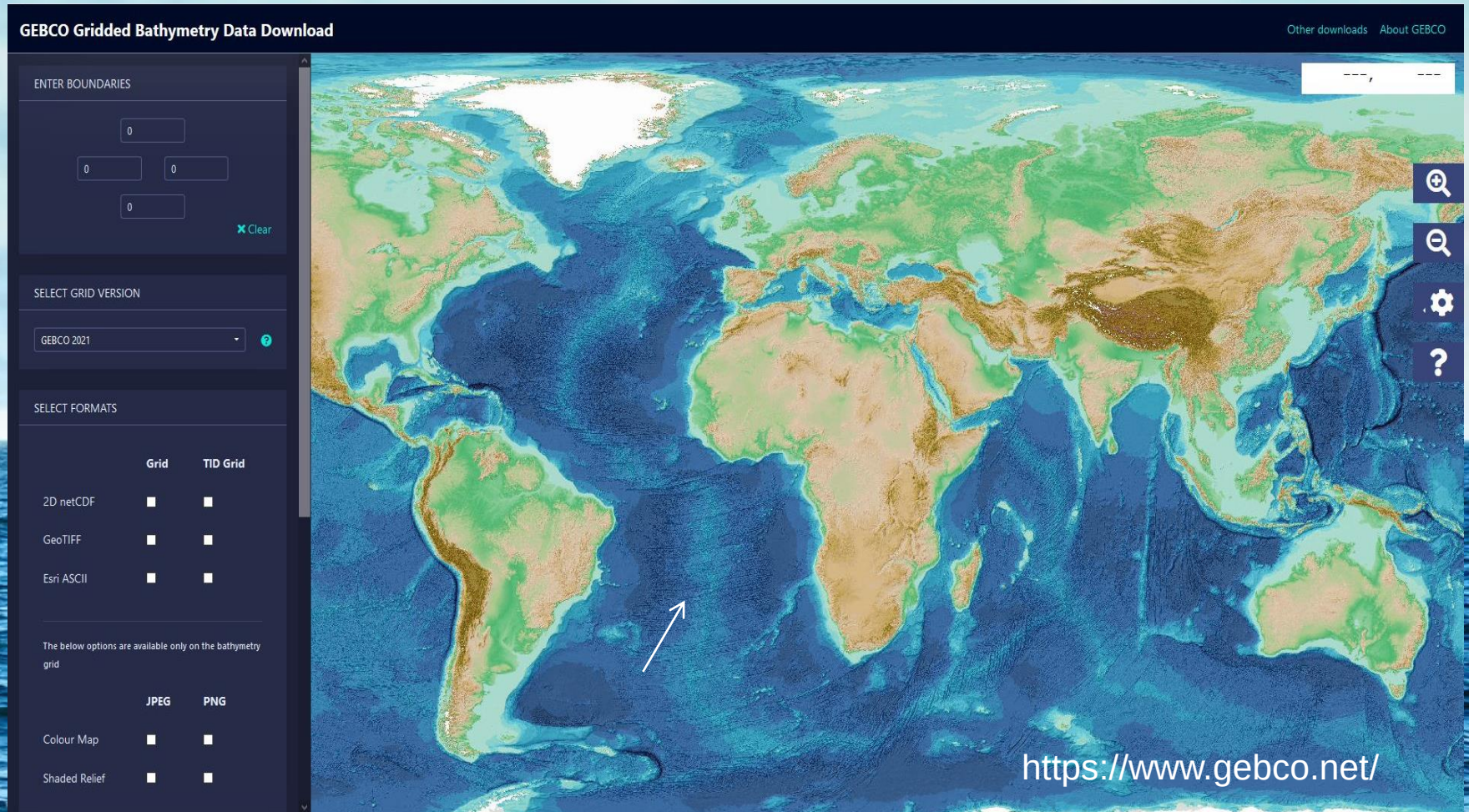
- Eco-sounders and sonar early 20th century
- General Bathymetric Chart of the Oceans, GEBCO in 1903

- The big unknown – but 70% of Earth surface
- Terrestrial vs marine observations
- Topography vs bathymetry
- 1860s – dredges, first soundings...



- Eco-sounders and sonar early 20th century
- General Bathymetric Chart of the Oceans, GEBCO in 1903

The Oceans...



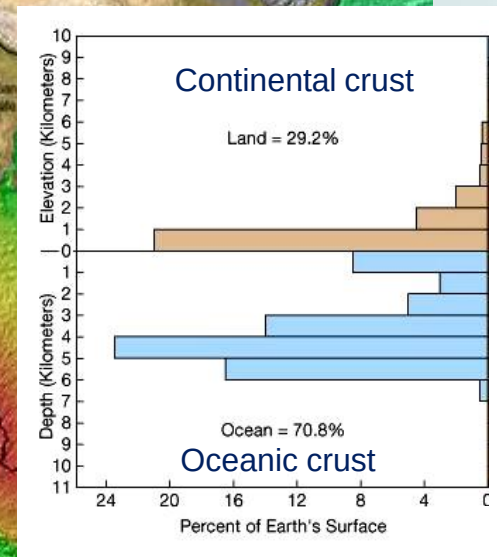
- 5 editions until 1982, now 30 arc minute grid (ca. 1 km)
- Confirmation of plate tectonics !!

Oceanic provinces...

Continental margins (22%)

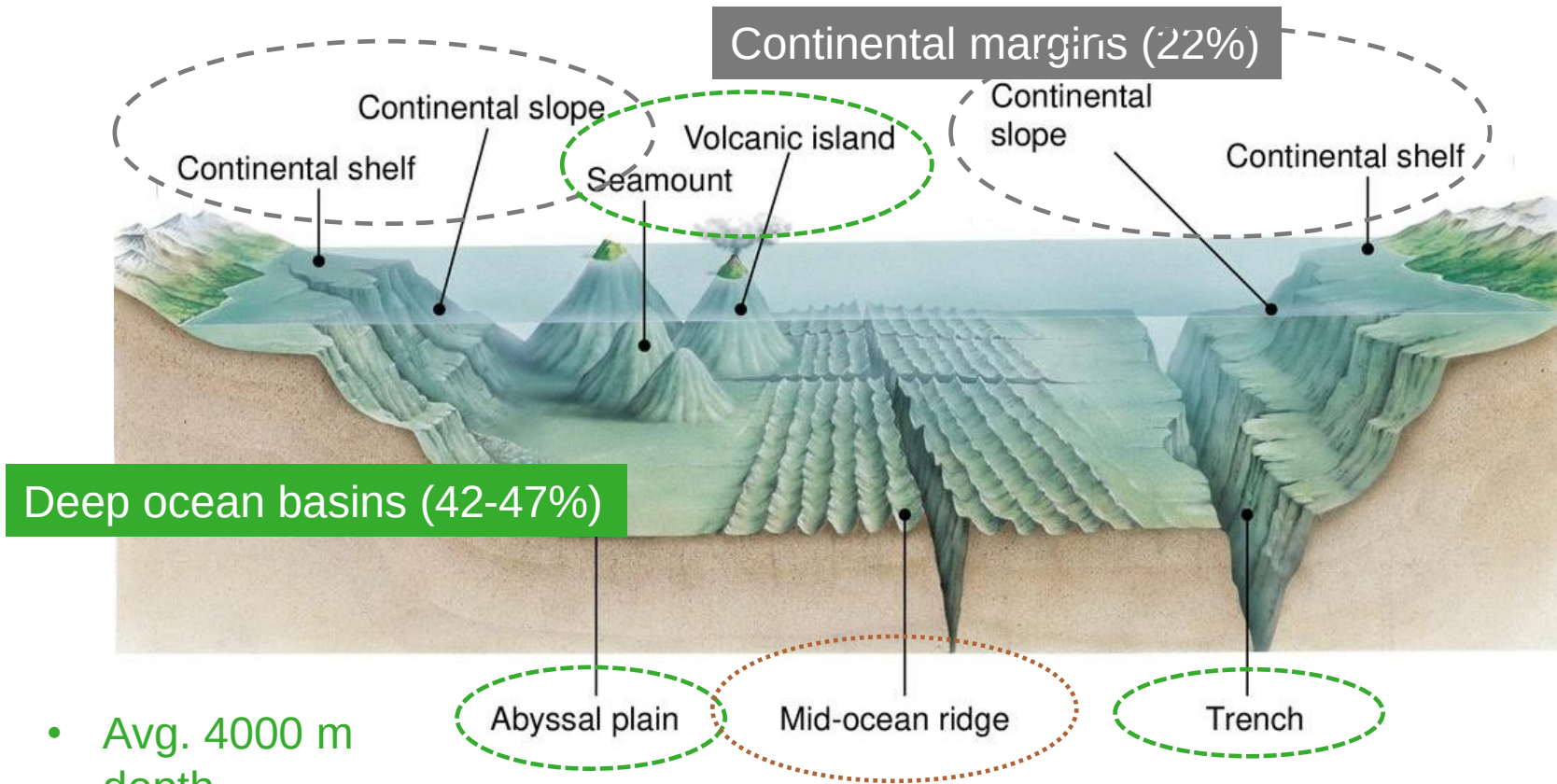
Deep ocean basins (42-47%)

Mid-ocean ridges (31%)



- 5 editions until 1982, now 30 arc minute grid (ca. 1 km)
- Confirmation of plate tectonics !!

Ocean floor – tectonic perspectives



- Avg. 4000 m depth
- Abyssal plains (flat, sediment)
- Abyssal hills (abundant) and seamounts

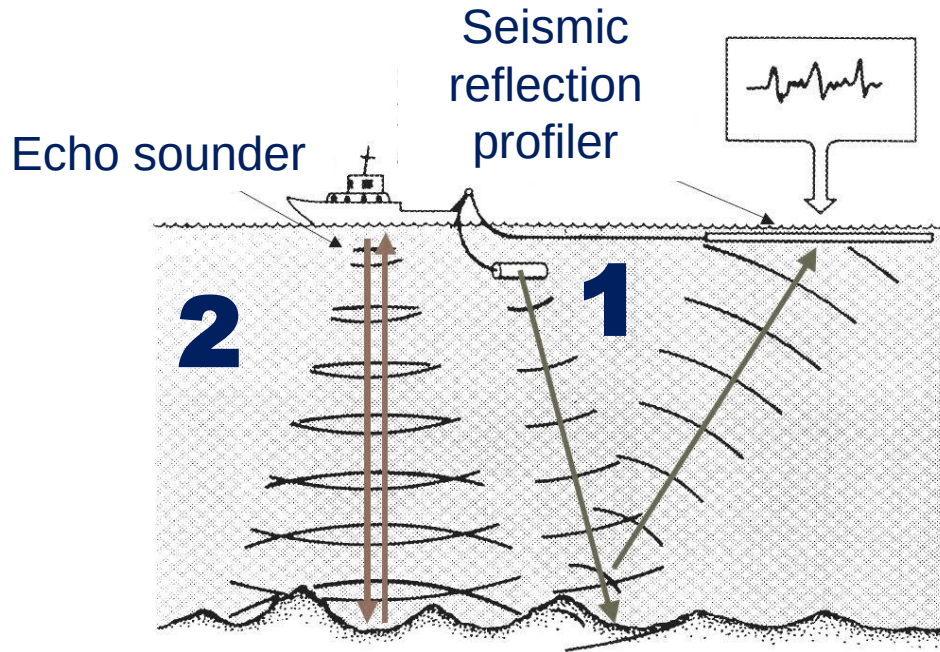
Mid-ocean ridges (31%)

- Geology = continents
- Sediment cover, canyons and fans
- (i) shelf (water > basin volume), (ii) shelf break (135 m), (iii) continental slope (~4 deg), (iv) continental rise (1-5 km)

- Depth 2,600 – 2,000 m
- Earth's longest mountain range (65,000 km)

Ocean floor mapping

- Only 15% of ocean measured by sonar...



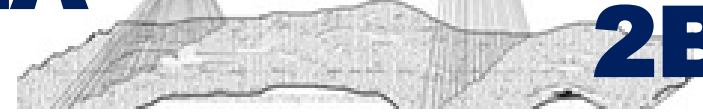
Side scan sonar

2A



Multi-beam sonar

2B



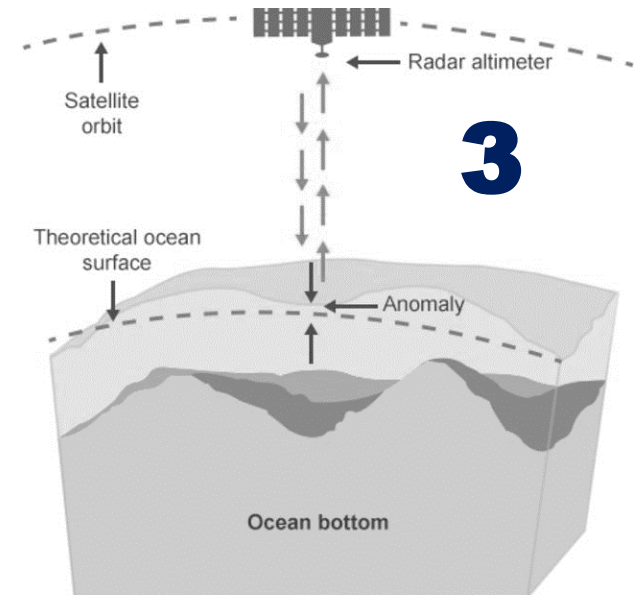
- ... like echo sounder, but images a 60 km swath of seafloor

- Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs)

4



Satellite altimetry



A – Deep sea...

