Università di Trieste
Corso di Laurea Magistrale in Esplorazione Geologica

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Geologia Marina

Parte IV

Modulo 6.1 Seabed mapping

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1 - Why we measure the depth of the Ocean? From leadlines to Seabed 2030

2 – Methods to acquire seabed bathymetry:

Using Sound: Single Beam, Sidescan Sonar, Multibeam, Interferometric Sonar

Using Satellite: satellite altimetry, gravity data, SAR

Using Light: LIDAR, laser line scan, video & photography, stereophotography

Remote sensing platforms and data integration for shallow water coastal areas – 'the white frame' problem

3 –Seabed and sub-seabed classification

The example of the Magic Project for marine geohazards assessment

The example of Hermes Project for mud volcano classification

The example of the Assi Failure for failure dynamic reconstruction

4 - Next generation: Automated seabed classification, Artificial Intelligence, Digital twins

5- Seabed Low and regulation: ONU, EU, Seabed 2030

Why we measure the depth of the Ocean?

☐ to satisfy the needs of society.

☐ The needs of society have changed through time

navigation for trade -- leadlines	- 5th century BC
discovery of new world (cartography)	- 1400-1800
telecommunication (telegraph)	- 1800
supervise submarines or listen to the enemies	- II WW and cold water
(20%) safety (geohazards) conservation (protection of marine ecosystems and habitat) economic reason (exploitation of planet resources)	- Today
(100%) All the Oceans will be mapped at high-resolution Seabed 2030	- 2030

History

70% of the Earth is covered by water, but so far just 19% of it has been surveyed (Mars, Venus and the Moon are better surveyed).

Hydrography as a science has changed dramatically since the first measurements were made by Alexander Dalrymple and James Cook 1700 with lead lines and sextants

Mark Twain (1835-1910) pilota dei battelli a vapore sul Mississippi derivi dal grido in uso nello slang della marineria fluviale degli Stati Uniti d'America per segnalare la profondità delle acque: *by the mark, twain*, ovvero: *dal segno, due* (sottinteso tese). Tale grido indica una profondità di sicurezza (appunto due tese, circa 3,7 metri).[

Where it all started: measuring bathymetry with **leadlines** *(photo: NOAA)*

Time-consuming

Limited number of measurements

May be affected by currents

XV- XVIII secolo - Grandi esplorazioni marittime --> cartografia

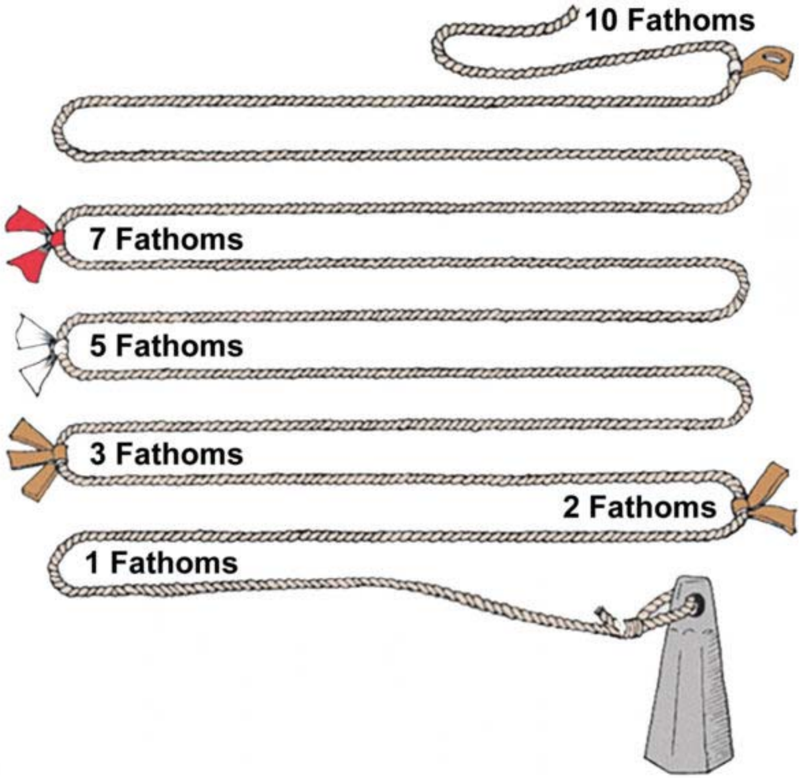
1 - Why we measure the depth of the Ocean?

One of the first and most valuable inventions in navigation was the **leadline**. Since the 5th century BC, the leadline has been used to both measure the depth of the water and determine the characteristics of the sea floor.

This tool is so simple and reliable that its design hasn't changed much in thousands of years. It consists of a lead weight attached to a rope that is marked at measured lengths. The bottom of the lead is concave, or cupped inward. Filling this space with something sticky, such as tallow (animal fat) or grease, is called "arming the lead" and is used to bring up bottom samples, such as sand, gravel, or mud, to show what was on the sea floor in that spot.

The length of line that it took to reach the bottom was measured and recorded, called a sounding. To collect sounding data to make nautical charts, mariners and scientists would take hundreds of soundings with the leadline from boats and ships before the development of echosounders and other high-tech electronic instruments. The deeper the water, the bigger the lead.

A traditional leadline is marked at measured intervals with red or white rags or strips of leather to make it easier to read: 2, 3, 5, 7, 10, 15, 20, and 25 fathoms. The person taking the soundings would throw the lead and its line overboard—holding on to the end—and let the line slide through his hands until the lead weight stopped at the bottom. Then he would note which marking was closest to the surface of the water and call out, "by the mark 5" if near the white rag marking five fathoms or "by the deep 6" if in between the white and red rags at 5 and 7 fathoms.



1 fathom = 6 feet= 1,828m (Imperial system of Units)

Underwater acoustic

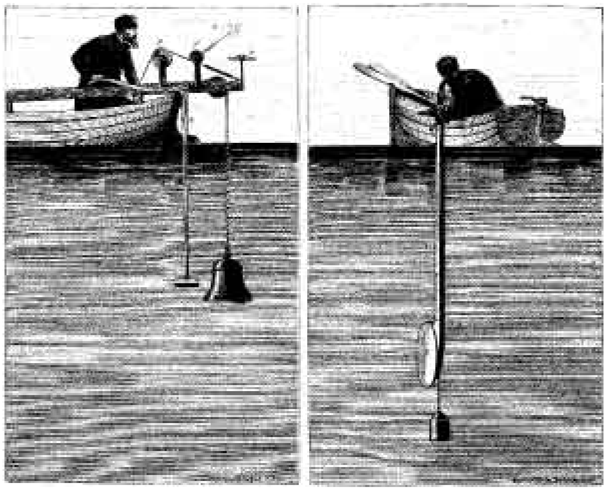
"If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you."
Leonardo da Vinci, 1490

The 1800s, the FWW and the Cold War

before the First World War, very few attempts were made to understand underwater sound. The main purpose was initially communications. The telegraph was discovered in the 19th century and it was thought that it might even be possible to communicate under water. It was already known that the speed of sound was higher under water than in air.

The hydrophone, an underwater microphone making it possible to receive sounds under water, was invented in 1889. When submarines were used for the first time during the First World War, the importance of this research increased.

Because radio waves do not travel well through good electrical conductors like salt water, submerged submarines are cut off from radio communication with their command authorities at ordinary radio frequencies.



In 1826 on Lake Geneva, Switzerland, **Jean-Daniel Colladon**, a physicist, and **Charles-Francois Sturm**, a mathematician, made the first recorded attempt **to determine the speed of sound in wate**r. In their experiment, the underwater bell was struck simultaneously with ignition of gunpowder on the first boat. The sound of the bell and flash from the gunpowder were observed 10 miles away on the second boat. The time between the gunpowder flash and the sound reaching the second boat was used to calculate the speed of sound in water. Colladon and Sturm were able to determine the speed of sound in water fairly accurately with this method. J. D. Colladon, Souvenirs et Memoires, Albert-Schuchardt, Geneva, 1893.

Discovery of sound in the Sea
https://dosits.org/people-and-sound/history-of-underwater-acoustics/

History of Hydrographic Surveying
https://nauticalcharts.noaa.gov/charts/history-of-hydrographic-surveying.html

1 - Why we measure the depth of the Ocean?

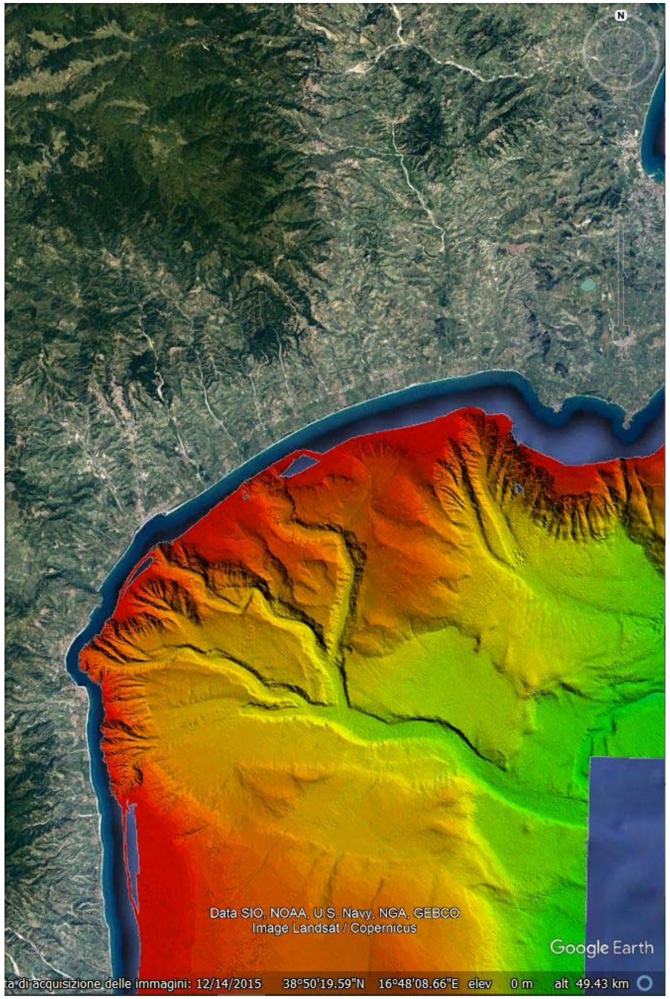
Sound waves from ships and **radio waves** from satellites are two of the most common ways to measure the depth of the sea.

Radio waves do not travel well through good electrical conductors like salt water,

Much like the land's surface with mountains and hills, the ocean floor or seabed isn't completely flat. There are flat surfaces, but there are all sorts of underwater landforms such as canyons, trenches and underwater volcanoes.

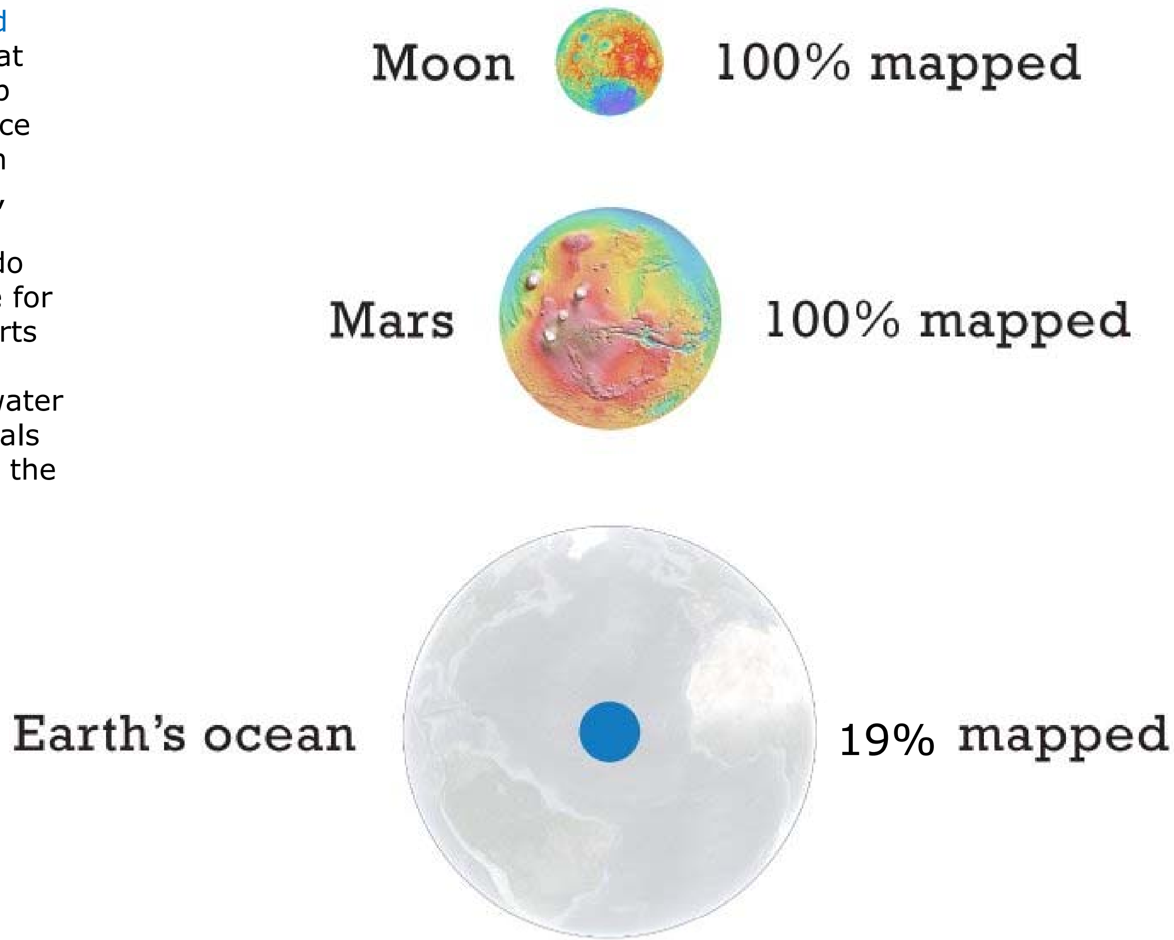
The average depth of the ocean is 3,700 meters (12,100 feet). But the deepest part ever recorded is located in the western part of the Pacific Ocean, in the Mariana Trench, at a depth of around 11,000 meters (36,200 feet).

Bathymetry is the scientific term for measuring the depth of water in oceans, lakes and rivers. Bathymetric maps are similar to land maps in that they show the different underwater landforms in a specific area. Scientists and researchers can use different methods to measure ocean depth.



It's easy to ignore what we cannot see.

While some satellite-based technology that we use to map the land surface can be used in shallow water, these technologies do not work once for the deeper parts of the ocean, because the water stops the signals from reaching the seafloor



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NATIONAL AQUARIUM

Satellite / RADAR (electromagnetic)

- Very much depth-limited
- Only useful for sea surface measurements, shallow waters or instruments close to seabed

Acoustic

- Good penetration of water column
- Information about depth and reflectivity of the seabed
- Still affected by attenuation: trade-off between depth & resolution

Light

- Basically same principle as RADAR or multibeam, using laser (i.e. visible light)
- For topographic surveys of the 'white zone': coastal areas & intertidal zone too shallow to map with multibeam
- Much larger coverage and data density: up to 1 measurement per m^2, vertical resolution ~1-10cm

www.biologyreference.com

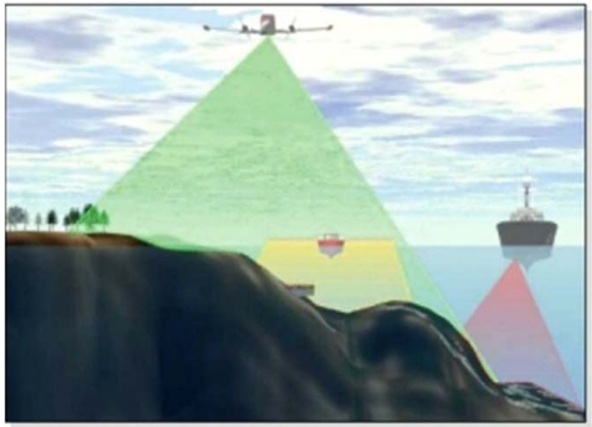
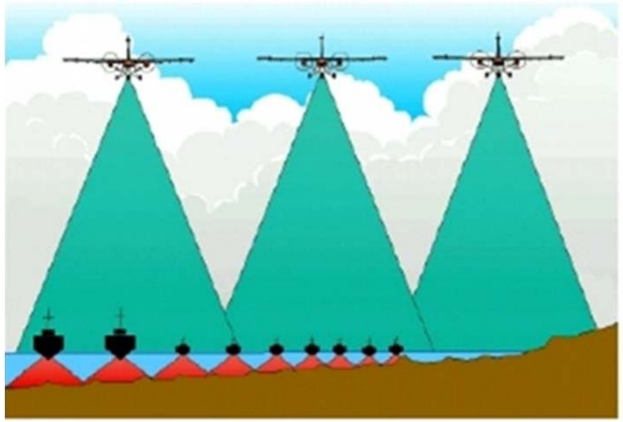
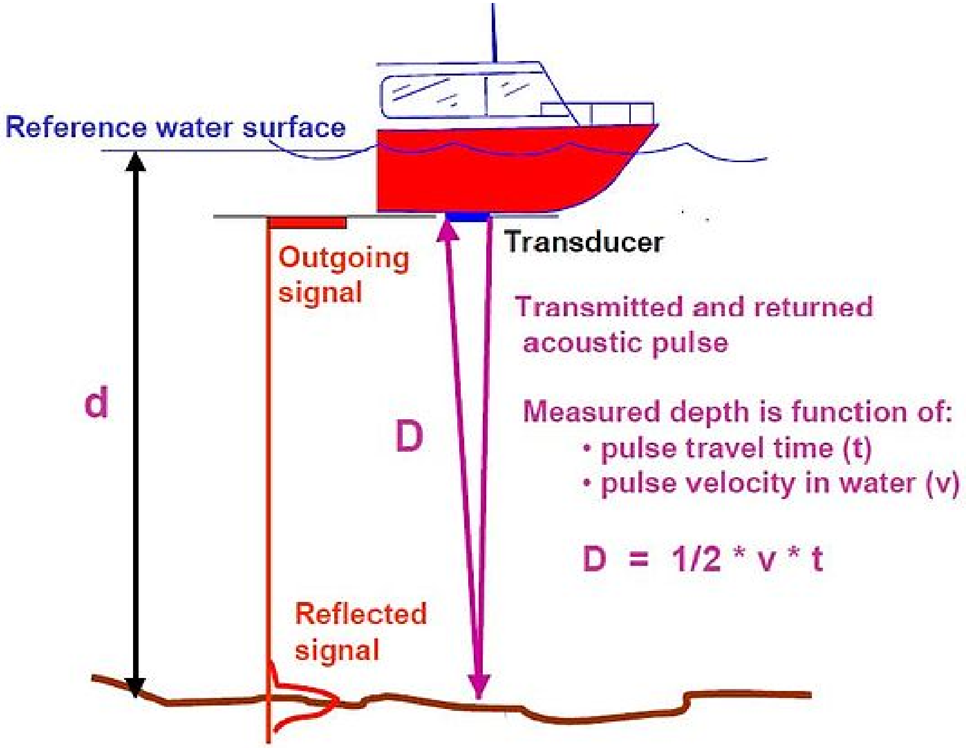


Image: ENCORA project



Using acoustic (sound)

(Echo)sounding: Single Beam Echosounder



Measure water depth as two-way travel time

- Repeated single acoustic pulse

- Considerably faster and much higher measurement density - along the track

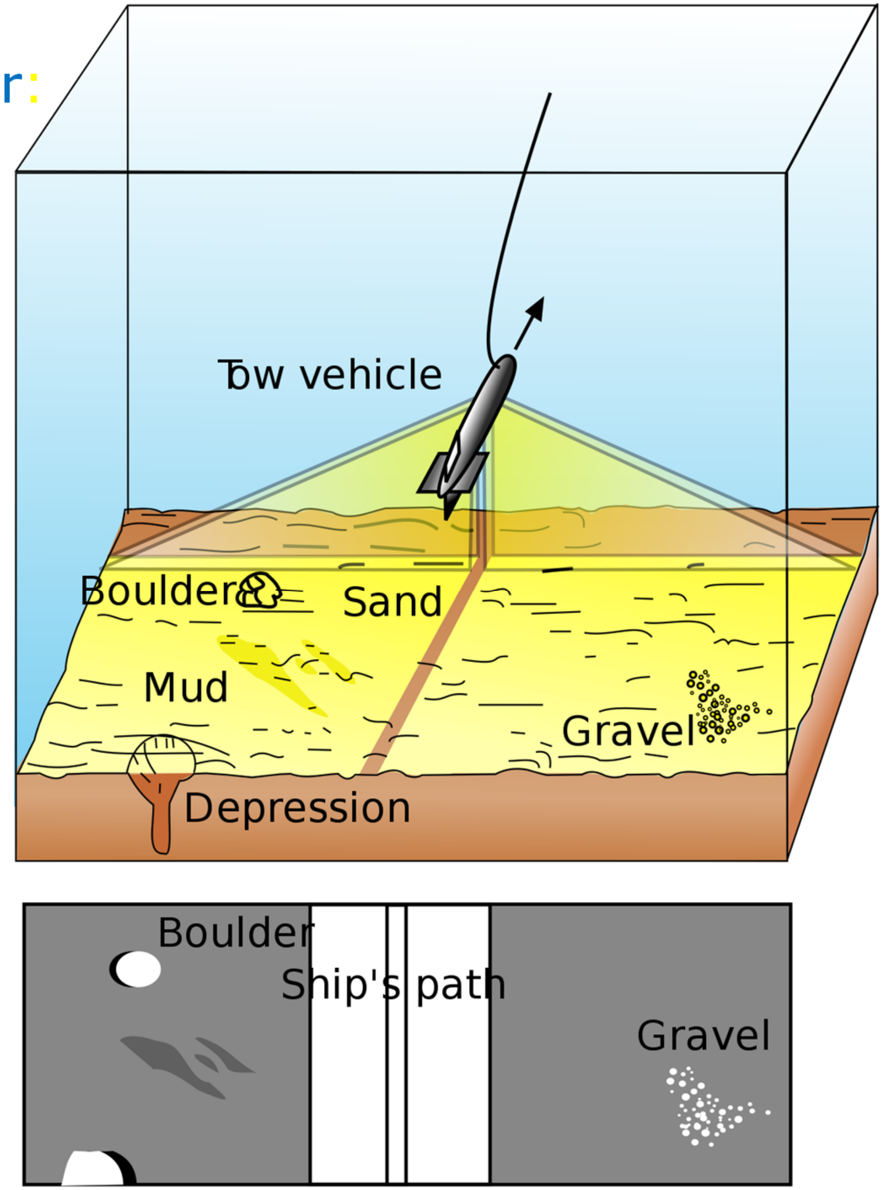
- Requires knowledge of sound velocity (density dependent)

(Echo)sounding: Sidescan sonar:

Two narrow acoustic pulses: one on either side of the system

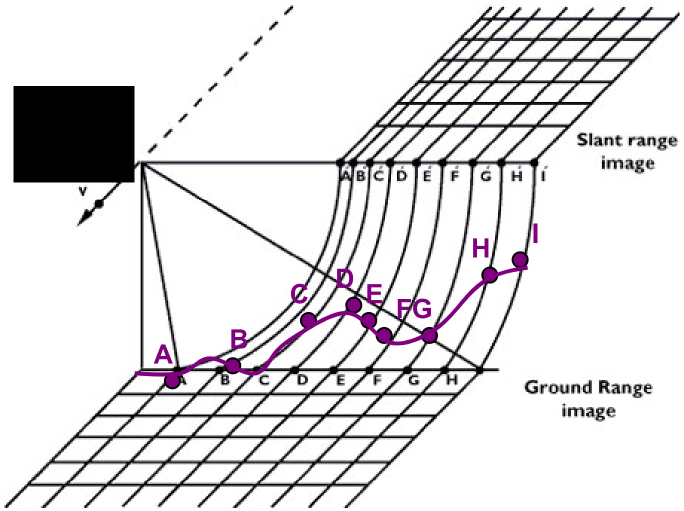
Hydrophones record backscatter strength in relation to time

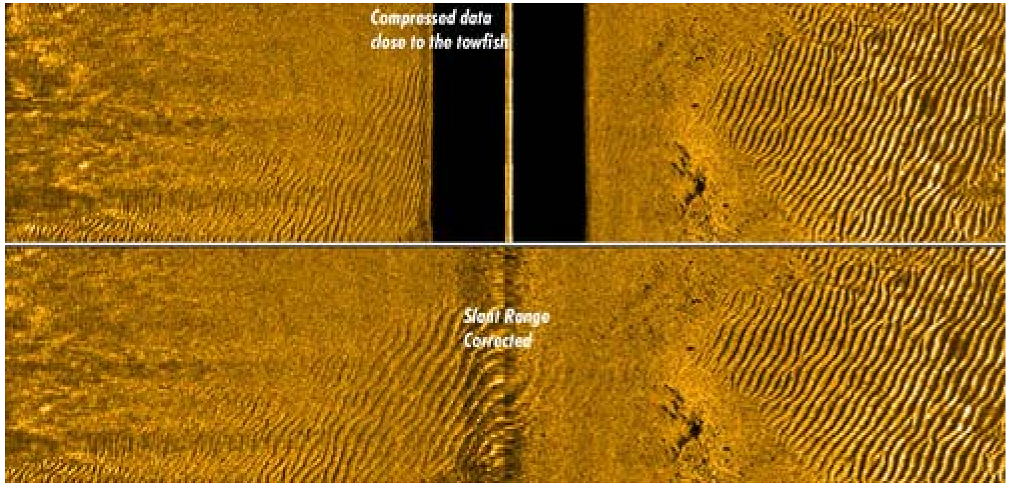
Backscatter is function of slope, seabed type and roughness



(Echo)sounding; Sidescan sonar:

slant-range correction



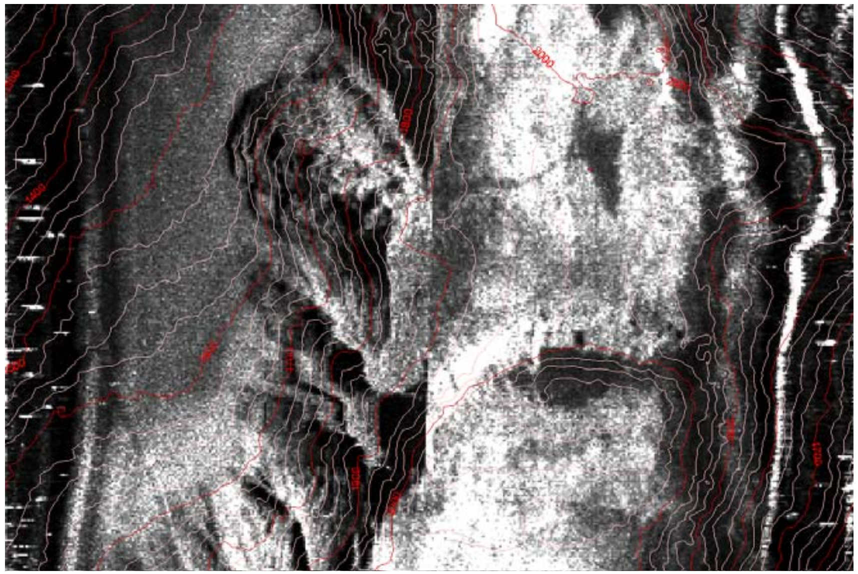


- Conversion of time-recording into spatial backscatter map

- Typically uses a 'flat seabed' assumption

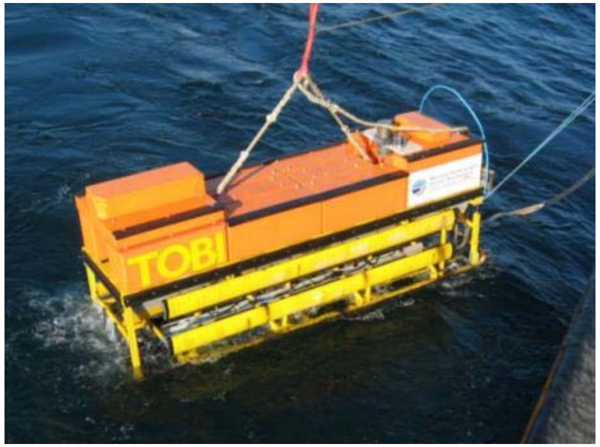
 - Not correct in complex terrain! (e.g. canyons)

 - Using bathymetric information, 'true slant-range correction' can be calculated

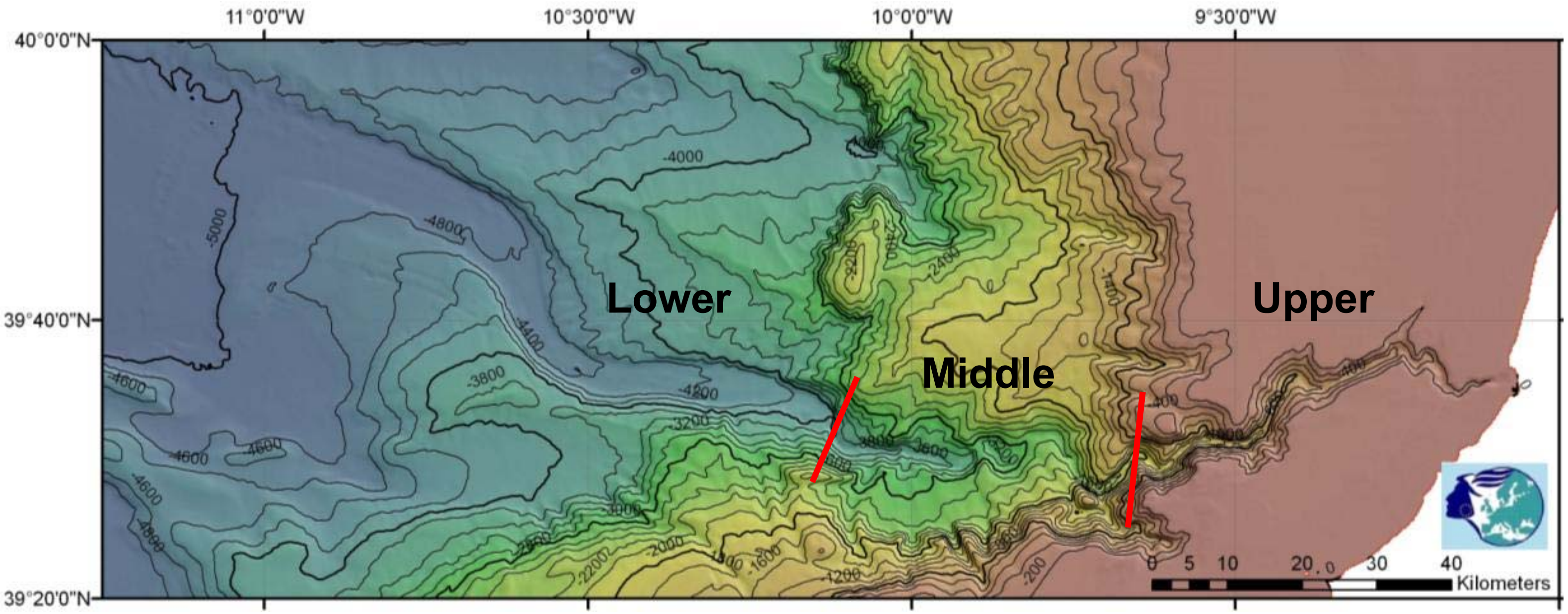


Sidescan example: TOBI

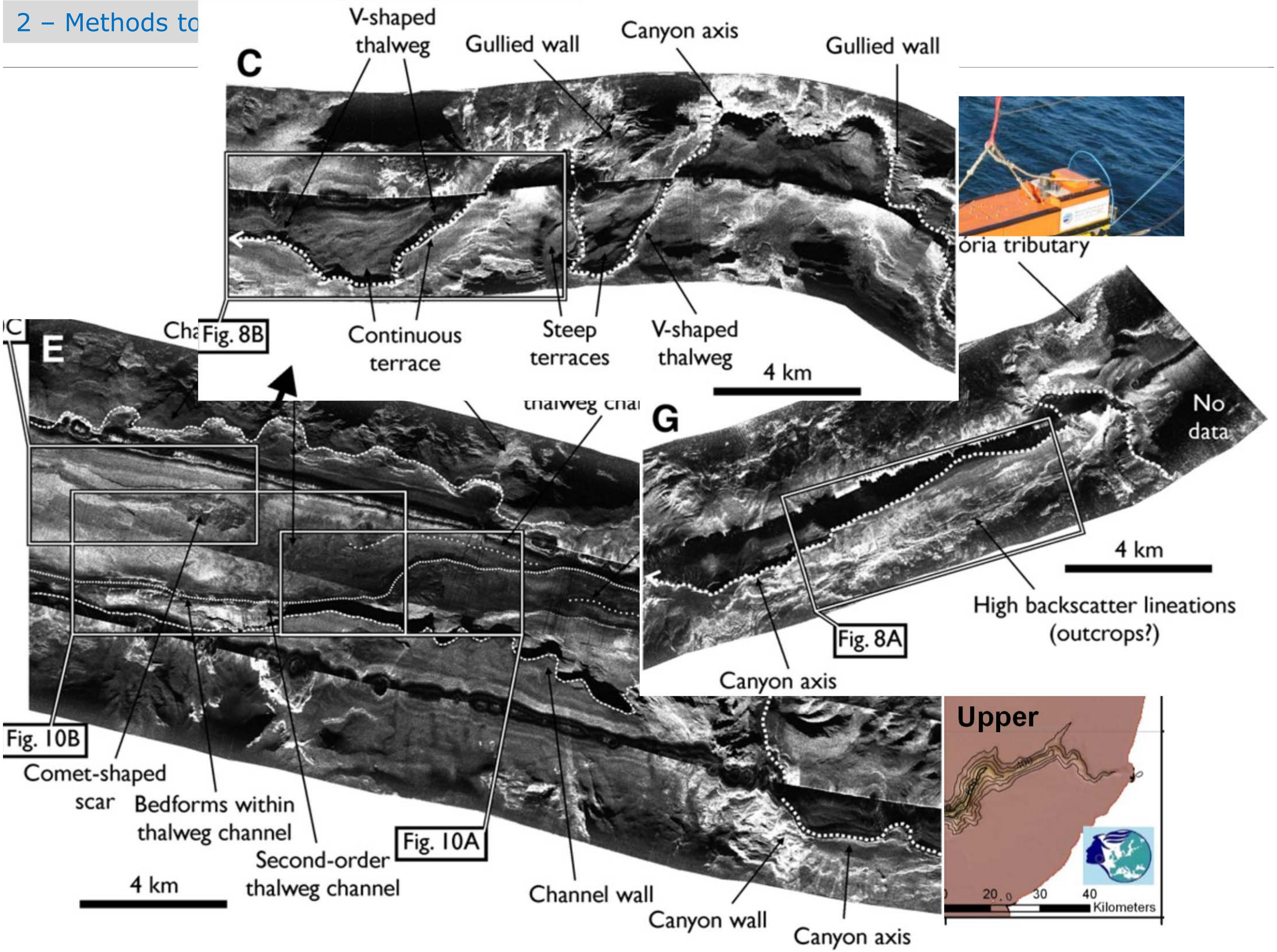
- Towed Ocean Bottom Instrument
- Contains 30kHz sidescan sonar, chirp, magnetometer & gravimeter
- Operated at 300 to 400 m off the seabed
- Swath width of 2 x 3km, 3 to 6 m pixel resolution



Sidescan sonar:

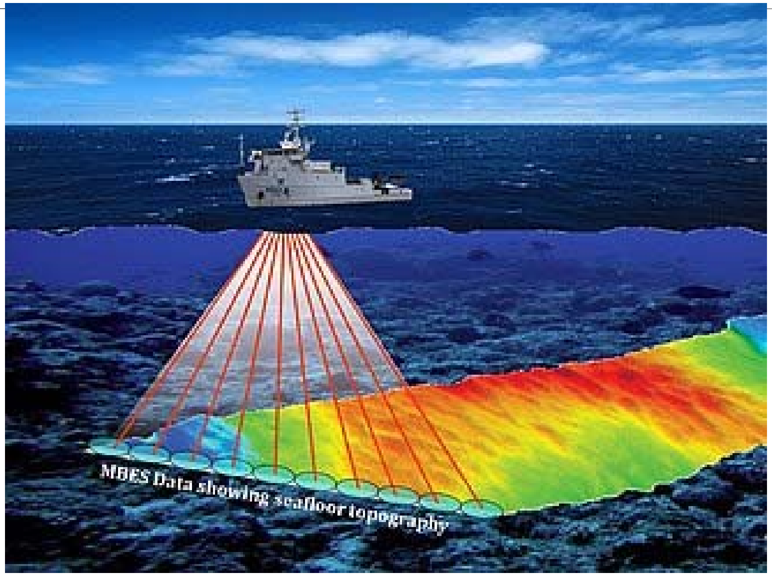


2 – Methods to


C
V-shaped thalweg
Gullied wall
Canyon axis
Gullied wall
Fig. 8B
Continuous terrace
Steep terraces
V-shaped thalweg
4 km
E
Fig. 10B
Comet-shaped scar
Bedforms within thalweg channel
Second-order thalweg channel
Fig. 10A
4 km
Channel wall
Canyon wall
Canyon axis
thalweg chai
G
ória tributary
No data
4 km
High backscatter lineations (outcrops?)
Fig. 8A
Canyon axis
Upper
20
30
40
Kilometers

Methods: (Echo)sounding

- originated for military applications: was developed in the early 1960s by the US Navy, in conjunction with General Instrument to map large swaths of the ocean floor to assist the underwater navigation of its submarine force
– Francis Parker Shepard in US Navy during 1stWW - In the Second World War, Shepard again worked for the US Navy, where his expertise and knowledge of seafloors was used to assist submarine operations.



