Università di Trieste
LAUREA MAGISTRALE IN GEOSCIENZE
Curriculum Geofisico
Curriculum Geologico Ambientale

Anno accademico 2019 – 2020

Geologia Marina

2019-20

Modulo 6.2 Pericolosità dei fondali sottomarini

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OUTLINE

- Concepts of hazard, vulnerability, risk, mitigation, resilience
- Natural marine geohazards
- The use of integrated acoustic methods ….
- …and examples of geohazard assessment in the Ionian sea

HAZARD

VULNERABILITY

RISK

MITIGATION

RESILIENCE

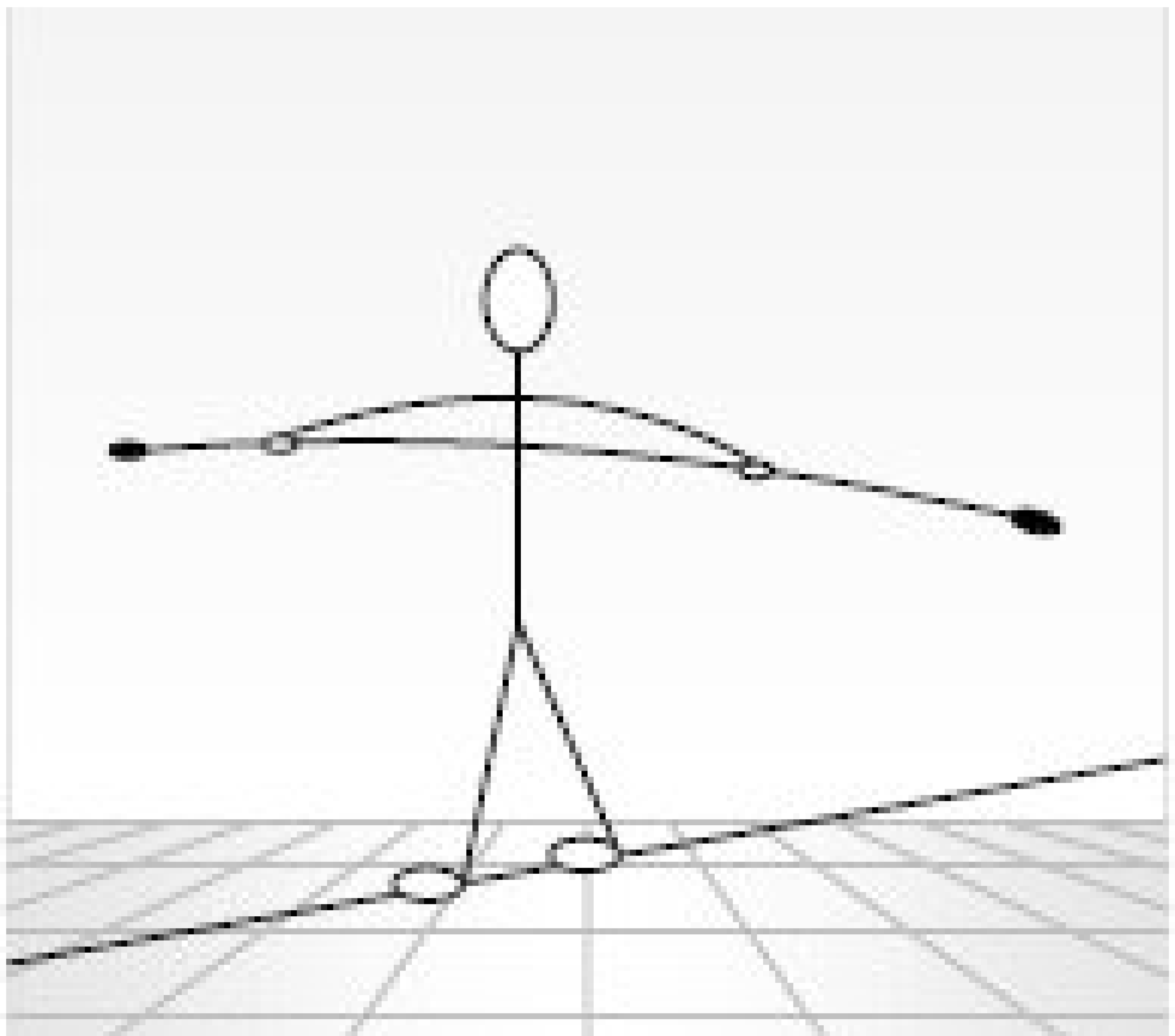
HAZARD: Is an **event** posing a threat to life, health, property or environment. Hazard assessment is the evaluation of the occurrence of a potentially damaging event, (where, when, how frequently, magnitude). The **identification of hazards** is the first step in performing **hazard assessment**

VULNERABILITY: is the **probability of being damaged** by a specific event (hazard)

RISK: is the **probability that exposure to a specific hazard will cause harm**. Thus, a hazard poses no risk if there is not exposure to that hazard

Risk = Hazard x Vulnerability

Risk and Mitigation



The **concept of *risk*** *is illustrated by the tightrope walker. In this example, the risk to the tightrope walker is falling off and getting killed—a high-risk activity!*

*If the highwire is only one meter above the ground the falling hazard still exists and the **chance of falling remains constant**, but the risk is considerably different than if the person were 100 metres above the ground.*

*Perhaps there is a crowd below the tightrope walker vulnerable to injury. The severity of impact to the tightrope walker and the crowd can be **mitigated** by a safety net, the chance of falling can be reduced by special training and the extent of injury can be mitigated by emergency medical response capability.*

Risk = Hazard x Vulnerability

Resilience

Japanese Earthquake Highway Repair

- Earthquake: March 11 2011
- Repair begun: March 17 2011
- Road ready: March 22 2011 (six days later)

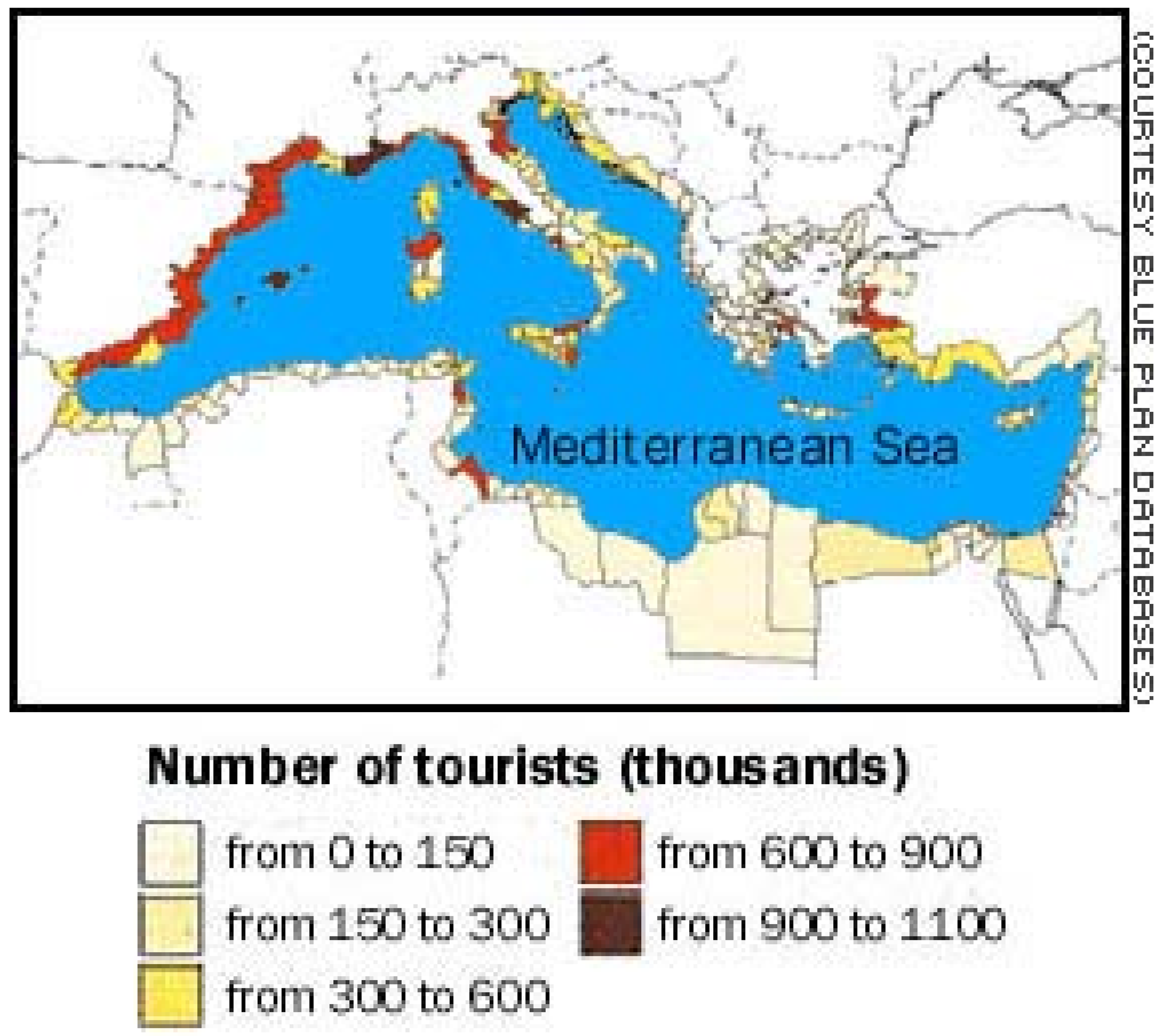
By Mail Foreign Service, 02:01 GMT, 24 March 2011

RESILIENCE: community's capacity to cope with and recover from impacts of natural hazards.

Risk = (Hazard x Vulnerability) - Resilience

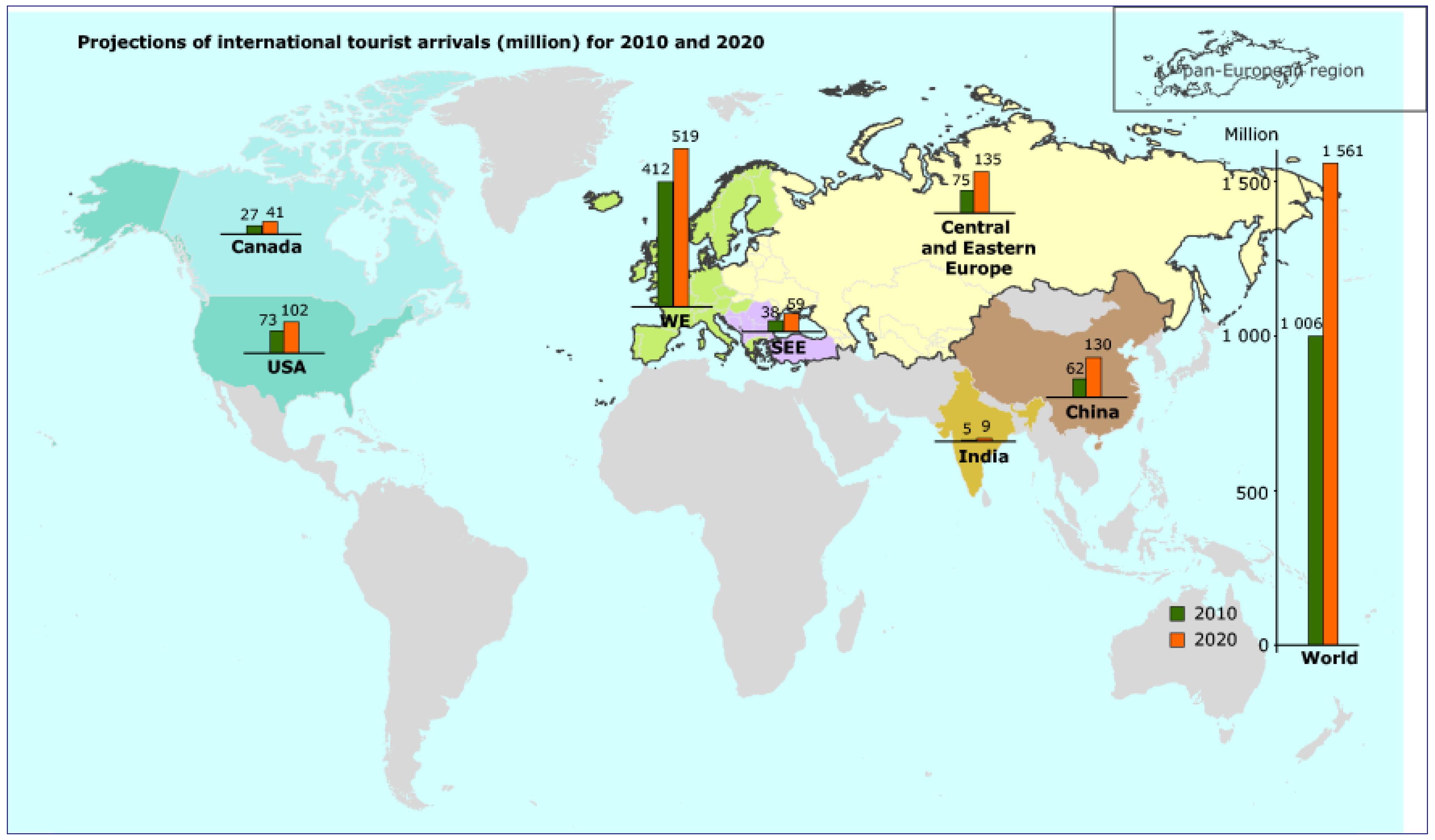
- **Very densely-populated coastline**: 160 million inhabitants sharing 46,000 km of coastline (**3.5 inhabitants per m of coastline**).

- **World's leading holiday destination**, receiving up 30% of global tourism and an average of 135 million visitors annually; this is predicted to increase to 235-350 million tourists by year 2025 (European Environmental Agency - EEA).



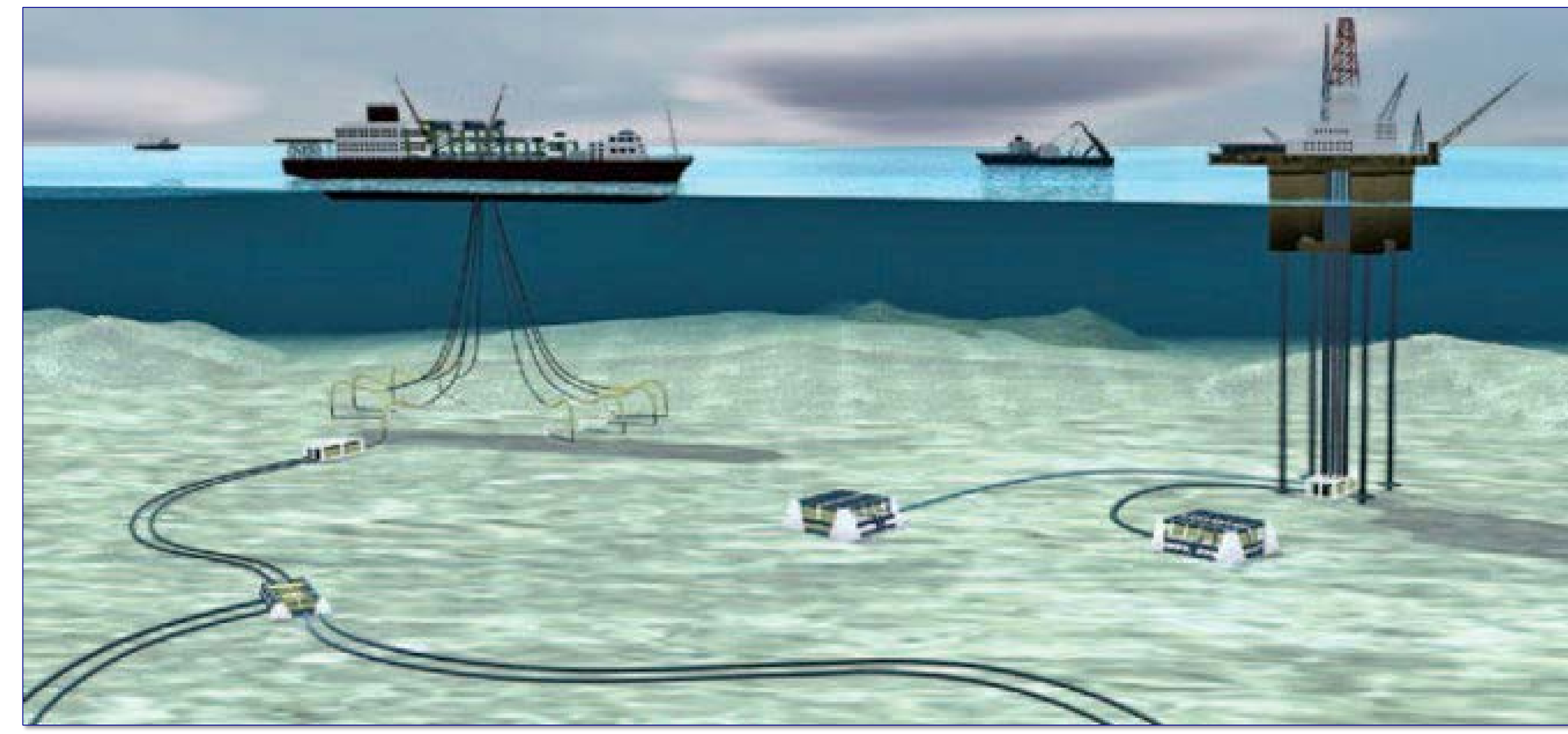
"By 2025, the annual crowd will soar to anywhere from 235 to 350 million tourists, according to the EEA."

Mediterranean tourism takes its toll. By Environmental News Network (ENN) March 14, 2000; http://archives.cnn.com/2000/NATURE/03/14/mediterranean.enn/index.html



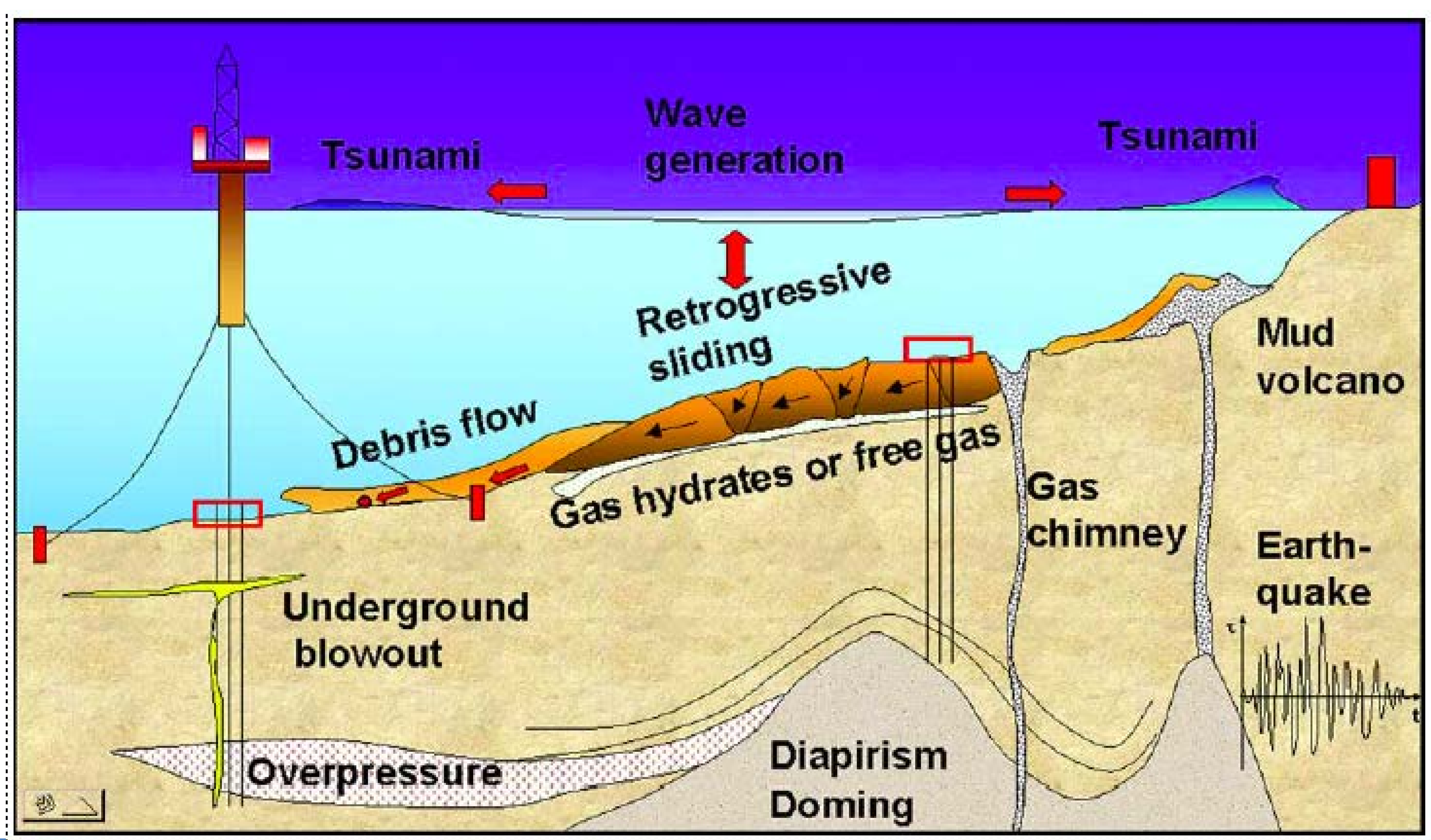
EEA web site http://www.eea.europa.eu
Copyright EEA, Copenhagen.

VULNERABILITY OF OFFSHORE

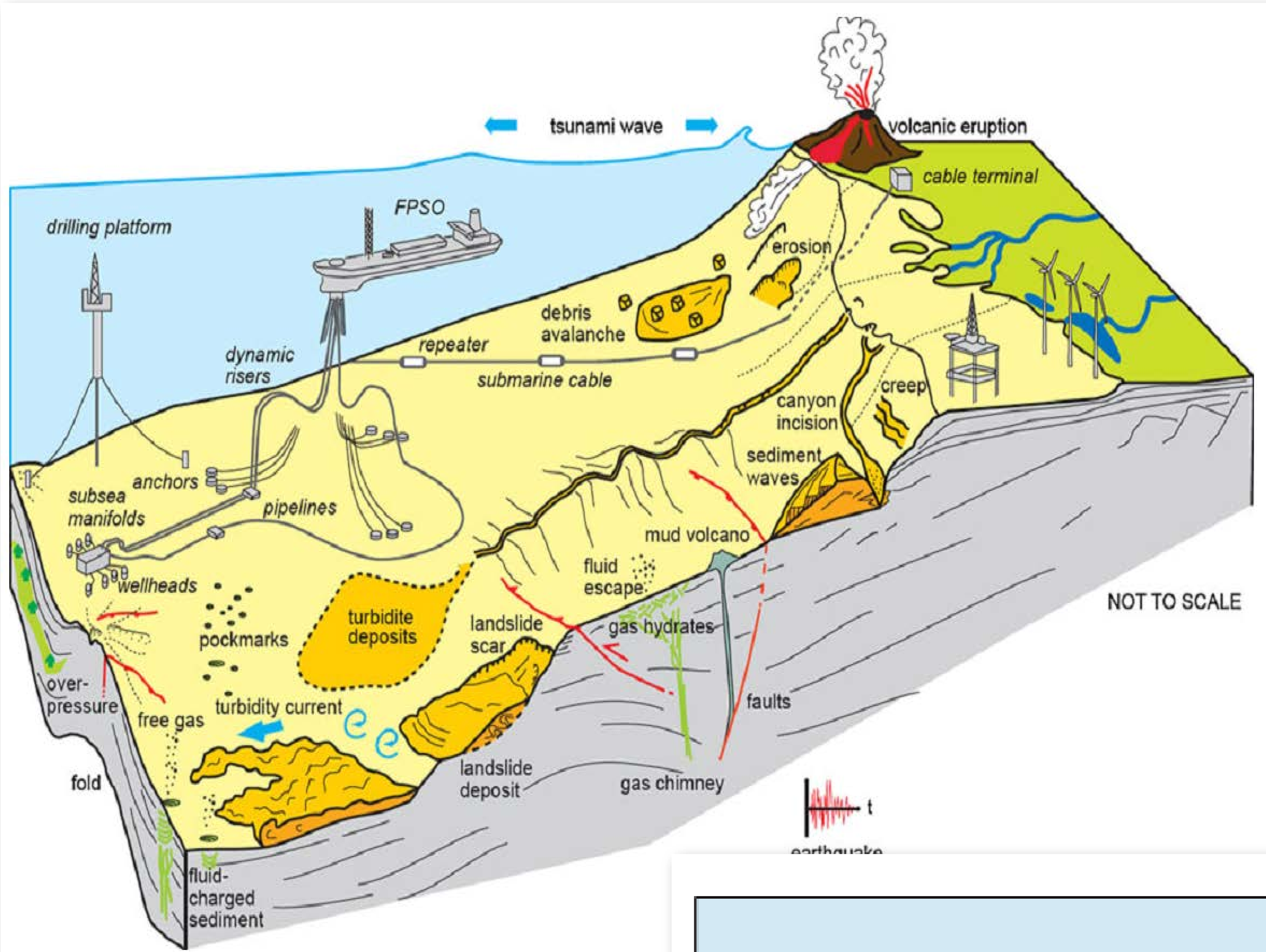


ISOVER Subsea Products SeaLine

Increasing economic use of the seafloor for energy, communications and mineral resources)



Courtesy NGI, Oslo. After Camerlenghi et al., 2007, *Scientific Drilling*

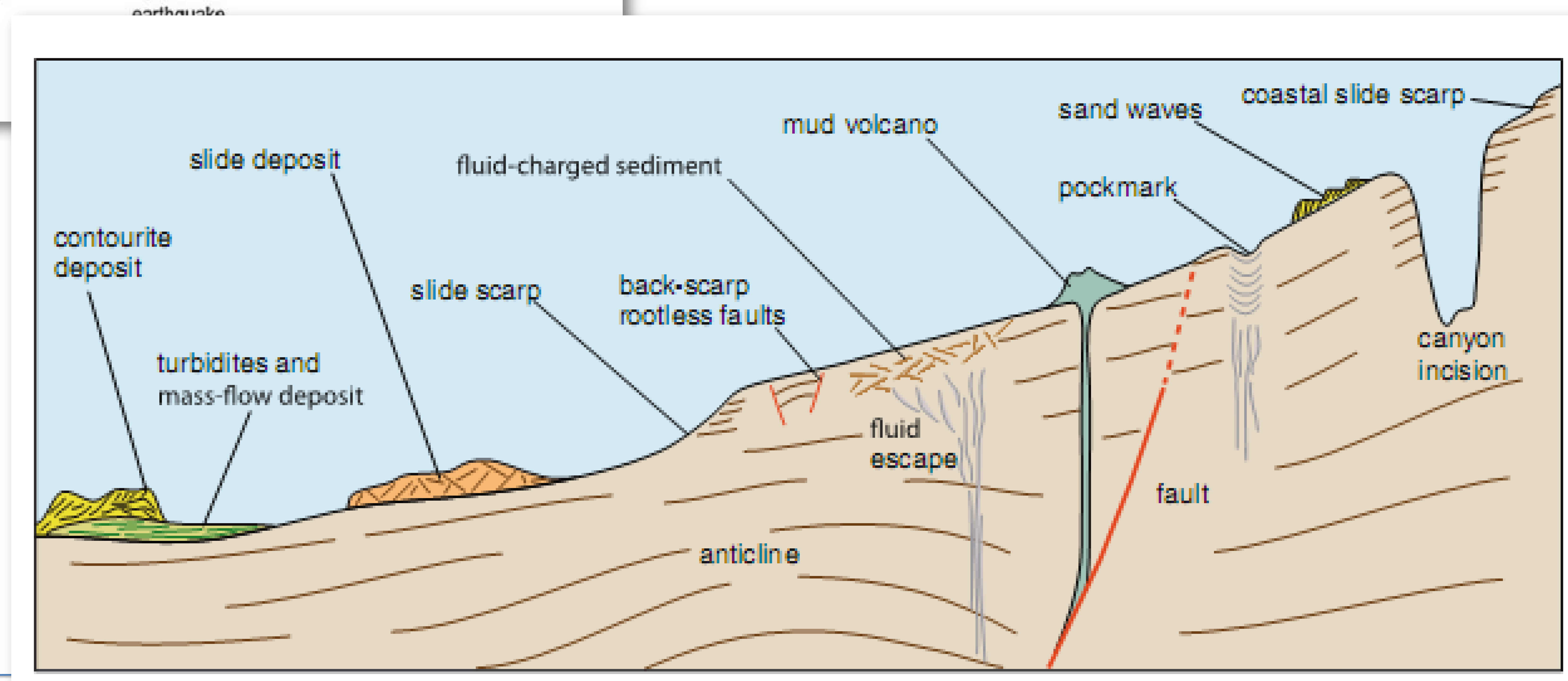


Chiocci et al. 2011

Geomorphic features as geohazard indicators:

scars and deposits, canyon headscarps and steep erosional flanks, fault-related seafloor unevenness, mud volcanoes, pock-marks, gravity flow deposits, erosional scours and bed-forms indicating sediment mobility at diverse temporal/spatial scale….