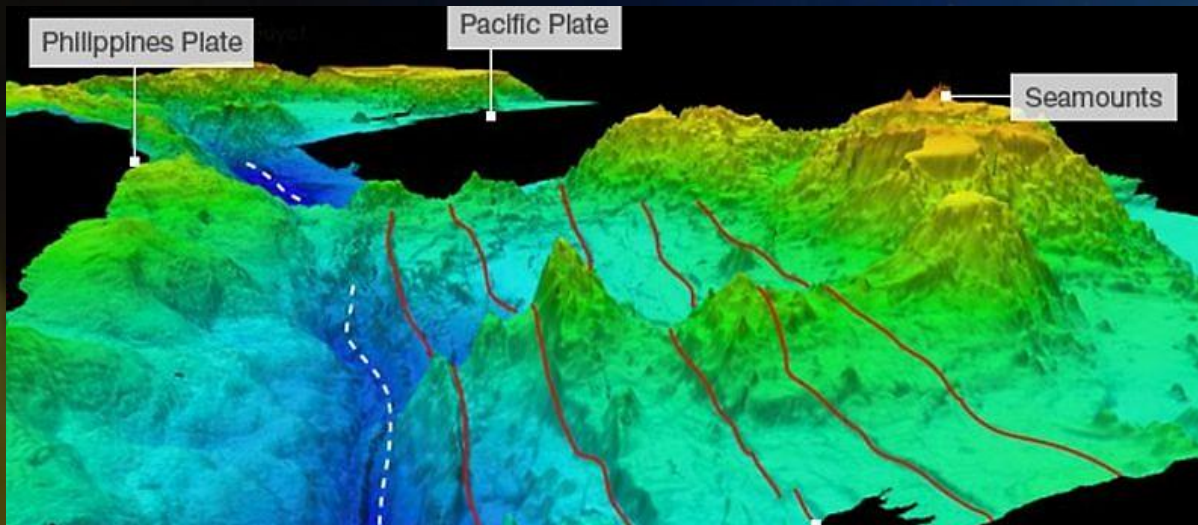
- The big unknown...
- Izu-Ogasawara Trench, south of Japan, deepest record of a fish - unknown snailfish species of the genus *Pseudoliparis* at a depth of 8,336m
- Two fish collected in traps at 8,022m deep in the Japan Trench



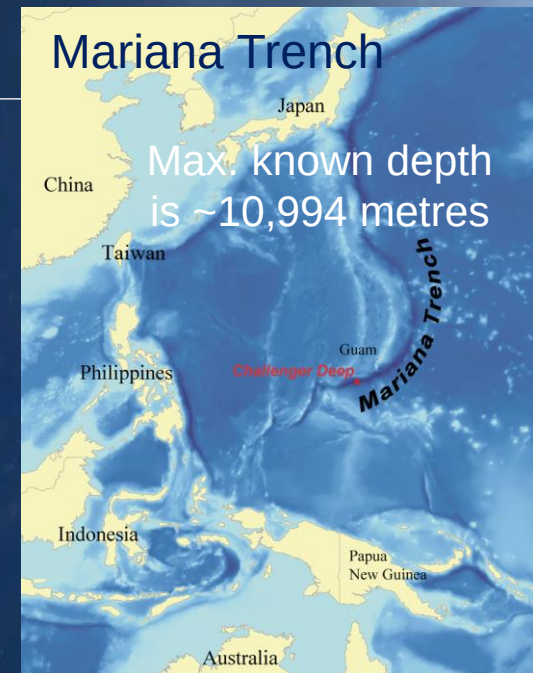
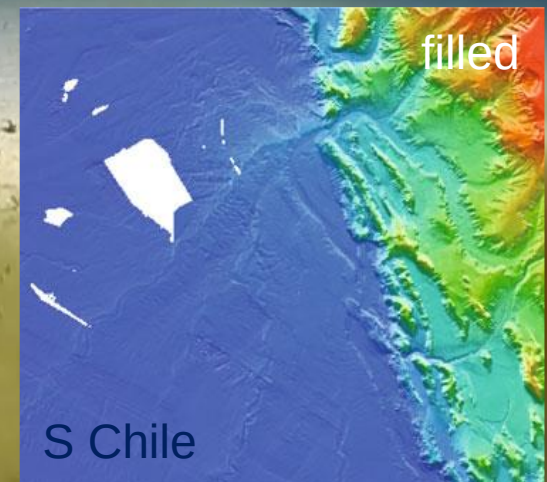
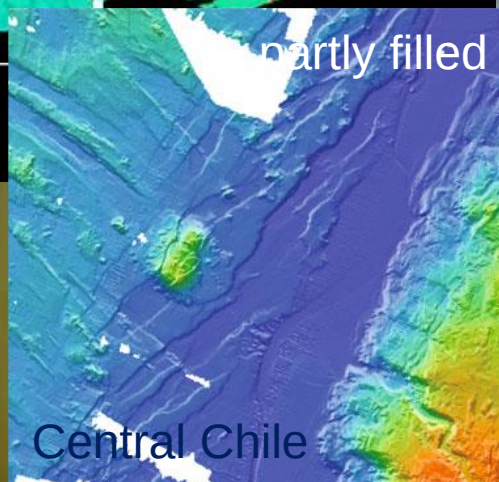
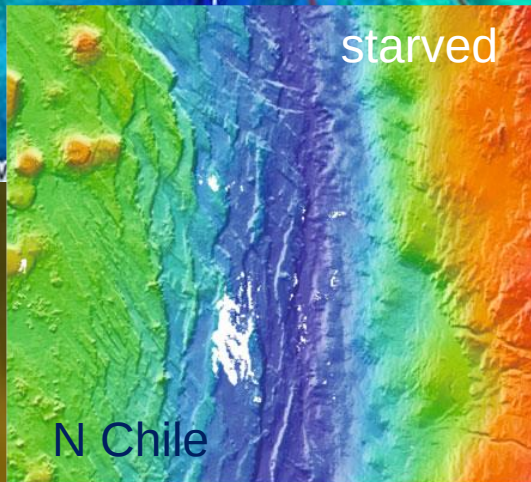
<https://www.youtube.com/watch?v=TktdNurphxA>

A – Deep sea trench

- Structural evolution - sediments filling vs starvation
- Sedimentary and tectonic history of the adjacent convergent margin

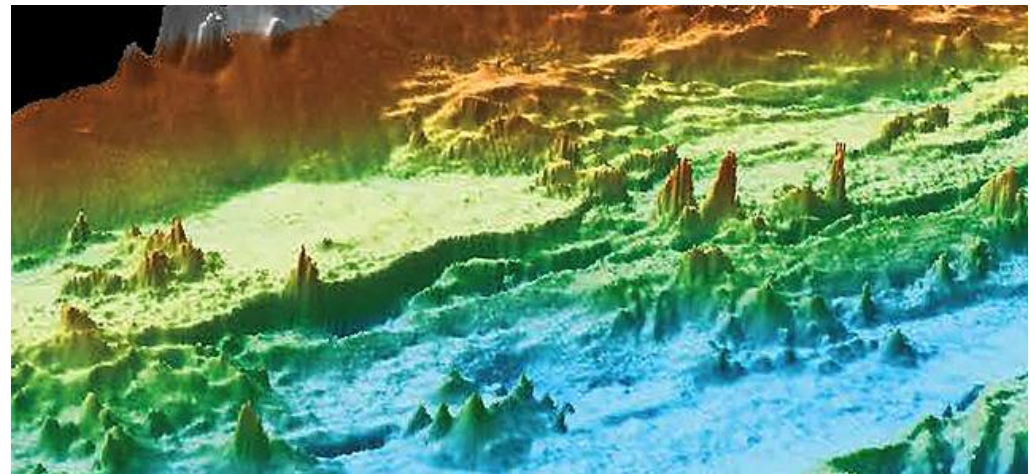
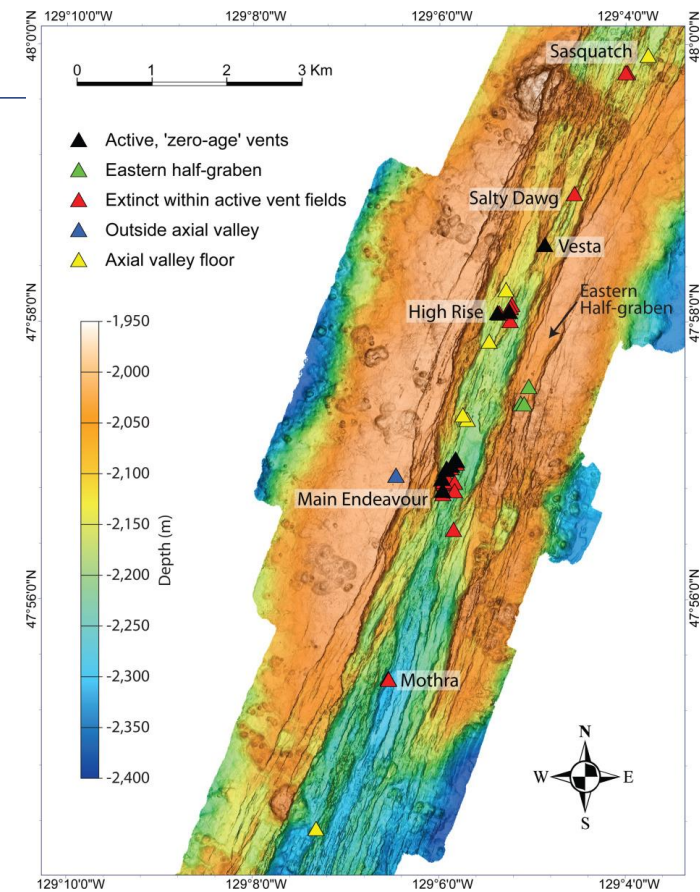
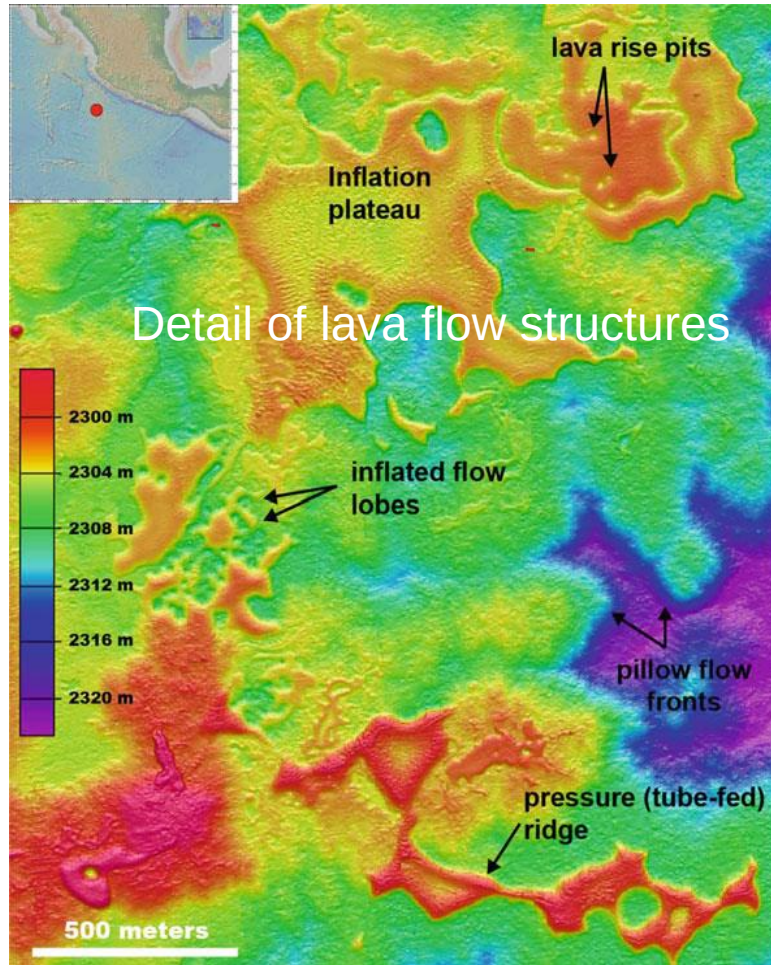


