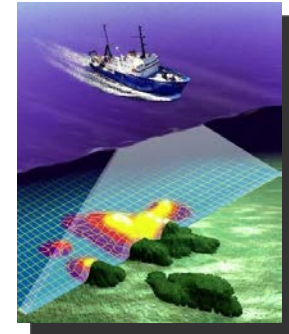
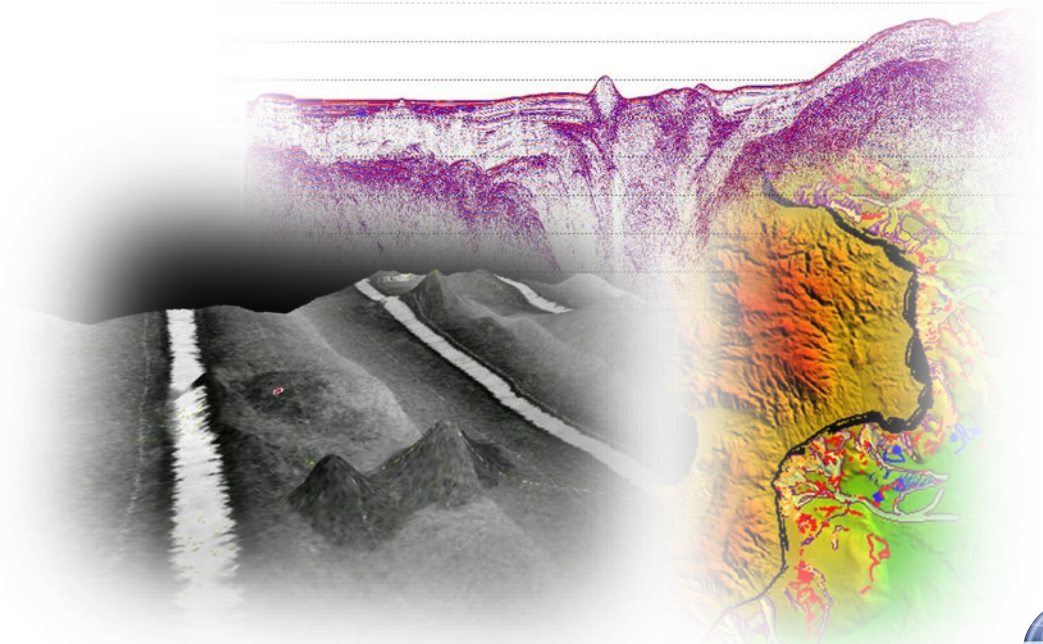


Corso di Geologia Marina Università di Trieste 2015- 2016



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

Silvia Ceramicola – OGS
sceramicola@inogs.it



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

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$



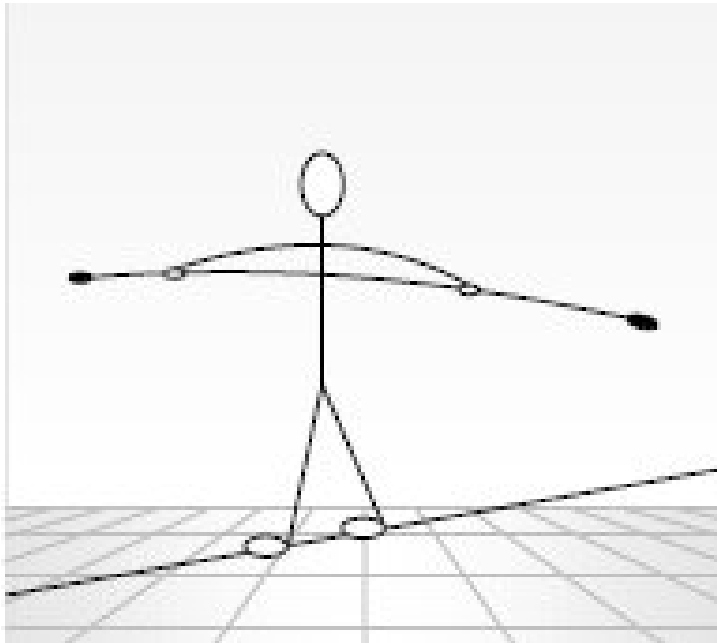
HAZARD: the road is frozen thus there is a risk for car accidents, if the road is empty (no exposure to hazard), no risks of car accidents

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

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

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.

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

Resilience

Japanese Earthquake Highway Repair

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



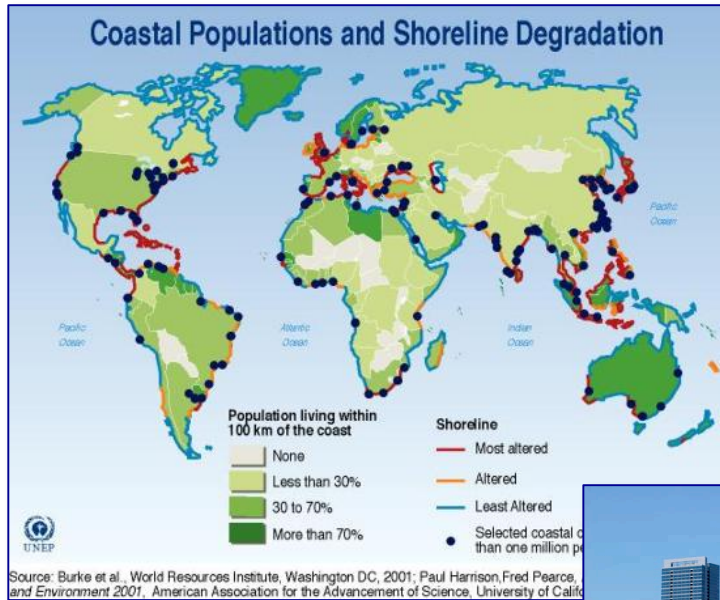
By Mail Foreign Service, 02:01 GMT, 24 March 2011

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

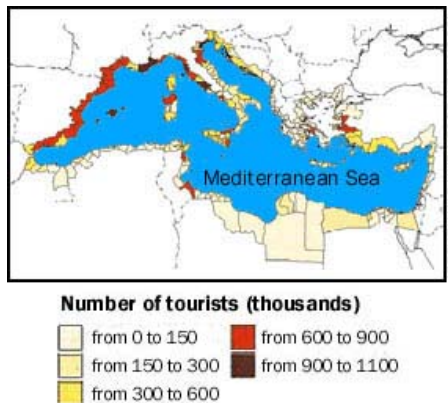


Top Ten World Largest Cities

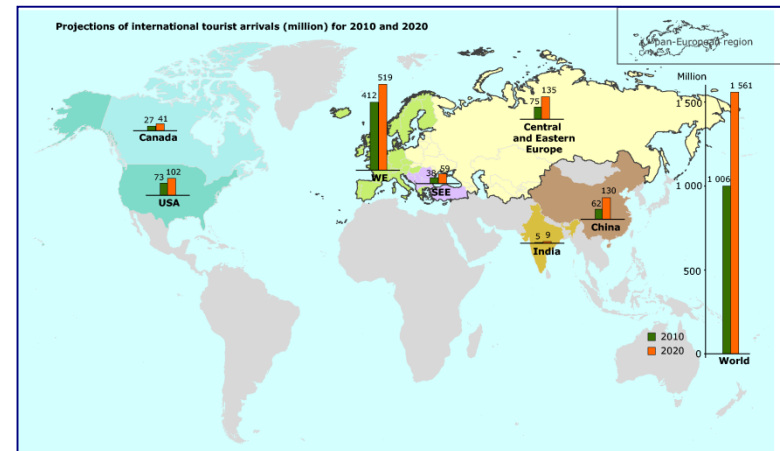
- Tokyo, Japan (coastal)
- Mexico City, Mexico
- Mumbai, India (coastal)
- São Paulo, Brazil
- New York City, USA (coastal)
- Shanghai, China (coastal)
- Lagos, Nigeria (coastal)
- Los Angeles, USA (coastal)
- Calcutta, India (coastal)
- Buenos Aires, Argentina (coastal)



- 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.”

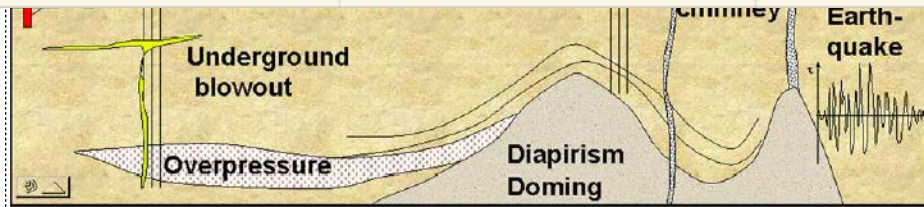
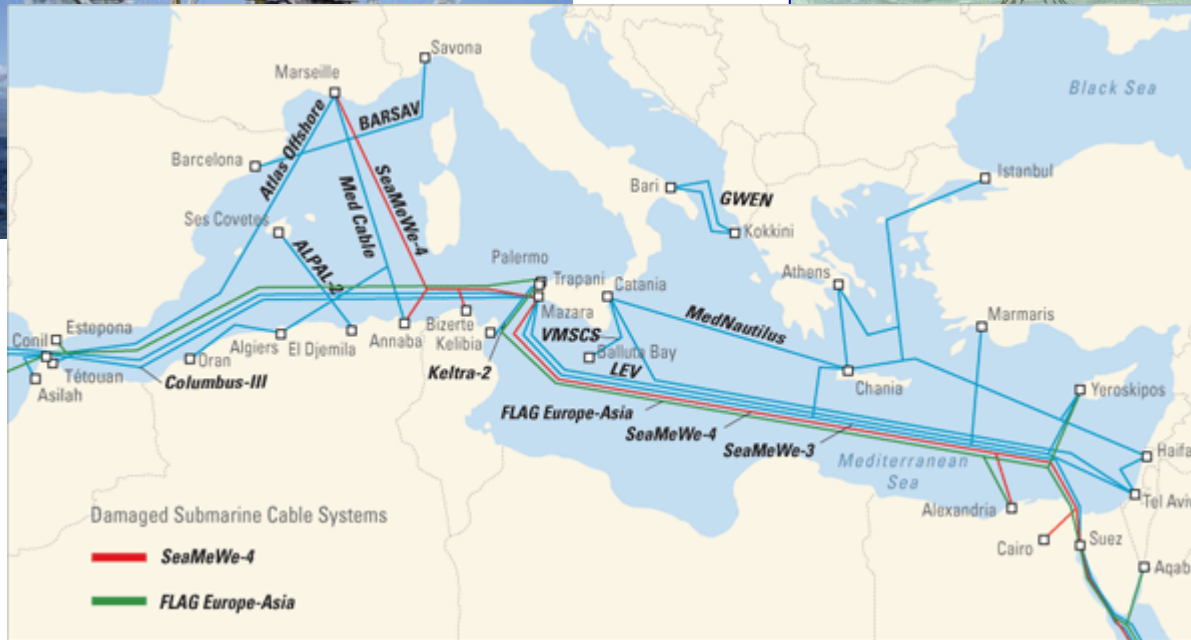
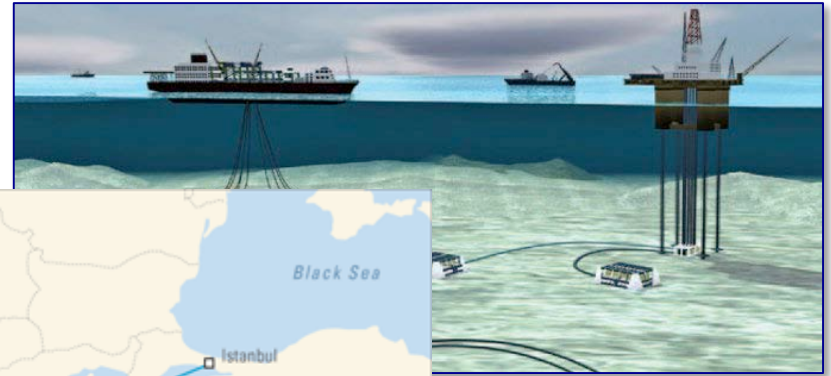


Mediterranean tourism takes its toll. By Environmental News Network (ENN) March 14, 2000;
<http://archives.cnn.com/2000/NATURE/03/14/mediterranean.en/index.html>

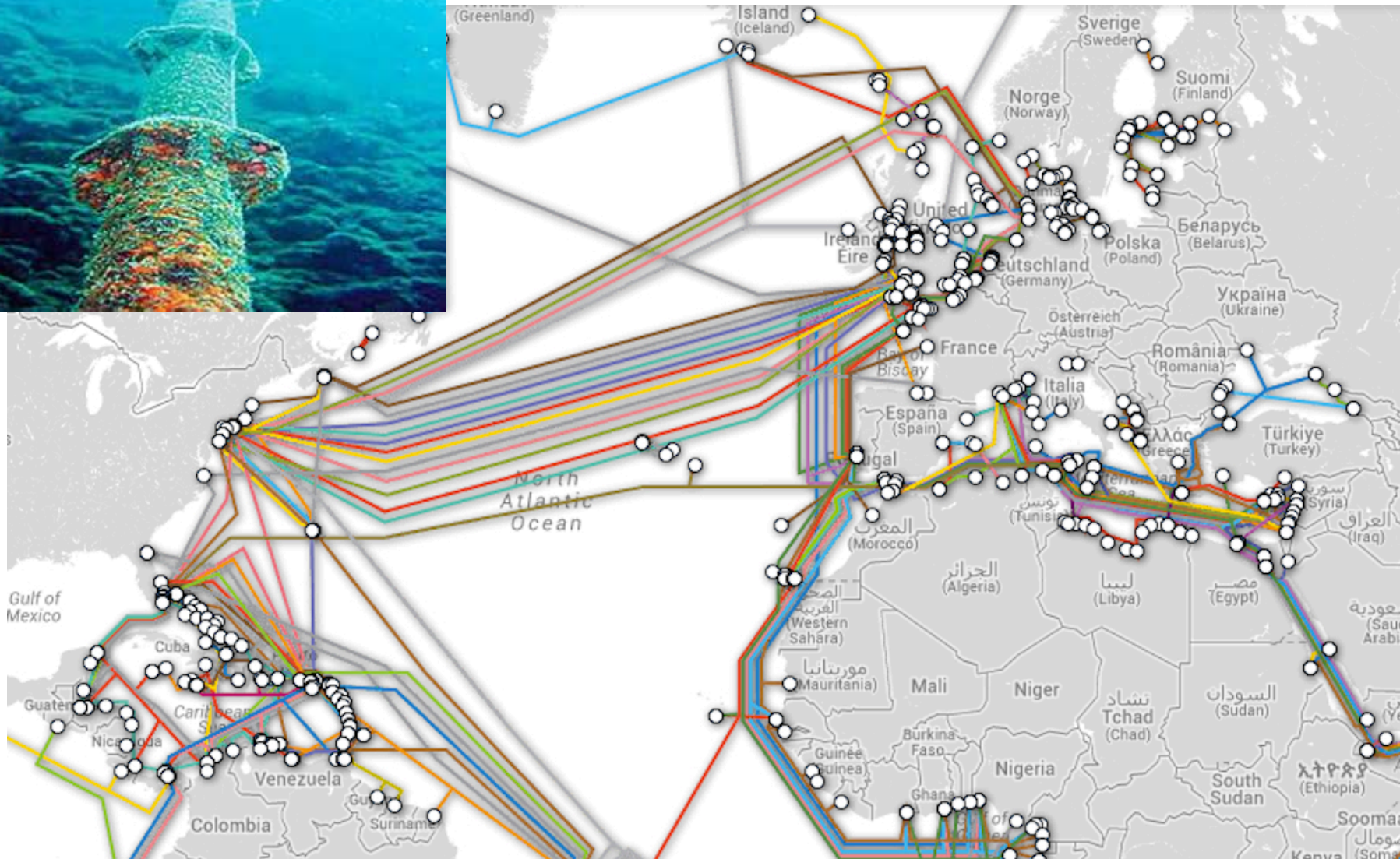
EEA web site <http://www.eea.europa.eu>
 Copyright EEA, Copenhagen.



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

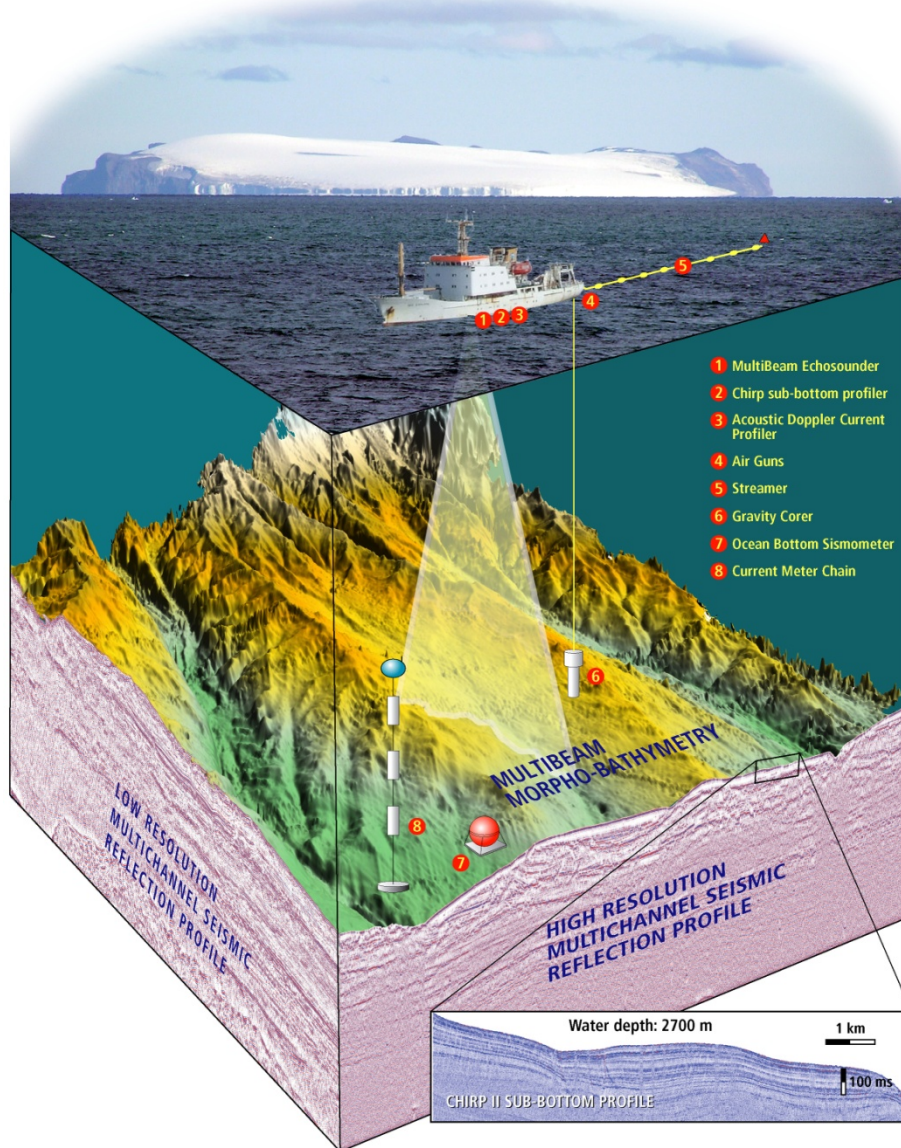


Cavi sottomarini

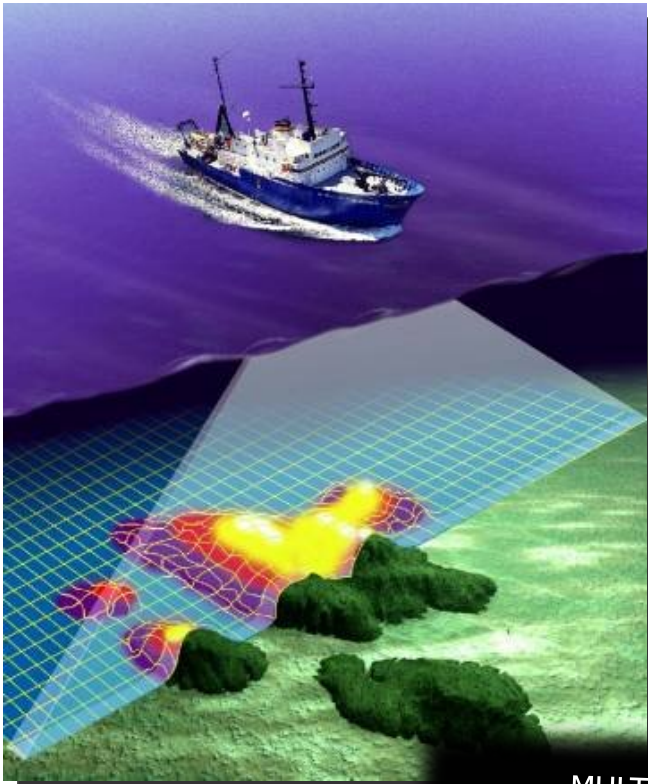


INTEGRATED ACOUSTIC METHODS

R/V OGS Explora



INTEGRATED ACOUSTIC METHODS – multibeam including reflectivity and water column



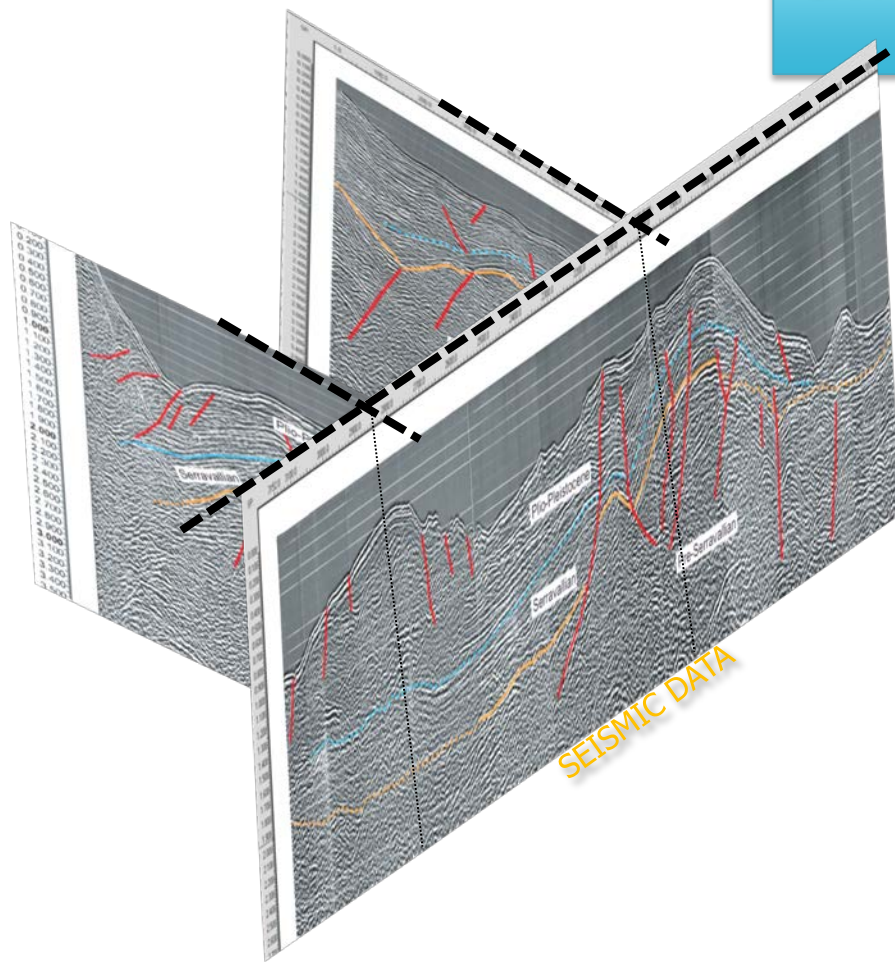
MULTIBEAM BACKSCATTER



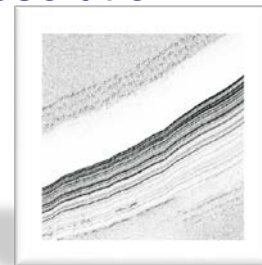
Seafloor mapping is the first step in making a census of the **geohazard-bearing features** present in a given offshore area. It often provides the only tool for a comprehensive **seafloor geohazard assessment over large areas** that are scarcely groundtruthed by acoustic prospection and sea-floor sampling.

