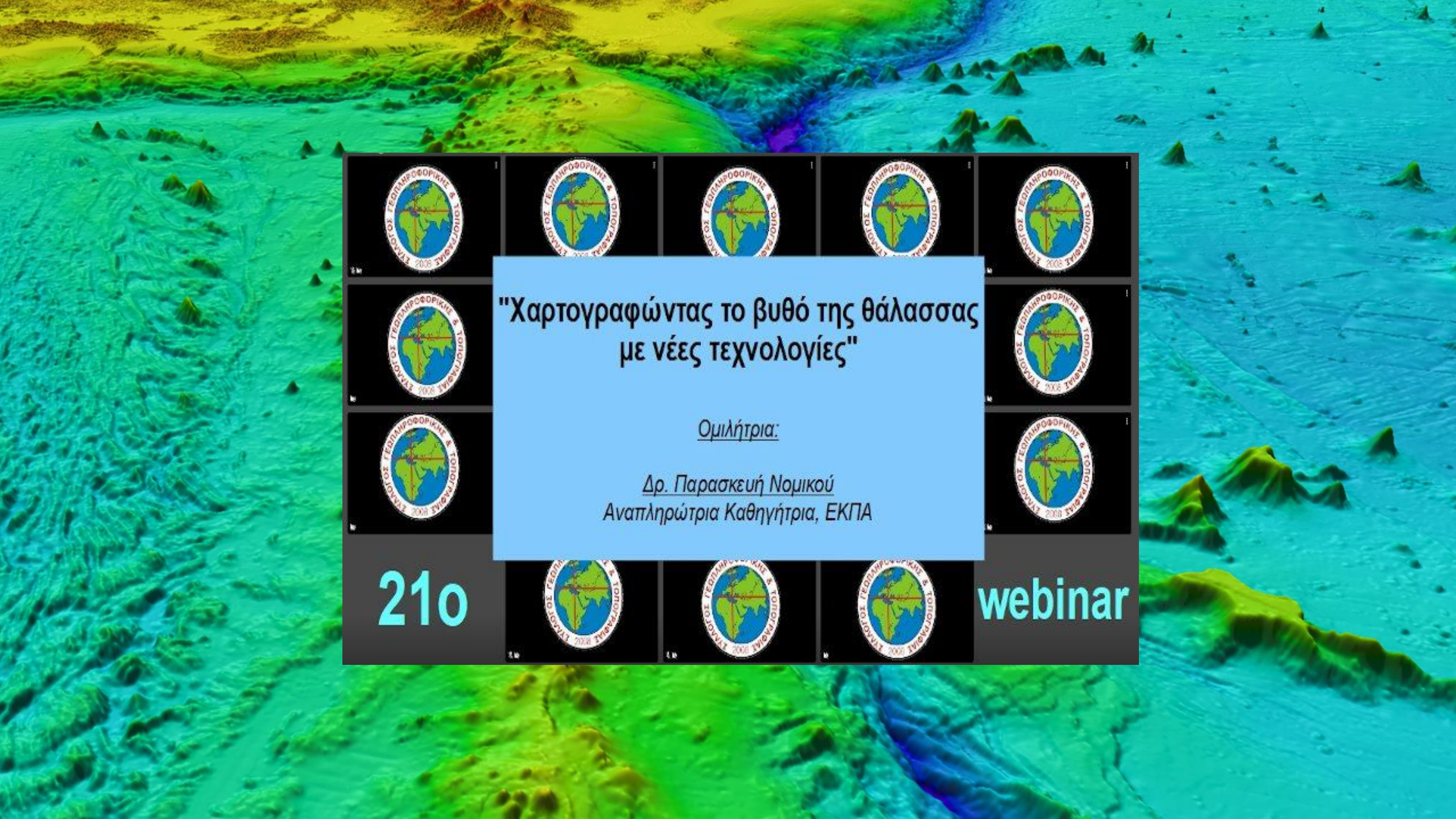

"Χαρτογραφώντας το βυθό της θάλασσας με νέες τεχνολογίες"
Ομιλήτρια:
Δρ. Παρασκευή Νομικού
Αναπληρώτρια Καθηγήτρια, ΕΚΠΑ
21ο
webinar

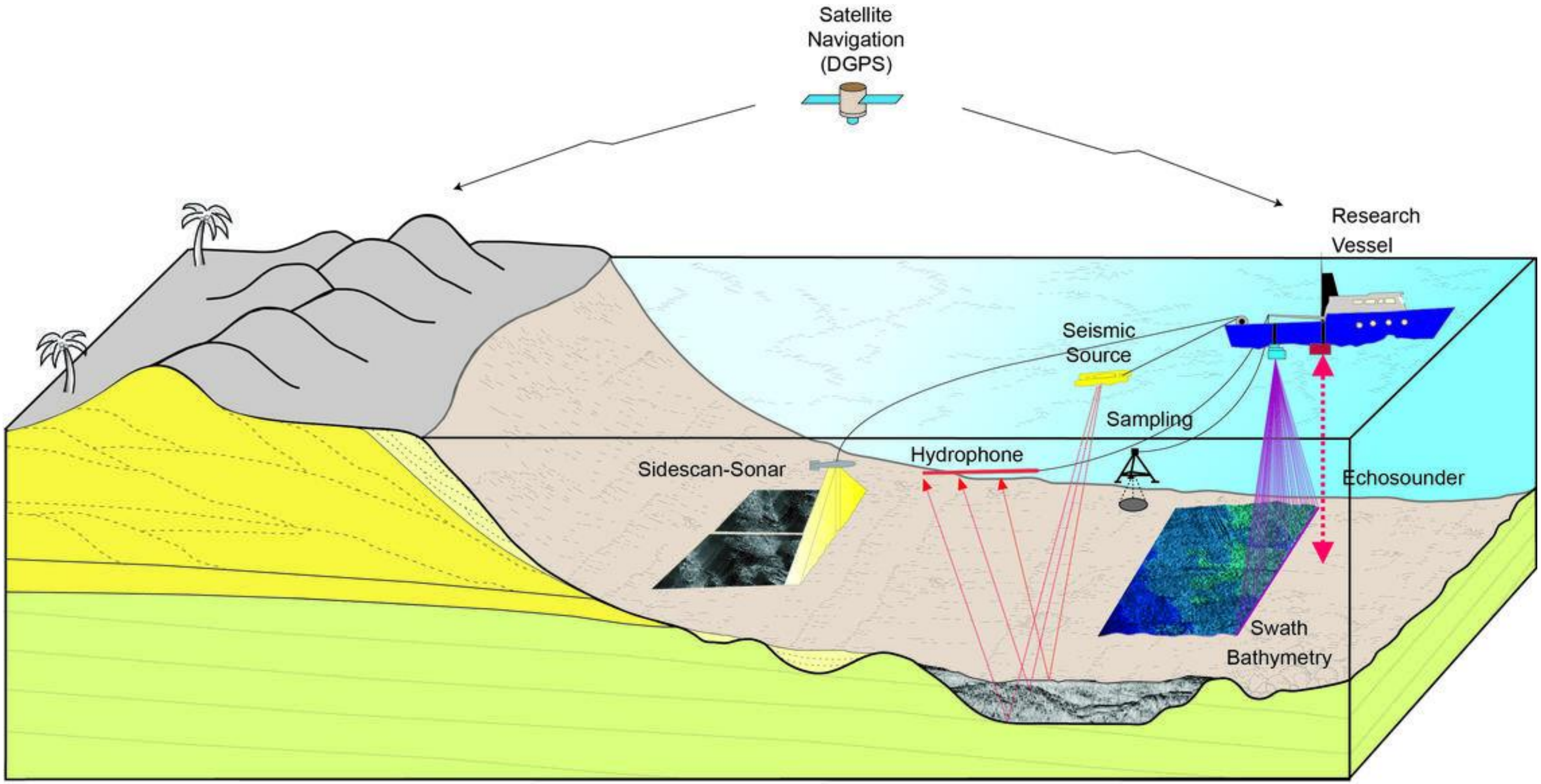
DEM – DIGITAL ELEVATION MODEL

DEM is a MODEL
that approximates the nature (Earth's surface) and its nominal ground

The models might be different concerning:

- their purpose of use
- quality of data sources
- interpolation algorithms
- experiences of operator
- etc…

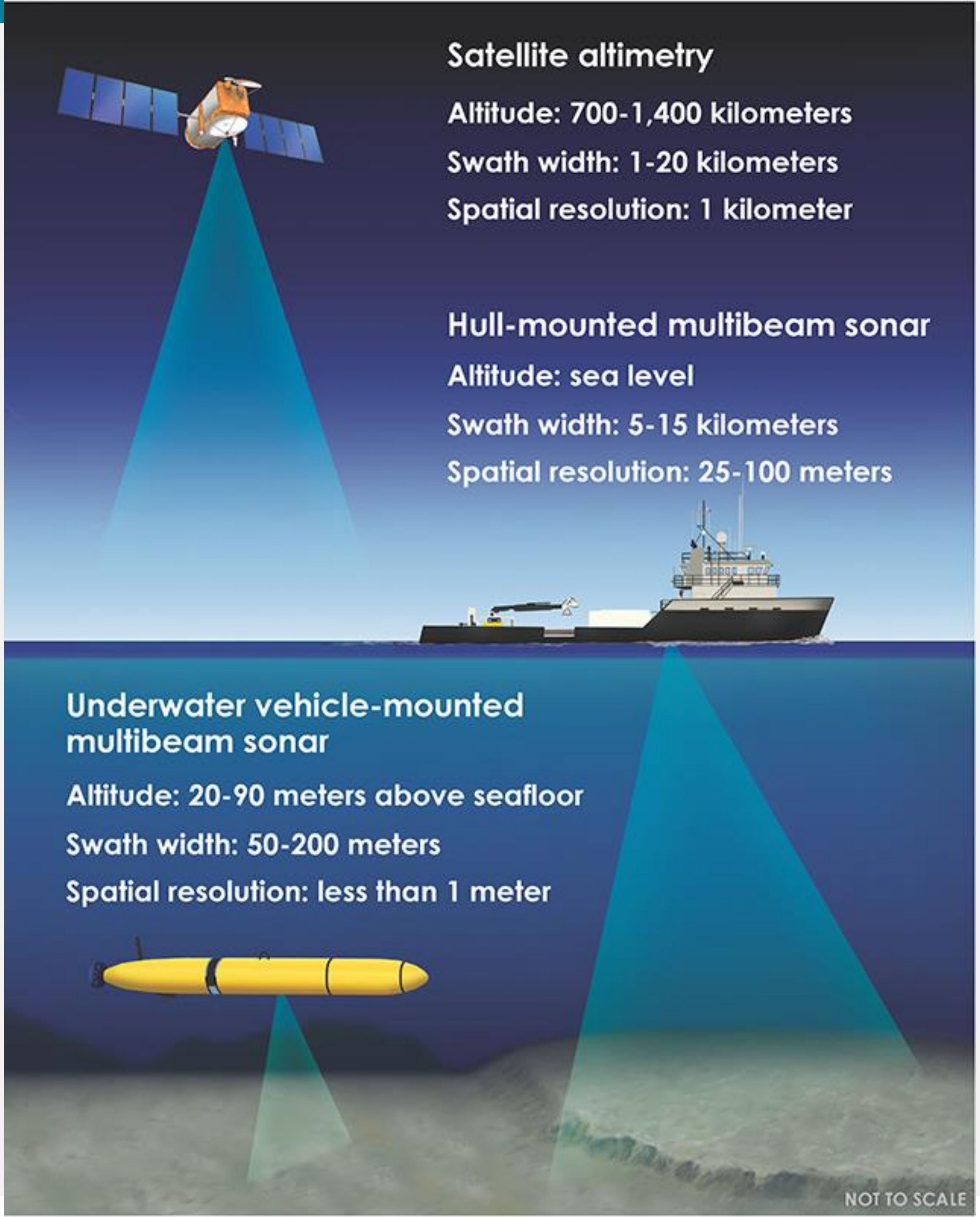
DEM should be carefully produced or chosen regarding purpose of required applications



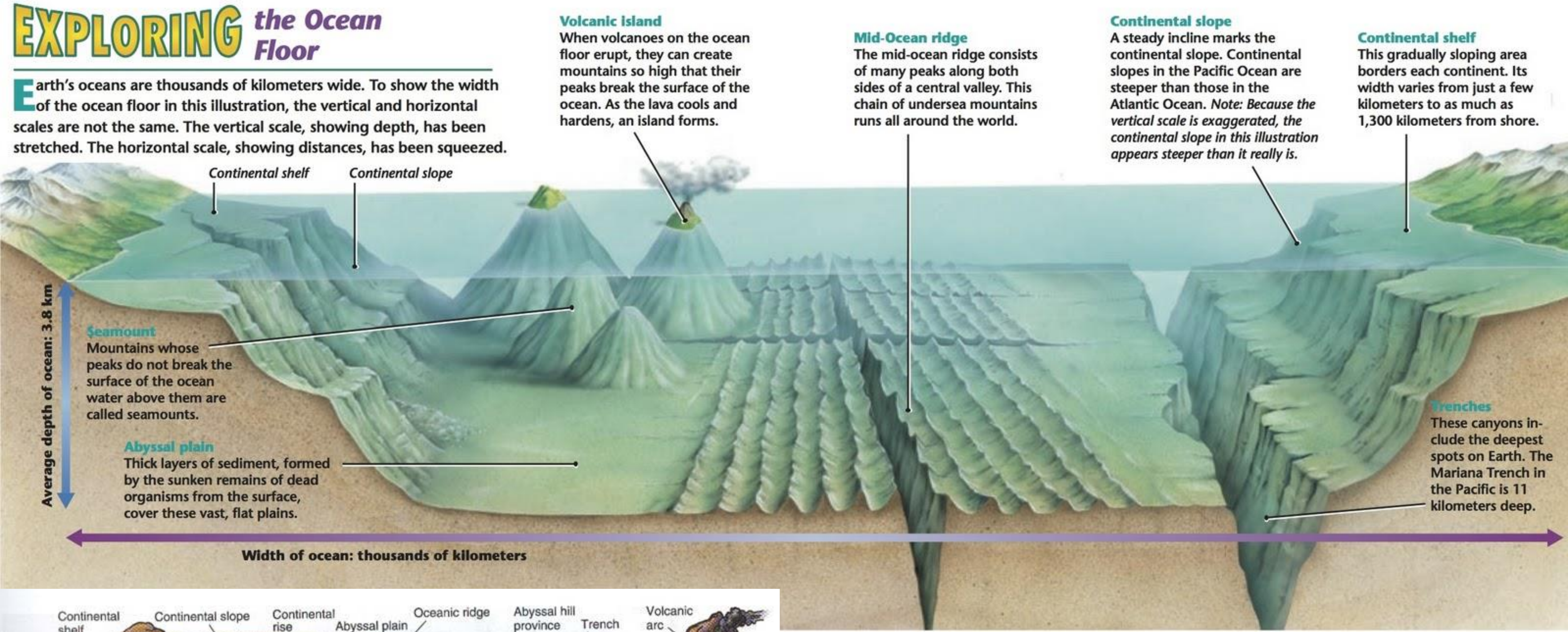
Graphic showing geophysical and sampling systems used to define the seafloor topography, surface sediments, and underlying geology. **Sidescan-sonar systems** acquire information about the surface of the seafloor, **swath bathymetric systems** measure the depth, or seafloor topography, **seismic sources** map the underlying geologic structure, **single-beam echosounders** map the depth at a point beneath the vessel, and **sampling systems** collect samples of the seafloor and can be equipped with digital camers and video systems to collect optical images of the seafloor.

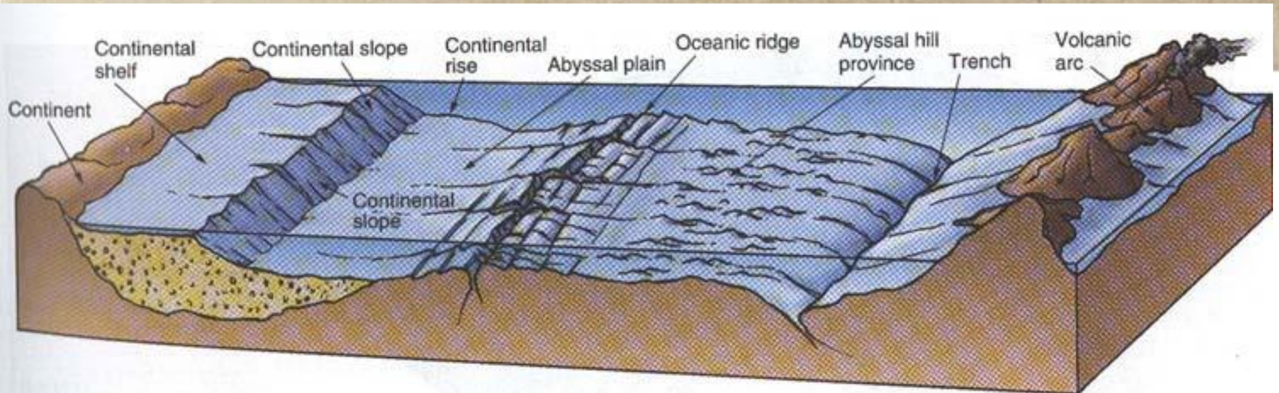
Sea Floor Exploration

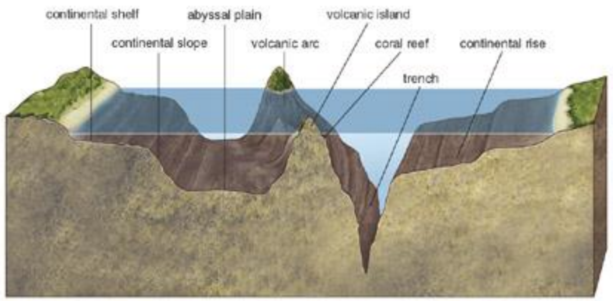
Seafloor Mapping

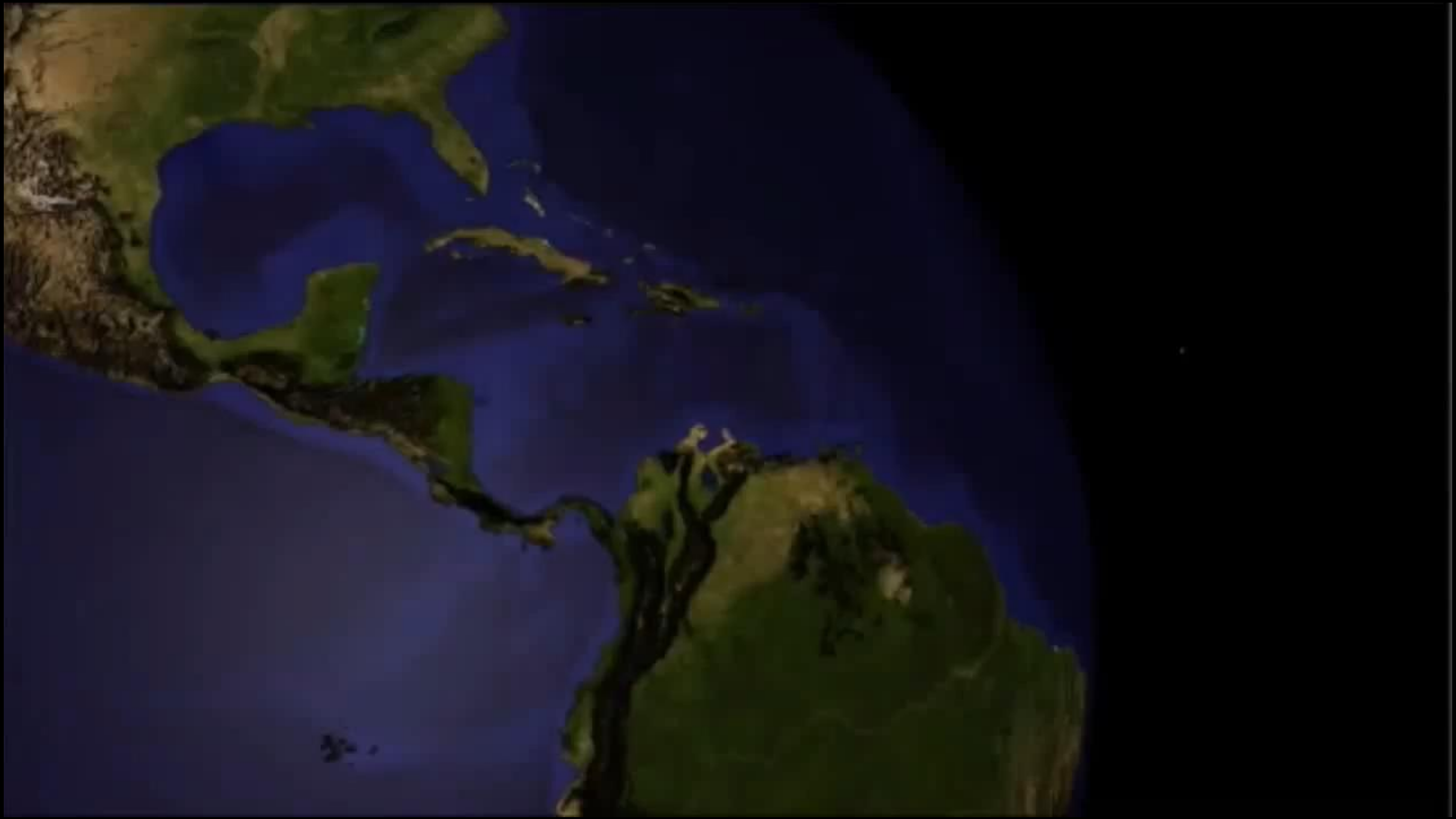


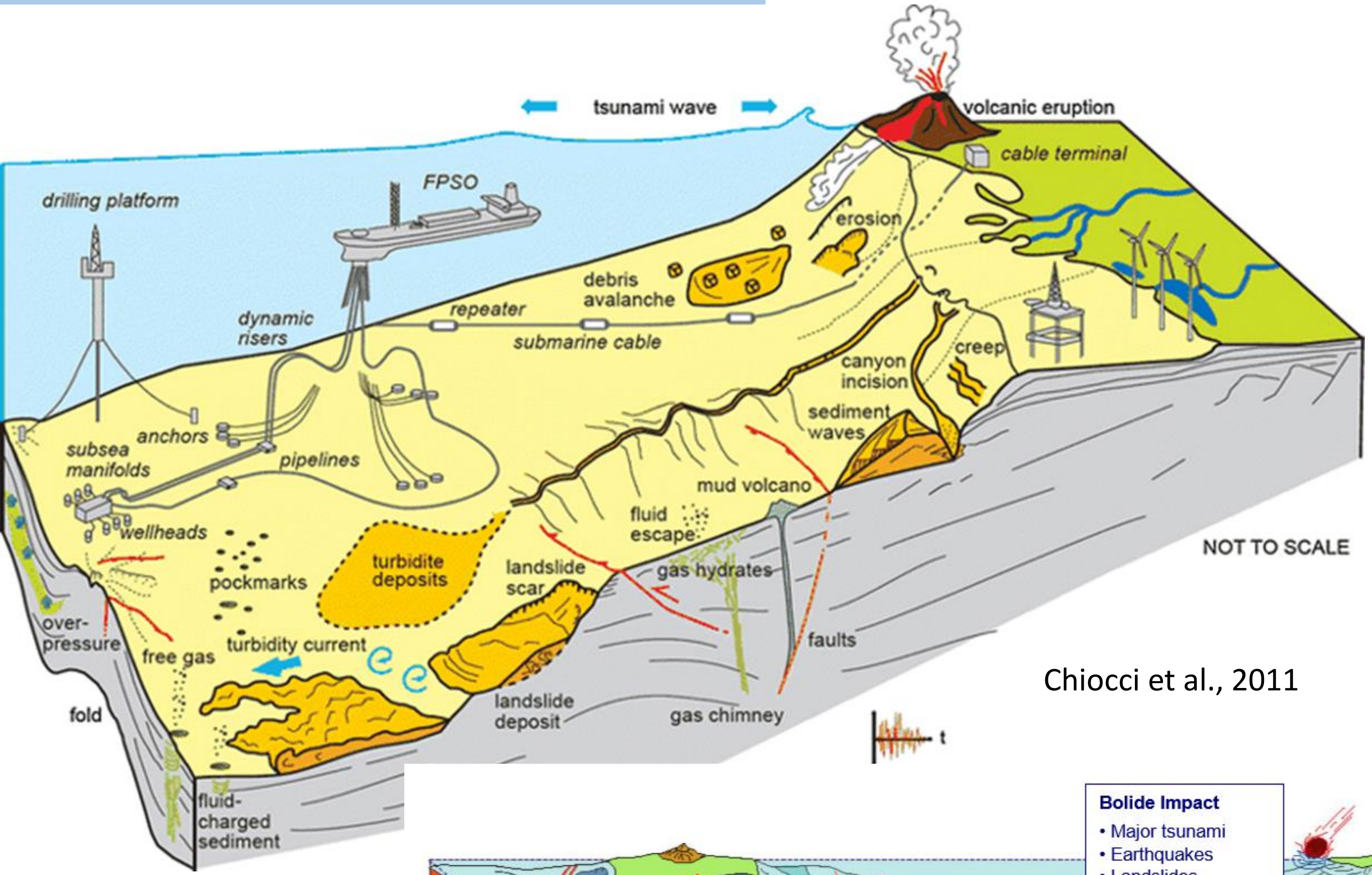
Three modern tools for collecting bathymetric data: **satellite altimetry, hull-mounted multibeam sonar and underwater vehicle-mounted multibeam sonar.** Satellite altimetry senses differences in the height of the ocean surface, which is subtly shaped by seafloor topography, as opposed to detecting bathymetry directly.


EXPLORING the Ocean Floor
Earth's oceans are thousands of kilometers wide. To show the width of the ocean floor in this illustration, the vertical and horizontal scales are not the same. The vertical scale, showing depth, has been stretched. The horizontal scale, showing distances, has been squeezed.
Volcanic island
When volcanoes on the ocean floor erupt, they can create mountains so high that their peaks break the surface of the ocean. As the lava cools and hardens, an island forms.
Mid-Ocean ridge
The mid-ocean ridge consists of many peaks along both sides of a central valley. This chain of undersea mountains runs all around the world.
Continental slope
A steady incline marks the continental slope. Continental slopes in the Pacific Ocean are steeper than those in the Atlantic Ocean. Note: Because the vertical scale is exaggerated, the continental slope in this illustration appears steeper than it really is.
Continental shelf
This gradually sloping area borders each continent. Its width varies from just a few kilometers to as much as 1,300 kilometers from shore.
Continental shelf
Continental slope
Seamount
Mountains whose peaks do not break the surface of the ocean water above them are called seamounts.
Abyssal plain
Thick layers of sediment, formed by the sunken remains of dead organisms from the surface, cover these vast, flat plains.
Trenches
These canyons include the deepest spots on Earth. The Mariana Trench in the Pacific is 11 kilometers deep.
Average depth of ocean: 3.8 km
Width of ocean: thousands of kilometers

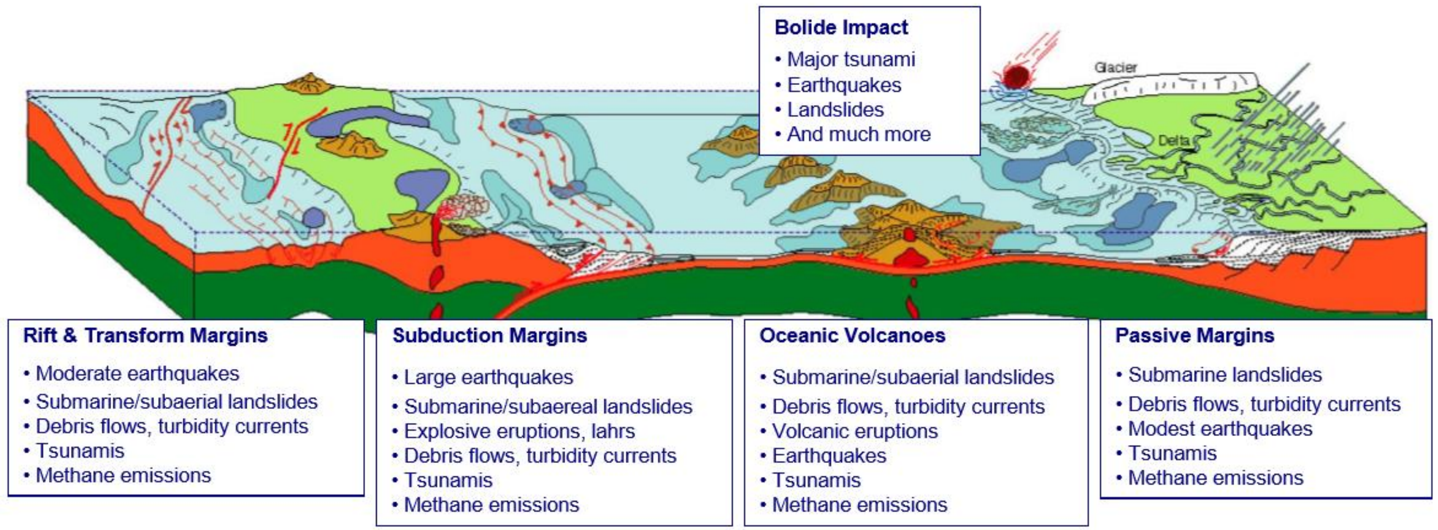

Continental shelf
Continental slope
Continental rise
Abyssal plain
Oceanic ridge
Abyssal hill province
Trench
Volcanic arc
Continent
Continental slope


continental shelf
abyssal plain
volcanic island
continental slope
volcanic arc
coral reef
continental rise
trench





Chiocci et al., 2011

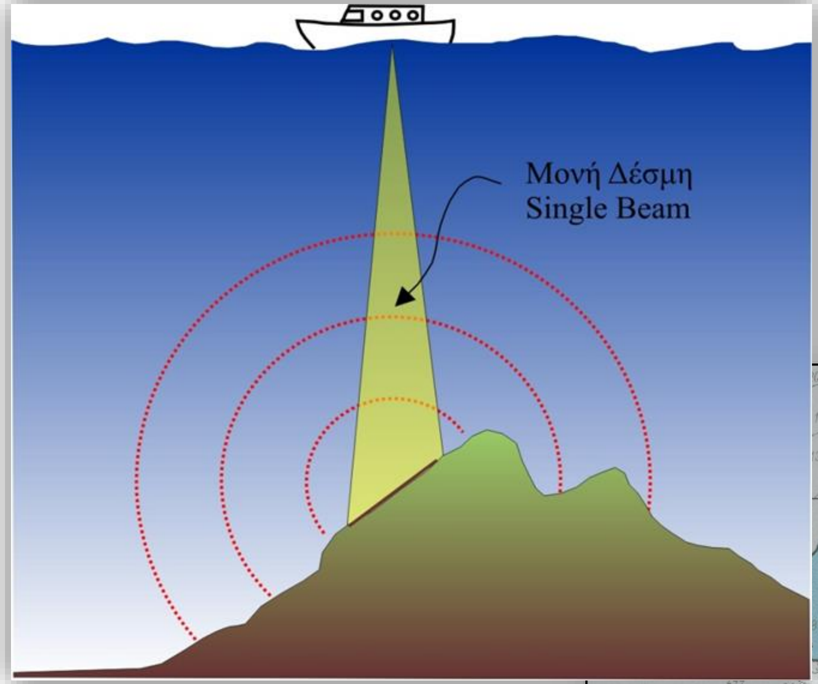


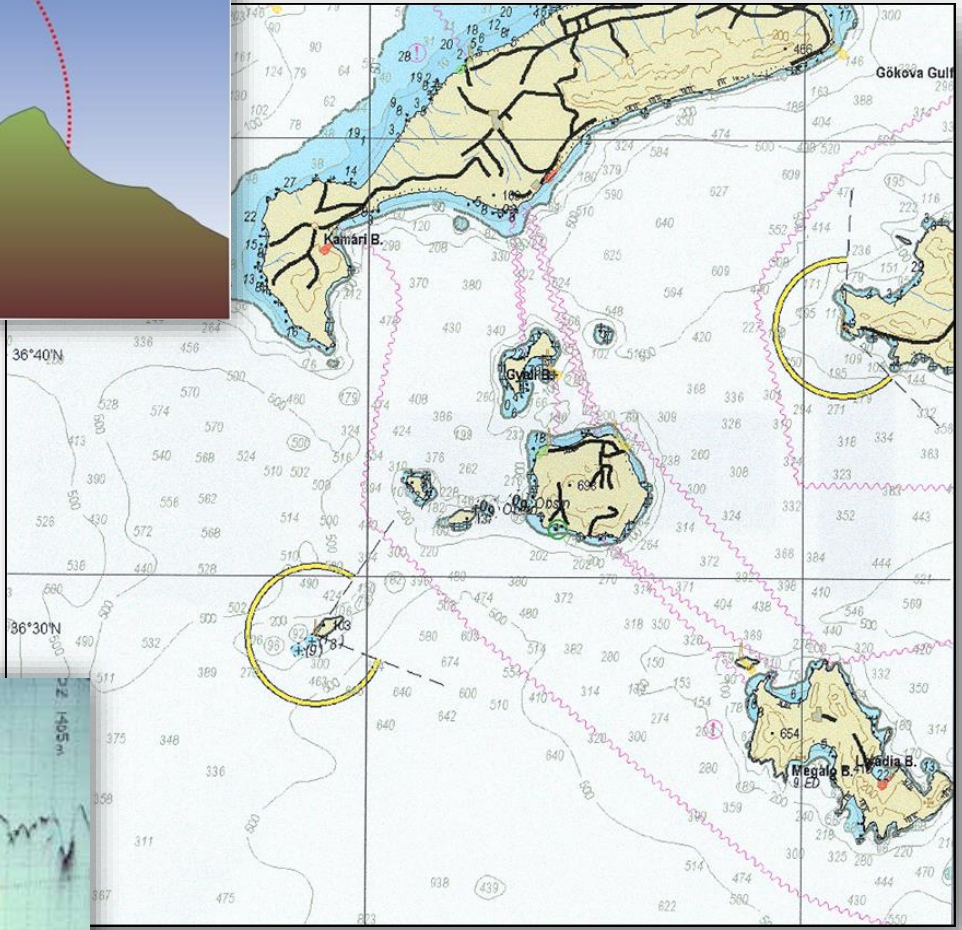
Morgan et al., 2009

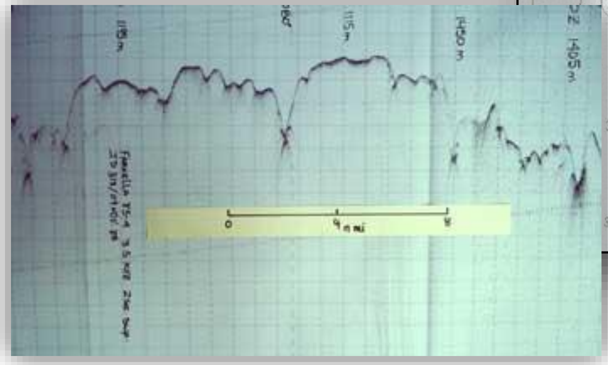
Knowing the depth, shape and type of the seafloor bathymetry and its' hydroacoustic backscatter is **fundamental** for understanding geomorphology and habitats, ocean circulation, tides, tsunami forecasting, fishing resources, sediment transport, bottom currents, environmental change, underwater geohazards, submerged remains of underwater cultural heritage, such as shipwrecks, artefacts and sunken cities, topography of archaeological sites, cable and pipeline routing, mineral extraction, oil and gas exploration and development, infrastructure construction and maintenance and much more *(Wintersteller et al., under review).*

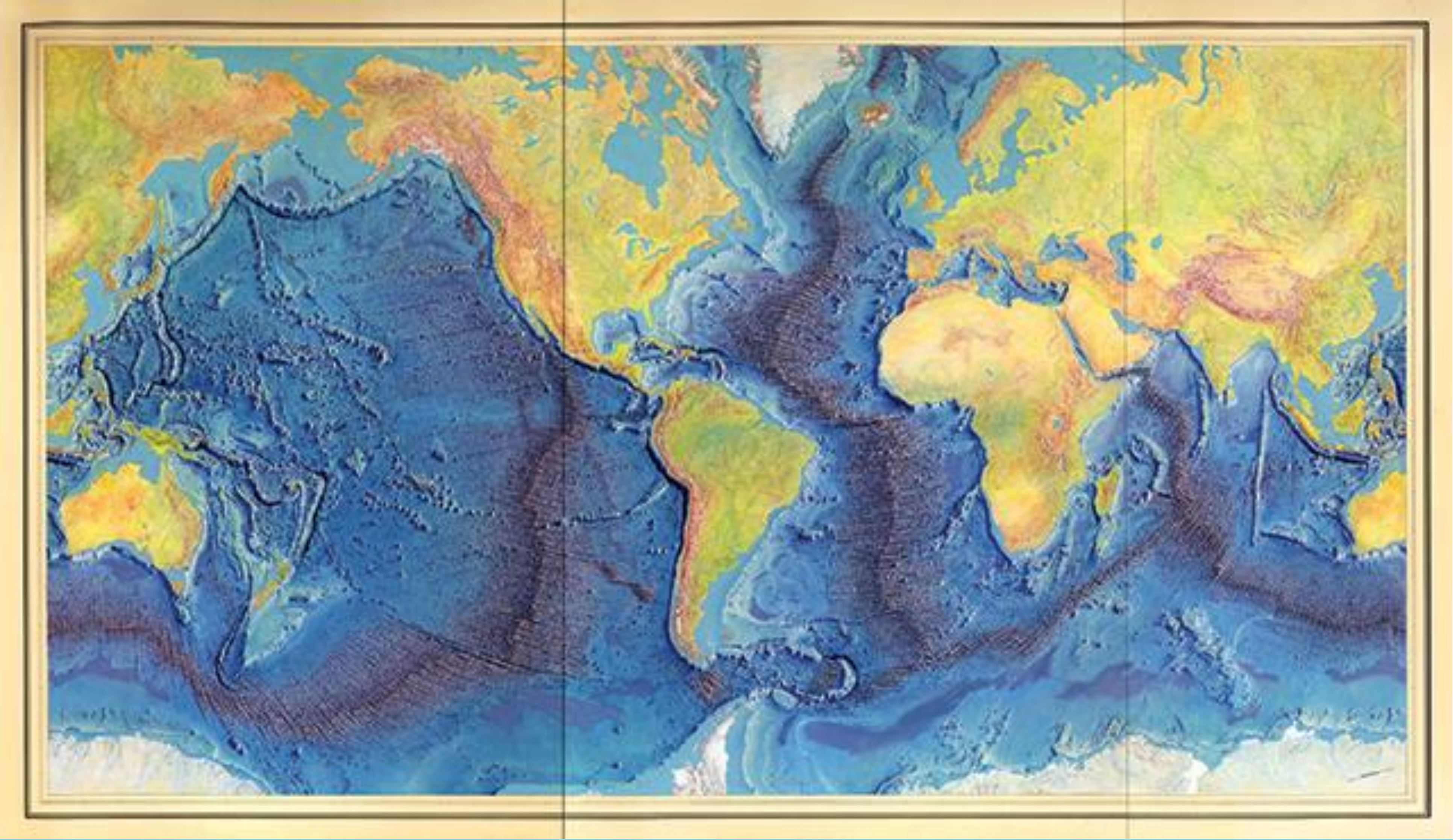
Single beam systems

In **single beam systems,** an acoustic pulse is emitted from a transducer and propagated in a single, narrow cone of energy directed downward toward the sea floor providing a single depth measurement for a location directly beneath the ship. The transducer(s) then “listens” for the reflected energy from the sea floor. Water depth is calculated by using the travel time of the emitted pulse. How long did it take the sound wave to travel from the transducer, to the sea floor, and back (i.e. two-way travel time). Two-way travel time is multiplied by the speed of sound in the ambient water (1500m/sec) and divided by two. The individual values of depth to the sea floor are subsequently contoured to generate bathymetric maps.



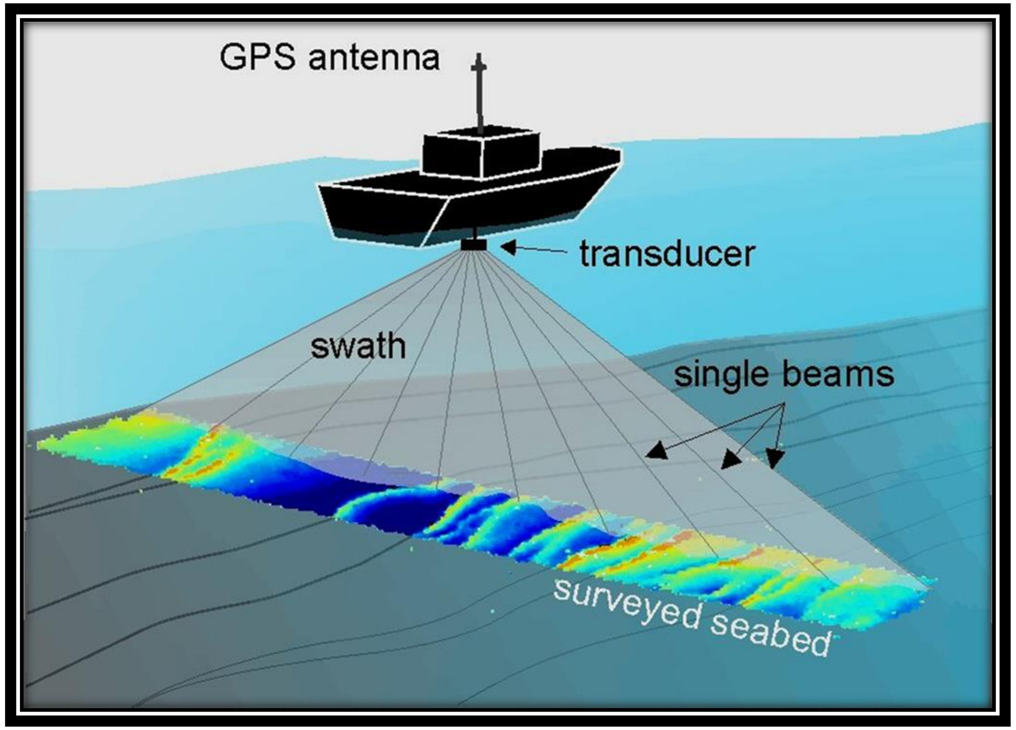




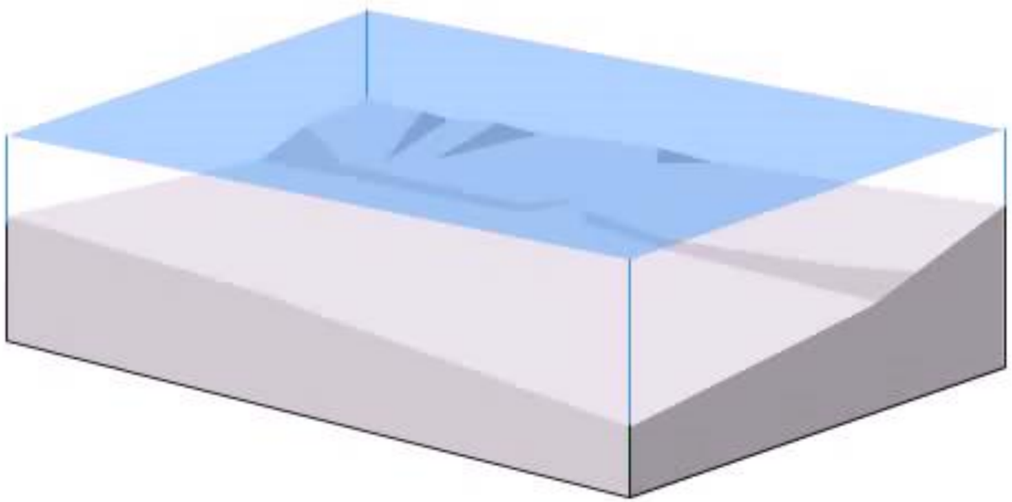


In the 1950s, Marie Tharp and Bruce Heezen, of what was then called the **Lamont Geological Observatory**, began creating seafloor maps based on single-beam sounding data from the U.S. Navy and other sources. Their compilation map of the global seafloor was published in 1977.
Credit: Library of Congress, Geography and Map Division.

Multibeam systems



SONDA BATIMÉTRICA

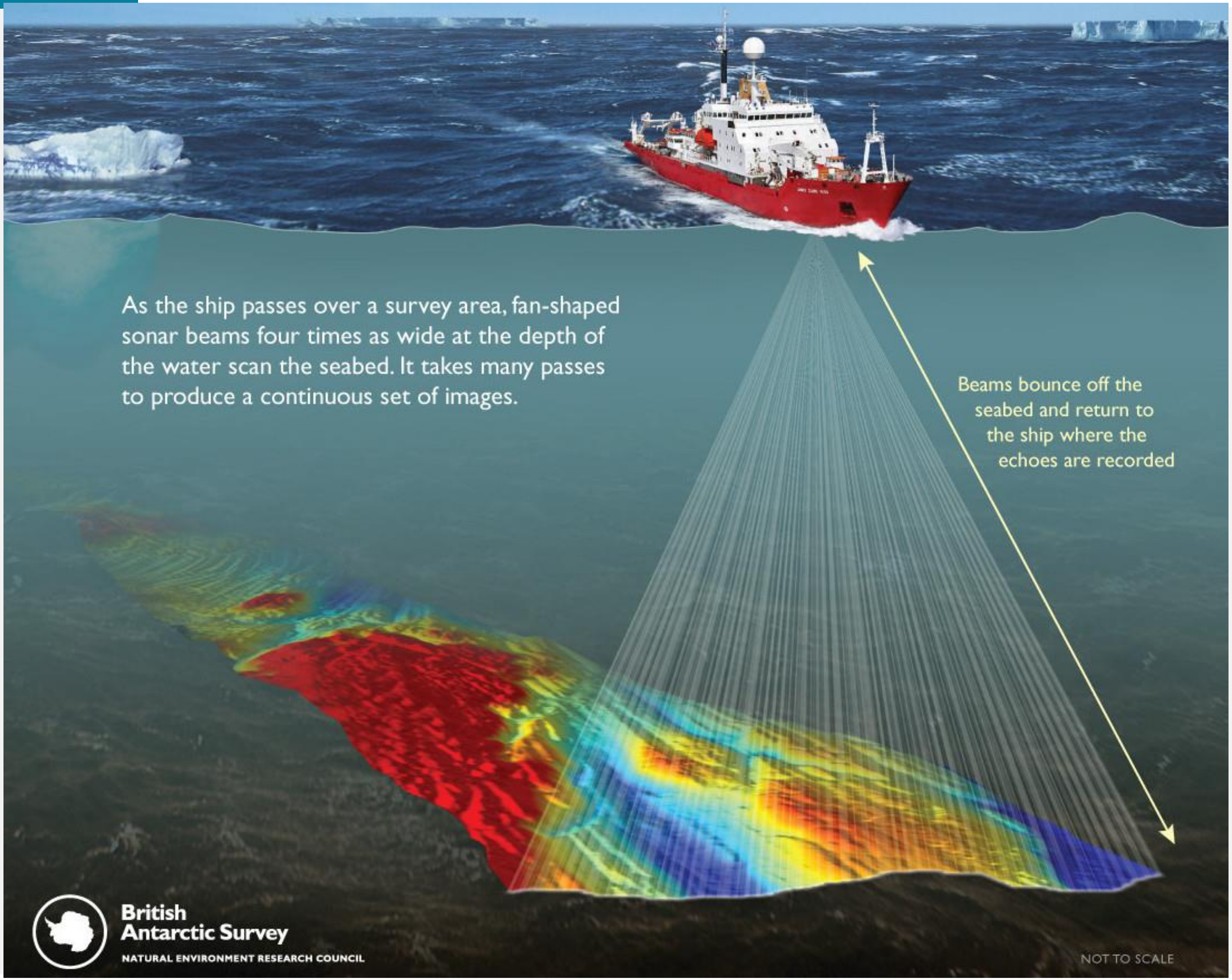


La sonda batimétrica permite realizar mapas batimétricos de detalle.
Aprieta el botón para ver como funciona.

Multibeam echosounder systems are used for seabed mapping. Sonar sounding systems, also known as swath, were developed in the early 1960's for military use. The multibeam emits sound waves in a fan shape providing a wide coverage of the bottom. The water depth is determined by measuring the double way transit time of an acoustic wave reflected on a seabed in combination with the sound velocity in the water. All the collected data are processed with appropriate software thus enabling us to construct very detailed and precise maps of the seafloor. Nowadays, these bathymetric maps consist the primary tool for every research.

They reveal in such detail the topography that we can identify several structures for example submarine canyons, slopes, landslides and faults.

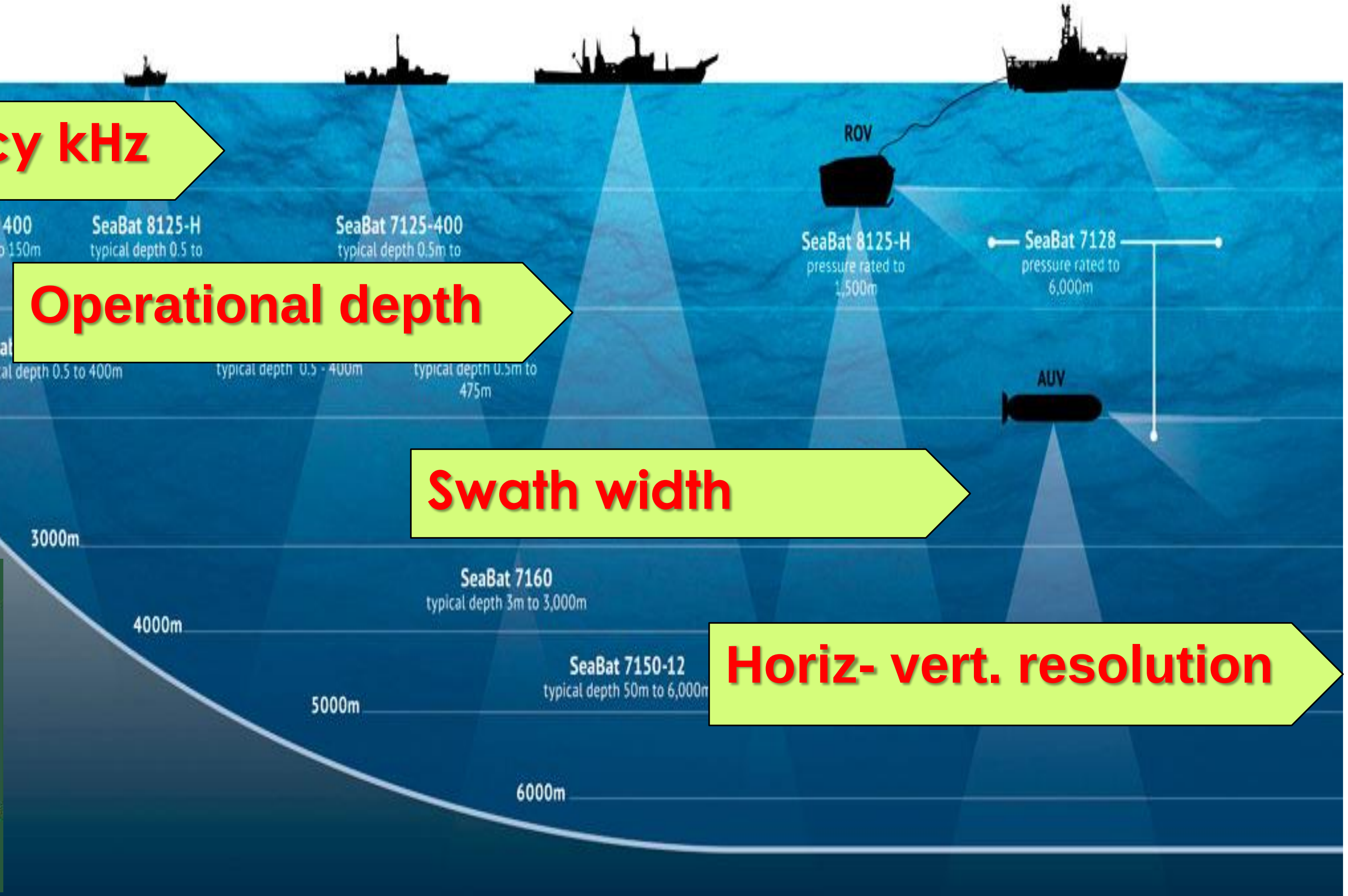
Multibeam systems

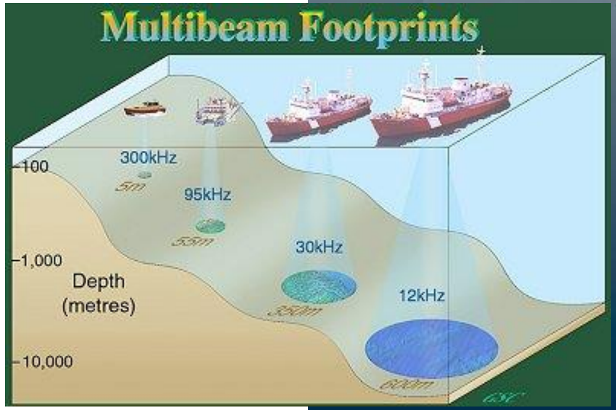


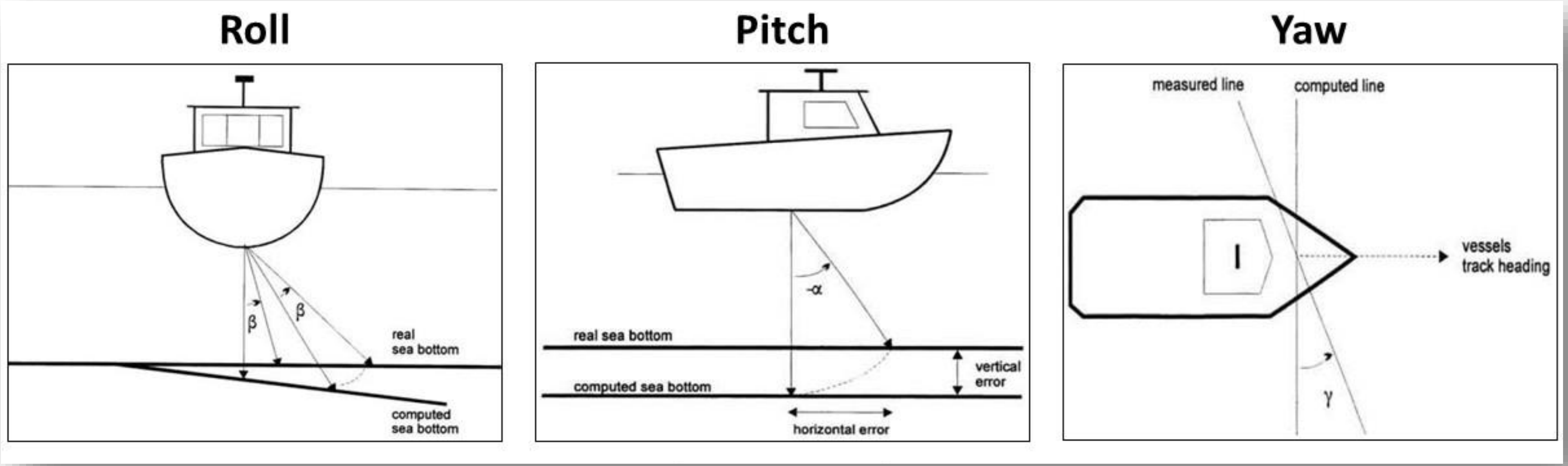
Multibeam systems emit sound waves in a fan shape beneath a ship's hull. The amount of time it takes for the sound waves to bounce off the seabed and return to a receiver is used to determine water depth.