Source: GCOM



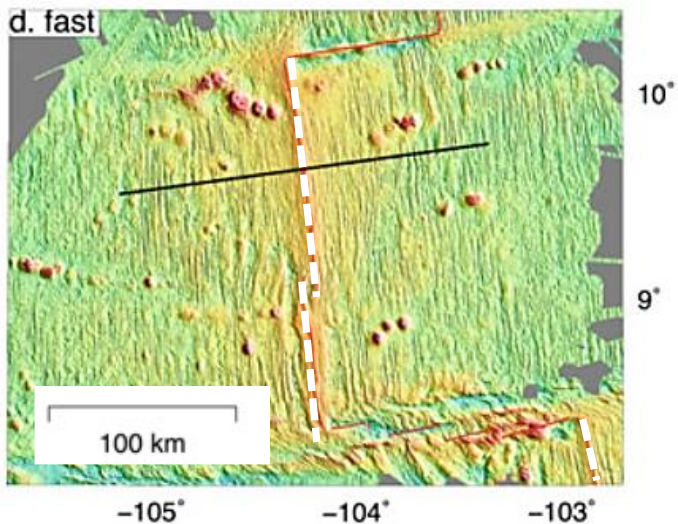
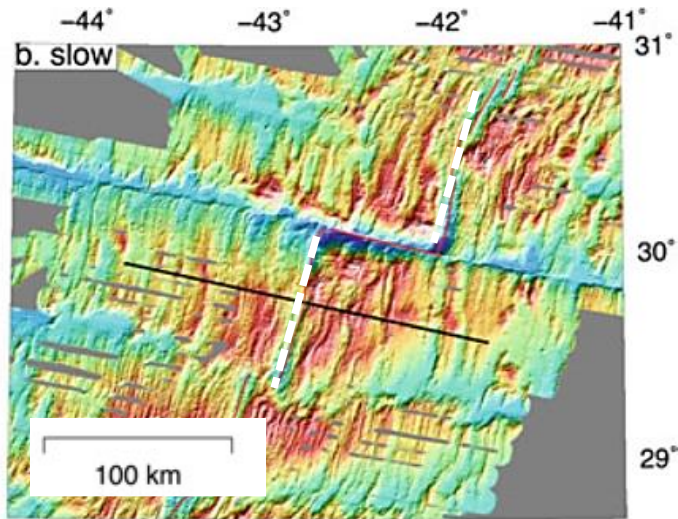
B – Mid-ocean ridges

- Volcanic, tectonic, hydrothermal and sedimentary processes sculpt geomorphology
- Erosion has only modestly affected these areas, so features can be well preserved



C – Abyssal hills and plains

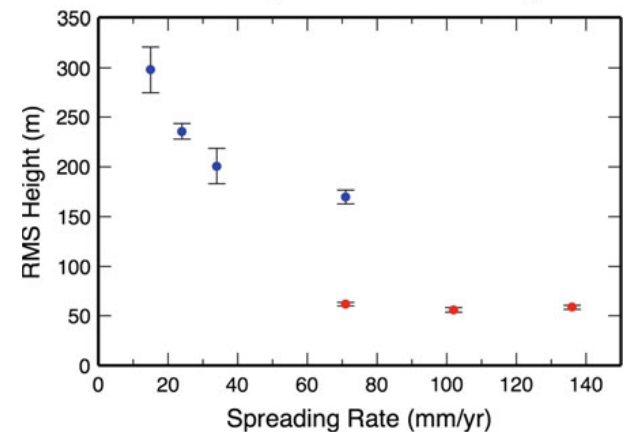
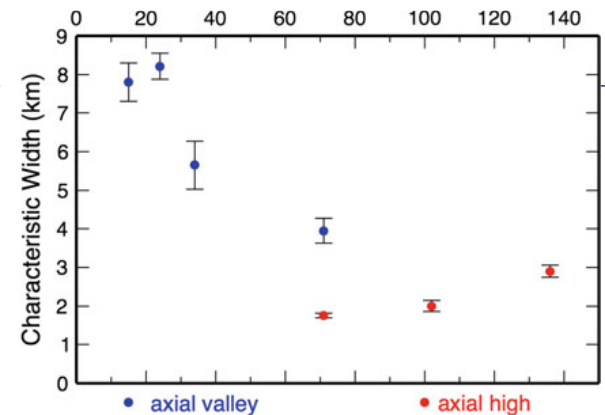
- Morphology due to extensional faulting...



- ... most abundant geomorphic structures on Earth

- Hill morphology sensitive to key aspects of seafloor

- The slower the spreading rate, the larger their dimensions
- Accretionary - thus preserves accurate records of changing spreading rate, lithospheric thermal structure, and plate boundary geometry

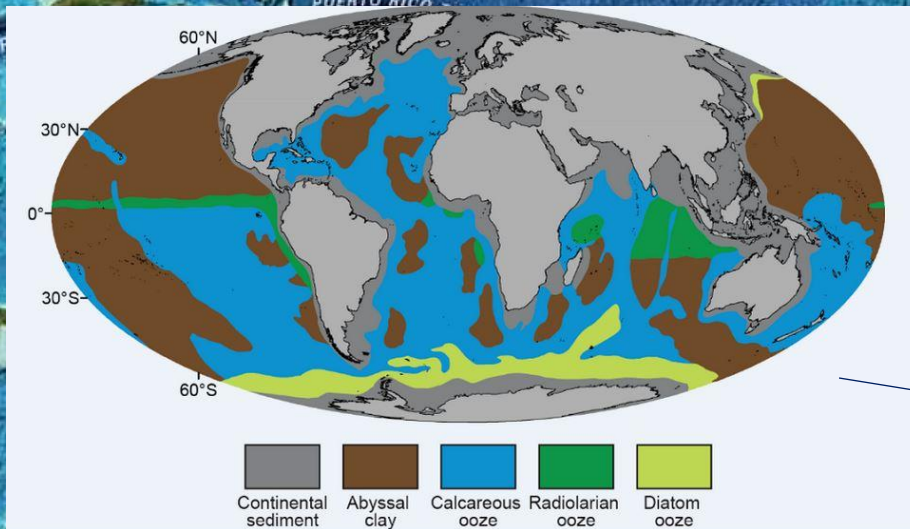


C – Abyssal hills and plains

- ... Spreading of the seafloor - **Abyssal plains** result from the blanketing of an originally uneven surface of oceanic crust by fine-grained sediments (clay & silt)

- Among the flattest, smoothest, and least explored regions on Earth - more than 50% of the Earth's surface

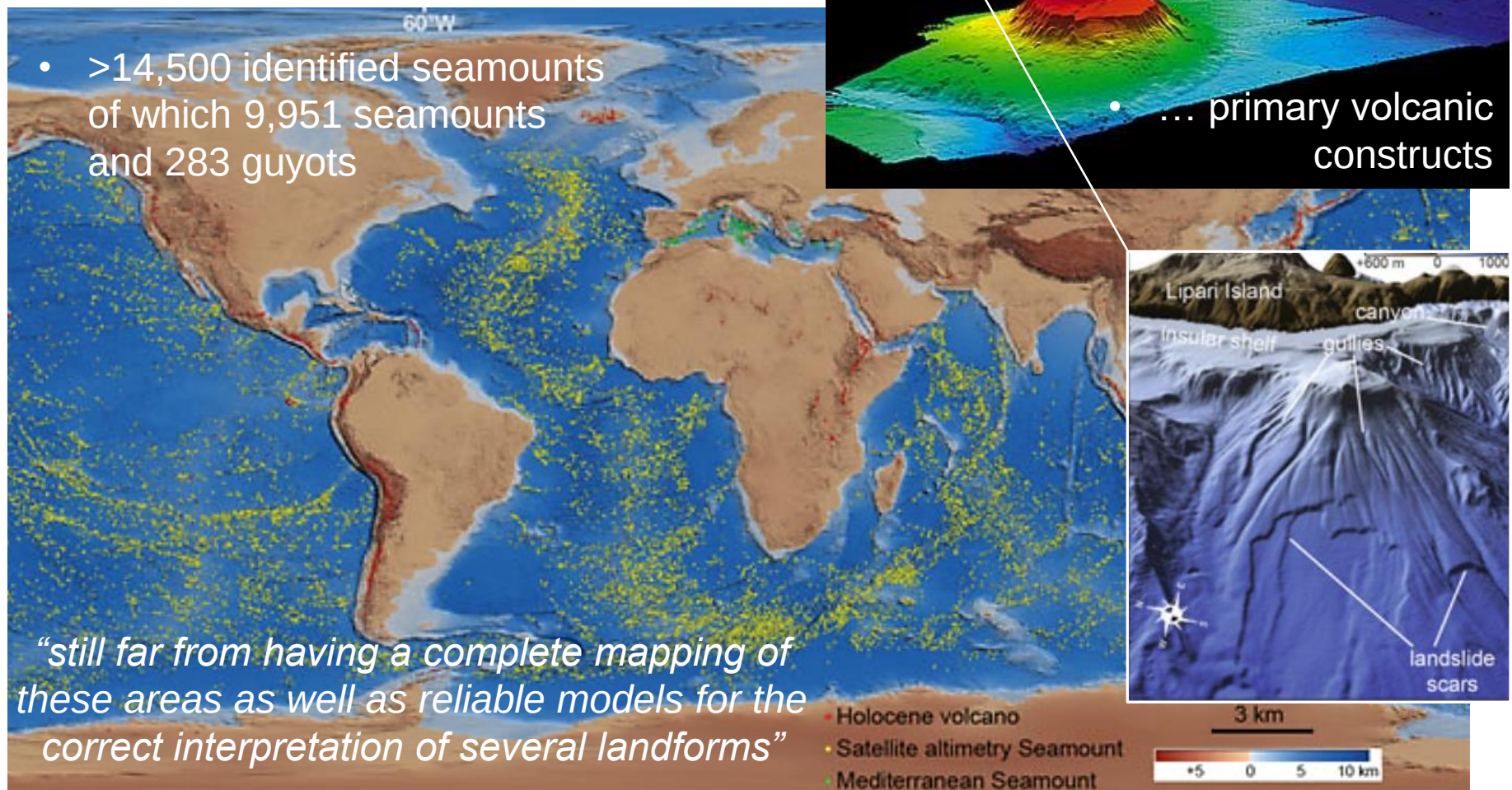
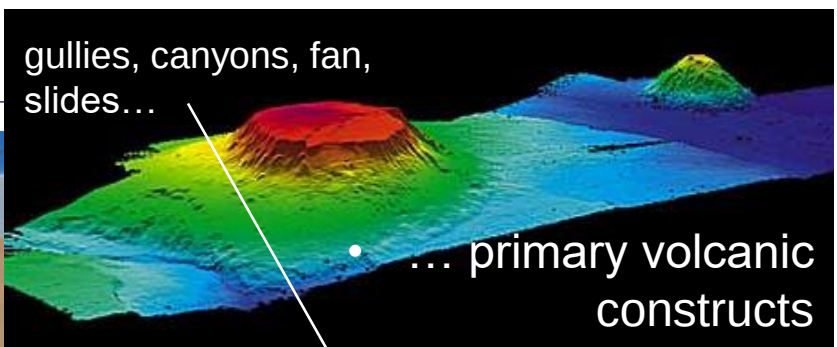
Between foot of a continental rise and a mid-ocean ridge



- The deep ocean floor is a graveyard with much of it made up of the remains of microscopic sea creatures called phytoplankton

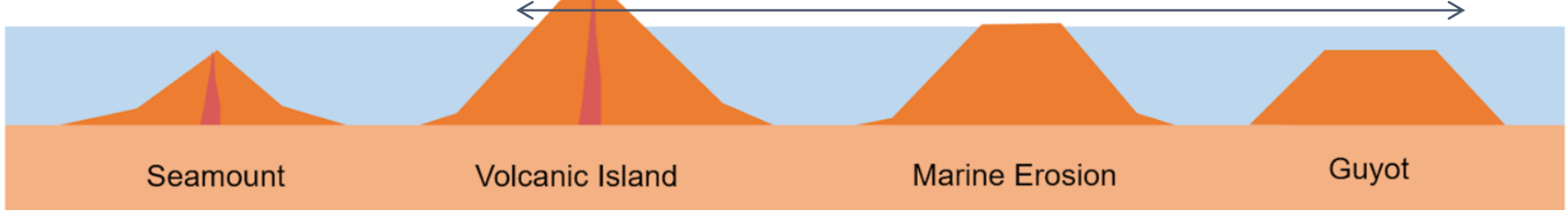
D – Seamounts...