By Chiocci et al 2011

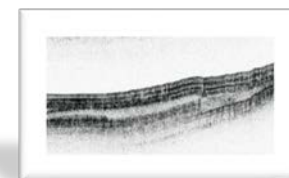
INTEGRATED ACOUSTIC METHODS – seismics and sub-bottom



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



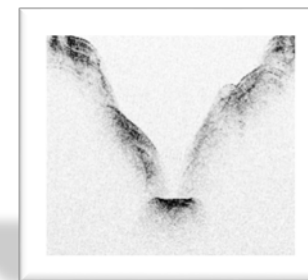
BB



BTB



H

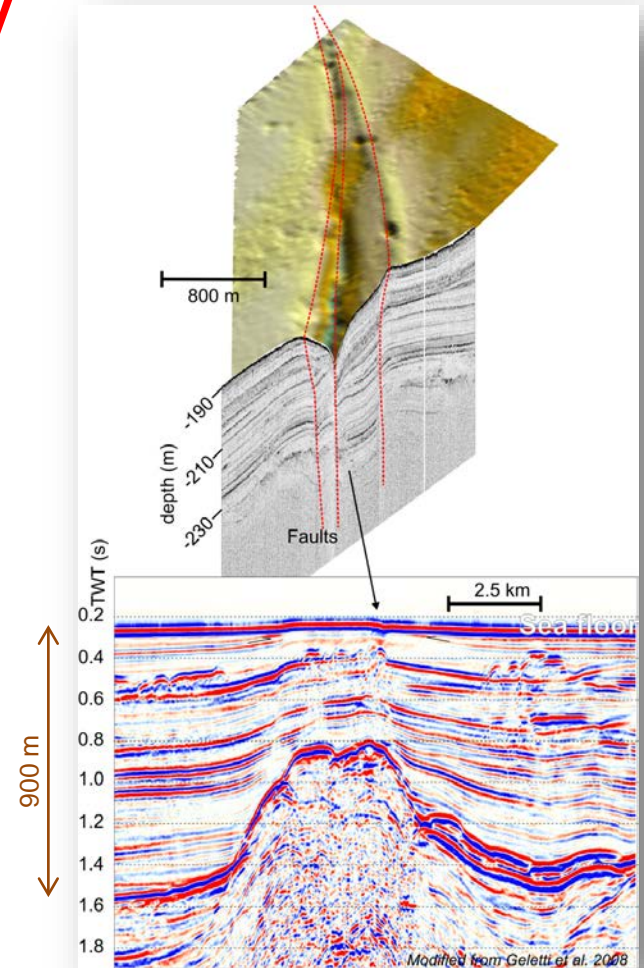


R

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

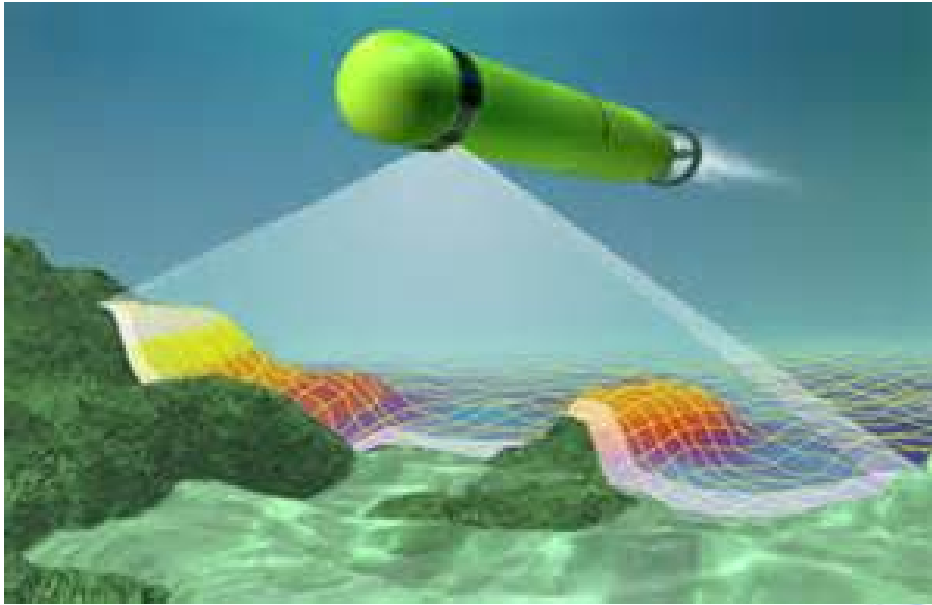
Methodology

- **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
- **Multidisciplinary**: geophysics/seismology/oceanography/biology



La tecnologia marina a robotica

- ROV e AUV



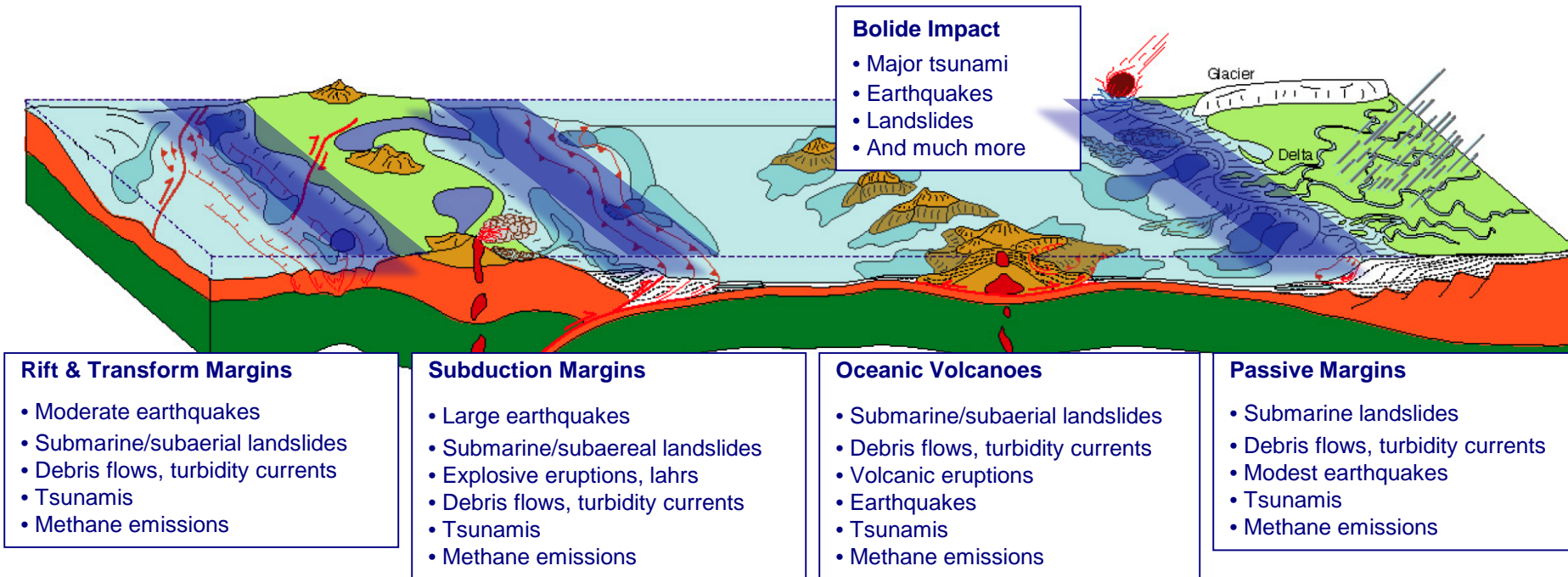


emepc
Estrutura de Missão para a
Extensão da Plataforma Continental

GS



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

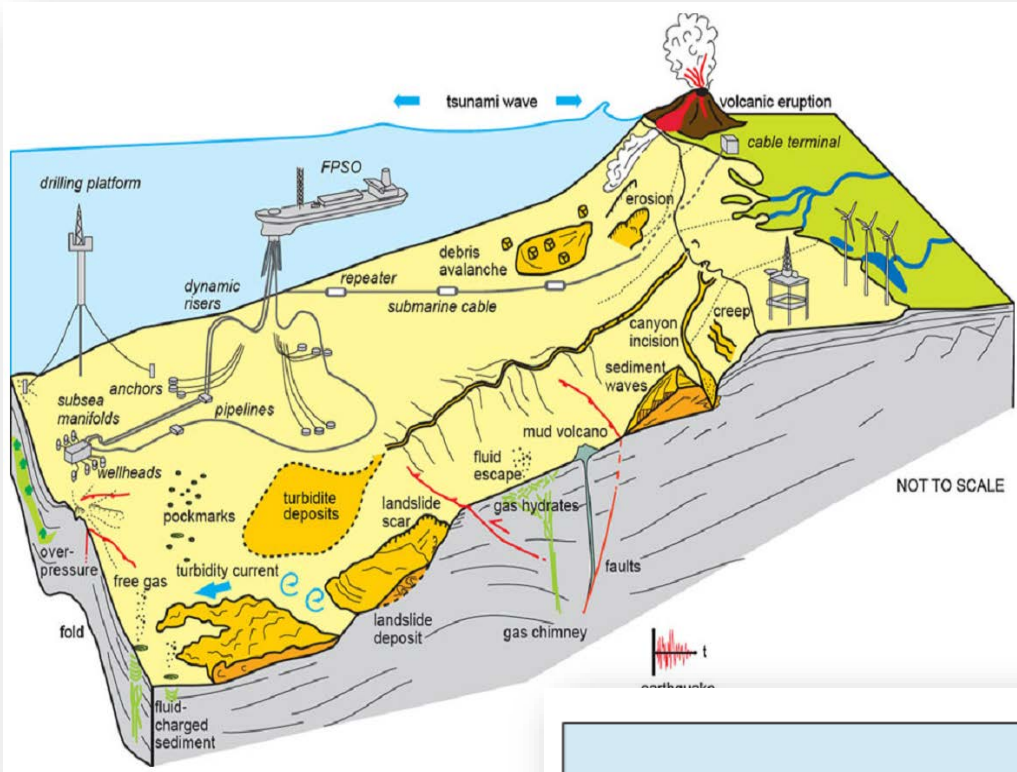


Adapted from Morgan et al., 2009. *Scientific Drilling*, available at: <http://www.iodp.org/geohazards/>



- **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** (CH₄, CO₂ mainly)
- **METEORITE IMPACTS** in the oceans



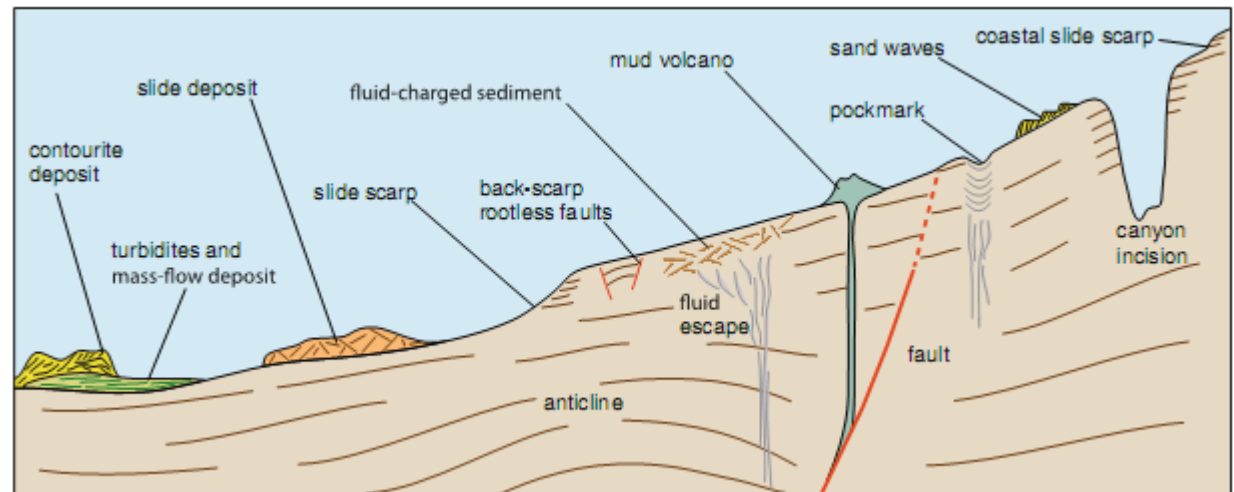


Chiocci et al. 2011

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

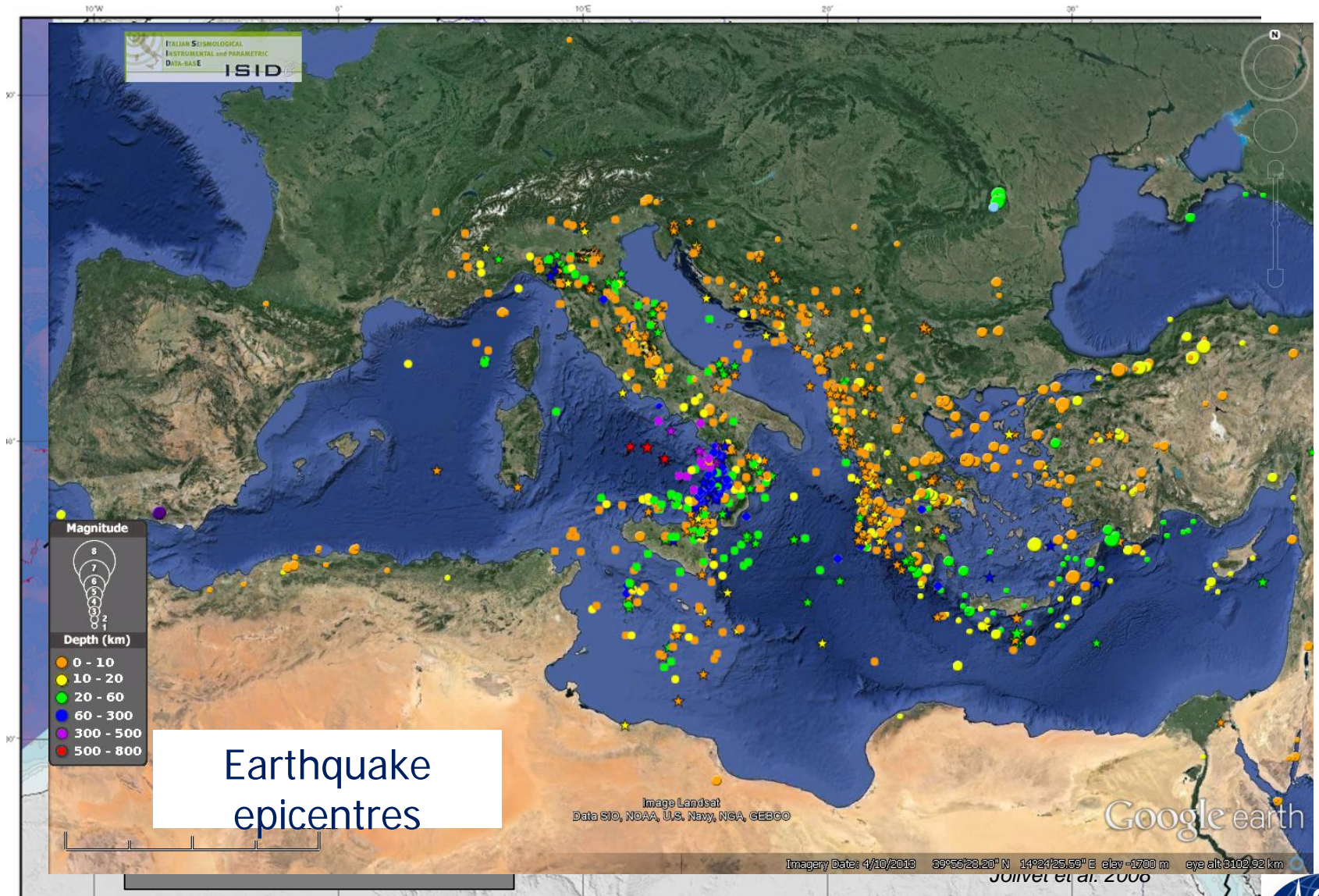
Geomorphic features as
geohazard indicators:

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

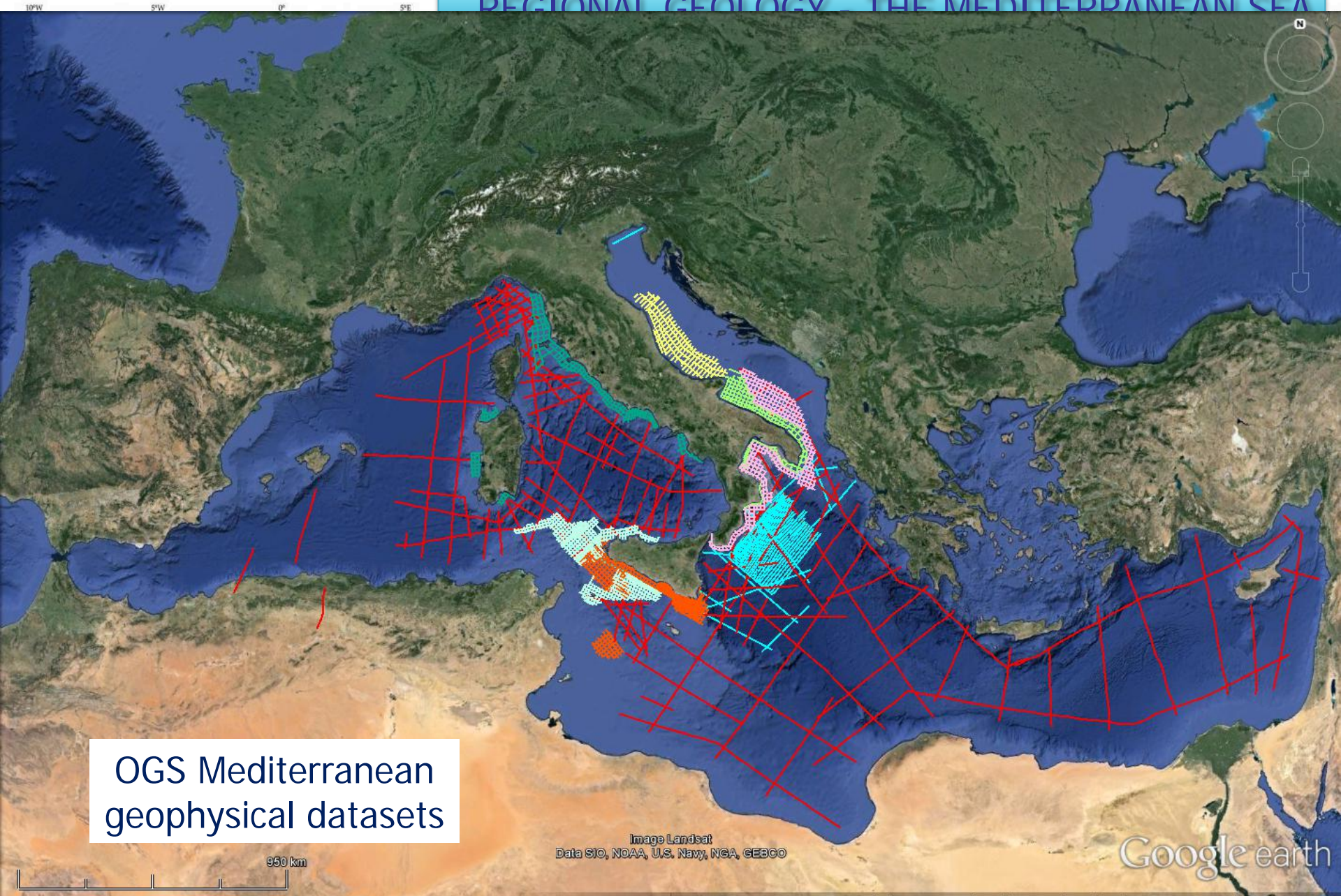
REGIONAL GEOLOGY - THE MEDITERRANEAN SEA



Geology does not care about coastlines!!

presenter: Silvia CERAMICOLA – OGS Trieste, Italy





OGS Mediterranean
geophysical datasets

Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth



Imagery Date: 4/10/2013 39°56'28.20" N 14°24'25.59" E elev -1700 m eye alt 3102.92 km

Reference 1: Bouché, L., Mauch, J., Leclercq, B., 2012, Morphobathymetry: Map of the Mediterranean Sea, publication CCGM/CCAMV, UNESCO, Paris.