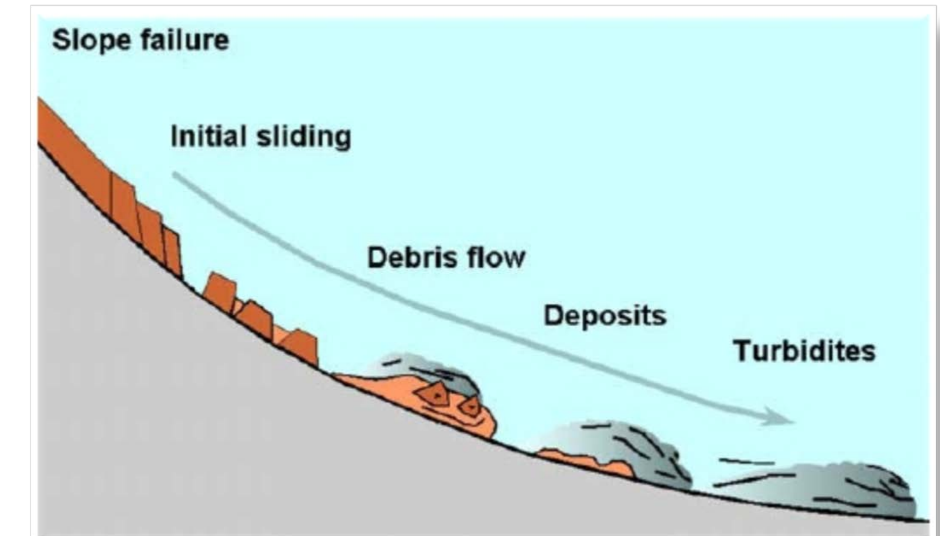
Everything that's active at sea bottom and below can create an hazard….

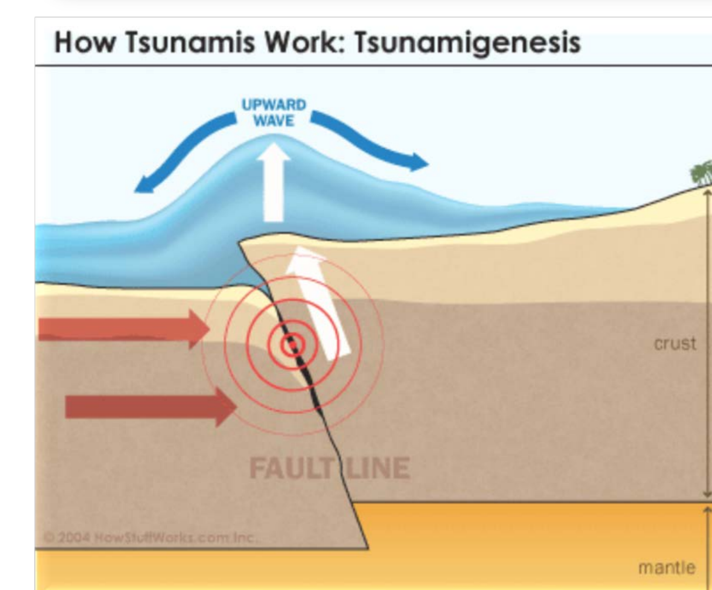


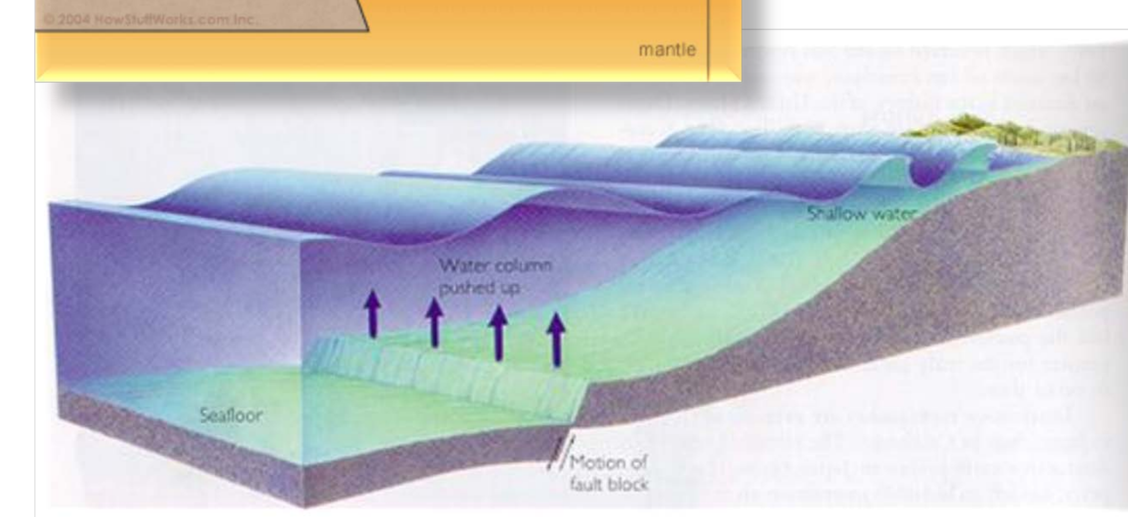
Chiocci and Ridente 2011

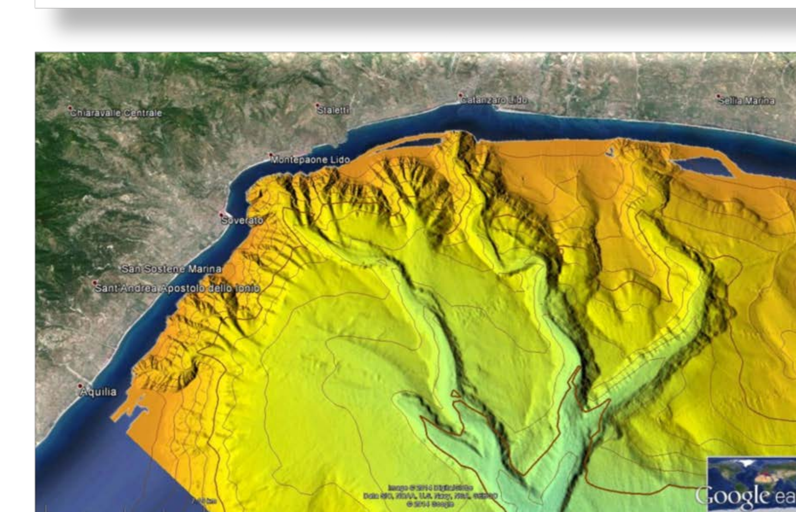
NATURAL MARINE GEOHAZARDS

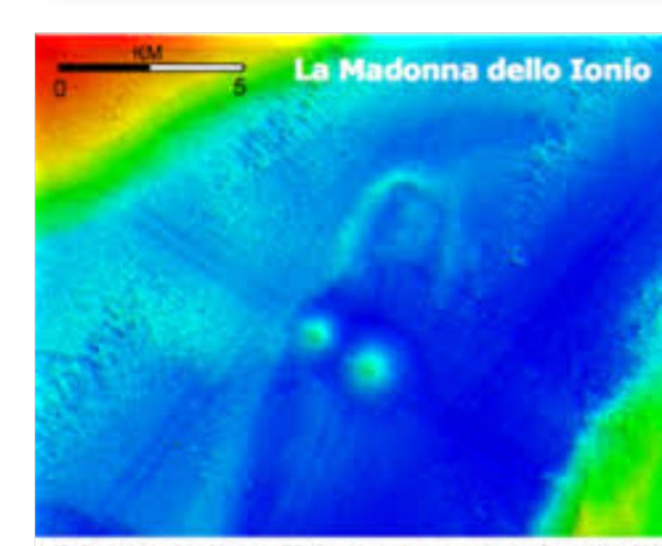
1. **SUBMARINE LANDSLIDES** including **VOLCANIC ISLAND ERUPTIONS** and **FLANK COLLAPSE**: sediment mass movements (turbidity currents, debris flows, slumps, retrogressive canyon headwalls)
2. **SEISMOGENIC FAULTS** (earthquakes originated below the sea floor)
3. **TSUNAMIS** (originated by earthquakes and/or landslides)
4. **SUBMARINE CANYONS** (coastal erosion)
5. **FLUID EMISSIONS** (CH_4, CO_2 mainly)
6. **METEORITE IMPACTS** in the oceans



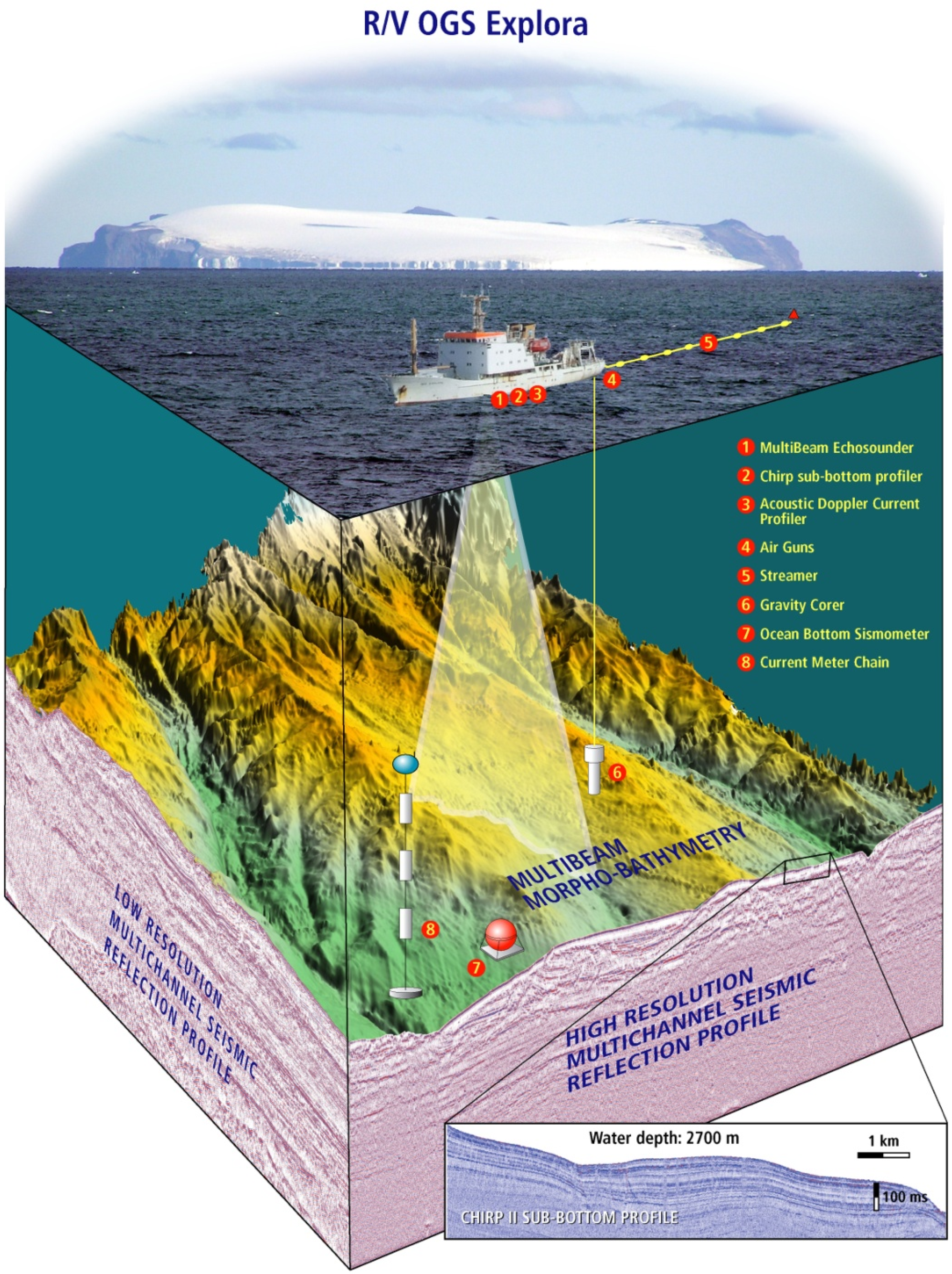








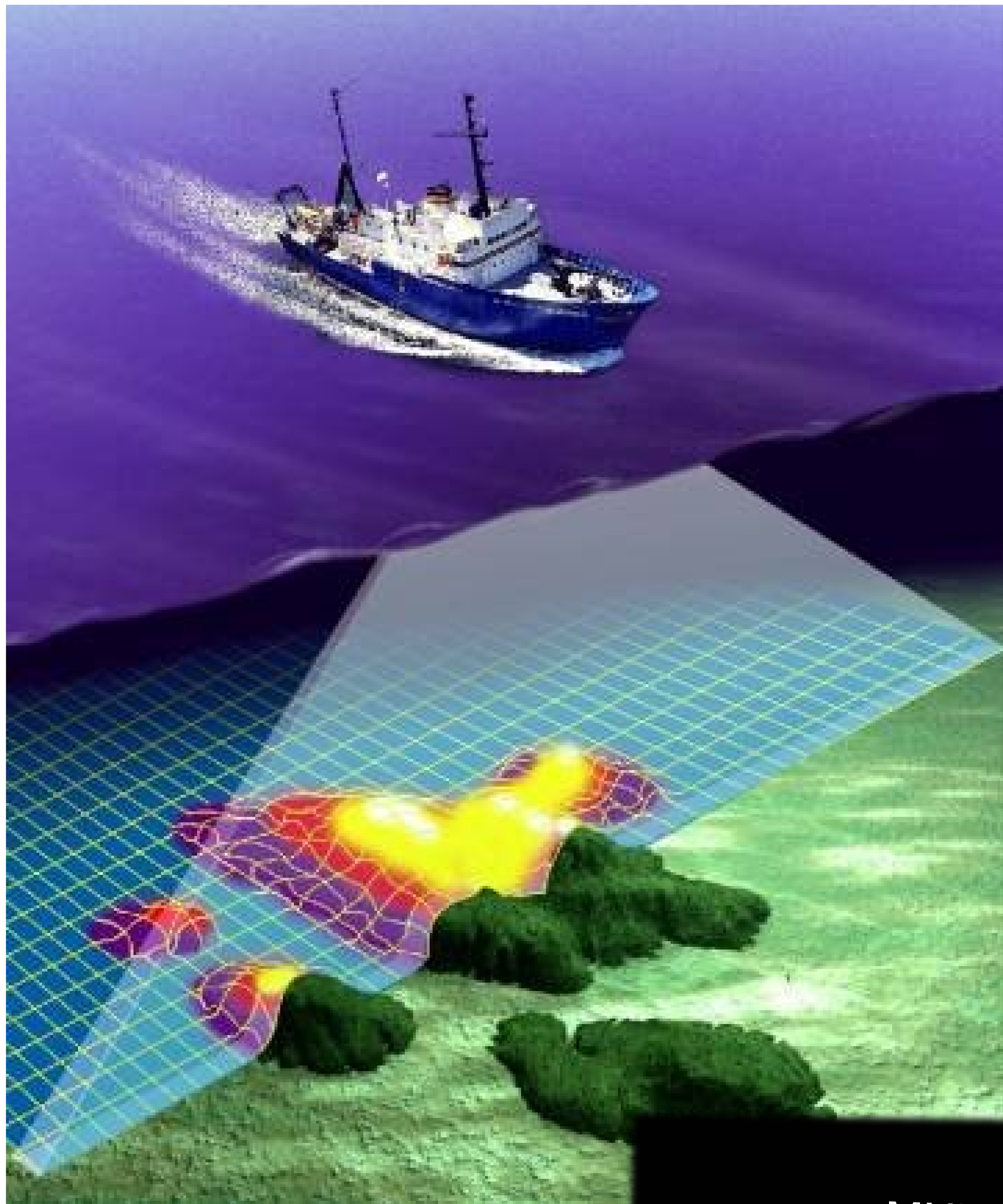
INTEGRATED ACOUSTIC METHODS



Integrating geophysical data at **different resolution** enable to investigate the **geological features** present on the seafloor and to depths of kilometers.

This allows to gain a **good understanding of the geological processes that are active** on the seafloor and beneath

SEAFLOOR MAPPING



Seafloor mapping is the first step in making a census of the **geohazard-bearing features** present in a given offshore area. It often provides
the only tool for a comprehensive **seafloor geohazard assessment over large areas** that are scarcely groundtruthed by acoustic prospection and seafloor sampling.

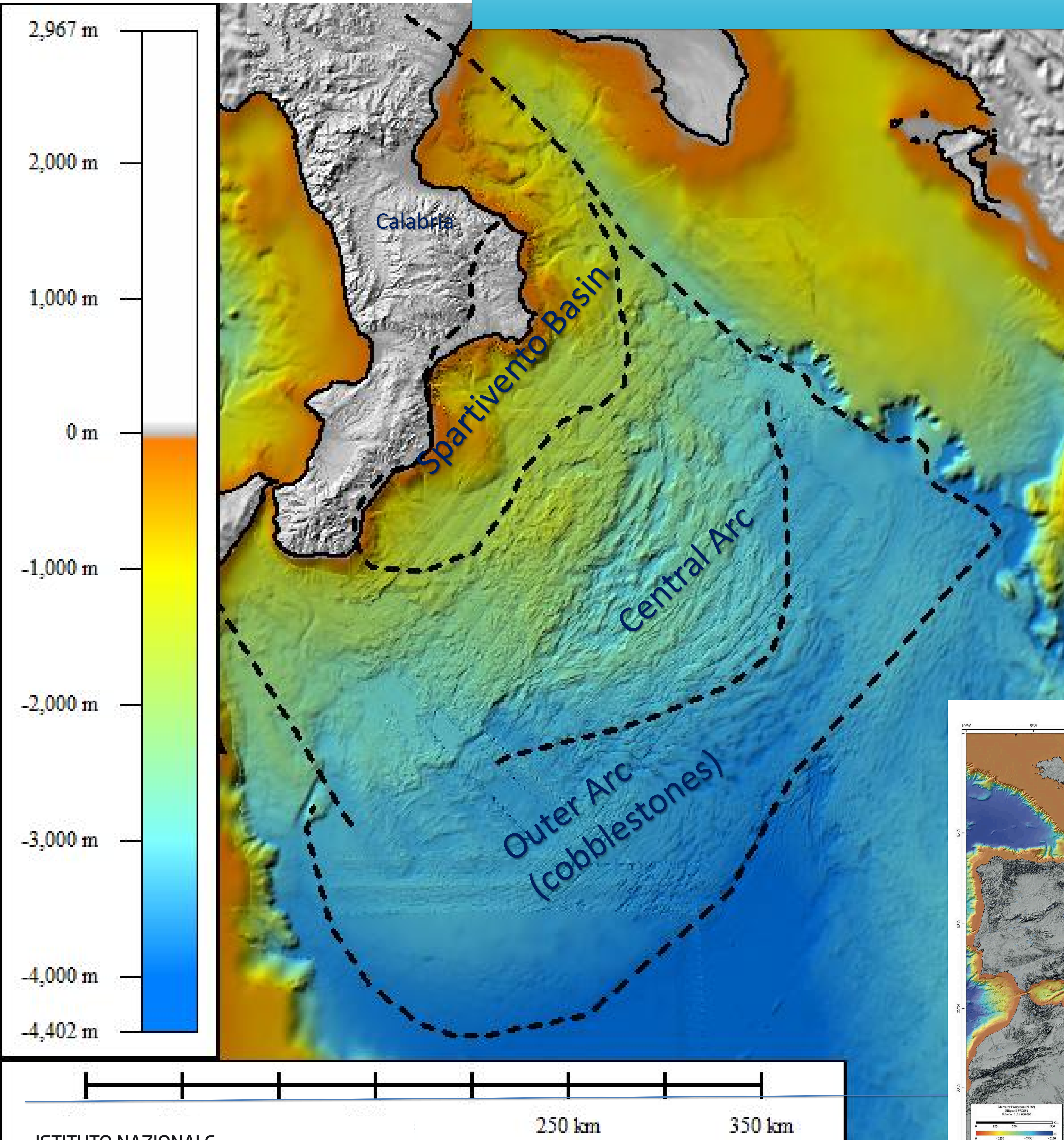
by Chiocci et al 2011

REMOTE AND AUTONOMOUS VEHICLES

1) obtain **very high-resolution** imaging of the seafloor (up to cm)

2) access remote settings (i.e. canyons)

THE IONIAN MARGIN A NATURAL LABORATORY FOR MARINE GEOHAZARDS



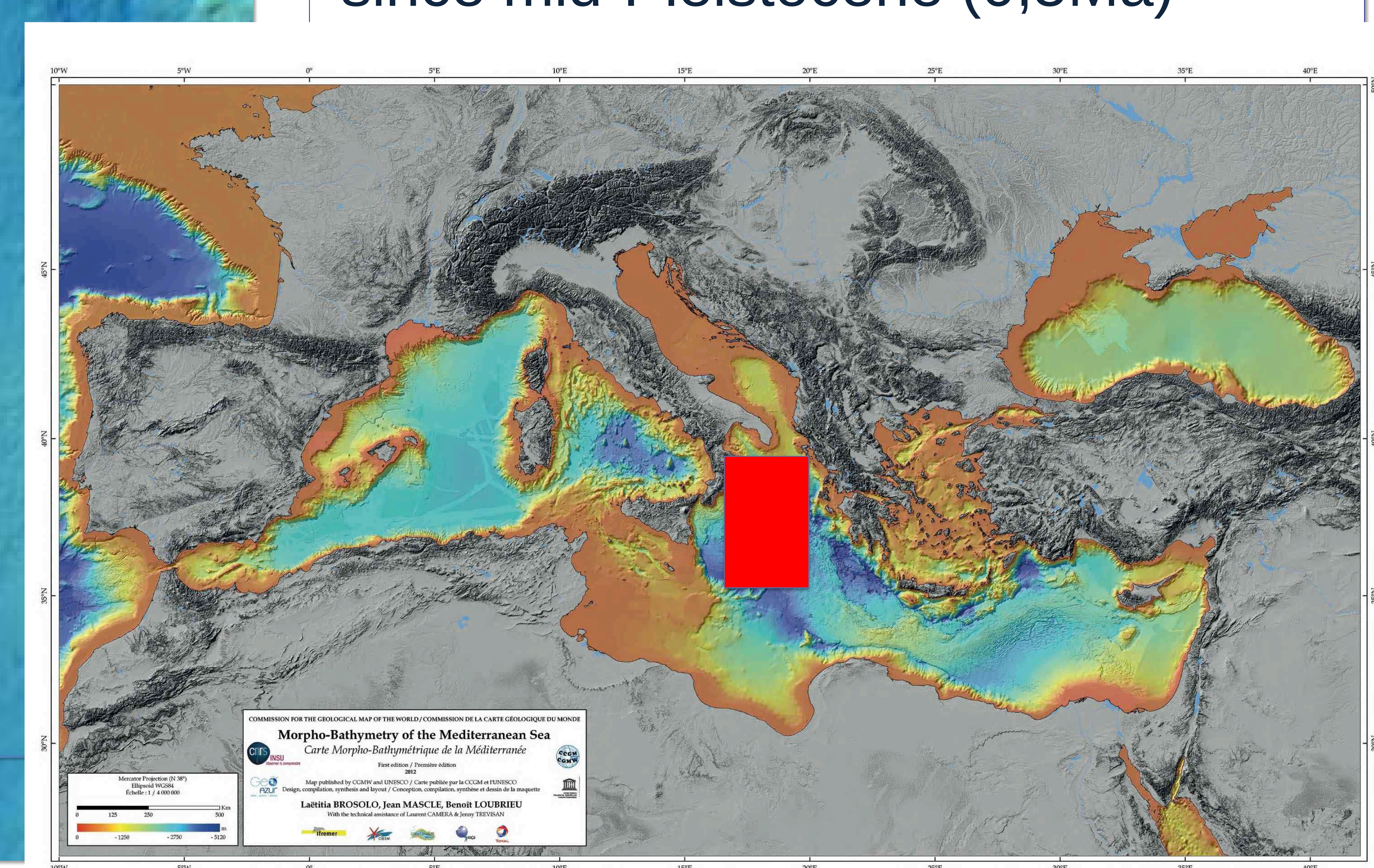
TECTONIC FRAMEWORK

Active continental margin (convergent) → **Subduction**

2 main processes related:

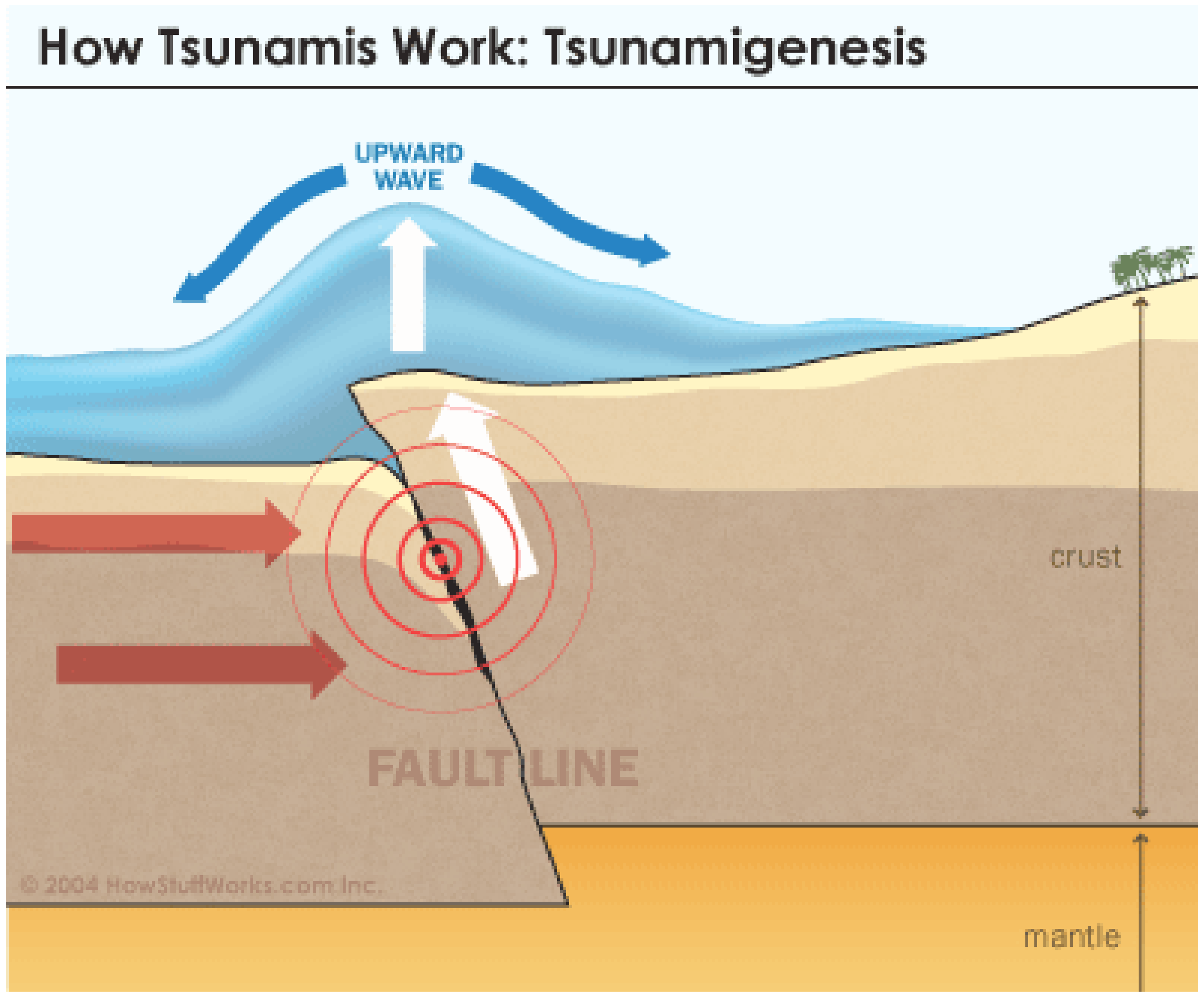
→ Frontal **compression** and forearc **extension** during the SE advance of the Calabrian accretionary prism since late Miocene (15 Ma);

