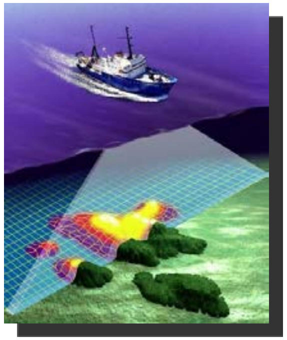
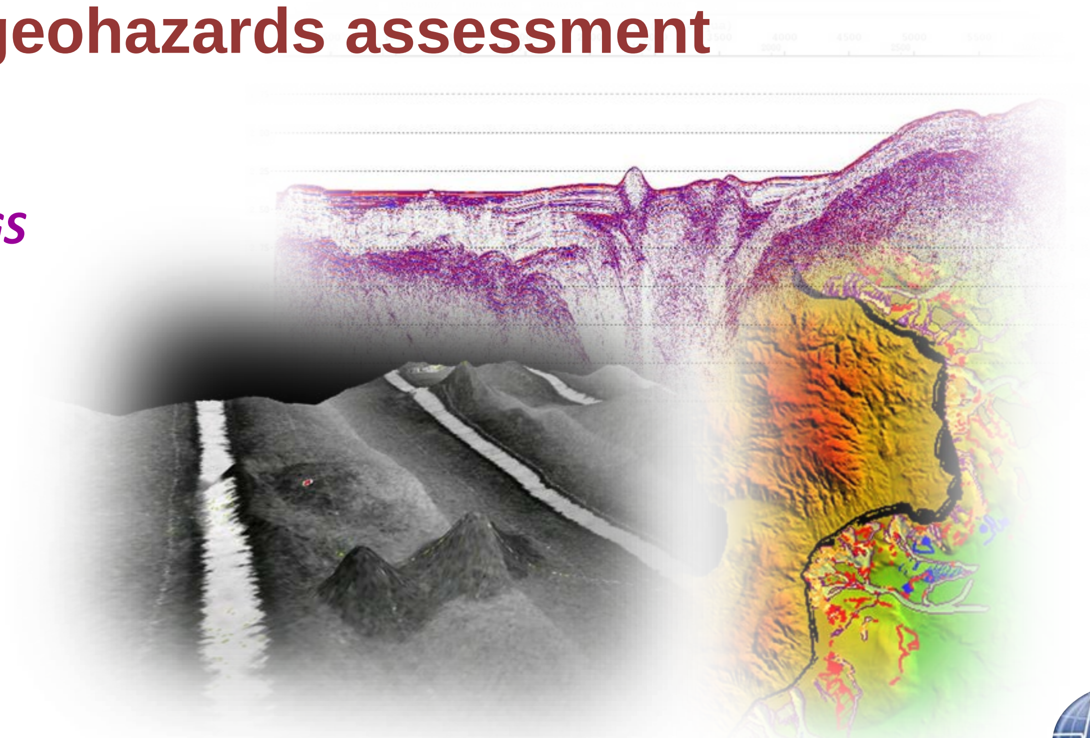
Corso di Geologia Marina
Università di Trieste 2015- 2016



PERICOLOSITA' MARINE– Regional-scale seafloor mapping and geohazards assessment



Silvia Ceramicola – OGS
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ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

OUTLINE

- Concepts of hazard, vulnerability, risk, mitigation, resilience
- Marine natural geohazards
- The use of integrated geophysical tools
- Regional-scale seafloor mapping ….
- …and examples of geohazard assessment in the Mediterranean 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 the **probability** of occurrence of a potentially damaging event, (where, when, how frequently, magnitude). 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

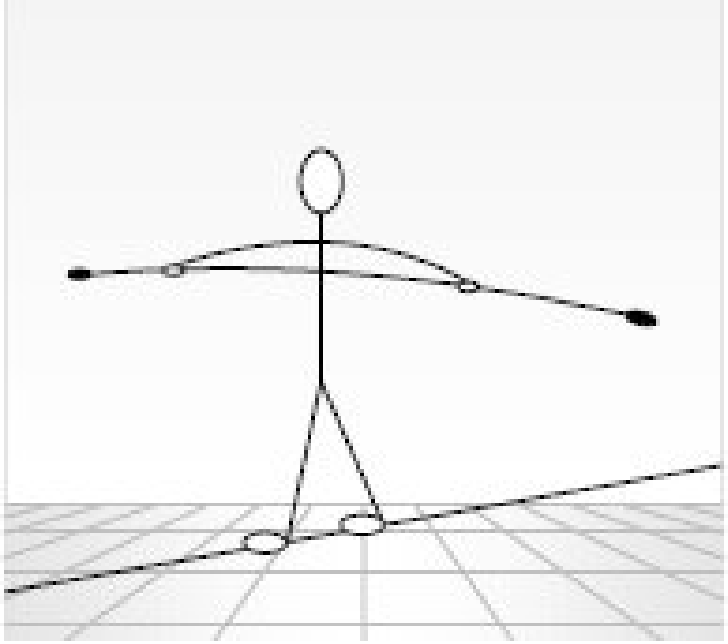
HAZARD: the road is frozen thus there is a risk for car accidents, if the road is empty (no exposure to hazard), no risks of car accidents

VULNERABILITY: exposure to losses (on ice, cars are more prone to have accidents)

RISK: the road is busy with cars driving at high speed - higher **probability** that ice will cause damage

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!*

Now consider that the highwire is only one metre 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.*

Risk *is a total concept of* ***likelihood of occurrence*** *of a hazard and the* ***severity of possible impacts****.*

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

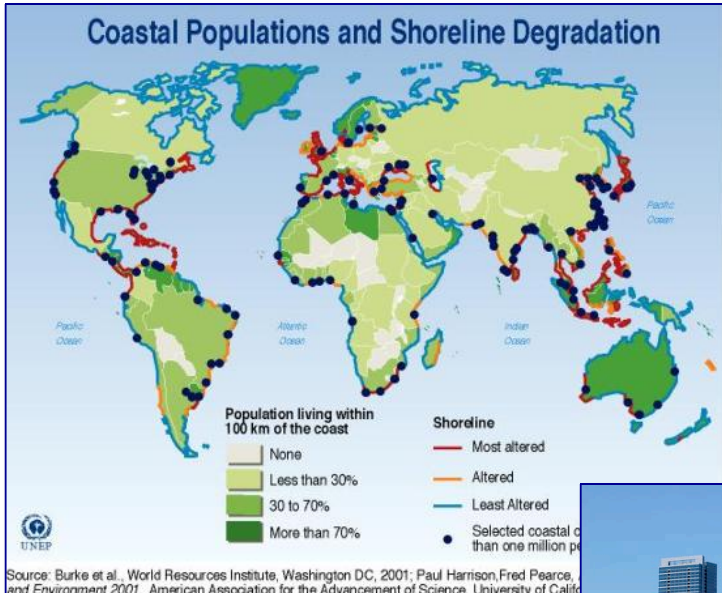
Japanese Earthquake Highway Repair

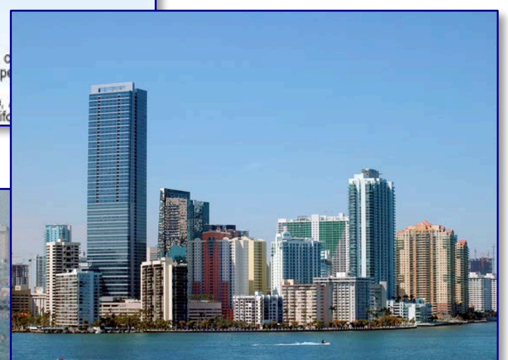
- **Earthquake: March 11 2011**
- **Repair begun: March 17 2011**
- **Road ready: March 22 2011 (six days later)**

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





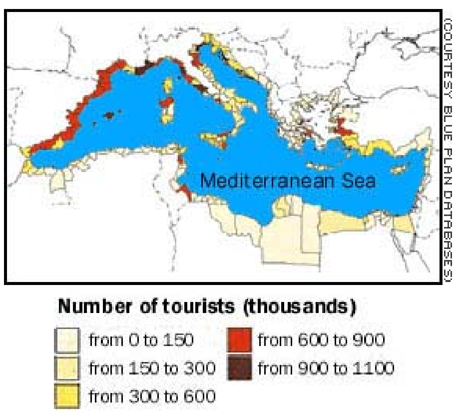
The overwhelming bulk of humanity is concentrated along or near coasts on just 10% of the earth's land surface

Top Ten World Largest Cities

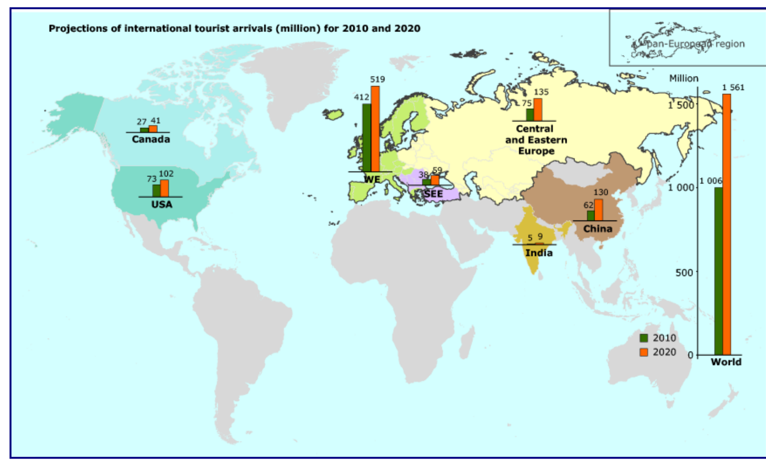
- Tokyo, Japan (coastal)
- Mexico City, Mexico
- Mumbai, India (coastal)
- Sáo Paulo, Brazil
- New York City, USA (coastal)
- Shanghai, China (coastal)
- Lagos, Nigeria (coastal)
- Los Angeles, USA (coastal)
- Calcutta, India (coastal)
- Buenos Aires, Argentina (coastal)

- 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).



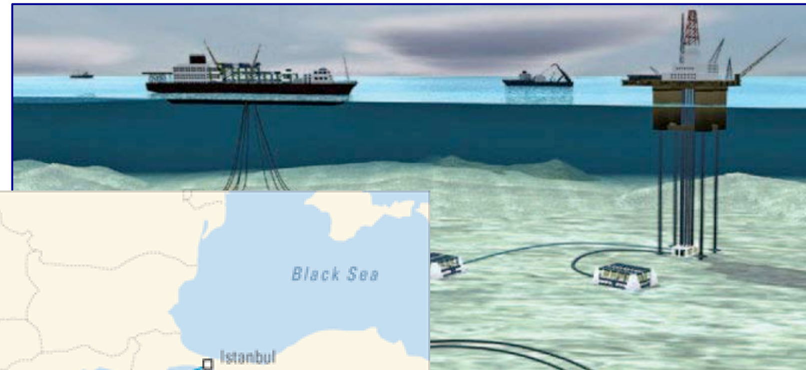
“By 2025, the annual crowd will soar to anywhere from 235 to 350 million tourists, according to the EEA.”



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.

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



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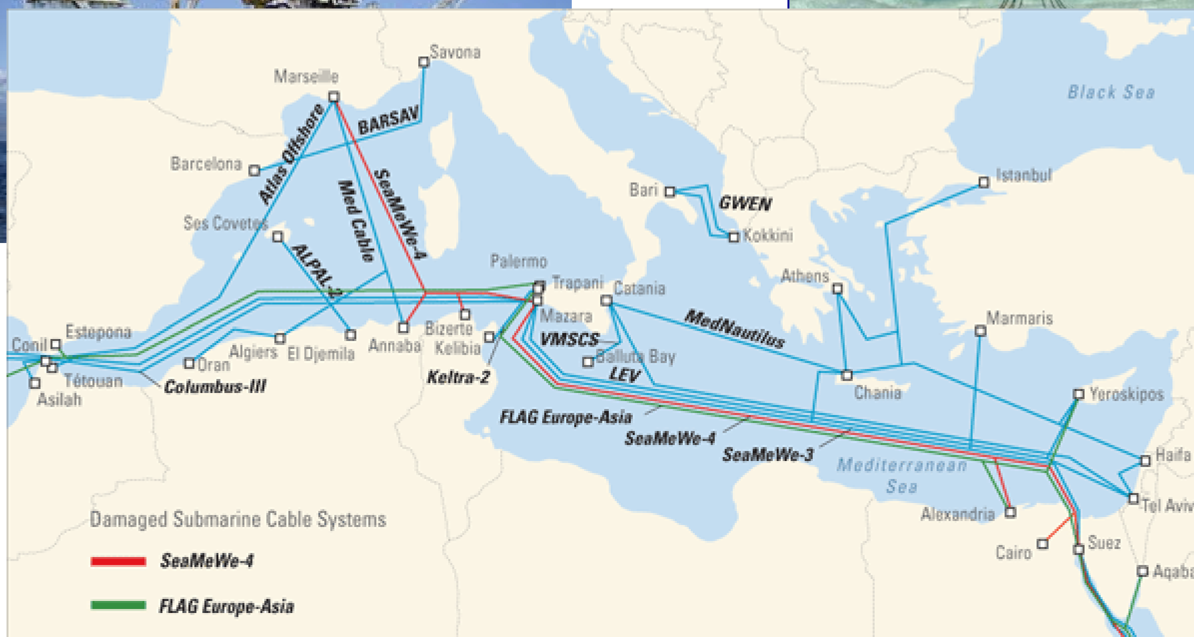
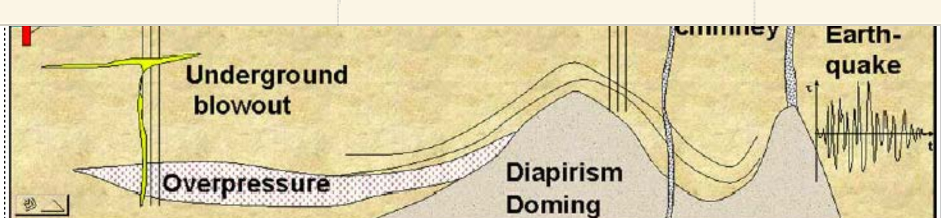
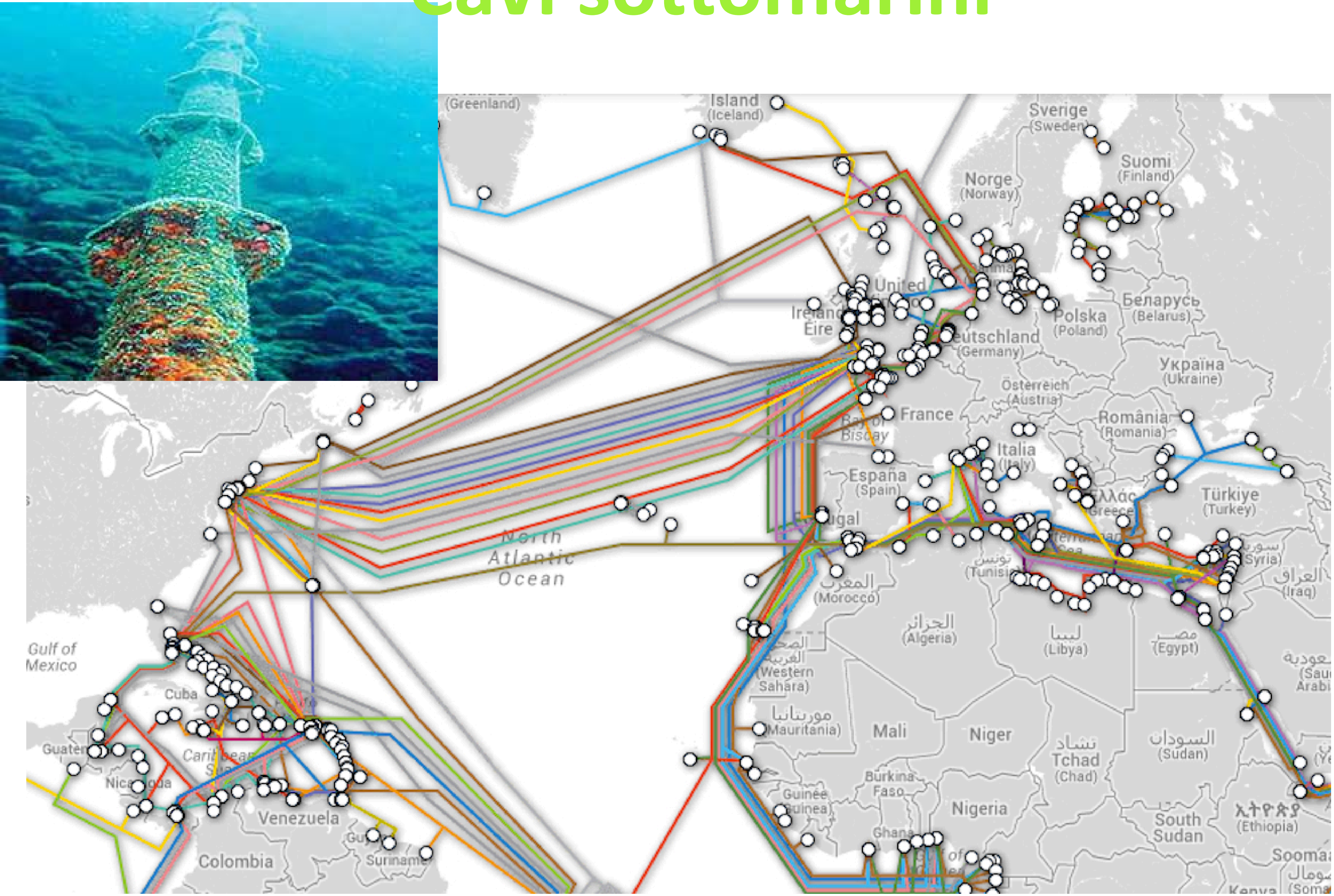