Multibeam Echosounder:

Fan of acoustic beams (between ~100 and ~550, depending on model)

Focussed down to ~1.5° along-track

Spread over 120 to 170° across-track (210 in extreme shallow water)

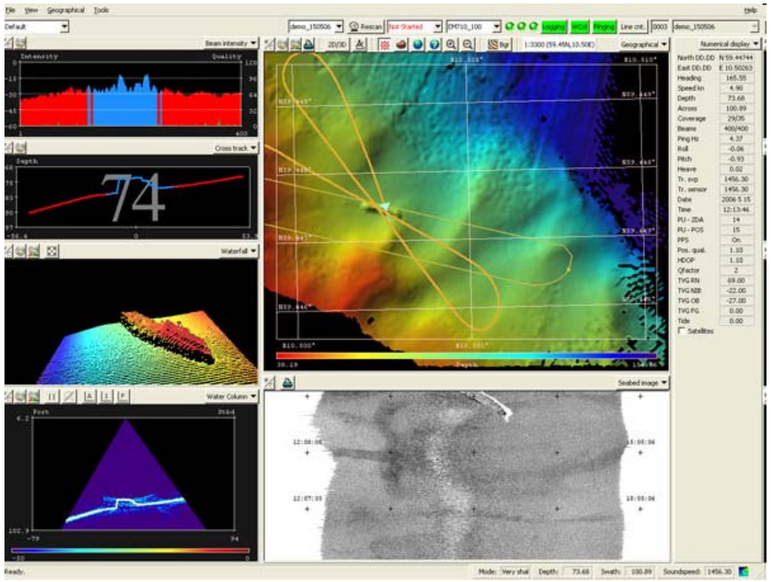
On a single transect, swath mapping can sound an area 10 to 60 km wide and as long as the distance traveled by the ship

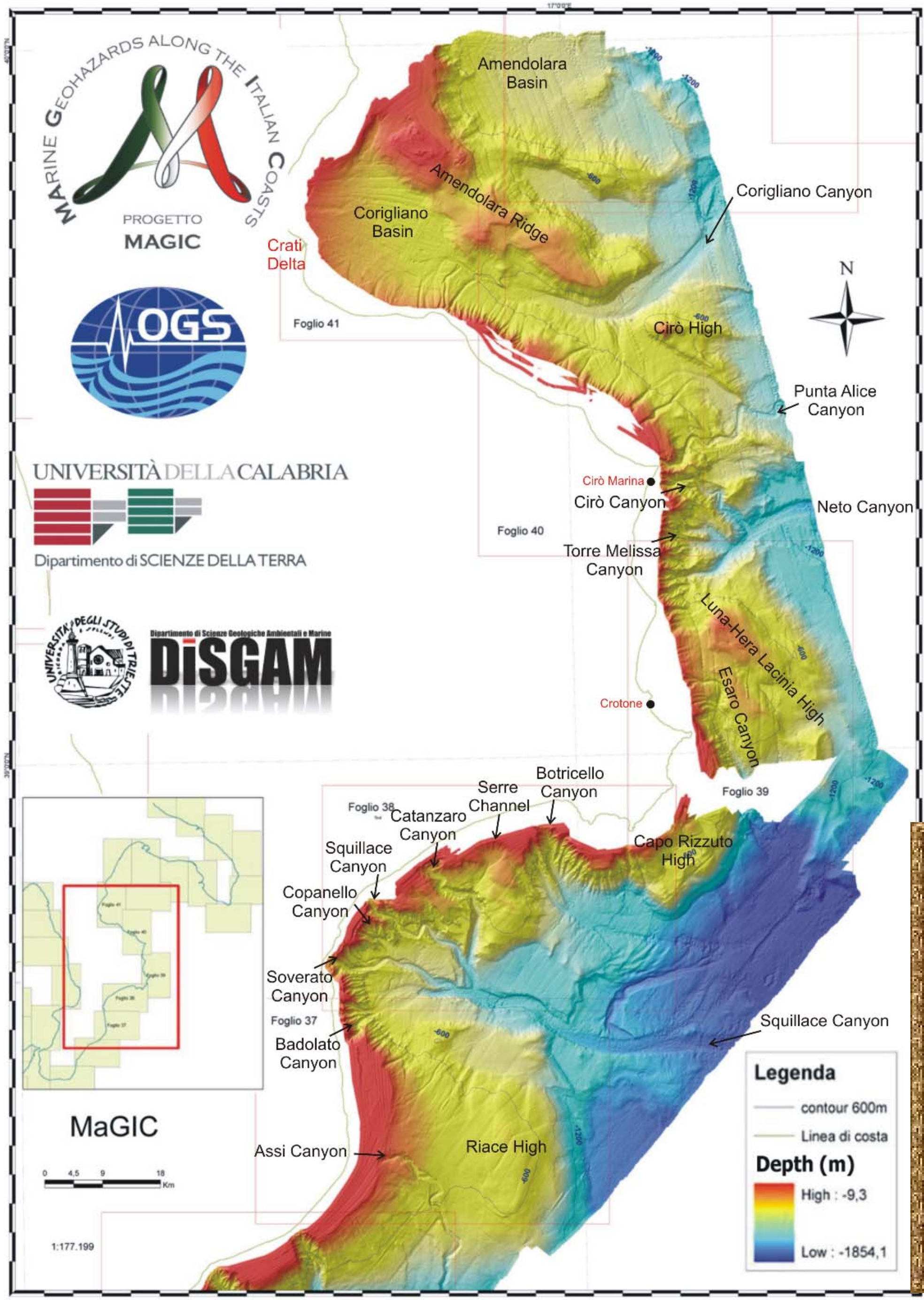
Acoustic frequency determines resolution and maximum workable water depth (from 500kHz to 12kHz – from 200m to 11000m)

Multibeam bathymetry and multibeam backscatter data are collected at the same time using a multibeam echosounder mounted on a survey vessel. While bathymetry measures ocean depth, backscatter can be used to measure sea floor hardness.

Data processing needs information on attitude of the ship (pitch, roll, heave)

Small low-power multibeam swath systems are also now suitable for mounting on an Autonomous Underwater Vehicle (AUV)

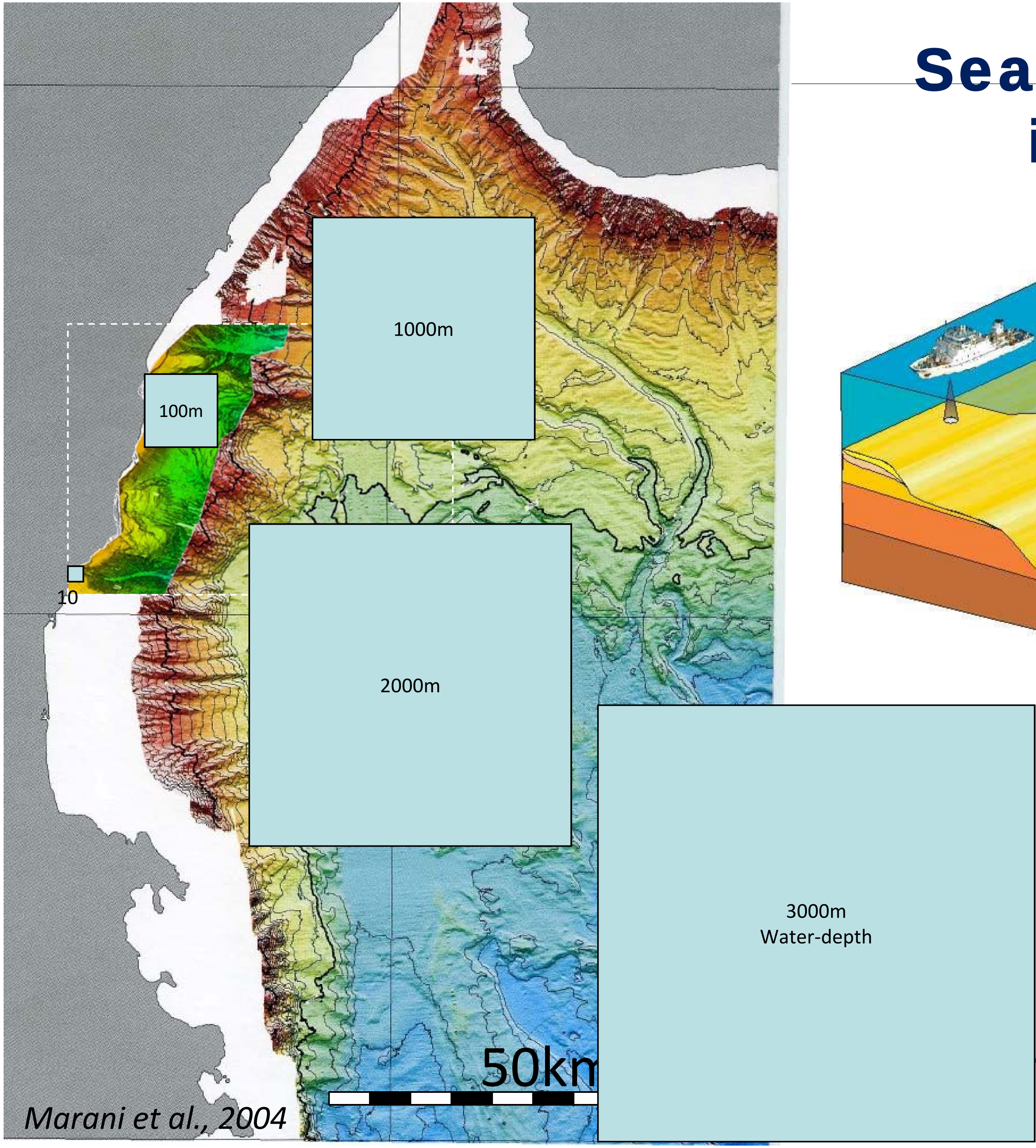


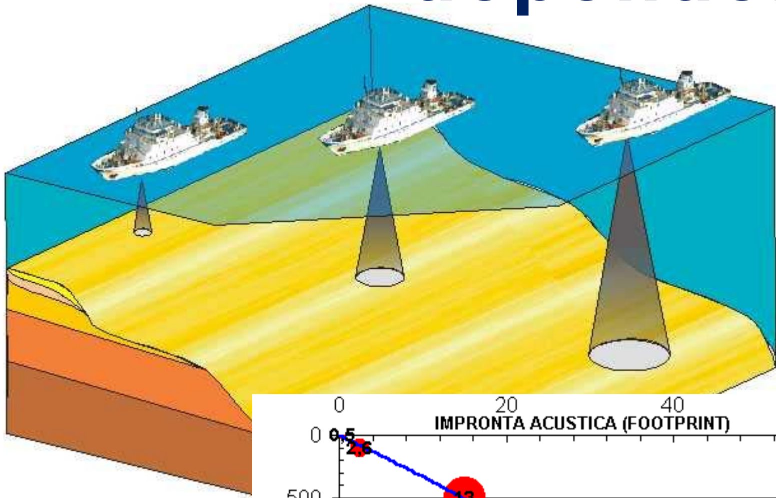


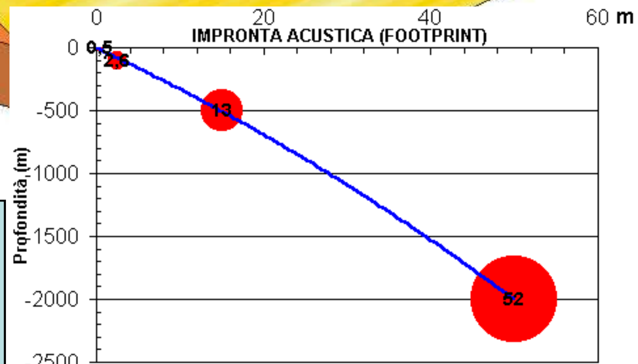
The “white frame”problem

Most of the time **geohazard indicators** (such as 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) **are located (or terminate) very close to the coastlines and provide important information on their hazard/risk** (and the gap with the terrestrial system).

Seafloor coverage is water-depth dependent







MBES coverage of a 24h survey at different water-depths

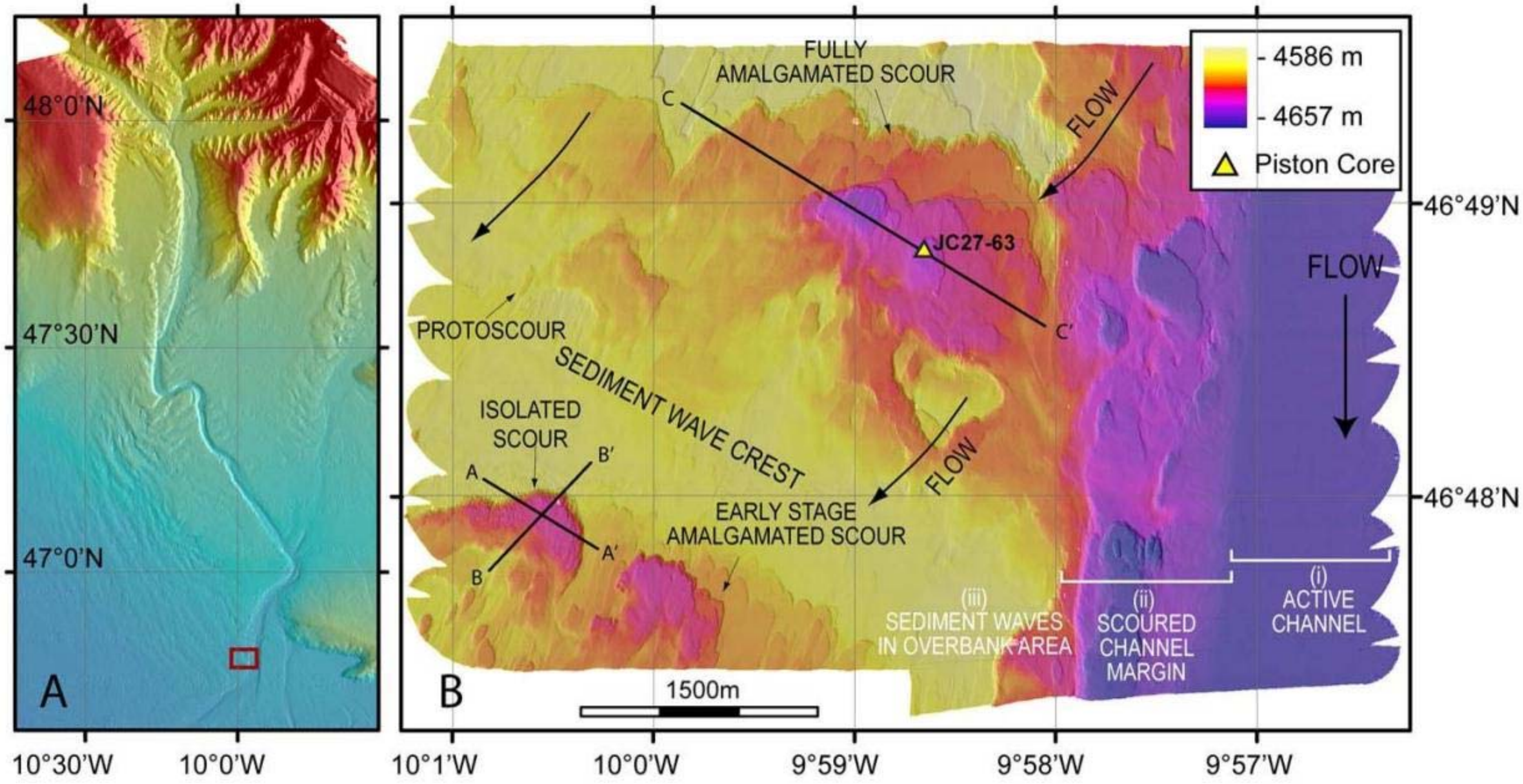
Methods: it's all about scale

Scale

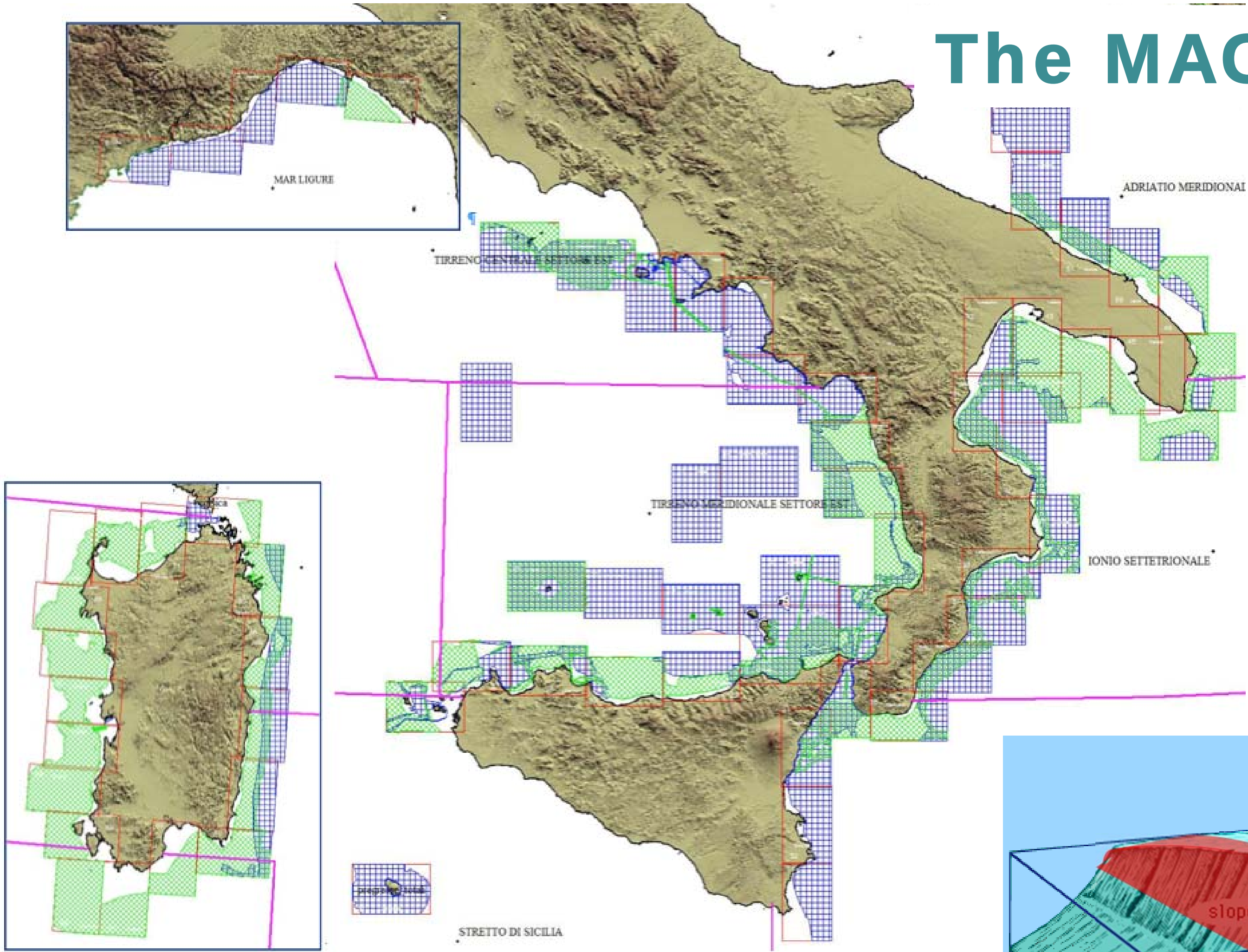
- Extent (coverage)
- Resolution (pixel size)

$\Rightarrow$ Often a trade-off!

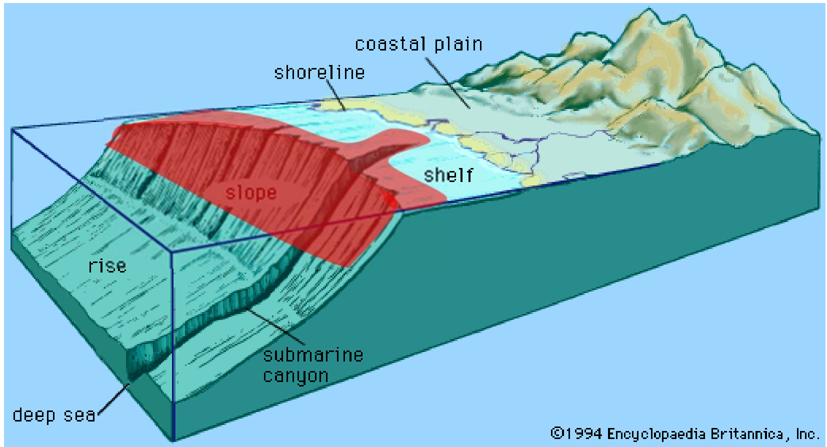
$\neq$resolving power: needs a few pixels!



The MAGIC strategy



Therefore MaGIC project planned to acquire data along the continental margins **with a reference depth range 50-500**.



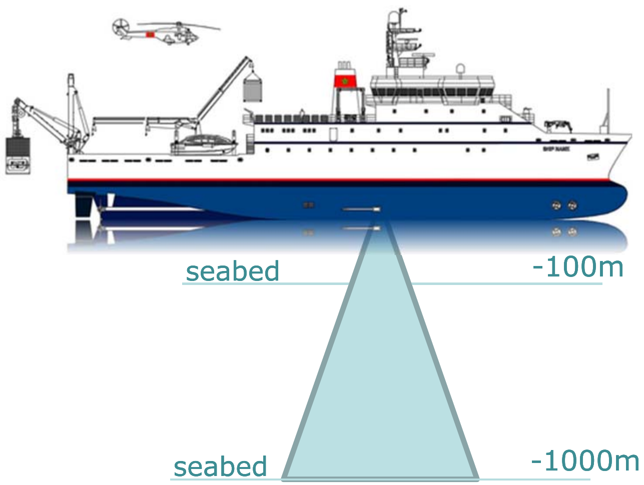
It can be extended in shallow waters (e.g. canyon head) and to deeper water if time allows on critical morphologies

It can be reduced in the outer shelf if relevant features are not present (e.g. Adriatic sea)

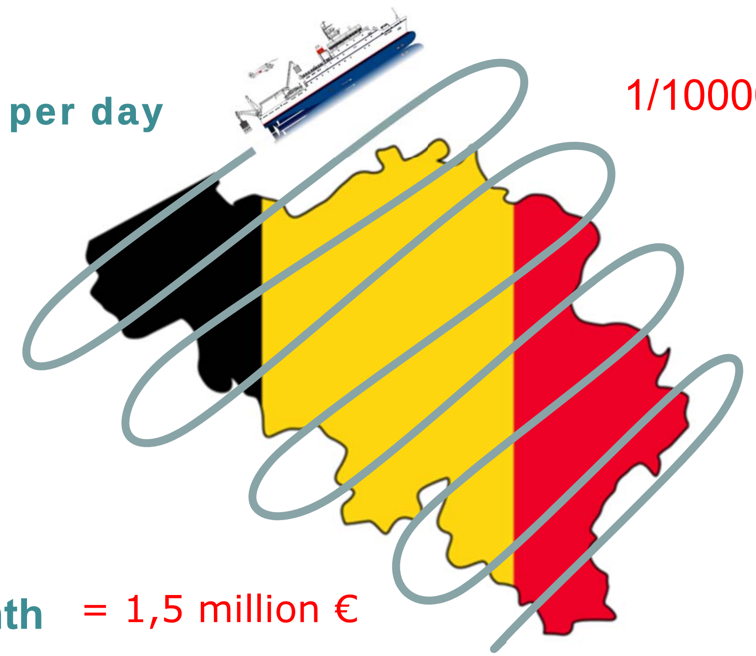
Costs are water-depth dependent…

…only 19% of our oceans have been mapped so far!!!

Acquiring a HR- DEM of a portion of seabed of the extension of Belgium:



= **50,000€ per day**

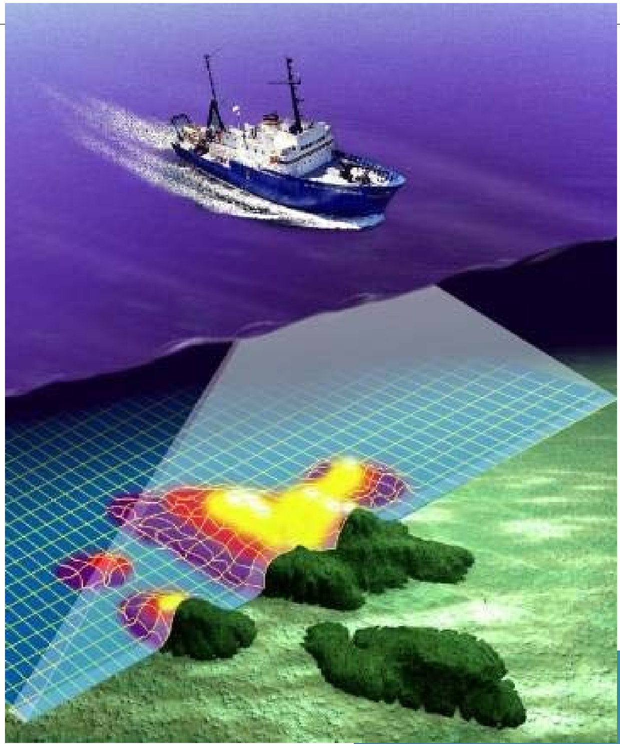


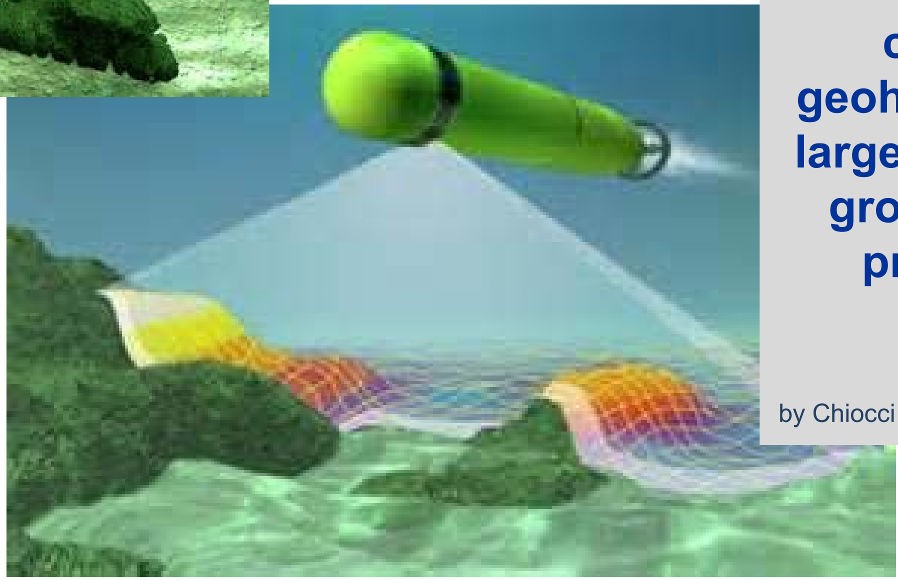
1/10000

at **-1000 m** (deep sea) → ca.**1 month** = 1,5 million €

at **-100 m** (coastal area) → ca. **1 year** over 15 millions €

Seafloor mapping



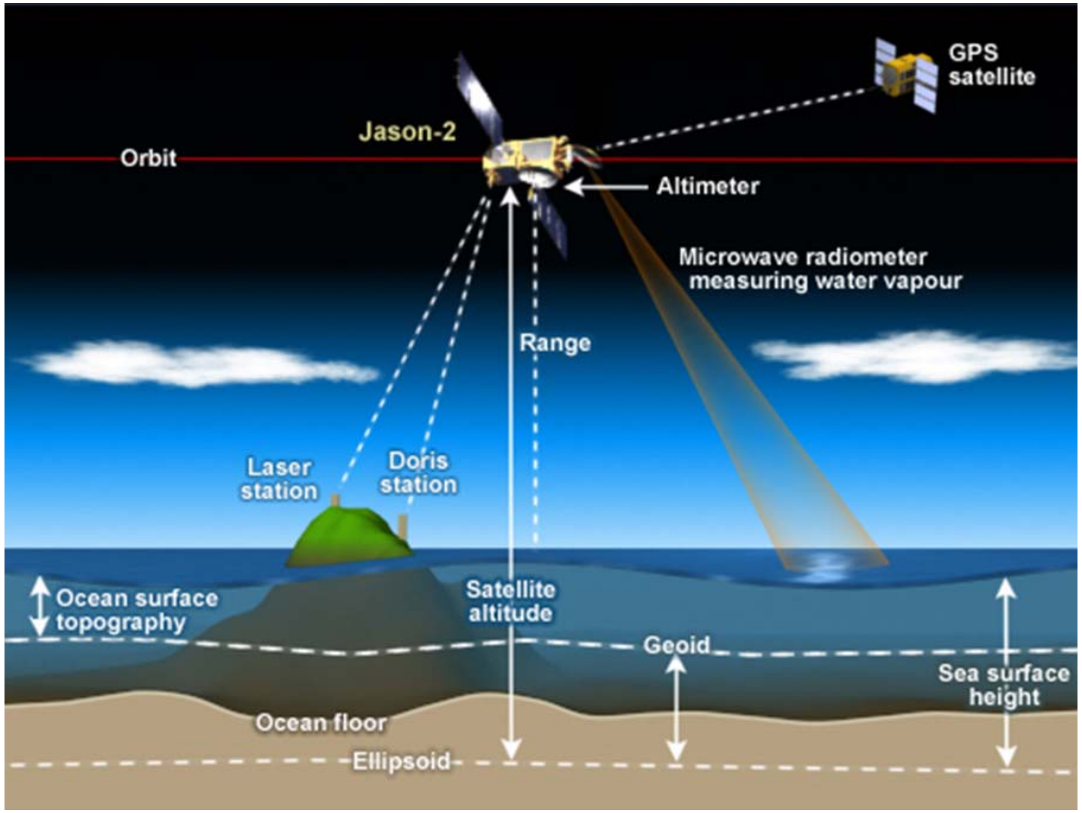


- To obtain very high-resolution imaging of the seafloor (up to cm)
- To access remote settings (i.e. canyons)

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

From satellite data



Altimetric Bathymetry

How Radar Altimetry Works –
An altimeter measures how high something is. Satellite radar altimeters measure the ocean surface height (sea level) by measuring the time it takes a radar pulse to make a round-trip from the satellite to the sea surface and back. Bathymetry is measurement of the depth of the ocean.