→ A **rapid uplift** (up to 1 mm/yr) of onshore and shallow shelf areas since mid-Pleistocene (0,5Ma)



ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

1) Faults and Earthquakes



active Fault: is a fault which had displacement (or generated earthquakes) during the geologically recent period (20ka)

capable Fault : an active fault able to generate superficial displacement of the seabottom in recent period (20ka)

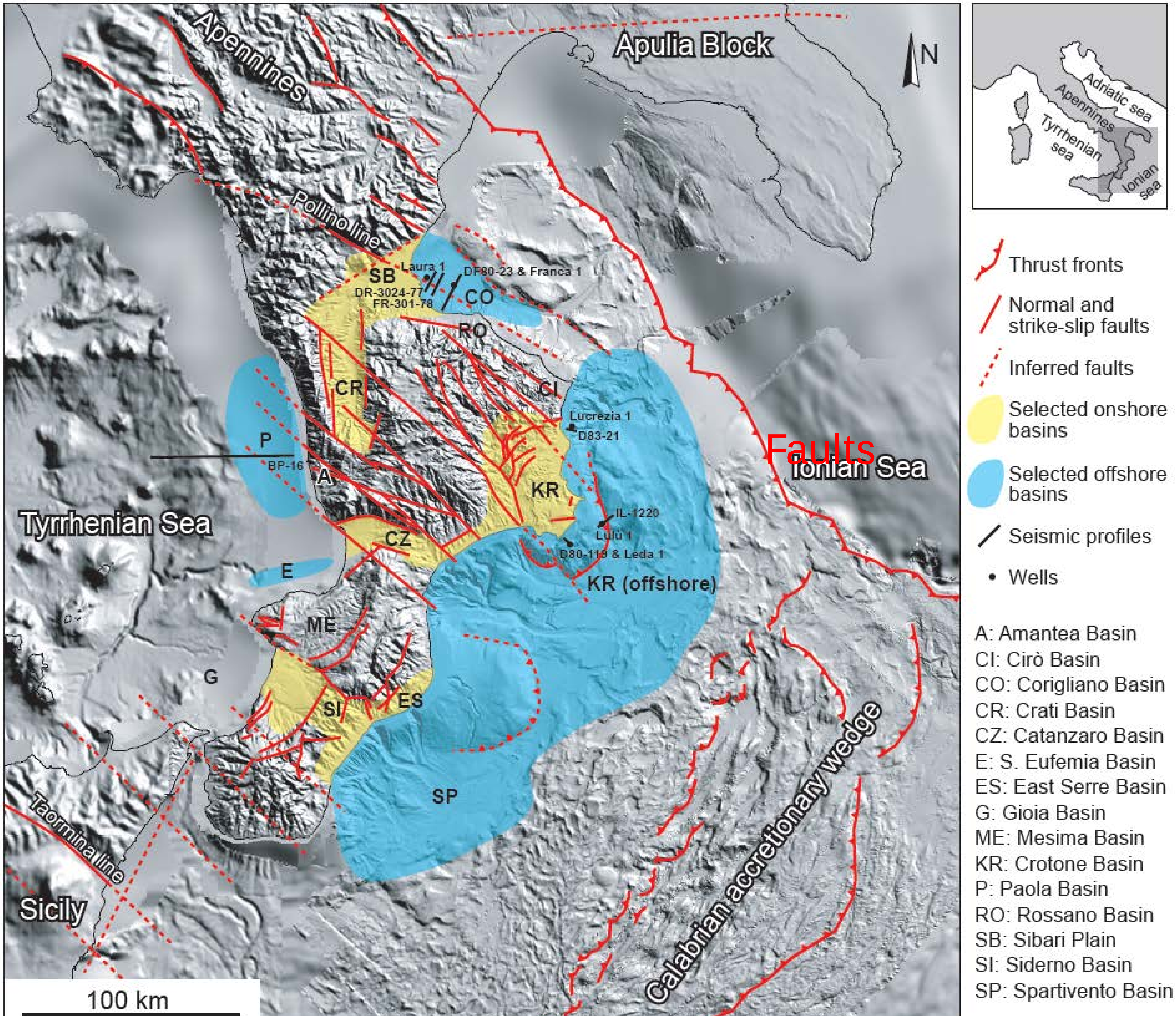
seismogenic Fault : an active fault capable of generating earthquakes in the upper lithosphere

aseismic Fault : faglia non attiva in tempi recenti con comportamento lento e continuo (crosta inferiore)

blind Fault: some faults do not break through to the sea bottom anywhere along their length (

It is possible to **identify** the faults that have displaced the seabottom (using acoustic methods), to **map** them and thus **assess their hazard** but it is NOT possible predict if and when they will be active again → **earthquakes are not predictable!**

‘Faults’ in the Calabrian margins

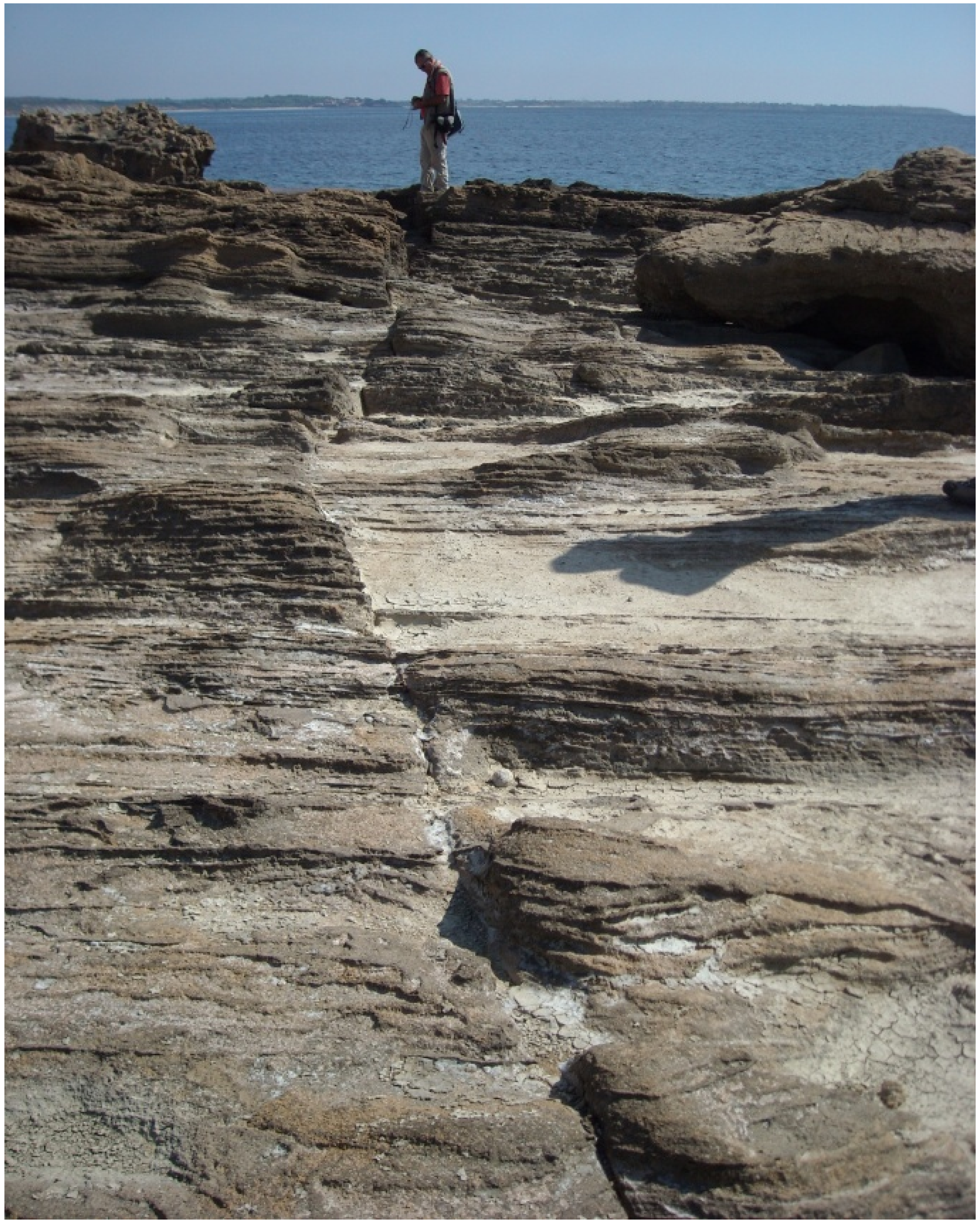


1) Fault systems do not stop at the coastline!!

2) Mapping fault systems allows to assess their distribution and characterise thier occurrence (lenghs, type, displacement....)

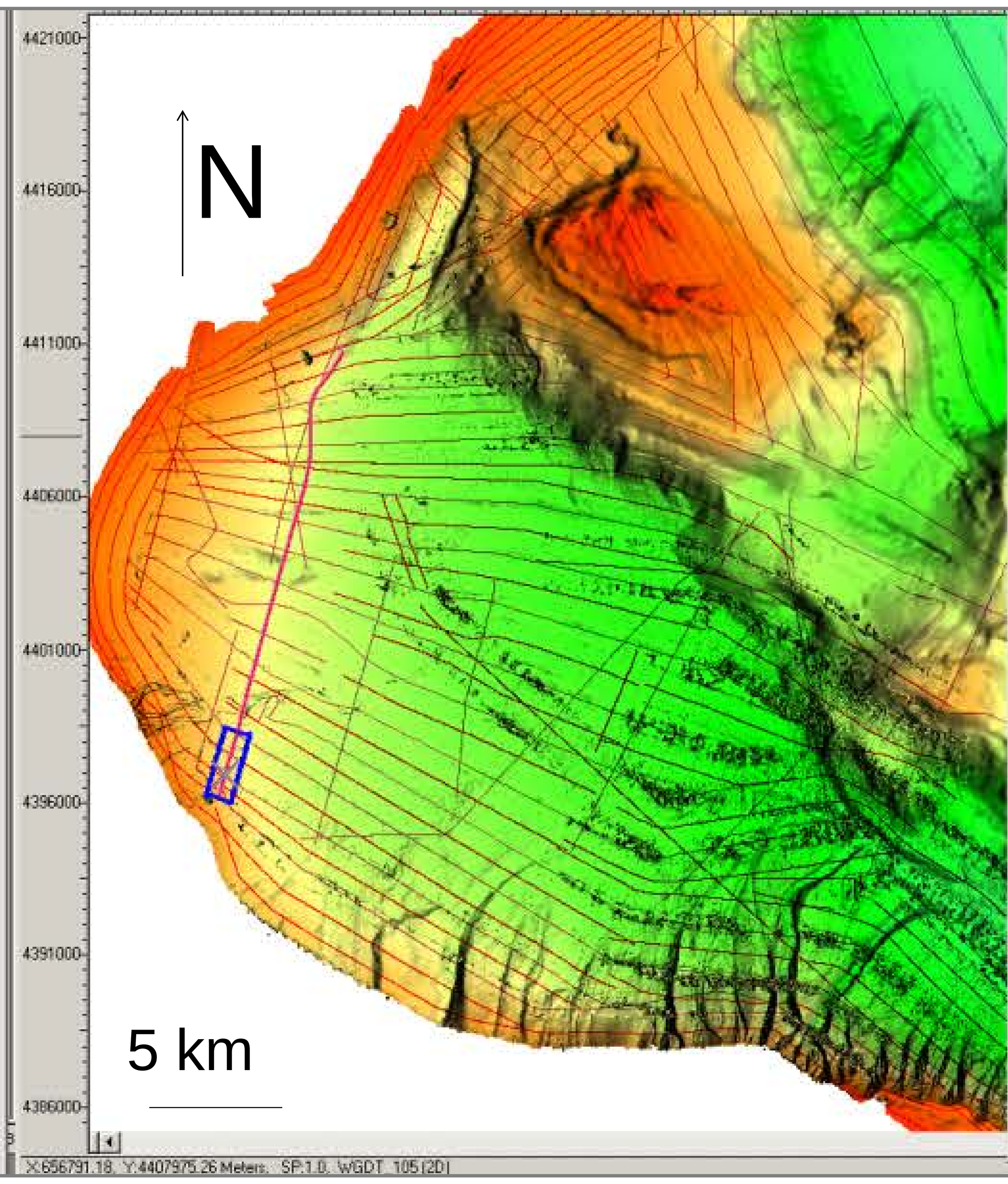
Zecchin et al. 2015

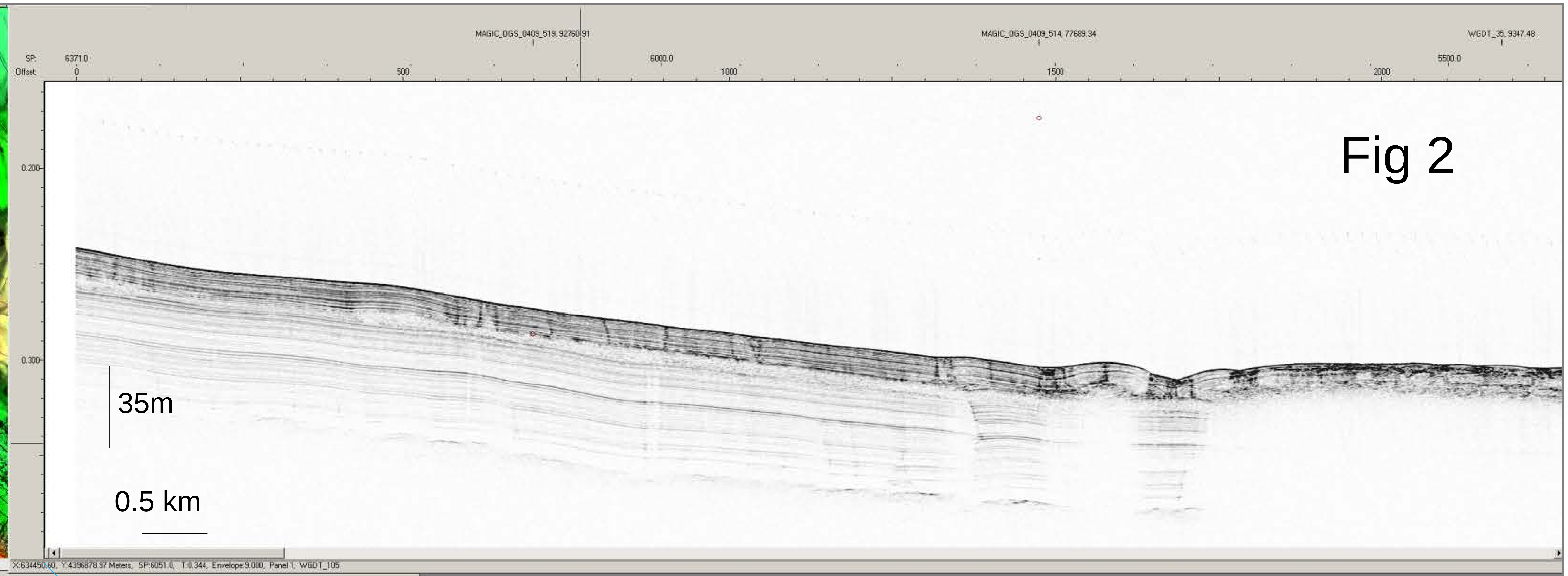
Onshore….



Examples of joints oriented N100-120° and dissecting the deposits of the Le Castella marine terrace (Calabria, Italy)

Offshore....





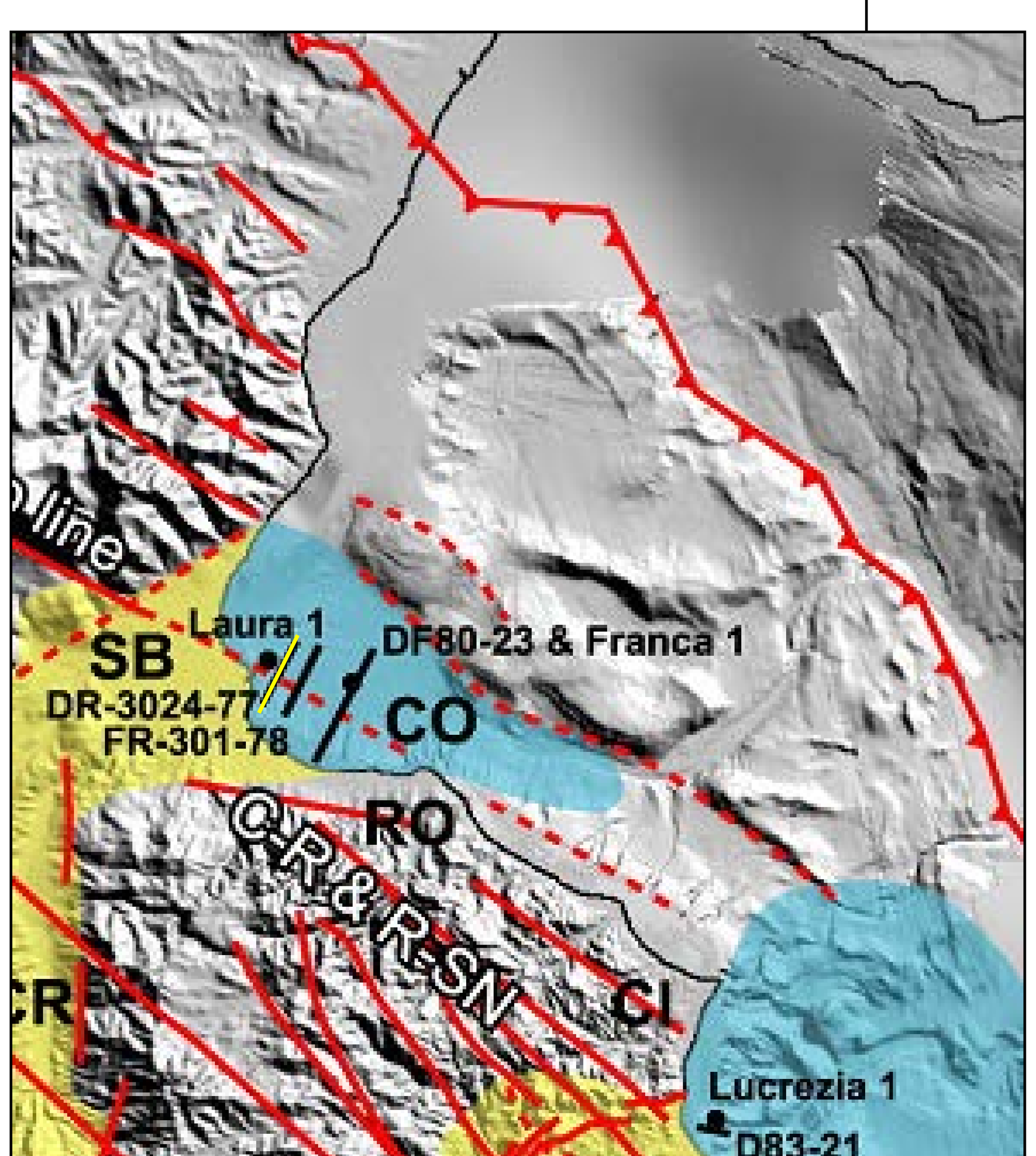
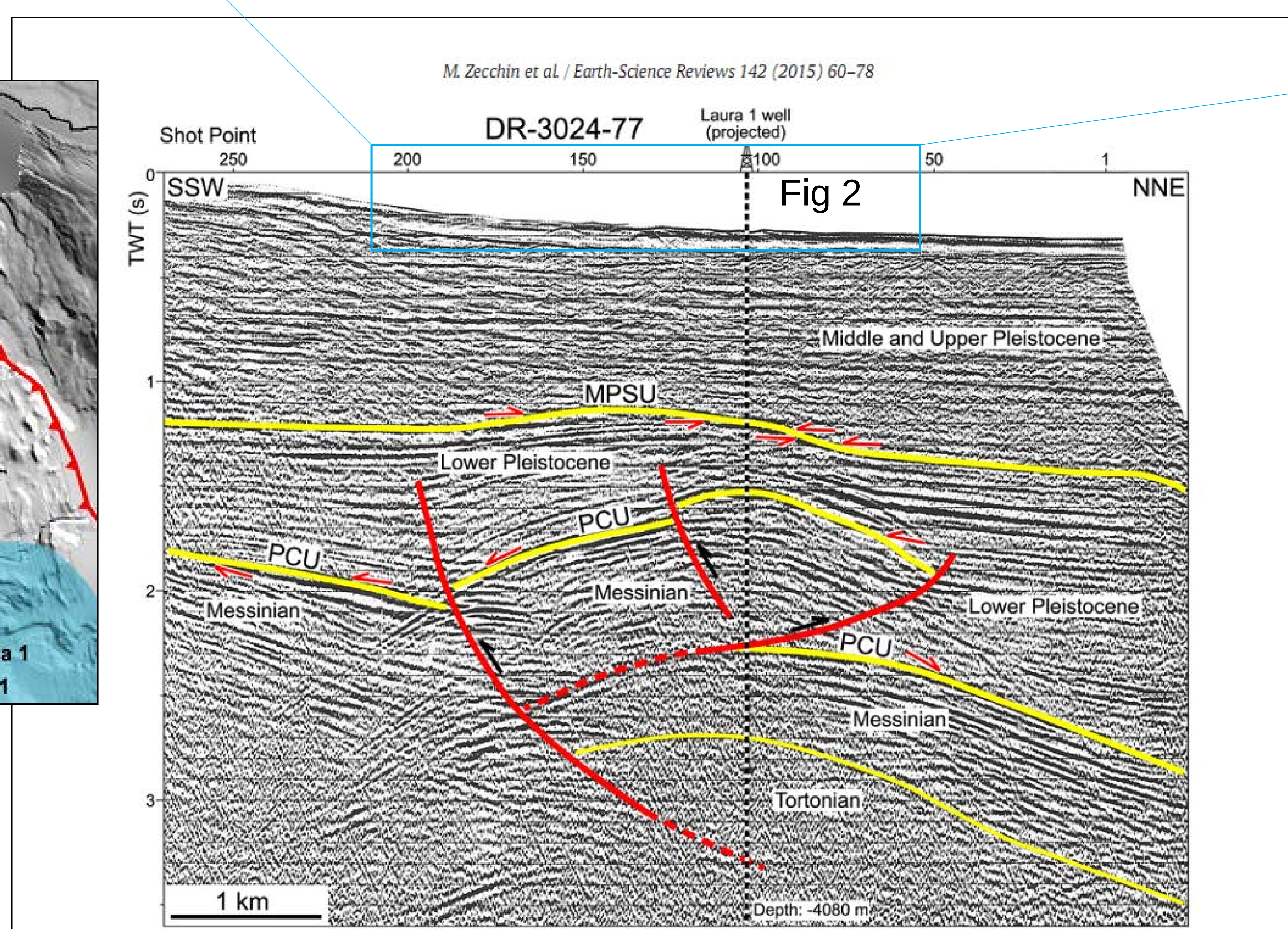


Fig 1



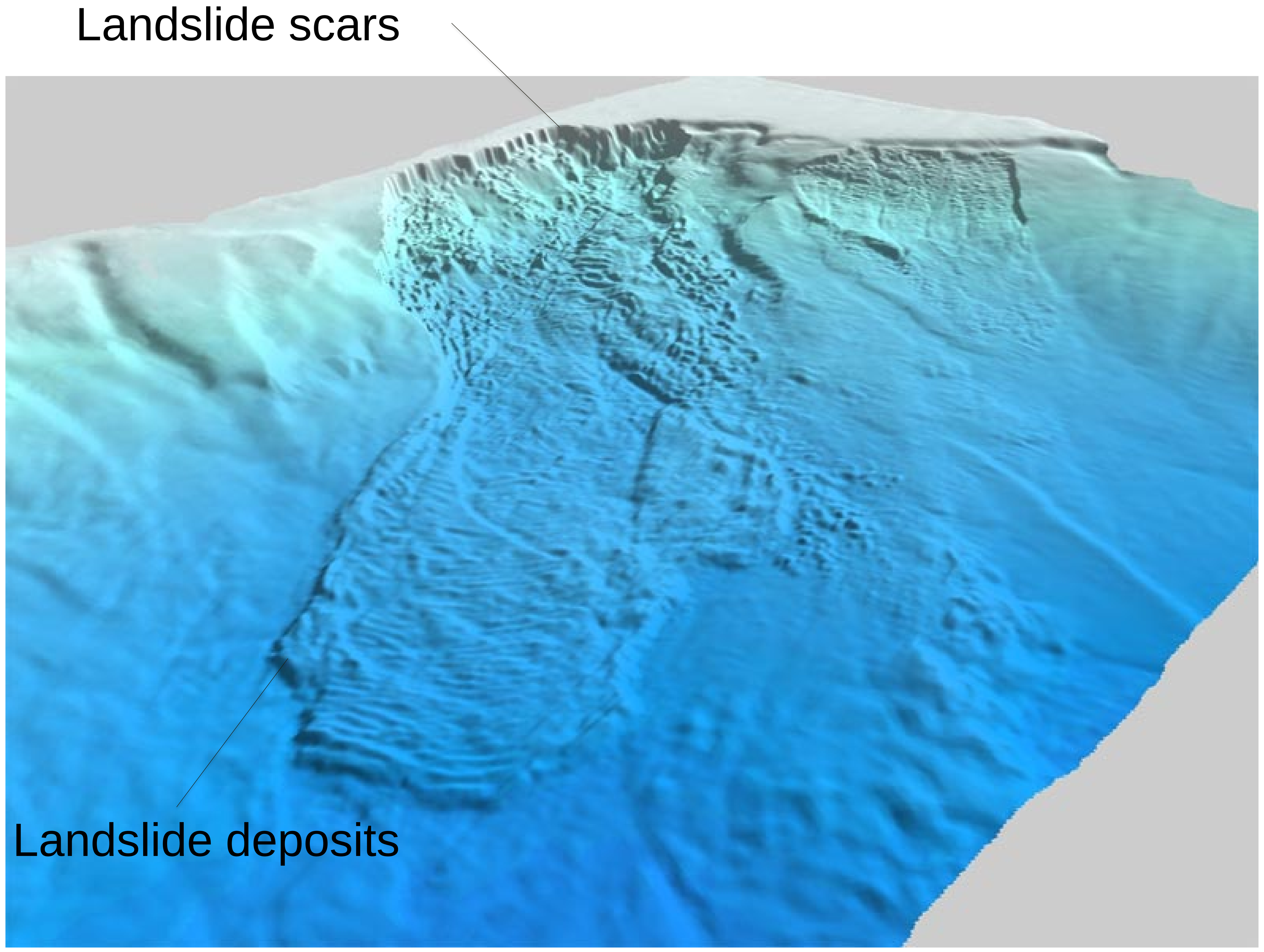
...things are more complicated!

possible problems:

1) Do we have the good **data resolution**?

2) Are we investigating **the right portion of seabed**?