REGIONAL GEOLOGY - THE MEDITERRANEAN SEA

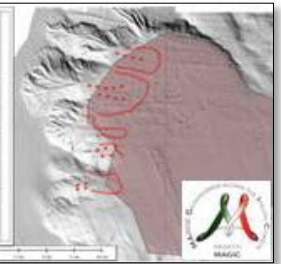
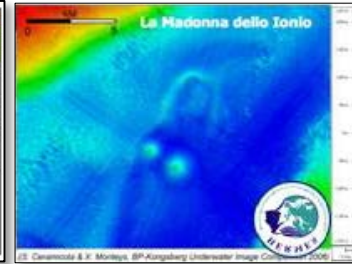
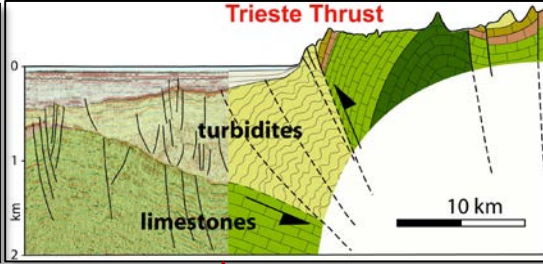
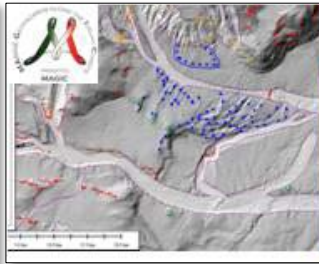
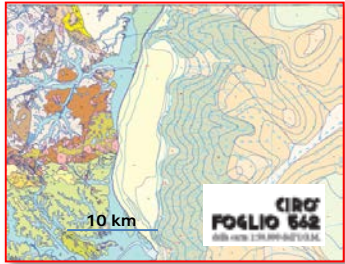
case studies in different Mediterranean settings
(passive margins vs active margins)

Onshore offshore linkage Canyon dynamics

Seismogenic faults

Mud volcanoes

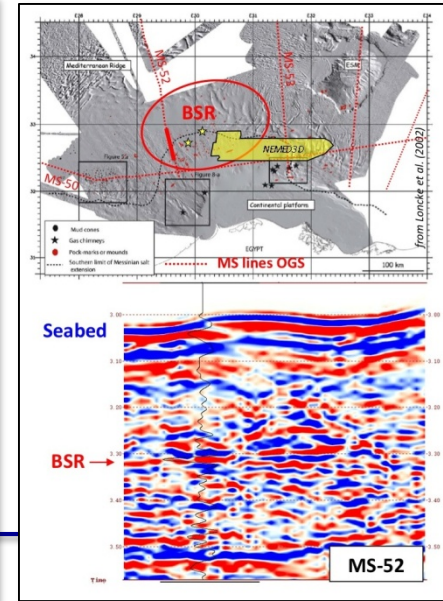
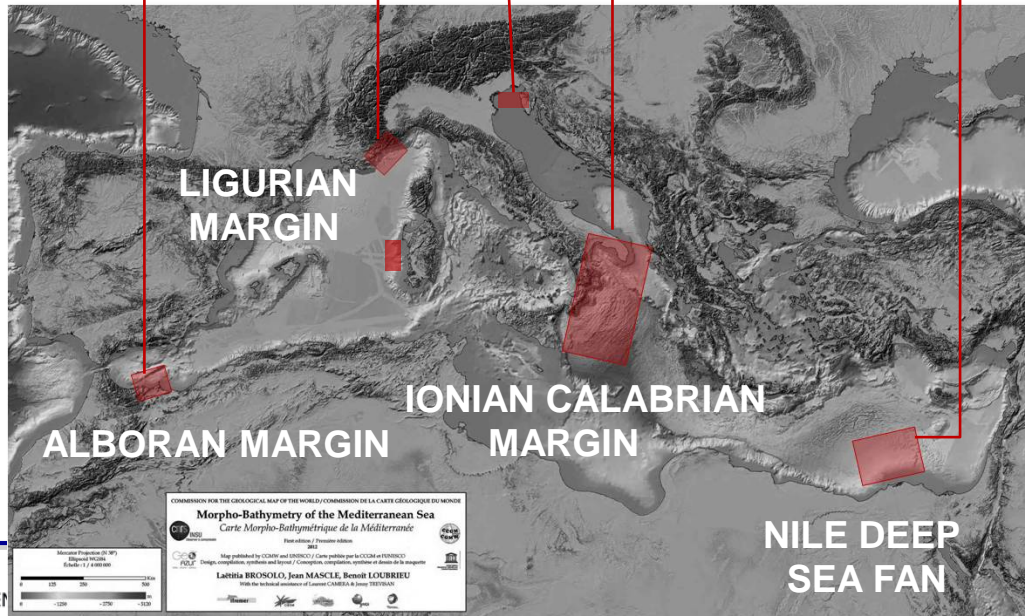
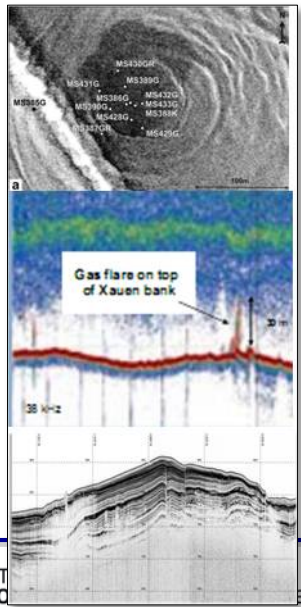
Mass failures



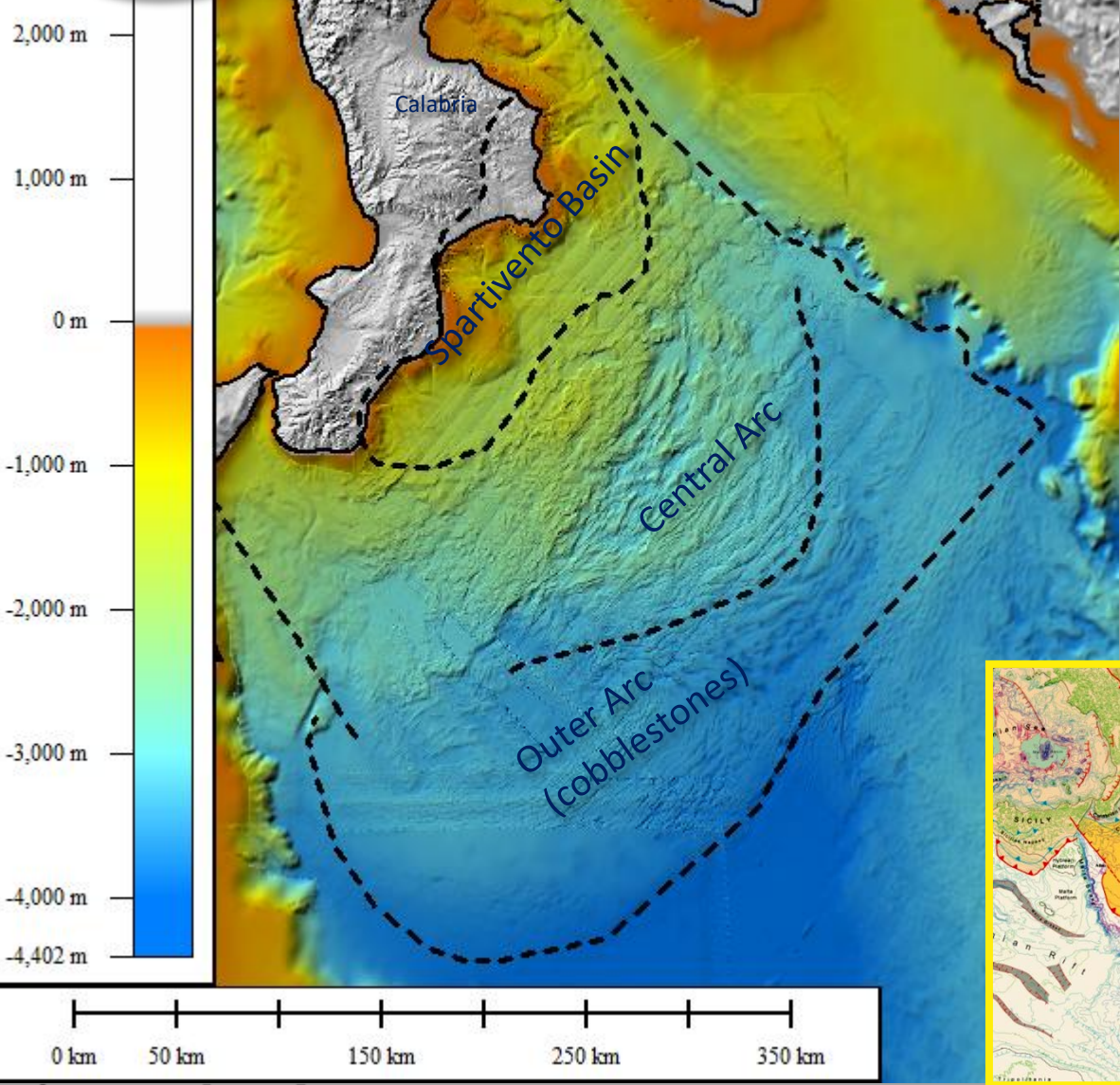
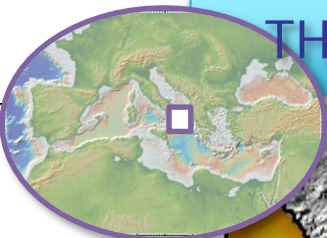
GEOHAZARDS, FLUID FLOWS & GAS HYDRATES, CANYON DYNAMICS

Mud volcanoes,
Gas flares in water column

Gas Hydrates & Seepage



THE IONIAN MARGIN A LABORATORY FOR MARINE GEOHAZARDS



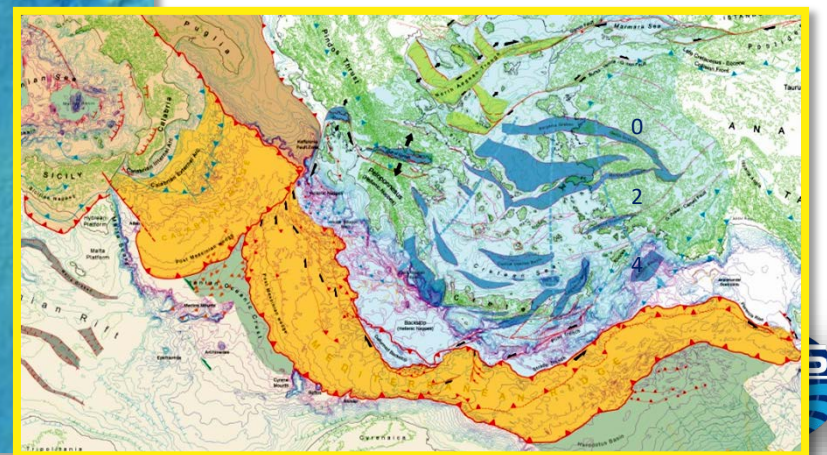
TECTONIC FRAMEWORK

Active continental margin (convergent) → Subduction

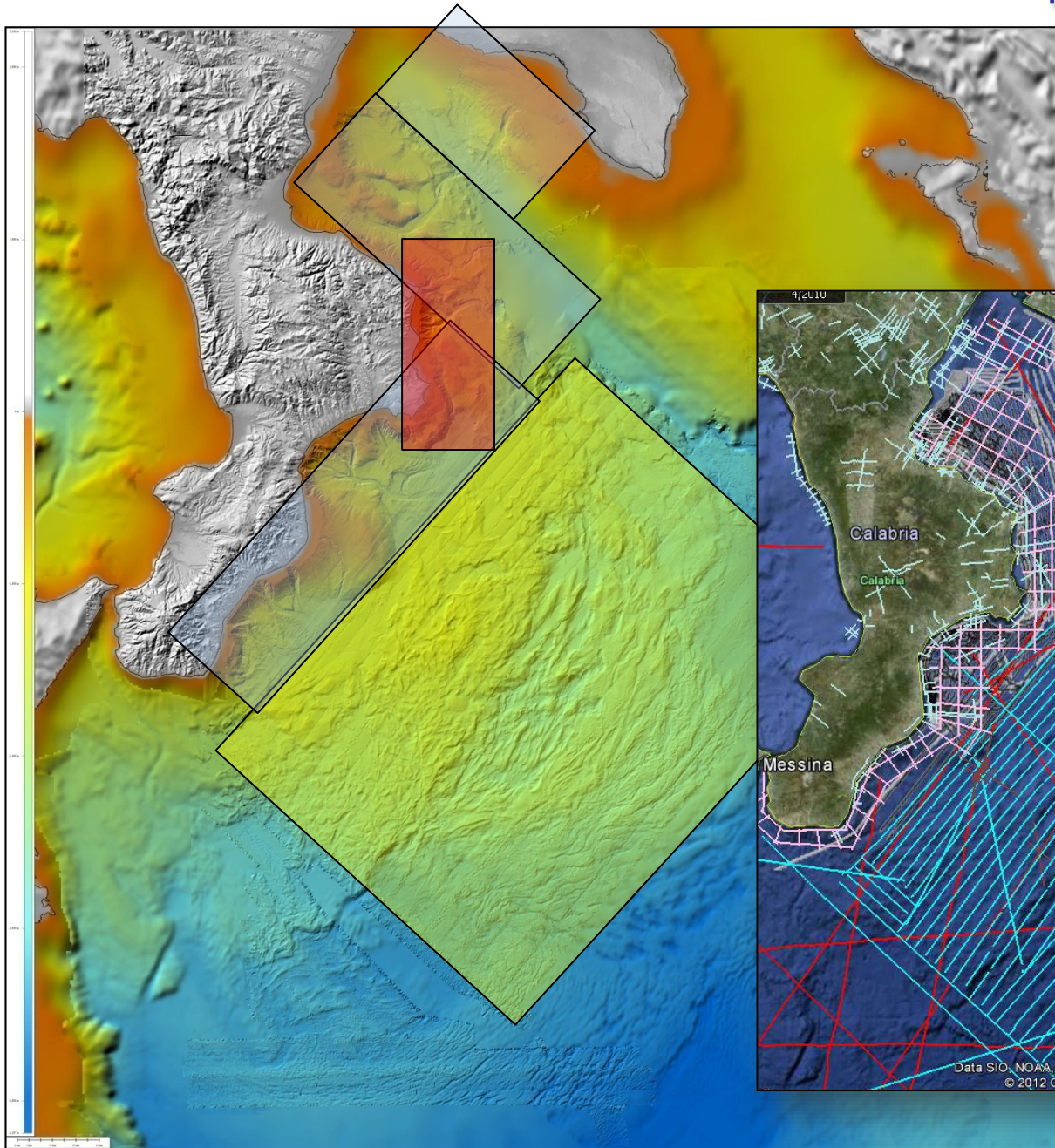
2 main processes related:

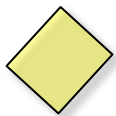
→ Frontal compression and forearc extension during the SE advance of the Calabrian accretionary prism since late Miocene;

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



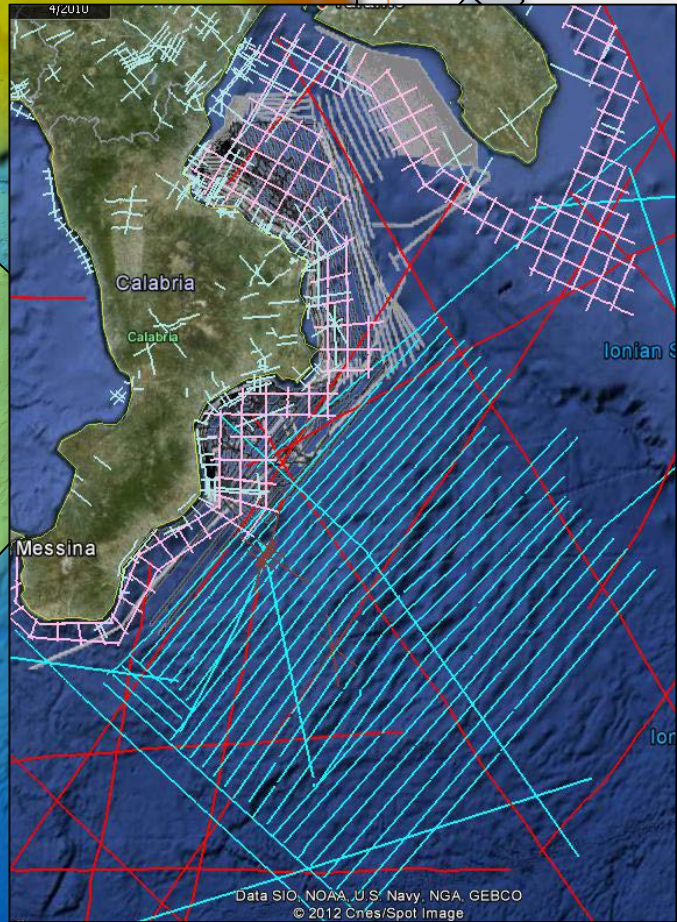
THE RESEARCH PROJECTS IN THE IONIAN MARGIN





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


 Italian Civil Protection (07-'12)
Grid of coastal areas

 Italian ISPRA Project '11)
Bathymetric mapping



 Research vessels

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

 shallow water - Joshua
(RESON 8125 - 0-70m)

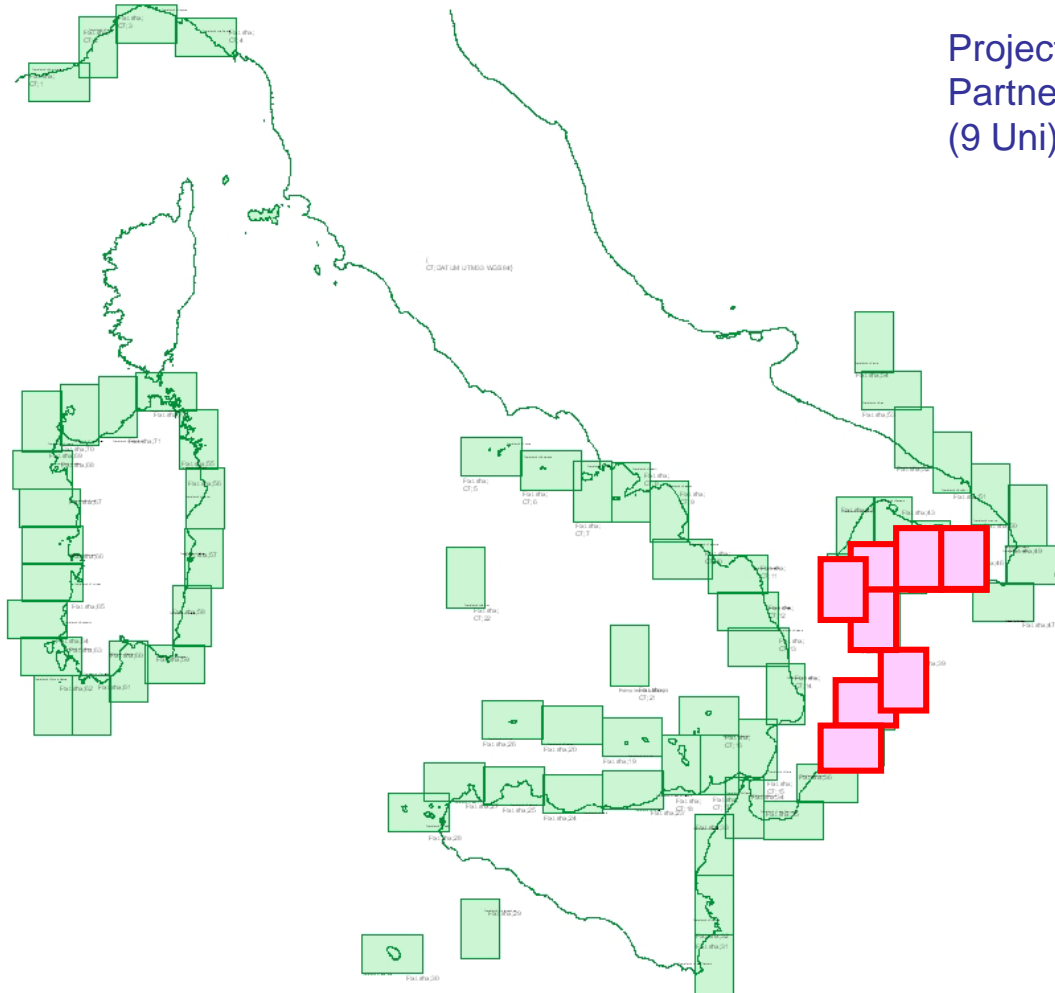
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image



