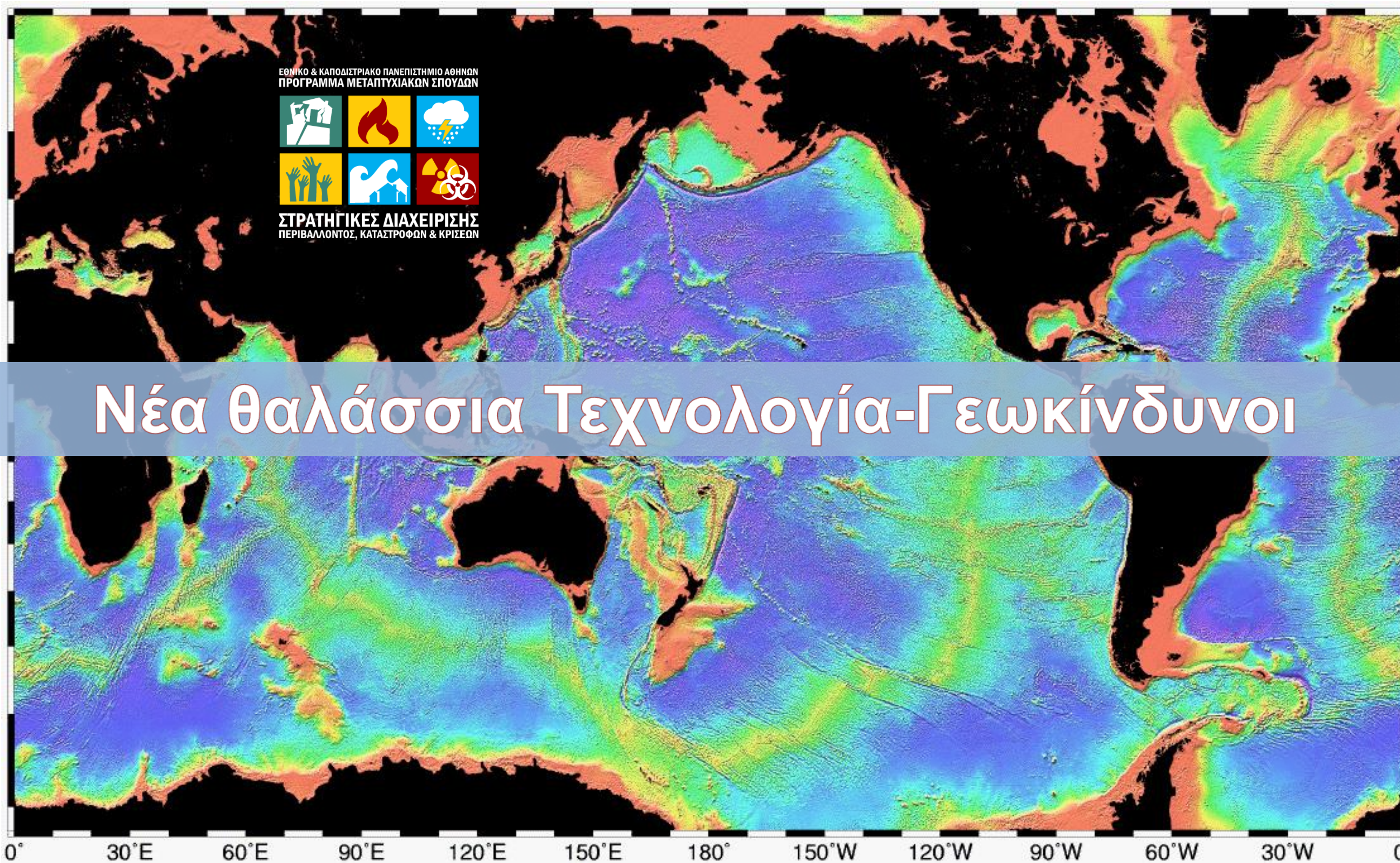
2ου Επιστημονικό Forum για τη Μείωση της Διακινδύνευσης από Καταστροφές στην Ελλάδα

14-15 Μαρτίου 2019, Αμφιθέατρο "Άλκης Αργυριάδης"

Νέα θαλάσσια Τεχνολογία-Γεωκίνδυνοι



Walter H. F. Smith and David T. Sandwell, Seafloor Topography Version 4.0, SIO, September 26, 1996

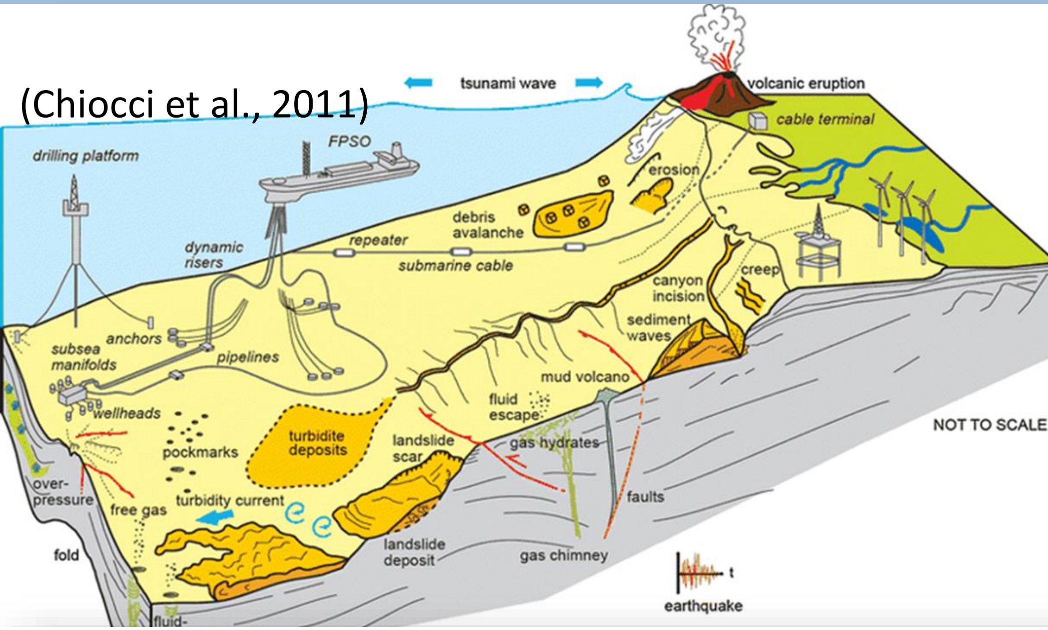
Παρασκευή Νομικού
Τμήμα Γεωλογίας και Γεωπεριβάλλοντος, ΕΚΠΑ

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
Εθνικό και Καποδιστριακό Πανεπιστήμιο Αθηνών

Κωνσταντίνος Καράντζαλος
Τμήμα Αγρονόμων Τοπογράφων Μηχανικών, ΕΜΠ

Offshore geohazards

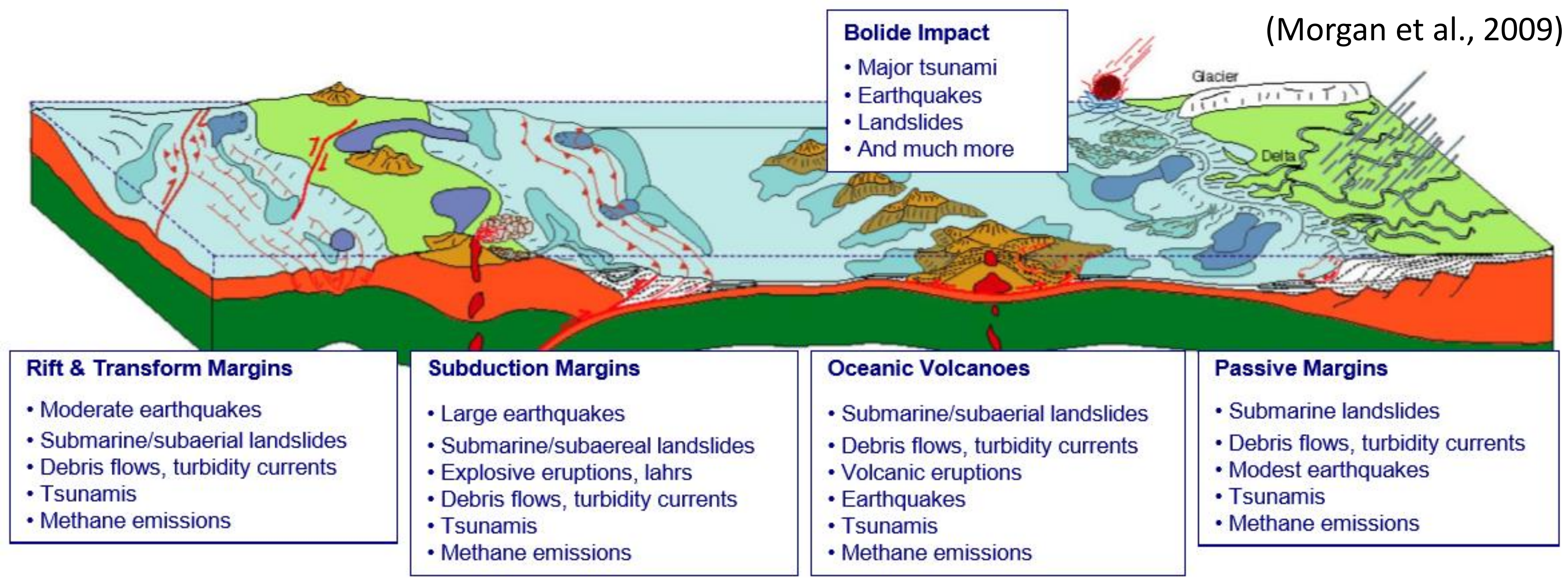
(Chiocci et al., 2011)



Examples of offshore geohazard target areas are therefore regions within:

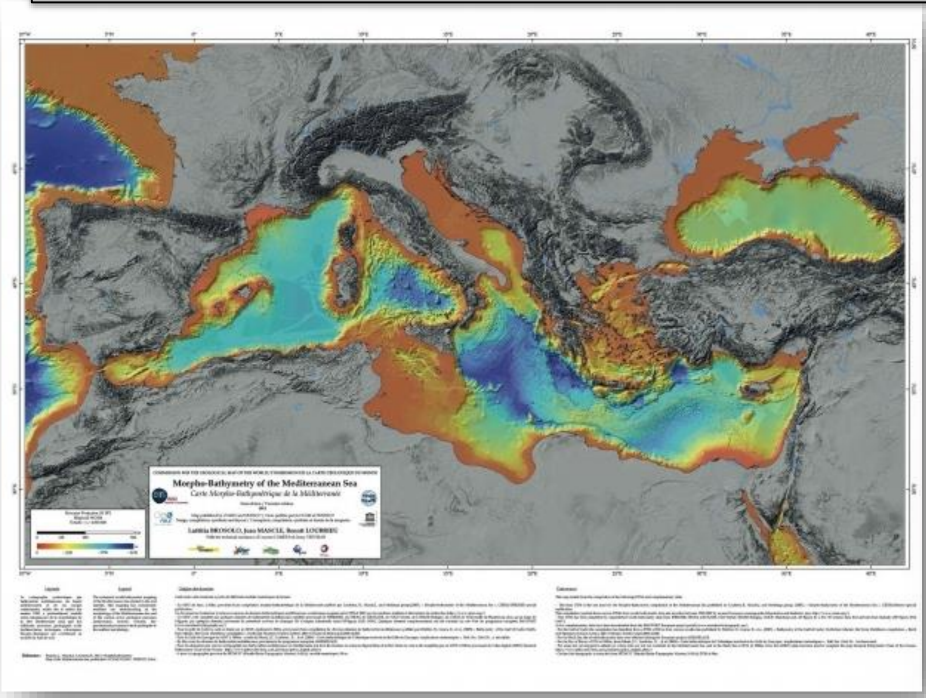
- Active fault systems and Seismicity
- Slope systems with slope instabilities and/or active submarine channels
- Canyon systems with active turbidity currents
- Volcanic systems and Oceanic islands
- Shallow (pressurized) gas systems and gas hydrates
- Exploration sites for assessing the environmental impact

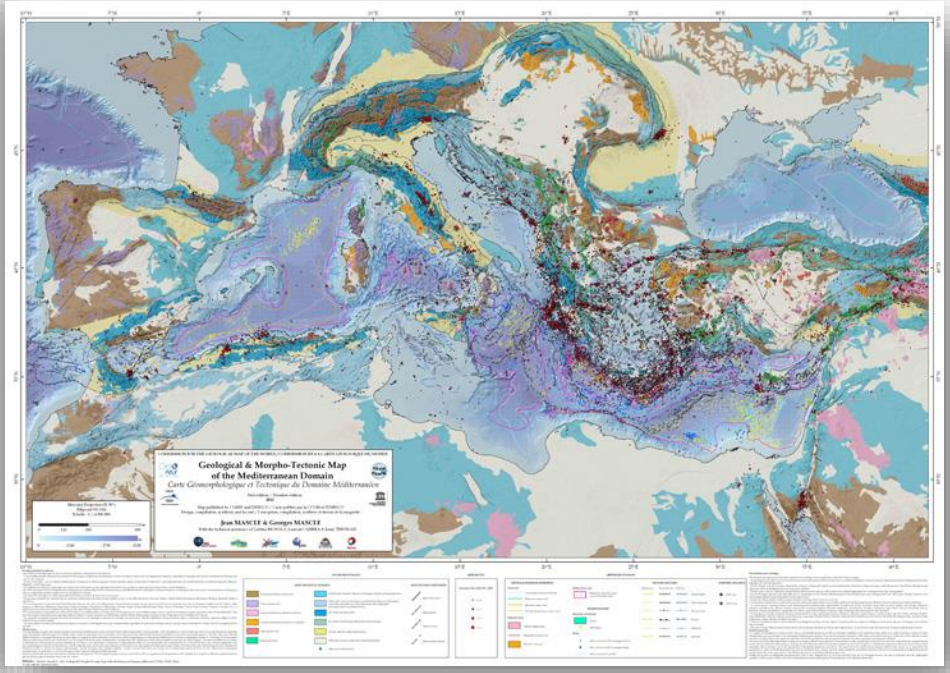
(Morgan et al., 2009)



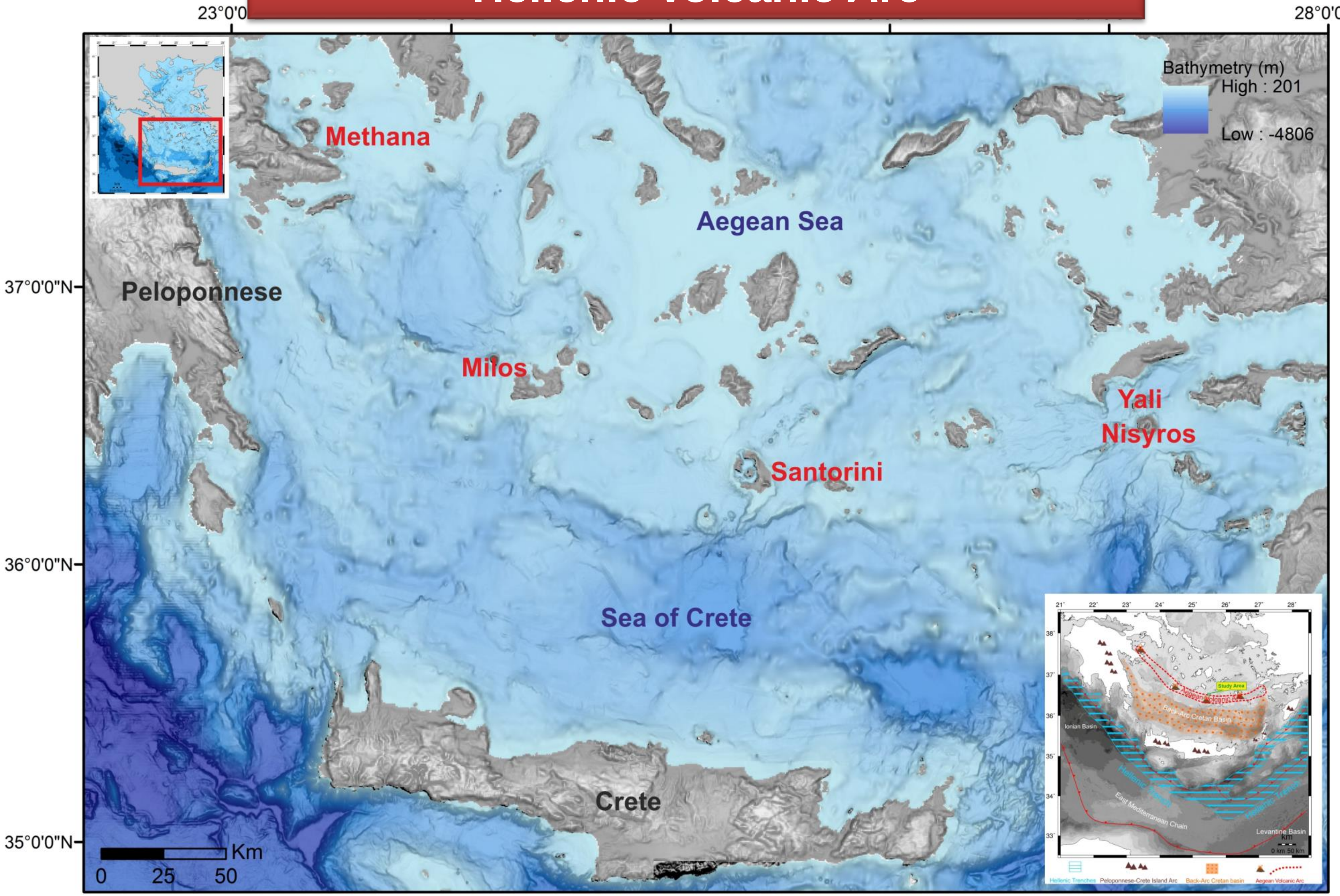
Mediterranean Sea

The Mediterranean coastline is very densely populated, totaling 160 million inhabitants sharing 46,000 km of coastline (3.5 inhabitants per m of coastline). World's leading holiday destination, receiving up 30% of global tourism and an average of 135 million visitors annually; this is predicted to increase to 235-350 million tourists by year 2025 (European Environmental Agency - EEA). When compared to other oceanic basins, the Mediterranean is more vulnerable to ***marine geohazards*** due not only to the high density of coastal population, but also to its small dimensions. The latter results in close proximity between tsunami sources (induced by either a submarine landslide or co-seismic seafloor displacement) and impact areas (Camerlenghi et l., 2010).

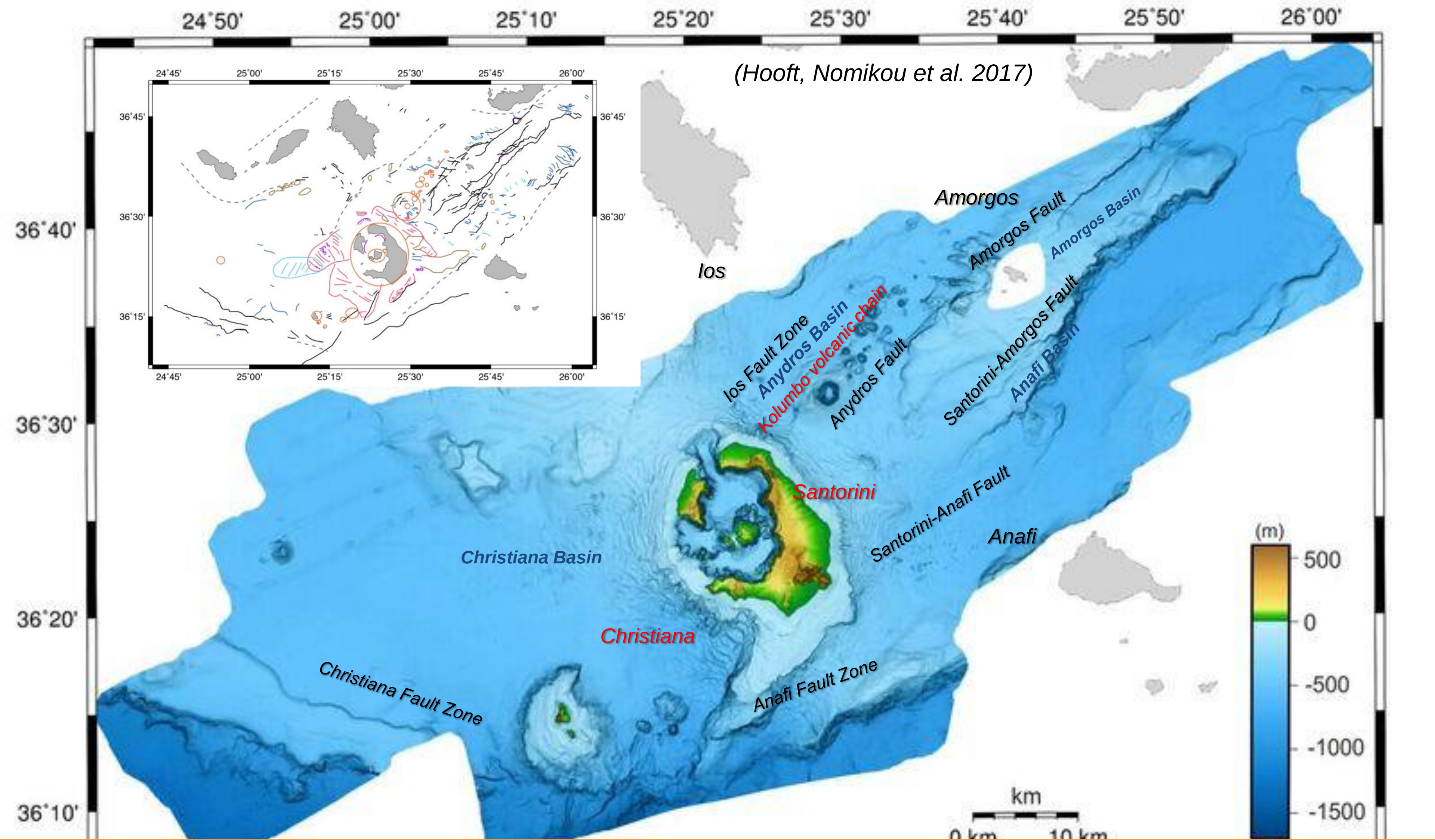




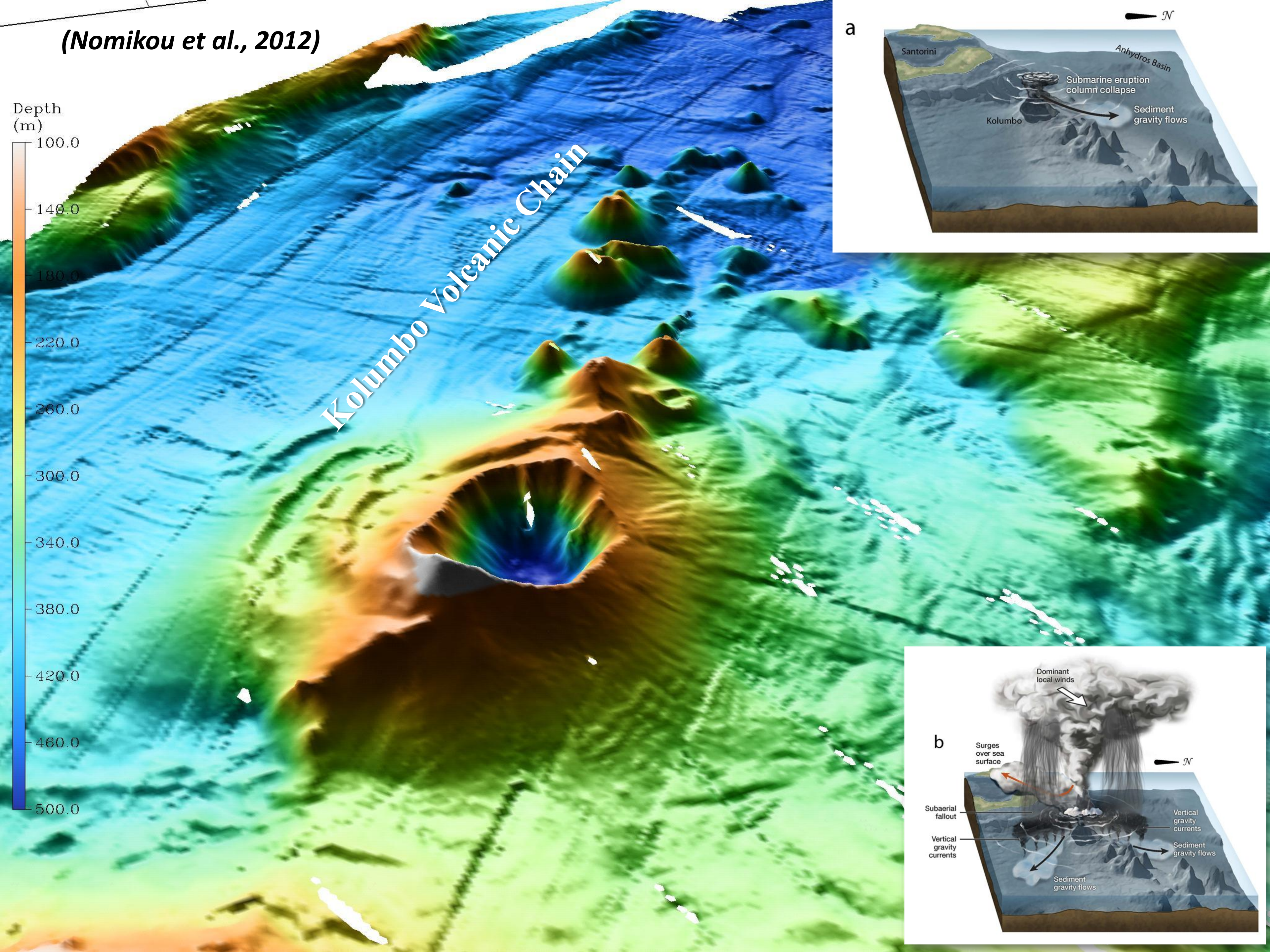
Hellenic Volcanic Arc



(Nomikou et al., 2012)

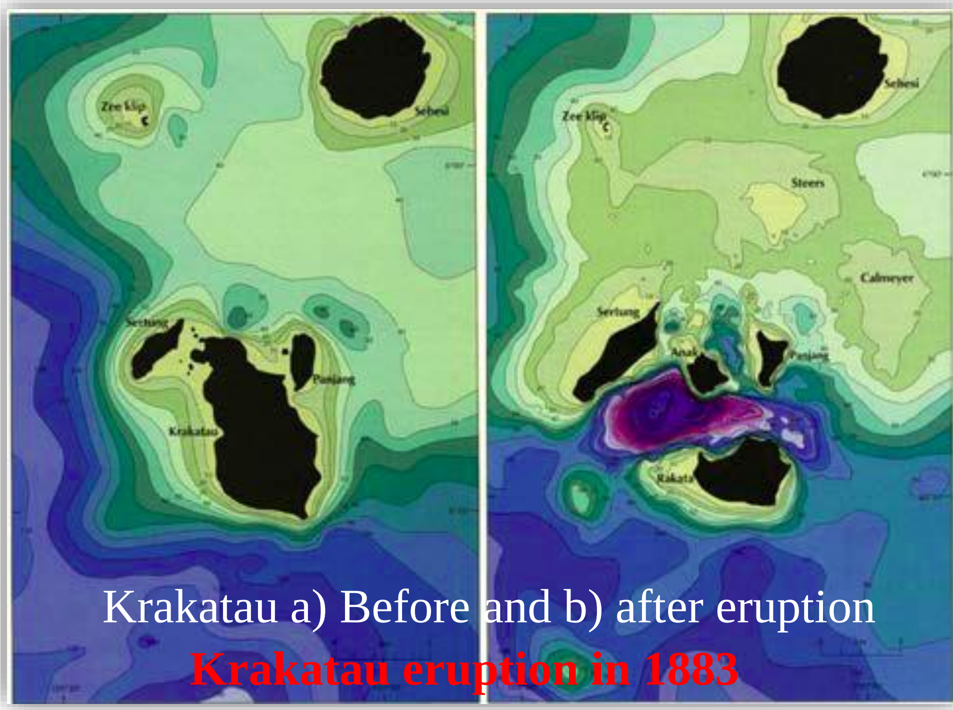


The new high resolution multi-beam bathymetry map (R/V Marcus Langseth's Simrad Kongsberg EM122 12kHz multibeam) of Christianna-Santorini-Amorgos was used to: **(i)** identify the areas of the most recent tectonic deformation and detail the geodynamic structure of the region between Santorini and Amorgos - 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.



