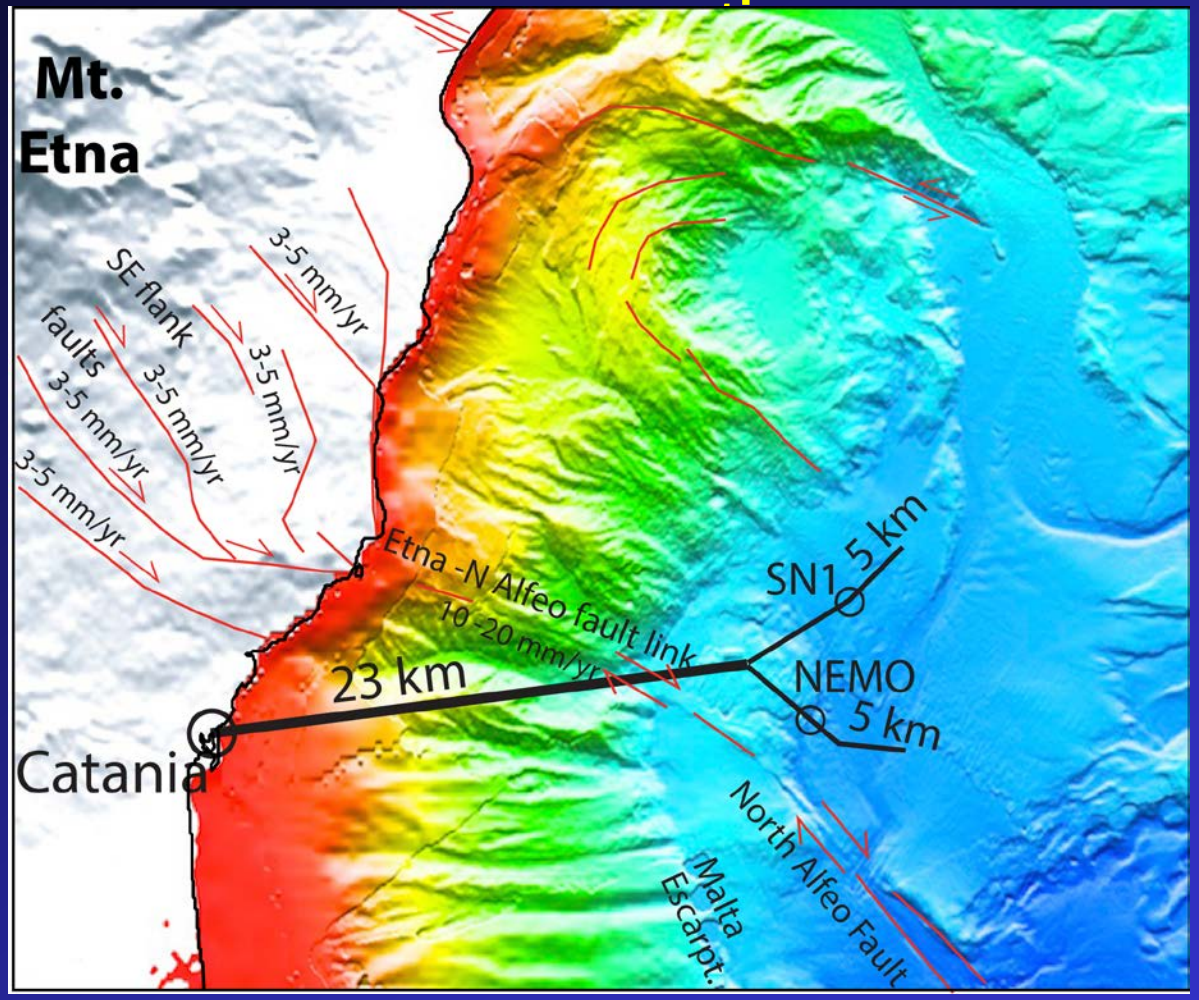
Active tectonics and destructive historical earthquakes in E Sicily/Calabria: results of recent marine surveys and the FOCUS project, a novel approach for studying submarine faults with fiber

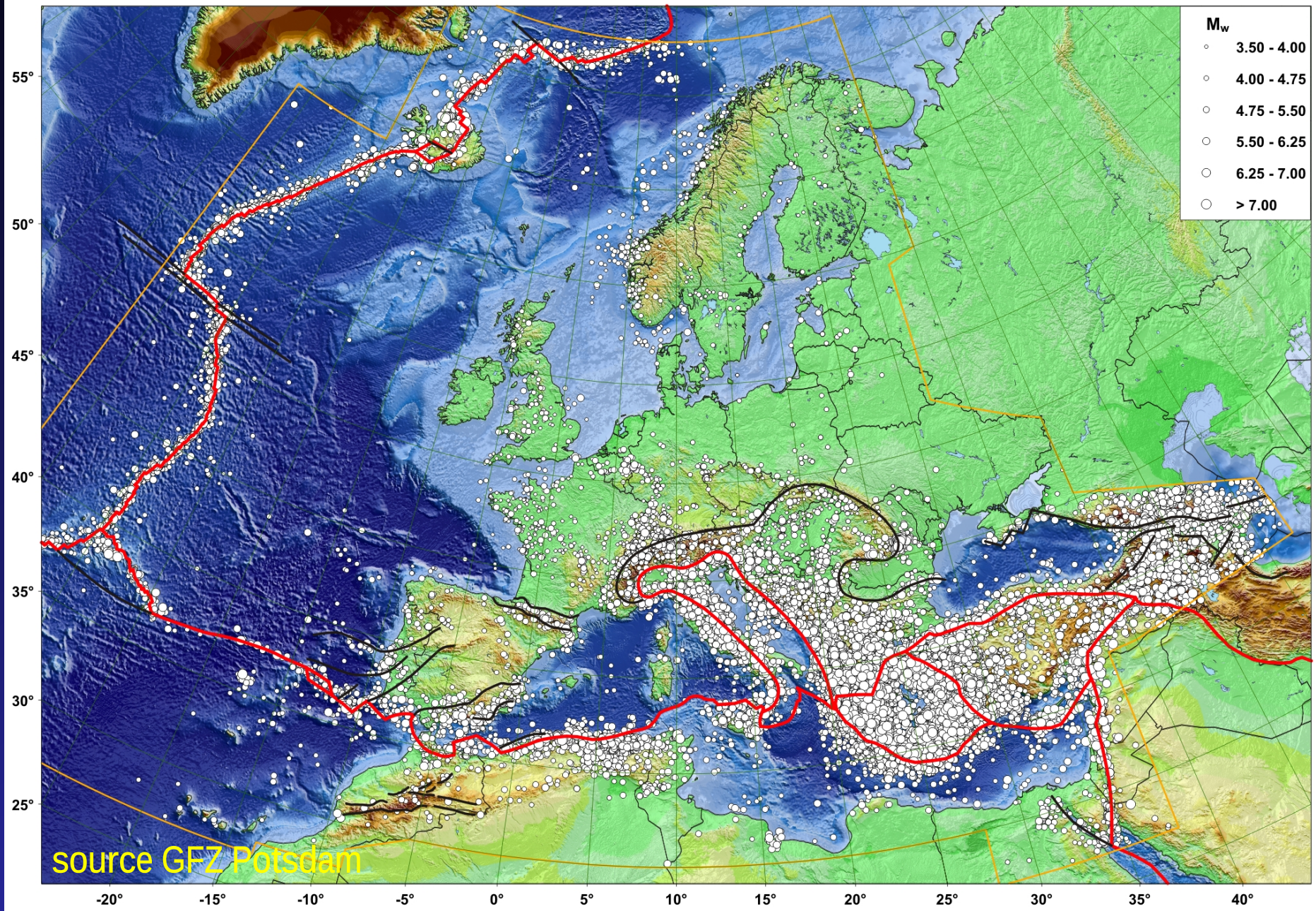


M-A Gutscher

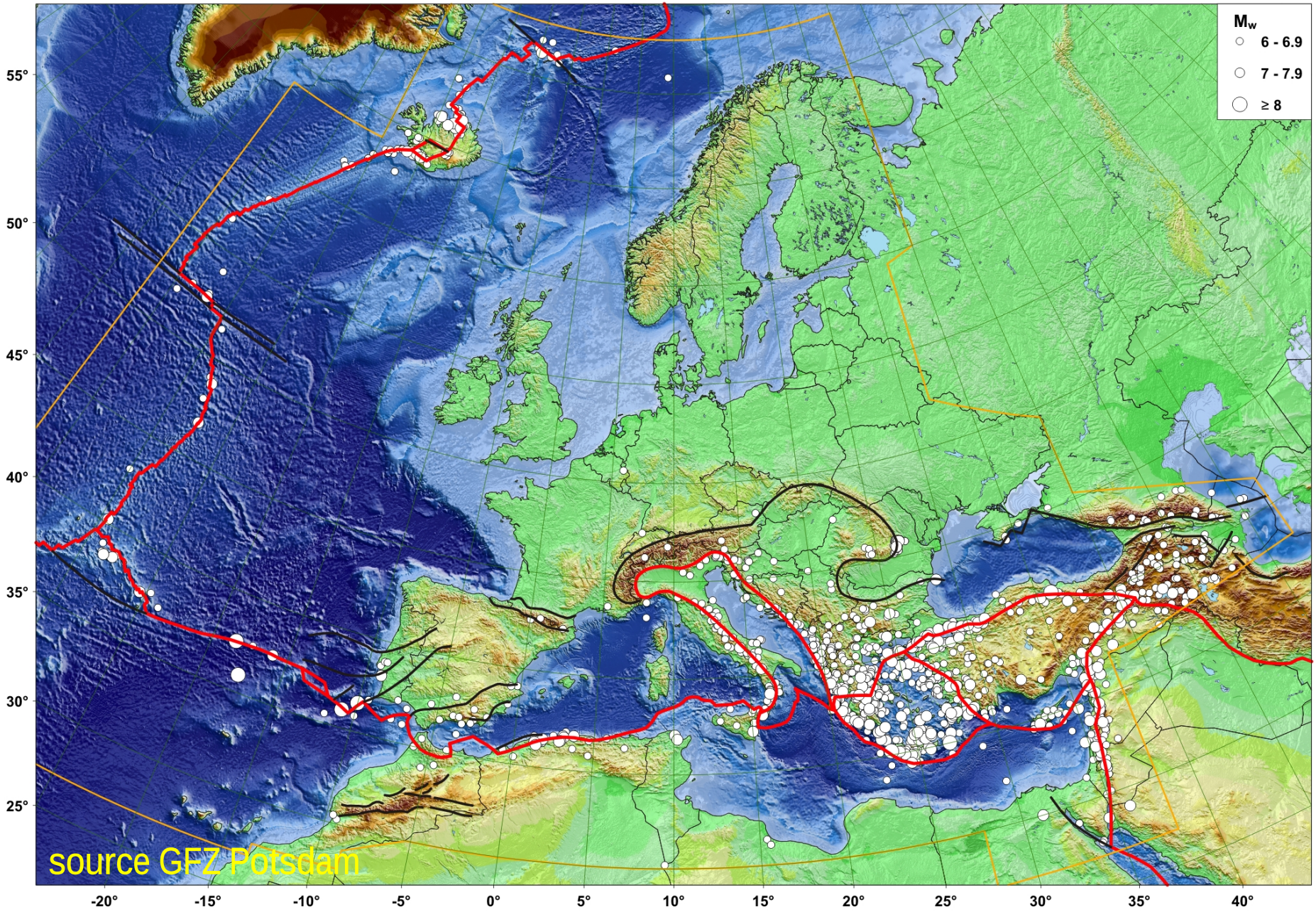
Brest, France

National Central University, Taiwan, 3 Nov. 2017

European - Mediterranean seismicity (M 3.5 - 8)



European - Mediterranean seismicity (M 6.0 - 8)



Seismic hazard

European Seismic Hazard Map

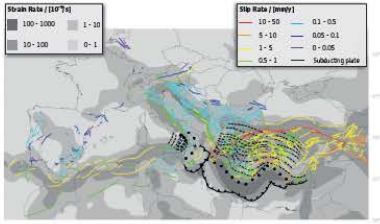
edited by D. Giardini, J. Woessner, and L. Danciu, Swiss Seismological Service, ETH Zurich, August 2013

The EU-FP7 SHARE Project

Europe has a long history of destructive earthquakes, and seismic risk can severely affect our modern society, as recently shown by the 1999 Izmit (Turkey) and the 2009 L'Aquila (Italy) events. Seismic hazard defines the likelihood of ground shaking associated with the occurrence of future earthquakes, and is the first step to evaluate seismic risk, the likelihood of damage and loss depending on vulnerability factors (e.g., the type, age and value of buildings and infrastructures, population density and land use). High hazard does not necessarily imply high risk: frequent large earthquakes result in high hazard but pose limited risk if they occur in remote areas, while even moderate earthquakes may expose densely populated areas to high seismic risk.

The collaborative project "Seismic Hazard Harmonization in Europe (SHARE)" was supported by the EU-FP7 to deliver the first state-of-the-art reference hazard model for Europe, replacing older maps. The SHARE hazard contributes to the Global Earthquake Model (GEM) and serves as input for risk mitigation policies such as the design of earthquake-resistant multi-storey buildings and critical infrastructures such as bridges or dams.

Active Faults in Euro-Mediterranean Region



Active faults and subducting plates in the Euro-Mediterranean region, differentiated by color from rapidly slipping (red) to slowly slipping (violet). Over 1,100 active faults have been mapped, covering more than 64,000 km of fault length. The background depicts the estimated rate of deformation of the Earth's crust derived from geological and geodetic data.

Map Content

The European Seismic Hazard Map displays the ground shaking (i.e. Peak Horizontal Ground Acceleration) to be reached or exceeded with a 10% probability in 50 years, corresponding to the average recurrence of such ground motions every 475 years, as prescribed by the national building codes in Europe for standard buildings. SHARE maps also the higher ground shaking recurring only every 1,000-5,000 years, of importance for critical infrastructures such as dams or bridges.

The ground shaking values depicted in the map reach over 0.5g (g is the gravitational acceleration). Low hazard areas (PGA≤0.1g) are colored in blue-green, moderate hazard areas in yellow- orange and high hazard areas (PEA>0.25g) in red.

The SHARE seismic hazard is assessed with a time-independent, probabilistic approach. Models of future ground shaking are based on the history of earthquakes of the past 1,000 years, on the knowledge of active faults mapped in the field, on the style and rate of deformation of the Earth's crust from GPS measurements, and on the instrumental recordings of strong ground shaking generated by past earthquakes.

The SHARE results do not replace the existing national design regulations and seismic provisions, which must be obeyed for today's design and construction of buildings.

Acknowledgements

Supported by the EU 7th Framework Program, the 4-year SHARE program brought together a core-team of over 50 leading scientists from 18 research institutions and 12 countries from Europe, North Africa and Turkey, and more than 250 additional European experts participating in workshops, providing their expertise and data.

SHARE was funded by the EU-FP7 (2007-2013) under grant agreement no. 226967.

SHARE hazard was computed using the GEM OpenQuake software. Maps were created using GMT (Wessels and Smith, 1991) and the poster was produced with Adobe Illustrator CS5.

Cite this map with:

D. Giardini, J. Woessner, L. Danciu, H. Crowley, F. Cotton, G. Grünthal, R. Pinho and G. Valensise and the SHARE consortium, SHARE European Seismic Hazard Map for Peak Ground Acceleration, 10% Exceedance Probabilities in 50 years, doi: 10.2777/30345, ISBN-13, 978-92-79-25148-1.

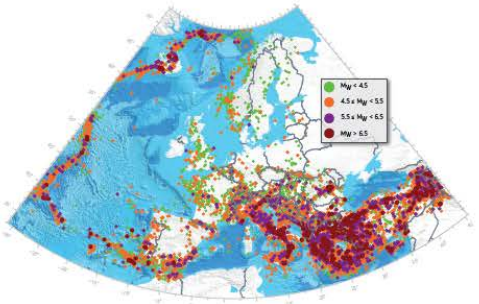
Online Access

All SHARE products, data and results, are provided through the project website at *www.share-eu.org* and the European Facility for Earthquake Hazard and Risk at *www.efehr.org*.

Legal Notice

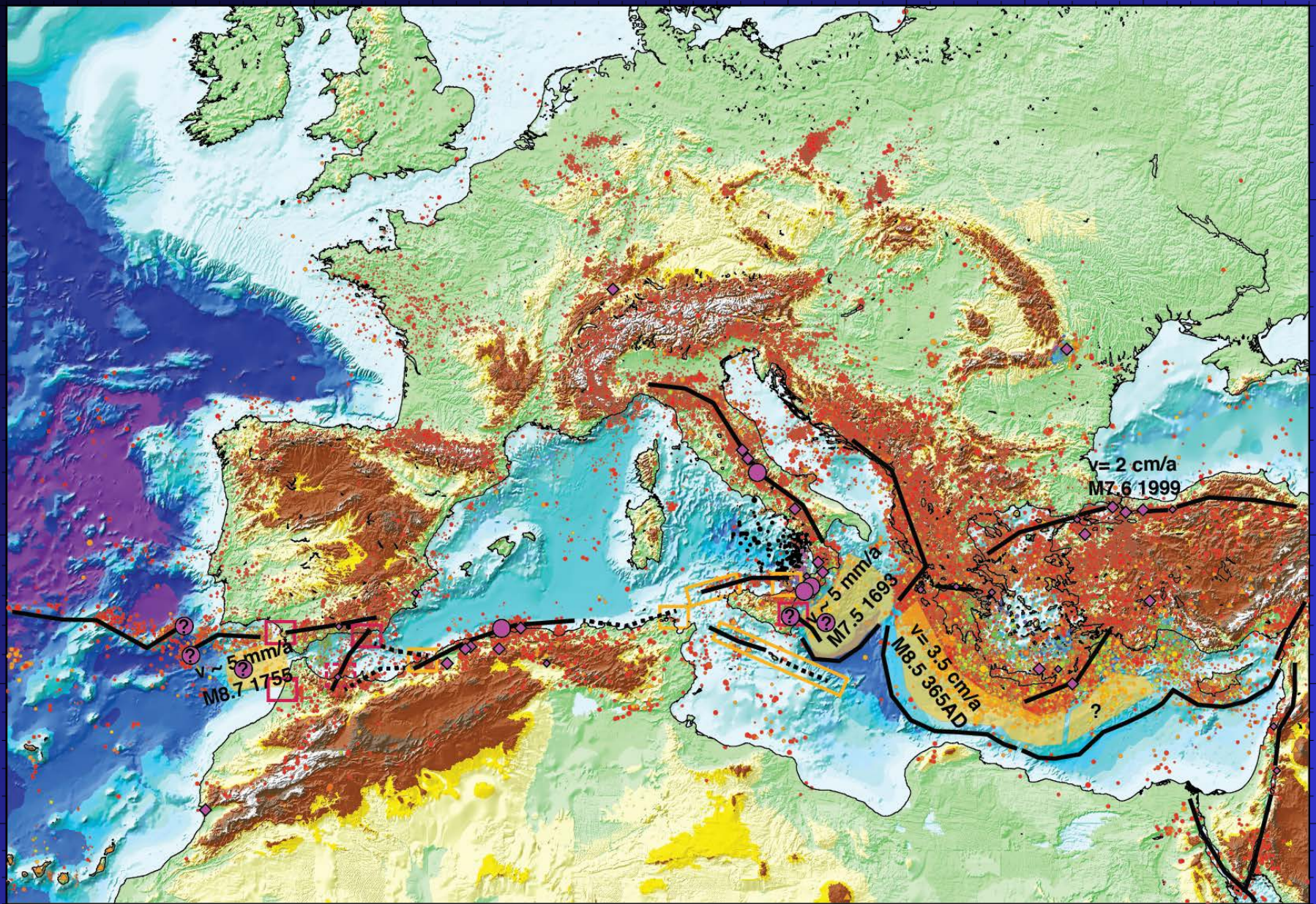
SHARE Partners

Earthquake History in Europe



Distribution of over 30,000 earthquakes with magnitudes larger or equal to 3.5 for the period 1000 – 2007, documented by their damaging effects through history or recorded with modern instrumental seismic networks.

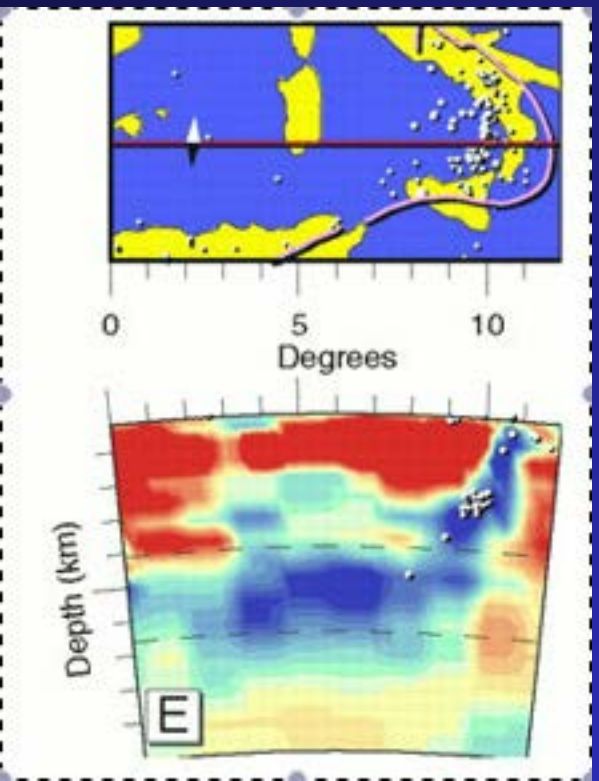
Africa - Eurasia plate boundary (Mediterranean): Faults mostly offshore, slow velocities (few mm to cm/year)

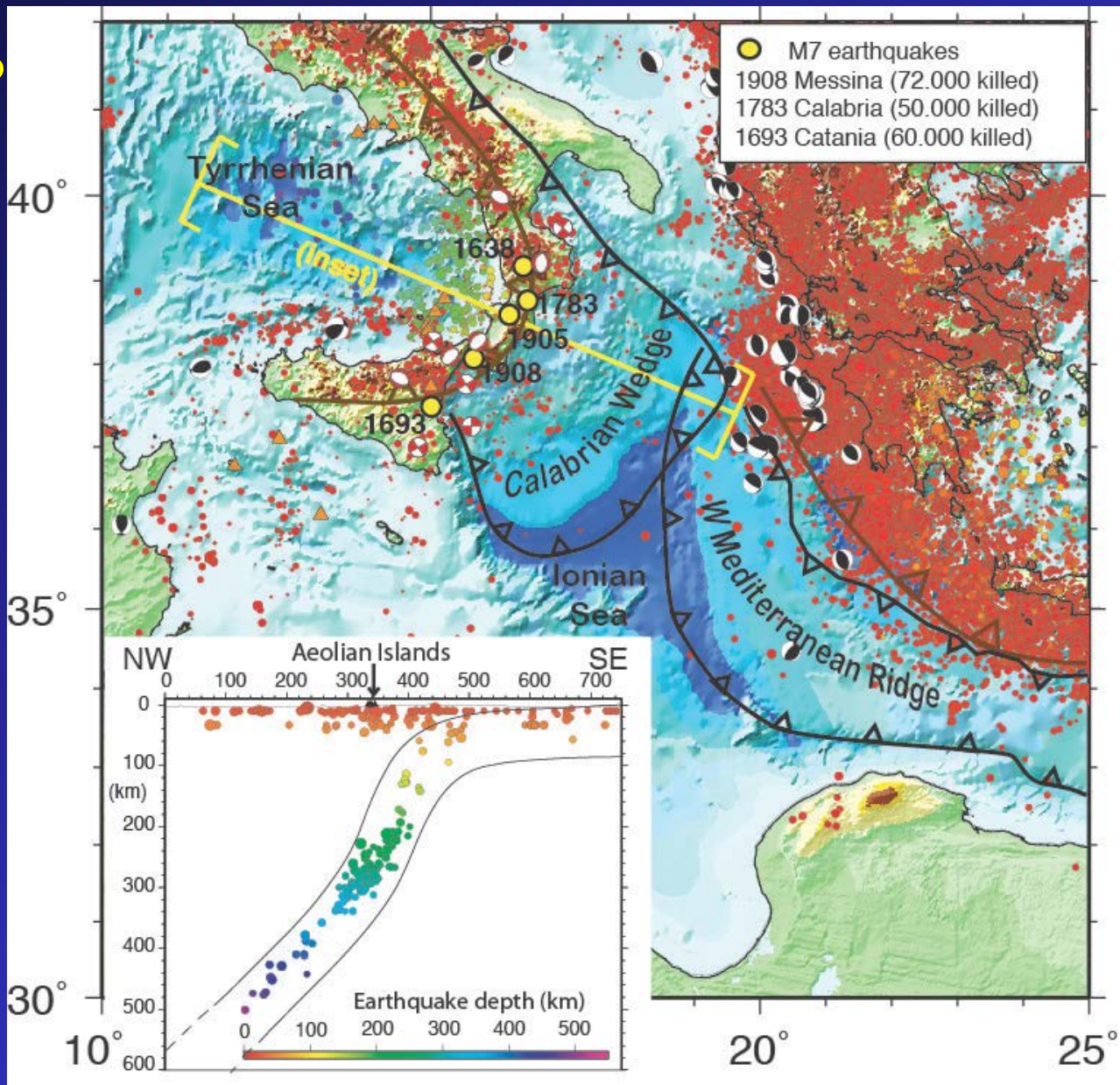


Southern Italy : - subduction zone (w. volcanic arc)
- strong historical seismicity - no known great earthquakes offshore

Is subduction still active? (magn. 8 earthquakes?)