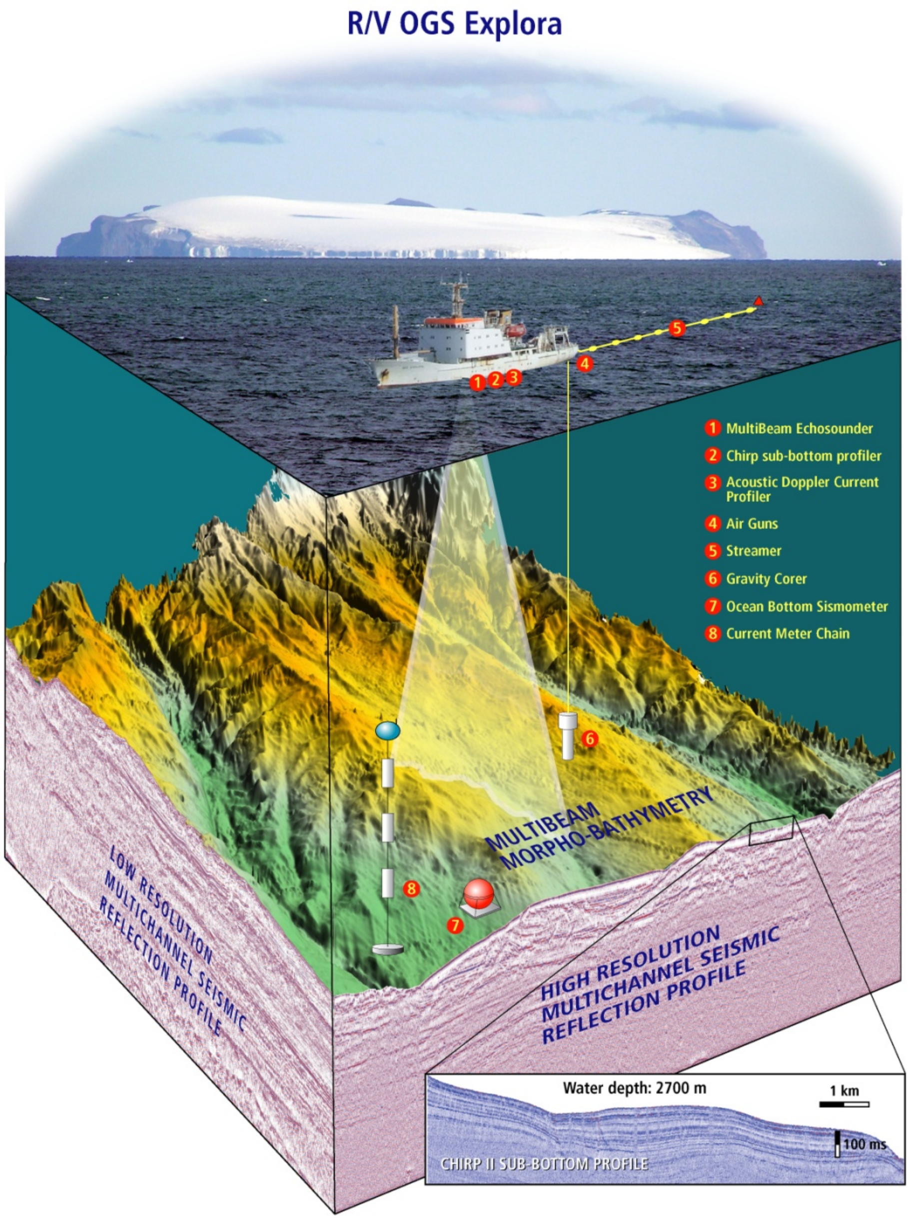


:esy NGI, Oslo. After Camerlenghi et al., 2007, *Scientific Drilling*

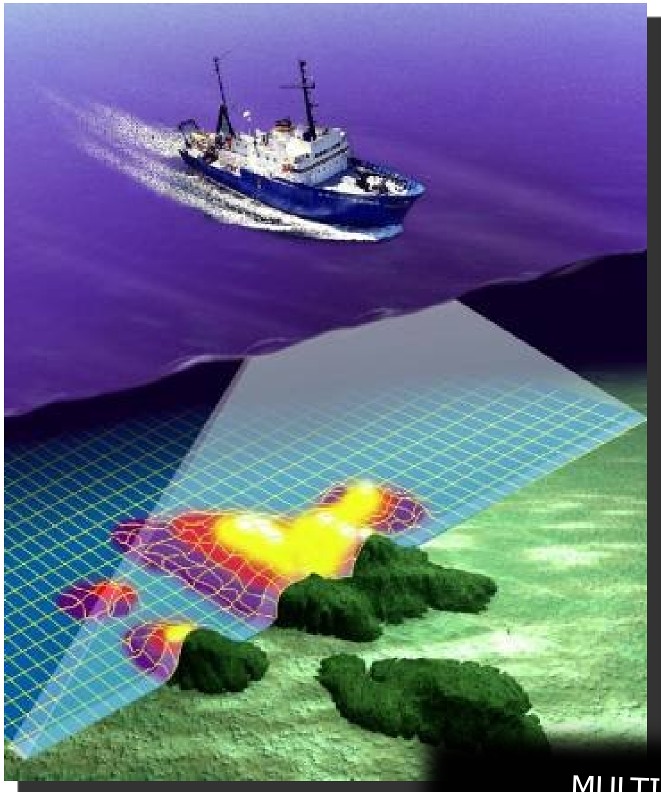
Cavi sottomarini



INTEGRATED ACOUSTIC METHODS



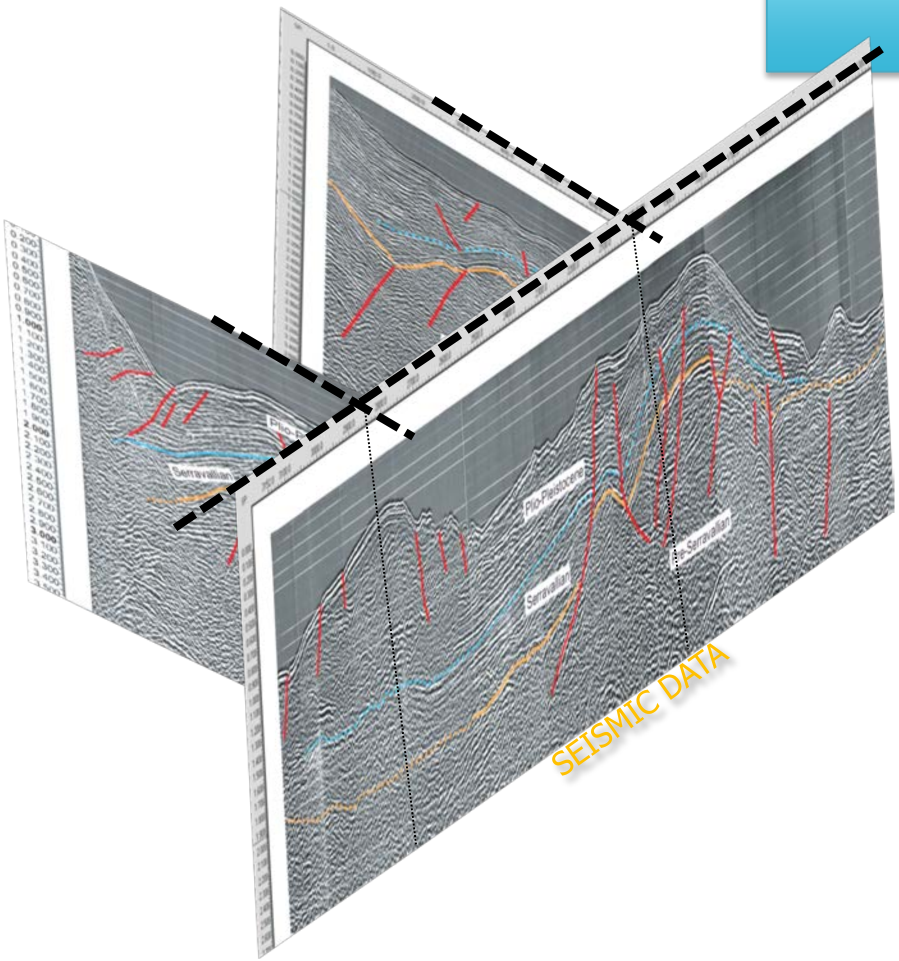
INTEGRATED ACOUSTIC METHODS – multibeam including reflectivity and water column



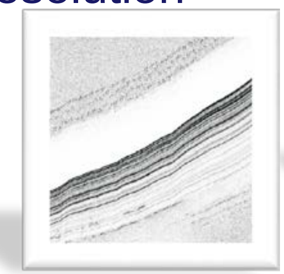
Seafloor mapping is the first step in making a census of the **geohazard-bearing features** present in a given offshore area. It often provides the only tool for a comprehensive **seafloor geohazard assessment over large areas** that are scarcely groundtruthed by acoustic prospection and sea-floor sampling.

By Chiocci et al 2011

INTEGRATED ACOUSTIC METHODS – seismics and sub-bottom



Higher frequency lower penetration; up to meters in near bottom sediments, higher resolution



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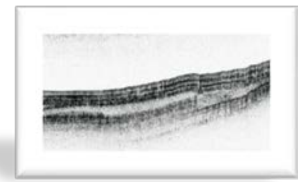


BTB

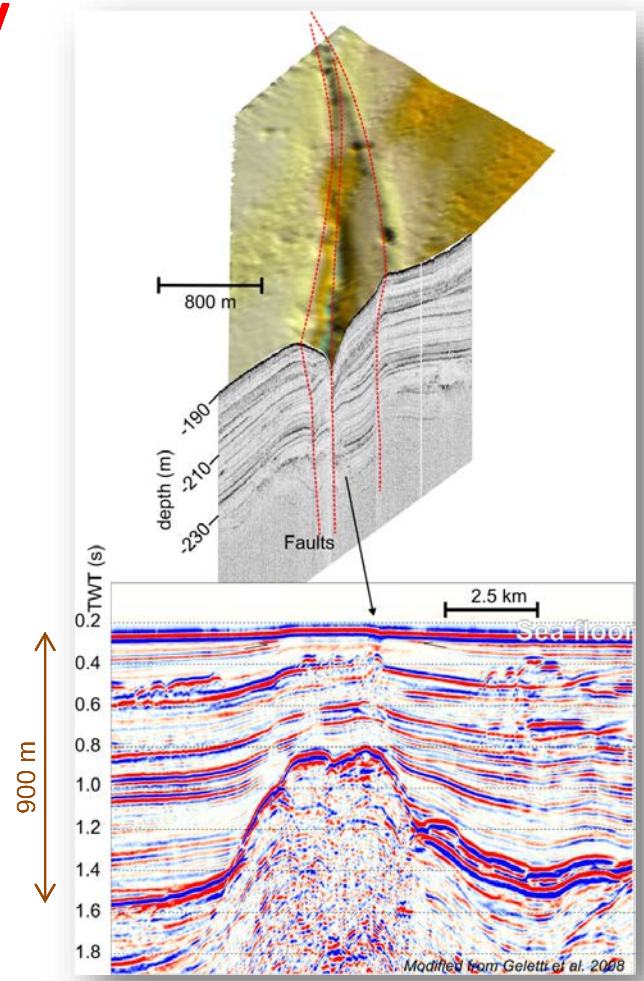
H

R

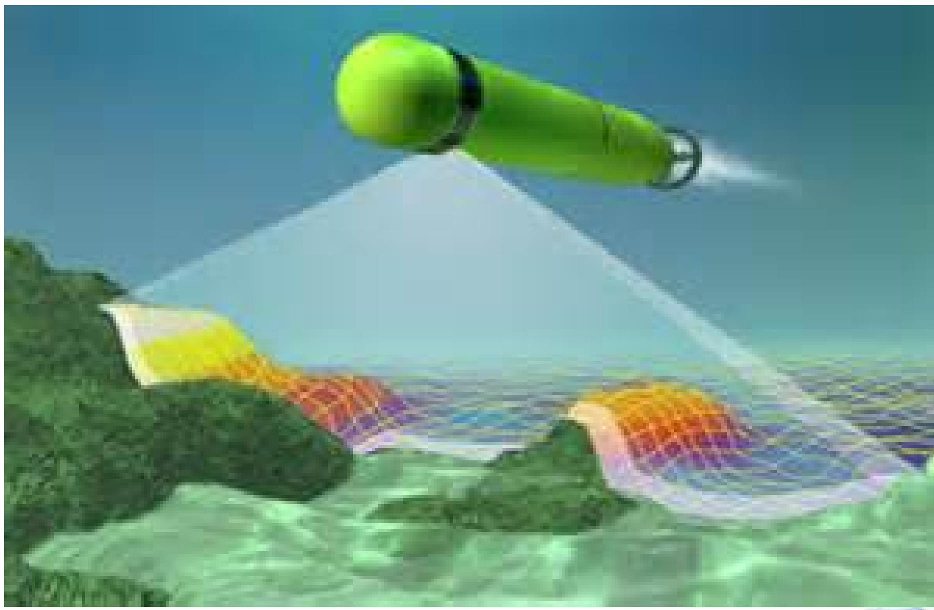
Lower frequency higher penetration; up to kms in deep sediments lower resolution

Methodology

- **Seabed mapping** (and water column imaging) using high-frequency swath and profiling systems (multibeam and single beam echosounders)
- Interpretive **integration** of morpho-bathymetry with different resolution 2D & 3D seismic data
- **Dating** of activity using sediment cores and ROV seabed observations
- **Offshore-onshore** linkages
- **Multidisciplinarity**:geophysics/seismology/oceanography/biology



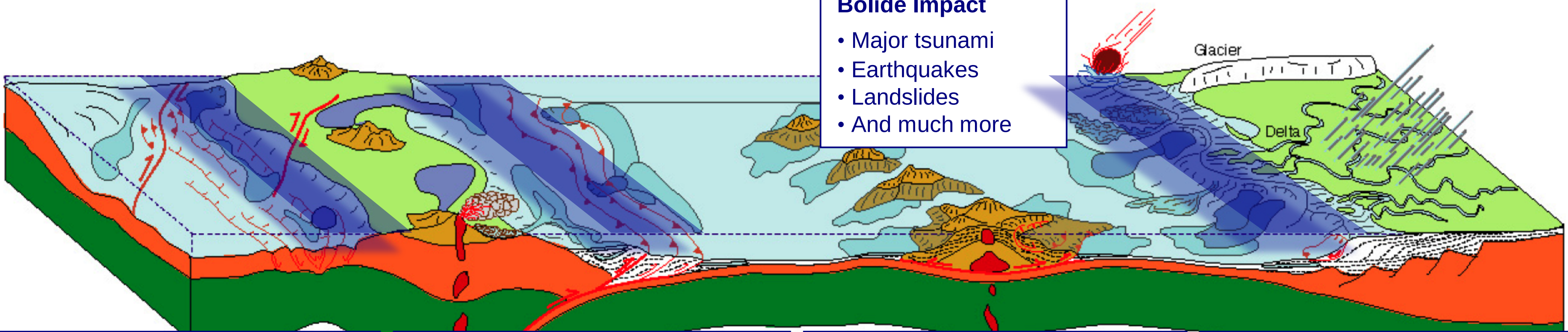
La tecnologia marina a robotica - ROV e AUV




emepc
Depth: 0631.27
Hdg: 164

SUBMARINE GEOHAZARDS OCCUR IN ALL OCEANIC ENVIRONMENTS
but
THEY CONCENTRATE ON CONTINENTAL MARGINS

Bolide Impact
- Major tsunami
- Earthquakes
- Landslides
- And much more



Rift & Transform Margins
- Moderate earthquakes
- Submarine/subaerial landslides
- Debris flows, turbidity currents
- Tsunamis
- Methane emissions

Subduction Margins
- Large earthquakes
- Submarine/subaereal landslides
- Explosive eruptions, lahrs
- Debris flows, turbidity currents
- Tsunamis
- Methane emissions

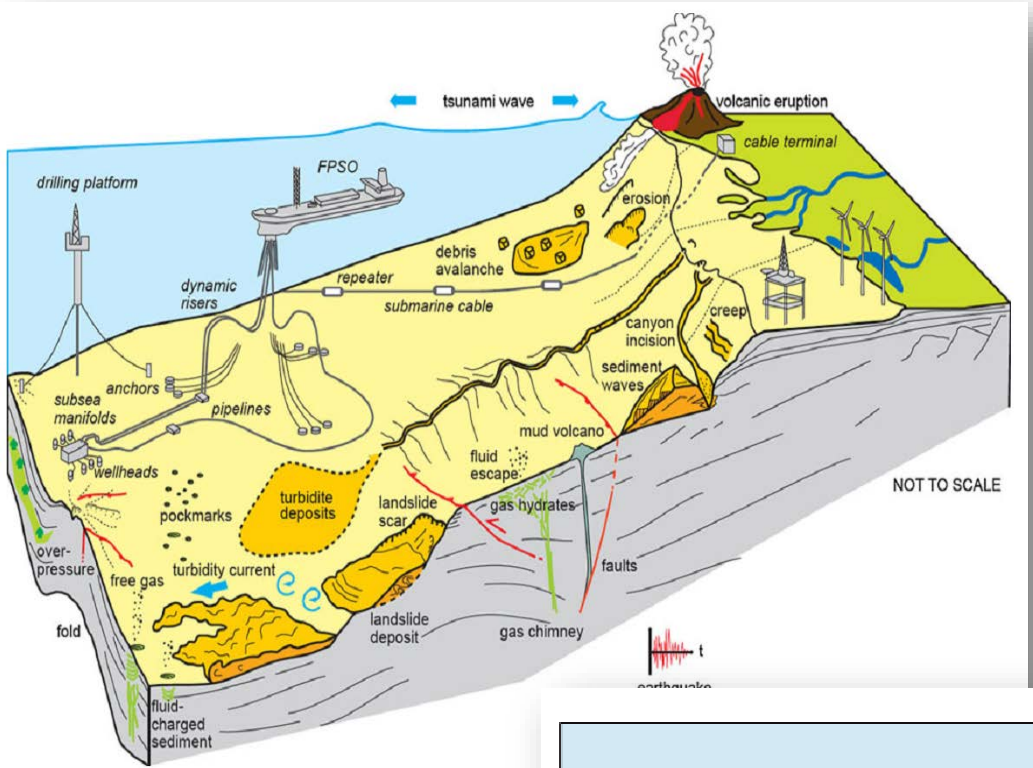
Oceanic Volcanoes
- Submarine/subaerial landslides
- Debris flows, turbidity currents
- Volcanic eruptions
- Earthquakes
- Tsunamis
- Methane emissions

Passive Margins
- Submarine landslides
- Debris flows, turbidity currents
- Modest earthquakes
- Tsunamis
- Methane emissions

Adapted from Morgan et al., 2009. *Scientific Drilling*, available at: http://www.iodp.org/geohazards/

- **SUBMARINE LANDSLIDES** including **VOLCANIC ISLAND ERUPTIONS** and **FLANK COLLAPSE**: sediment mass movements (turbidity currents, debris flows, slumps, retrogressive canyon headwalls)
- **SEISMOGENIC FAULTS** (earthquakes originated below the sea floor)
- **TSUNAMIS** (originated by earthquakes and/or landslides)
- **GAS/FLUID EMISSIONS** (CH_4, CO_2 mainly)
- **METEORITE IMPACTS** in the oceans

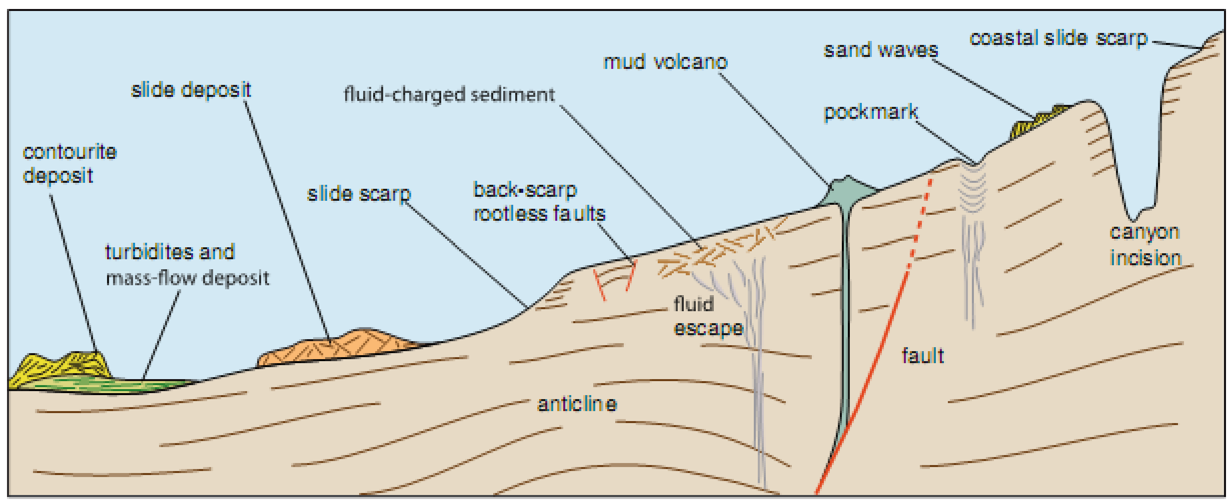
MARINE GEOHAZARDS



Chiocci et al. 2011

Geomorphic features as geohazard indicators:

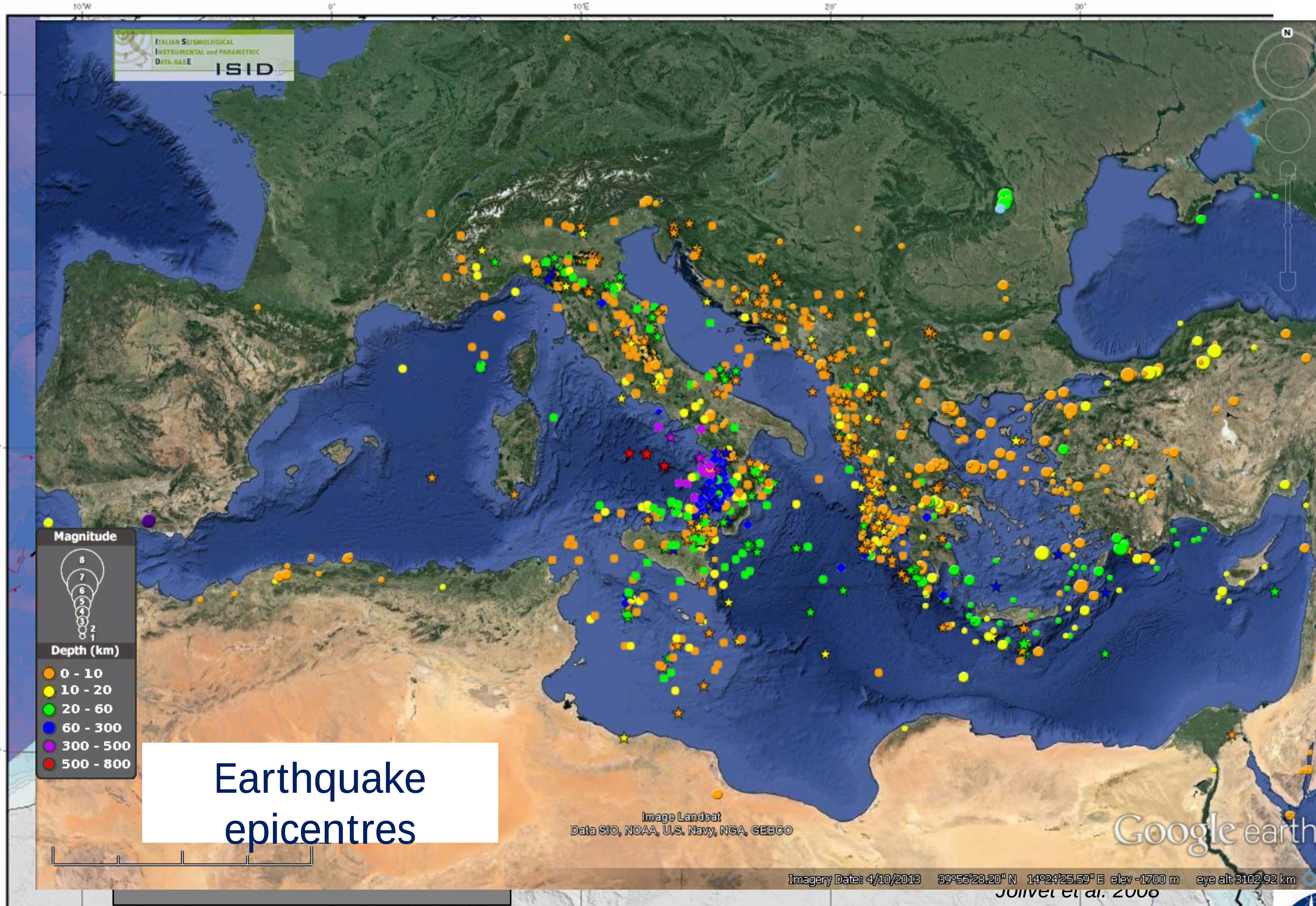
scars and deposits, canyon headscarps and steep erosional flanks, fault-related seafloor unevenness, mud volcanoes, pock-marks, gravity flow deposits, erosional scours and bed-forms indicating sediment mobility at diverse temporal/spatial scale….