Multibeam echosounder

Large Depth ➡ large angle
Big footprint ➡ less resolution

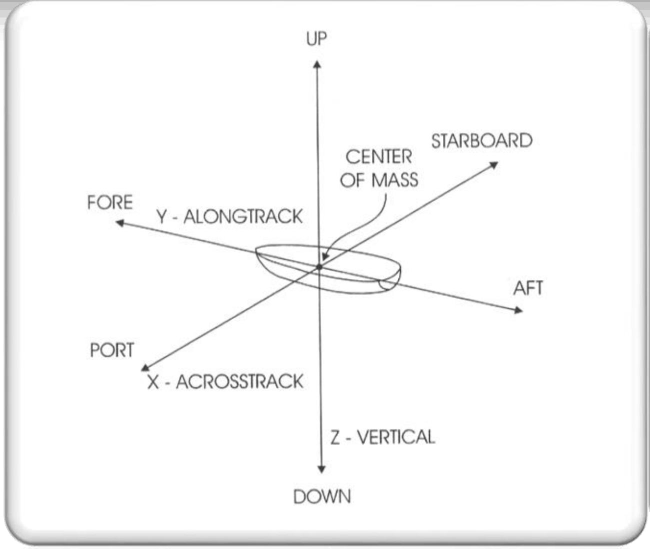


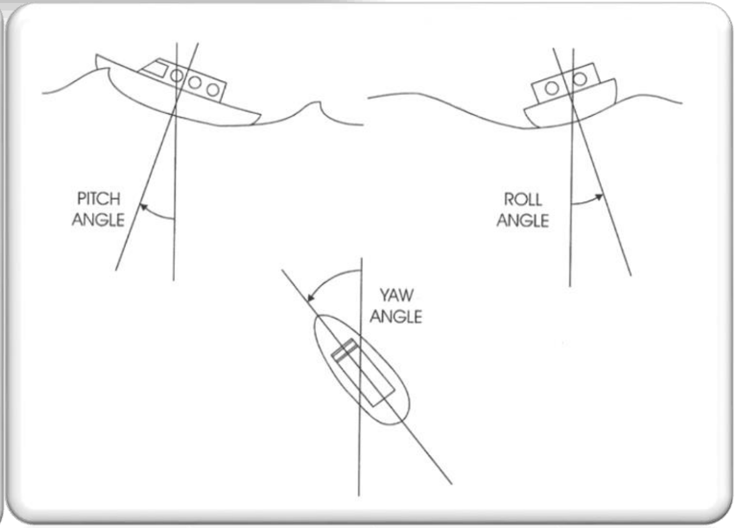




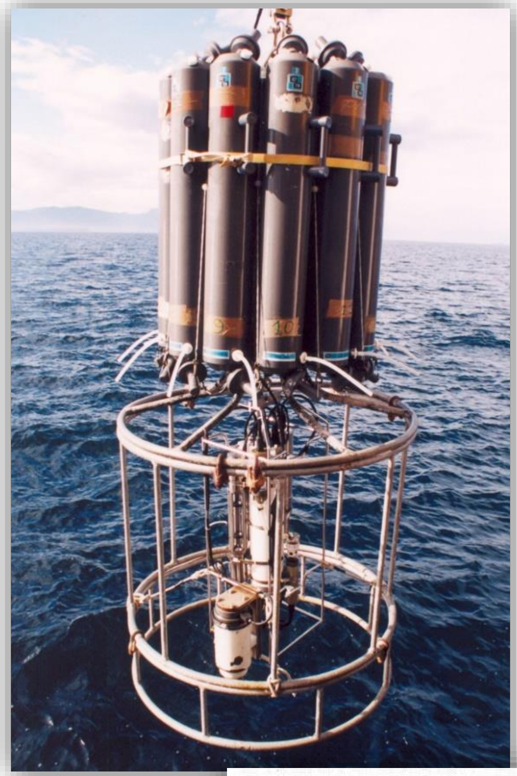
Motions

In order to accurately position multibeam sonar soundings on the ocean floor, it is necessary to precisely know each of the following: · ***horizontal position of the transducer*** · ***attitude of the transducer*** (roll, pitch and heading) · ***elevation of the transducer*** (heave and tide) · ***speed of sound through the water column***

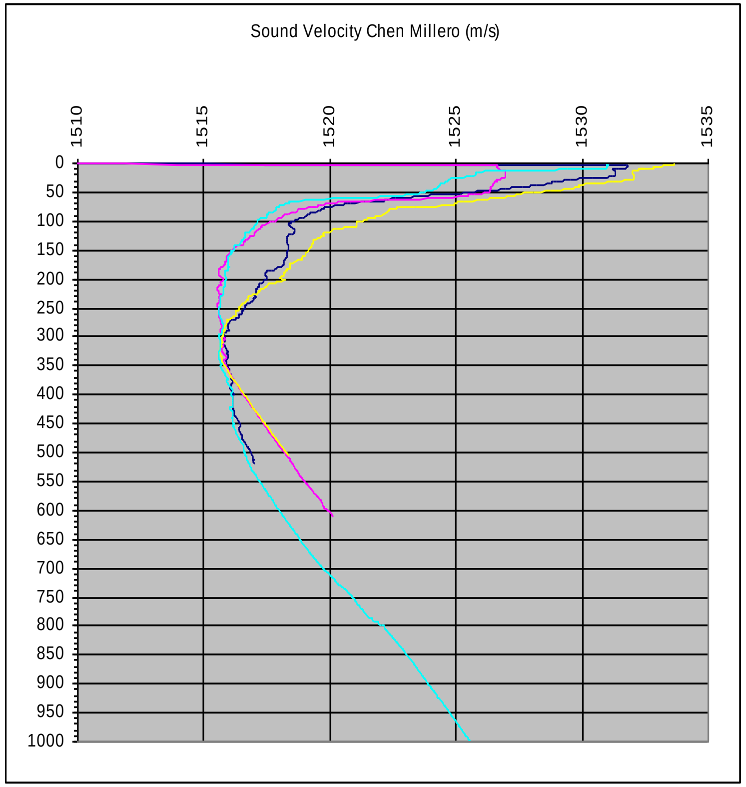


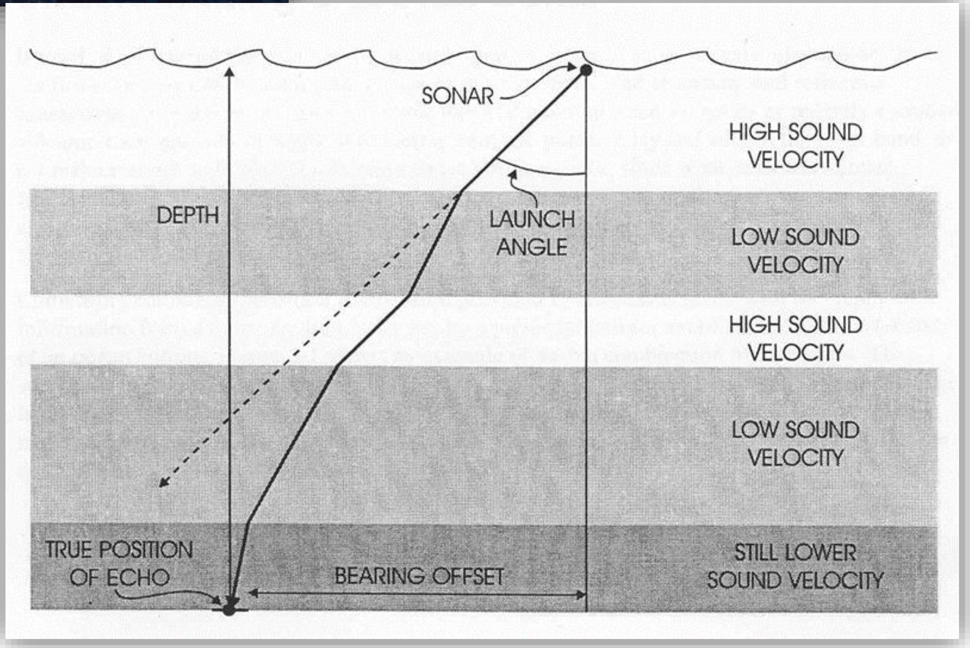


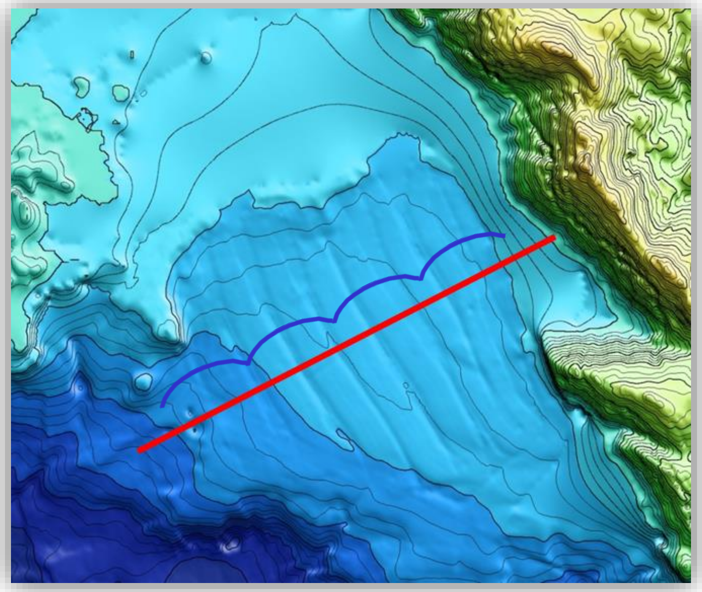
A **yaw** motion is a side-to side movement of the bow and stern of the ship. The transverse/Y axis, lateral axis, or **pitch** axis is an imaginary line running horizontally across the ship and through the centre of gravity. A **roll** motion is an up-or-down movement of the bow and stern of the ship.



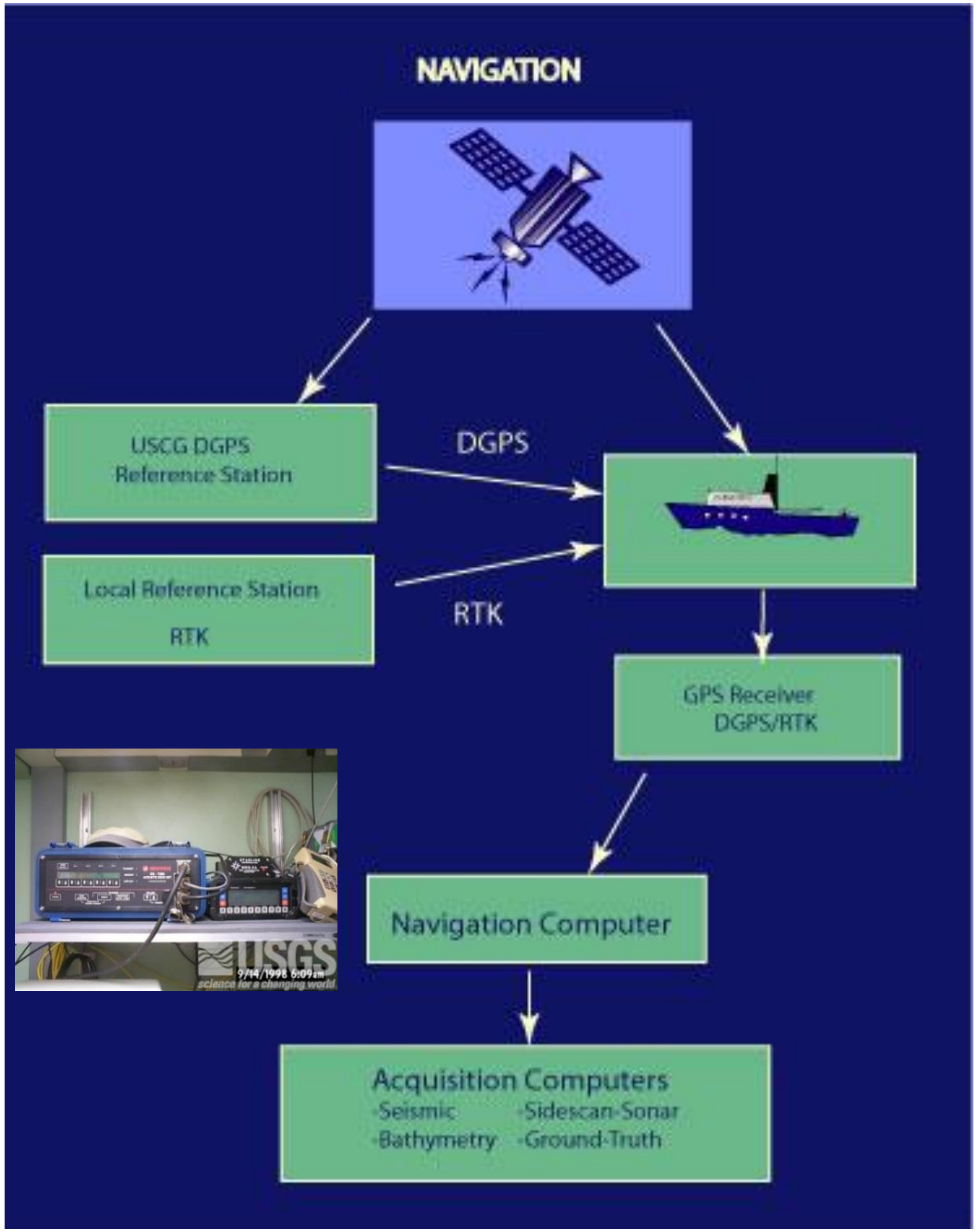
CTD stands for conductivity, temperature, and depth, and refers to a package of electronic instruments that measure these properties.





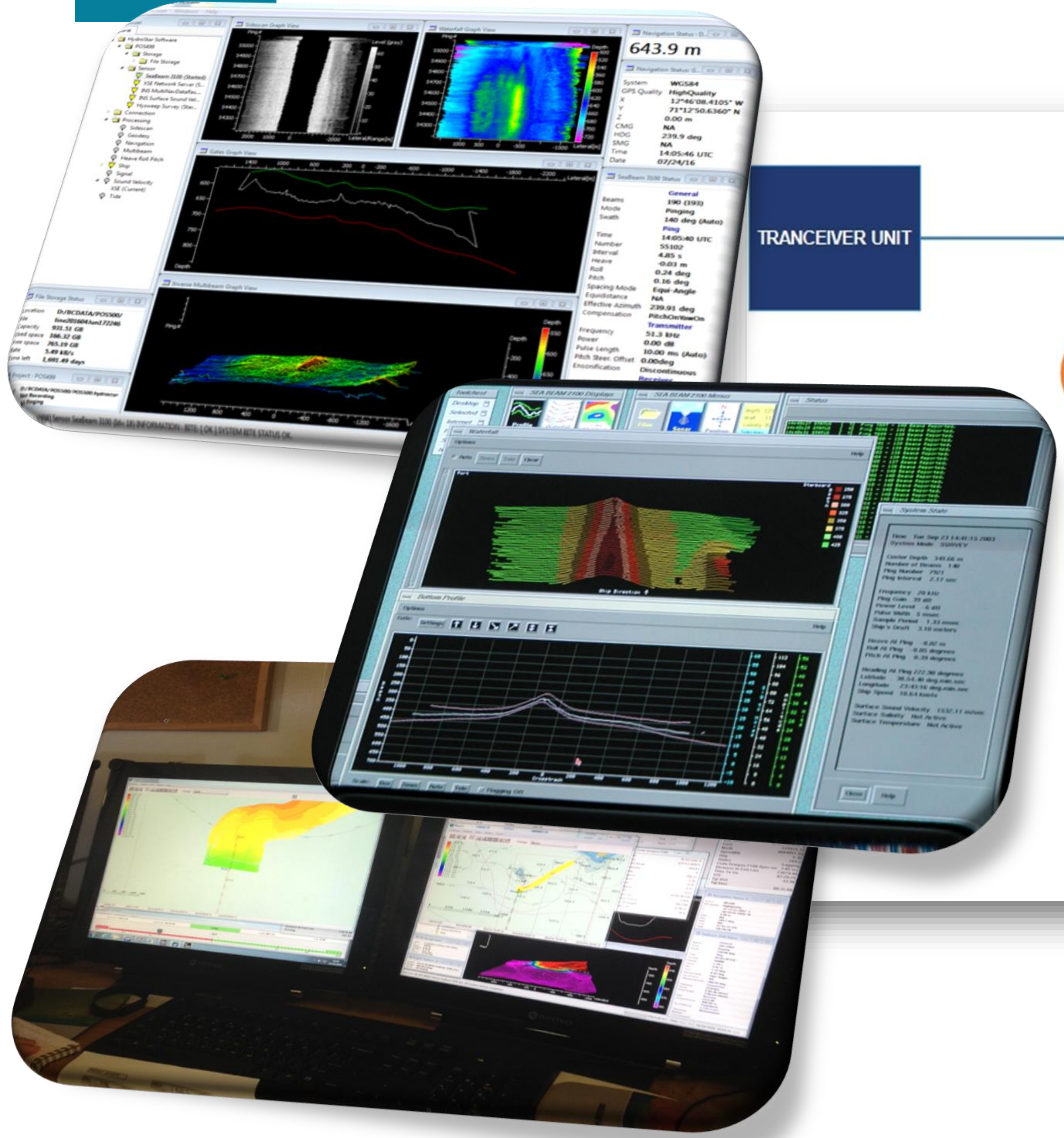


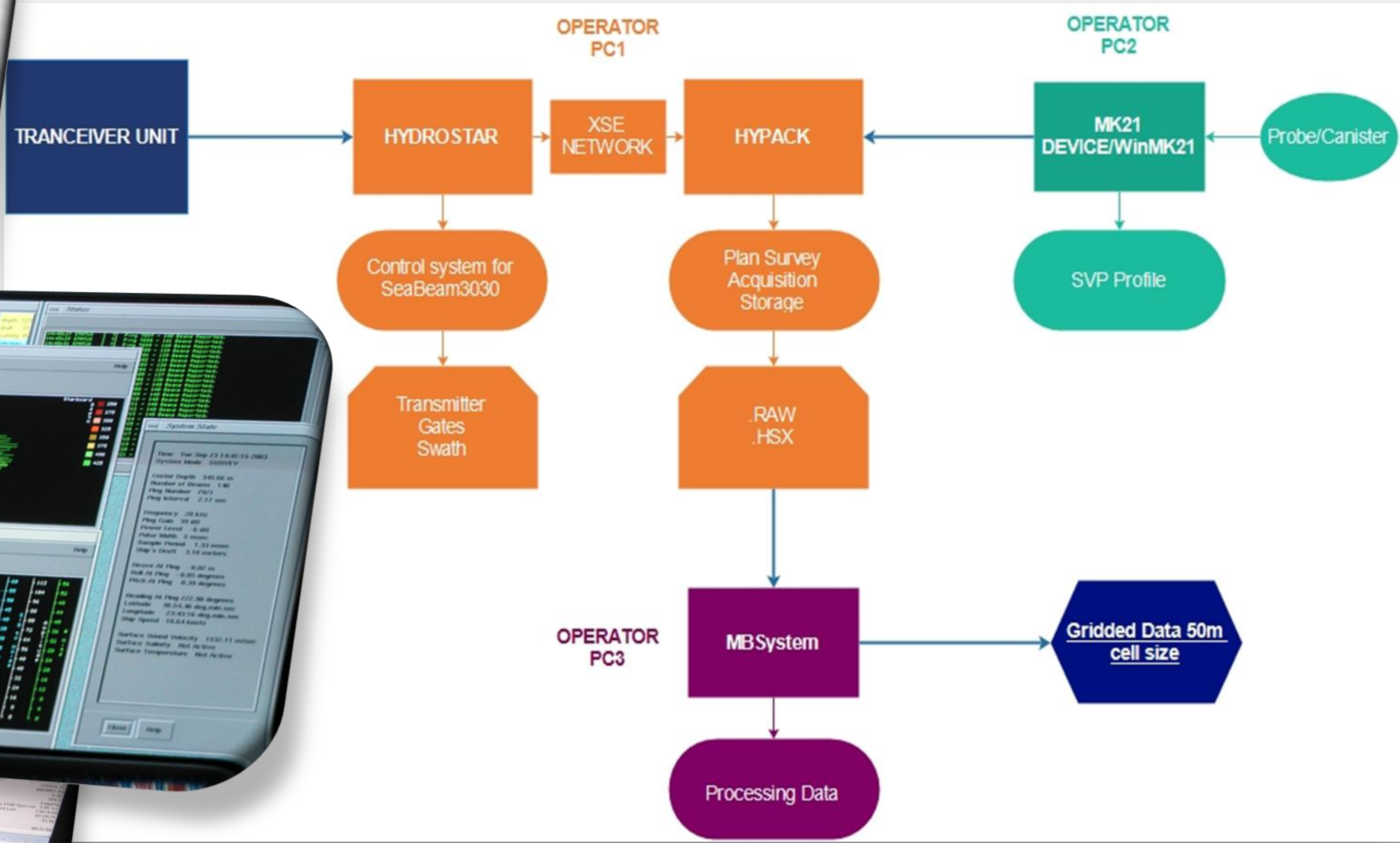
Navigation systems



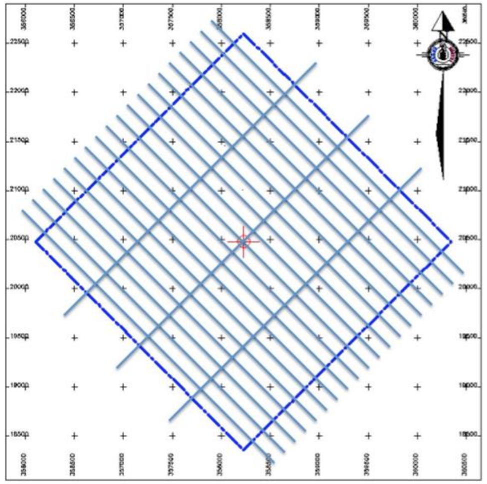
The Global Positioning System (GPS) consists of 24 to 27 satellites. The satellite broadcasts a signal that contains the position of the satellite and the precise time the signal was transmitted. By knowing its distance from three or more satellites, the receiver can calculate its position by solving a set of equations, based on the principal of triangulation. Various corrections and techniques can be applied to increase accuracies to 2 to 3 centimeters (Wells, 1986).

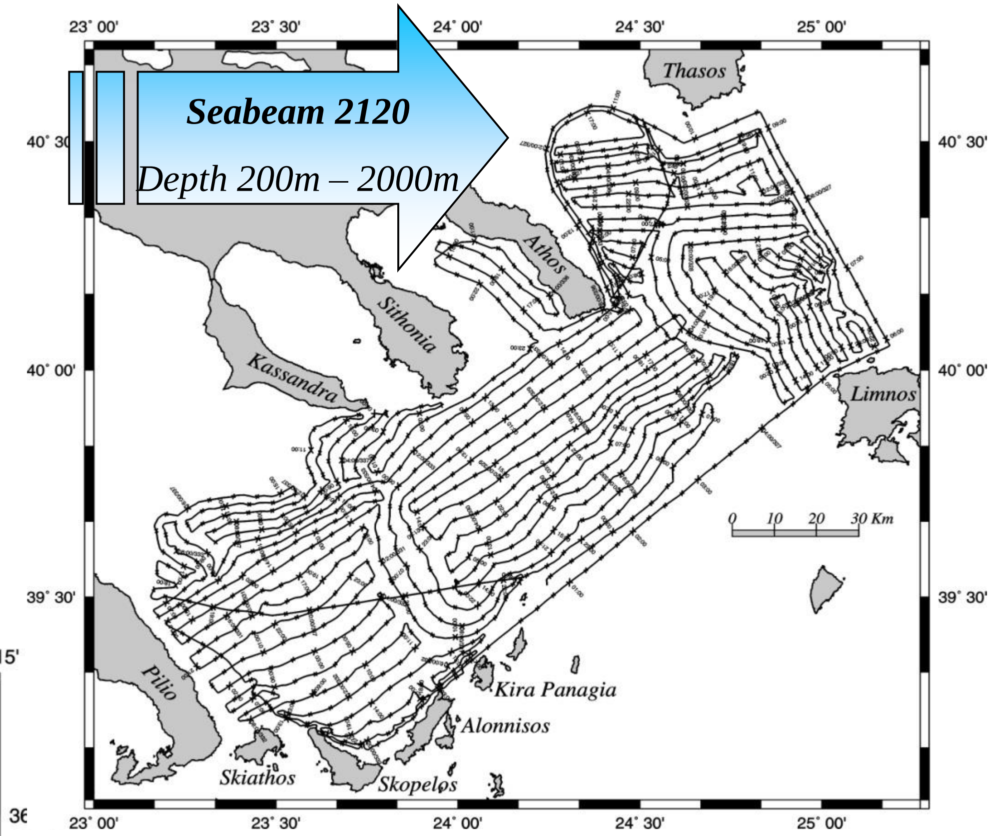
ACQUISITION

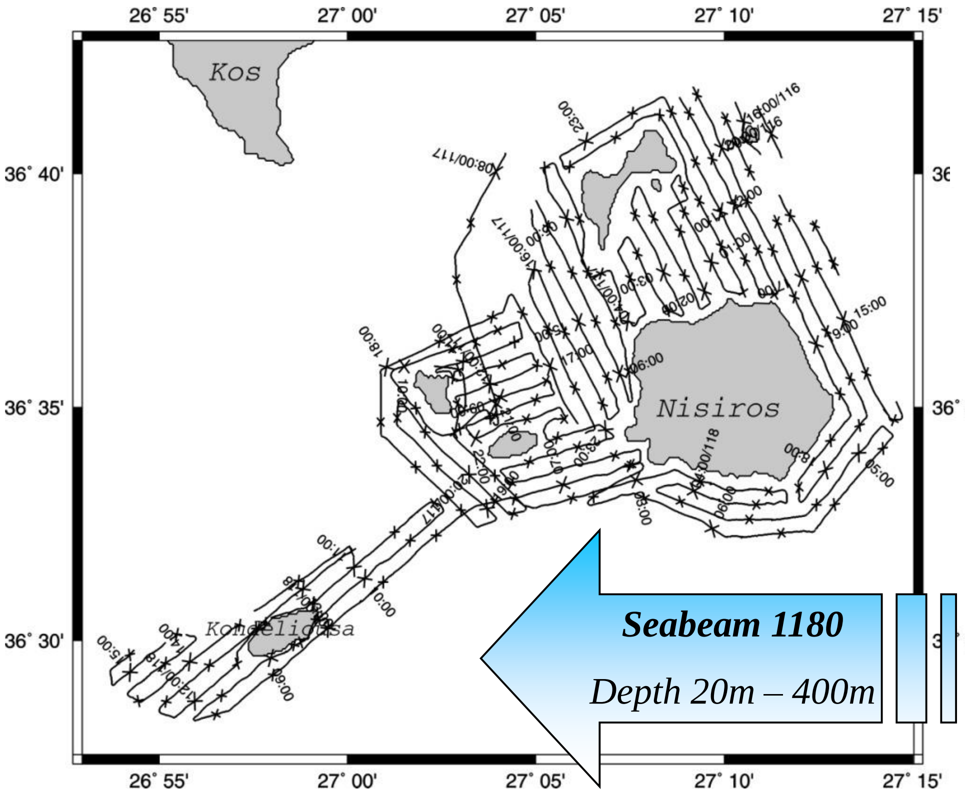


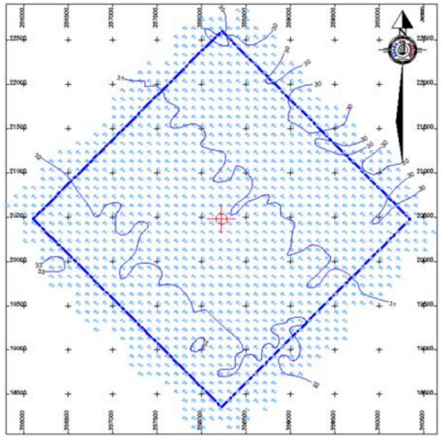


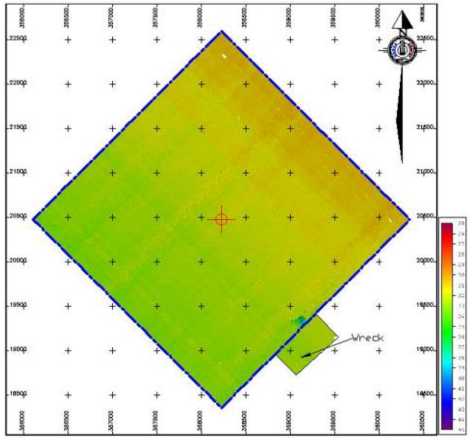
Collecting swath data











PROCESSING

Bathymetry

Research vessel

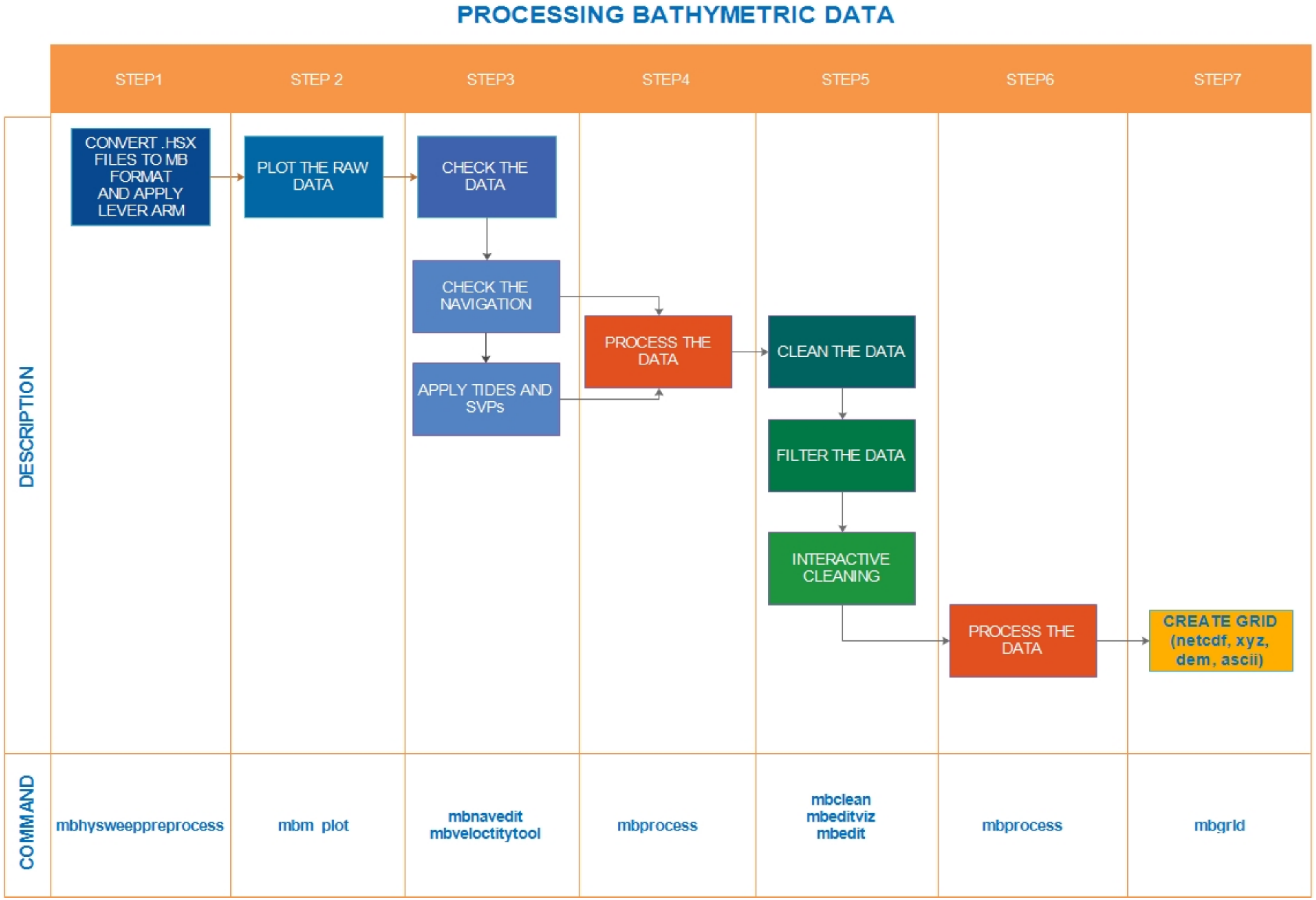
Multibeam system

Data acquisition:Hydrostar-Hypack

Data processing: MB-System

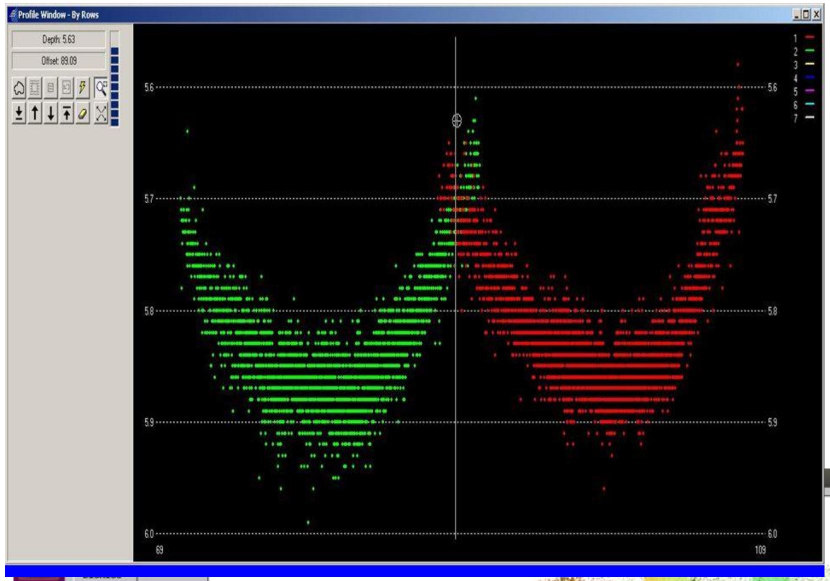
Grid cell size 50m

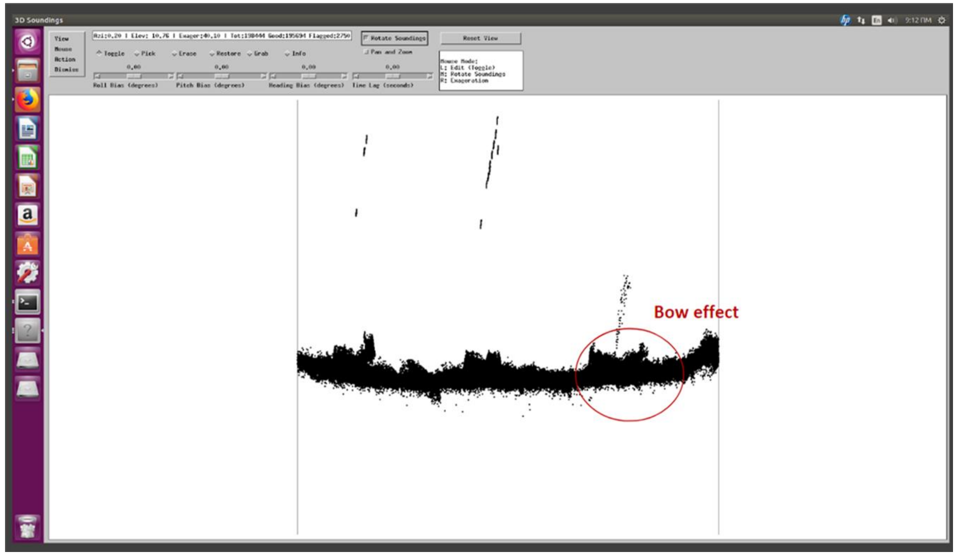
ArcGis 10.1/Global mapper

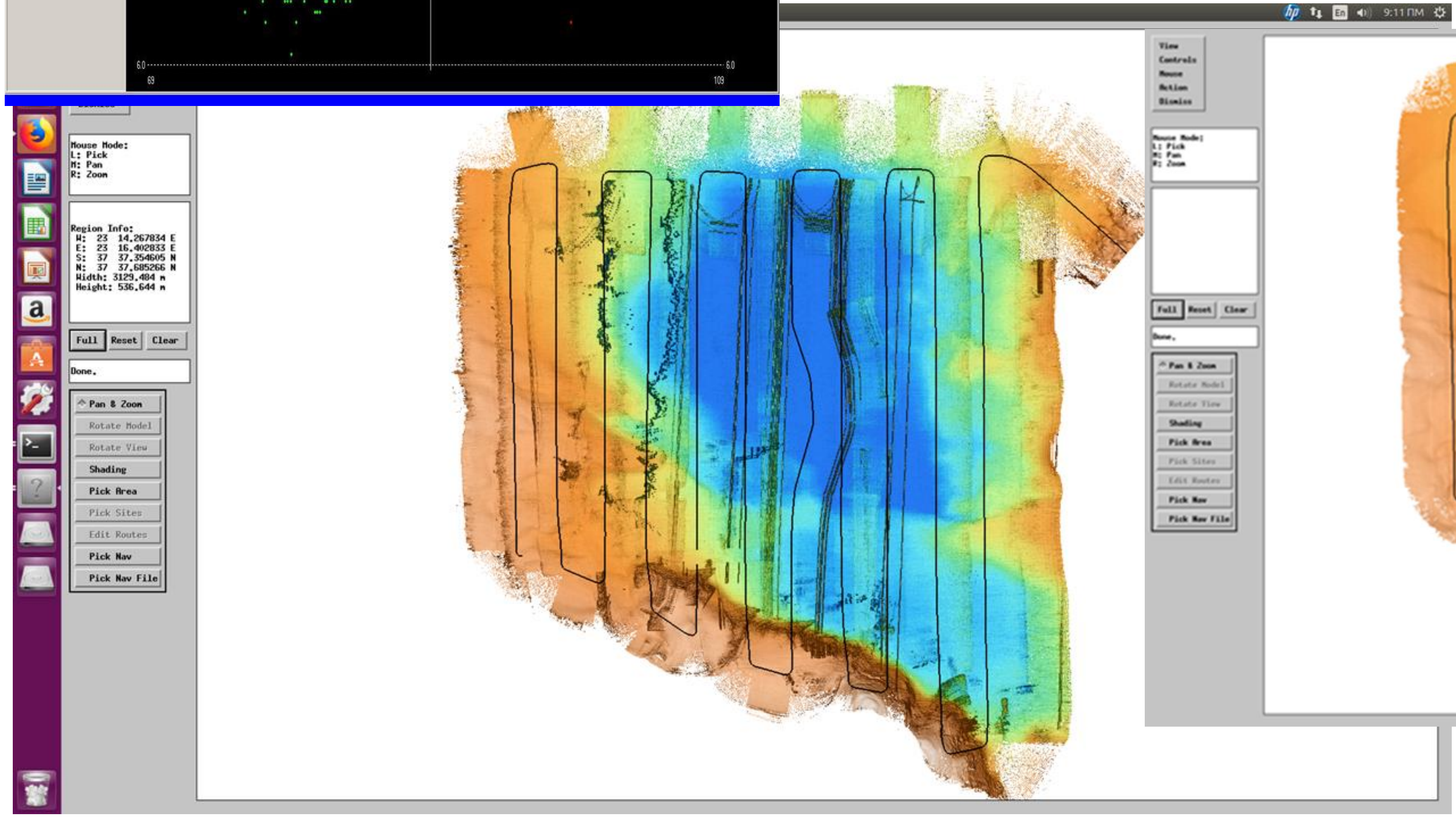


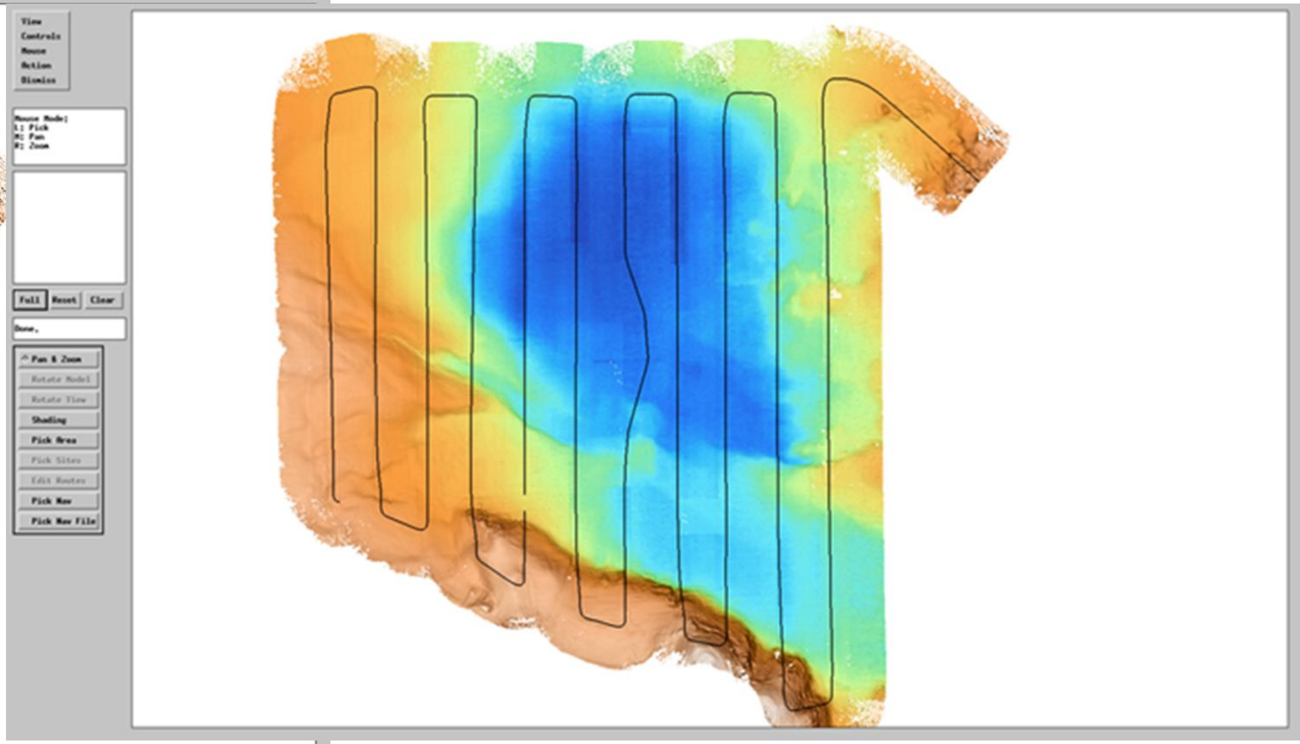
MB SYSTEM

SOUND VELOCITY PROFILE

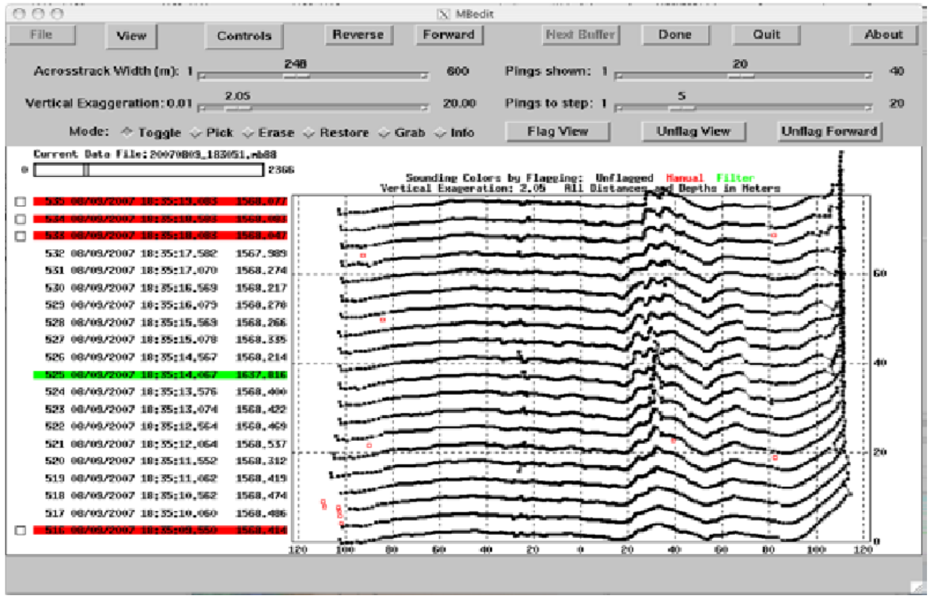


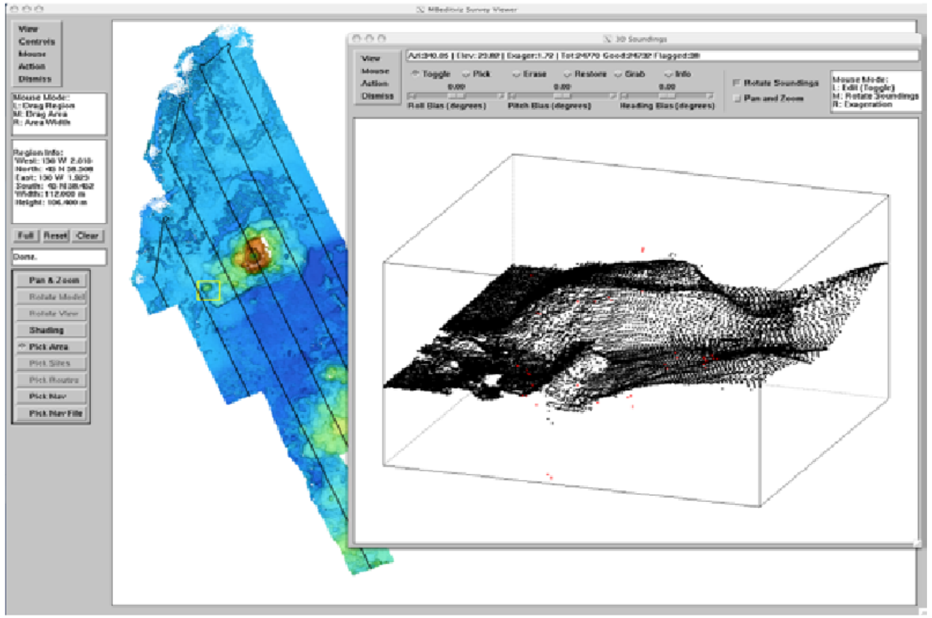


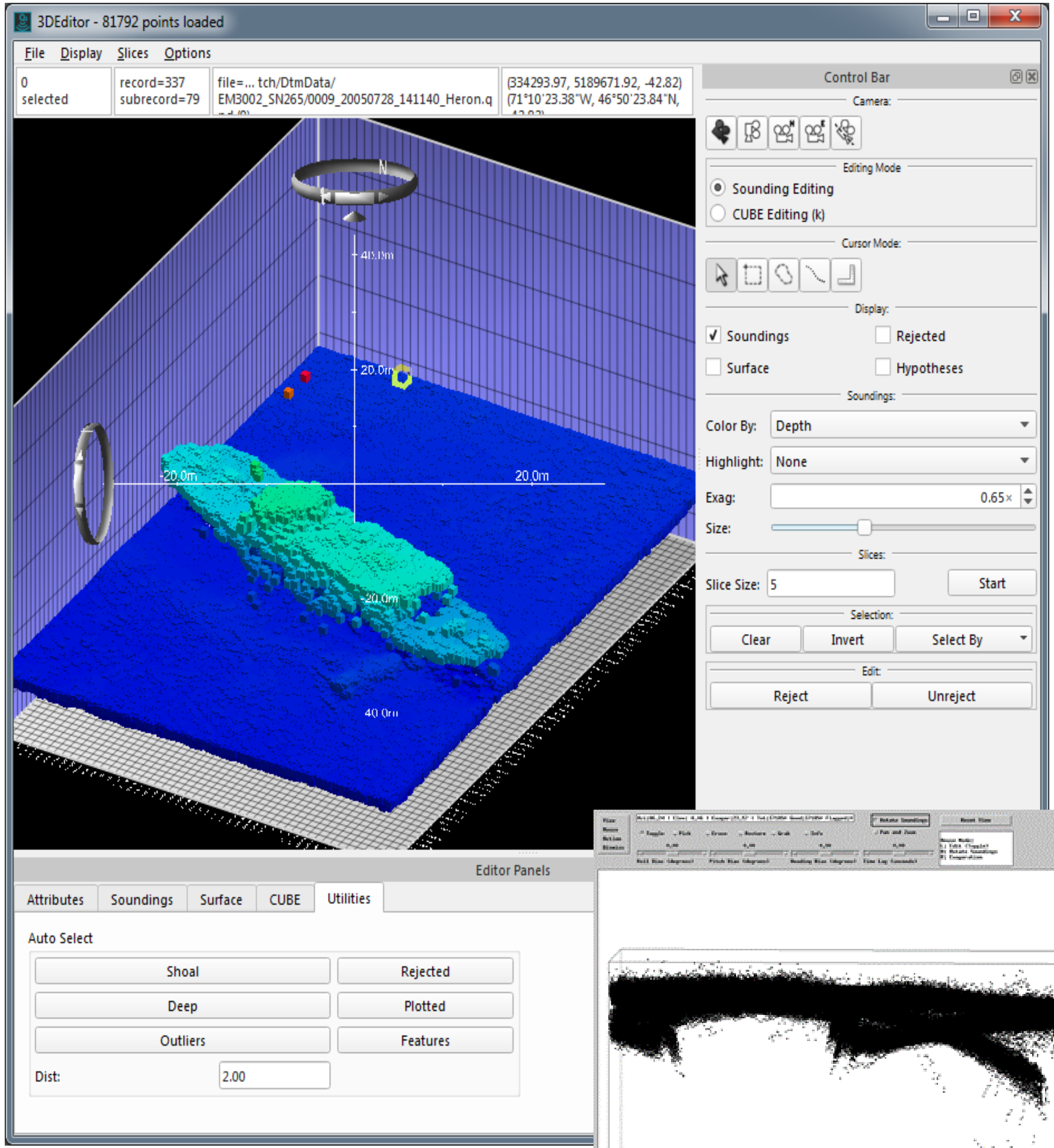


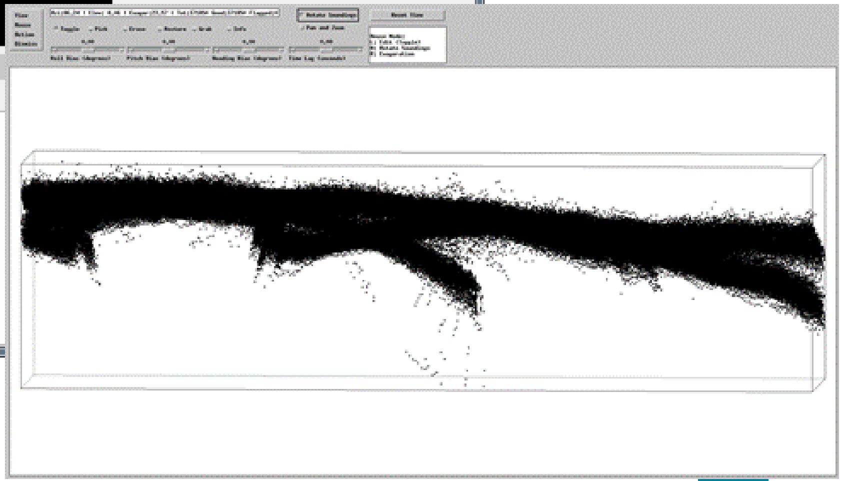


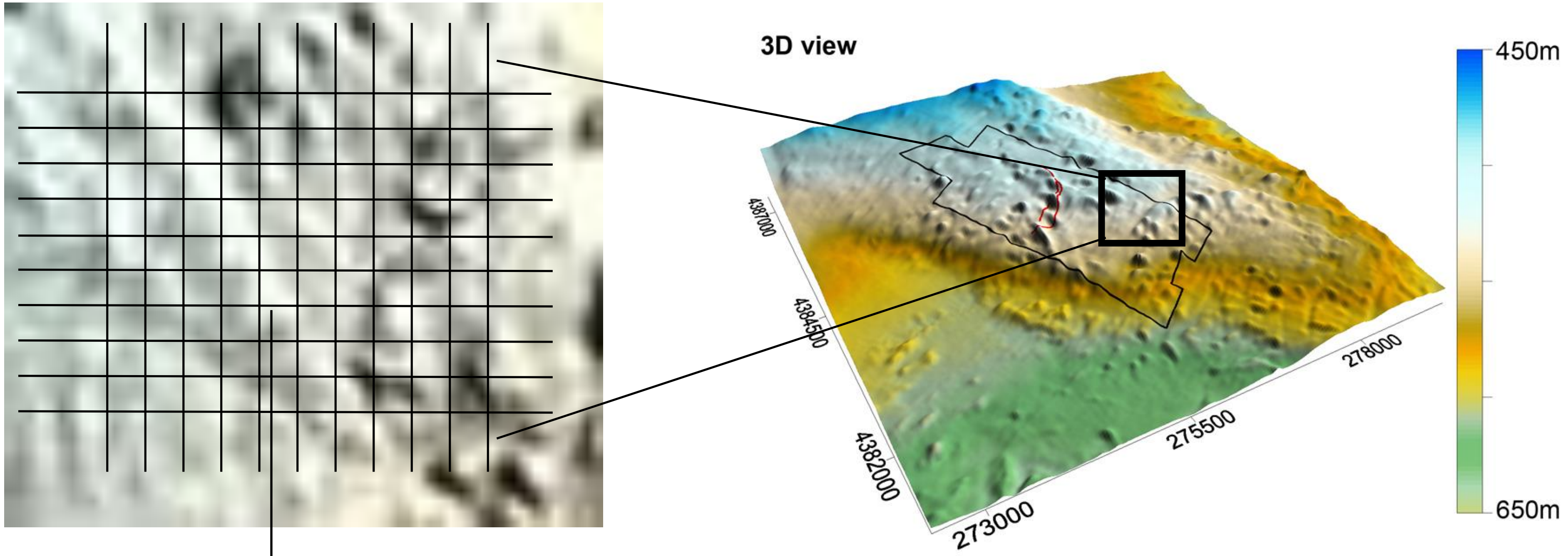
INTERACTIVE DATA CLEANING









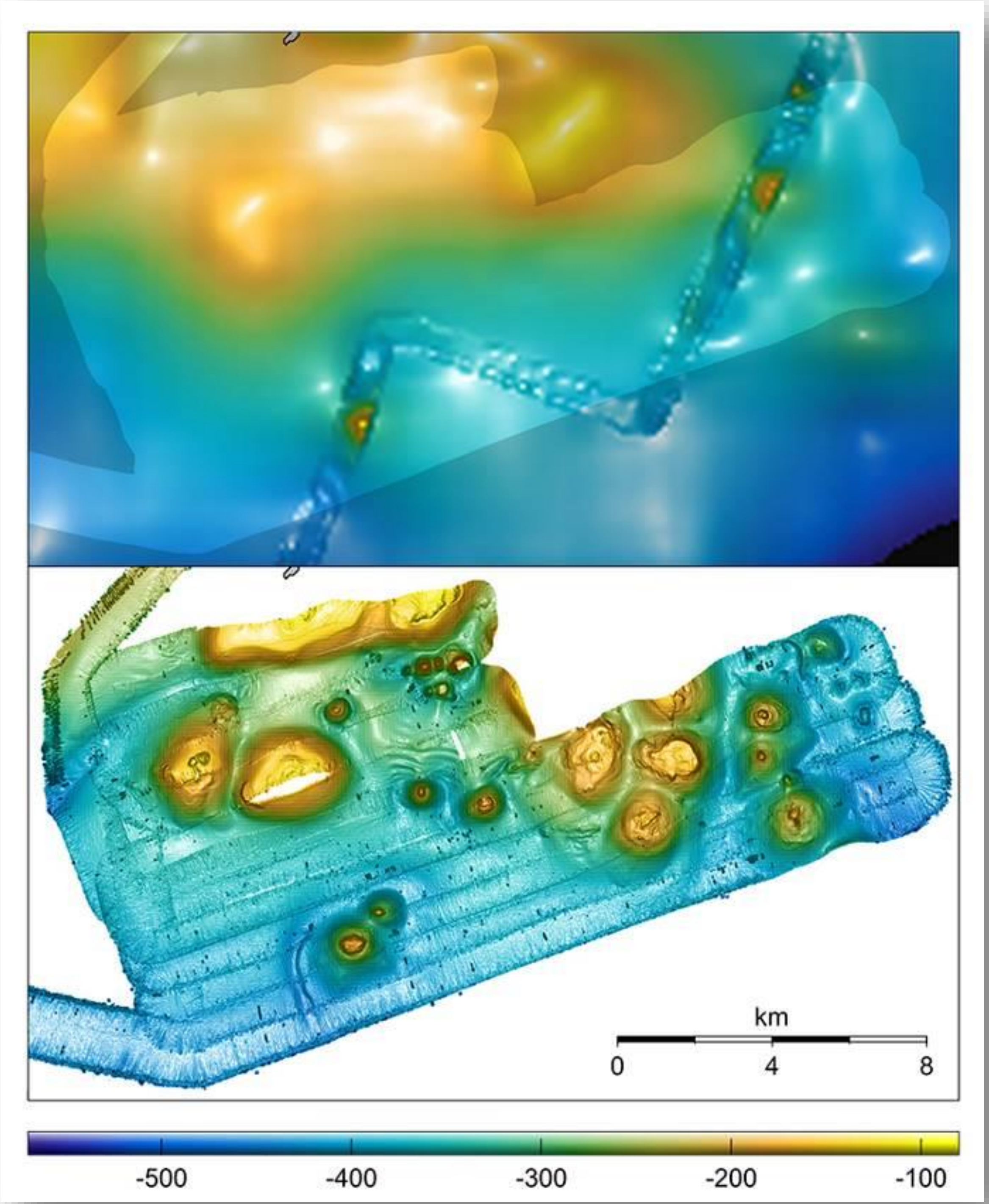


x, y, **z**

Each cell has a geographic location (x,y) associated to a depth value (z) originated from all soundings falling into the cell

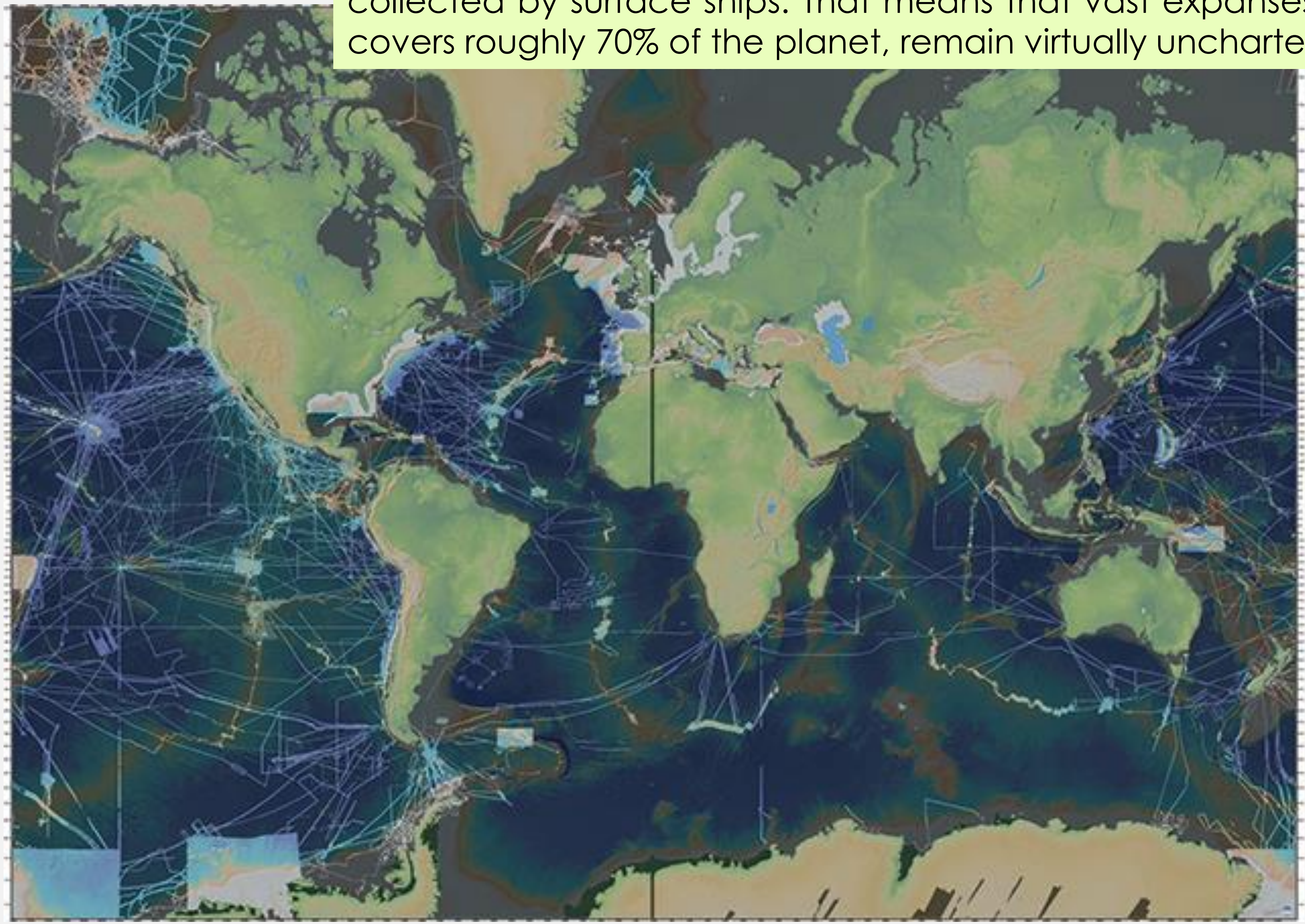
The resolution of a DTM (grid cell size) cannot be smaller of the *footprint*

(credits to Alessandra Savini)



The bathymetry comparison above is from an area south of Floreana Island, Galápagos.
The top image is the area's bathymetry before the August 2015 expedition, mapped to a resolution of about 1 km per pixel.
The bottom image shows bathymetry mapped during the expedition with a resolution of 10 meters per pixel, two orders of magnitude difference.
Image
Credit: Adam Soule,

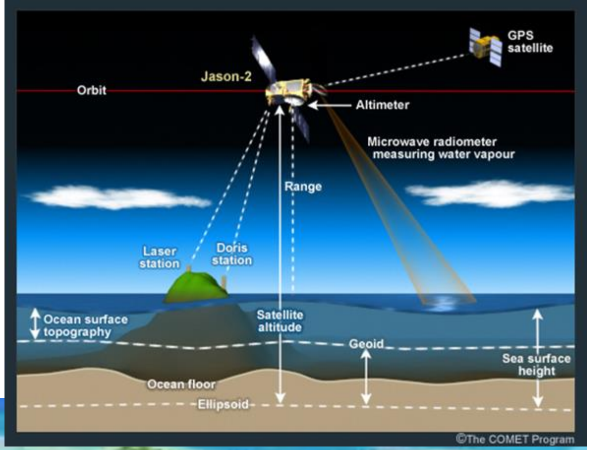
Just 10% of the seafloor globally has been mapped using modern bathymetric data collected by surface ships. That means that vast expanses of the ocean floor, which covers roughly 70% of the planet, remain virtually uncharted.