The MaGIC Project



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



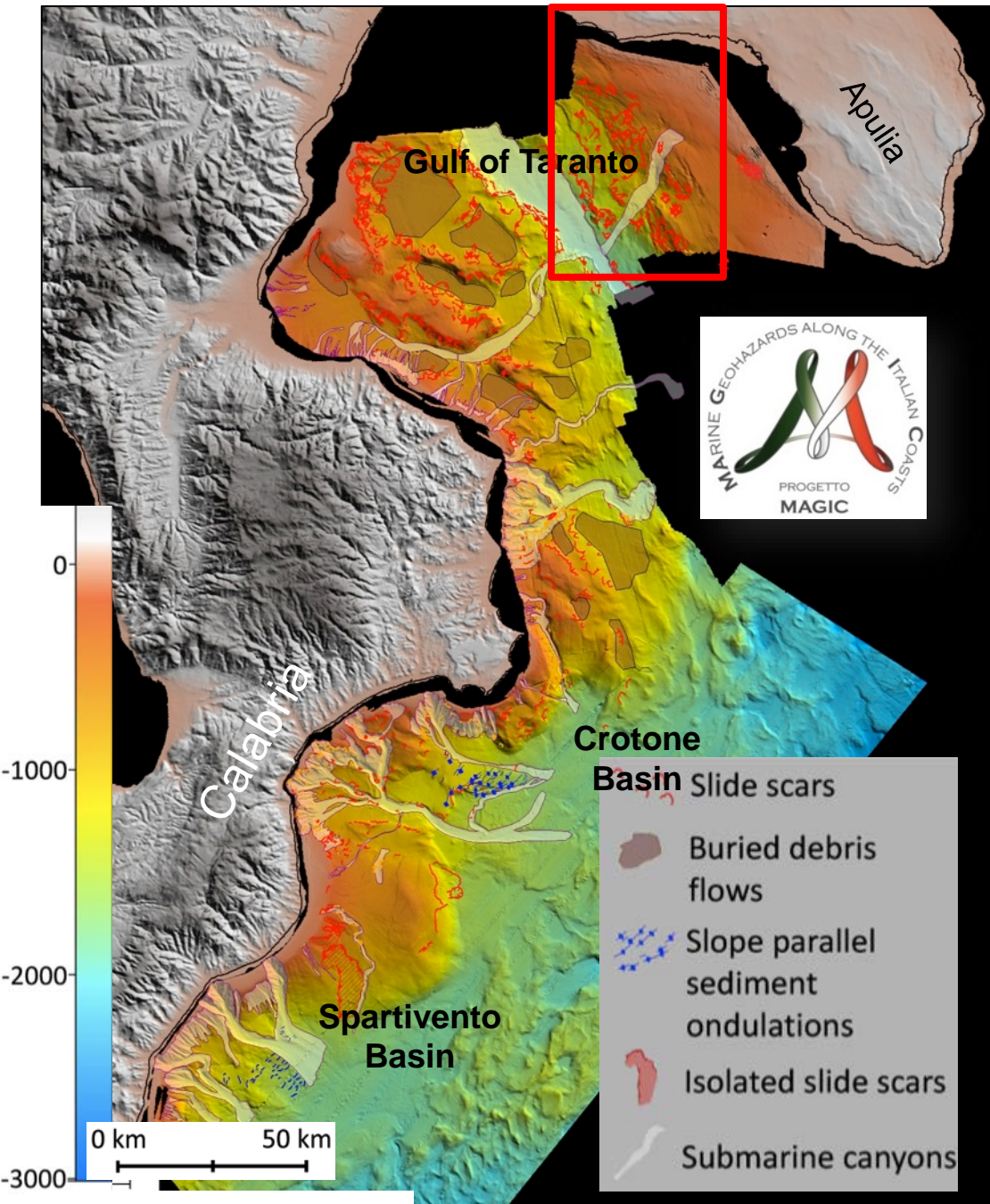
OBJECTIVES:

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.

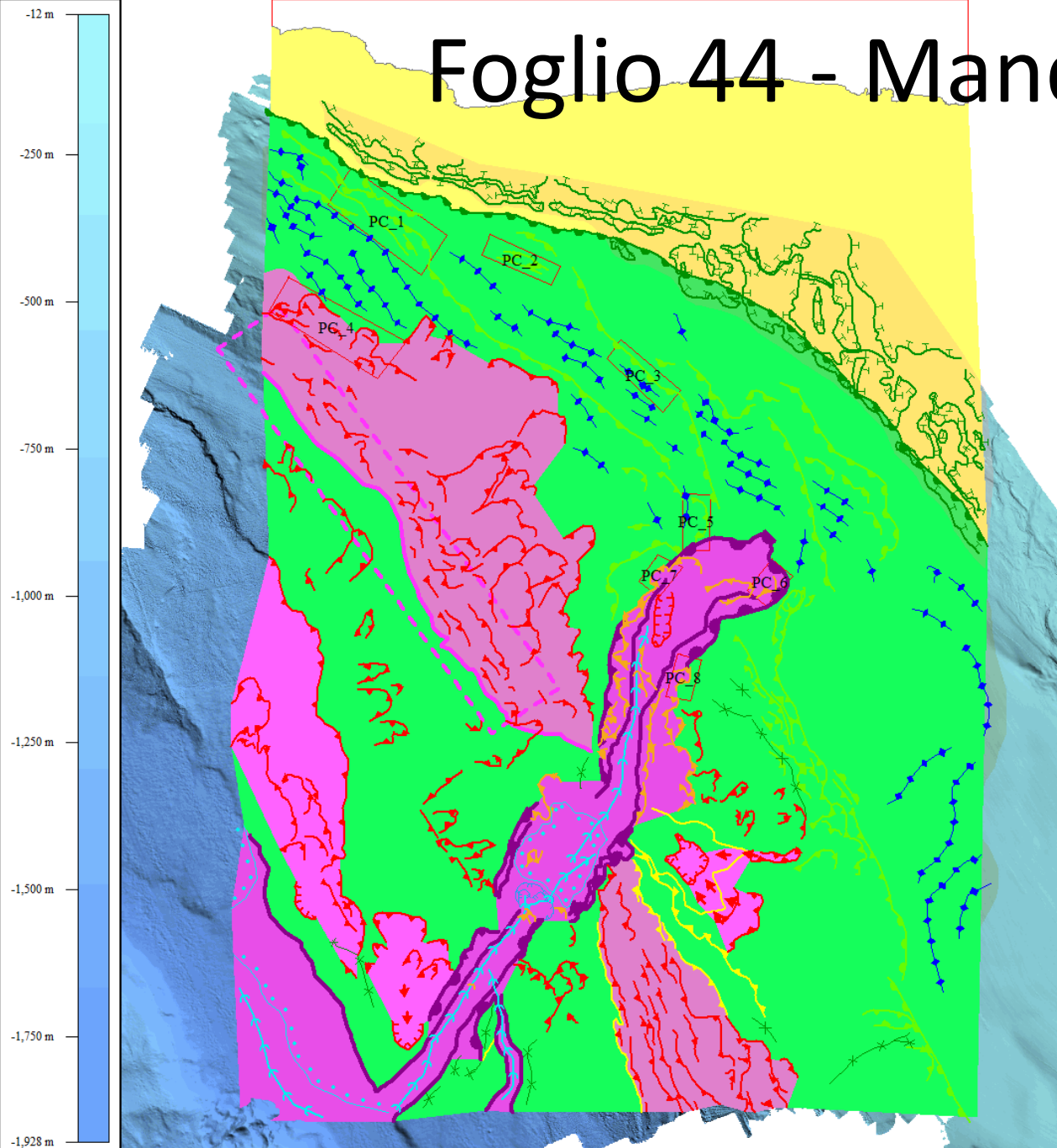
Method 1 Seabed mapping



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



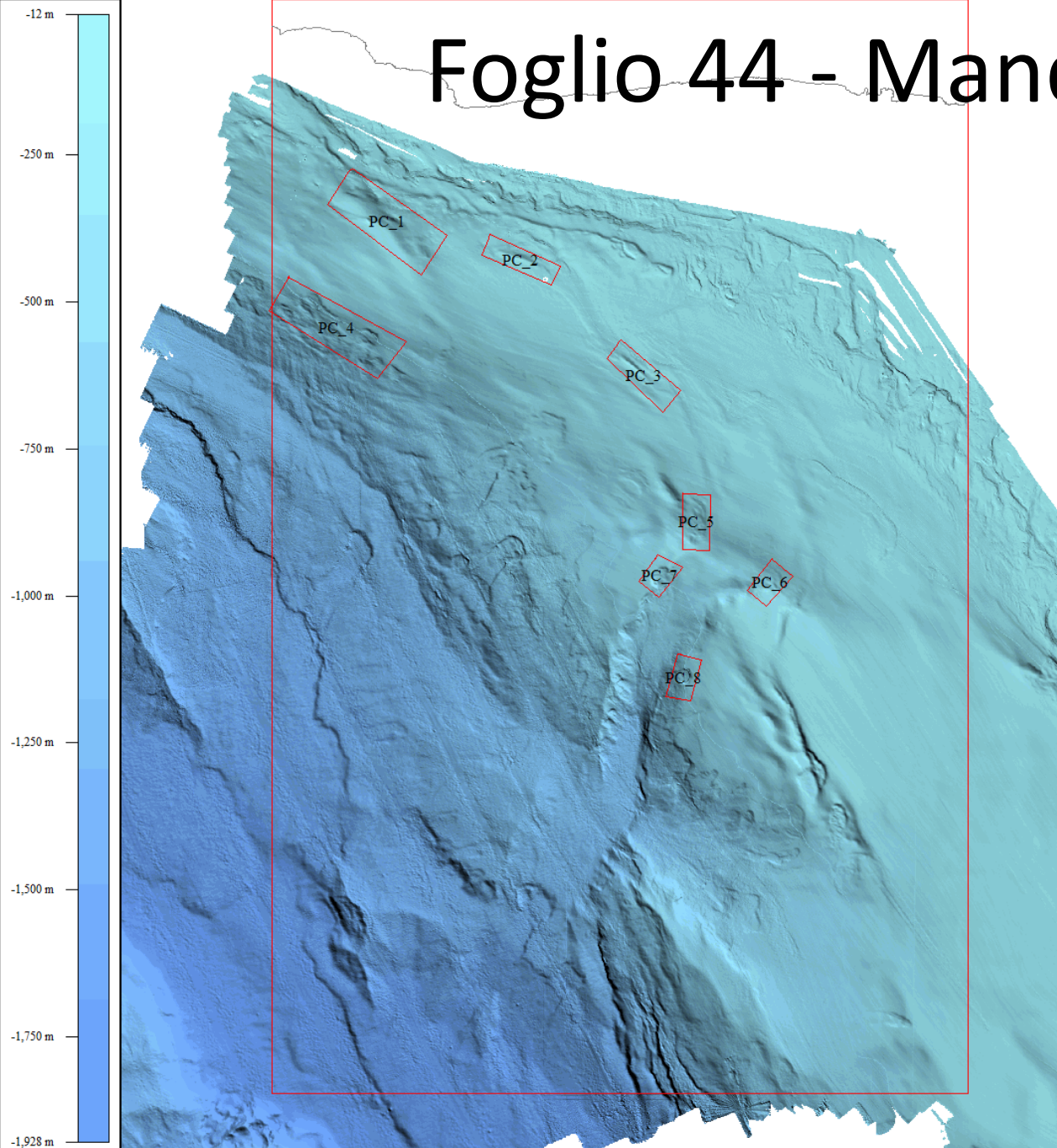
Foglio 44 - Manduria



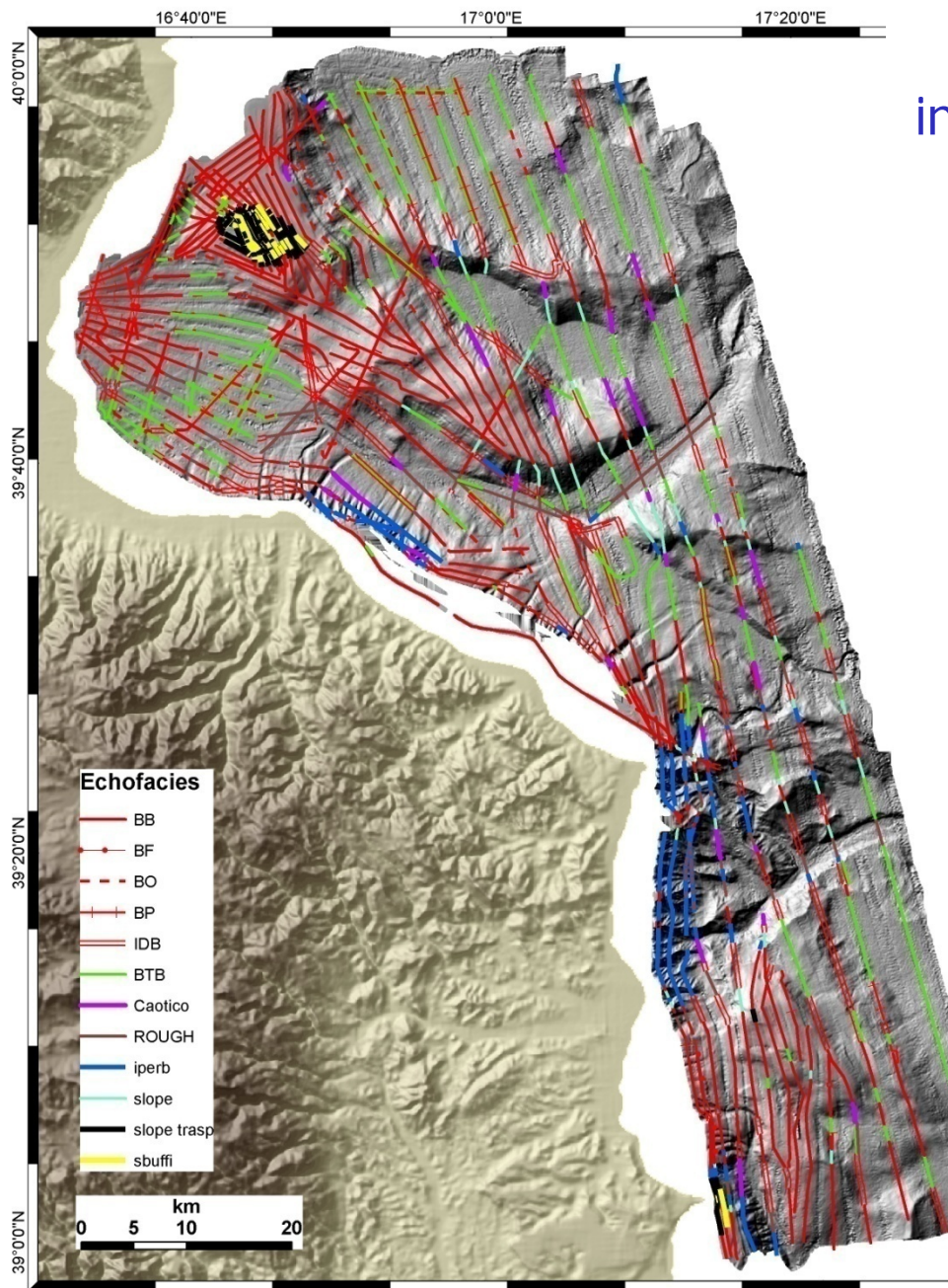
3 map layers
to identify
critical points



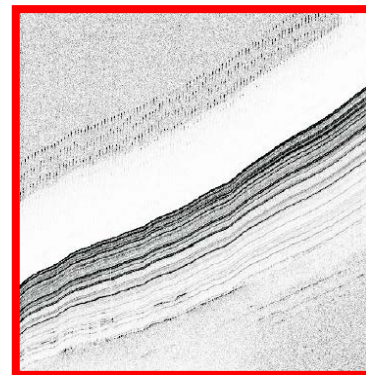
Foglio 44 - Manduria



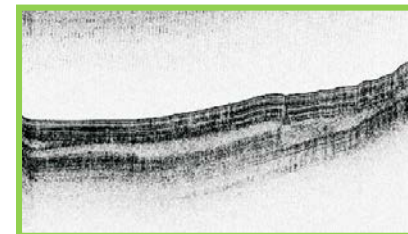
3 map layers
to identify
critical points