- >14,500 identified seamounts of which 9,951 seamounts and 283 guyots



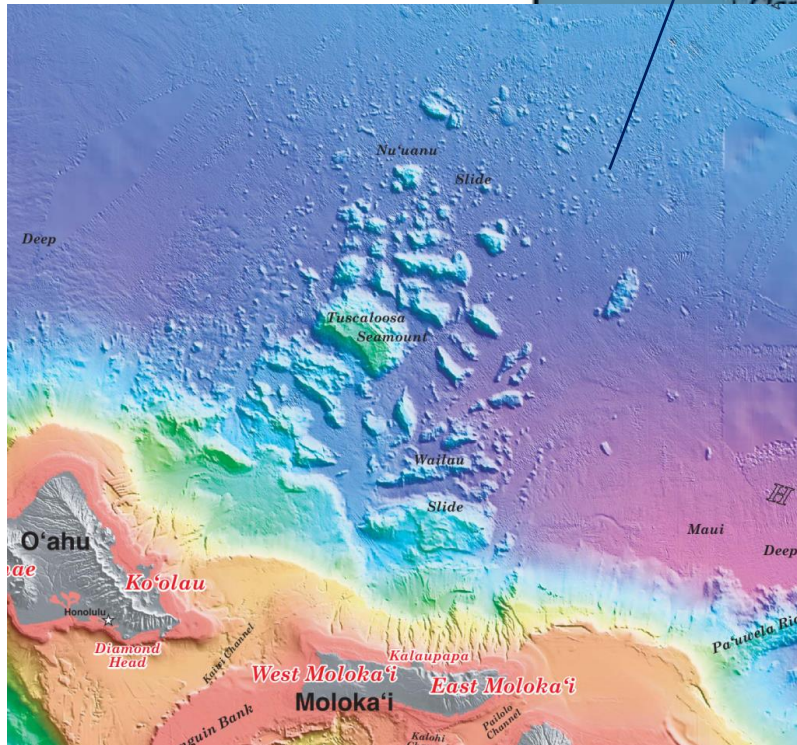
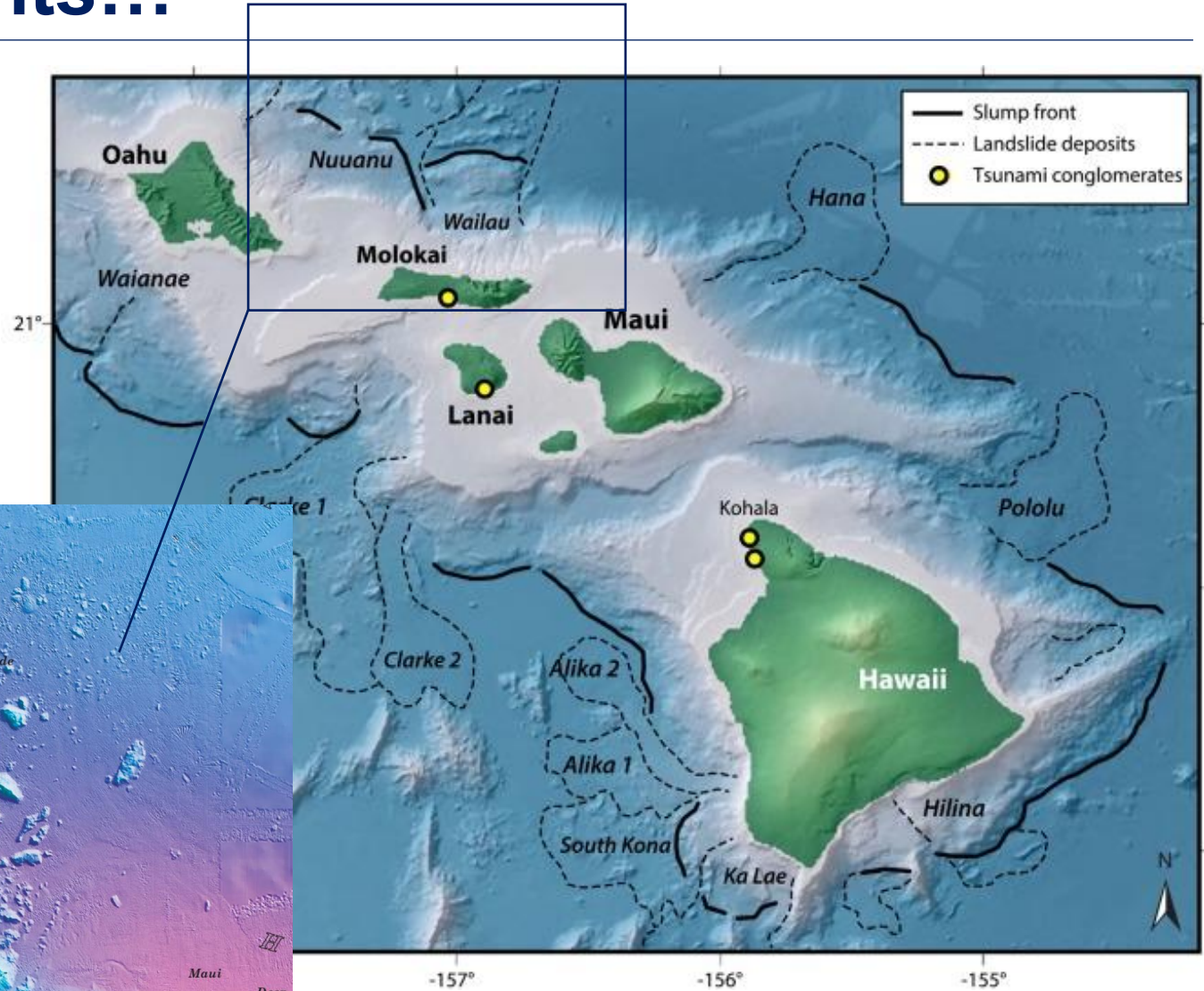
“still far from having a complete mapping of these areas as well as reliable models for the correct interpretation of several landforms”

wave erosion and sea-level fluctuations



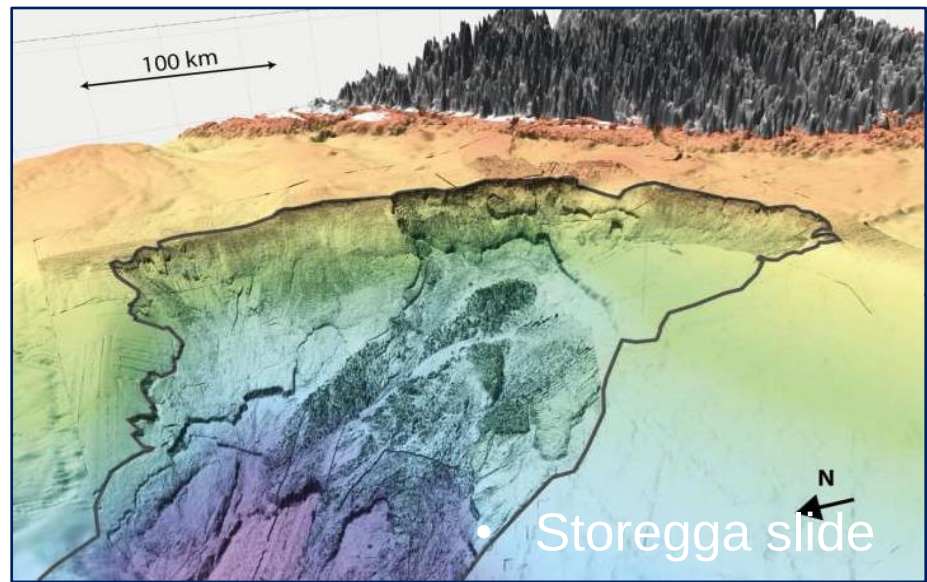
D – Seamounts...

- Eastern side of the three Koolau Complex volcanoes collapsed in the Nuuanu-Wailau landslide complex;

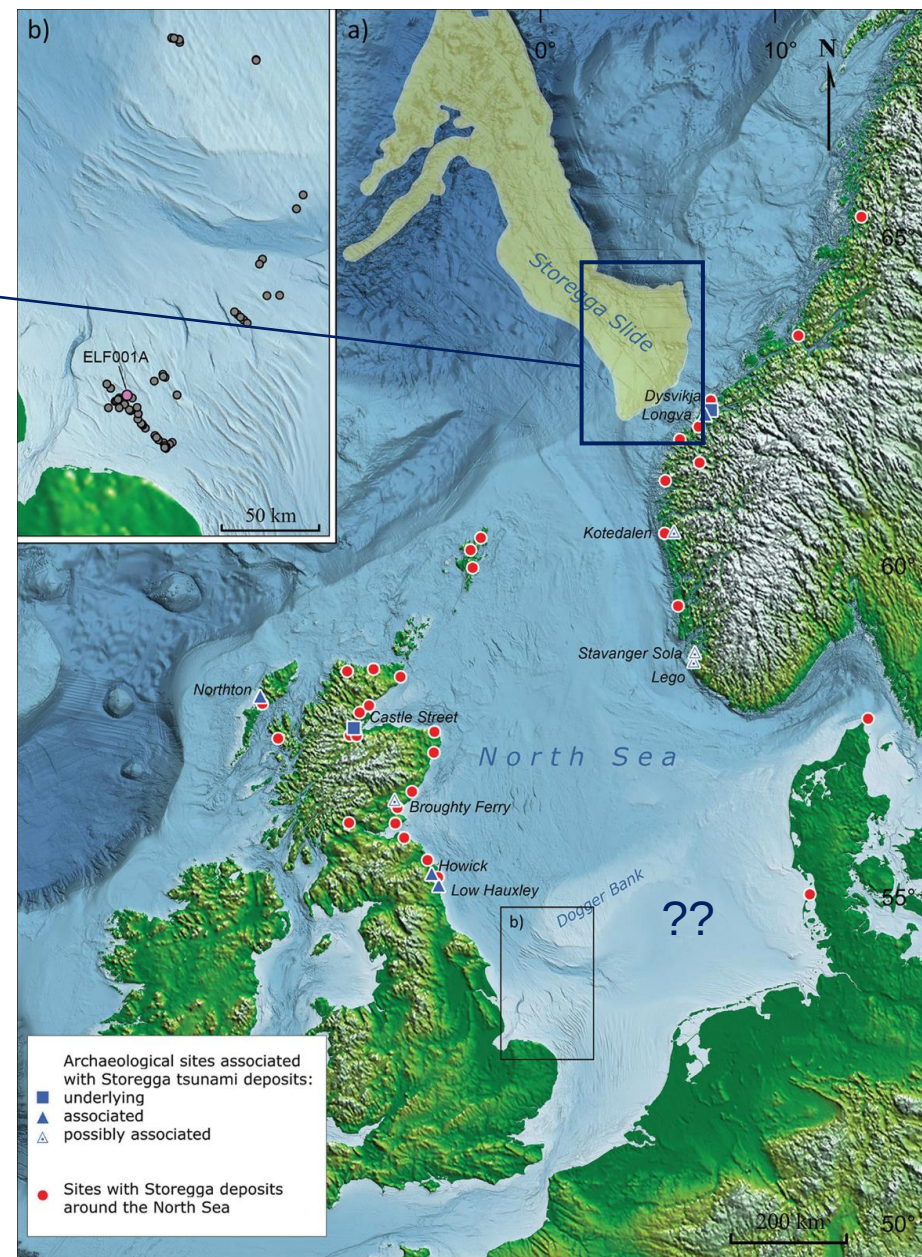


- With a volume of $\sim 7000 \text{ km}^3$ among largest on Earth
- Travelled more than 200 km from the island

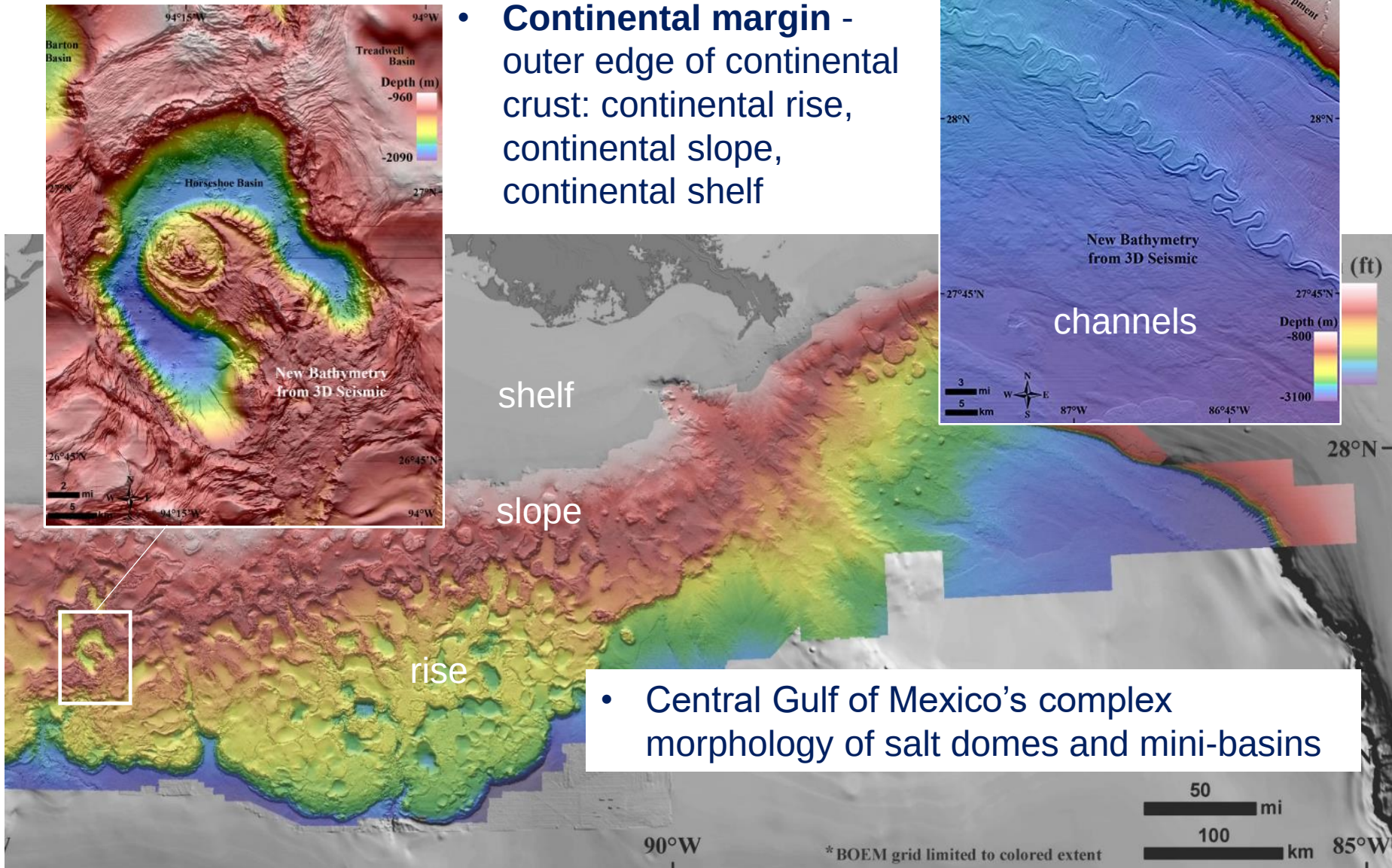
D – Submarine landslides...