Chiocci and Ridente 2011

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

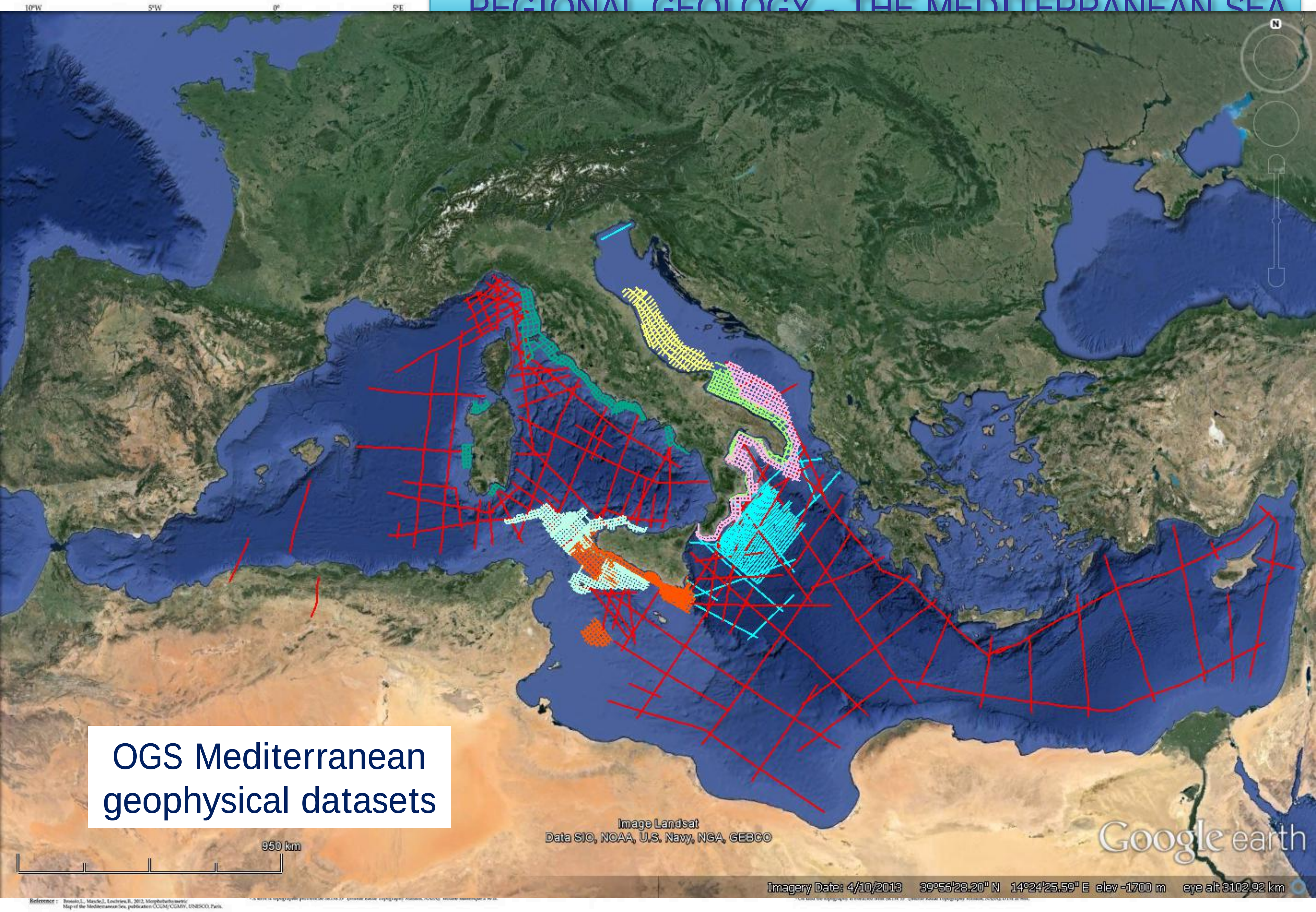
REGIONAL GEOLOGY - THE MEDITERRANEAN SEA



Earthquake epicentres

Geology does not care about coastlines!!

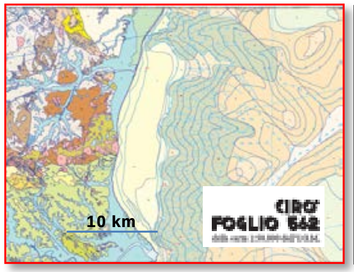
REGIONAL GEOLOGY - THE MEDITERRANEAN SEA

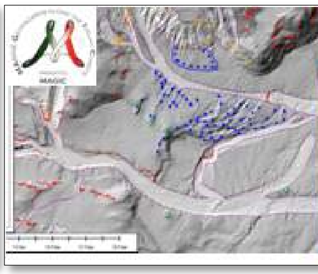


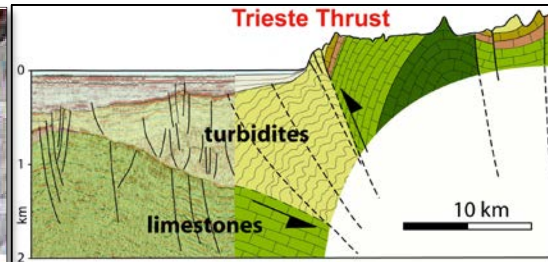
OGS Mediterranean geophysical datasets

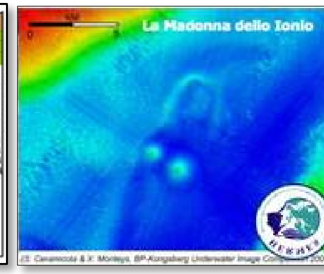
case studies in different Mediterranean settings (passive margins vs active margins)

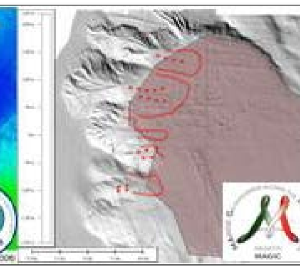
Onshore offshore linkage *Canyon dynamics* *Seismogenic faults* *Mud volcanoes* *Mass failures*







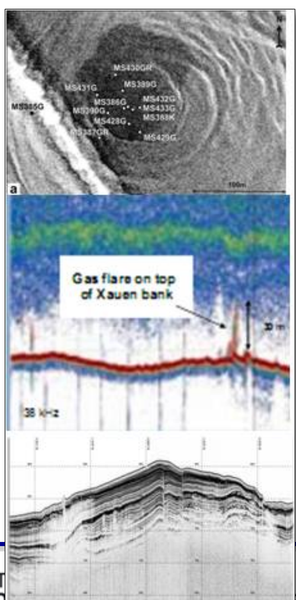


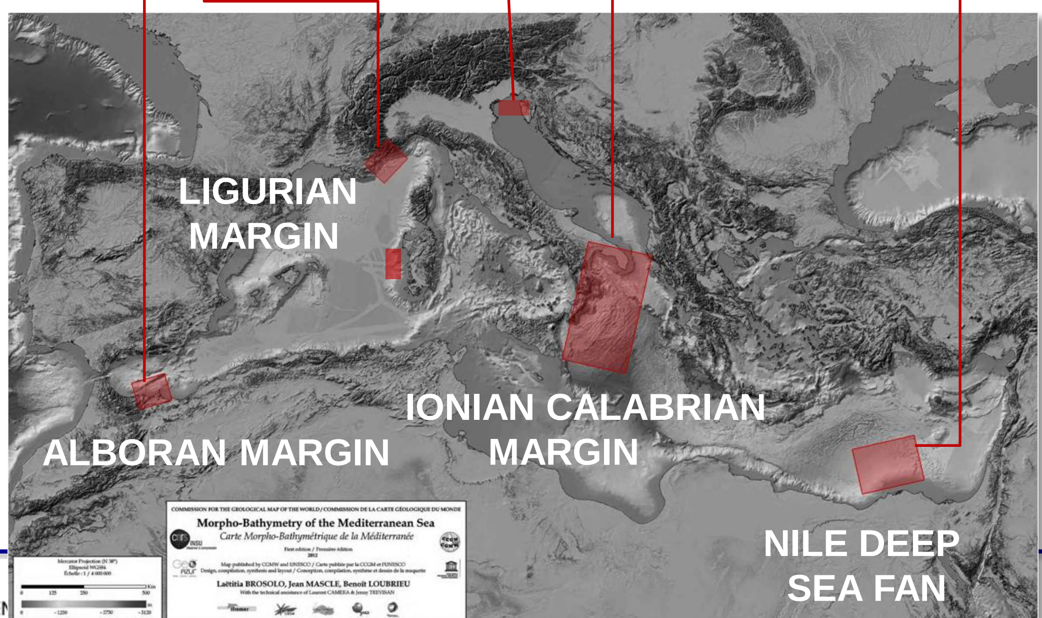


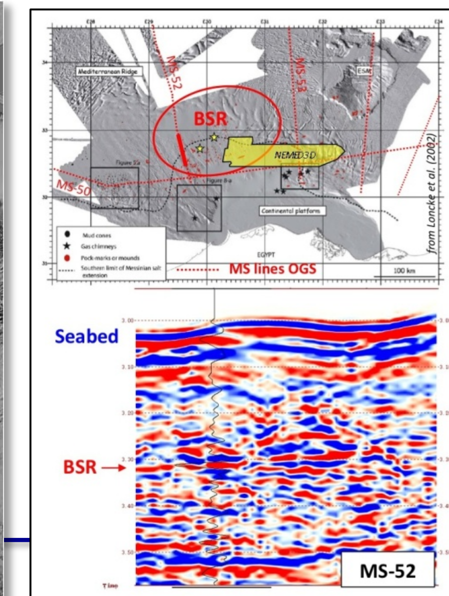
GEOHAZARDS, FLUID FLOWS & GAS HYDRATES, CANYON DYNAMICS

Mud volcanoes,
Gas flares in water column

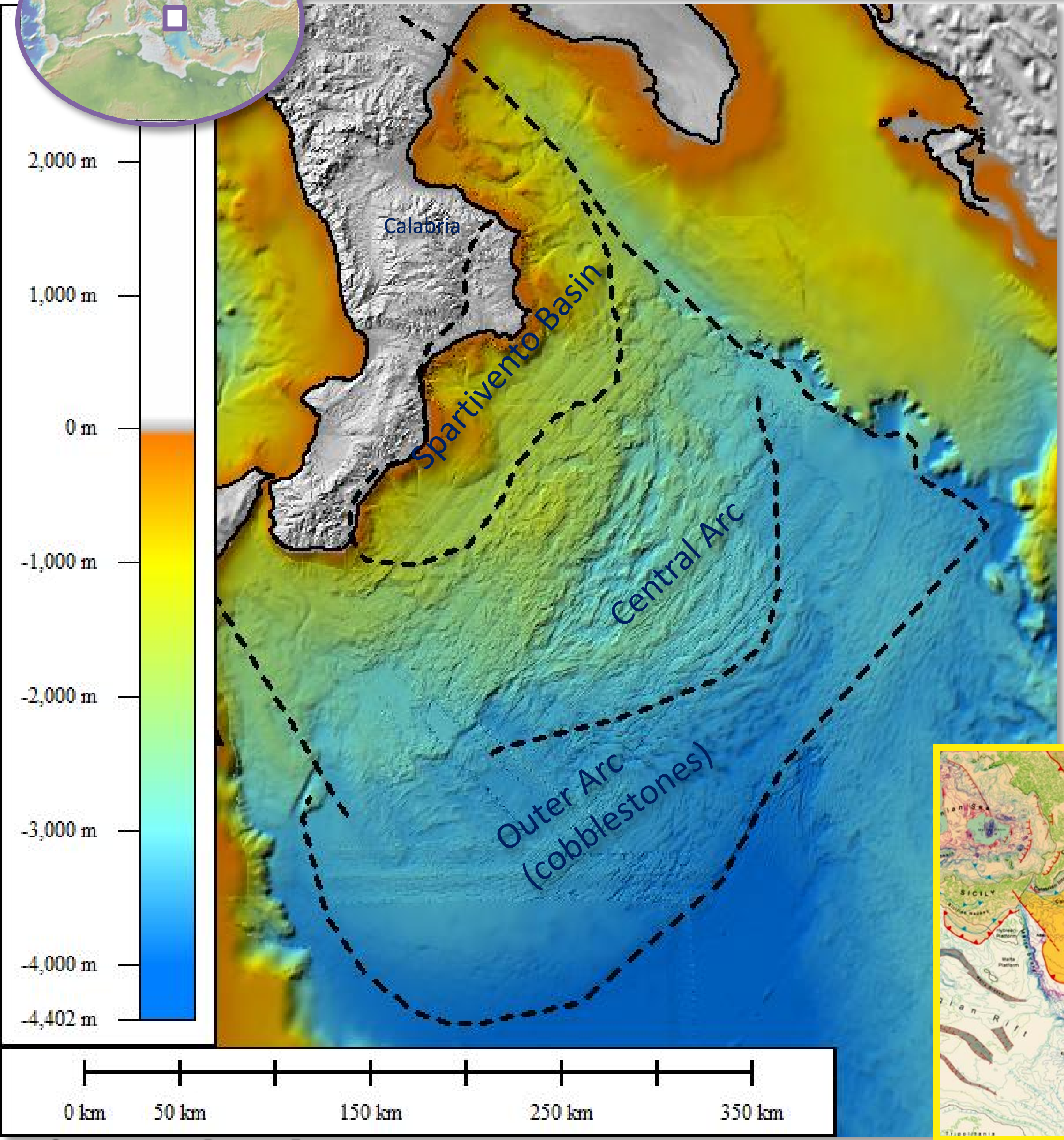
Gas Hydrates & Seepage







THE IONIAN MARGIN A LABORATORY FOR MARINE GEOHAZARDS



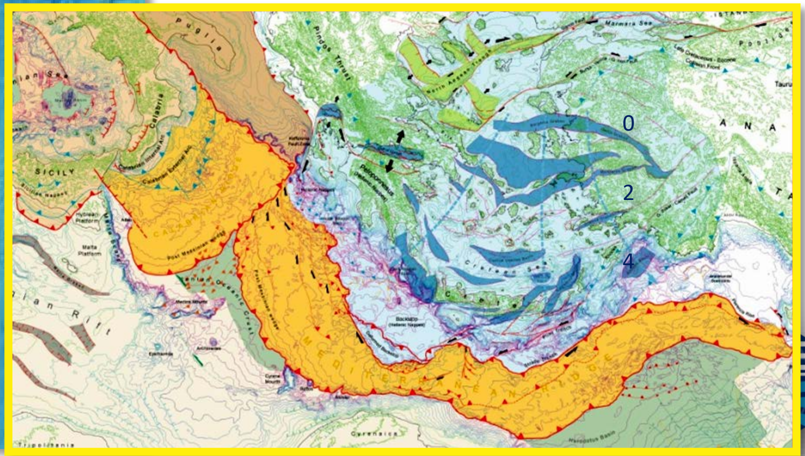
TECTONIC FRAMEWORK

Active continental margin (convergent) → Subduction

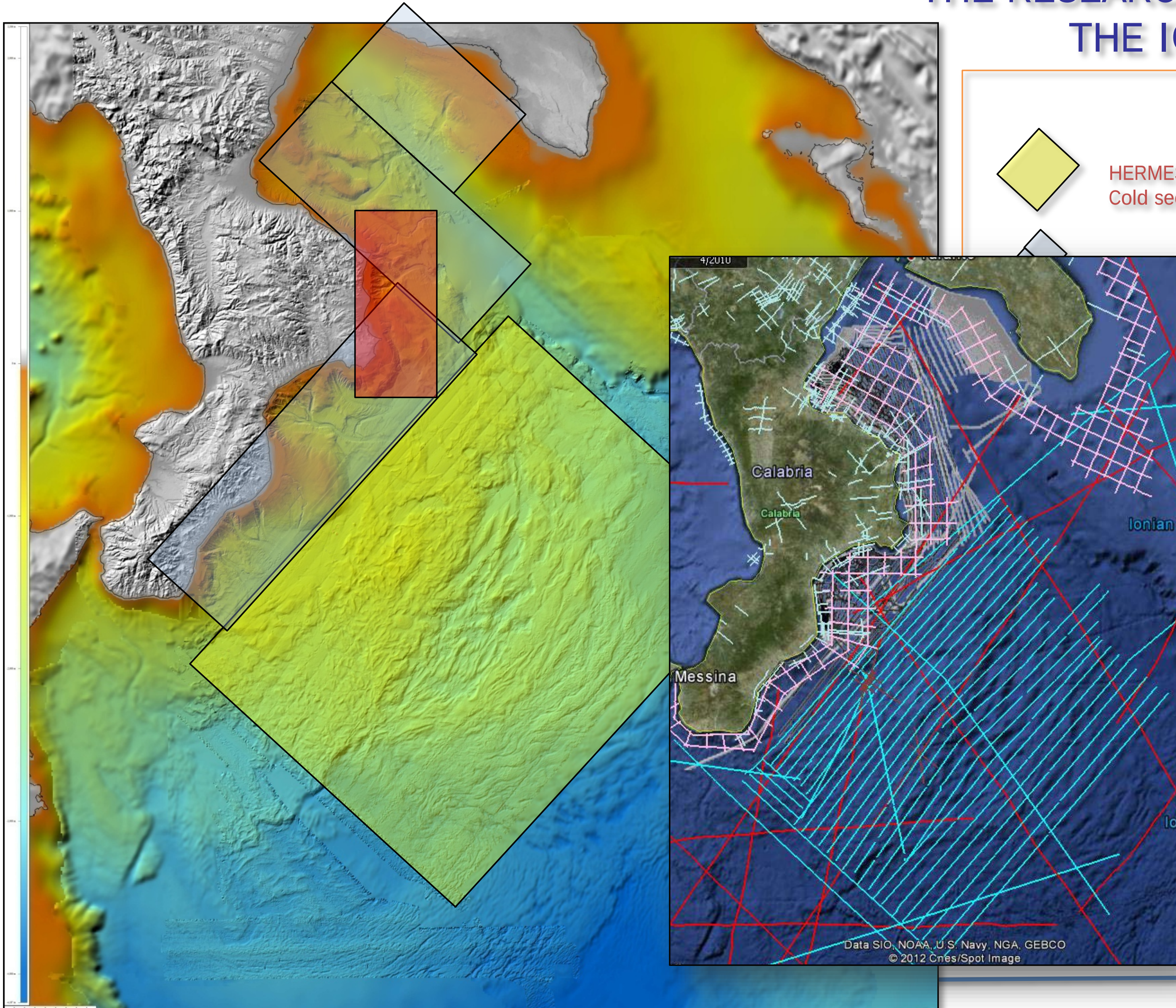
2 main processes related:

→ Frontal compression and forearc extension during the SE advance of the Calabrian accretionary prism since late Miocene;