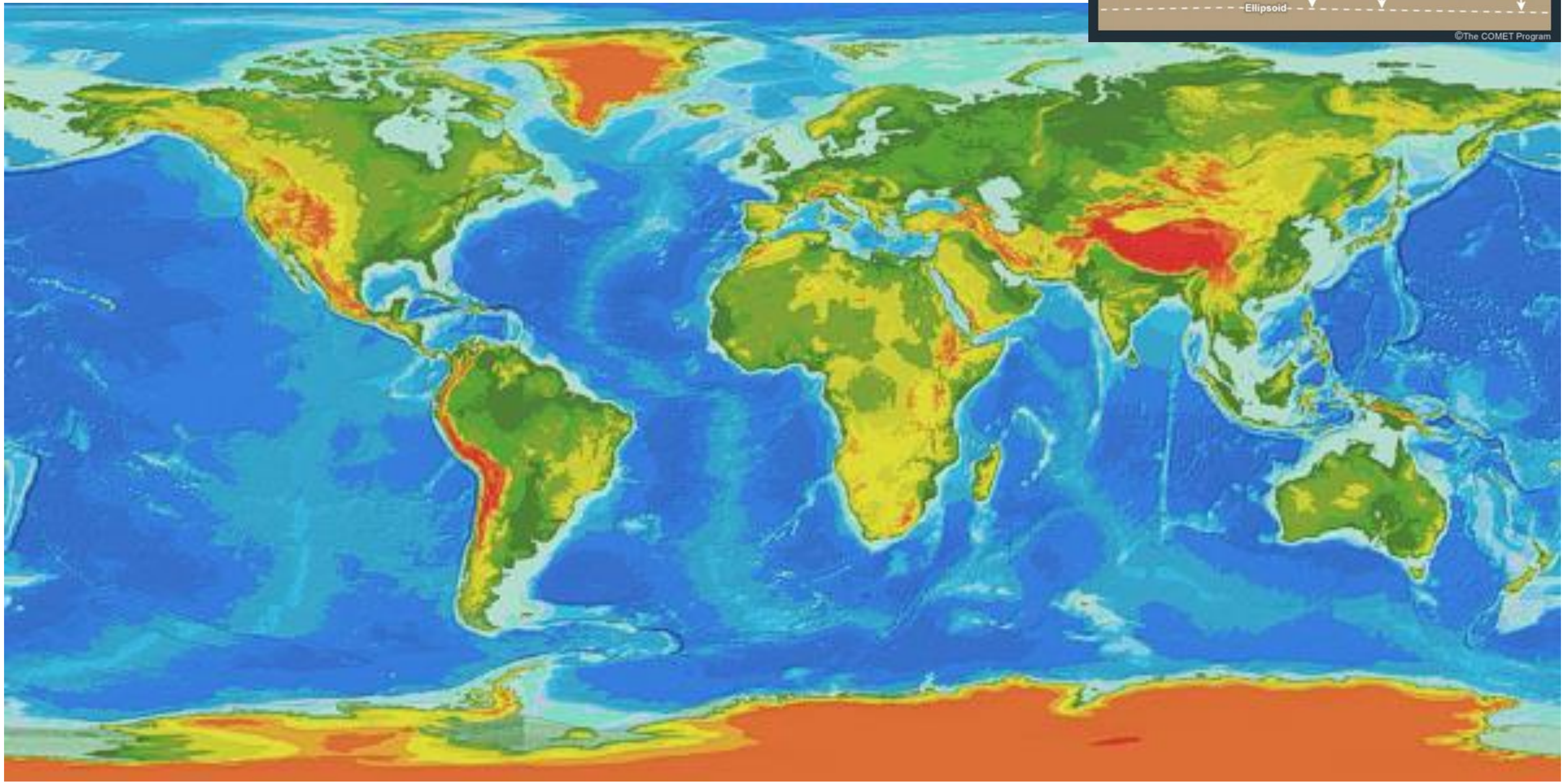


Publicly available multibeam data included in the Global Multi-Resolution Topography Synthesis covers only about 8 percent of the seafloor, (unshaded areas), although coverage is higher over continental margins and plate boundaries. Credit: image from the Global Multi-Resolution Topography Synthesis, hosted by the IEDA Marine Geoscience Data System.

https://www.gebco.net/about_us/seabed2030_project/

Satellite altimeters measure sea surface height and other characteristics of the ocean surface, which are linked to underlying processes and structures. This makes the data useful for understanding the full depth of the global ocean, from the surface down to the sea floor.

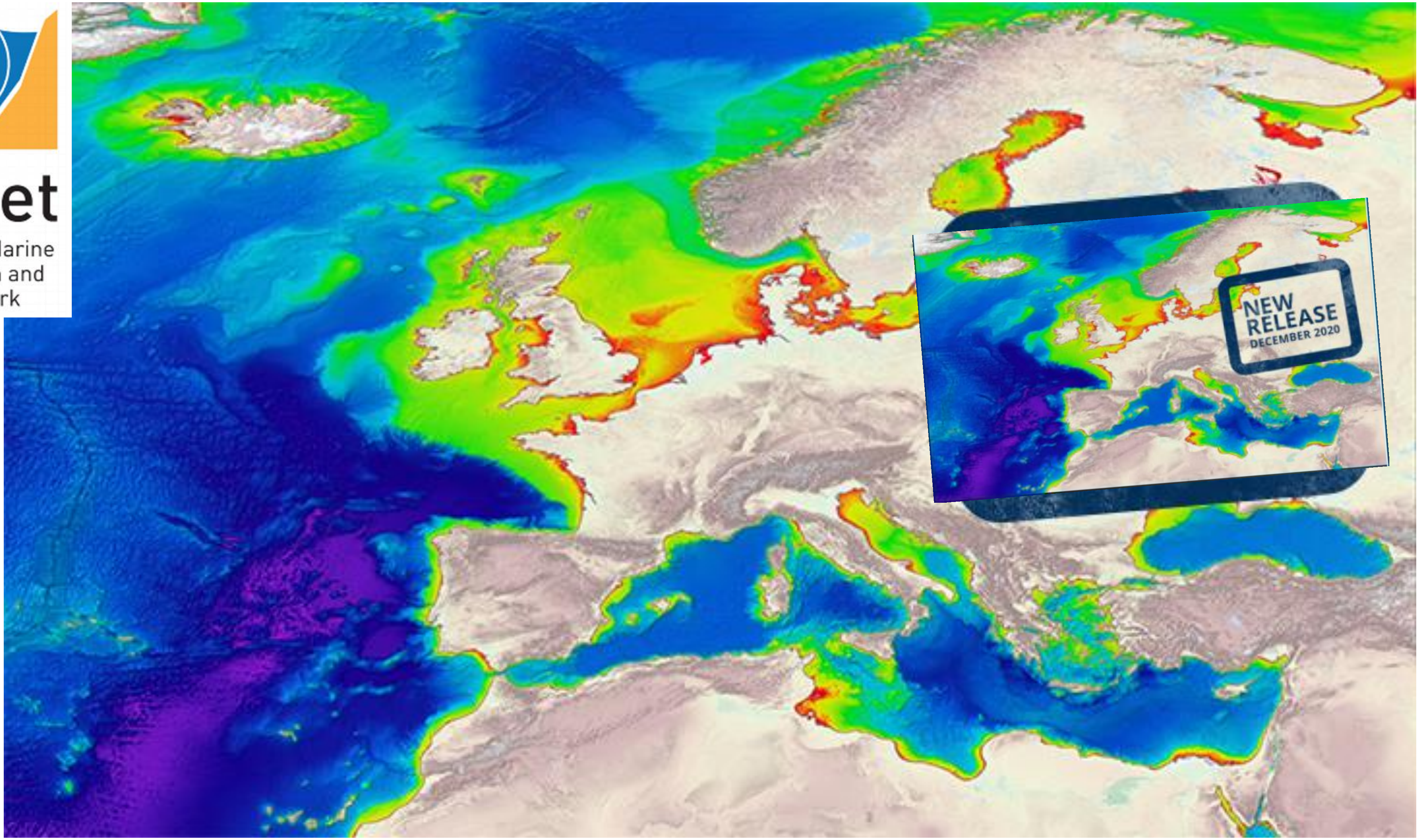




Global bathymetry and elevation data at 30 arc seconds resolution (1Km): SRTM30_PLUS (Becker et al., 2009)

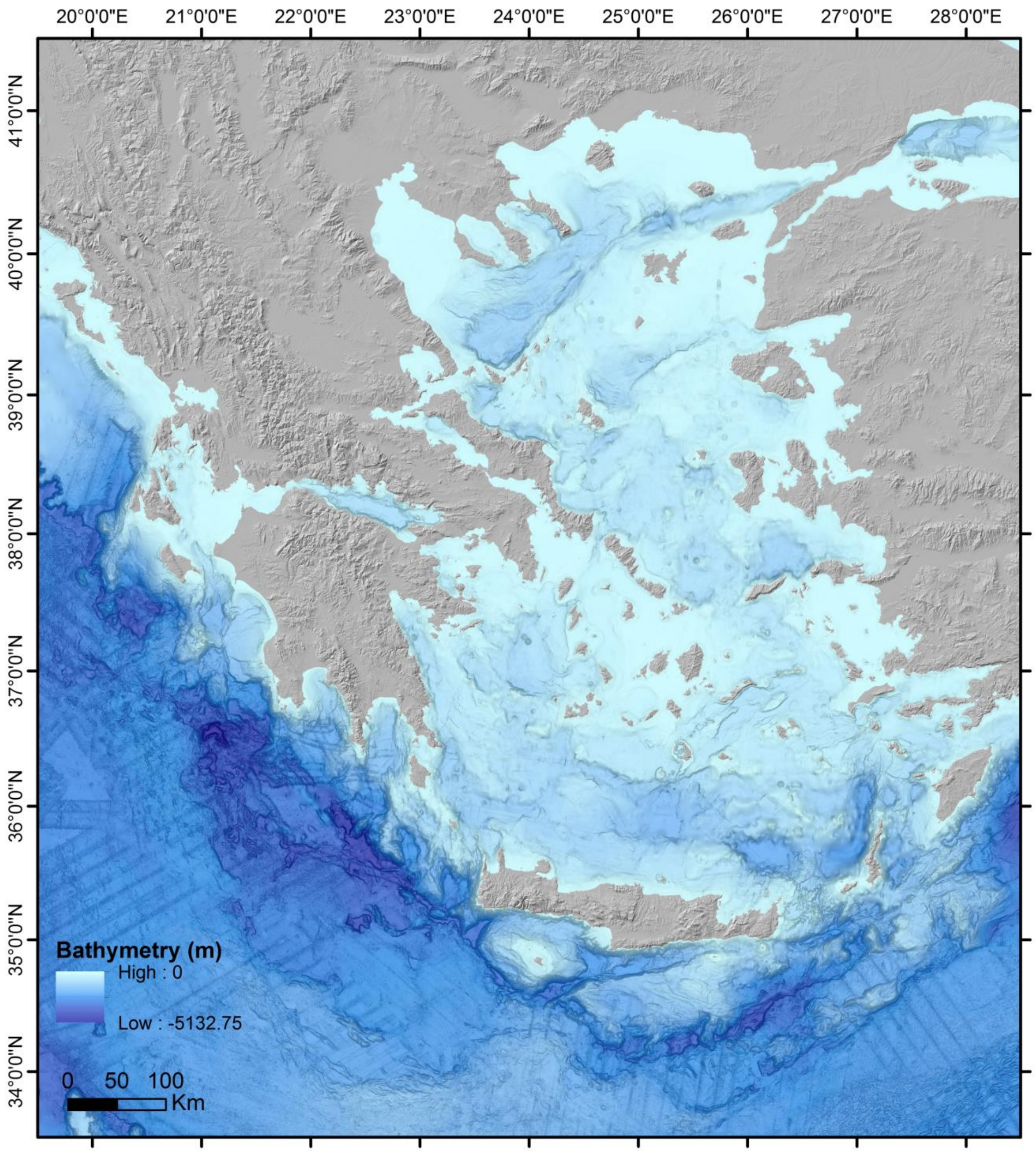
EMODnet
European Marine Observation and Data Network

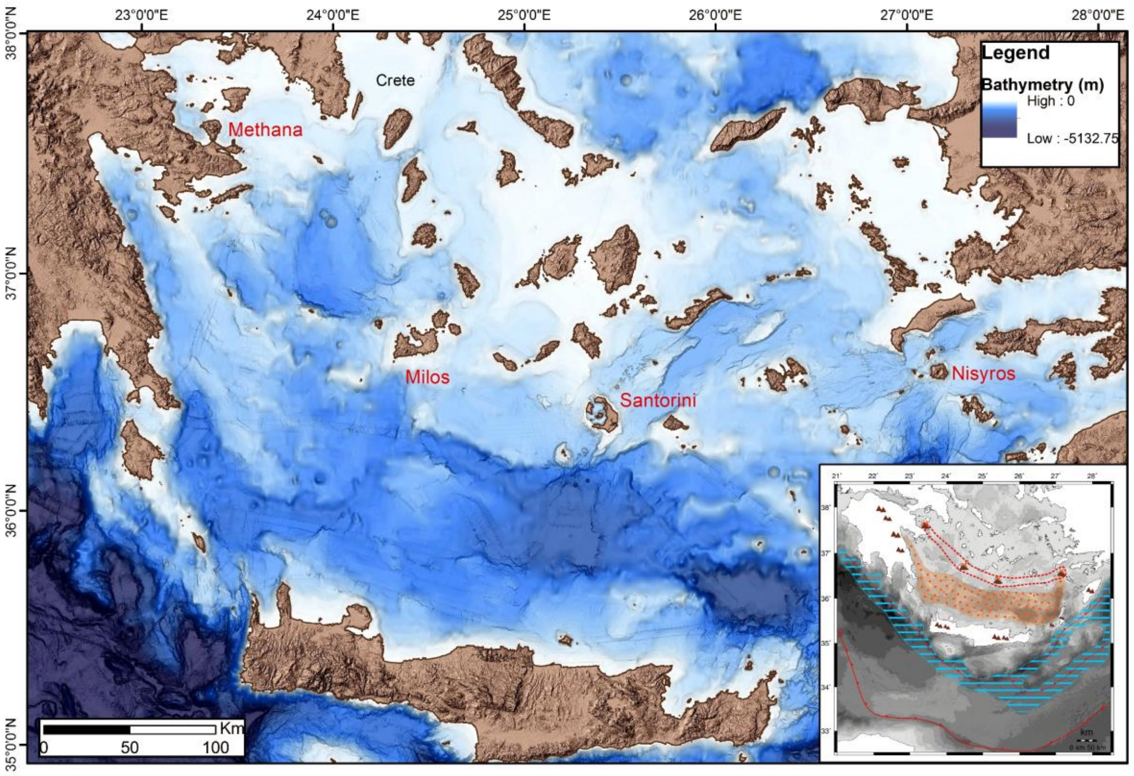
DTM with 1/16 * 1/16 arc minutes (circa 115 * 115 metres) grid resolution covering all European seas



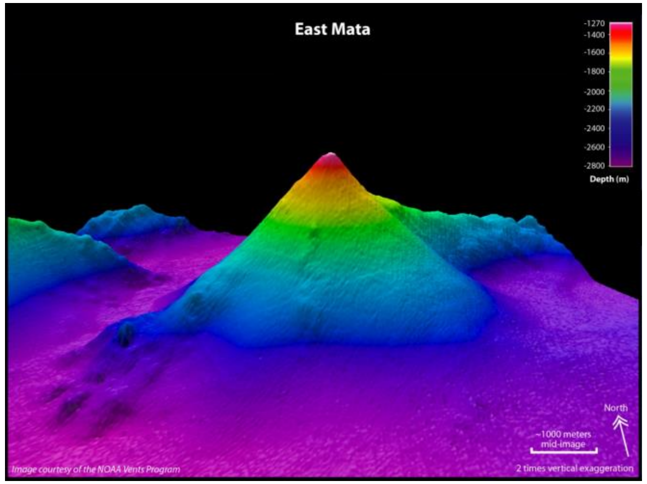
A harmonised **EMODnet** Digital Terrain Model (DTM) is generated for European sea regions from selected bathymetric survey data sets, composite DTMs, Satellite Derive Bathymetry (SDB) data products, while gaps with no data coverage are completed by integrating the GEBCO Digital Bathymetry (https://www.emodnet-bathymetry.eu/).

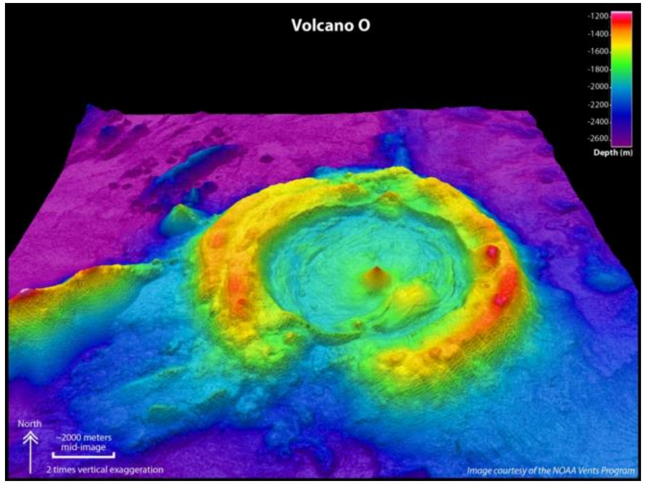
Hellenic Volcanic Arc

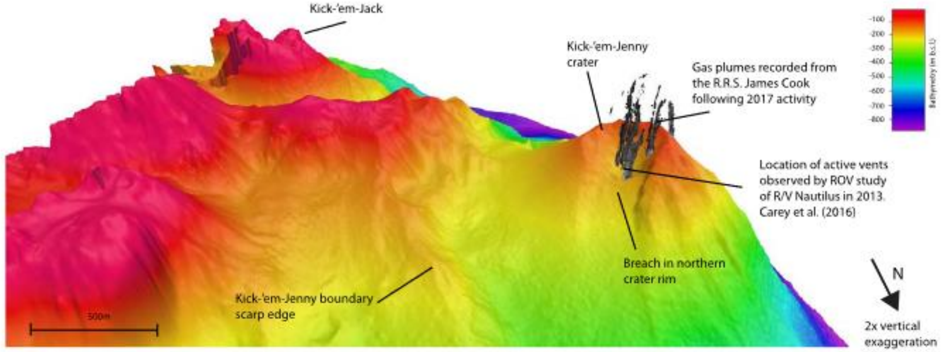


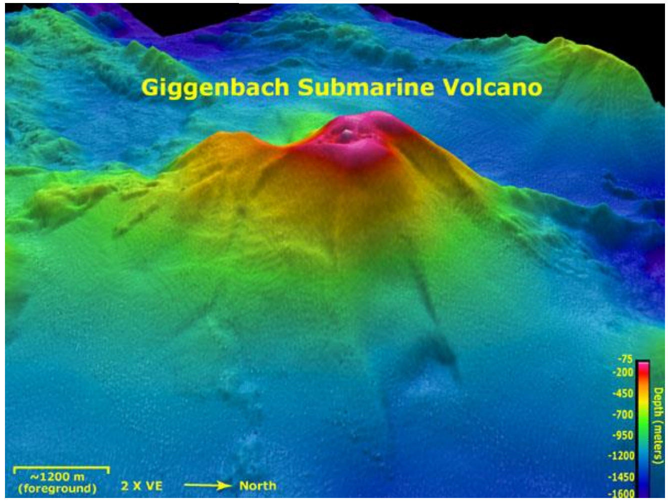


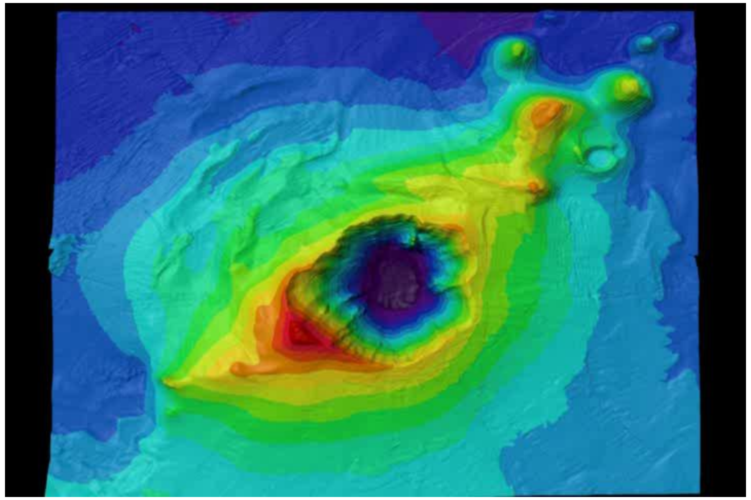
(Nomikou et al., 2012)





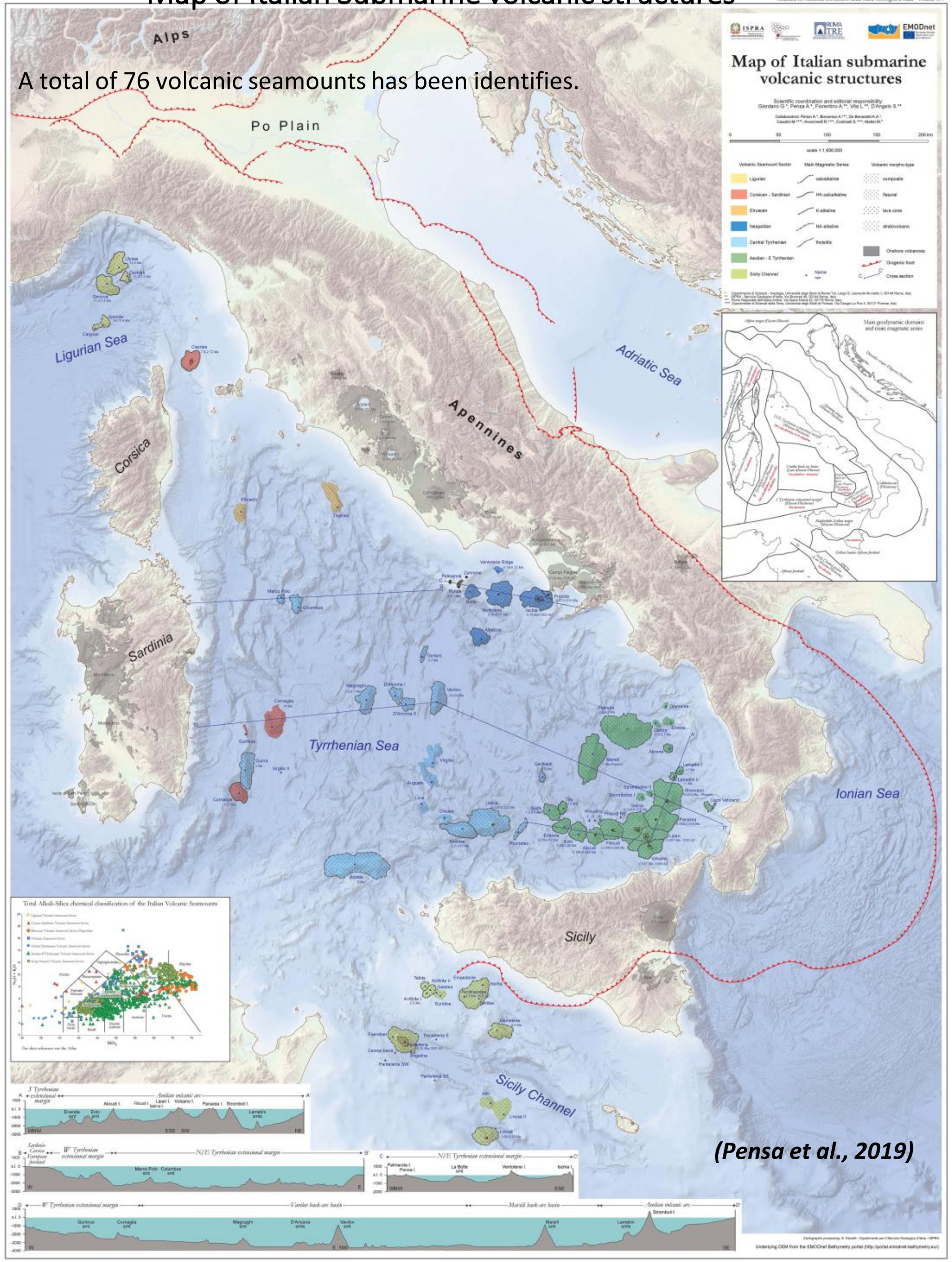




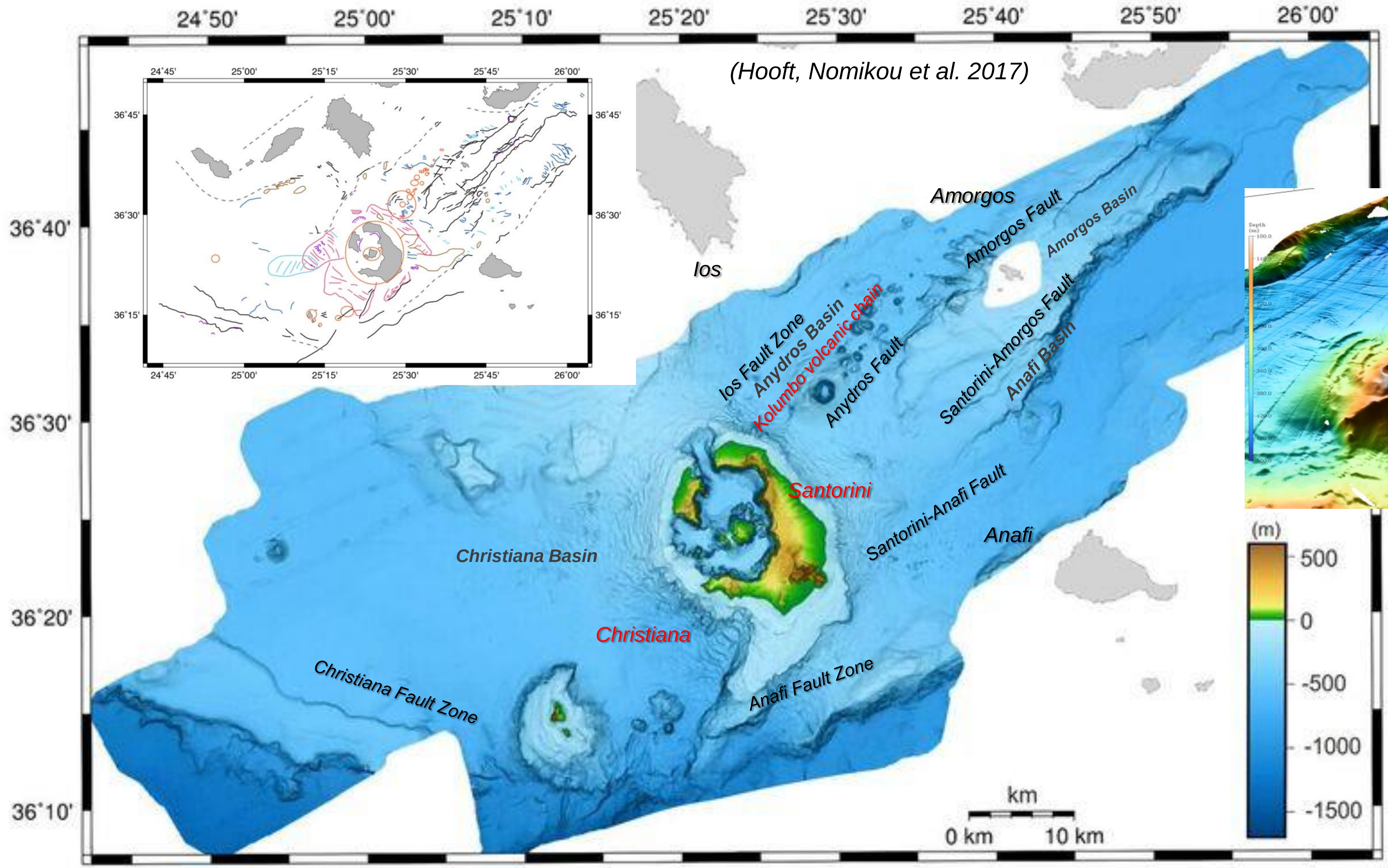


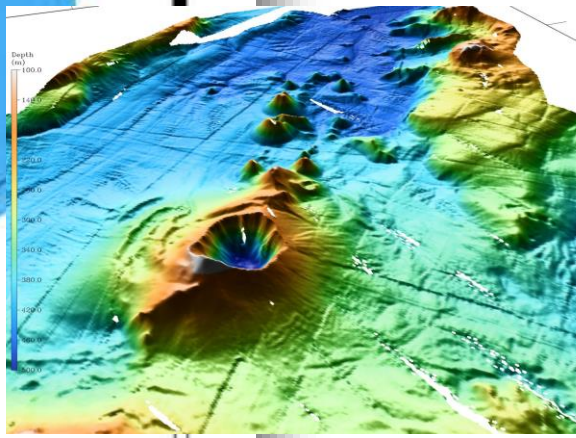
Map of Italian Submarine volcanic structures

A total of 76 volcanic seamounts has been identifies.

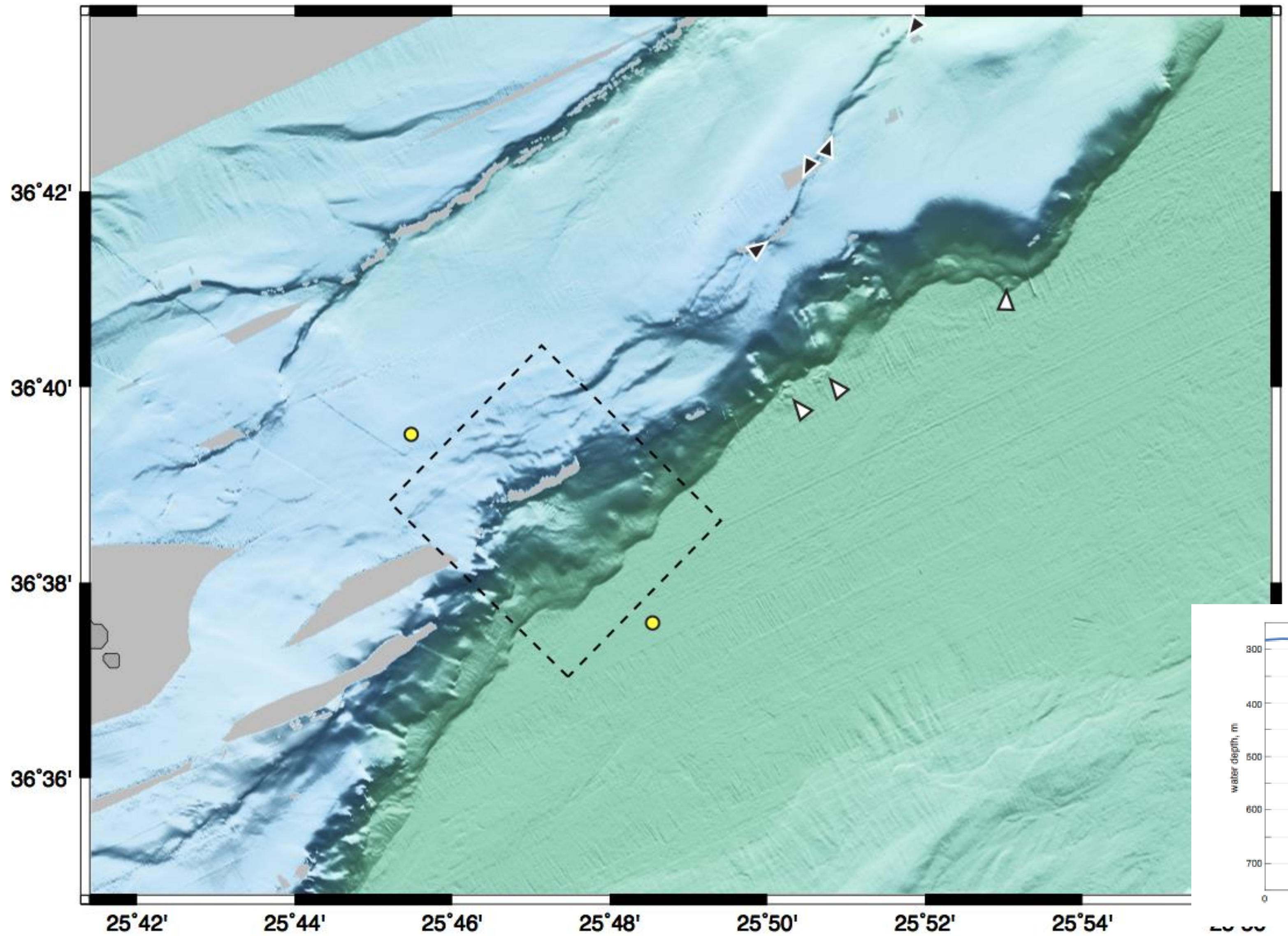


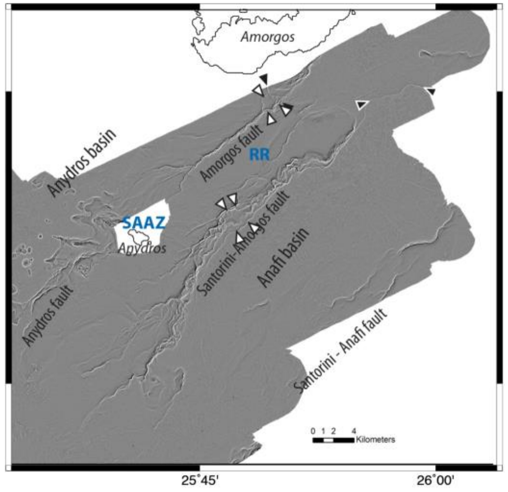
(Pensa et al., 2019)



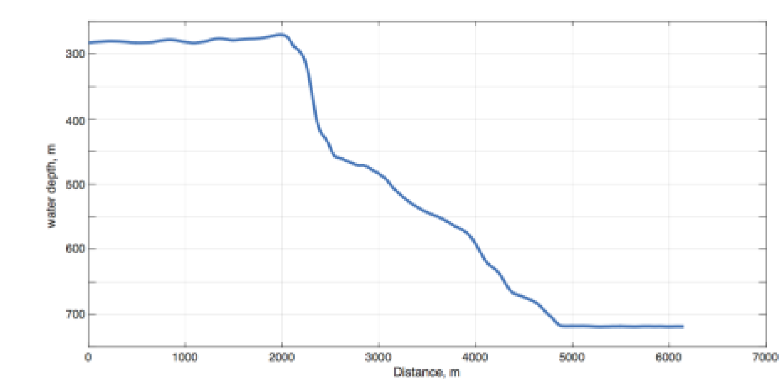


The new high resolution multi-beam bathymetry map of Christianna-Santorini-Amorgos was used to: **(i)** identify the areas of the most recent tectonic deformation and detail the geodynamic structure of the region between Santorini and Amorgos - the site of the largest Greek earthquake in the 20th century **(ii)** discover and describe new seafloor volcanic edifices along the Hellenic volcanic arc and along the NE extension of the Kolumbo volcanic chain; and **(iii)** locate and describe mass wasting features along the active faults as well as pyroclastic flow deposits on the flanks of Santorini volcano.

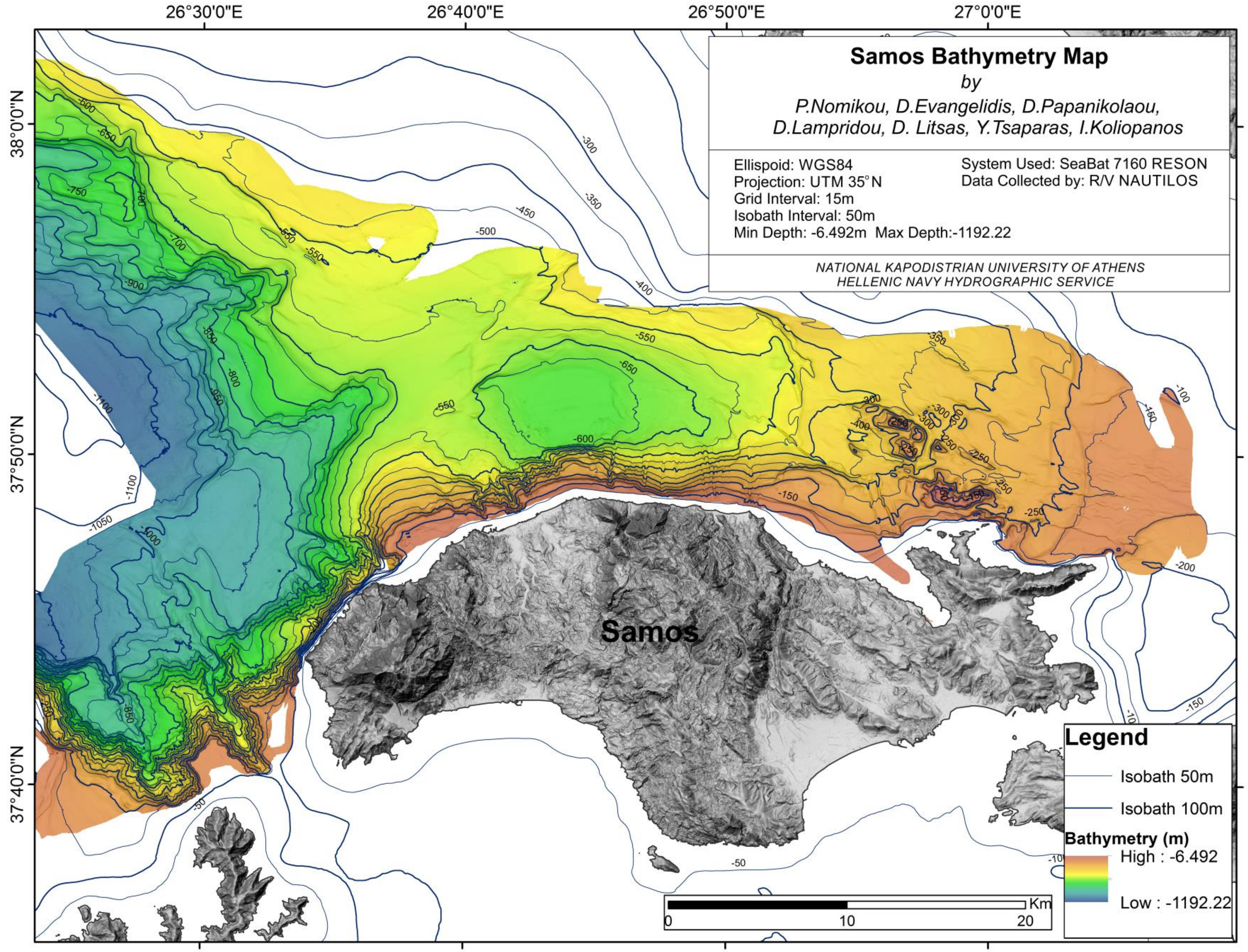




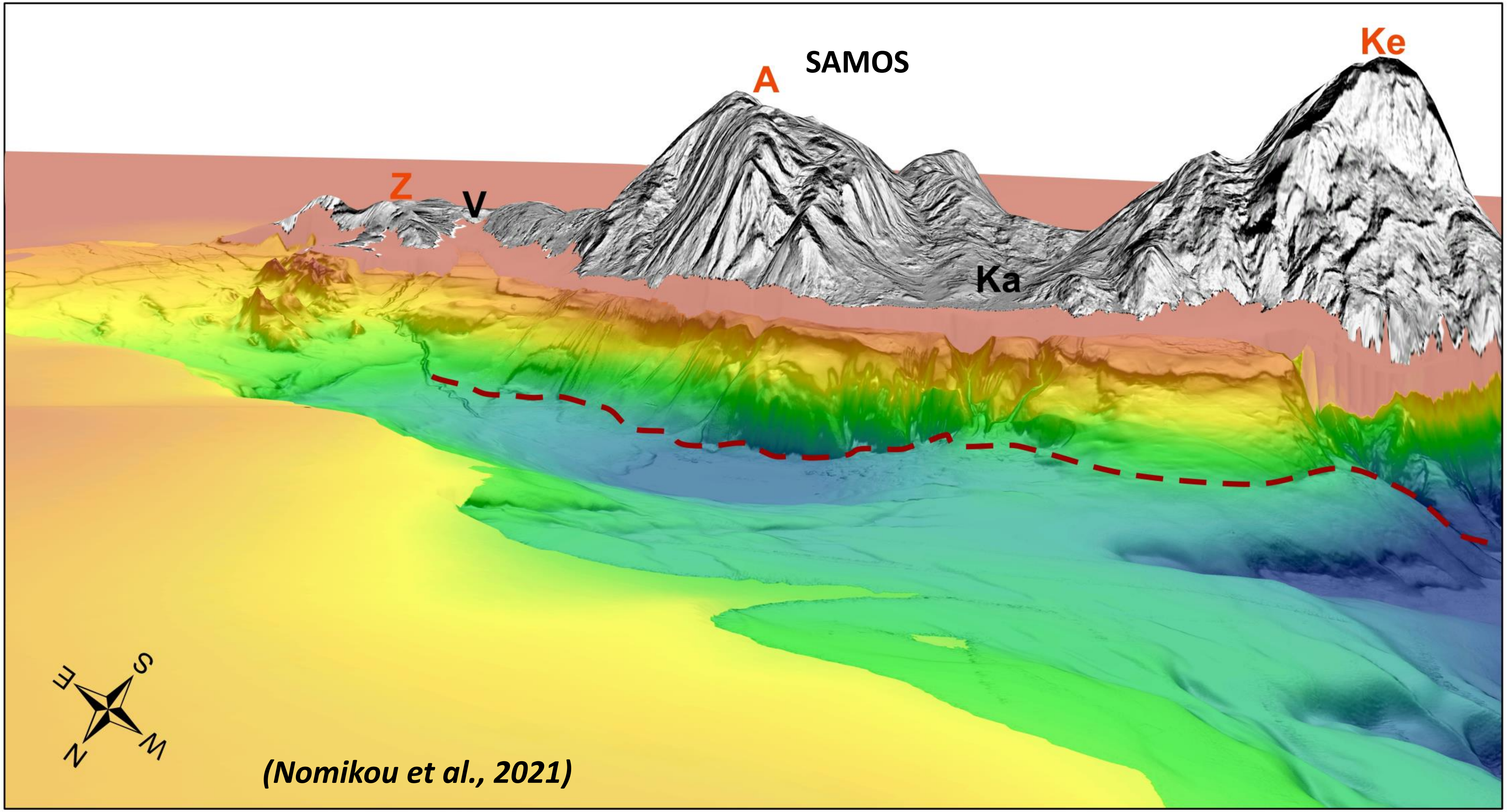
(Hooft, Nomikou et al. 2017)



Large landslide along the center of the **Santorini-Amorgos Fault**. Large lobate landslide (dashed box) and recent seafloor deposits along the northern portion of the base of the fault scarp (white arrows). Note the sharpness of the Amorgos Fault in the northern part of the map and the secondary normal faults (black arrows). The headwall scarp has a slope of 35%, while the landslide toe has a slope of ~13%.