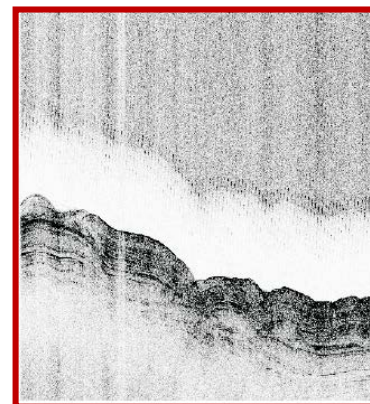
METHOD 2: integration with echofacies



Uniformly bedded



Bedded
buried transparent



Irregular discontinuously
bedded

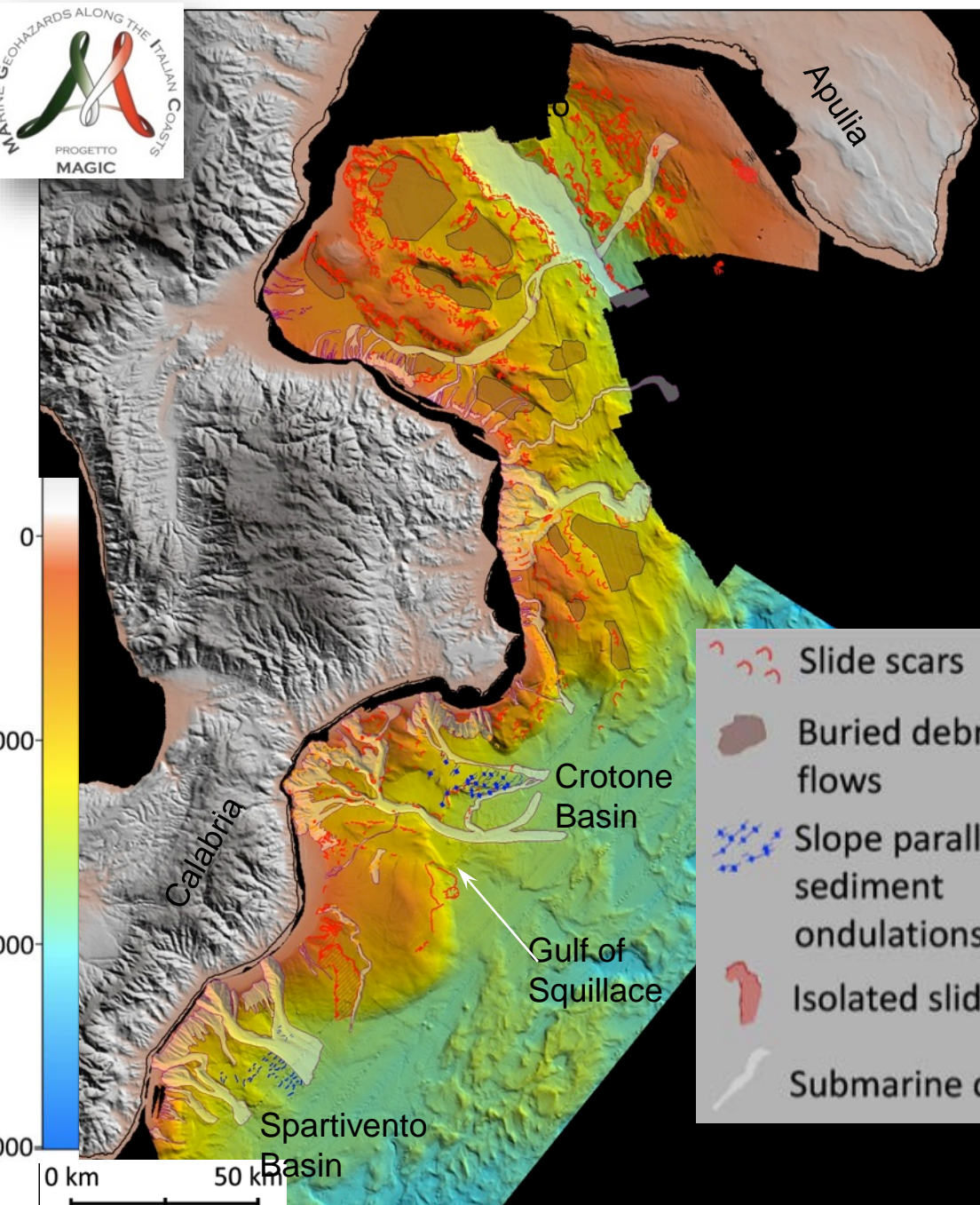


Irregular discontinuous

Chirp profiles



IMCA FEATURES OF SLOPE SEDIMENT FAILURE



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

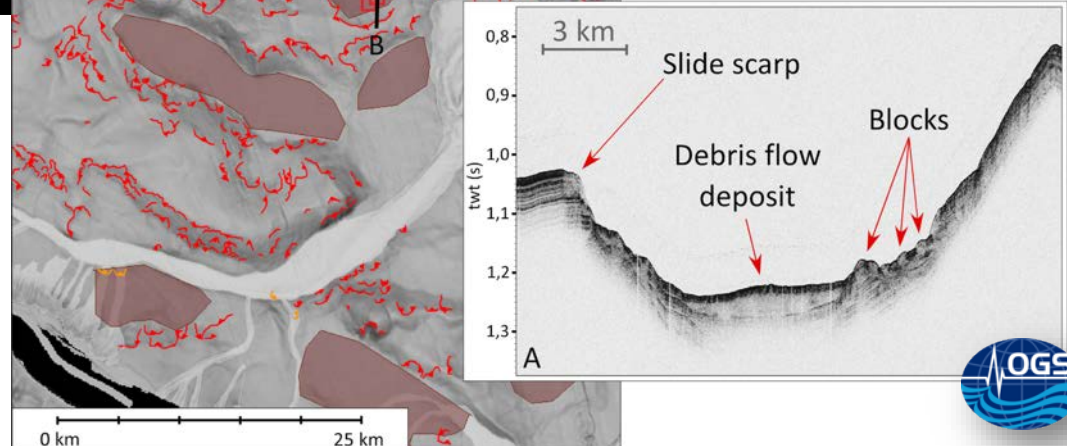
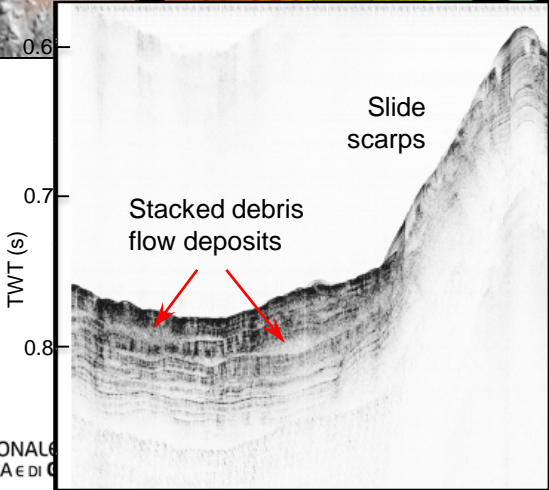
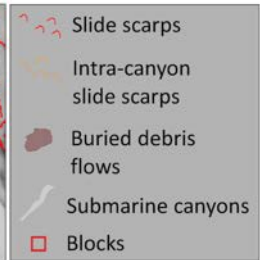
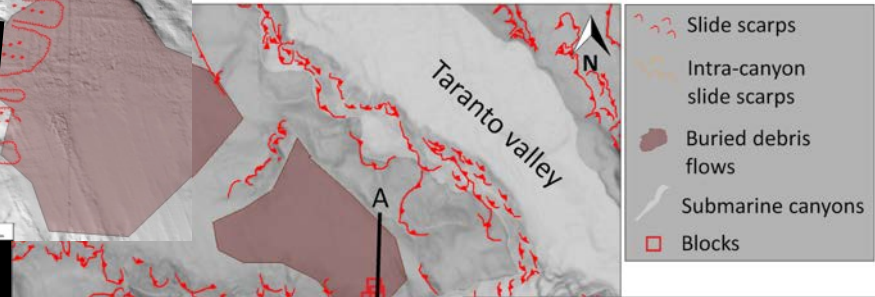
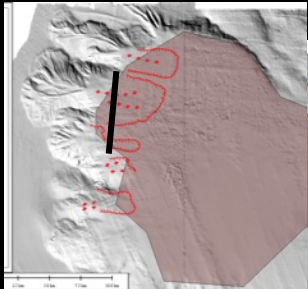
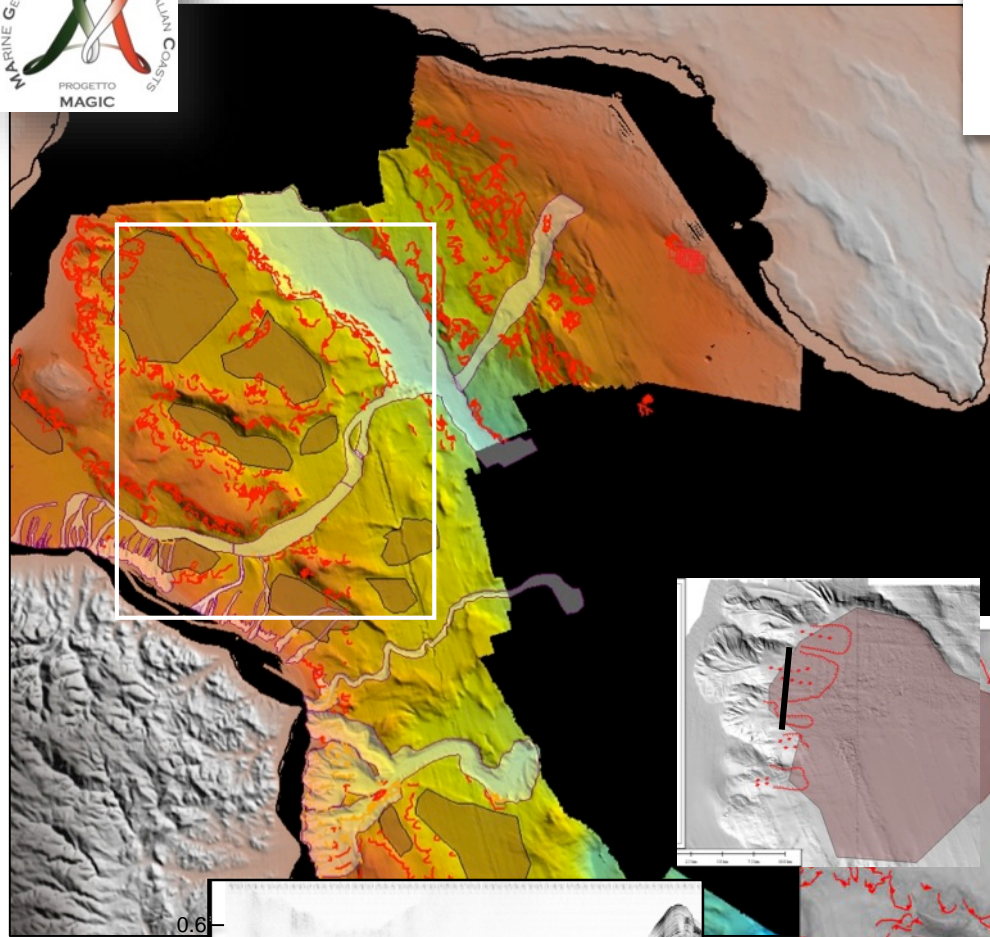
2 Isolated Slide Scars (ISSs) on open slopes (all margins)

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

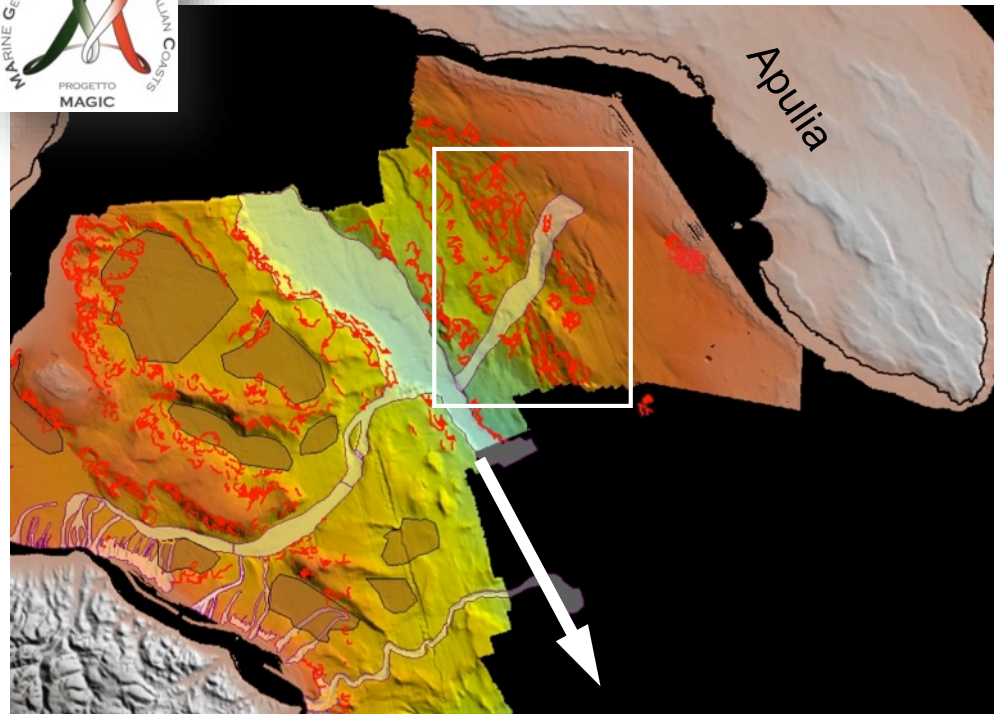
4 Slope-Parallel Sediment Undulations (SPSU) (southern Calabrian margin)

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?

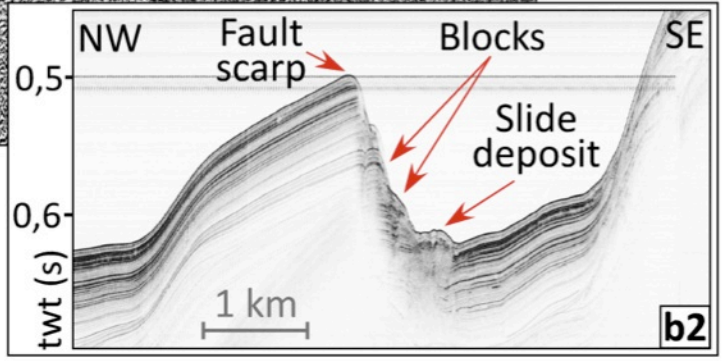
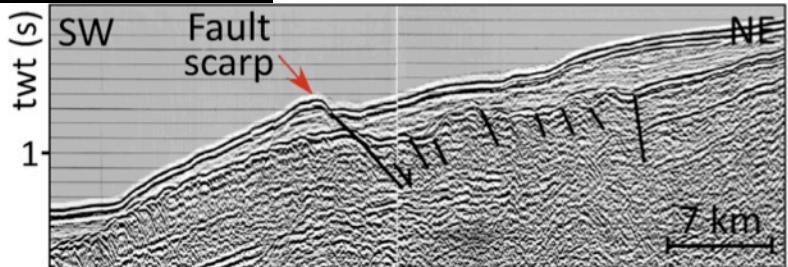
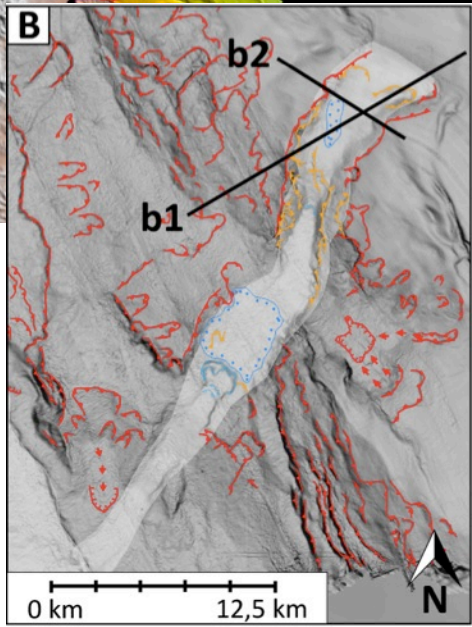


ISOLATED SLIDE SCARS (ISS) ON OPEN SLOPES



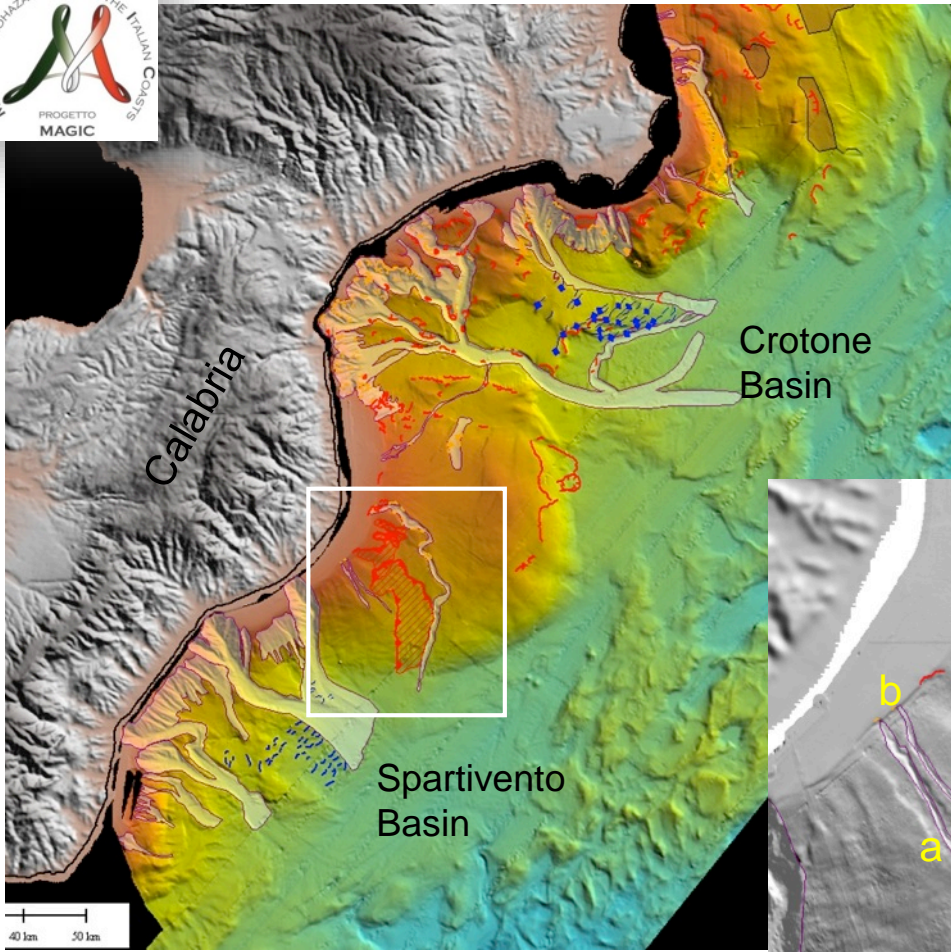
Apulian slope:

- failure deposits presumed to have moved down the Taranto canyon
- Largest : *Manduria failure* (c. 13 km³), resembles a canyon but no connection to hydrographic system, linked to slide scars and deposits – retrogressive failure?



- Above faults, possible tectonic control

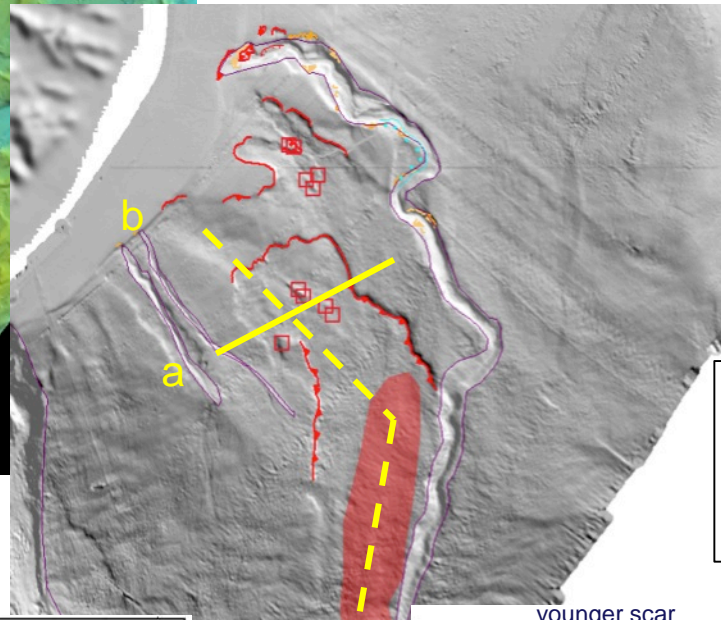
ISOLATED SLIDE SCARS (ISS) ON OPEN SLOPES



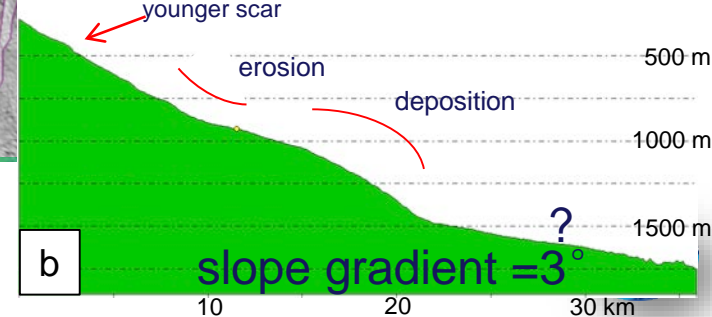
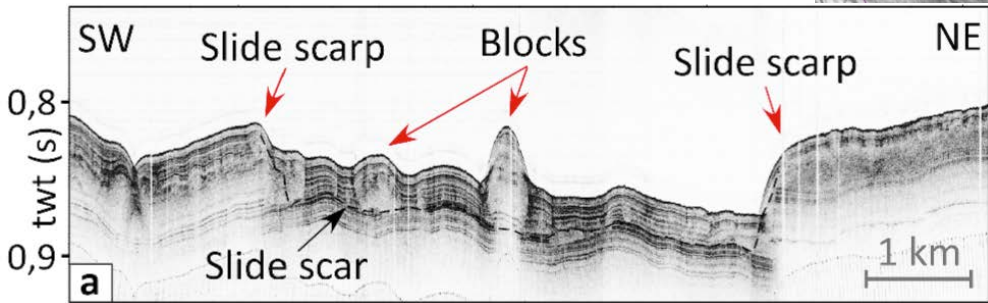
>18 x 6 km, 50 m high scarps

Calabrian slope

- Largest: *Assi failure* (c. 2 km³)
- Most recent of a series (cuts older deposits, scarps upslope)

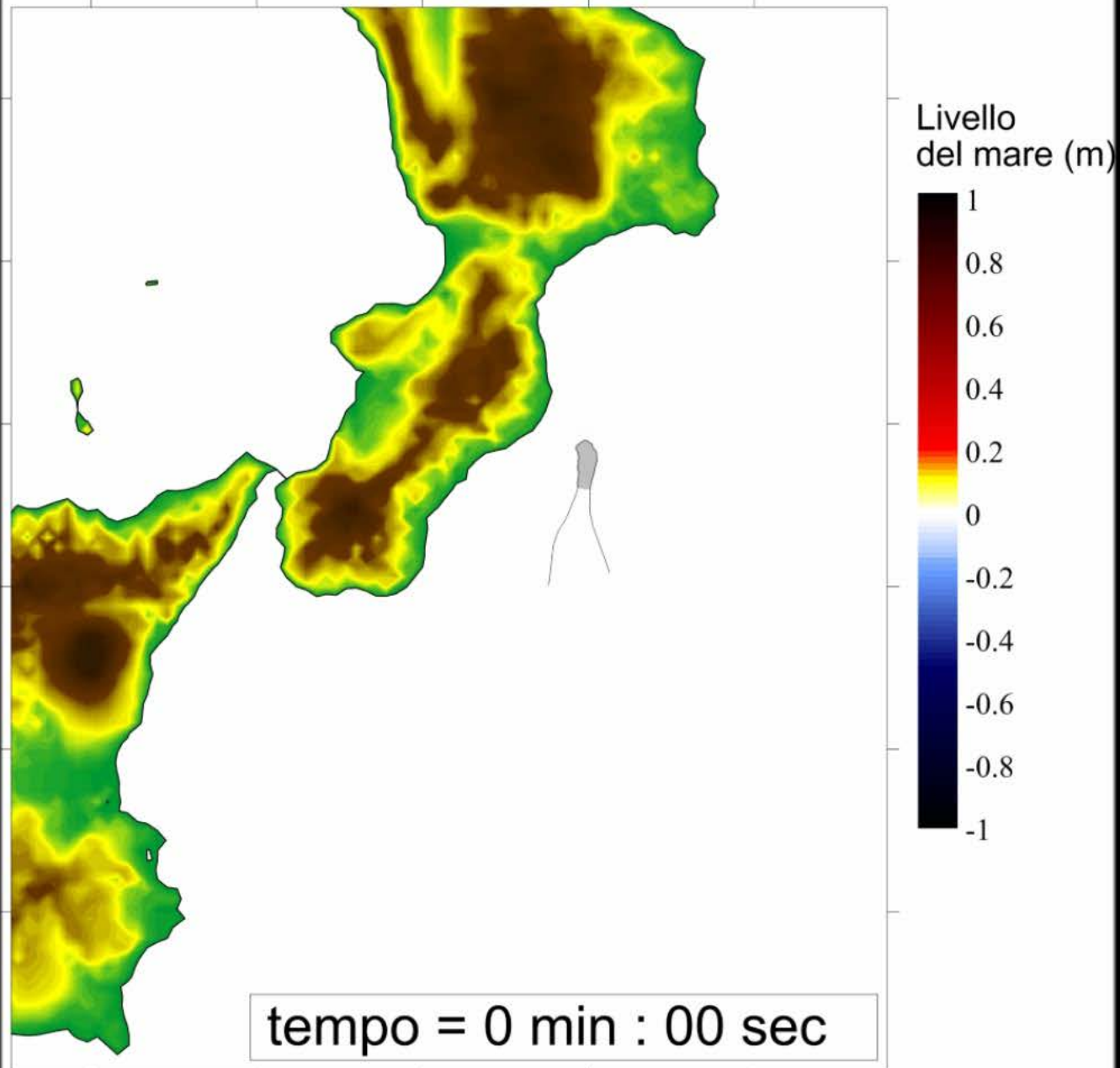


Tsunami modeling:
 coastal waves up to
 1 m high (Zaniboni
 et al. 2012)