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



THE RESEARCH PROJECTS IN THE IONIAN MARGIN



HERMES (EC Project '05-'09)
Cold seeps

Italian Civil Protection
'07-'12)
rd of coastal areas

alian ISPRA Project '11)
al mapping

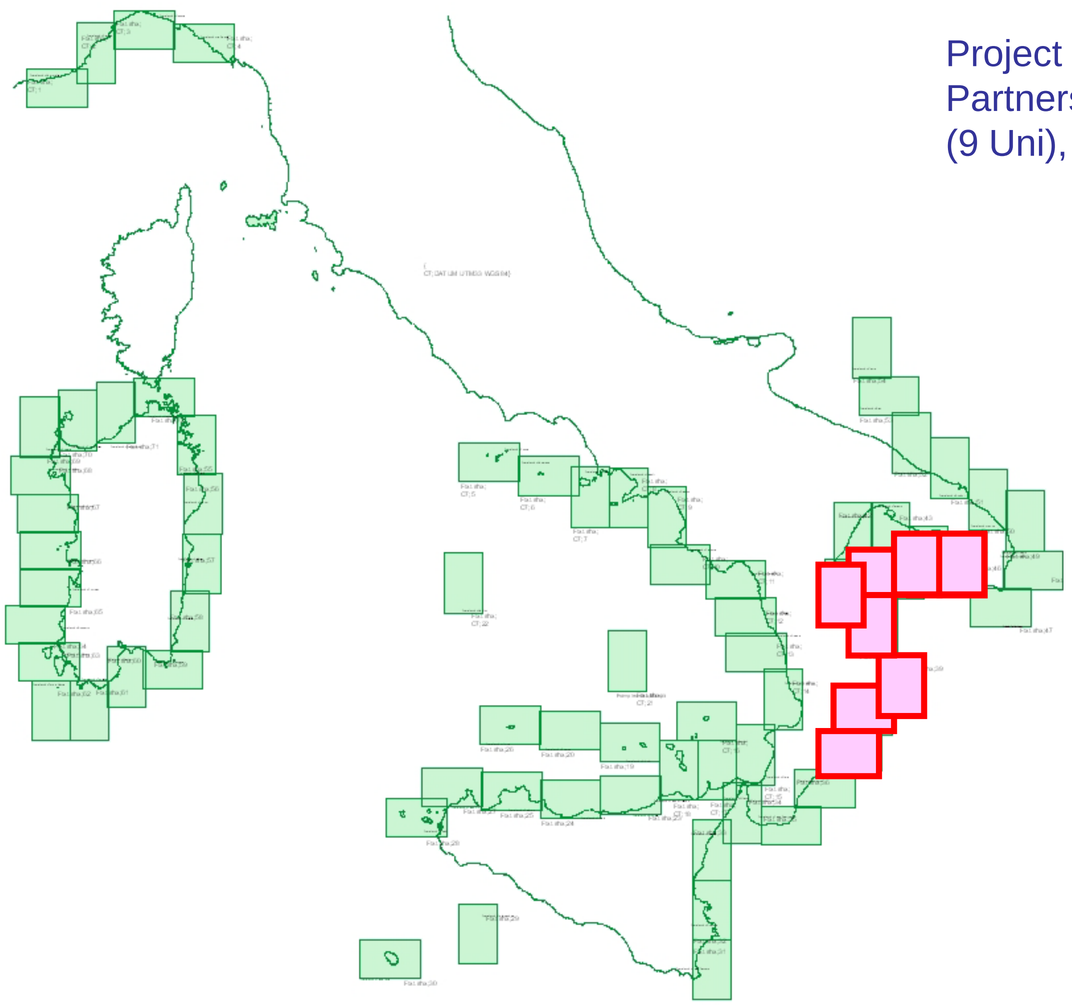
arch vessels

deep water - OGS Explora
(RESON 8111-8150-50-3000m)

shallow water – Joshua
(RESSON 8125 - 0-70m)

The MaGIC Project

Project Leader: Prof. Francesco L. CHIOCCI
Partners: CNR (IGAG, ISMAR, IAMC), CONISMA (9 Uni), and OGS



OBJECTIVES:

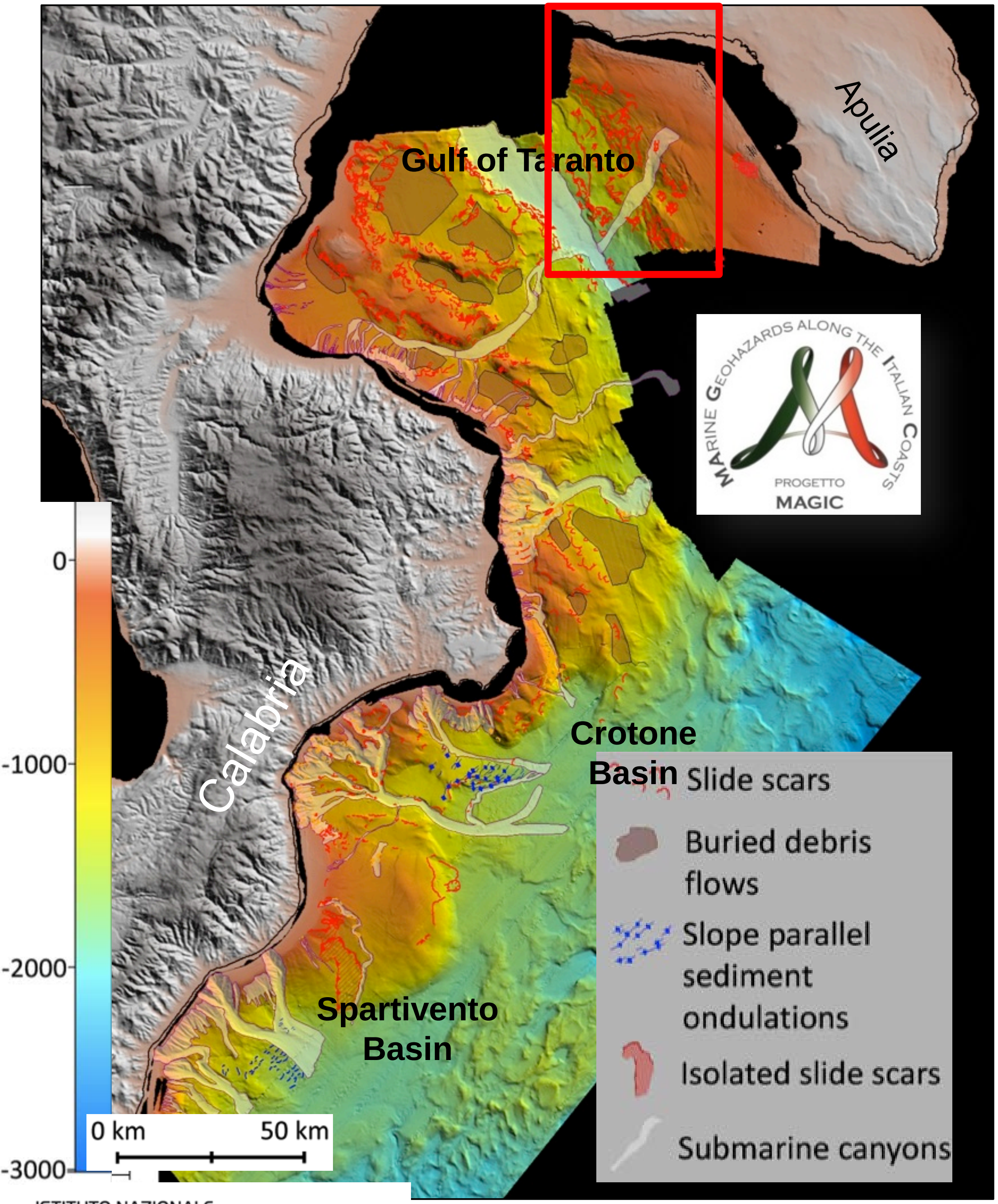
The main objective of is to provide the National Civil Protection Department with accurate depiction of surficial geology and related geohazards on the most sensitive and hazard-prone areas.

The definition of the geohazard of the seafloor is based on the assumption that rapid variations on the seafloor can interact directly or indirectly with antropich or human activities.

The final product is a bathymetric database as reference for compiling maps of geohazards at the seafloor.

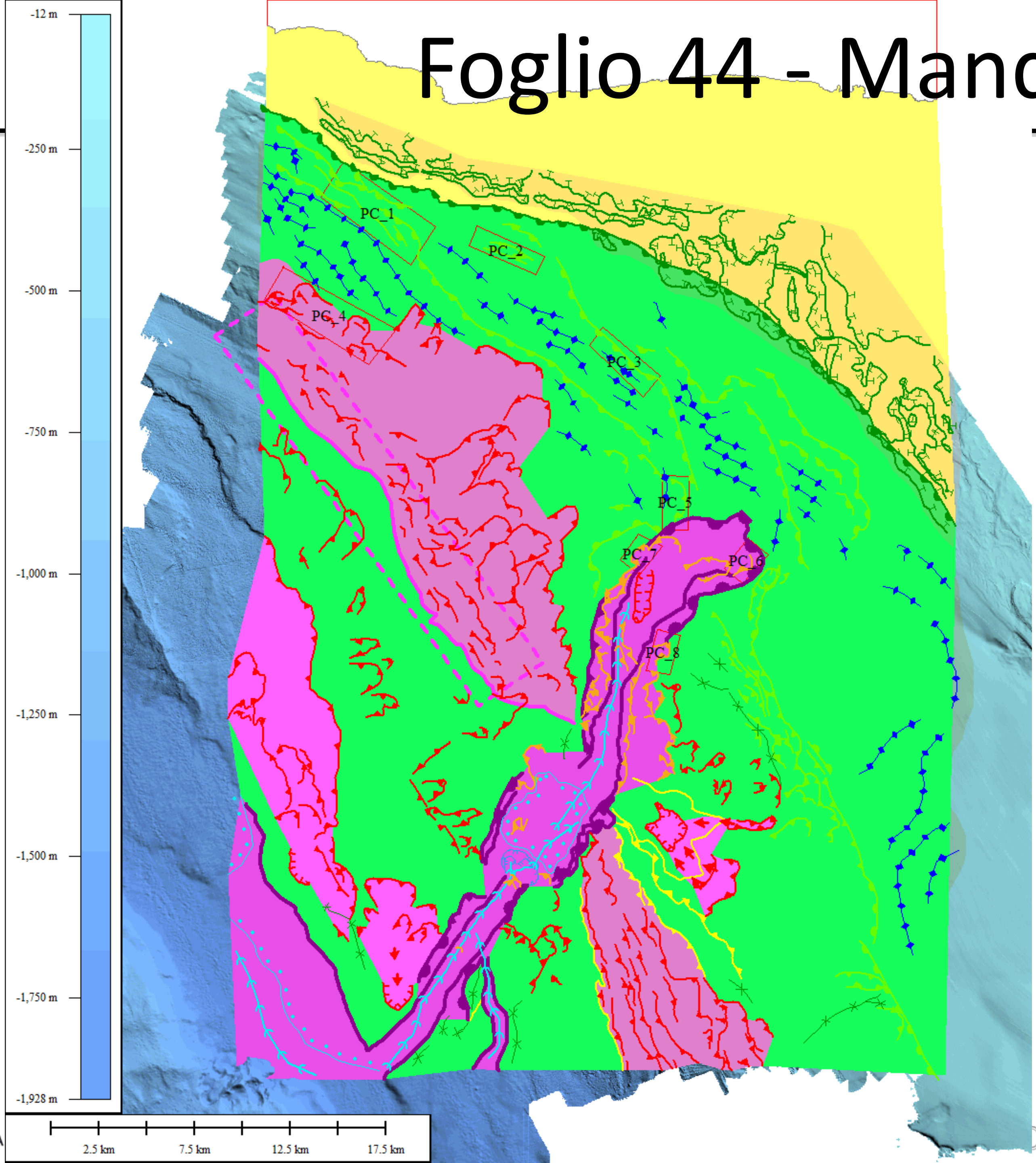
OGS 8 maps (scale 1:50.000) :

Method 1
Seabed mapping



Ceramicola et al. (2014 - Submarine Mass Movement and their Consequences, Springer)

Foglio 44 - Manduria



3 map layers to identify critical points

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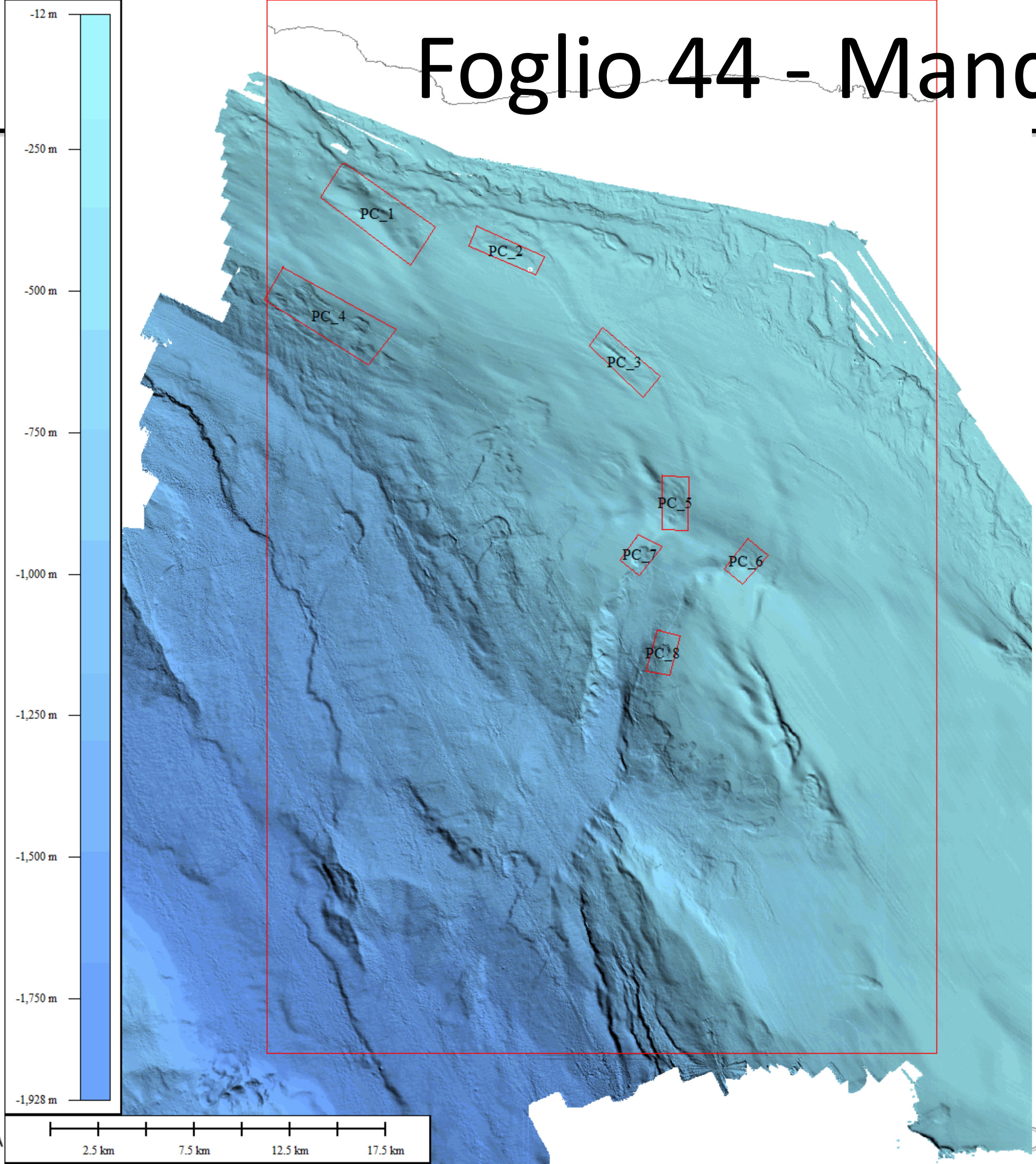
OGS Trieste, Italy

Foglio 44 - Manduria



3 map layers to identify **critical points**

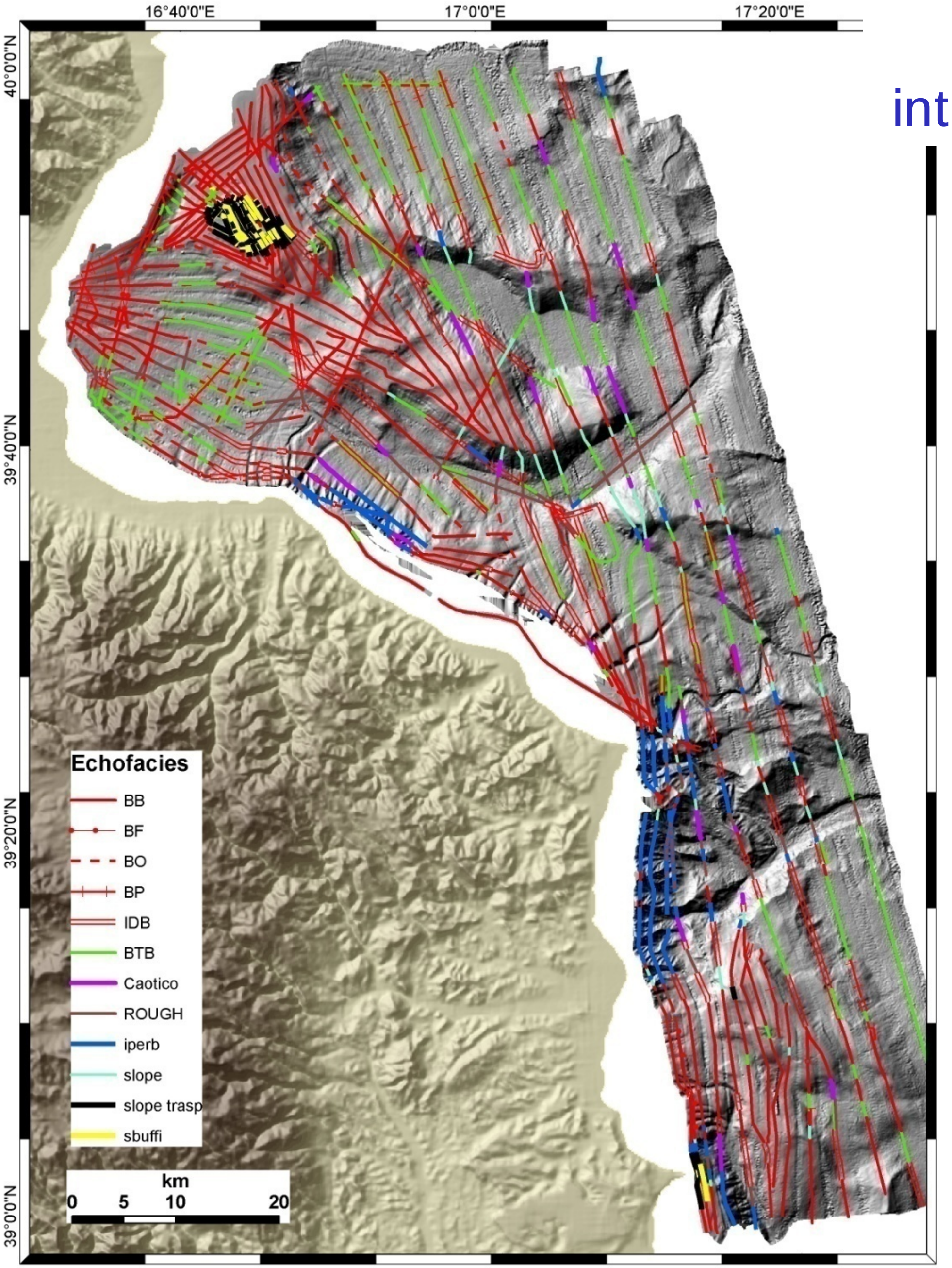
MARINE GEOHAZARDS ALONG THE ITALIAN COASTS
PROGETTO MAGIC

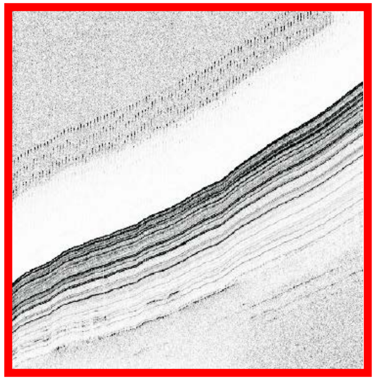
ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA

OGS

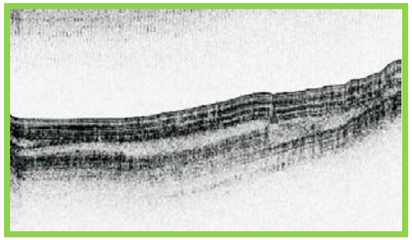
OGS Trieste, Italy

METHOD 2: integration with echofacies



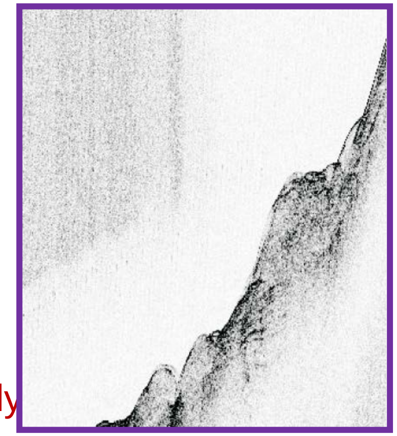


Uniformly bedded



Bedded
buried transparent

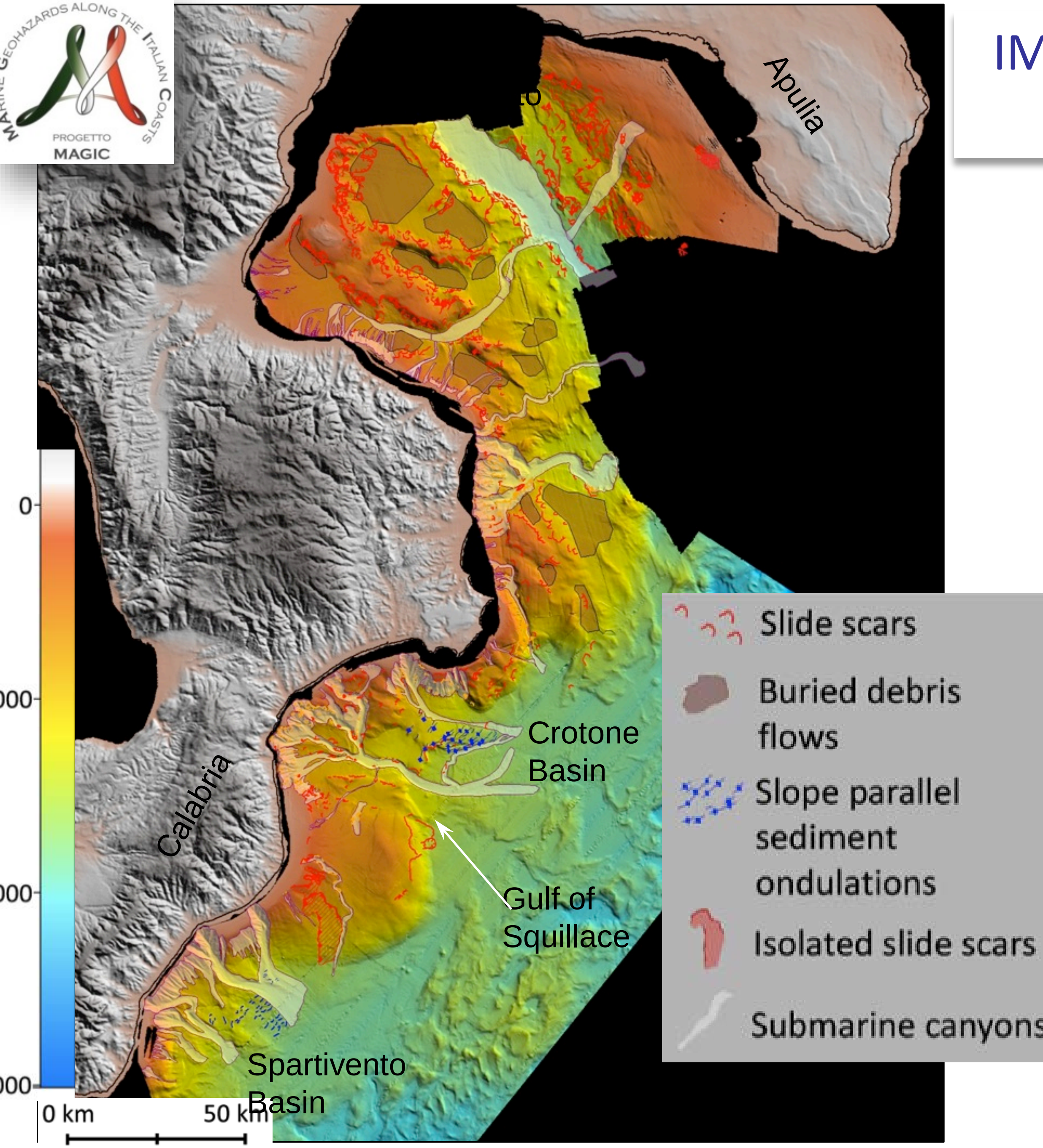
Irregular discontinuously bedded



Irregular discontinuous

Chirp profiles

IMCA FEATURES OF SLOPE SEDIMENT FAILURE



1 Mass Transport Complexes (MTCs) in intra-slope basins (northern Calabrian margin)

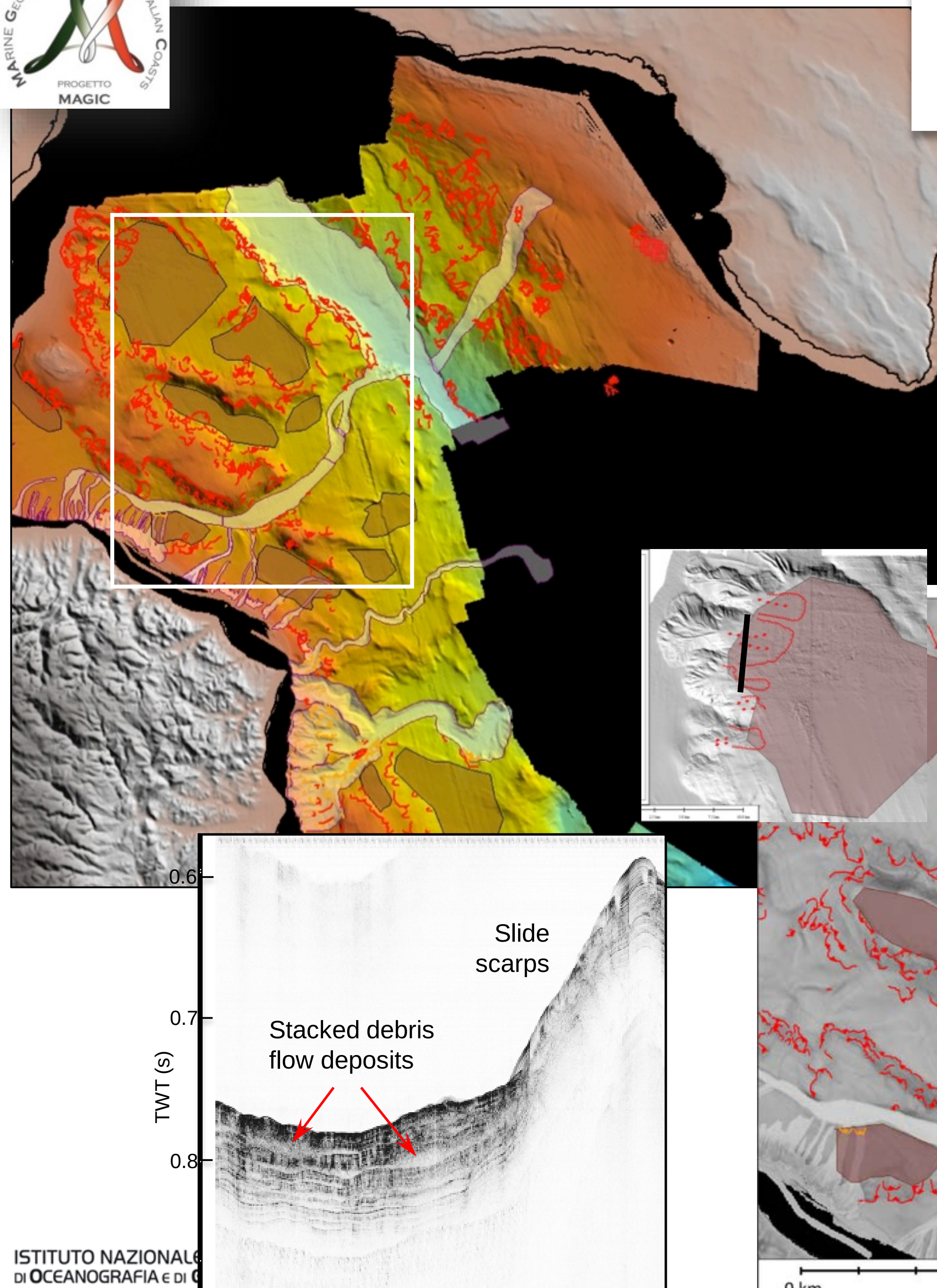
2 Isolated Slide Scars (ISSs) on open slopes (all margins)

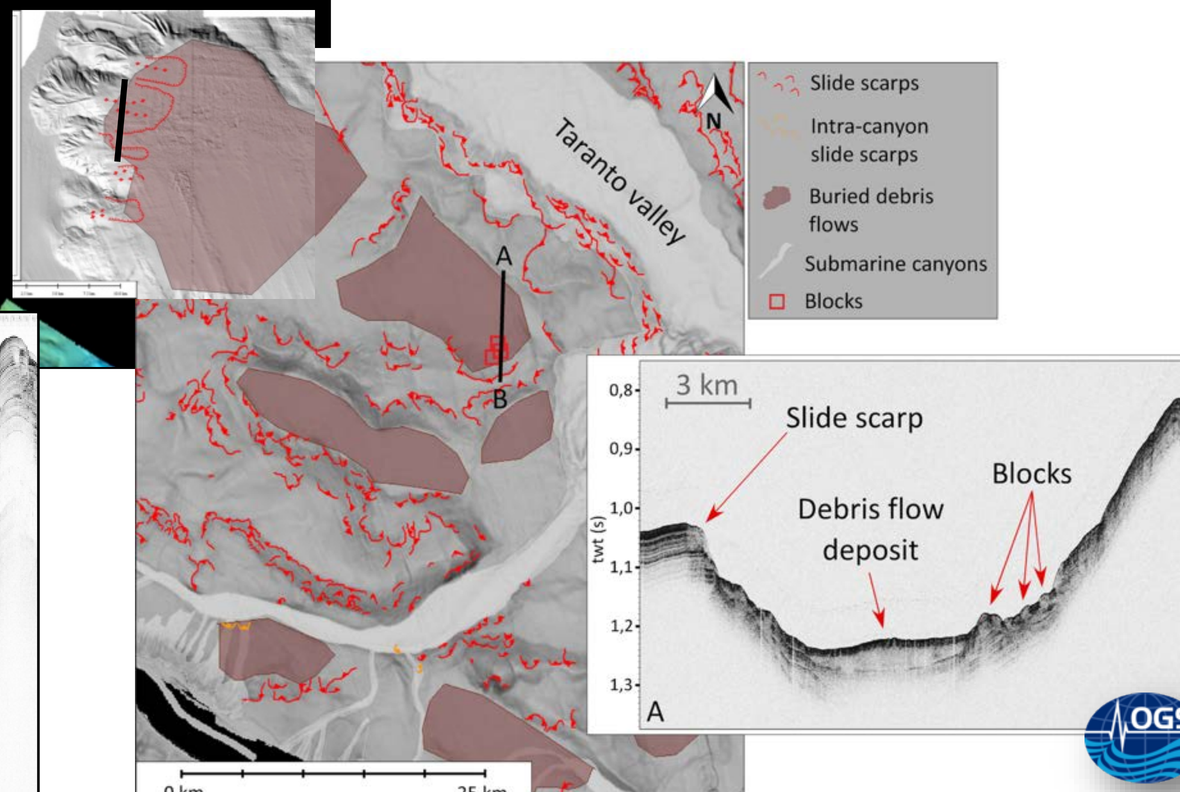
3 Headwall & Sidewall Scarps in Submarine Canyons (HSC) (Calabrian margin)

4 Slope-Parallel Sediment Undulations (SPSU) (southern Calabrian margin)

MASS TRANSPORT COMPLEXES (MTCs) IN INTRA-SLOPE BASINS

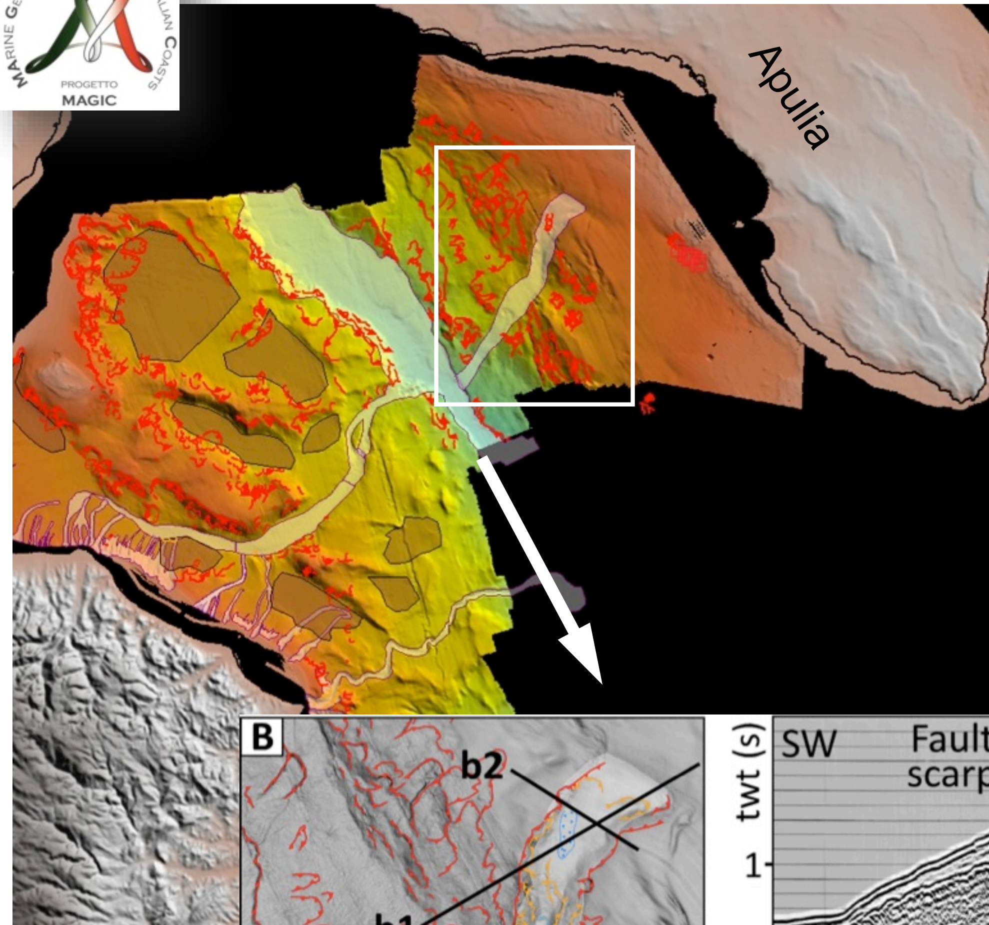
- Seabed scarps (red lines) surrounding intra-basinal deposits (polygons)
- Morphological and stratigraphic evidence of multiple failures
- Seismic triggering along fault-bounded transpressive structures?





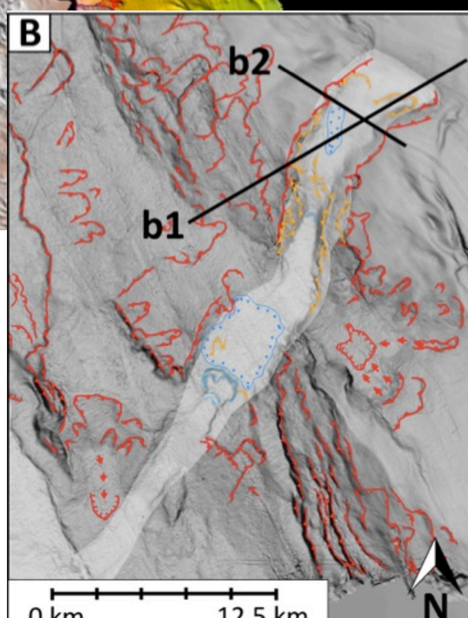
MARINE GEOHAZARDS ALONG THE ITALIAN COASTS
PROGETTO MAGIC

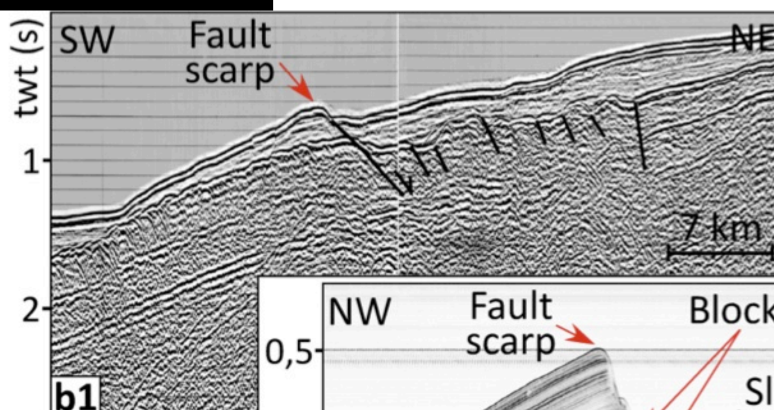
ISOLATED SLIDE SCARS (ISS) ON OPEN SLOPES

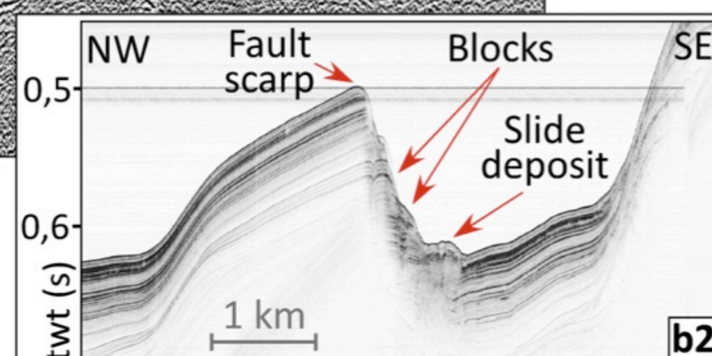


Apulian slope:

- failure deposits presumed to have moved down the Taranto canyon
- Largest : *Manduria failure* (c. 13 km^3), resembles a canyon but no connection to hydrographic system, linked to slide scarps and deposits – retrogressive failure?