Which submarine faults are active ?



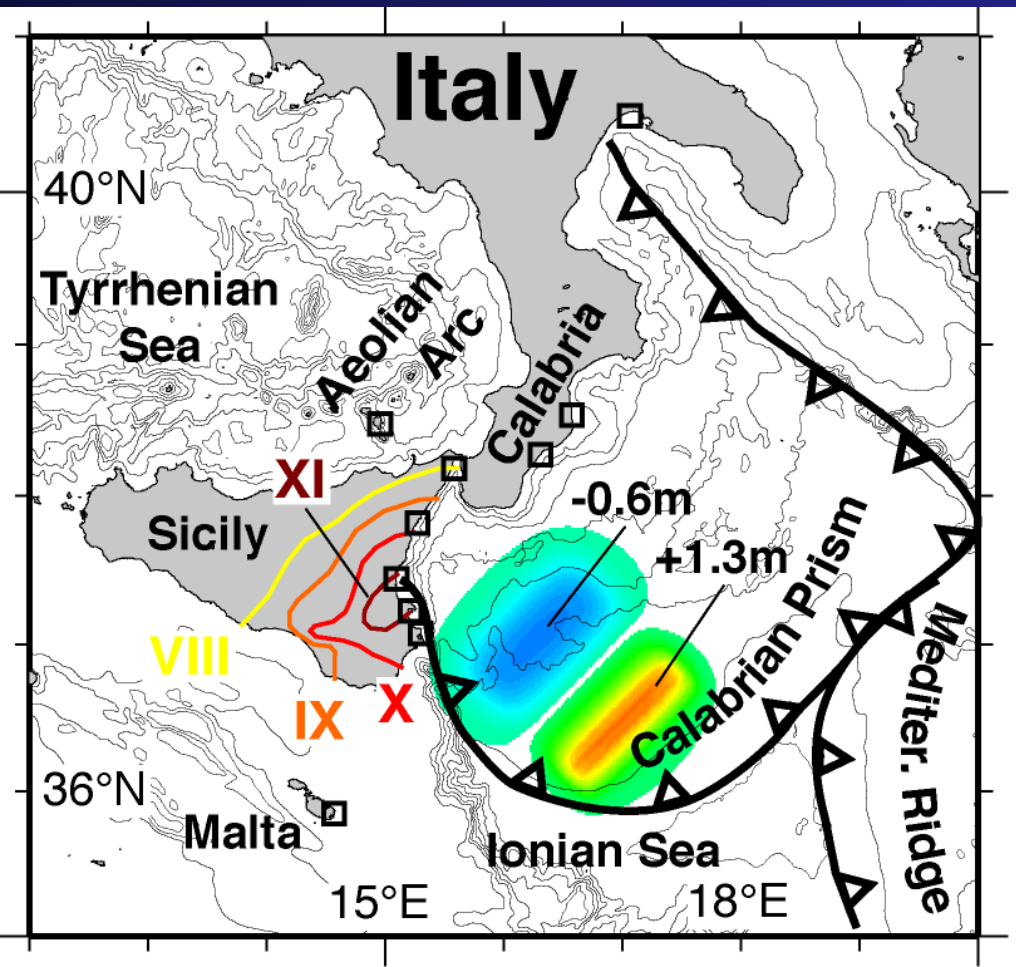


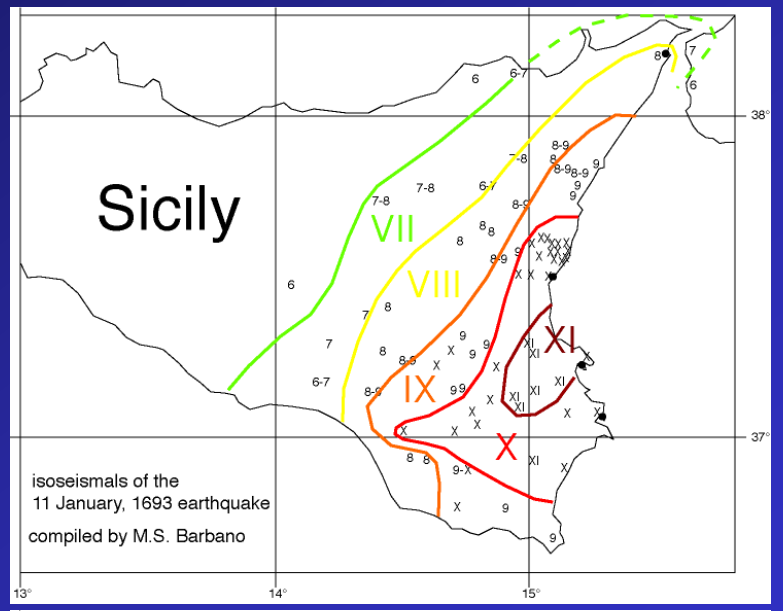
Historical seismicity and tsunamis:

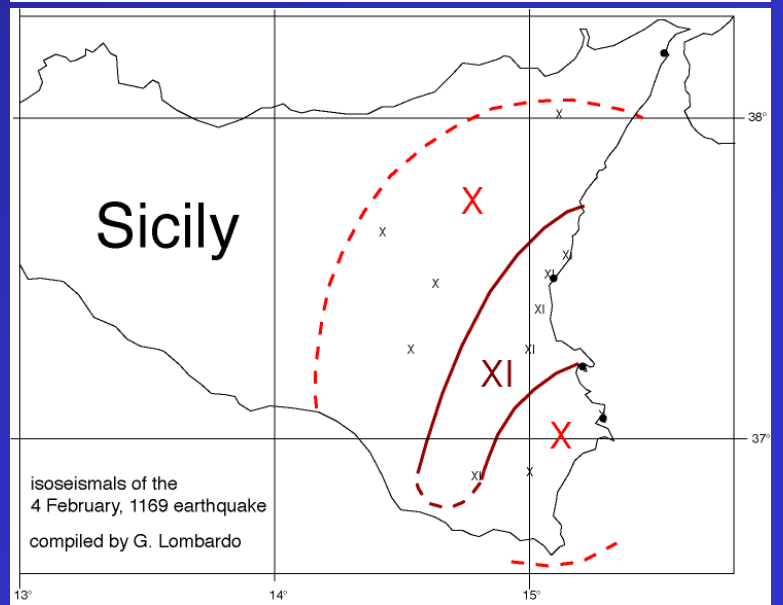
- 1693 and 1169, intensity 11, isoseismals open to the sea, tsunami → submarine fault

- Possible subduction interface events (?)

Catane 1693: séisme magn. 7.4
tsunami 5-10m (60.000 morts)

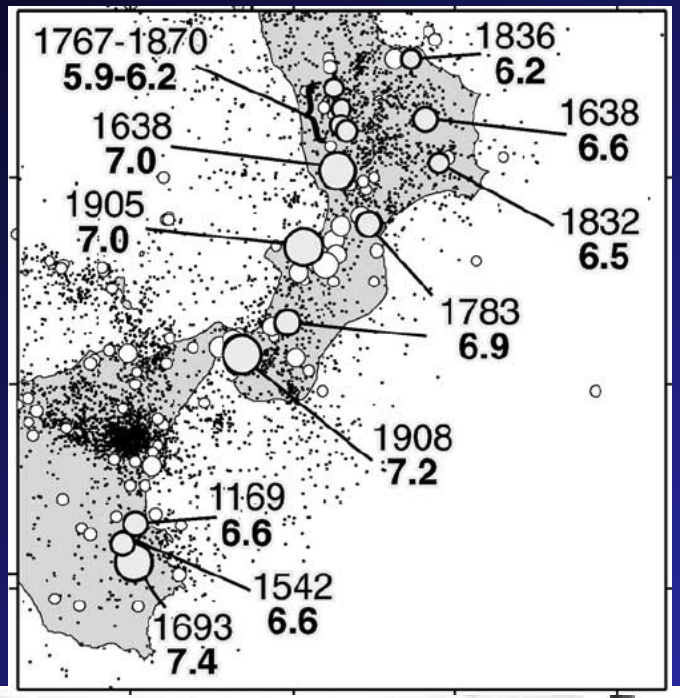


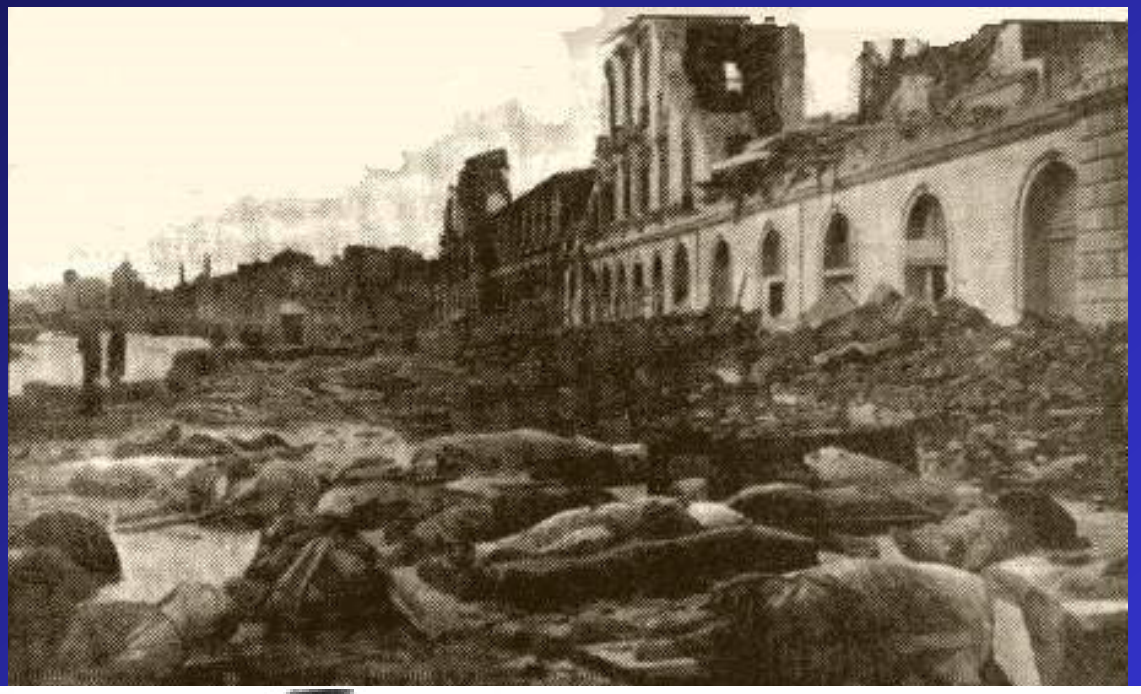




Southern Italy (Calabria / E Sicily): a region hit by strong historical earthquakes and tsunami

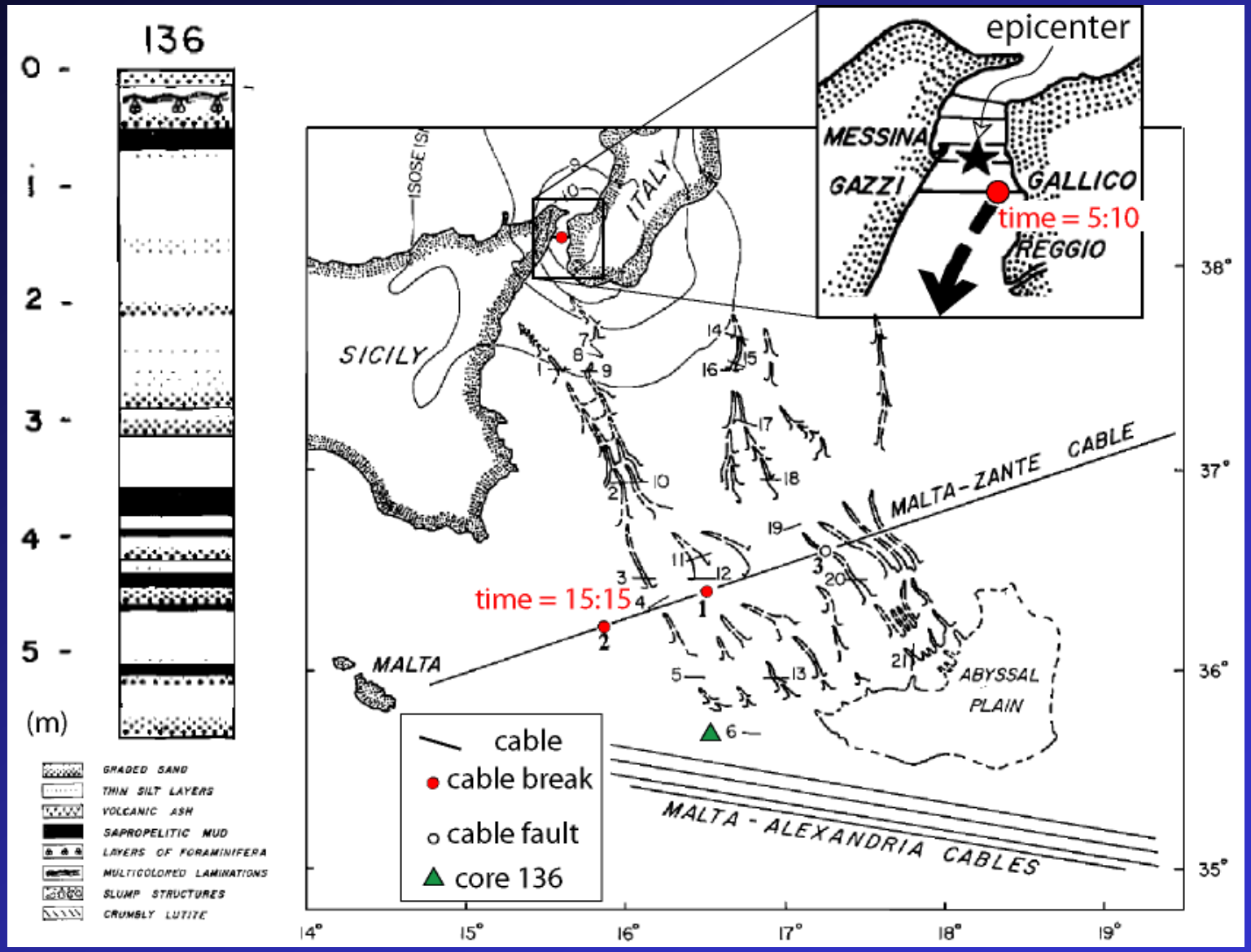
Messina 1908: earthquake magn. ≥7, tsunami 5-10m (72.000 dead)



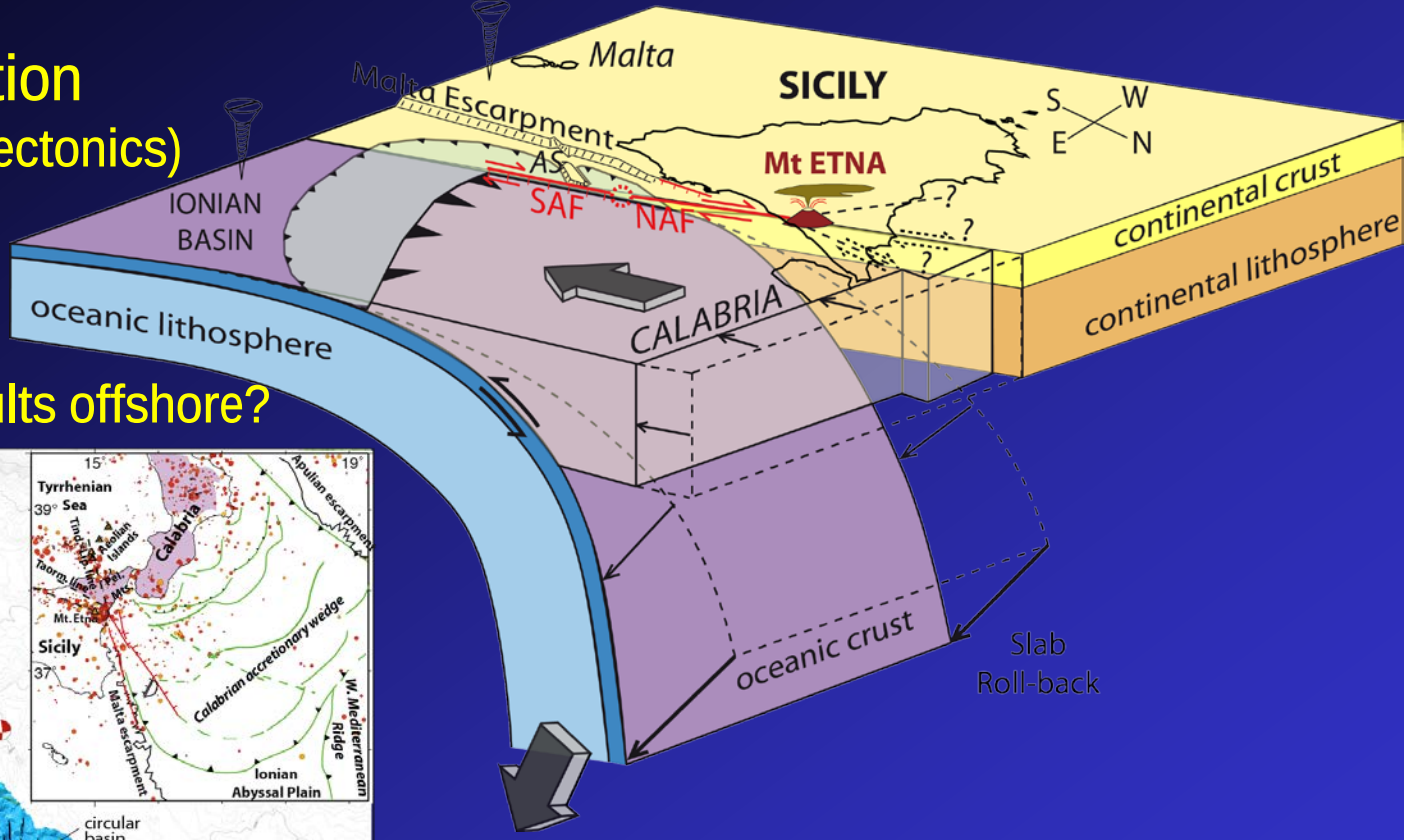


1908 Messina earthquake - early telecommunication cables

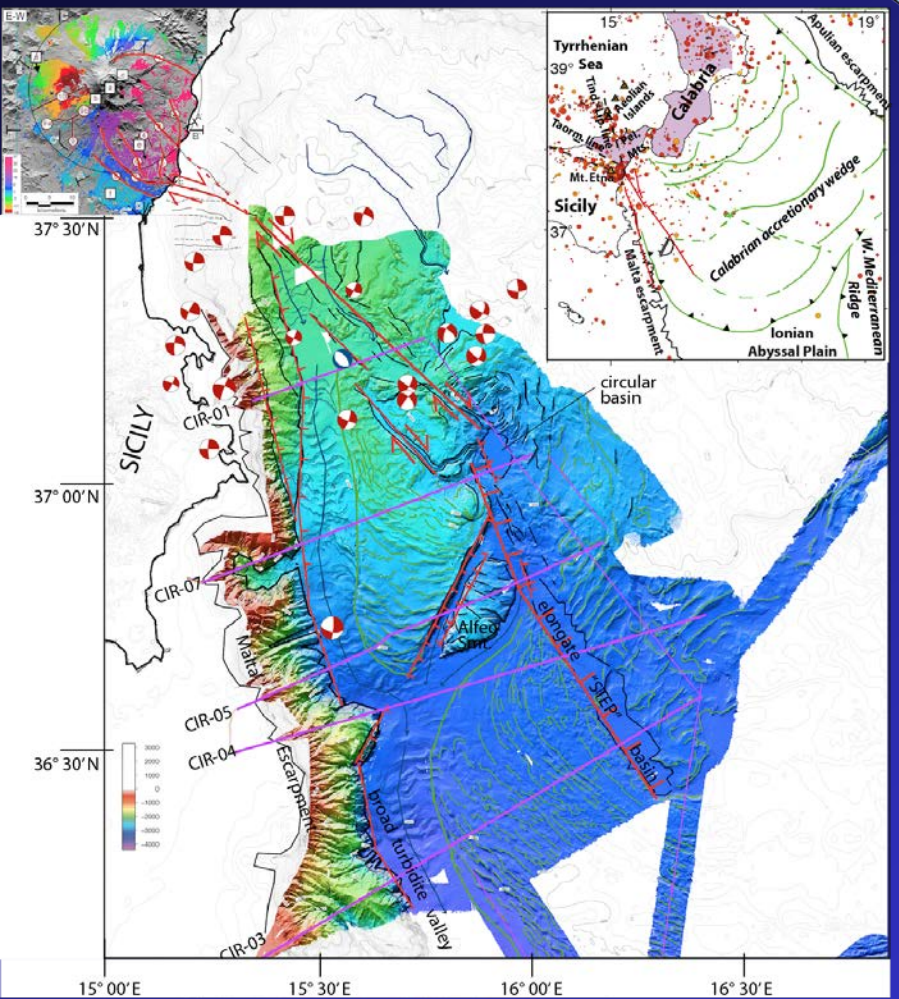
"Textbook example": earthquake → submarine landslide → cable rupture → turbidite deposit (Ryan and Heezen, GSA Bull. 1965)



Tectonic interpretation
(Gutscher et al., 2016, Tectonics)



Where are the active faults offshore?