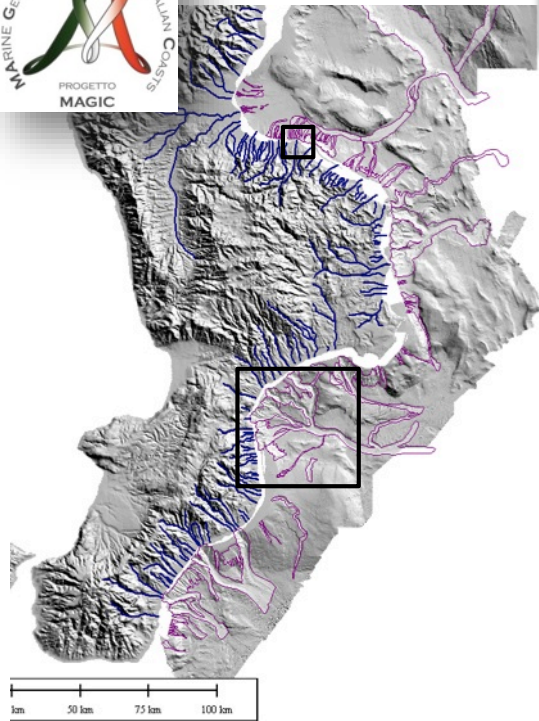


Maremoto dalla frana di Assi

Gruppo di Ricerca Maremoti - Università di Bologna

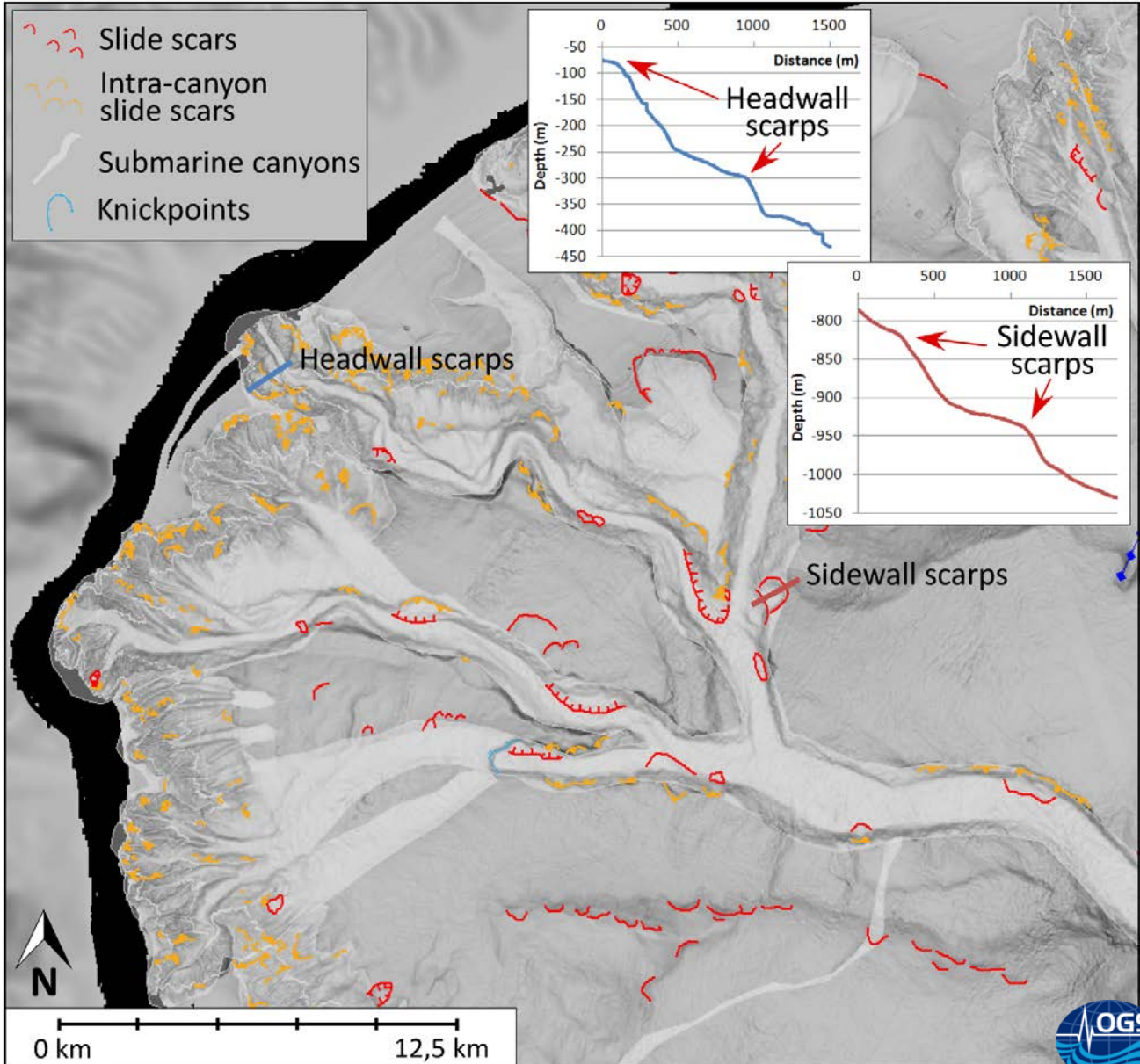
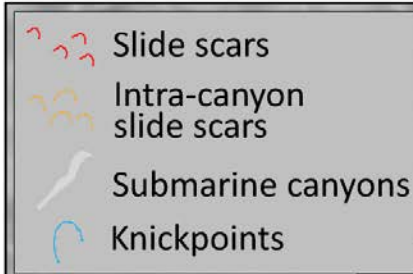


HEADWALL & SIDEWALL SCARPS IN CANYONS (HSC)

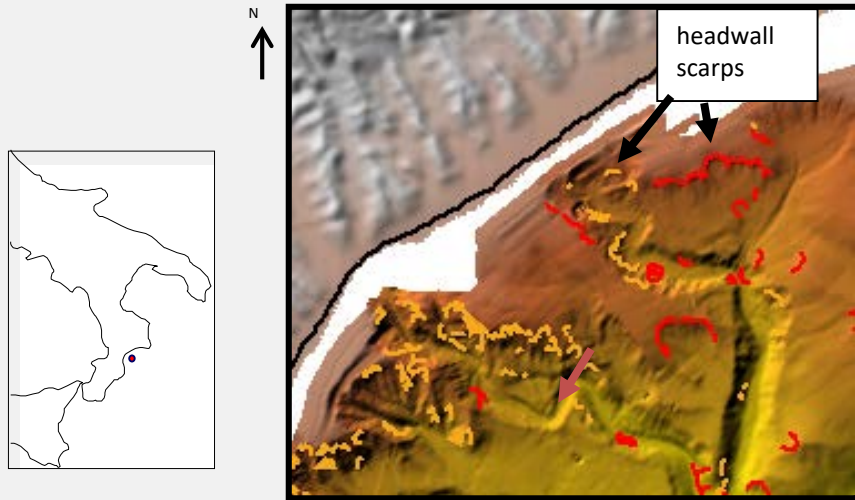


Gulf of Squillace

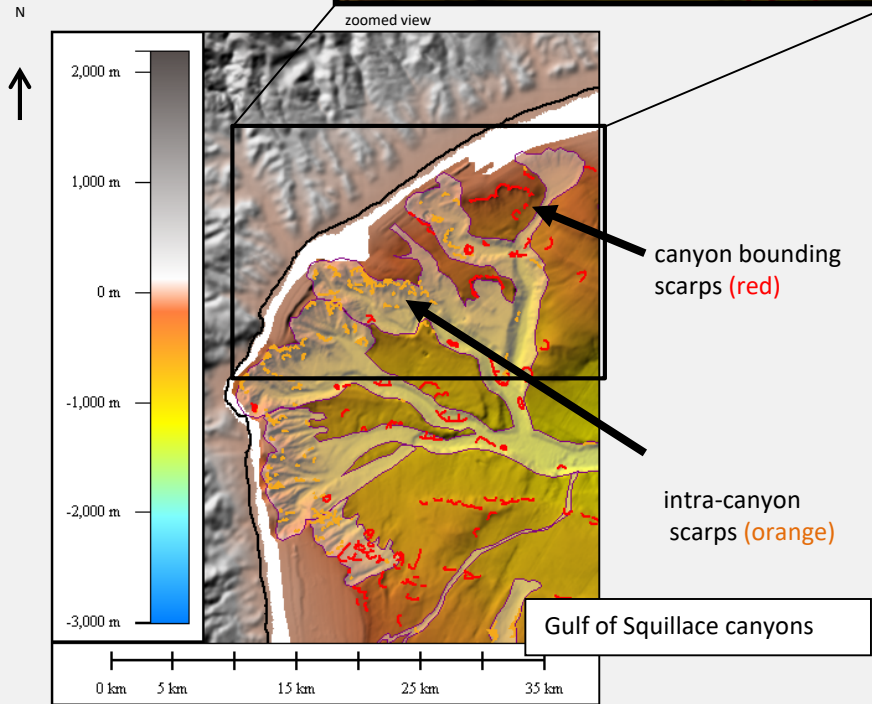
- largest canyon system, highly dendritic
- scarps 30-150 m high
- c. 6 km³ mobilised (in 1st order branches)
- record retrogressive growth of canyon heads (some 1-3 km from coast)



4. Canyon headwall scarps



zoomed view

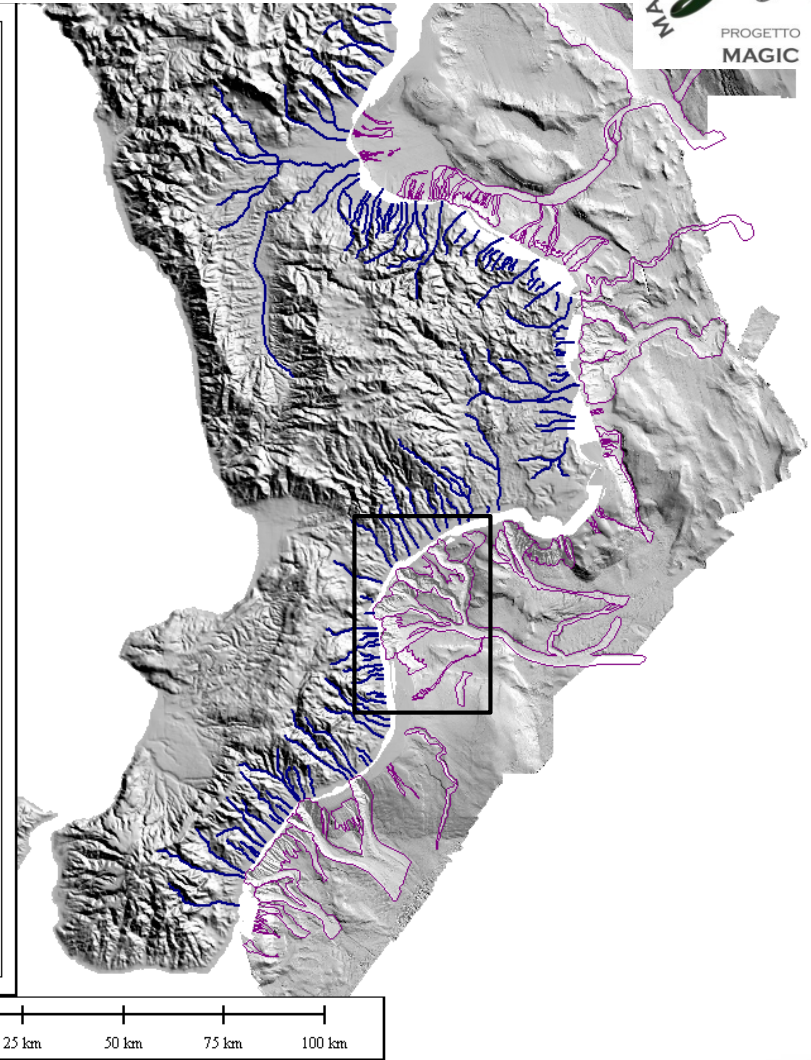


canyon bounding scarps (red)

intra-canyon scarps (orange)

Gulf of Squillace canyons

Canyon headwalls



Canyon headwall hazard



Canyon di Catanzaro (Golfo di Squillace), Calabria Ionica

Canyon headwall hazard

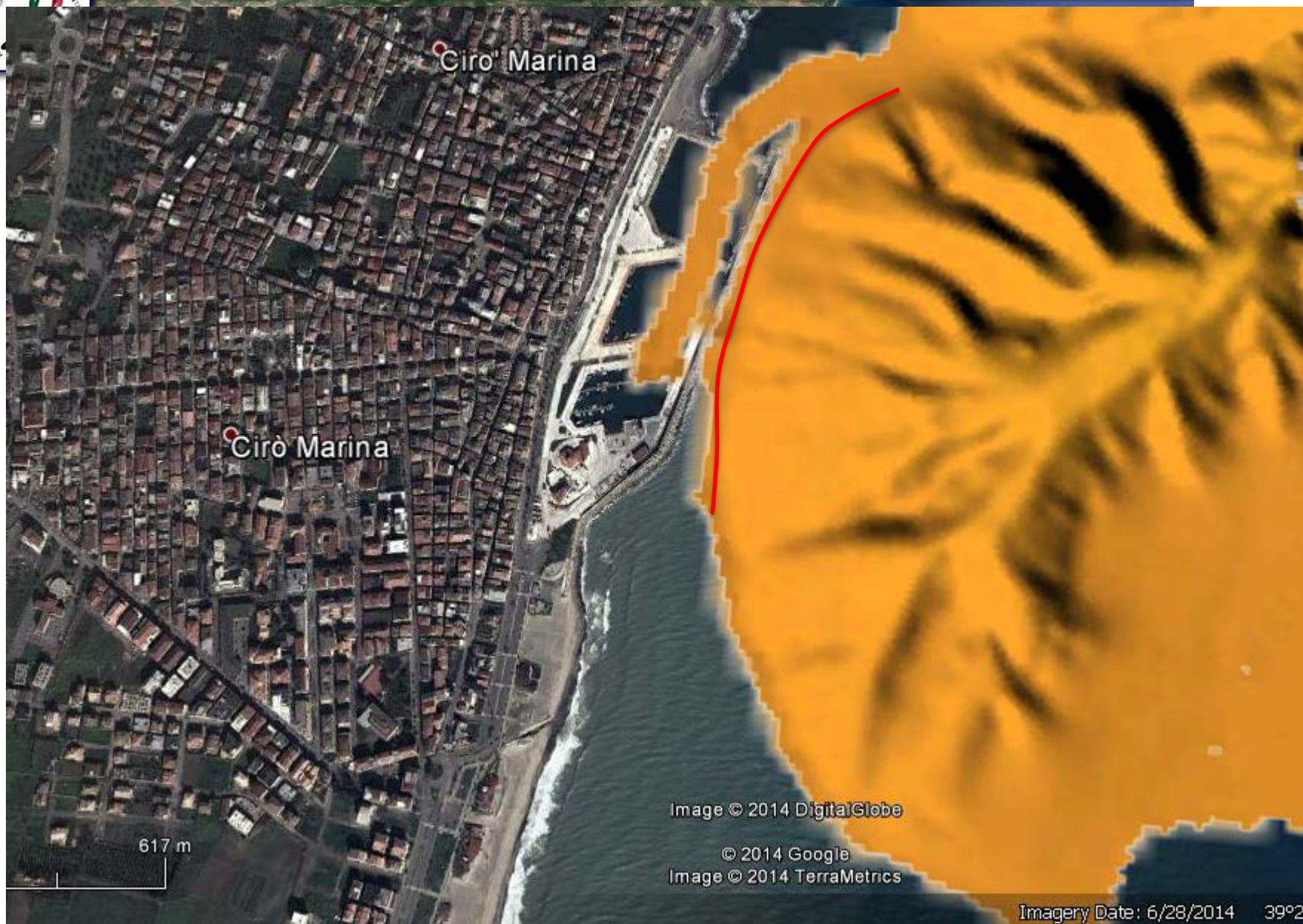


Image © 2014 DigitalGlobe

© 2014 Google

Image © 2014 TerraMetrics

Imagery Date: 6/28/2014 39°22'

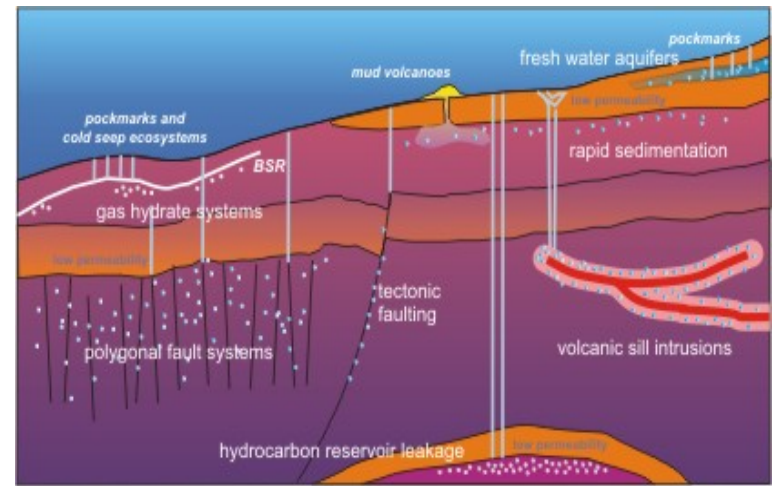


Porto di Cirò Marina
Ore 11:00 del 01 Dicembre 2013
Foto by Sergio Marino

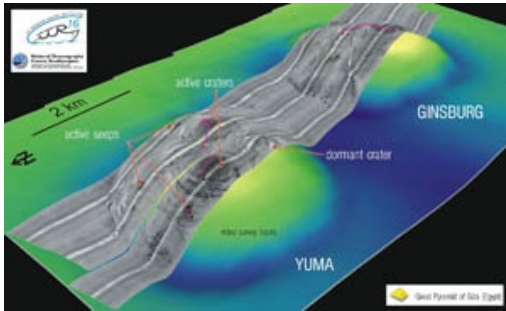
COLD SEEPS EXAMPLES

I COLD SEEPS

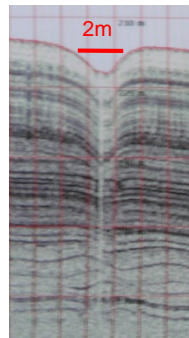
- MUD VOLCANOES (CONIC PIES)
- POCKMARKS
- CARBONATIC CRUSTS
- BRINE POOLS
- GAS HYDRATES



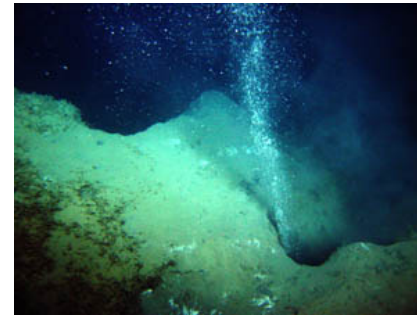
Schema della circolazione dei fluidi nei sedimenti, Berndt (2005)



Vulcani di fango (Golfo di Cadice)



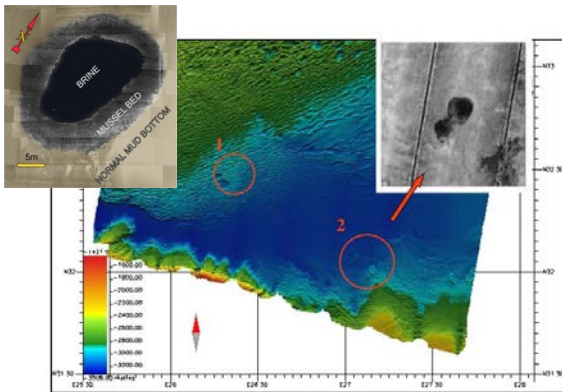
Pockmarks - Mar Adriatico



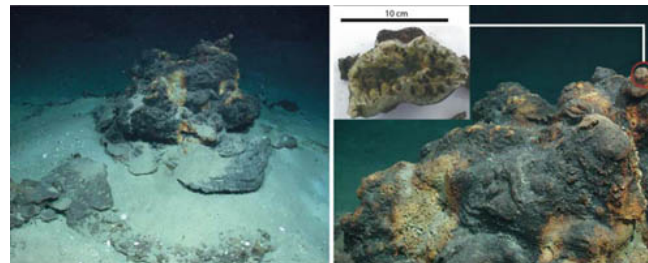
Fuoriuscite di metano
Hakon Mosby Mud Volcano



Le salse di Nirano (Modena)