2) Submarine landslides

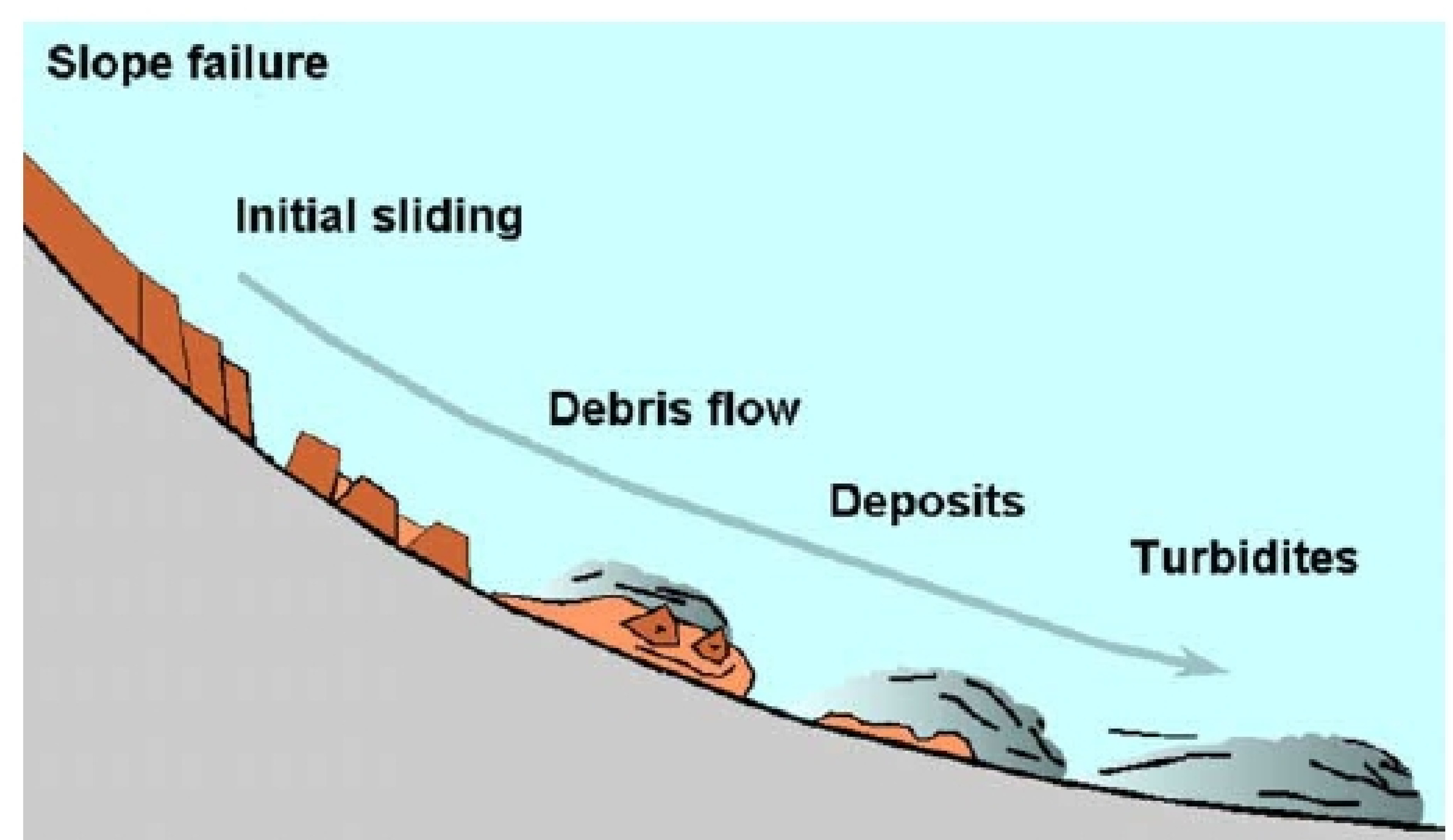


are able to **transport sediments** across the continental shelf and into the deep ocean.

A submarine landslide can be initiated by different **trigger mechanisms** such as:

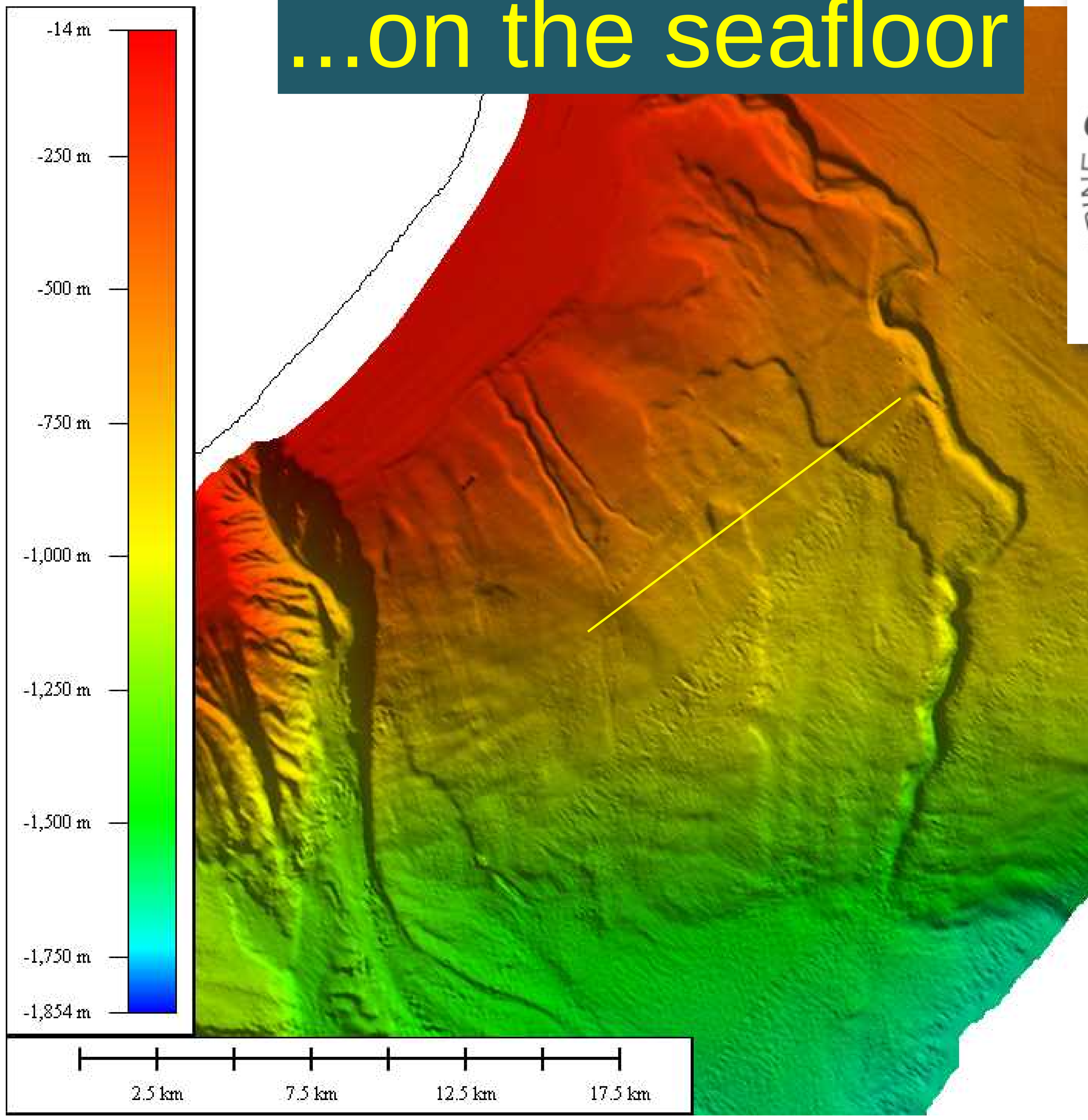
- i) presence of weak geological layers,
- ii) overpressure due to rapid accumulation of sedimentary deposits,
- iii) earthquakes,
- iv) storm wave loading and hurricanes,
- v) gas hydrates dissociation,
- vi) groundwater seepage and high pore water pressure,
- vii) glacial loading,
- viii) volcanic island growth,
- ix) oversteepening.

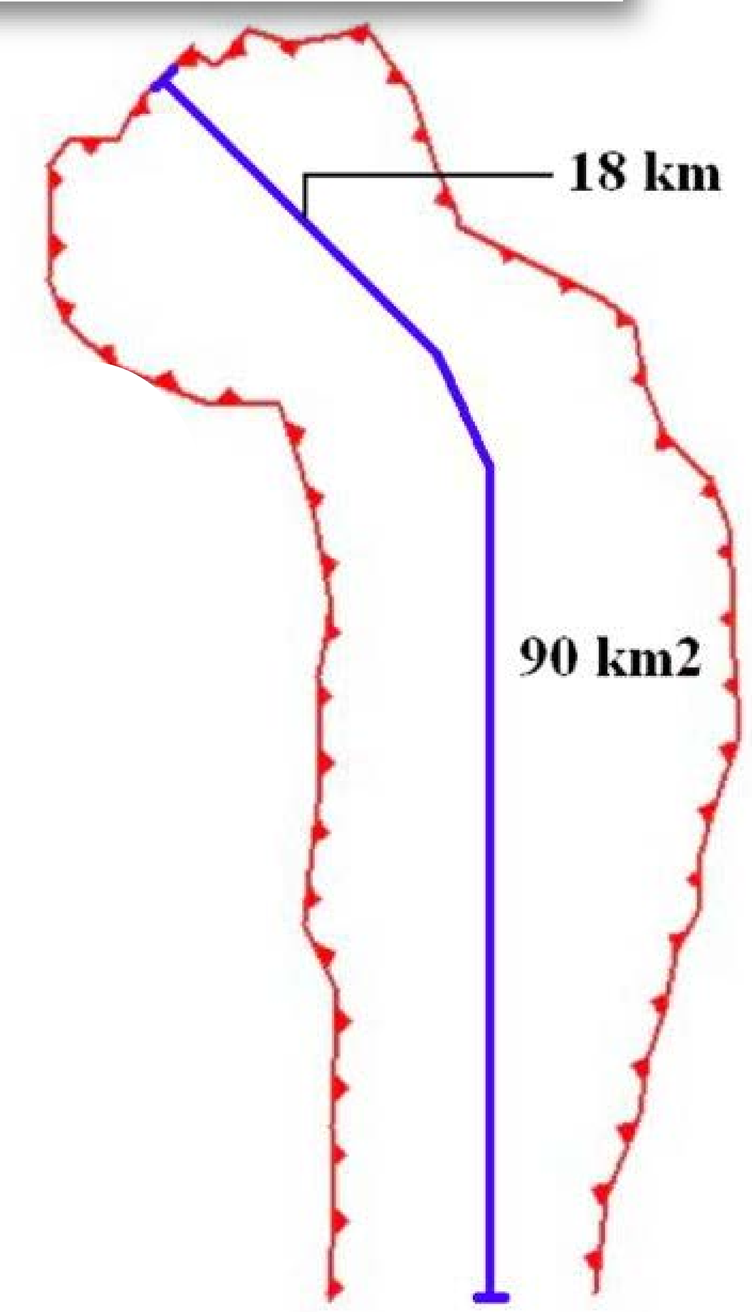
Huge landslides, mobilizing **hundreds to thousands of km^3** of sediment and rock, they take place in a variety of different geological settings including planes as low as 1° and can **cause significant damage** to life (human and/or marine ecosystems) as well as coastal and deep sea infrastructures



The Assi Failure

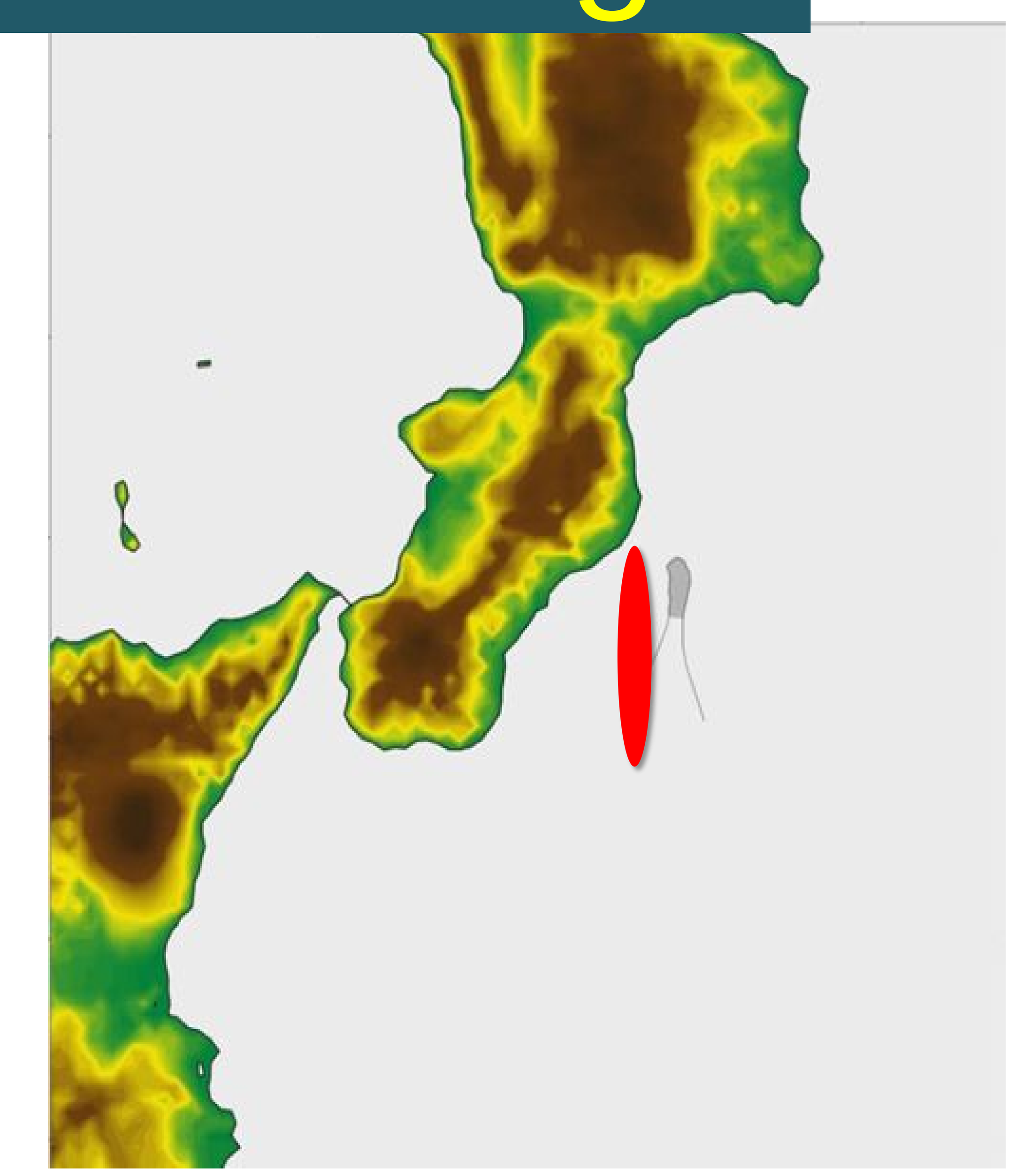
...on the seafloor



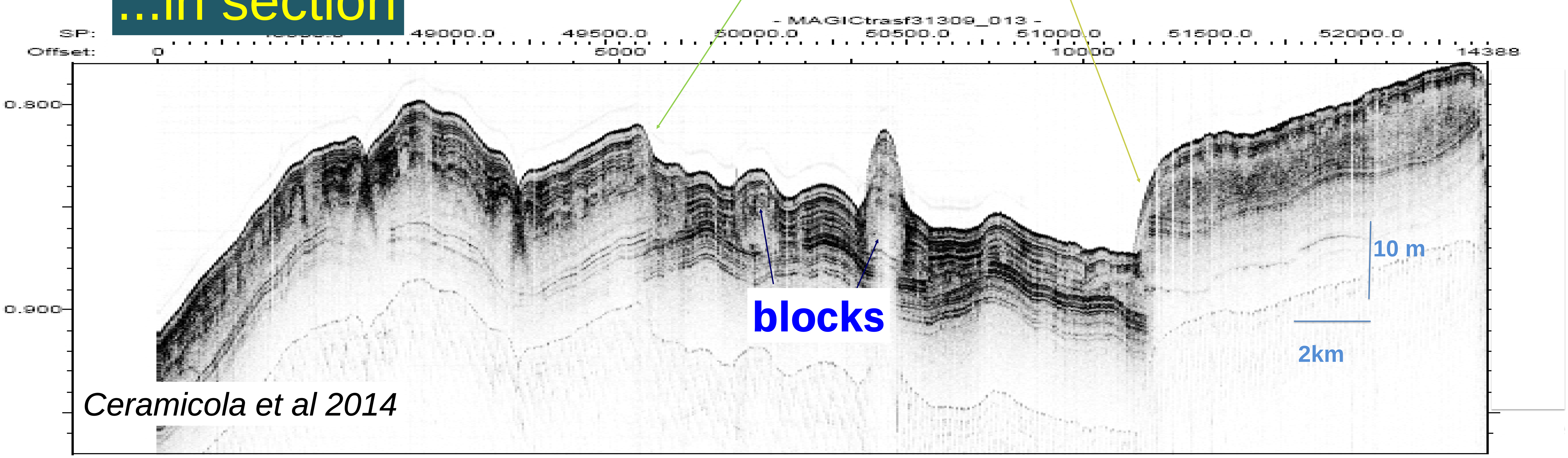


...the Calabrian margin

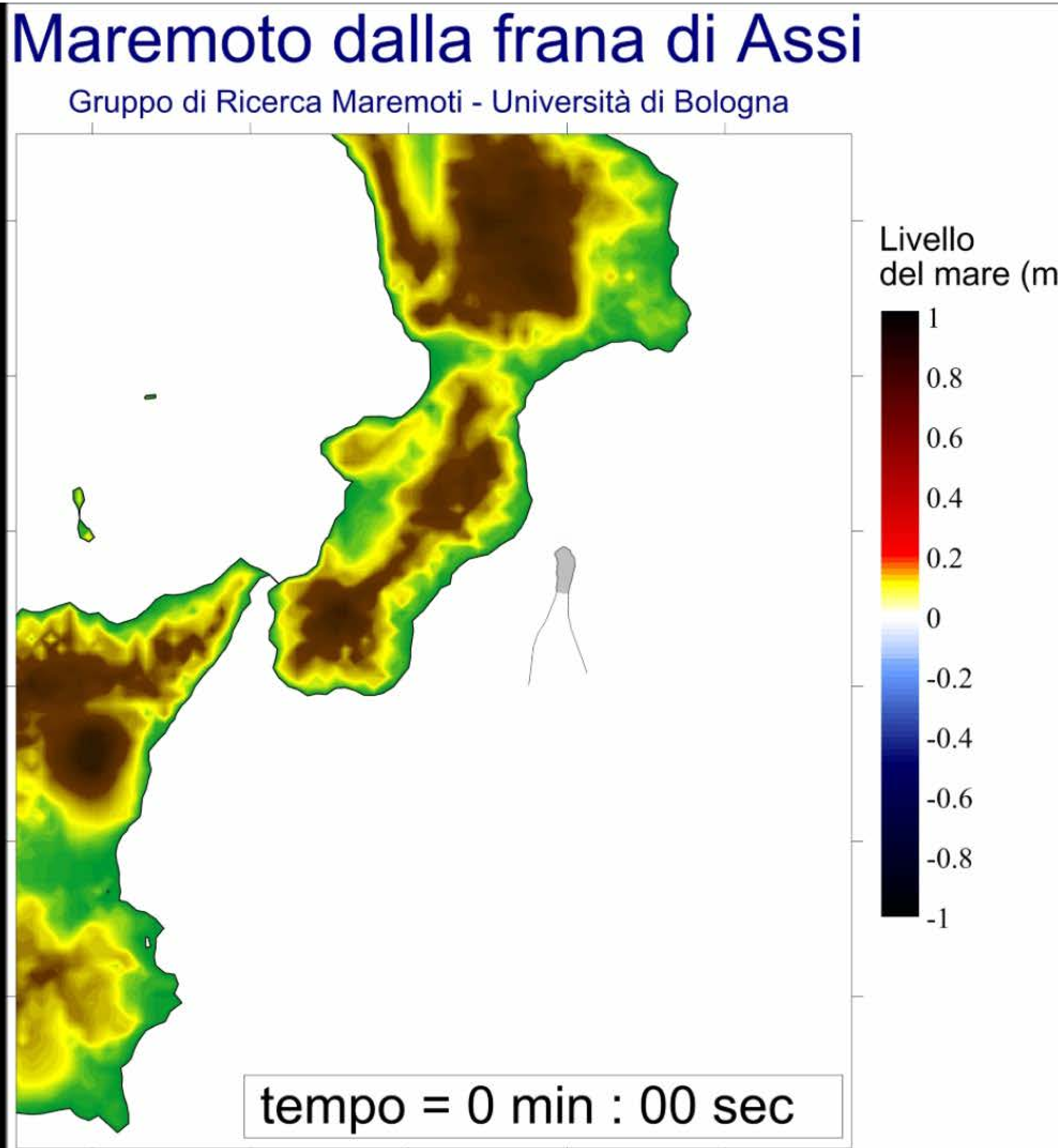
Volume of sediments of the failure is about $2 km^3$



...in section

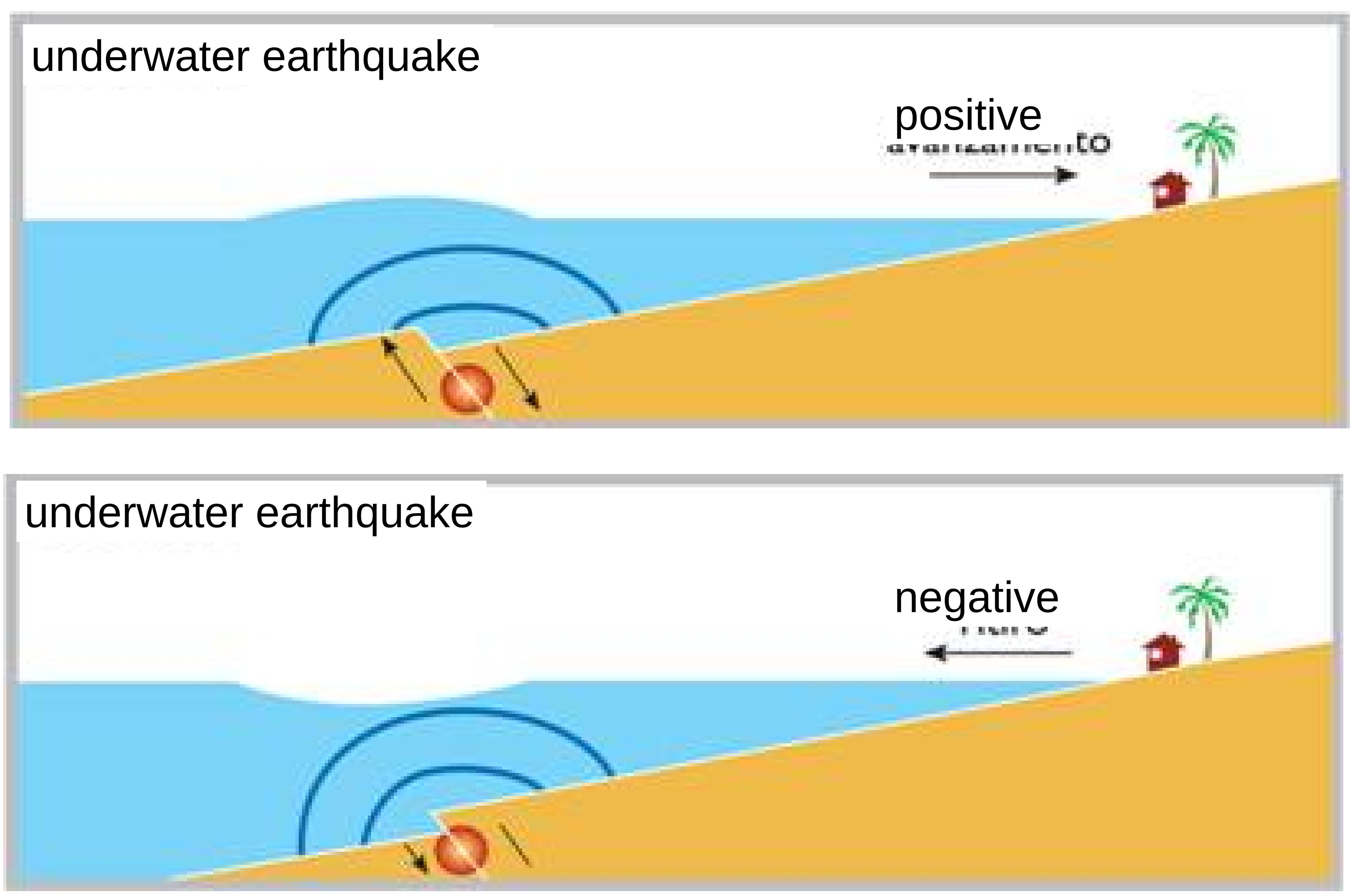


Ceramicola et al 2014

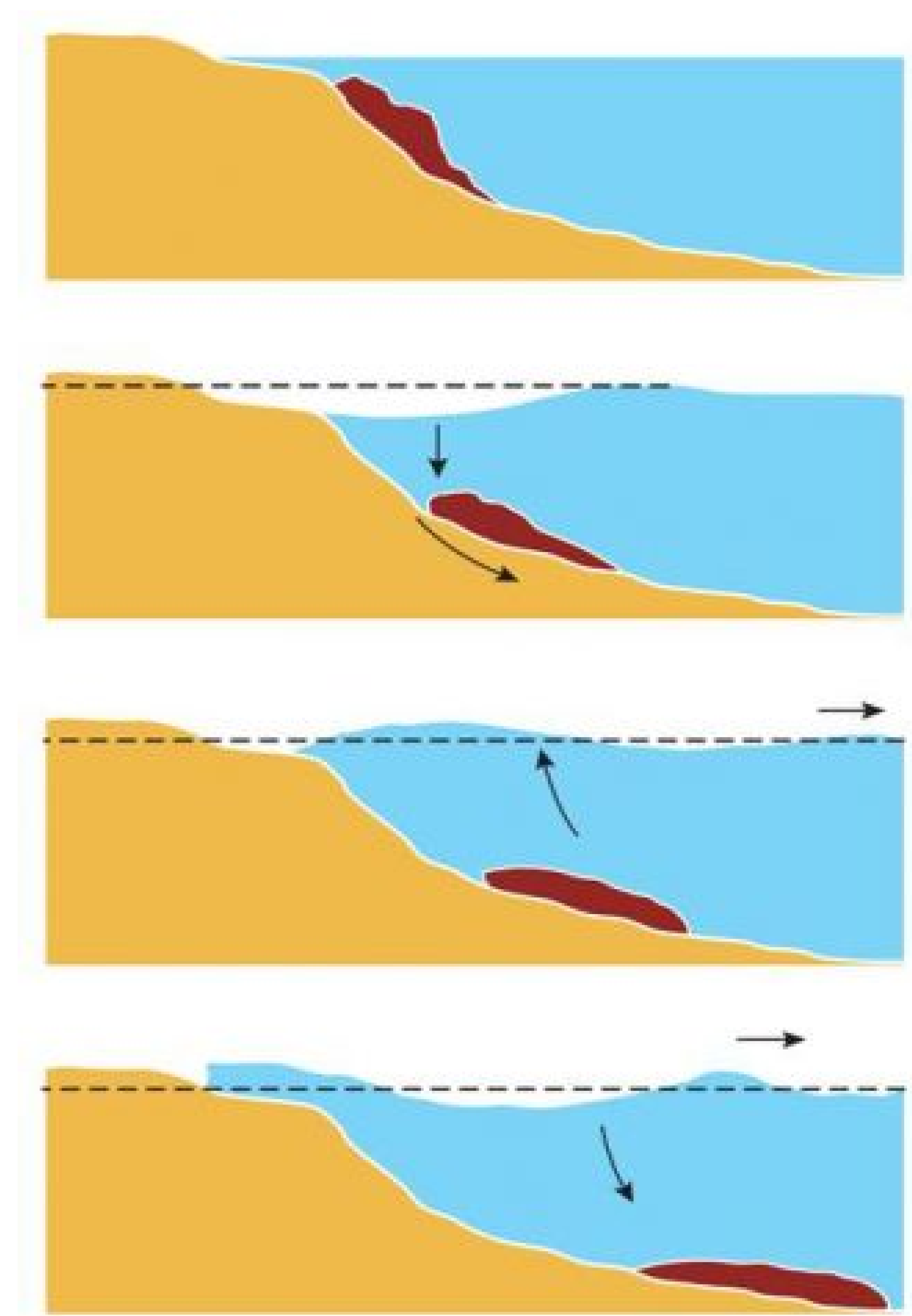


Maremoto dalla frana di Assi
Gruppo di Ricerca Maremoti - Università di Bologna
Livello
del mare (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
tempo = 0 min : 00 sec