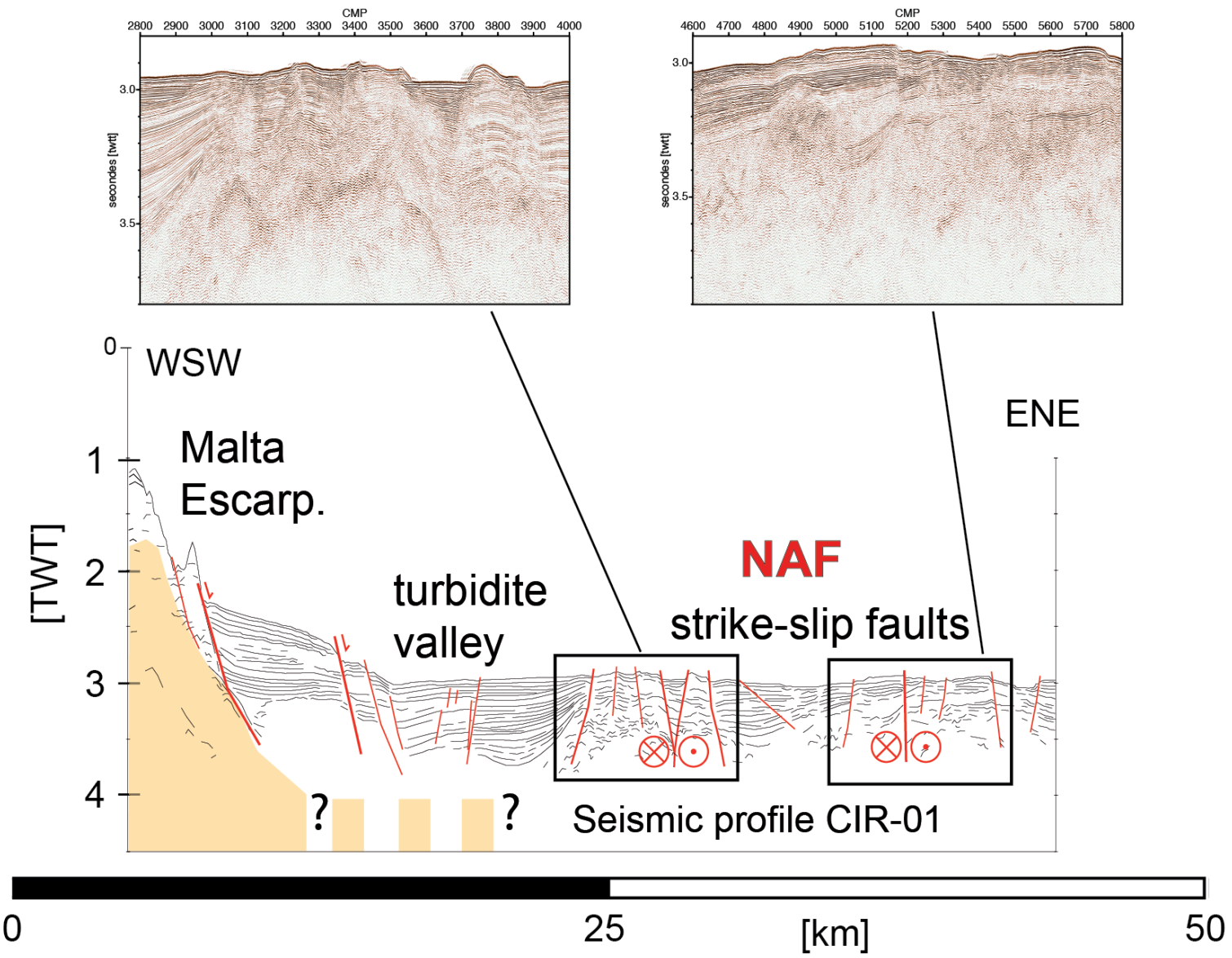
Newly mapped major fault system :

North and South Alfeo faults (2 x 80 km)

Strike-slip (dextral) and transtension

CIRCEE survey North Alfeo Fault - Strike-slip faulting

(Gutscher et al., 2016, Tectonics)



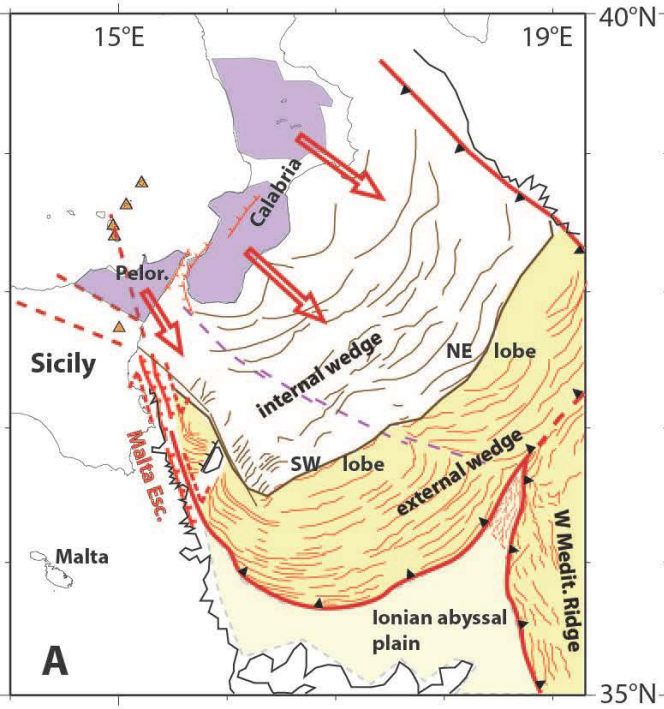
Geodynamics
(Gutscher et al., 2017, EPSL)

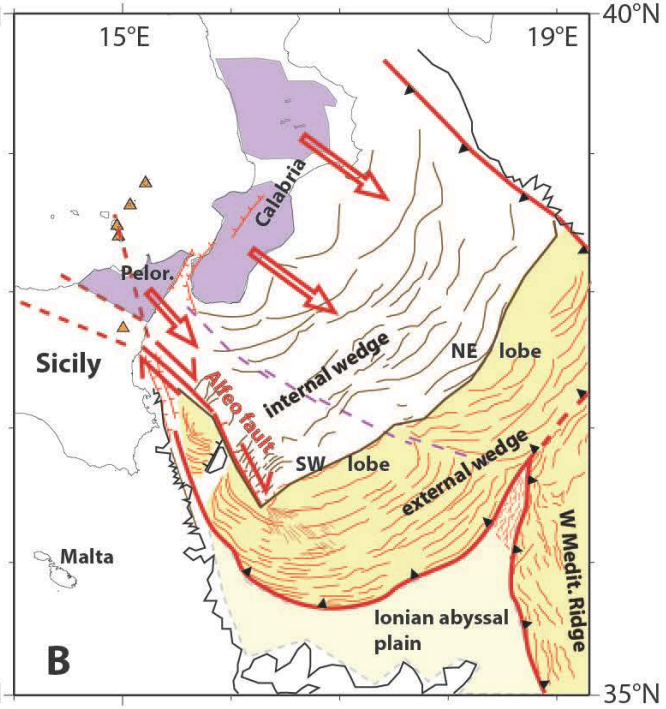
Three competing models:

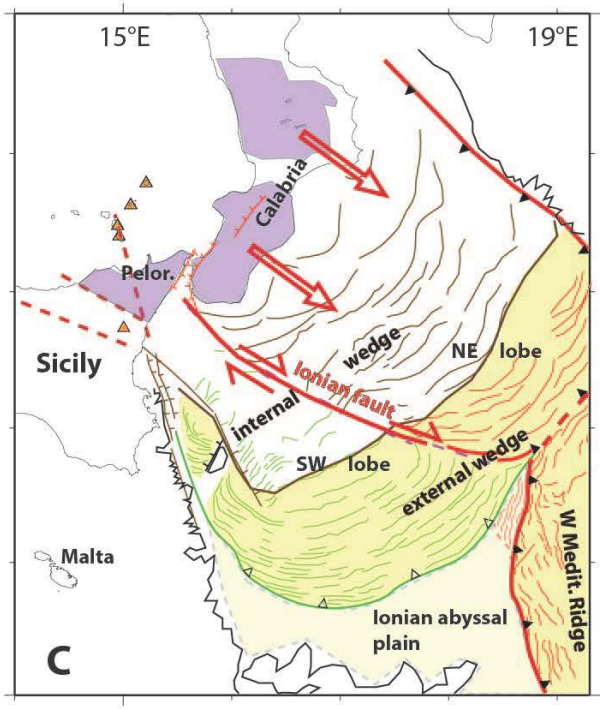
tear fault =
Malta Escarpment

tear fault =
Alfeo fault system

tear fault =
Ionian fault







(Argnani & Bonazzi, 2005, Tectonics; Argnani et al., 2012, NHESS;

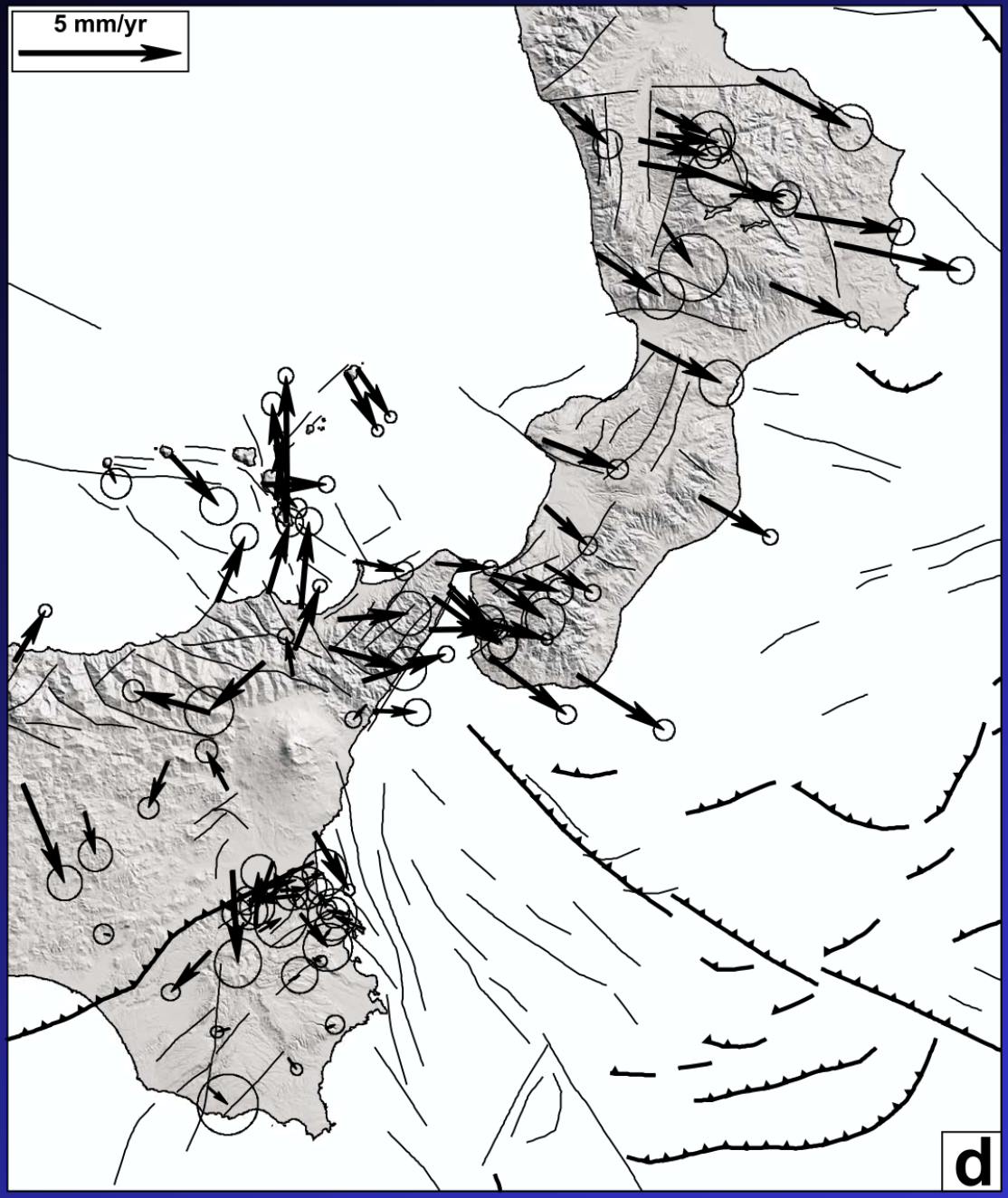
Govers and Wortel, 2005, EPSL)

(Gutscher et al., 2016, Tectonics)

(Polonia et al., 2011, Tectonics;

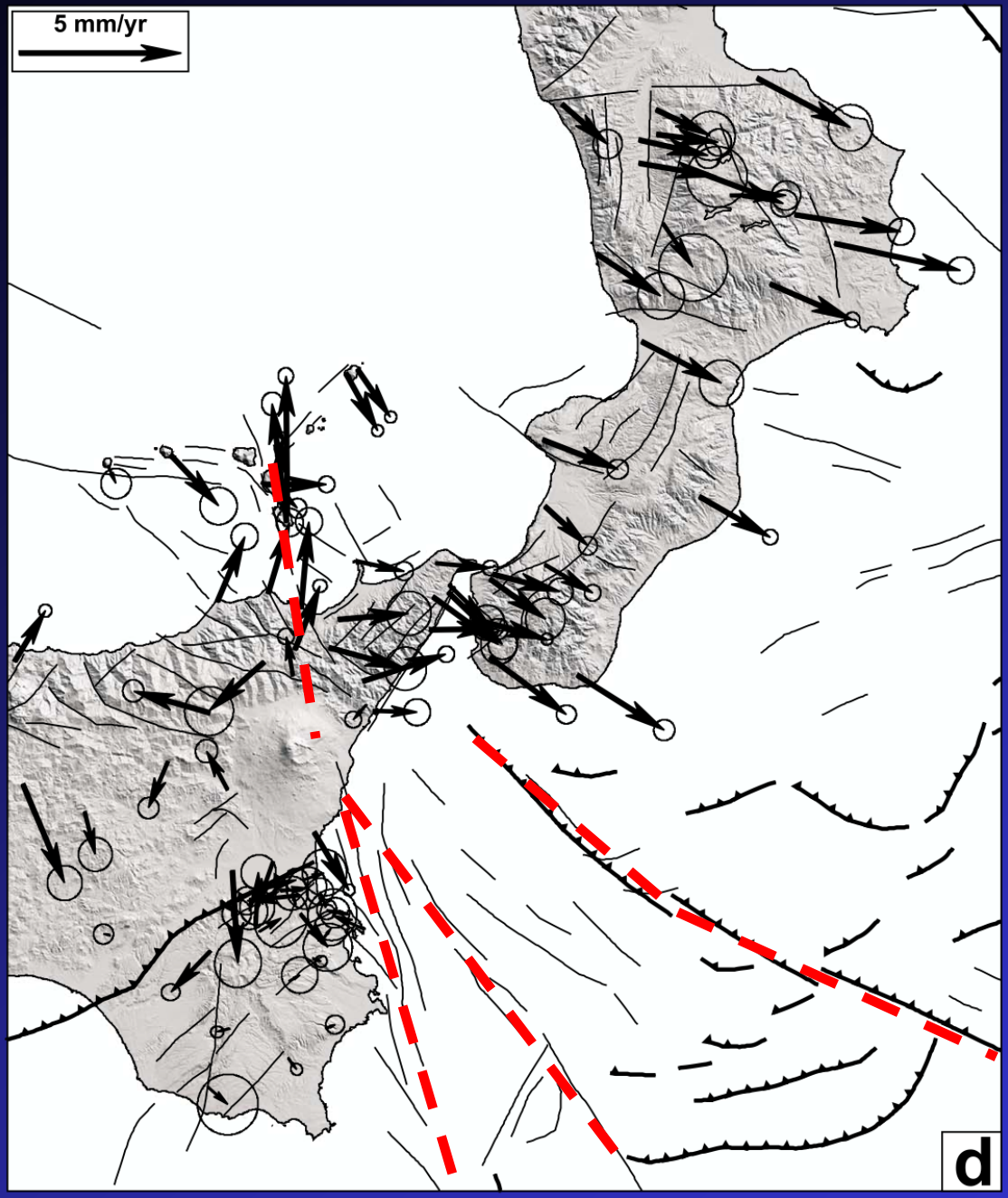
Polonia et al., 2016; Tectonophys)

S Italy region: GPS vectors (Palano et al., 2012, JGR)



E to SE motion of a “Calabrian” block at 3-5 mm/a (Nubia fixed refer. frame)

S Italy region: GPS vectors (Palano et al., 2012, JGR)



Typical GPS studies are not possible offshore…

→ "terra incognita"

Where are the active strike-slip faults offshore?

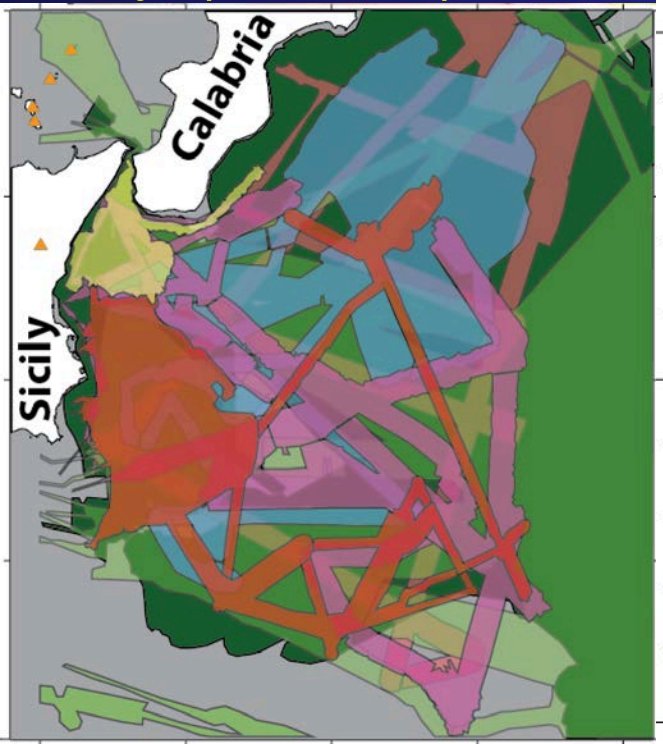
What are the displacement rates?

Newly published map

bathymetry (60m grid)

(Gutscher et al. 2017, EPSL)

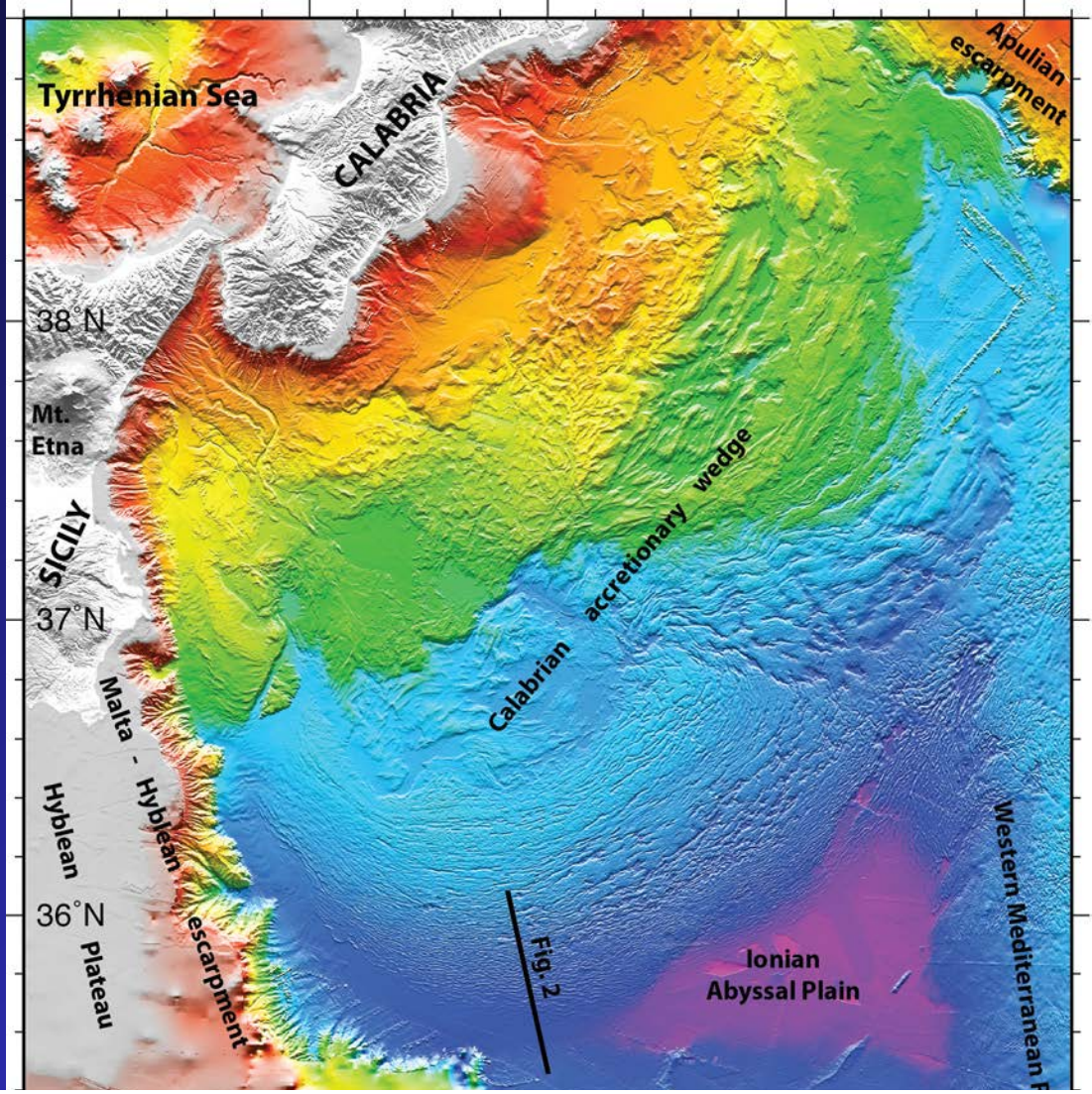
6 new marine geophysical surveys (2011 - 2015)

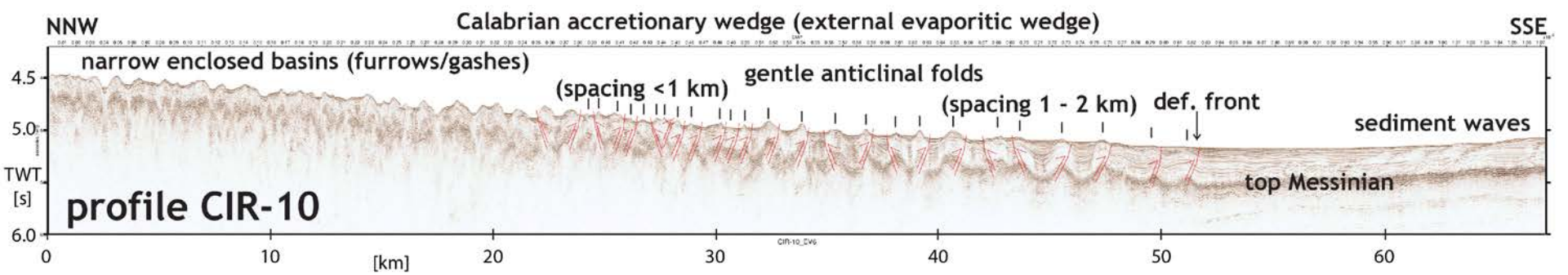


Tyrrhenian Sea
CALABRIA
Apulian escarpment
38°N
Mt. Etna
SICILY
37°N
Malta - Hyblean escarpment
Hyblean Plateau
Calabrian accretionary wedge
36°N
Ionian Abyssal Plain
Western Mediterranean Ridge
Medina seamounts
15°E
16°E
17°E
18°E
19°E