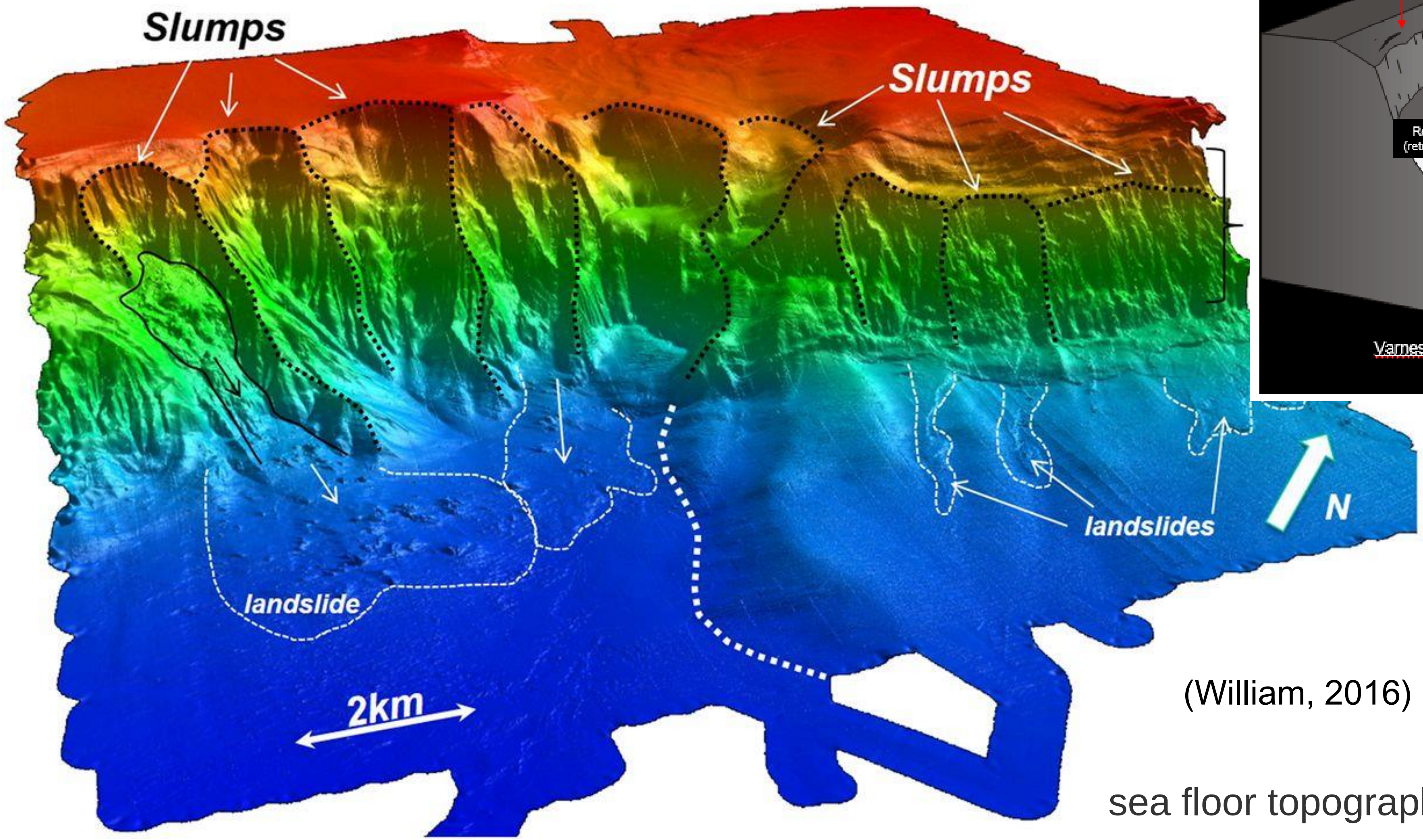


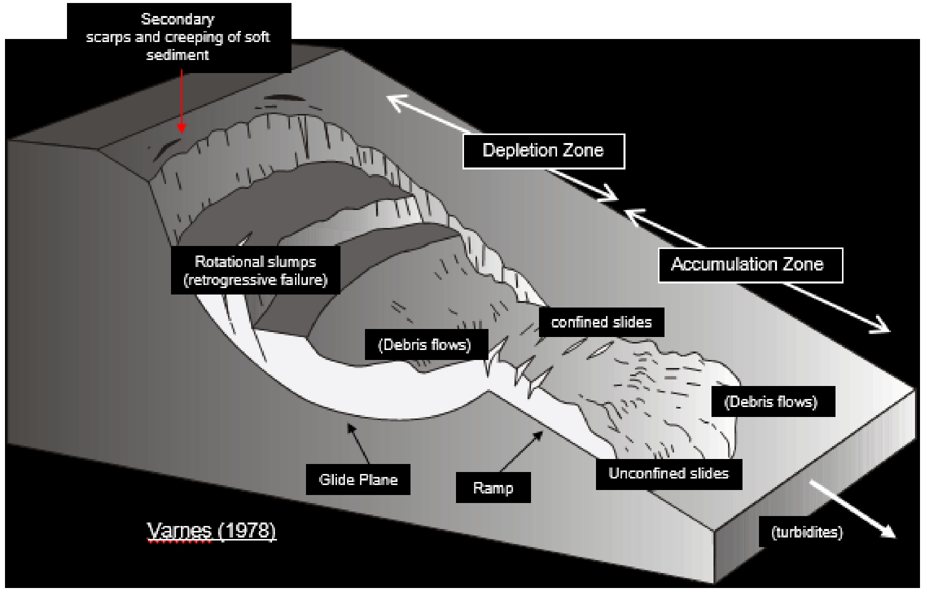
(Nomikou et al., 2021)



Legend	
A : Ambelos Ke : Kerketeas Z : Zoodochos Pighi Ka : Karlovassi V : Vathy	Fault trace

Submarine Landslides



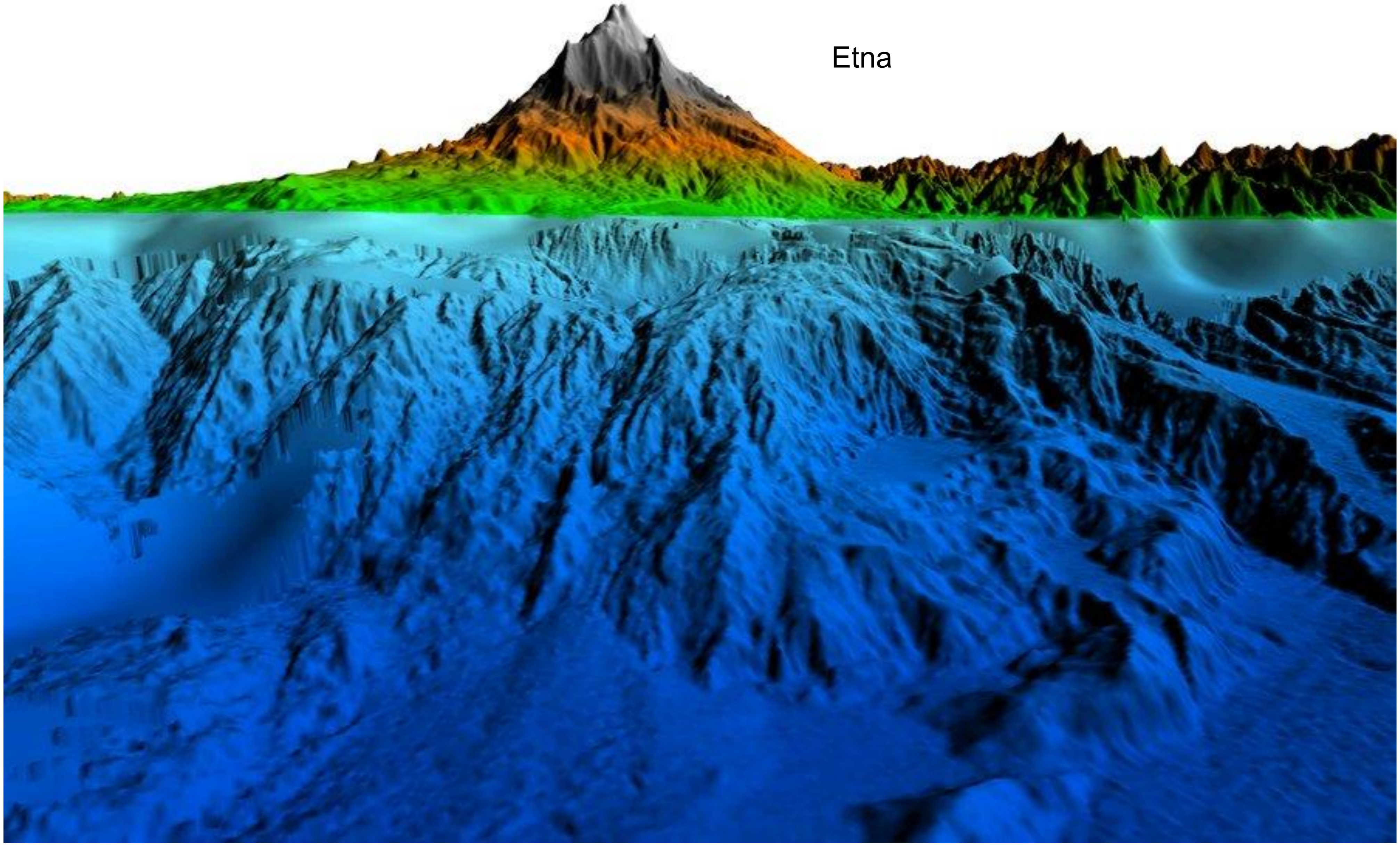


(William, 2016)

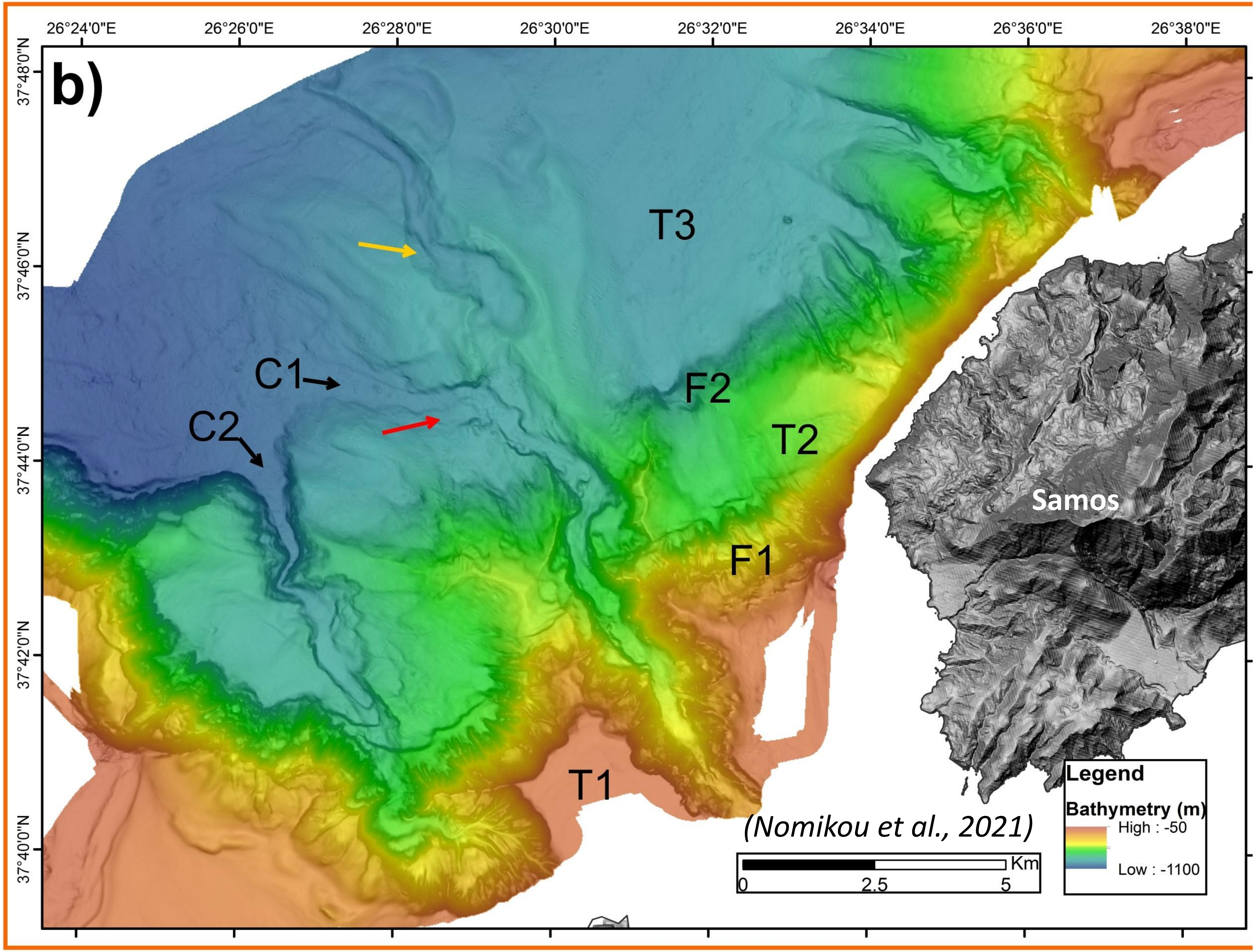
sea floor topography in the Gulf of Mexico

Submarine landslides are one of the main agents through which sediments are transferred across the continental slope to the deep ocean. They are ubiquitous features of submarine slopes in all geological settings and at all water depths. Hazards related to such landslides range from destruction of offshore facilities to collapse of coastal facilities and the generation of tsunamis (Camerlenghi 2013).

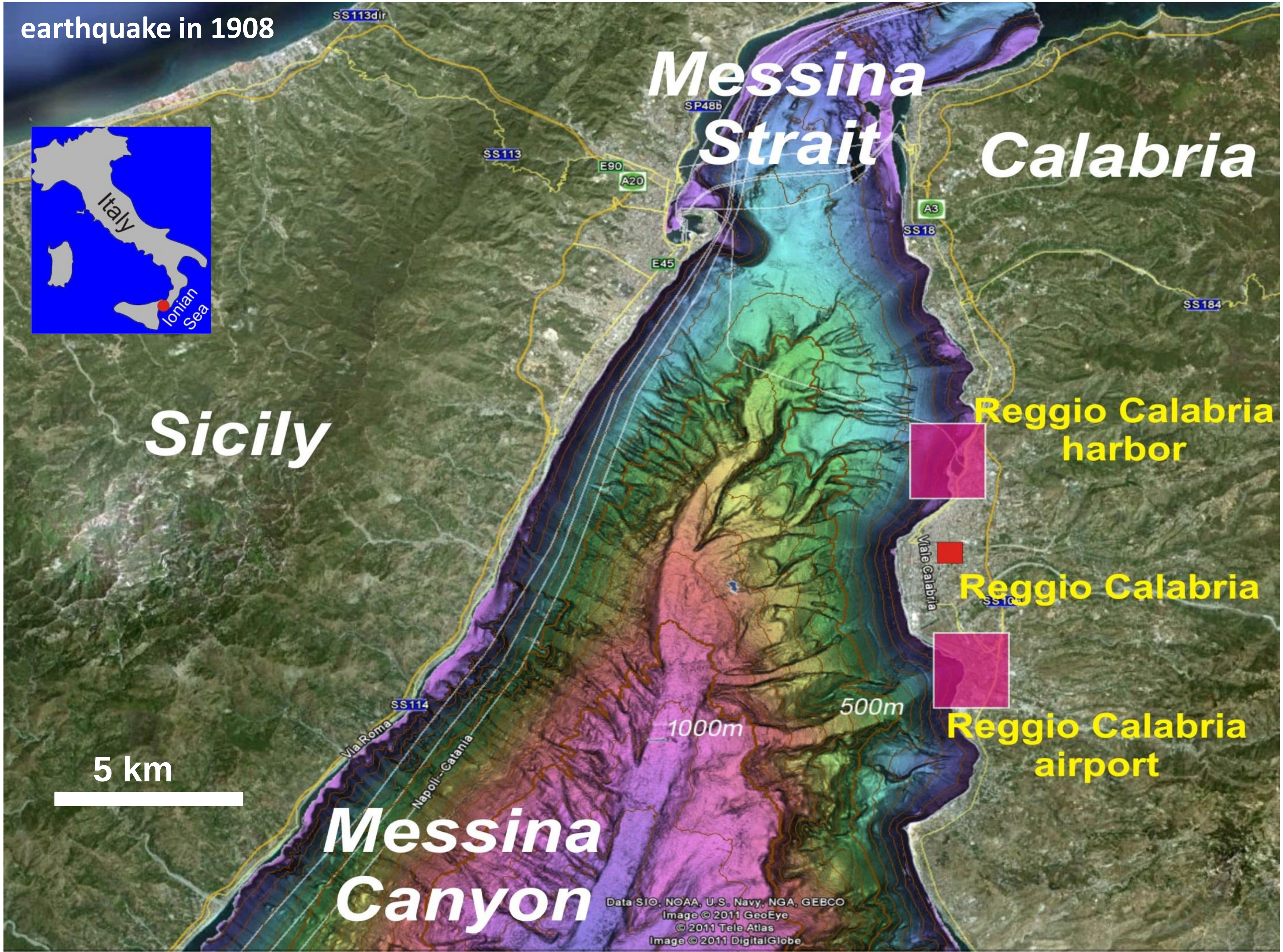
Submarine Landslides

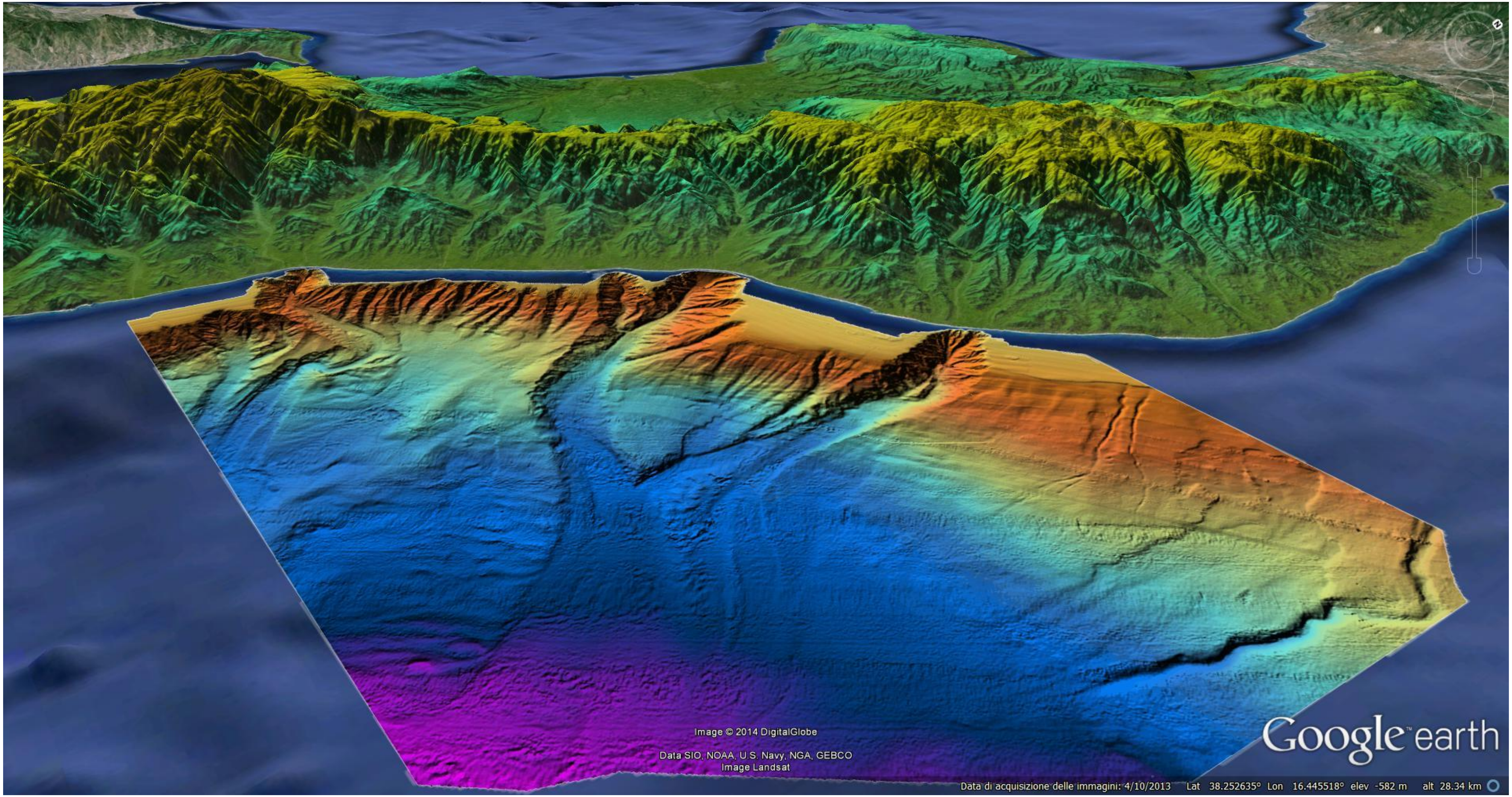


Graphics/Image: Felix Gross, GEOMAR



b)
26°24'0"E
26°26'0"E
26°28'0"E
26°30'0"E
26°32'0"E
26°34'0"E
26°36'0"E
26°38'0"E
37°48'0"N
37°46'0"N
37°44'0"N
37°42'0"N
37°40'0"N
T3
C1
F2
C2
T2
Samos
F1
T1
(Nomikou et al., 2021)
Km
0
2.5
5
Legend
Bathymetry (m)
High : -50
Low : -1100


earthquake in 1908
Messina Strait
Calabria
Italy
Ionian Sea
Sicily
Reggio Calabria harbor
Reggio Calabria
Reggio Calabria airport
Viale Calabria
500m
1000m
5 km
Messina Canyon
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2011 GeoEye
© 2011 Tele Atlas
Image © 2011 DigitalGlobe



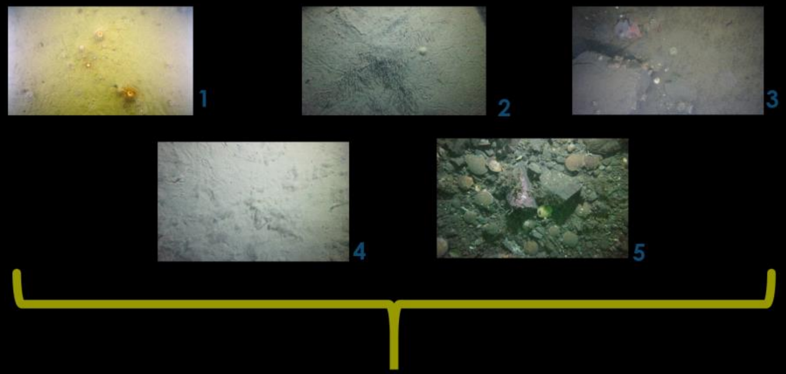
(credits to Alessandra Savini)

Seafloor Mapping from Multispectral Multibeam

Bedford Basisn, Canada

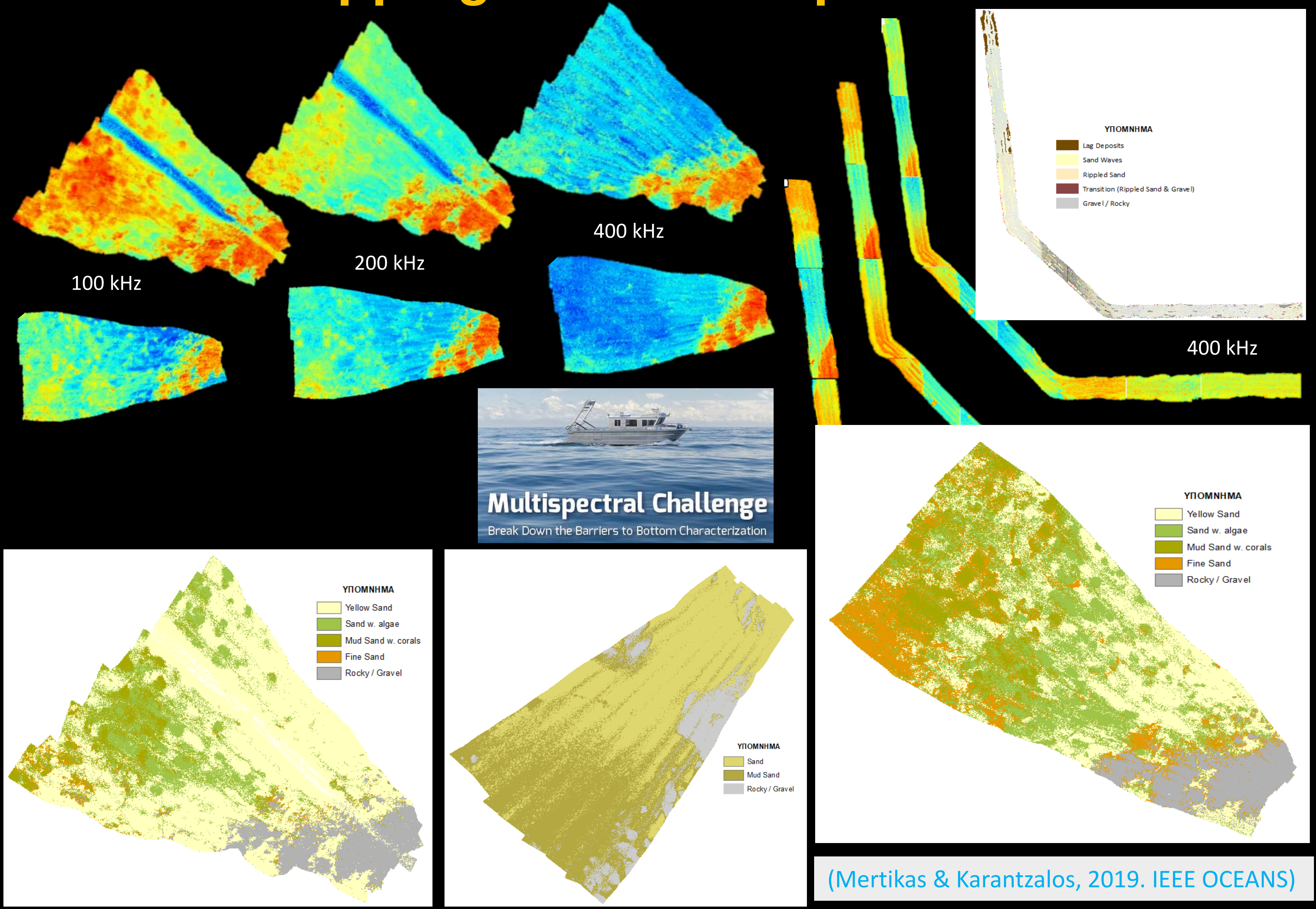
Patricia Bay, Canada

Portsmouth / NewBex, U.S.A.



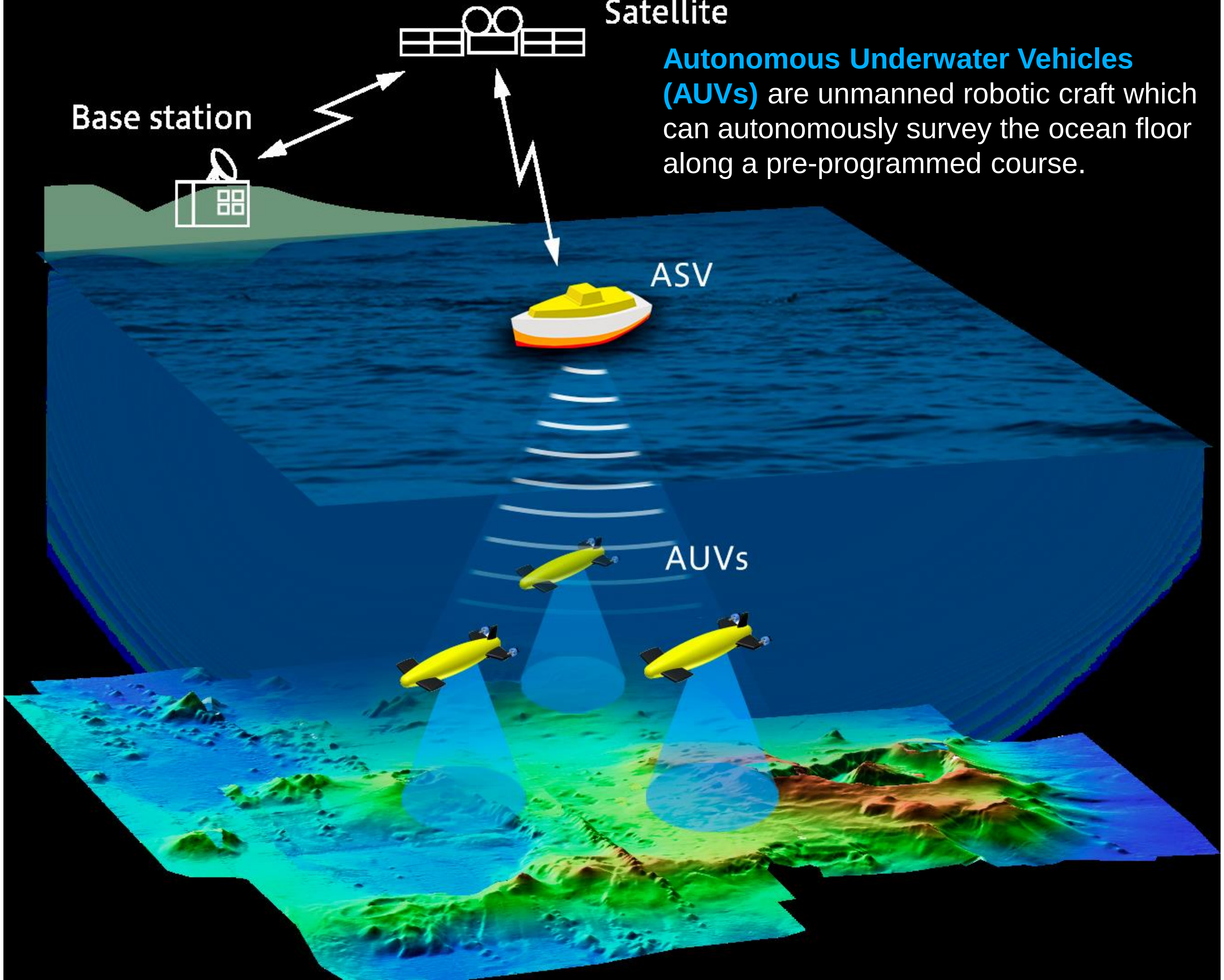
1. Κίτρινη άμμος (Yellow Sand)
2. Άμμος με άλγη (Sand w. algae)
3. Λασπώδης άμμος με κοράλια (Muddy Sand w. corals)
4. Άμμος (Sand)
5. Βράχια / Χαλίκια (Rocky / Gravel)

Seafloor Mapping from Multispectral Multibeam

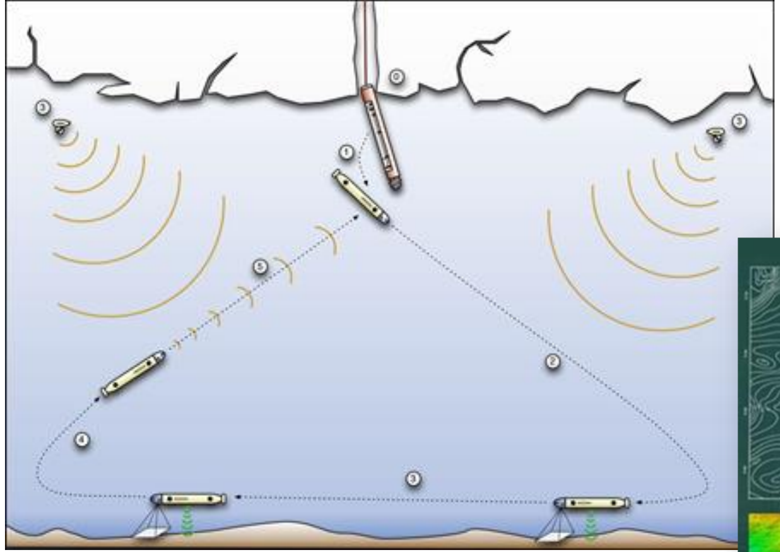


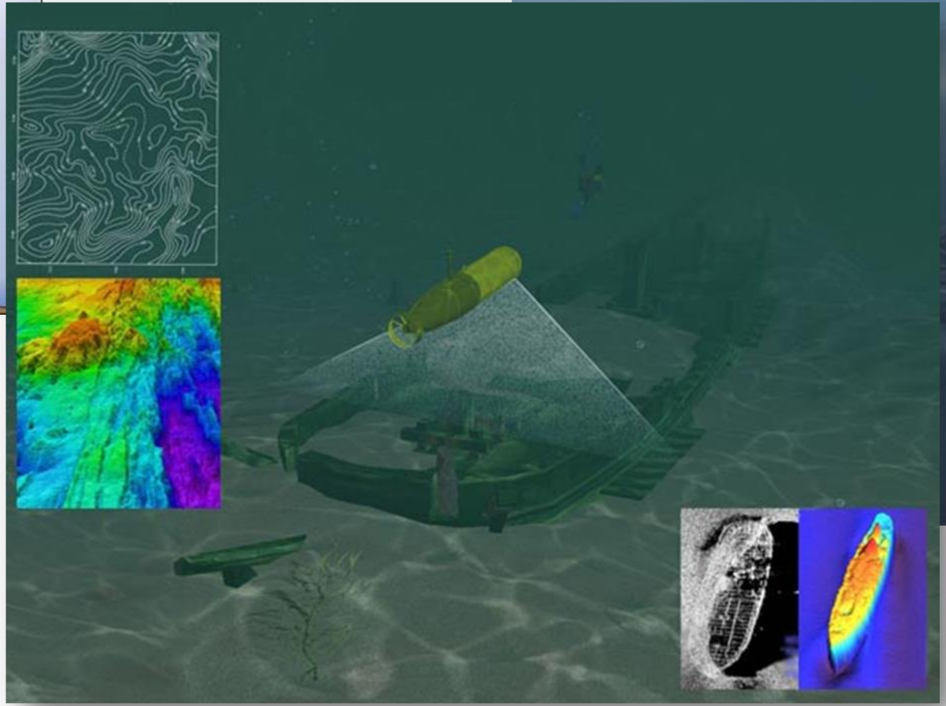
(Mertikas & Karantzalos, 2019. IEEE OCEANS)

Since radio waves are mostly ineffective underwater, communication, positioning, etc., will be conducted via underwater acoustics. Because an AUV can get much closer to the ocean floor than a surface vessel, it can capture superior high-definition data.



Autonomous Underwater Vehicles (AUVs) are unmanned robotic craft which can autonomously survey the ocean floor along a pre-programmed course.

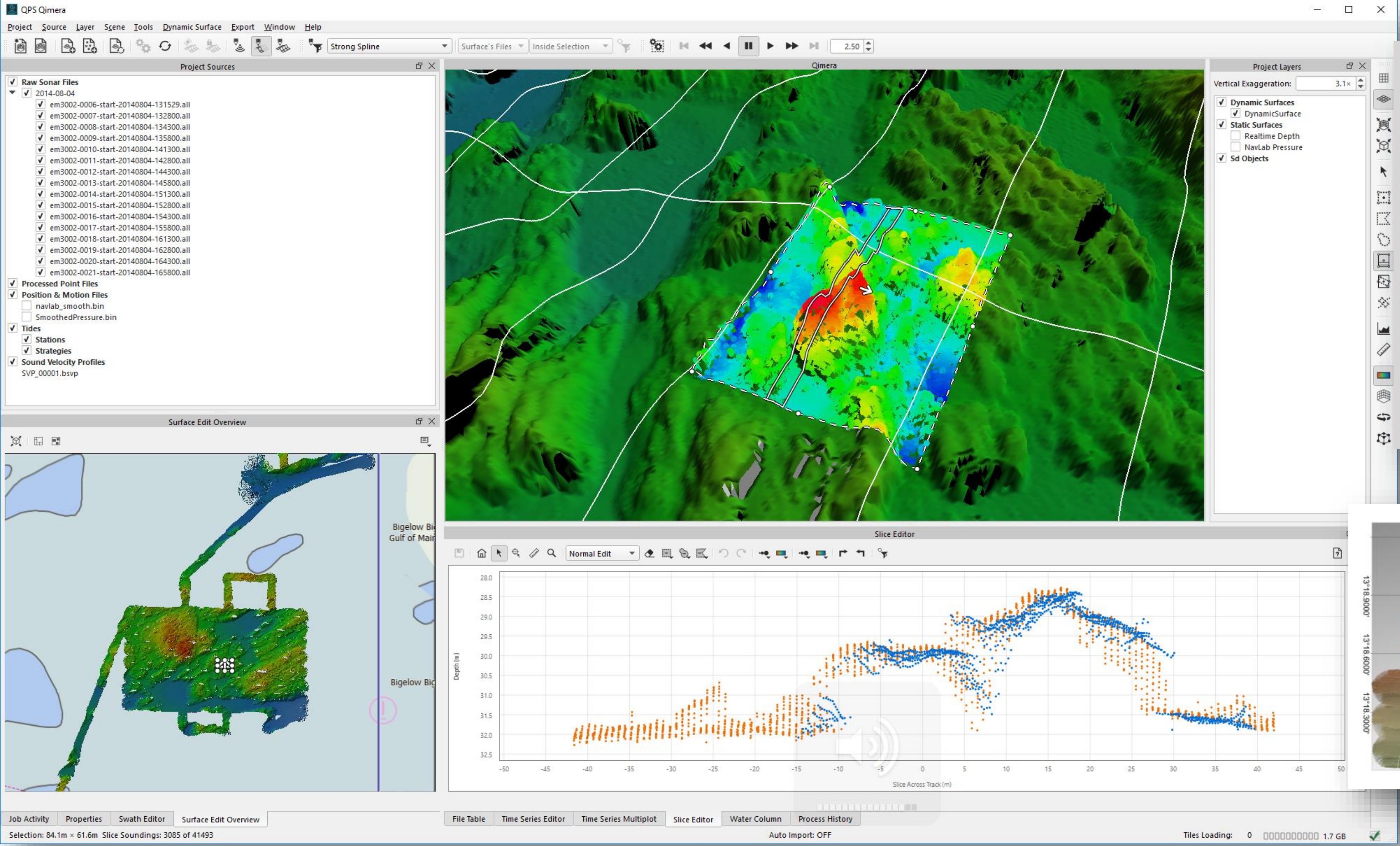


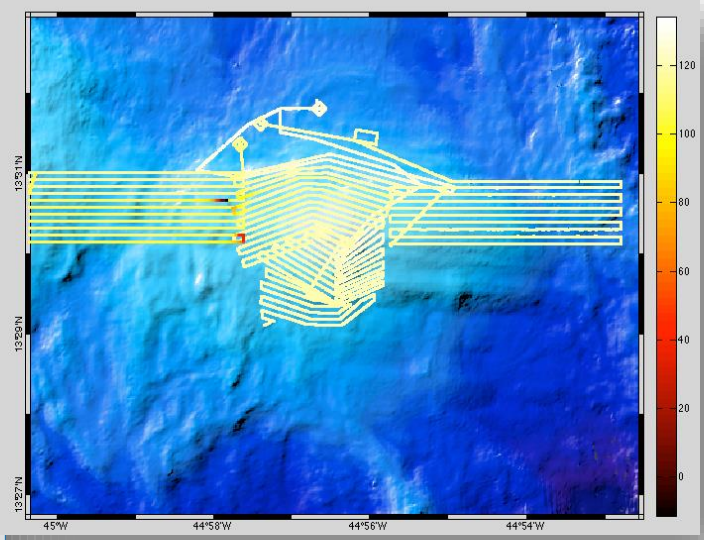


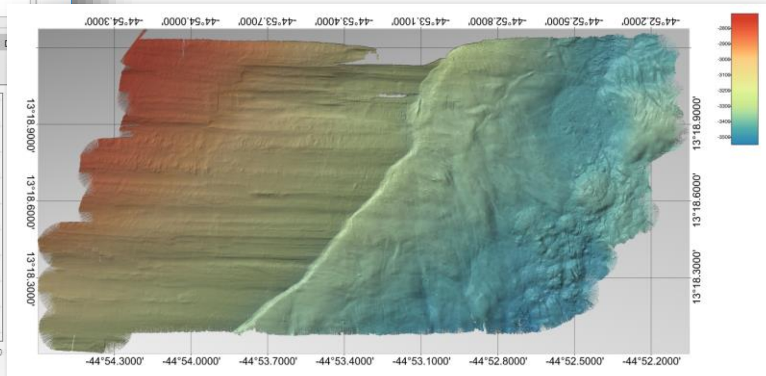
AUVs are unmanned underwater robots akin to the ***Curiosity* rover NASA** uses on Mars. As their (autonomous) name suggests, AUVs operate independently of humans. AUVs have no physical connection to their operator, who may be on shore or aboard a ship. Rather, AUVs are self-guiding and self-powered vehicles.

AUVs may glide from the sea surface to ocean depths and back. Others can stop, hover, and move like blimps or helicopters do through the air. Solar-powered AUVs can spend a portion of their time at the surface, blurring the distinction between undersea and surface vehicles.


ABYS
MAX WORKING LOAD 2000L

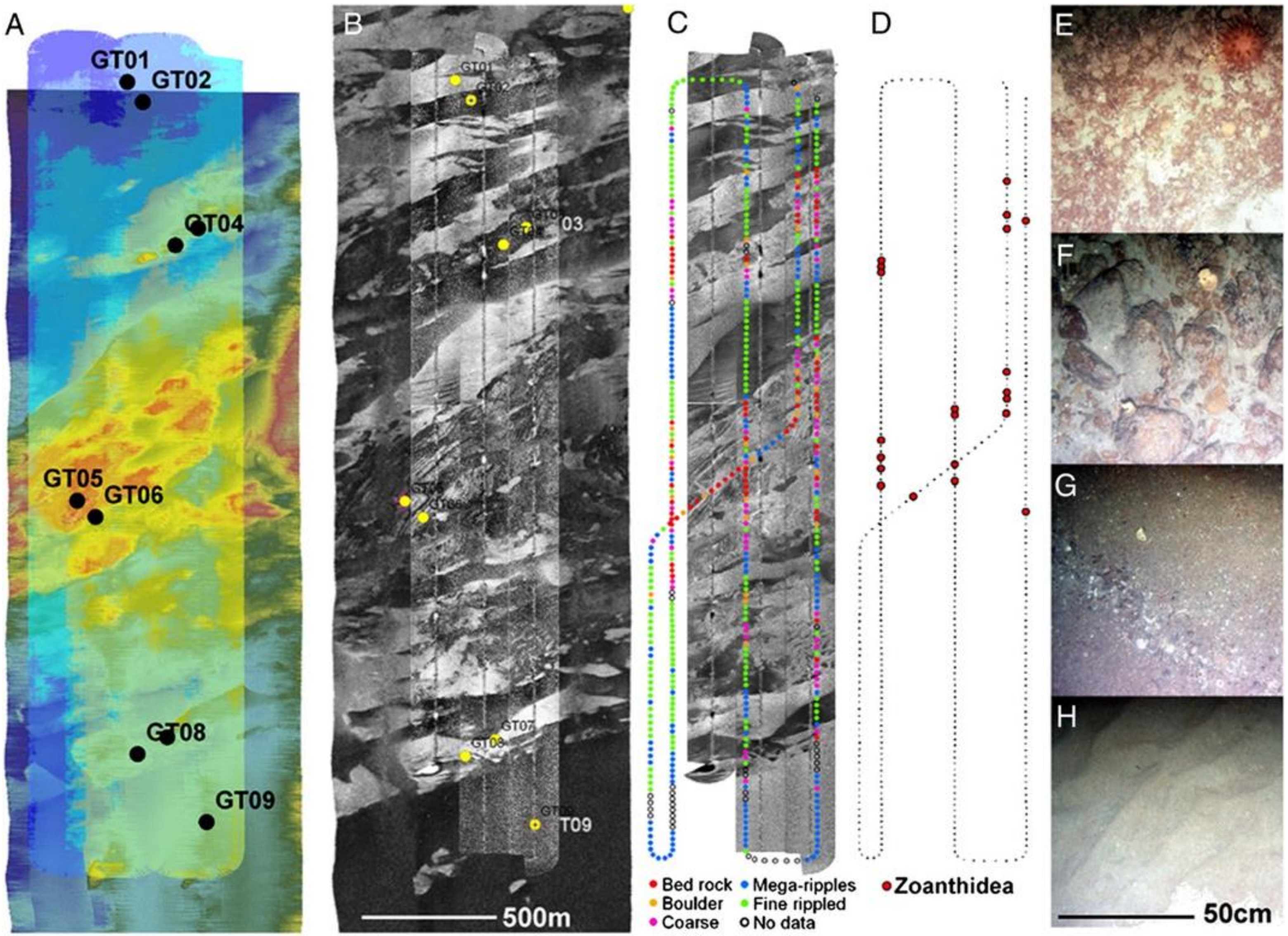




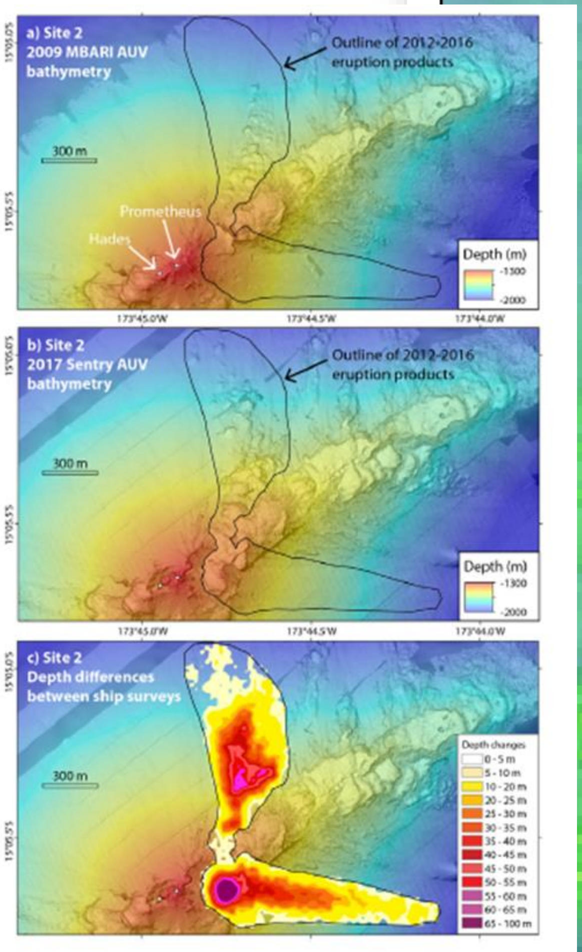


During a mission, AUVs have assigned tasks that may involve traveling a certain path and collecting information about the areas traveled. They can be configured with different sensors and communication systems to provide real-time information back on land or to a ship over the horizon. With limited or no interaction with an operator, AUVs must be designed with the intelligence to perform their tasks, identify problems, and adapt to different situations.

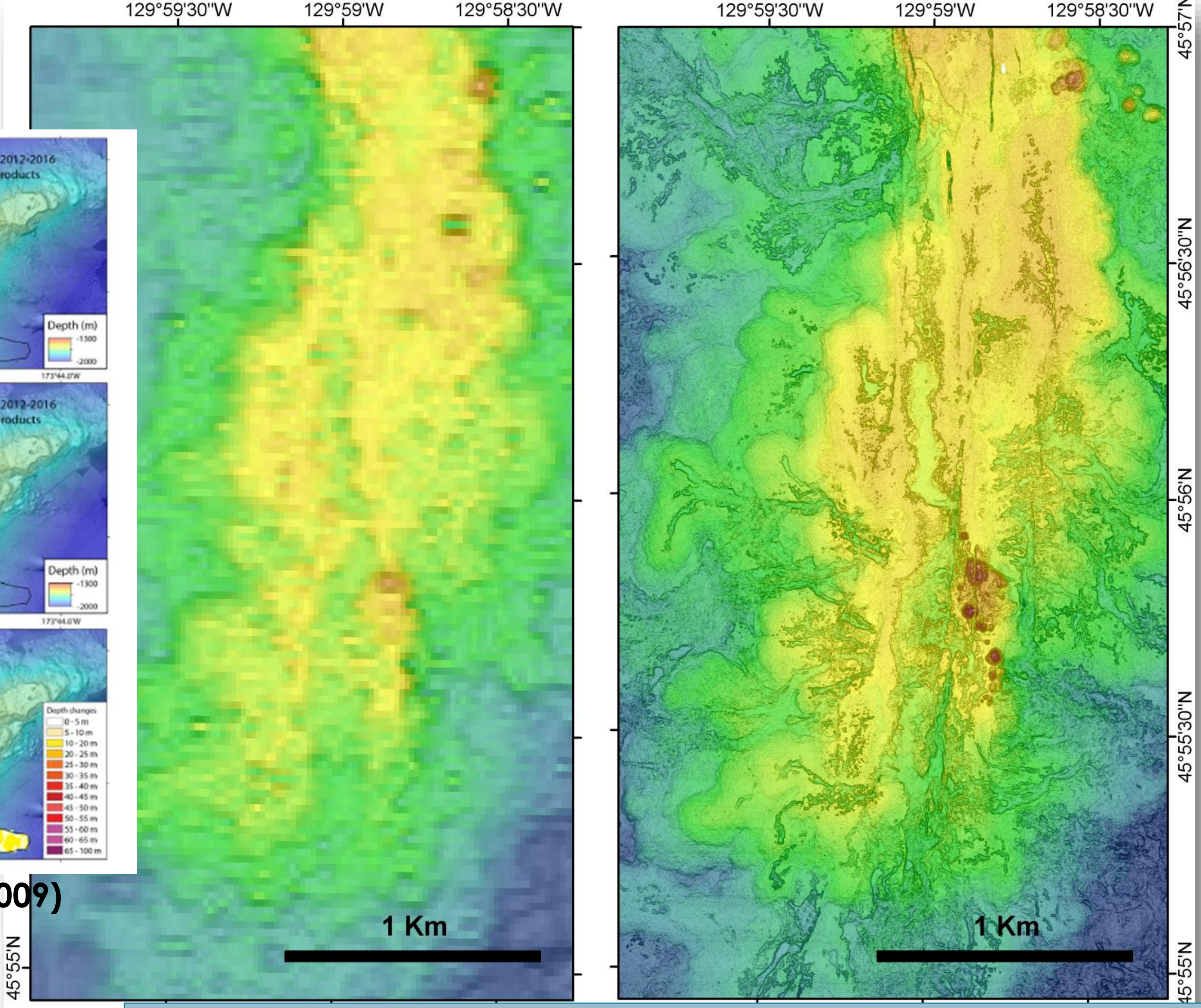
AUVs are capable of carrying a variety of sensor payloads relevant to marine geoscience, including geophysical instruments (MBES, SBP, SSS, magnetometer), geochemical instruments (electrochemical redox sensors), seafloor-imaging tools (high-definition monochrome or colour cameras) and oceanographic instruments (CTD, (ADCPs)).



Autosub6000 survey in the Haig Fras area. (A) AUV MBES overlain on RV Cefas Endeavour MBES data (reds, topographic highs; blues, lows). (B) AUV high-frequency SSS over vessel MBES backscatter data (dark, high backscatter; light, low). (C) Photographic seabed classification over AUV SSS (note reversed phase; dark low backscatter, light high). (D) Occurrence of abundant colonial anemones (Zoanthidea). (E–F) Example seabed classification images: bedrock, boulder, mega-ripples, fine rippled (Wynn et al., 2014) .



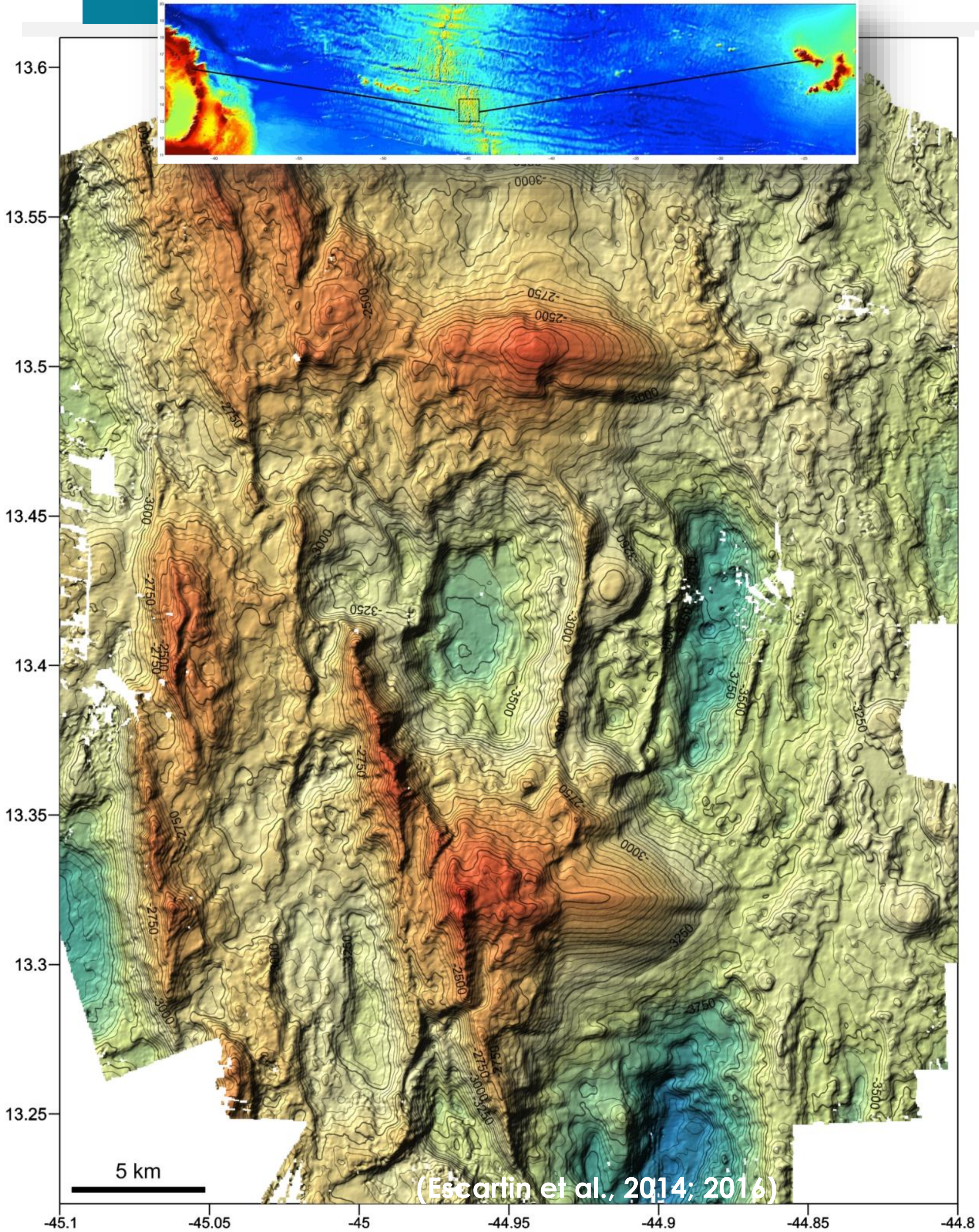
(Chadwick et al., 2009)



The Submarine Volcanism project has been mapping the summit and rift zones of Axial Seamount since documenting the flows of the 1998 eruption with ship-board multibeam sonar a few months afterward. Subsequent expeditions have coupled AUV bathymetry with ROV observations, allowing precise determinations of the extent of new lava flows after the 2011 and 2015 eruptions.