3) Tsunamis

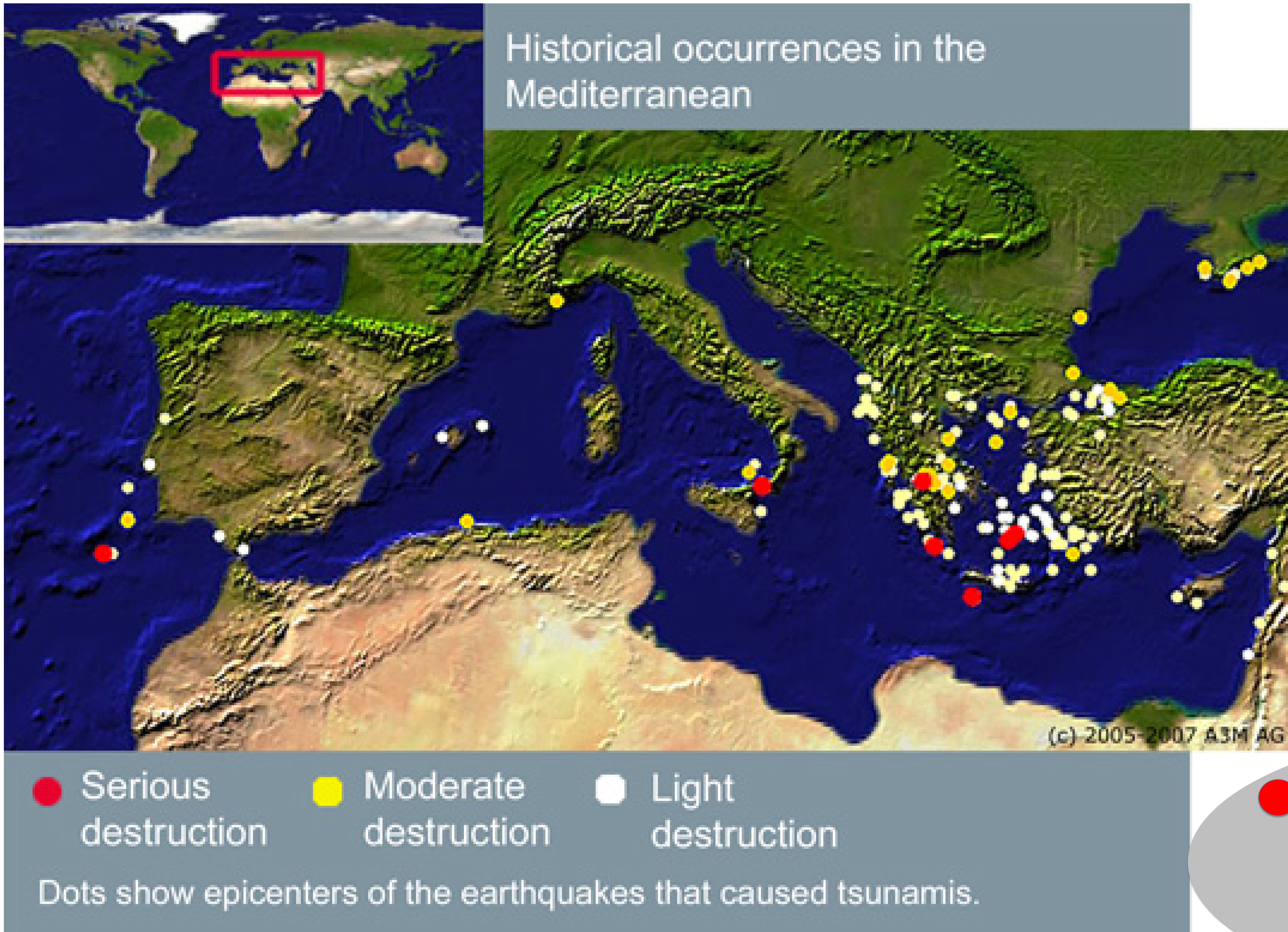


submarine landslide



A tsunami is a series of **ocean waves** that send **surges of water**, sometimes reaching heights of over 30 meters, onto land. They are different from waves generated by storms as they involve the entire water column. These walls of water **can cause widespread destruction** when they crash ashore.

Tsunamis in the Med



Tsunamis threaten the coasts and beaches **all over the world.**

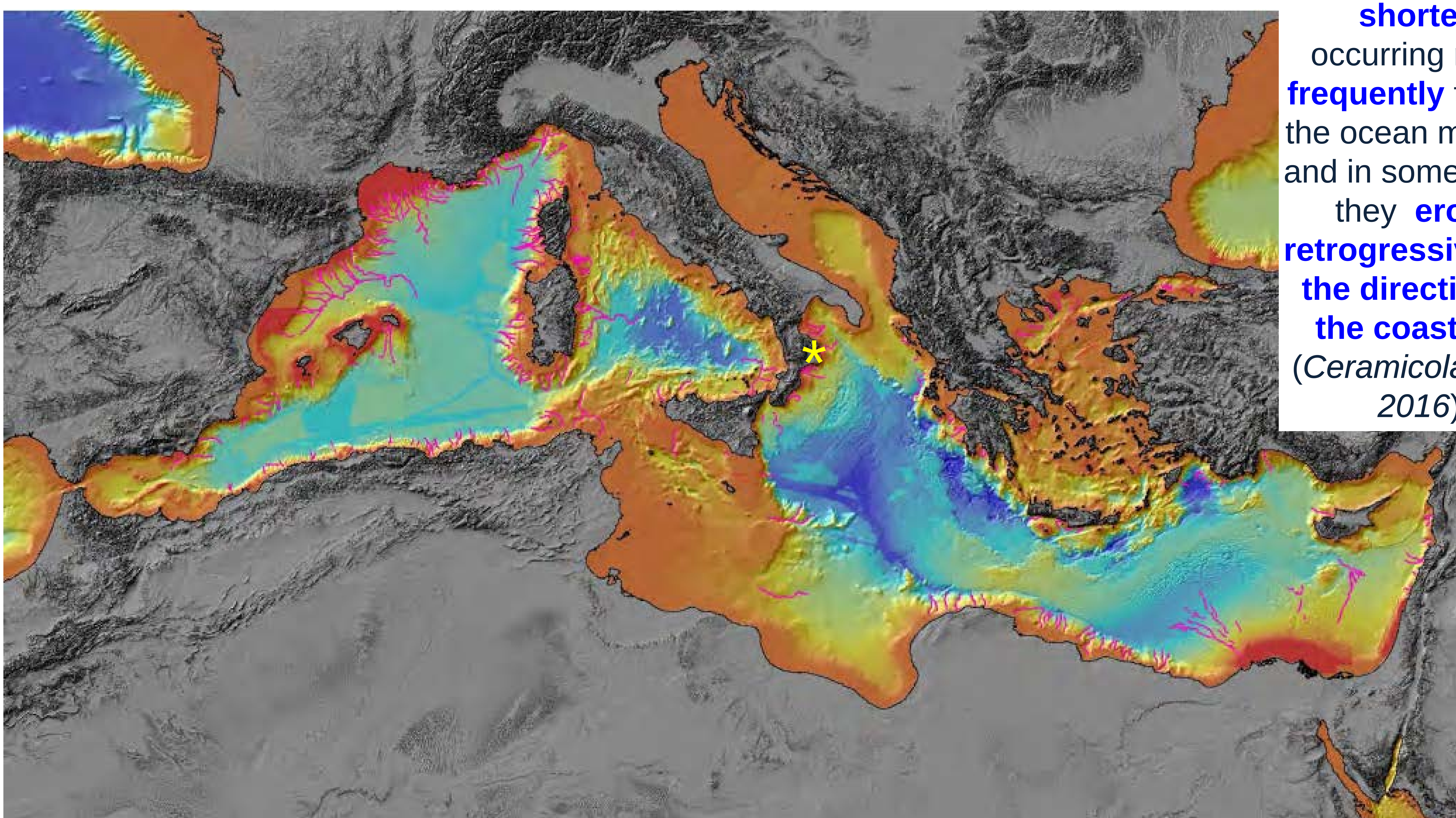
They occur in all oceans and **seas**, including the Mediterranean, the Atlantic, the Indian, the Pacific and in **large lakes**.

About **10%** of all tsunamis reach the beaches of the **Mediterranean Sea**.

28 December 1908: Due to an earthquake and the ensuing tsunami, the city of Messina in Italy was almost completely destroyed. More than 75 000 people were killed.

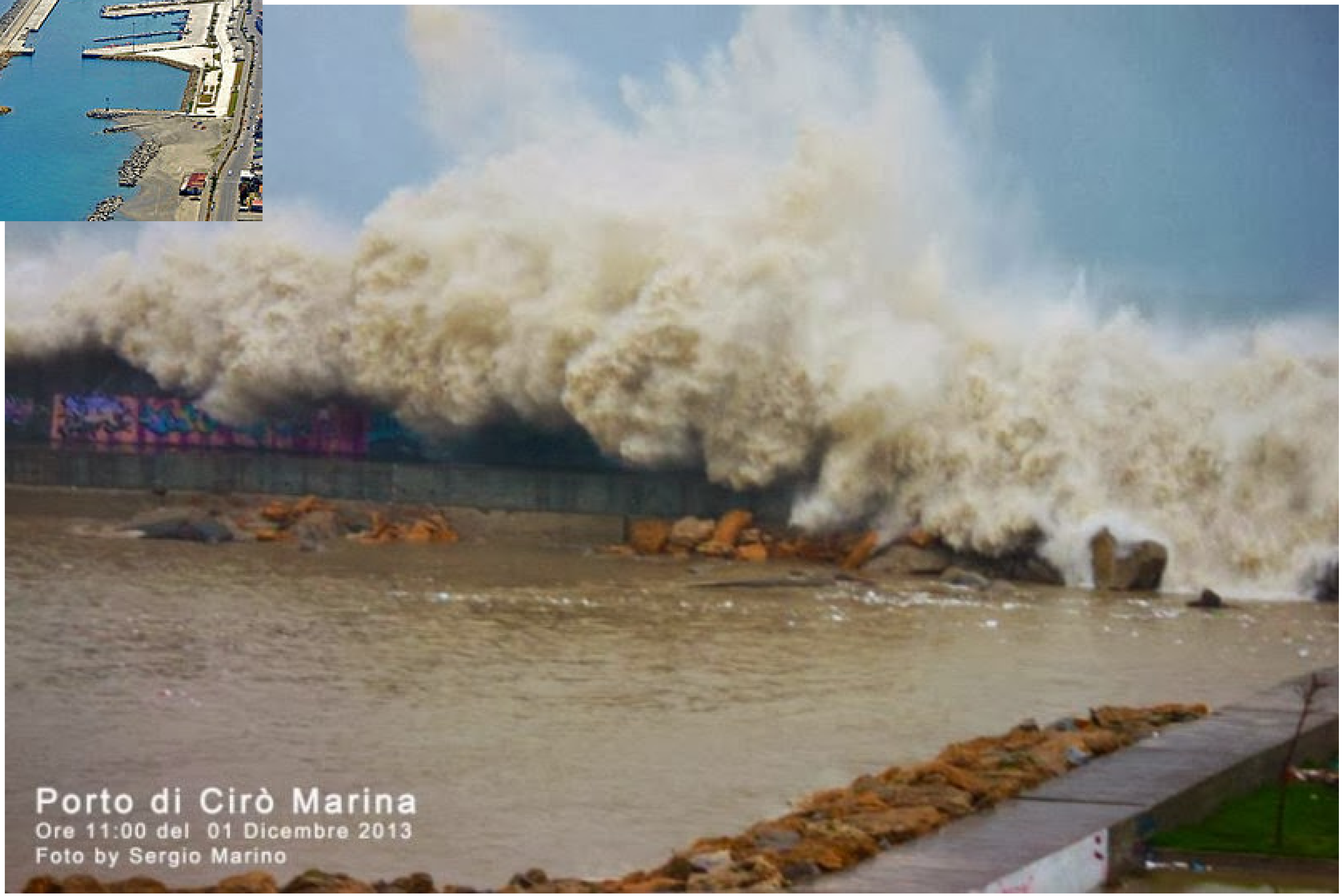
Tsunamis in the Med travel quickly from cost to cost (in hours) and so it is difficult to settle an efficient **warning system!**

4) Submarine canyons in the Med

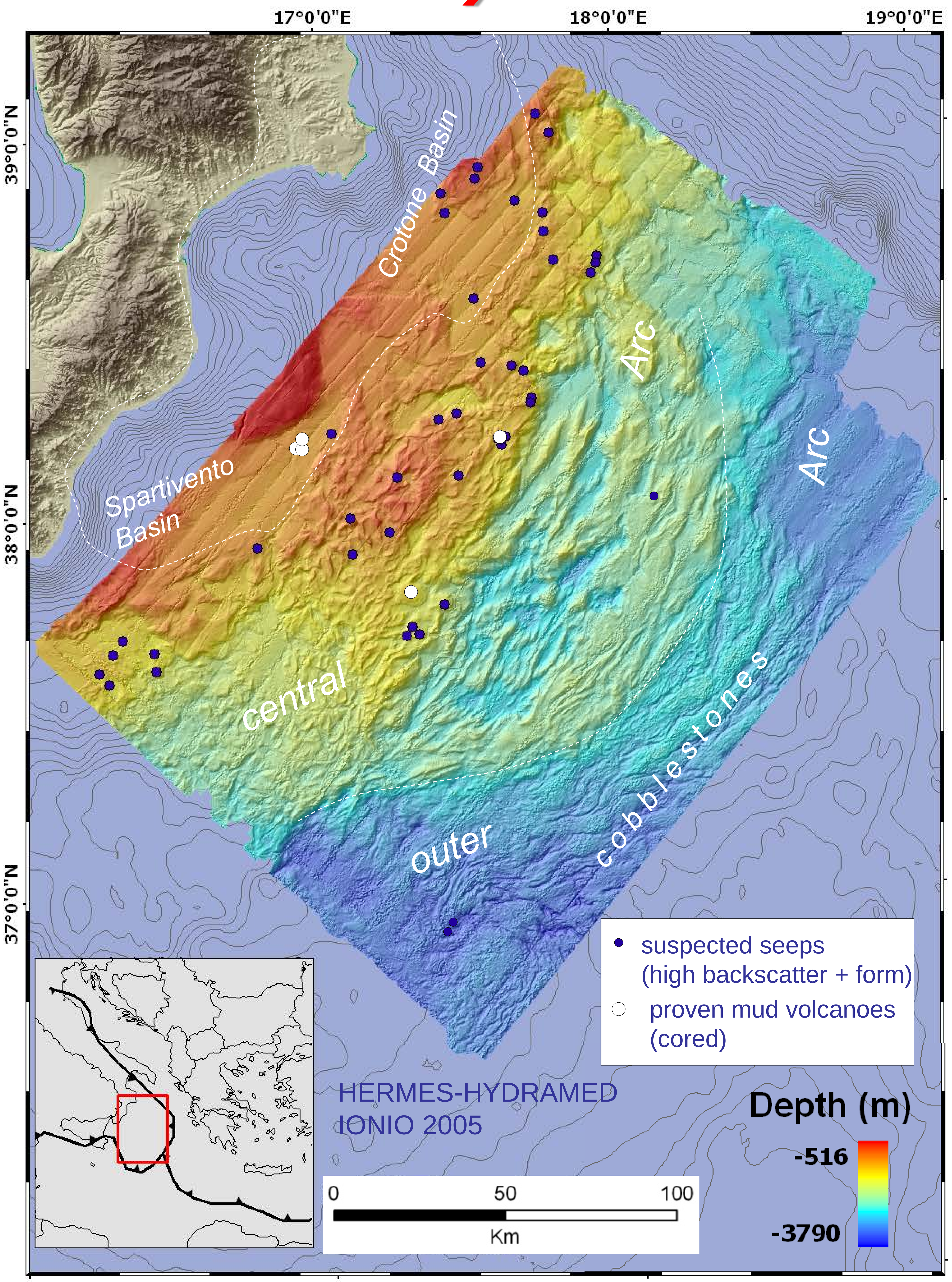


...they are **shorter**, occurring more **frequently** than in the ocean margins and in some cases they **erode retrogressively in the direction of the coast line** (*Ceramicola et al. 2016*)

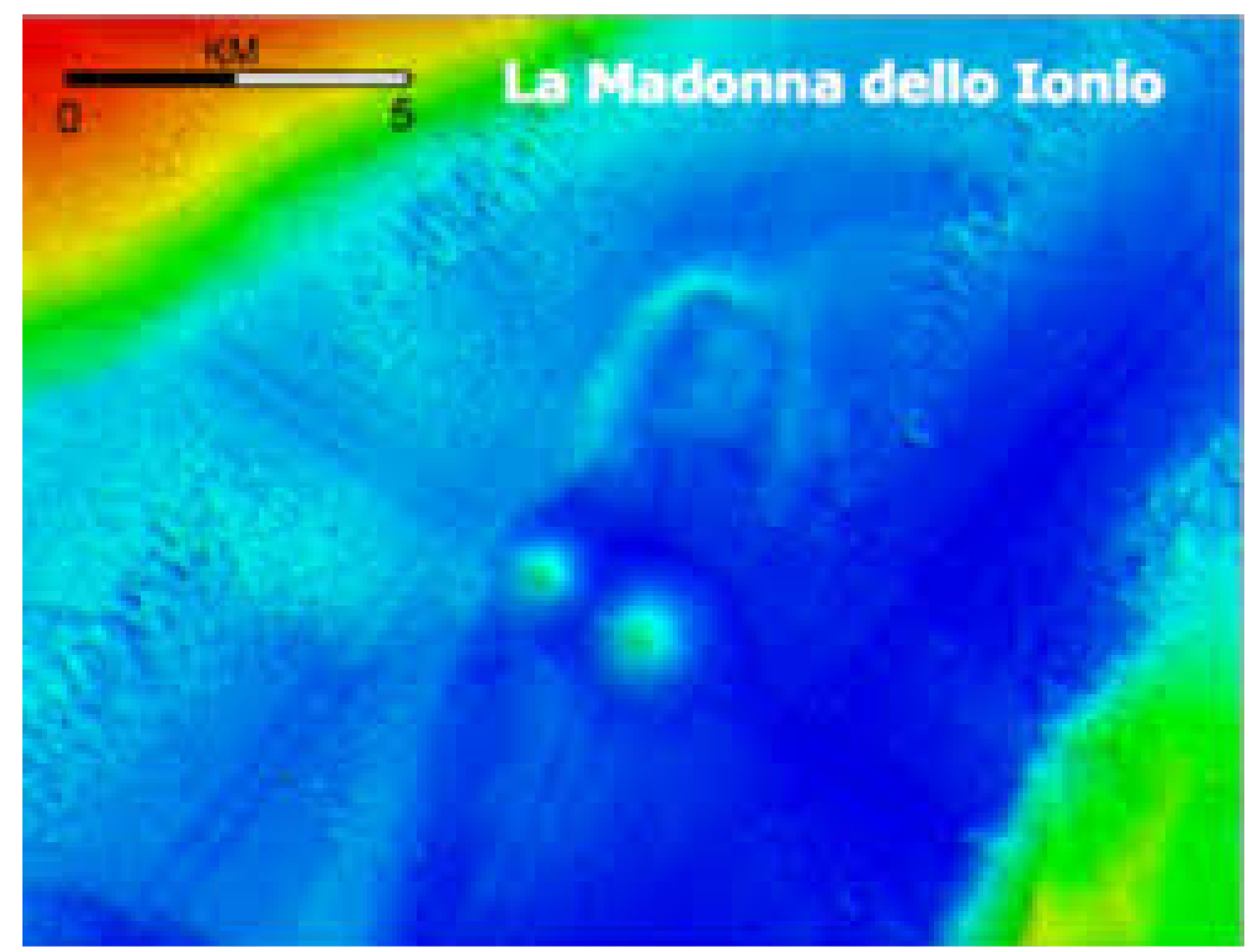
The Ciro' submarine canyon


Porto di Cirò Marina
Ore 11:00 del 01 Dicembre 2013
Foto by Sergio Marino

5) Fluid emissions



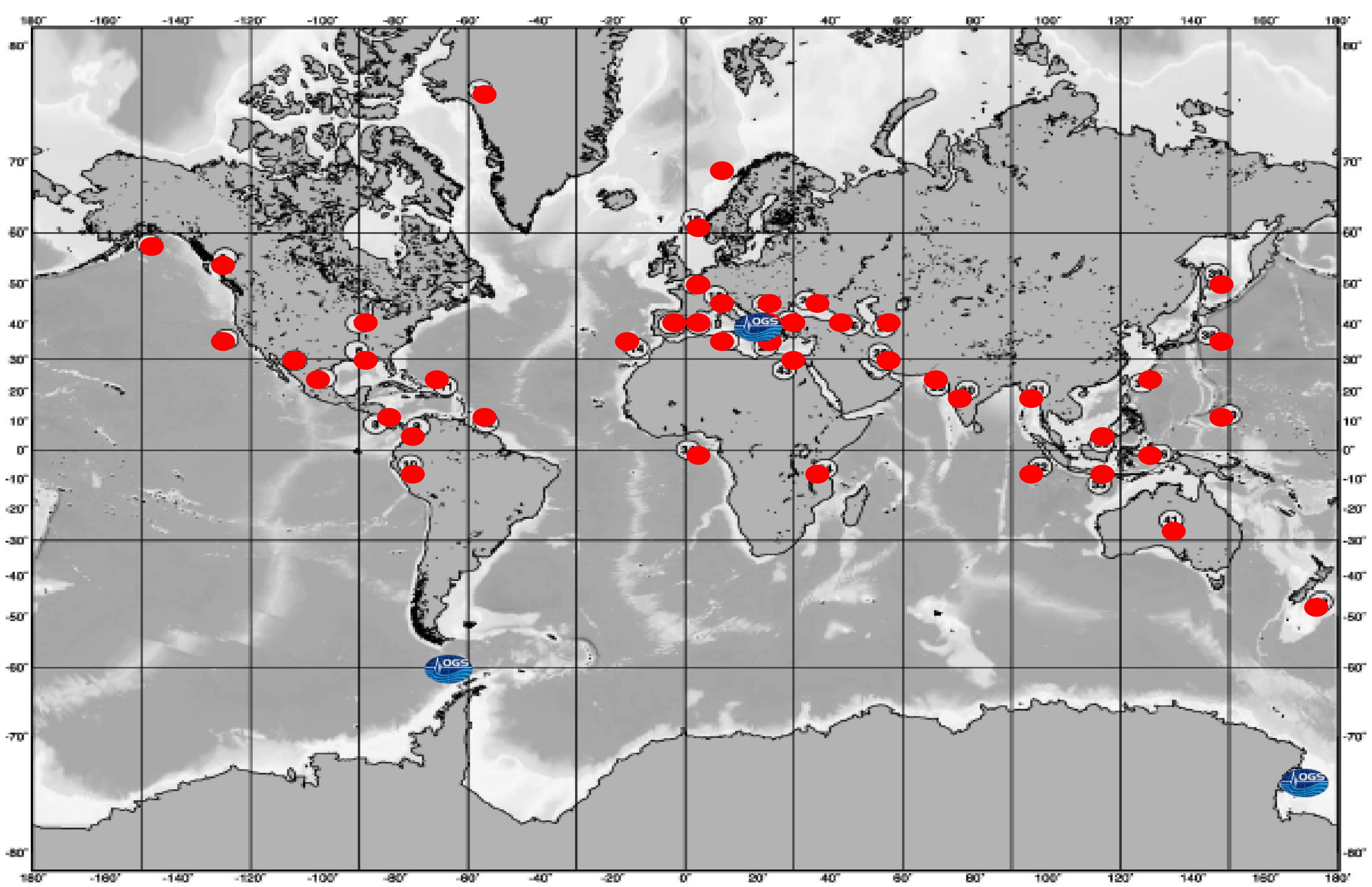
Using different geophysical and geological methods we have been able to identify 54 mud volcanoes, map their distribution, characterise their activity and assess possible geohazards