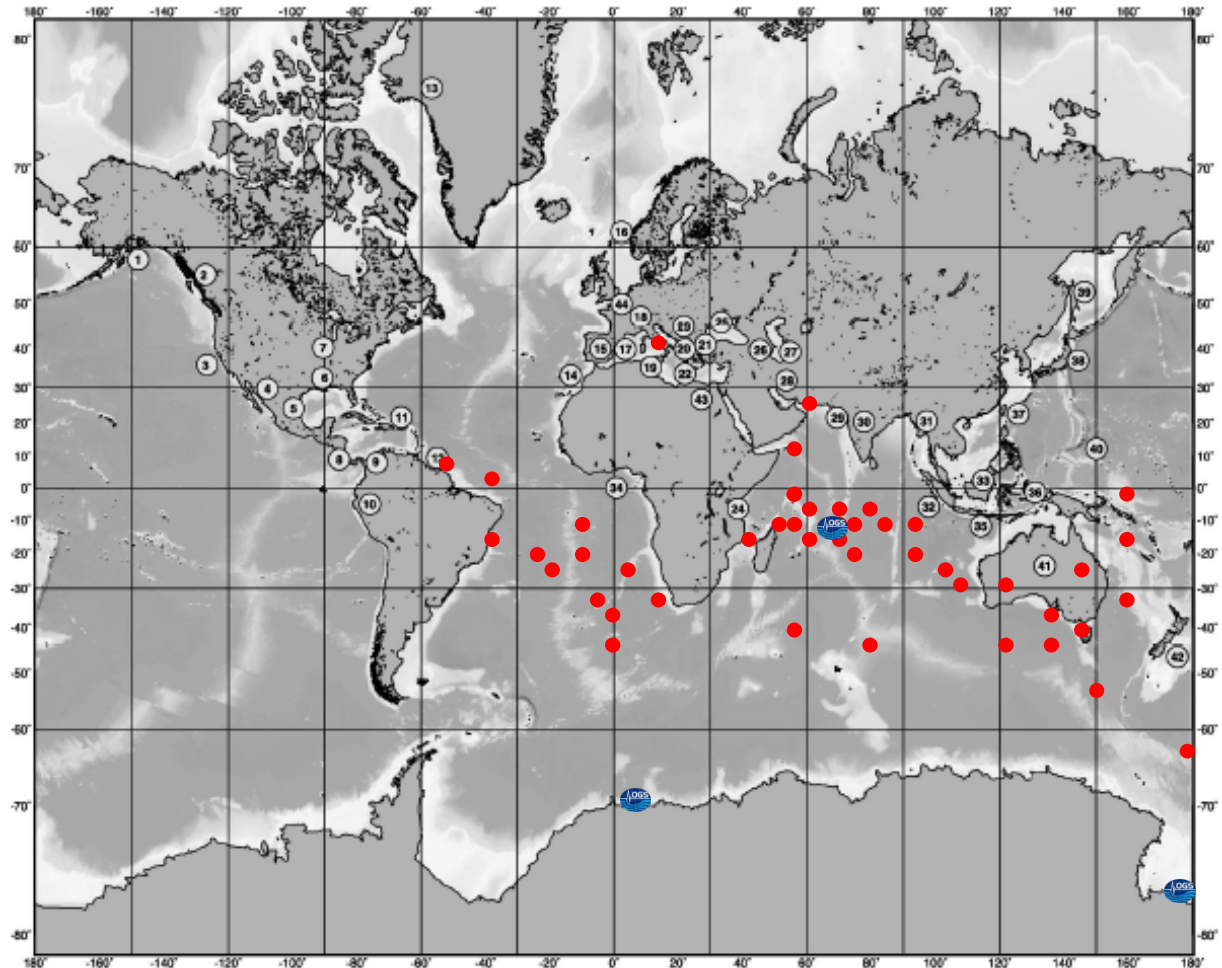
Brine salmastre (Delta del Nilo)



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

Why do we study COLD SEEPS?

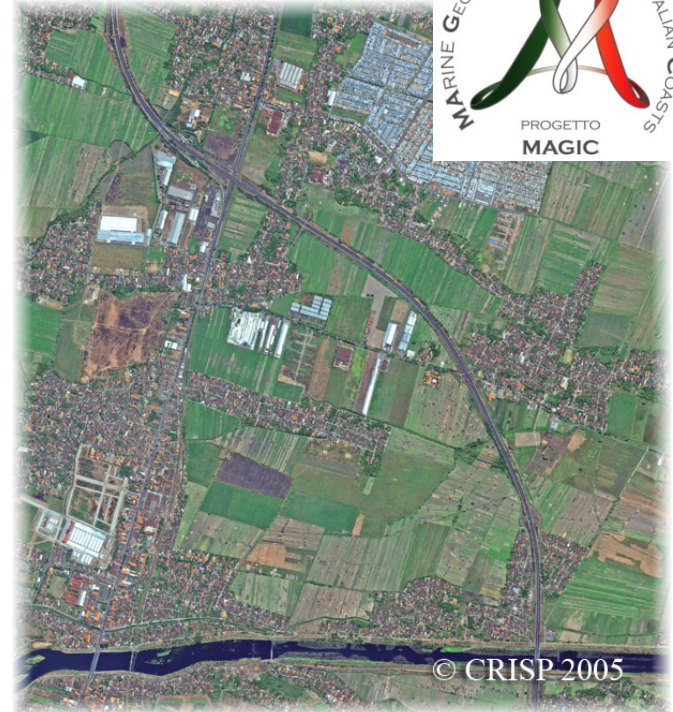
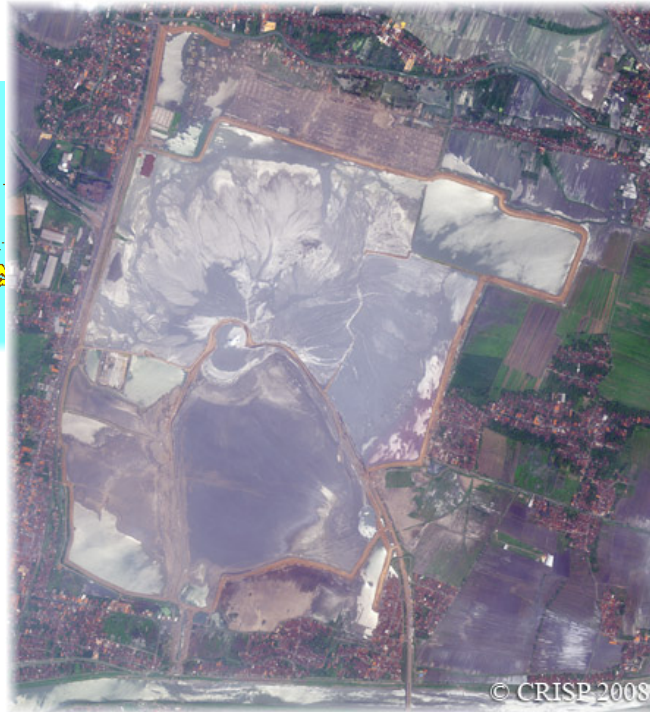
- because we do not know their functioning through time
- geosphere biosphere interaction
- impact of gas emission (greenhouse) in the atmosphere
- responsible for slope instability in association with gas hydrates (geohazards)
- gas hydrates represent a potential economic resource



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



1 KM



LA PERICOLOSITA'

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

Ikonos Satellite images (CRISP)



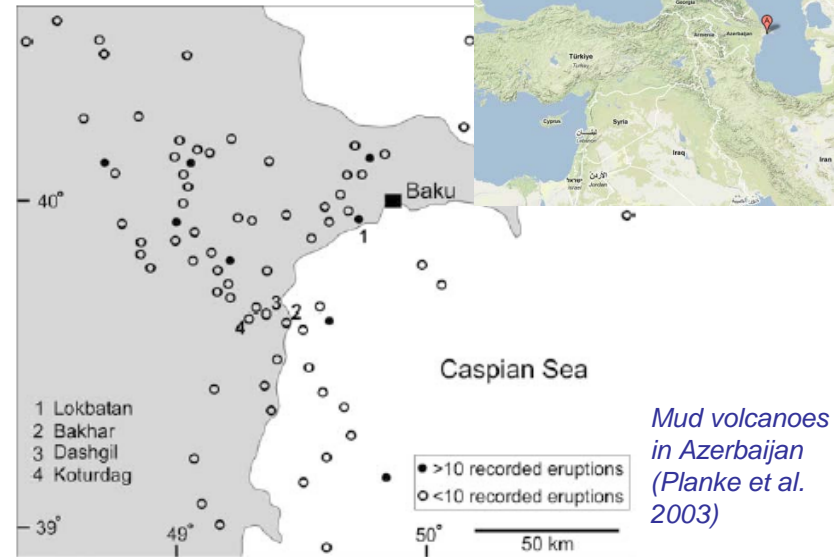
CBC News 2008



Bledug Kuwu MV, Java centrale, 2009

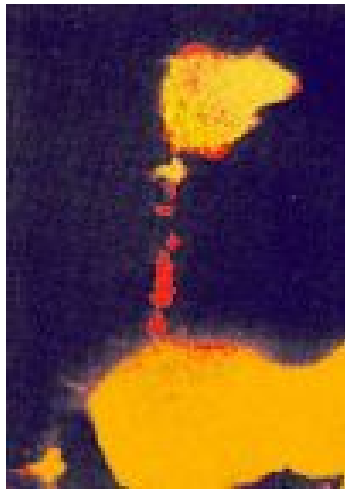


Lokbatan MV (B. Asbrink 2003 - Azerbaijan International)



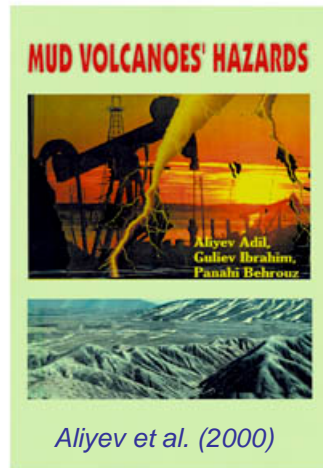
Mud volcanoes in Azerbaijan (Planke et al. 2003)

LA PERICOLOSITA'

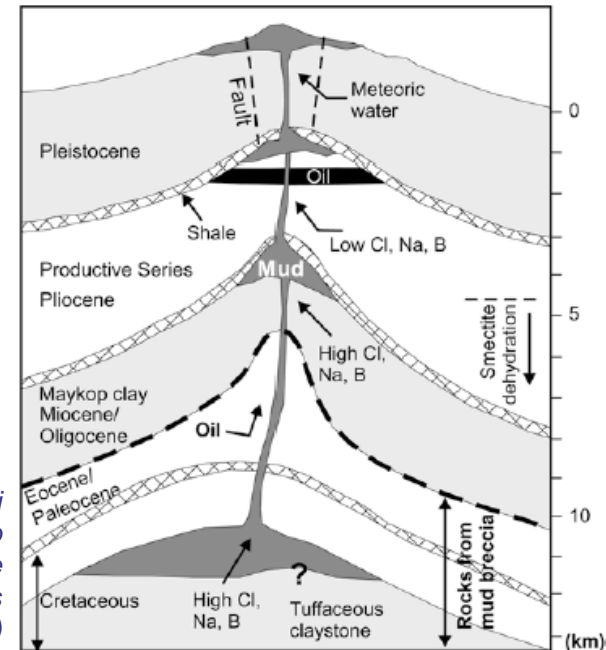


www.martinhovland.com

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

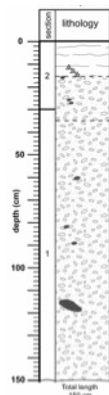
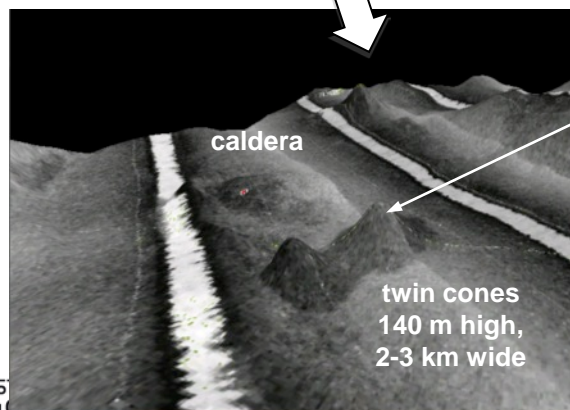
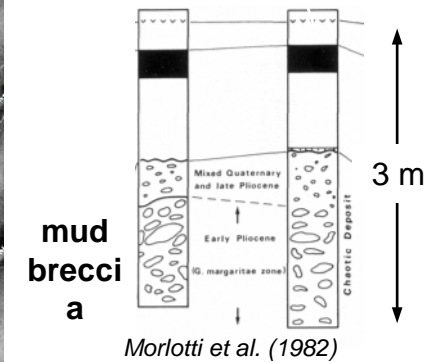
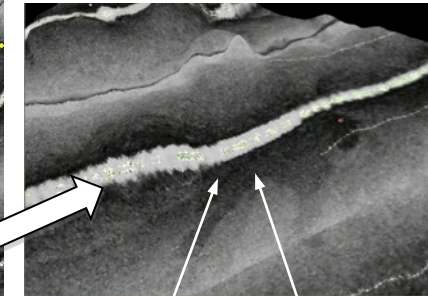
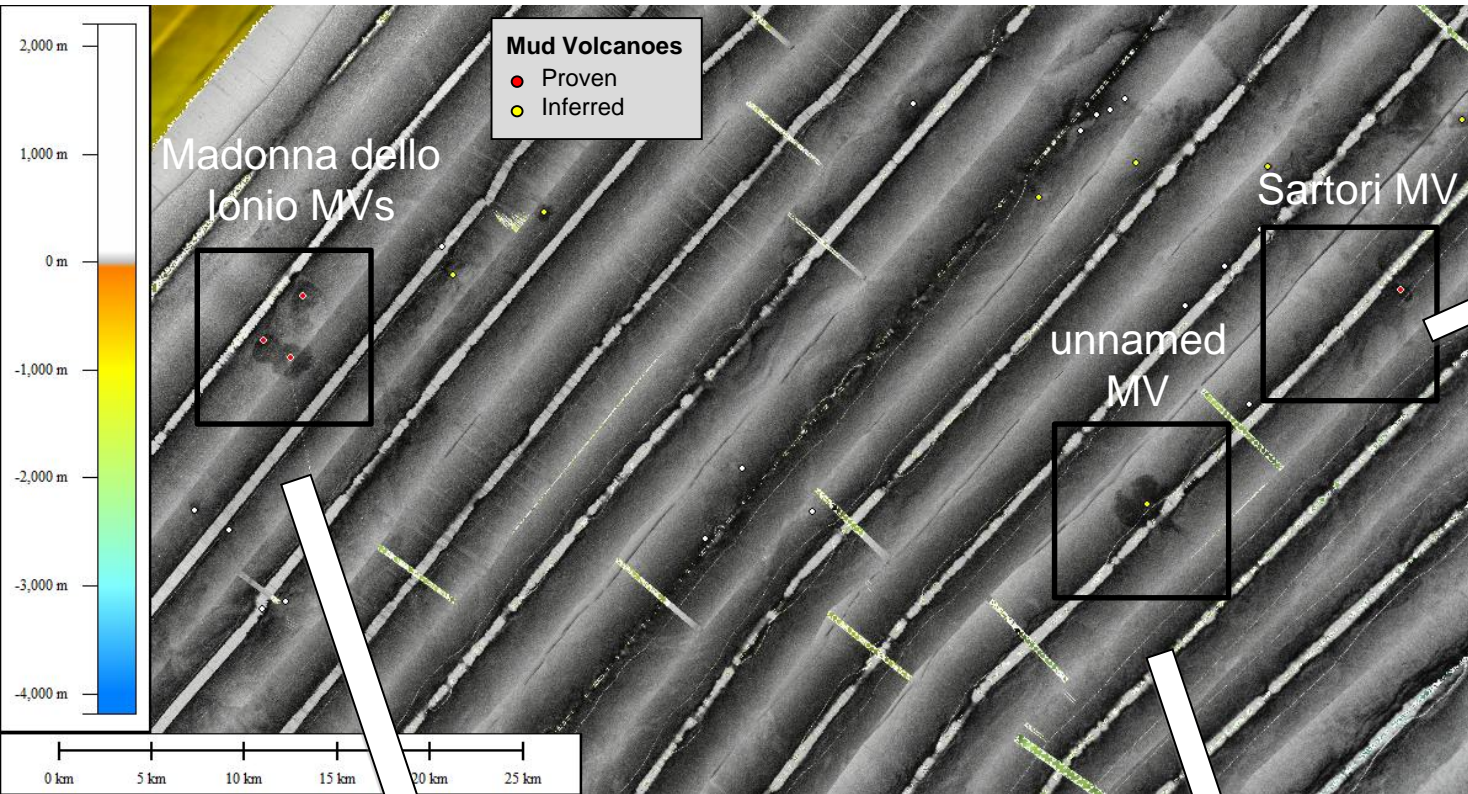


Aliyev et al. (2000)

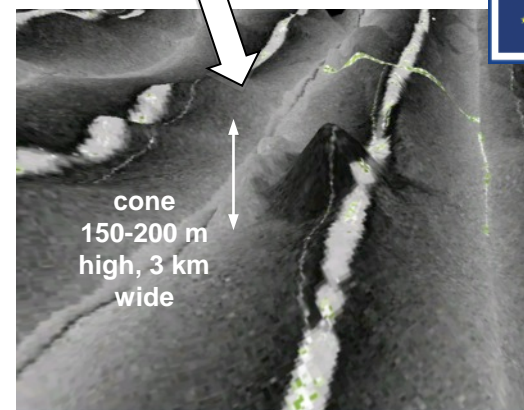


Conceptual model of Azeri mud volcanism - deep roots (12 km), multiple mud chambers (Planke et al. 2003)

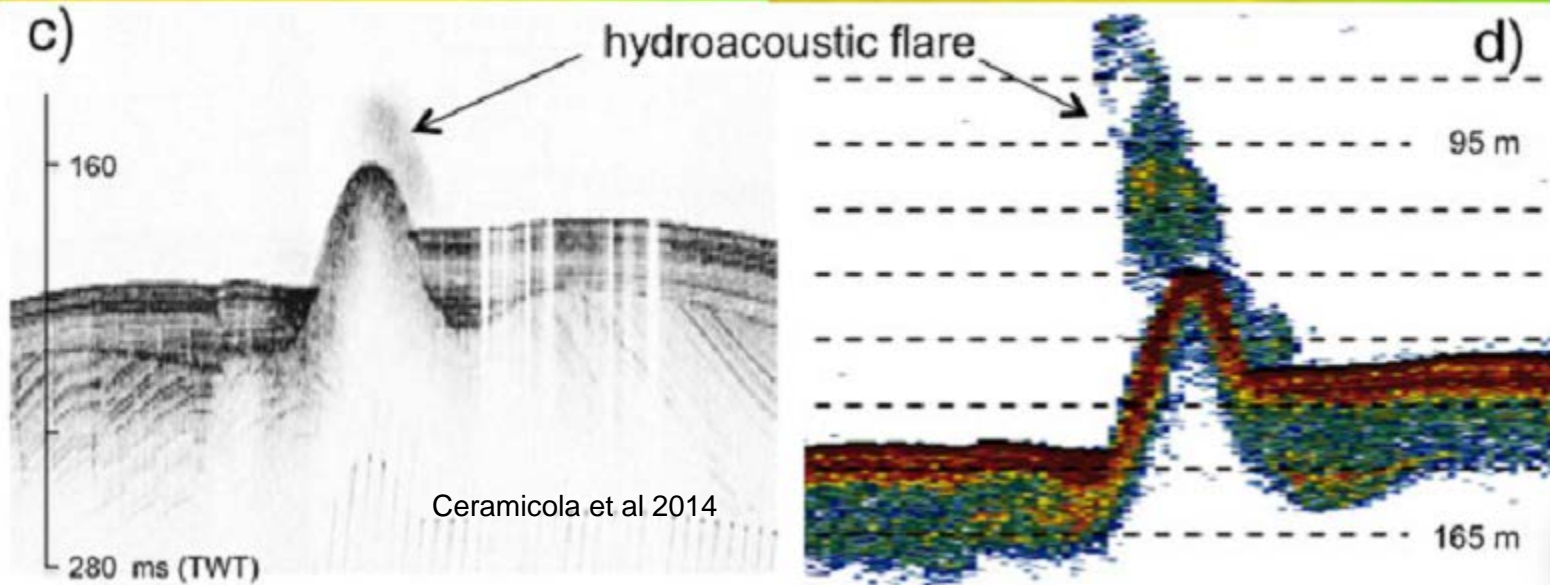
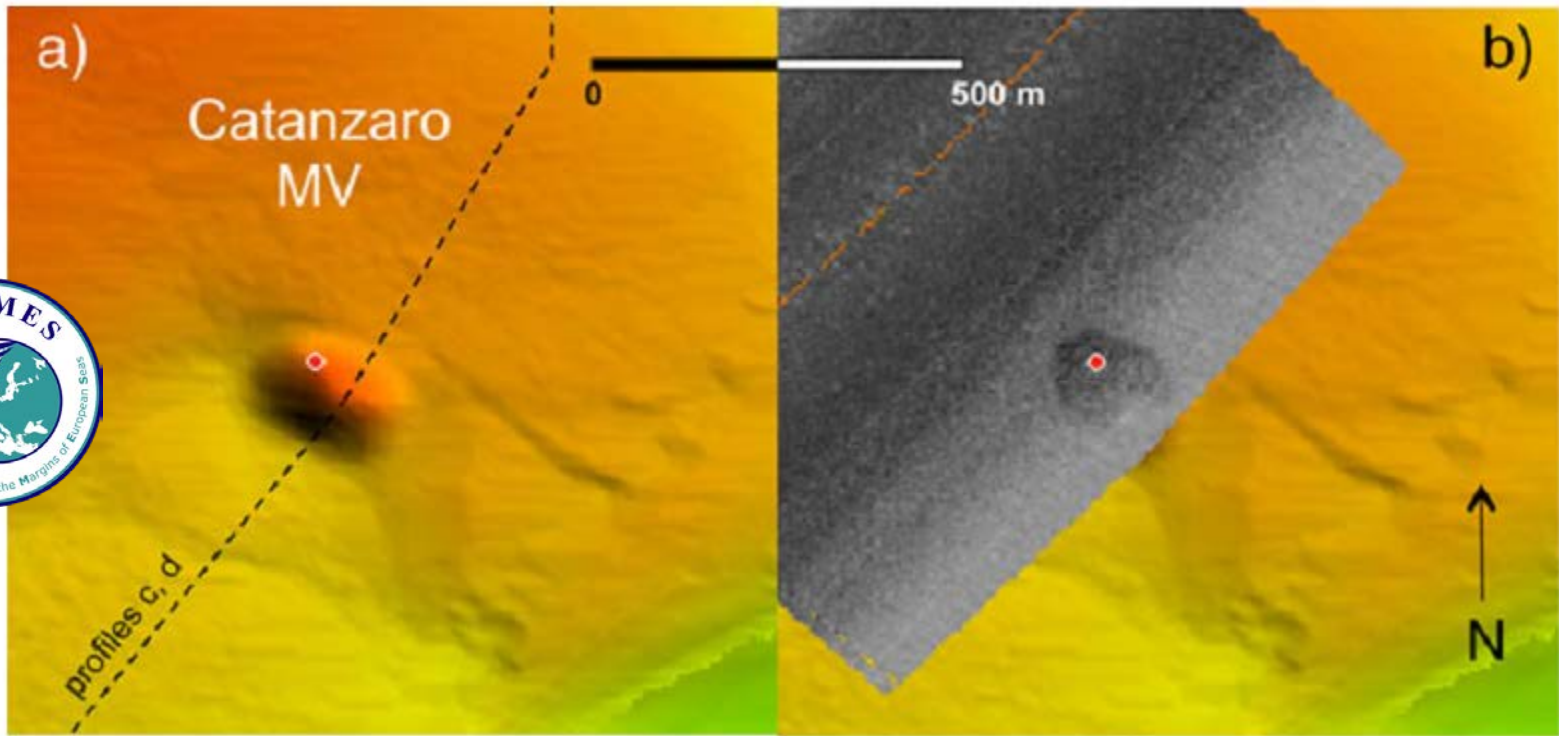
Use of multibeam morpho-bathymetry + backscatter data to map mud volcanoes (Calabrian Arc)