Bathymetric map and seismic reflection profile

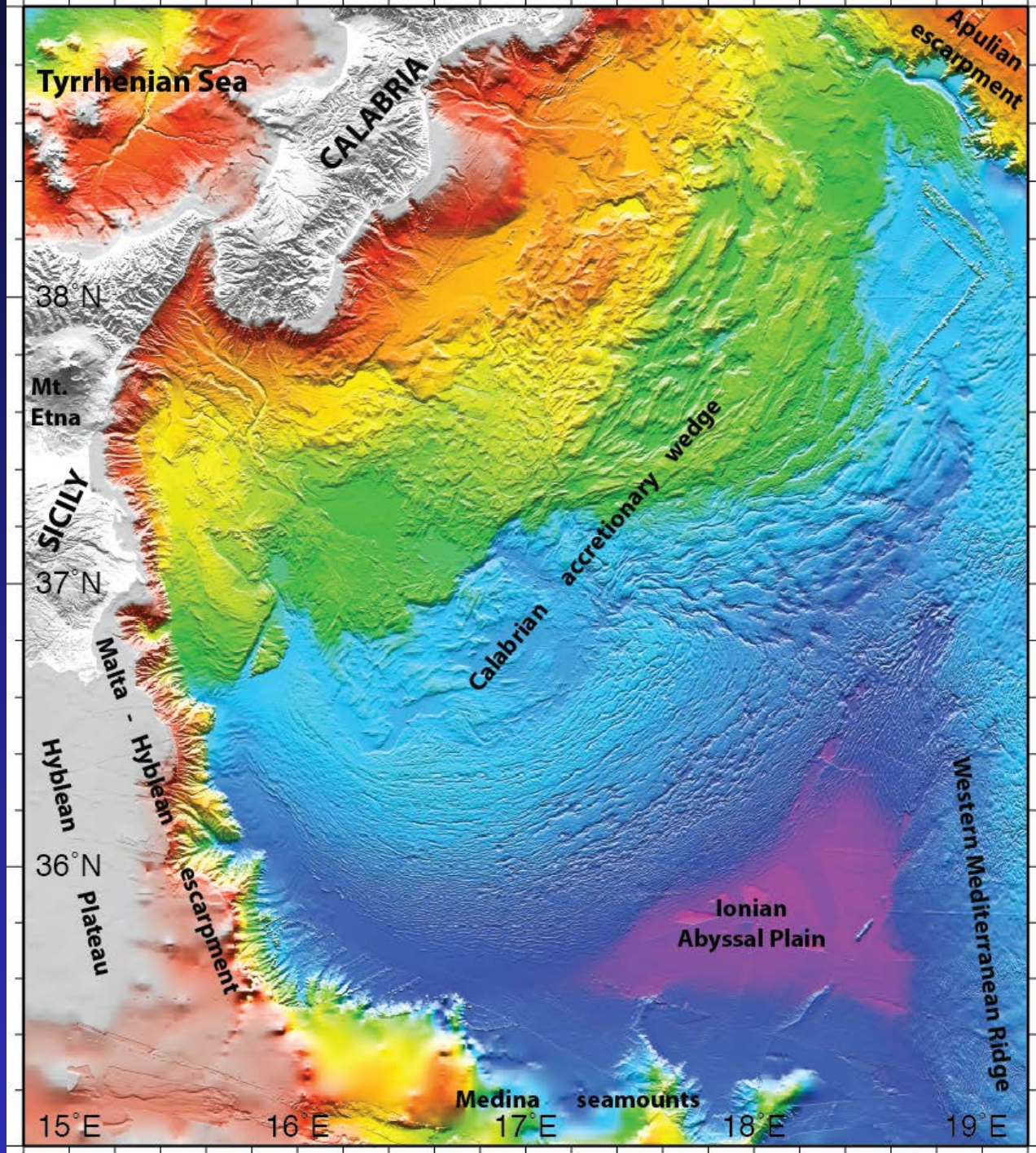
(Gutscher et al. 2017, EPSL)





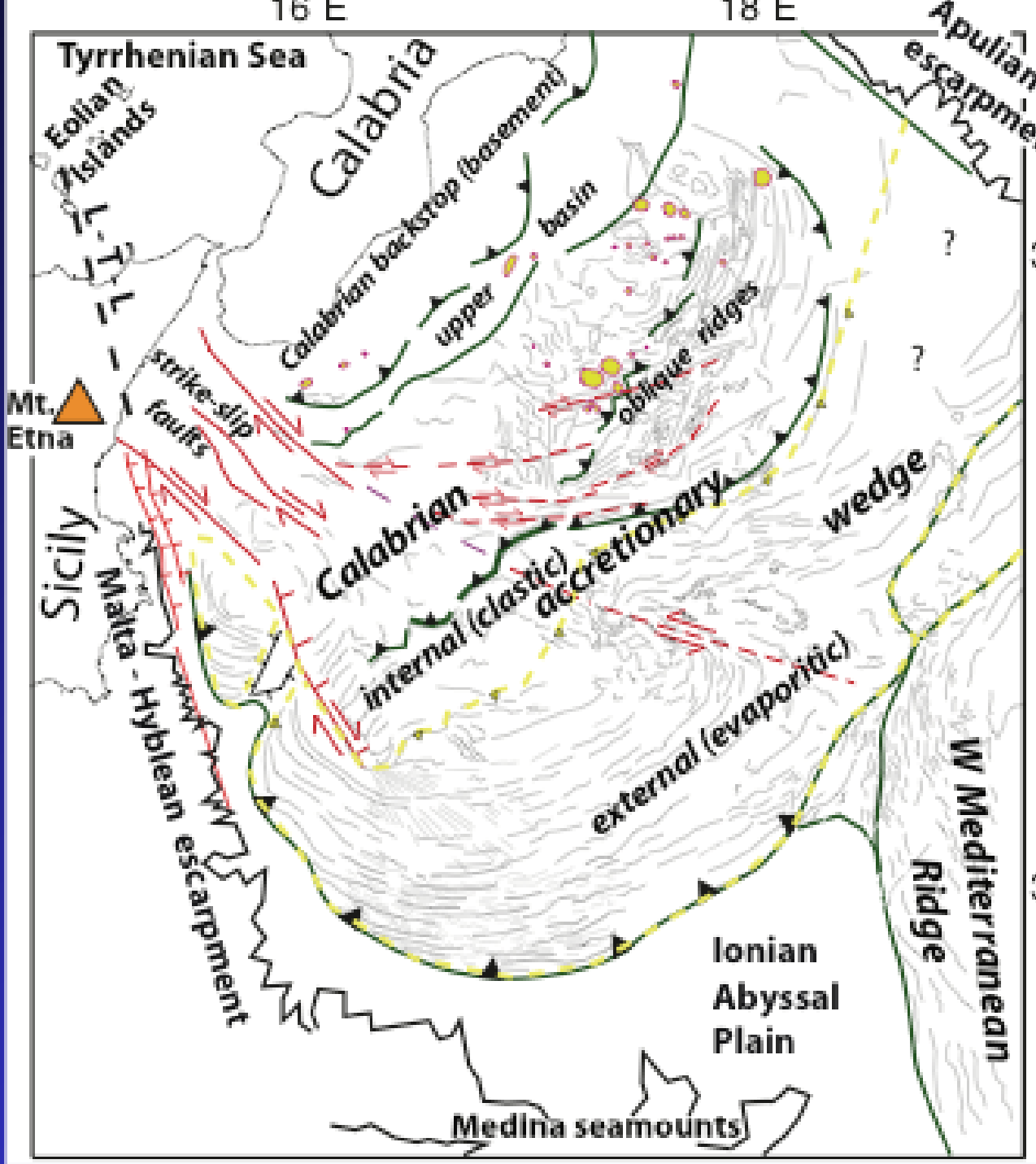
Bathymetry and major tectonic elements

(Gutscher et al. 2017, EPSL)



Simplified tectonic map

Several major faults offshore (strike-slip)

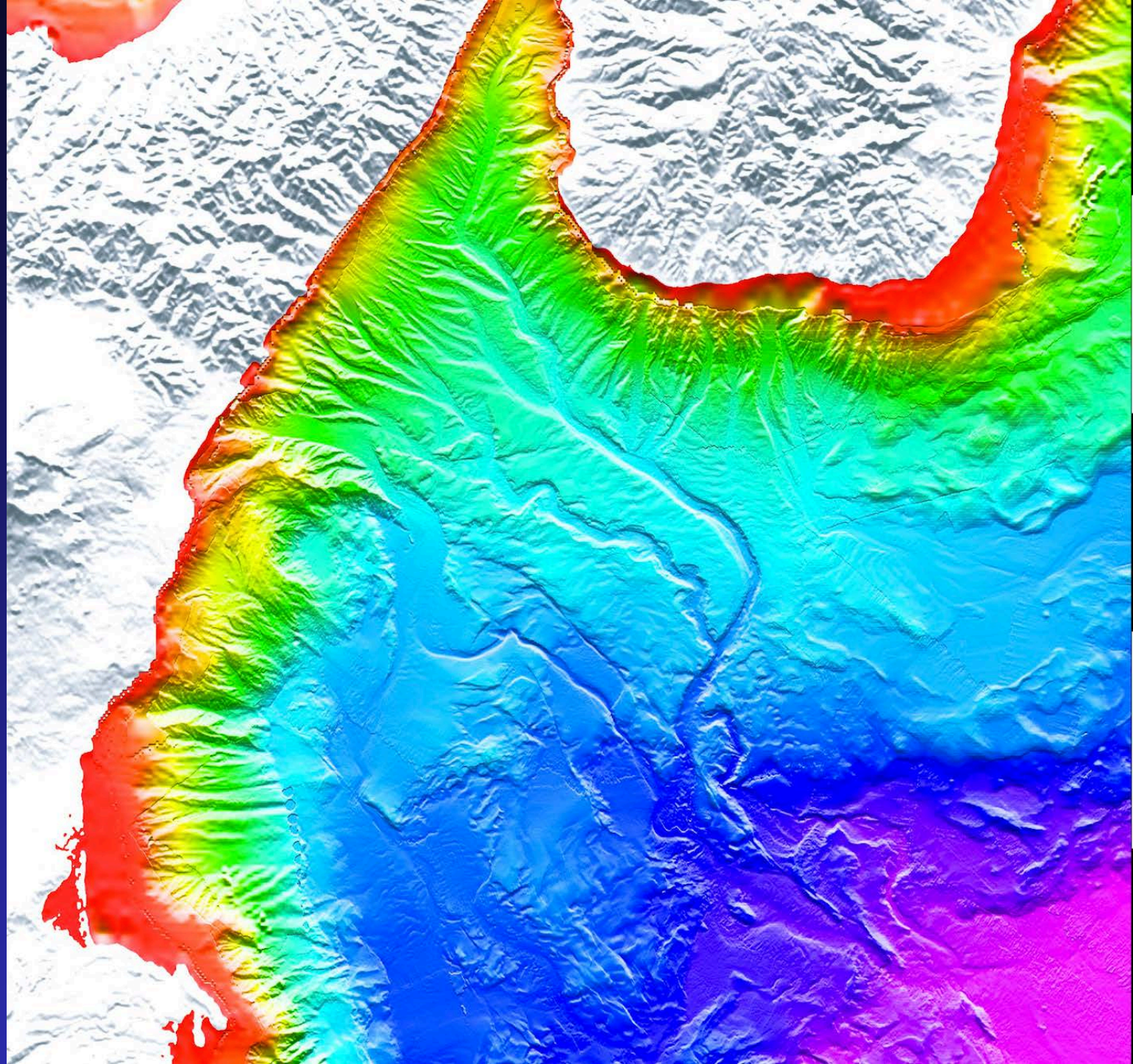


Ionian Sea

Bathymetry

60m grid

(Gutscher et al., 2017, EPSL)



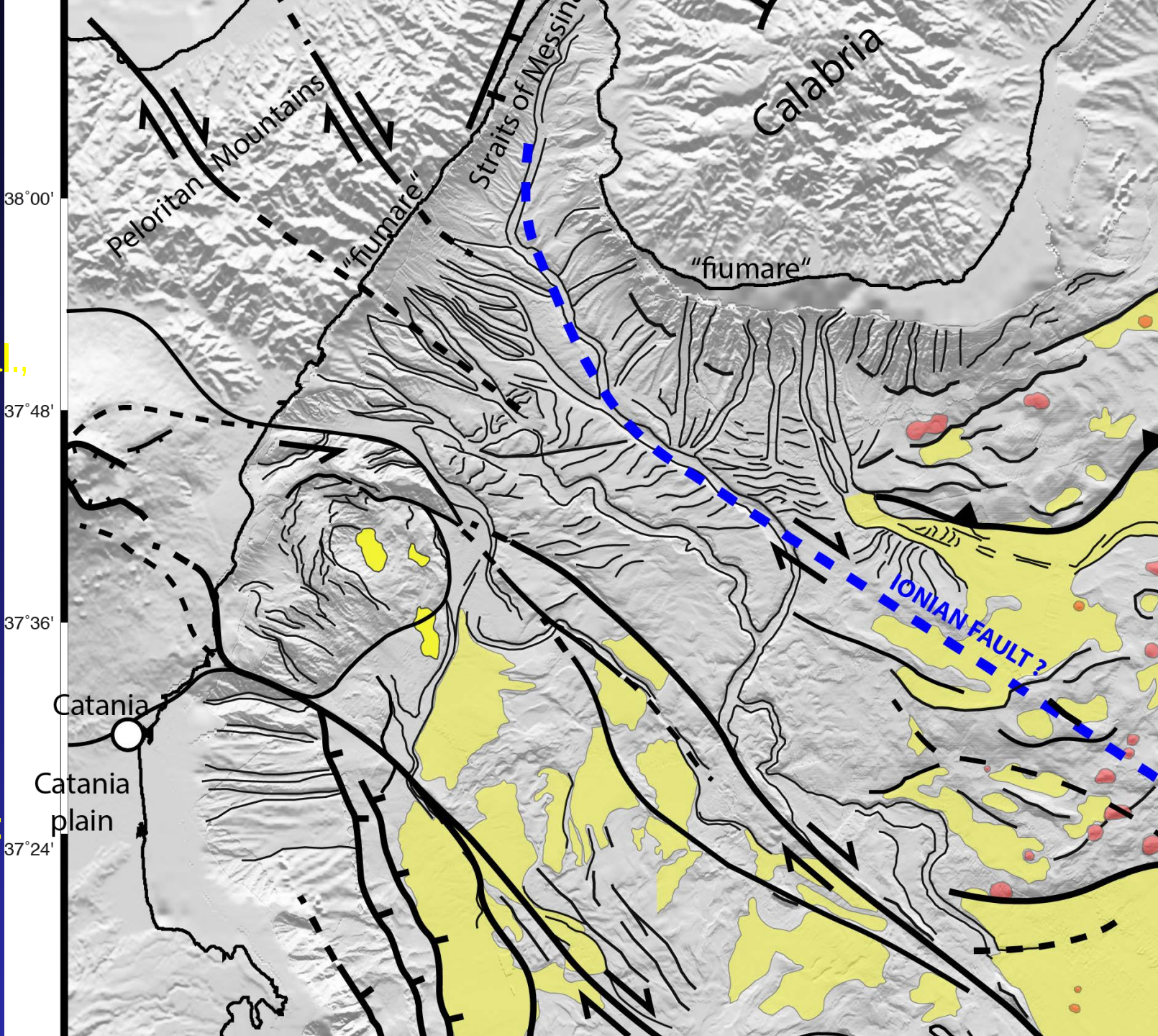
Ionian Sea

Bathymetry

60m grid

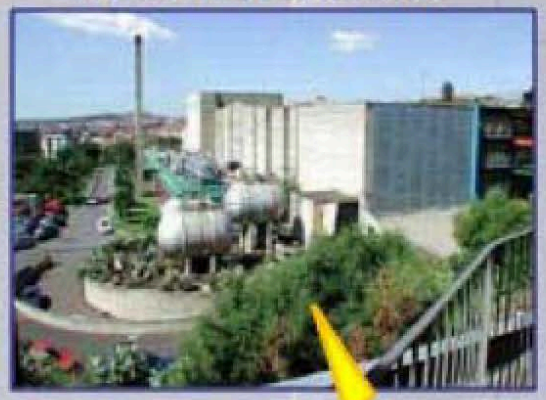
(Gutscher et al., 2017, EPSL)

Interpretation: Major faults offshore



NEMO (NEutrino Mediterranean Observatory) and EMSO Node (European Multidisciplinary Seafloor and water-column Observatory)

LNS-INFN Catania



Internet
Radio Link

LNS Test Site Laboratory
at the port of Catania

20 km

5 km

5 km

Test Site North

Depth 2100 m

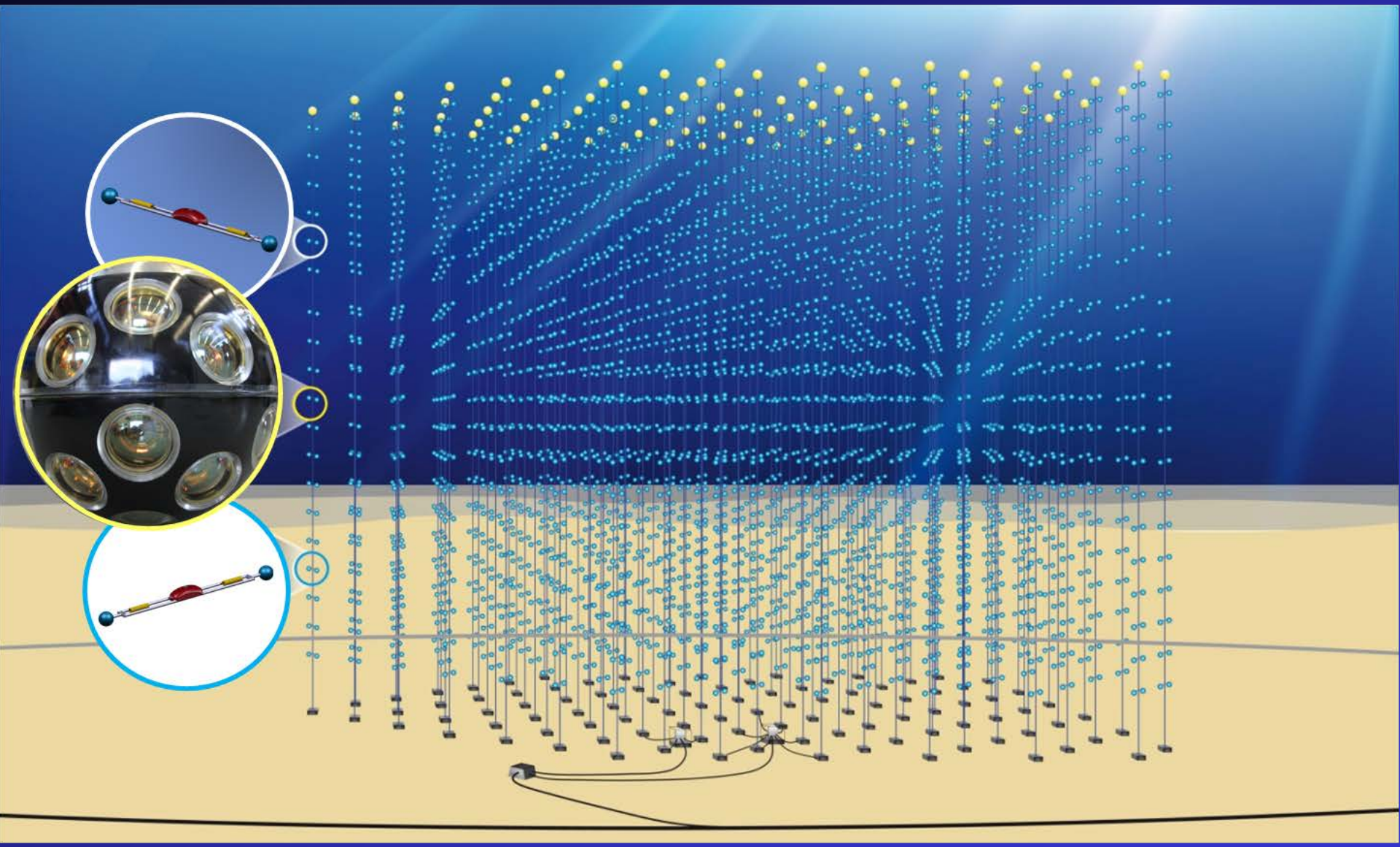
4 hydrophones
Seismic sensors
Enviromental sensors

Test Site South

4 hydroph

KM3Net (Kilometer cube Neutrino telescope)

Estimated cost ~0.25 - 0.5billion €



NEMO / EMSO

KM3NeT =

Kilometer cube

Neutrino Telescope

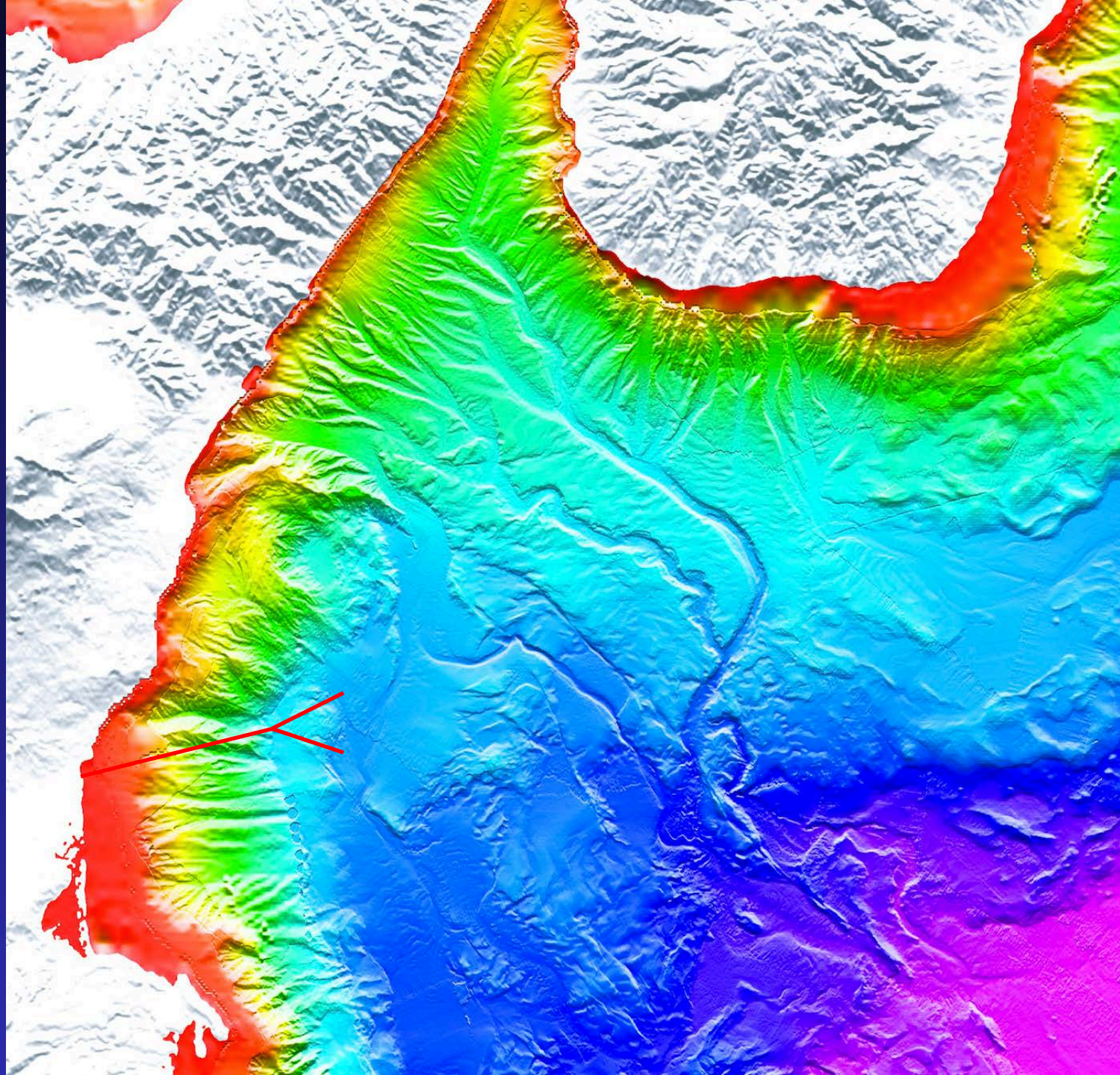
(cost ~ billions €)