Mars, Venus and Earth's Moon are better mapped than Earth. These other planetary bodies have dry surfaces, making their surface topography accessible to laser or radar measurements of their elevation. Seventy percent of Earth's surface topography is under the oceans, and cannot be directly sensed by lasers or radars.

We use satellite radar altimeter measurements of the ocean surface height (sea level) to infer the presence of mountains below. Mountains on the sea floor add extra pull to Earth's gravity field, drawing more water around them and bulging the sea surface outward. This way of estimating depth we call "altimetric bathymetry".

https://www.star.nesdis.noaa.gov/socd/lsa/AltBathy/

Satellite Altimetry

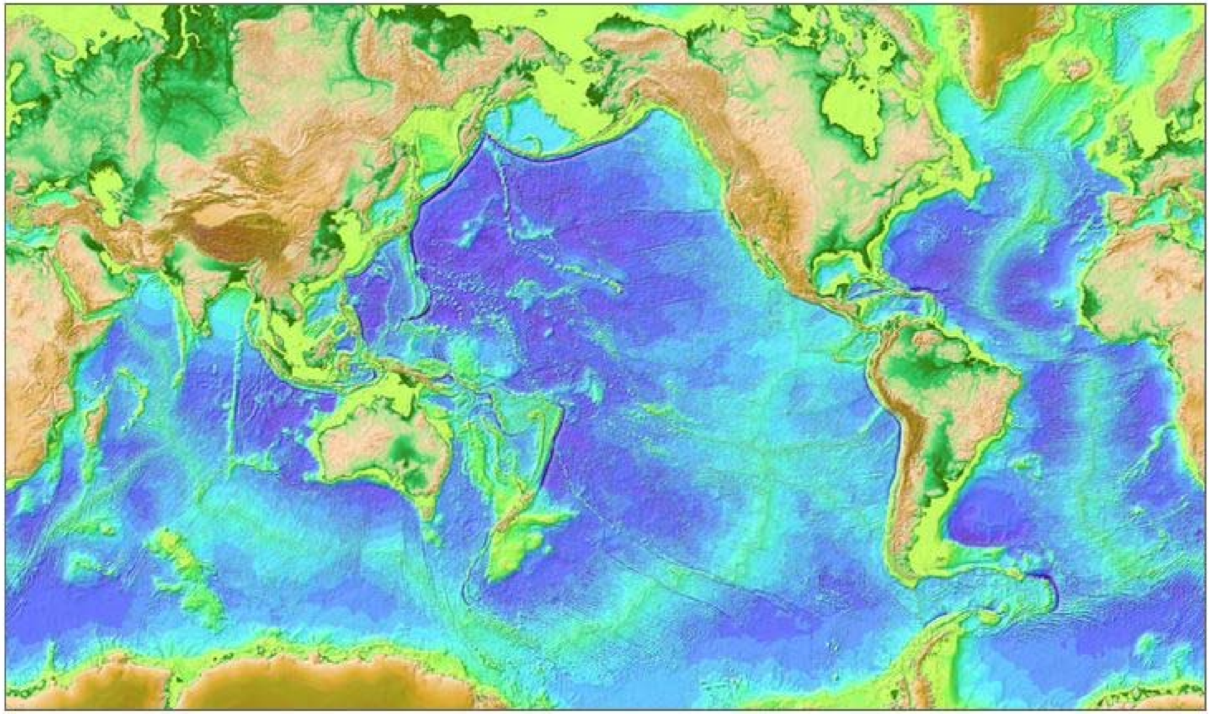
The basis of satellite altimetry is the known process of emitting a radar pulse and measuring the time it takes for the reflection to be detected. The biggest errors that mostly affect the altimetry-derived sea level are the orbit errors and errors in the environmental and geophysical corrections applied. It can be said that the satellite altimetry is unique among ocean remote sensing techniques because it provides us with much more information on the Earth`s gravitational field: the shape and the structure of the ocean floor, the integrated heat and the salt content of the ocean and the geostrophic ocean currents, than any other remote sensing technique. The global coverage measurements and the revisit time of several days makes this method one of the most frequently used. The accuracy of satellite altimetry varies between the satellites. The average claimed accuracy for global mean sea level averaged over a 10 day orbital cycle is 2-4mm. The biggest disadvantage of satellite altimetry is “the contamination of the radar signal near the coast when the reflection of the radar pulse is partly due to the ocean surface and partly to land” (Gomis, Monserat et al., 2012). As a consequence, the standard altimetry data is unreliable at distances shorter than 40 km from the coast. Whereas most debates were previously related to the resolution and the accuracy, the cost of purchasing satellite images has dropped significantly over the past years. However, there is one large disadvantage of satellite imagery: the inability to wait for improved weather conditions (i.e. cloud coverage). We are probably approaching the day when we will have both aerial cameras and Lidar systems combined in one device to provide both data at the same time.

Another advantage of satellite imagery is the fact that we can use them as a time lapse. This information is vital to humanity to realize how large our impact on the planet is as well as to understand the range of natural disasters such as hurricanes, tsunamis and fires in recent years.

https://www.star.nesdis.noaa.gov/socd/lsa/AltBathy/

Seabed topography from gravity data derived from satellite

The gravitational pull of a mountain adds to Earth's overall gravity, and this introduces small tilts in the direction that gravity pulls. By this mechanism, undersea mountains tilt sea level. We can use satellite radar measurements of sea level to detect these tilts and infer the presence of uncharted mountains below the sea surface.
This cartoon exaggerates the effect for clarity. In reality, though an undersea mountain can be a few kilometers high, the bump in sea level it produces is only a few meters high. A typical seamount tilts the sea surface by a very small angle, around 30 micro-radians. We are trying to measure these tilts to 1 micro-radian to discover the unknown topography of the sea floor. One microradian of sea surface slope means that sea level changes by 1 mm vertically for each 1 km you move horizontally. That is about 1/16th inch in one mile.

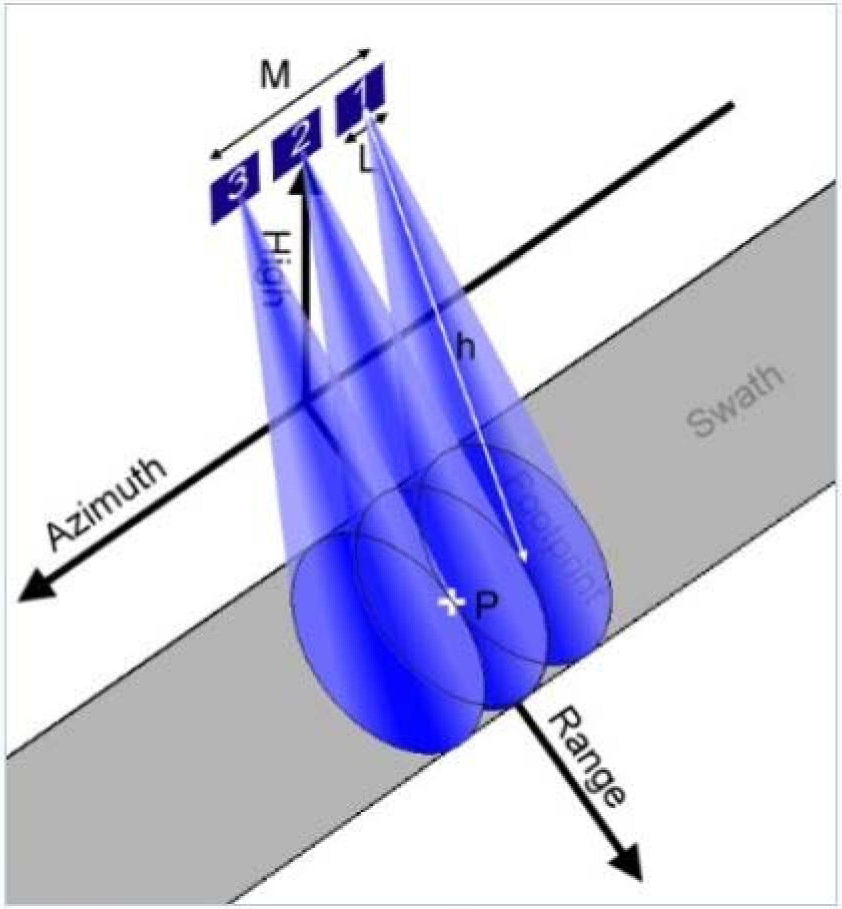


Global Seafloor Topography - measured & estimated from gravity data derived from satellite altimetry and shipboard depth soundings. (Poster available)

https://www.star.nesdis.noaa.gov/socd/lsa/AltBathy/

Using satellite data

Synthetic Aperture Radar (SAR)
SAR is a method that is used for capturing the seafloor further from the coast. SAR works by detecting the changes in the wavelengths in the deep waters. The radar works by transmitting electromagnetic waves and then collecting, digitizing and storing their echoes for later processing. The backscatter data detected by SAR depends on the roughness of the sea surface and the length scale of the roughness.



Principio di funzionamento del SAR. Lo stesso punto P è illuminato più volte dal radar in movimento.

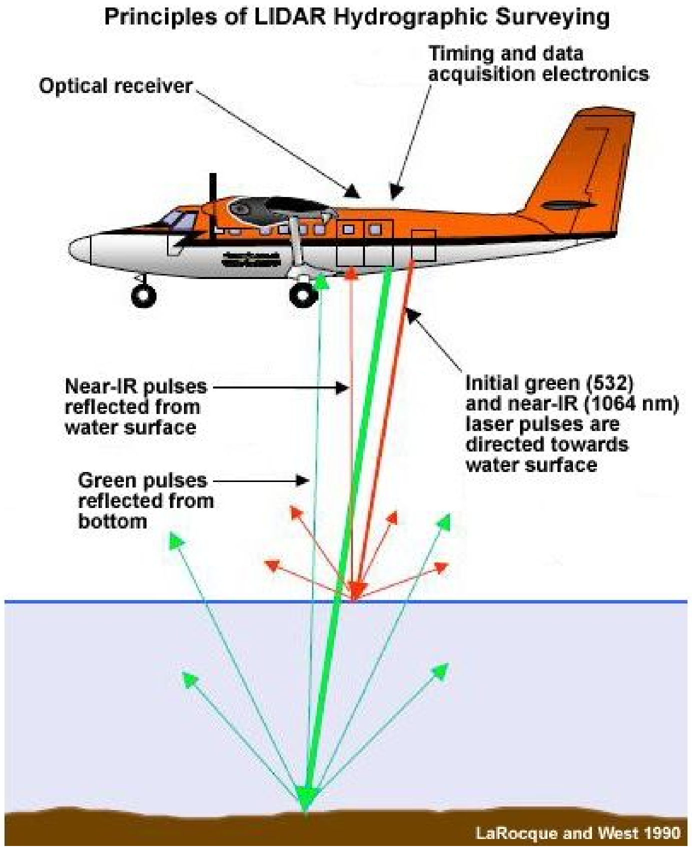
Using light - Remote sensing: airborne

Light Detection and Ranging (Lidar)

Lidar is a method that uses both **green and red light** to survey a coastal region above and below sea level. The green light penetrates into the water body and captures the seafloor, whereas the red light is not able to penetrate the water body and therefore bounces back from the water surface. By using both colours it is easy to distinguish the water surface from the water column and water body floor.

As mentioned above, the most crucial thing to take into account is the Secchi Depth. Another important consideration is the power of the system. The more powerful the Lidar system is, the more it will penetrate into the water. Therefore, the Lidar systems on the market are split into one of two types depending on their penetration into the water column. One system type is able to reach 1 to 1.5 times Secchi depth and the other 2.5 to 3 times Secchi depth. At ideal viewing conditions the sea/river bed can be detected down to around 10m depth.

Other issues for the airborne cameras and lasers are the weather condition (fog, high surface waves, rain, and sun glint), bad detection and recognition of underwater features, and the data gaps due to vegetation or suspended sediment issues with bad backscattering. These gaps need to be filled by hydrographic surveys.



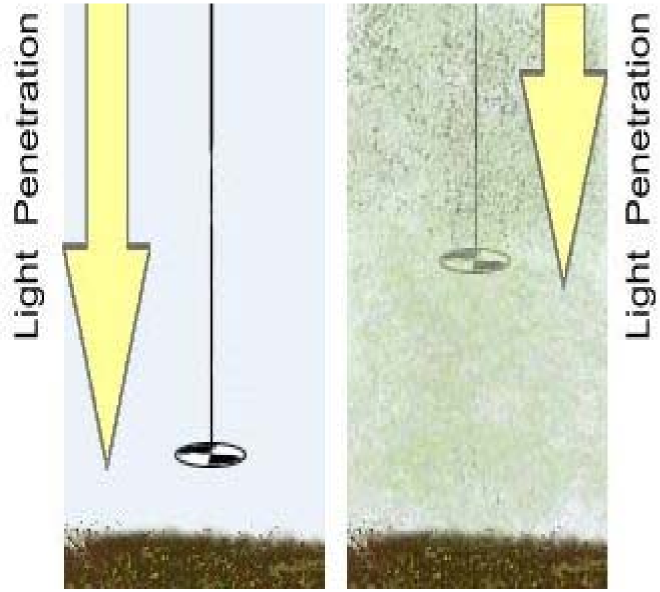
The Lidar data has a more area-wide homogeneous spread and a substantially bigger density of points per square metre when compared to the data derived from an echo sounder, SBES or MBES, which makes the morphological model produced from the Lidar data more plausible. The measurements both have: a very high-accuracy (± centimetres, depends on the depth) and a very high-resolution (between 20 to 30 points per m2). There are different types of measures describing the quality of the Lidar systems: vertical and horizontal accuracy, depth of the water measurement, distribution of the points and footprint size.

Using light - Remote sensing: airborne

Airborne Remote Sensing
When discussing airborne remote data gathering one must not forget 'Secchi Depth', the methodology used to measure water turbidity or transparency.

This measure is crucial for the accuracy of all airborne surveying techniques because it is the ability of the light to penetrate into the water. The turbidity or the transparency depends on the amount of particles within the water column.

To measure the water clarity we need a 'Secchi Disk'. The most effective seasons for measuring 'Secchi Depths' are spring and autumn (spring has slightly better Secchi depths, but autumn has a longer time window and the weather is easier to predict).



The working depth of LIDAR is limited by turbidity in the water column

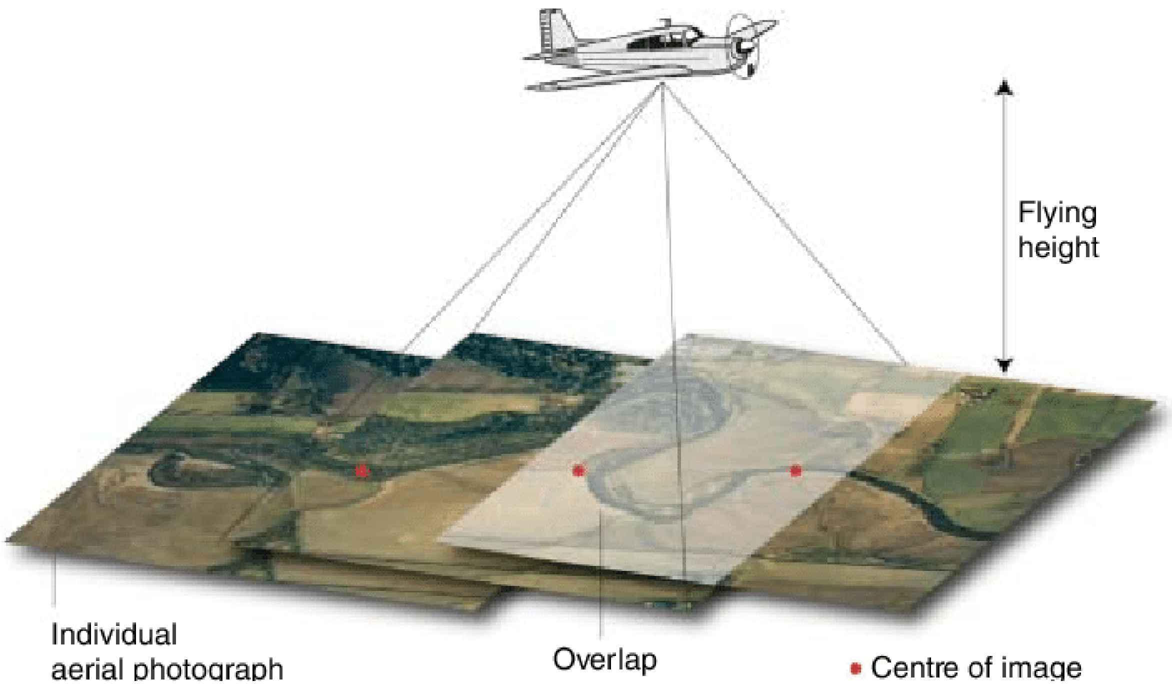
Using light - Remote sensing: airborne

Aerial Photogrammetry

Essentially photogrammetry is a combination of various aerial photography shots to create 2D or 3D models and derive measurements from them. Aerial photogrammetry is the process of taking pictures of large areas of land by mounting advanced digital cameras from the underside of an airplane.

If we compare the resolutions of aerial photography and satellite images, then the aerial photography has significantly better values. Comparing results from providers shows that Vexcel, for example, can provide aerial photography with a resolution of around 6.5cm. Satellite imagery is also quite accurate: GeoEye-1 can supply the user with panchromatic imagery down to 4.1cm resolution.

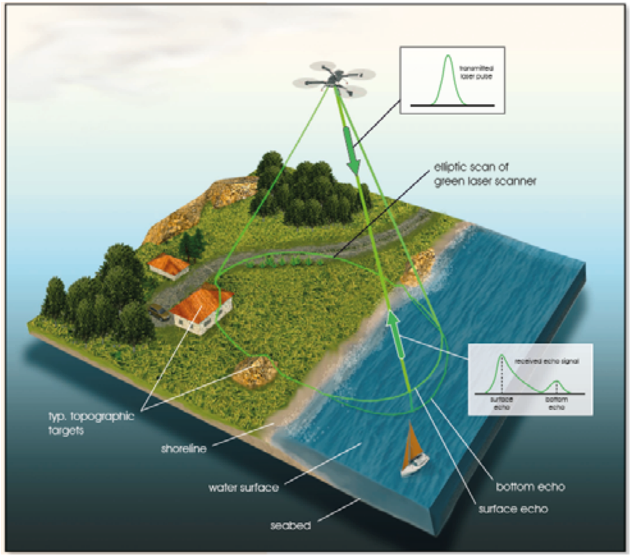
However, nowadays the resolution is just a small part of the specifications. The development of 3D models, GIS and CAD connections and the advances in automated image extraction are shifting the aerial photogrammetry to advanced work flows.



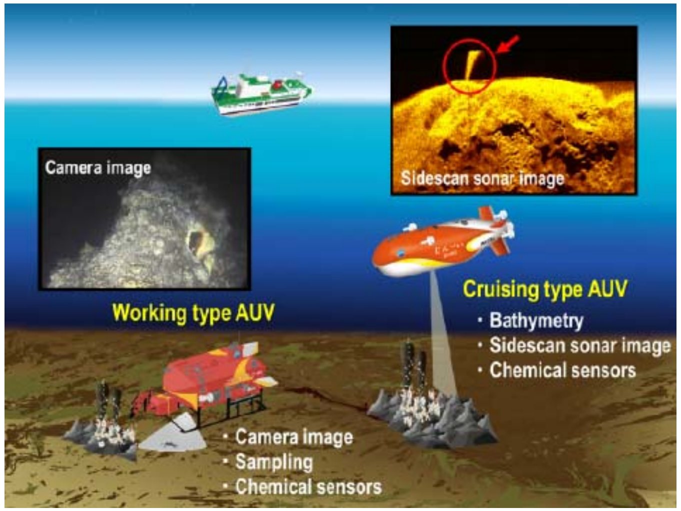
Gilvear Bryant 2016

Combining methods and data integration

Big research vessels are very expensive (50k€ a day) and maybe are not sustainable for acquisition in shallow waters /coastal areas (e.g. noise, pollution, ship traffic), **new integrated methods** (smaller, cheaper, easily deployable and possibly carbon free) can be used for acquire high resolution bathymetry to monitoring coastal areas (0-100m) and to fill the gap of the "white frame" problem.



Airborne Laser Bathymetry (LiDAR)



AUV and ROV surveys (High-resolution!)

Combining methods and data integration

Affordable Data Map
It is evident that bathymetric airborne laser scanning, photogrammetry and satellite imagery will not replace traditional hydrographic surveys, however, these techniques are complementary to shallow-water mapping.

The combined method of airborne satellite imagery, Lidar systems or aerial photogrammetry together with acoustic surveys, leads to a powerful and very effective manner to create maps of the seafloor.

This is due to the fact that the acoustic surveys in areas with shallow waters (5-10m) require significant efforts and costs and are quite often very difficult to access.

Furthermore, the overlapping between both methods can serve as a calibration and validation of the methods and as a proof of the quality of the data.

There has been great progress on many fronts including computation, knowledge, services and last but not least, in software and hardware.

So the best technique to choose depends greatly on the target and the goal.

Methods: remote sensing platforms and limitations

Satellites & planes

- Use optical/electromagnetic methods
- Satellite altimetry for broadscale map of ocean topography
- Aerial and satellite photography for coastal areas

Ships

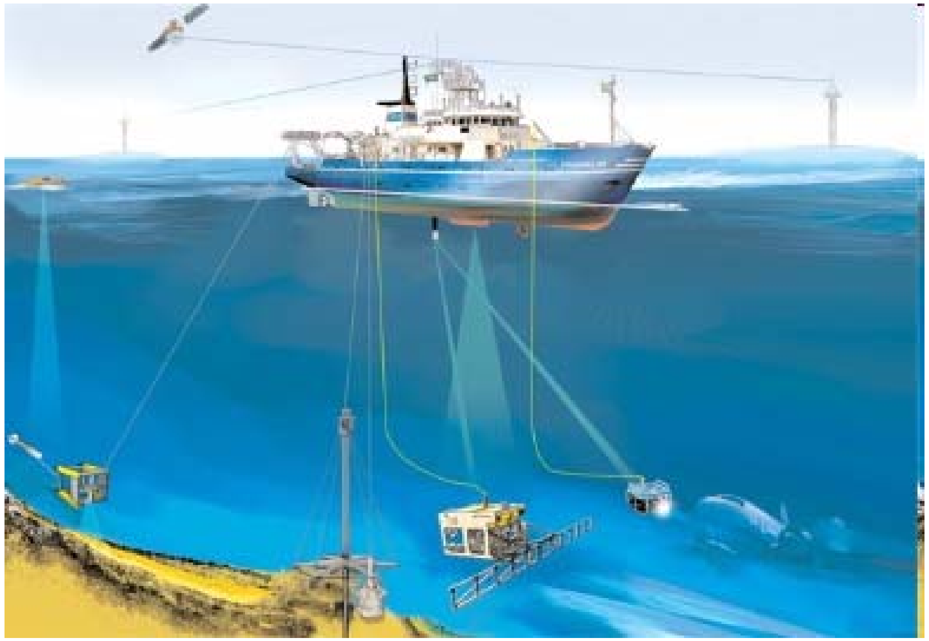
- Main platform for seabed mapping
- Good positioning (DGPS)
- Stays at sea surface: variable altitude above seabed

Towed vehicles

- Simple solution to bring instruments closer to seabed
- Large uncertainty in instrument position

Robotic vehicles (ROV, AUV)

- Bring instruments to any desired distance from seabed
- Surveys at constant altitude
- Moderate navigational accuracy



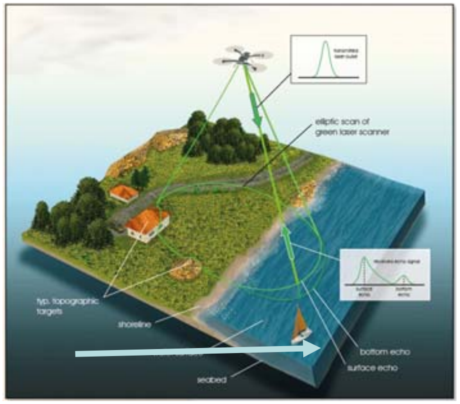
Kongsberg Maritime

Coastal monitoring of marine geohazards - future perspective

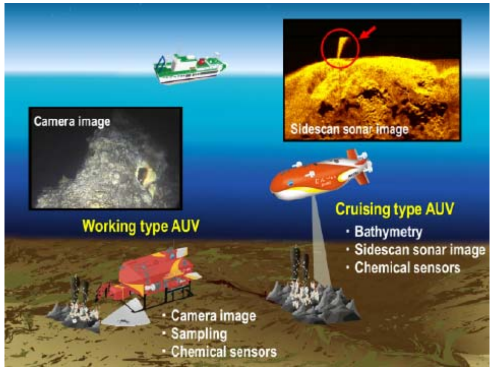
New frontiers for marine geohazard assessment :

We already have the 'big picture' (MBES regional data) and we have identified the **critical areas**, we now need

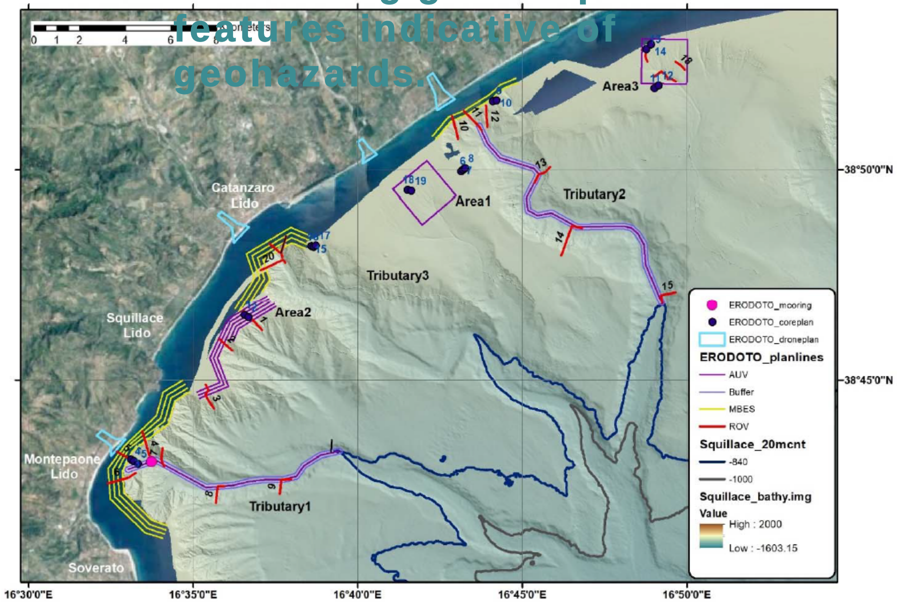
- to **fill the gap land-sea** (to solve the white frame problem)
- and to develop **long-term initiatives** to carry out **repeated surveys for monitoring geomorphic features indicative of geohazards.**

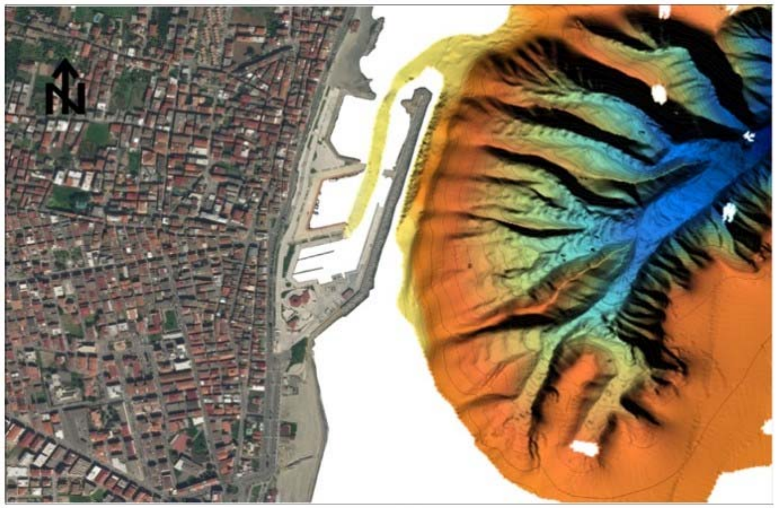


Airborne Laser Bathymetry (ALB)



Autonomous Underwater Vehicles





The example of the **Squillace** and the **Ciro'** retrogressive canyon headwalls

Seabed classification: what to map??

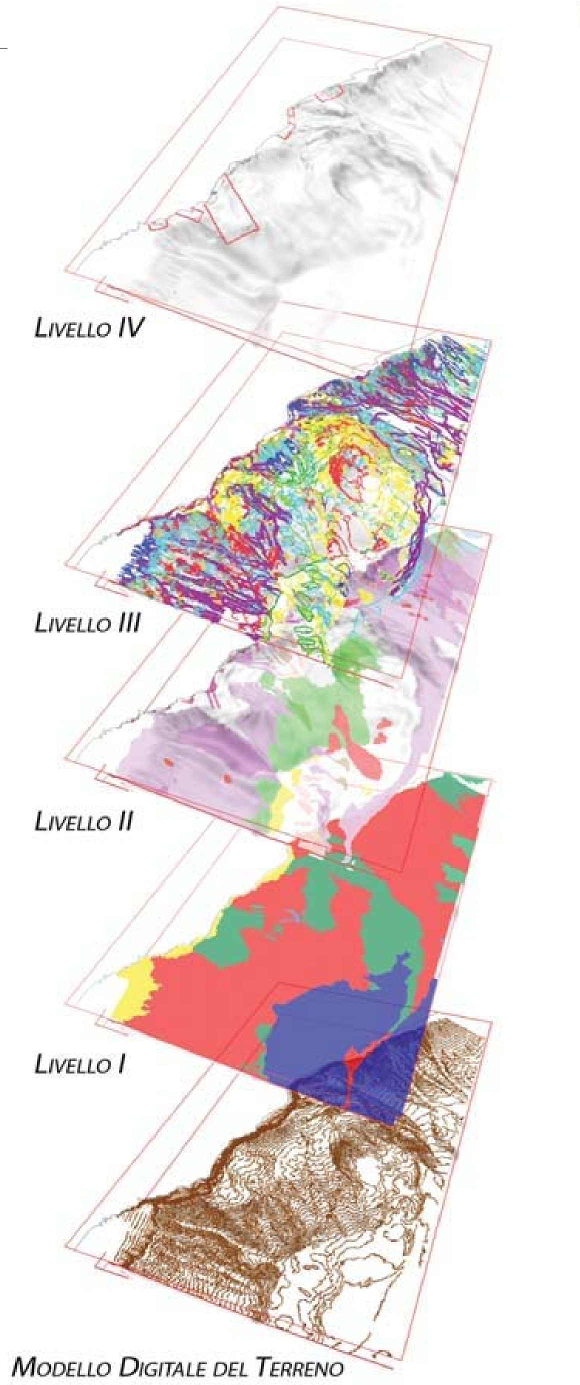
Classification maps are subject to ground verification in order to identify the compositions and bottom type that characterize each class.

Such data may come from in-situ sediment grab sampling, the use of a dredge, trawl net, visual imagery or surveys using Remotely Operated Vehicles (ROVs).

Geographic Information Systems (GIS) can be used to integrate data from different sources, including ground truth data.

The seabed classification map can be combined with other information about the area, such as fish distribution and abundance or vegetation characteristics, to establish habitat groups based on associations.