- Storegga tsunami is 7320 ± 20 14C yr BP



D – Continental Margins



D – Continental Margins

- **Submarine Canyon:** Steep-sided valley cut into the seabed of the continental slope, sometimes extending well onto the continental shelf, having nearly vertical walls, and occasionally having canyon wall heights of up to 5 km

- 9,477 submarine canyons, covering about 11% of the ocean floor

coastal plain

continental shelf

continental slope

The ROV experiences a 'black out' as it is encased within the relatively dense basal layer.

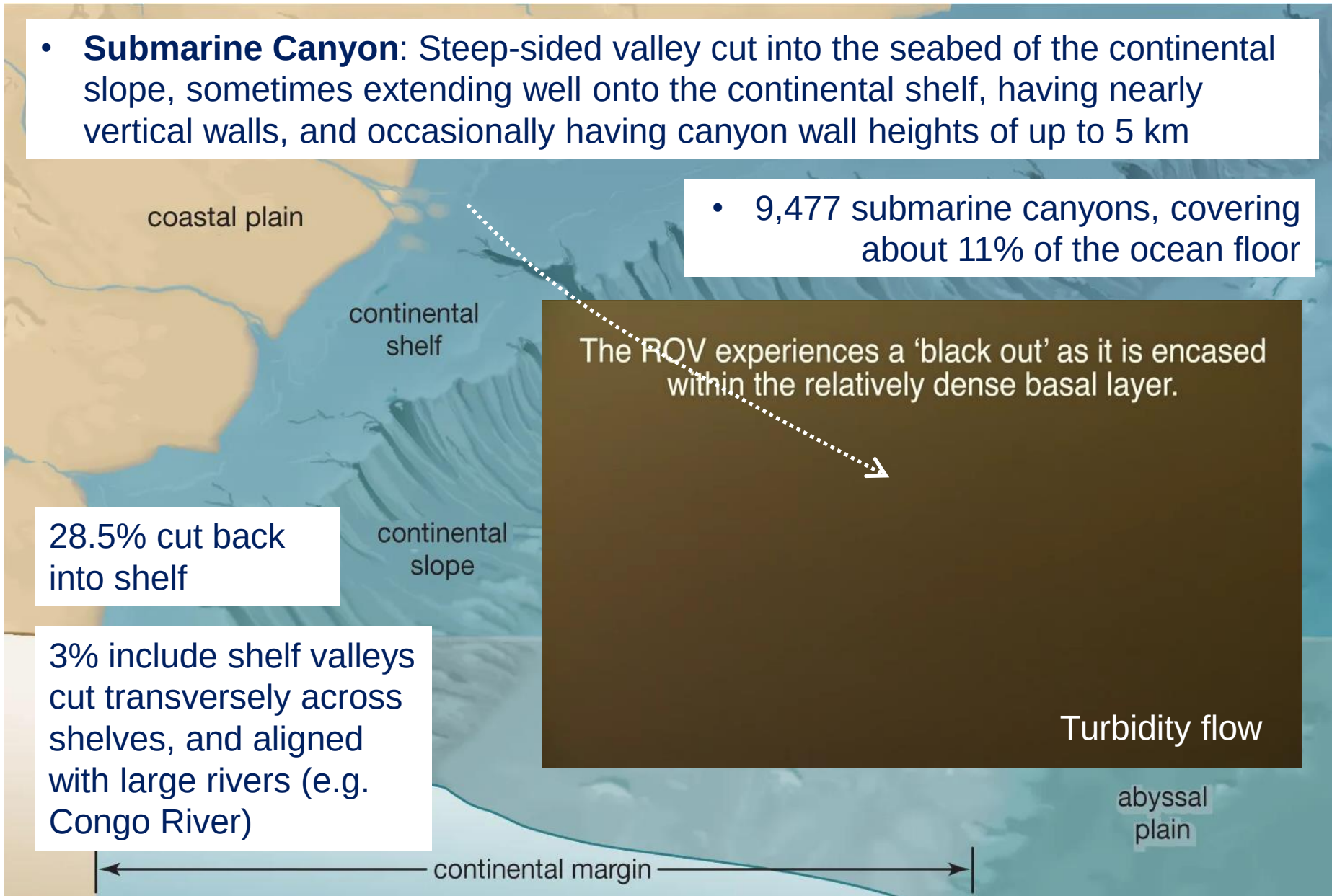
28.5% cut back into shelf

3% include shelf valleys cut transversely across shelves, and aligned with large rivers (e.g. Congo River)