(Nomikou et al., 2012)
Depth (m)
100.0
140.0
180.0
220.0
260.0
300.0
340.0
380.0
420.0
460.0
500.0
Kolumbo Volcanic Chain
a
N
Santorini
Anhydros Basin
Submarine eruption column collapse
Kolumbo
Sediment gravity flows
b
N
Dominant local winds
Surges over sea surface
Subaerial fallout
Vertical gravity currents
Vertical gravity currents
Sediment gravity flows
Sediment gravity flows

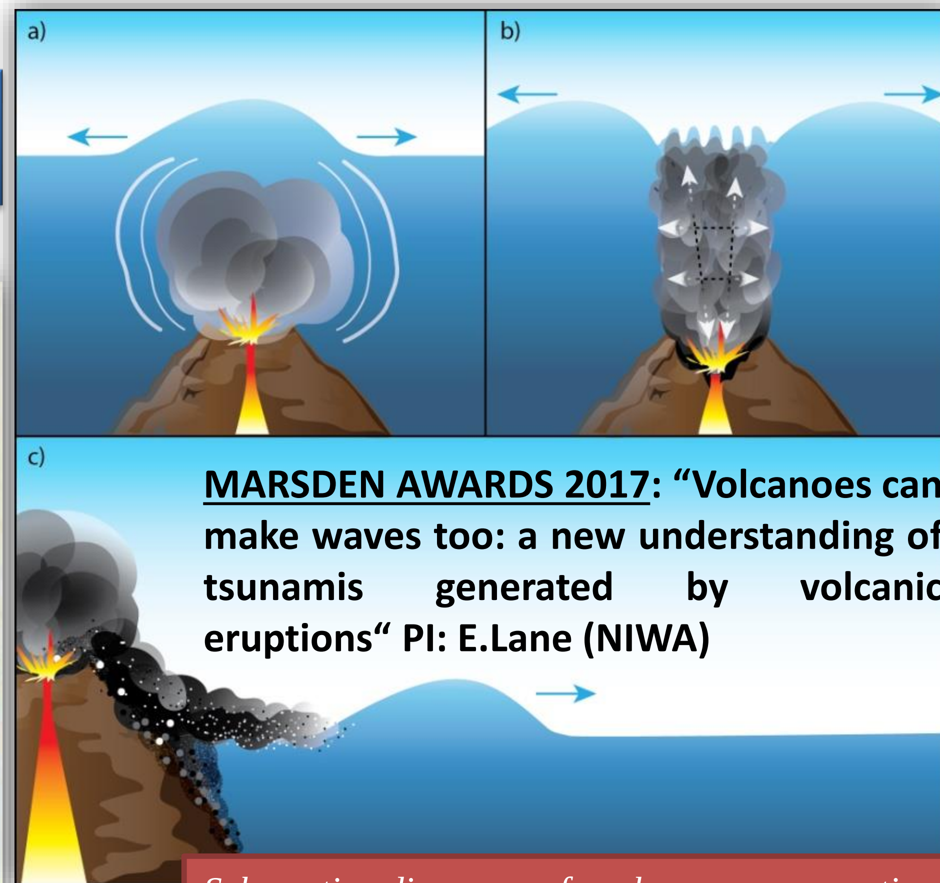
NSF-NERC Caldera-forming eruptions – how do they generate tsunamis?" PI: D.Tappin



Krakatau a) Before and b) after eruption

Krakatau eruption in 1883

19 tsunamis were generated, with the largest during the final climactic event, which devastated adjacent coastlines with 30-40m high waves



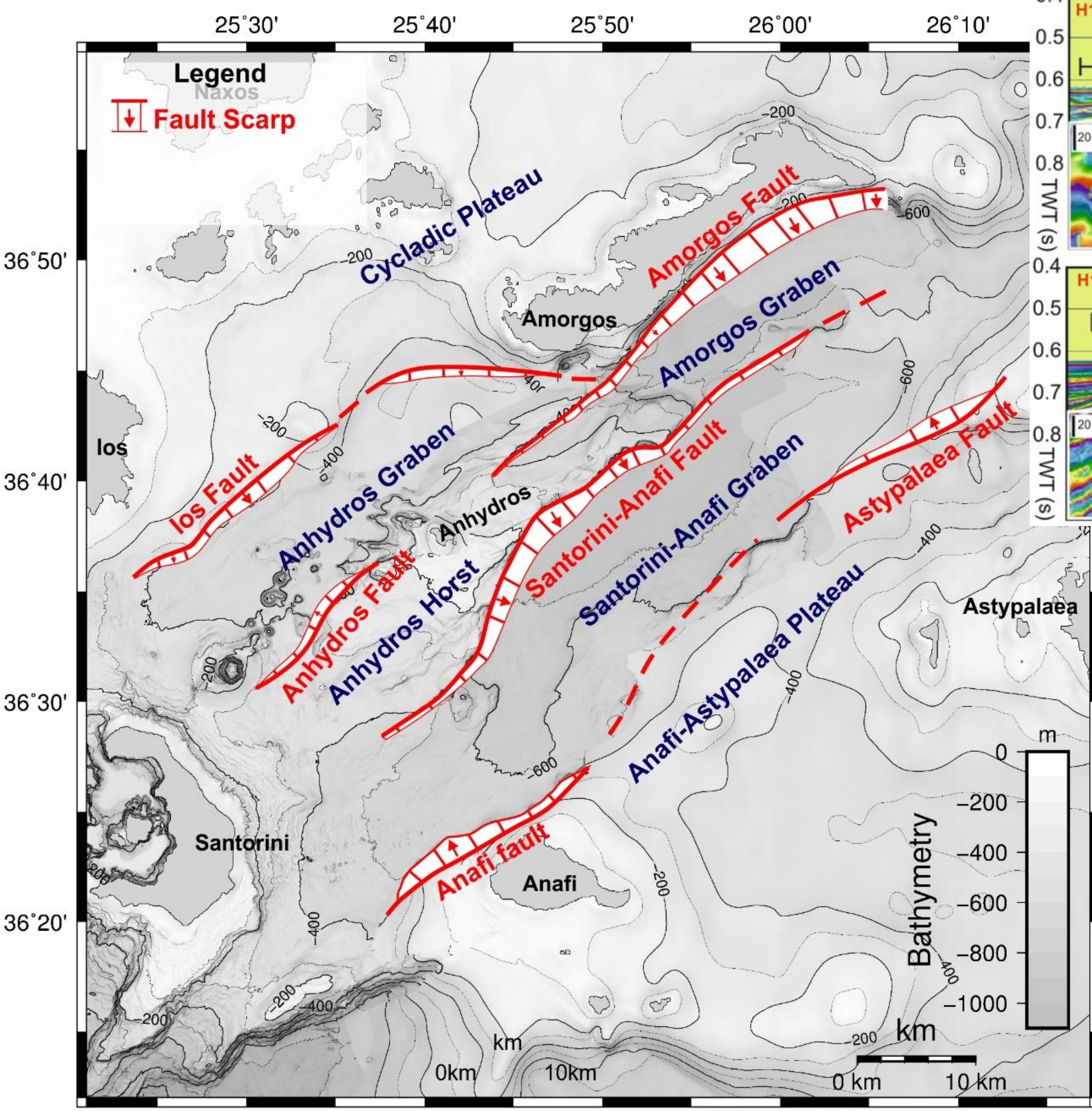
MARSDEN AWARDS 2017: "Volcanoes can make waves too: a new understanding of tsunamis generated by volcanic eruptions" PI: E.Lane (NIWA)

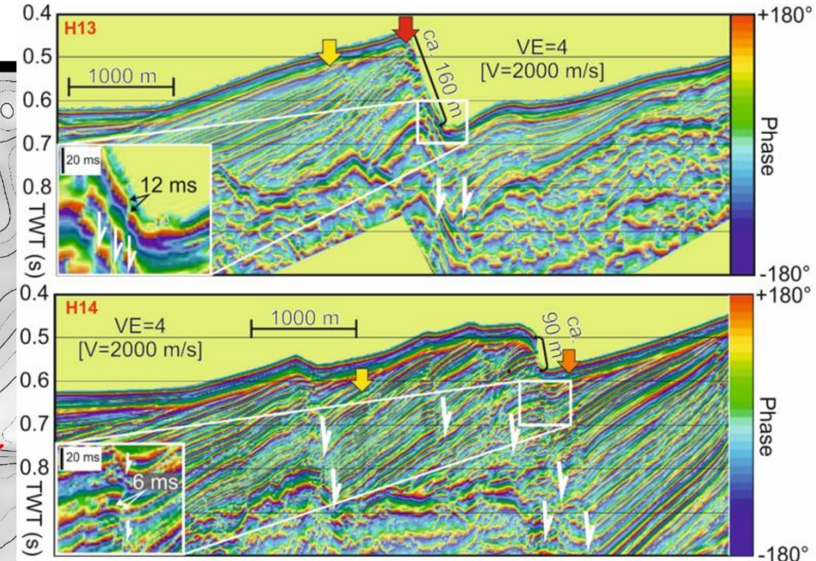
Schematic diagram of volcanoes generating tsunamis a) discrete explosions; b) eruption columns; and c) pyroclastic flows.

Using an integrated physical-numerical approach we will replicate aspects of the generation process and use this knowledge to determine key elements of the fascinating phenomena involved in volcanoes generating tsunamis.

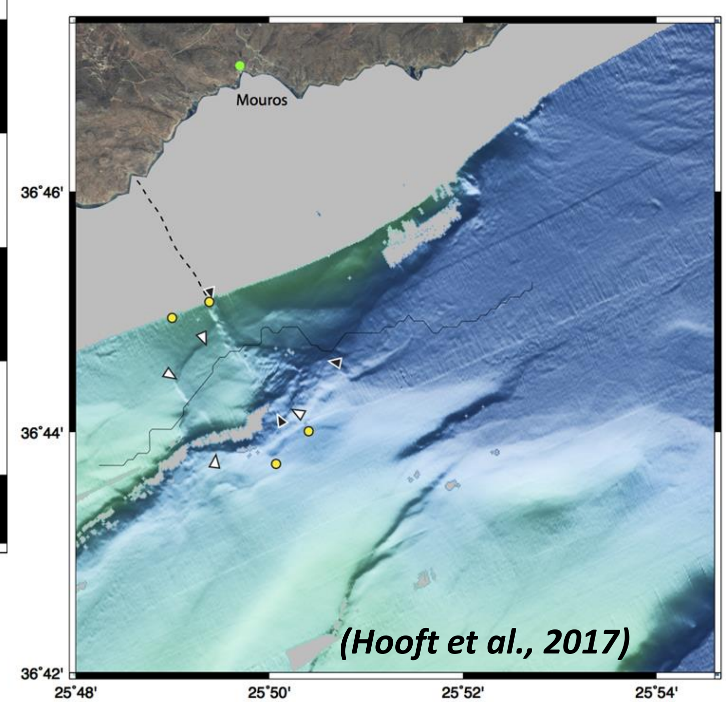
Earthquakes

1956 Amorgos Earthquake



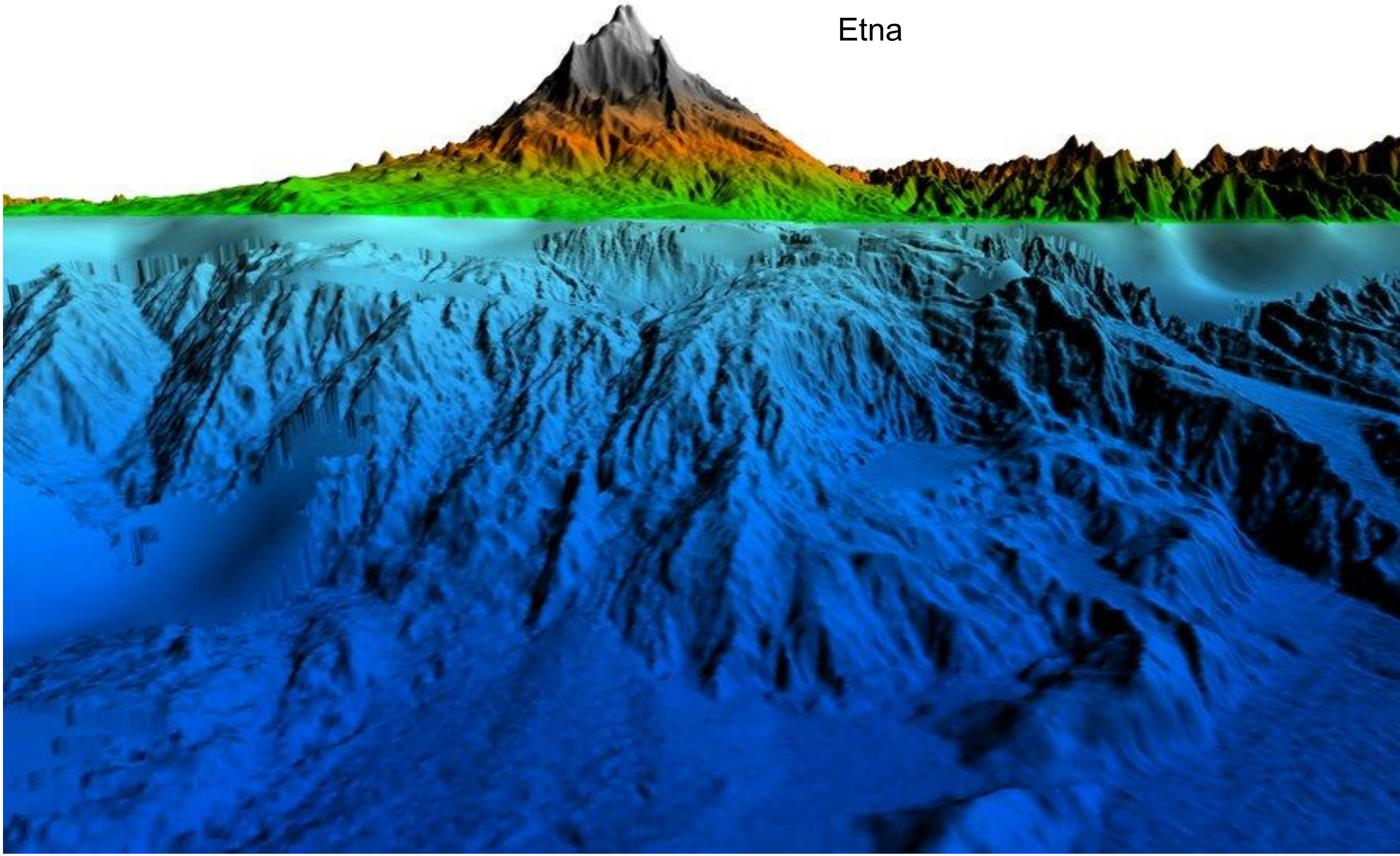


(Nomikou et al., 2018)



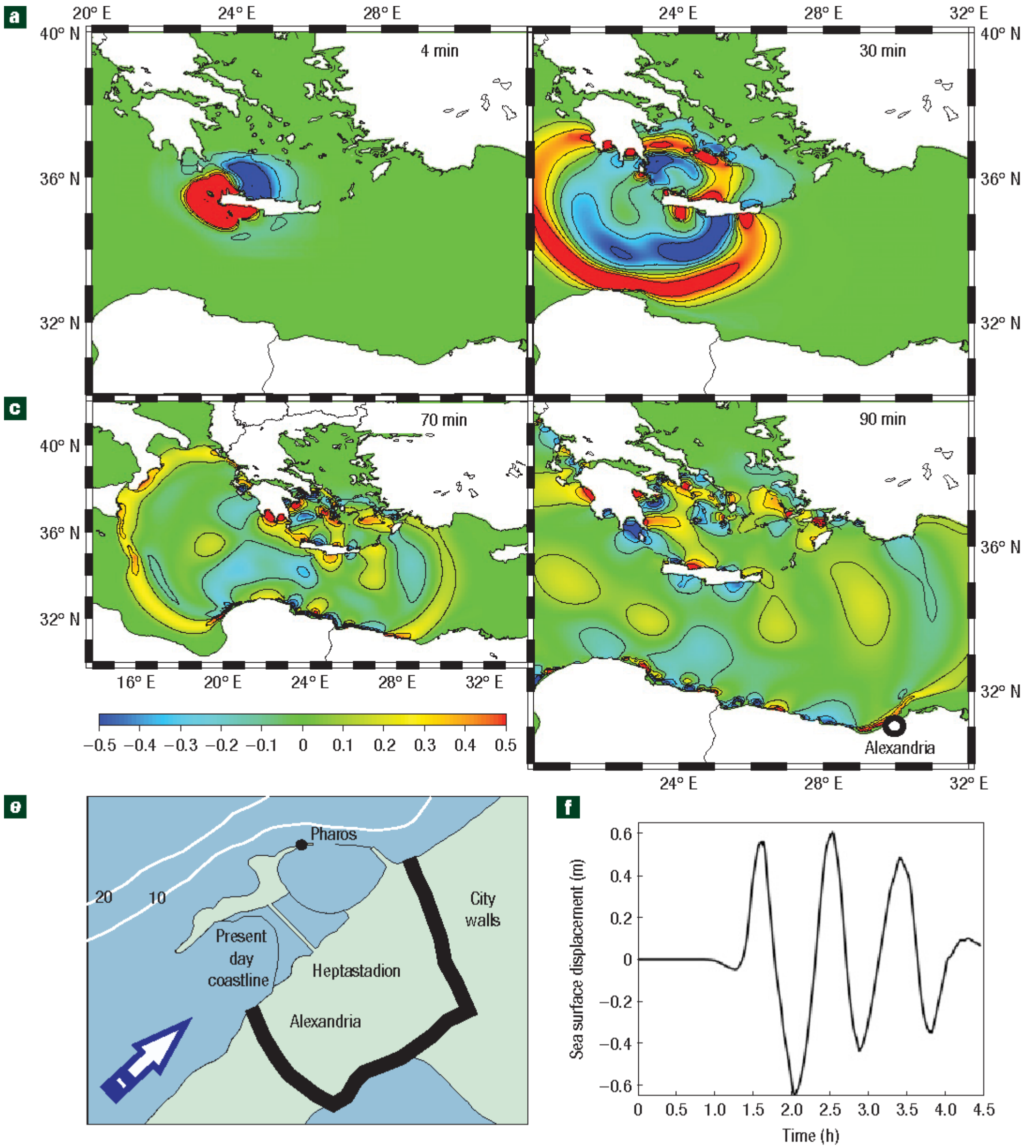
(Hooft et al., 2017)

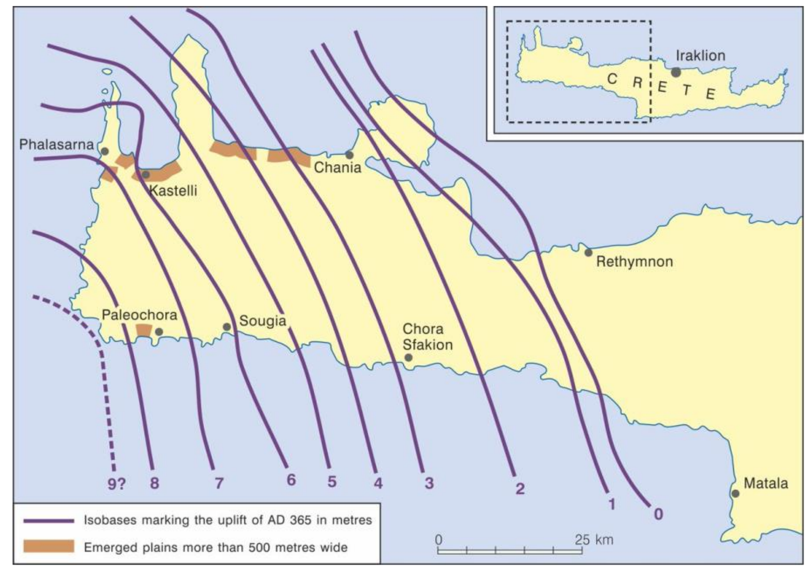
Landslides



Graphics/Image: Felix Gross, GEOMAR

Tsunami



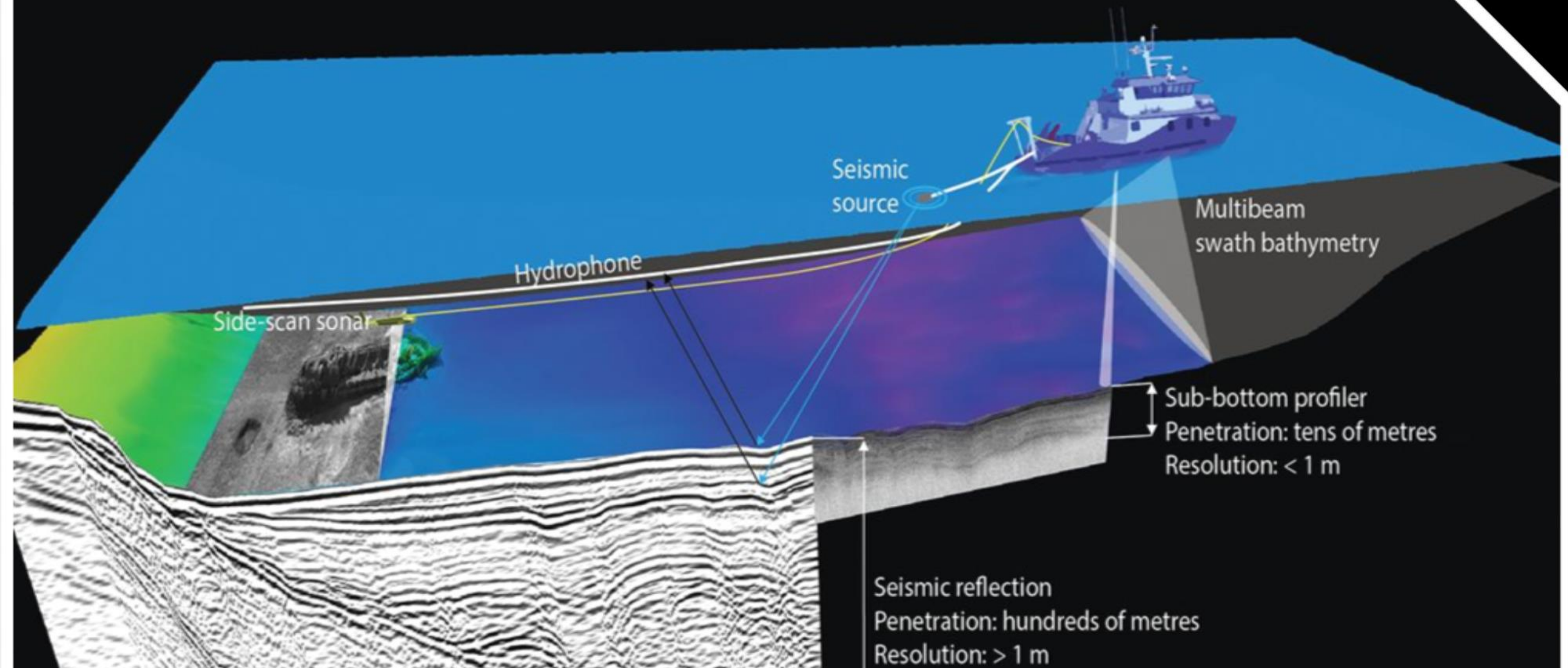


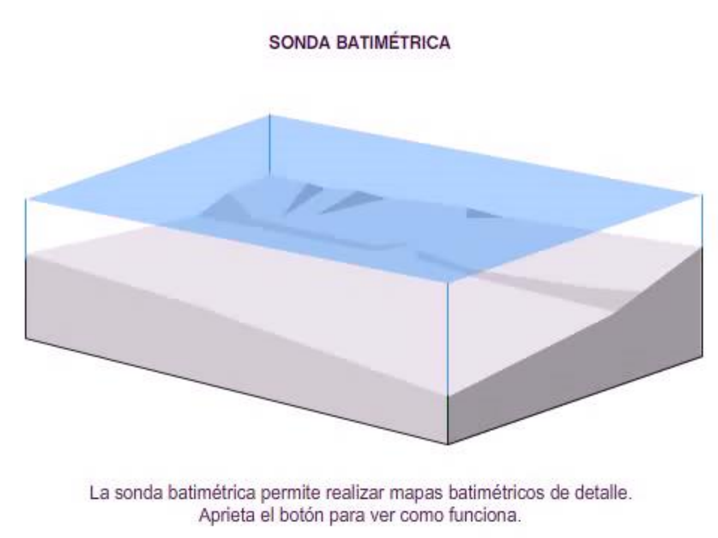
(Shaw et al., 2008. Nature)