Left: ship-collected bathymetry at 20m resolution
Bottom: AUV-collected bathymetry at 1m resolution (Paduan et al., 2009)

ODEMAR cruise in 2013



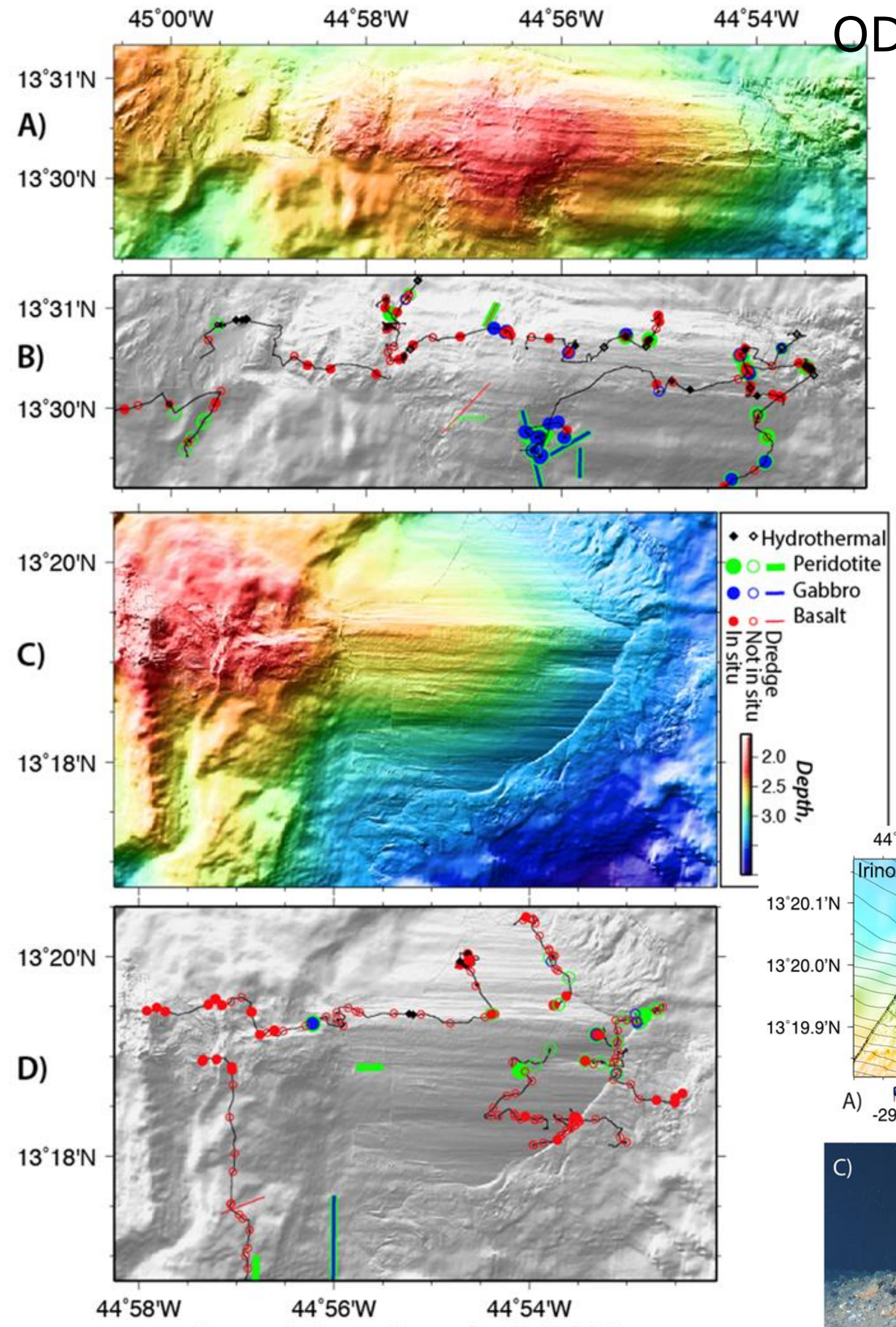
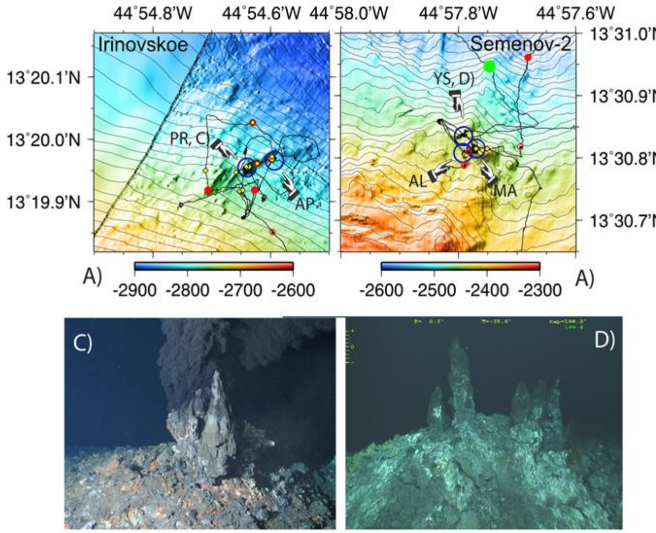
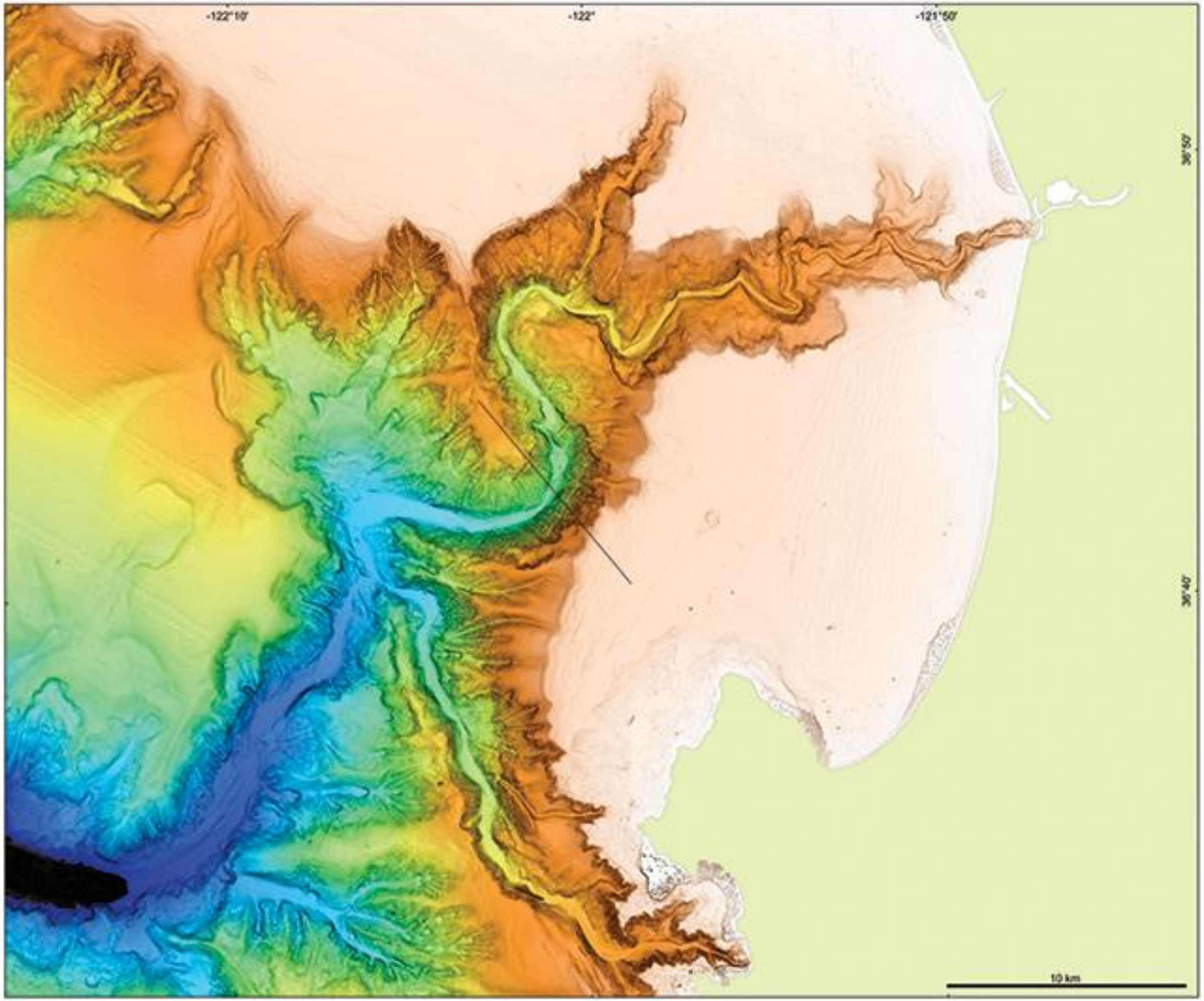
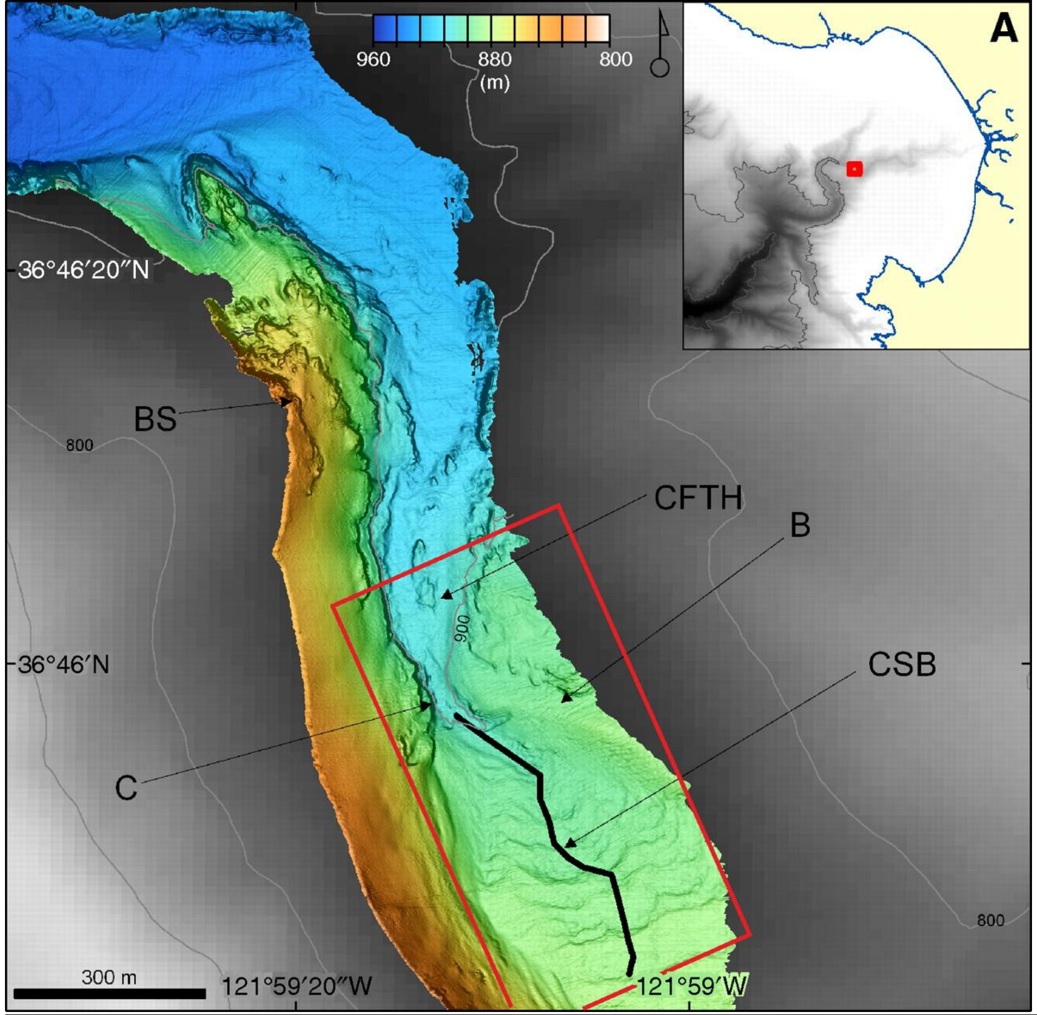


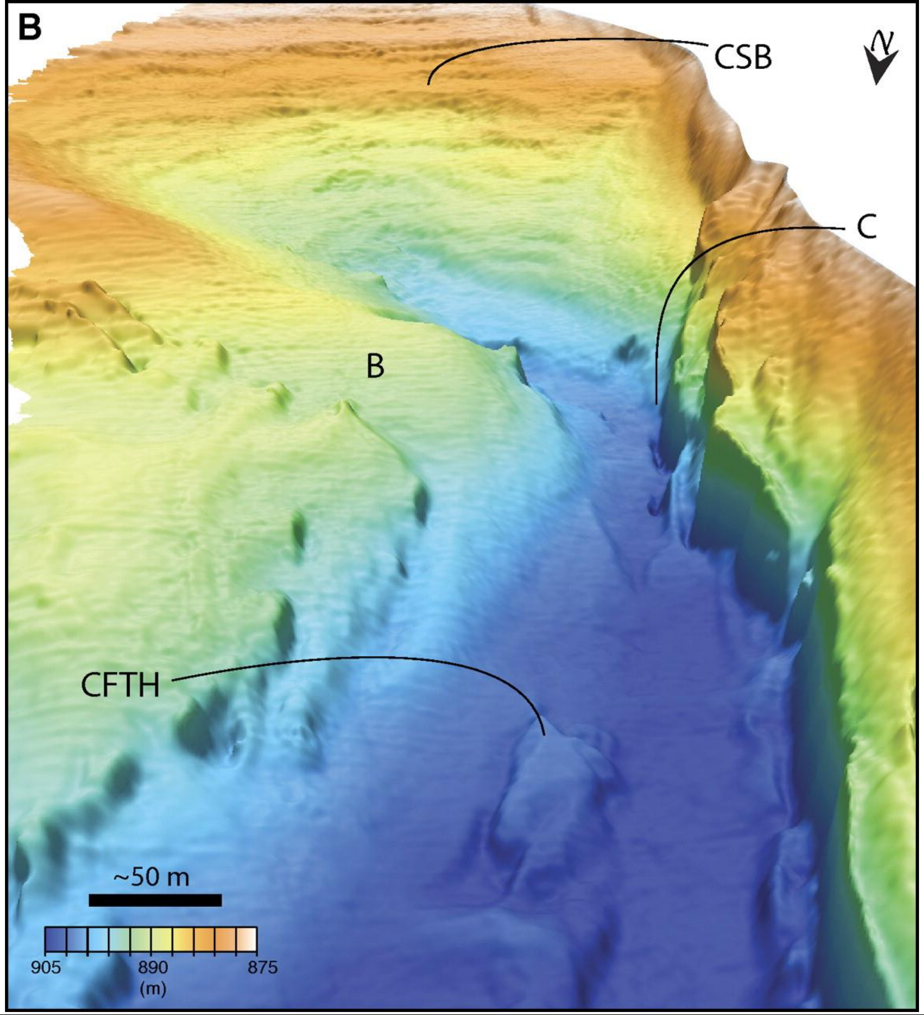
Figure 2, Escartín et al., G3 (2016)





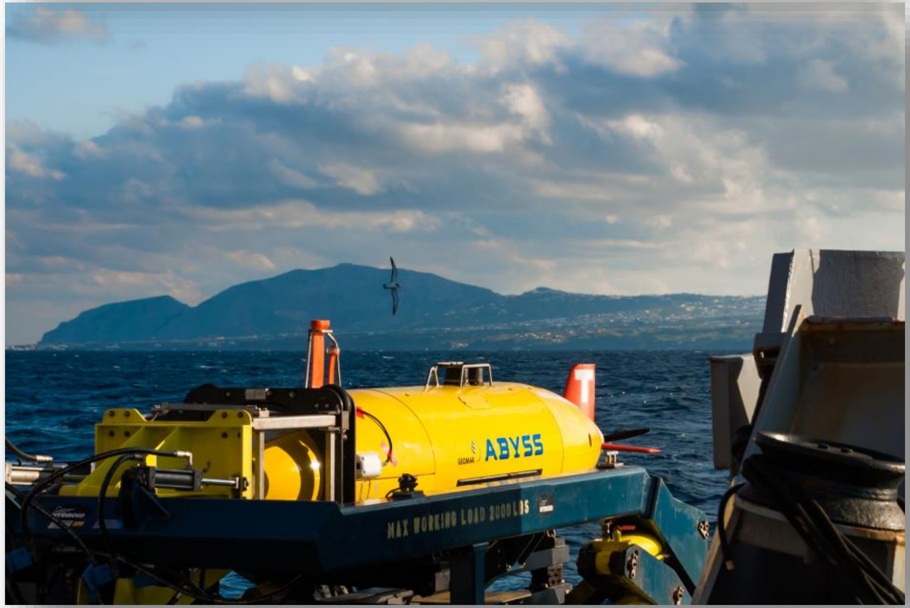
In addition to volcanism and seismicity, high-resolution mapping is helping researchers study other seafloor processes and environments, such as underwater landslides in Monterey Canyon off California. Credit: ©2012 Monterey Bay Aquarium Research Institute.



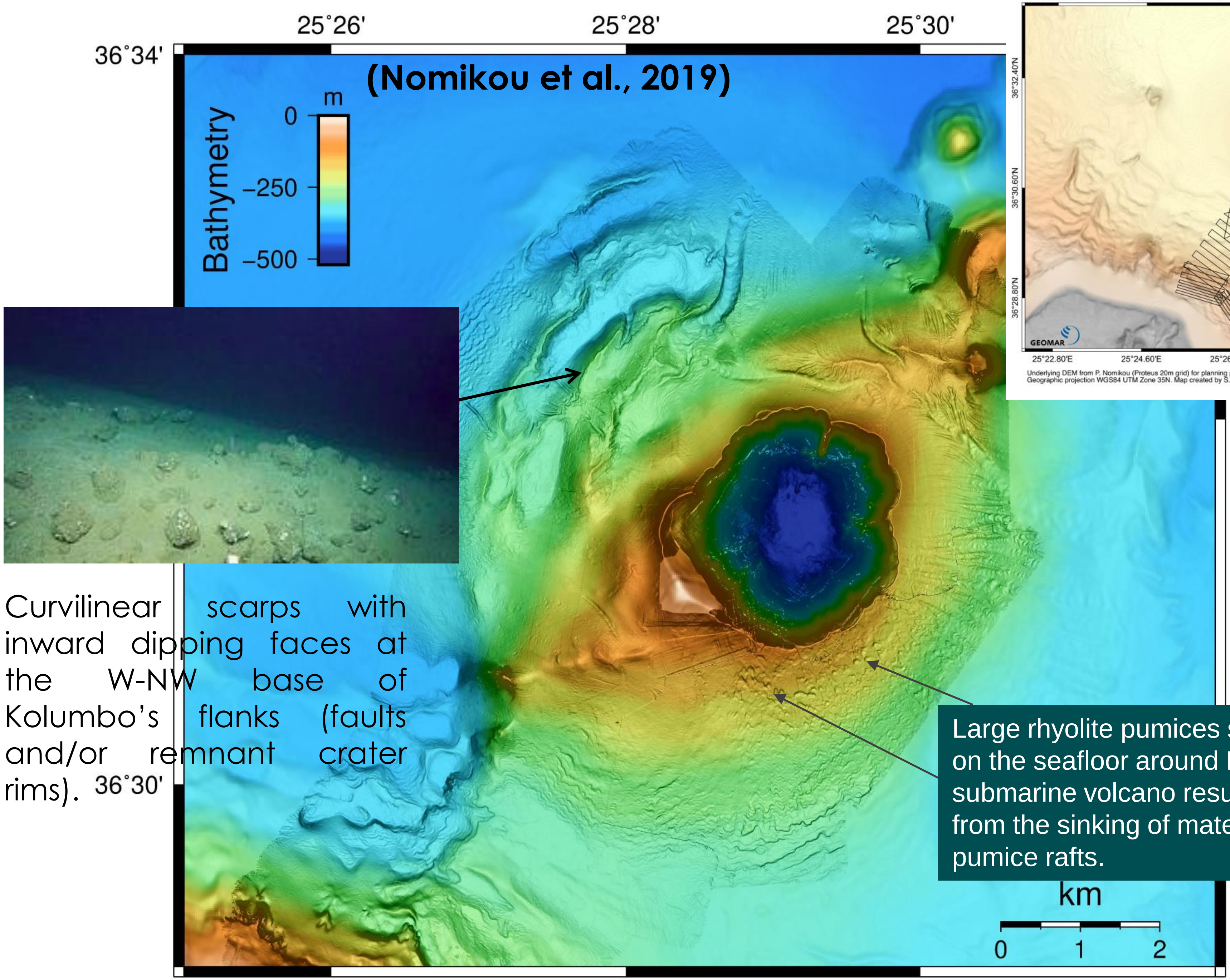


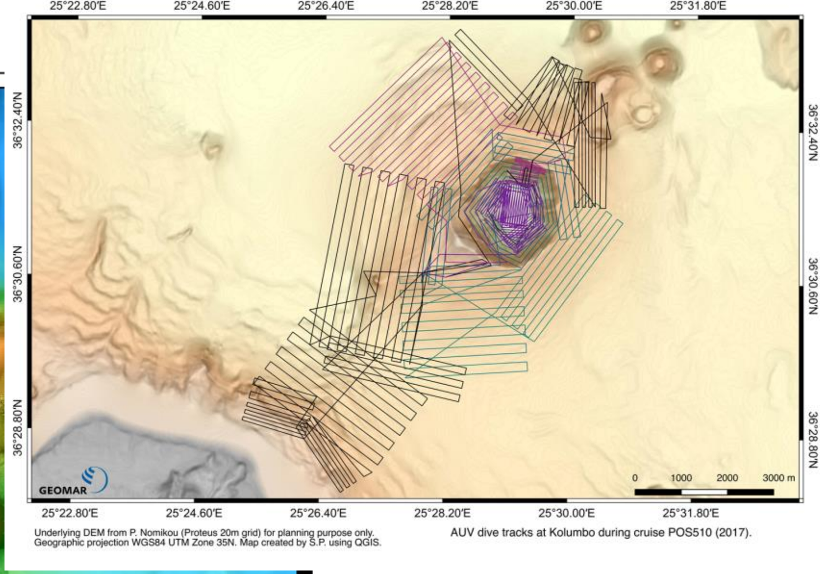
A prospective view of one segment of the canyon floor extending between 905 m and 875 m water depth with a vertical exaggeration of 2.5.

Map showing AUV–collected multibeam data (color scale) from the floor of Monterey Canyon where the axial channel ranges from 884 m to 954 m water depths. AUV data are overlain on surface vessel–collected multibeam data shown with gray scale and 100 m bathymetric contours. A distinct canyon floor topographic high (CFTH) forms a 4-m-high central ridge that extends parallel to the canyon axis for 100 m. Layers suggestive of bedded strata occur on both sides of the canyon adjacent to the canyon floor topographic high. Note the occurrence of broad crescent-shaped bedforms (CSB) upstream of both the constriction and bench (B) on the inside bend of this meander (Wynn et al., 2014).



AUV Abyss *deployed from the* ***R/V POSEIDON*** *during the POS510 cruise in 2017*

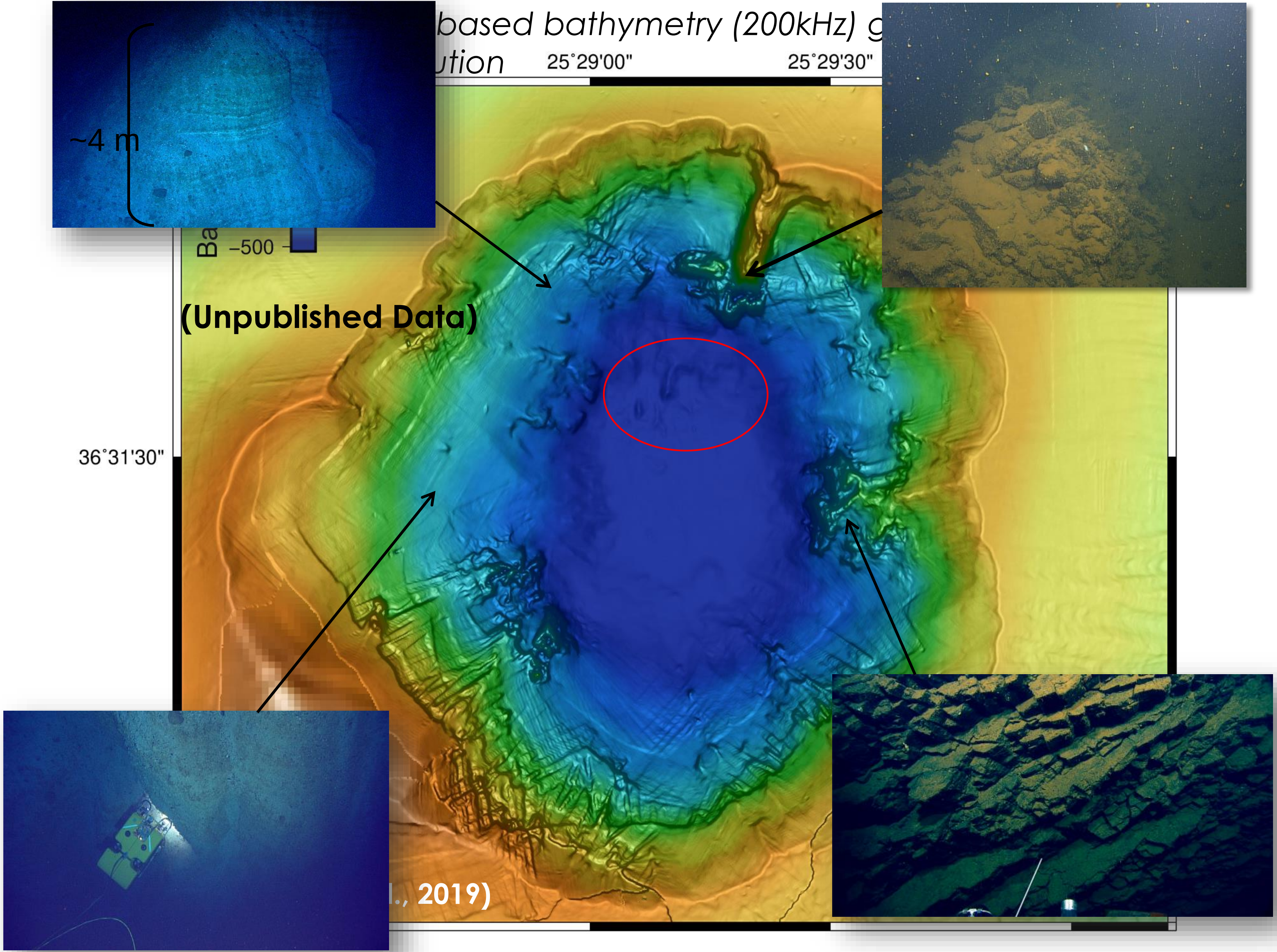




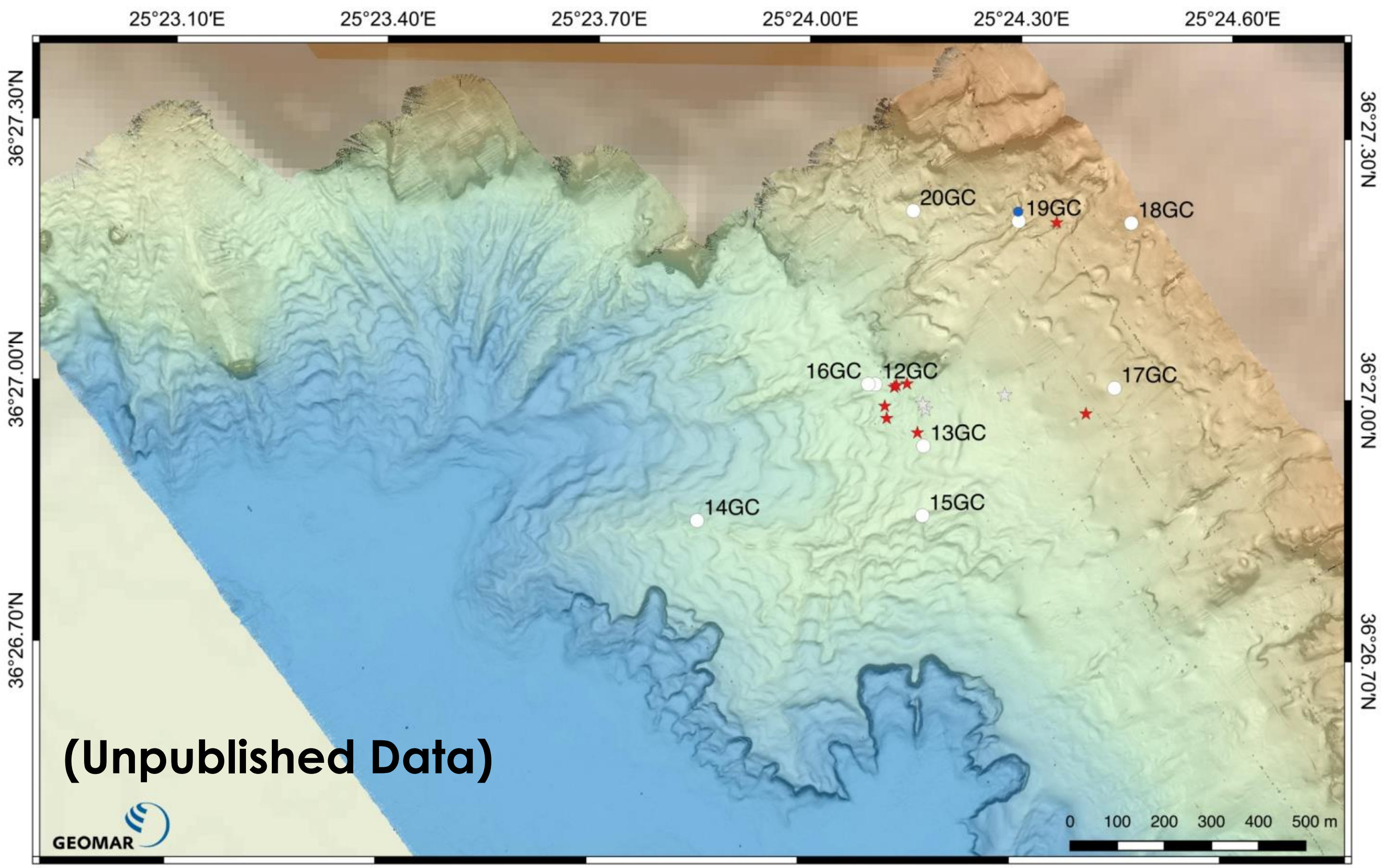
Curvilinear scarps with inward dipping faces at the W-NW base of Kolumbo's flanks (faults and/or remnant crater rims).

Large rhyolite pumices scattered on the seafloor around Kolumbo submarine volcano resulting from the sinking of material from pumice rafts.

AUV-based bathymetry (200kHz) gridded at 2m resolution

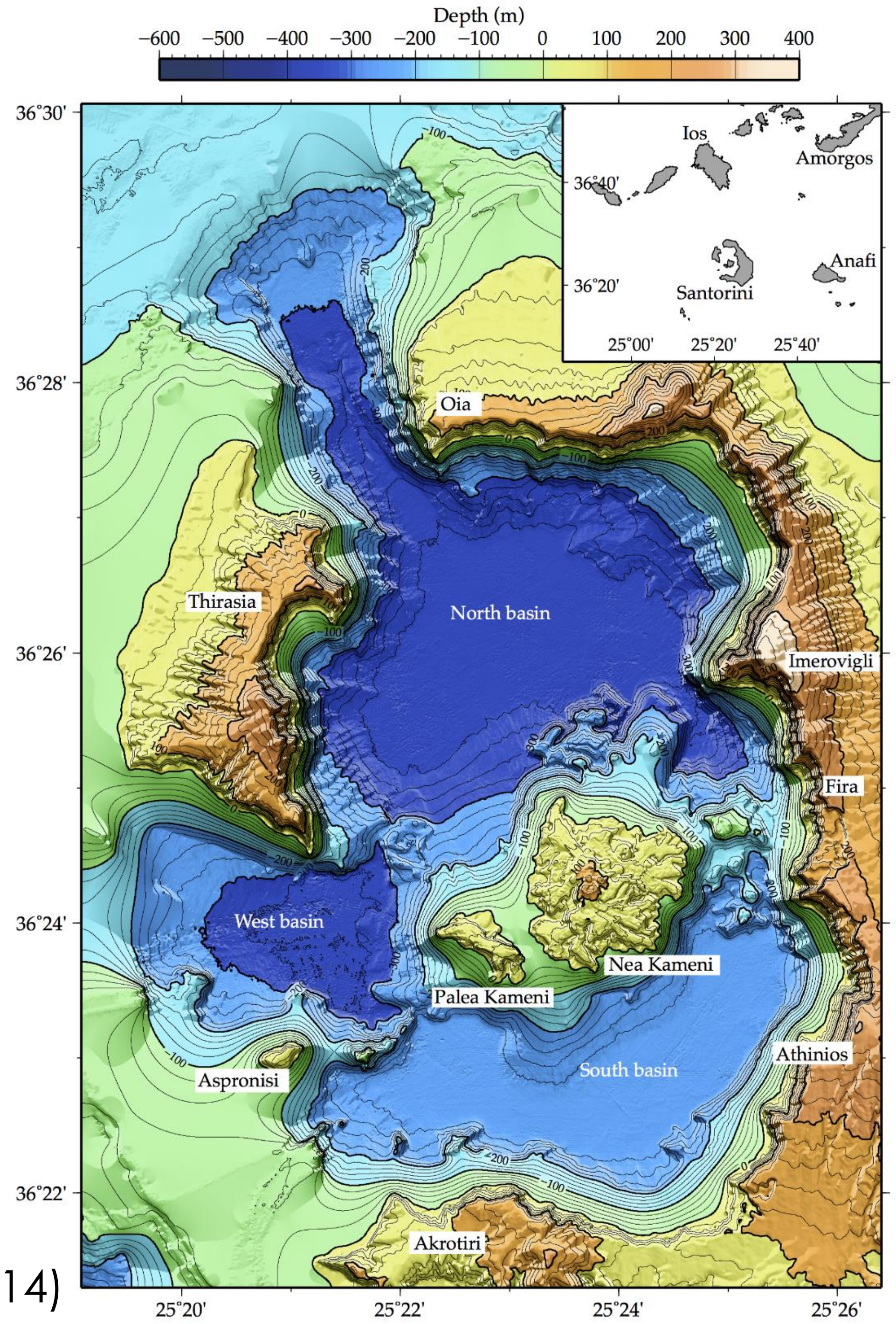

based bathymetry (200kHz) g
tion
25°29'00"
25°29'30"
~4 m
Ba
−500
(Unpublished Data)
36°31'30"
l., 2019)

POS510, March 2017



Underlying DEM from P. Nomikou (Proteus 20m grid) for planning purpose only.
Geographic projection WGS84 UTM Zone 35N. Map created with QGIS

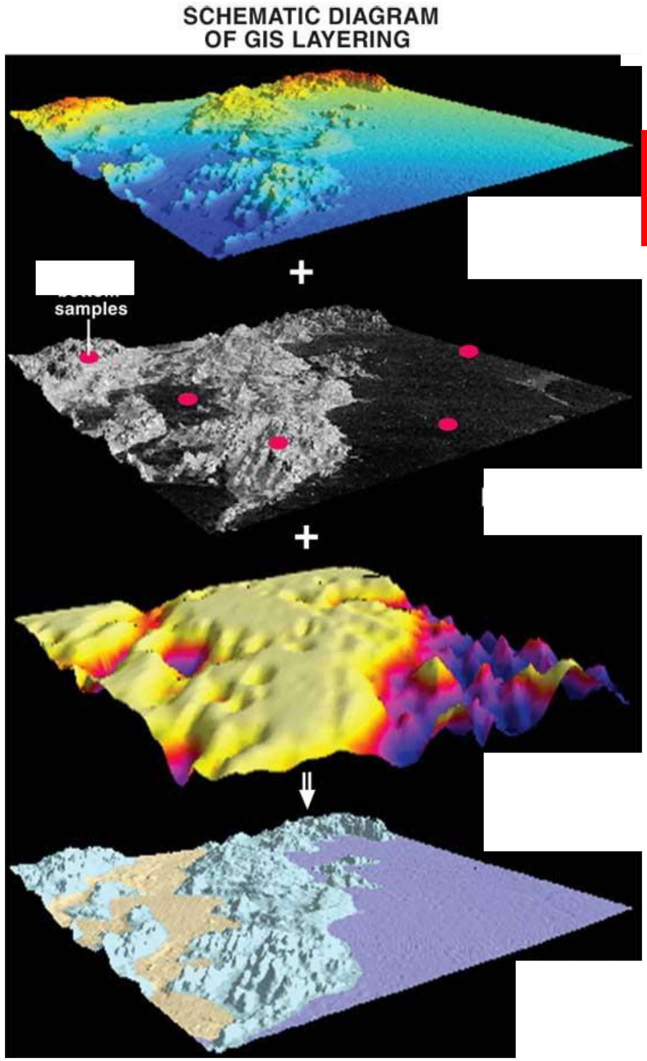
Stations and raw AUV bathymetry (AUV dive 0259).
Data is gridded at 1m resolution.



(Nomikou et al., 2014)

In the last decades, Geographic Information Systems (GIS) allowed the detailed analysis of earth surface processes, whereas the development in Remote Sensing (RS) offered increasingly detailed Digital Elevation Models (DEMs) and multispectral imagery – both for land surface and the seafloor

ON-SHORE - NEAR-SHORE - **OFFSHORE** ……. **REMOTE DATA** ?



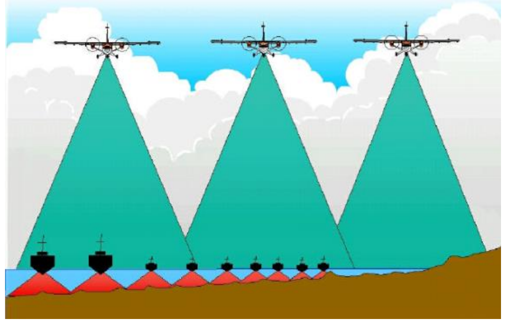
ON-SHORE	**NEAR-SHORE**	**OFFSHORE**
Land TOPOGRAPHY	Near-shore TOPOGRAPHY	seafloor TOPOGRAPHY
+	+	+
single or multiple SPECTRAL BANDS (satellite/aerial Remote Sensing)	Single or multiple SPECTRAL BANDS only in very transparent water	Seafloor BACKSCATTERING (even in multiple frequency)
+	+	+
SEISMIC	SEISMIC	SEISMIC
↓	↓	↓
Geologic Map ⟵	Geologic Map	⟶ Geologic Map

DATA MUST BE COLLECTED AT PROPER **RESOLUTION**

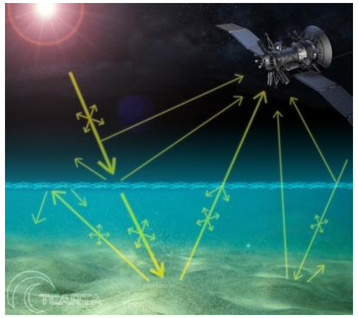
(credits to Alessandra Savini)

NEAR-SHORE ELEVATION DATA SOURCE

Airborne LIDAR bathymetry



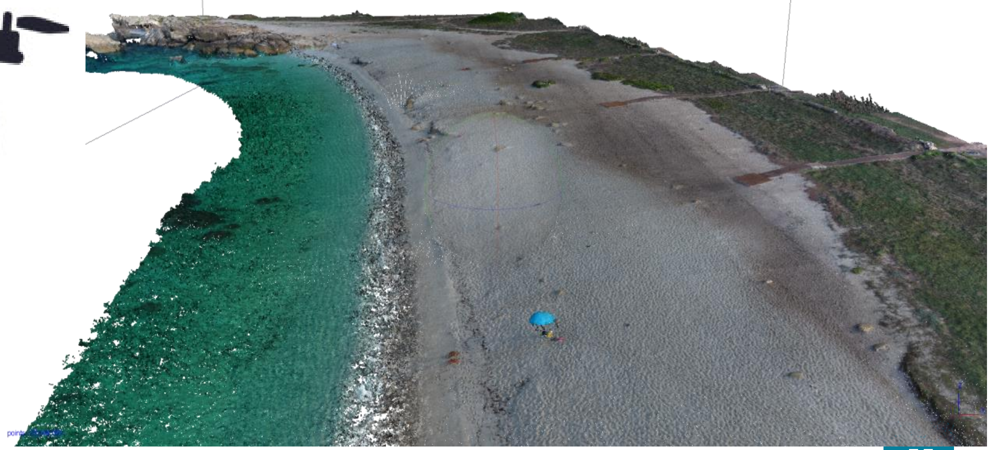
Satellite derived bathymetry



In progress…

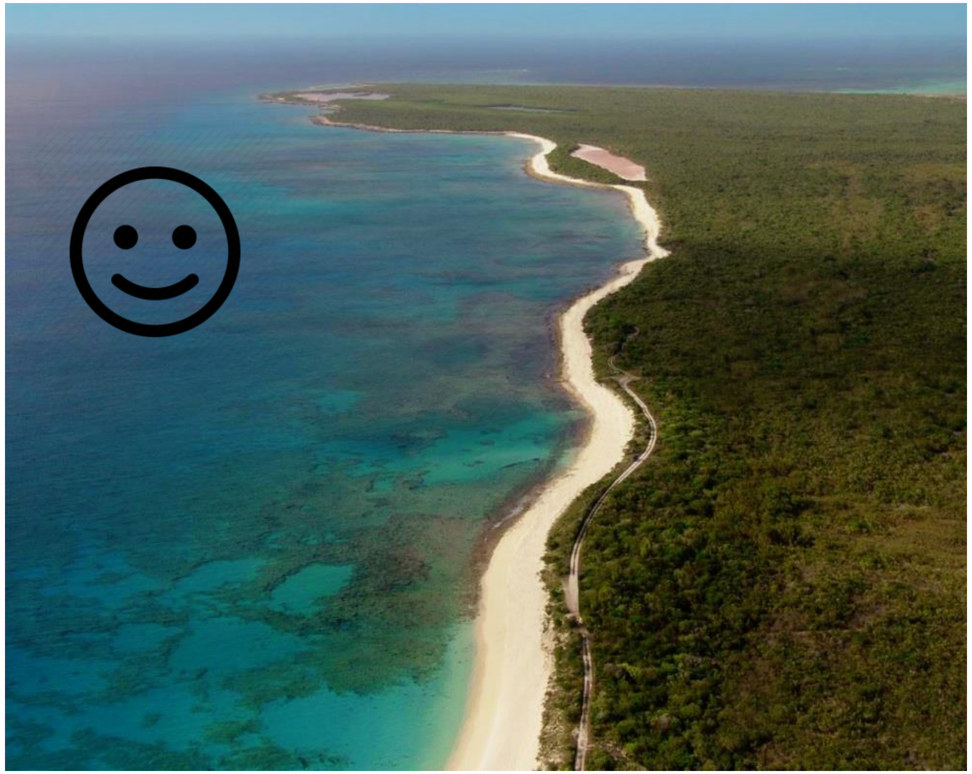
There is currently a lack of shallow water bathymetric data around the world due to the high costs, lead-time, and health and safety issues involved in collecting this data using the more traditional data collection methods of Multi Beam Echo Sounder (MBES) from boats or Light Detection and Ranging (LiDAR) from aircraft.

Aerial imagery processed by Structure from Motion



(credits to Alessandra Savini)

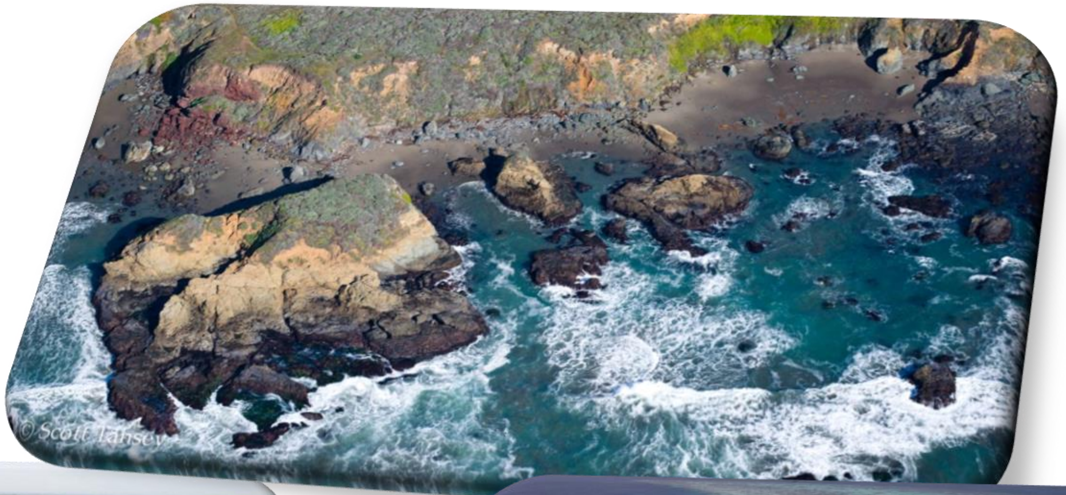
Water column quality
is the most significant **limitation** for ALB and DRONE surveys

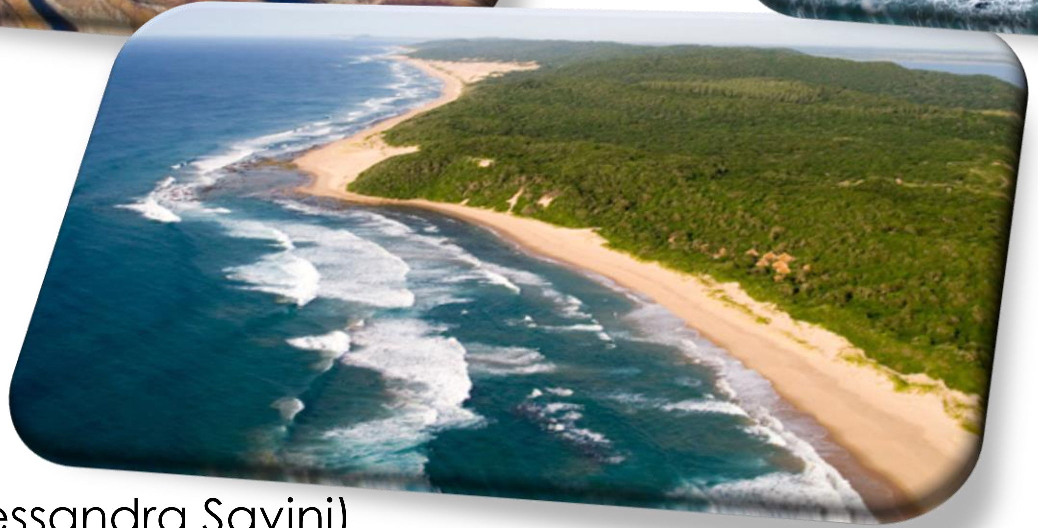


(credits to Alessandra Savini)

NEAR-SHORE ELEVATION DATA

The type of coast (rocky vs depositional, etc…) strictly affect methods and techniques of elevation data collection in the near-shore

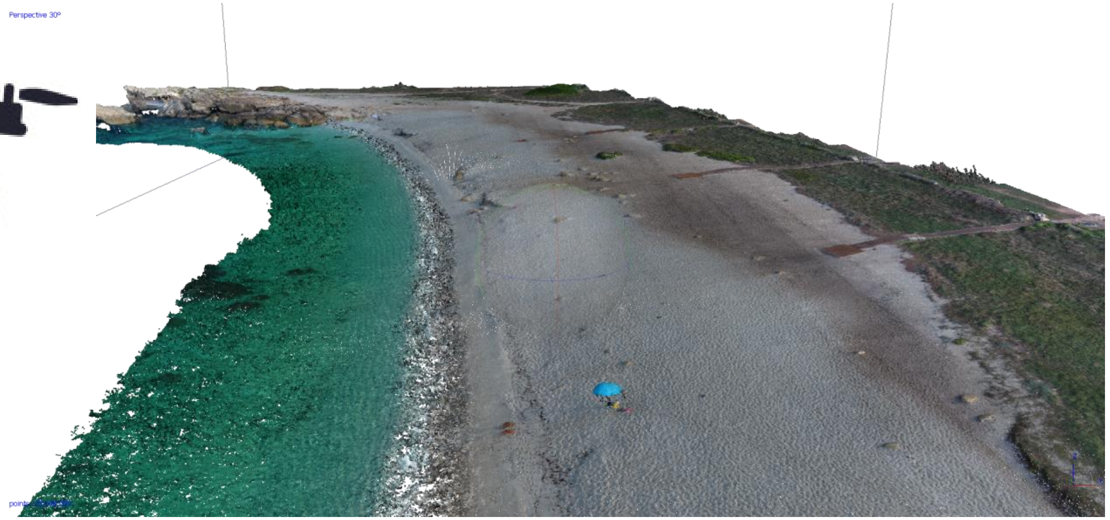




(credits to Alessandra Savini)

NEAR-SHORE ELEVATION DATA

Aerial imagery processed by Structure from Motion… When?

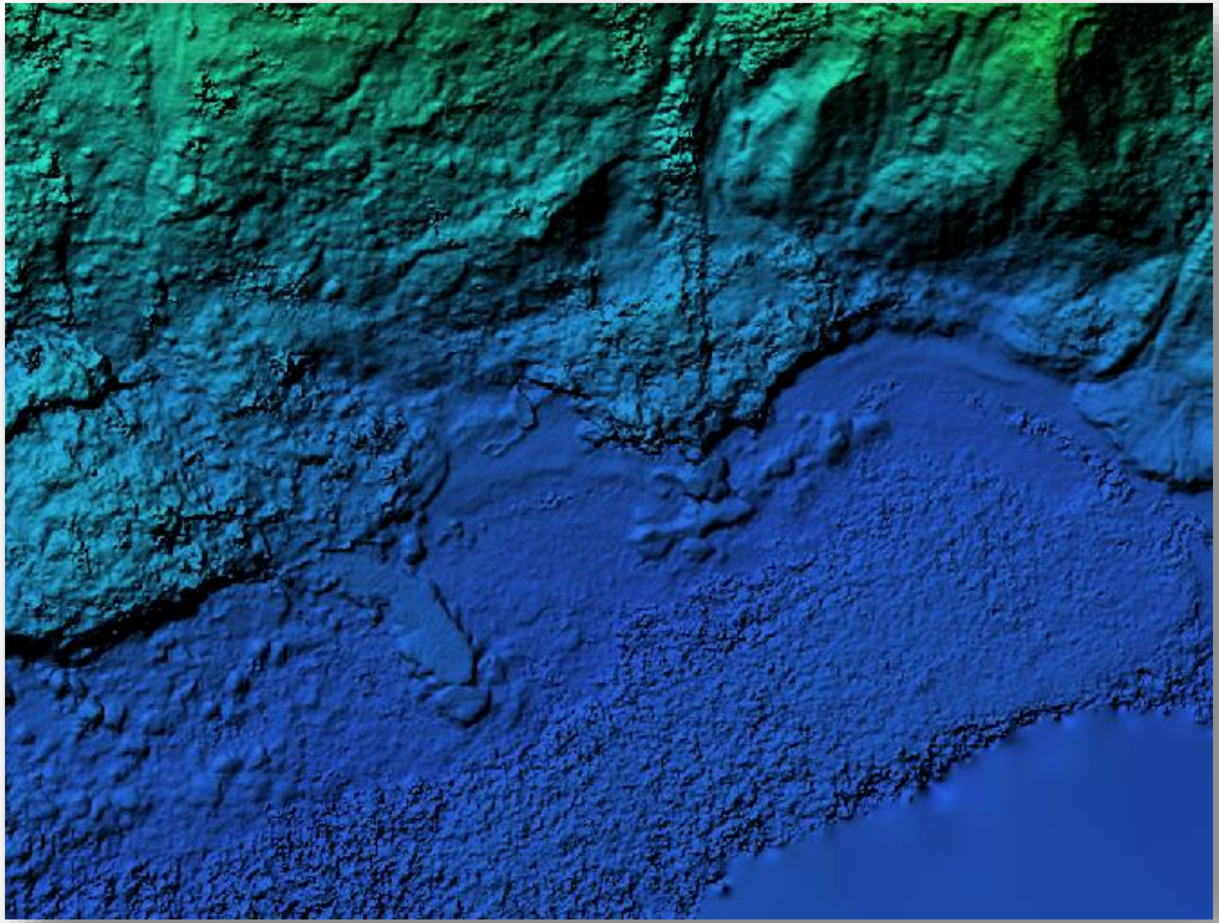


- Nearshore zone must be gently sloping or not too steep
- Water transparency must be high
- Significant water movement must be absent (no waves)
- No sun reflection at the sea surface

(credits to Alessandra Savini)

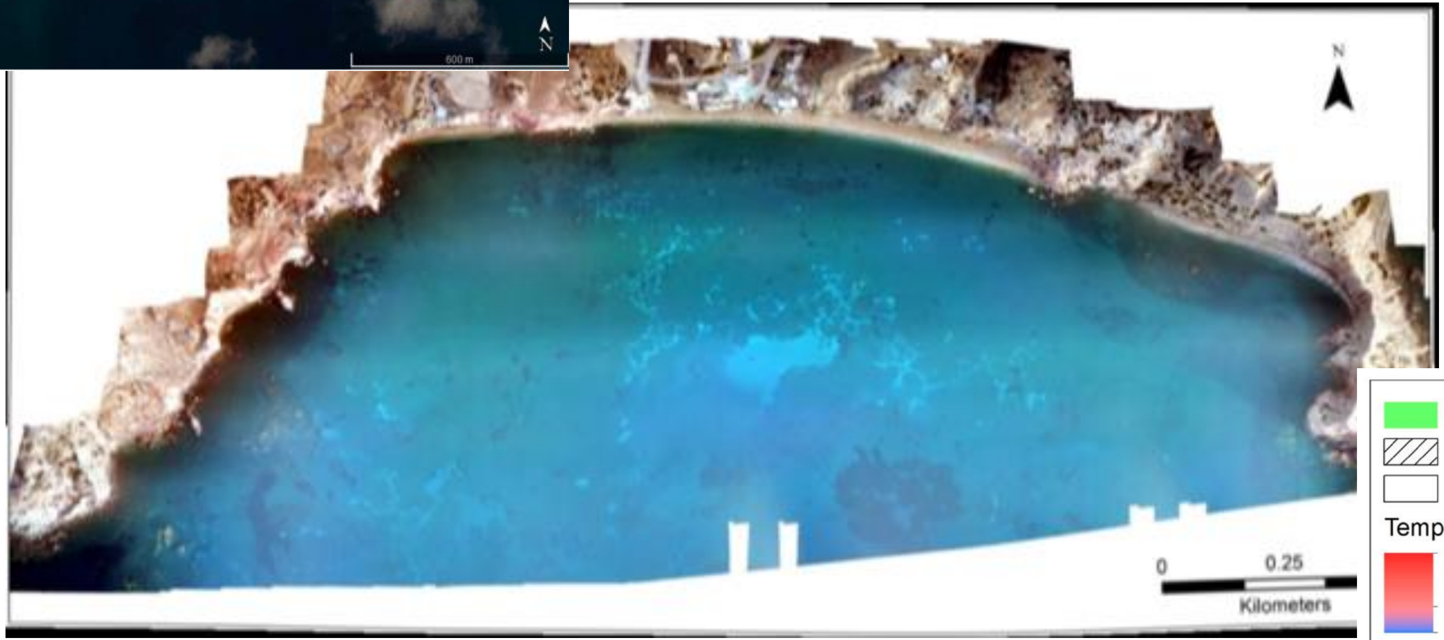
NEAR-SHORE ELEVATION DATA

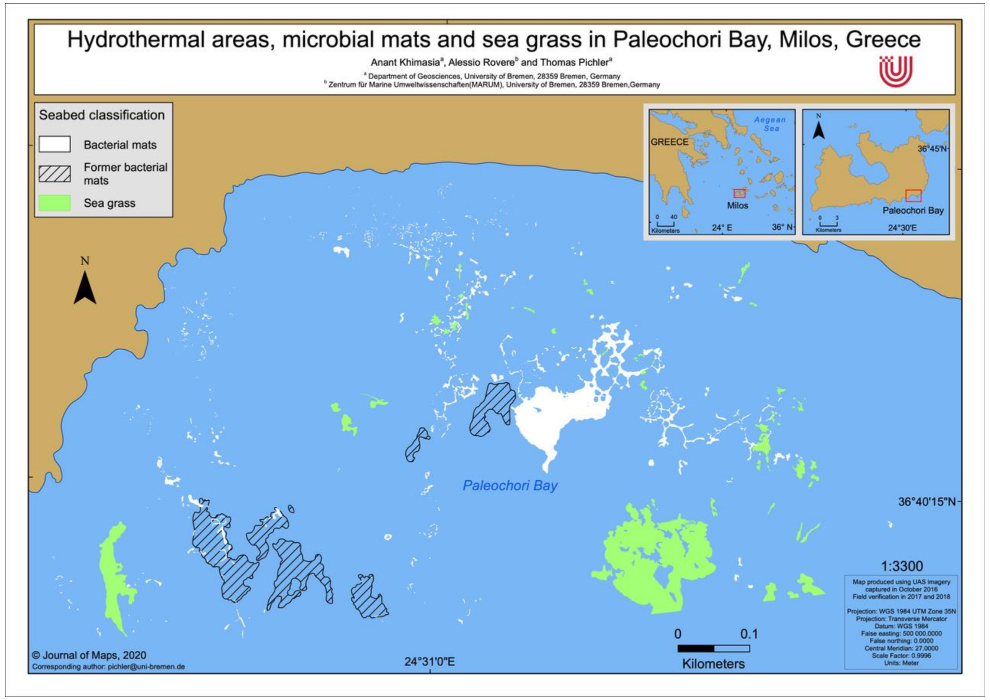
Sciacca (AG), Italy
July 2018

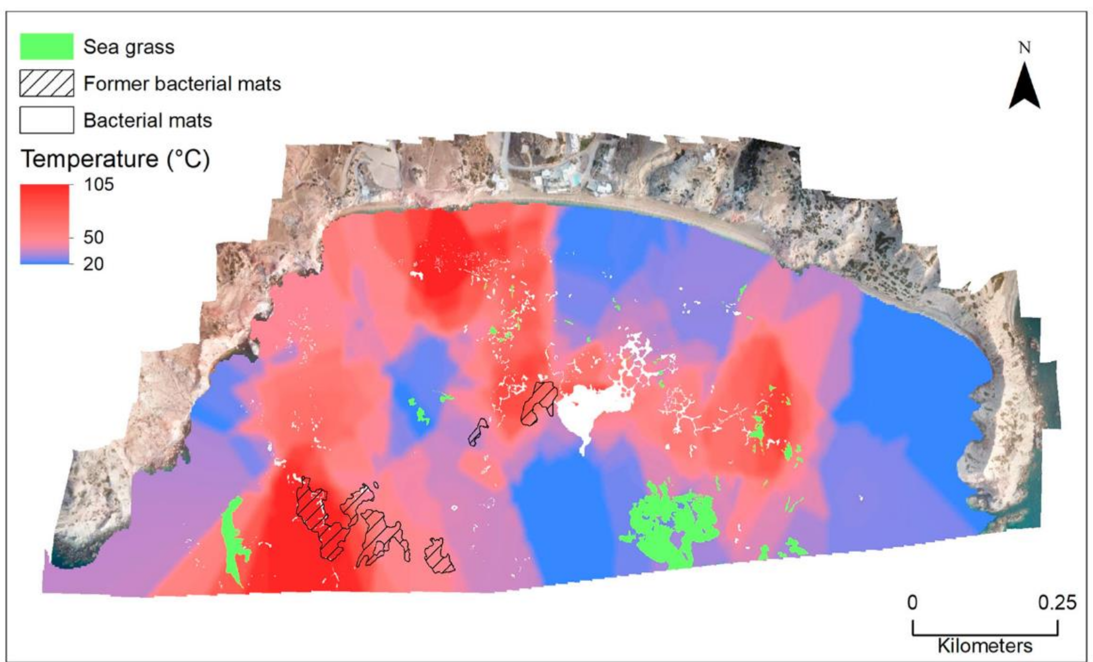


(credits to Alessandra Savini)

Paleochori Bay, Milos



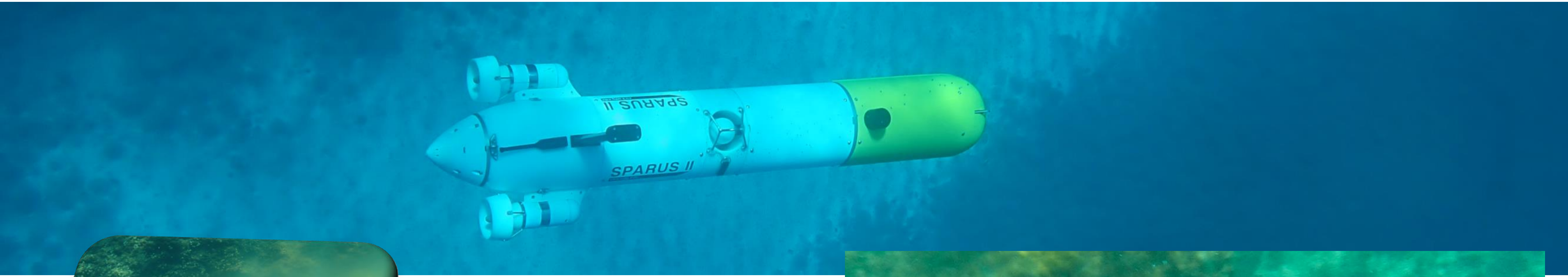


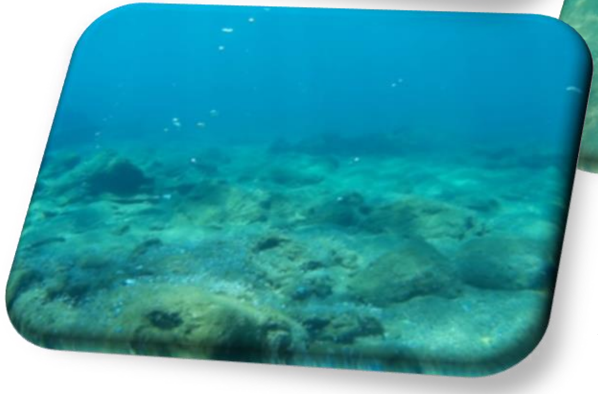


Khimasia et al., 2020

AUV mapping-SPARUS II

Mapping the shallow vent field south of Milos



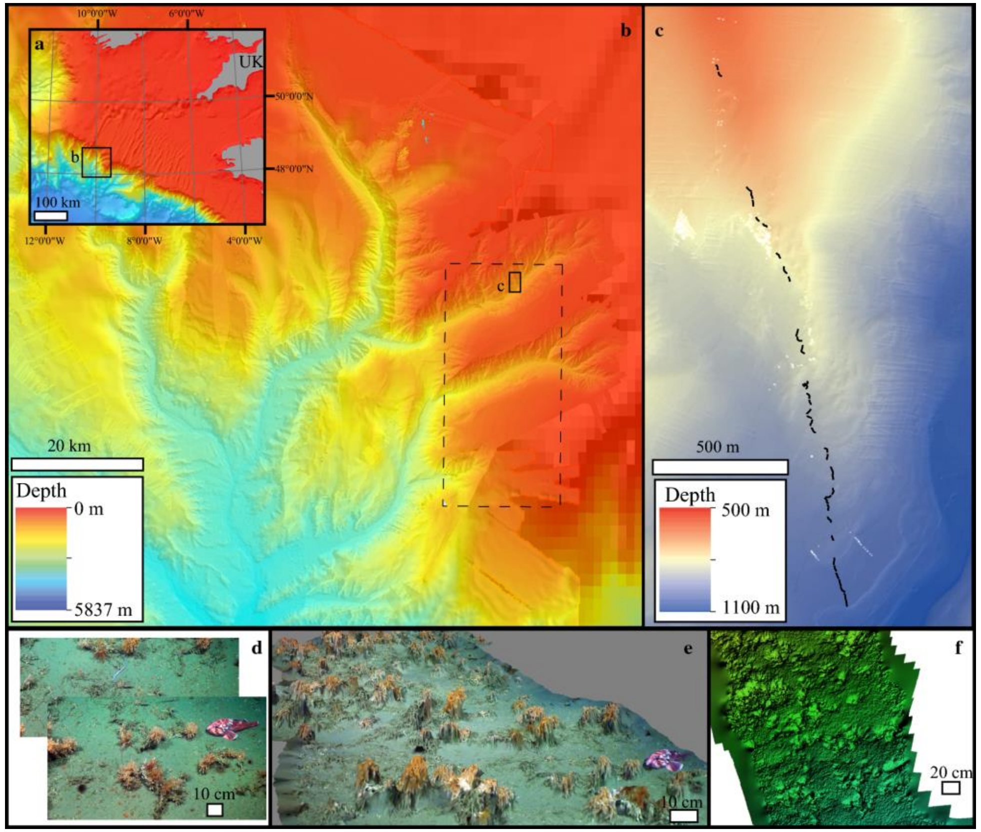


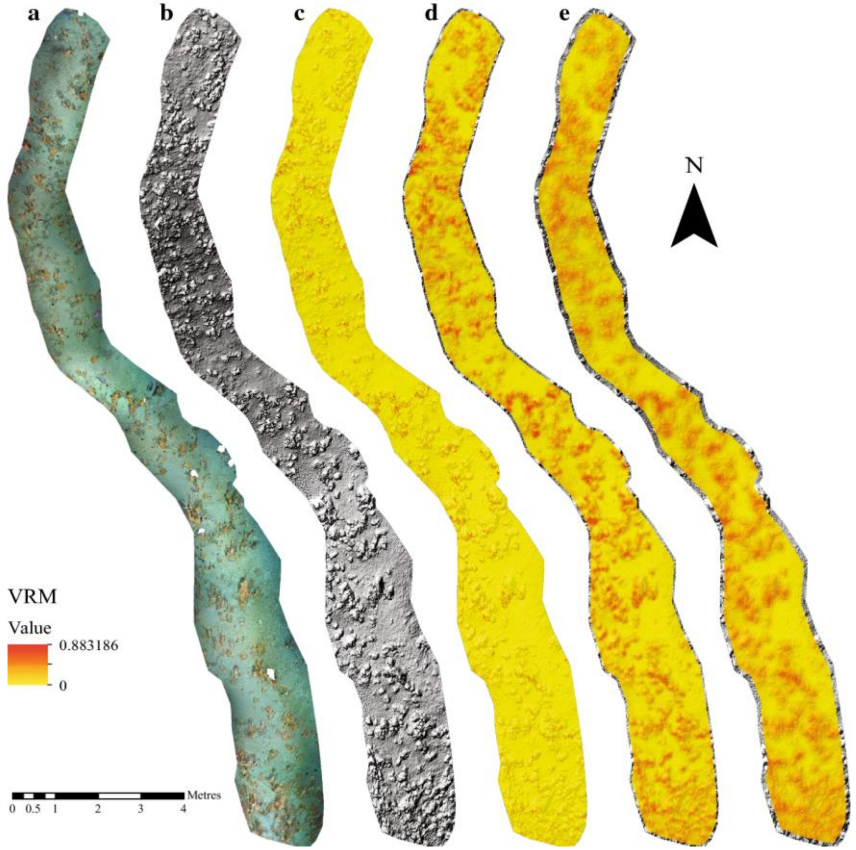
SPARUS II AUV is a lightweight hovering vehicle with mission-specific payload area and efficient hydrodynamics for long autonomy in shallow water (200 meters).