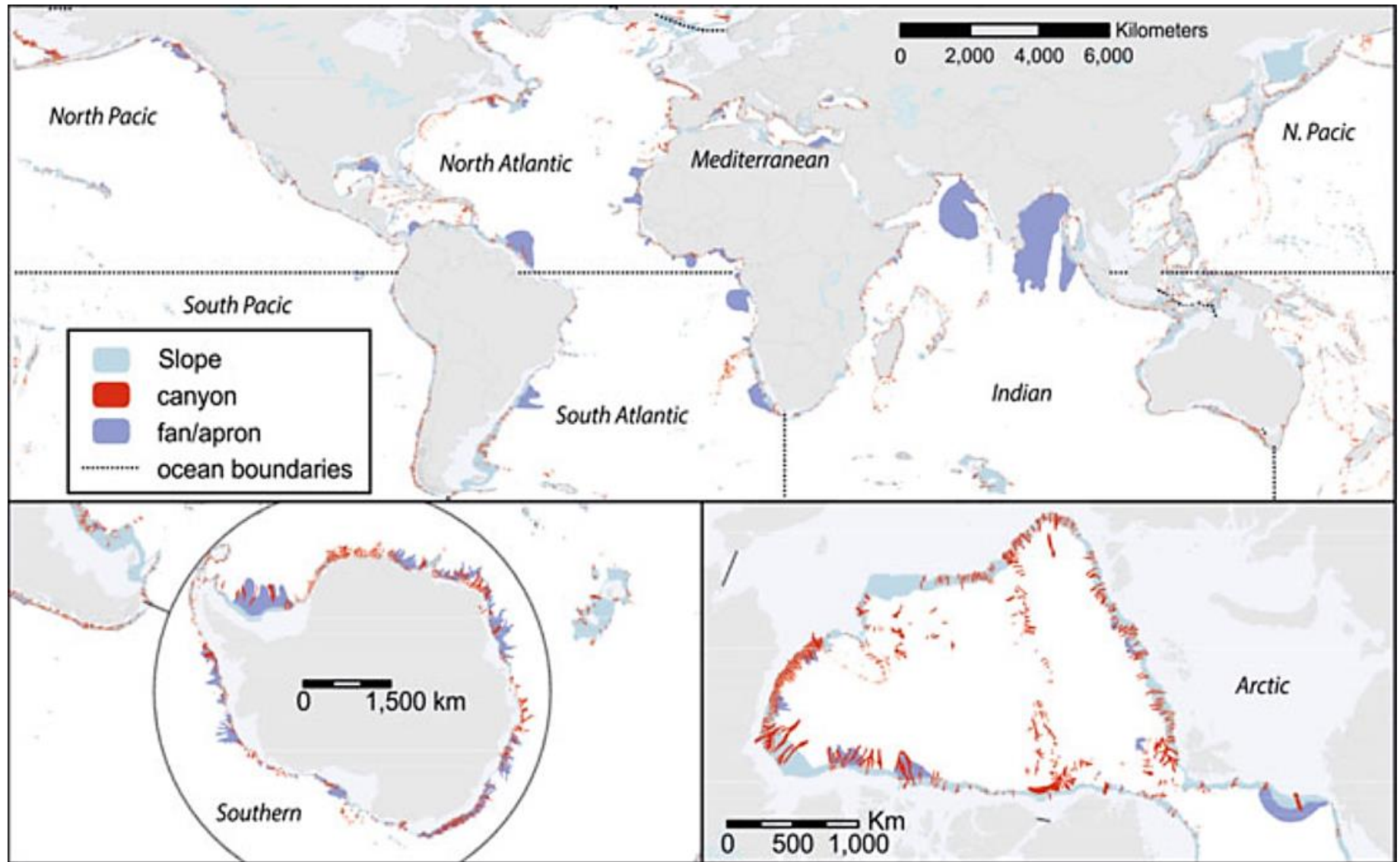
Turbidity flow

abyssal plain

continental margin

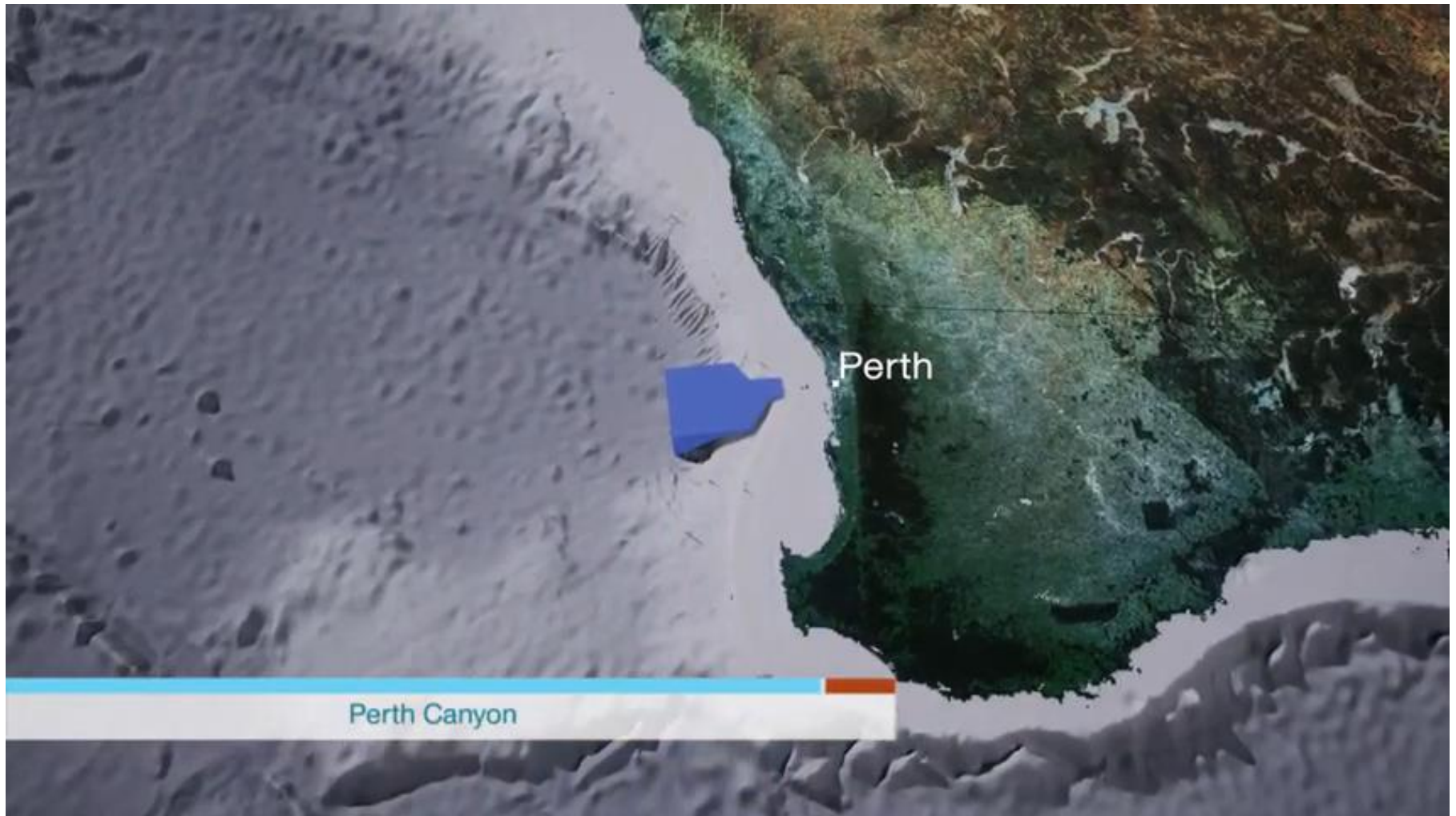


D – Continental Margins



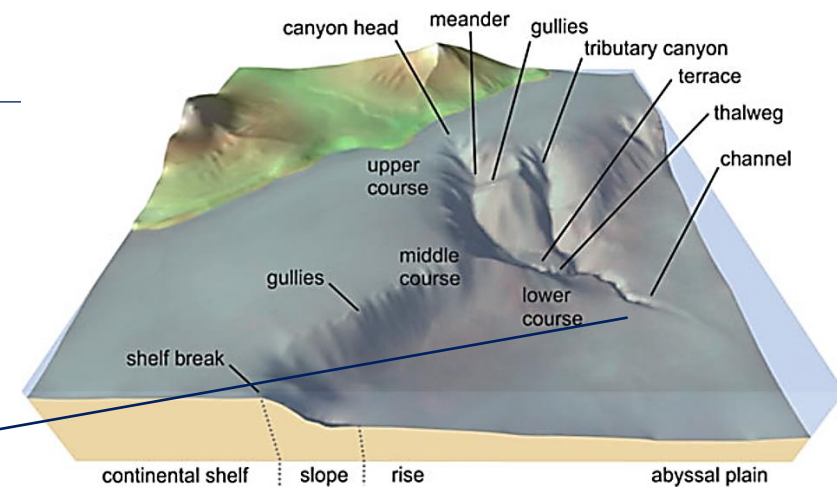
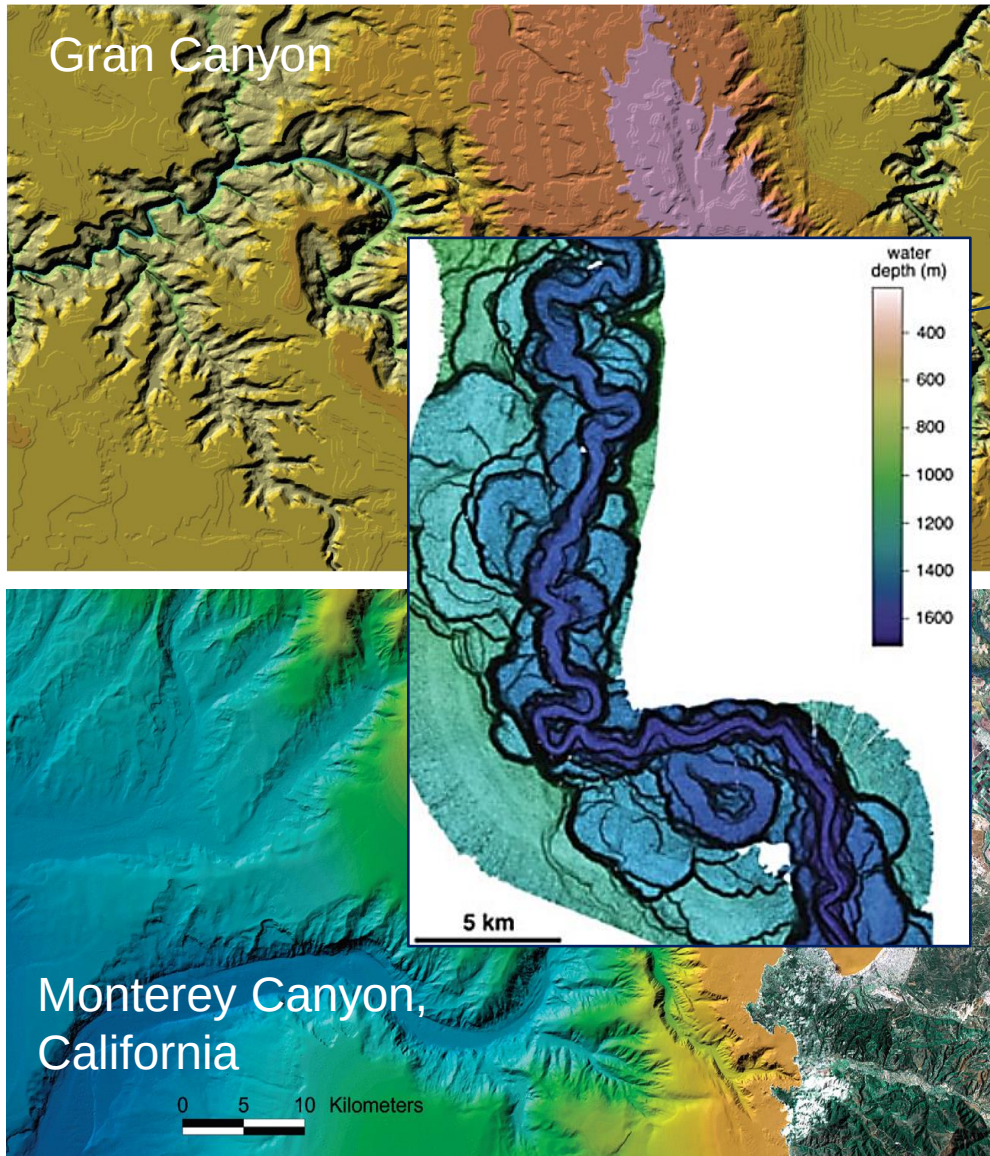
<https://www.youtube.com/watch?v=BO-Ed2EPZZ4>

D – Continental Margins



<https://www.youtube.com/watch?v=BO-Ed2EPZZ4>

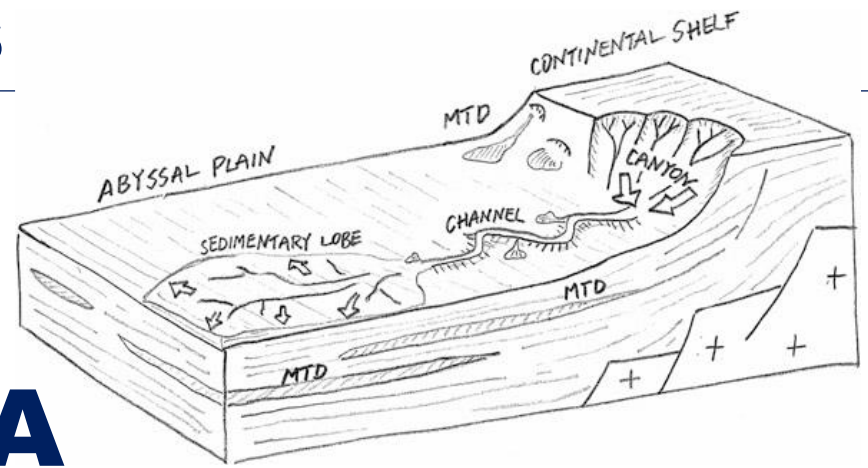
D – Continental Margins



- Canyon head with distinct rim
- Upper: meandering, deeply incised and V-shaped (steep walls with gullies and slide scars)
- Middle: smoother and U-shaped
- Lower: low relief, transition to ... channel confined by **depositional** levées... fan apron
- Sediment deposits formed less than 2.6 million years ago and canyon head is possibly only 21,000 years old

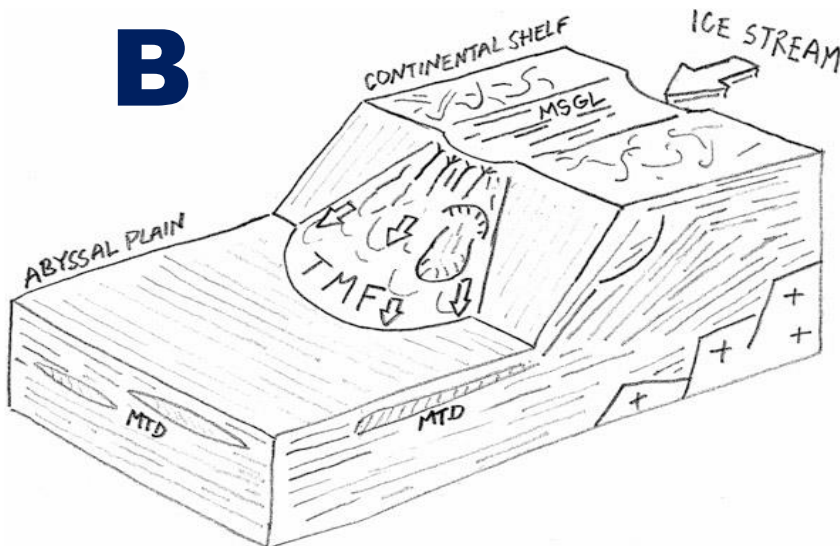
D – Continental Margins

- Deep sea channels (incl. levées) convey sediments from shelf to abyssal plain via turbidity currents (e.g. in canyons)
- At mouth of the channels deposition occurs in large, subdued sedimentary lobes.
- Slope failure determines the deposition of **mass transport deposits** (MTD) characterizing slope and abyssal plains



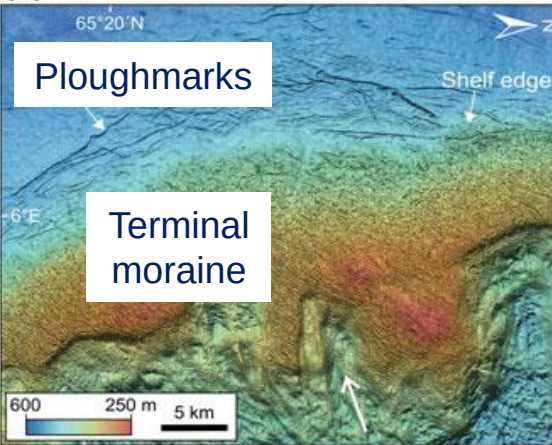
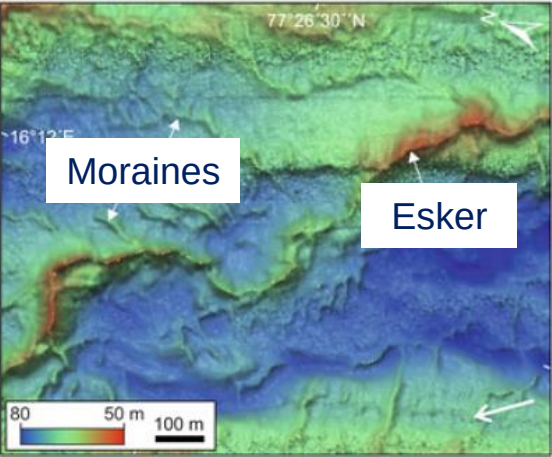
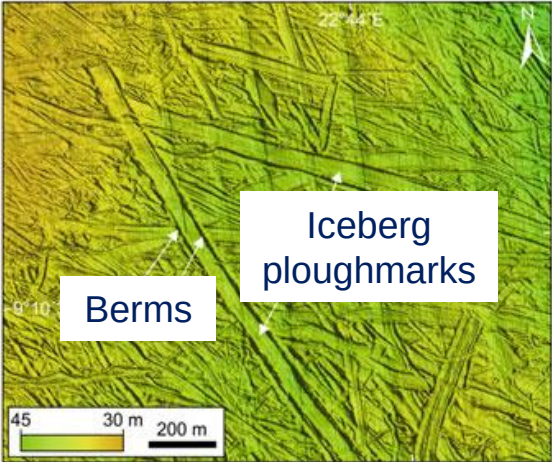
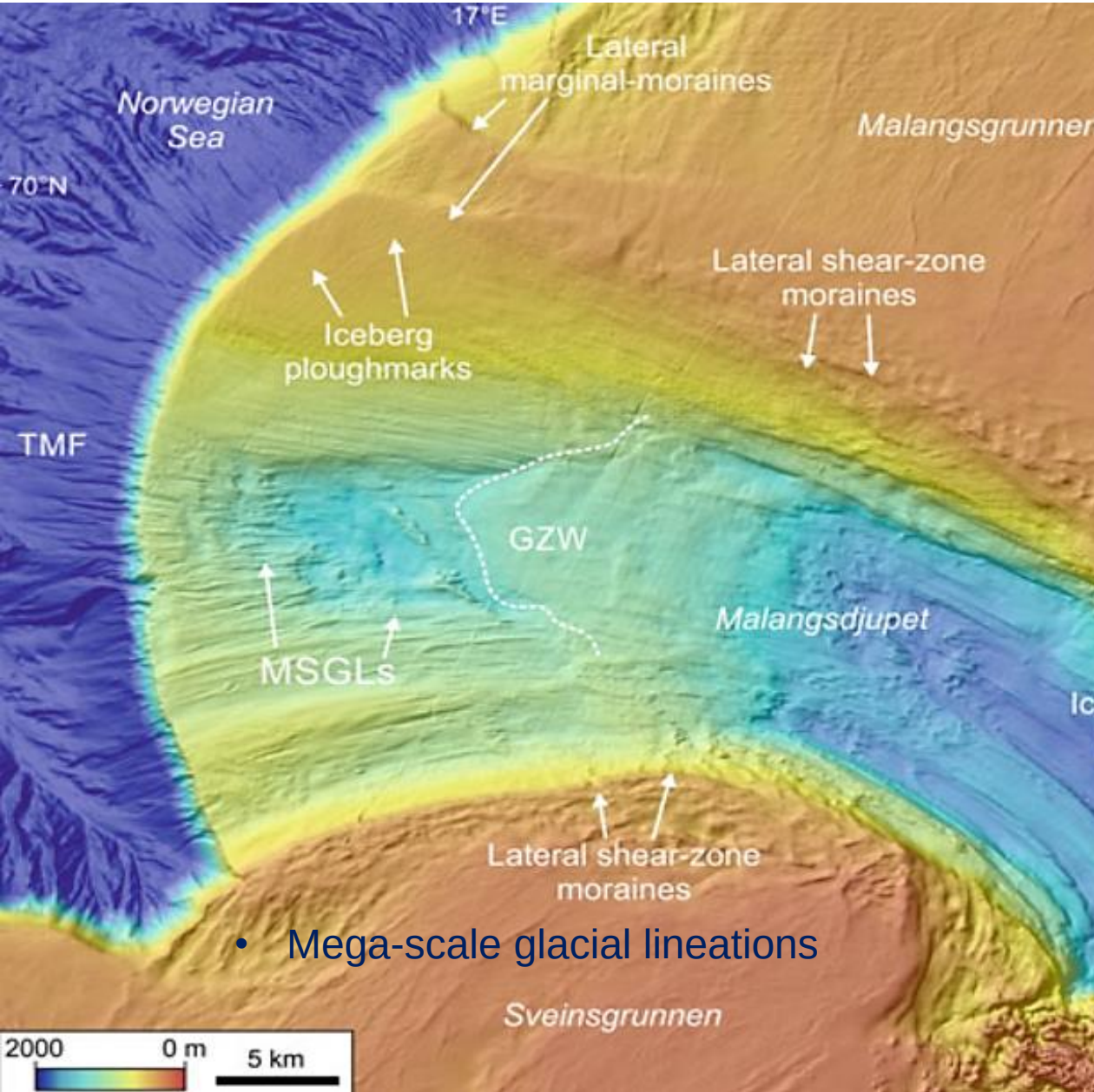
A