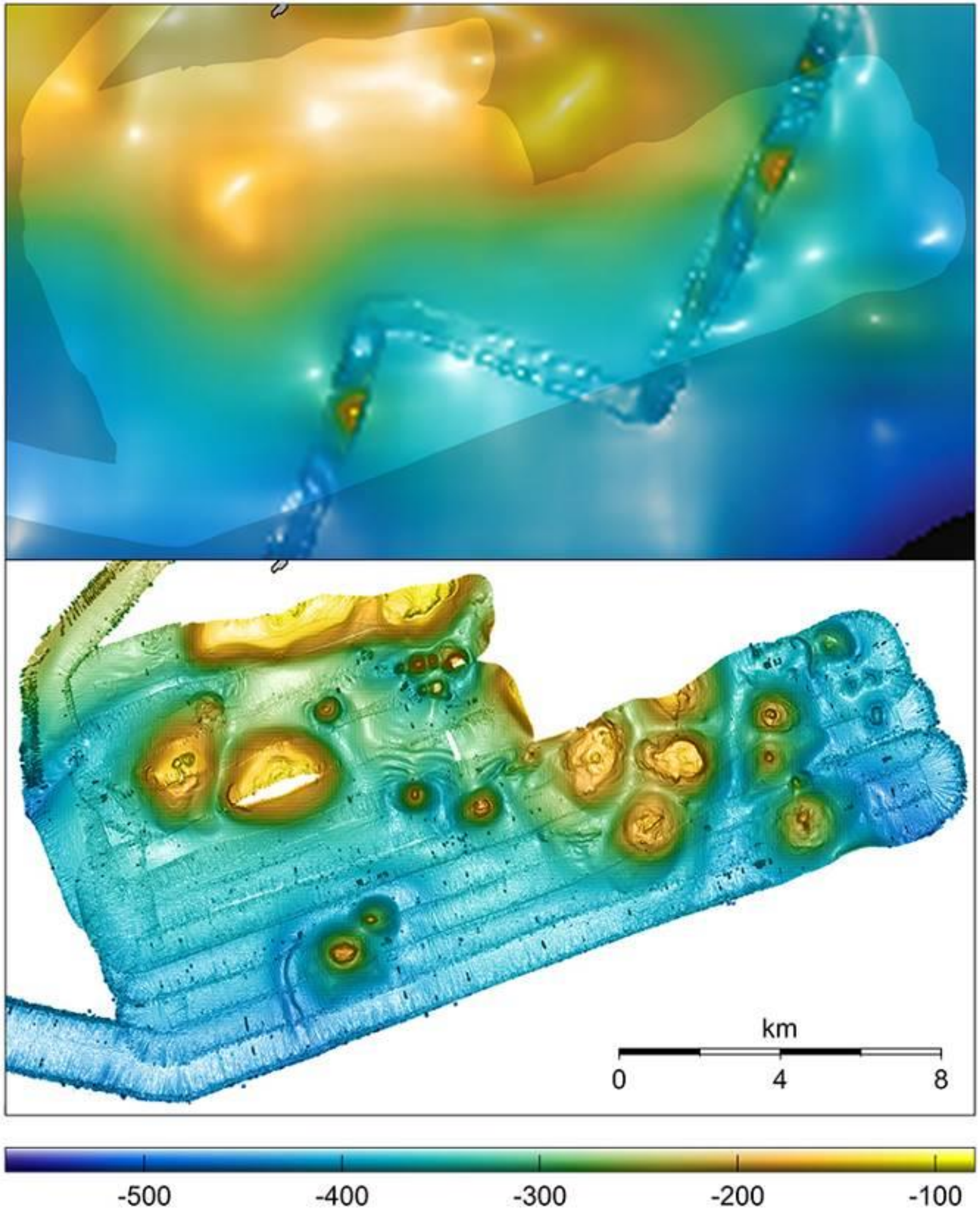
In the year **365** the Crete Earthquake took place which was followed by a tsunami around the Eastern Mediterranean that destroyed Alexandria. It is said that earthquake had a magnitude of around eight which resulted in a wide destruction affecting huge parts of Greece, Cyprs, Sicily, Lybia, Egyp and even Spain! The resulting tsunami (it was an undersea earthquake) killed thousands of people.

Sea Floor Exploration

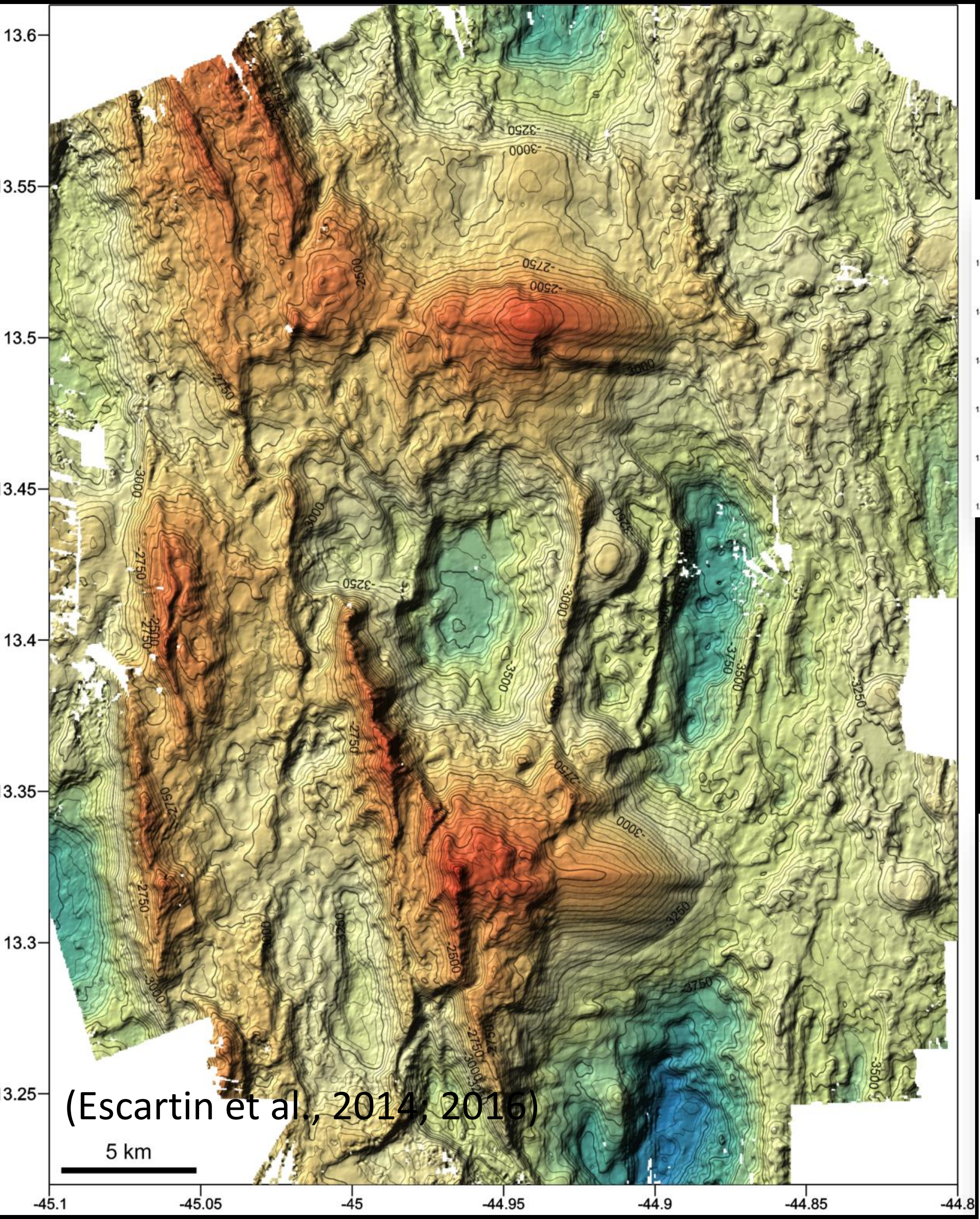
UNDERWATER SURVEY

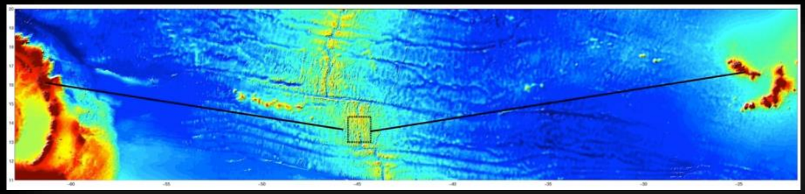


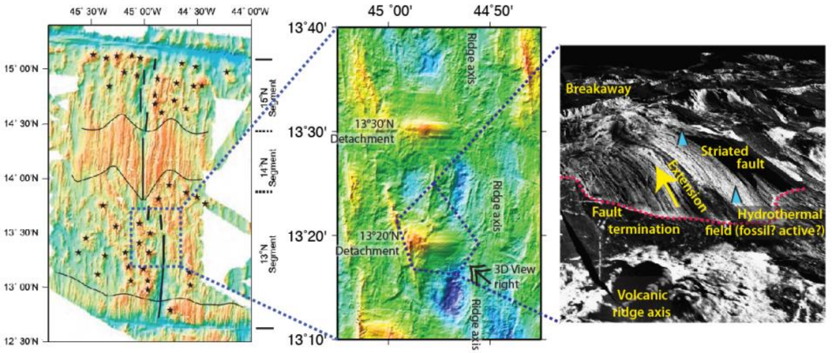




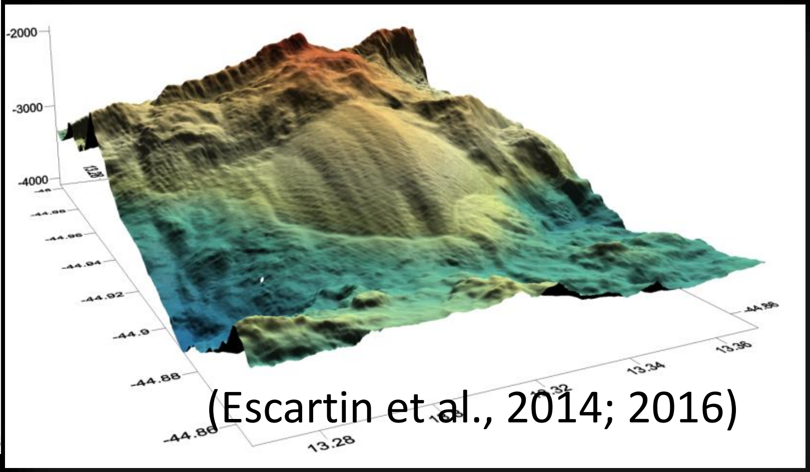
The bathymetry comparison above is from an area south of Floreana Island, Galápagos. The top image is the area's bathymetry before the August 2015 expedition, mapped to a resolution of about 1 km per pixel. The bottom image shows bathymetry mapped during the expedition with a resolution of 10 meters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





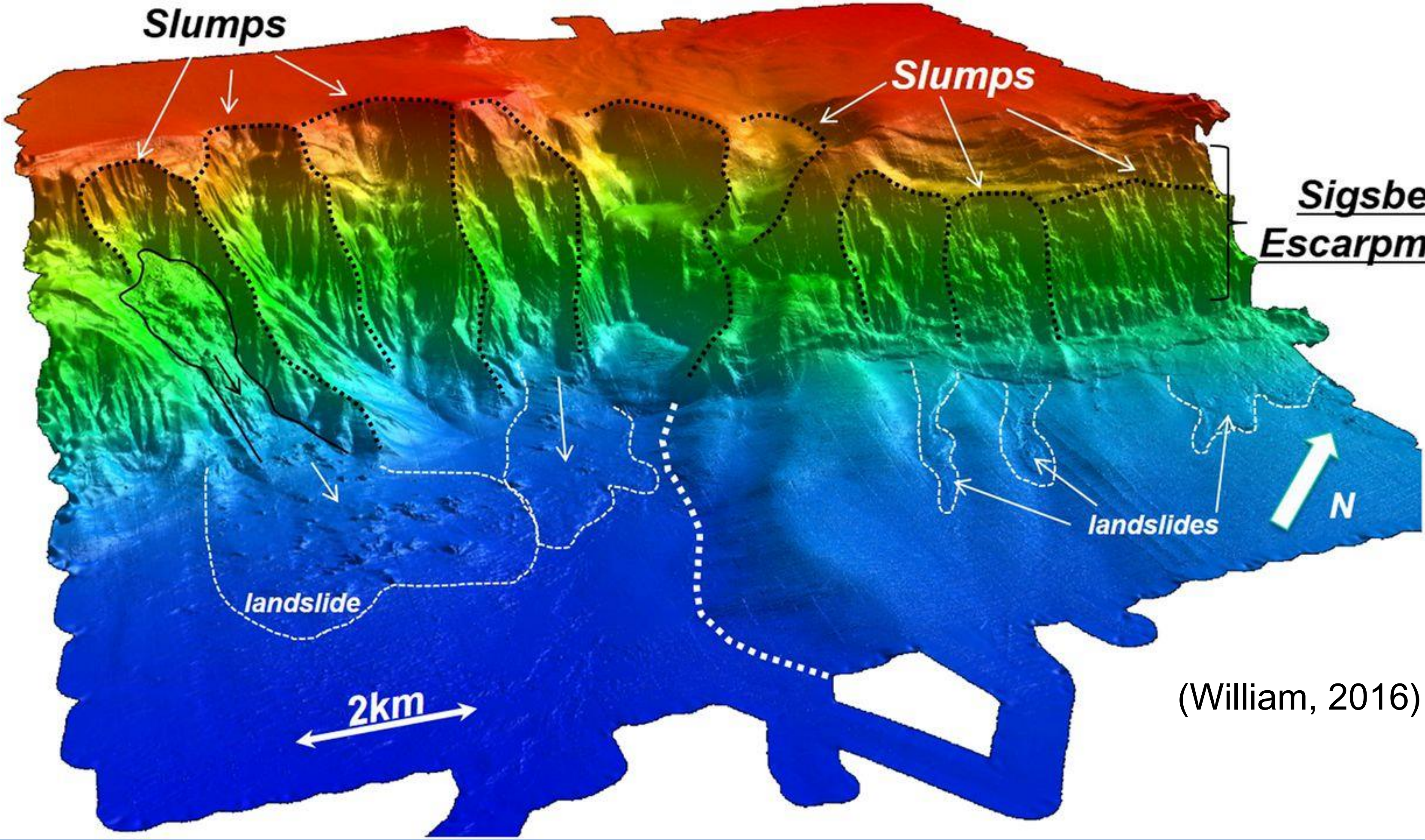


Overview map of the area mapped with SeaBat 7150 mounted on N/O Pourquoi Pas? The data shown are gridded with a spatial cell size of 30-40 meters (Escartin et al., 2014; 2016)



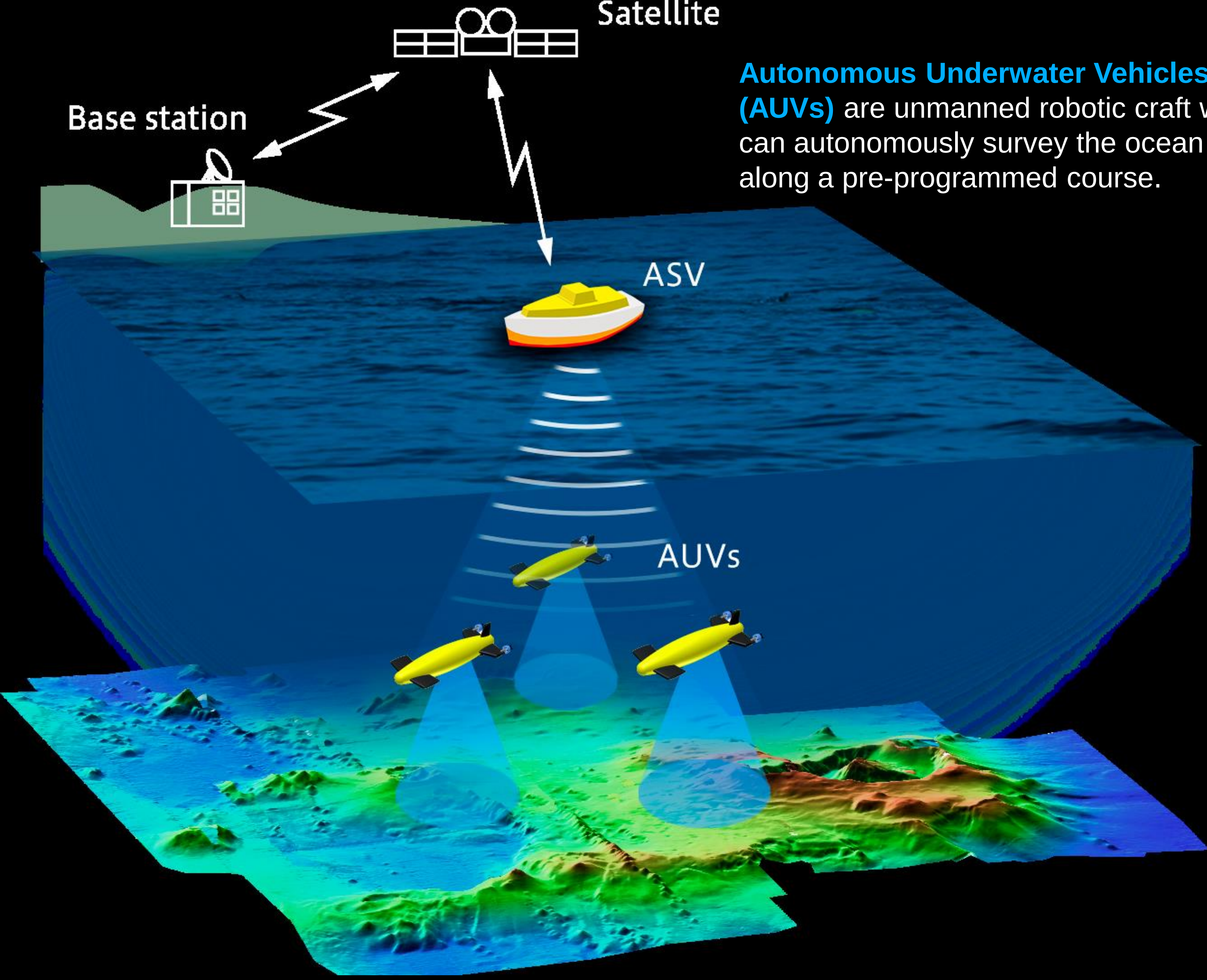
Submarine landslide

sea floor topography in the Gulf of Mexico



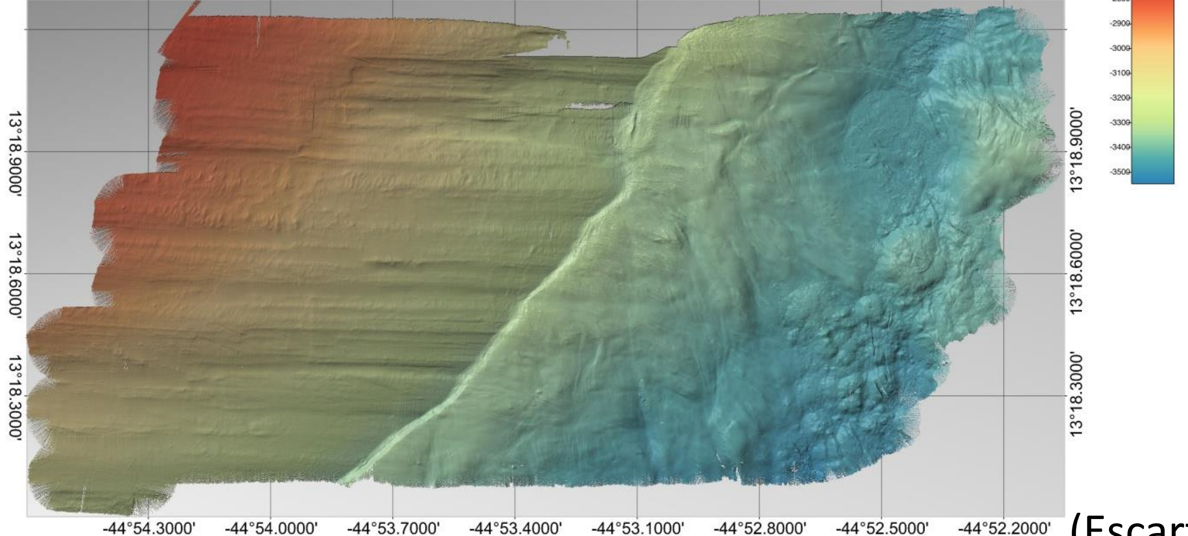
(William, 2016)

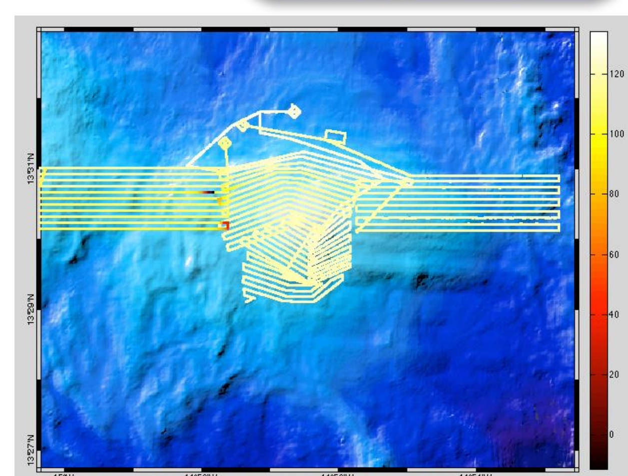
Submarine landslides are one of the main agents through which sediments are transferred across the continental slope to the deep ocean. They are ubiquitous features of submarine slopes in all geological settings and at all water depths. Hazards related to such landslides range from destruction of offshore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



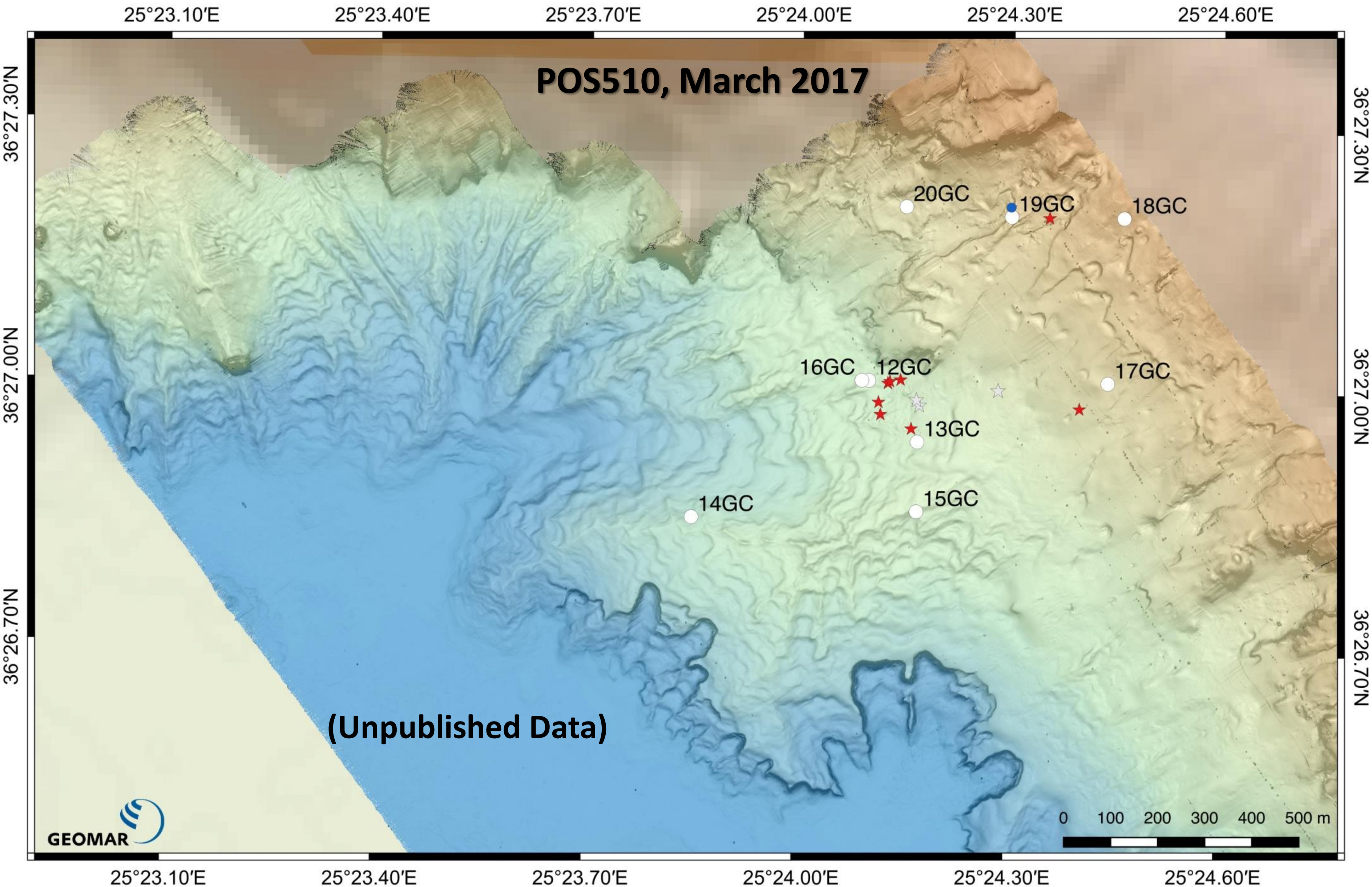
Autonomous Underwater Vehicles (AUVs) are unmanned robotic craft which can autonomously survey the ocean floor along a pre-programmed course.