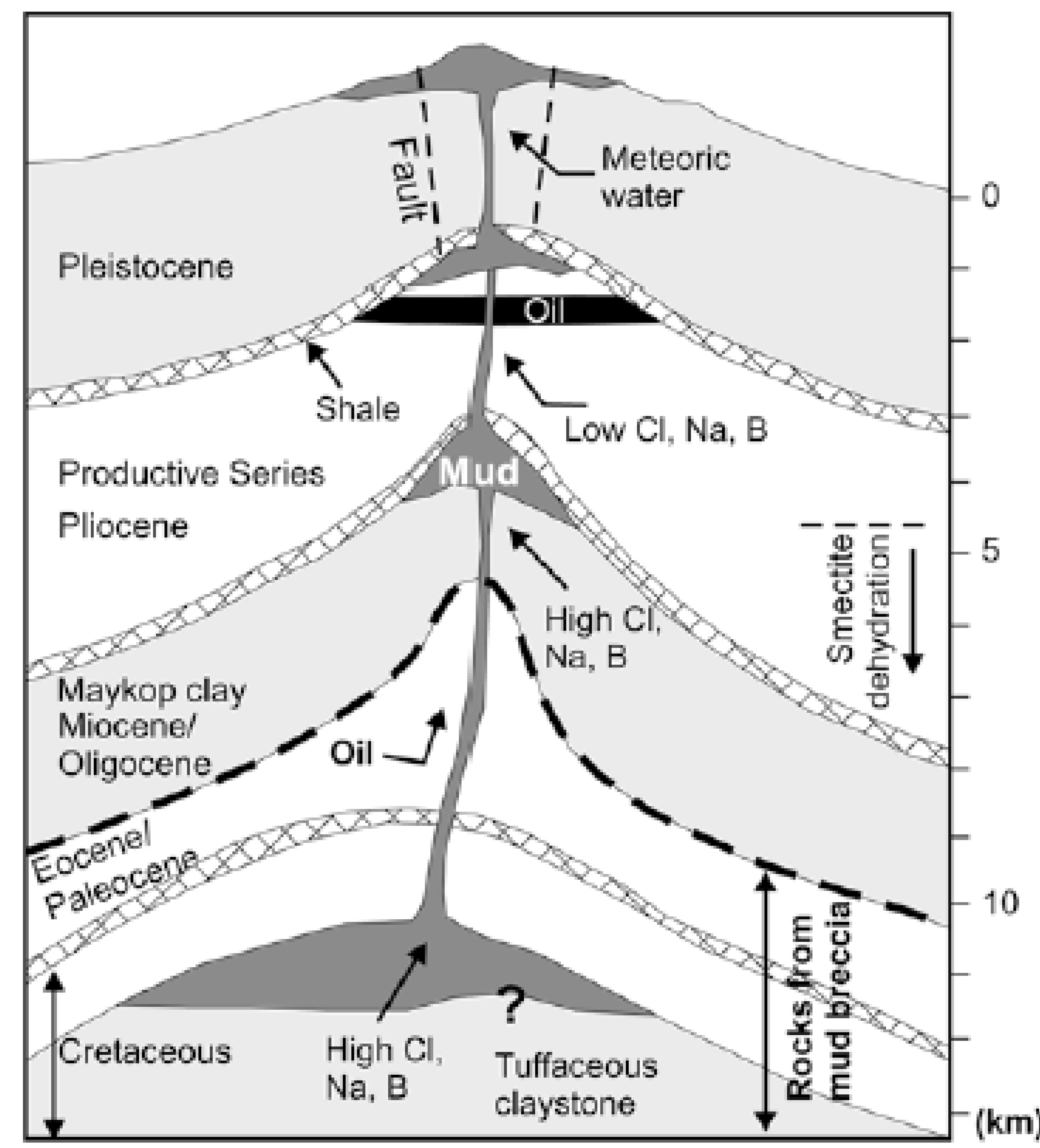
discovered by OGS in 2015

Ceramicola et al. 2014

Fluid emissions



Mud volcanoes occurrence on continental margins worldwide (*Kopf 2002)*

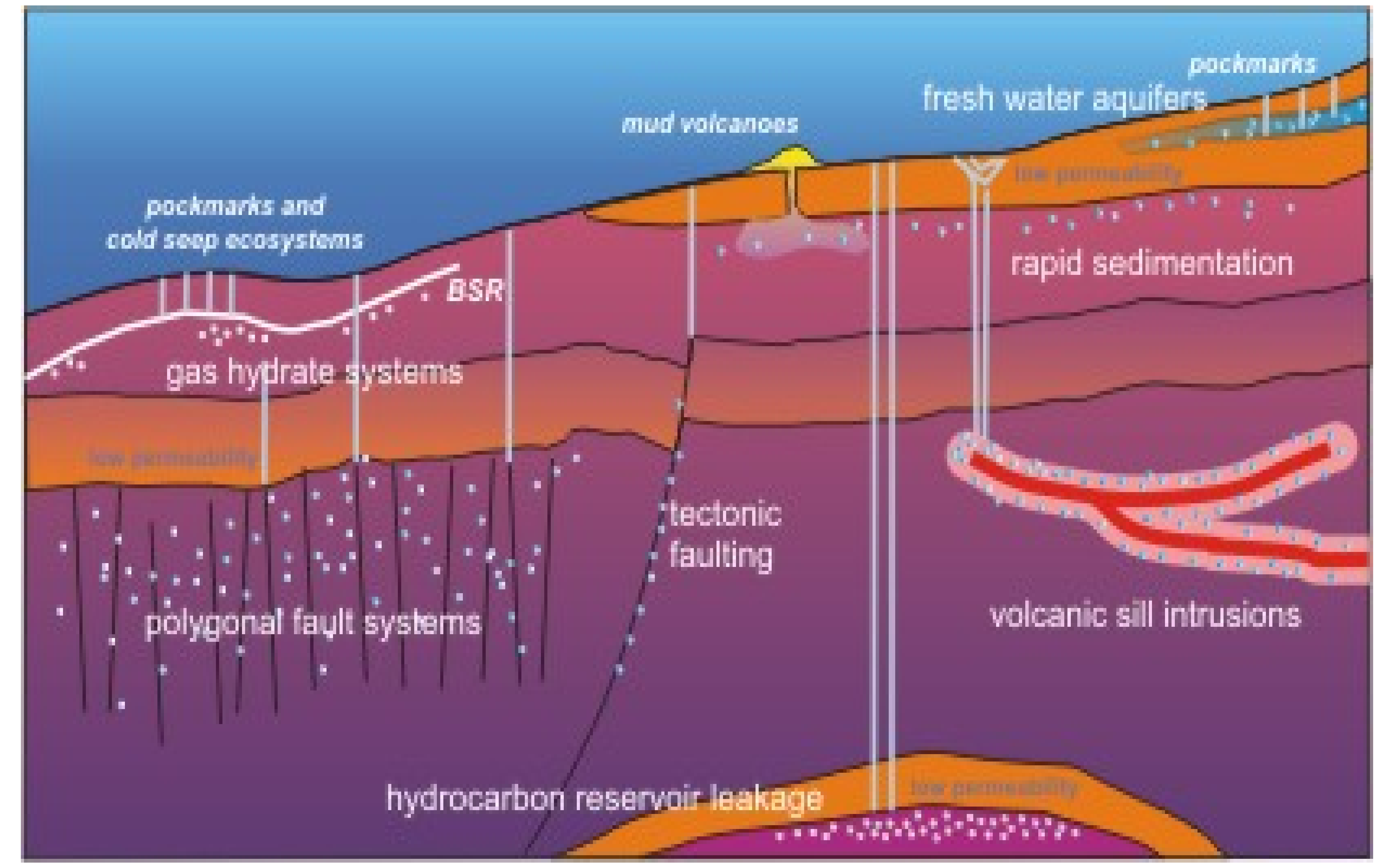


Conceptual model of functioning of Azeri mud volcanism – deep rooting (12 km), multiple mud chambers
(*Planke et al. 2003*)

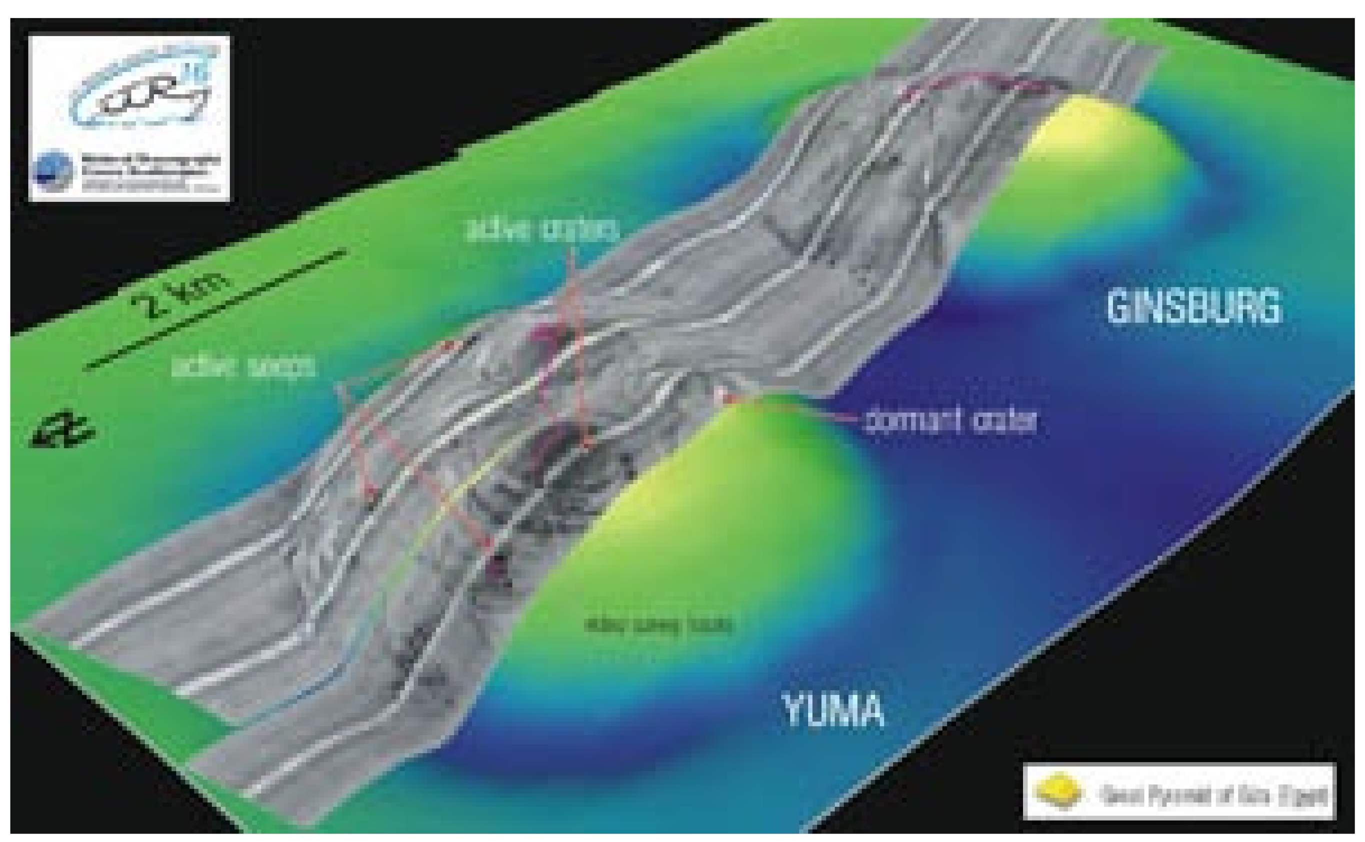
COLD SEEPS EXAMPLES

I COLD SEEPS

- MUD VOLCANOES (CONIC PIES)
- POCKMARKS
- CARBONATIC CRUSTS
- BRINE POOLS
- GAS HYDRATES



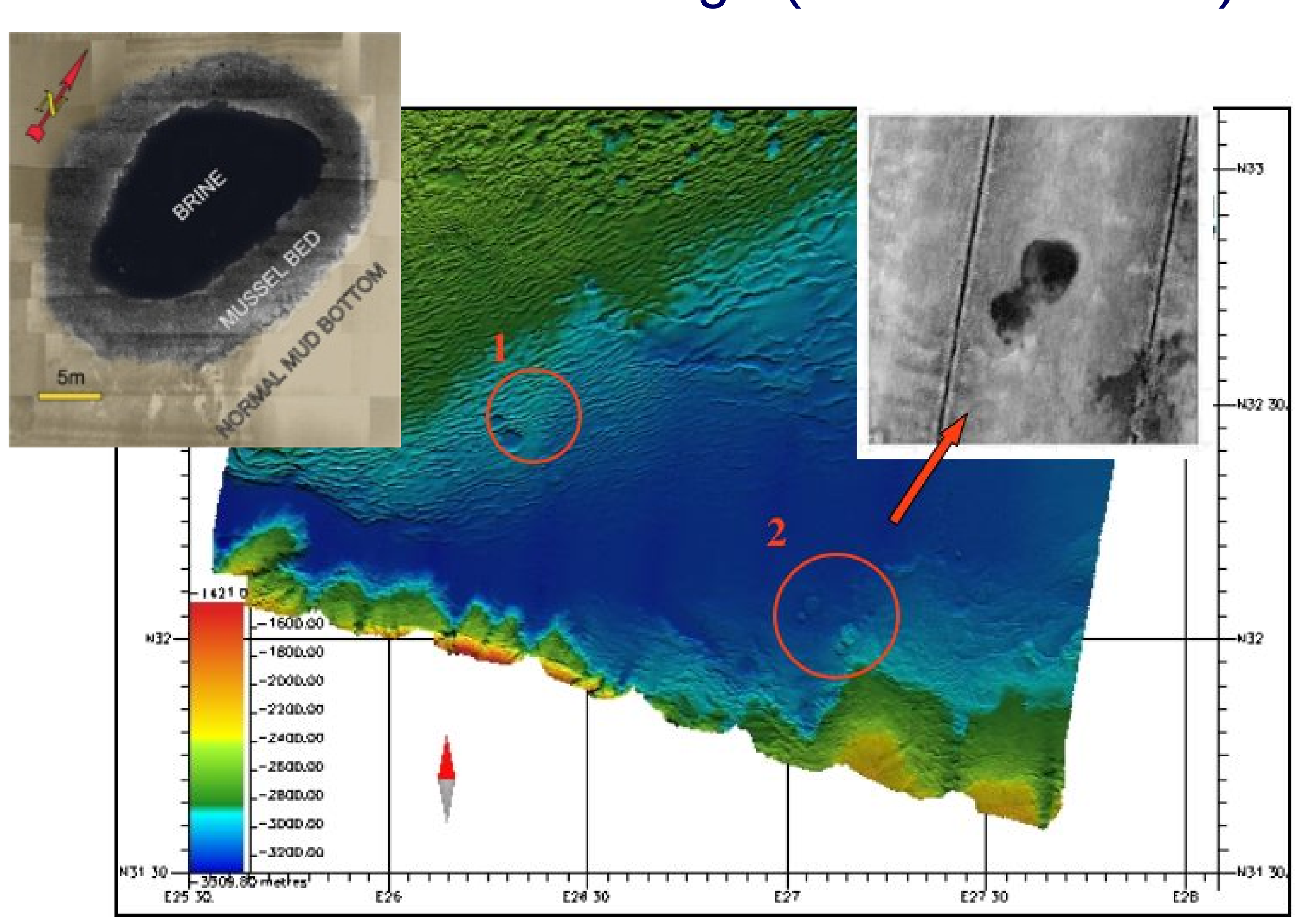
Schema della circolazione dei fluidi nei sedimenti, Berndt (2005)



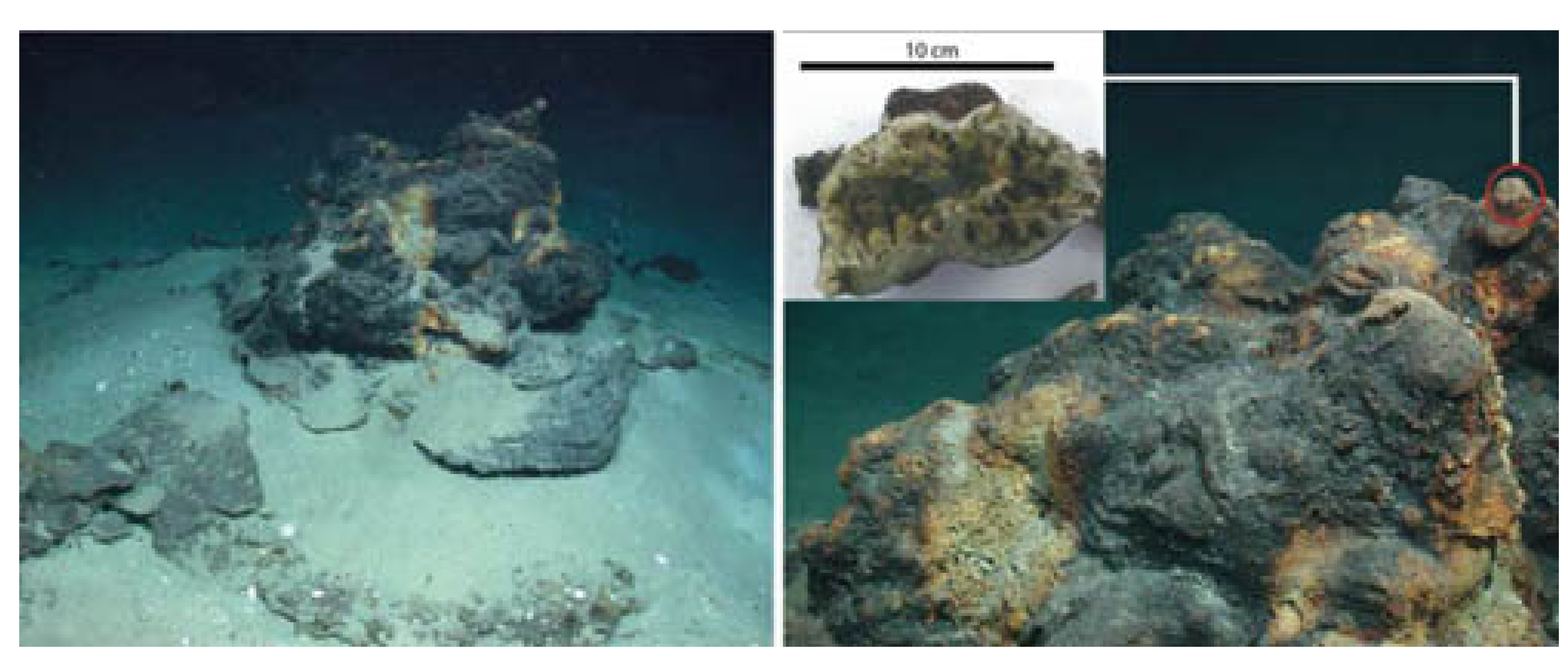
Vulcani di fango (Golfo di Cadice)

Pockmarks - Mar Adriatico

Fuoriuscite di metano
Hakon Mosby Mud Volcano



Brine salmastre (Delta del Nilo)

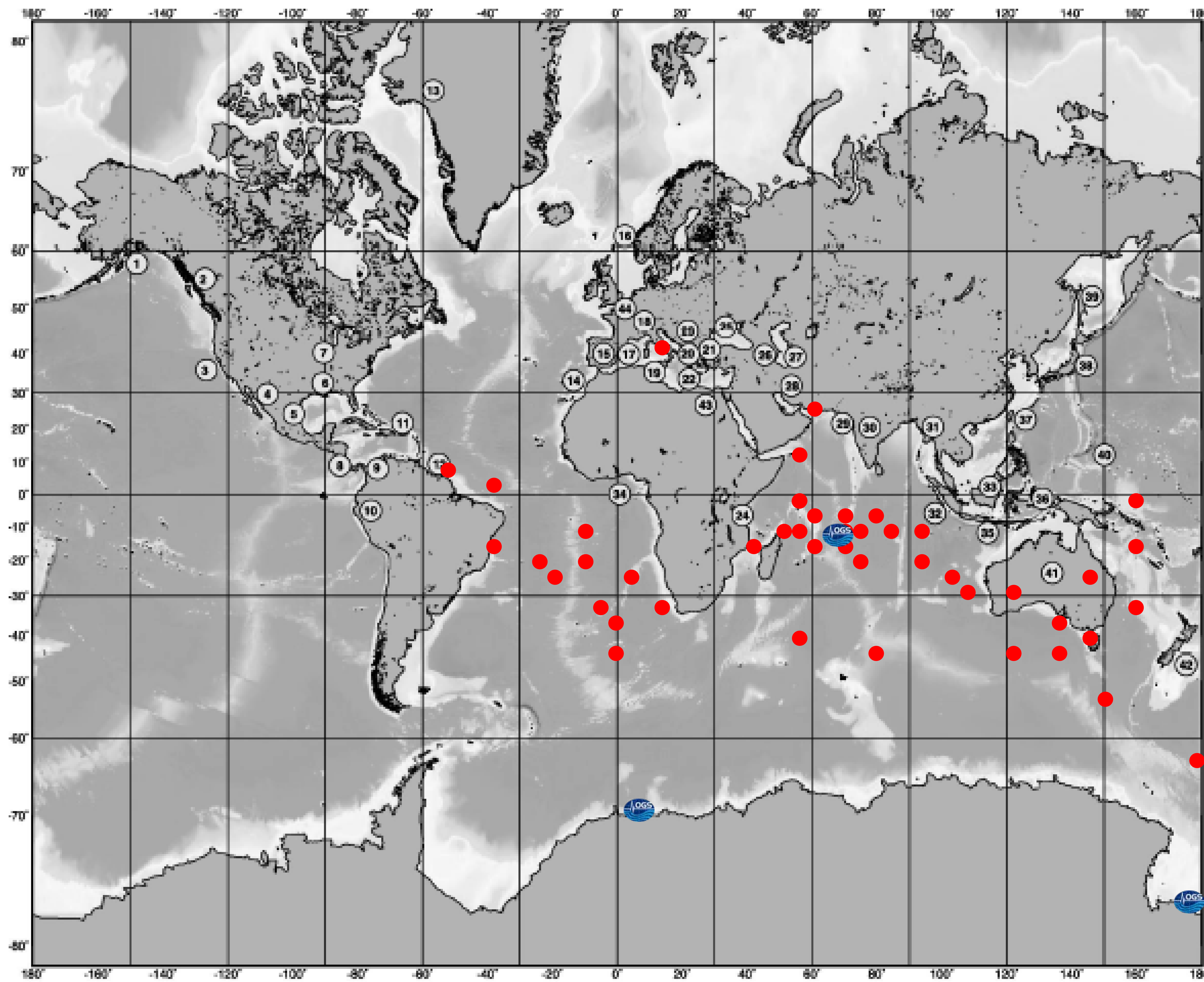


Croste carbonatiche - Vulcano di Fango Amon (Delta del Nilo)

Le salse di Nirano (Modena)

Why do we study COLD SEEPS?

- because we do not know their functioning through time
- geosphere biosphere interaction
- impact of gas emission (greenhouse)in the athmosphere
- responsable for slope instability in association with gas hydrates (geohazards)
- gas hydrates represent a potential economic resourse



Distribuzione dei vulcani di fango nel mondo, Kopf (2002)

Volcano di fango Lusi, Java orientale, Indonesia (dal 2006)

Lusi Mud Volvano, W-Java, Indonesia (erupting since 2006)

It began erupting mud more than a decade ago and hasn't stopped since.

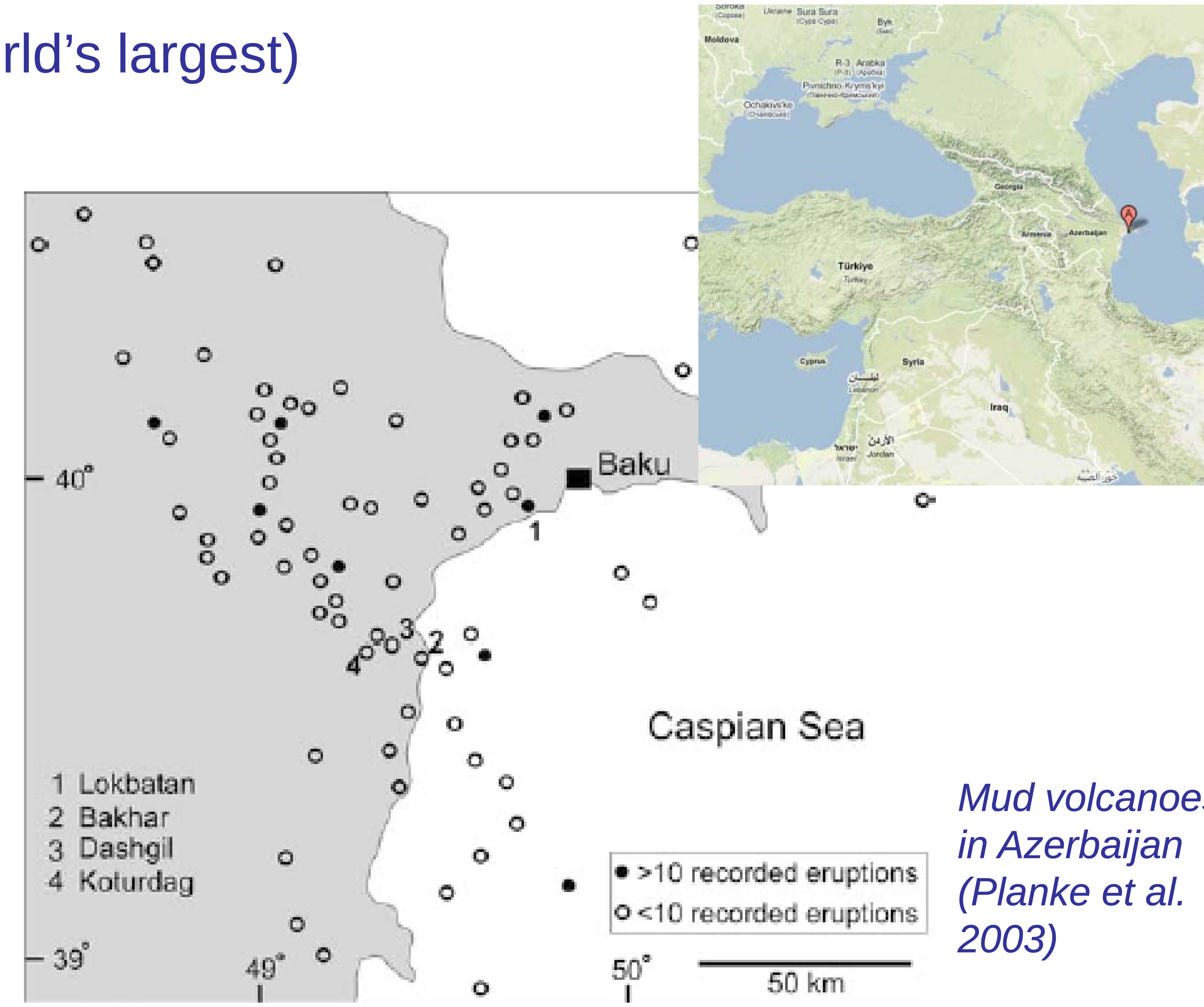
At its peak 180,000 cubic metres of mud a day spewed to the surface.

Ikonos Satellite images (CRISP)

1 KM

Azerbaijan mud volcanoes (among world's largest)

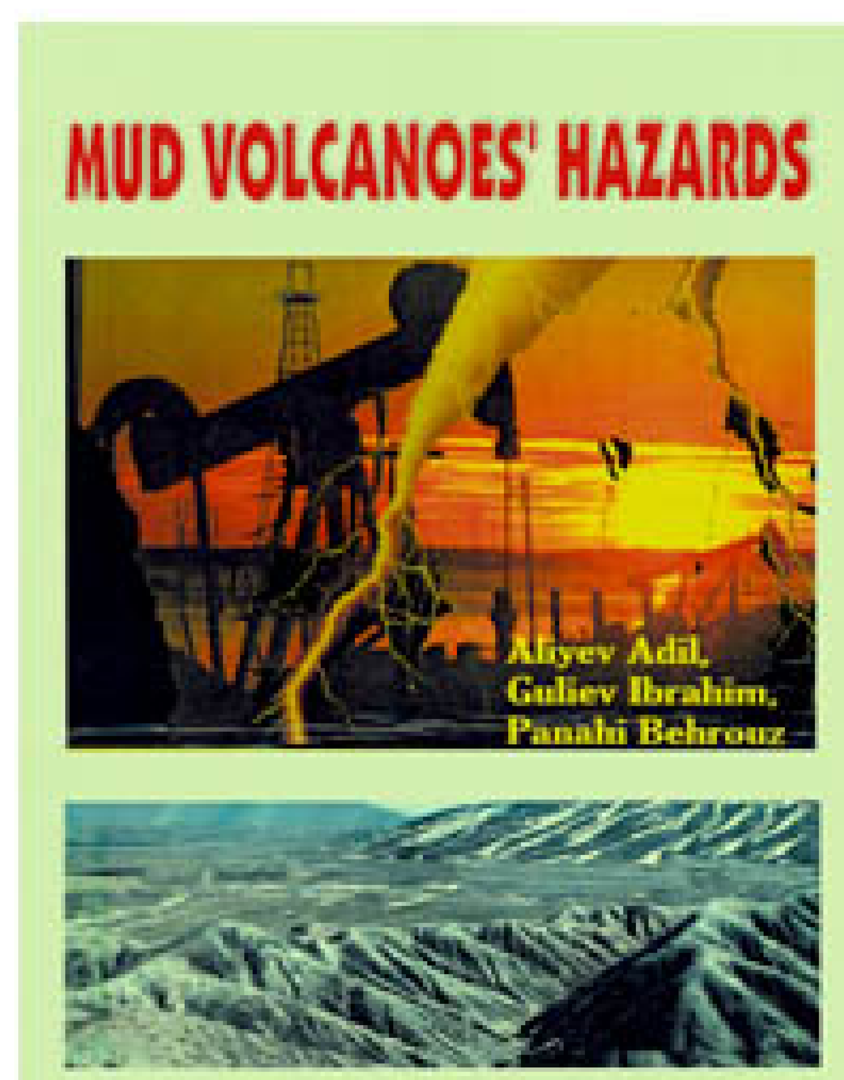
Lokbatan MV (B. Asbrink 2003 - Azerbaijan International)