AUV mapping-SPARUS II

Underwater photogrammetry: the use of photography in surveying and mapping to ascertain measurements between objects

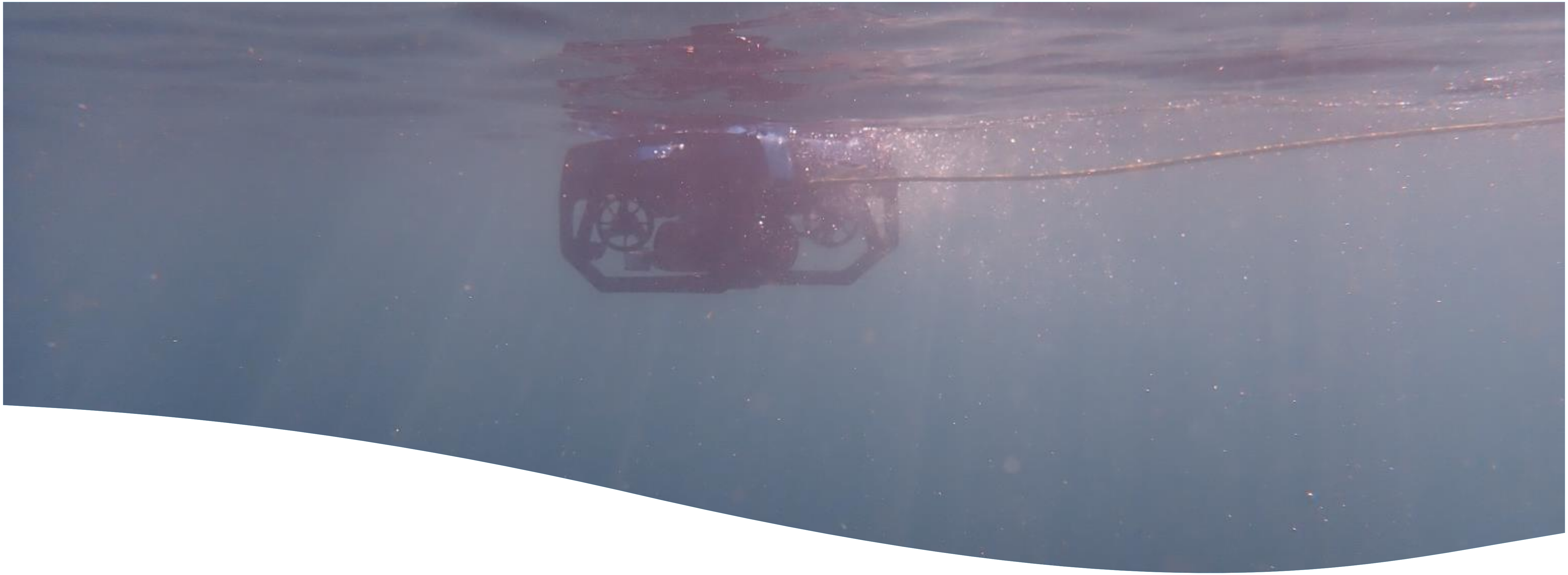
Underwater 3D reconstruction techniques such as Photogrammetry are among the latest of these advancements, which has primarily been utilized for seafloor habitat characterization, bathymetry mapping, marine environment inspections and archaeological surveys



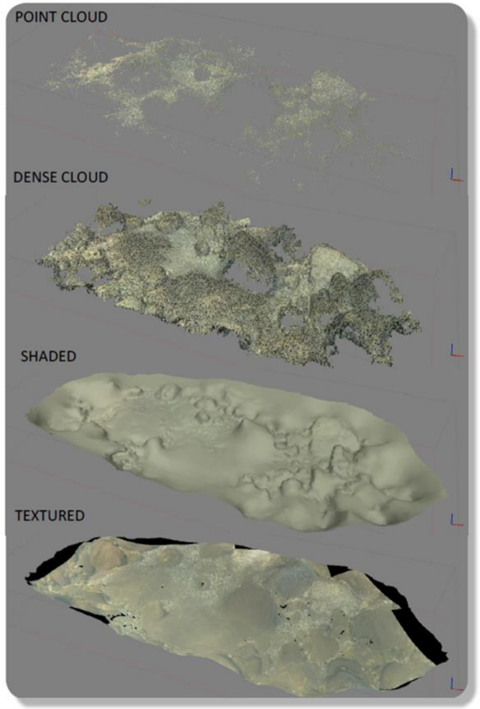


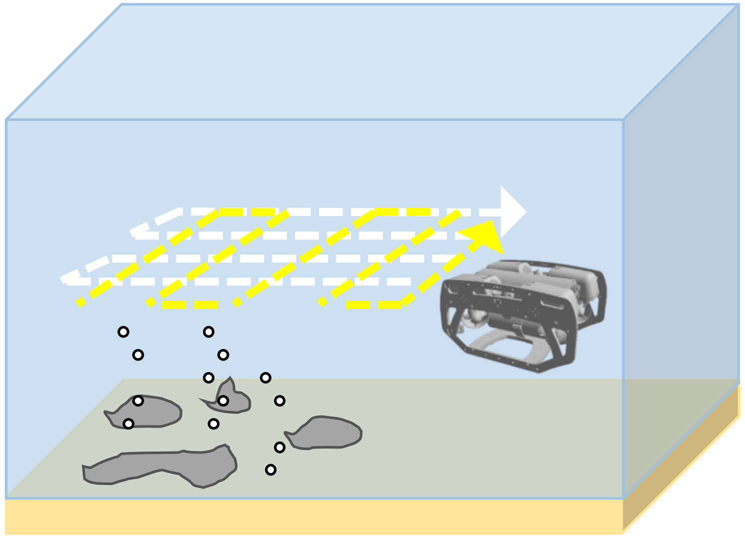
Sub-transect X as an example. **a** orthomosaic, **b** hillshade/digital elevation model and vector ruggedness measure values at **c** 1.5, **d** 9.5 and **e** 19.5 cm per pixel neighbourhood analysis

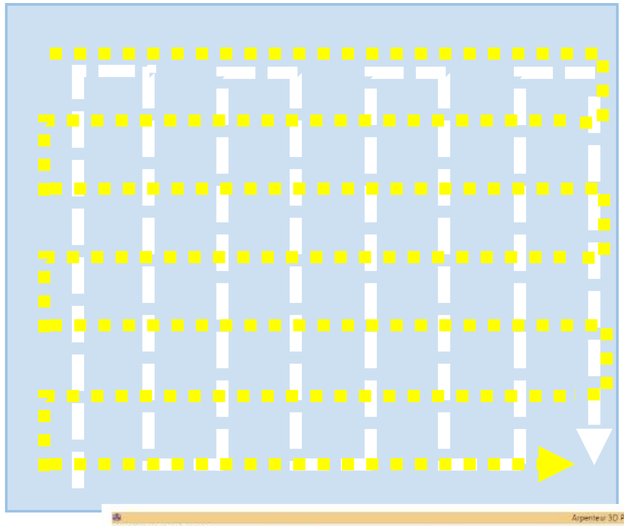
Eastern Whittard Canyon outlined: **d** Example image sequences. **e** 3D reconstruction of a reef transect. **f** Digital elevation model of the coral reef (Price et al., 2019)



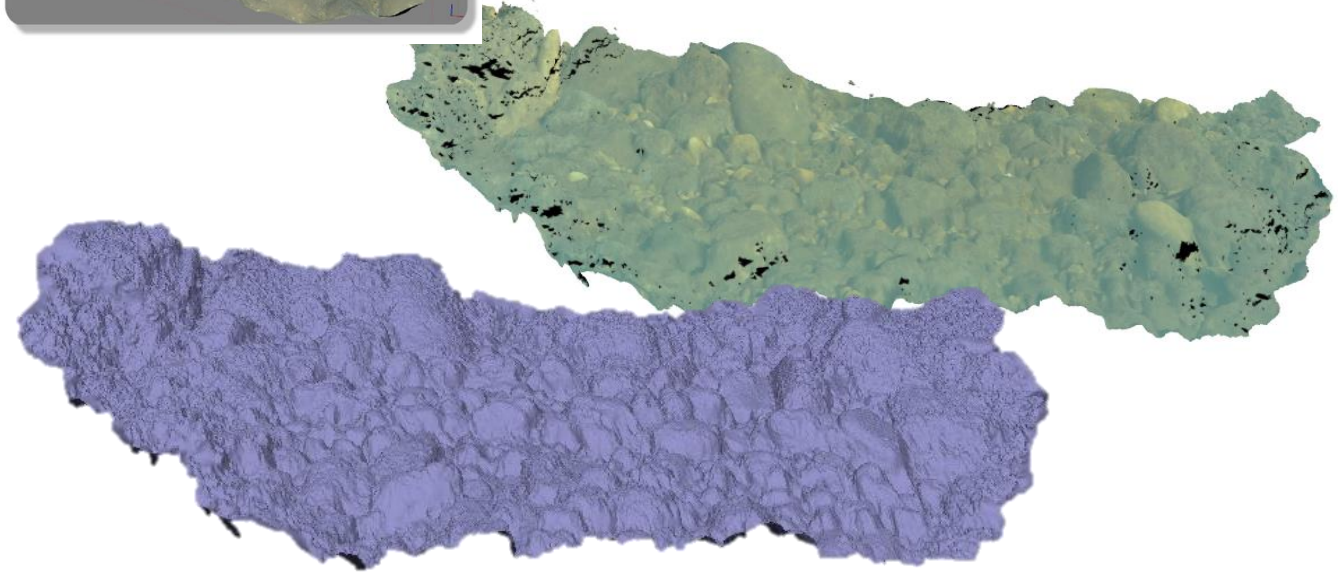
ROV Mapping

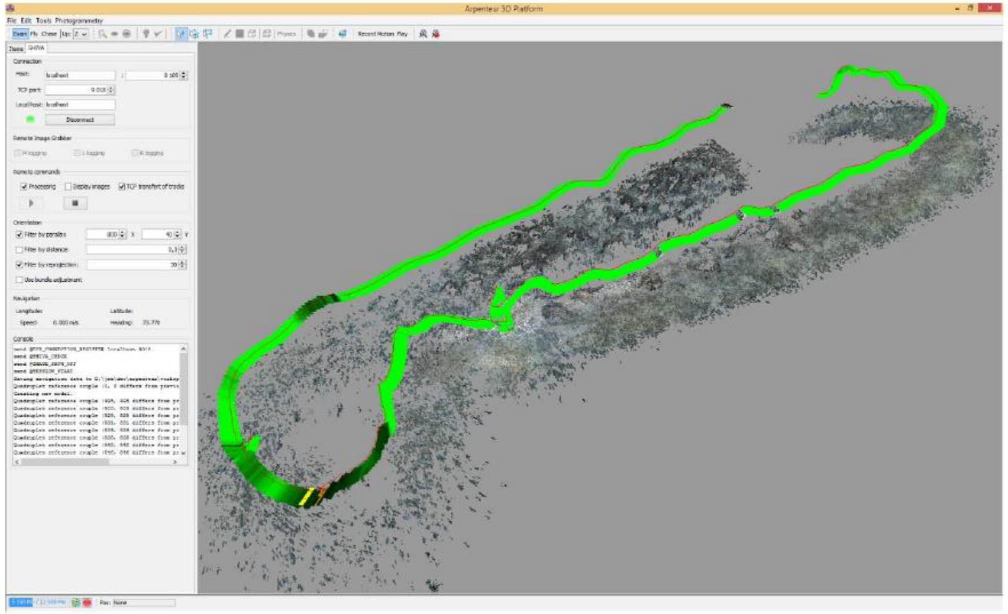






3D representation of raster pattern over vent field showing camera field of view. And top down view of raster pattern survey.





Real time visual odemetry display as seen on-board the ship. This figure shows the 3D point cloud calculated over the surveyed zone and the position of the vehicle for each photo pair (Drap et al., 2015).

(Teague et al., 2017)

3DTeLC

Erasmus+

SANTORINI SUMMER SCHOOL

UNDERWATER ROV SURVEY

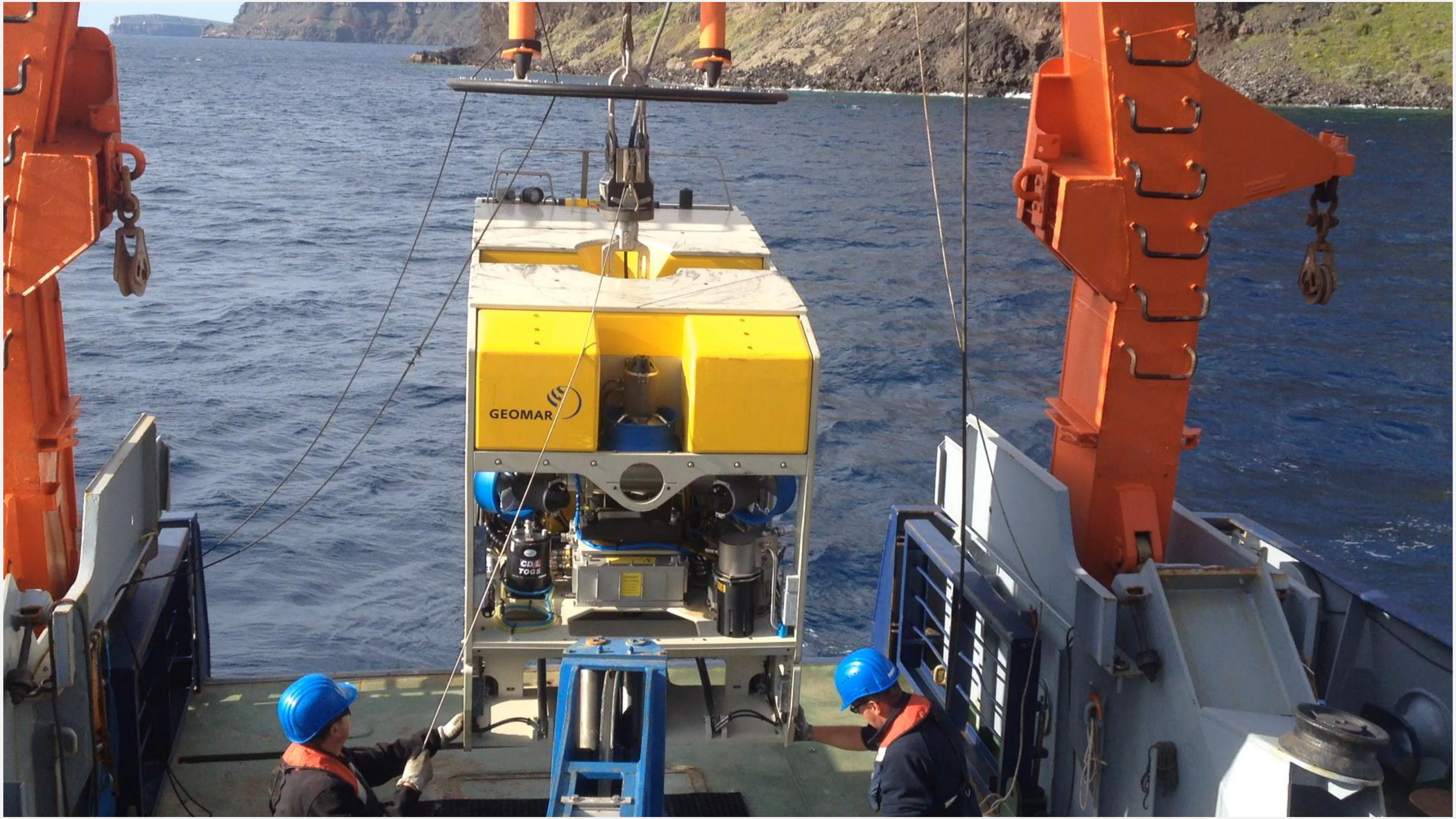
P. Nomikou, V. Antoniou, O. Vlasopoulos, S. Poulos
Faculty of Geology and Geoenvironment

Erasmus+

HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

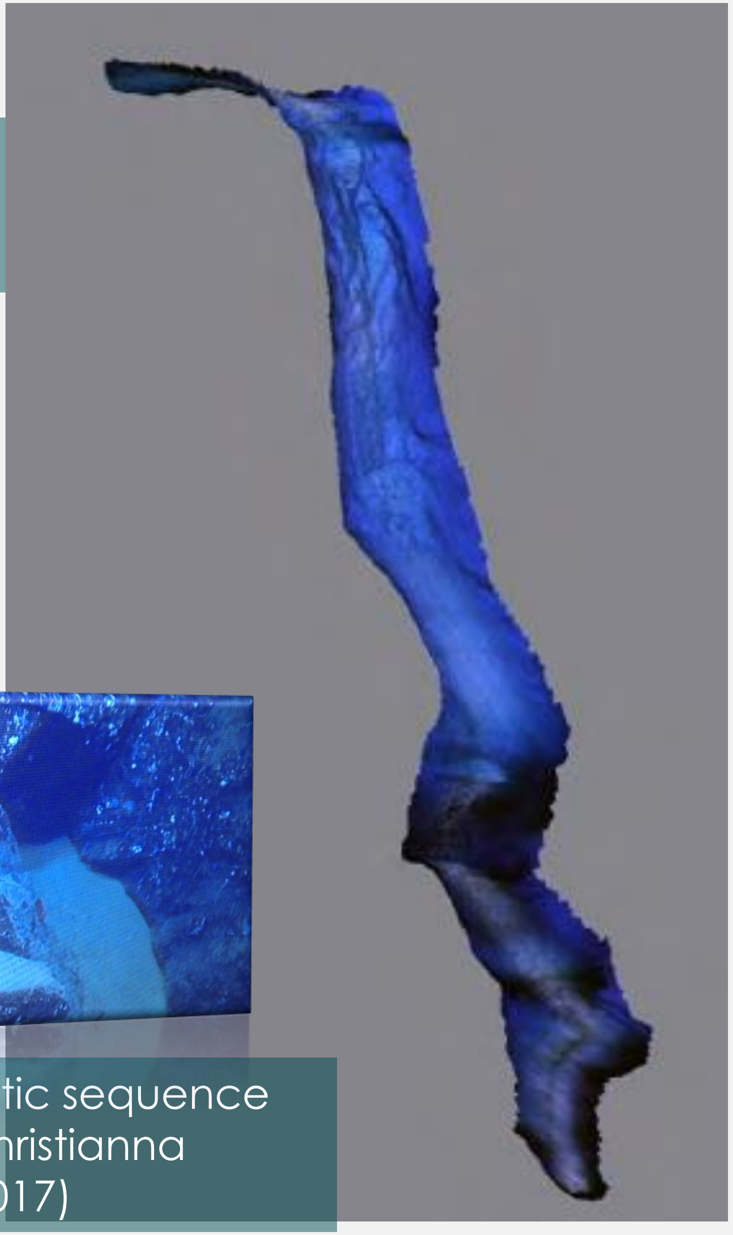
Marine Geoarchaeology

Aegina, September 2019


GEOMAR

Photogrammetric survey in Santorini (POS511)

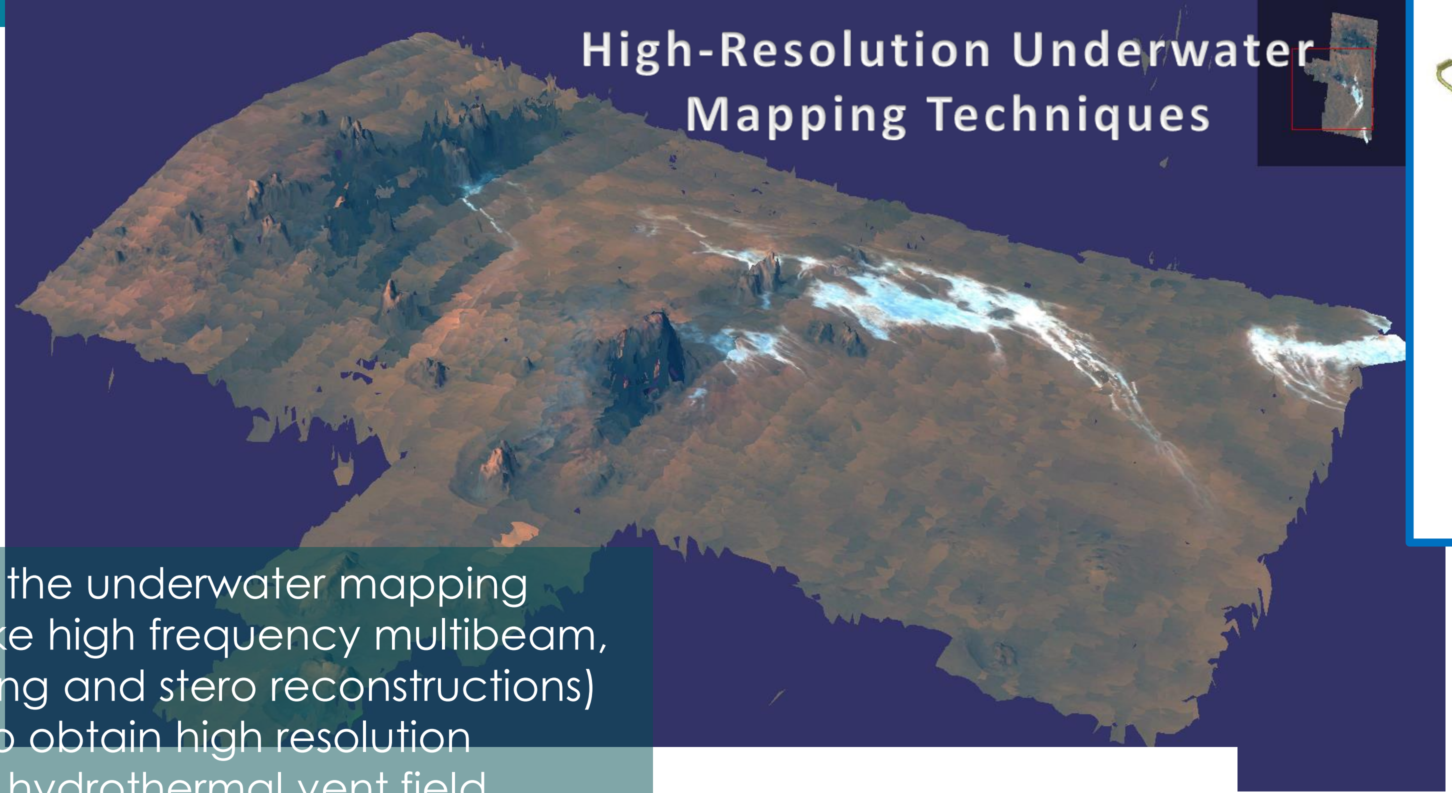
During this cruise, one main objective was photogrammetry of the sea floor, i.e. of steep rocky walls.



ROV Phoca with the DeepSurveyCam mounted on the starboard drawer so that the direction of vision (horizontal to vertical) was changed by moving the drawer. The DeepSurveyCam flash provided by 2 high power LED strobe arrays, held in the manipulator ORION arms of the vehicle and therefore adaptable to lighting demands at the seafloor,

Profile shows the volcanoclastic sequence at the northeastern part of Christianna volcanic island (Jorg et al., 2017)

High-Resolution Underwater Mapping Techniques



By combining the underwater mapping techniques (like high frequency multibeam, photomosaicing and stero reconstructions) we are able to obtain high resolution images of the hydrothermal vent field showing the vents and white bacterial mat.

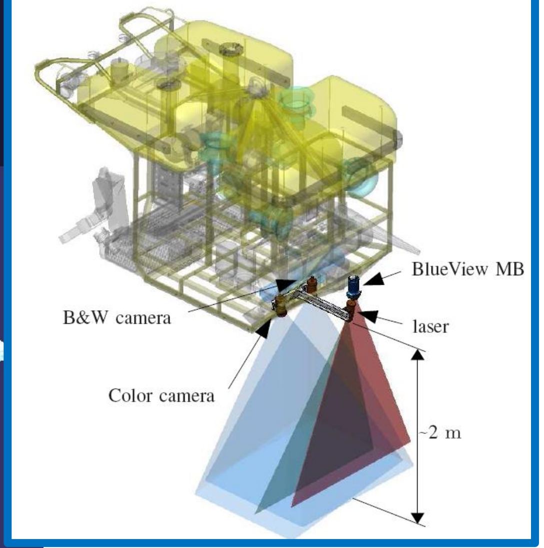
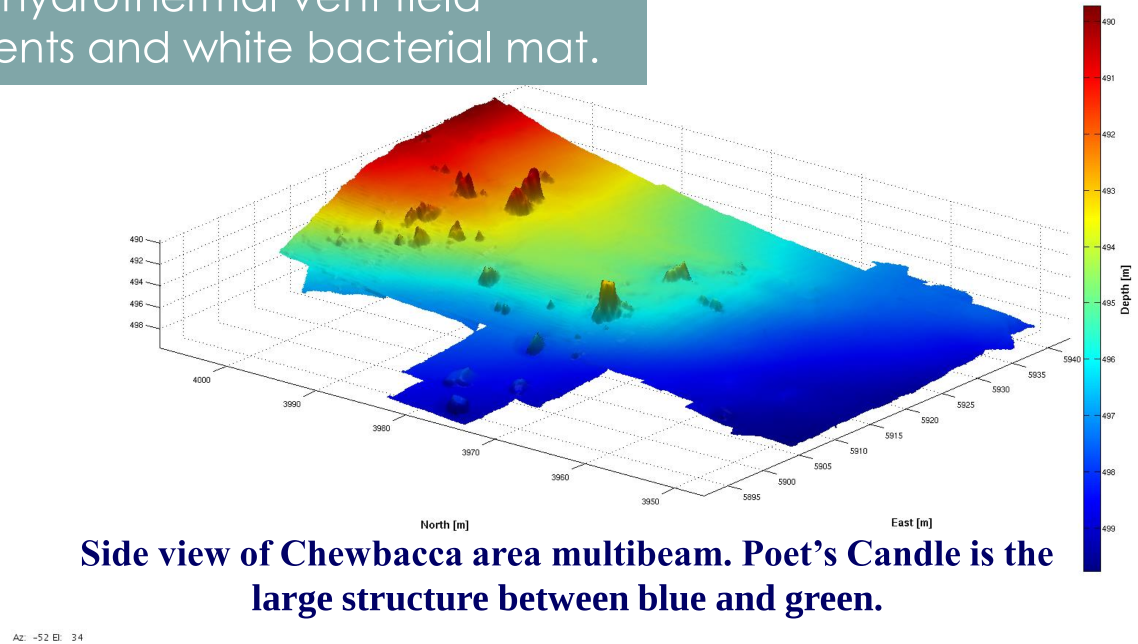


Image based techniques
Photomosaicing
Stereo reconstructions

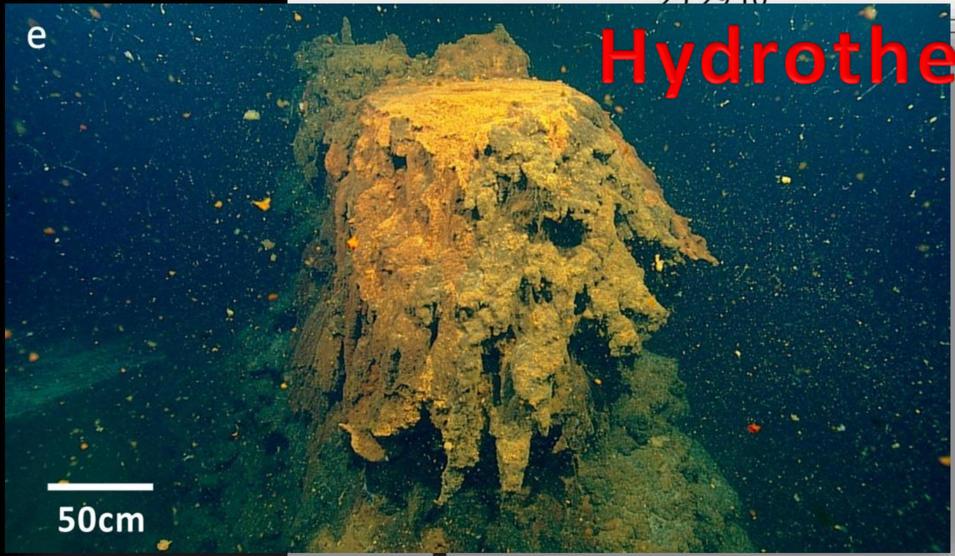
Visual survey in the Poet’s Candle area showing the vents and white bacterial mat. Twenty-seven hundred individual stereo pairs were used to create the final image (Roman et al., 2012).

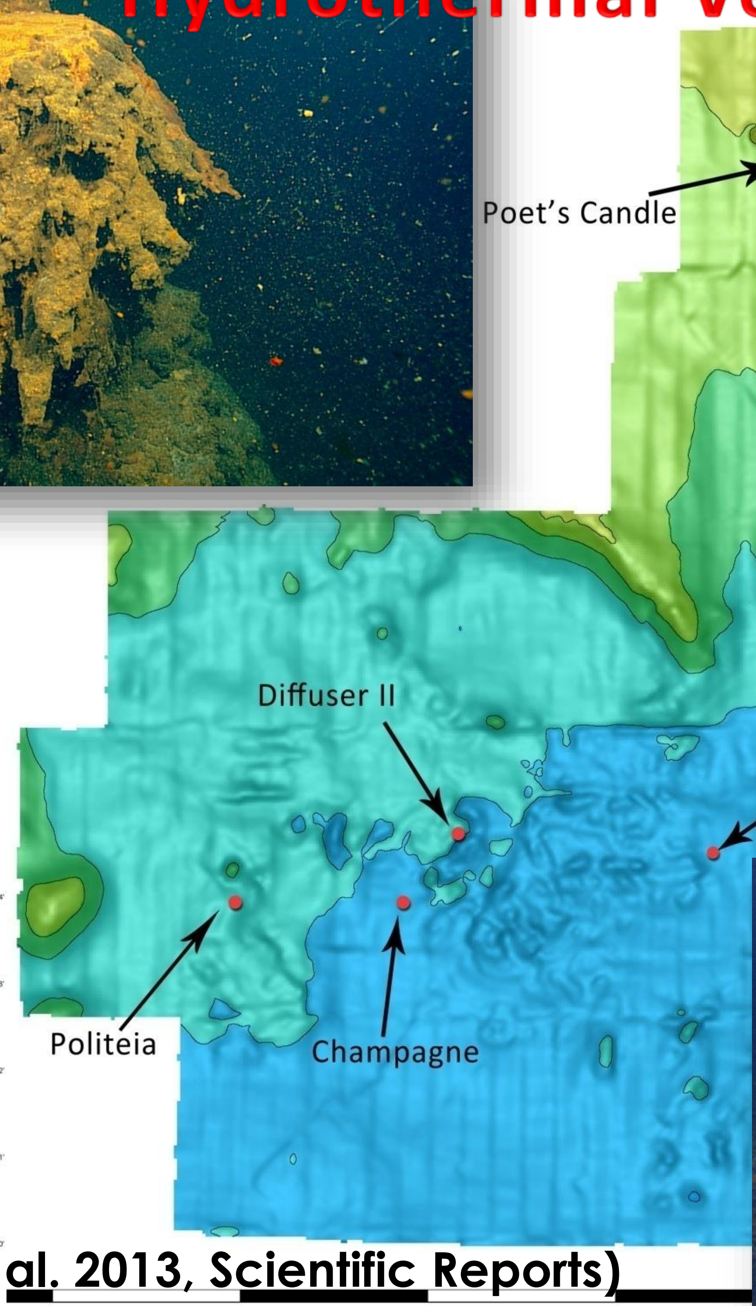


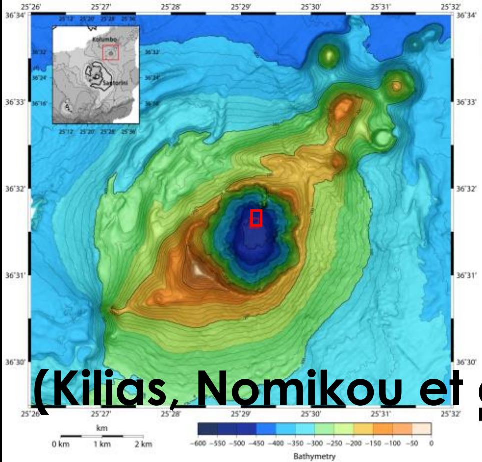
Side view of Chewbacca area multibeam. Poet’s Candle is the large structure between blue and green.

High frequency multibeam
Frequencies > 500 kHz

Hydrothermal Vent Field

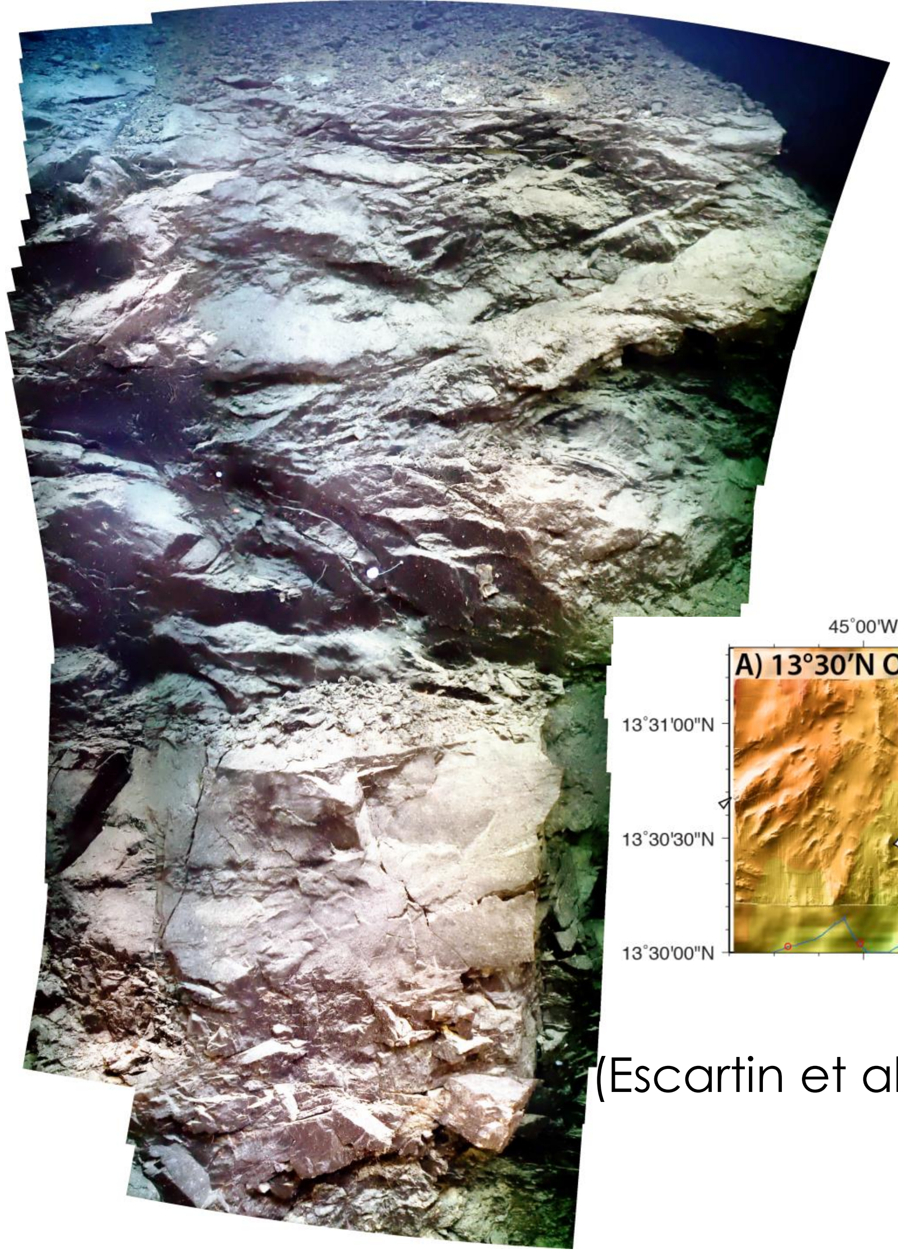


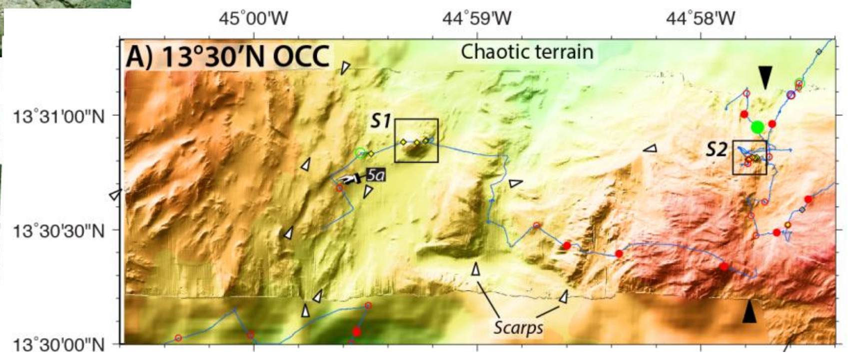




(Kilias, Nomikou et al. 2013, Scientific Reports)

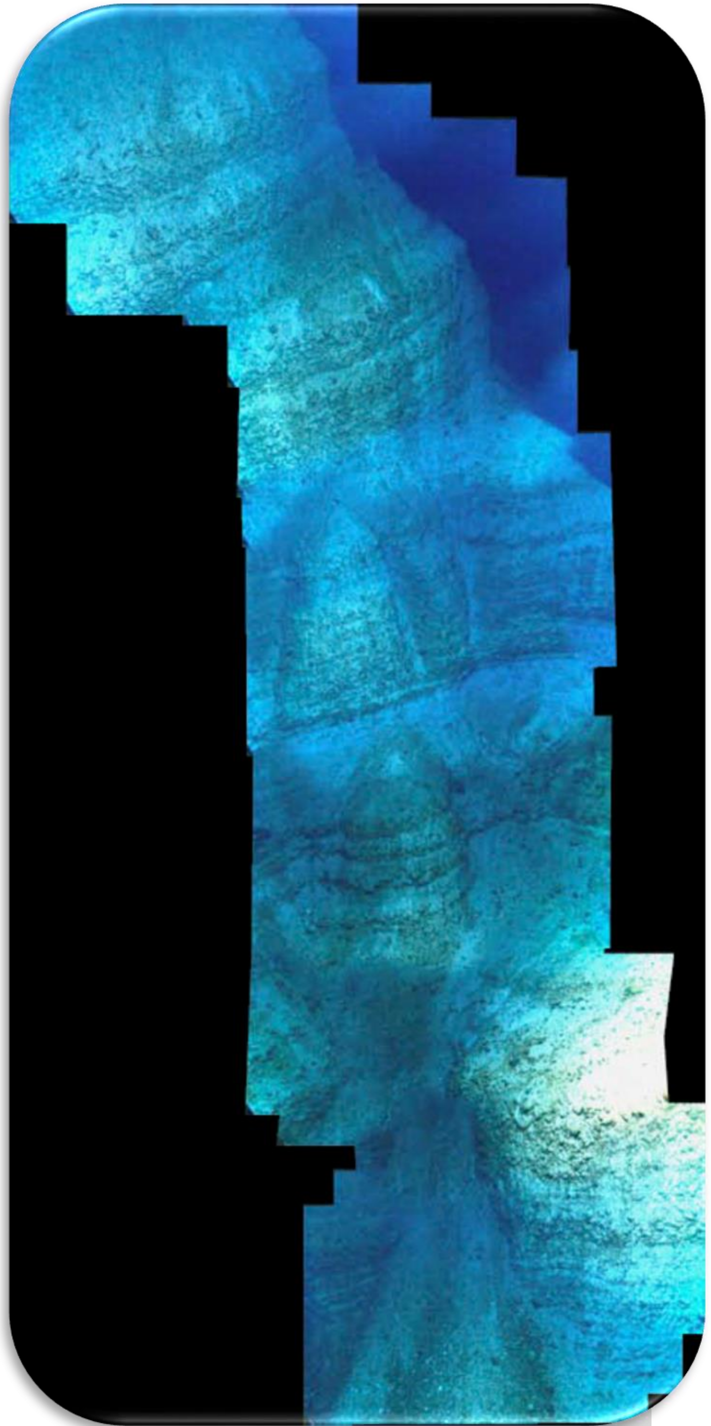
Hydrothermal Vent Field





(Escartin et al., 2016)

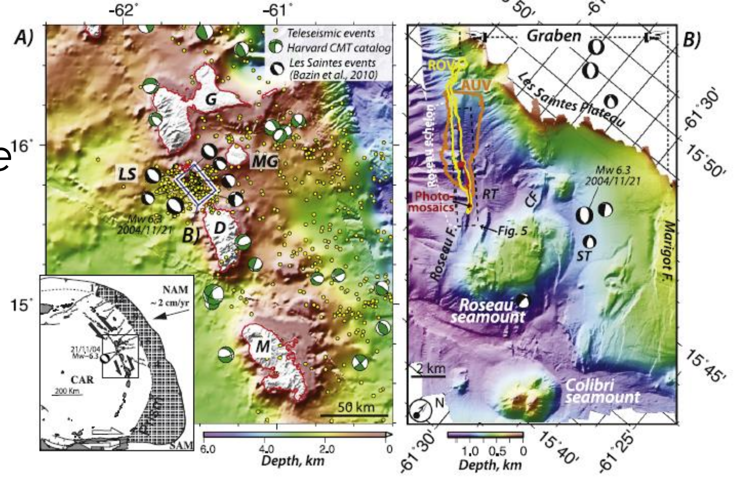
Cross-section of the 13°30'N *detachment fault zone along a vertical fault scarp, ~8-10 m high*

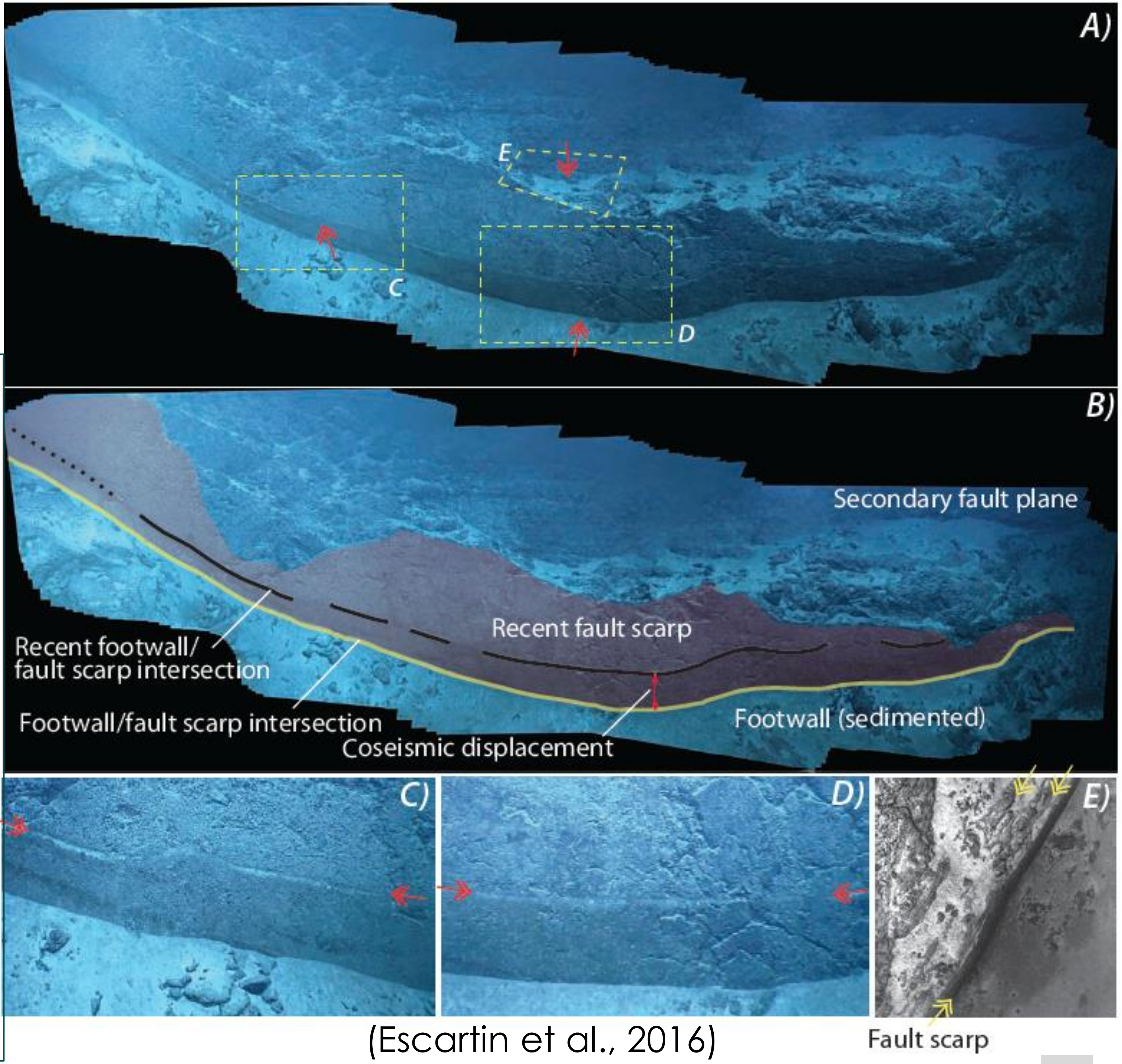


(Cartner et al., 2014)

Stratified pumice deposits were observed on the SW crater wall (Kolumbo)

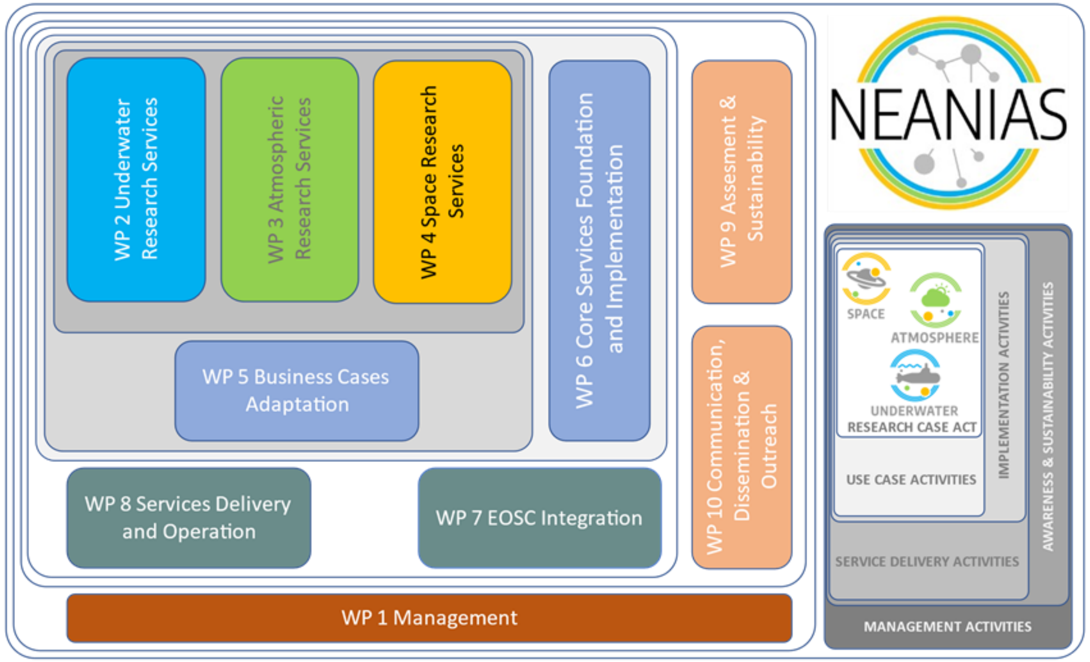
21/11/2004 Les Saintes earthquake

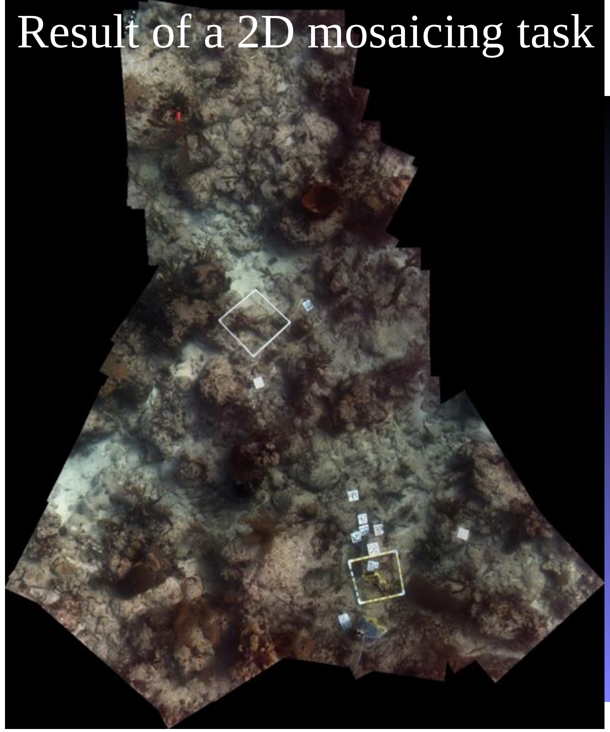


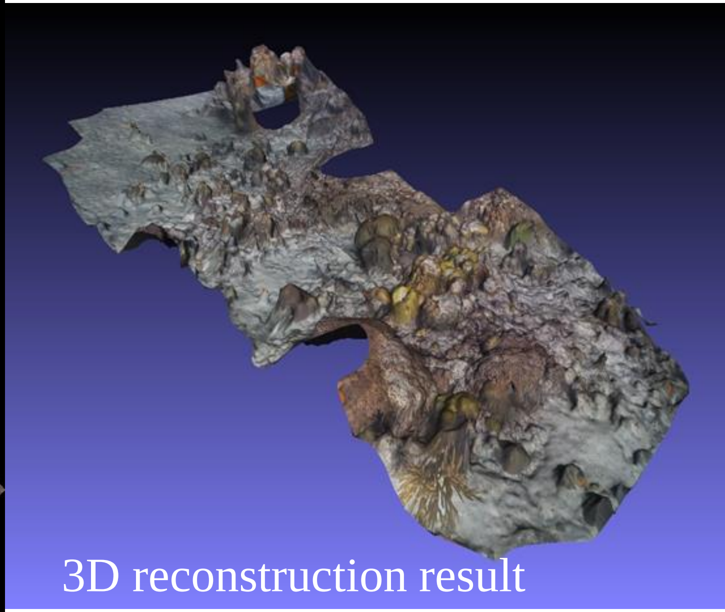


Video - derived three-dimensional terrain reconstruction of an exposed, subvertical fault slip plane (A), and videomosaic of the same outcrop with interpretation of features overlain (B); the reconstruction is ~20 m long, with actual vertical scaling shown in E. (C) and (D) show close-ups of the base of the fault free-plane (located in A and B), showing a ribbon of slip surface exposed during the 2004 seismic event (coseismic scarp) bound by a line of sediment adhered to the slip plane. E) Coseismic displacement, measured from the height of the coseismic slip (red line), shows a maximum of ~0.9 m along the preserved fault slip surface, that has a maximum height of ~3m (black line).