On the N Alfeo

fault and in

a major turbidite

valley

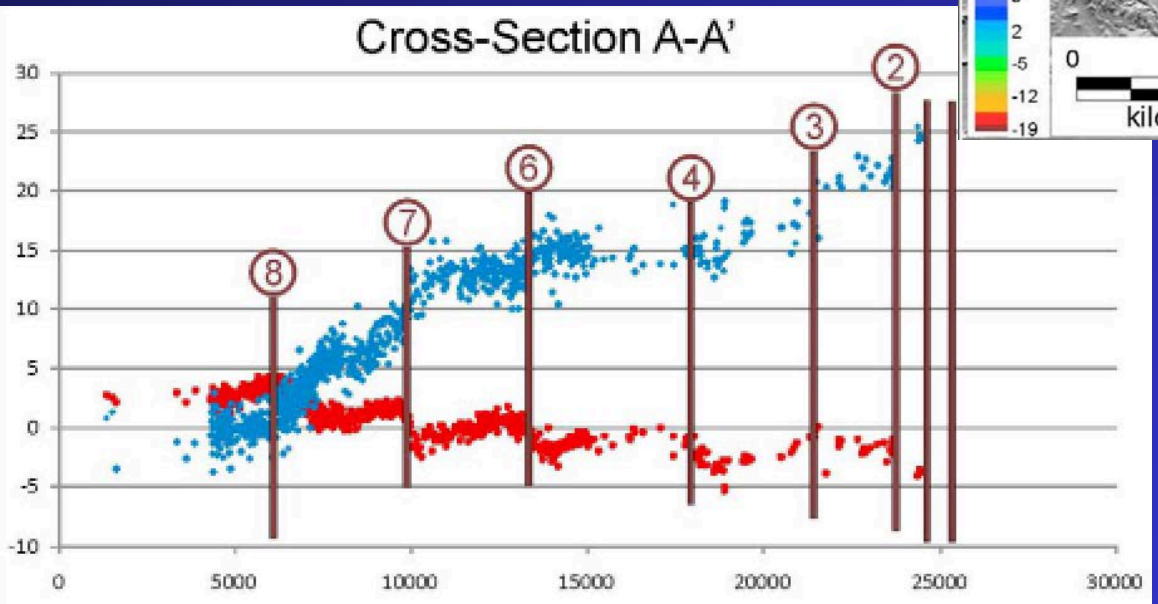


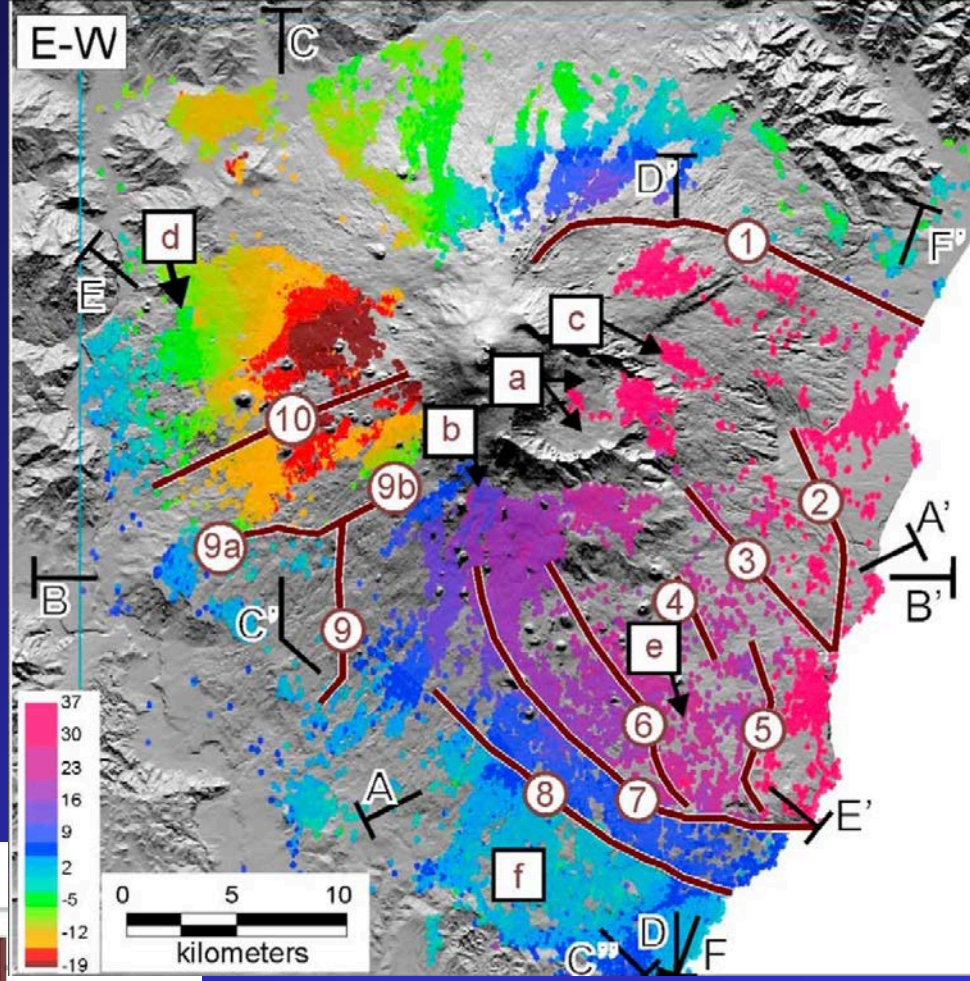
Etna flank faults:

InSAR observations of deformation

(Bonforte et al., 2011, G3)

discrete jumps of 3-5mm/yr

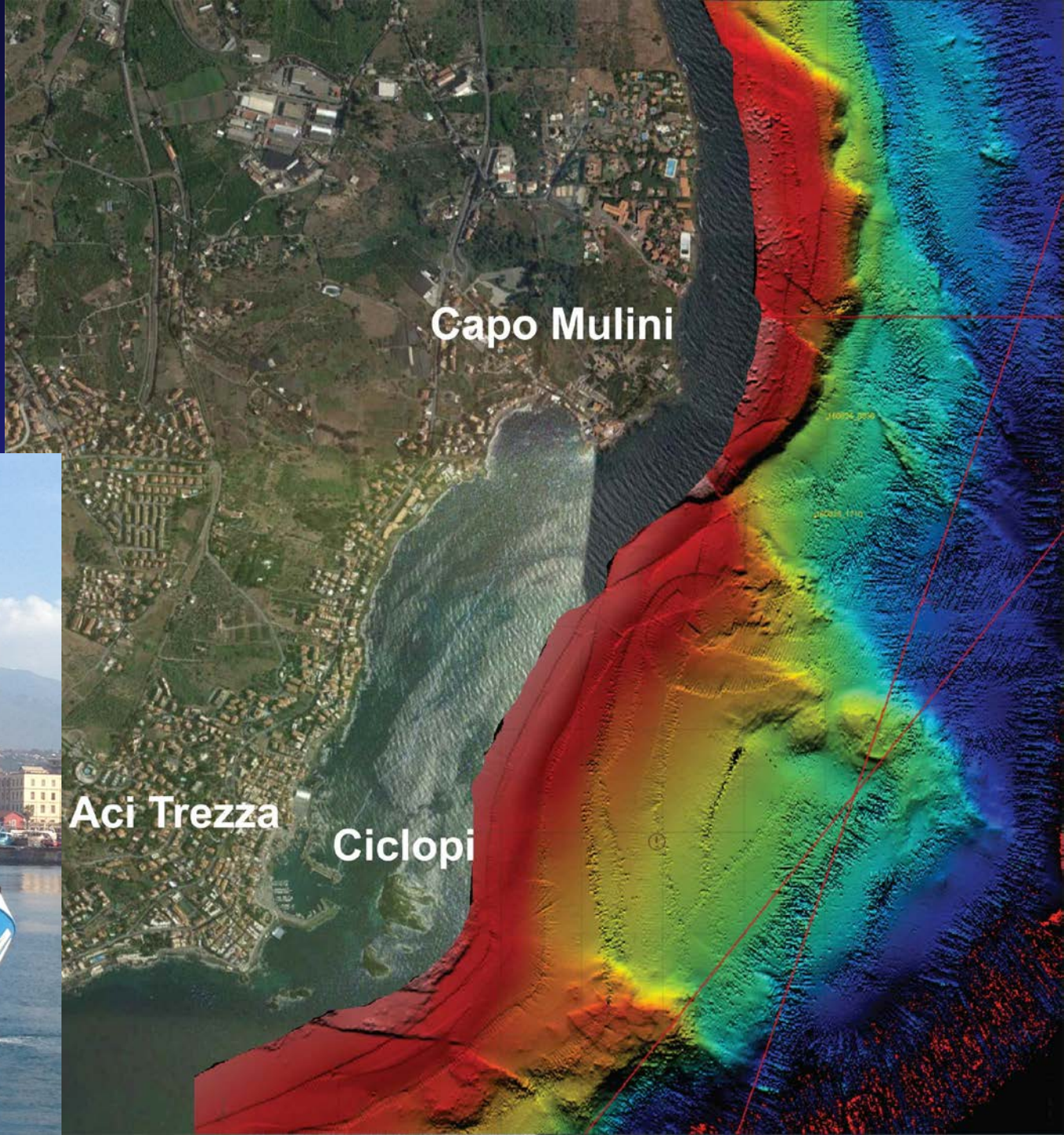




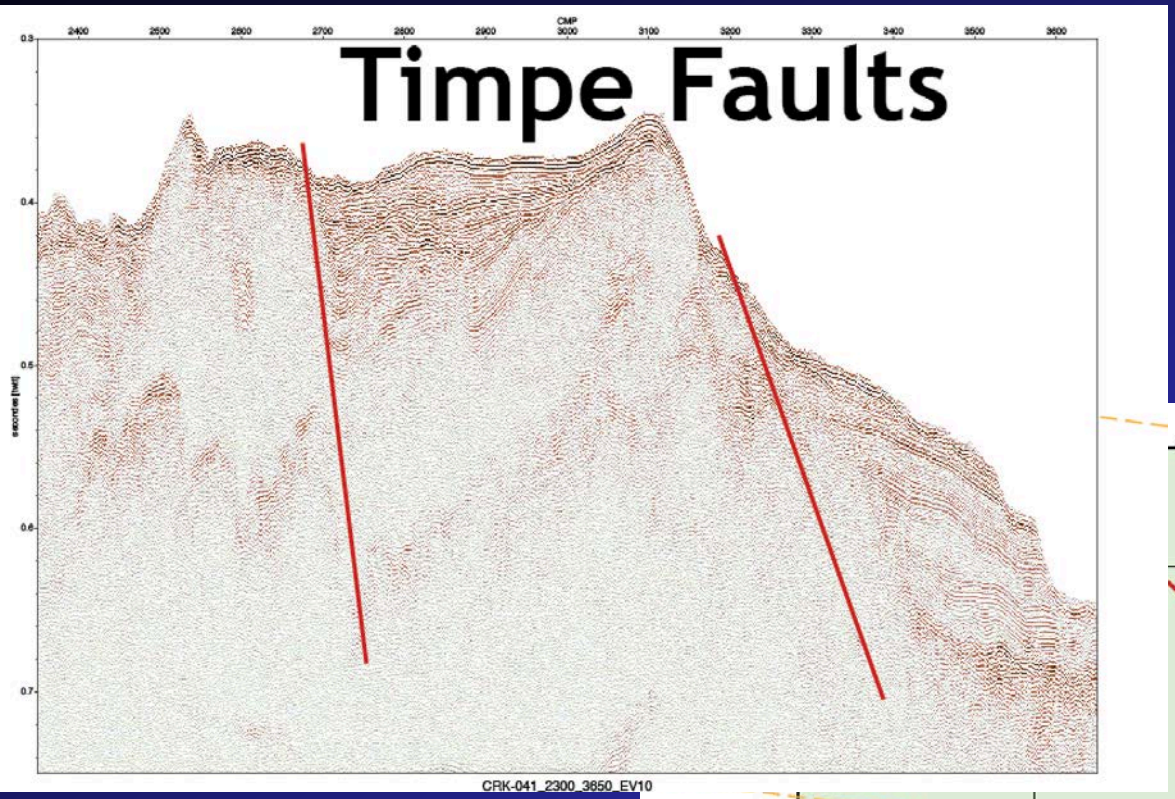
CRACK survey : vessel TethysII

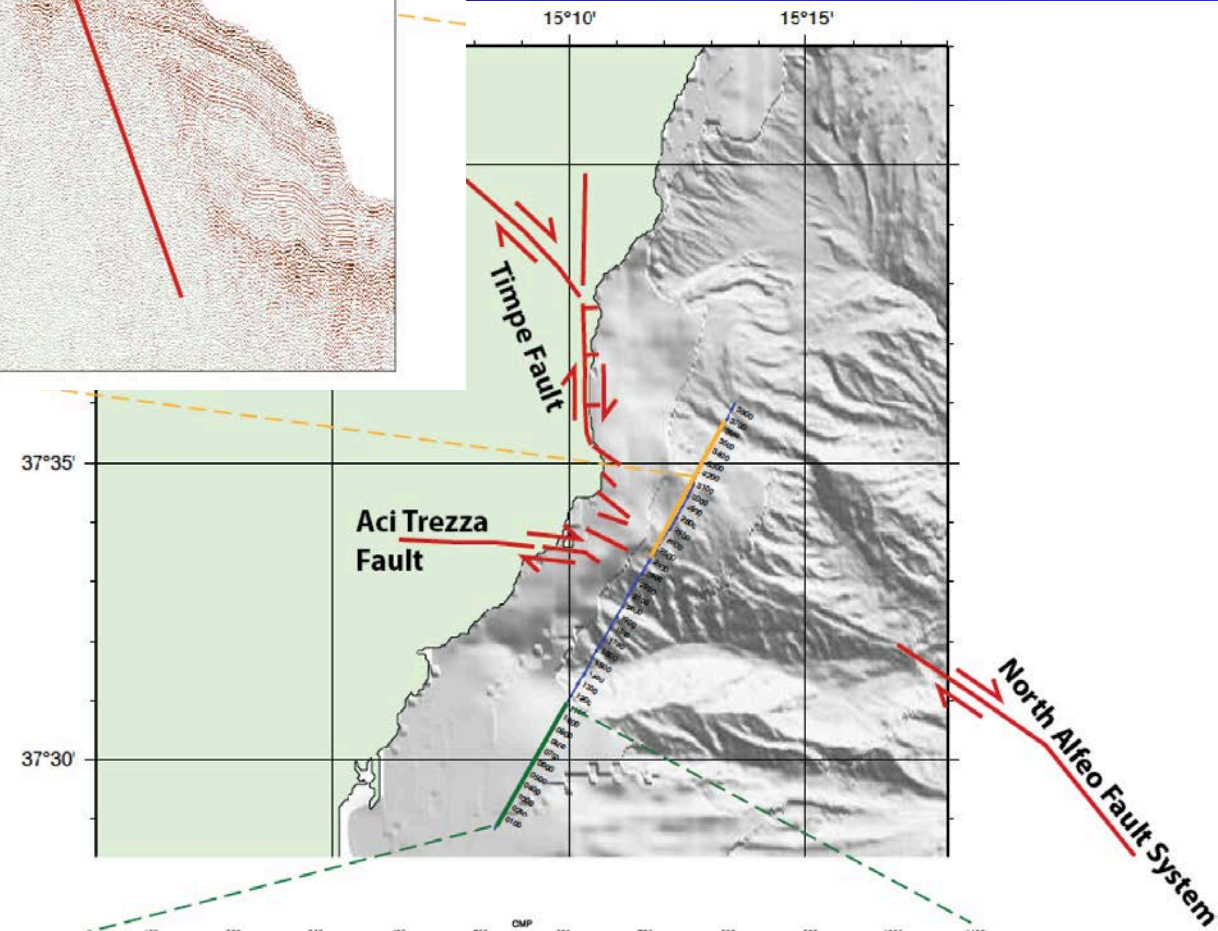
(Aug/Sep 2016)

bathymetry, sparker seismics

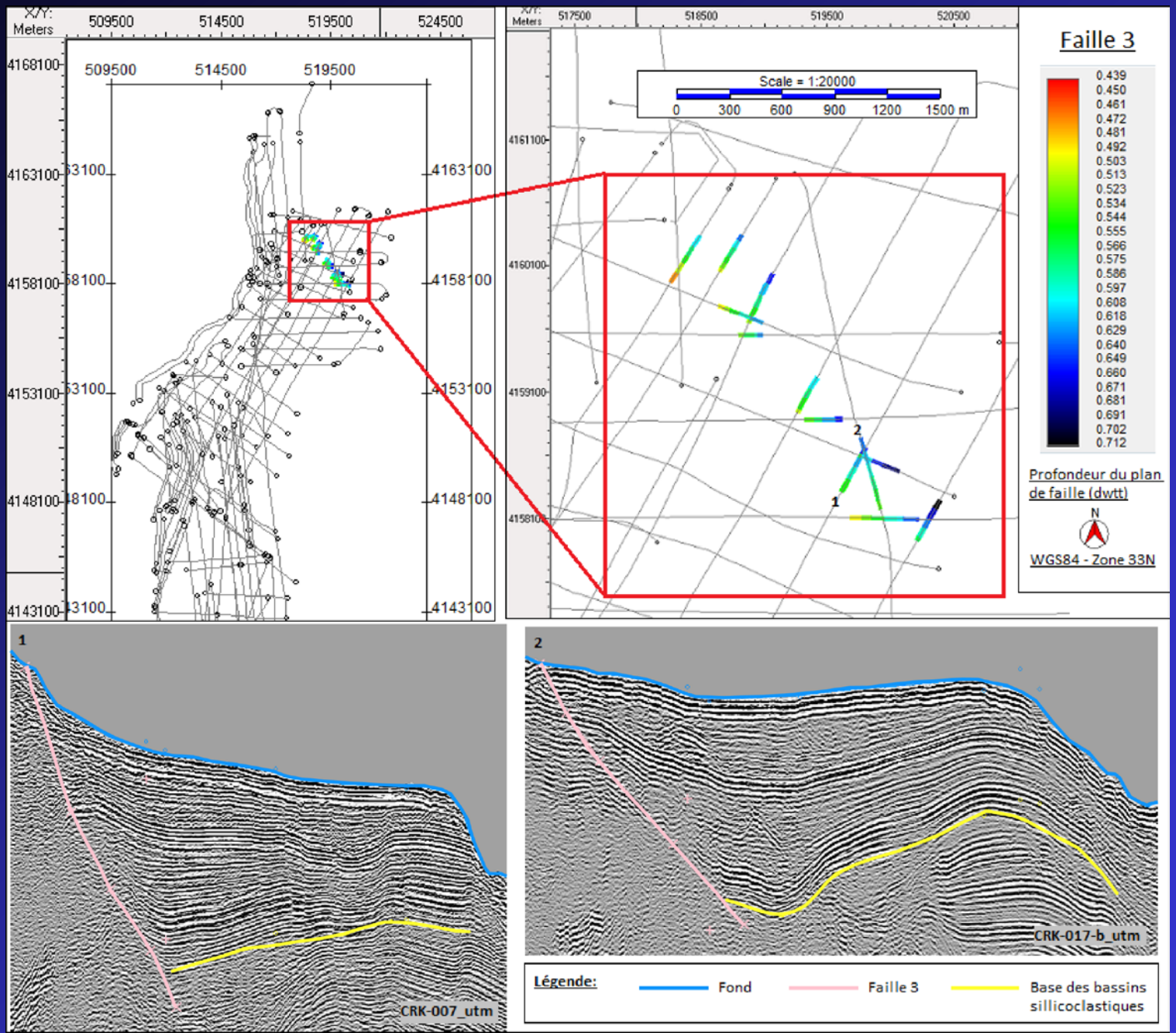


CRACK survey : sparker seismic profiles - Etna flank faults

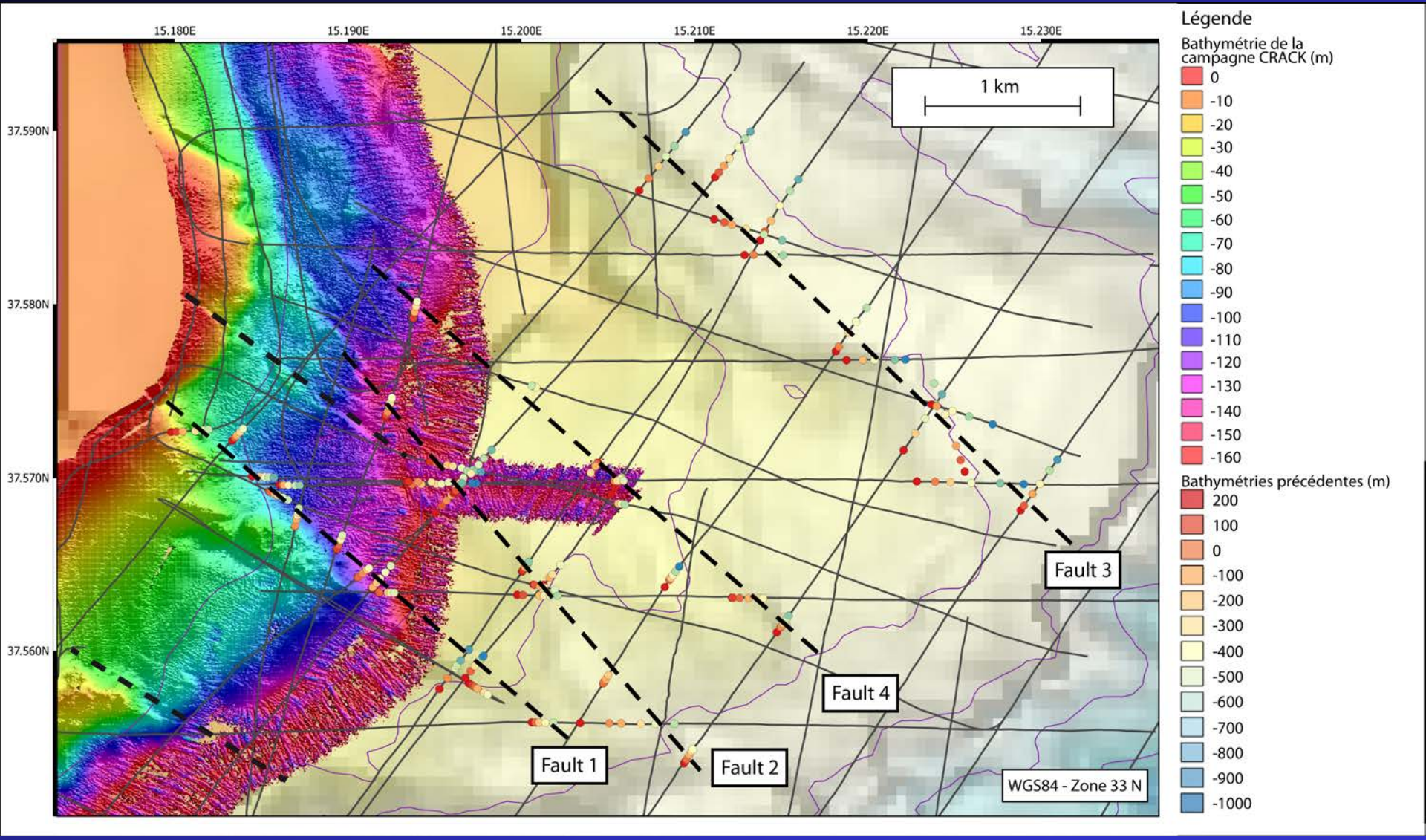




Etna flank faults (Masters project C. Lempereur, 2017 - unpubl.)