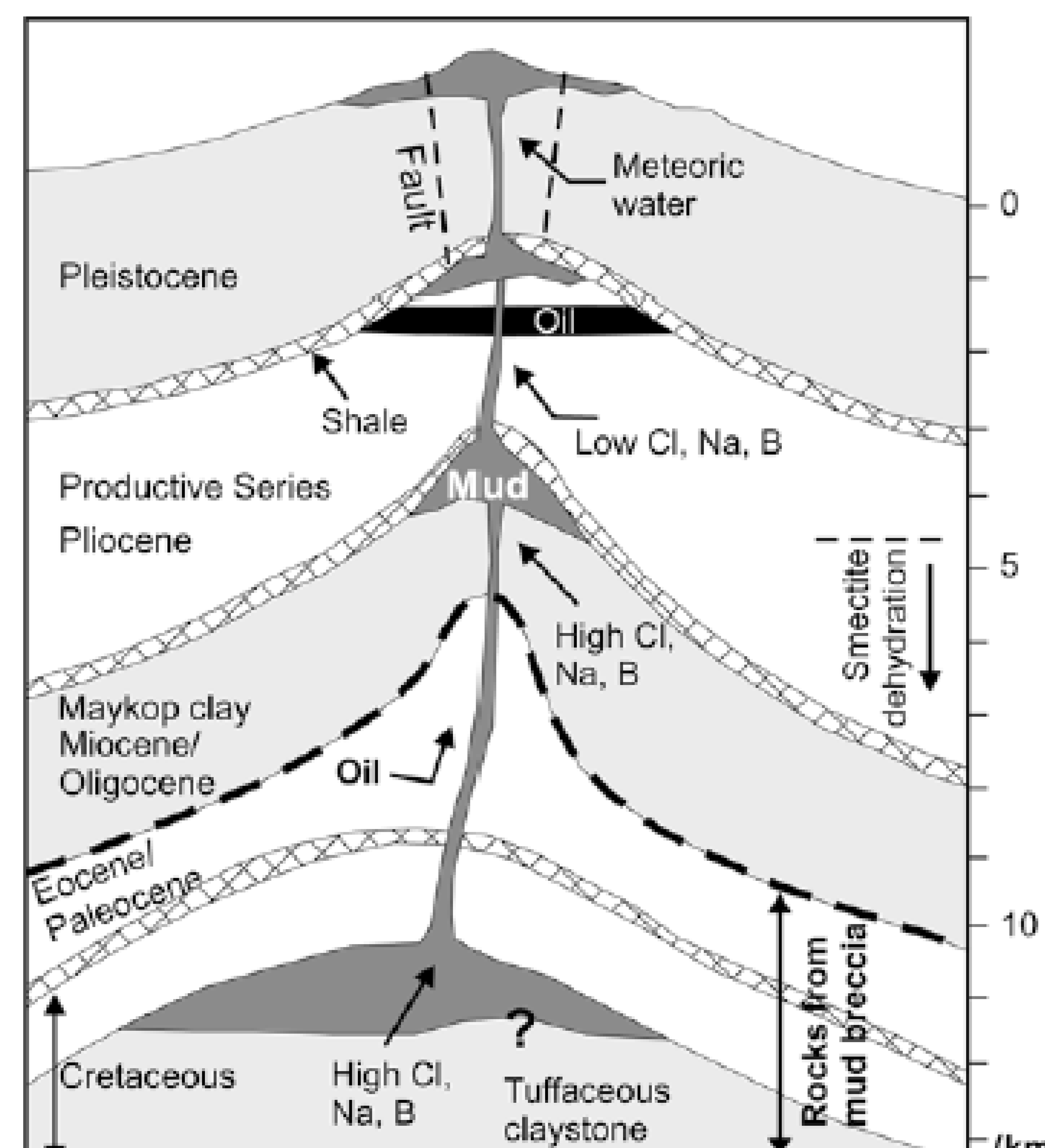
Mud volcanoes in Azerbaijan (Planke et al. 2003)

www.martinhovland.com

Self-igniting supersonic gas blowout - height 750 m, distance 20 km from Baku (1958)

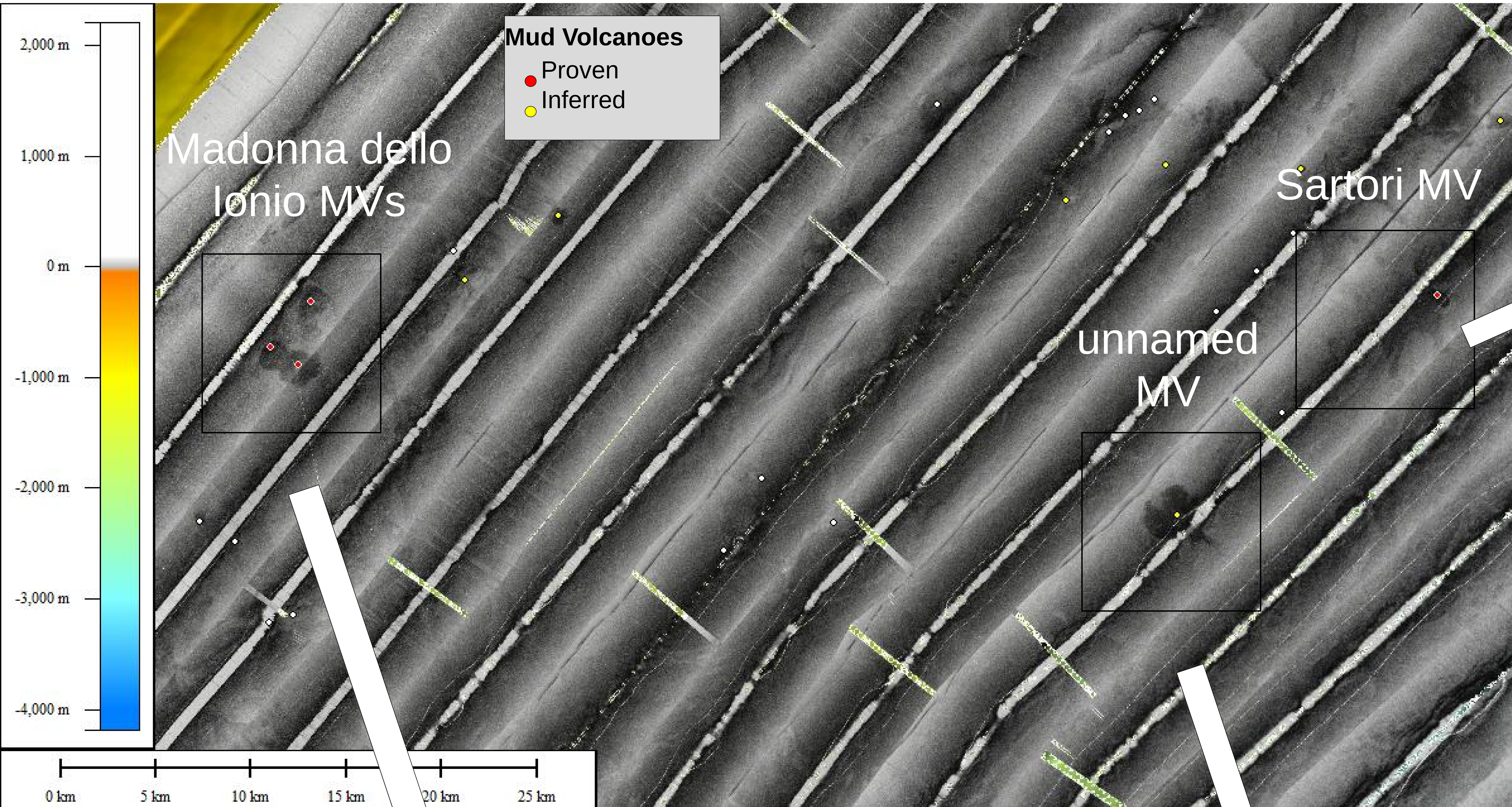


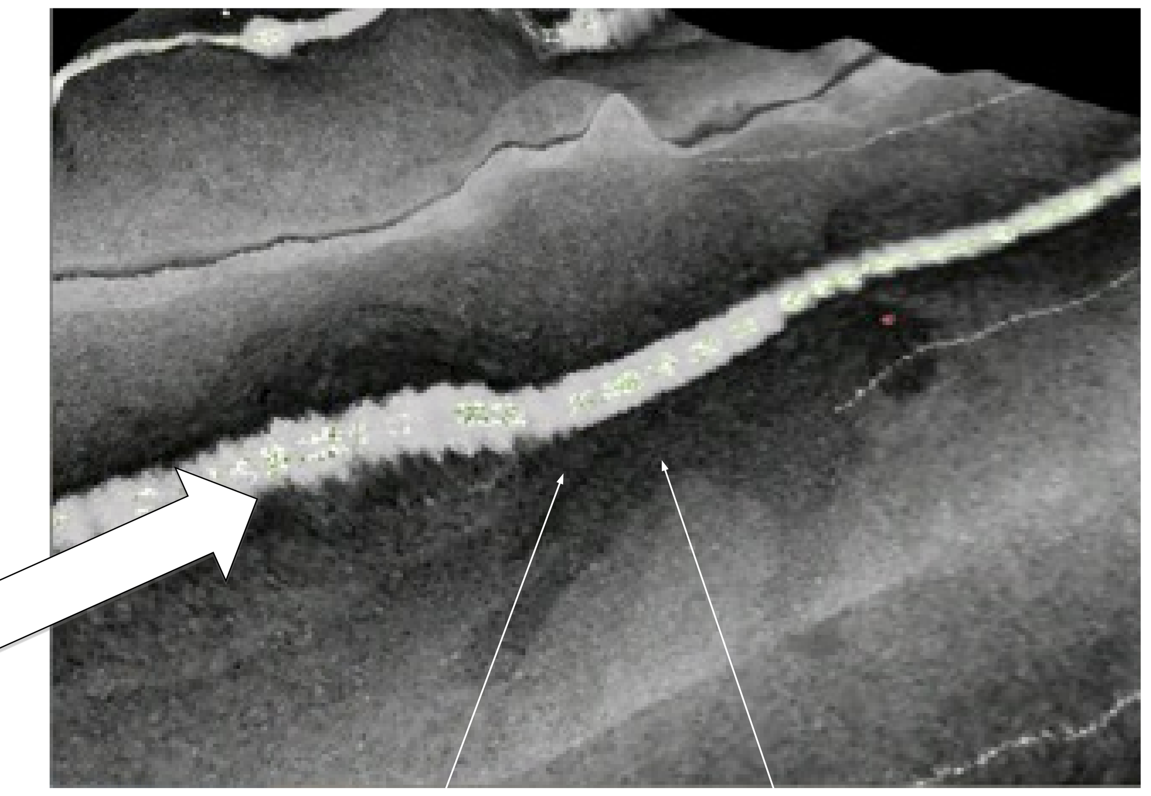
Aliyev et al. (2000)

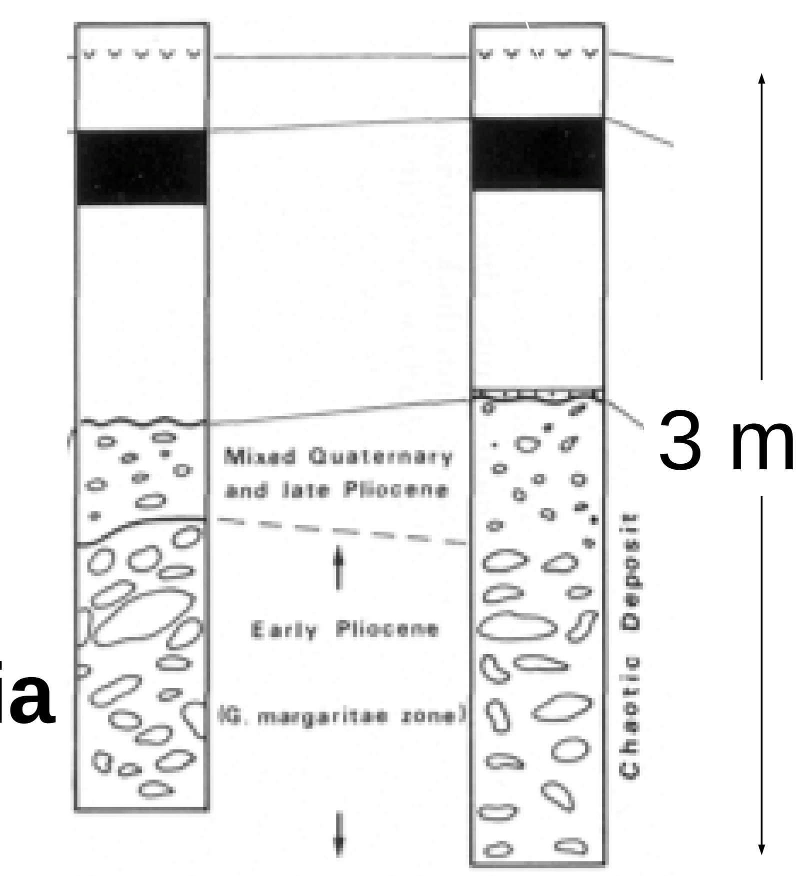


Conceptual model of Azeri mud volcanism - deep roots (12 km), multiple mud chambers (Planke et al. 2003)

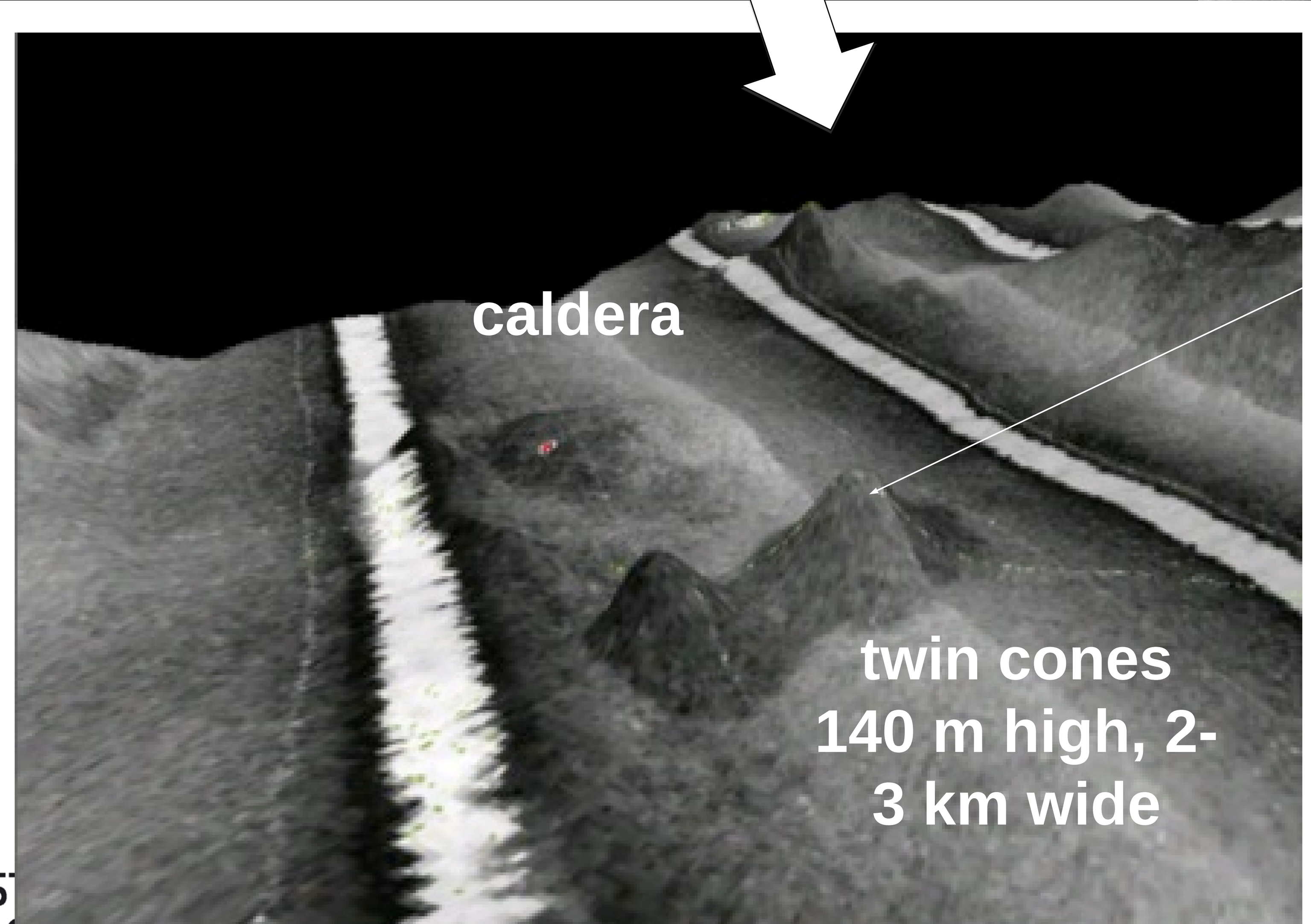
Use of multibeam morpho-bathymetry + backscatter data to map mud volcanoes (Calabrian Arc)

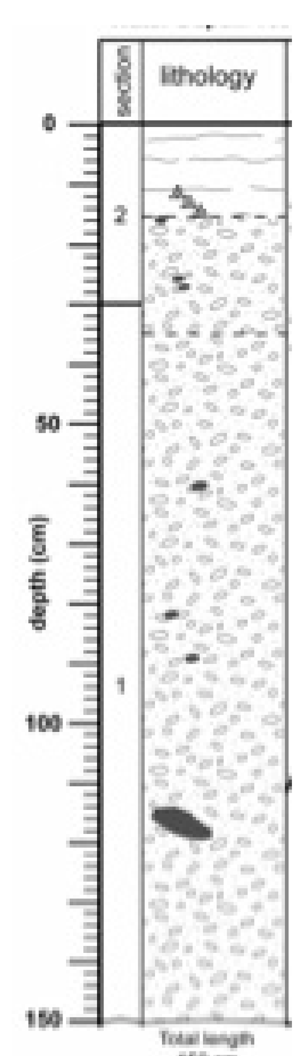




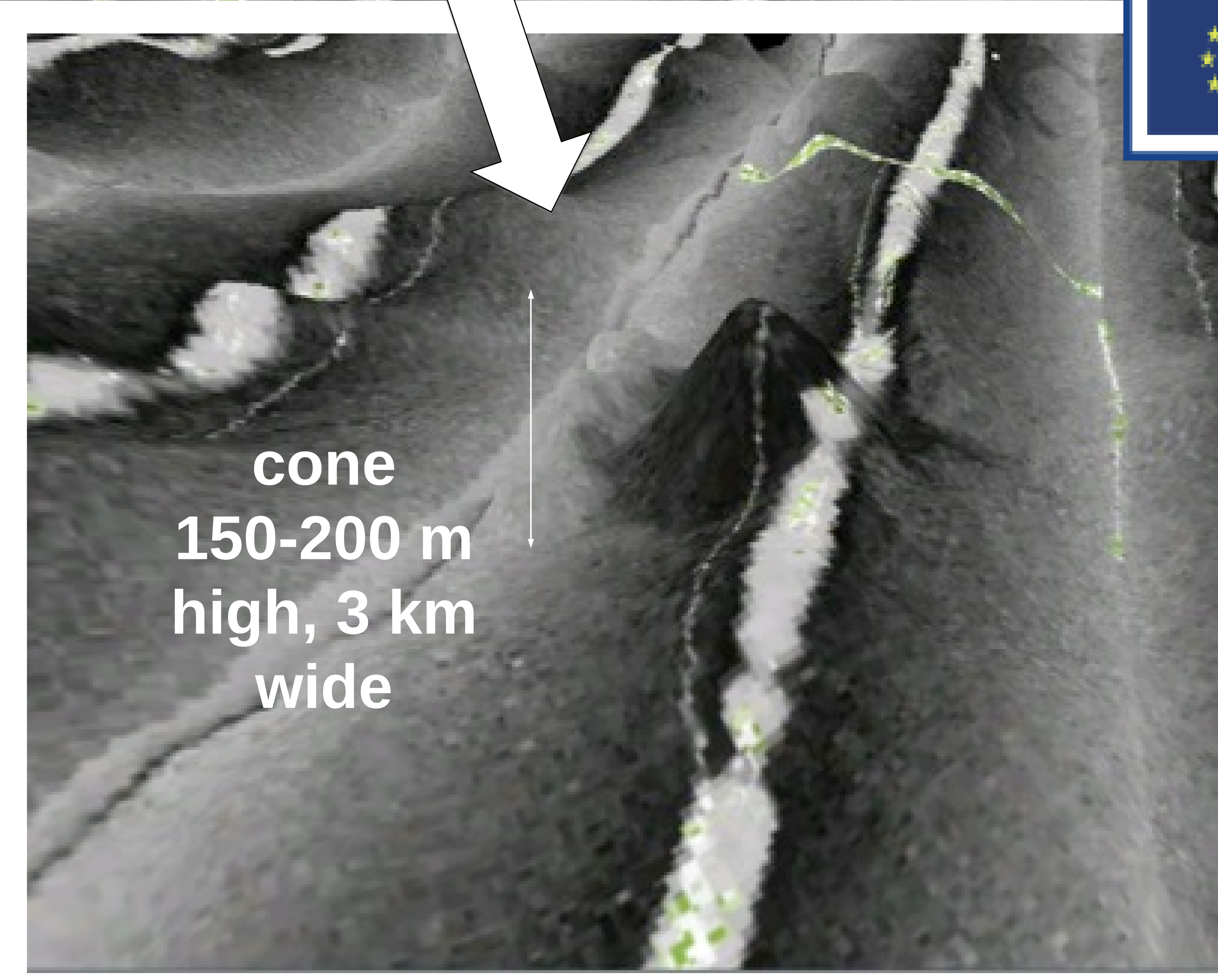


Morlotti et al. (1982)





mud breccia

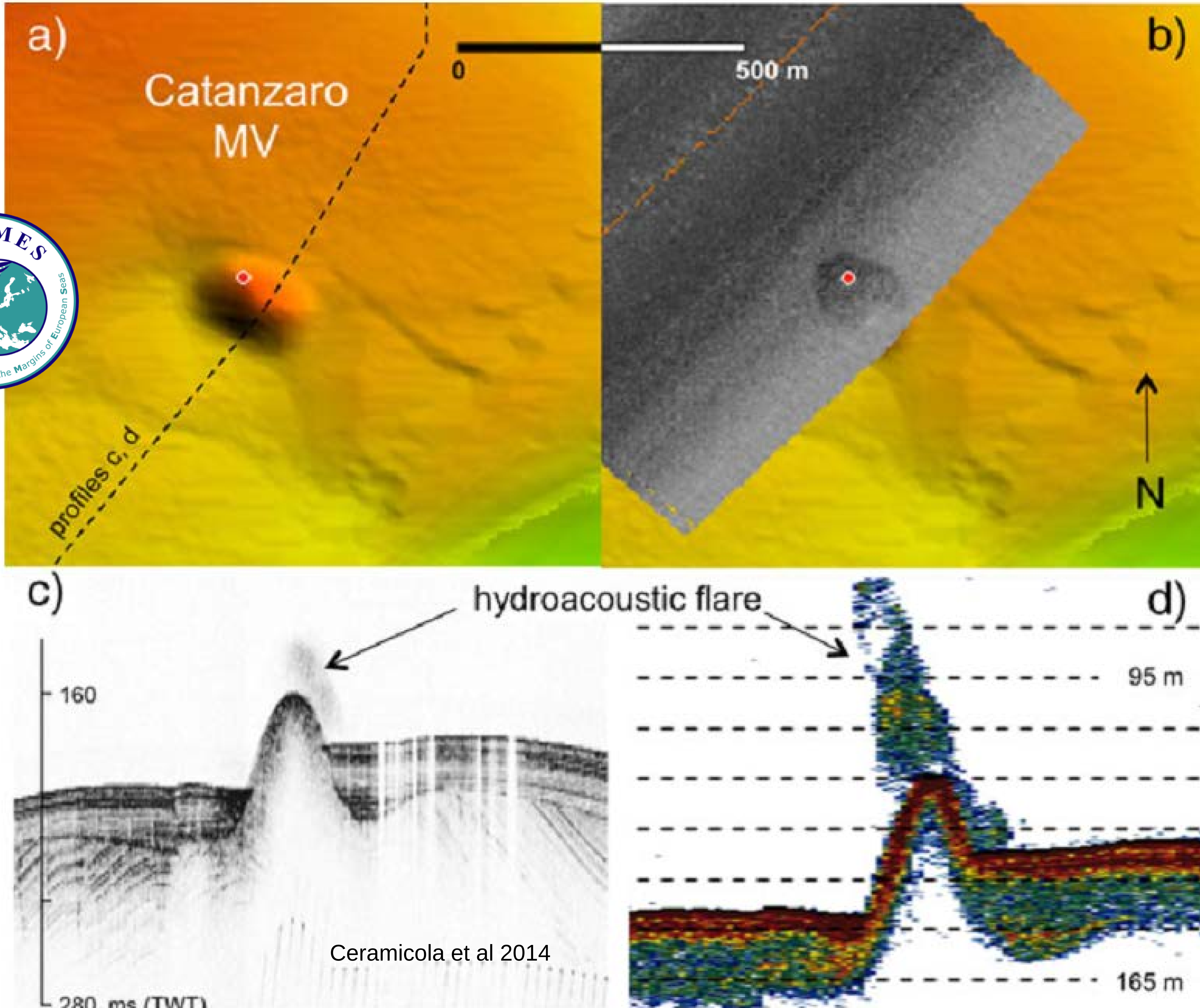


HYDRAMED

HERMES
Hotspot Ecosystem Research on the Margins of European Seas

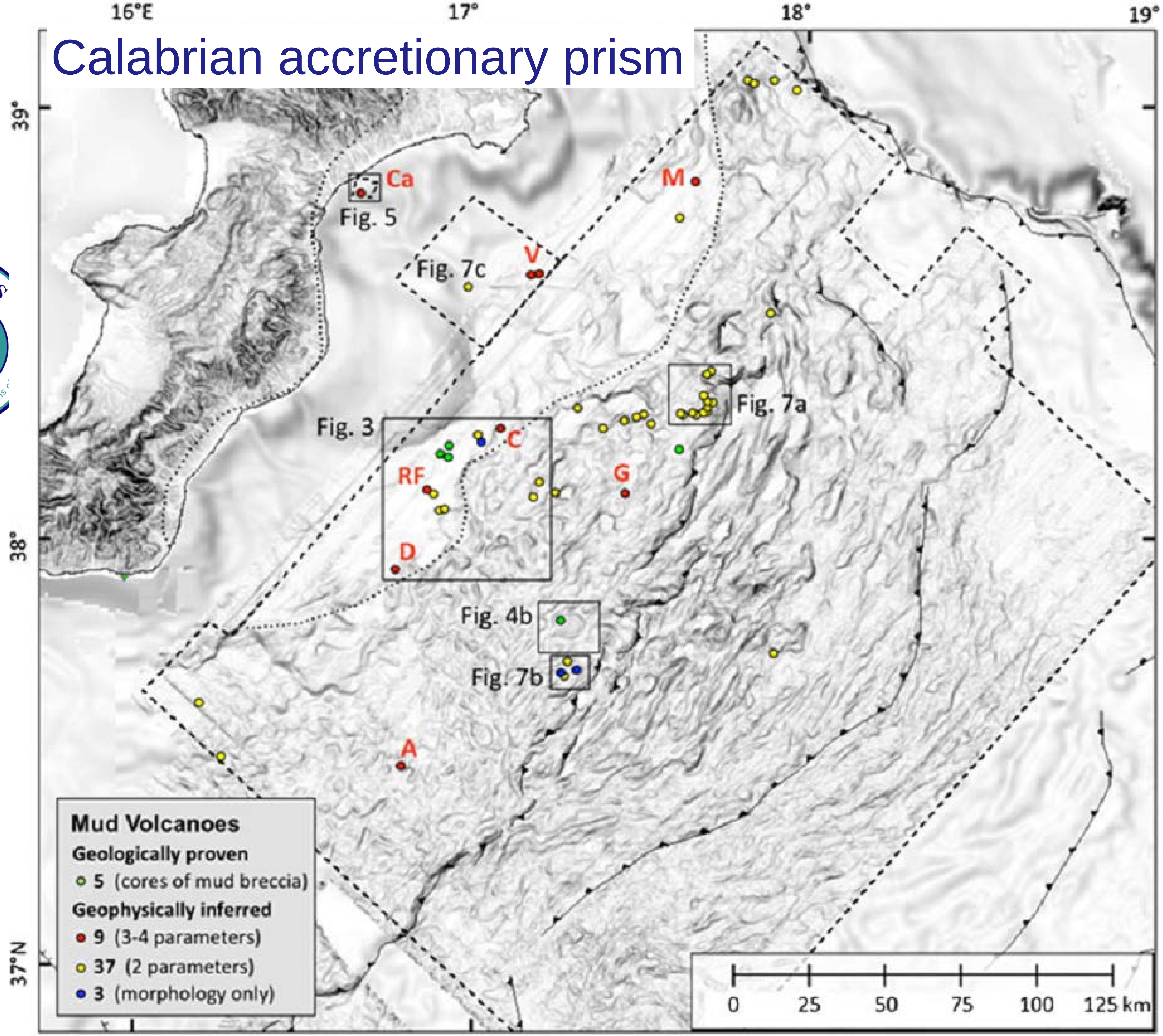
Ceramicola et al. (2014)