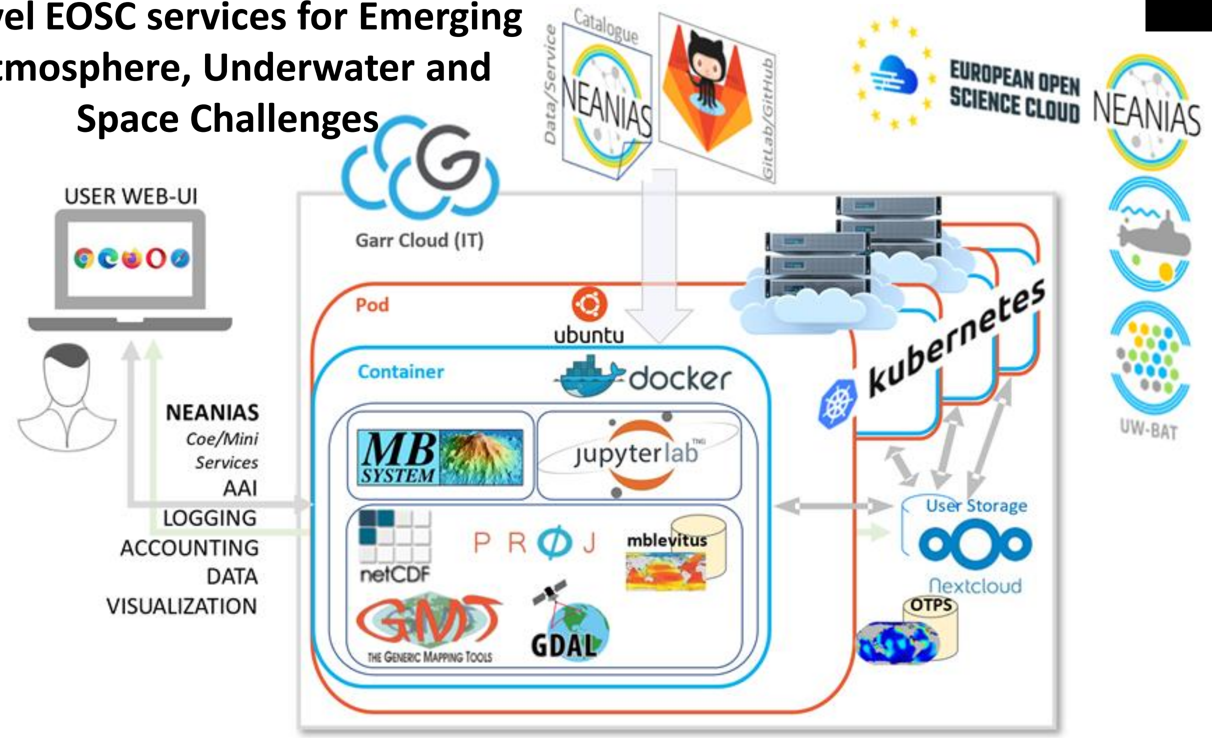
(Escartin et al., 2016)

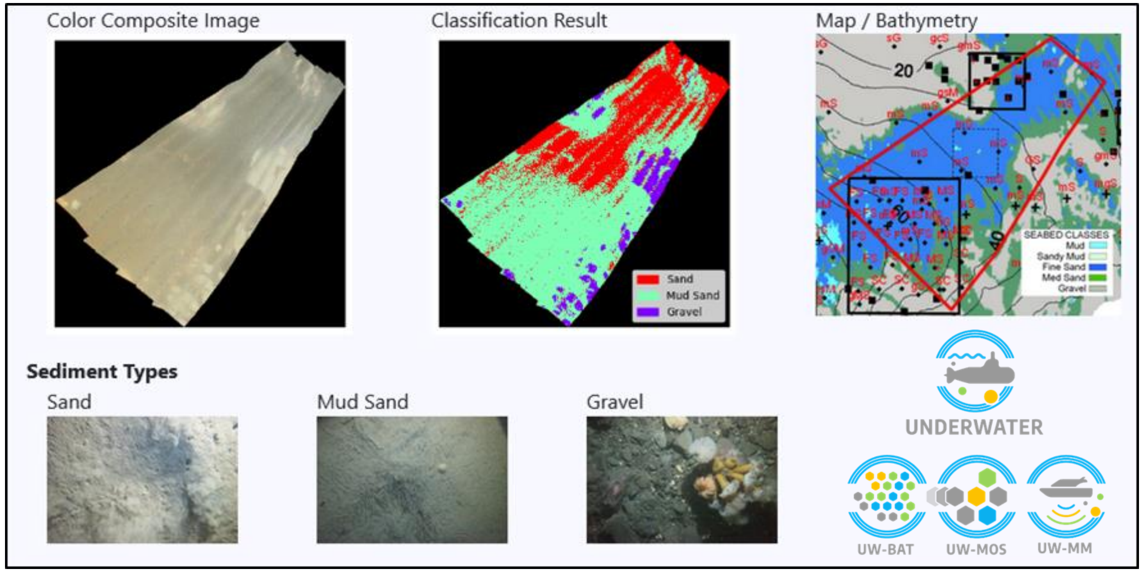






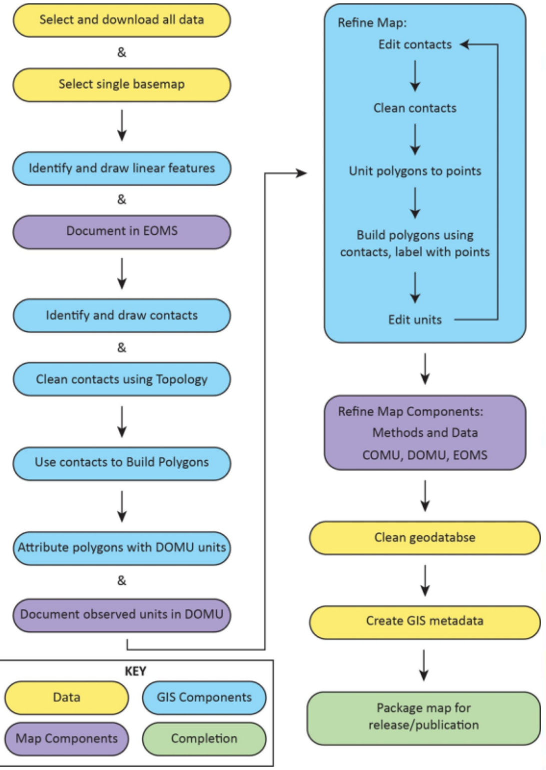
Novel EOSC services for Emerging Atmosphere, Underwater and Space Challenges

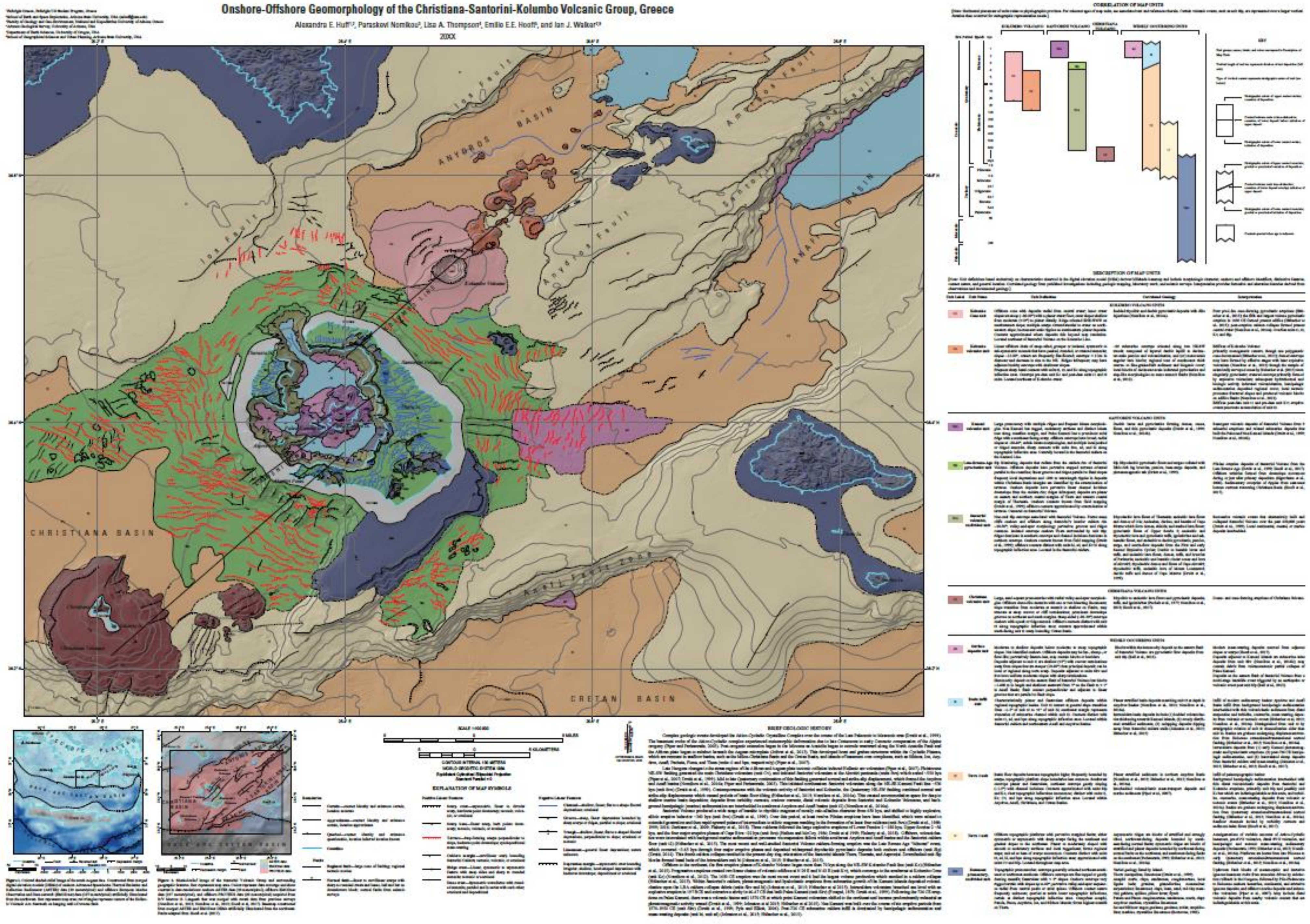


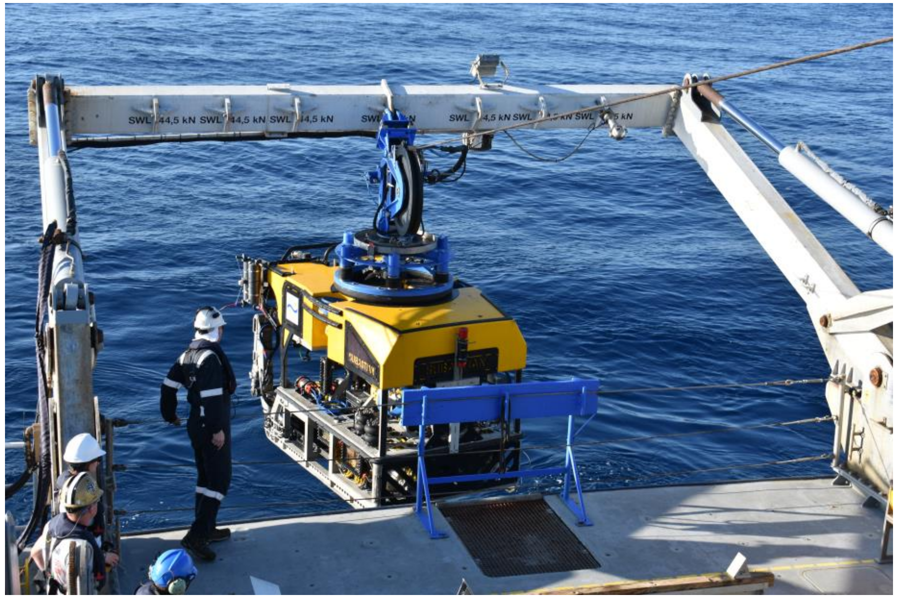


Applying Planetary Mapping Methods to Submarine Environments: Onshore-Offshore Geomorphology of Christiana-Santorini-Kolumbo Volcanic Group, Greece

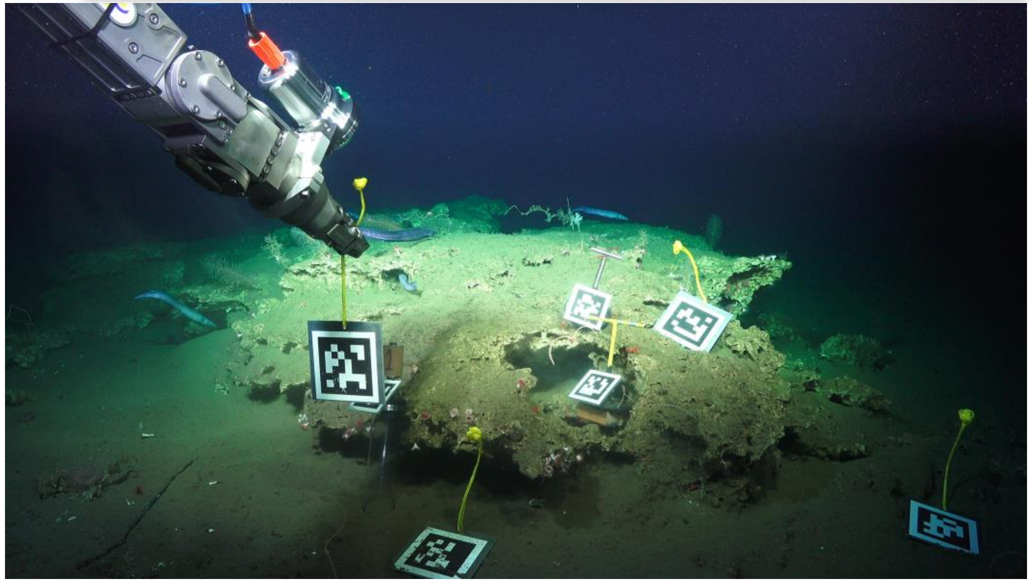
Huff et al., (in press) Journal of Maps

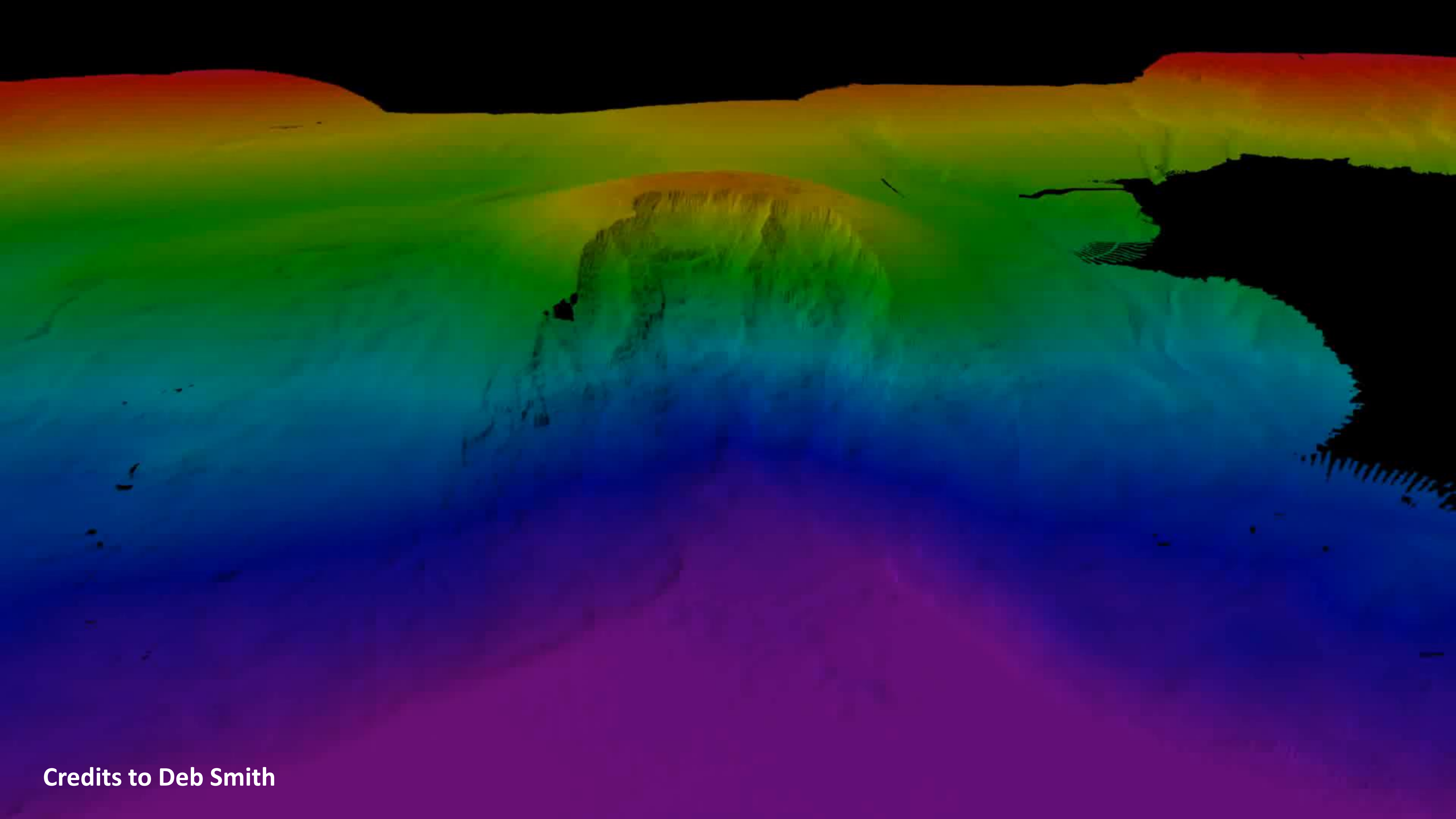


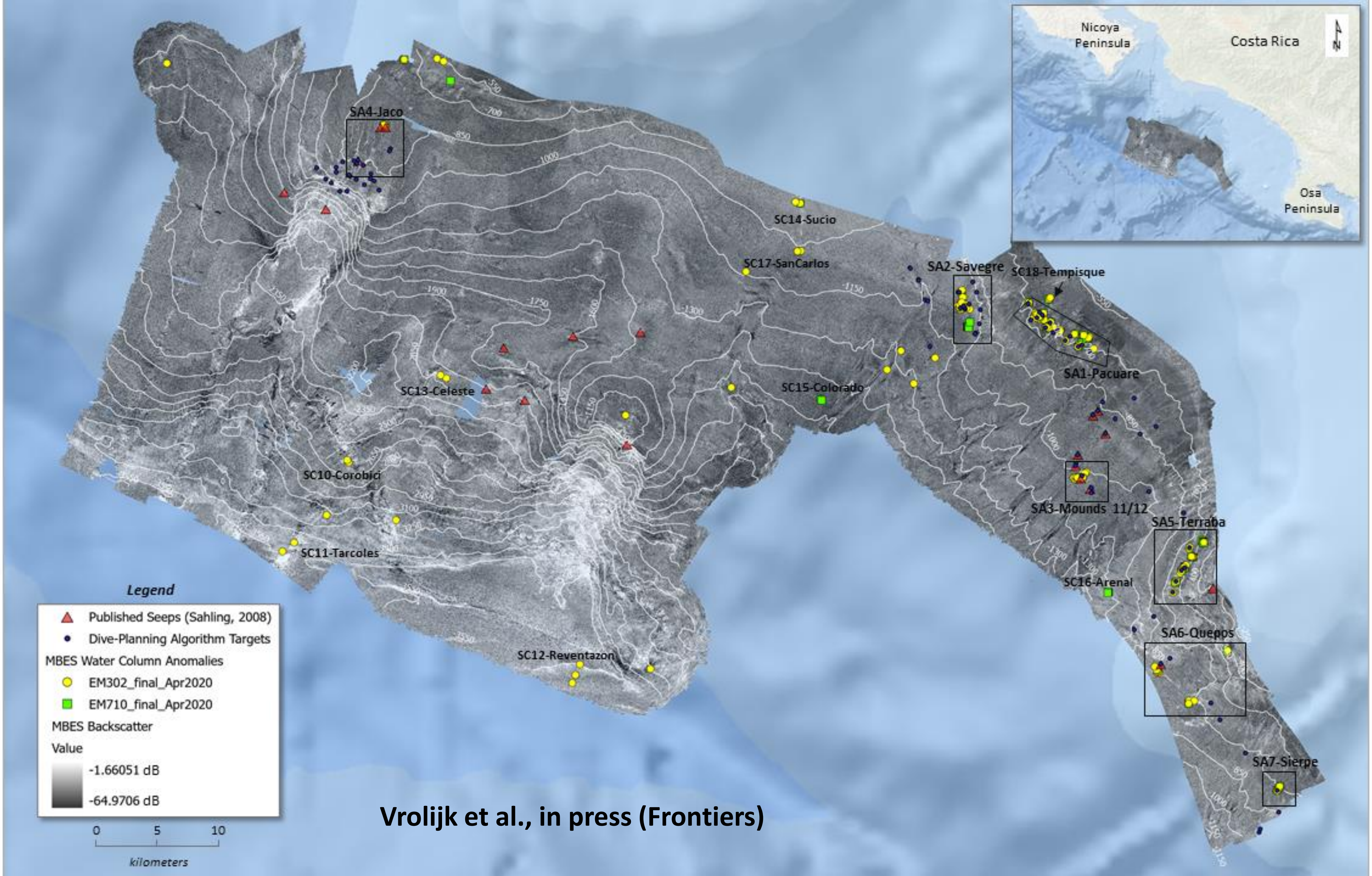




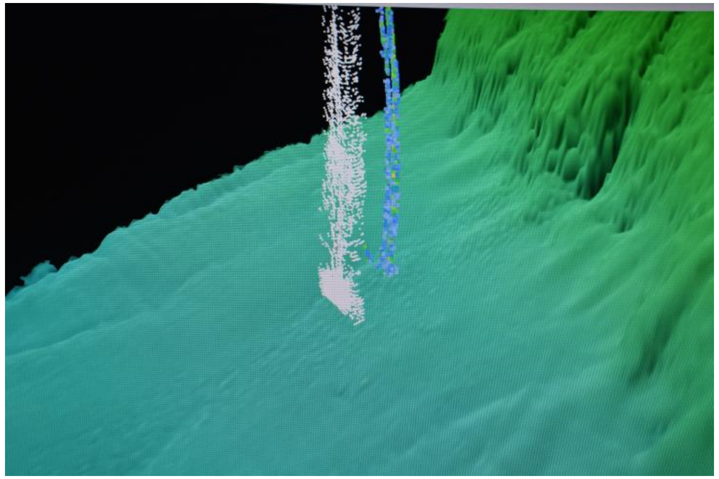
Exploration for seeps on the Costa Rica margin during the R/V Falkor 181210 cruise in December, 2018 (R.Camilli)

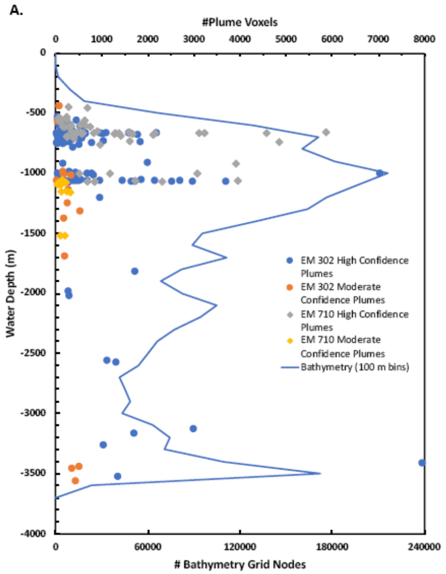


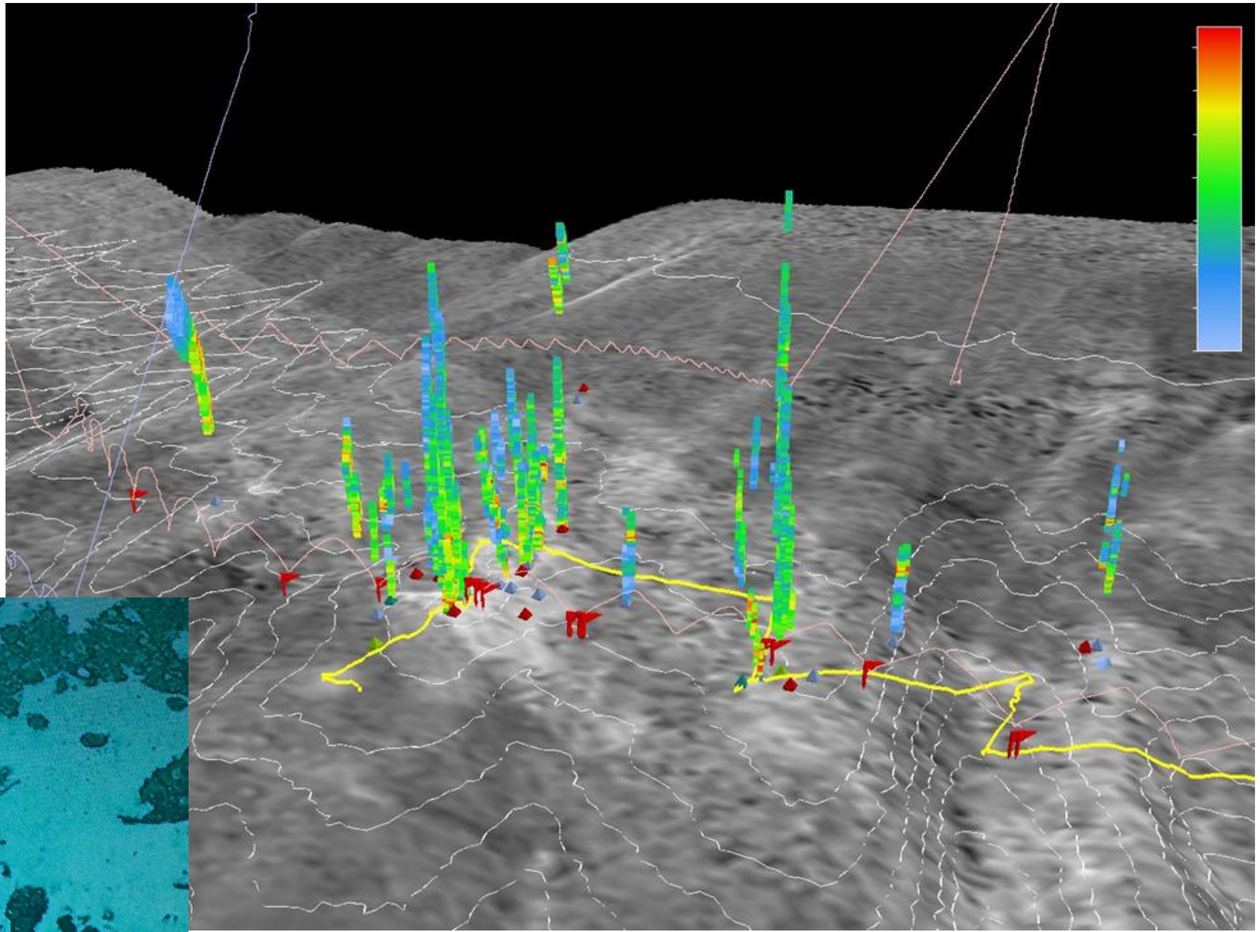

Credits to Deb Smith



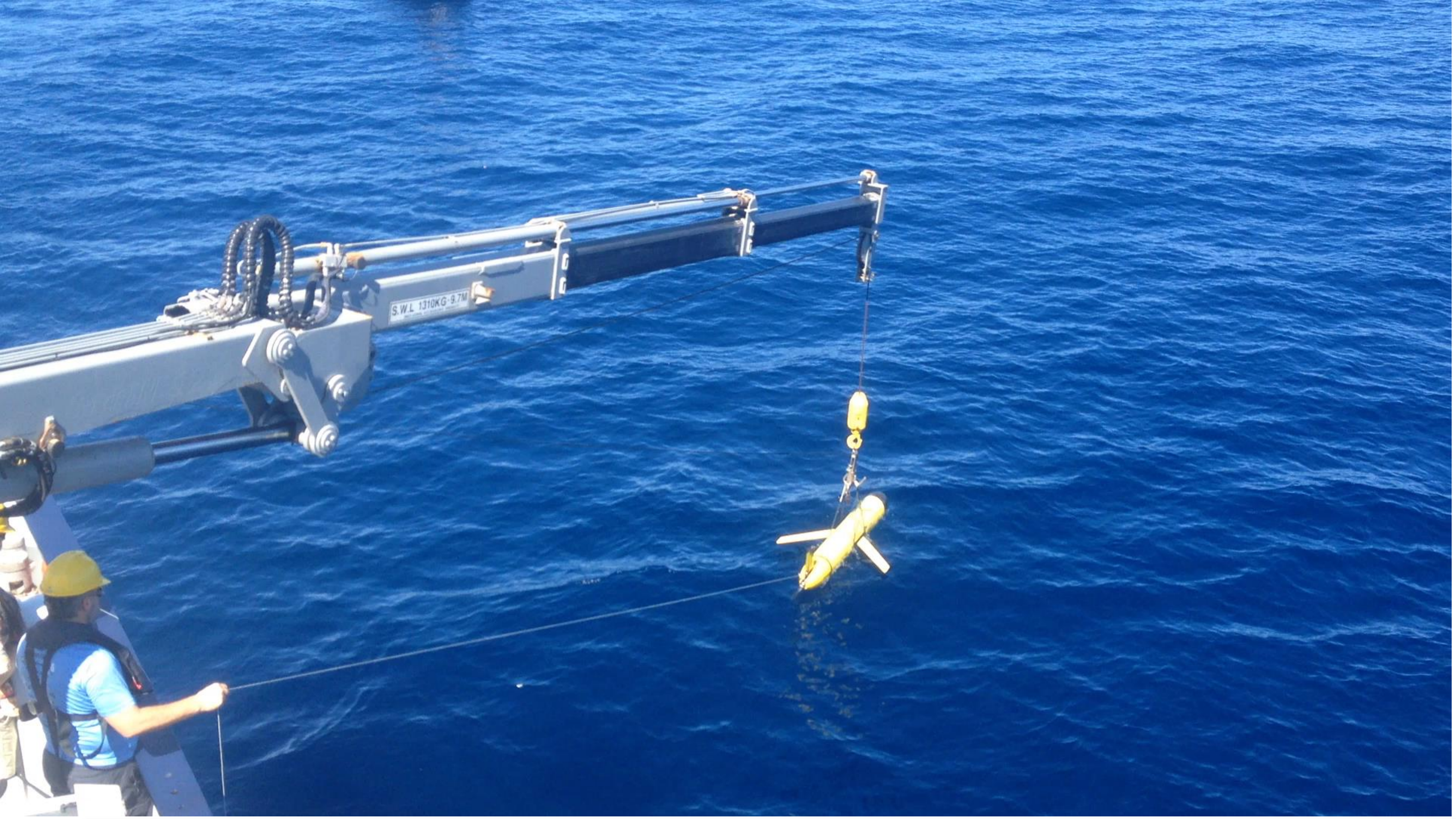
Vrolijk et al., in press (Frontiers)







Vrolijk et al., in press (Frontiers)



Gliders are autonomous underwater vehicles, or **AUVs**, that navigate underwater. They do not need a human crew onboard or cables connecting them to research vessels at the sea surface to operate. These gliders are programmed by researchers to go where they are needed to do research, and are small enough to be deployed by small boats while still carrying a variety of sensors. They collect observations along saw tooth paths through the water, giving scientists a clearer understanding of the temperature, salinity, currents, acoustic, optical, and biogeochemical properties in the ocean. These measurements are then used to determine and understand ocean circulation and its role and influence on the global climate.

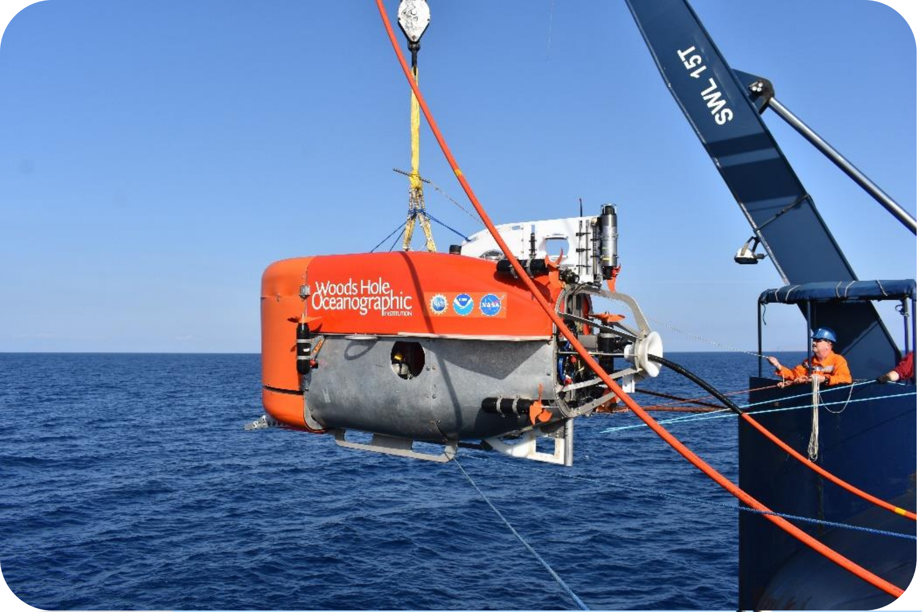
Η αποστολή, που αποτελούνταν από 30 επιστήμονες από τις ΗΠΑ, την Ελλάδα, την Αυστραλία και τη Γερμανία, δοκίμασε νέες «έξυπνες» τεχνολογίες με αυτόνομα υποβρύχια οχήματα, τα οποία στο μέλλον μπορεί να αξιοποιηθούν για την εξερεύνηση εξωγήινων ωκεανών σε μακρινούς δορυφόρους του Δία και του Κρόνου, όπως ο Εγκέλαδος και η Ευρώπη, όπου θα αναζητηθούν υποθαλάσσια ίχνη ζωής σε ακραία και πιθανώς επικίνδυνα περιβάλλοντα.

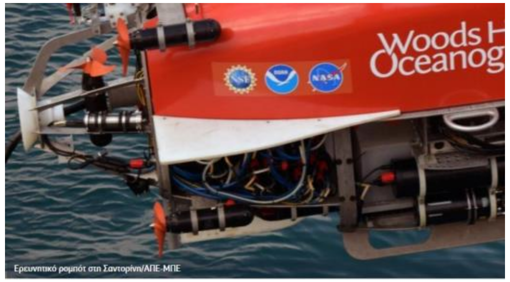
HROV *Nereid Under Ice*

The **Nereid Under-Ice (NUI)** vehicle enables exploration, detailed examination, and sampling of biological and physical ice-margin and under-ice environments through the use of high-definition video and a 7-function electro-hydraulic manipulator arm, in addition to a range of acoustic, chemical, and biological sensors tailored to suit the needs of an individual expedition. The goal of the NUI system is to provide scientific access to under-ice and ice-margin environments that is presently impractical or infeasible.

https://www.whoi.edu/what-we-do/explore/underwater-vehicles/nereid-under-ice/

Credits to Mike Toillion

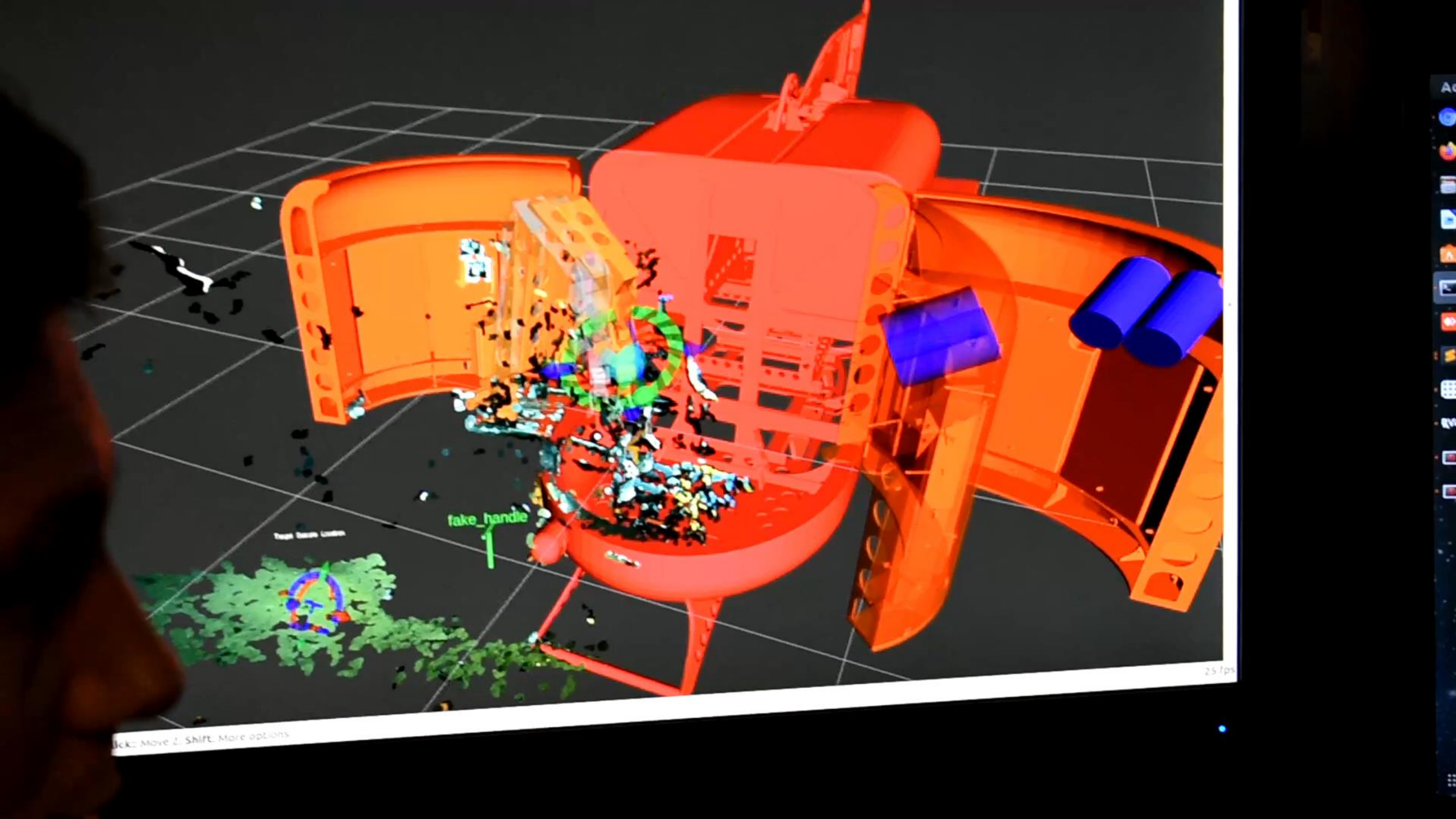




Παγκόσμια πρωτιά στη Σαντορίνη: Ρομπότ πήρε δείγμα από υποθαλάσσιο ηφαίστειο

HROV *Nereid Under-Ice* is built to travel up to 40 kilometers (25 miles) laterally underwater, rather than the few hundred feet of a typical ROV, while still receiving control signals and transmitting data, including high-definition video, back to operators located on a ship via a hair-thin fiber optic tether. Instead of receiving power from this tether, as a traditional ROV does, *Nereid Under-Ice* carries its own battery power on board, which makes the tether much lighter and smaller. In addition, it also carries a full suite of acoustic, chemical, and biological sensors for investigating the underwater environment, as well as a seven-function electro-hydraulic manipulator arm. The vehicle is rated to dive 2,000 meters (6,500 feet) beneath the surface to sample or survey the mid-water or sea floor.

PI: R. Camilli (WHOI)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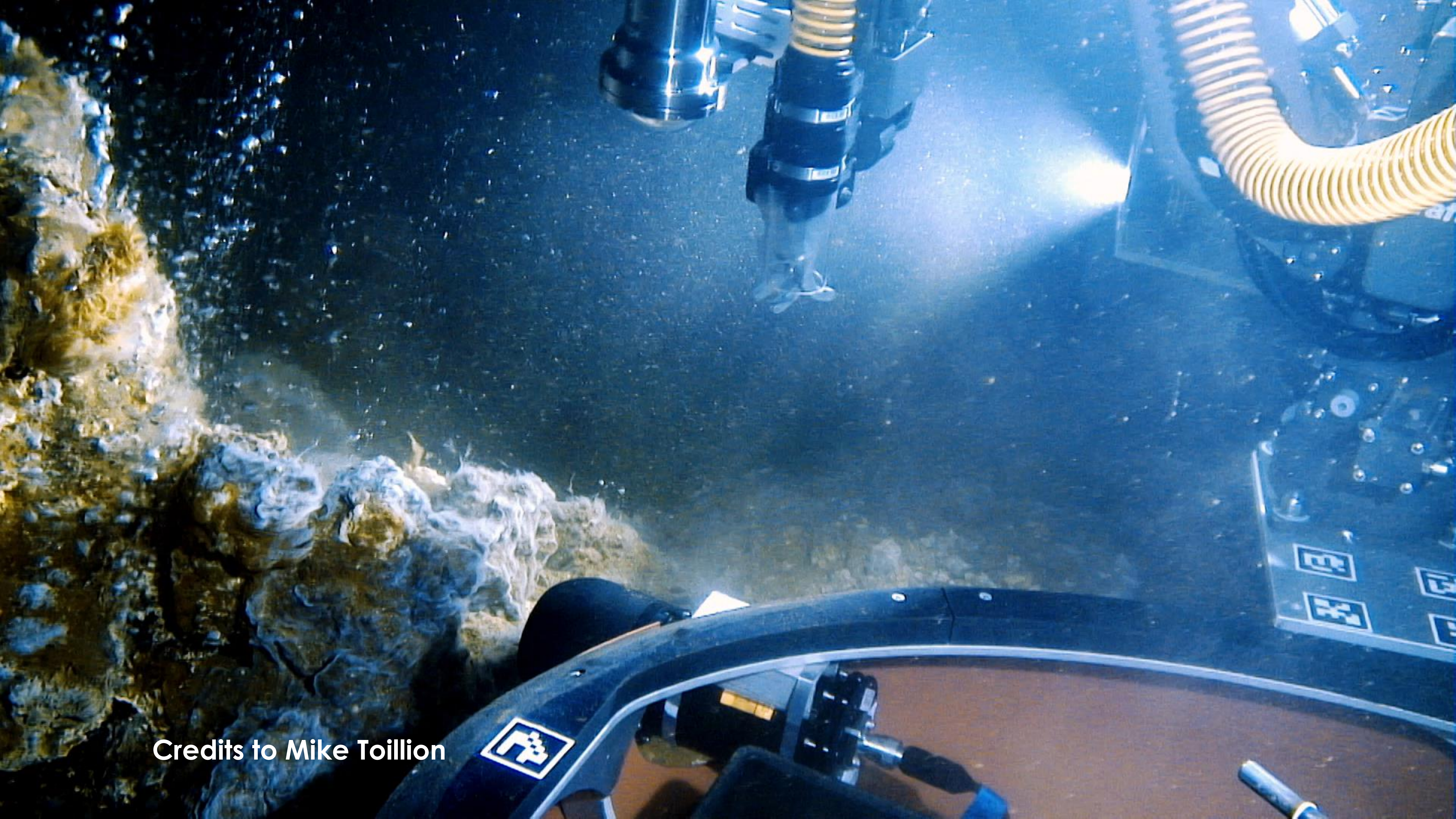

Credits to Mike Toillion

VIRTUAL DIVER: An Innovative Platform for Virtual Underwater Experiences Targeting the Cultural and Tourism Industries

in a nutshell

The underwater environment beyond its natural unique beauties has a great scientific interest as it pertains all fields of marine research; despite this, it has not been adequately exploited for cultural and tourism purposes. Virtual and augmented reality technologies have advanced considerably in re-producing and re-presenting unreachable large-scale environments. To this end, this work presents an integrated interactive framework for exploring the underwater world such as submerged cities, shipwrecks, sunken harbors, diving and marine parks, either in situ via augmented reality, or remotely via virtual reality. The developed framework, named VIRTUALDIVER, will enable domain experts to design immersive xReality experiences and users to experience environments that are typically accessed only by underwater vehicles in cost-intensive, scientific missions. This will promote the underwater cultural heritage, and natural environment through the development of innovative research, teaching, tourism and creative products.

VIRTUAL DIVER: An Innovative Platform for Virtual Underwater Experiences Targeting the Cultural and Tourism Industries

Capturing of real-world scenes in 3D models for the visualization in VR is based on a multimodal Mapping Methodology:

Multimodal mapping for VR

i) a methodology and the system of acquiring heterogeneous-bathymetric, visual and multi-spectral data

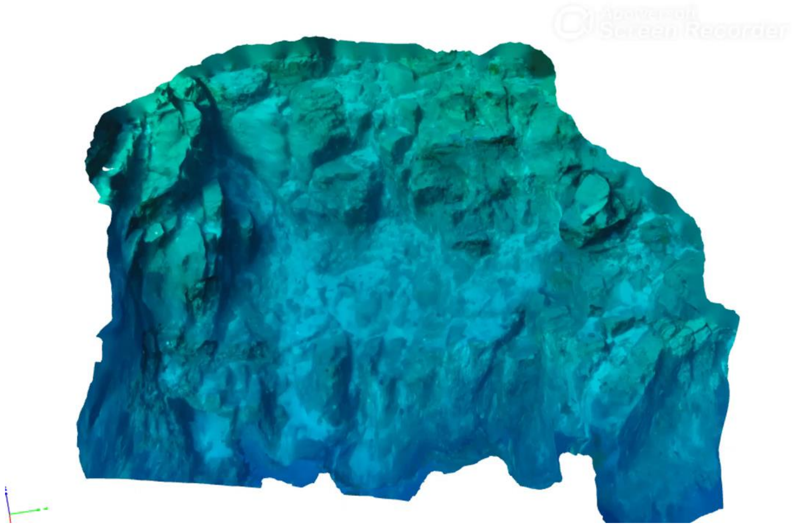
ii) an innovative Structure-from-Motion approaches that compensate the refraction in underwater image creation for 3D reconstruction of small details and adopting incremental approaches to deal with a large number of images

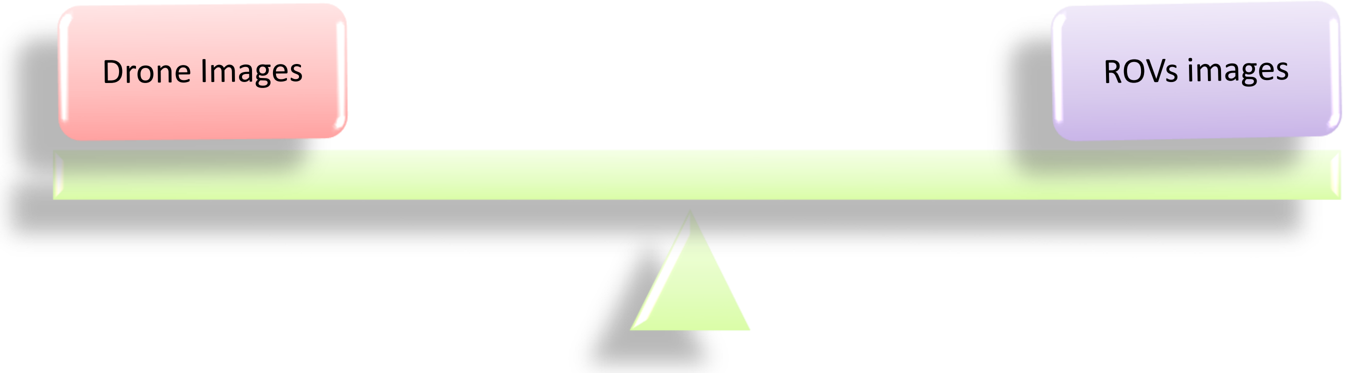
iii) a combination of image processing techniques to restore the warm colors of underwater scenes that suffer from light absorption in water

iv) co-registration algorithms to combine heterogeneous data for the creation of novel texture for the reconstructed 3D models and photomosaics

v) classification of multispectral data using deep learning algorithms for recognizing geological materials and create new synthetic texture for seabed models

In **VIRTUAL DIVER**, images captured by drone and ROVs using open-source 3D reconstruction software (Colmap, Meshroom) were processed, combined with custom algorithms.

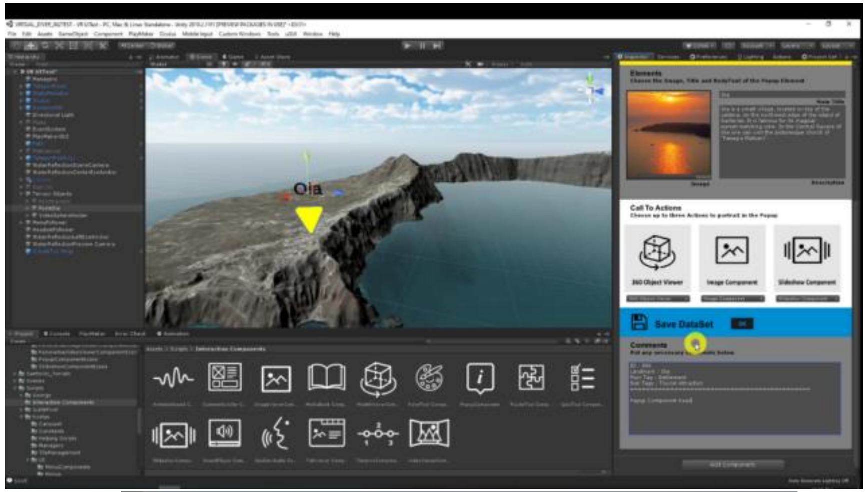




User Interface Design

The interactive components were complimented with a set of UI designs that promote simplicity and ease of use. The goal was to give the design team a familiar User Interface to work with in order to create seamless interactive narratives. The same design principles were applied to all the interactive components (visual and functional consistency) providing thus a unified experience for the design team.

(Nomikou et al, 2020)



Tablets Smartphones in-situ interaction	VR Headset hotels, cruise boats, from home	VR Headset + Specialized peripherals hotels, cruise boats, specially designed space
experience • geolocation • augmented reality • 3D content • multimedia	**experience** • narrative immersion • surround sound • 3D content • multimedia	**experience** • narrative immersion • surround sound • emphasis on kinaesthetics (fly,dive) • 3D content • multimedia
		
• for mainstream use needs typical tablet/smartphone ideal solution for mass tourism	• special use needs VR glasses would be mainstream in 3 years	• very special use needs VR Glasses + Specialized peripherals already commercialized as setup

The platform will be able to assimilate real (or virtual) environments with the help of different media such as tablets or virtual reality glasses, as well as more specialized peripherals. This product will be a tool for supporting businesses and professionals operating in the field of Culture and Tourism, enhancing special aspects of tourism such as cruises, diving, scientific and other.