- Polar latitudes: driver for sediment here are ice streams - ice thickness allows for grounding of the ice below sea level
- Leaves impressive **mega-scale glacial lineations (MSGSL)** on sea floor out to continental shelf break
- Sediment transferred down continental slope via dense debris flows forming **trough-mouth fans (TMF)**
- Collapsing TMFs favour MTDs
- Massive sediment input does not allow for the formation of deep sea canyons (but may create short-lived gullies)

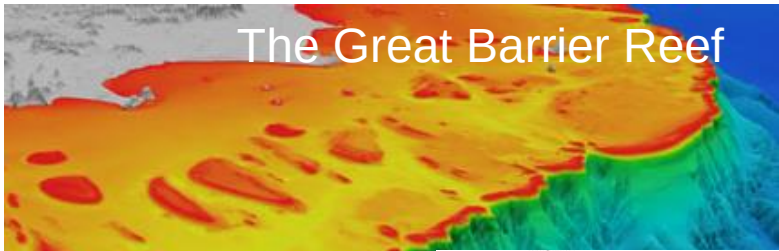


B

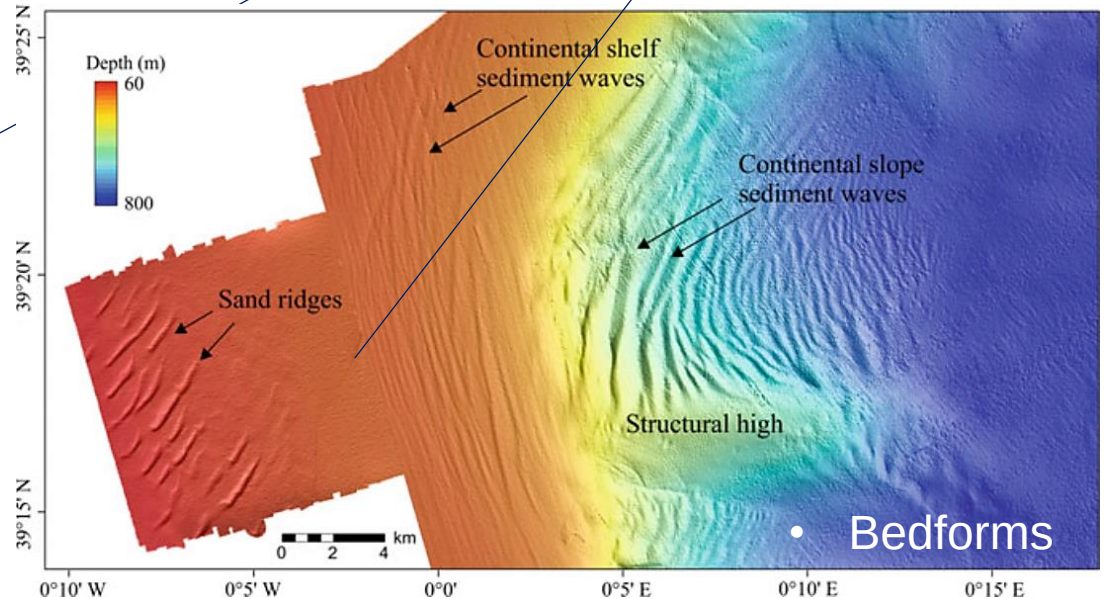
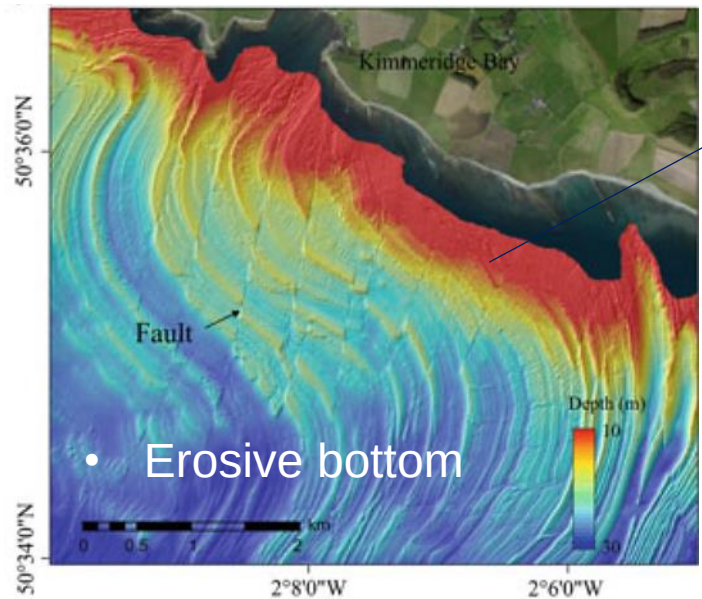
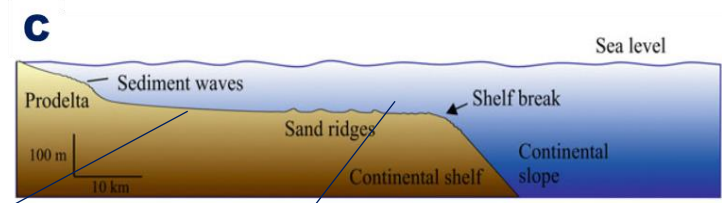
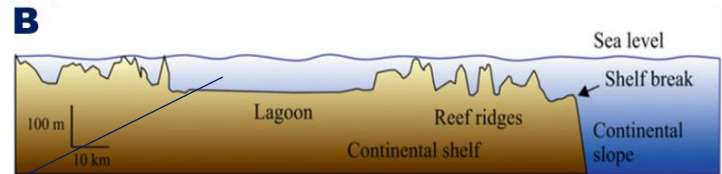
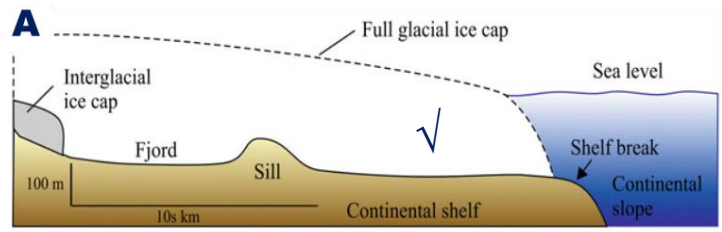
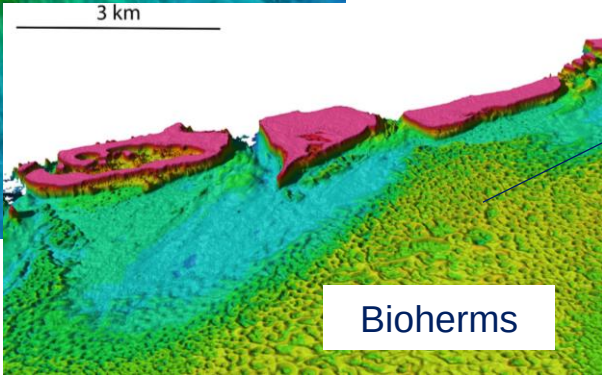
D – Continental Margins



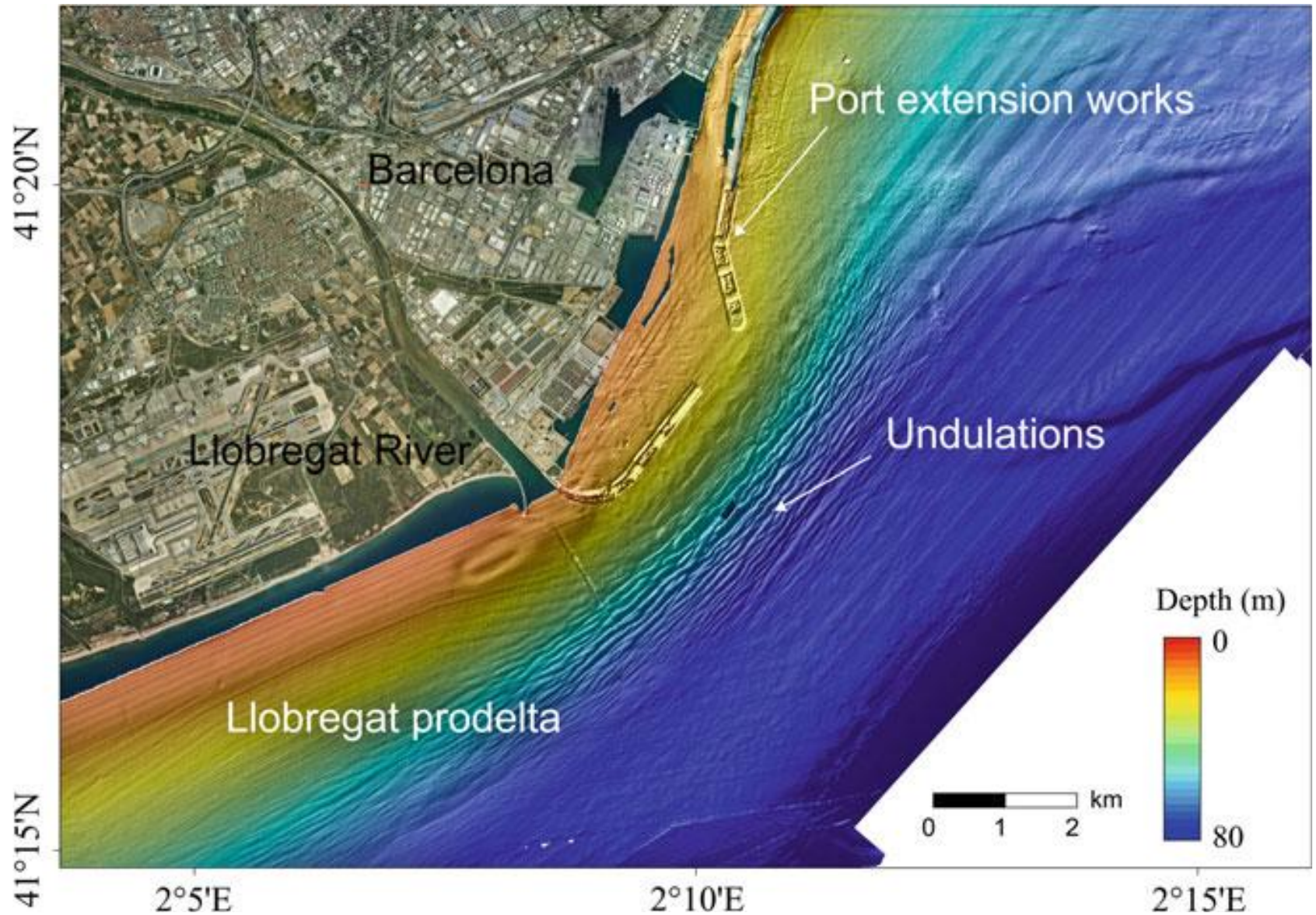
D – Continental Shelf...