MARINE GEOHAZARDS ALONG THE ITALIAN COASTS
PROGETTO MAGIC



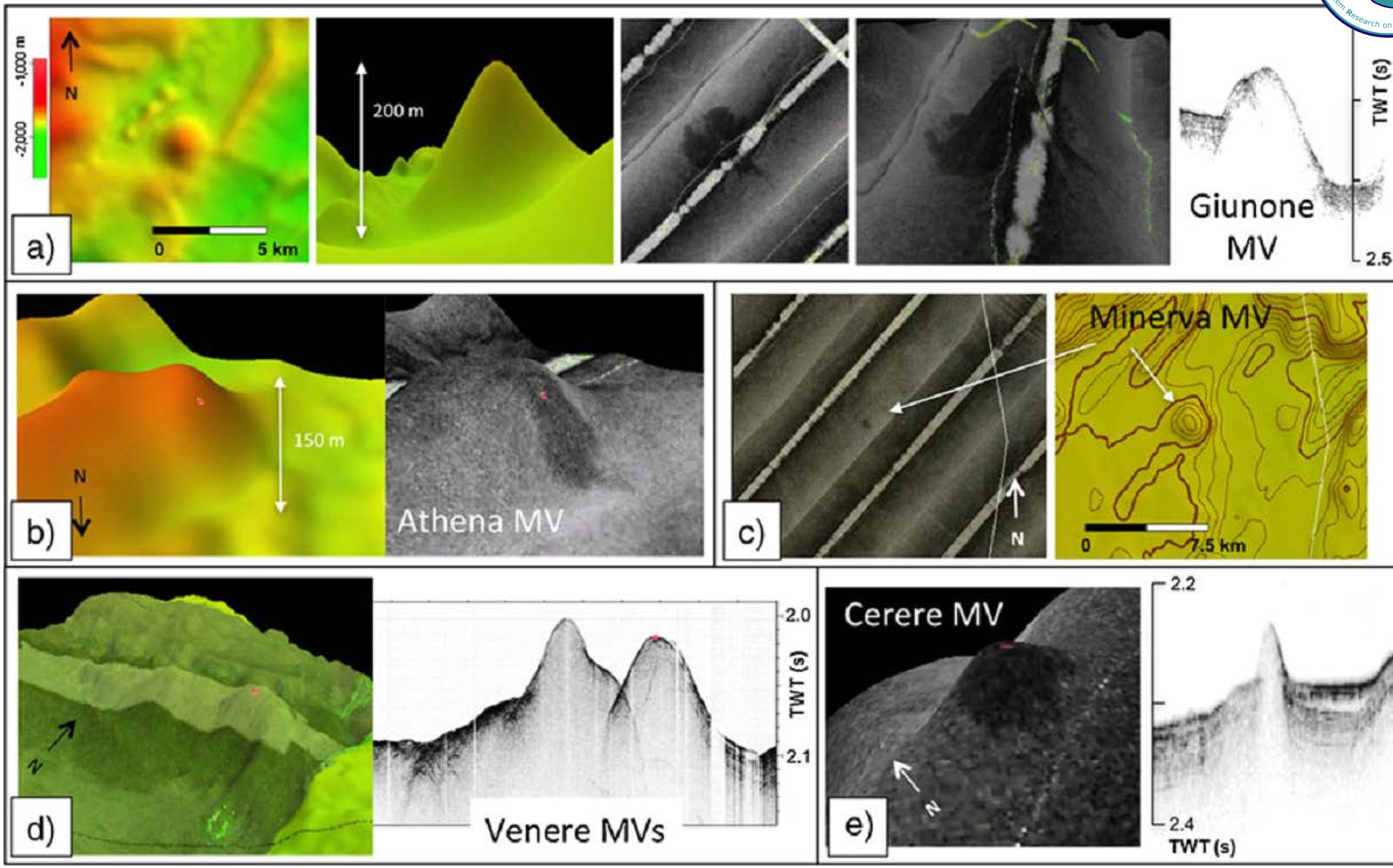
ISTITUTO N...
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

Calabrian accretionary prism



Ceramicola et al 2014

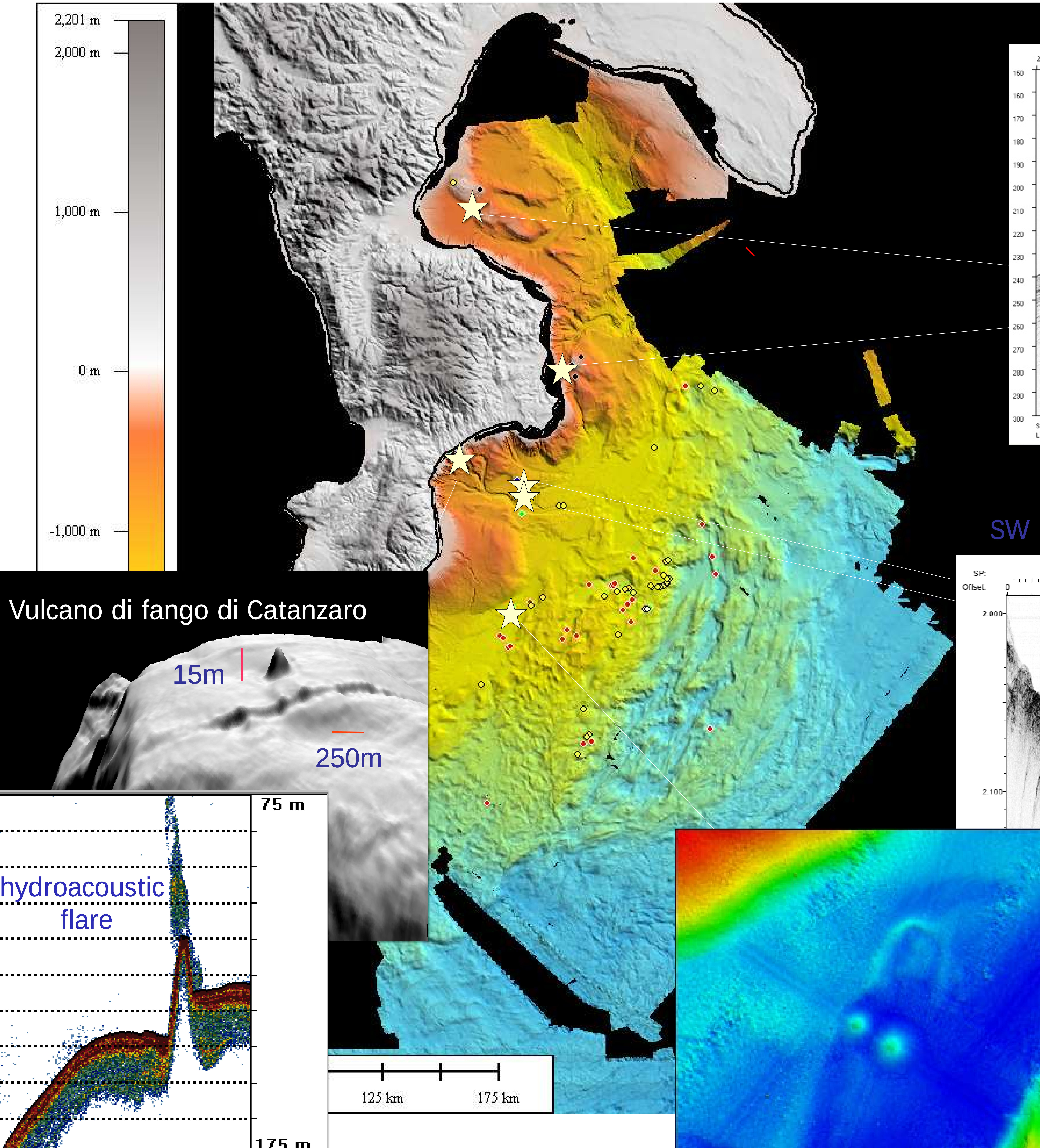
ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

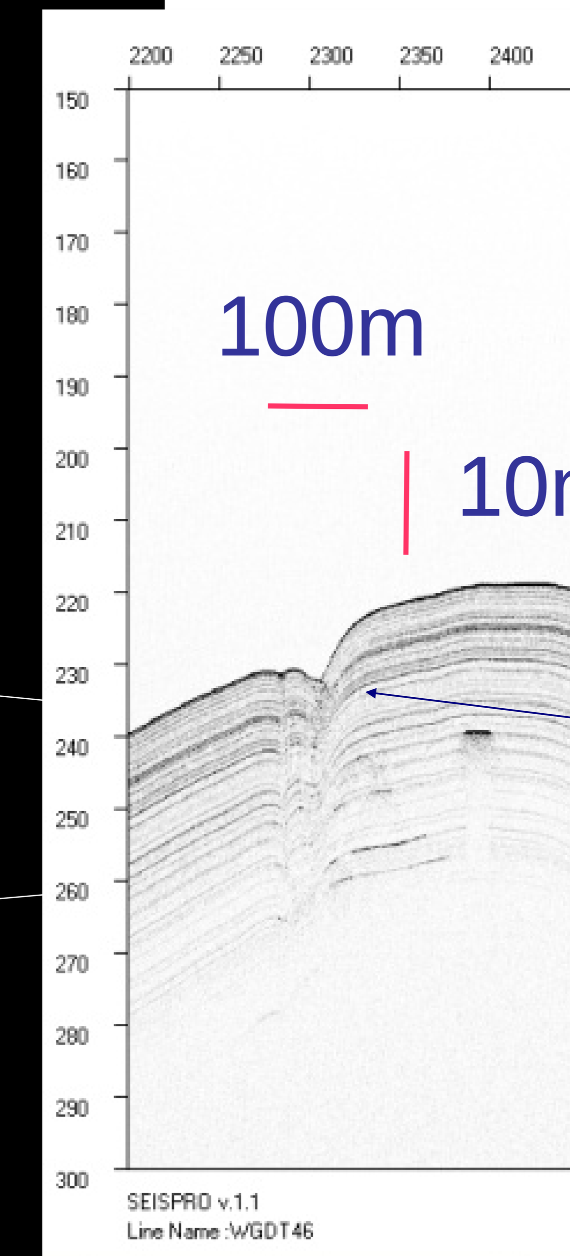


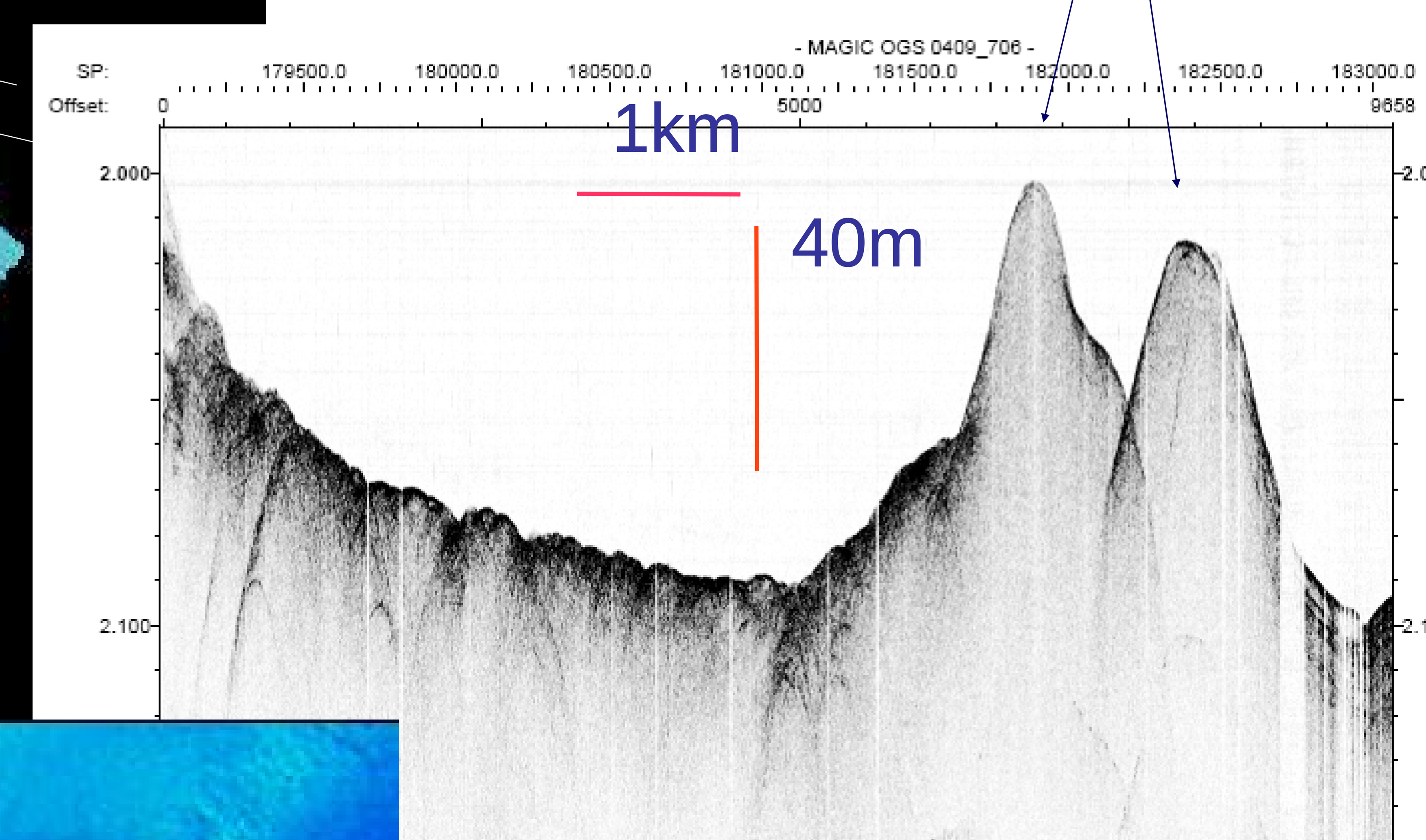
Ceramicola et al 2014

ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

SEABED SEEPAGE MAPPING



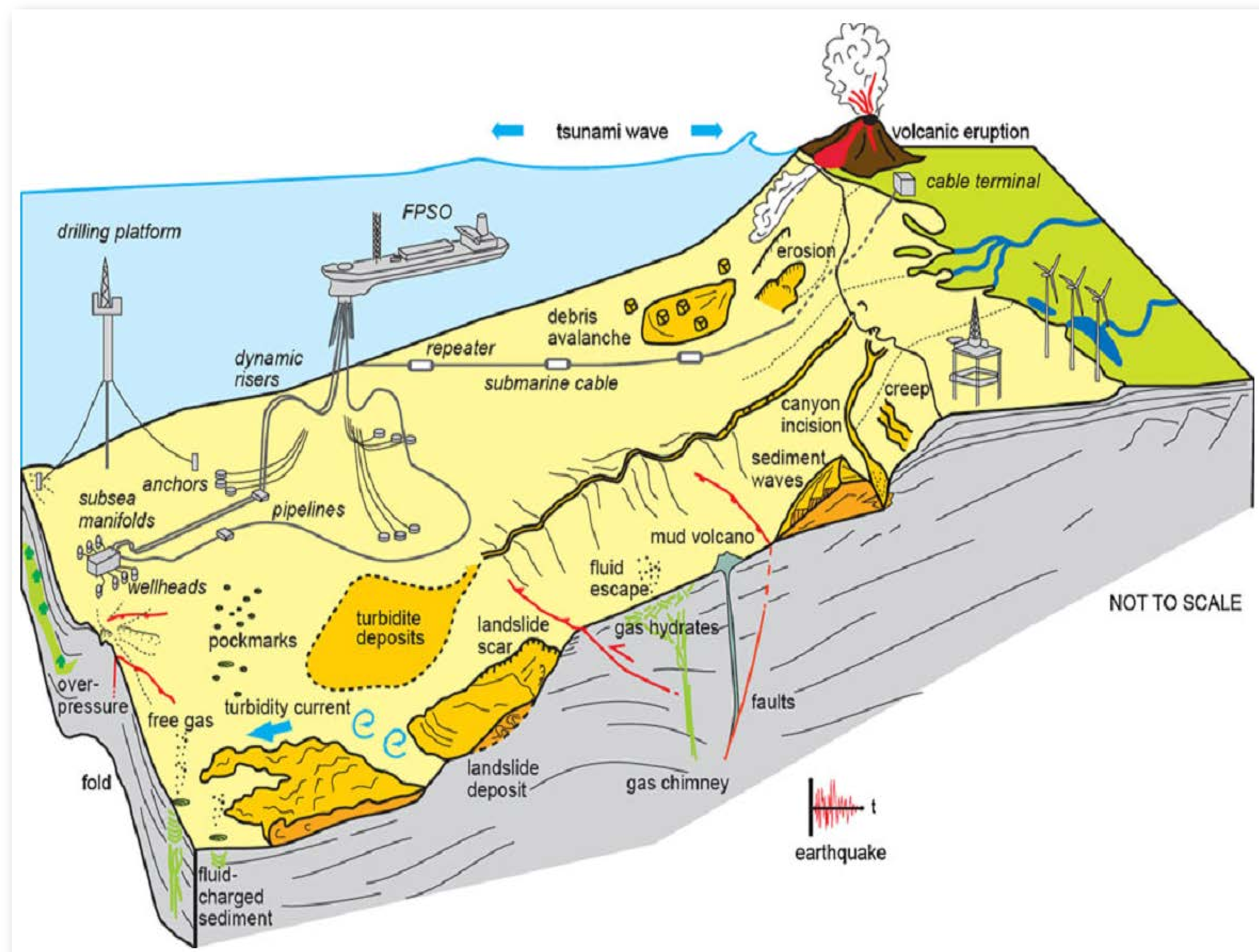




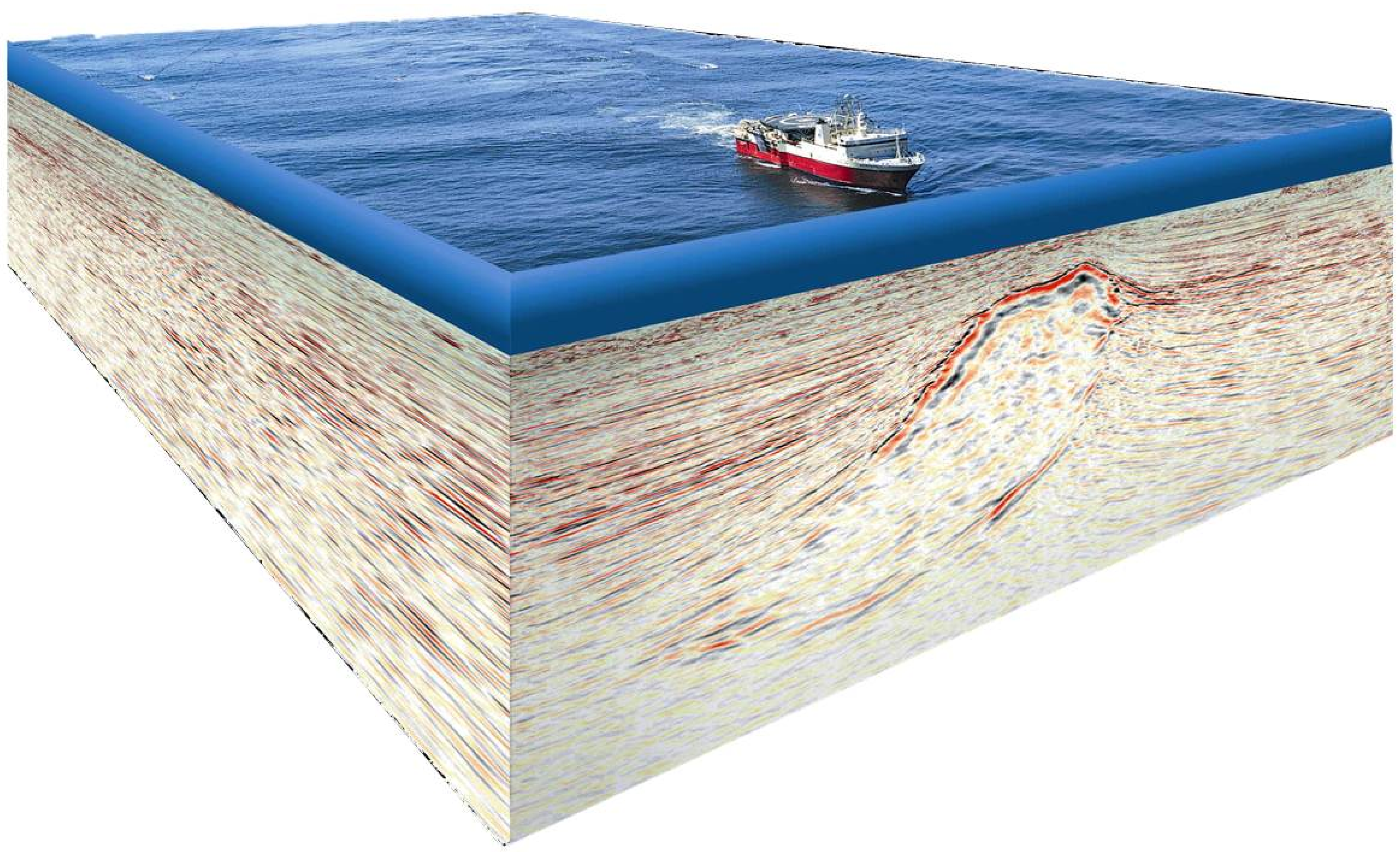
siti individuati nel
argine calabro ionico sottocosta,
olti di piu' sul prisma di accrezione

Concluding…..

1) The submarine portion of continental margins can be 'disturbed' by ***natural geohazards: faults, landslides, retrogressive erosional canyons and fluid emissions…*** *Their activity at seafloor can damage humans and (costal and deep sea) infrastructures.*



Concluding…..

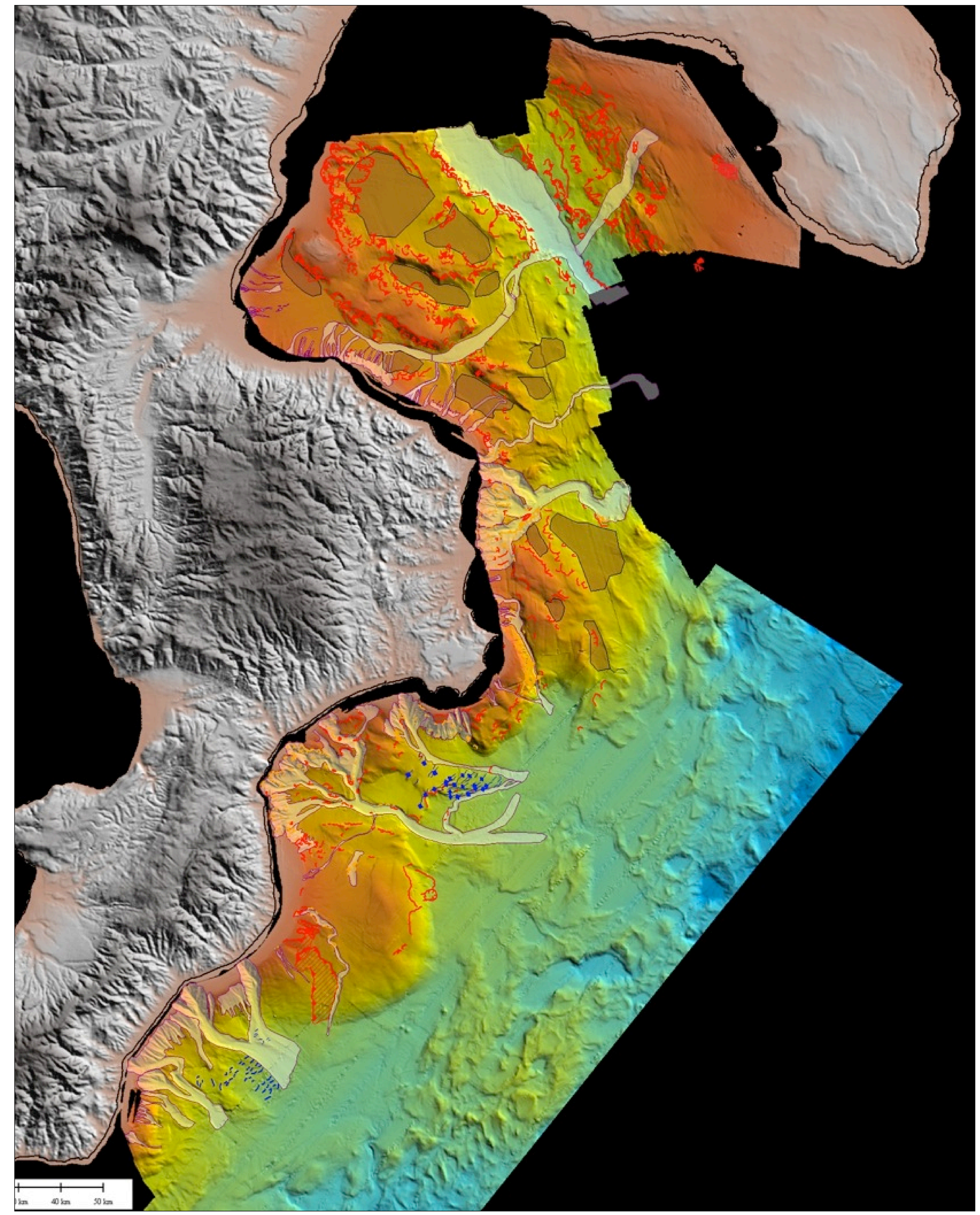


2) Integrated ***marine geophysical methods (including robotics)*** *at different resolutions (up to cm) enable researchers to reach remote areas of our oceans and* ***identify marine geohazards***

Concluding…..

3) ***Marine geohazards assessment*** *is about identifying, mapping, and characterizing geohazards occurrence (their parameters and the processes that regulate their occurrence),*

4) ***Marine geohazard assessment*** *is a prerequisite to undertake successful risk managment and risk mitigation of coastal and deep sea areas*



Further reflections

- Assessment of submarine geohazards is of broad scientific and social importance notably in the densely populated Mediterranean region
- Seimogenic faults, failure, gas seepage, tsunami and their interaction (cascading effects)
- Understanding (mechanisms and locations) of the geohazards of our seabed: maps of geohazards of all European seas, eventually Mediterranean Sea
- developing research/industry collaborative actions by means of the research vessels for sensitive infrastructures (nuclear power plant- submarine cable/pipelines)

Critical questions

1) *What's the difference between hazard and risk?*

2) *Which are the most harmful marine geohazards in the Med in your opinion and why?*

3) *Why in the Med an alerting system could be not as efficient as in the Pacific ocean?*

4) *Why seabed mapping is important to assess marine geohazards?*

Bibliography

Some books and papers on marine geohazards

- Submarine geomorphology. Ed. Springer, Editors: A. Micallef, S. Krastel A. Savini Ed. Springer
- Submarine mass movements and their consequences: international symposium (1st to 7th volume) . Springer Ed.
- Regional-scale seafloor mapping and geohazard assessment. The experience from the Italian project MaGIC (Marine Geohazards along the Italian Coasts)PrFL Chiocci, D Ridente - Marine Geophysical Research, 2011 – Springer-
- Submarine mass-movements in the Ionian Calabrian margin and their consequences for marine geohazards: S. Ceramicola, S., Praeg, D. Coste, M., Forlin, E. Colizza, F. Critelli, S. (2014).. In Submarine Mass Movements and Their Consequences, 6th International Symposium, Advances in Natural and Technological Hazards Research (Krastel et al., Eds); Springer Science + Business Media B.V. Ch. 26, pp. 295-306, doi:10.1007/978-3-319-00972-8_26.

International projects on marine geohazards

SLATE: Projeect http://itn-slate.eu/project/

IGCP 640 S4Slide http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/international-geoscience-programme/igcp-projects/geohazards/project-640-new-2015/

On the WEB

Preparedness and Disaster

https://www.youtube.com/watch?v=IWVevsBhLBo

Meet "Disaster" and "Preparedness" -- two characters who will help you understand why you need to take personal responsibility to prepare yourself and your family for potential emergencies. Produced by the Metropolitan Emergency Managers Committee with funding support from the Kansas City Regional Homeland Security Coordinating Committee's Urban Area Security Initiative grant.

Media and outreach

TWIST

TIDAL WAVE IN SOUTHERN

Salerno – 25 maggio 2013

Emergency exercise simulating a tsunami wave against the coast of Salerno, following a submarine failure along the volcano Palinuro

24 -25 -26 -27 October 2013

Croatia, France, Greece, Italy
Malta, Portugal, Spain

Ackowledgments/Credits

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