This process allows classification maps derived from multibeam data to help characterize the seabed and more effectively manage its use. (derived variables: slope, aspect, seabed rugosity, habitat patchiness…)



The MAGIC Project:

a milestone in the seafloor mapping for marine geohazards,

OGS Seminars - Trieste, 9th October 2020

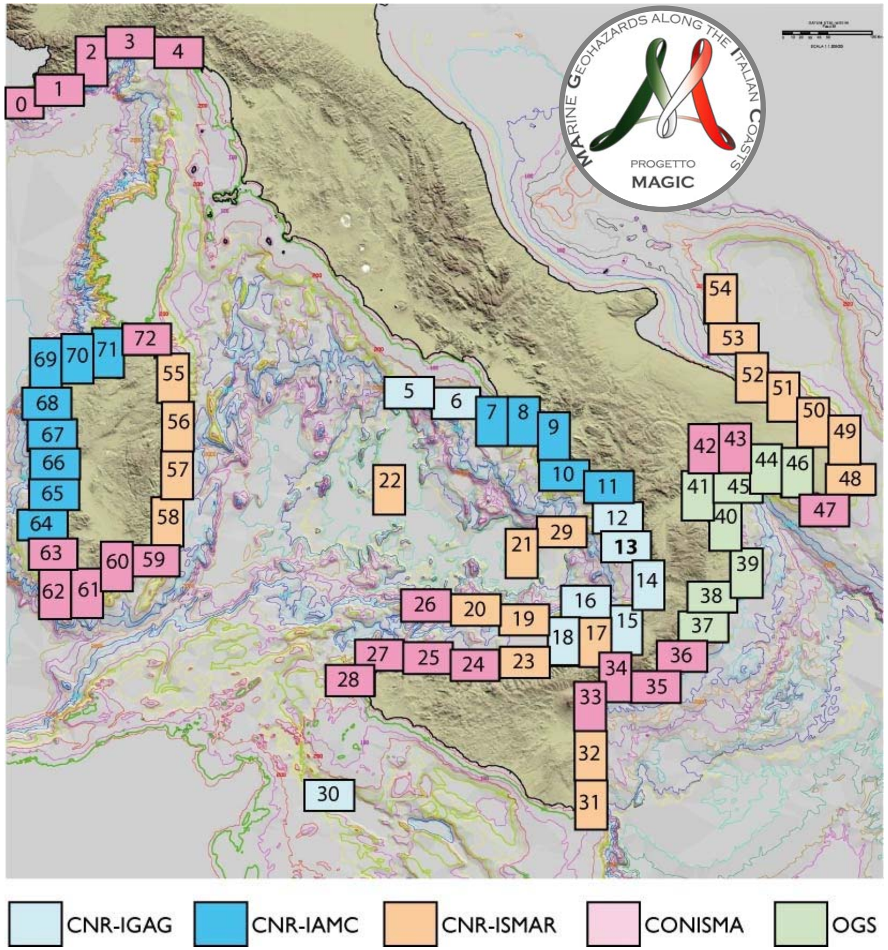
MAGIC project: *MA*rine *G*eohazards along the *I*talian *C*oasts

Aim of the Project:
Provide (for the first time) the Italian DPC with a basic tool for monitoring and managing marine geohazards (and risks) at national level.

Timeframe:
From December 2007- to June 2013
(5½-year period)

Funded by:
Italian Civil Protection Department (DPC)

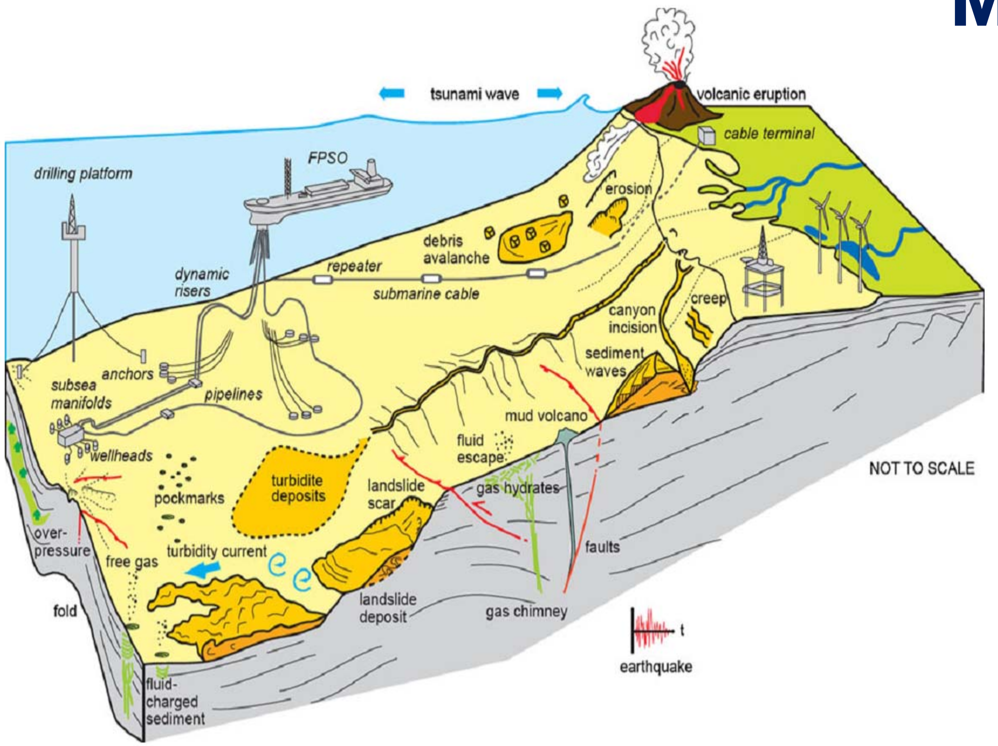
5.25 M€ direct funding +
2 M€ ship-time CNR/OGS co-funding



Seafloor mapping with Multibeam Echosounder (MBES) of the most vulnerable Italian margins in the depth range between 50-500m to produce **73 sheets 1:50.000**

presenter: Silvia CERAMICOLA – OGS Trieste, Italy

Marine geohazards

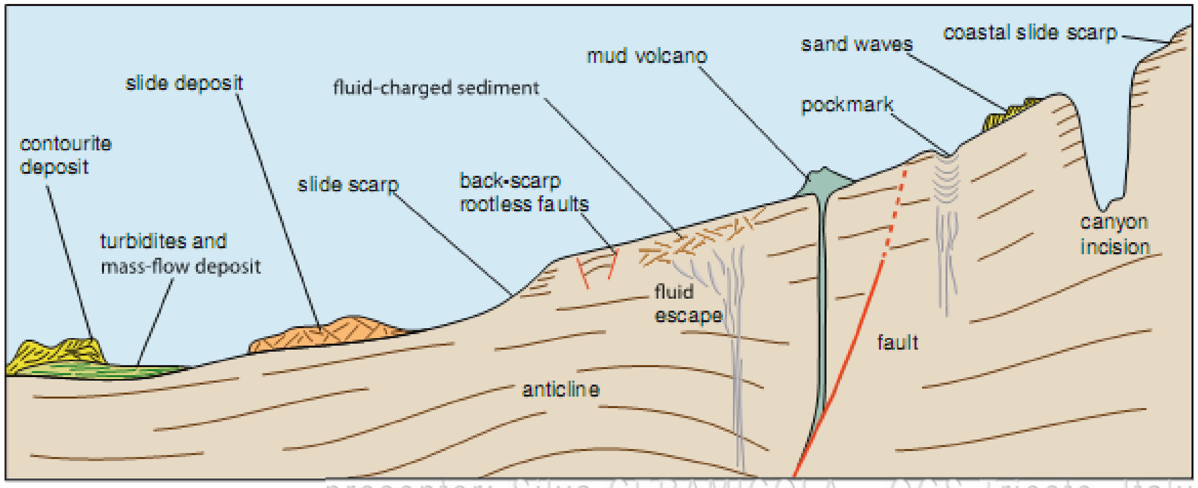


Chiocci et al. 2011

Geomorphic features are bathymetric landforms on the seabed surface and can be used 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….

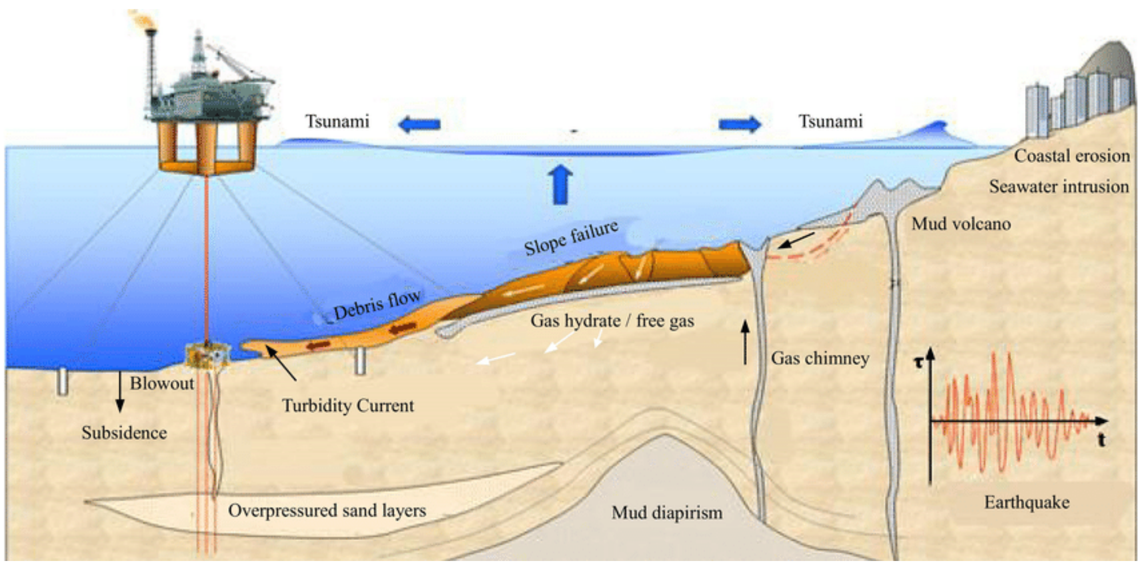
Everything that's active at sea bottom and below can create an hazard….



Chiocci and Ridente 2011

Marine geohazards

Geohazard Feature	Causative event	Effects	Consequences	Recent historical examples
Landslide scar and deposit	Sediment failure	Gravity flow	Cable break	Algeria 2003[7]
		Tsunami	Coastal inundation	Stromboli 2002[8]
Canyon head	Seafloor erosion and sediment failure	Retrogressive erosion	Coastal landslide	Finneidfjord 1996[9]
				Punta Alice 2006[10]
		Tsunami	Coastal inundation	Nice 1979[11]
		Gravity flow	Cable break	Gioia Tauro 1977[12]
Mud volcano, pockmark	Fluid escaping the seafloor	Fluidification of sediment	Weakening of soil	Patras Gulf 1993[13]
		Gas eruption	Navigation problems	Scoglio d'Affrica 2017[14]
Active faults	Earthquake	Submarine landslide	Cable break	Pingtung 2006[15]
		Land shaking	Structure collapse	Messina 1908[16]
		Tsunami	Coastal inundation	
Submarine and insular volcanoes	Eruption	Emissions in oceans and atmosphere	Navigation problems	Hierro 2011-'12[17]
	Caldera or sector collapse	Tsunami	Coastal inundation	Anak Krakatoa 2018[18]



Wang et al 2018, *energies, MDPI*

Marine geohazards are natural, real and complex and their occurrence can arm people and infrastructures

- ✓ Increasing economic use of the seabed for energy, communications and mineral resources.
- ✓ Very densely-populated coastlines of certain European regions

The *ex*-Italian Mediterranean research fleet

The whole Italian marine geological community and infrastructures were involved in the project:

Istituto di Geologia Ambientale e Geoingegneria (**IGAG- CNR**), Roma
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (**OGS**), Trieste
Istituto di Scienza del Mare (**ISMAR – CNR**), Bologna
Istituto per l’Ambiente Marino e Costiero (**IAMC- CNR**), Napoli
Sette Università del Consorzio Nazionale Interuniversitario per le scienze del Mare (**Conisma**)

Italy

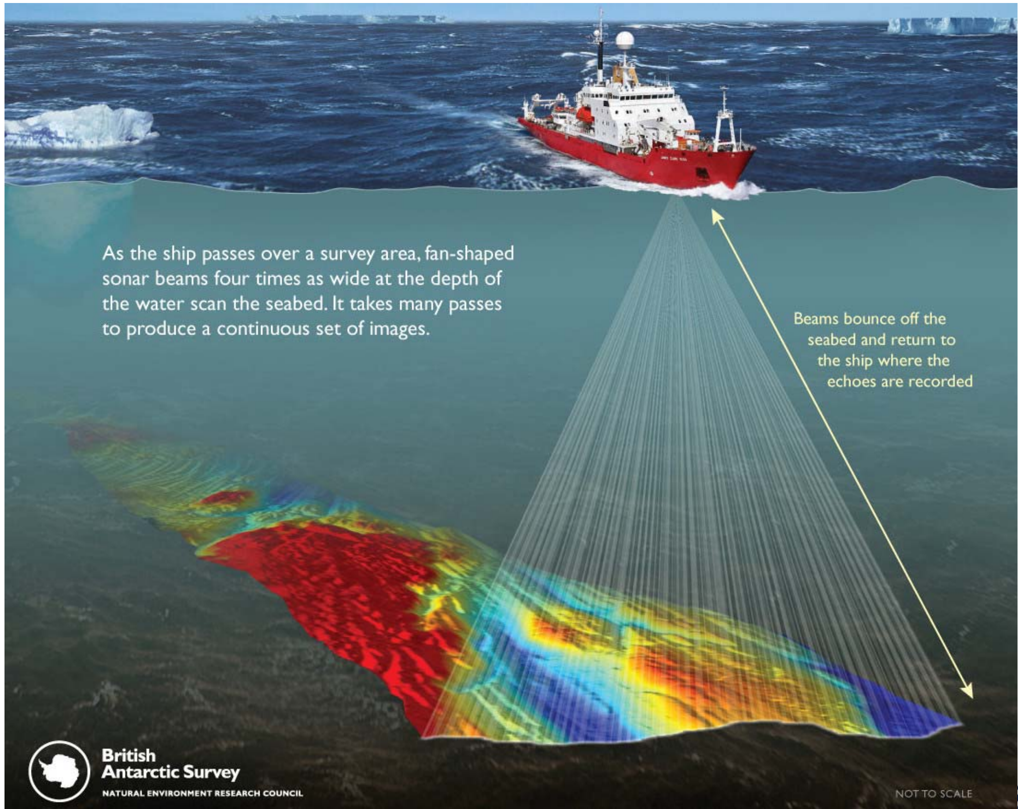
The Magic MBES acquisition and processing standards (TC)

TECHNICAL COMMITTEE UIET

shutterstock.com • 1570180501

Set the **standards** so that all the acquisitions and the data processing were carried out using **same parameters and same procedures**,

On each MAGIC survey we embarked a 1 o 2 members of the TC to make sure the **standards where accomplished** and the problems 'solved' **at the same way.**



Criteria of representation of geohazard features

How do we define criteria of objective interpretation and homogenous representation **independent from context an interpreter experience**?

1 - show all the available information, maintaining a ***good readability*** *of the map*

2 - set up criteria to define, identify and map geohazard features ***homogeneously***

3 - establish ***a hierarchy*** *among the information, trough different mapping levels*

The solution adopted was to map ALL and ONLY features having morphobathymetric expression

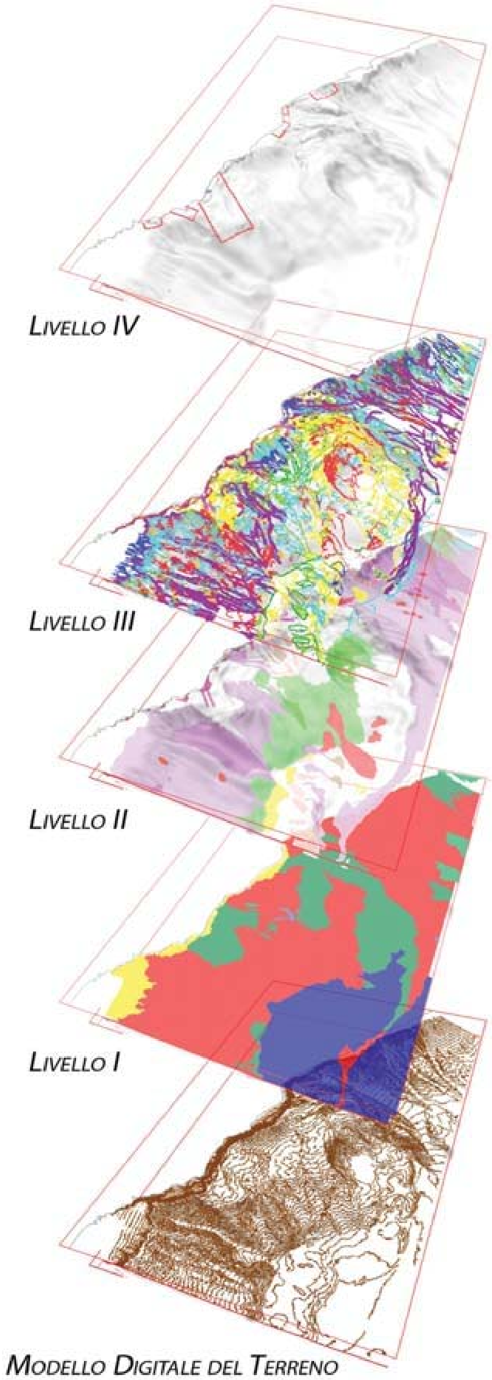
The Magic legend

LEGENDA

1.1 Ciglio di Erosione Generica
1.2 Ciglio di Nicchia di Frana Semplice
1.3 Area di Traslazione
1.4 Ciglio di Nicchia di Frana Complessa
1.5 Ciglio di Nicchia di Frana Intracanale
1.6 Bordo di Canyon
1.7 Bordo di Area a Erosione Diffusa
1.8 Ciglio di Canale Secondario o Semplice
1.9 Ciglio di Canale con Argine
1.10 Ciglio di Terrazzamento Intracanale
1.11 Ciglio di Gradino Intracanale
1.12 Ciglio di Terrazzo deposizionale
1.13 Ciglio di Scarpata di Faglia
1.14 Ciglio Indefinito
1.15 Ciglio di Piattaforma Continentale
1.16 Base di Scarpata

1.17 Bordo di Thalweg di Canale Secondario o Semplice
1.18 Bordo di Thalweg di Canyon
1.19 Letto di Canale a Profilo Arrotondato
1.20 Letto di Canale Con Profilo a V
2.1 Solco Erosivo
2.2 Area a Depressioni Erosive
2.3 Duna (Cresta/Area a)
2.4 Area a Megaripple
2.5 Onda di Sedimento (Cresta/Area a)
2.6 Impronte da Ostacolo
3.1 Deposito Intracanale
3.2 Deposito da Flusso Gravitativo non Canalizzato
3.3 Corpo di Frana a superficie regolare
3.4 Corpo di Frana a Hummocky/Area a
3.5 Corpo di Frana a Blocchi/Area a
3.6 Colata Lavica

4.1 Rilievo di Origine Incerta
4.2 Depressione di Origine Incerta
4.3 Pockmark/Area a
4.4 Area ad Espulsione di fluidi
4.5 Vulcano di fango/Area a
4.6 Diapiro di fango/Area a
4.7 Area con Fessure di Trazione
4.8 Cresta di Pieghe di Compressione/Area a
4.9 Area con Deformazioni da Creep
4.10 Cresta (lama, arrotondata)
4.11 Substrato Litoide Affiorante
4.12 Substrato Vulcanico Affiorante
4.13 Biocostruzione
4.14 Centro Eruttivo (certo/incerto)



The Magic seabed classification

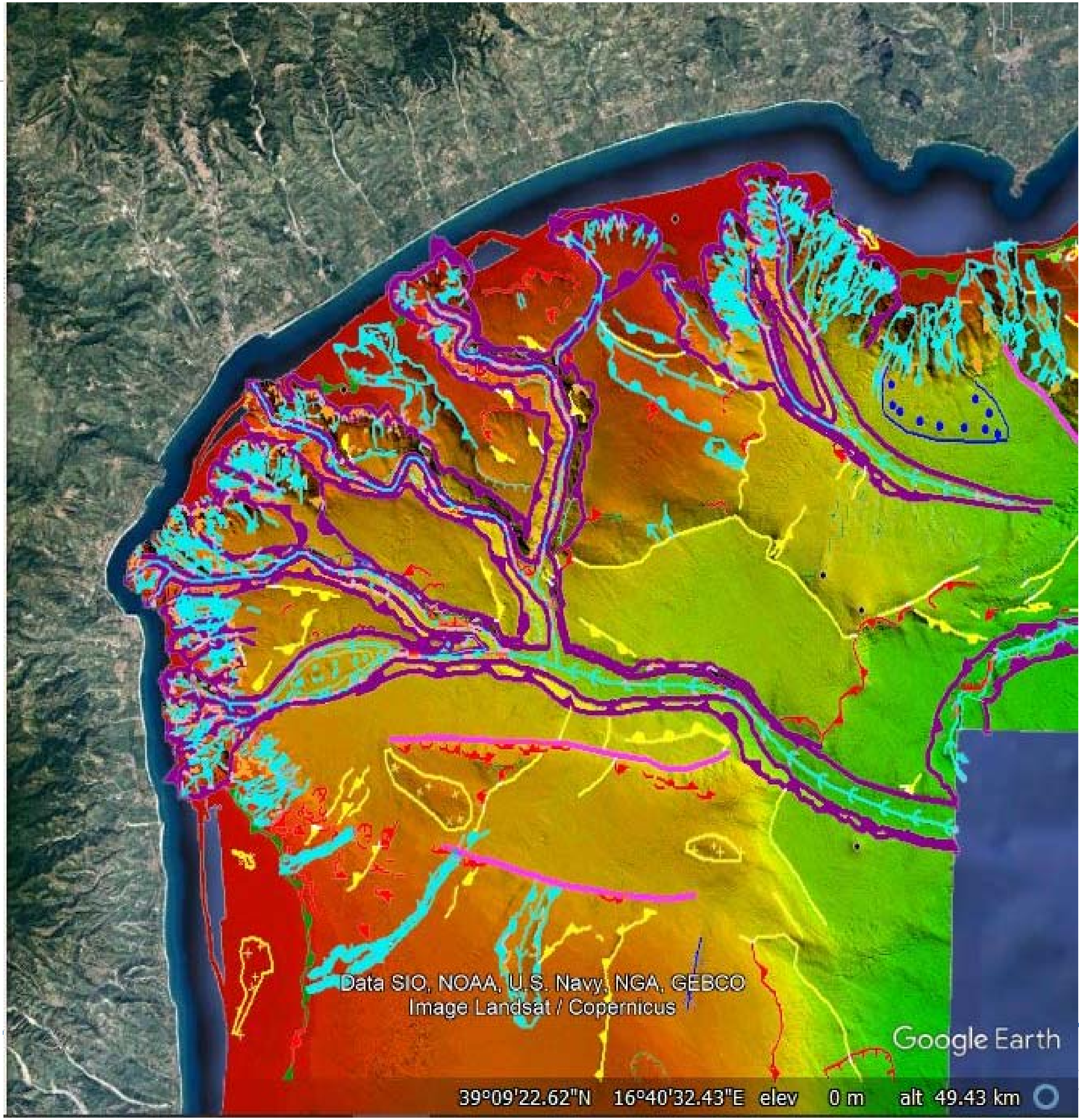
Four level representation model

1st Physiographic domains (1:250.000 areas)

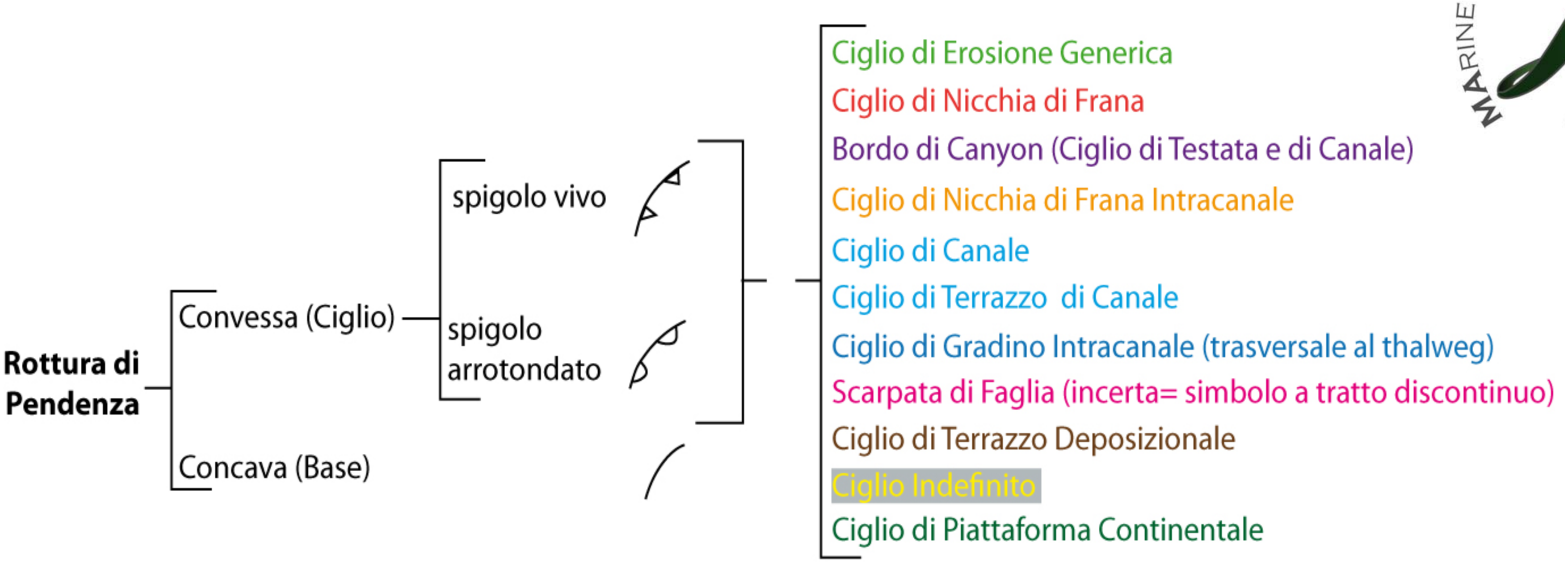
2nd Morphostructural units (1:50.000 areas + database)

3rd Morphologic features (1:50.000 vectors)

4th Critical points (detailed scale - variable highlights)


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth
39°09'22.62"N 16°40'32.43"E elev 0 m alt 49.43 km

The Magic 'Global Mapper'



3rd Morphologic features
(1:50.000 vectors)

Global Mapper

Marble Geographics

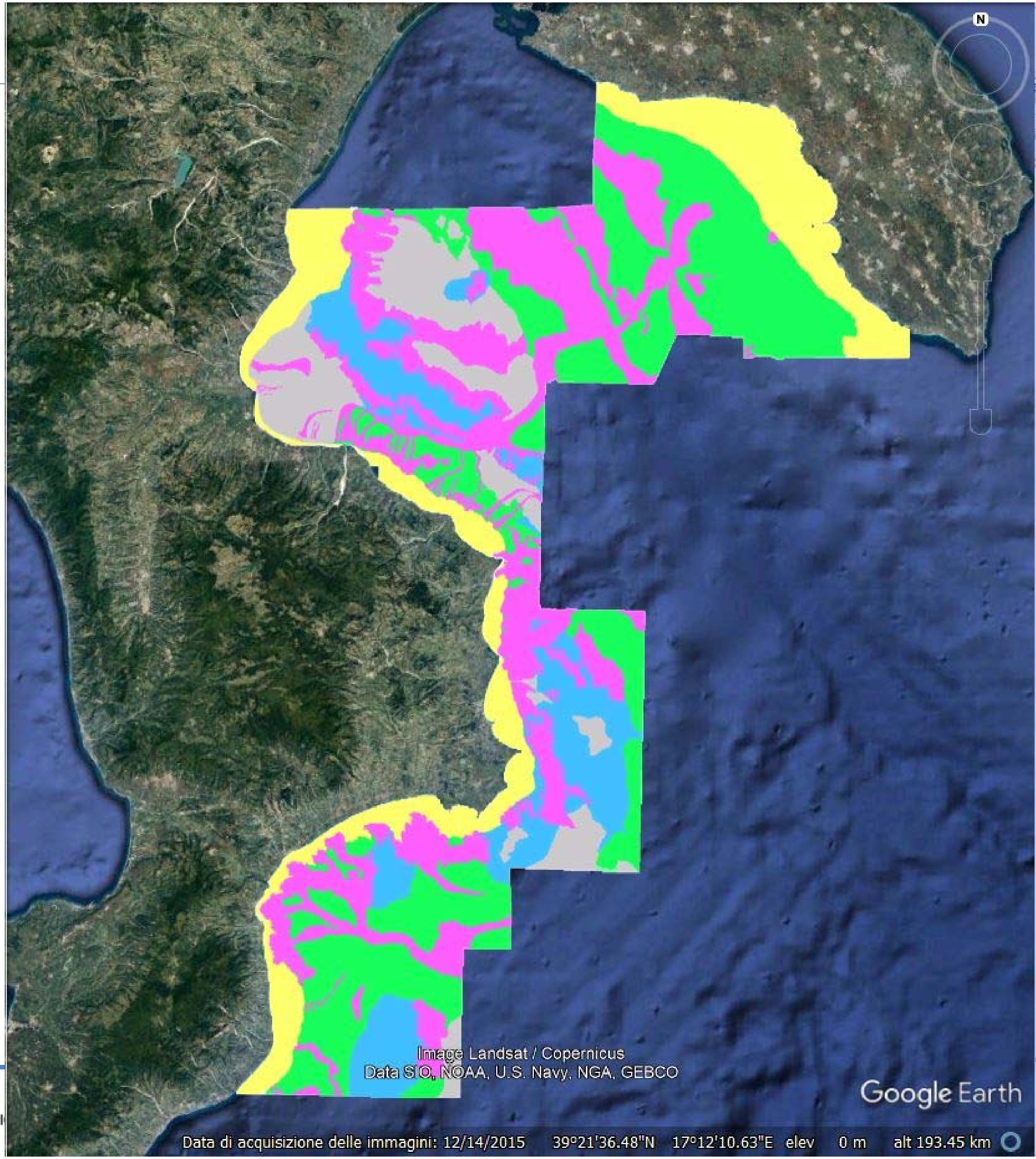


Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
Data di acquisizione delle immagini: 12/14/2015 39°21'36.48"N 17°12'10.63"E elev 0 m alt 193.45 km