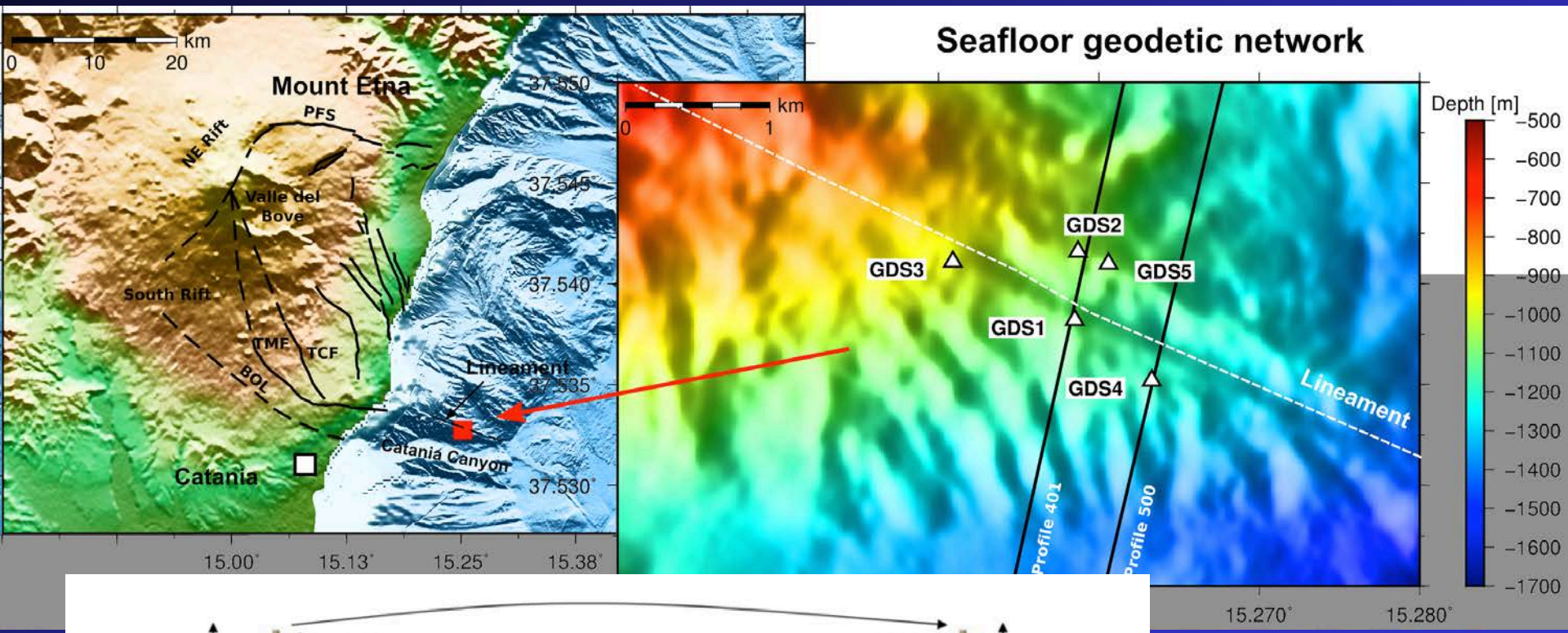
Etna flank faults (Masters project C. Lempereur, 2017 - unpubl.)

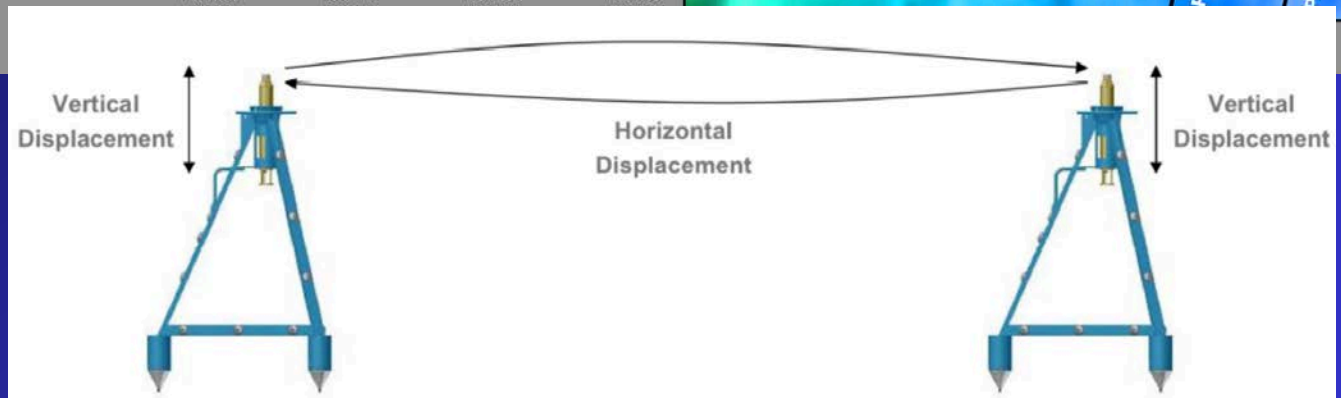


Link between Etna flank faults and the North Alfeo Fault

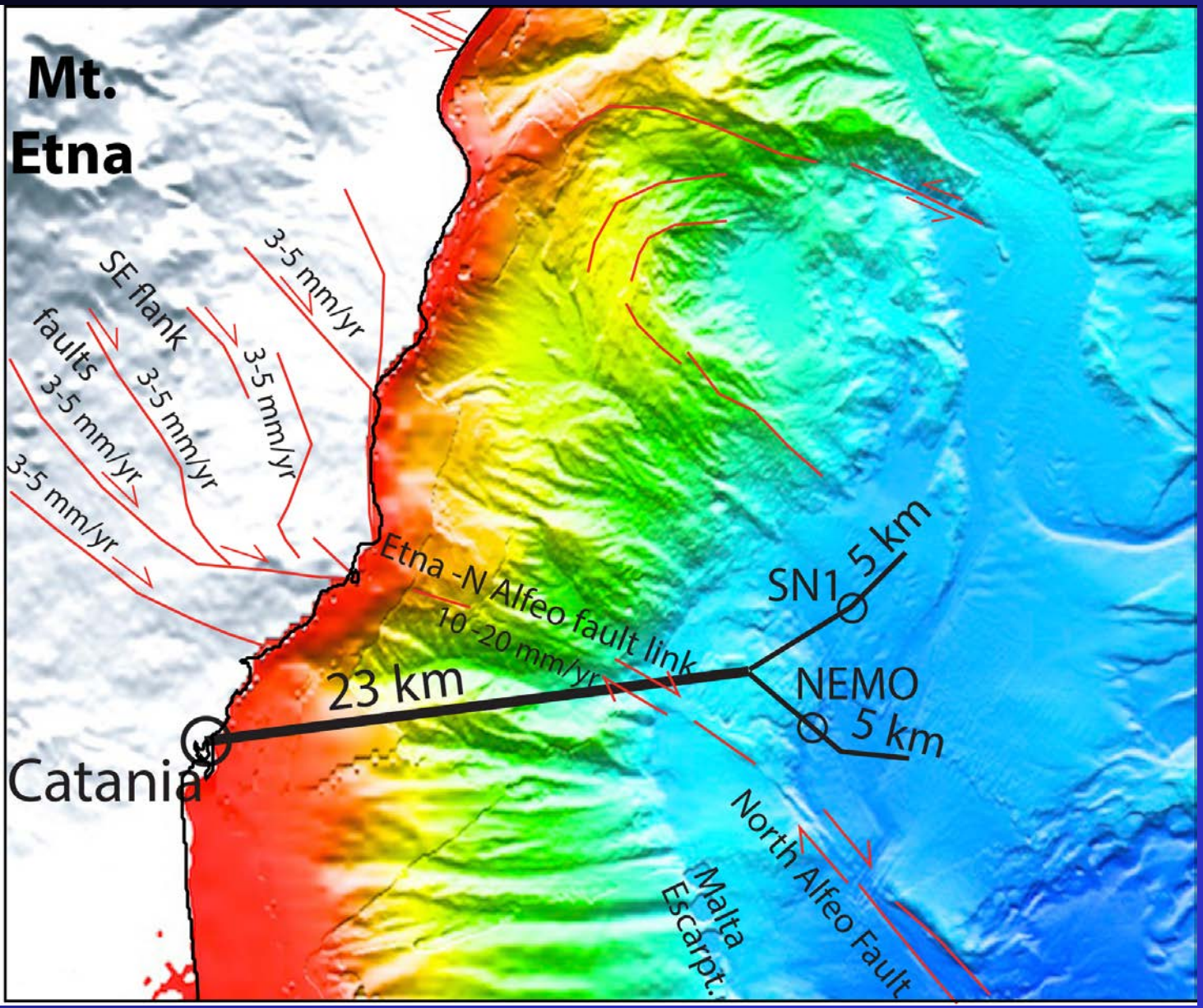
Seafloor geodetic survey (5 stations) in progress Apr. 2016 - 2018

Geomar, Kiel (H. Kopp, M. Urlaub) & Univ. Kiel (S. Krastel, F. Gross)





Fiber Optic Cable Use for Seafloor studies of seismic hazard and deformation: FOCUS (ERC Advanced grant proposal, 3.5 M€ requested)



IUEM-OSU
GEOSCIENCES OCEAN
CNRS-UBO-UBS

ifremer

20 YEARS OLD
IDIL
FIBRES OPTICS
System & components for science & industry

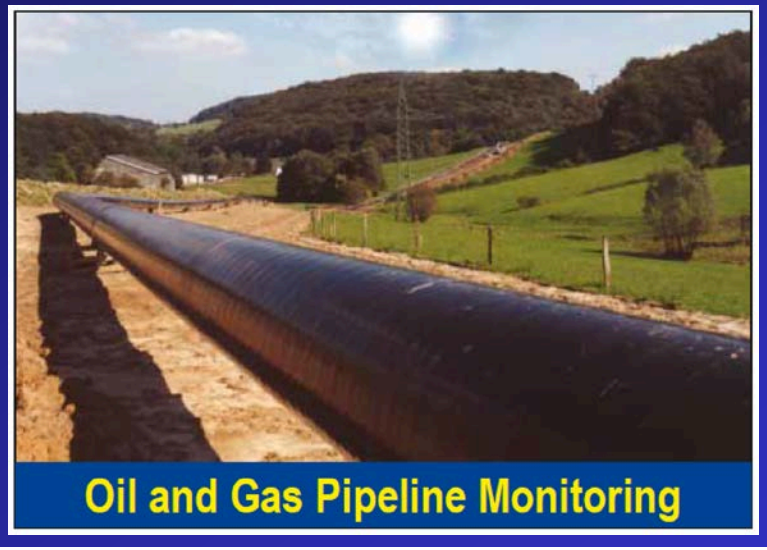
INGV

GEOMAR
Helmholtz-Zentrum für Ozeanforschung Kiel

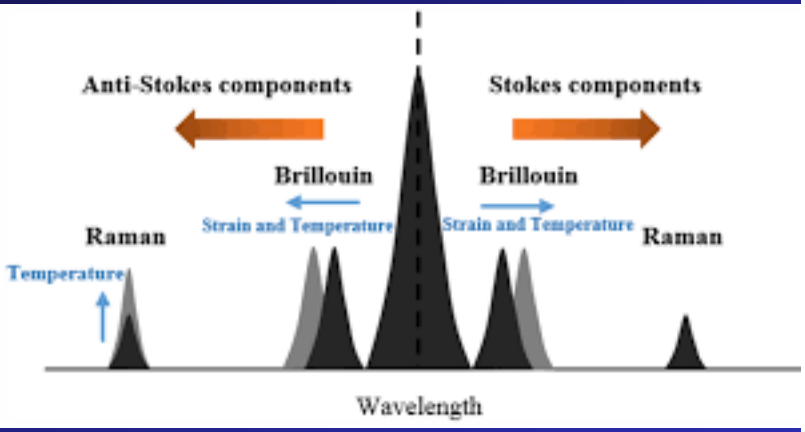
Fiber optic strain cables: BOTDR (Brillouin Optical Time Domain Reflectometry)

- Structural health monitoring of large structures (bridges, dams, pipelines, tunnels, mines)

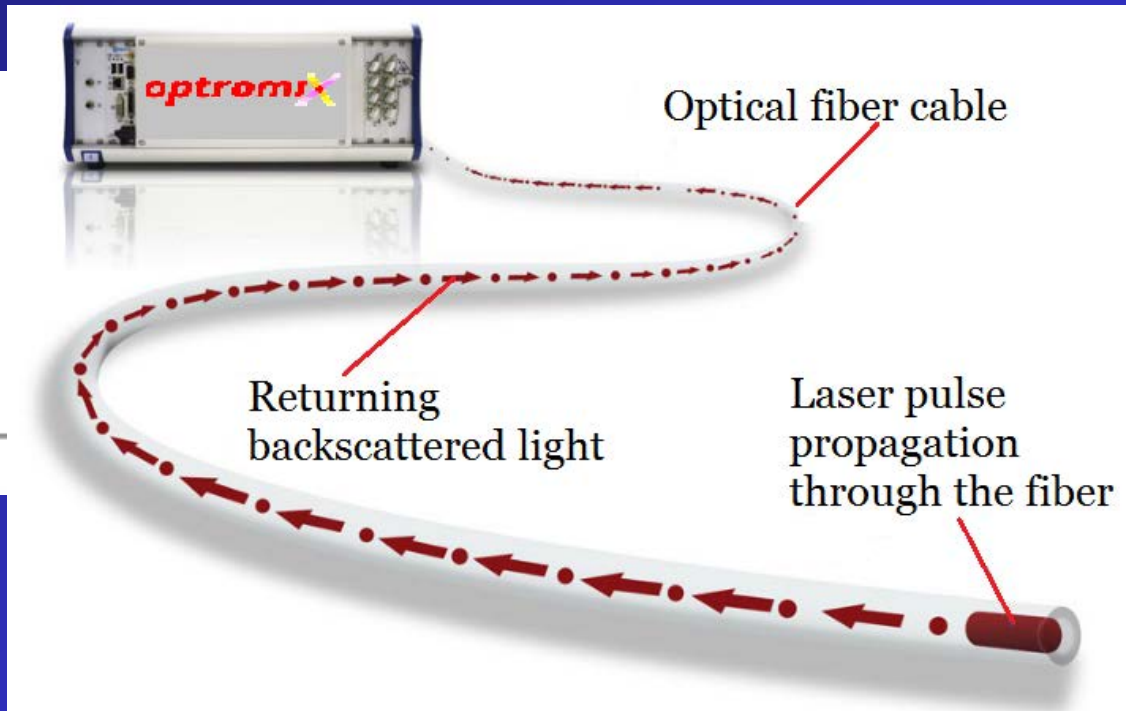
Structural Health Monitoring (SHM)



Oil and Gas Pipeline Monitoring



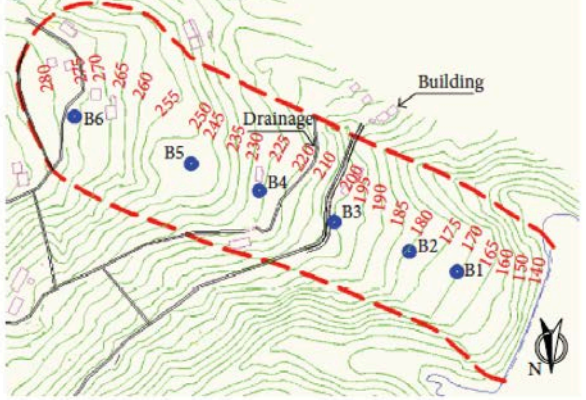
50 μm resolution at
10's of km distance



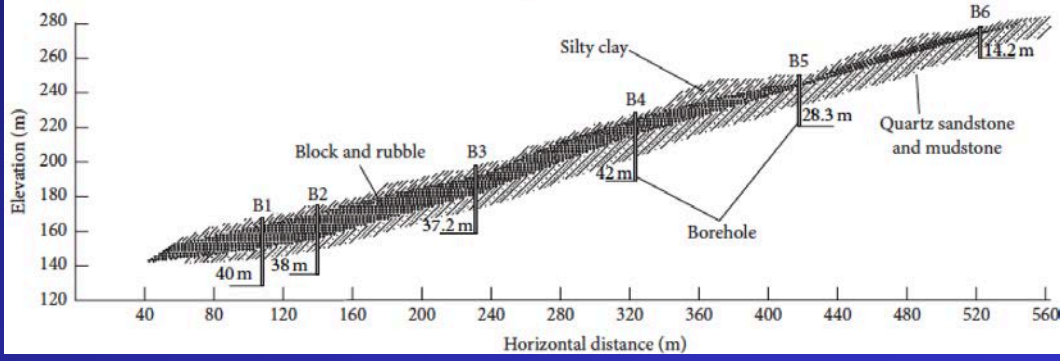
Strain cables :

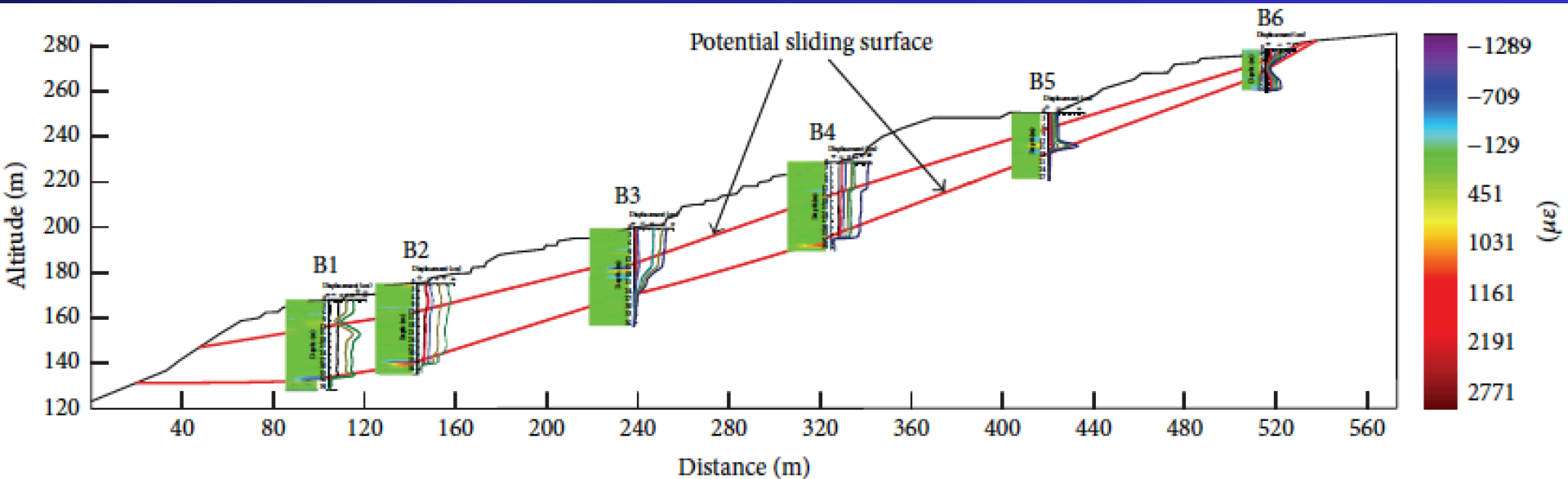
- BOTDR Monitoring of natural hazards (landslides)

(Sun et al., 2016, J. Sensors)



(a)

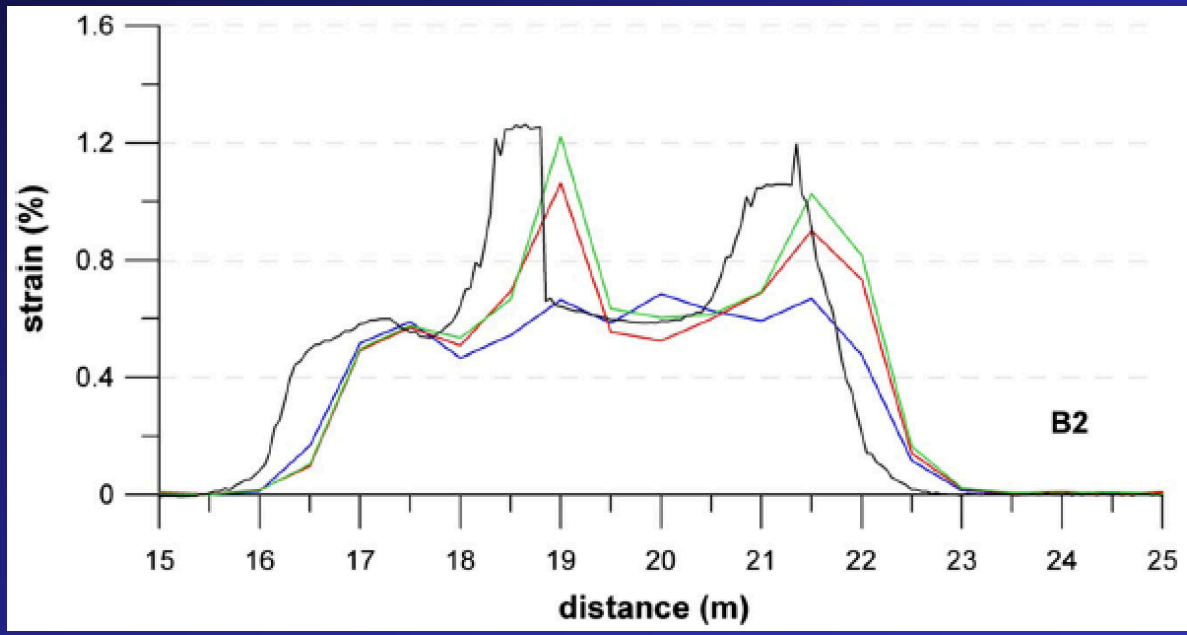


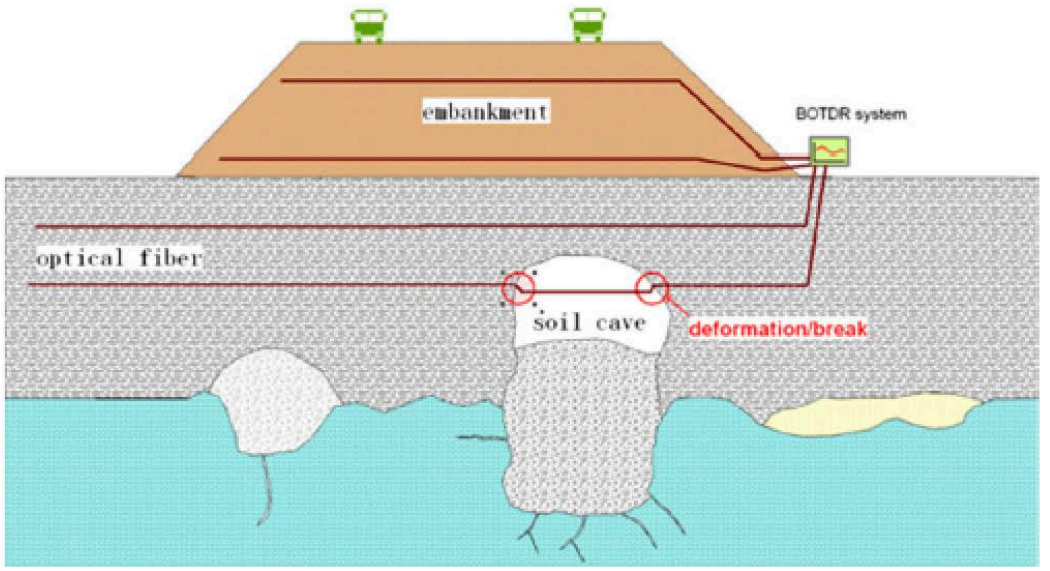


Strain cables :