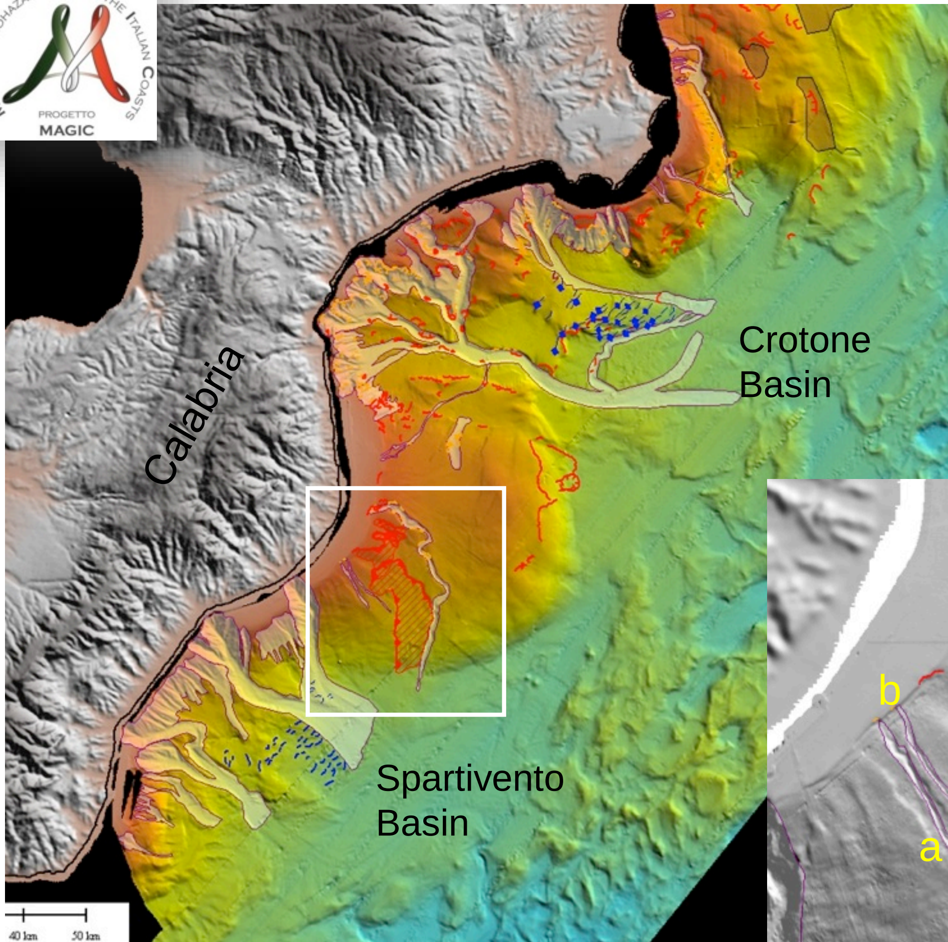


- Above faults, possible tectonic control

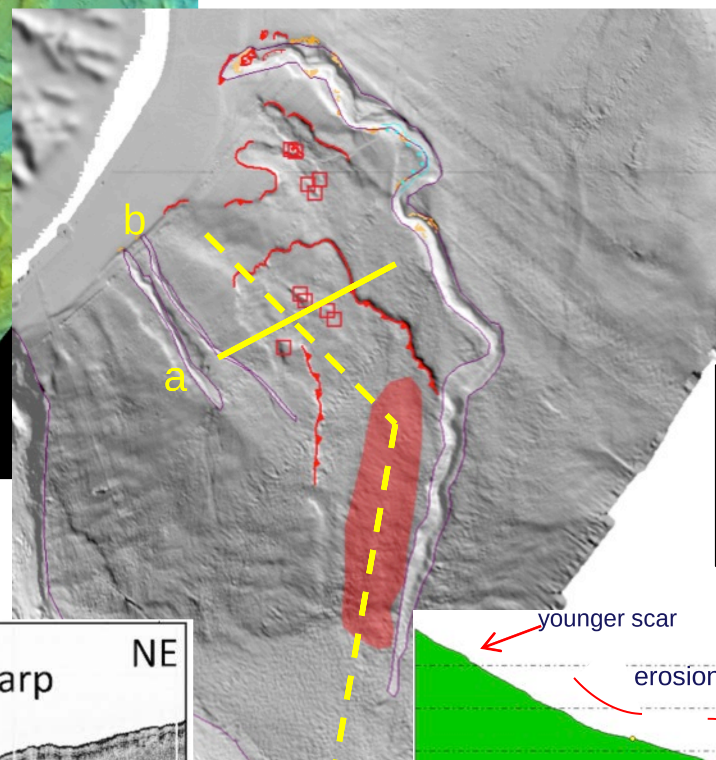
ISOLATED SLIDE SCARS (ISS) ON OPEN SLOPES

Calabrian slope

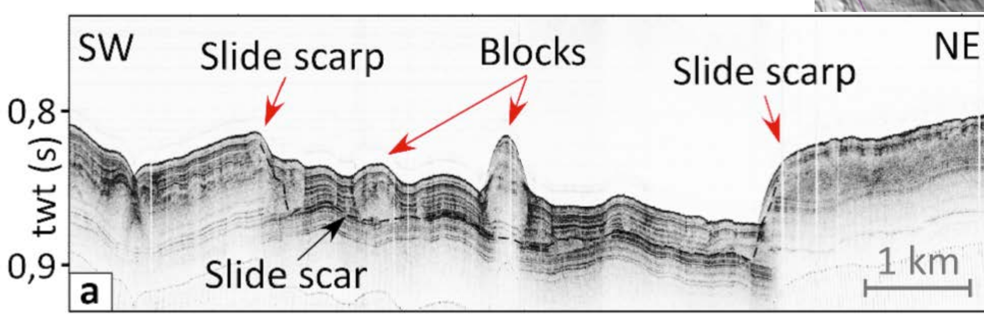
- Largest: *Assi failure* (c. 2 km^3)
- Most recent of a series (cuts older deposits, scarps upslope)

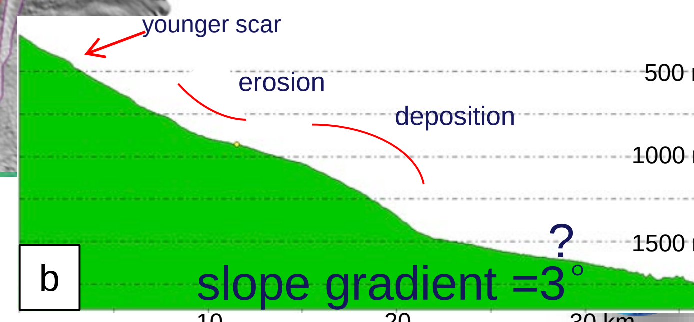


>18 x 6 km, 50 m high scarps



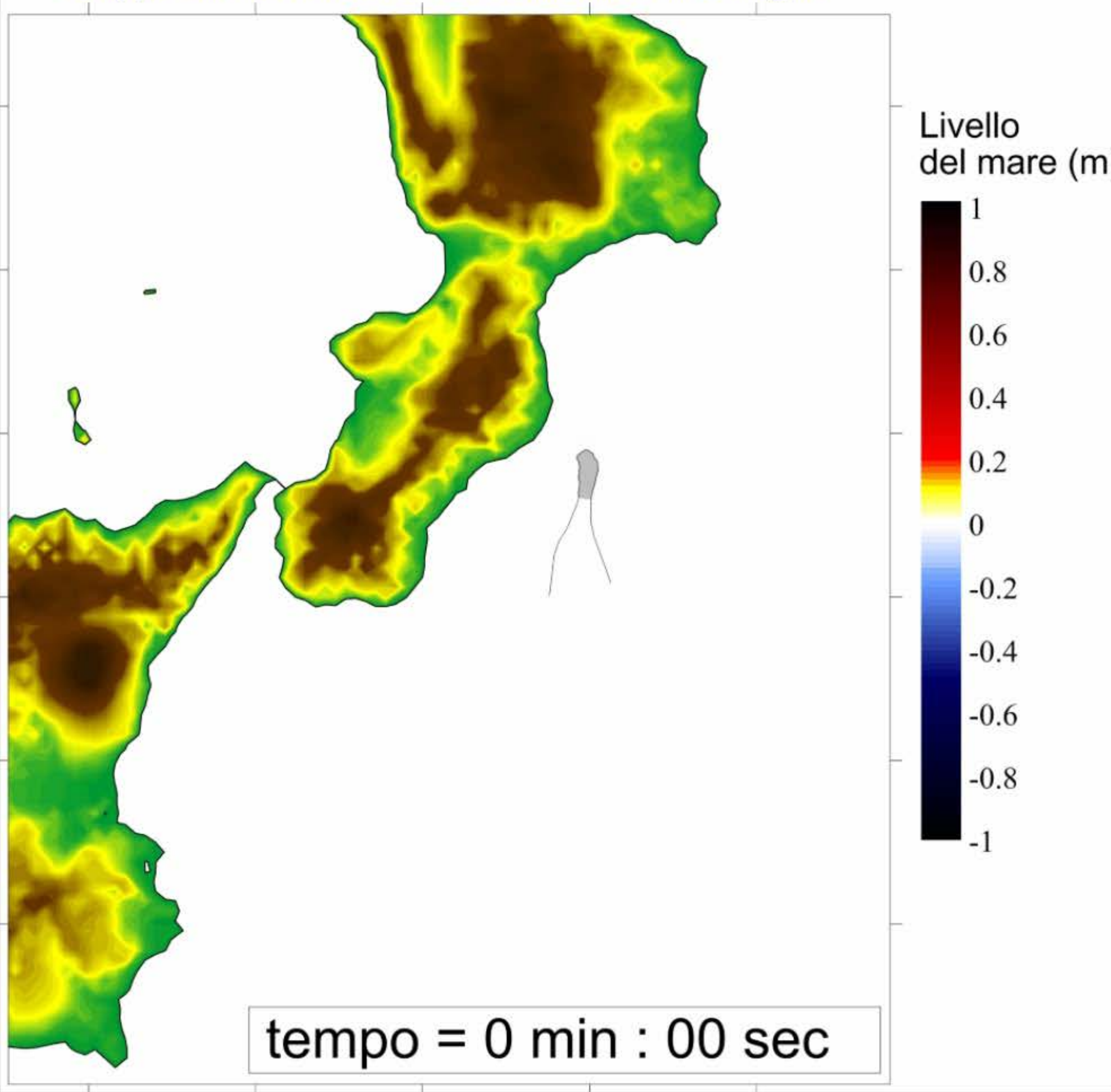
Tsunami modeling: coastal waves up to 1 m high (Zaniboni et al. 2012)



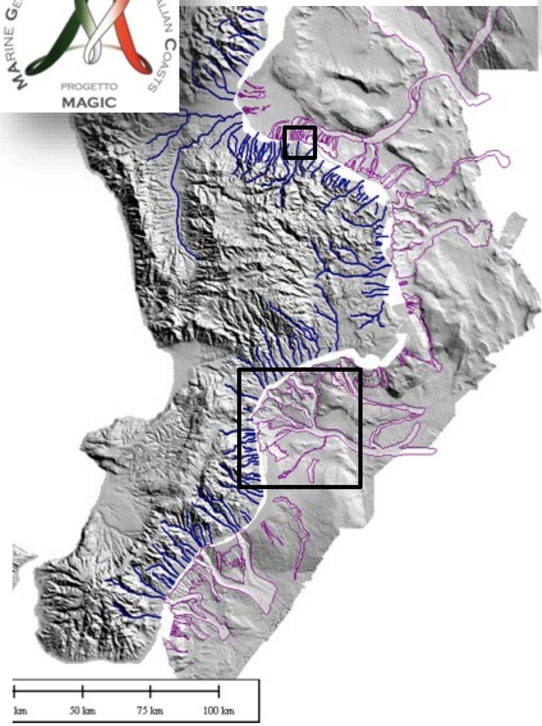


Maremoto dalla frana di Assi

Gruppo di Ricerca Maremoti - Università di Bologna

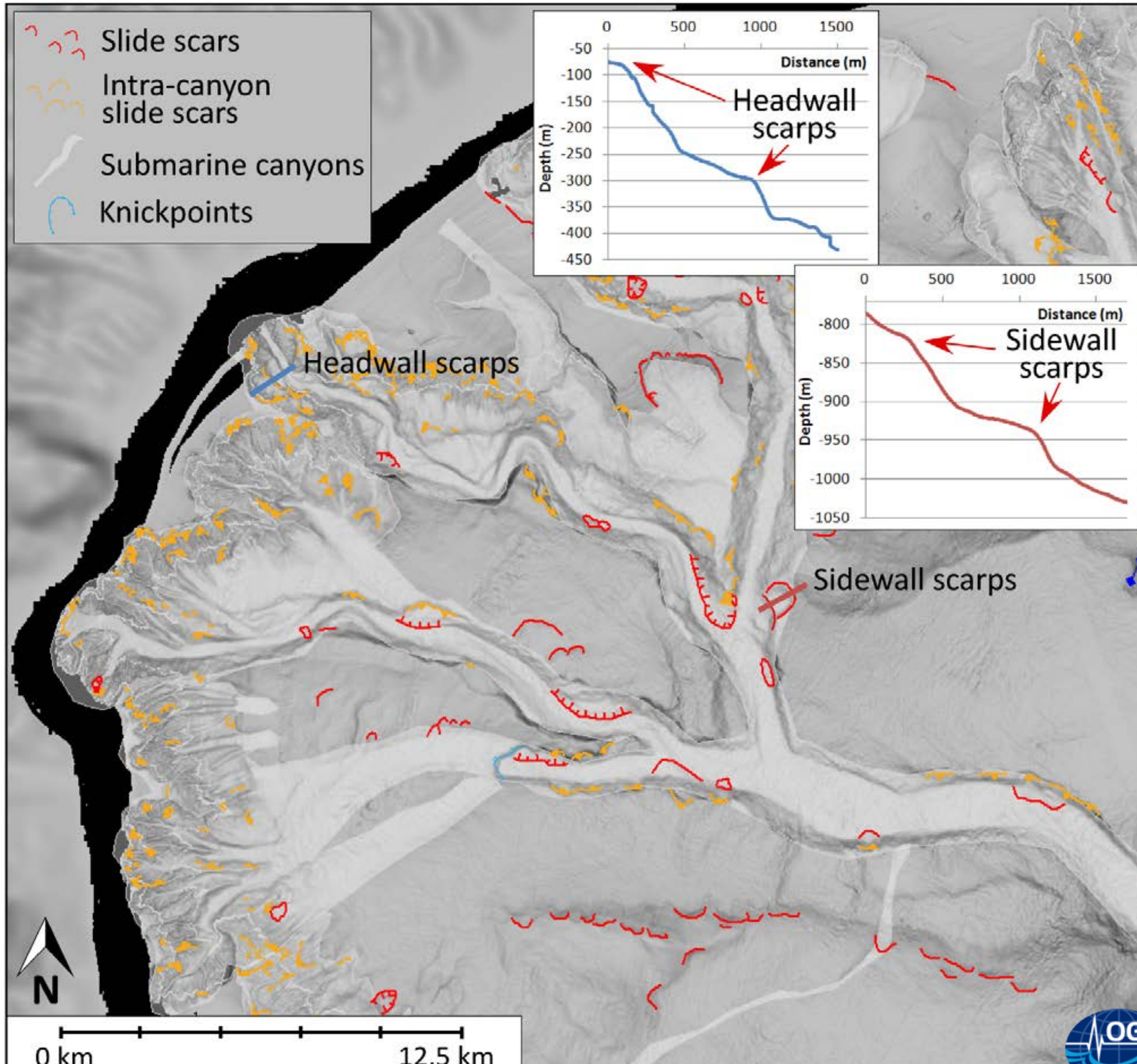


HEADWALL & SIDEWALL SCARPS IN CANYONS (HSC)



Gulf of Squillace

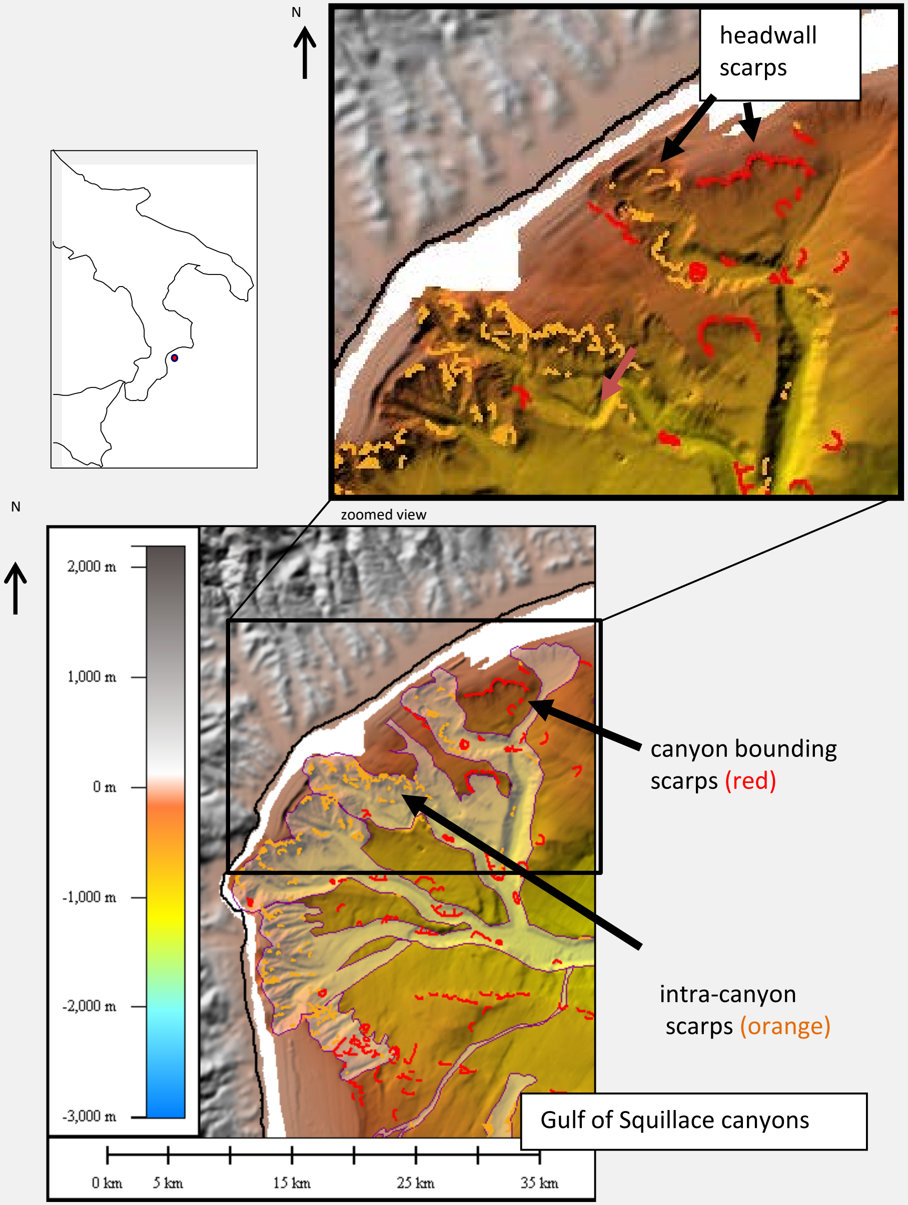
- largest canyon system, highly dendritic
- scarps 30-150 m high
- c. 6 km^3 mobilised (in 1st order branches)
- record retrogressive growth of canyon heads (some 1-3 km from coast)