AUV Abyss deployed by the side of the N/O Pourquoi pas? During the ODEMAR Cruise in 2013





(Escartin et al., 2014; 2016)



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.

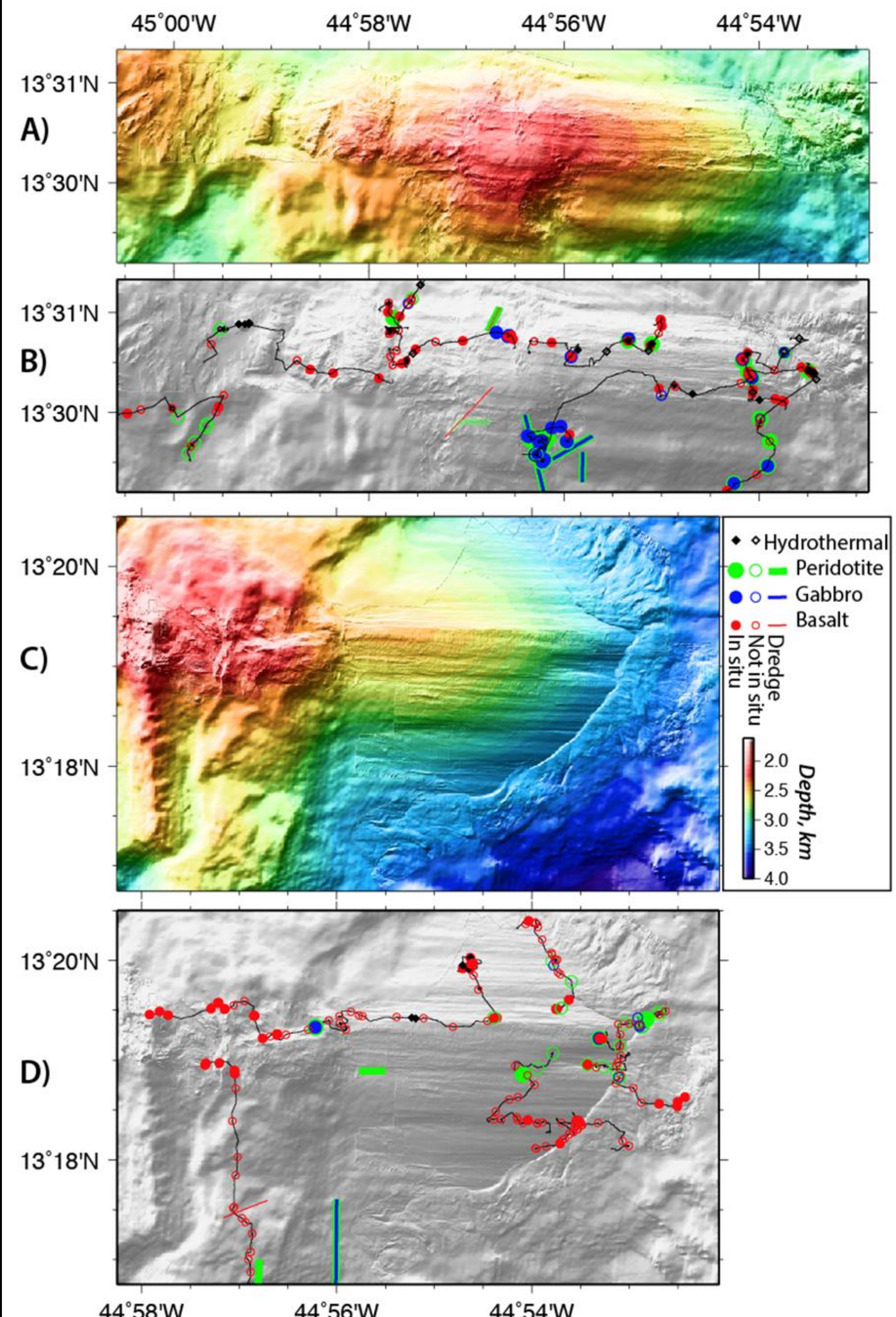
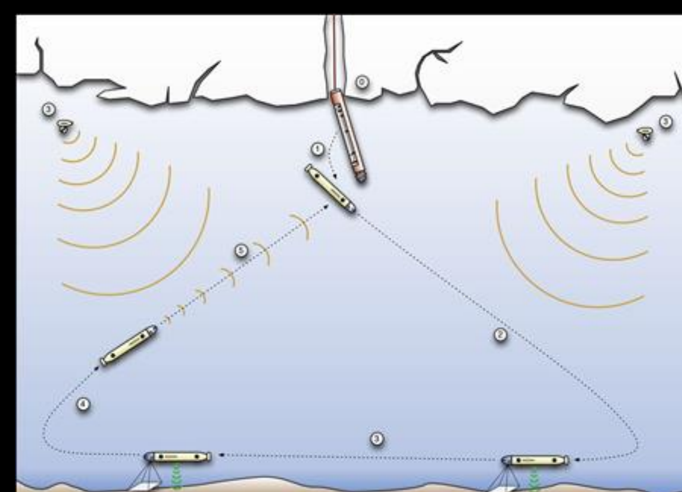
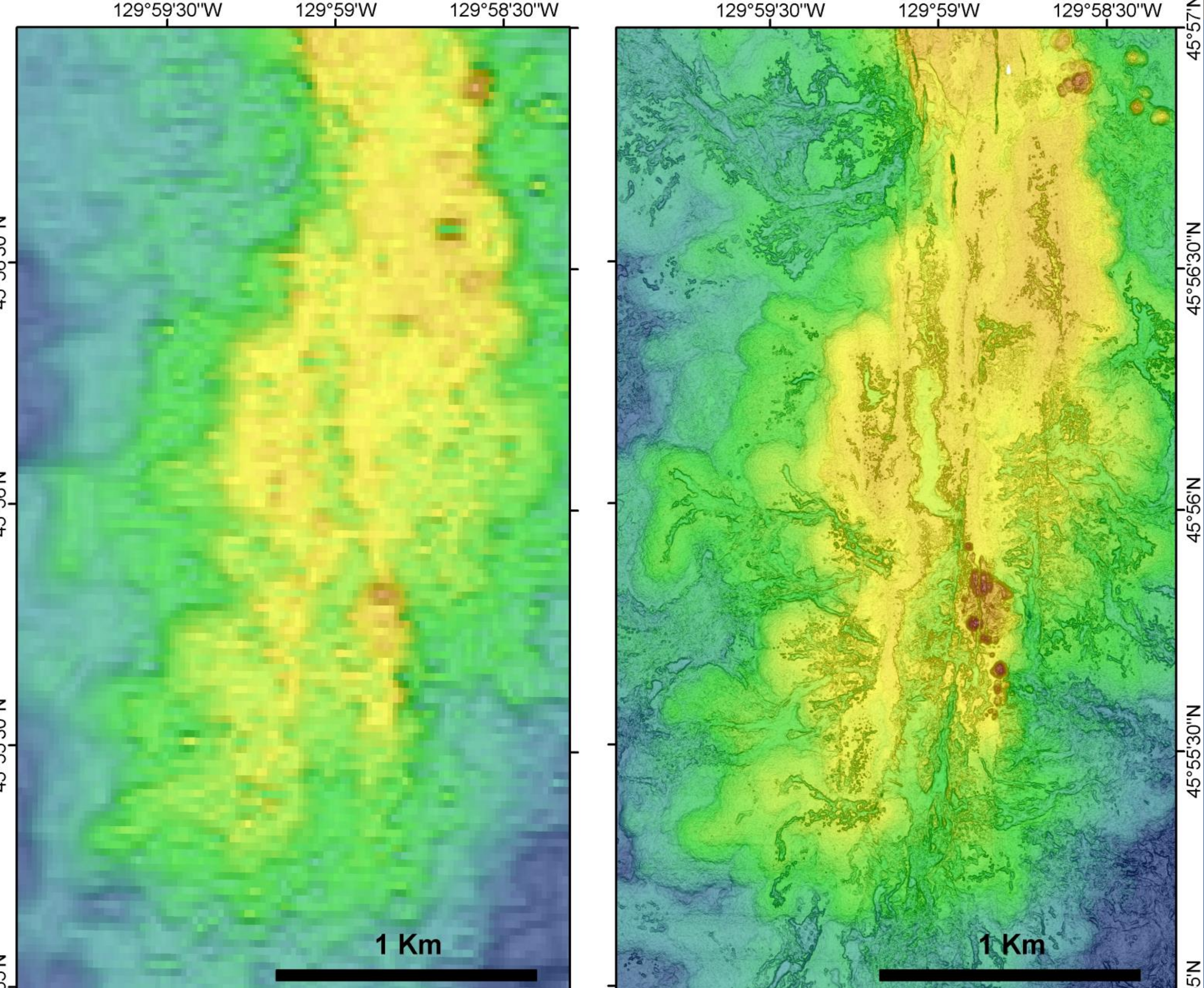


Figure 2, Escartín et al., G3 (2016)

AUV microbathymetry (merged with shipboard bathymetry) and primary rock types of samples recovered during ODEMAR ROV dives (black thin lines), and dredges (coloured lines of different thickness).

A) Microbathymetry of the 13°30'N OCC.
B) Shaded relief of the 13°30'N OCC and primary lithologies sampled.
C) Microbathymetry of the 13°20'N OCC.
D) Shaded relief of the 13°20'N OCC and primary rock types sampled. Locations of the two microbathymetric maps are shown in Figure 1. The limit of the AUV surveys is visible at the transition from the smooth shipboard bathymetry (40x40 m pixels) and the AUV bathymetry (2x2 m pixels).

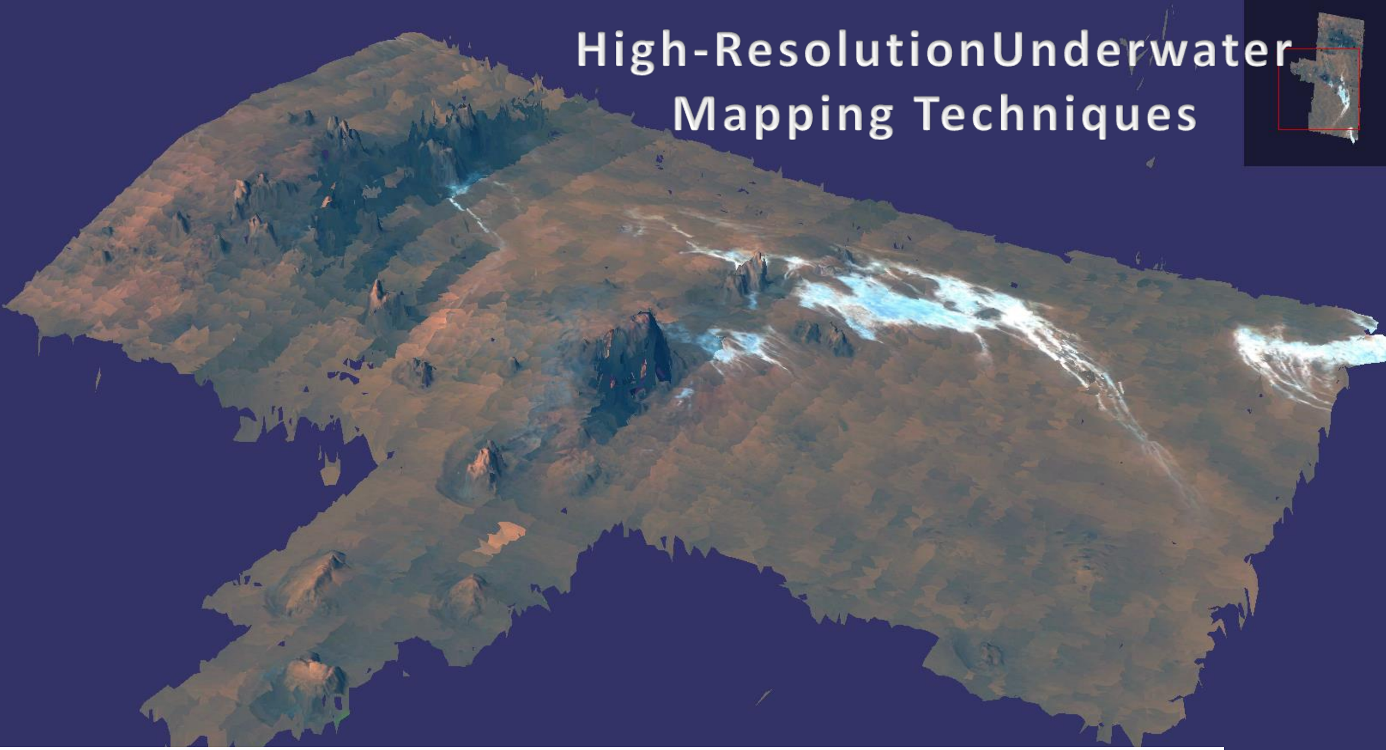




Left: ship-collected bathymetry at 20m resolution
Bottom: AUV-collected bathymetry at 1m resolution
(Paduan et al., 2009)

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.

High-Resolution Underwater Mapping Techniques



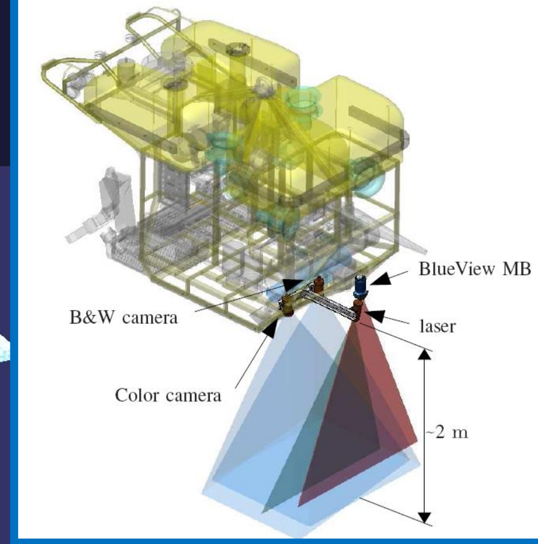
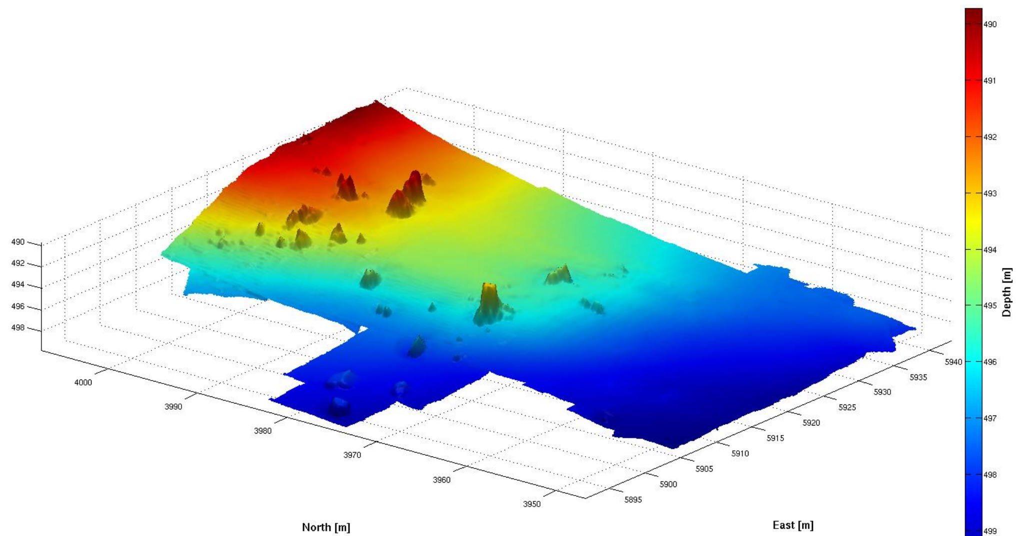


Image based techniques
Photomosaicing
Stereo reconstructions

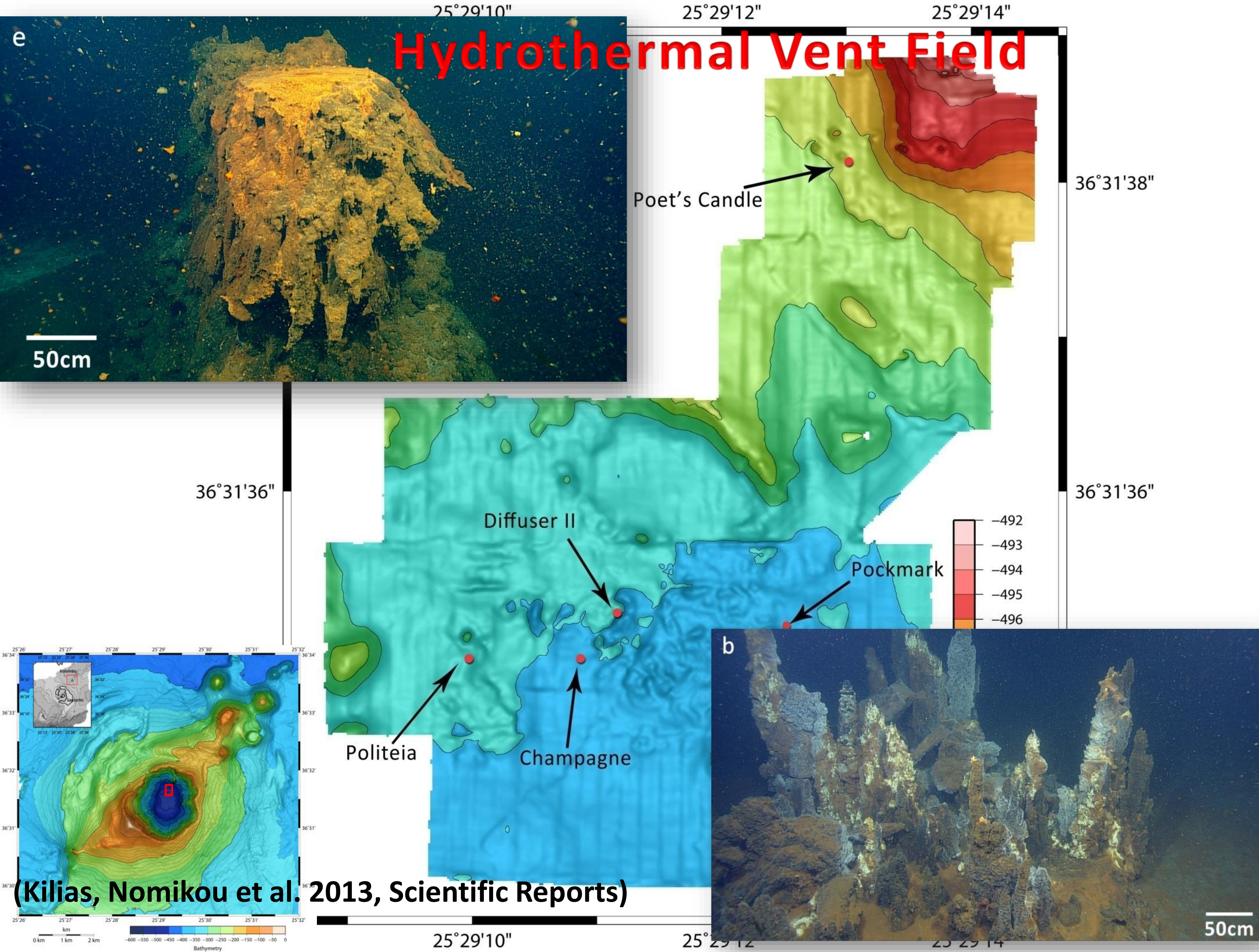
Visual survey in the Poet's Candle area showing the vents and white bacterial mat. Twenty-seven hundred individual stereo pairs were used to create the final image.



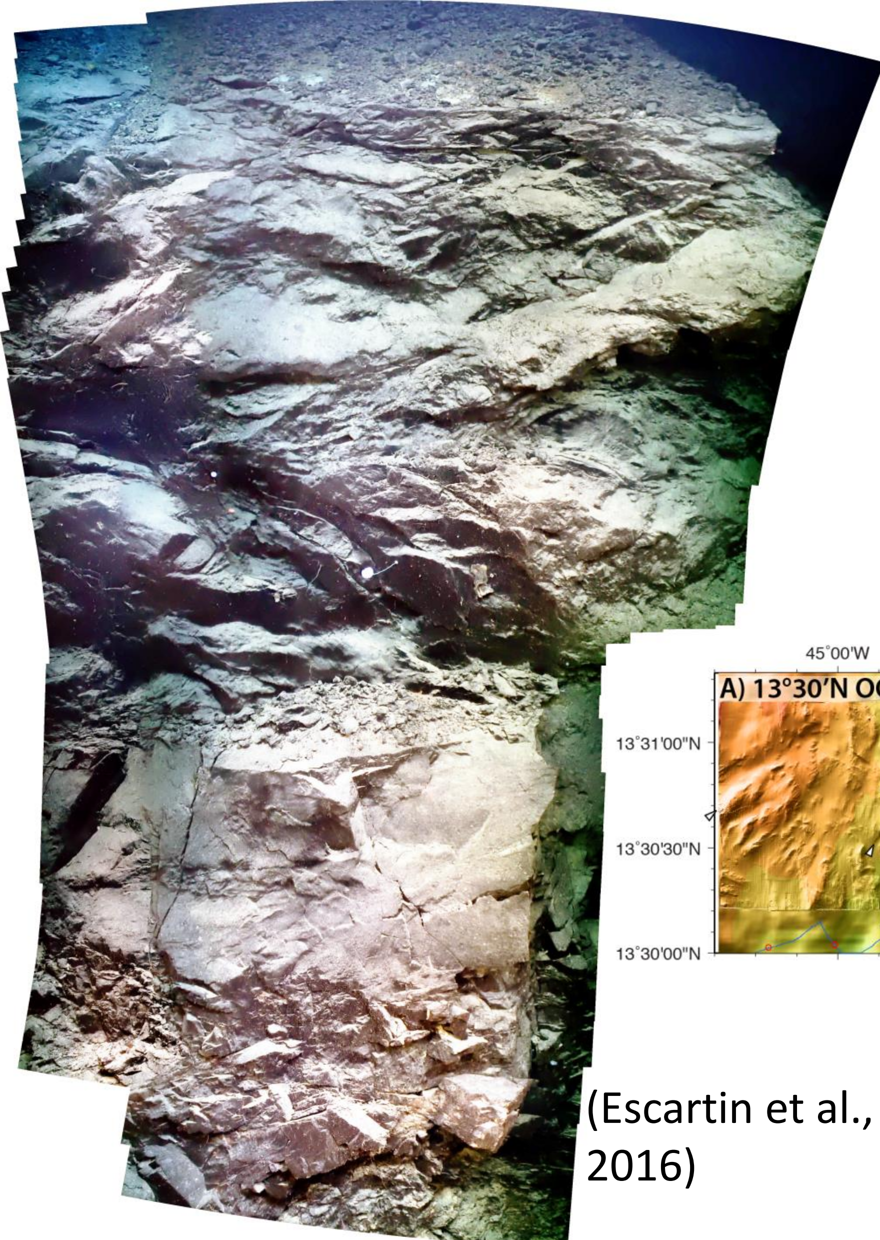
Side view of Chewbacca area multibeam. Poet's Candle is the large structure between blue and green.