VIRTUAL Diver

Multichannel Seismic data

Research Vessel

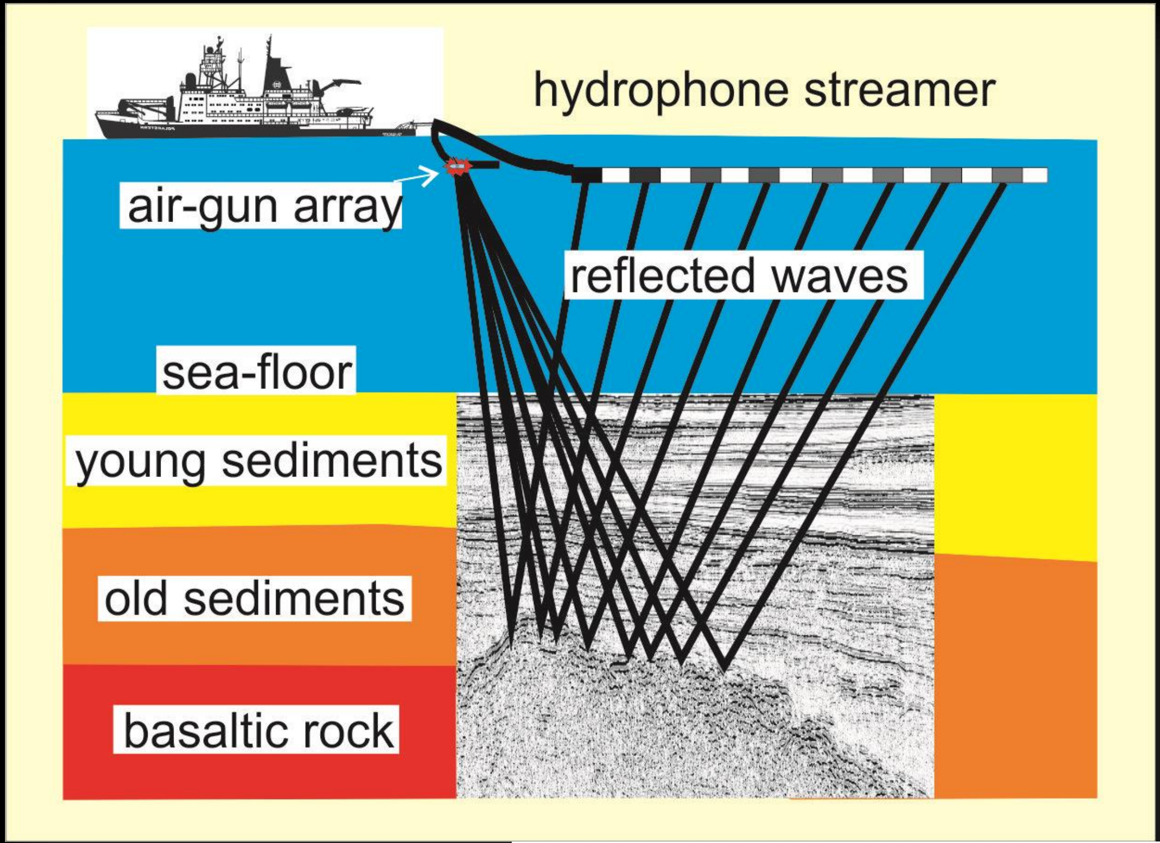
Delta Sparker/airgun

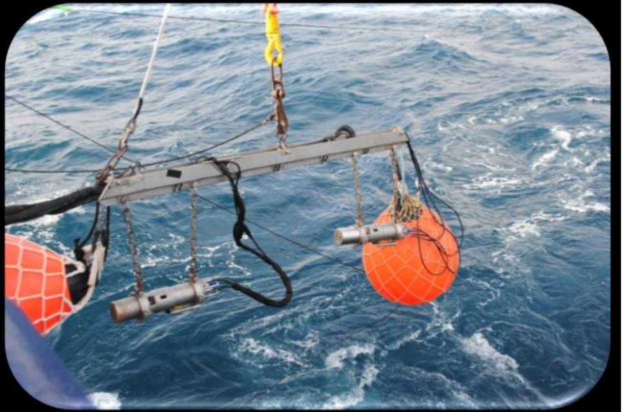
24/16 channel streamer

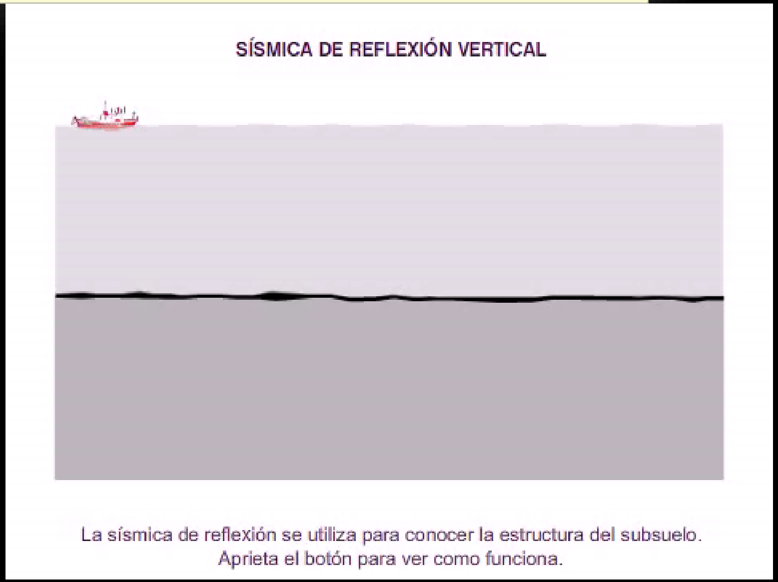
Processing: Seismic Unix/Vista

Post-processing: Vista

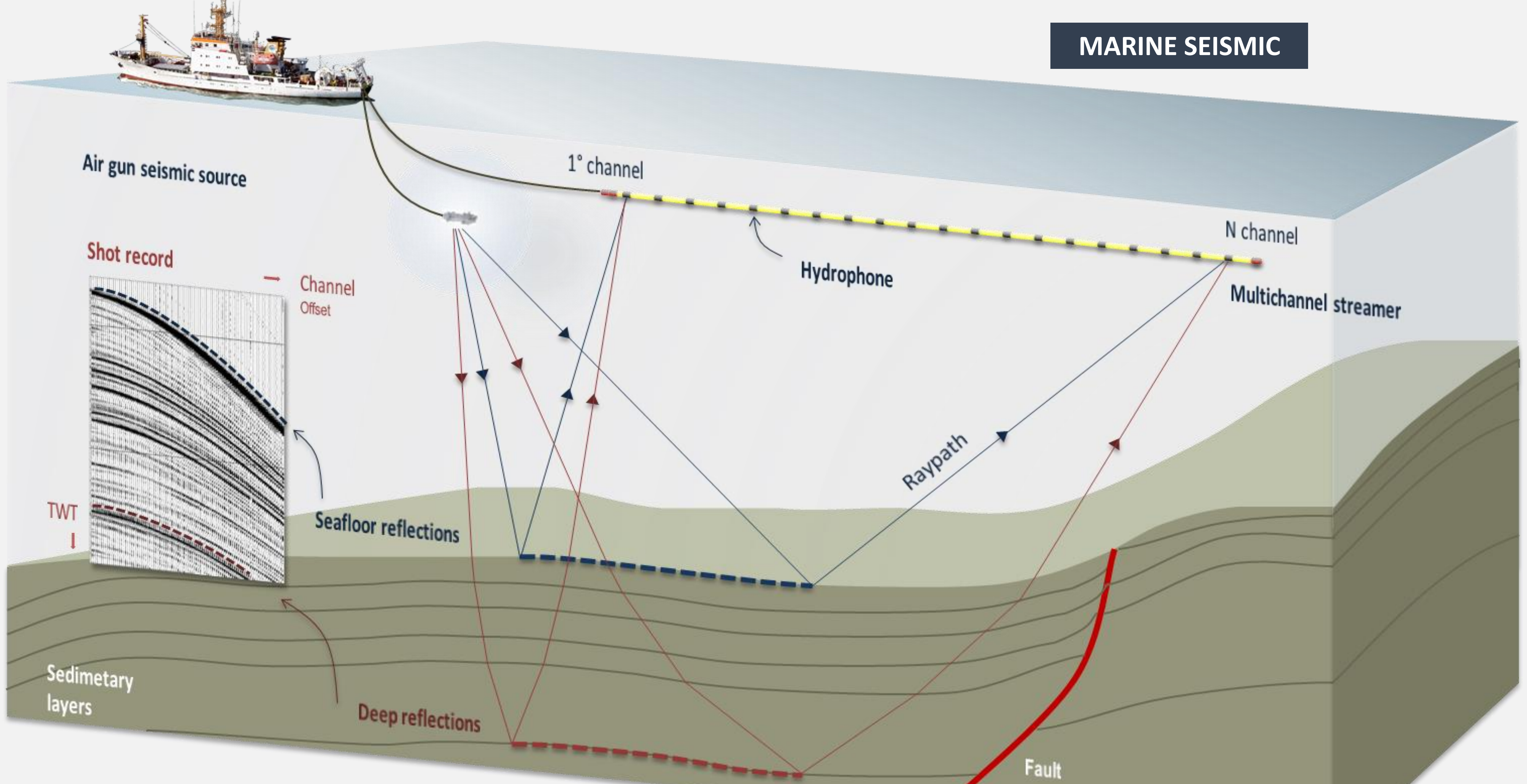
Final SEG-Y files







MARINE SEISMIC

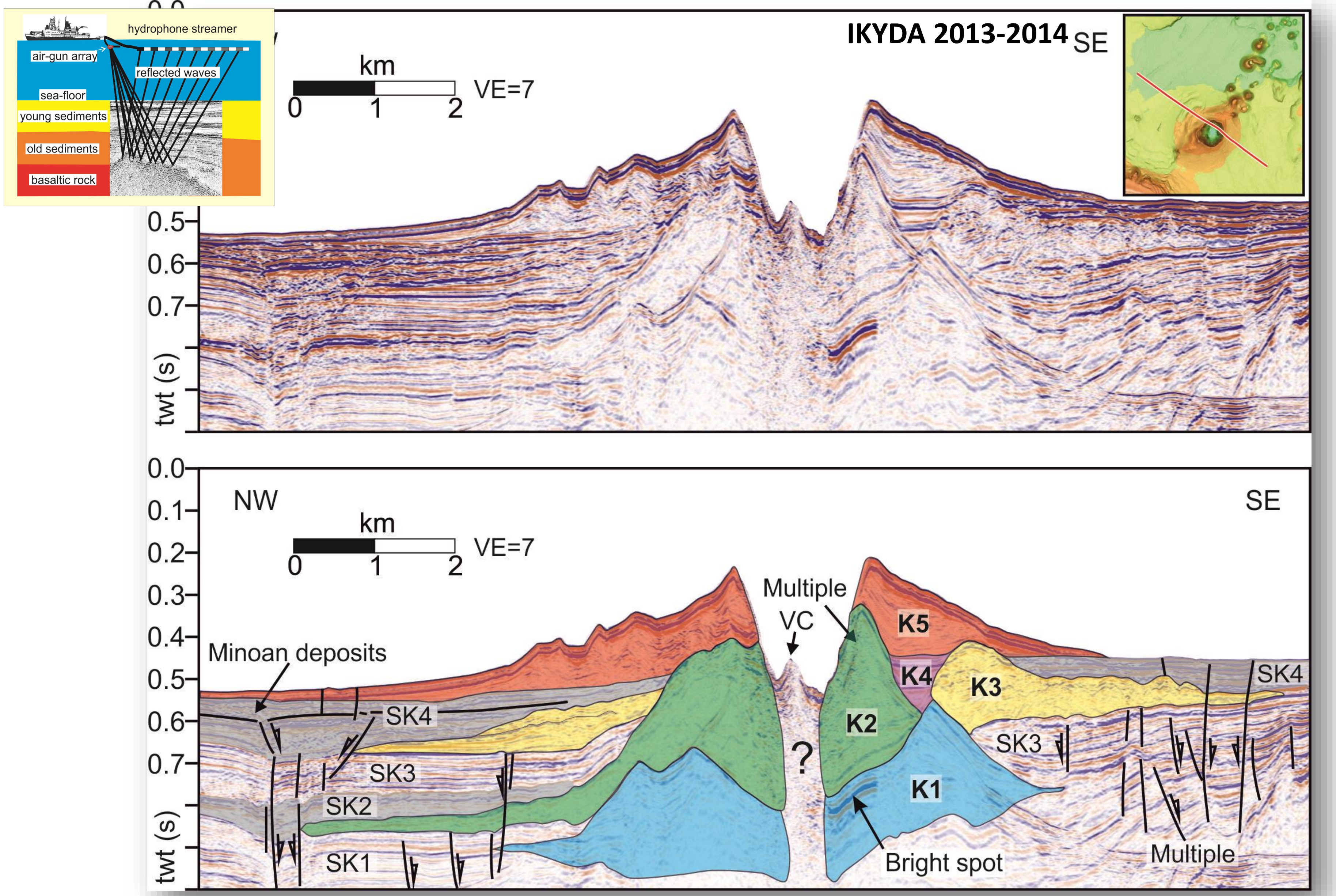


MARINE SEISMIC DATA ACQUISITION

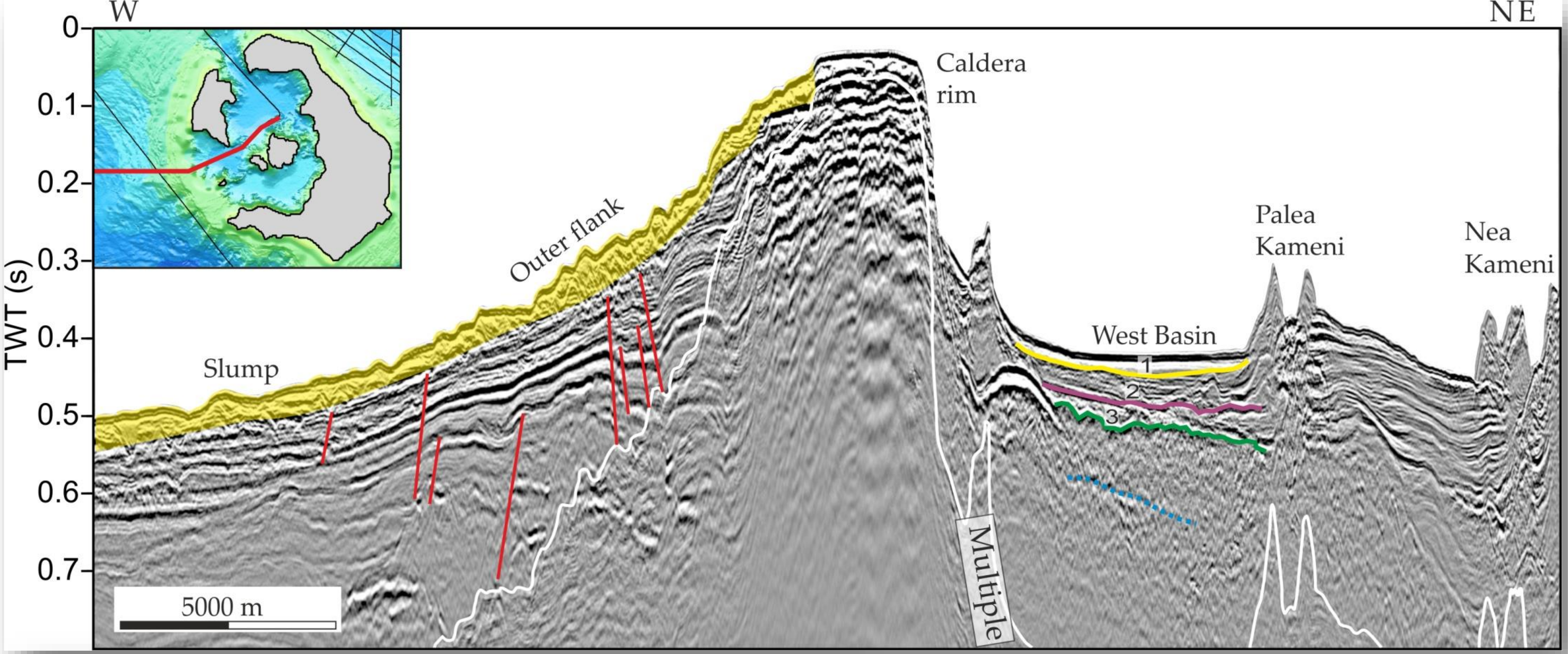
Basic Principles by Fabrizio Zgur

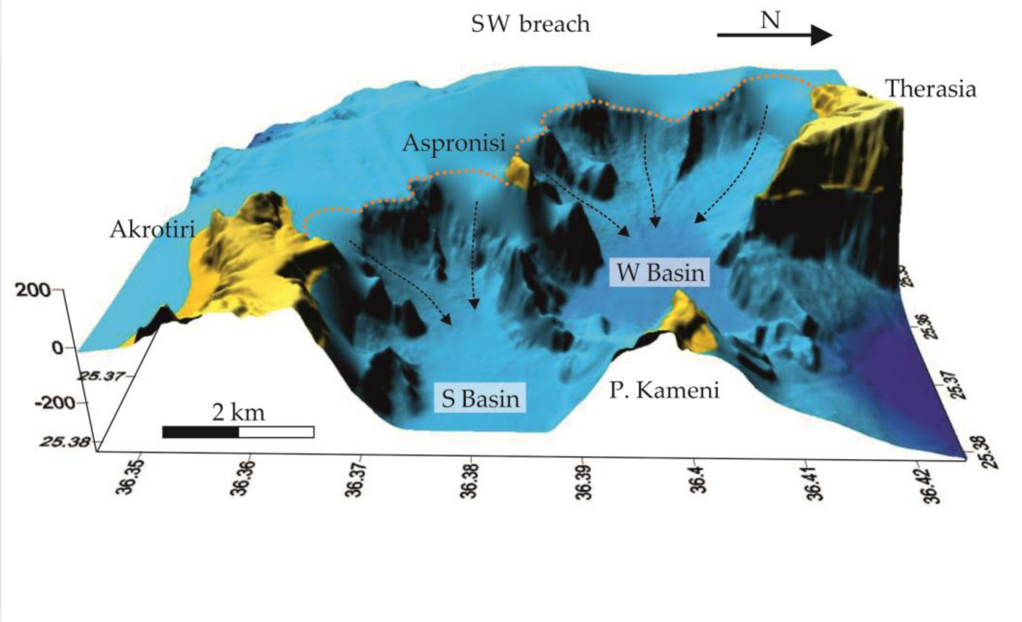
ACQUISITION SYSTEMS

MULTICHANNEL STREAMER



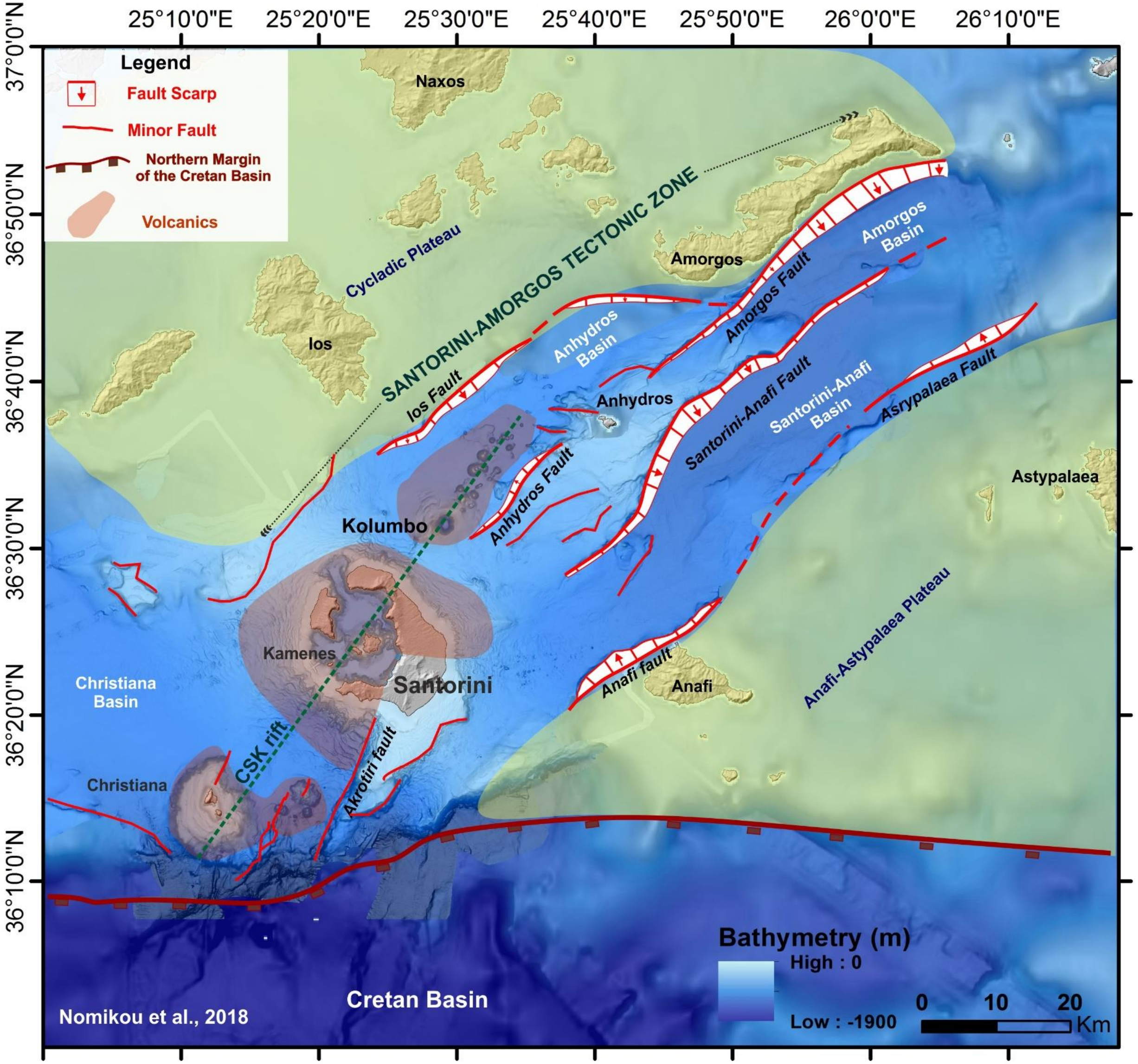
The reflection seismic interpretation of the multi channel profiles reveals the 3D-structural evolution of Kolumbo volcano which comprises three major (K1, K2 and K5) and one to two (K3 and K4) smaller eruptive phases.
(Hubscher et al., 2015; Nomikou 2016)





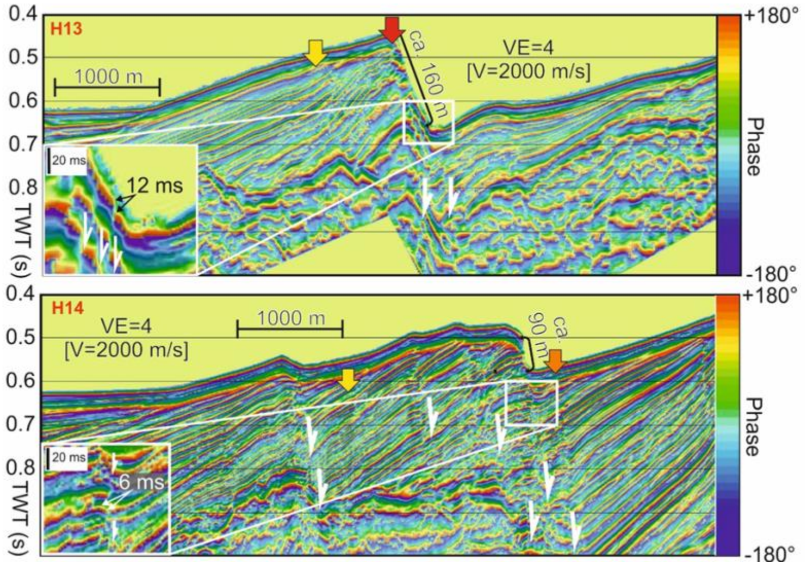
The southwest straits are morphologically fresh, and have landslide scars with well preserved headwalls and intervening septa. The headwalls are steeper than that of the NW strait, and are less scarred by secondary slumping and drainage channels (Nomikou et al., 2016).

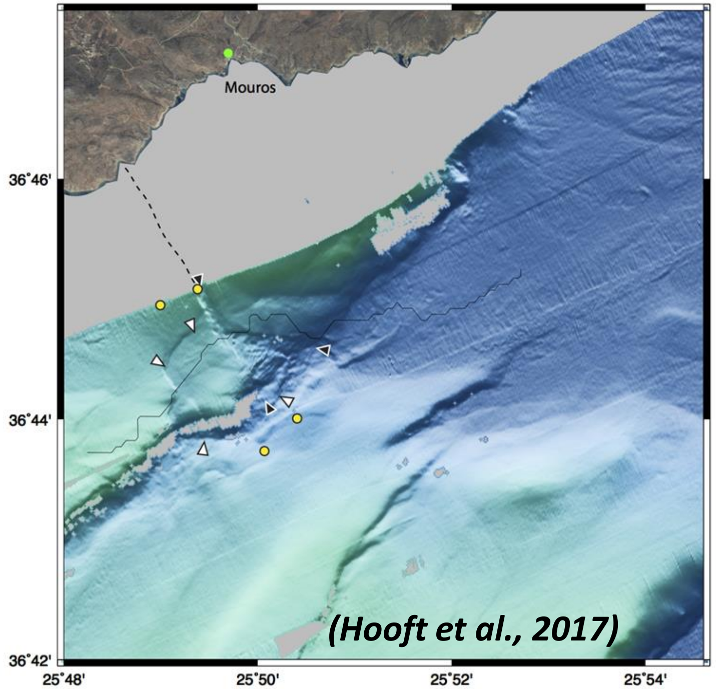
Earthquakes

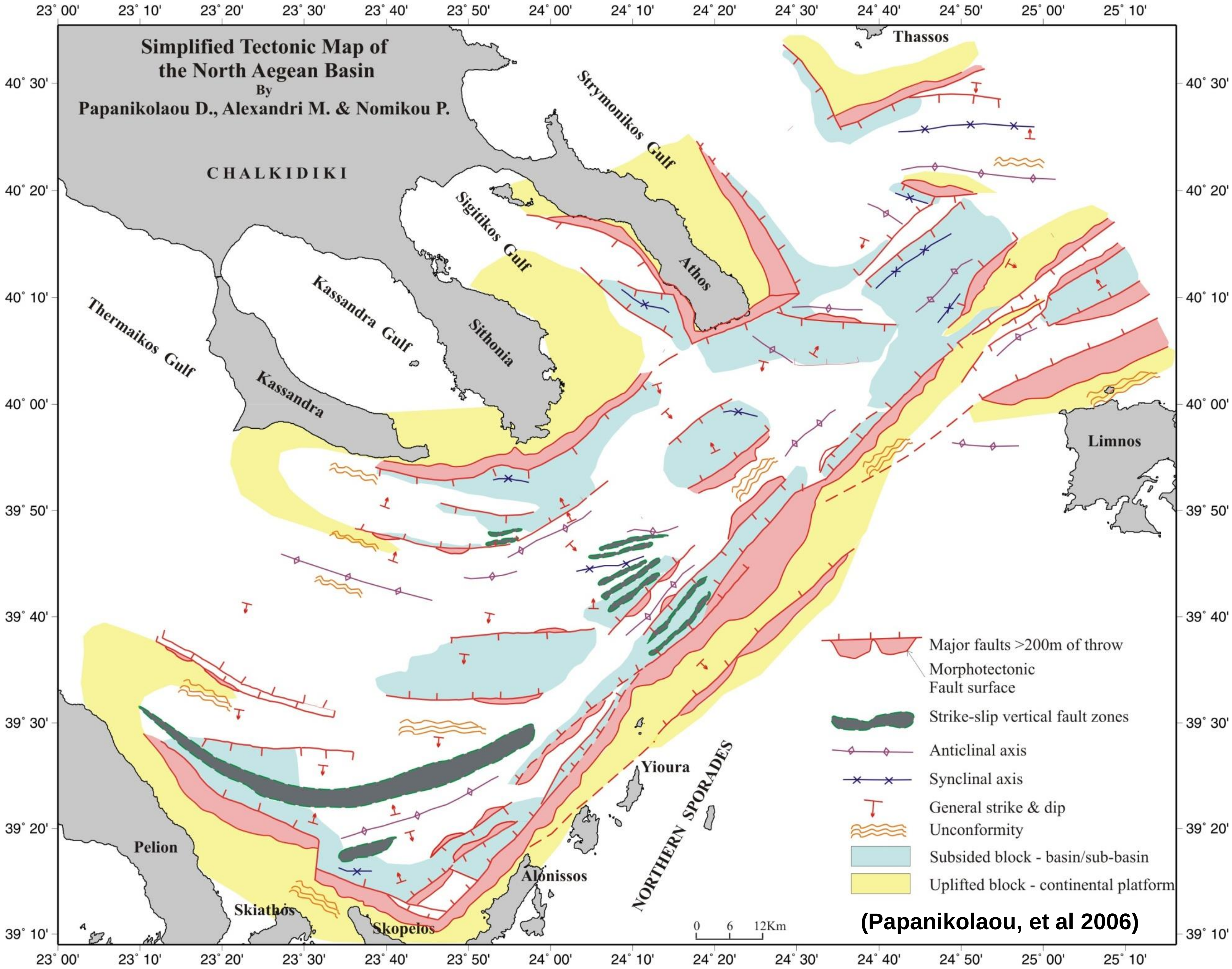


(Nomikou et al., 2018)

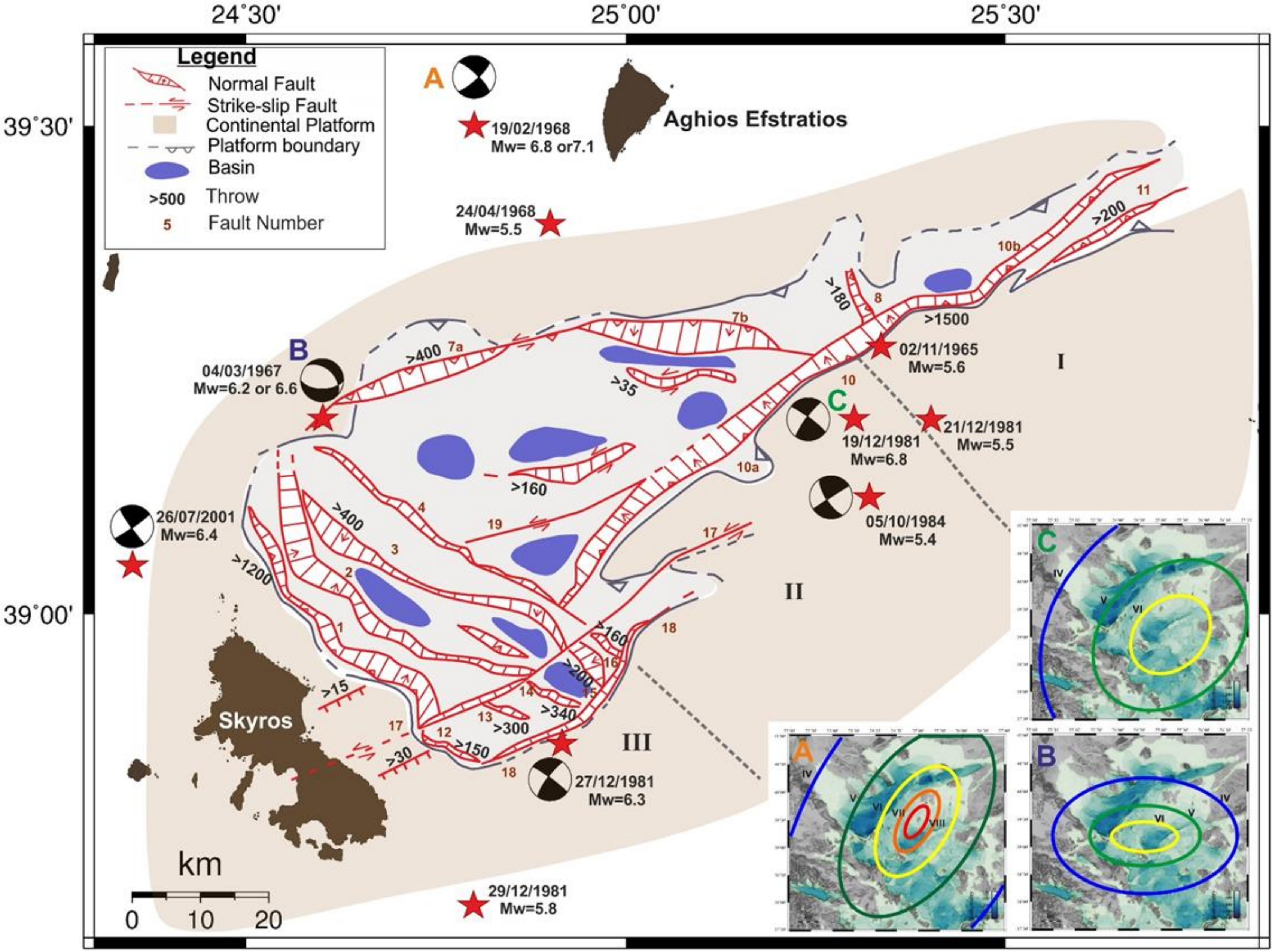
1956 Amorgos Earthquake



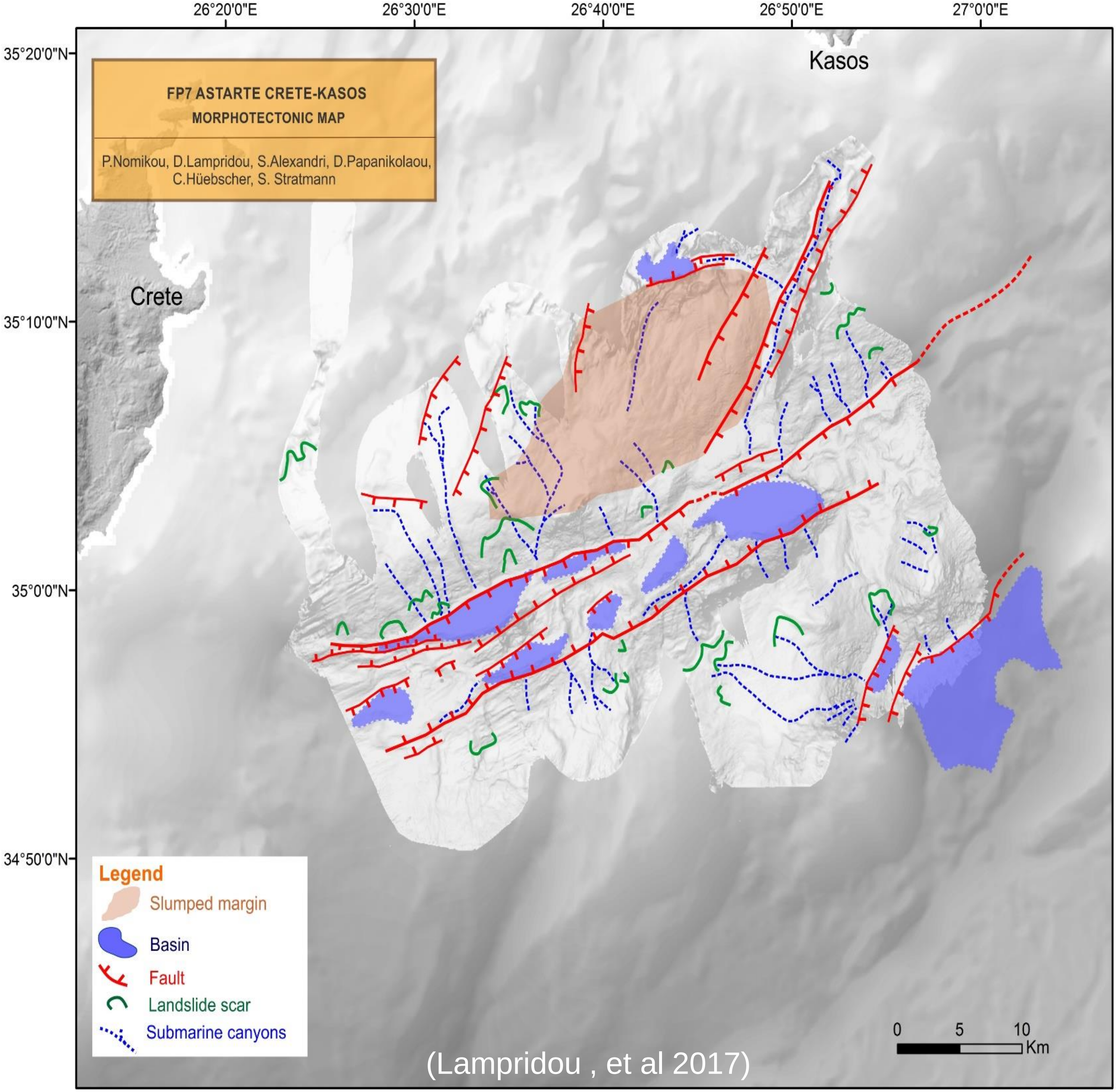




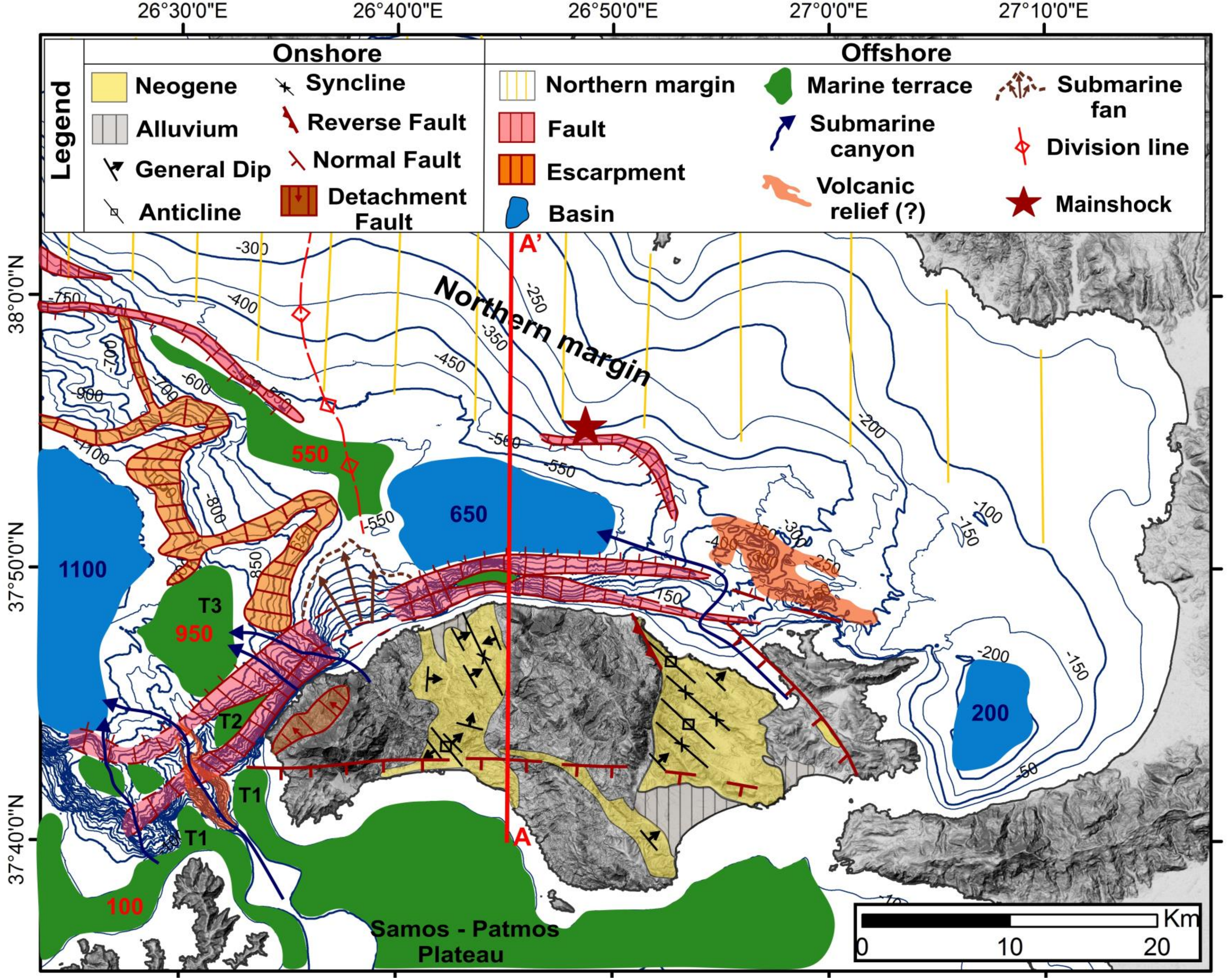
(Papanikolaou, et al 2006)



(Papanikolaou et al., 2018)

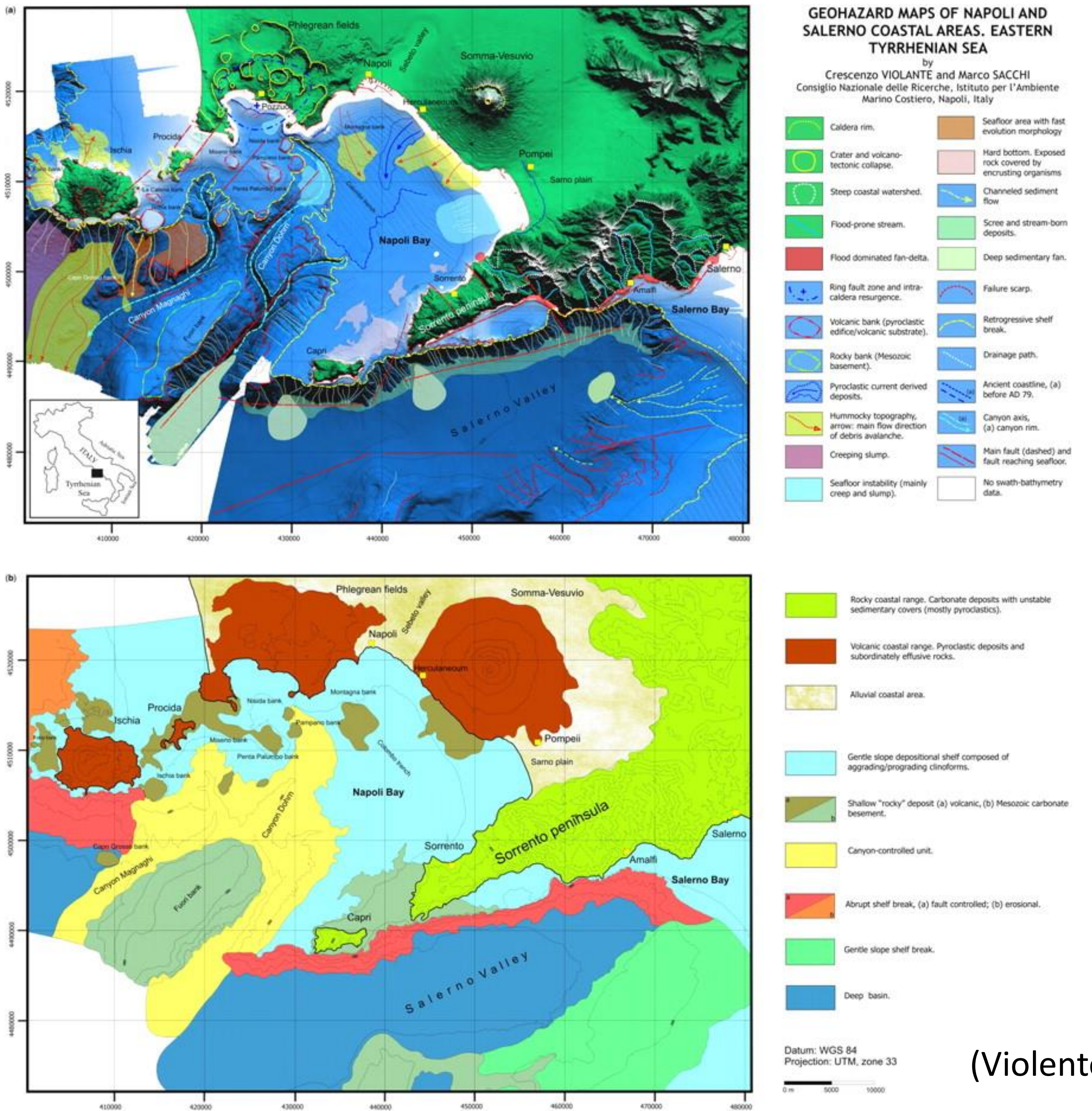


The Crete – Kasos studied area comprises a more than 50km long basin in the ENE-WSW direction with an average width of 10km . Along the shallow slopes of the two marginal fault zones outside the basin a large number of submarine canyons and landslides occur as well as a slumbed area of 20X30km at the northern margin, whose overall vertical displacement seems to exceed 400m



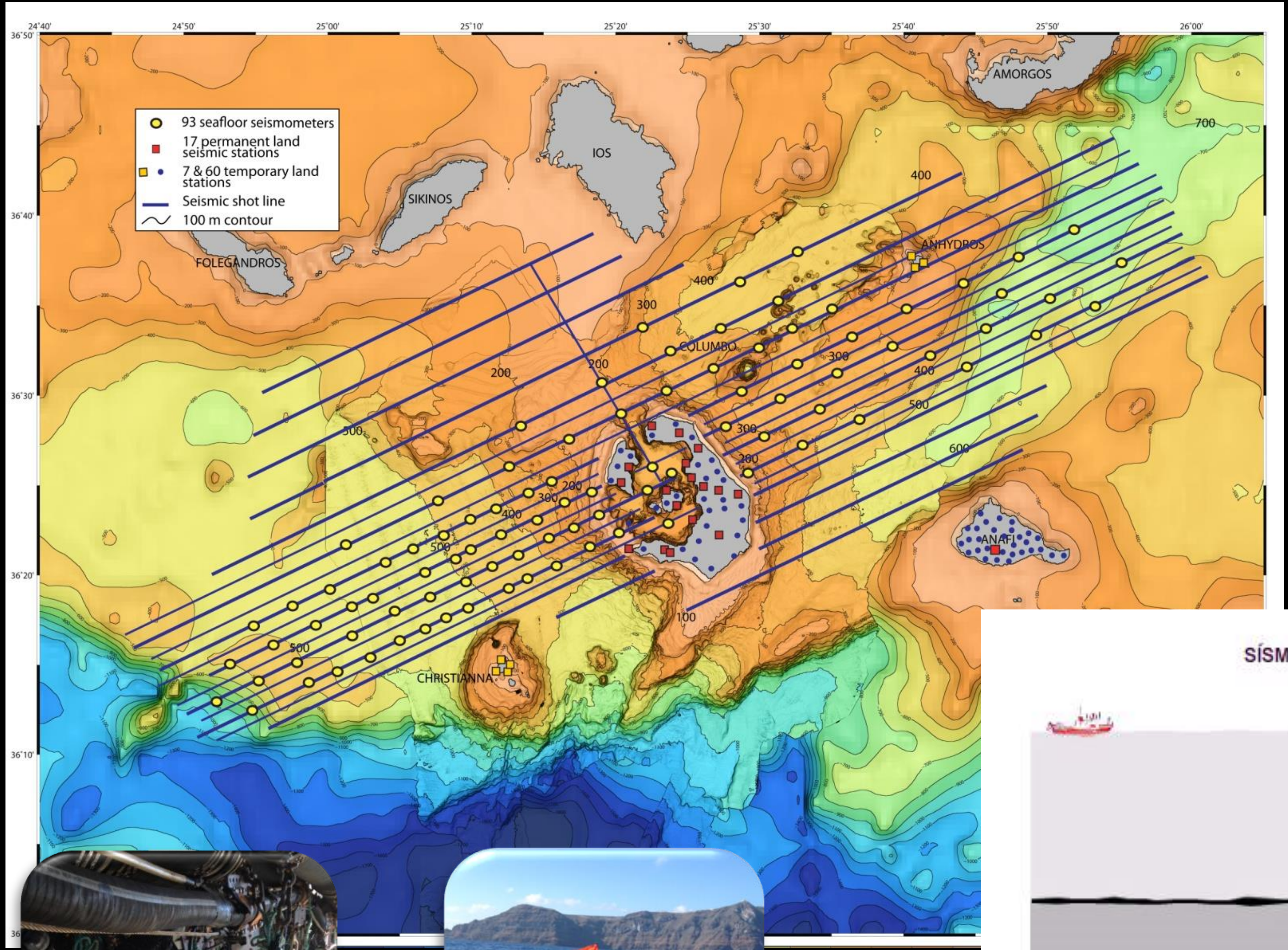
(Nomikou et al., 2021)

GEOHAZARDS MAPS

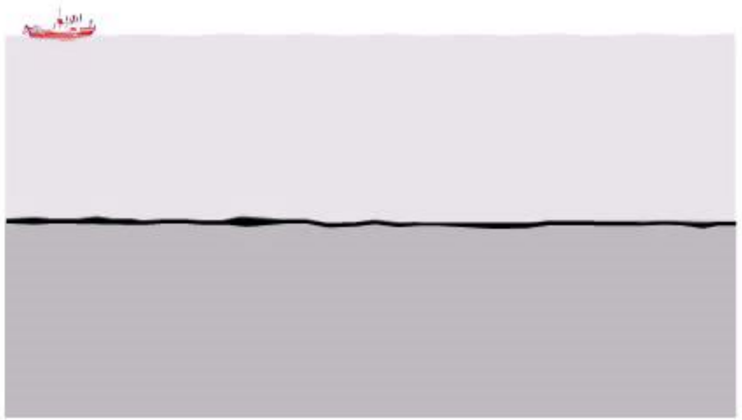


(Violente, 2009)

Santorini Seismic Experiment



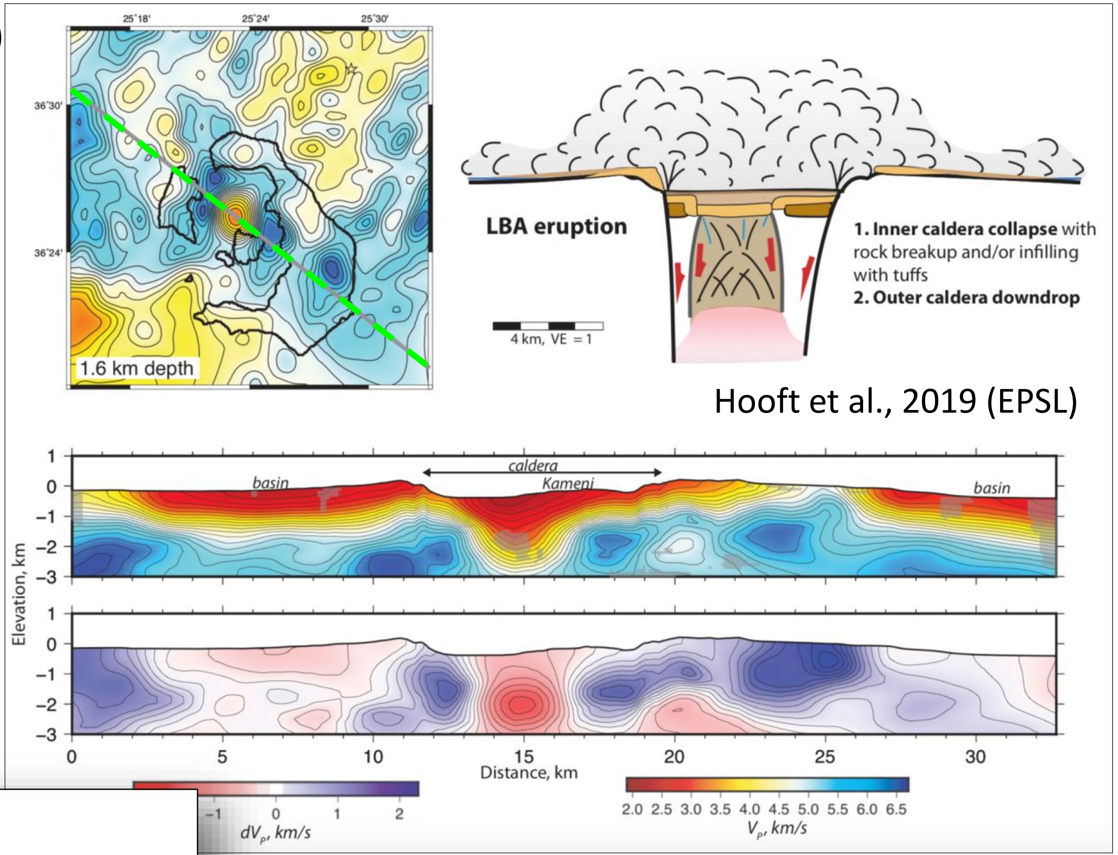
SÍSMICA DE REFRACCIÓN



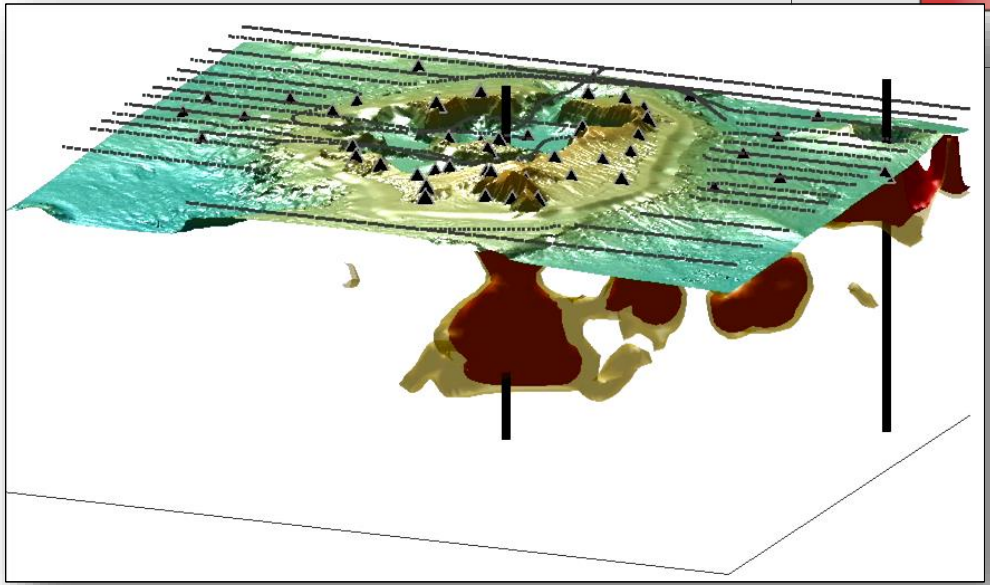
La sísmica de refracción permite diferenciar las capas del subsuelo y conocer sus propiedades mediante el estudio de la propagación de las ondas sísmicas. Aprieta el botón para ver como funciona.

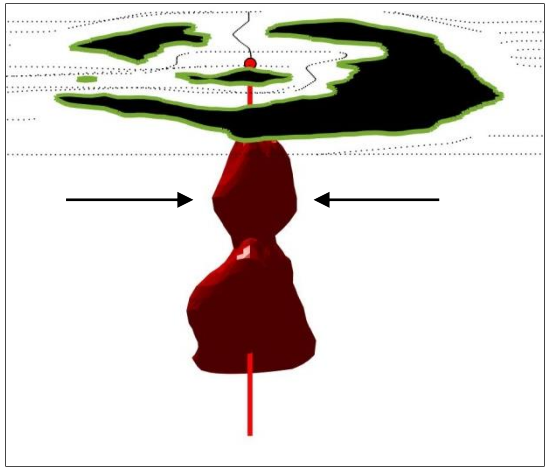
Proteus project: Tomography Results (1-3 km)

- Travel-time tomographic inversion of P_g first-arrivals (Toomey et al., 1994)
- 1-3 km Depth Results
  - Low velocity anomaly attributed to excess porosity
  - Inner caldera collapse feature



Hooft et al., 2019 (EPSL)

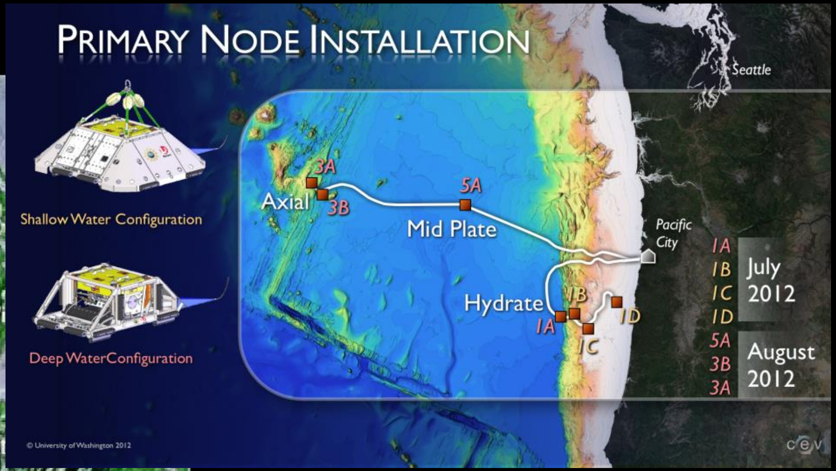




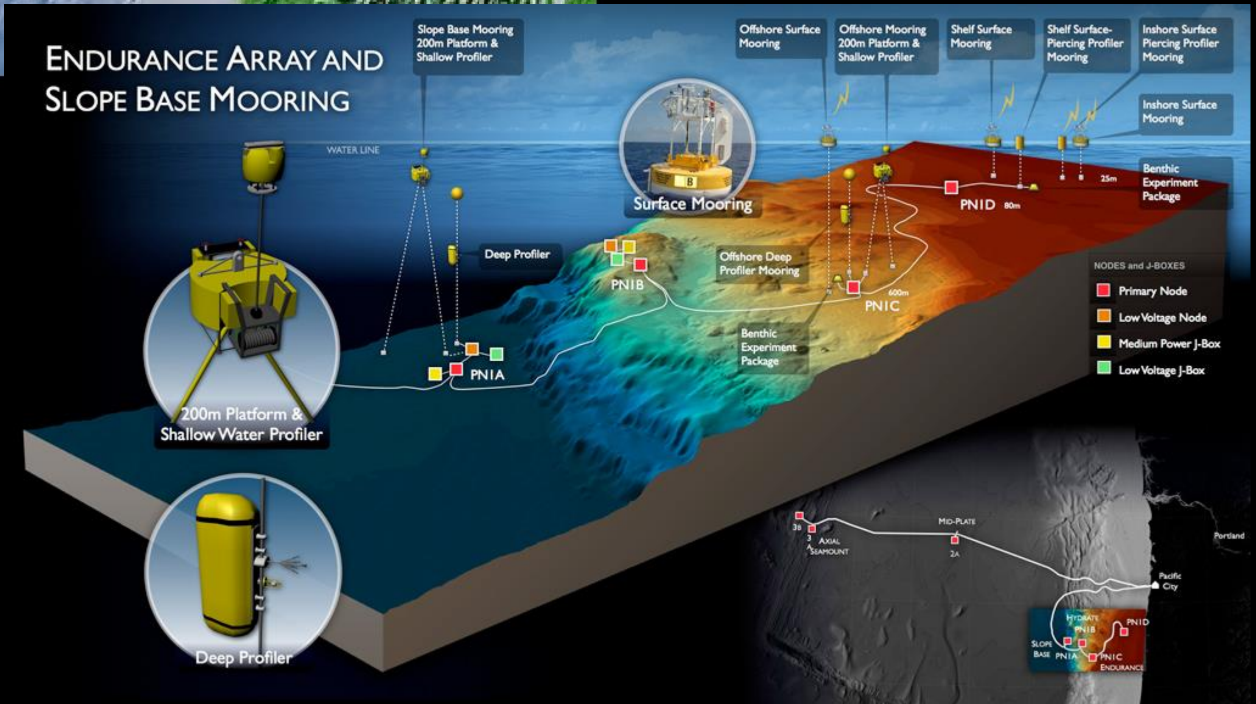
(McVey et al., 2018)-AGU first results

The Ocean Observatories Initiative, funded by the NSF, is planned as a networked infrastructure of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean and seafloor. A fully integrated system, OOI will collect data on coastal, regional and global scales and transmit that data in real-time to onshore scientists.

NEPTUNE Canada and USA



The OOI presents a remarkable opportunity to connect land based seismic networks and GPS observations with seismic and pressure measurements offshore using similar sensors and real-time connectivity



“

YOU NEVER KNOW WHAT YOU WILL FIND WHILE EXPLORING ……..THE SEA FLOOR

Ευχαριστώ πολύ !