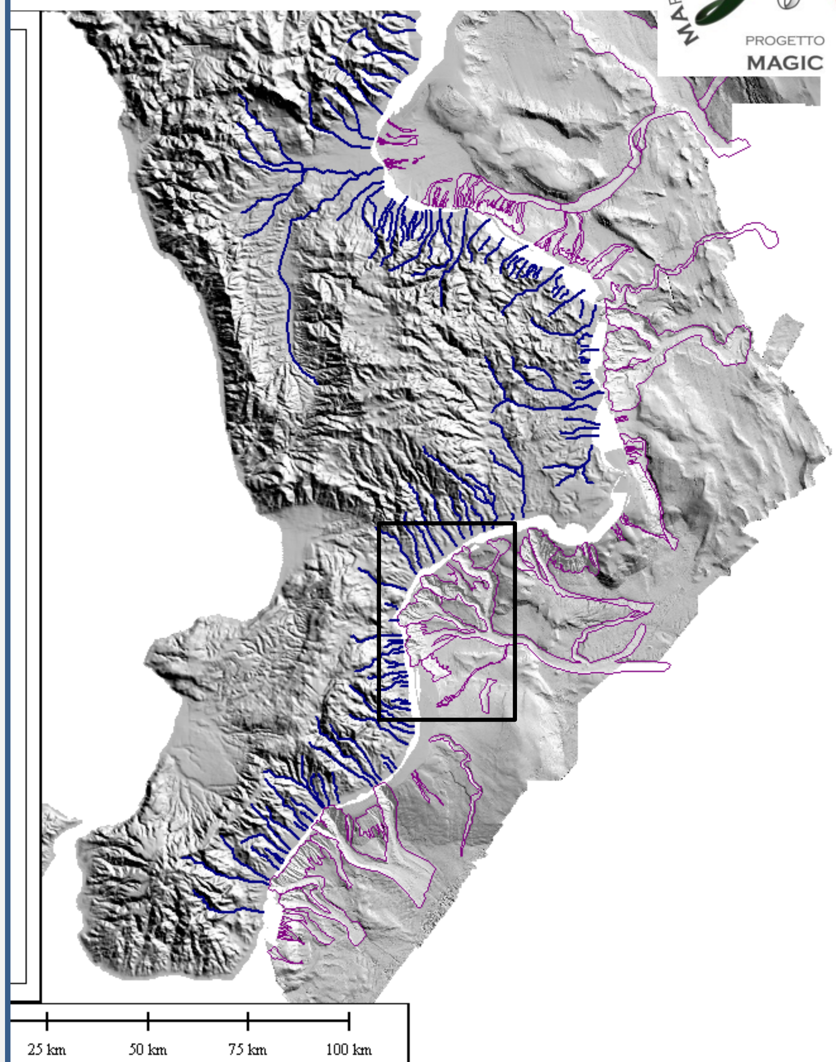


Ceramicola et al. 2014, in *Submarine Mass Movements andTheir Consequences*

Canyon headwalls

4 . Canyon headwall scarps

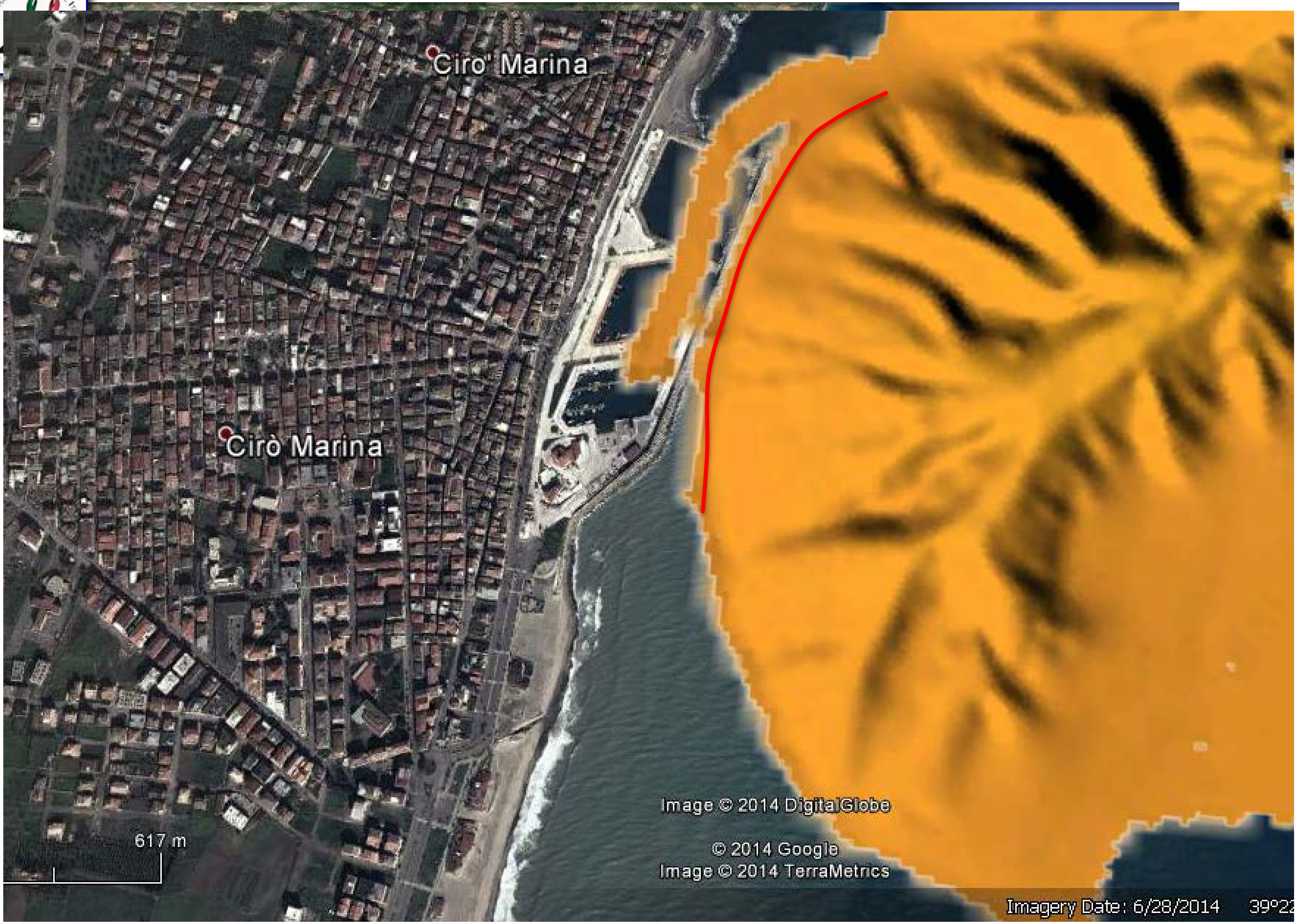




Canyon headwall hazard

Canyon di Catanzaro (Golfo di Squillace), Calabria Ionica

Canyon headwall hazard

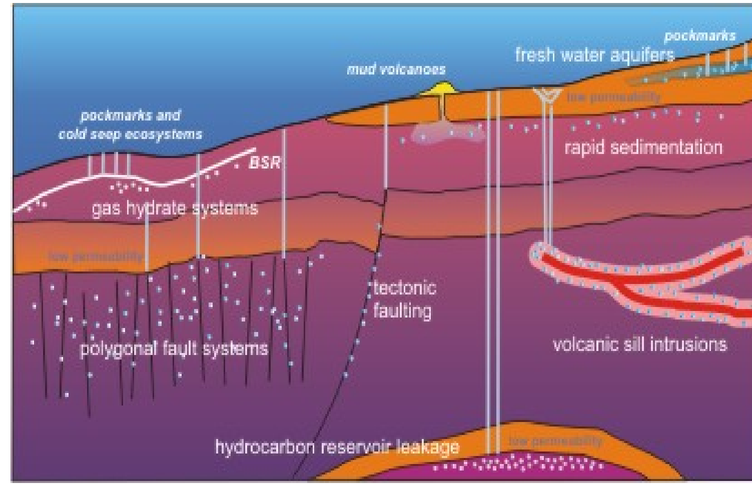



Porto di Cirò Marina
Ore 11:00 del 01 Dicembre 2013
Foto by Sergio Marino

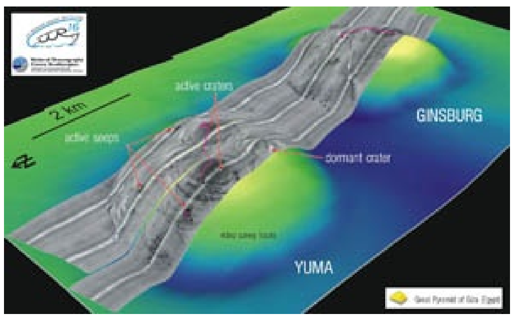
COLD SEEPS EXAMPLES

I COLD SEEPS

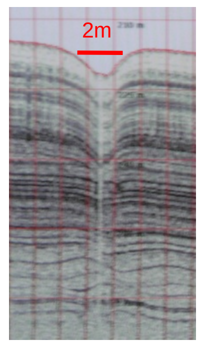
- MUD VOLCANOES (CONIC PIES)
- POCKMARKS
- CARBONATIC CRUSTS
- BRINE POOLS
- GAS HYDRATES



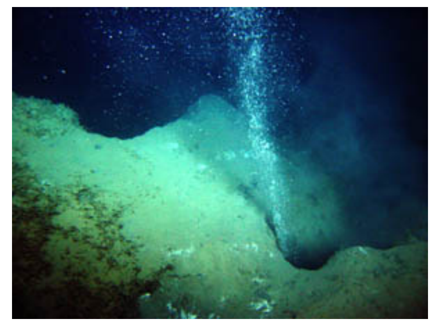
Schema della circolazione dei fluidi nei sedimenti, Berndt (2005)



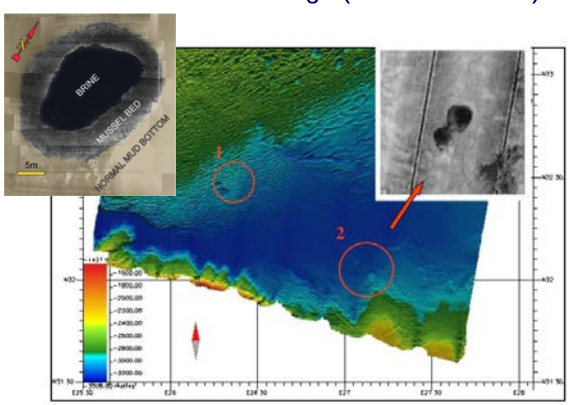
Vulcani di fango (Golfo di Cadice)



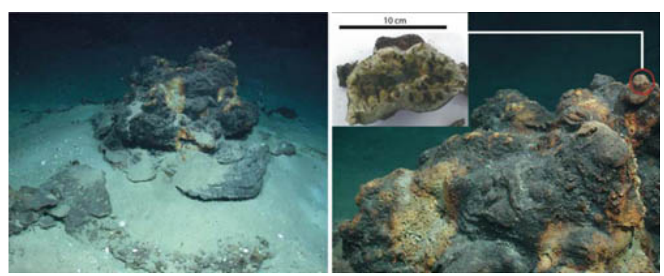
Pockmarks - Mar Adriatico



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?

MARINE GEOHAZARDS ALONG THE ITALIAN COASTS
PROGETTO MAGIC

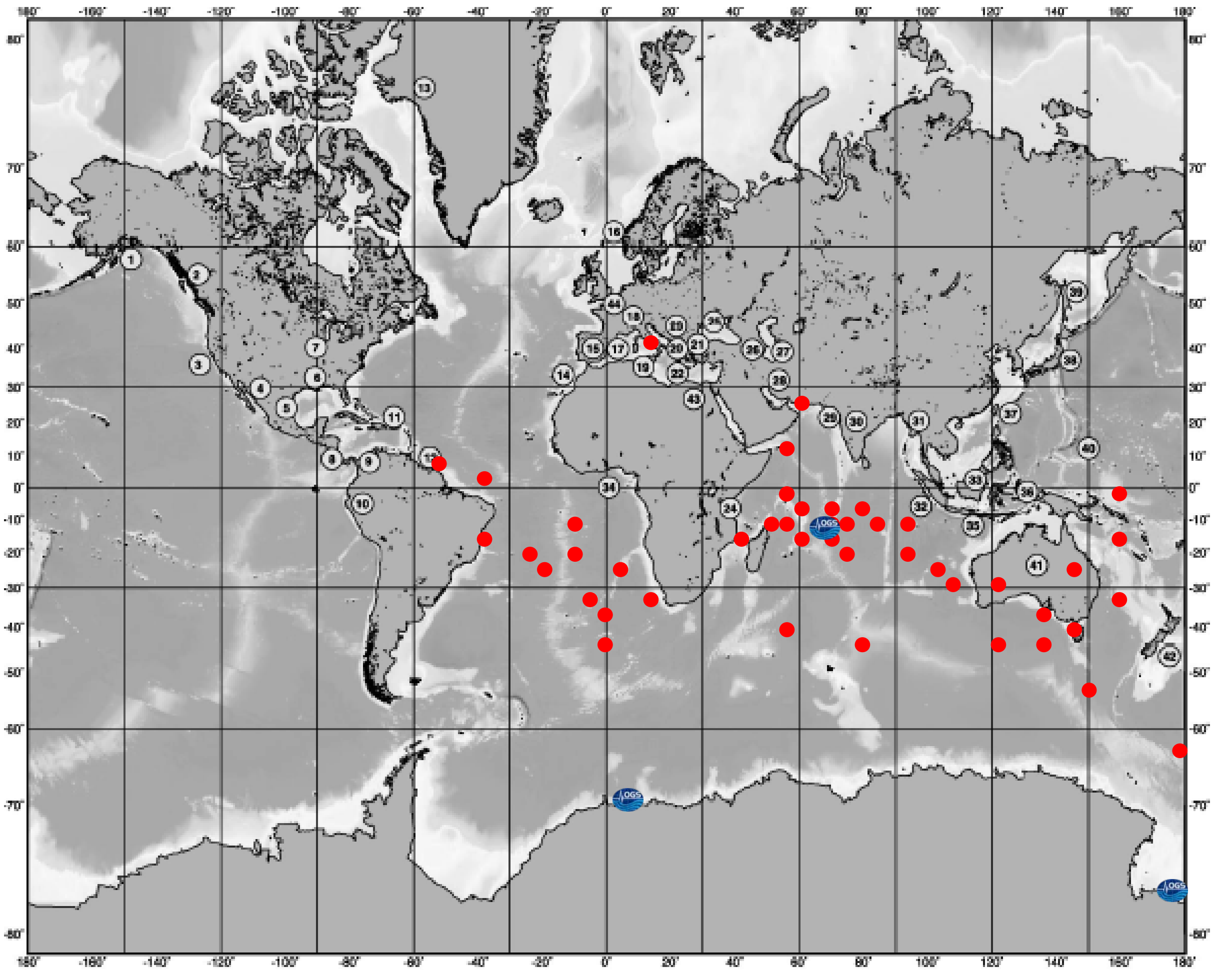
- because we do not know their functioning through time

- 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

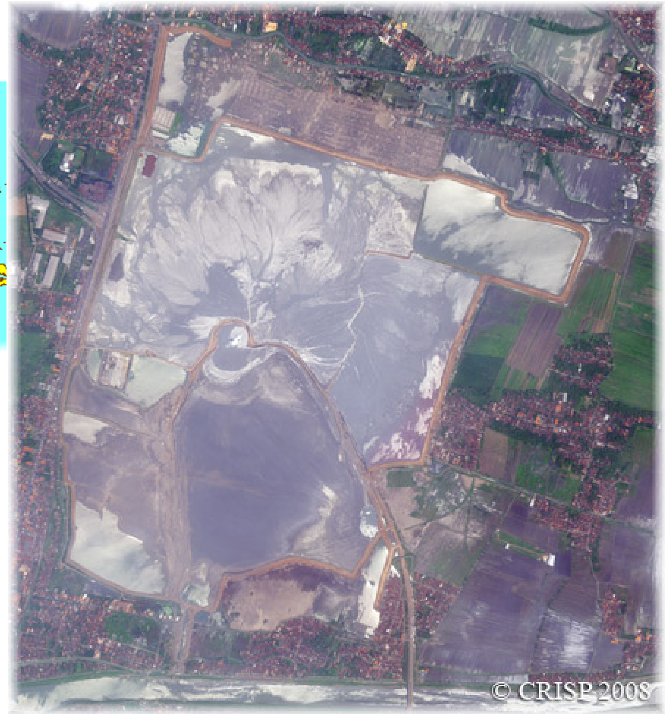


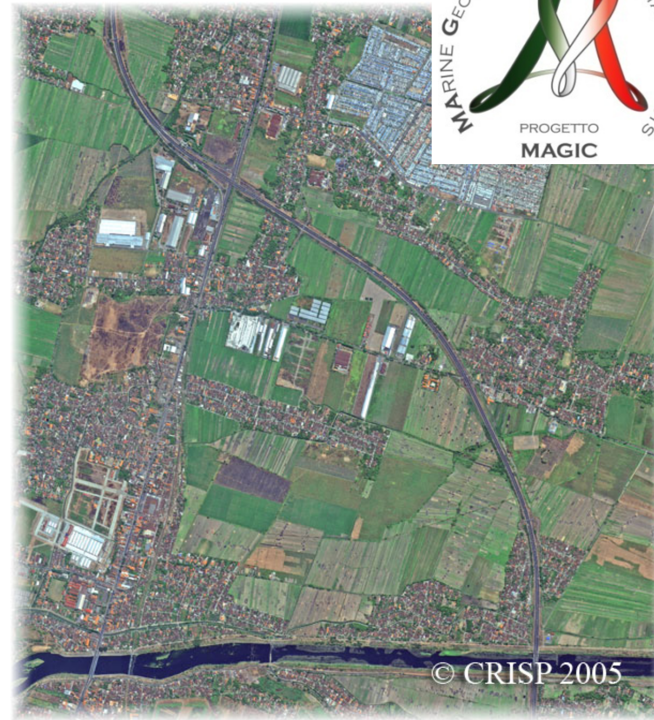
Distribuzione dei vulcani di fango nel mondo, Kopf (2002)

LA PERICOLOSITA'

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

1 KM





Ikonos Satellite images (CRISP)

CBC News 2008

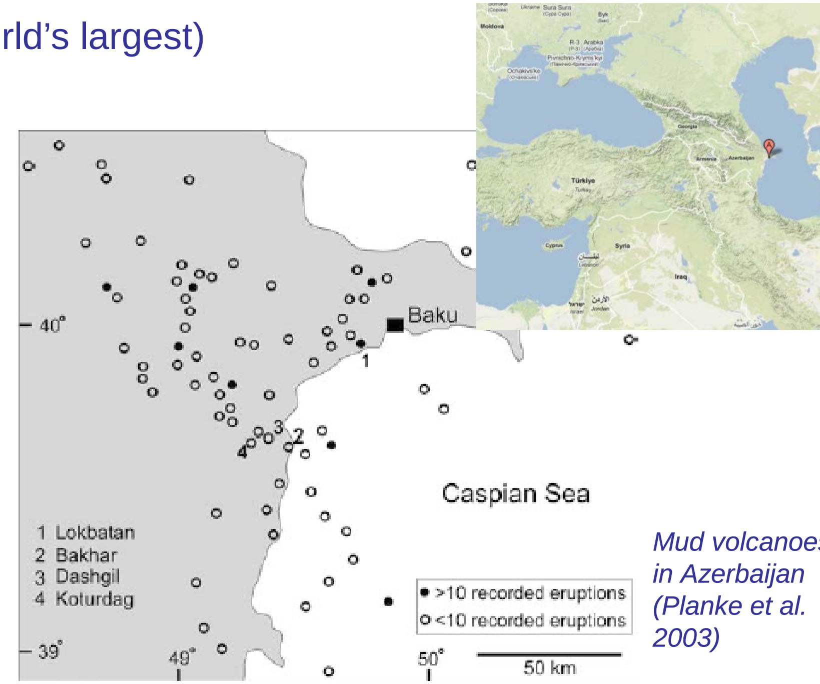
Wired Science Feb. 2010

Bledug Kuwu MV, Java centrale, 2009

LA PERICOLOSITA'

Azerbaijan mud volcanoes (among world's largest)

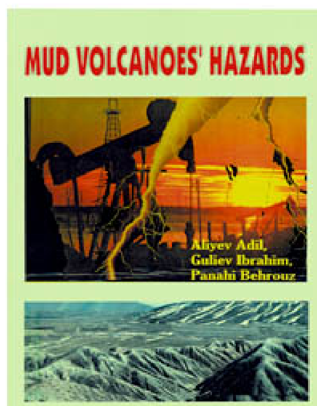
Lokbatan MV (B. Asbrink 2003 - Azerbaijan International)



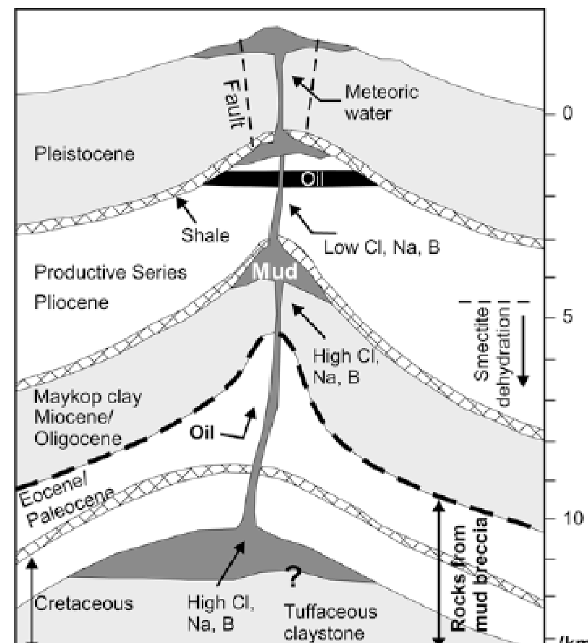
Mud volcanoes in Azerbaijan (Planke et al. 2003)

www.martinhovland.com

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

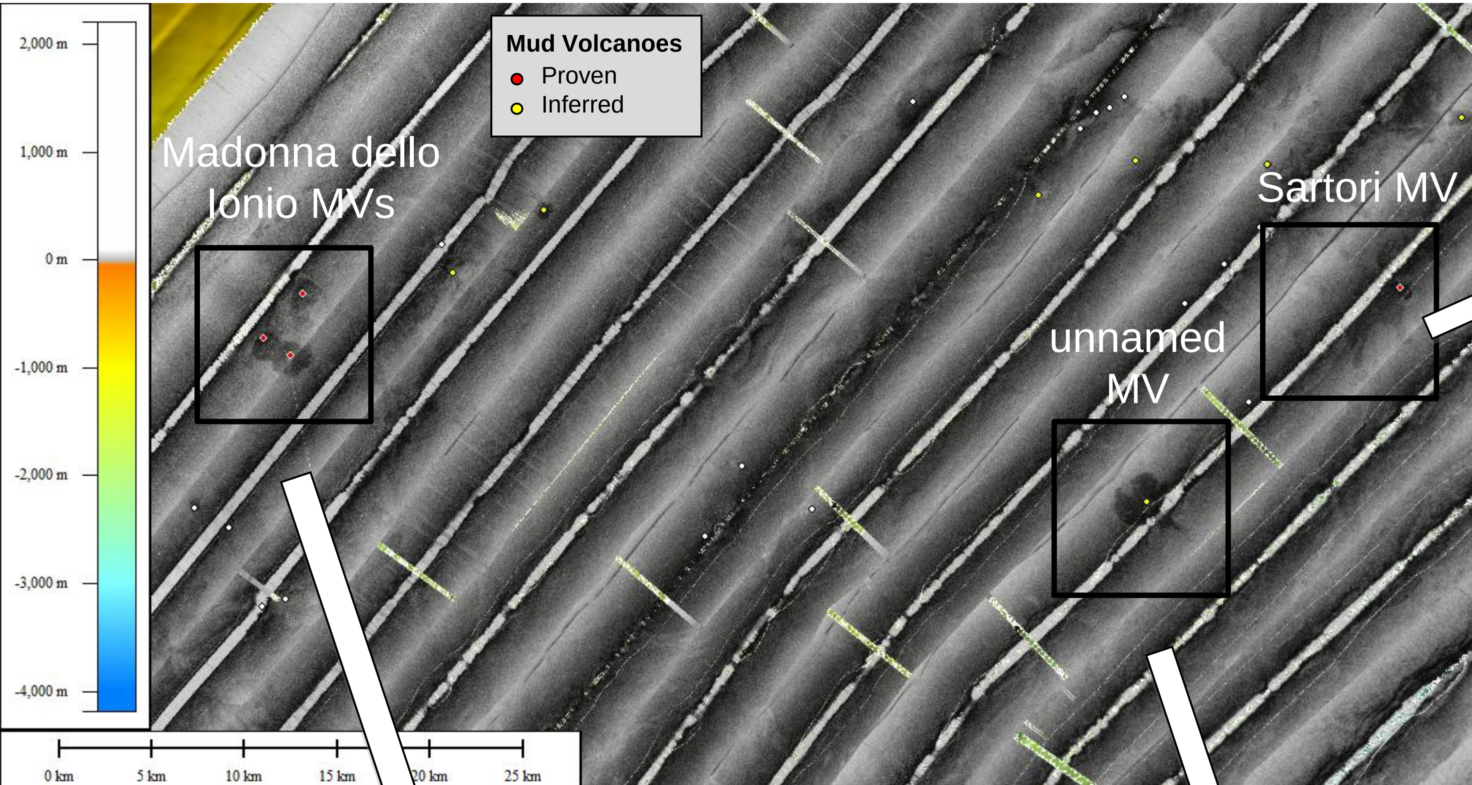


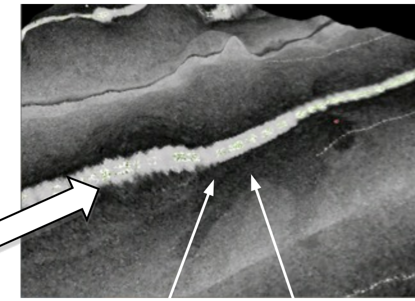
Aliyev et al. (2000)