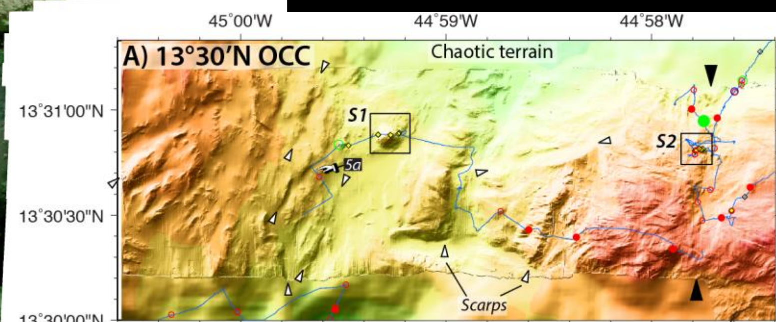
High frequency multibeam
Frequencies > 500 kHz

Hydrothermal Vent Field



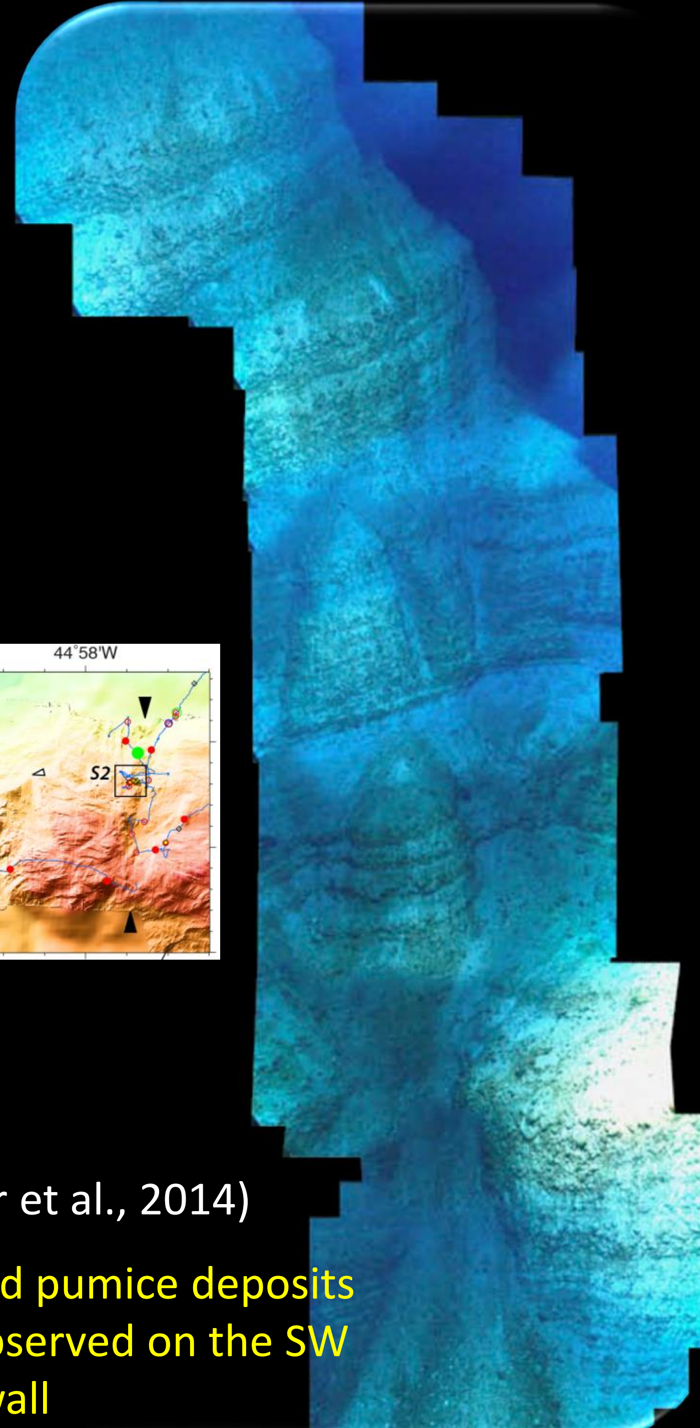
(Kilias, Nomikou et al. 2013, Scientific Reports)





(Escartin et al., 2016)

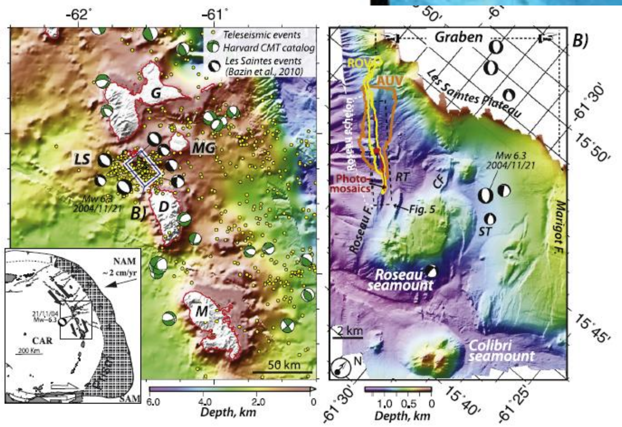
Cross-section of the 13°30'N *detachment fault zone along a vertical fault scarp, ~8-10 m high*

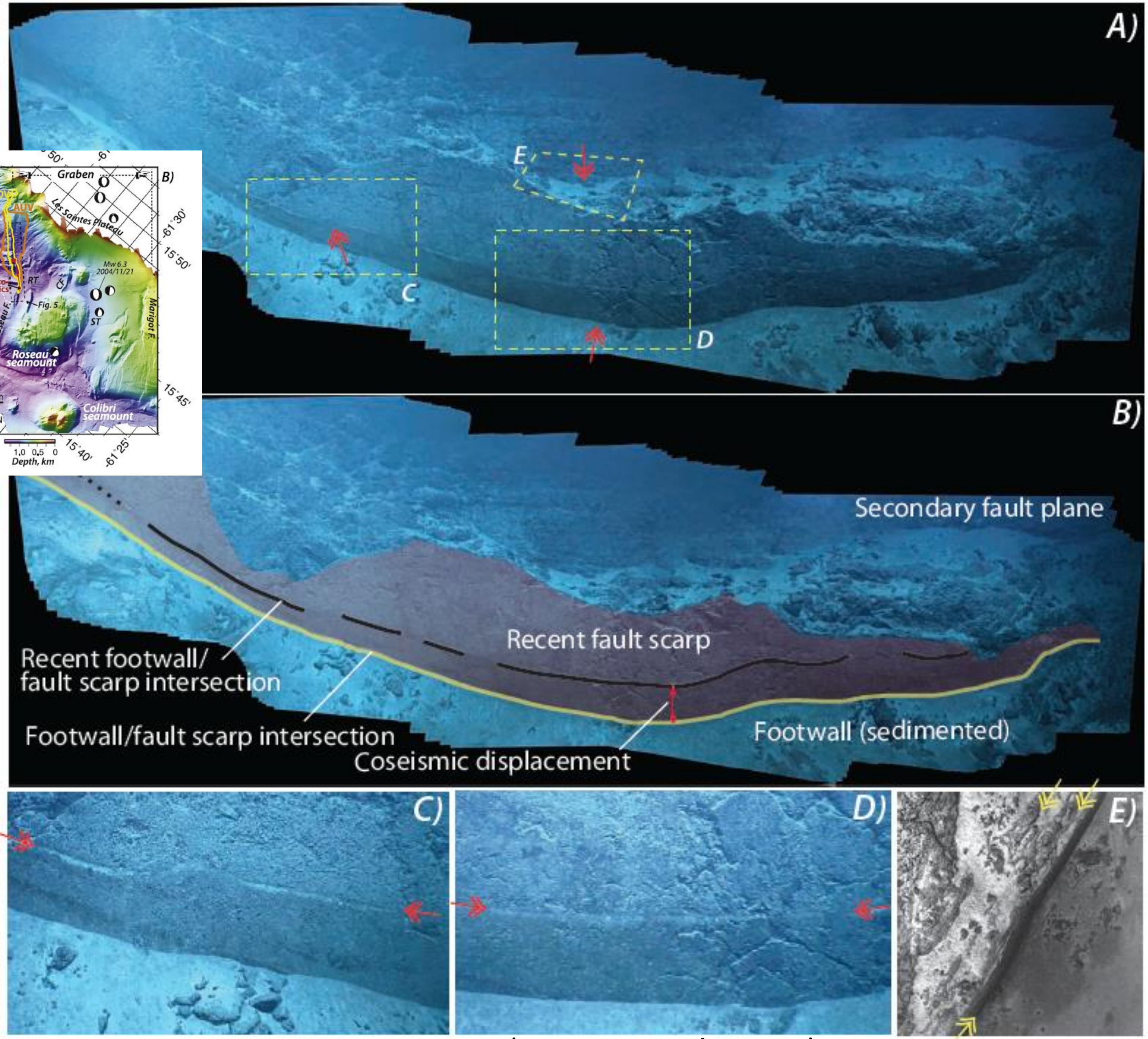


(Cartner et al., 2014)

Stratified pumice deposits were observed on the SW crater wall

21/11/2004
Les Saintes
earthquake



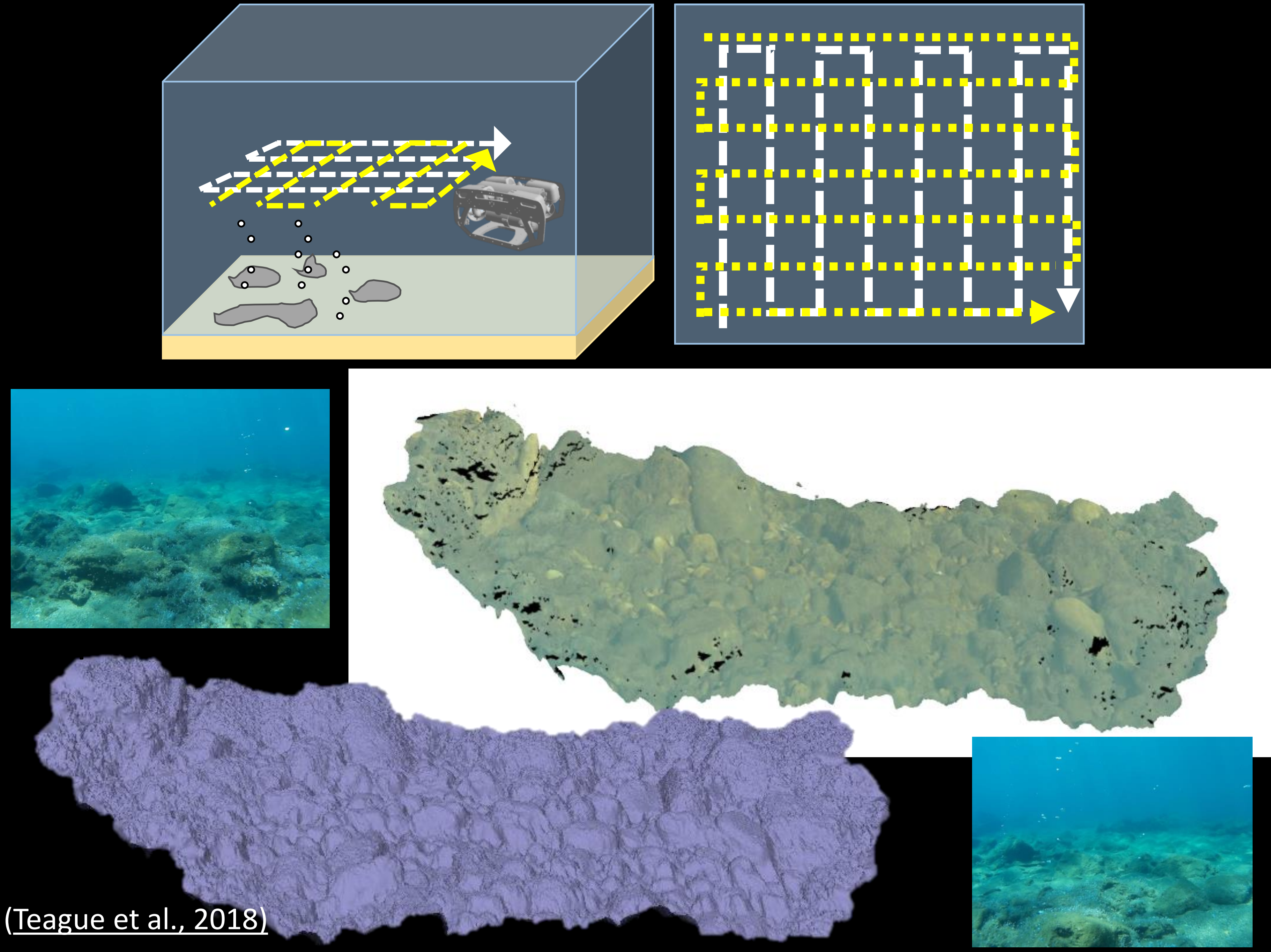


(Escartin et al., 2016)

Exploring offshore hydrothermal venting using low-cost ROV and photogrammetric techniques: a case study from Milos Island, Greece

The use of low-cost, Remotely Operated Vehicle (ROV) and underwater photogrammetry techniques, Structure from motion (SfM) for 3D reconstruction of shallow hydrothermal vent sites around Paleochori Bay, Milos Island, Greece. Venting fields were Characterised through interactive bathymetry models produced from still images taken from camera onboard ROV flown over areas of interest in double raster pattern

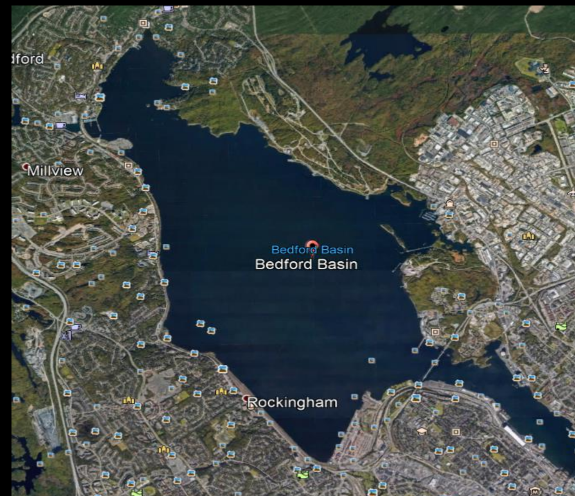
(Teague et al., 2018)



(Teague et al., 2018)

Seafloor Mapping from Multispectral Multibeam

Bedford Basisn, Canada

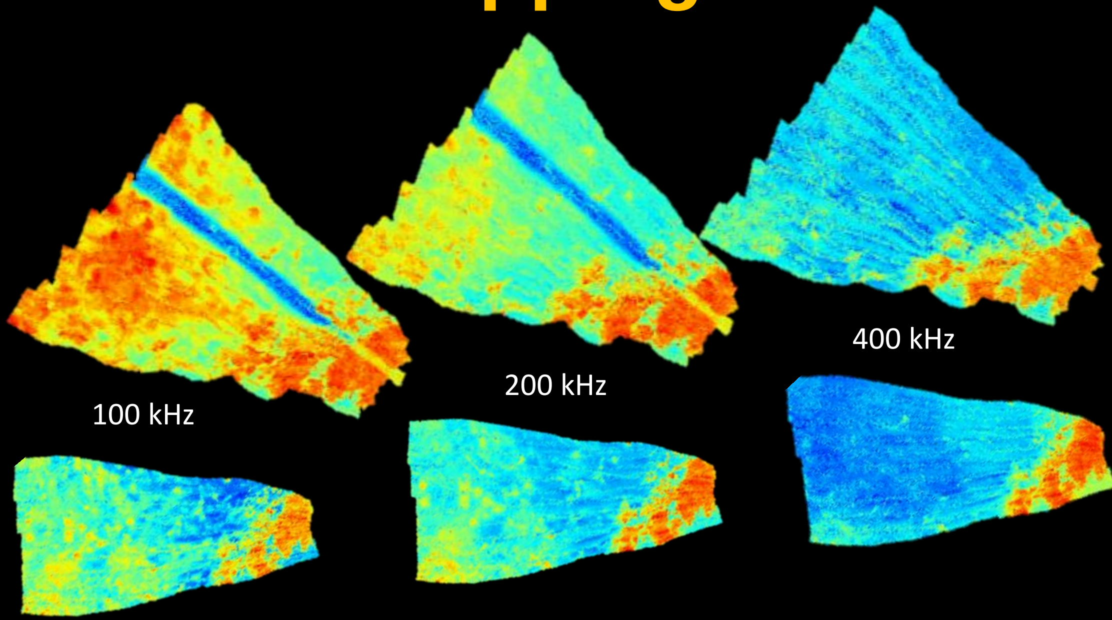


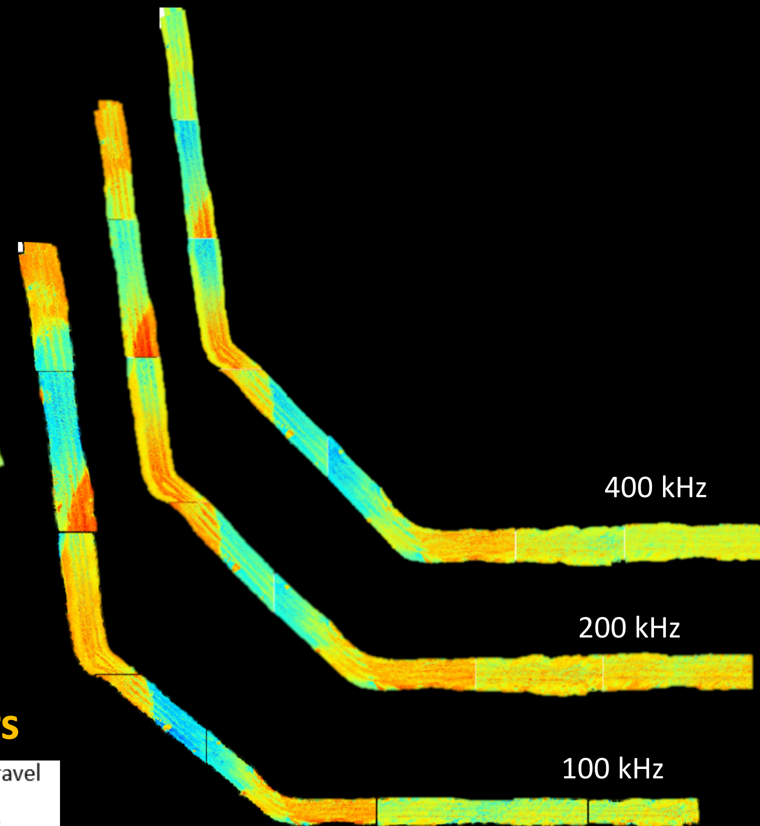
Patricia Bay, Canada

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





Novel Machine Learning *(single)* Model for all Seafloors

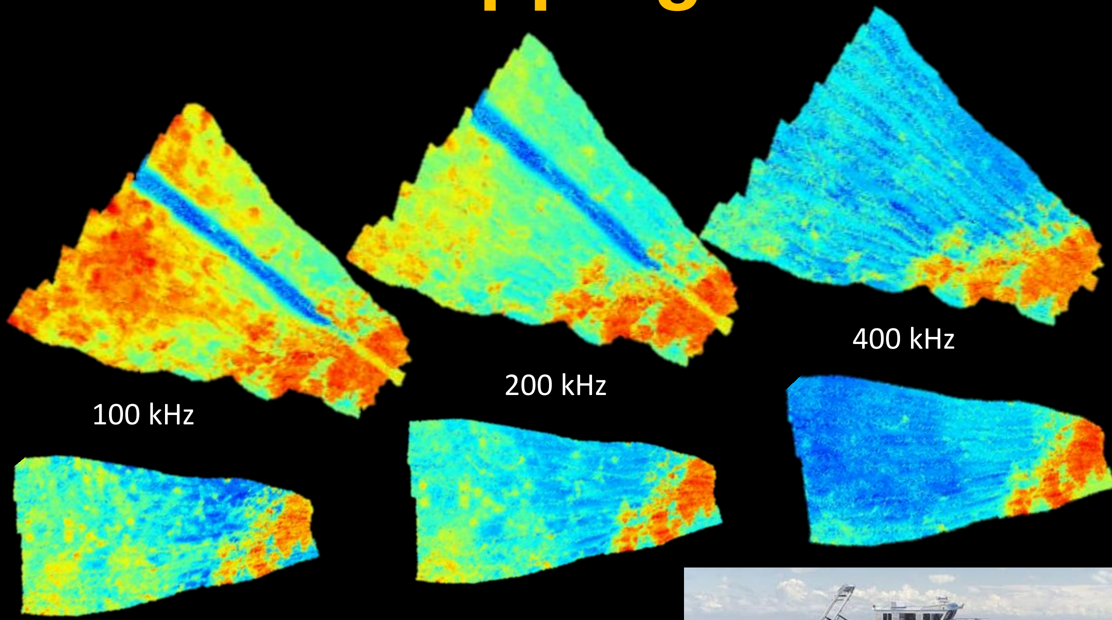
Prediction	Yellow Sand	Sand with algae	M.S.C.	Fine Sand	Rocky / Gravel
Yellow Sand	**97%**	5%	0%	0%	0%
Sand with algae	3%	**92%**	0%	0%	0%
Mud Sand with corals (M.S.C)	0%	2%	**98%**	10%	0%
Fine Sand	0%	1%	2%	**90%**	0%
Rocky / Gravel	0%	0%	0%	0%	**100%**

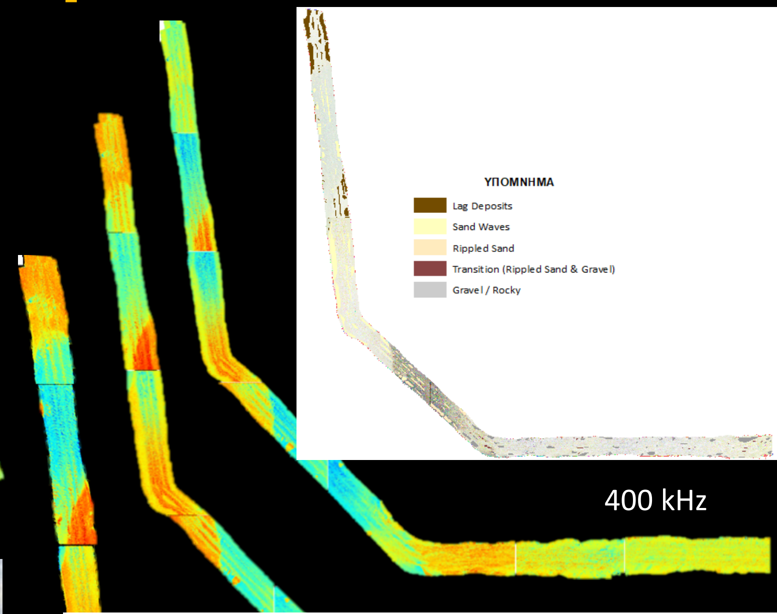
Overall Accuracy = 96%

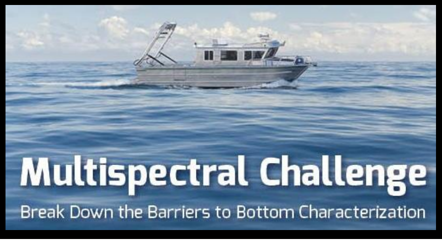
Categories	**UA**	**PA**	**Pixels of Ground Truth**
Yellow Sand	97%	98%	726670
Sand with algae	92%	94%	341968
Mud Sand with corals (M.S.C)	98%	91%	535967
Fine Sand	90%	96%	370125
Rocky / Gravel	100%	100%	468989

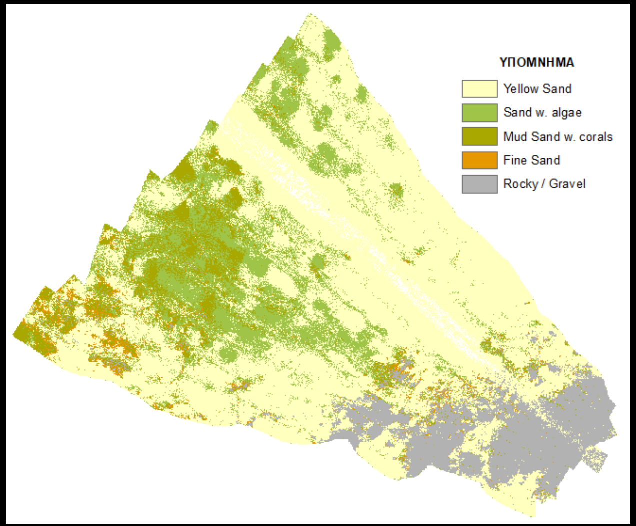
(Mertikas & Karantzalos, 2019. IEEE OCEANS)