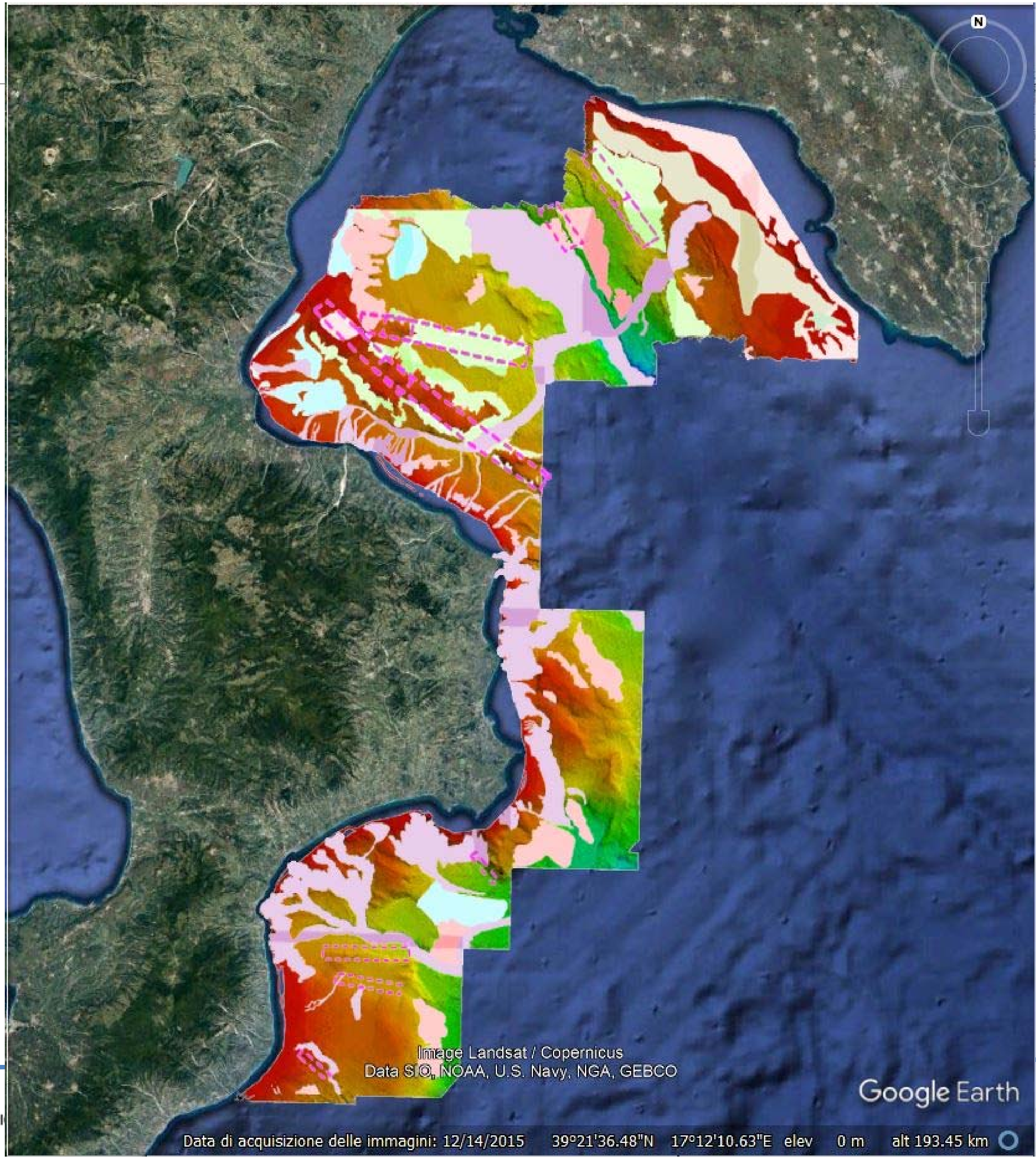

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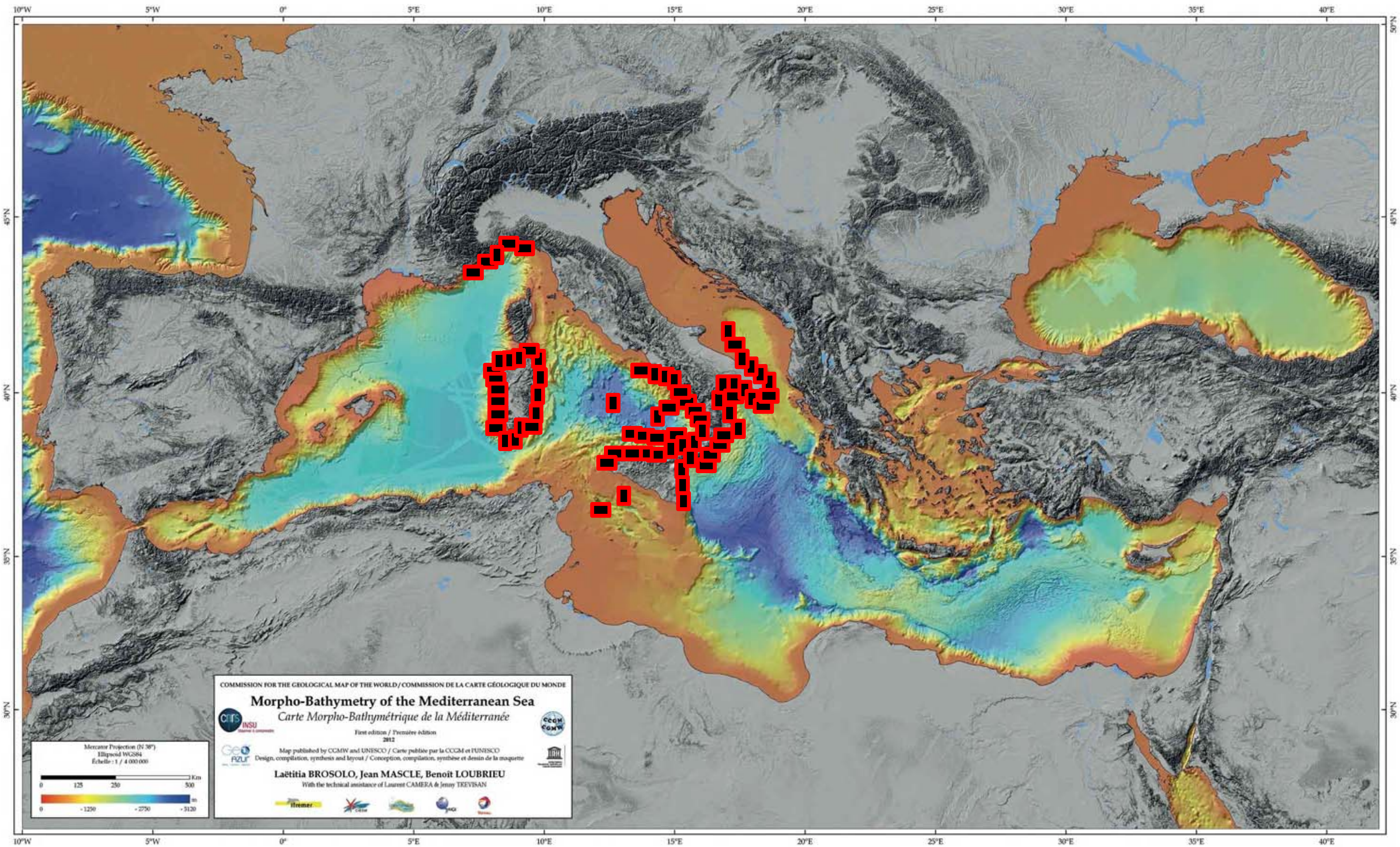
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
Data di acquisizione delle immagini: 12/14/2015 39°26'53.66"N 17°01'19.56"E elev 0 m alt 235.21 km


Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
Data di acquisizione delle immagini: 12/14/2015 39°26'53.66"N 17°01'19.56"E elev 0 m alt 235.21 km


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth
ta di acquisizione delle immagini: 12/14/2015 38°50'19.59"N 16°48'08.66"E elev 0 m alt 49.43 km

MAGIC contribution to seabed compilation of the Mediterranean sea



The lesson learned from MAGIC

Strengths

- **Defragmented** the Italian scientific community
- Favoured **coordi... activities** of... vessels a... differen...
- Create... **seab...** proces... became... the Med (a...
- Provided the D... **maps of the mari... geohazards** of the most critical Italian continental margins.

Weaknesses

- We did not have funding to ...he **'white frame'** ...area for ...e ...rd
- ...did not succeed to reach **policymakers and stakeholders**

....In the meantime there are no more Italian research vessels available in the Mediterranean Sea
to acquire new geophysical data...

Sub-surface seabed classification

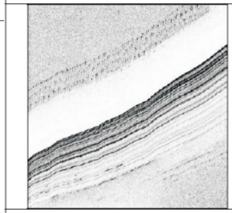
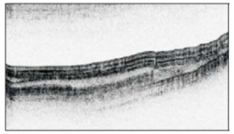
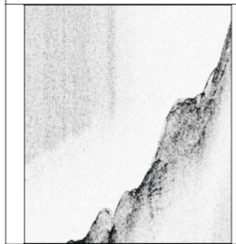
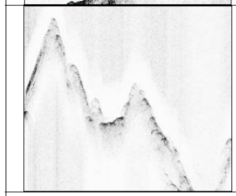
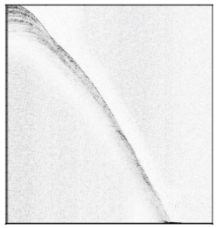
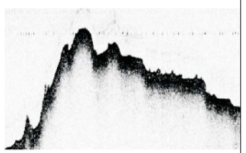
Sub-surface seabed classification is commonly referred to as sub-bottom profiling and is generally used for geological assessment of the sub-surface characteristics.

Sub-bottom profiling can return information from tens to hundreds of meters below the seafloor.

From sub-surface classifications, scientists and engineers can characterize rock and sediment types, as well as pore fluids.

This information is used for many applications, such as slope failure analysis and hydrocarbon exploration.

ECHOFACIES ANALYSES

FACIES ACUSTICA	NOME	DESCRIZIONE	INTERPRE-TAZIONE	PROCESSI SEDIMENTARI
	Bedded BB	Orizzonti piano-paralleli, continui, di ampiezza decrescente verso il basso fino a facies acustica trasparente.	Torbiditi, emipelagiti, o contouriti	Correnti di torbida o sedimentazione emipelagica o sedimentazione da correnti di fondo
	Buried Transparent Bedded BTB	Facies acustica composta da una unità superiore e inferiore tipicamente Bedded (BB) con intercalata una o più unità trasparenti.	Debris flows seppelliti	Mass wasting (mass flow) + Correnti di torbida o sedimentazione emipelagica o sedimentazione da correnti di fondo
	Chaotic C	Facies acustica da trasparente a caotica passante verso il basso a riflettori piano-paralleli discontinui e di bassa ampiezza. Presenza di iperboli di diffrazione in corrispondenza del fondale.	Prodotti di mass wasting (Slides, debris flows)	Erosione e rideposizione dovuti a mass wasting: (slumps, slides & debris flows)
	Hyperbolae H	Facies acustica composta da iperboli di diffrazione larghe e irregolari in corrispondenza del fondale e del sottofondo.	Nicchie di distacco o scarpata di testata di canyon (slope artifacts)	Testate di canyon in erosione e retroattive
	Slope S	Facies acustica caratterizzata da un riflettore di bassa ampiezza e relativamente continuo sul fondo mare e un sottofondo trasparente. La facies passa a Bedded (BB) verso l'alto del pendio	Copertura sedimentaria indisturbata su pendii molto ripidi	Sedimentazione emipelagica o sedimentazione da correnti di fondo su pendii ripidi
	Rough R	Facies acustica caratterizzata da un riflettore del fondo continuo e a elevata ampiezza. Facies acustica sorda	Segnale riconducibile e sia a depositi grossolani non consolidati, sia ad affioramenti rocciosi, sia a banchi di coralli	Correnti di torbida, o substrato roccioso sedimentario o cristallino o banchi corallini

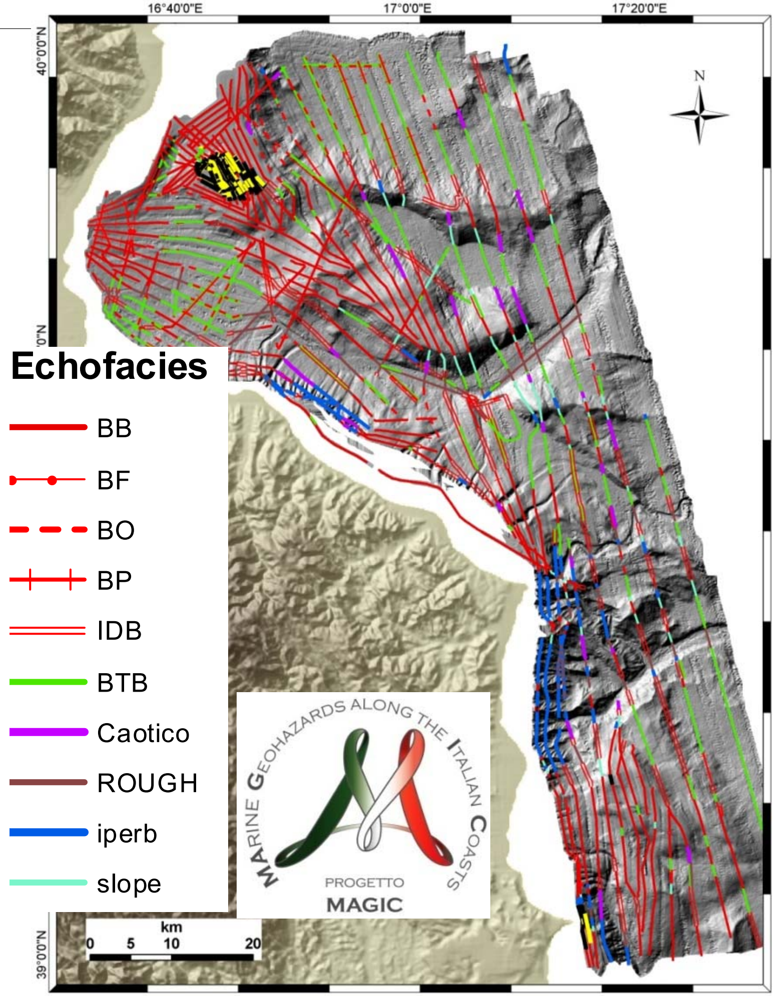
La definizione degli ambienti deposizionali e relativi depositi delle unità affioranti e delle unità recenti depositate sul margine è stata ricavata dall'interpretazione delle echo-facies sismiche osservate nei pro fili sub-bottom.

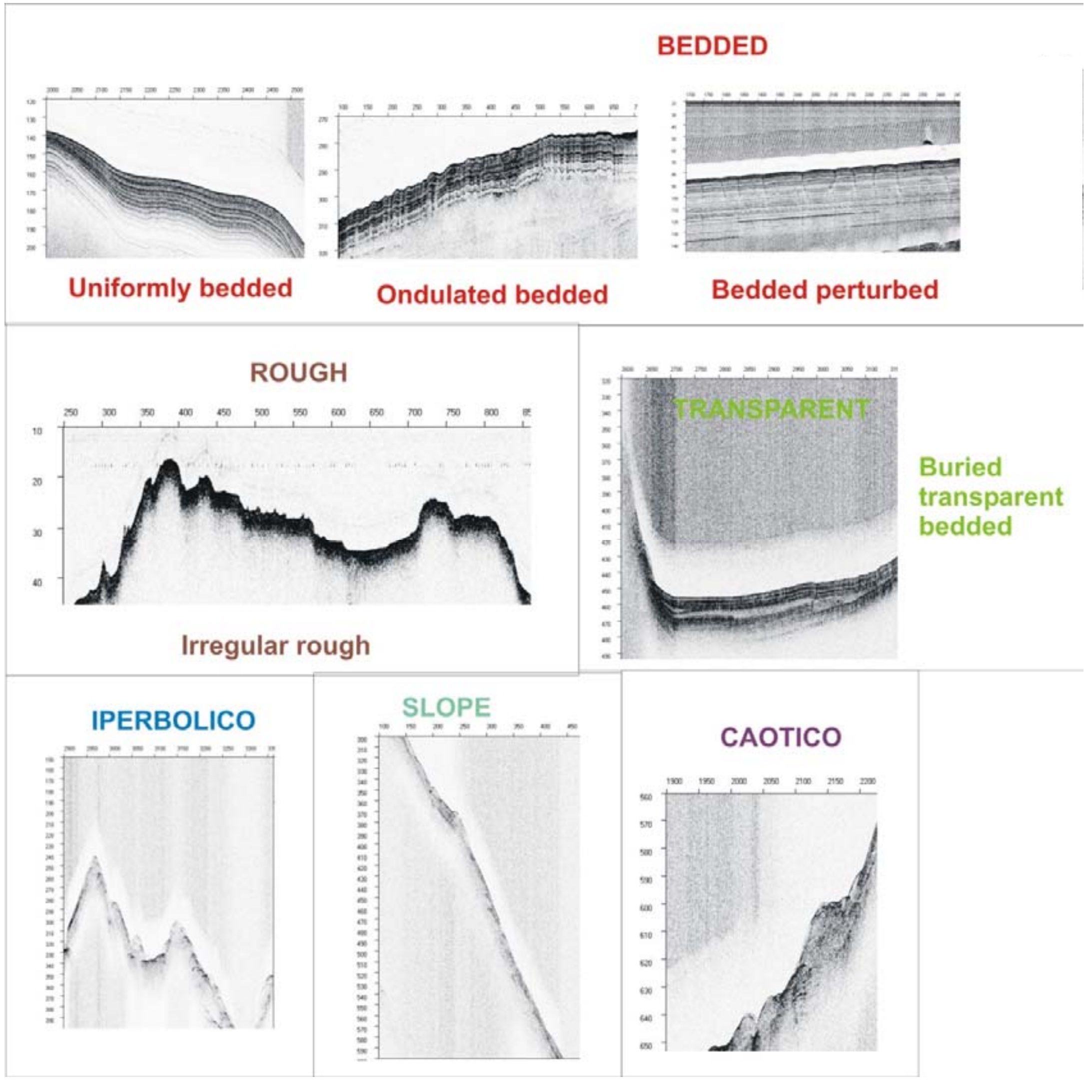
Il metodo consiste nella mappatura delle facies acustiche identificate sui profili Chirp utilizzando il contesto fisiografico fornito dal rilievo morfobatimetrico.

Questo metodo utilizza la complementarietà delle informazioni ricavate dallo studio del rilievo morfobatimetrico di un'area di fondo mare e dal carattere acustico dei sedimenti marini rilevati nella parte più superficiale (100/300 m) delle prospezioni sismiche.

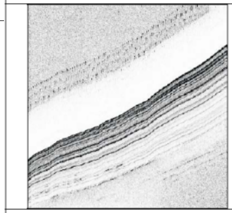
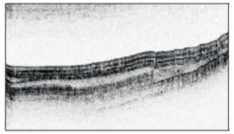
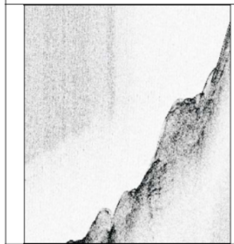
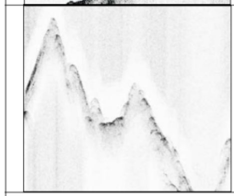
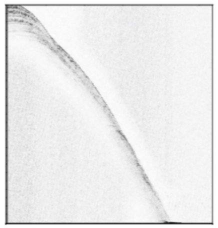
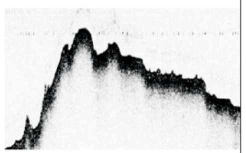
Il metodo (modified after Damuth 1975) permette di identificare i principali pattern deposizionali e i processi a loro associati, avvenuti a partire dal tardo Pleistocene e di capire se questi processi siano stati controllati tettonicamante o meno.

ECHOFACIES ANALYSES





ECHOFACIES ANALYSES

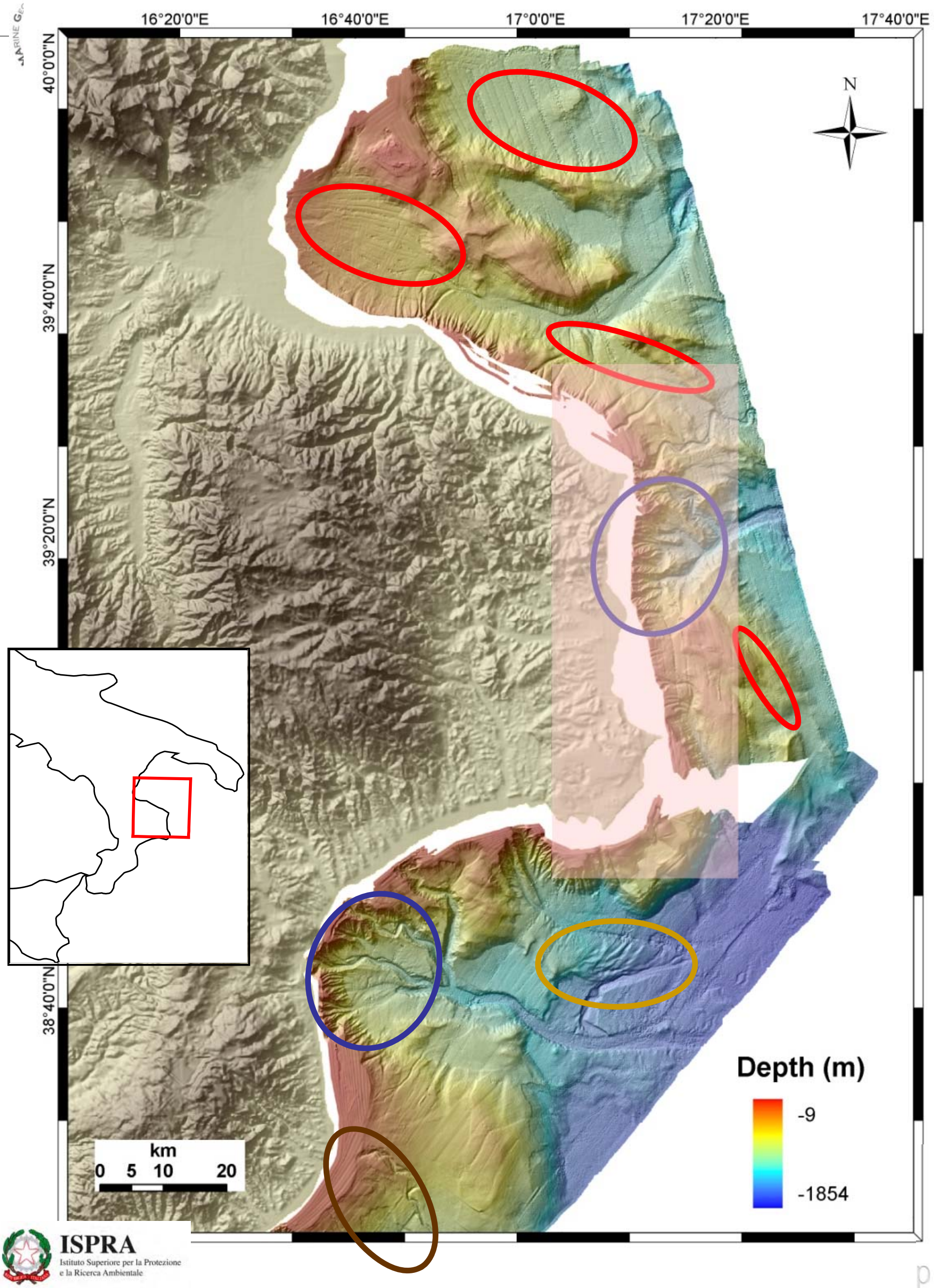
FACIES ACUSTICA	NOME	DESCRIZIONE	INTERPRE-TAZIONE	PROCESSI SEDIMENTARI
	Bedded BB	Orizzonti piano-paralleli, continui, di ampiezza decrescente verso il basso fino a facies acustica trasparente.	Torbiditi, empelagiti, o contouriti	Correnti di torbida o sedimentazione emipelagica o sedimentazione da correnti di fondo
	Buried Transparent Bedded BTB	Facies acustica composta da una unità superiore e inferiore tipicamente Bedded (BB) con intercalata una o più unità trasparenti.	Debris flows seppelliti	Mass wasting (mass flow) + Correnti di torbida o sedimentazione emipelagica o sedimentazione da correnti di fondo
	Chaotic C	Facies acustica da trasparente a caotica passante verso il basso a riflettori piano-paralleli discontinui e di bassa ampiezza. Presenza di iperboli di diffrazione in corrispondenza del fondale.	Prodotti di mass wasting (Slides, debris flows)	Erosione e rideposizione dovuti a mass wasting: (slumps, slides & debris flows)
	Hyperbolae H	Facies acustica composta da iperboli di diffrazione larghe e irregolari in corrispondenza del fondale e del sottofondo.	Nicchie di distacco o scarpata di testata di canyon (slope artifacts)	Testate di canyon in erosione e retroattive
	Slope S	Facies acustica caratterizzata da un riflettore di bassa ampiezza e relativamente continuo sul fondo mare e un sottofondo trasparente. La facies passa a Bedded (BB) verso l'alto del pendio	Copertura sedimentaria indisturbata su pendii molto ripidi	Sedimentazione emipelagica o sedimentazione da correnti di fondo su pendii ripidi
	Rough R	Facies acustica caratterizzata da un riflettore del fondo continuo e a elevata ampiezza. Facies acustica sorda	Segnale riconducibile sia a depositi grossolani non consolidati, sia ad affioramenti rocciosi, sia a banchi di coralli	Correnti di torbida, o substrato roccioso sedimentario o cristallino o banchi corallini

La definizione degli ambienti deposizionali e relativi depositi delle unità affioranti e delle unità recenti depositate sul margine è stata ricavata dall'interpretazione delle echo-facies sismiche osservate nei pro fili sub-bottom.

Il metodo consiste nella mappatura delle facies acustiche identificate sui profili Chirp utilizzando il contesto fisiografico fornito dal rilievo morfobatimetrico.

Questo metodo utilizza la complementarietà delle informazioni ricavate dallo studio del rilievo morfobatimetrico di un'area di fondo mare e dal carattere acustico dei sedimenti marini rilevati nella parte più superficiale (100/300 m) delle prospezioni sismiche.

Il metodo (modified after Damuth 1975) permette di identificare i principali pattern deposizionali e i processi a loro associati, avvenuti a partire dal tardo Pleistocene e di capire se questi processi siano stati controllati tettonicamente o meno.



MASS TRANSPORT PROCESSES

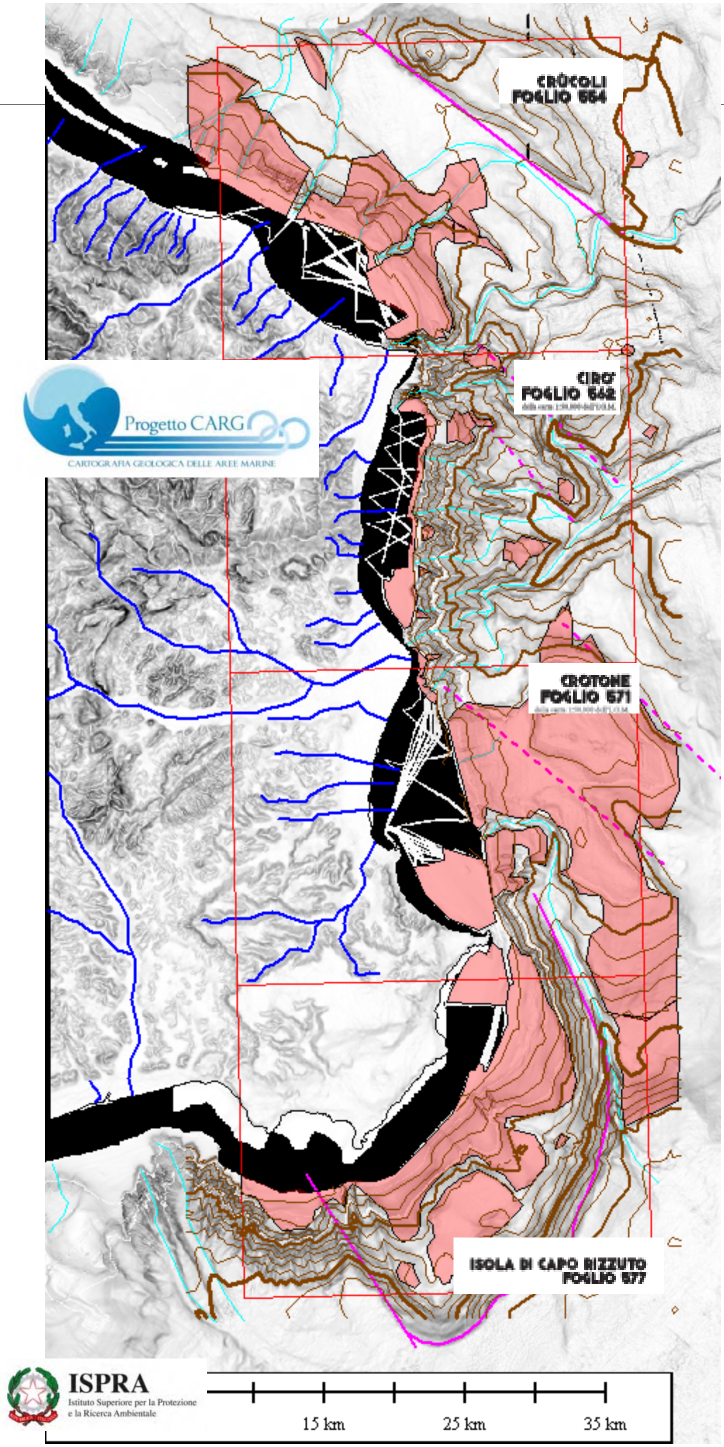
1 MTCs within intra-slope basins
Northern margin:
slide scars at seabed,
buried deposits in intra-slope basins

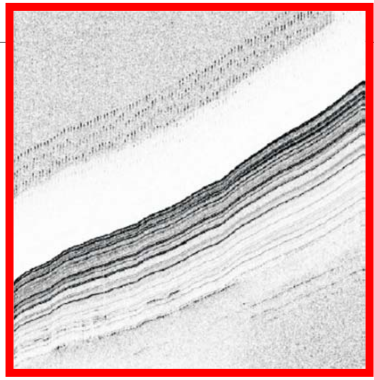
2 Slide scars on steep slopes
Southern margin:
multiple slide scars at seabed