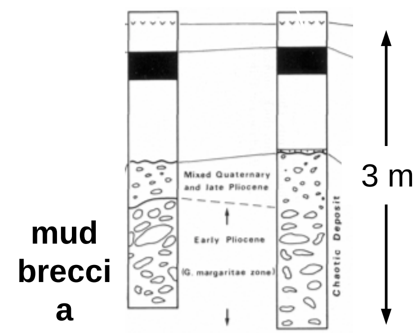


Conceptual model of Azeri mud volcanism - deep roots (12 km), multiple mud chambers (Planke et al. 2003)

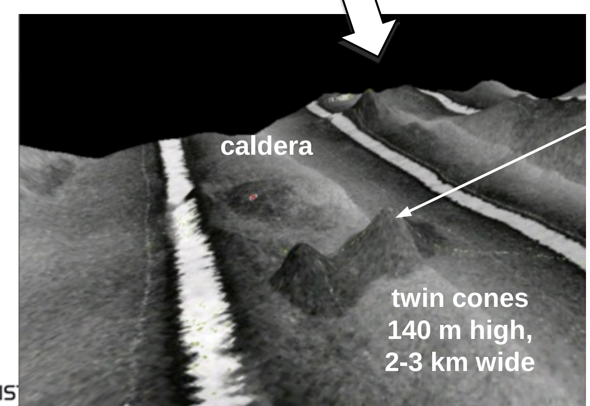
Use of multibeam morpho-bathymetry + backsca data to map mud volcanoes (Calabrian Arc)

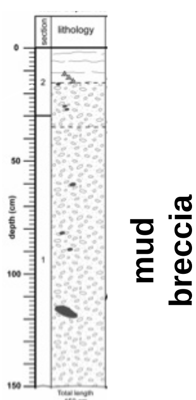


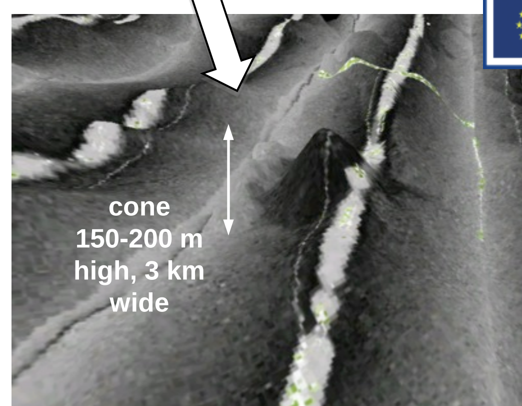




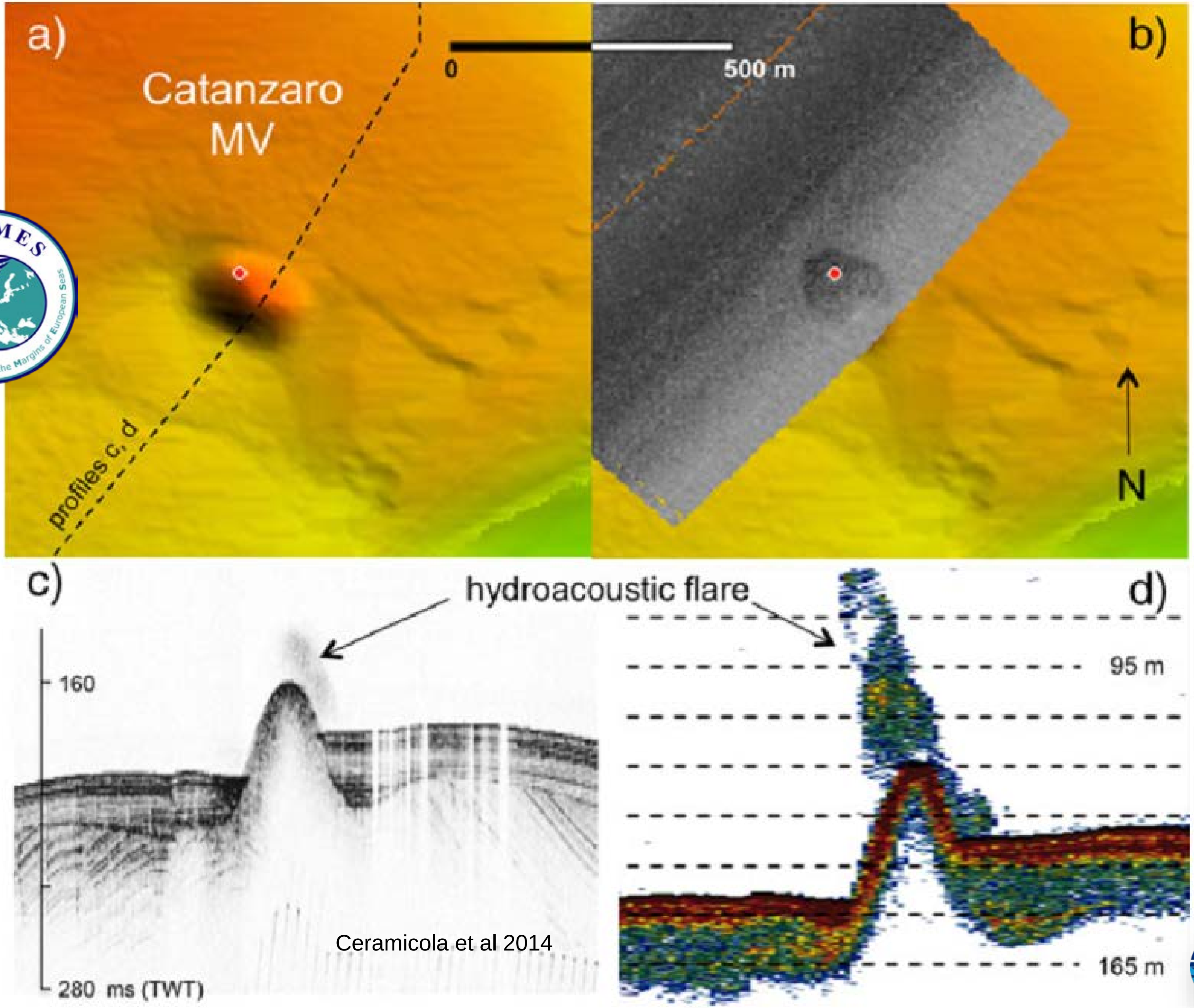
Morlotti et al. (1982)





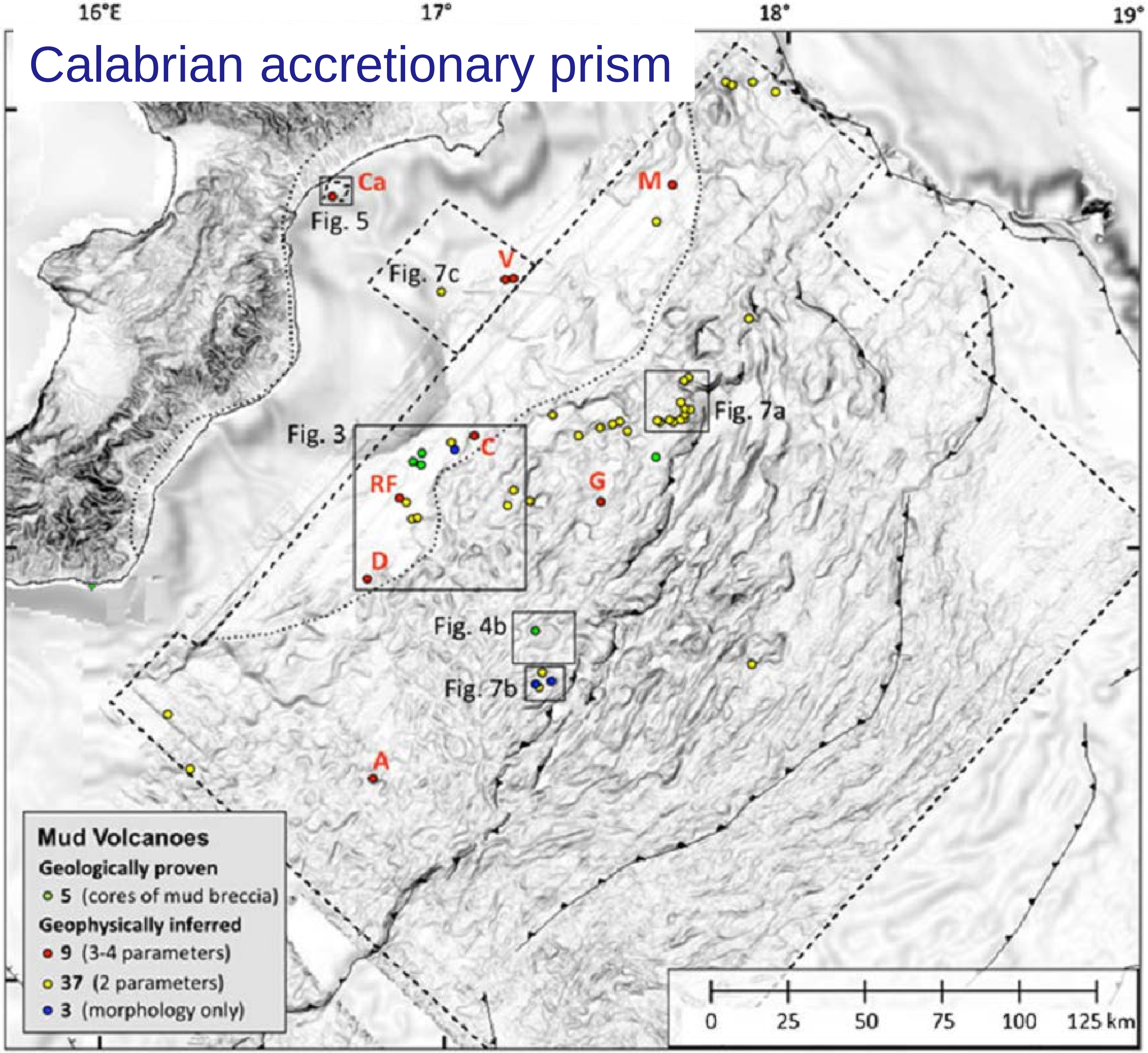


Ceramicola et al. (2014)

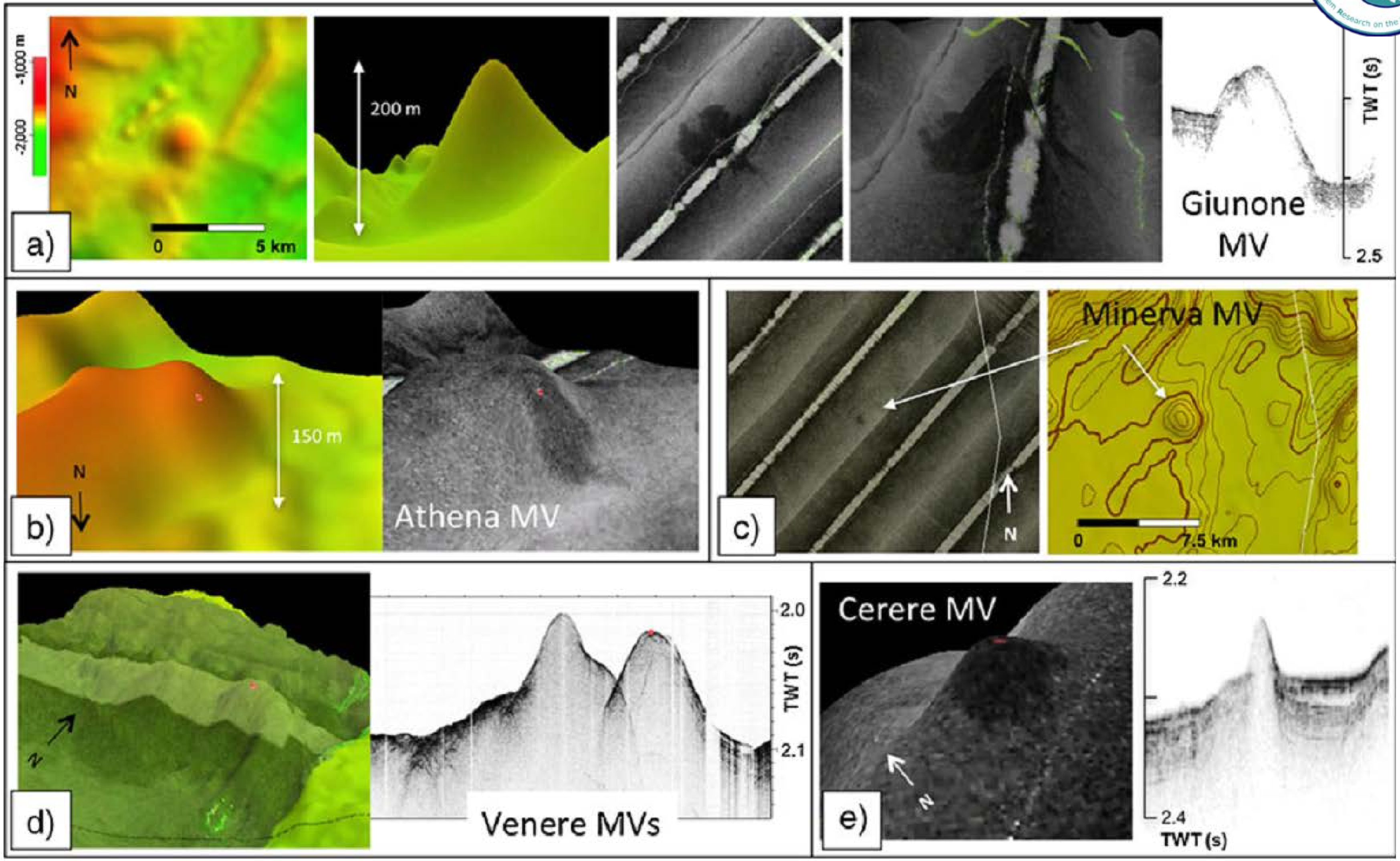


Ceramicola et al 2014

Calabrian accretionary prism

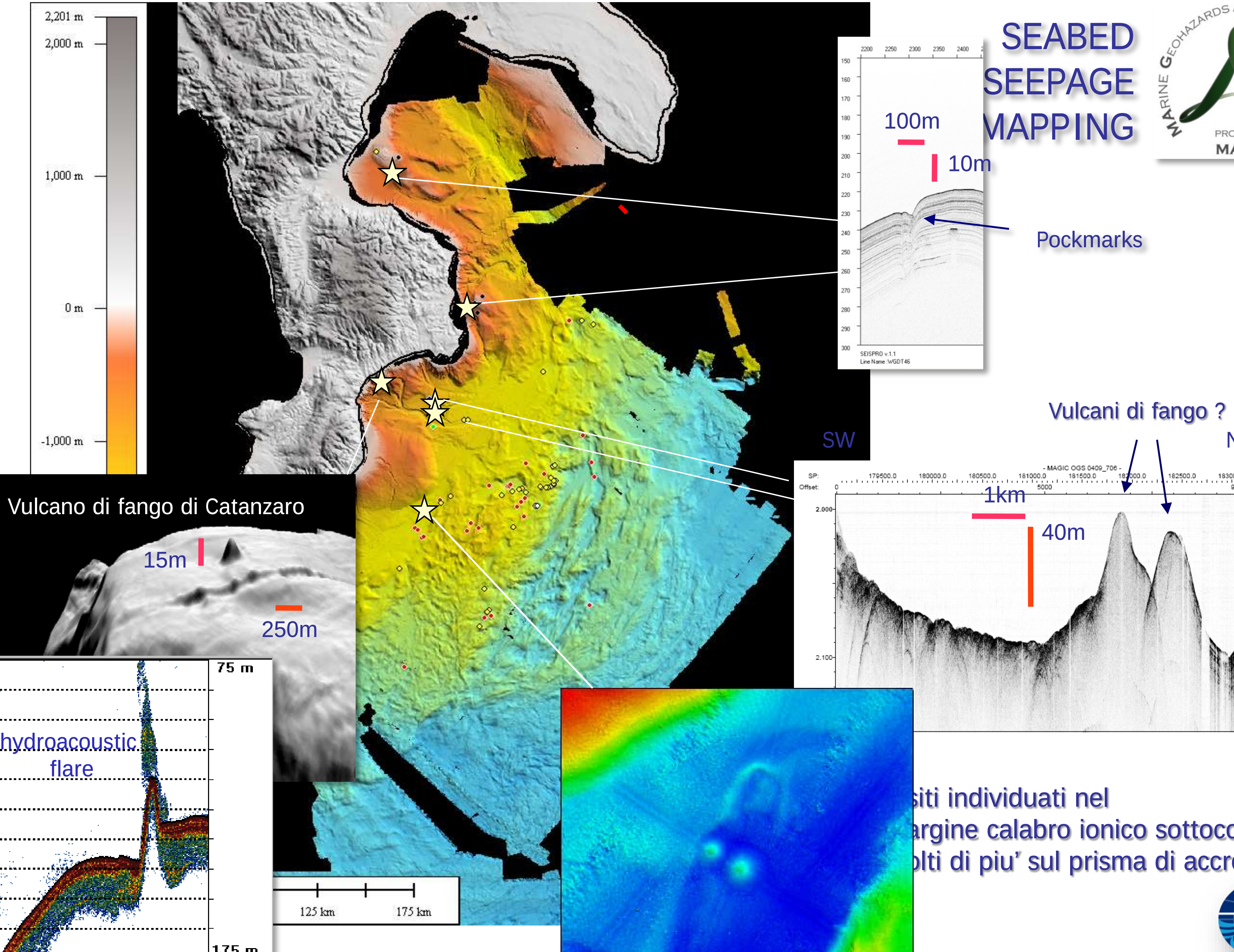


Ceramicola et al 2014



Ceramicola et al 2014

SEABED SEEPAGE MAPPING



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

ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

presenter: Silvia CERAMICOLA – OGS Trieste, Italy

Final remarks

- Regional-scale seafloor mapping is the first step in making a census of the **geohazard-bearing features** present in a given offshore area

- **Integrating different acoustic methods** allows to identify and map seafloor and near-bottom activity and thus assess marine geohazards

- We have seen examples of different process **active at seafloor**: gravitational failures able to generate tsunamis, retrogressive canyon headwalls, fluid/gas seepage, seismogenic faults, all of them identified though regional scale seafloor mapping

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

Conclusions/Future work

- 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 r/v OGS Explora for sensitive infrastructures (nuclear power plant- submarine cable/pipelines)

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

- European Commission, Unesco, Department Civil Protection of Italy, Italian Ministry for the Research (MIUR)

Preparedness and Disaster