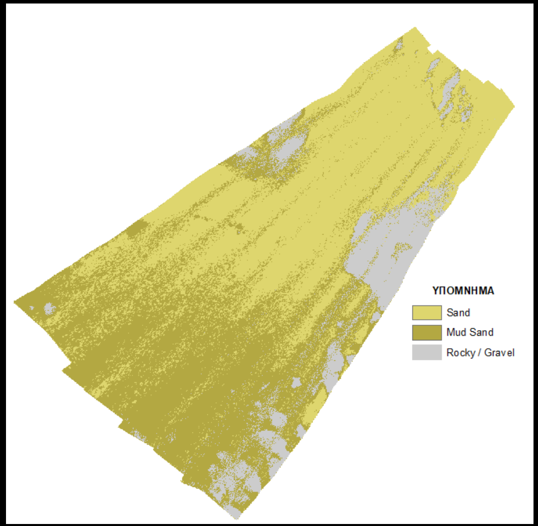
Seafloor Mapping from Multispectral Multibeam

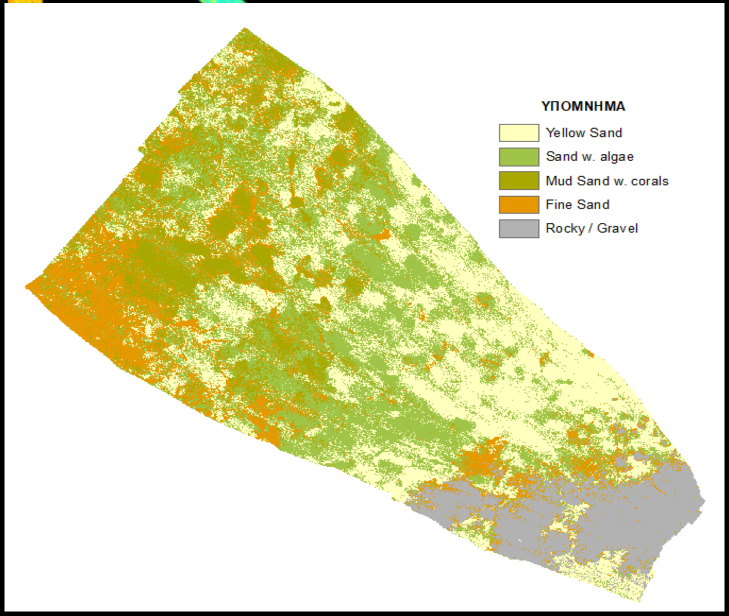






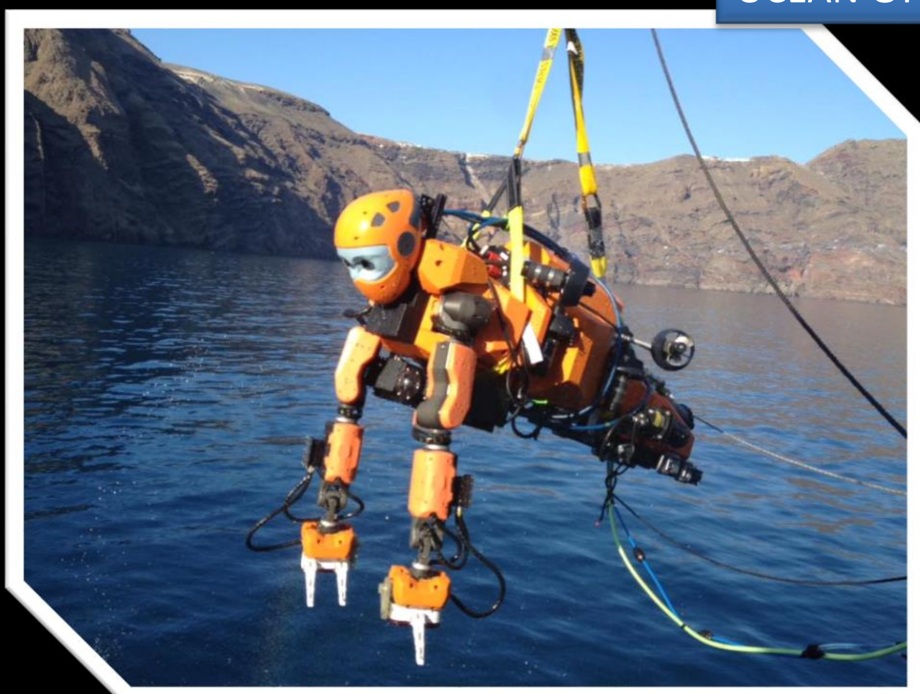






(Mertikas & Karantzalos, 2019. IEEE OCEANS)

OCEAN ONE



Multichannel Seismic data

Research Vessel

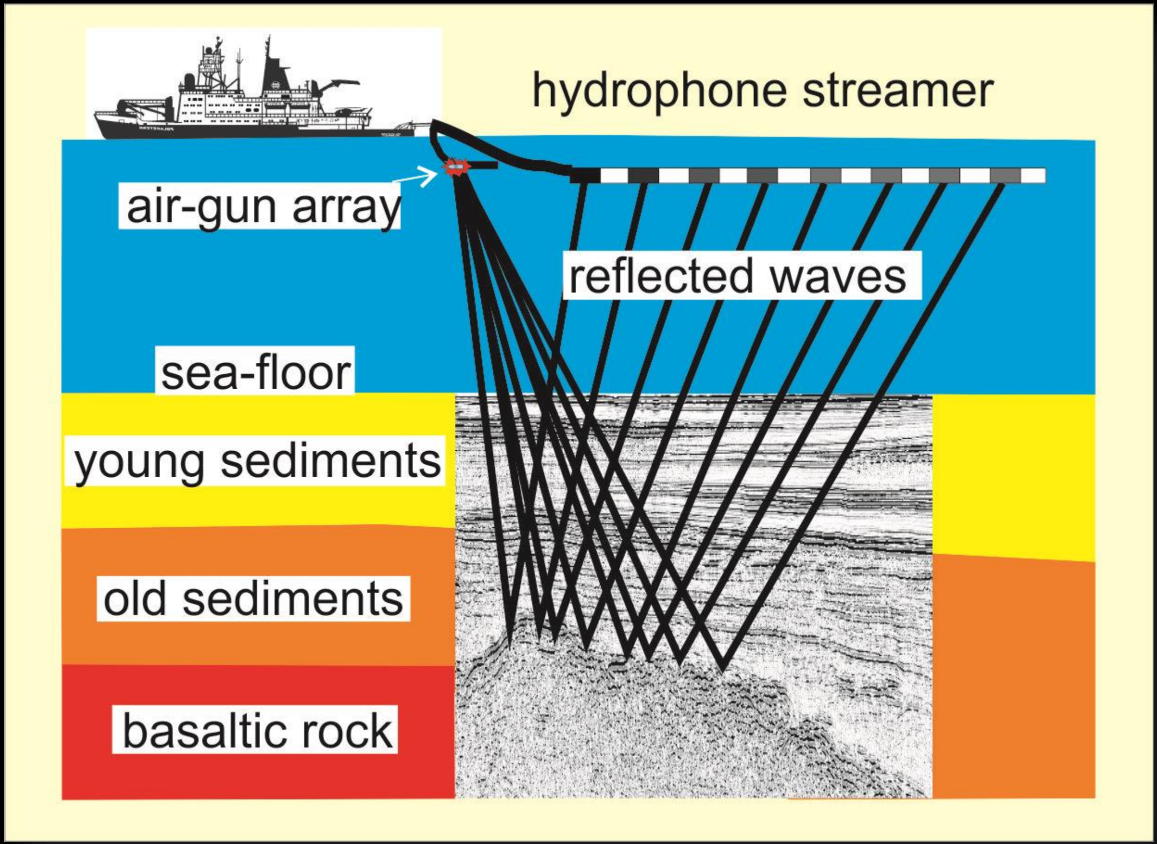
Delta Sparker/airgun

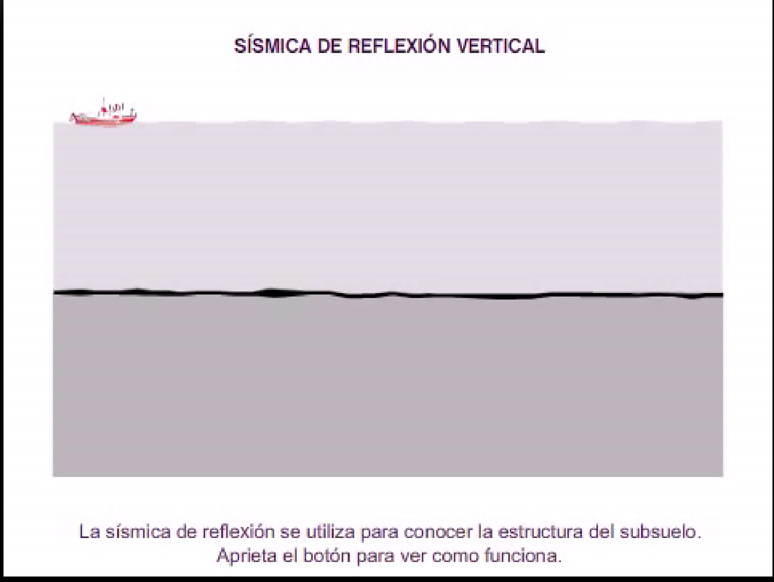
24/16 channel streamer

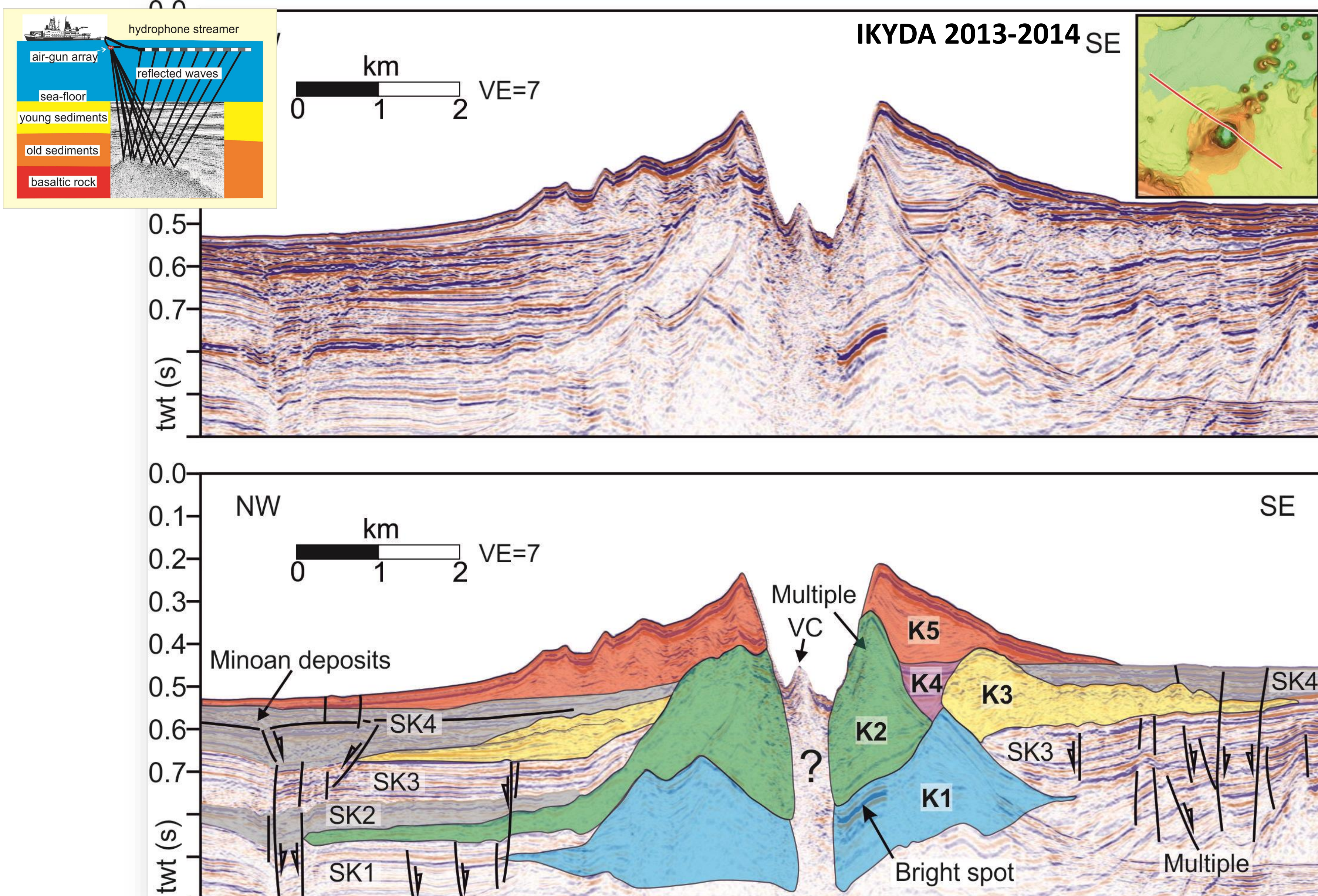
Processing: Seismic Unix/Vista

Post-processing: Vista

Final SEG-Y files

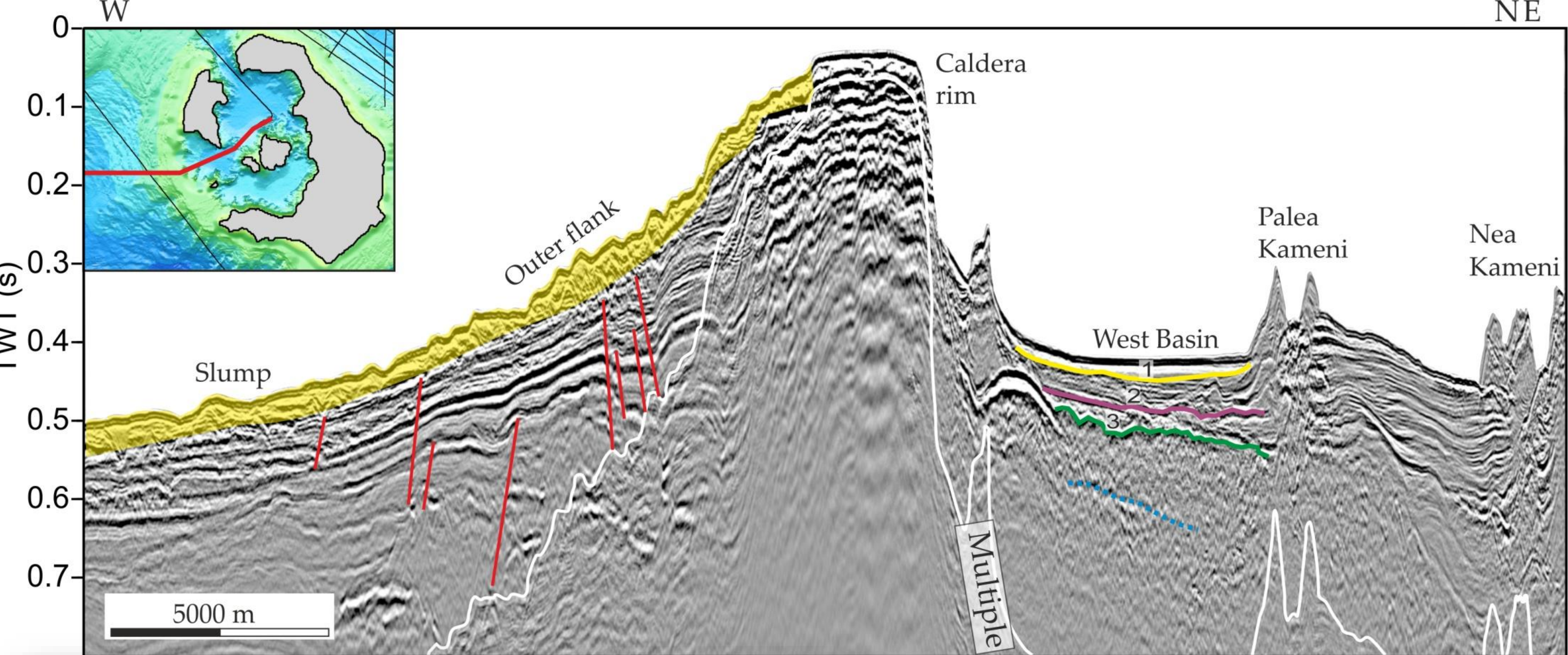


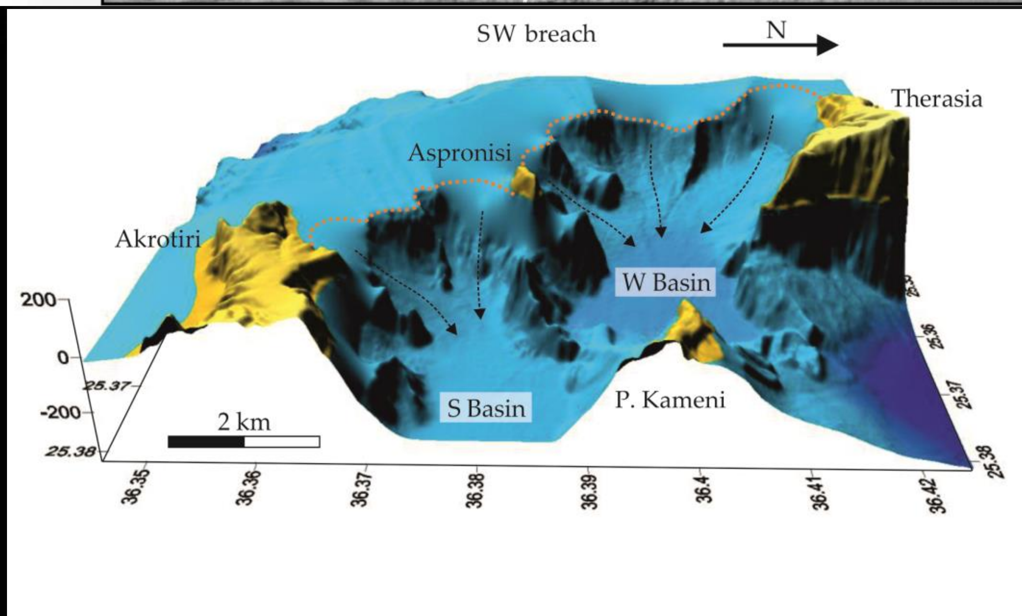




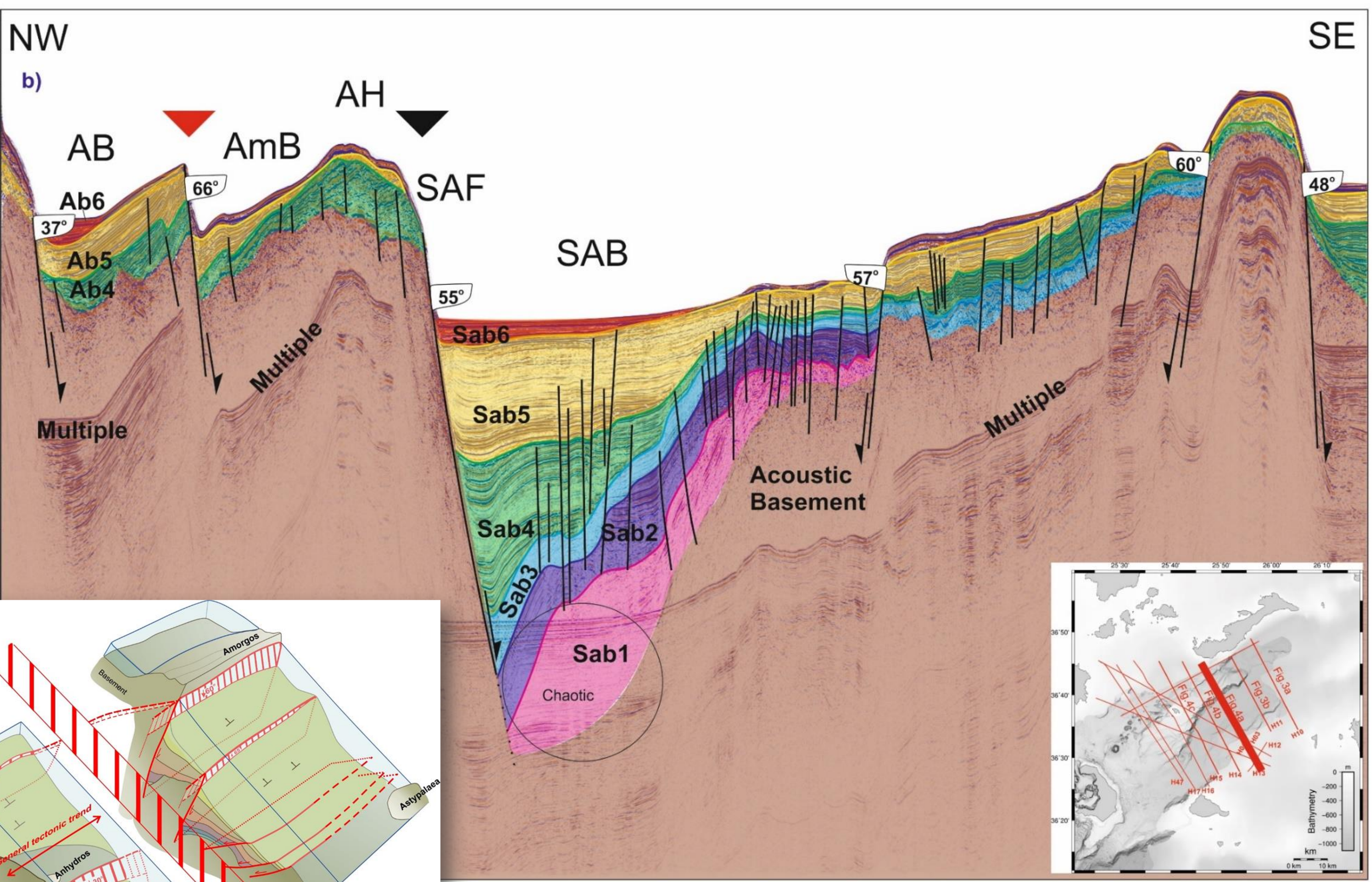
The reflection seismic interpretation of the multi channel profiles reveals the 3D-structural evolution of Kolumbo volcano which comprises three major (K1, K2 and K5) and one to two (K3 and K4) smaller eruptive phases.

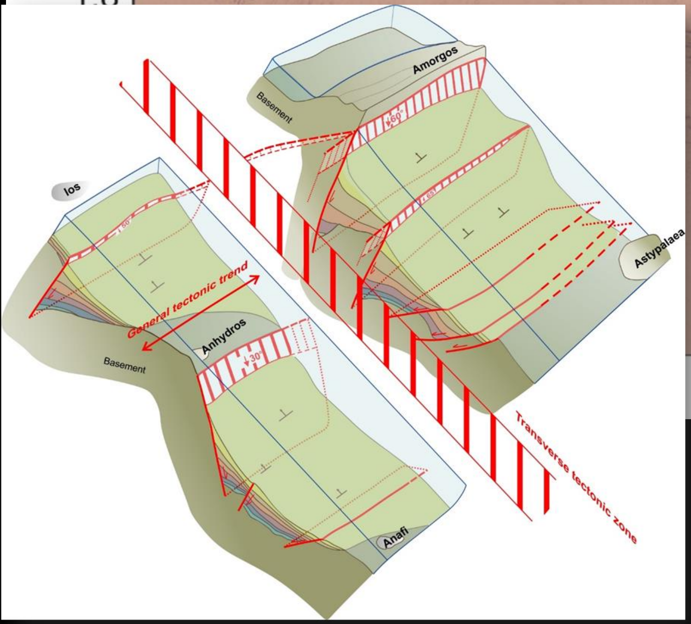
(Hubscher et al., 2015; Nomikou 2016)



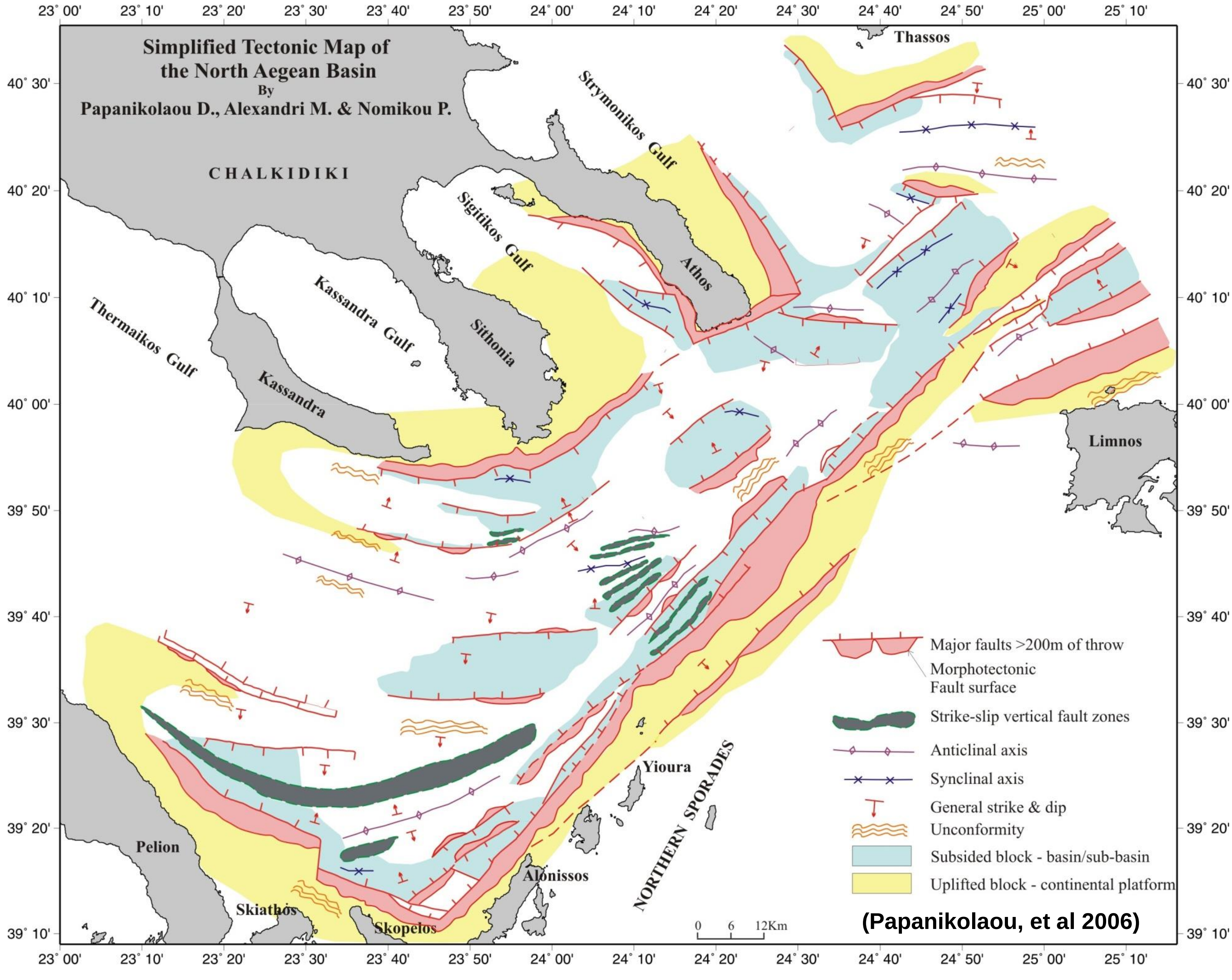


The southwest straits are morphologically fresh, and have landslide scars with well preserved headwalls and intervening septa. The headwalls are steeper than that of the NW strait, and are less scarred by secondary slumping and drainage channels (Nomikou et al., 2016).