3 Gravity sliding above evaporites (?)
Southern margin:
elongate features, parallel to slope, above diapiric structures

4 Canyon headwalls
Numerous small scarps up to 50m high

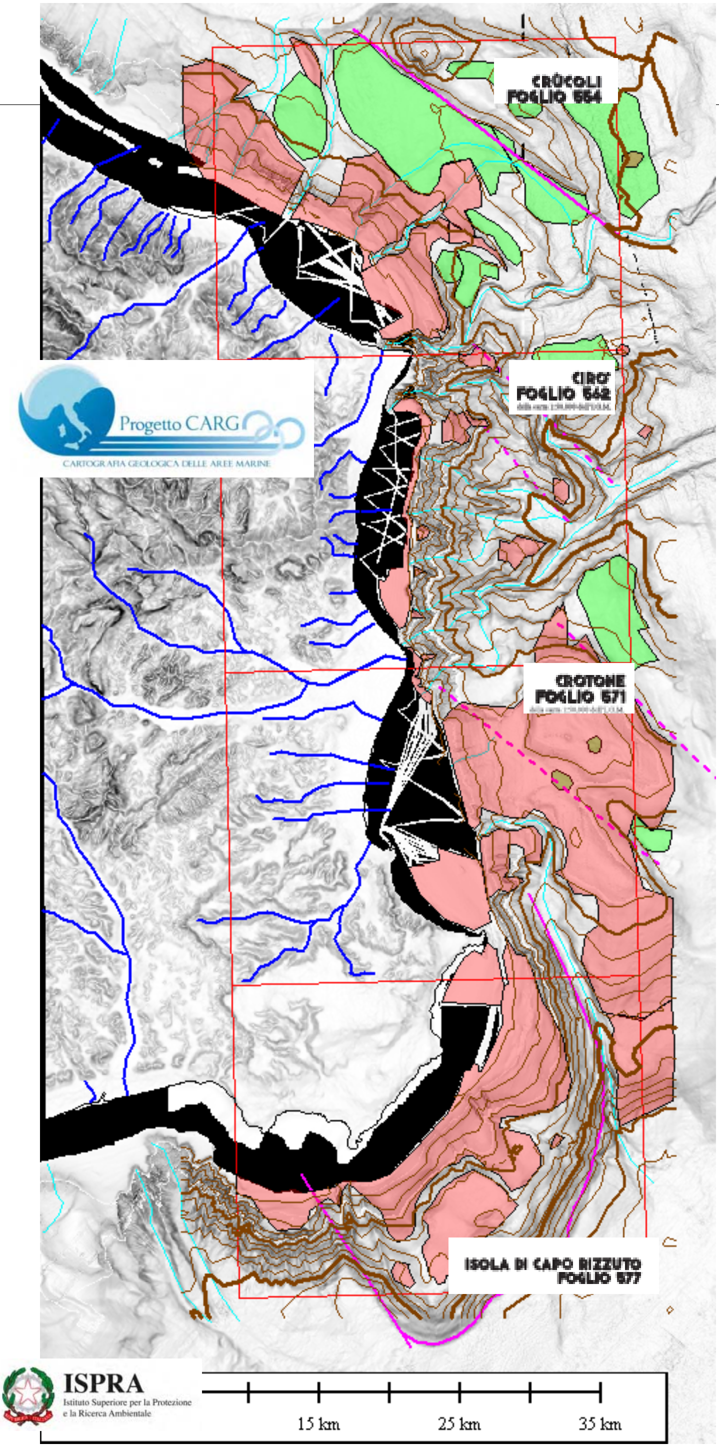
ECHOFACIES ANALYSES

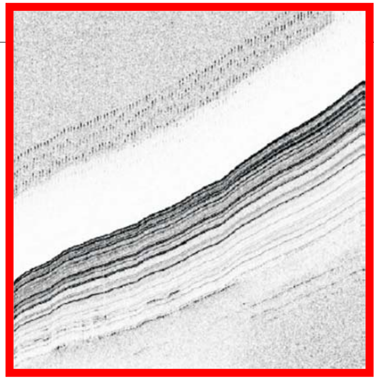




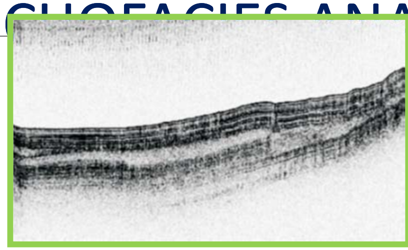
Uniformly bedded

ECHOFACIES ANALYSES



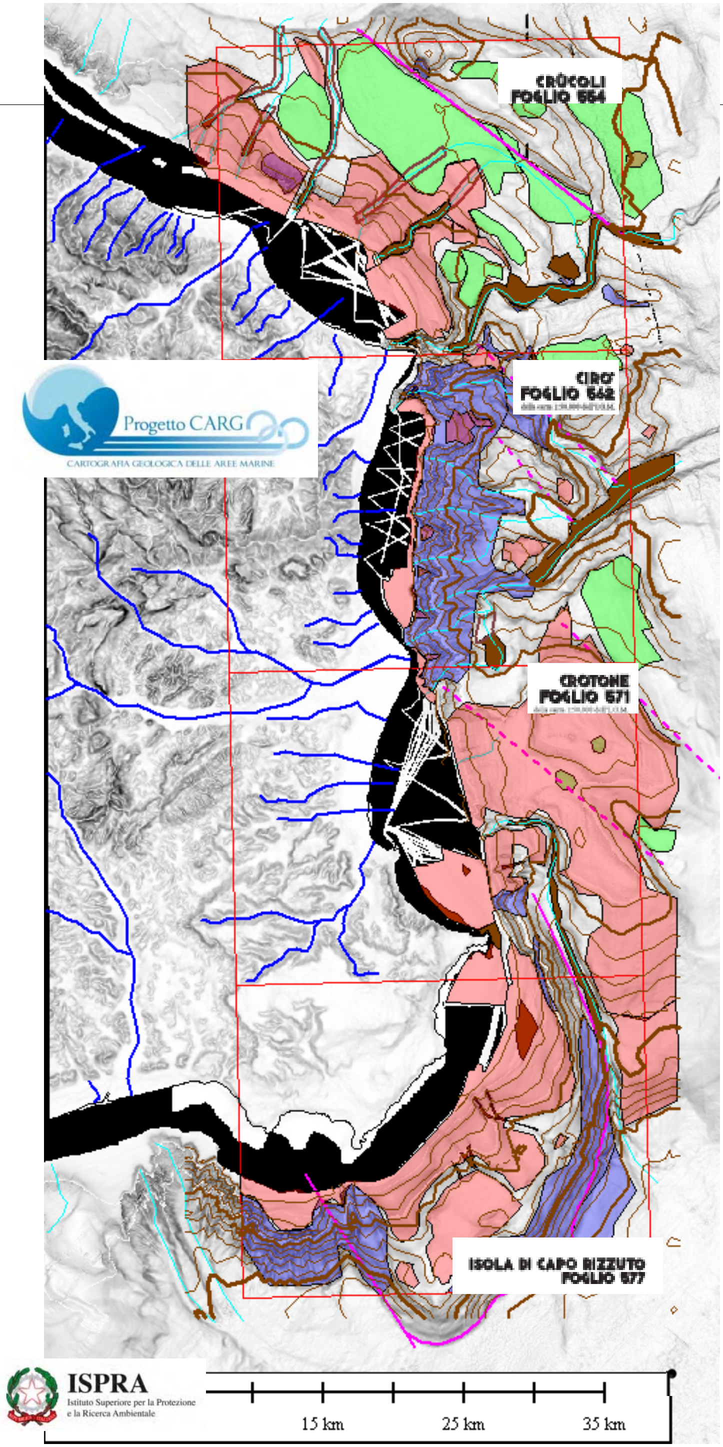


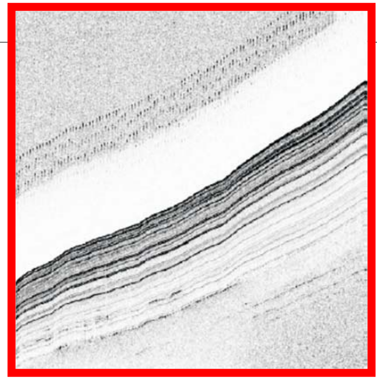
Uniformly bedded



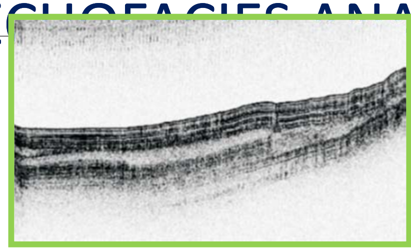
Bedded
buried transparent

ECHOFACIES ANALYSES



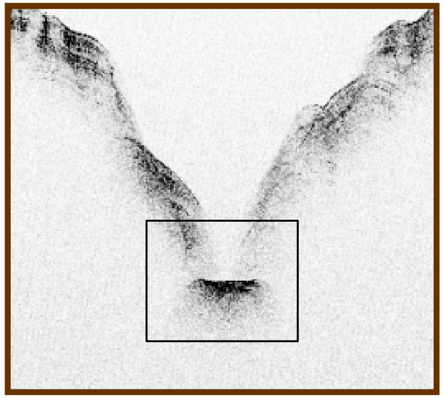


Uniformly bedded



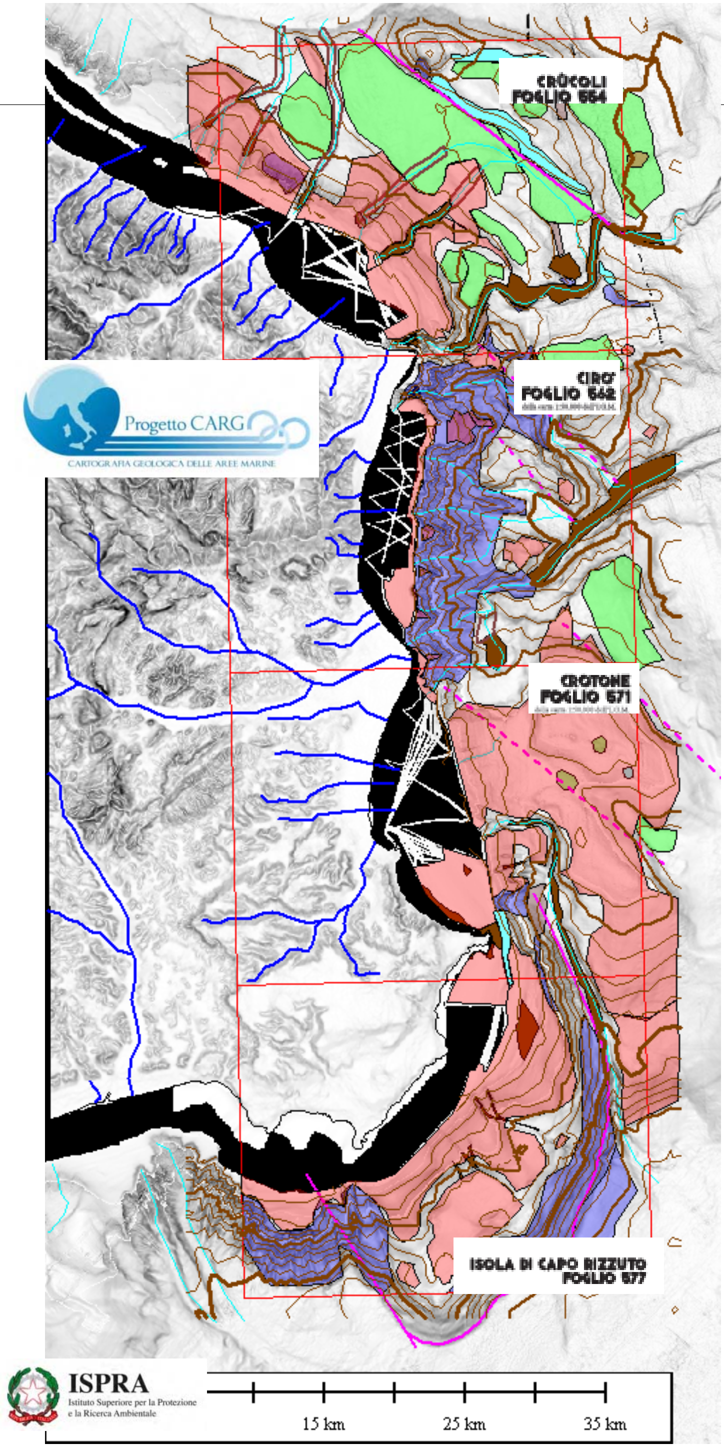
Bedded
buried transparent

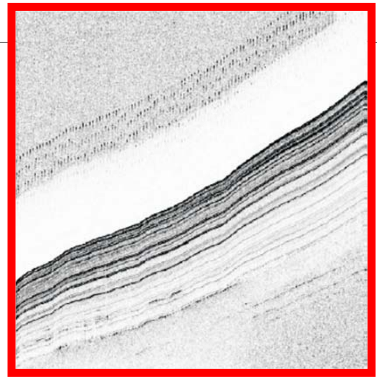
Hyperbolic



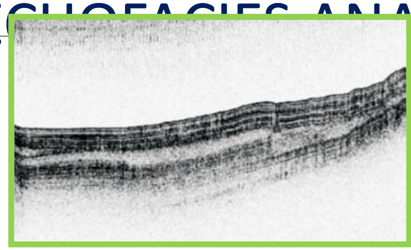
Rough

ECHOFACIES ANALYSES

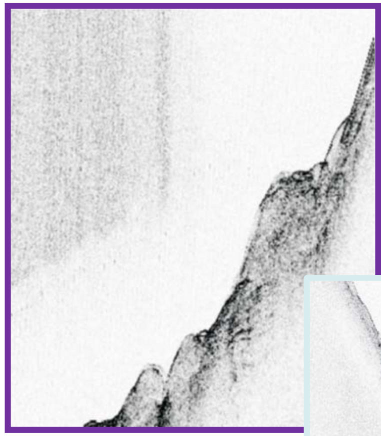




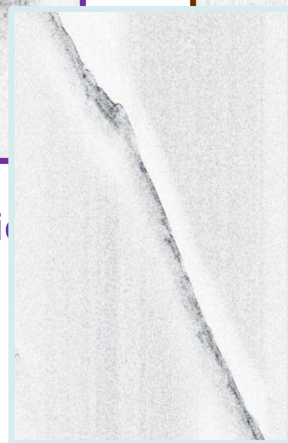
Uniformly Bedded



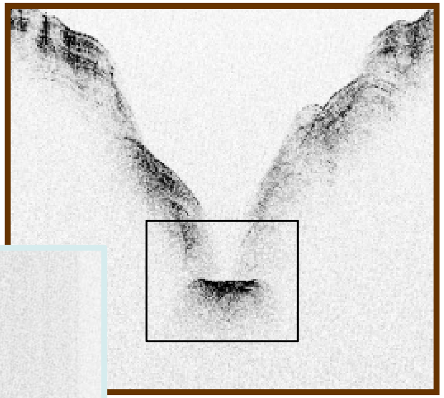
Bedded
buried transparent



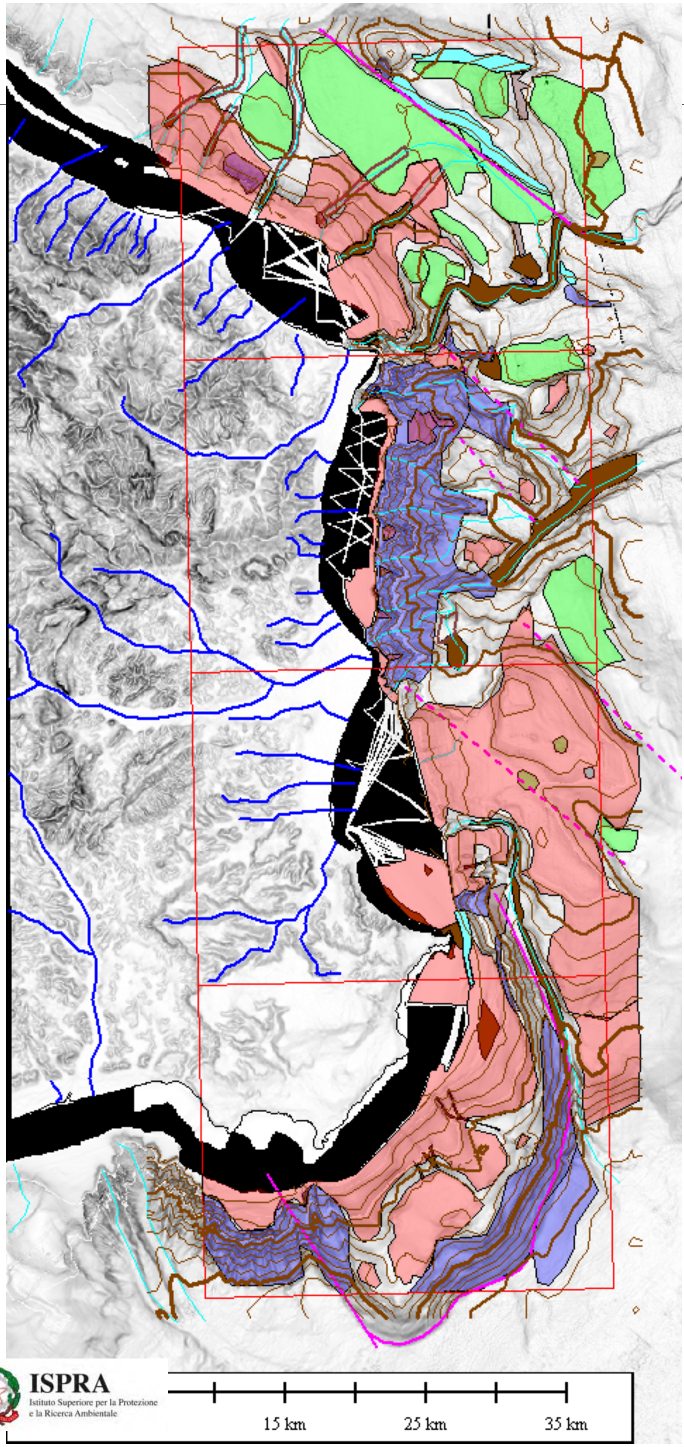
Hyperbolic



Slope



Rough



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Ambiente di piattaforma Continentale

BB — Deposito di piattaforma

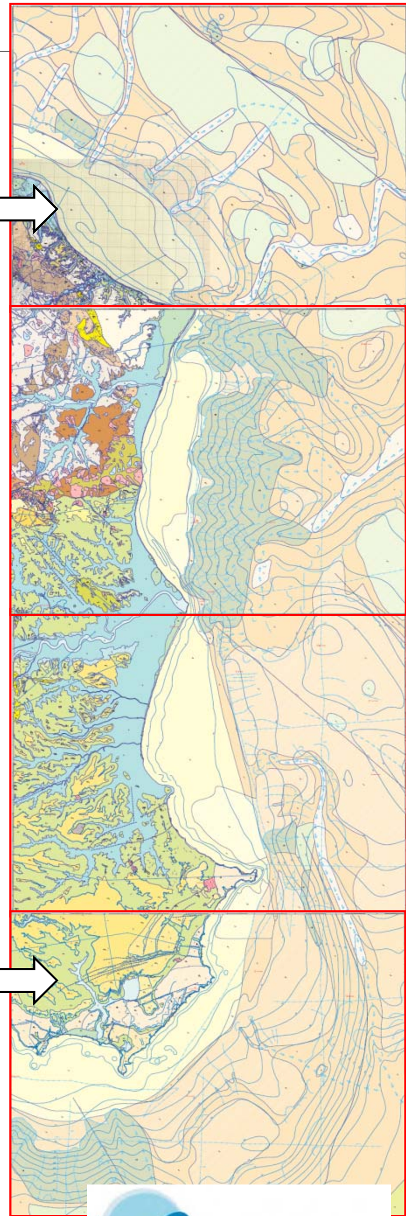
Ambiente di scarpata continentale e di bacino

BTB — Deposito da flussi gravitativi non canalizzati

BB — Deposito di scarpata continentale

R — Deposito gravitativo di riempimento di canyon

H — Substrato affiorante indifferenziato



CRUCOLI FOGLIO 564

CIRO' FOGLIO 562

CROTONE FOGLIO 571

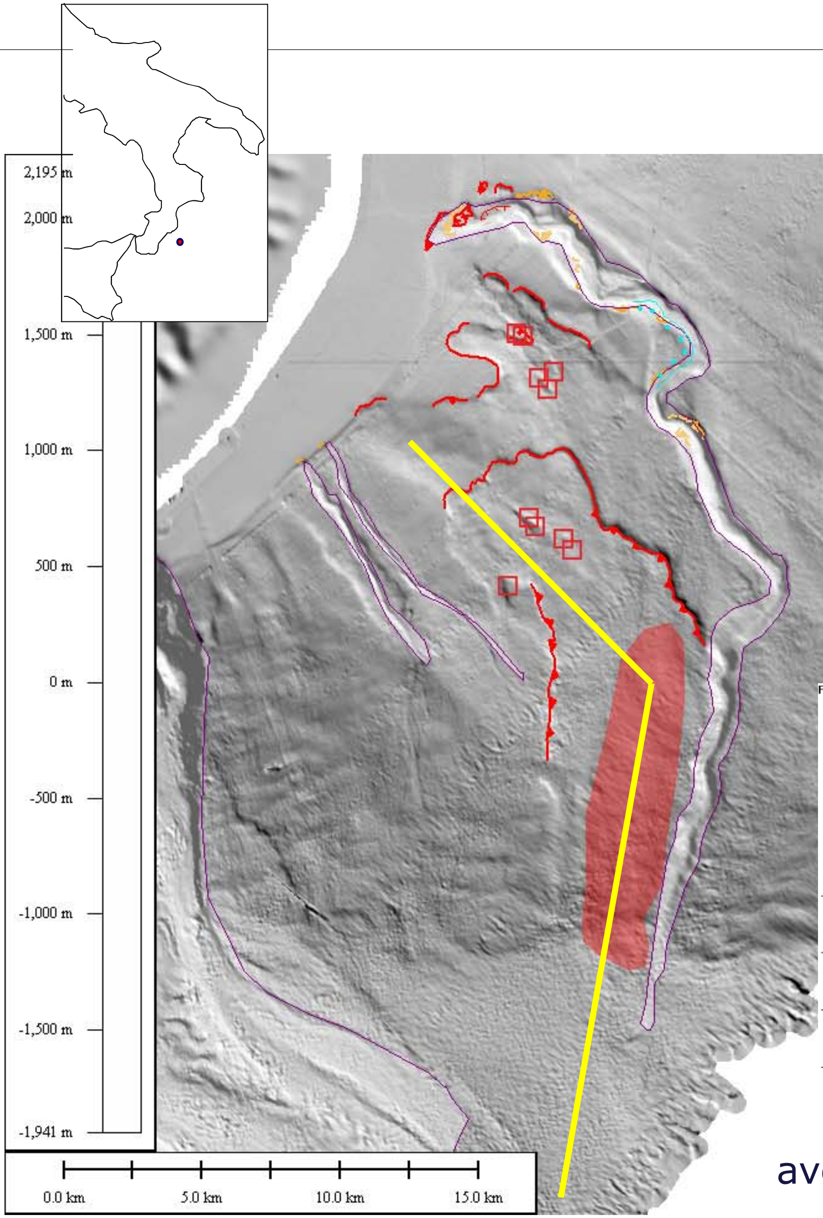
ISOLA DI CAPO RIZZUTO FOGLIO 577

Progetto CARG
CARTOGRAFIA GEOLOGICA DELLE AREE MARINE

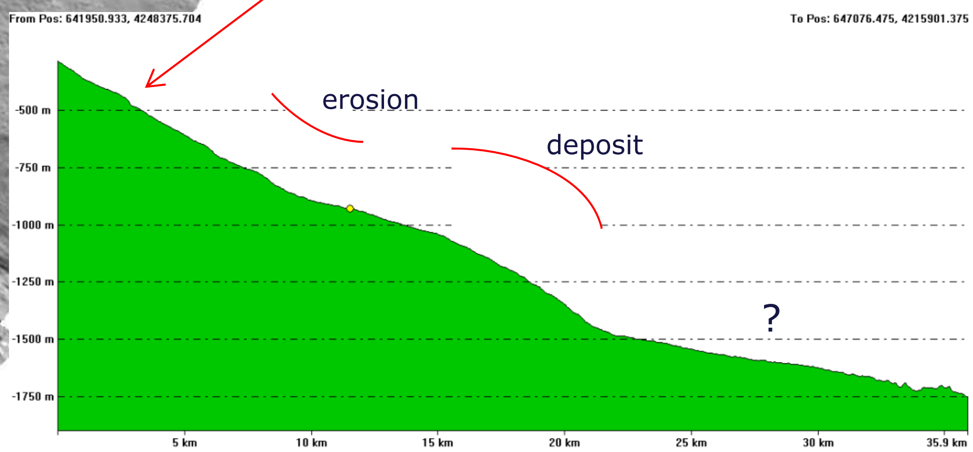
OGS

Slide Scars on steep slopes

single and multiple events



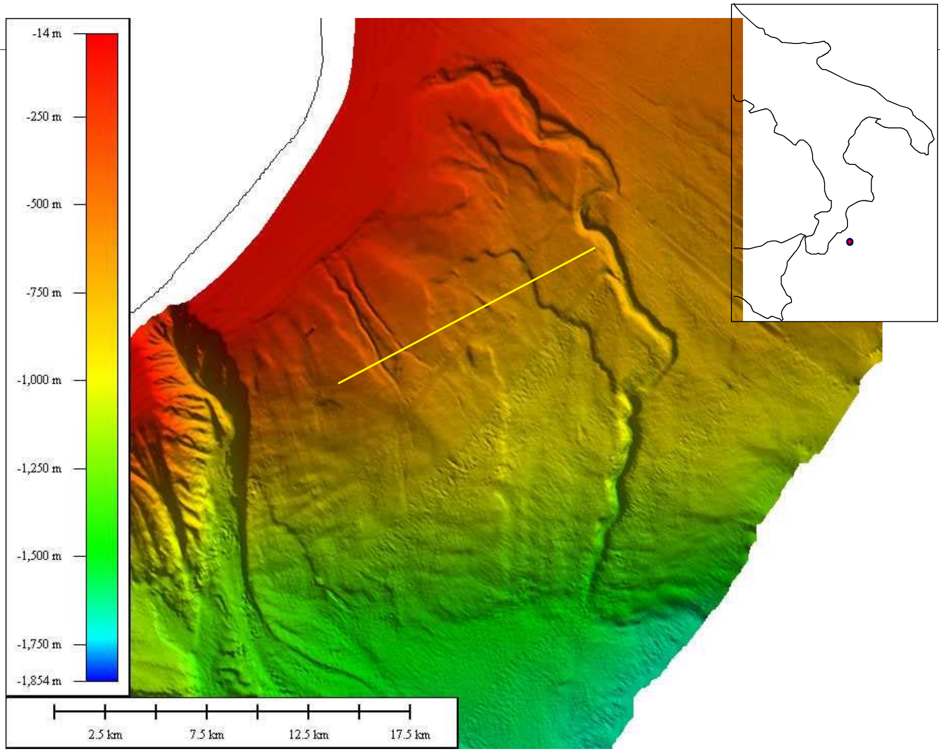
Assi failure

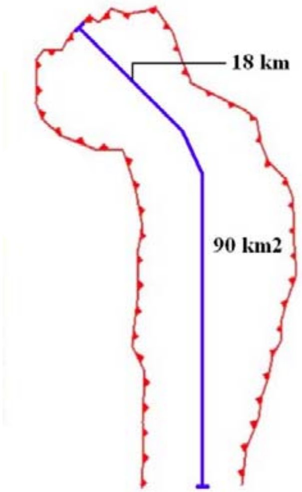


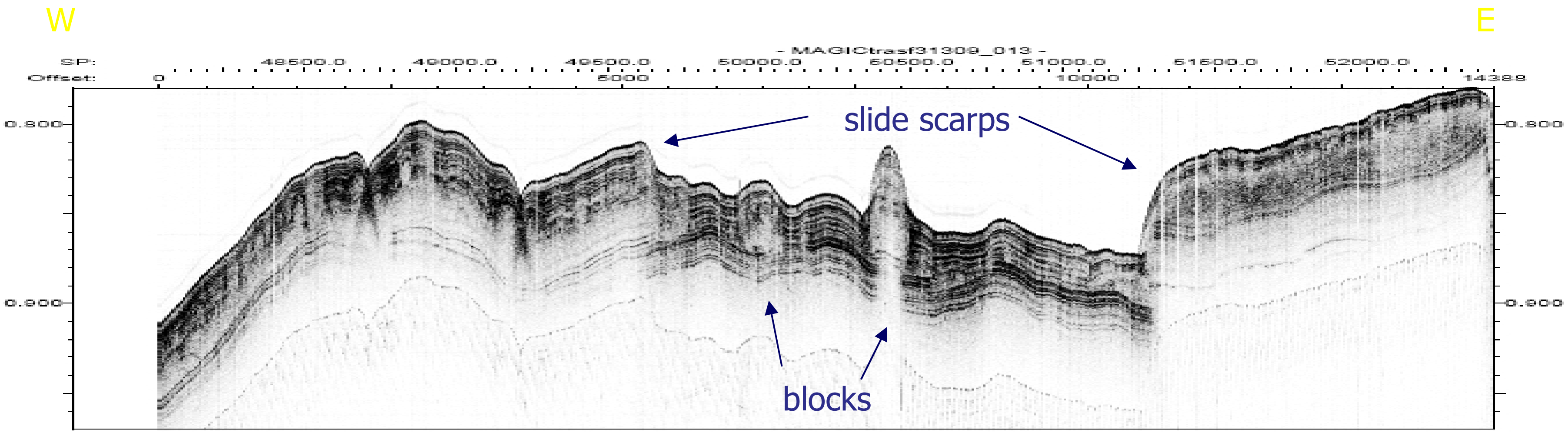
average slope gradient =3°

Isolated Slide Scars – ISS

single and multiple events







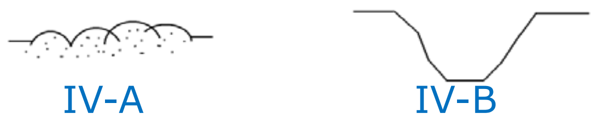
Facies acustiche

Nella zona interessata sono state identificate 11 facies acustiche in base alla chiarezza, continuità, trasparenza e geometria del riflettore del fondo mare e dei riflettori interni.

Facies acustiche con prevalenza di riflettori piano paralleli

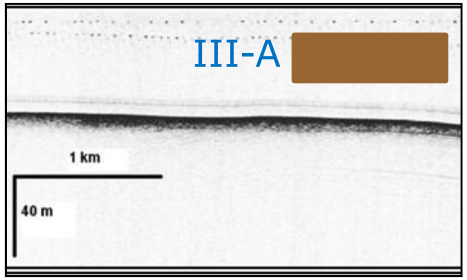
Facies acustiche in prevalenza trasparenti

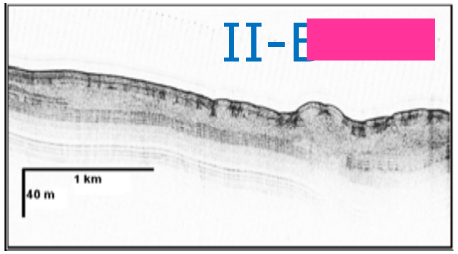
Facies acustica sorda

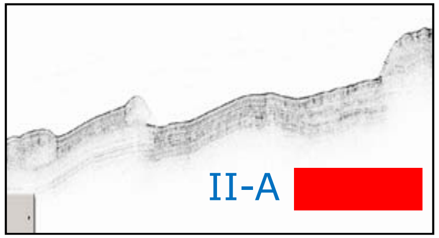


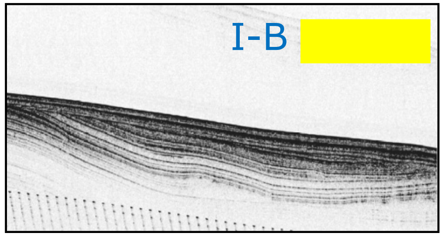
Facies acustiche ondulate

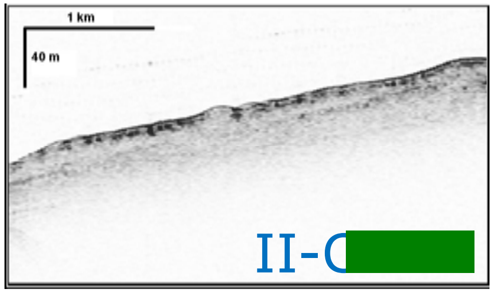
Facies acustiche

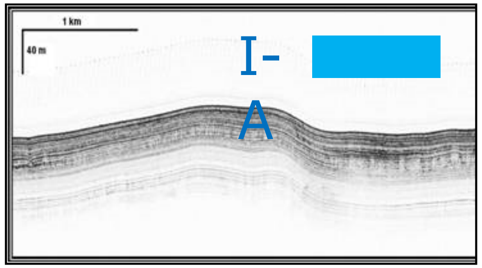


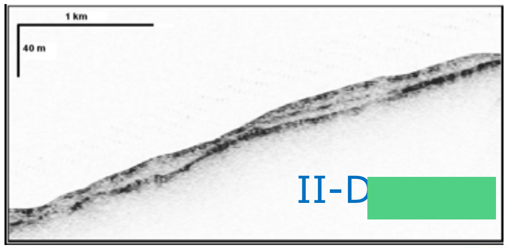




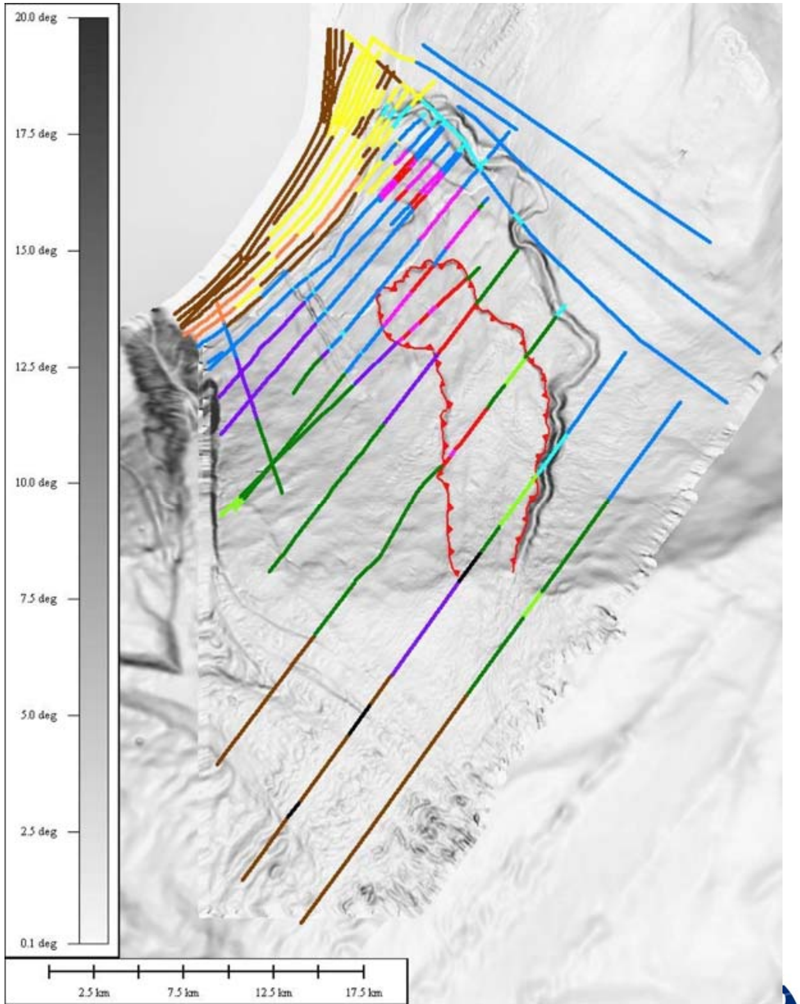






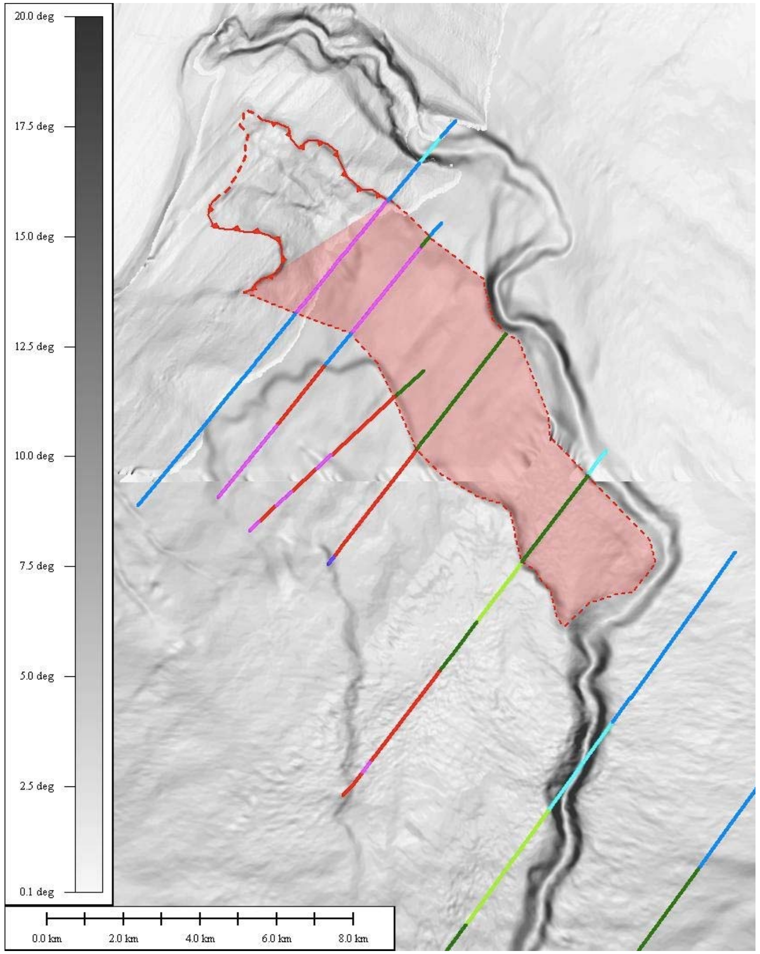


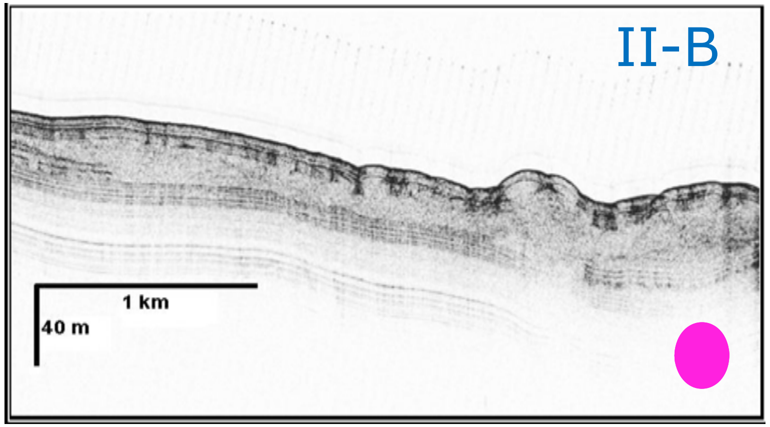
Mappa della classificazione acustica del fondale