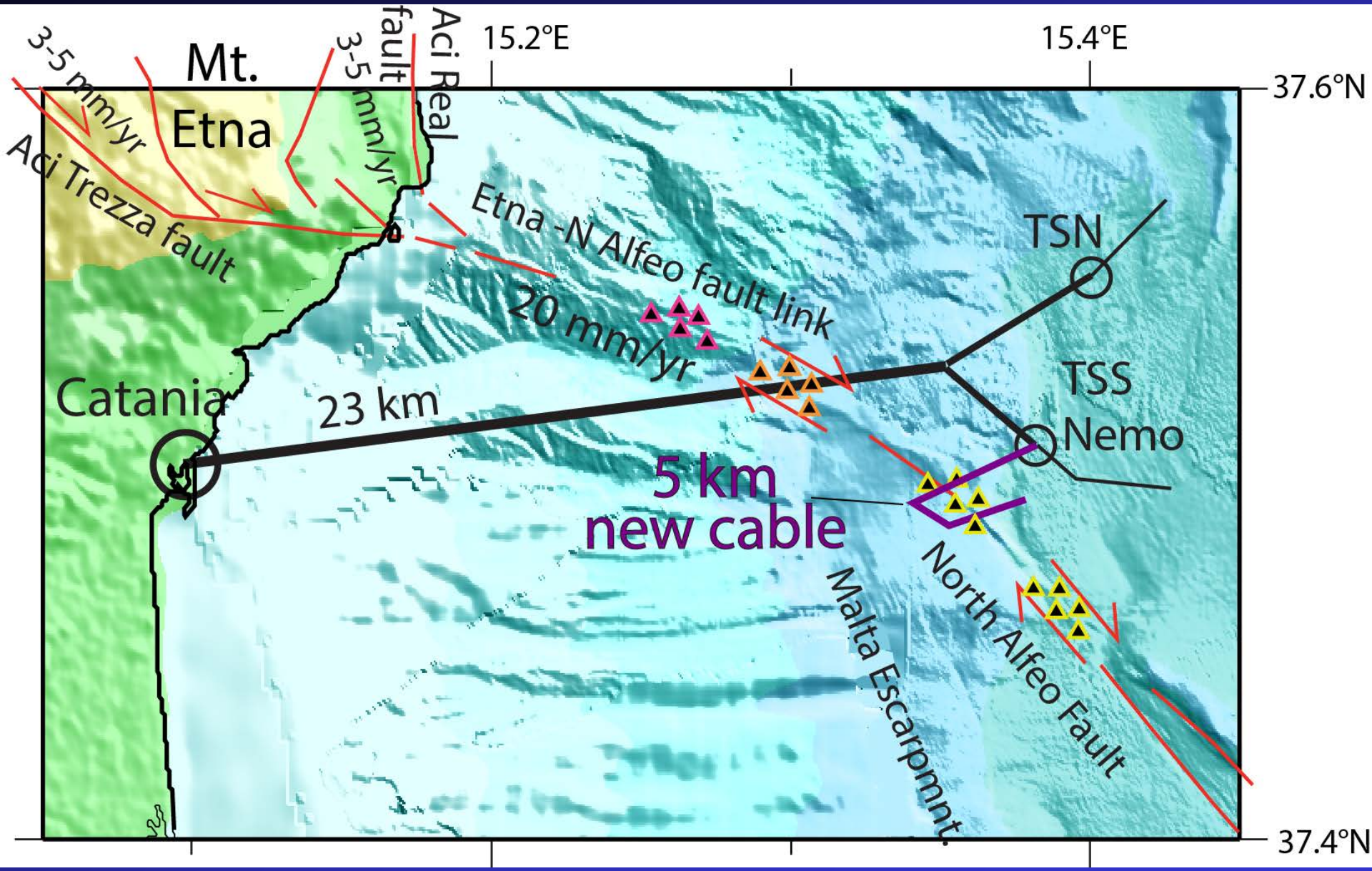
- BOTDR Monitoring of natural hazards (sinkholes)

(Jiang et al., 2016, Environ. Earth Sci.)





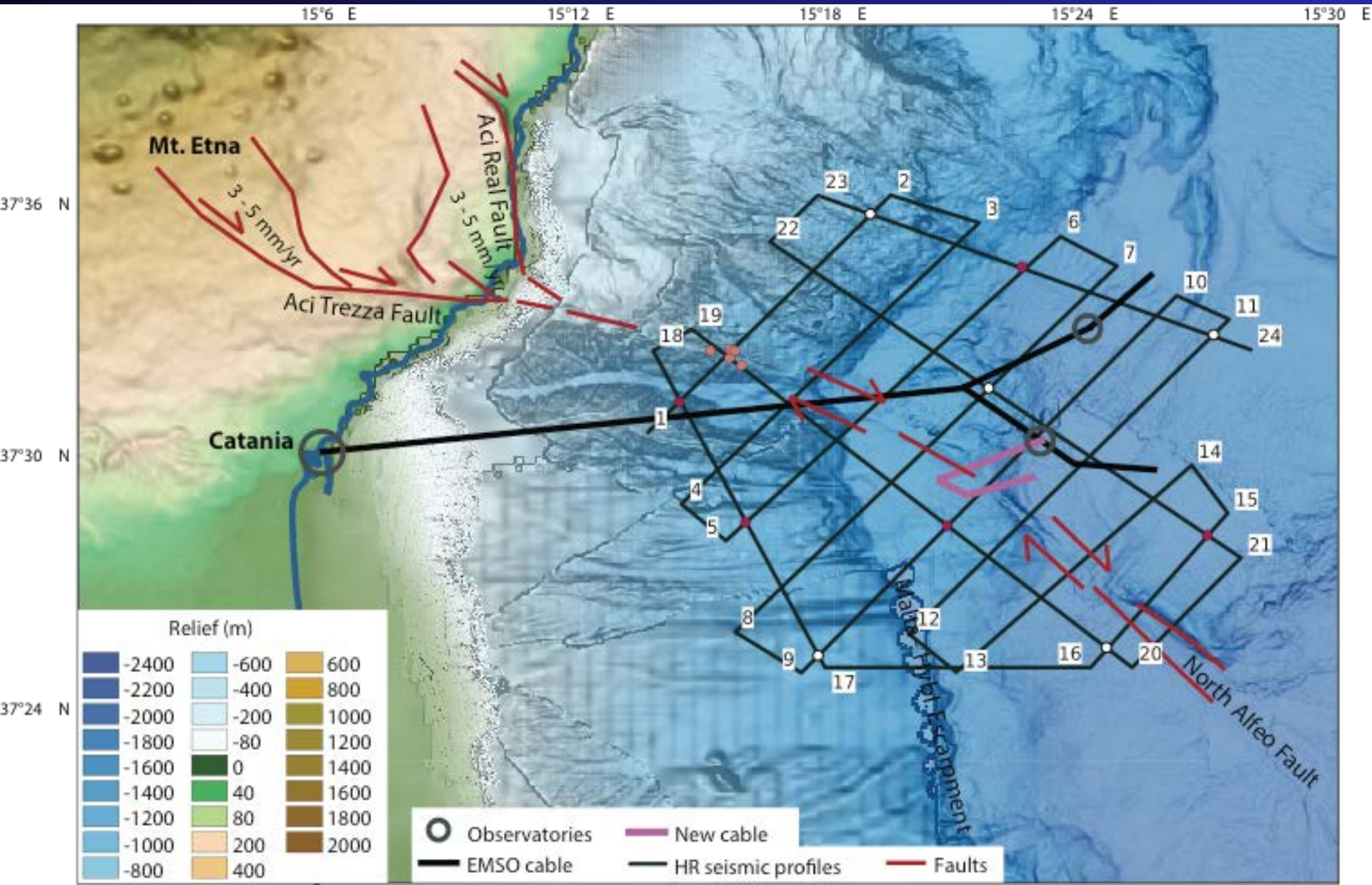
FOCUS: EMSO cable + new 5-km long fiber optic strain cable, calibrate observations using 3 new networks of submarine geodetic stations



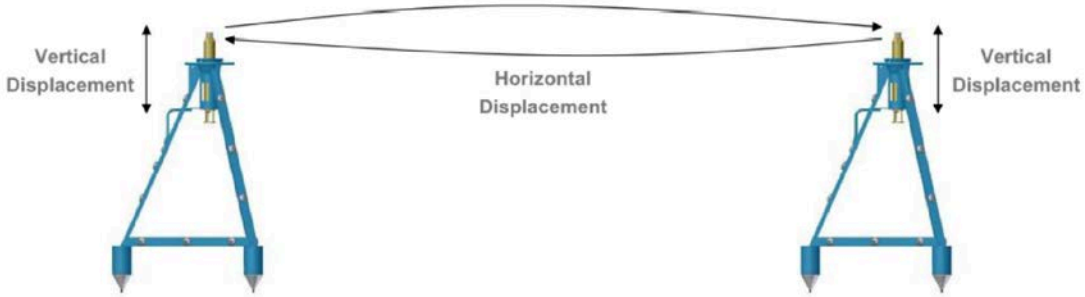
FOCUSSED marine expedition: AUV micro-bathymetric survey

15°6 E
15°12 E
15°18
37°36 N
37°30 N
37°24 N
Mt. Etna
3 - 5 mm/yr
Aci Real Fault
3 - 5 mm/yr
Aci Trezza Fault
Catania
Malta Hyblean Escarpment
North Alfeo Fault
Relief (m)
-2400
-2200
-2000
-1800
-1600
-1400
-1200
-1000
-800
-600
-400
-200
-80
0
40
80
200
400
600
800
1000
1200
1400
1600
1800
2000
AUV bathy (day 1)
AUV bathy (day 2)
AUV bathy (day 3)
AUV bathy (day 4)
EMSO cable
Faults

FOCUSSED marine expedition: HR seismic profiles

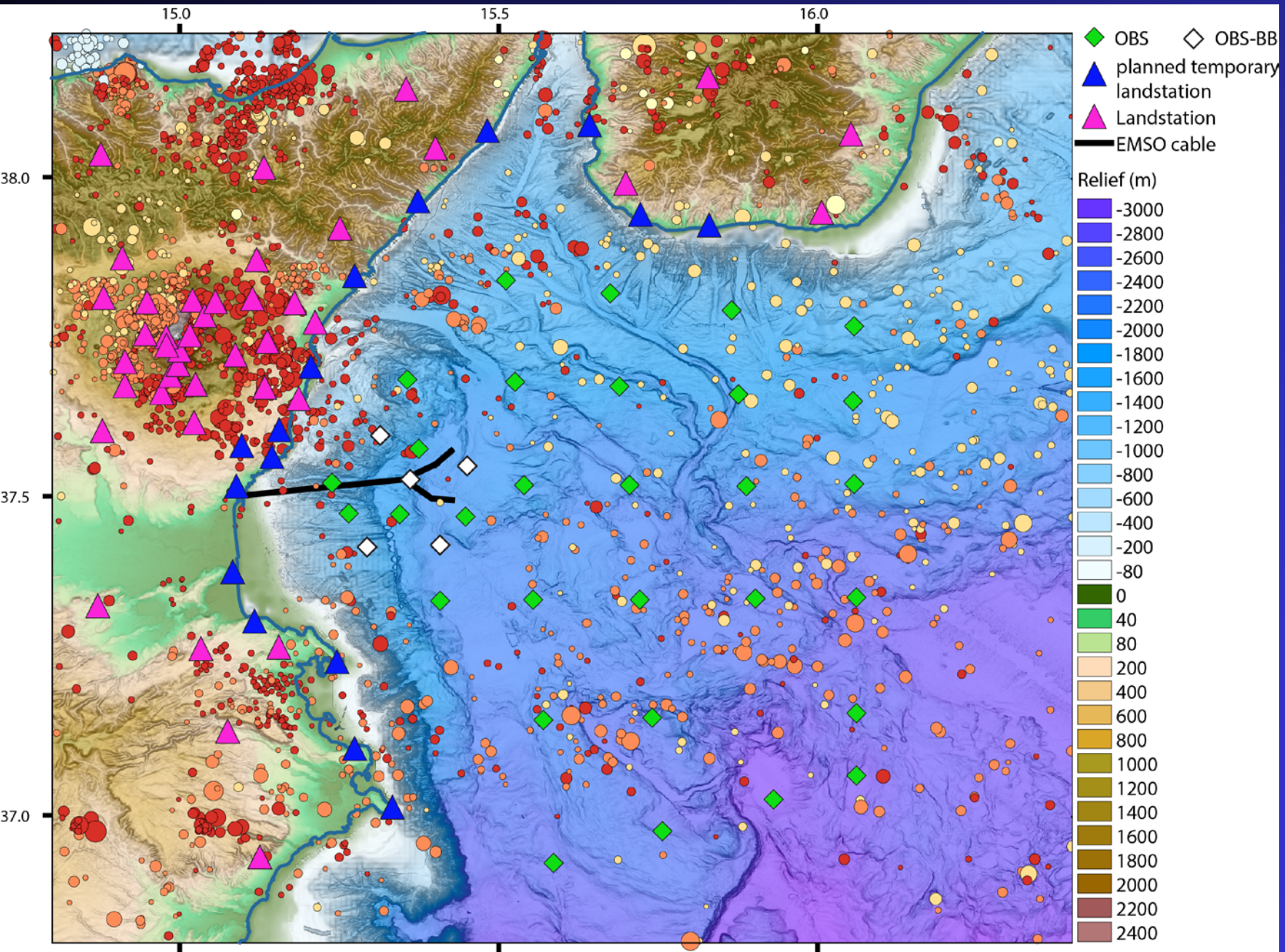


FOCUSSED marine expedition: Seafloor geodetic stations

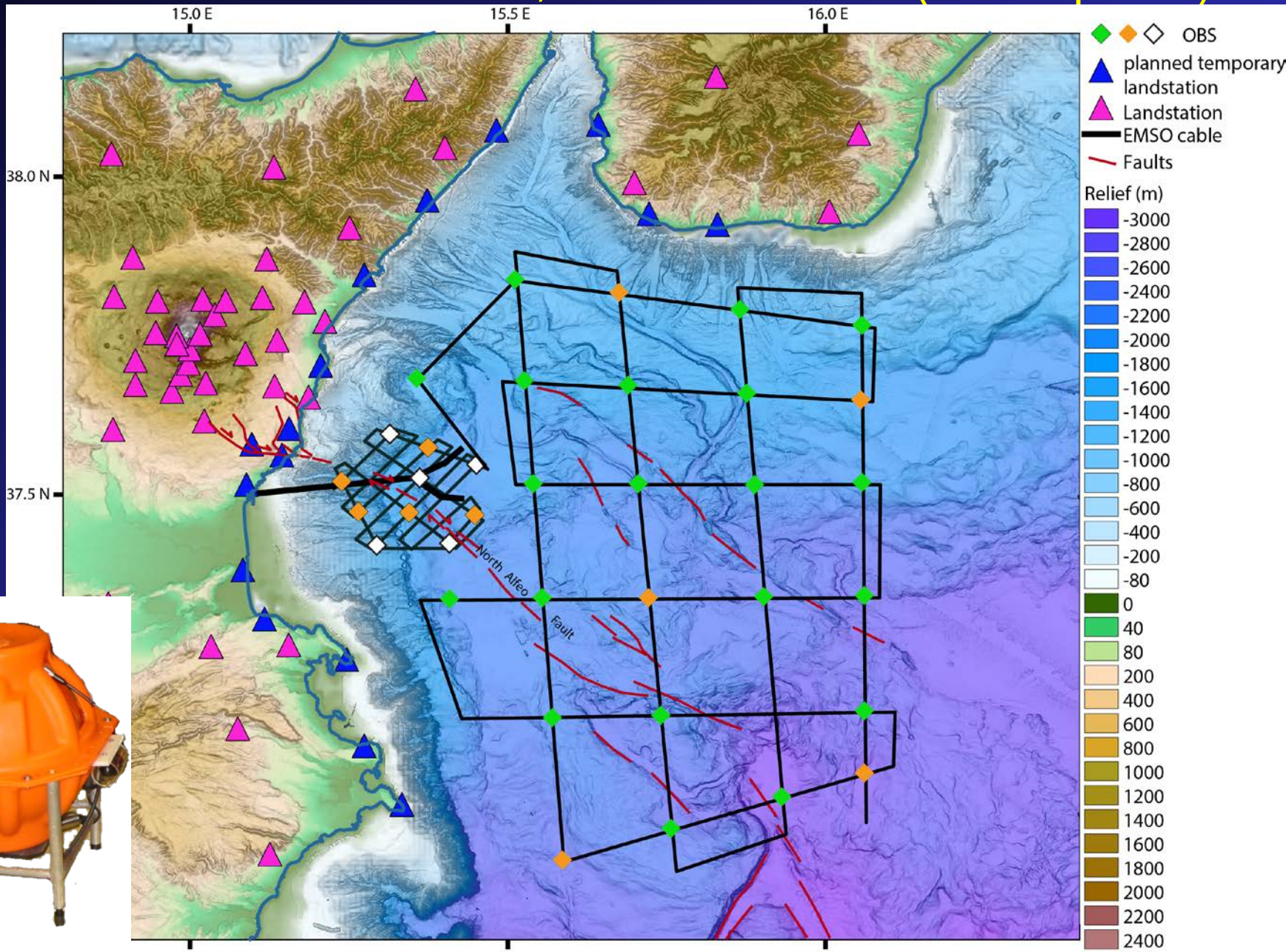


15°6 E
15°12
37°36 N
37°30 N
37°24 N
Mt. Etna
3 - 5 mm/yr
Aci Real Fault
3 - 5 mm/yr
Aci Trezza Fault
Catania
zone 1
zone 2
zone 3
Malta Hyblean Escarpment
North Alfeo Fault
Relief (m)
-2400 -2200 -2000 -1800 -1600 -1400 -1200 -1000 -800
-600 -400 -200 -80 0 40 80 200 400
600 800 1000 1200 1400 1600 1800 2000
EMSO cable
New cable
AUV zone
Observatories
Faults
Geodetic stations existing network
Geodetic stations new networks

FOCUSSED marine expedition: regional seismicity



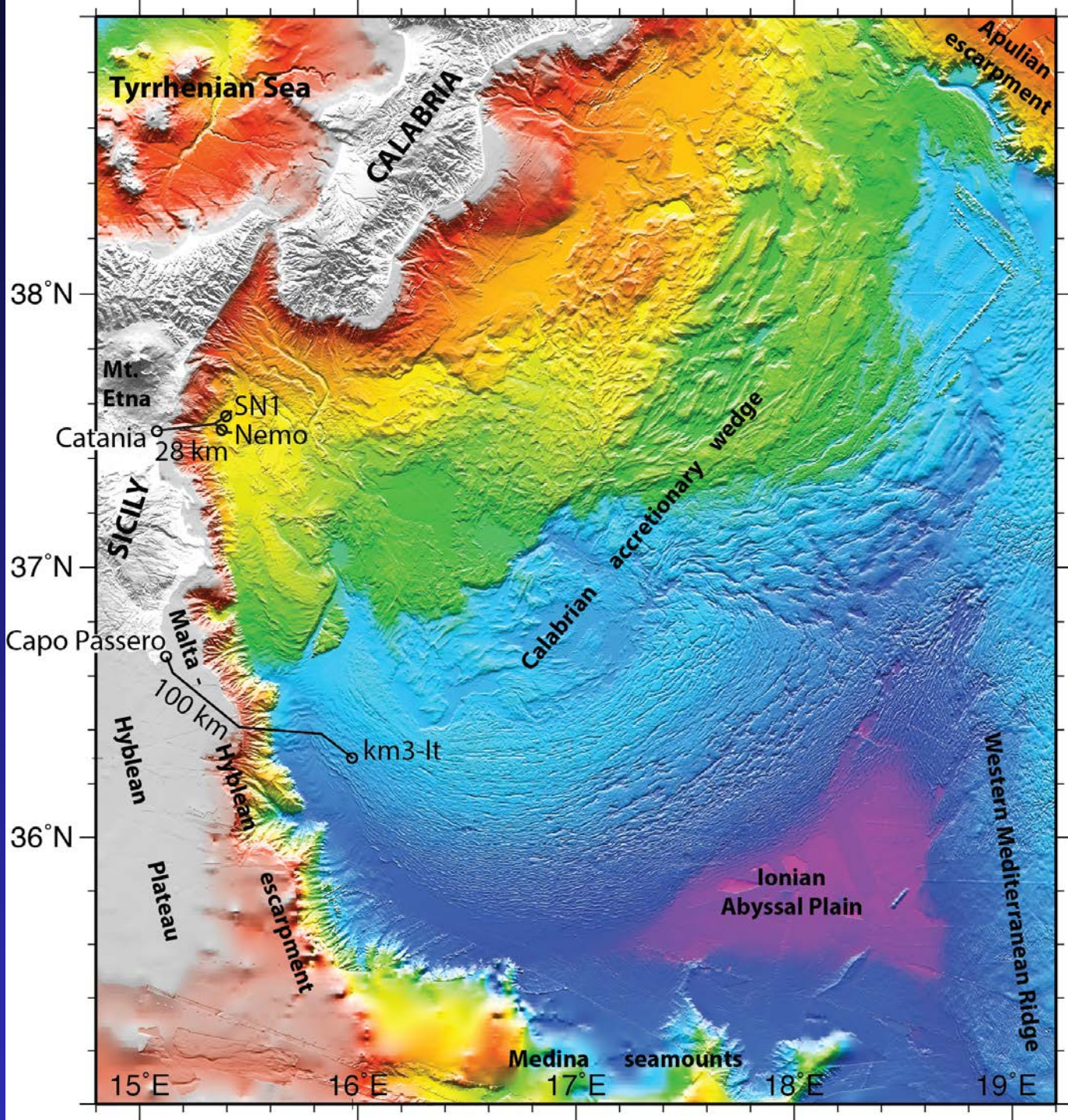
FOCUSSED marine expedition: Land-sea seismological experiment
15 Ifremer and 20 Geomar OBS, INGV land stations (+15 temp. stat.)