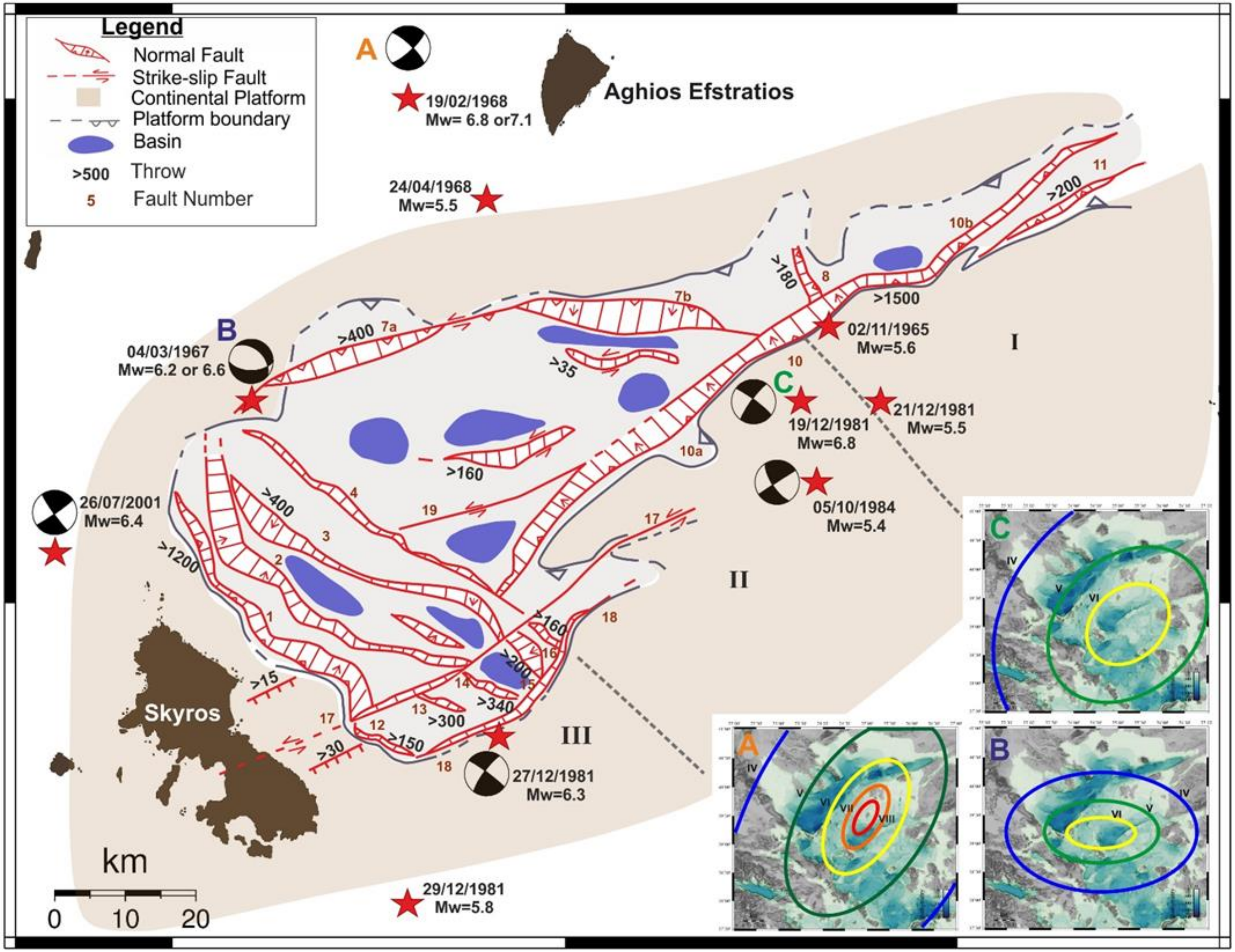




Seismic profiles showing the major fault zones at the western part of Santorini volcano (Nomikou et al., 2018)



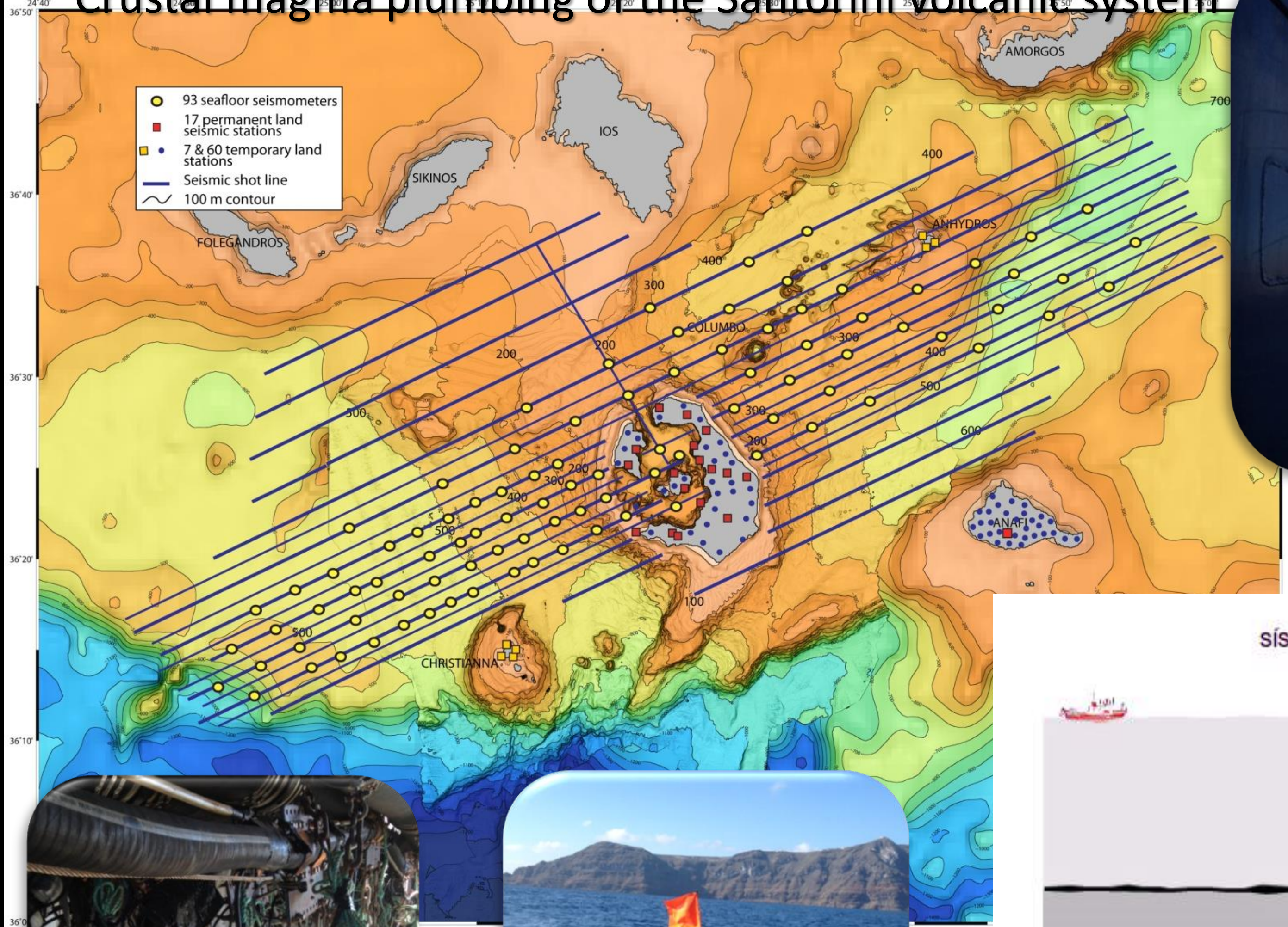
(Papanikolaou, et al 2006)



(Papanikolaou et al., 2018)

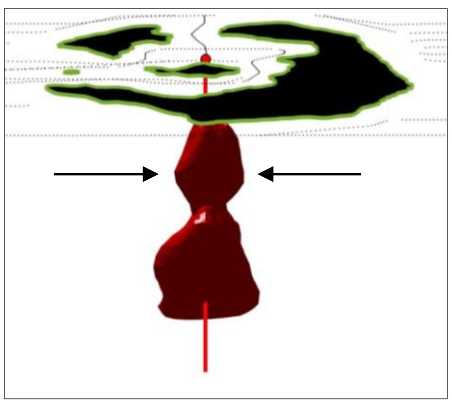
Santorini Seismic Experiment

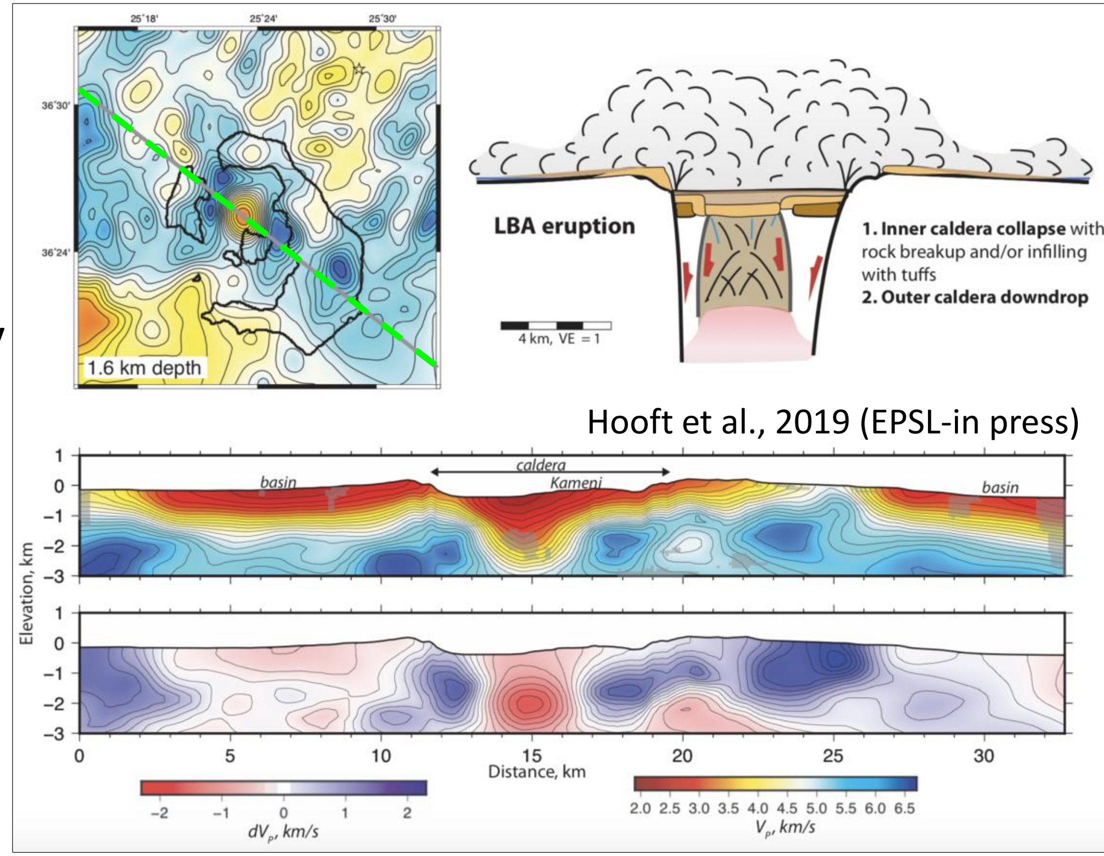
Crustal magma plumbing of the Santorini volcanic system



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





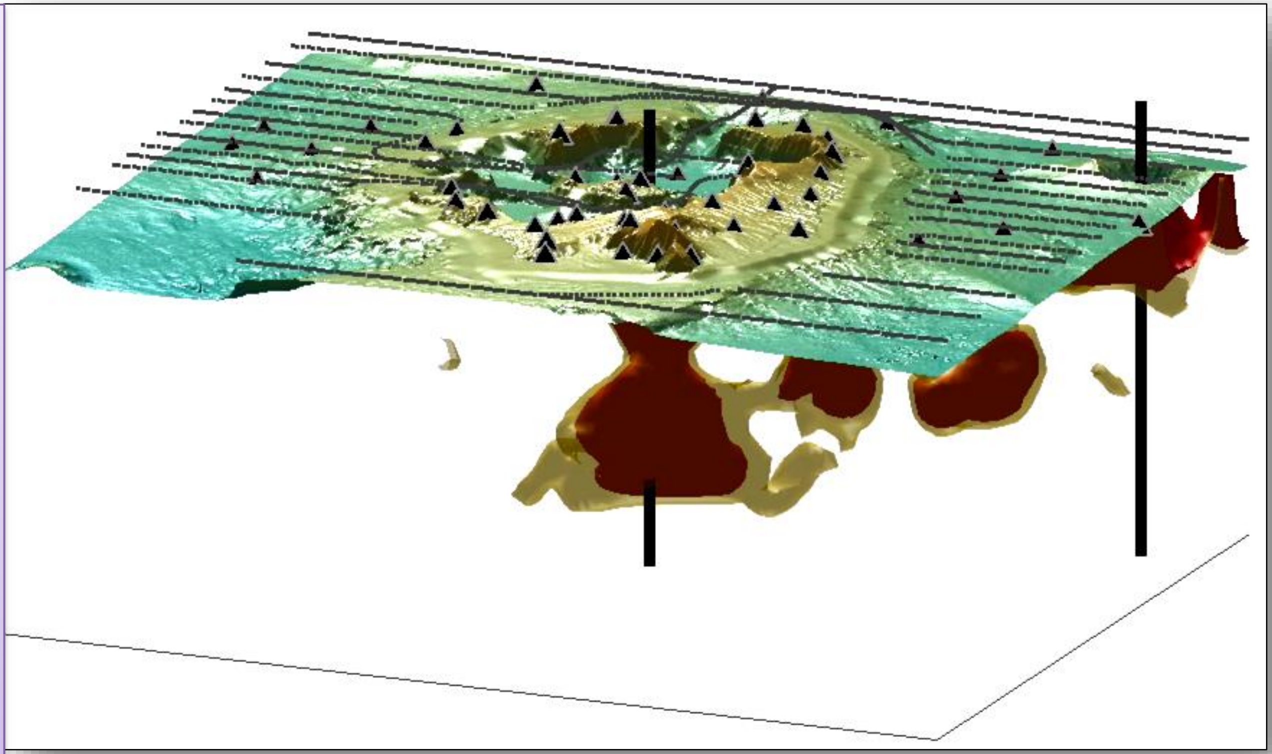
Low velocities near the seafloor delineate sedimentary basins on the flanks of the volcano. The deeper low-velocity anomaly north of the Kameni islands corresponds to the high-porosity column within the north-central caldera. Higher velocities are due to metamorphic and/or plutonic rocks.

Upper crustal magma chamber properties using P-wave tomography at Santorini Volcano, PROTEUS seismic project:

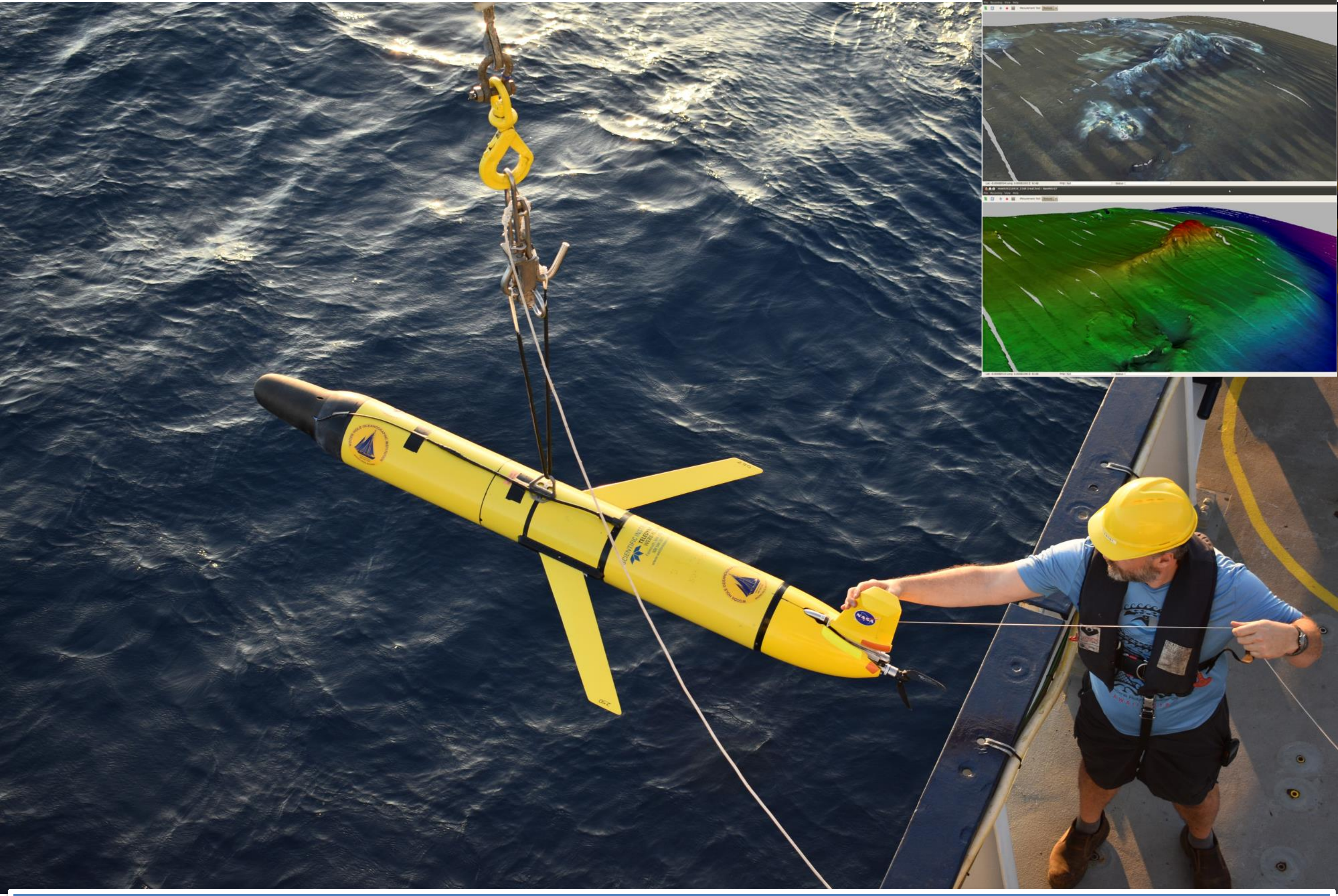
1) Shallow crustal magma chamber under Santorini, consistent with inflation source and petrologic observations

2) Minimum volume and intrusion rate agree with long-term magmatic cycle

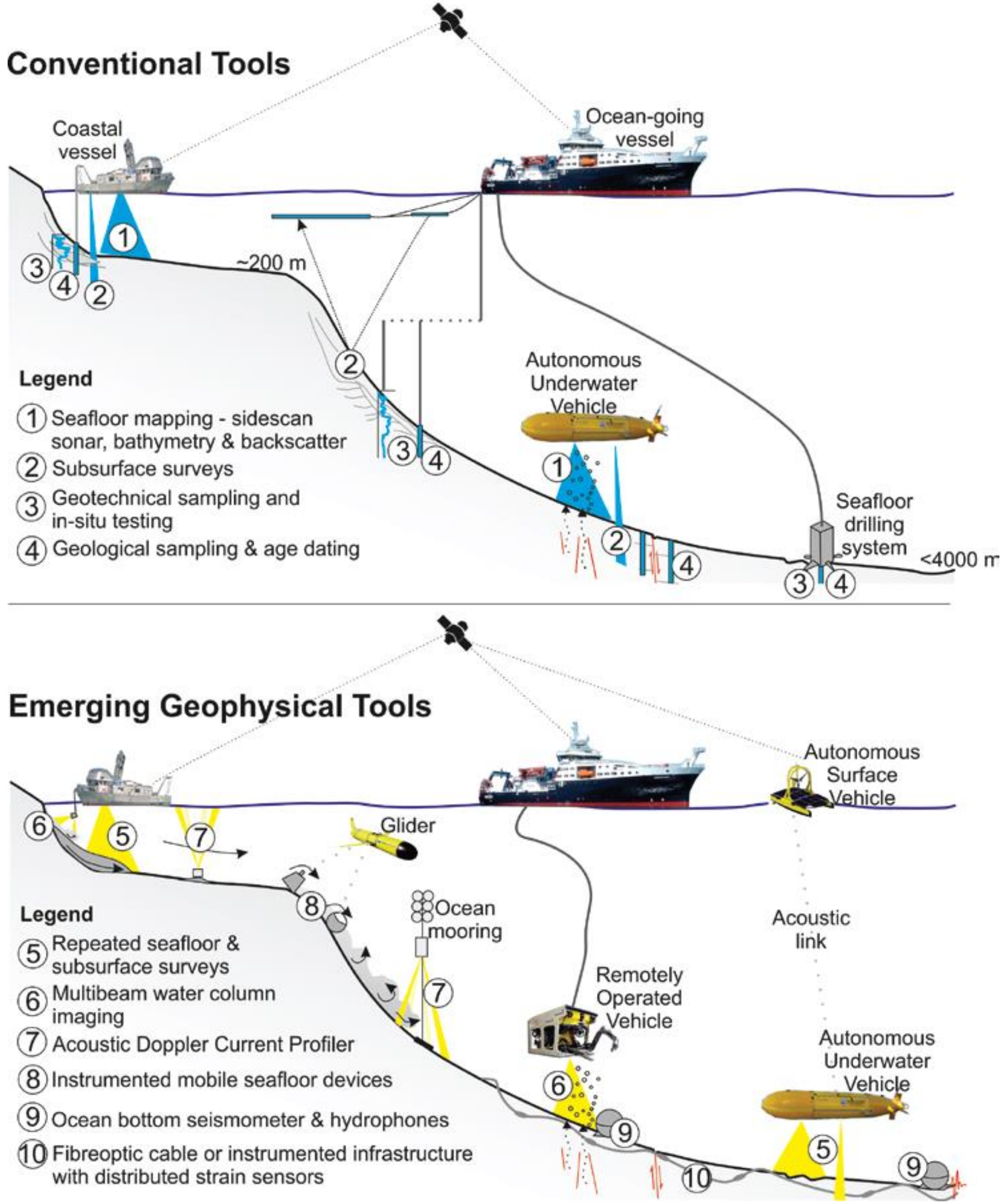
3) Additional methods are required to improve size and melt content estimates



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



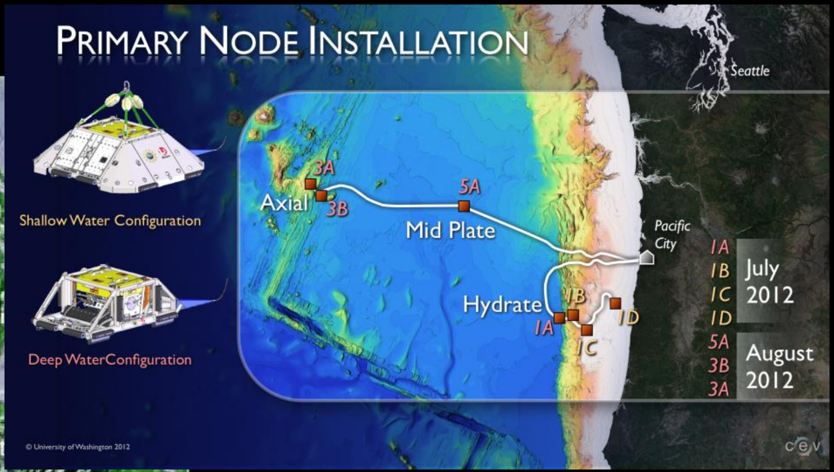
NASA project 2016-2019: Autonomous exploration and characterization of biological assemblages and correlated geochemical features within hazardous marine volcanic systems.