**mud
breccia**



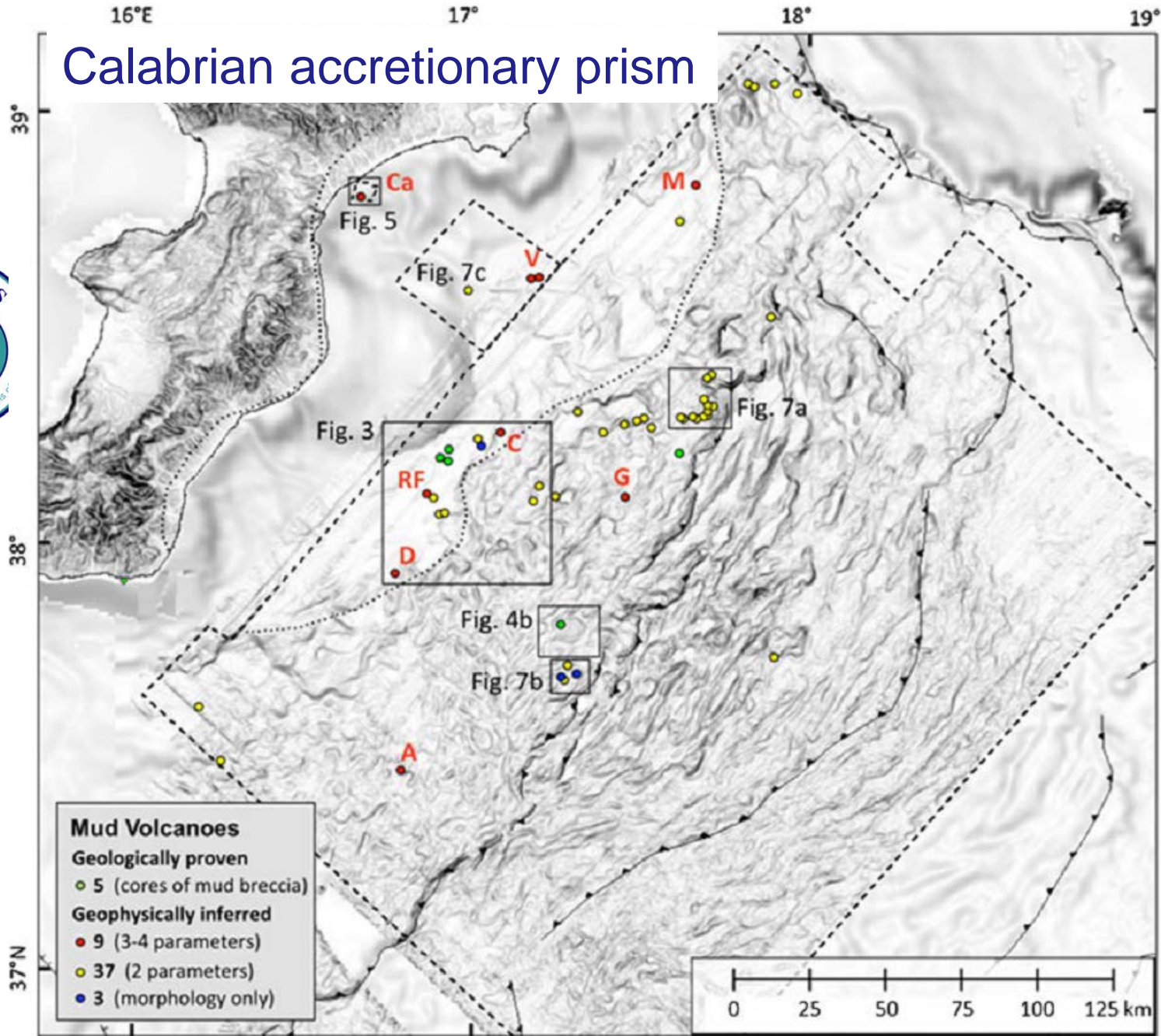
Ceramicola et al. (2014)

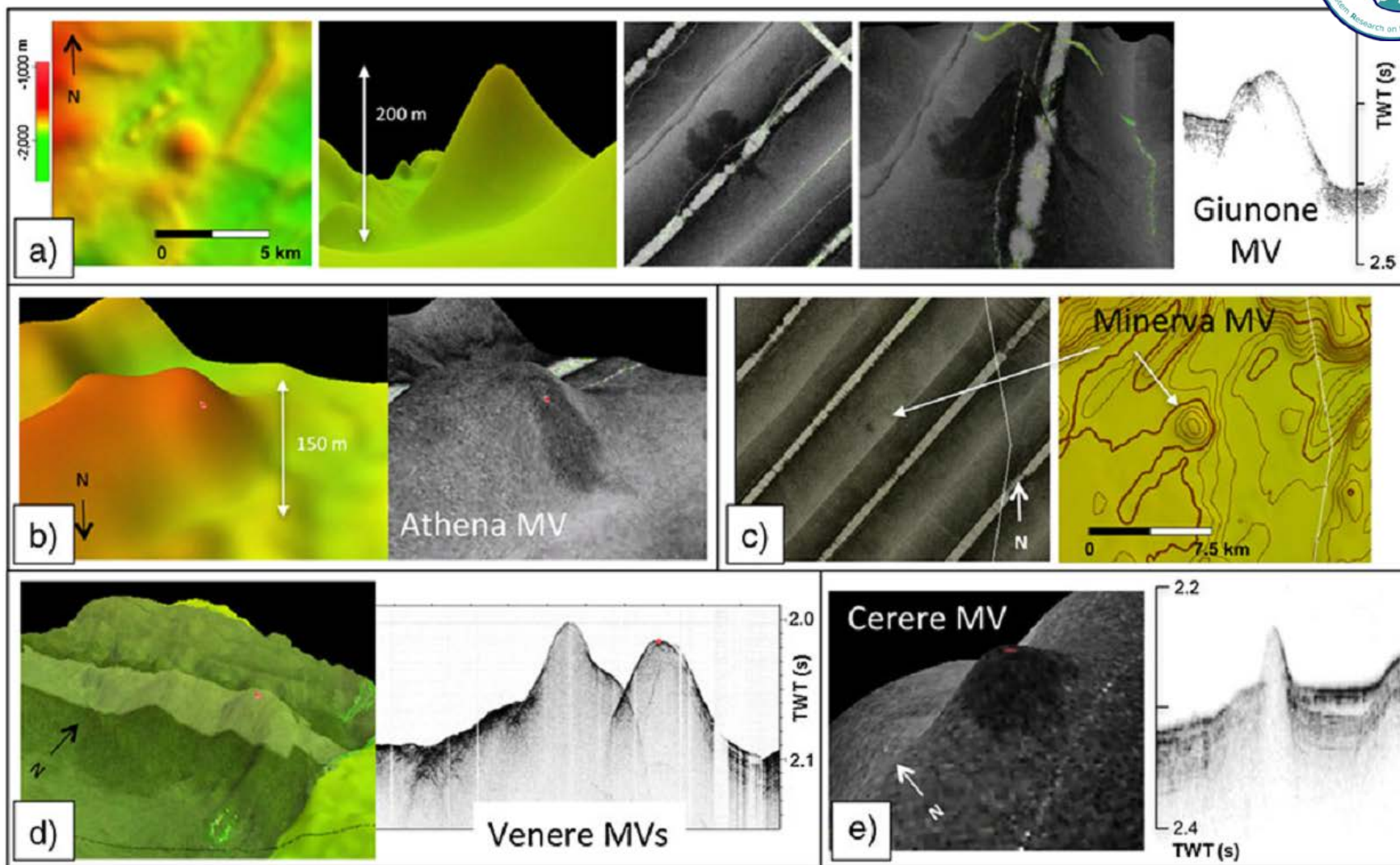


Ceramicola et al 2014



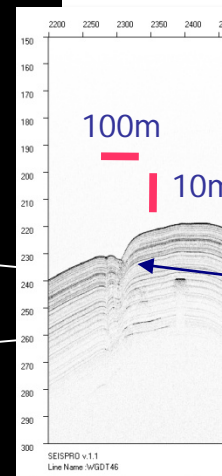
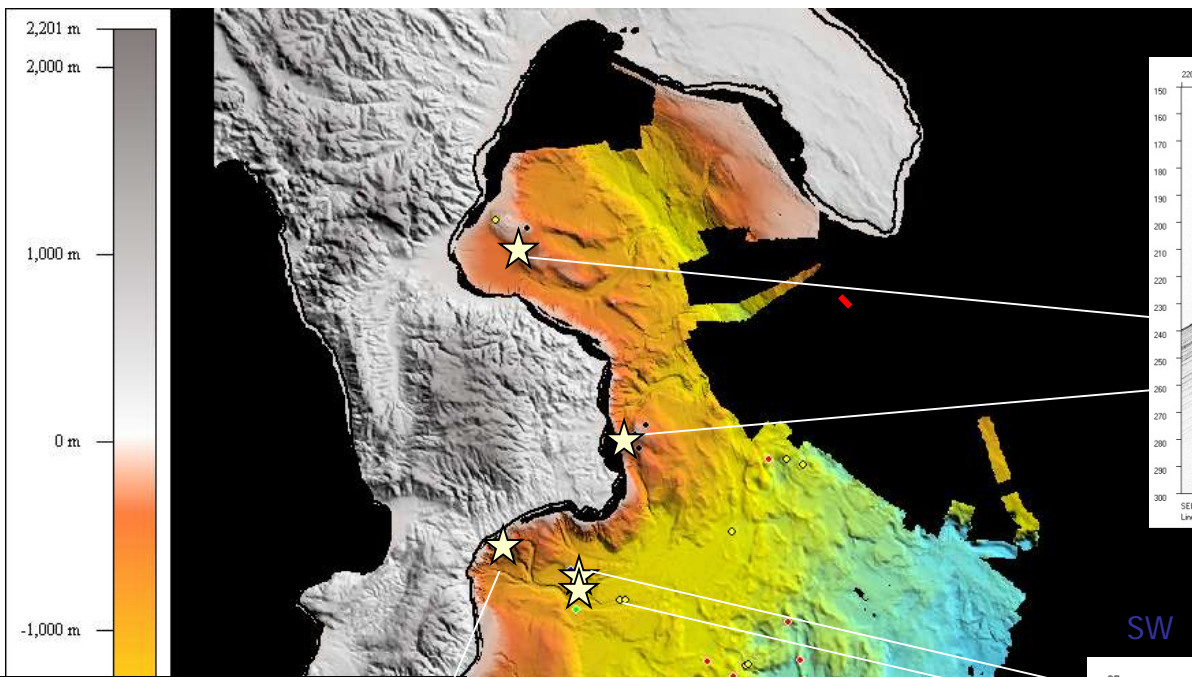
Calabrian accretionary prism





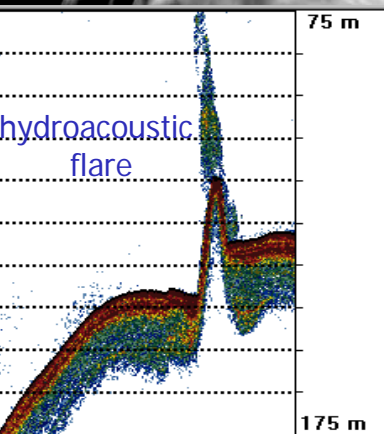
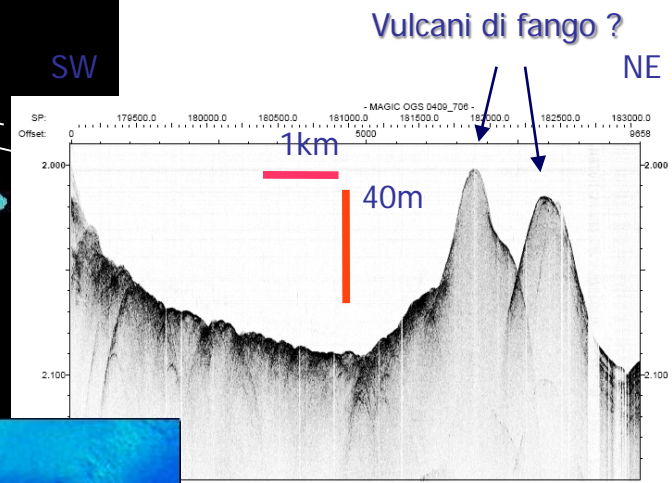
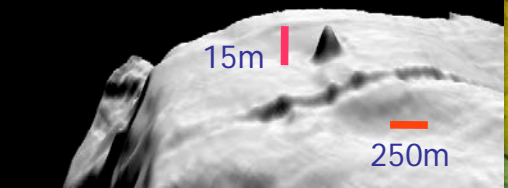
Ceramicola et al 2014

SEABED SEEPAGE MAPPING

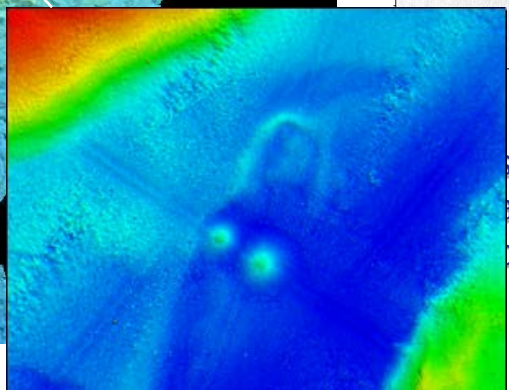


Pockmarks

Vulcano di fango di Catanzaro



hydroacoustic flare



siti individuati nel margine calabro ionico sottocosta, molti di piu' sul prisma di accrezione

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 management 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, tsunامي 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

IO NON RISCHIO maremoto

Que faut-il savoir et faire AVANT le raz-de-marée

Que dois-tu savoir ?
 Situ vis, travailles ou vas en vacances dans une aire côtière, apprends à reconnaître les phénomènes qui peuvent signaler l'arrivée d'un raz-de-marée :

- Un fort tremblement de terre que tu as ressenti directement ou dont tu as été informé
- Un bruit sourd et croissant qui provient de la mer, comme celui d'un train ou d'un avion volant en rase-motte
- Un retrait de la mer soudain et inhabituel, un soulèvement rapide du niveau de la mer ou une grande vague étendue sur tout l'horizon

Rappelle-toi que les maisons et les bâtiments proches de la côte ne sont pas toujours sûrs.

- La sûreté d'un édifice dépend de plusieurs facteurs, par exemple la typologie et la qualité des matériaux employés dans la construction, la façon où il se trouve, la distance du rivage, la nature et l'étage, l'exposition plus ou moins directe à l'impact de l'onde
- Généralement les étages hauts d'un édifice en béton, si l'édifice est bien construit, peuvent offrir une protection convenable

Que dois-tu faire ?
 Connaître le milieu où tu vis, tu travailles ou séjournes, est important pour mieux réagir en cas d'urgence :

- Renseigne-toi auprès des responsables (locux de la Protection Civile au sujet du plan d'urgence de la commune, des zones dangereuses, des voies et des temps d'évacuation, de la signalisation à suivre et des aires d'attente à rejoindre en cas d'urgence
- Renseigne-toi sur la sécurité de ta maison et des endroits qui l'entourent
- Assure-toi que ton école et ton lieu de travail ont un plan d'évacuation et que des exercices d'entraînement sont faits périodiquement
- Prépare-toi à l'urgence avec ta famille et fais un plan sur la façon de rejoindre les voies de fuite et les aires d'attente
- Garde chez toi un coffret pharmaceutique prêt à l'usage et des réserves d'eau et nourriture

APPRENDRE À PRÉVENIR ET RÉDUIRE LES EFFETS DU RAZ-DE-MARÉE EST UNE TÂCHE QUI NOUS REGARDE

Partage ce que tu sais en famille, à l'école, avec les amis et collègues ; la diffusion d'informations sur le risque du raz-de-marée est une responsabilité collective, à laquelle nous devons tous contribuer.

IO NON RISCHIO maremoto

BUONE PRATICHE DI PROTEZIONE CIVILE

La campagna IO NON RISCHIO maremoto. Un no risk sea in the risk sea. Le site web: www.iononrischio.it

È collaborata con:

- Protezione Civile
- INGV
- ANPAS
- ISPRA
- OGS

IO NON RISCHIO è un progetto di informazione realizzato sui temi del rischio maremoto e sismico, con il contributo del Ministero delle Infrastrutture e dei Trasporti, della Regione Campania, della Provincia di Salerno e della Regione Lazio. Partecipano al progetto le associazioni di volontariato e di protezione civile, le associazioni di categoria, le associazioni di promozione sociale, le associazioni di volontariato e di protezione civile, le associazioni di promozione sociale, le associazioni di volontariato e di protezione civile.

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IO NON RISCHIO maremoto

Cosa fare DURANTE il maremoto

Se sei in spiaggia o in una zona costiera e riconosci almeno uno di questi fenomeni:

- Forte terremoto che hai percepito direttamente o di cui hai avuto notizia
- Improvviso e insolito ritiro del mare, rapido innalzamento del livello del mare o grande onda estesa su tutto l'orizzonte
- Rumore cupo e crescente che proviene dal mare, come quello di un treno o di un aereo a bassa quota

• Alzati e raggiungi rapidamente l'area vicina più elevata (per esempio una collina o i piani alti di un edificio).

• Avverti le persone intorno a te del pericolo imminente.

• Corri ai piedi seguendo la via di fuga più rapida. Non usare l'automobile, potrebbe diventare una trappola.

Se sei in mare potresti non accorgerti dei fenomeni che accompagnano l'arrivo di un maremoto, per questo è importante ascoltare sempre i comunicati radio: se sei in barca e hai avuto notizia di un terremoto sulla costa o in mare, partiti al largo, se sei in porto abbandona la barca e mettila al sicuro in un posto elevato.

Cosa fare DOPO il maremoto

Rimani nell'area che hai raggiunto e scorgi chi vuole tornare verso la costa: alla prima onda potrebbero seguire altre più pericolose.

- Assicurati delle condizioni di salute delle persone intorno a te, se, se possibile, presta i primi soccorsi.
- Rivolgiti alle autorità per capire quando lasciare il luogo in cui ti trovi e cosa fare.
- Usa il telefono solo per reali necessità.

Se la tua abitazione è stata interessata dal maremoto, non rientrare prima di essere autorizzati.

Non mangiare cibi che siano venuti a contatto con l'acqua e con i materiali trasportati dal maremoto: potrebbero essere contaminati. Non bere acqua del rubinetto.

Il maremoto può essere generato da un sisma o da attività vulcanica: informati, quindi, anche su cosa fare in caso di terremoto o eruzione.

www.protezionecivile.gov.it www.anpas.org www.ingv.it
www.reluis.it www.isprambiente.gov.it www.ogs.trieste.it

Acknowledgments/Credits

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



Preparedness and Disaster