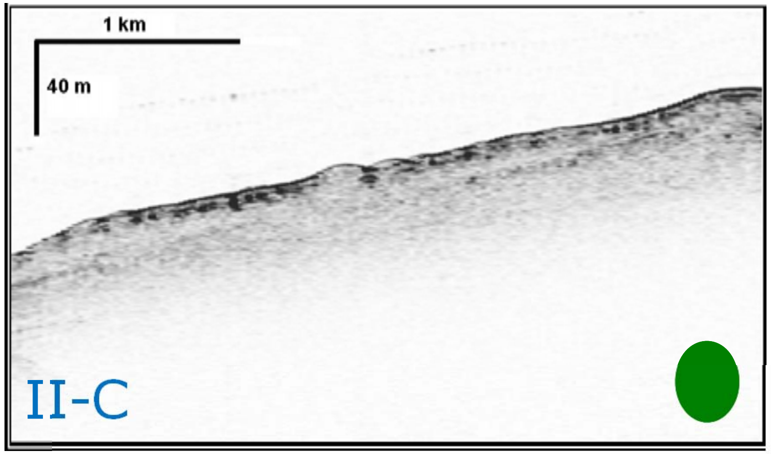


Facies acustiche

Settore Nord

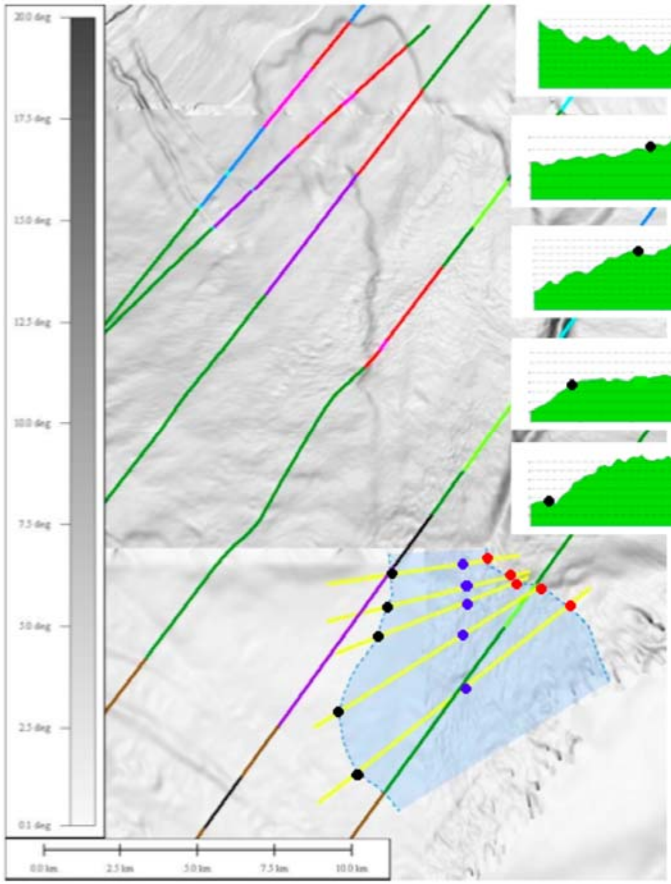


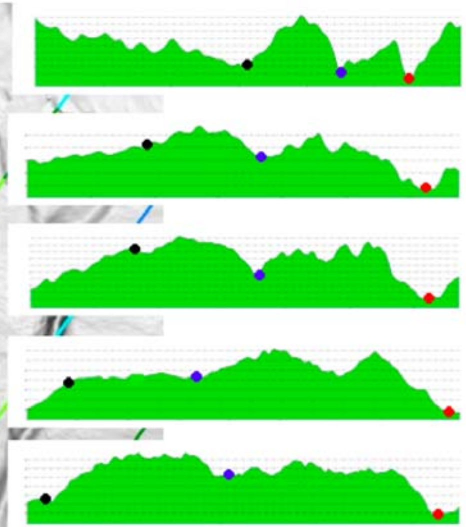




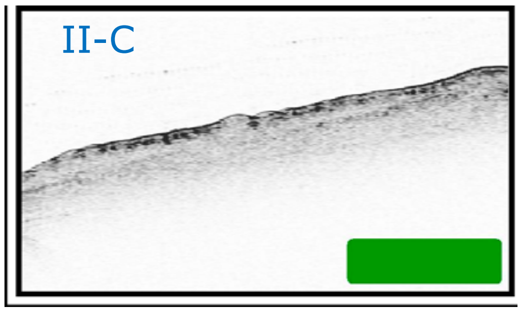
Facies acustiche

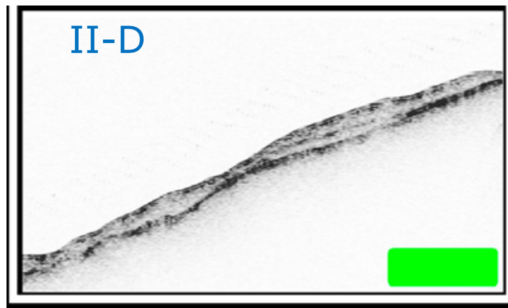
Settore Sud





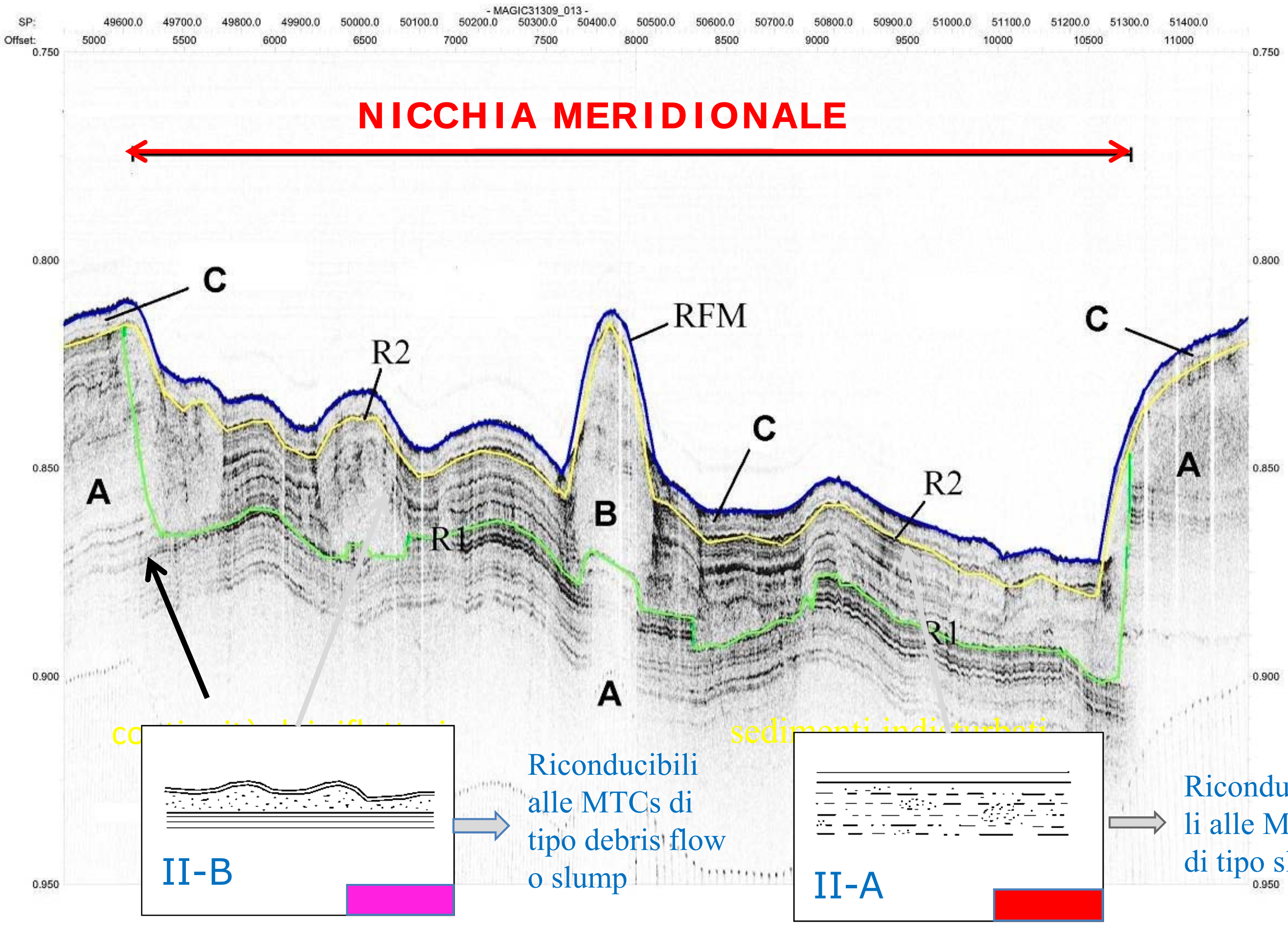
Zona di accumulo del materiale franato nel Bacino di Spartivento





Stratigrafia sismica

Settore Sud

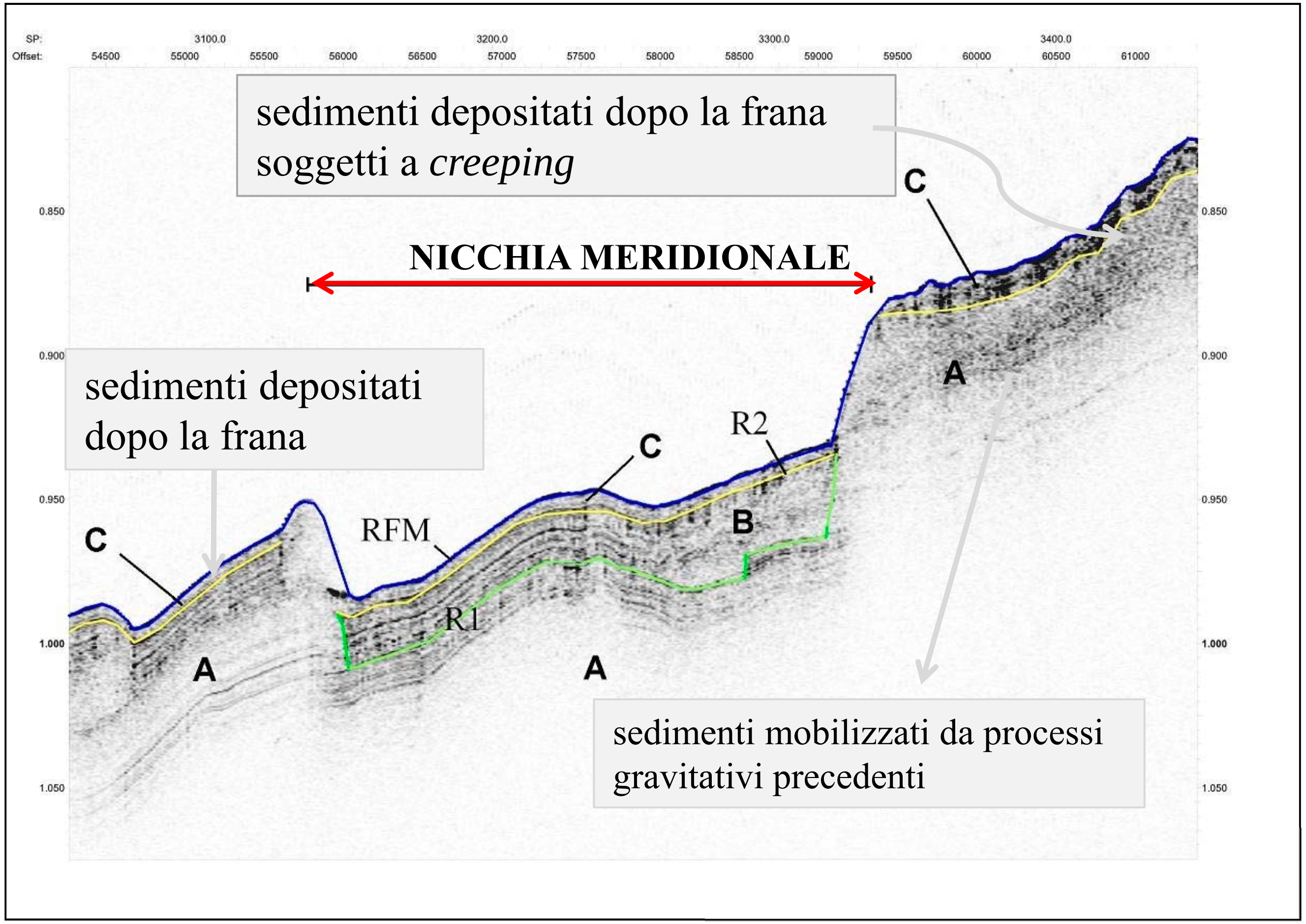


Riconducibili alle MTCs di tipo debris flow o slump

Riconducibili alle MTCs di tipo slide

Stratigrafia sismica

Settore Sud



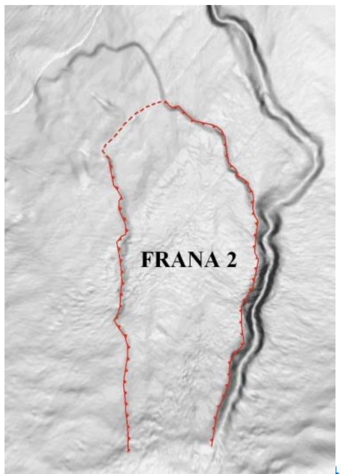
Dinamica gravitativa

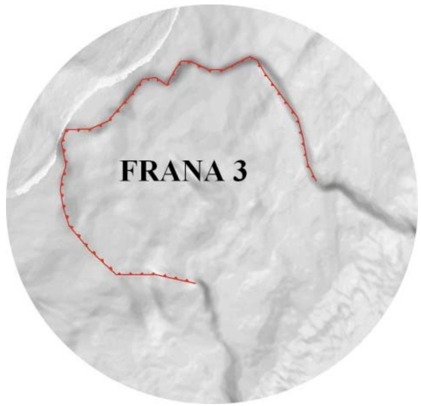
Dall'interpretazione delle facies acustiche e della morfobatimetria è stato stabilito che il versante è stato soggetto a tre distinti eventi gravitativi:

Frana 1: la frana più vecchia, no depositi, superficie concava, lineamento nicchia discontinuo, spessore unita C (post-frana) è più spesso, incisa dalla frana 3.

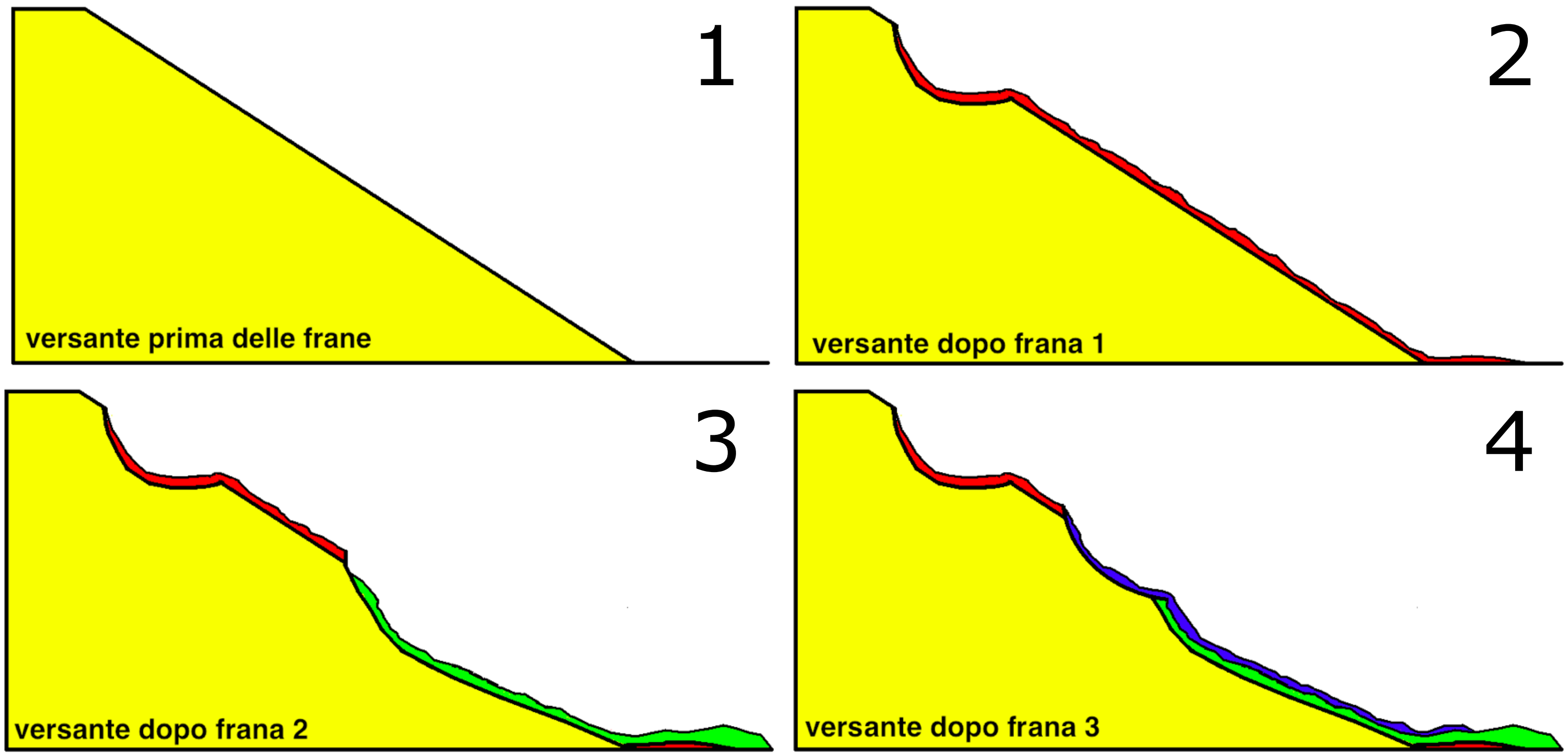
Frana 2: forma (restringimento), maggiori quantità di materiale traslato nella zona restringimento, depositi multipli di materiale franato nelle regioni meridionali.

Frana 3: è la frana più recente associata alla parte superiore della nicchia meridionale.

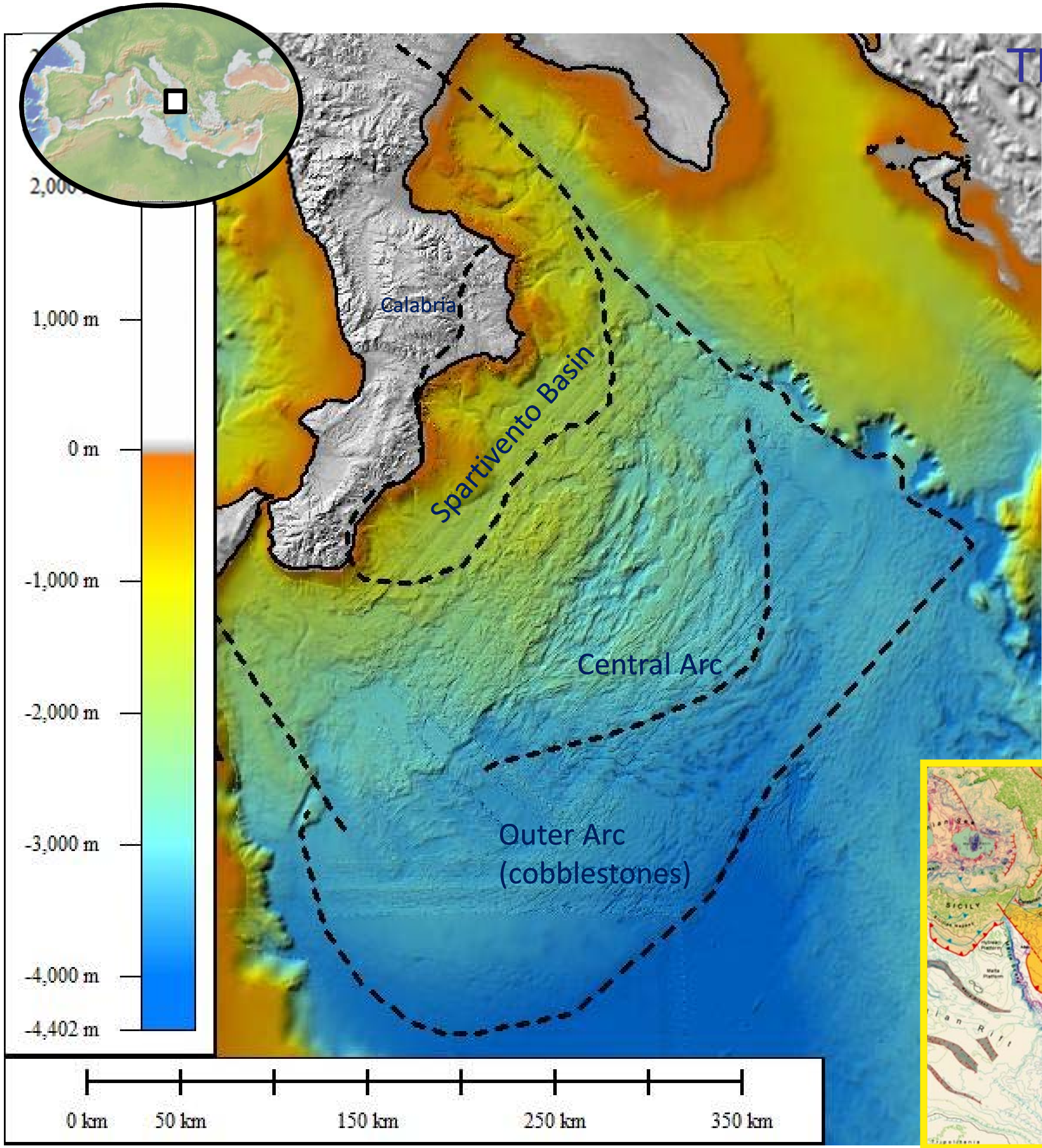




Dinamica gravitativa



THE IONIAN MARGIN



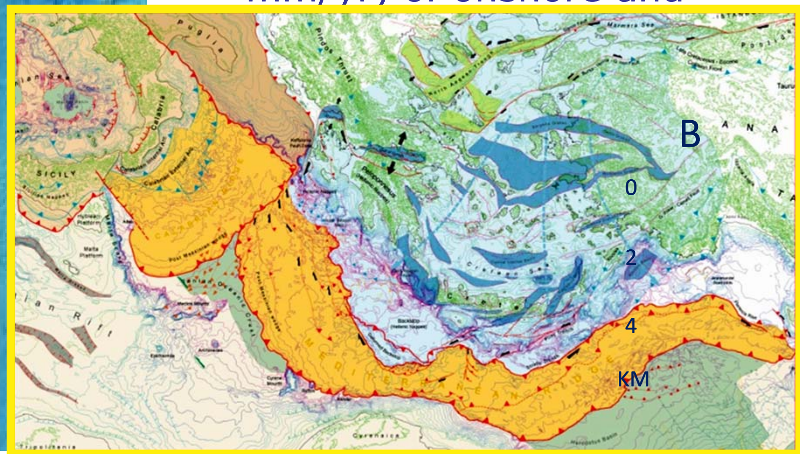
TECTONIC FRAMEWORK

Active continental margin (convergent) → Subduction

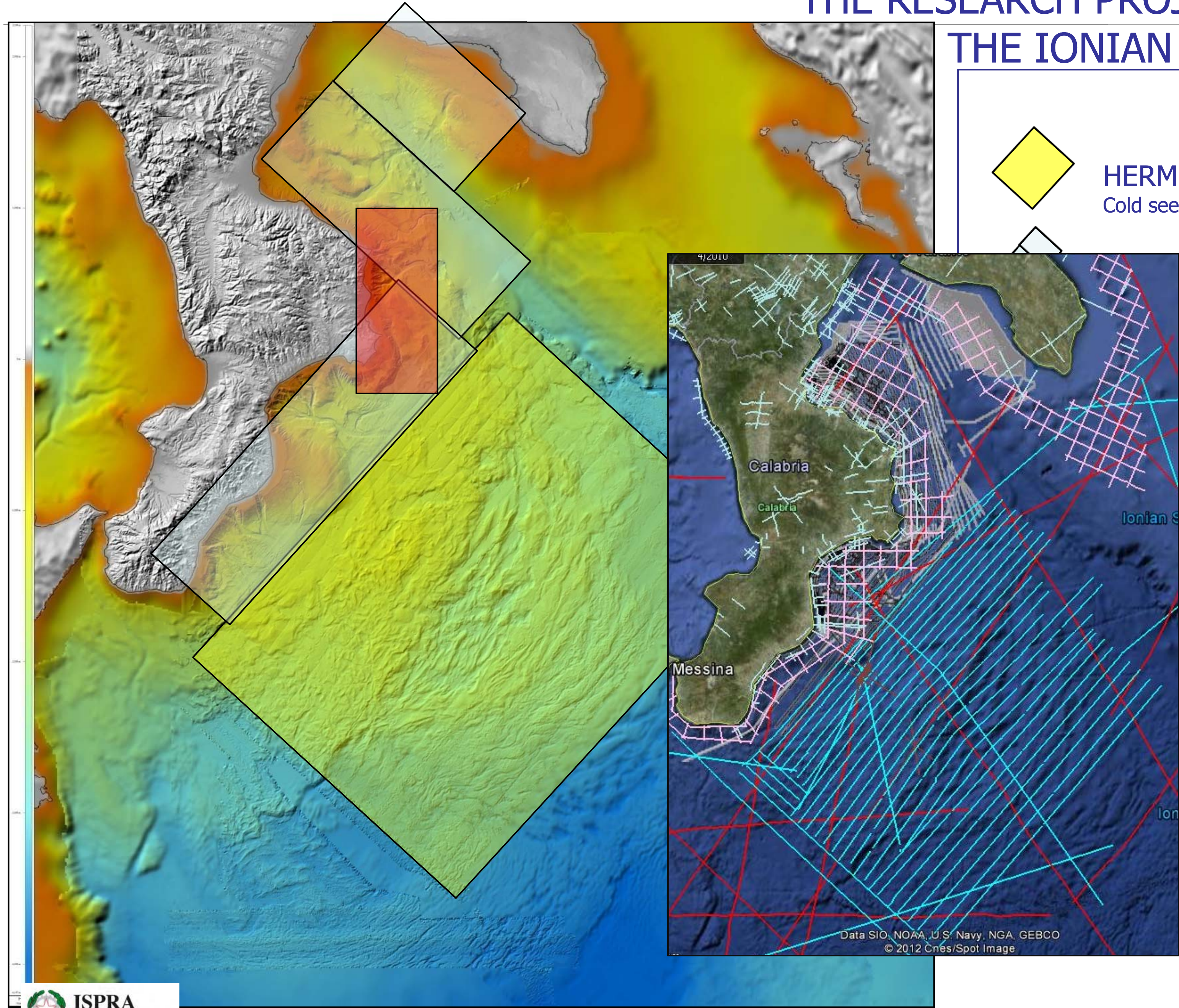
2 main processes related:

→ 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



THE RESEARCH PROJECTS IN THE IONIAN MARGIN



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

C (Italian Civil Protectio
t '07-'12)
rd of coastal areas

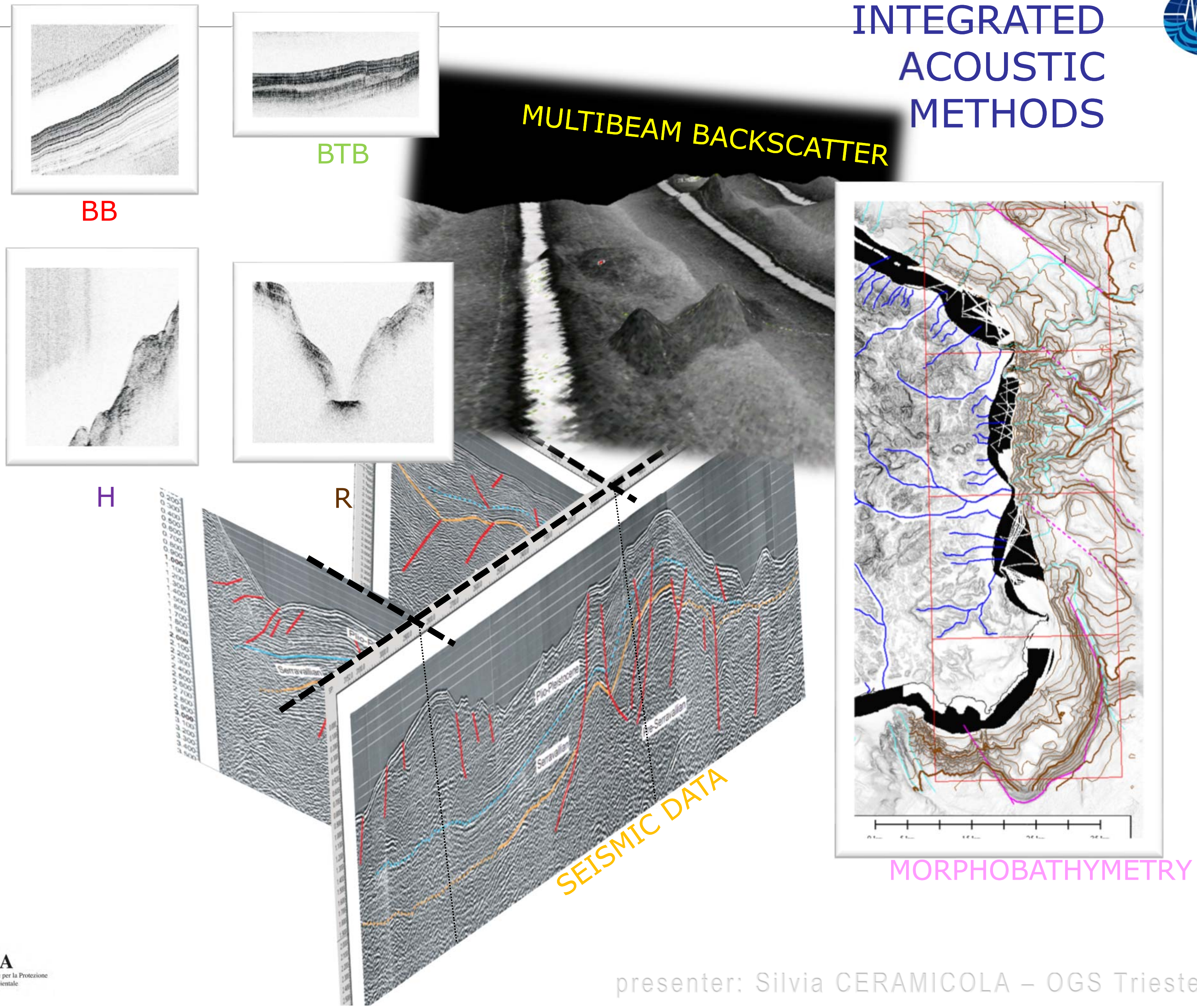
(Italian ISPRA Project '
al mapping

search vessels

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

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

INTEGRATED ACOUSTIC METHODS



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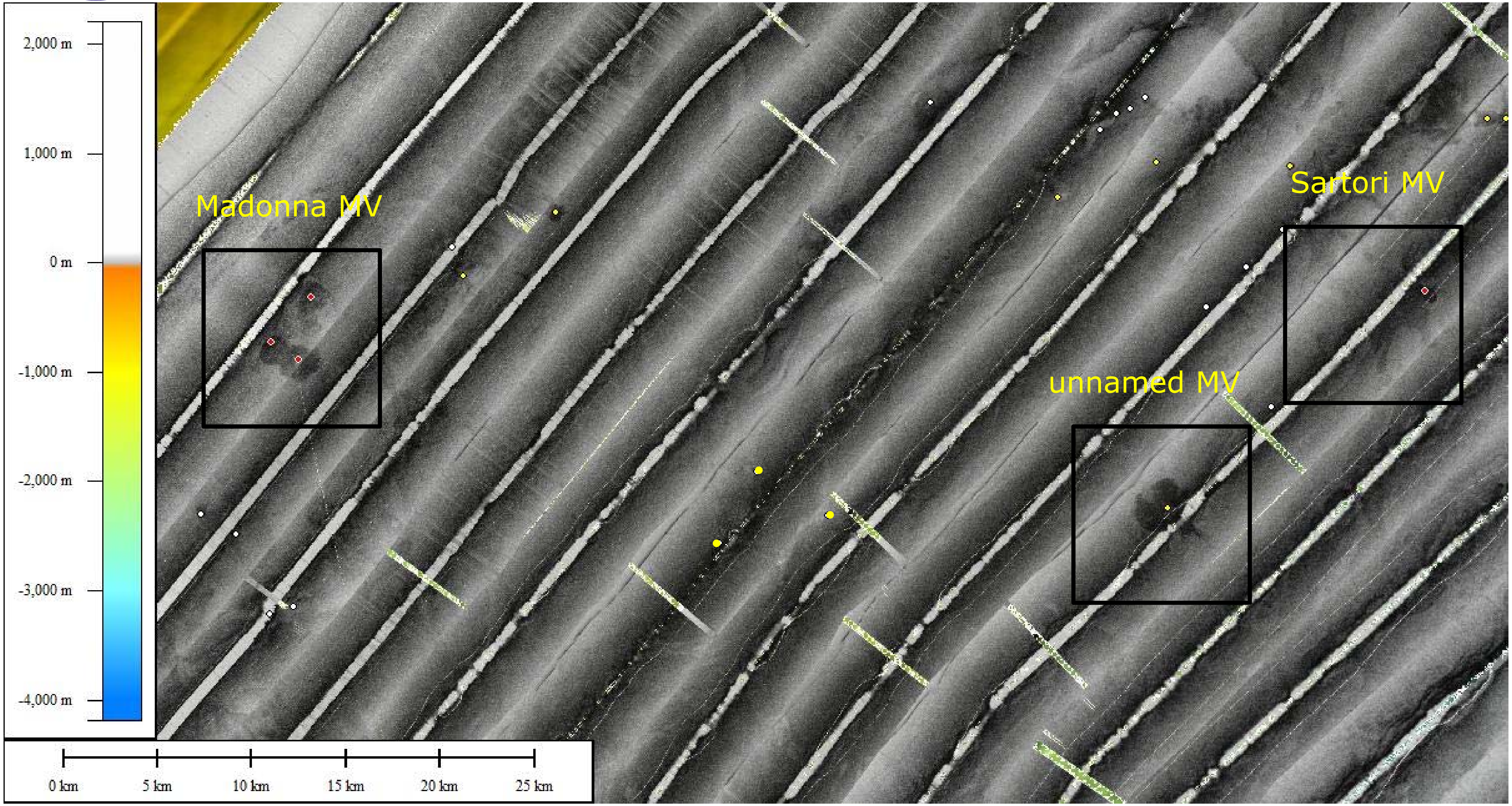
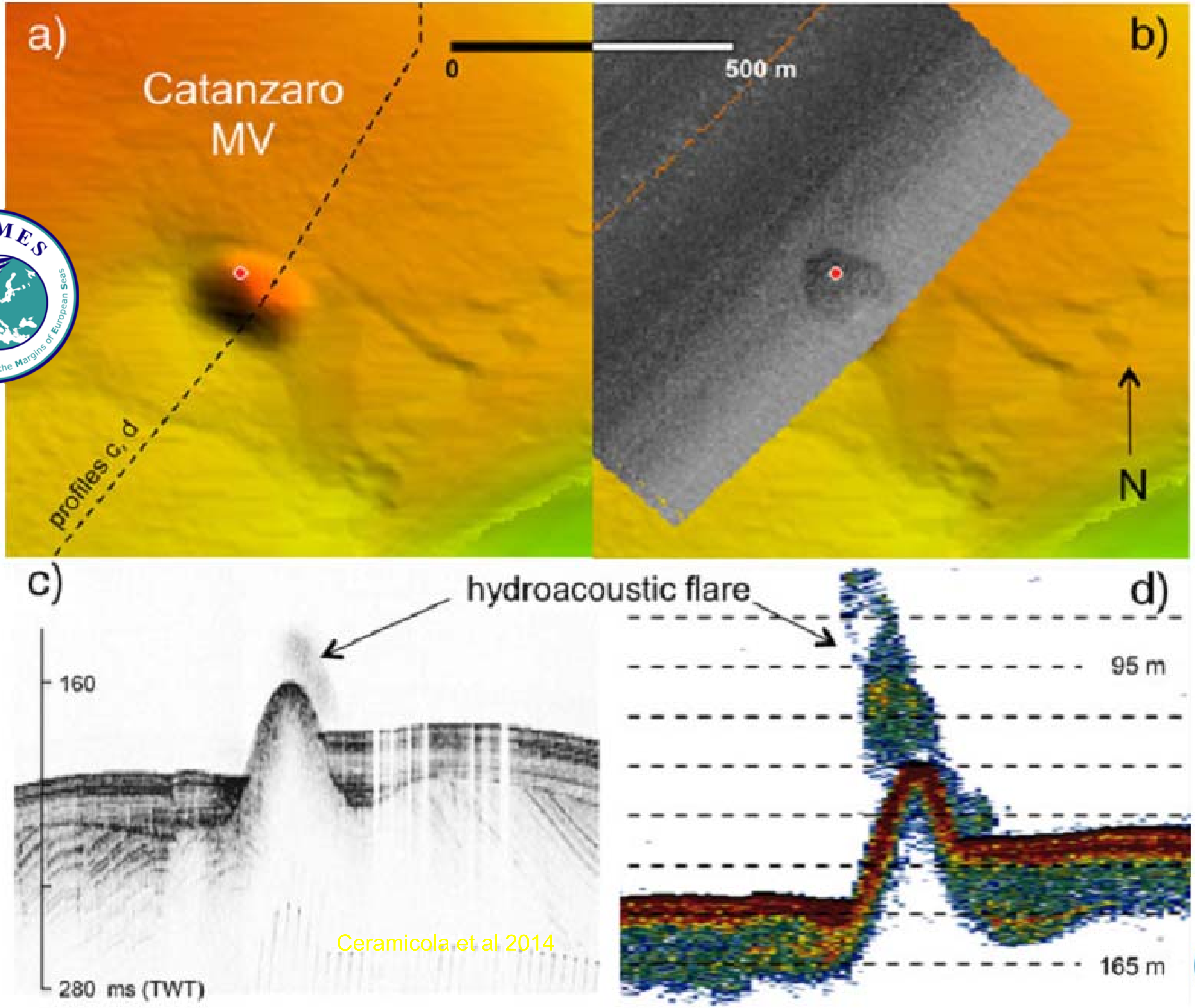
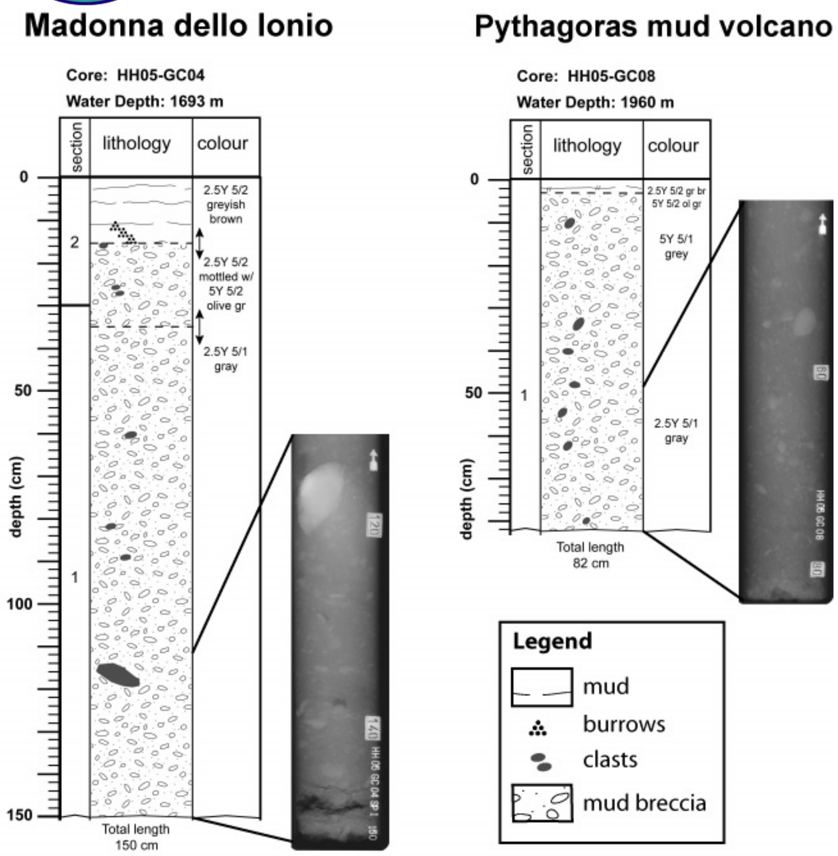
MORPHOLOGY + BACKSCATTER



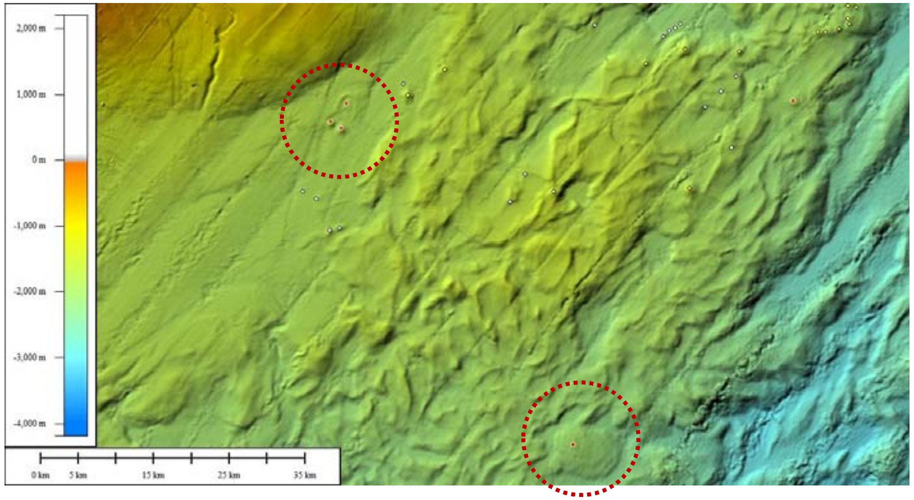

a)
Catanzaro
MV
0
500 m
b)
profiles c, d
N
c)
hydroacoustic flare
d)
160
280 ms (TWT)
95 m
165 m
Ceramicola et al 2014

CORING



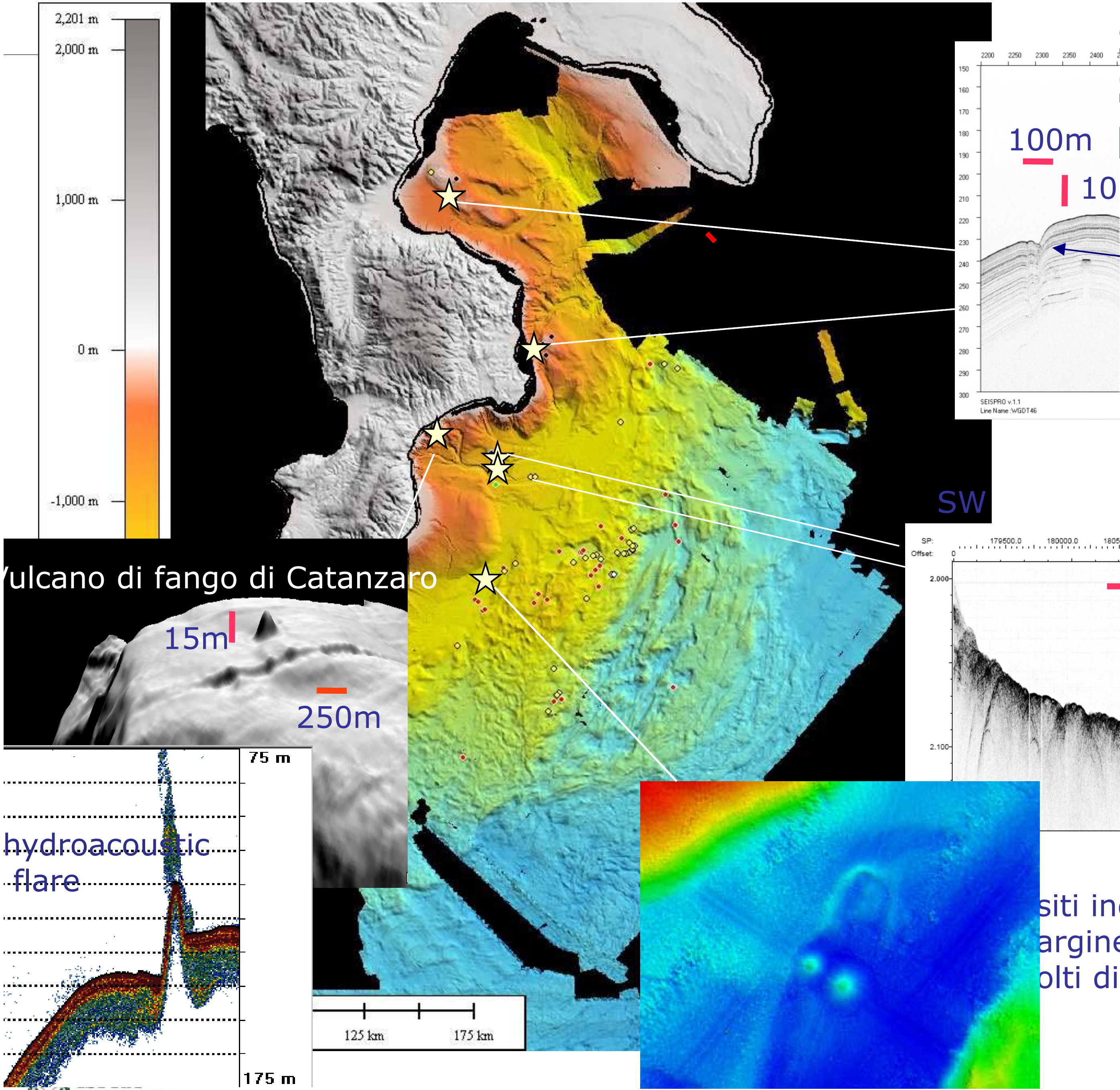
(*Praeg et al. 2009 M&PG*)

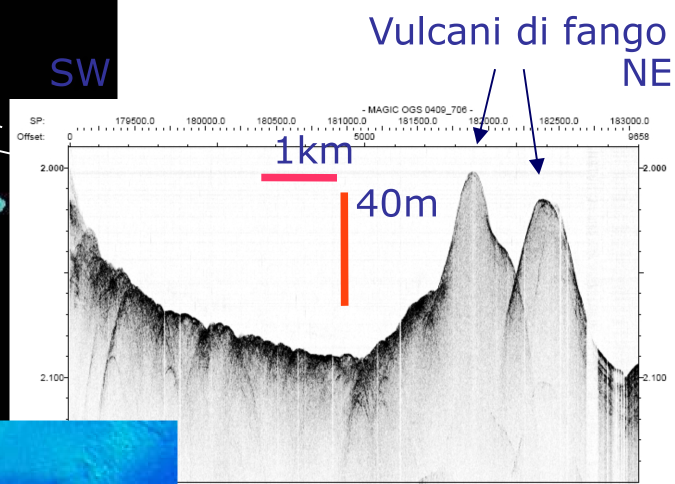
Analyses of samples of clasts and mud from 5 cores up to 1.8 m long



Analyses of samples of clasts and mud from 5 cores up to 1.8 m long

SEABED SEEPAGE MAPPING





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

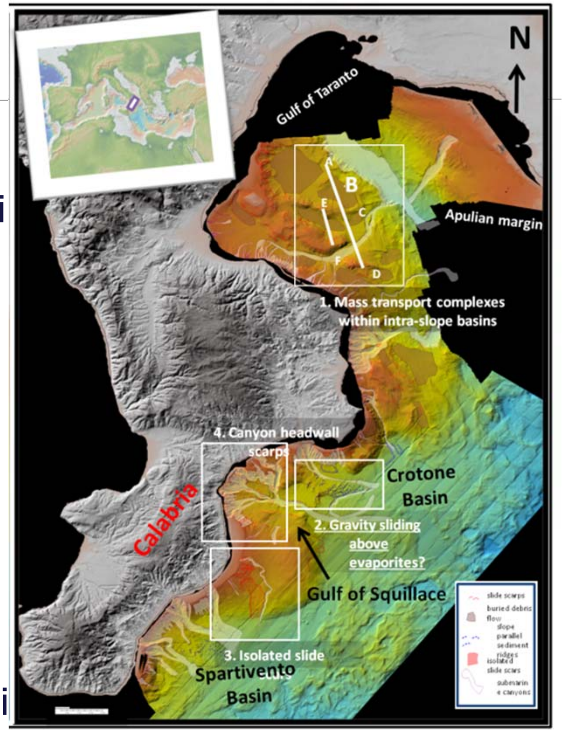
CONCLUSIONI

- I margini ionici calabro e apulo sono sede di processi geologici attivi (faglie, frane sottomarine, fuoriuscite di fluidi). Questi processi hanno rilevanza per le loro potenziali conseguenze come geohazards. Il loro studio e la mappatura dei fondali marini stanno diventando obiettivi prioritari delle grandi agenzie finanziztrici (nazionali e internazionali).

- Un vasto e eterogeneo dataset geofisico e geologico è stato acquisito da OGS in quest’area all’interno di vari progetti nazionali e europei dal 2005 ad oggi che è stato integrato in un database digitale insieme a dati pubblici batimetrici (Gebco, Medimap), sismici e di pozzo (Ministeriali).

- Integrated acoustic mapping dei margini ionici calabro e apulo è stato realizzato utilizzando differenti approcci interpretativi: l’integrazione dell’informazione morfobatimetria con quella della riflettività del fondale (backscatter) e l’analisi delle echofacies sono due esempi.

- Questi due differenti approcci sono stati utilizzati al fine di identificare e mappare, per esempio, fuoriuscite di fluidi lungo il prisma di accrezione calabro e per ricostruire i ambienti deposizionali lungo il margine calabro e apulo (piattaforma, scarpata e bacino)



5- Seabed Low and regulation: EZZ, ONU, EU, Seabed 2030

European Commission

Healthy oceans, seas, coastal and inland waters is one of five dedicated mission areas under Horizon Europe, the EU's next research and innovation framework programme.

European Commission/Maritime Affairs and Fisheries/Sustaniable Ocean
https://ec.europa.eu/oceans-and-fisheries/ocean_en

A European Green Deal
https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

The 5 EU Missions

1. Adaptation to Climate Change: support at least 150 European regions and communities to become climate resilient by 2030
2. Cancer: working with Europe's Beating Cancer Plan to improve the lives of more than 3 million people by 2030 through prevention, cure and solutions to live longer and better
3. Restore our Ocean and Waters by 2030
4. 100 Climate-Neutral and Smart Cities by 2030
5. A Soil Deal for Europe: 100 living labs and lighthouses to lead the transition towards healthy soils by 2030

5- Seabed Low and regulation: EZZ, ONU, EU, Seabed 2030

Sustainable oceans

International ocean governance

Discover how the EU contributes to the healthy and productive management of the world's oceans for the benefit of the current and future generations.

Sea basins

The EU is surrounded by the Atlantic and Arctic Oceans, the Baltic, the North Sea, the Mediterranean, and the Black Sea.

Clean and healthy oceans

Marine pollution including plastics has no borders. The Commission is working to promote cleaner sea in the EU and worldwide.

European Atlas of the Seas

Explore, collate and create your own sea map. For teachers, students, journalists, companies and more!

Blue economy

The sustainable blue economy creates growth and jobs. It also helps us fight climate change, restore biodiversity and use marine resources responsibly

Marine biodiversity

Protection of marine biodiversity is a key objective, including for the EU common fisheries policy.

Sustainable ocean finance

Sustainable blue economy finance principles provide a framework for financing a sustainable ocean economy.

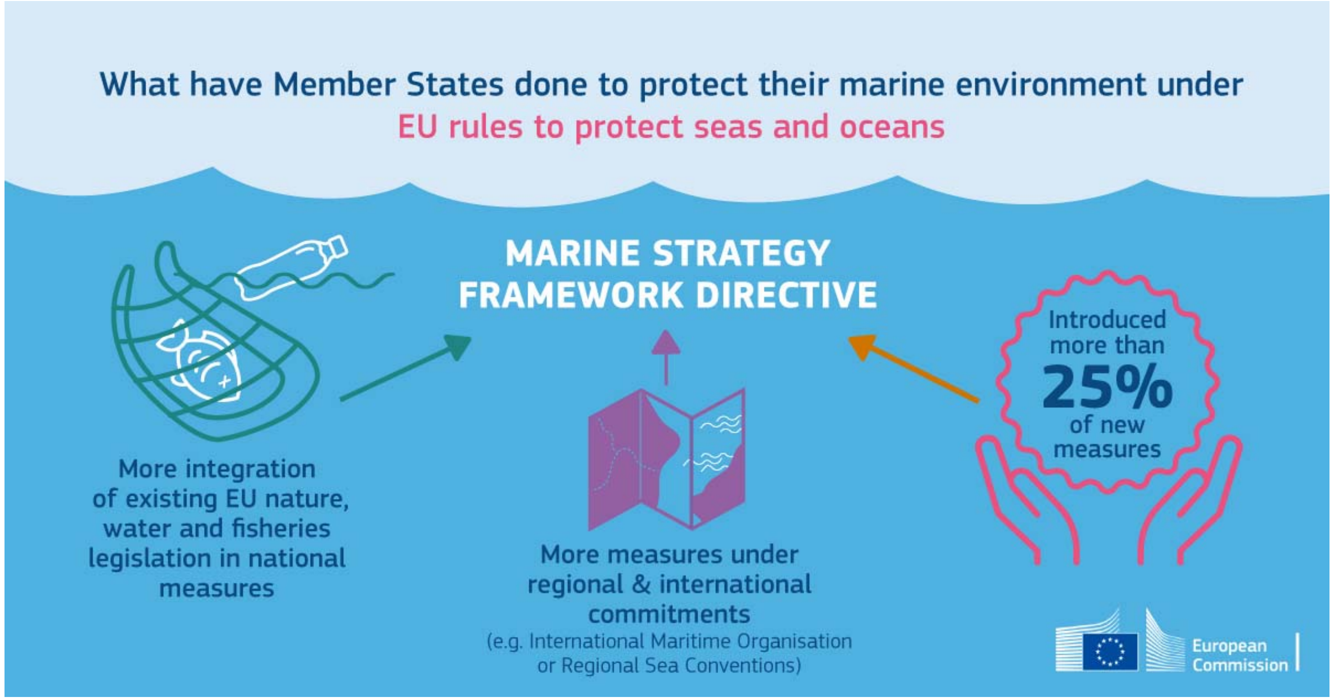
Maritime Forum

Website that aims to improve communication amongst EU maritime policy stakeholders.

https://ec.europa.eu/oceans-and-fisheries/ocean_it

MSFD Marine Strategy Framework Directive 2008

The aim of the European Union's ambitious Marine Strategy Framework Directive is to protect more effectively the marine environment across Europe. It came into force on June 2008 and was transposed into each member's state national legislation by mid 2010

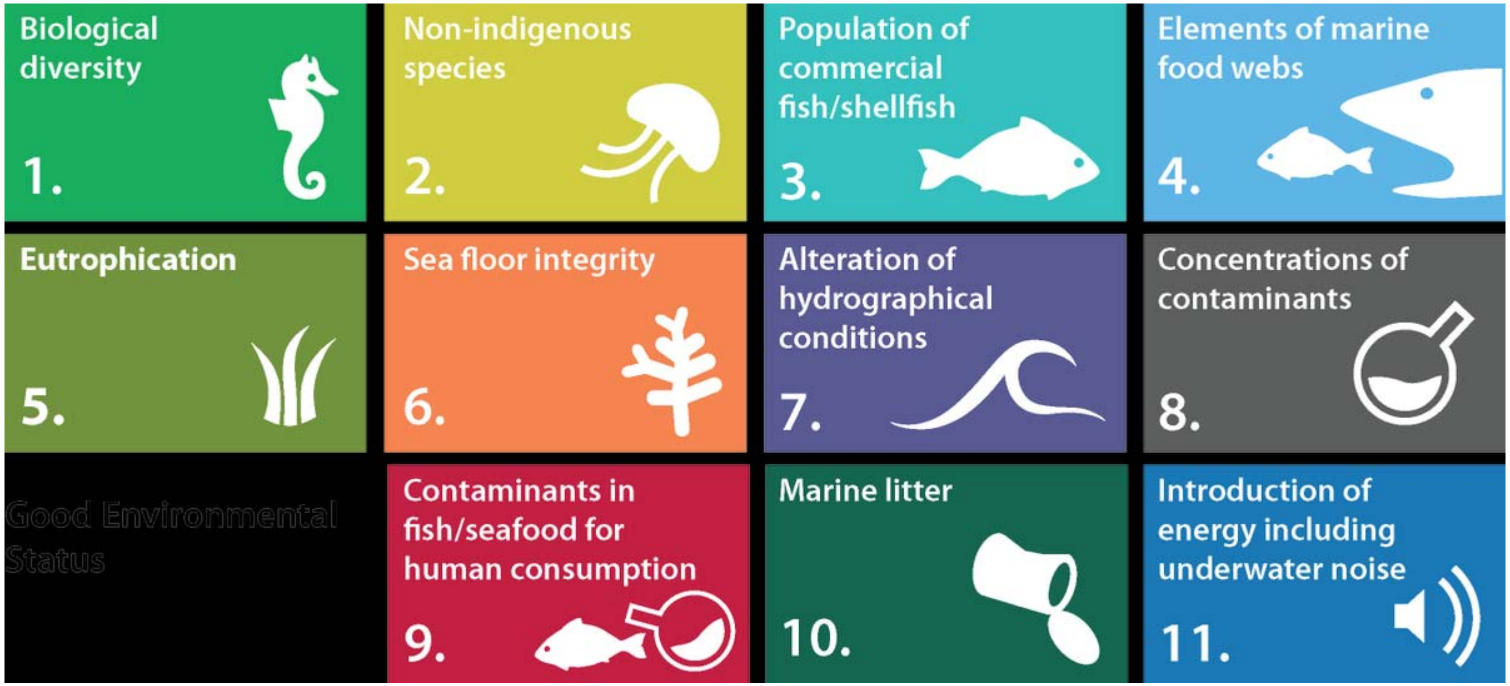


[Directive 2008/56/EC](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056

https://ec.europa.eu/info/research-and-innovation/research-area/environment/oceans-and-seas_en

Good environmental Status (GES)

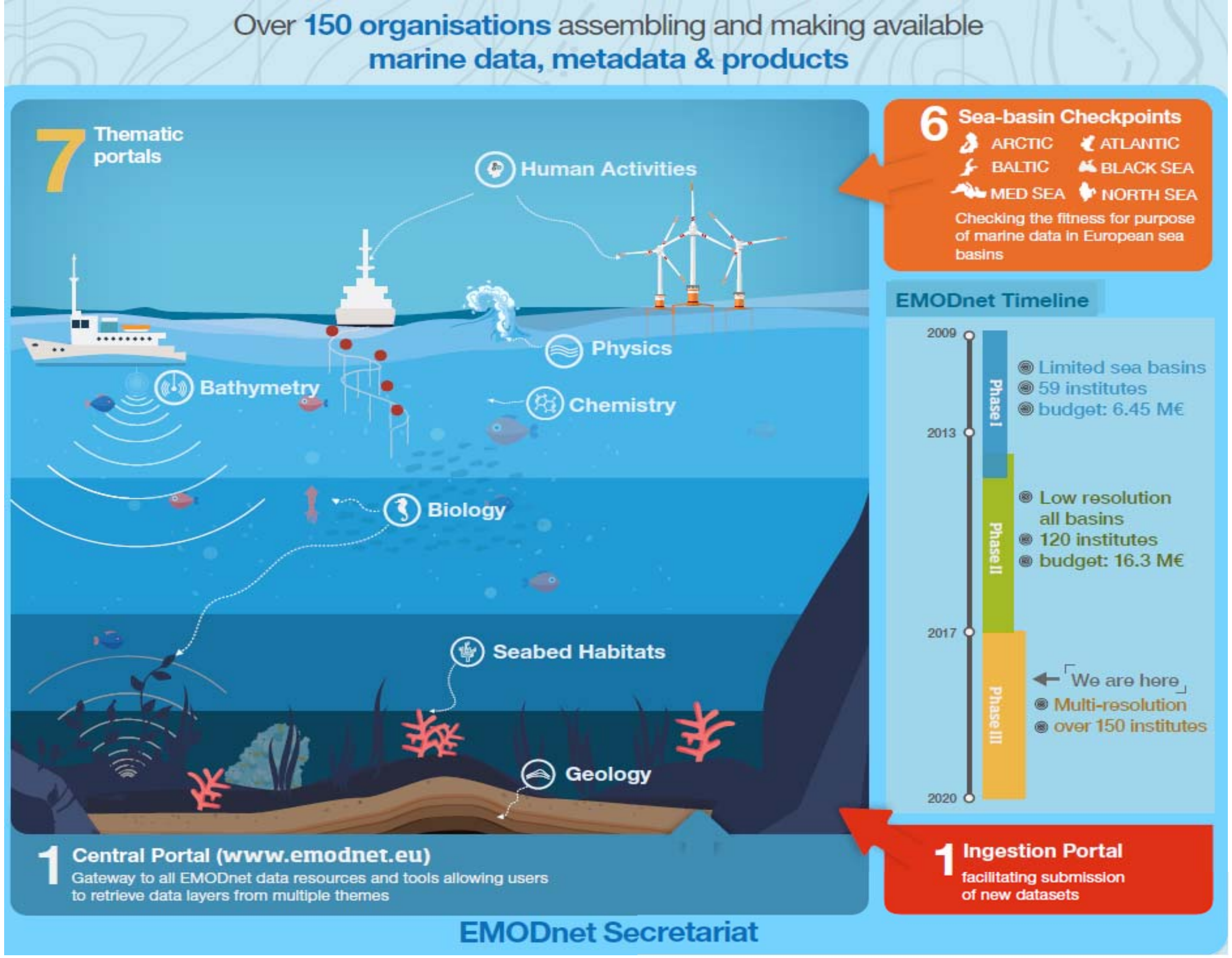
The main goal of the Marine Directive (is to achieve Good Environmental Status of EU marine waters by 2020. The Directive defines Good Environmental Status (GES)




How EU Member States develop marine strategies
Assess
Define ideal environmental state of seas
Set targets
Monitor
Identify and implement actions needed
CLEAN, HEALTHY AND PRODUCTIVE SEAS
European Commission

EMODnet

THE EUROPEAN MARINE OBSERVATION AND DATA NETWORK



http://www.emodnet.eu/

The European Marine Observation and Data Network (EMODnet) is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products

Blue growth require knowledge in several disciplines in order to be able to support sustainable growth in the marine and maritime sectors as a whole

81% OF THE SEABED IS STILL UNKNOWN

Blue economy promote a sustainable use the resources for economic growth, improved livelihoods and jobs, while preserving the health of the ocean ecosystems

Gain a better knowledge of the seabed (safety conserv

The Nippon Foundation-GEBCO Seabed 2030 Project

https://seabed2030.org/

100% of the ocean floor mapped by 2030

Seabed 2030 is a collaborative project between the Nippon Foundation of Japan and the General Bathymetric Chart of the Oceans (GEBCO). It aims to bring together all available bathymetric data to produce the definitive map of the world ocean floor by 2030 and make it available to all.

The project was launched at the United Nations (UN) Ocean Conference in June 2017 and is aligned with the UN's Sustainable Development Goal #14 to conserve and sustainably use the oceans, seas and marine resources.

European Marine Board https://www.marineboard.eu/

JPI Ocean https://www.jpi-oceans.eu/

5- Seabed Low and regulation: EZZ, ONU, EU, Seabed 2030

UN Ocean Science Decade

Outcomes and Challenges

The Decade is a transformative vision to deliver the

1. A **clean ocean** where sources of pollution are ident
2. A **healthy and resilient ocean** where marine ecos
3. A **productive ocean** supporting sustainable food s
4. A **predicted ocean** where society understands and
5. A **safe ocean** where life and livelihoods are protect
6. An **accessible ocean** with open and equitable acce
7. An **inspiring and engaging ocean** where society u

The Decade vision and outcomes will require the engage include: scientists, governments, academics, policy make

ent

FAIR data are data which meet principles of findability, accessibility, interoperability, and reusability
(Wilkinson, Mark D.; Dumontier, Michel; Aalbersberg, IJsbrand Jan; Appleton, Gabrielle; et al. (15 March 2016)

Recognition and classification of subsea structures using artificial intelligence and high-performance computing

PRACE
PARTNERSHIP FOR ADVANCED COMPUTING IN EUROPE

The mission of PRACE (Partnership for Advanced Computing in Europe) is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society.

PRACE seeks to realise this mission by offering world class computing and data management resources and services through a peer review process.

KEEP
CALM
AND
AVOID
GEO HAZARDS

Thank you for your attention...