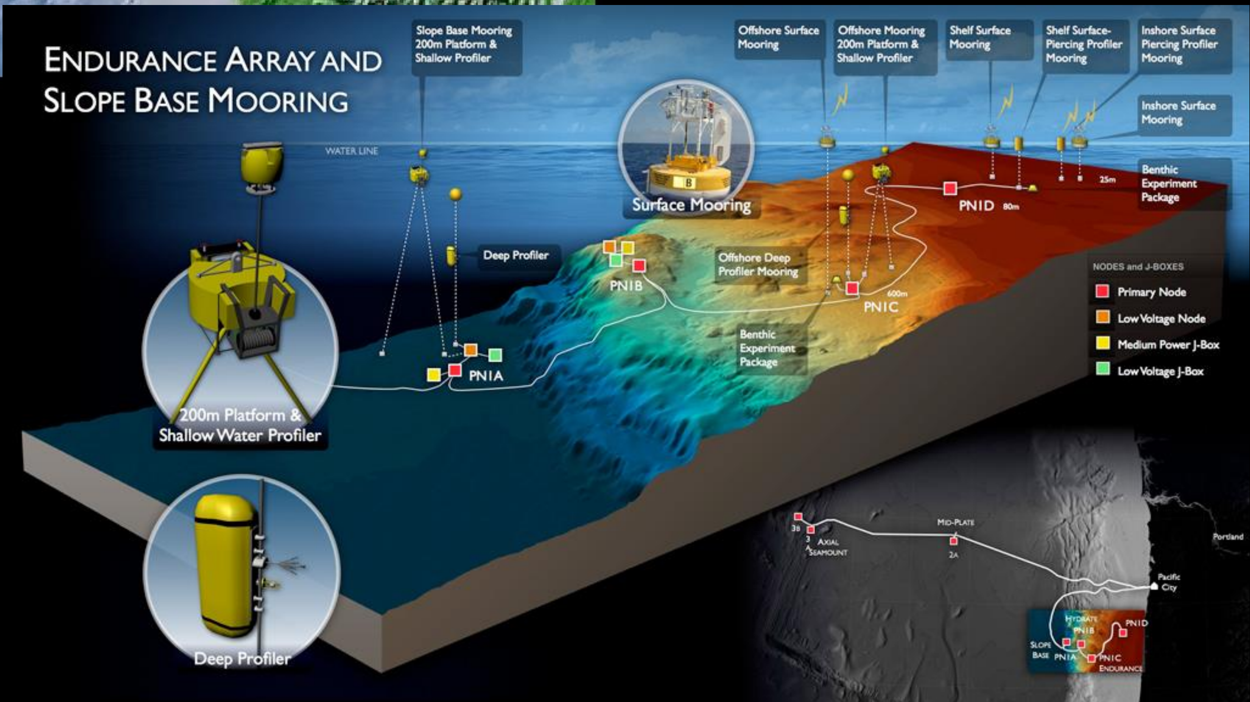


Clare et al., 2017

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.

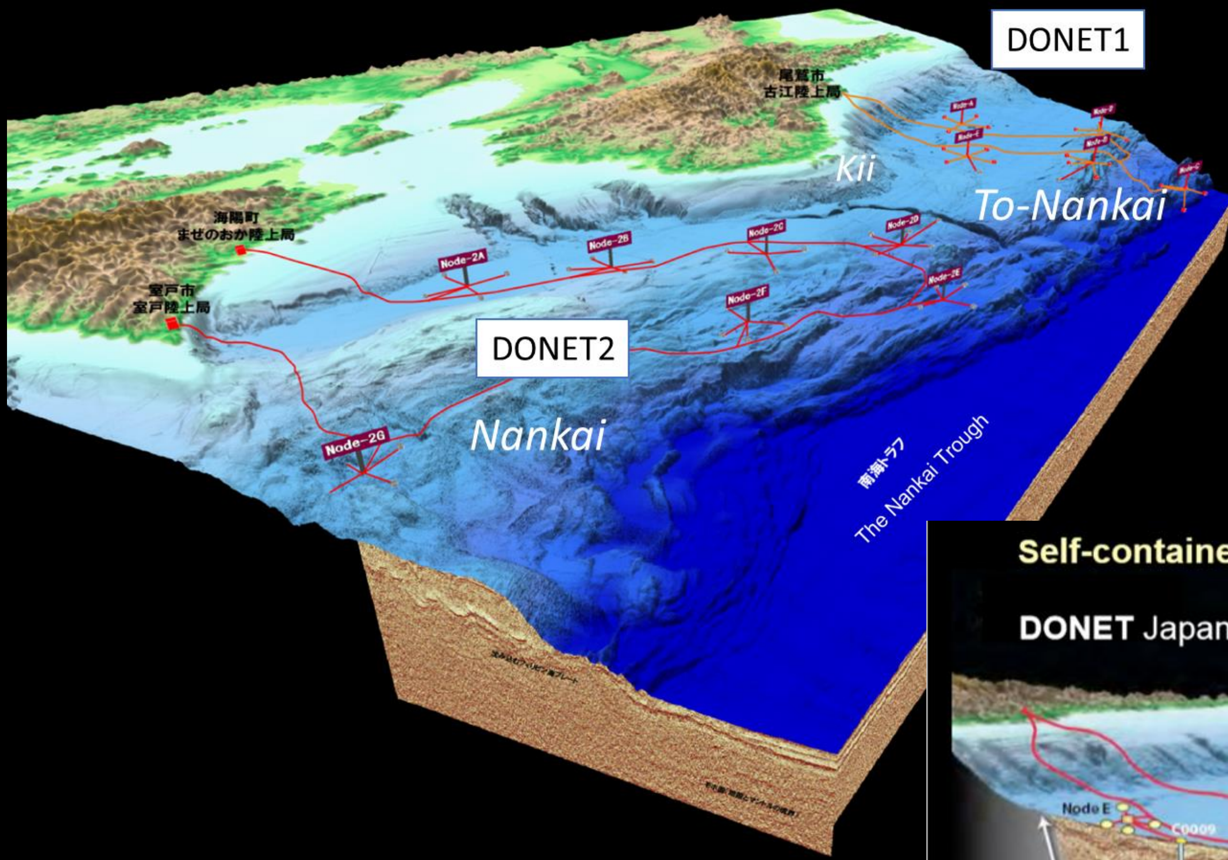
NEPTUNE Canada and USA



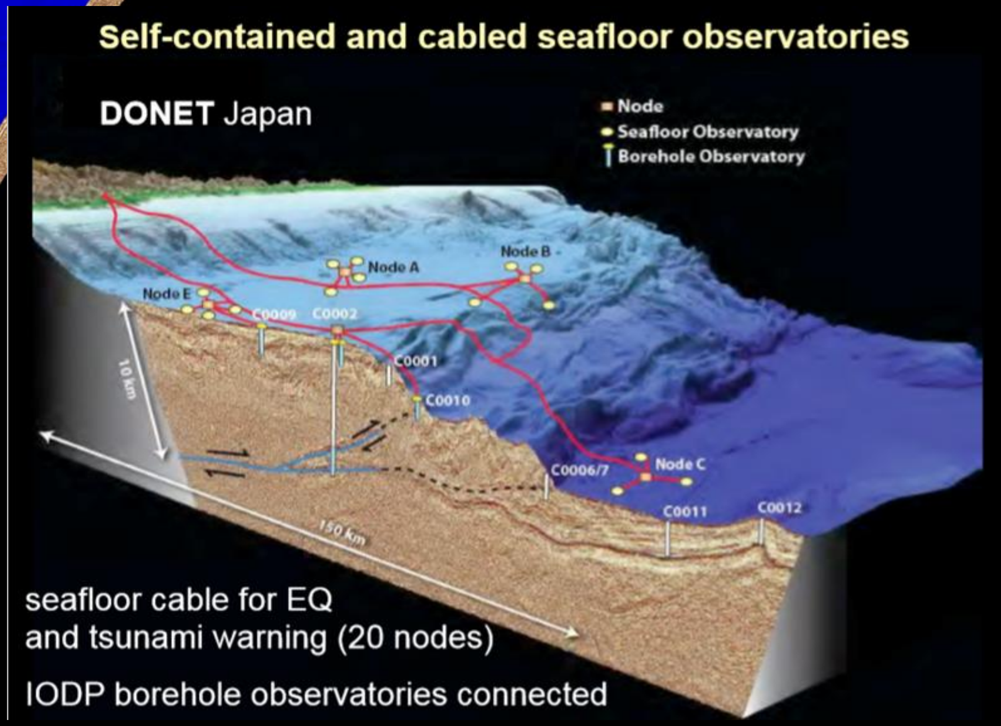


The OOI presents a remarkable opportunity to connect land based seismic networks and GPS observations with seismic and pressure measurements offshore using similar sensors and real-time connectivity

Japan



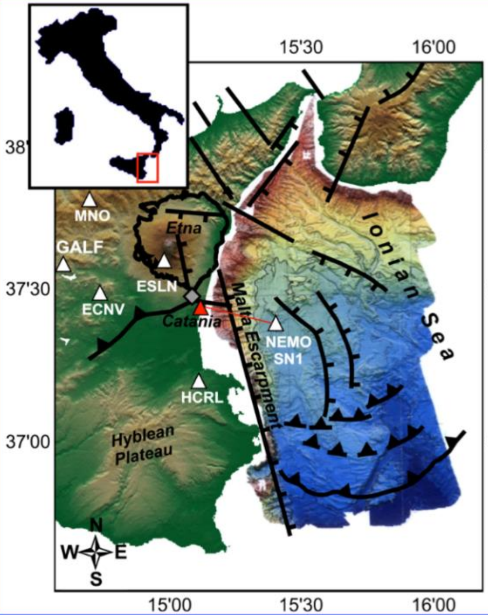
The combination of seismometers and pressure gauges permits discrimination of the earthquake's motion of the seafloor from the ocean's response in the form of surface tsunami waves right at the source location.

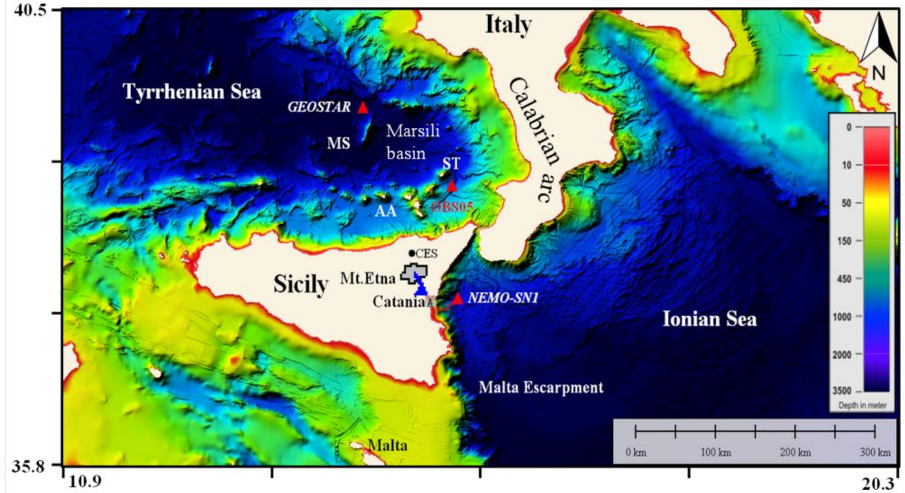


The Japanese do have a seafloor cable for earthquakes and tsunami warning and understand the value of warnings as early as possible to save lives ashore.

An *European observatory network* involving potential geohazard fields in Mediterranean needs to be supported by:

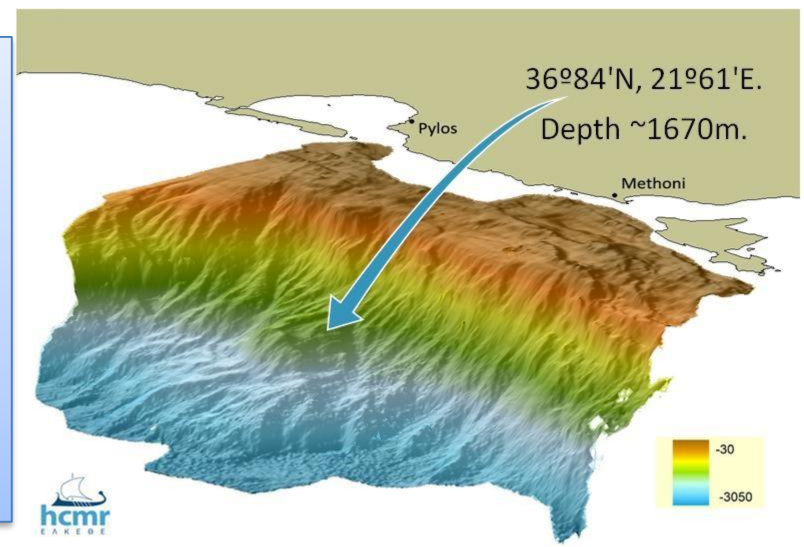
i) Geohazard Seabed Mapping and Geological Site Characterization, ii) Fault Offsets and Fault Activity Analysis, iii) Pore Pressure Analysis, iv) Gas Hydrate Quantification and Stability Modeling, v) Tsunamigenic Geohazard evaluations, vi) Hazard Impact Assessment



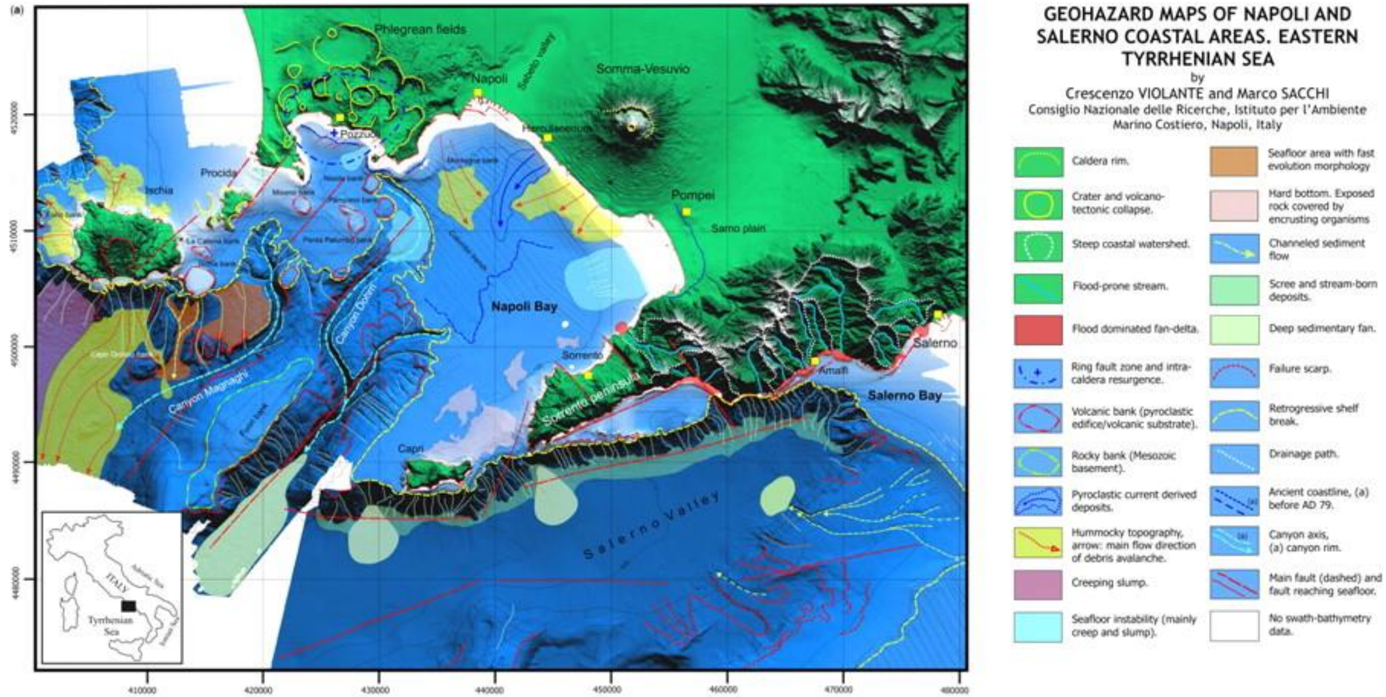


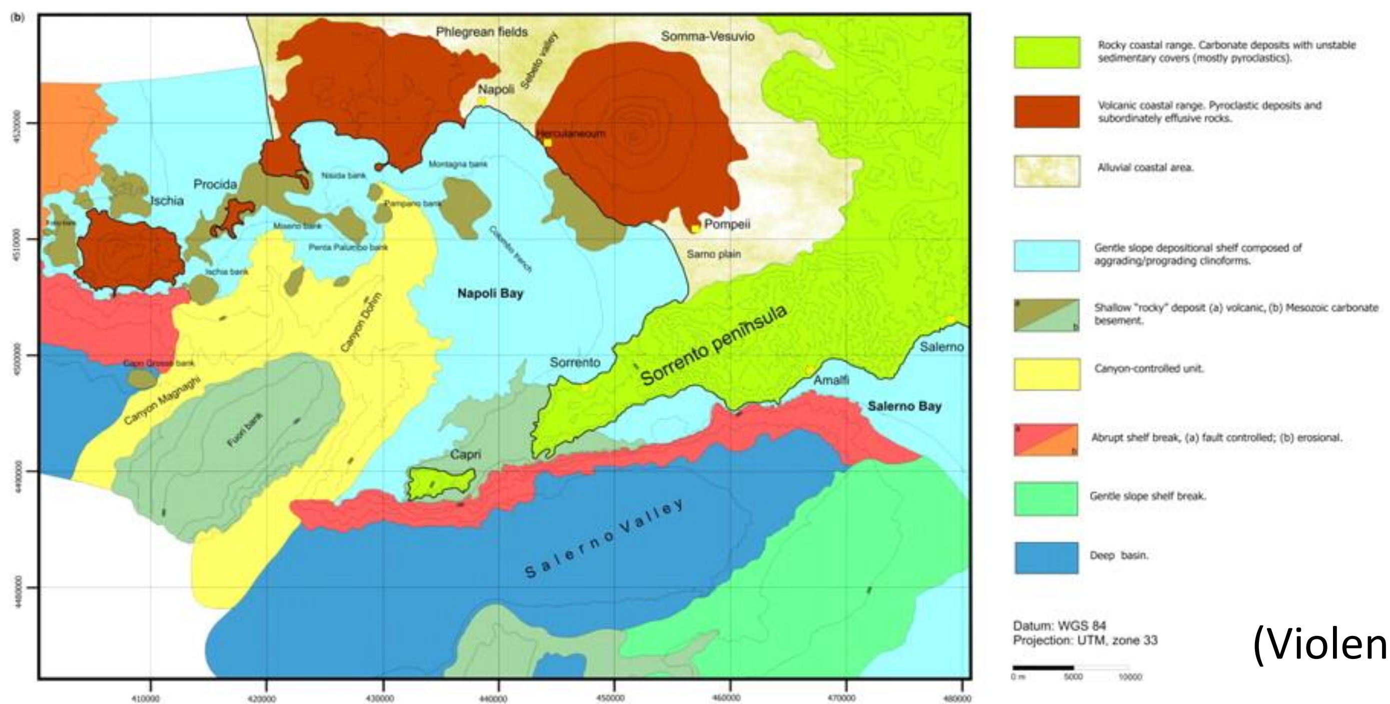
EMSO

Real-time long-term monitoring of oceanic circulation, deep-sea processes and ecosystems evolution. Study of episodic events such as earthquakes, submarine slides, tsunamis, benthic storms, biodiversity changes, pollution. Simultaneous data relative to: seismology, geodesy, sea level, fluid and gas vents, physical oceanography and biodiversity imaging at different scales.



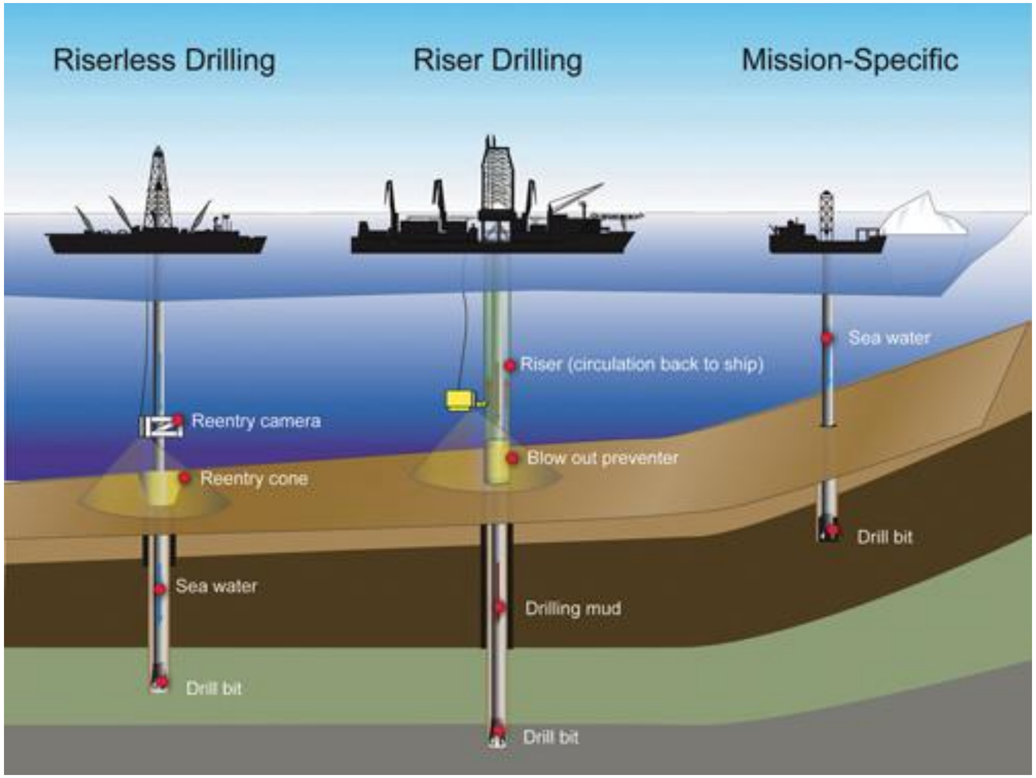
GEOHAZARDS MAPS

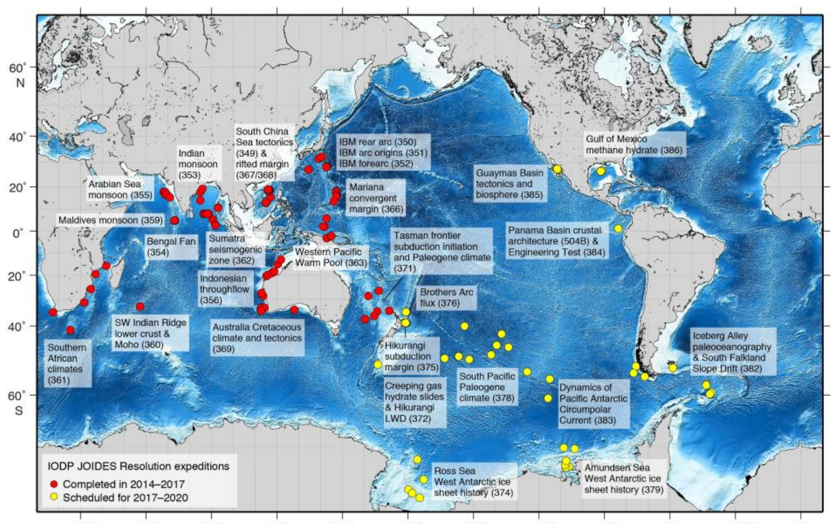




(Violente, 2009)

Integrated Ocean Drilling Program (IODP)





Understanding the spatial and temporal variability of submarine geohazards, their physical controls, and their societal effects requires a diverse array of observational techniques. Ocean drilling can be a key element in understanding oceanic geohazards, given that <u>the submarine geologic record preserves structures and past evidence</u> for earthquakes, landslides, volcanic collapse, and even bolide impacts. This record can be read and interpreted through drilling, coring, in situ characterization, observatory studies, monitoring, and laboratory studies to provide insight into future hazards and associated risks to society (Morgan et al., 2009).

VIRTUAL Diver

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Erasmus+

3DTeLC

Virtual reality for geohazards and geological studies

(Nomikou et al., 2018; 2019)