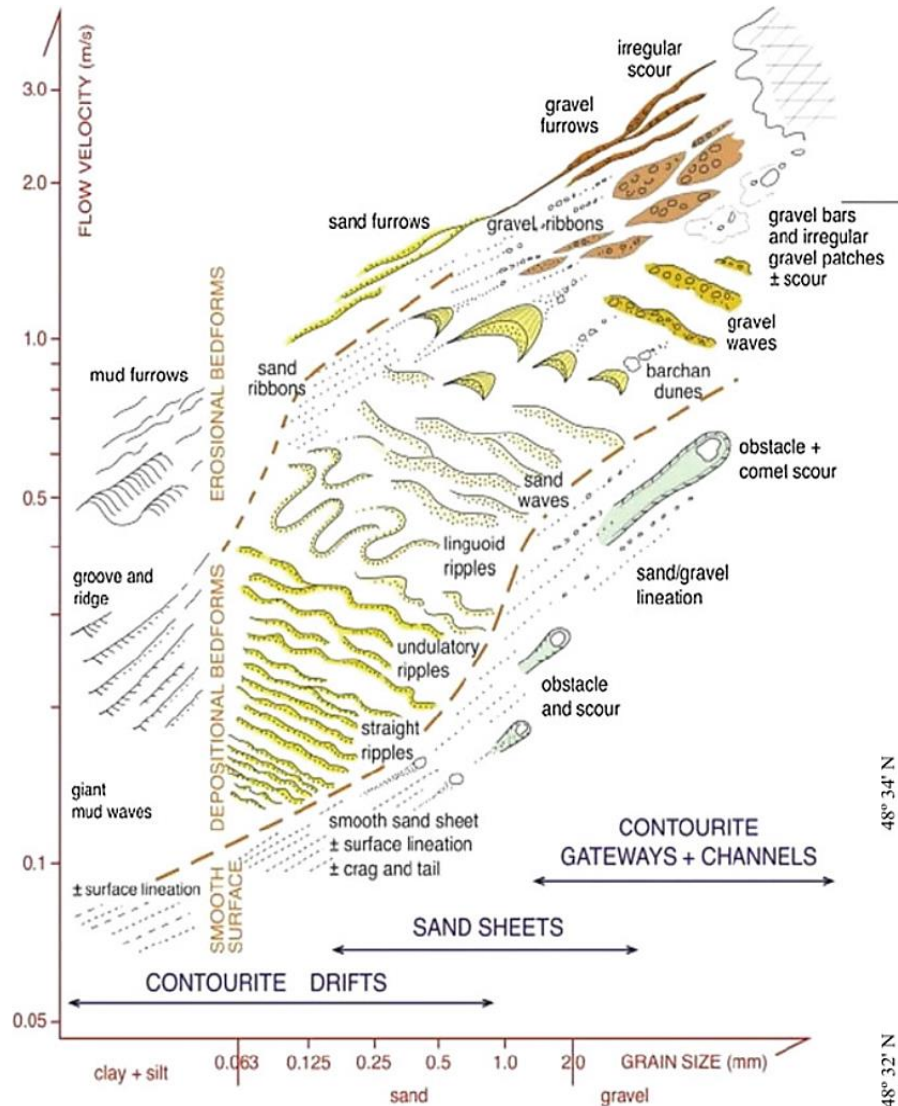
- Reefs



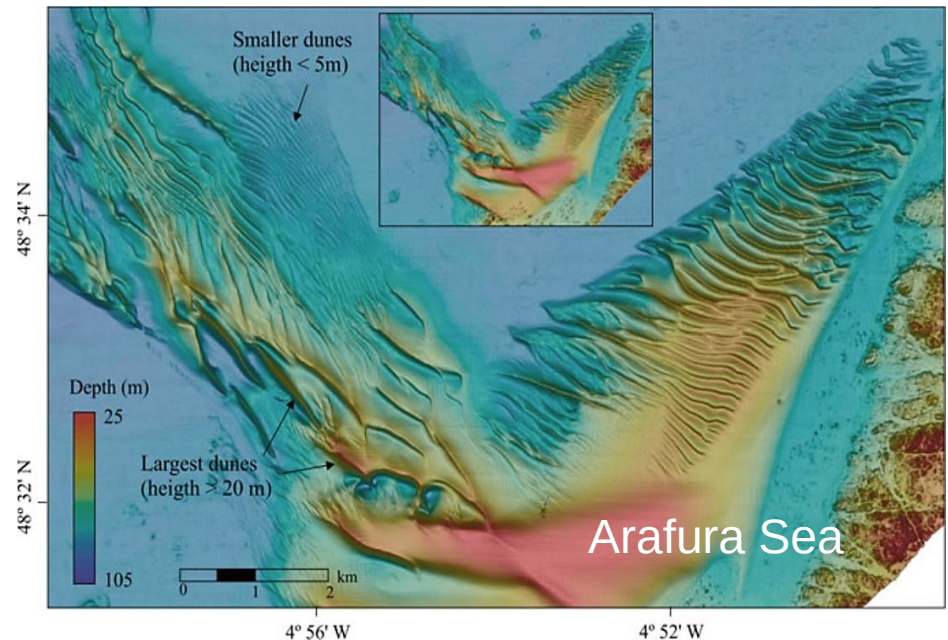
D – Continental Shelf...



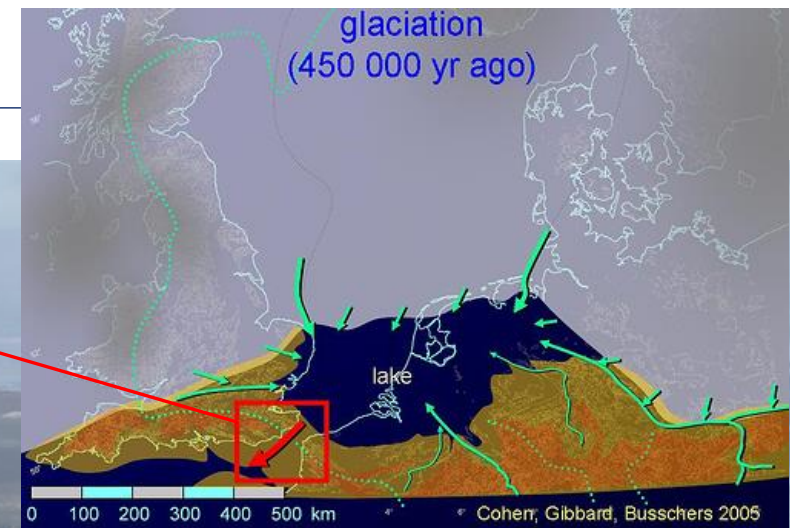
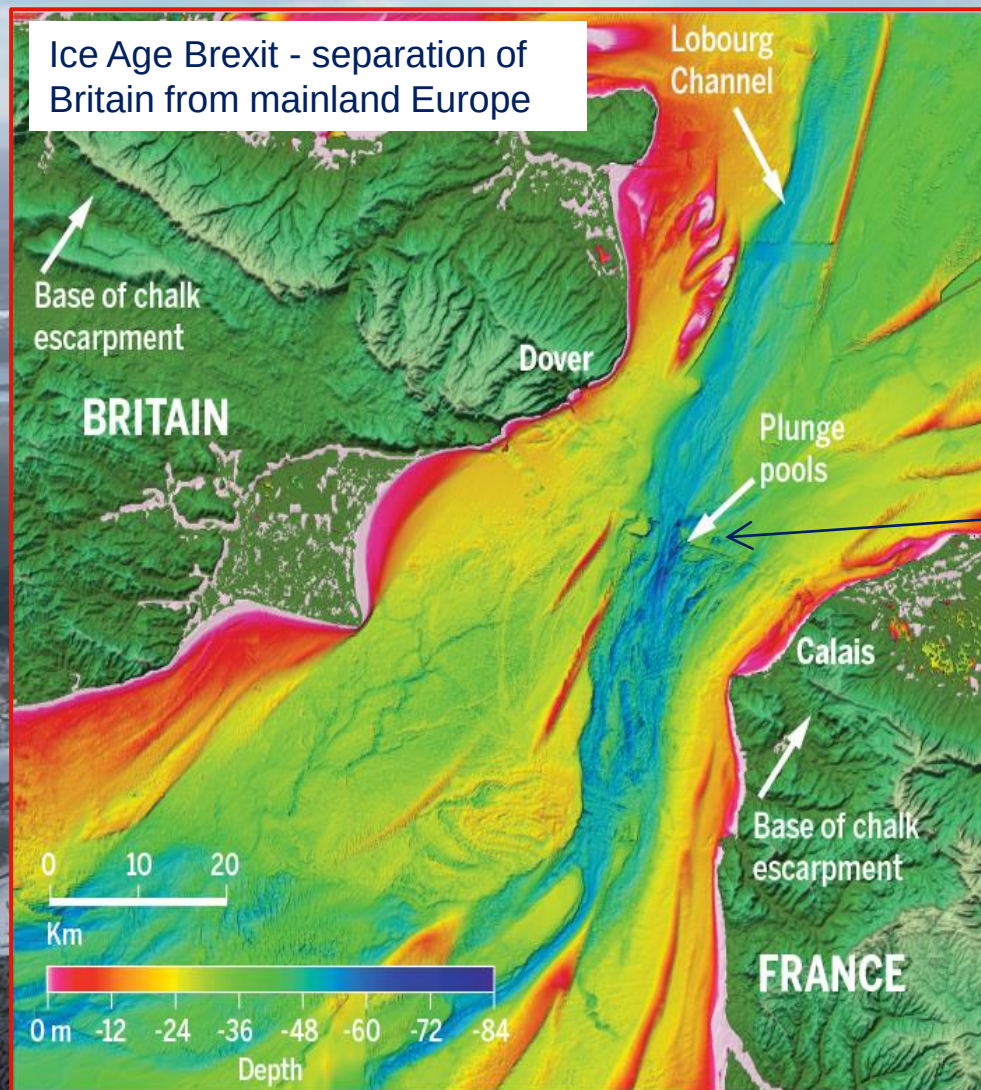
D – Continental Shelf



- Large range of depositional and erosive bedforms associated with bottom currents in deep water - with indication of where different bedforms occur (drifts, sand sheets, gateways and channels).
- The bedforms are controlled in part by **flow velocity** (y-axis) and in part by **grain size** of the sediment (x-axis)

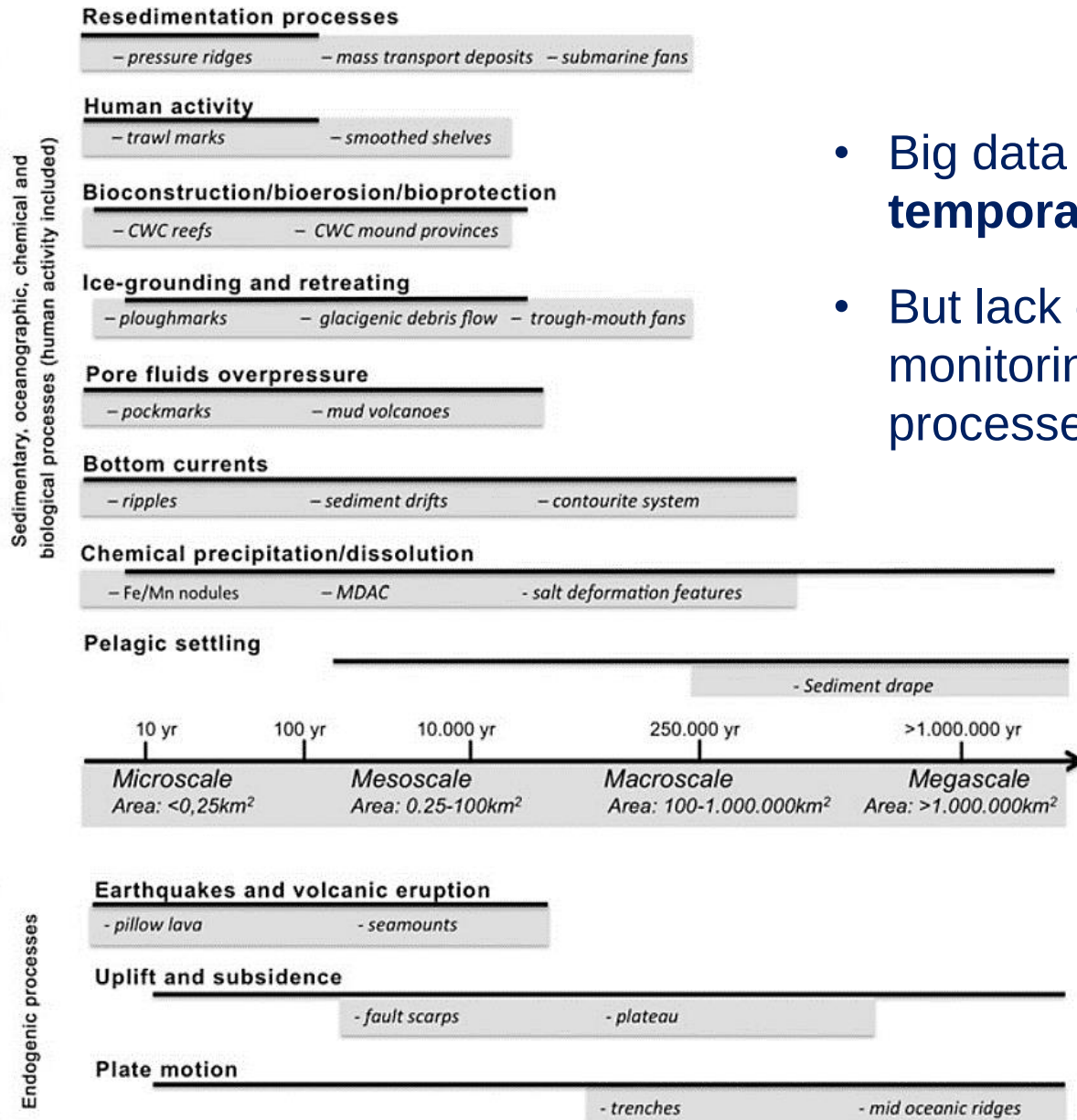


D – Continental Shelf



- Sediment-infilled depressions deeply incised into bedrock = giant **plunge pools**
- Spill-over of large proglacial lake...
- ... caused breach of **rock ridge** in two erosive episodes
- ... by waterfalls and subsequent dam breaching
- Large-scale re-routing of NW European drainage

Conclusions



- Big data at **multiple spatio-temporal scales**
- But lack of direct observation and monitoring of geomorphic processes
- Lots can be learned from submarine landscapes via interaction with subaerial geomorphology and geomorphologists...