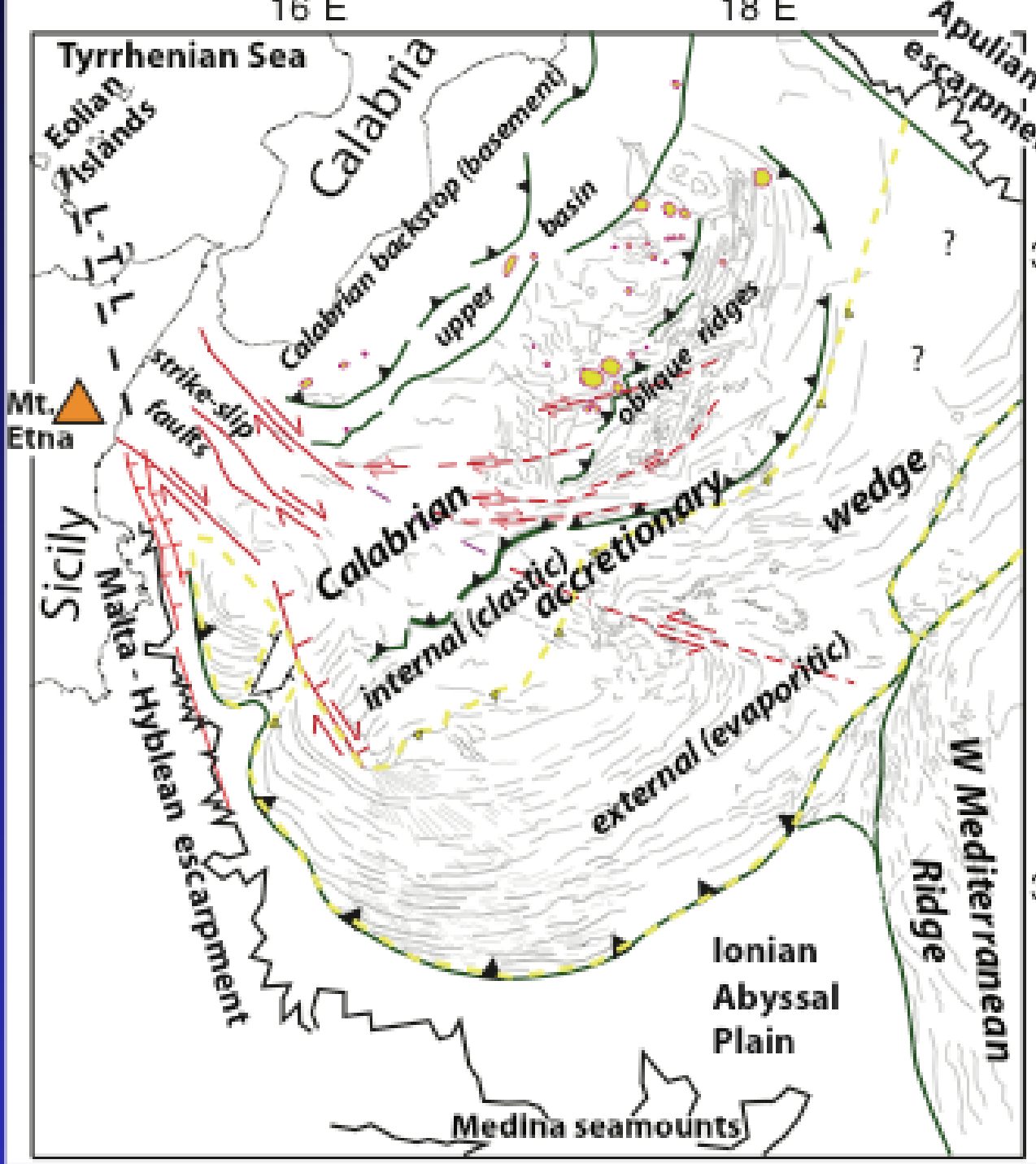
2 EMSO fiber optic cables offshore Eastern Sicily:

Catania (28 km)

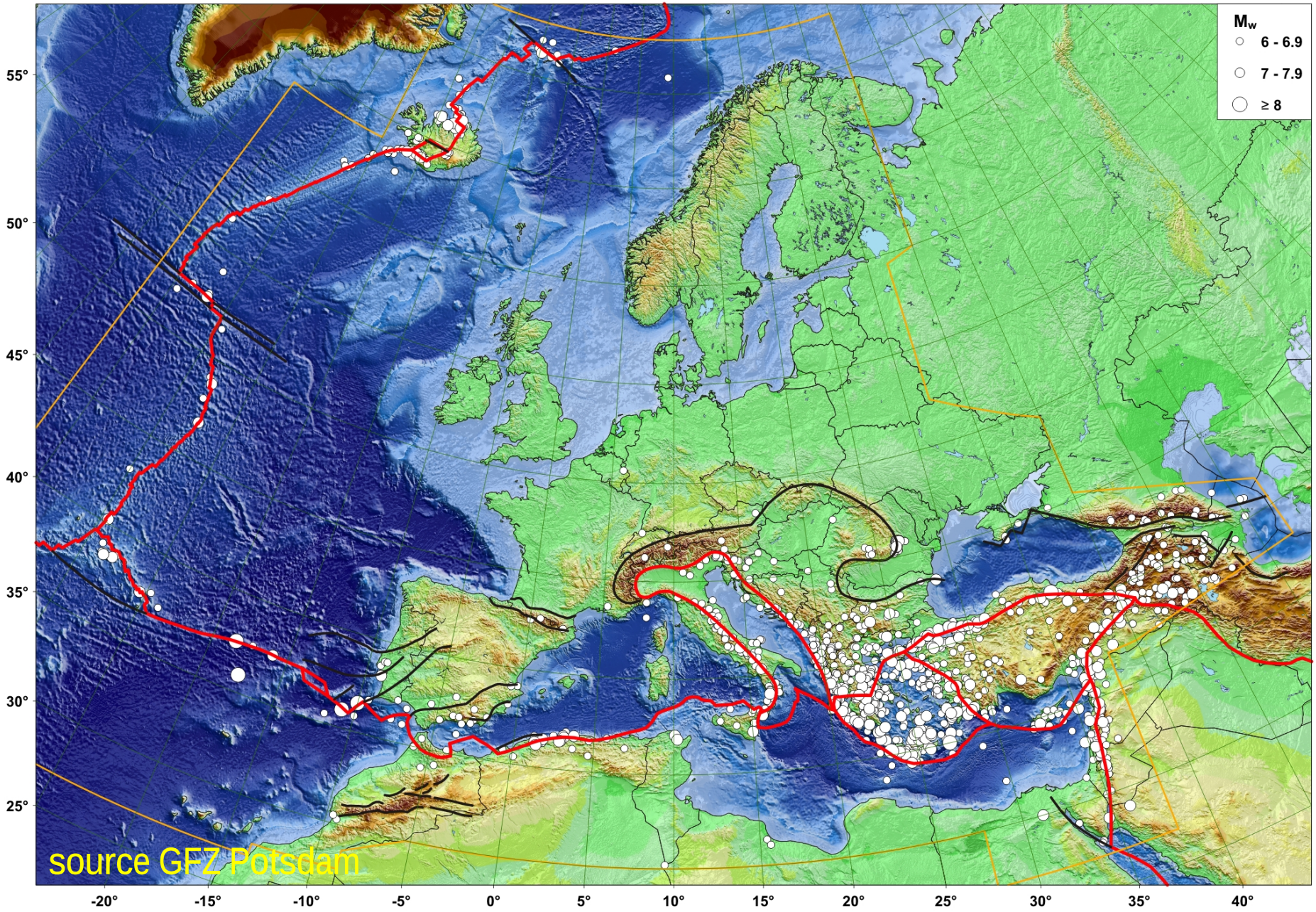
C. Passero (100 km)



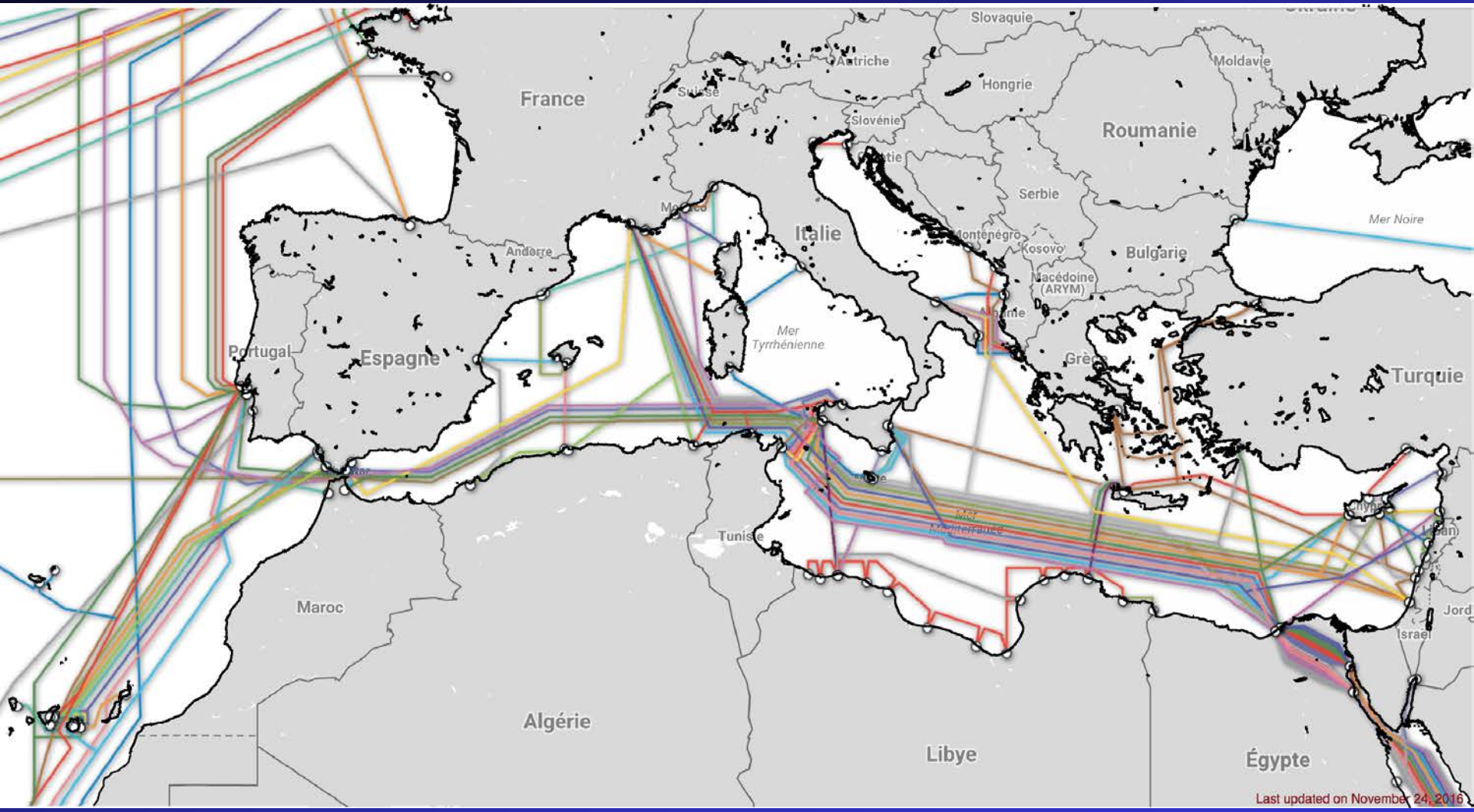
Tectonic map and fault kinematics



European - African plate boundary



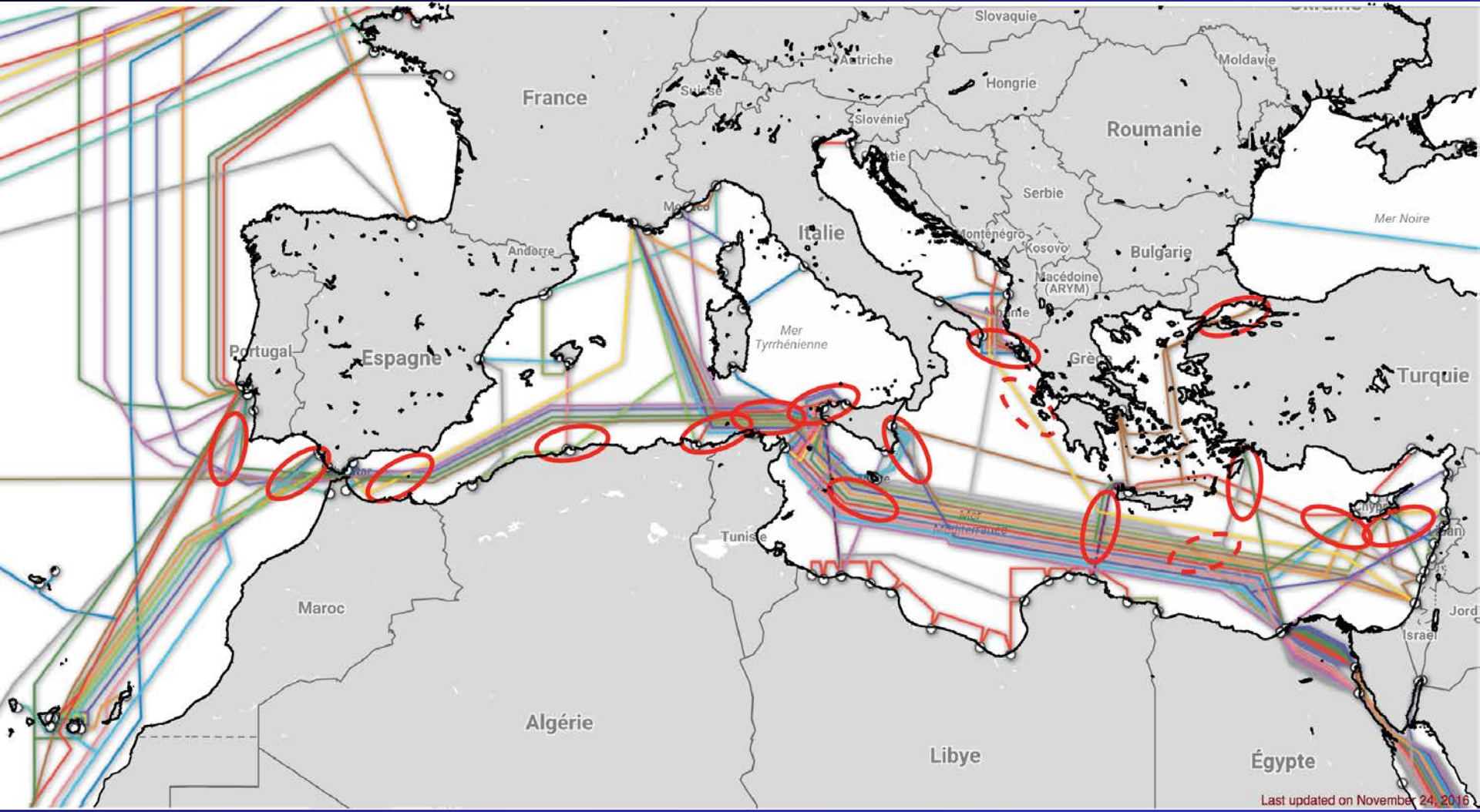
European - Mediterranean telecommunication cables map



Source: www.submarinecablemap.com (Tele Geography) Nov. 2016

European - Mediterranean telecommunication cables:

Crossing the Eurasia - Africa plate boundary



Conclusions / Outlook :

- active strike-slip faults offshore E Sicily (seismics, bathymetry)

with connection to Etna flank faults (known from InSAR, GPS) 3-5mm/yr displacements and observed in shallow water / coastal surveys

ERC project FOCUS:

- New approach : laser reflectometry (BOTDR method) on fiber optic cables

Main target - Catania EMSO cable (28 km) crossing N Alfeo fault

2 other EMSO cables : Capo Passero SE Sicily (100 km)

Molene Island W Brittany (2 km)

- Planned cruise 2019 site survey of cable - fault intersection

(seafloor geodesy, microbathymetry, seismics, OBS network)

Thanks for your attention!

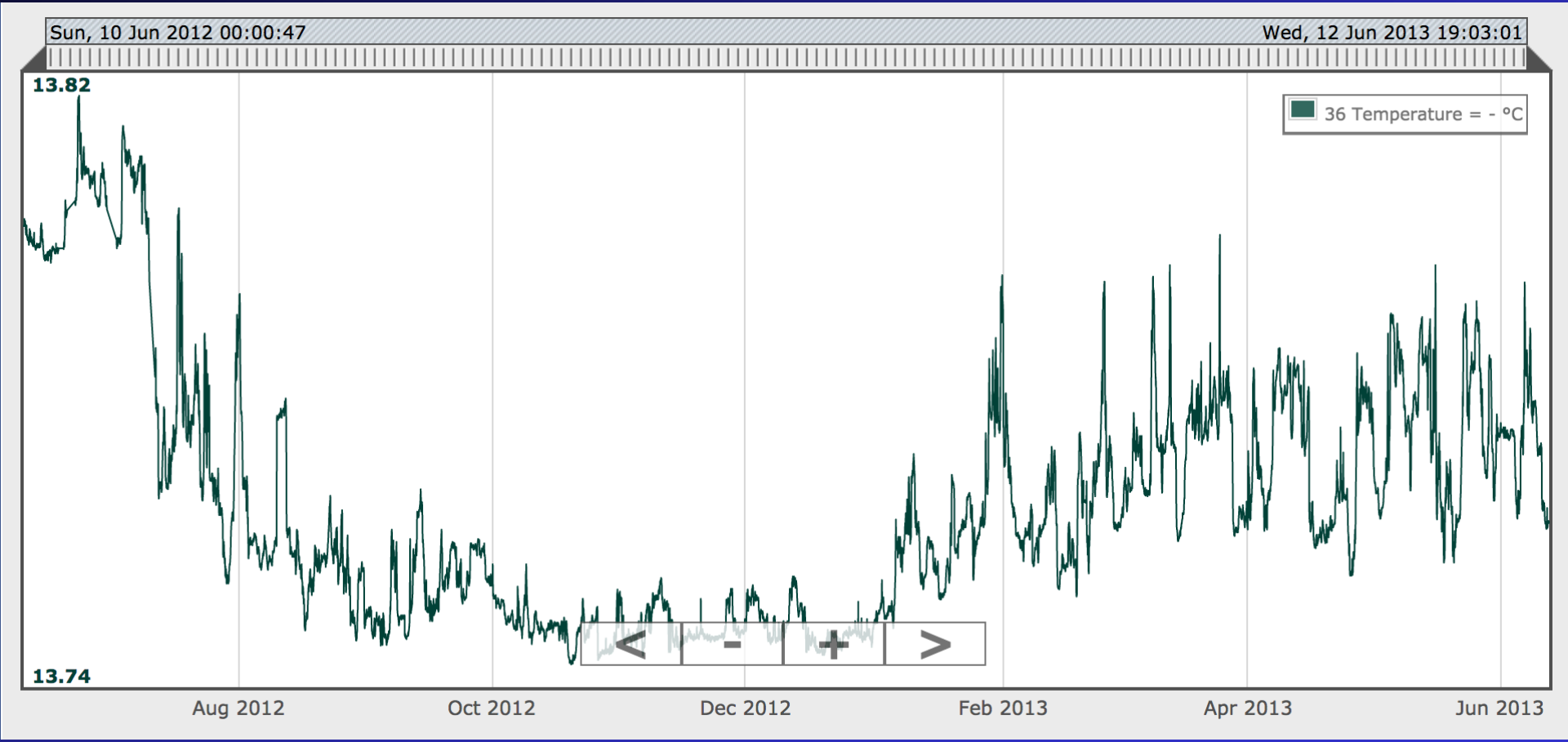
Seafloor temperature:

1 year (Jun 2012 - Jun 2013)

EMSO Ionian Sea (2100m depth)

Temperature is nearly constant

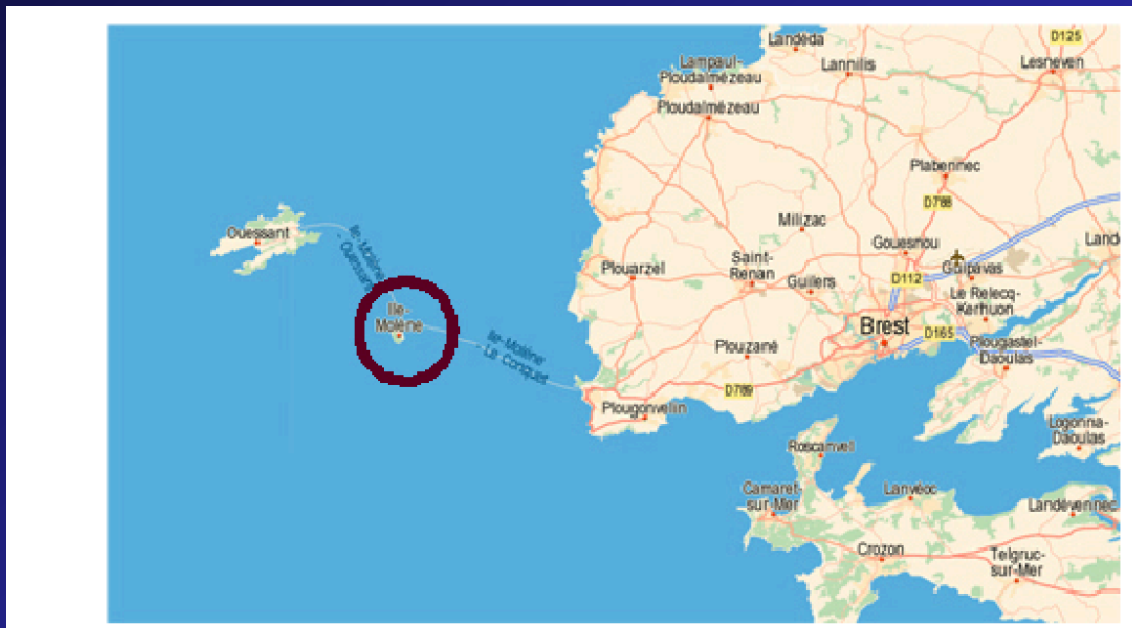
0.08° C maximum fluctuation

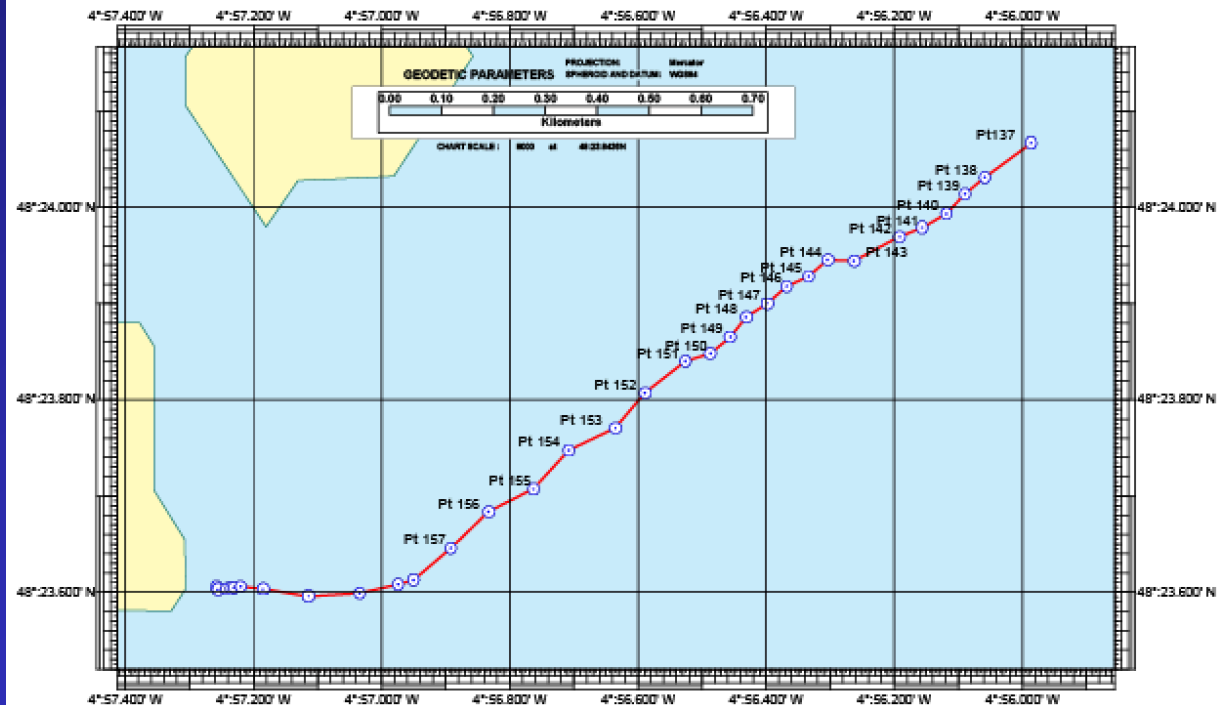


Preliminary tests with the BOTDR method on a local cable:

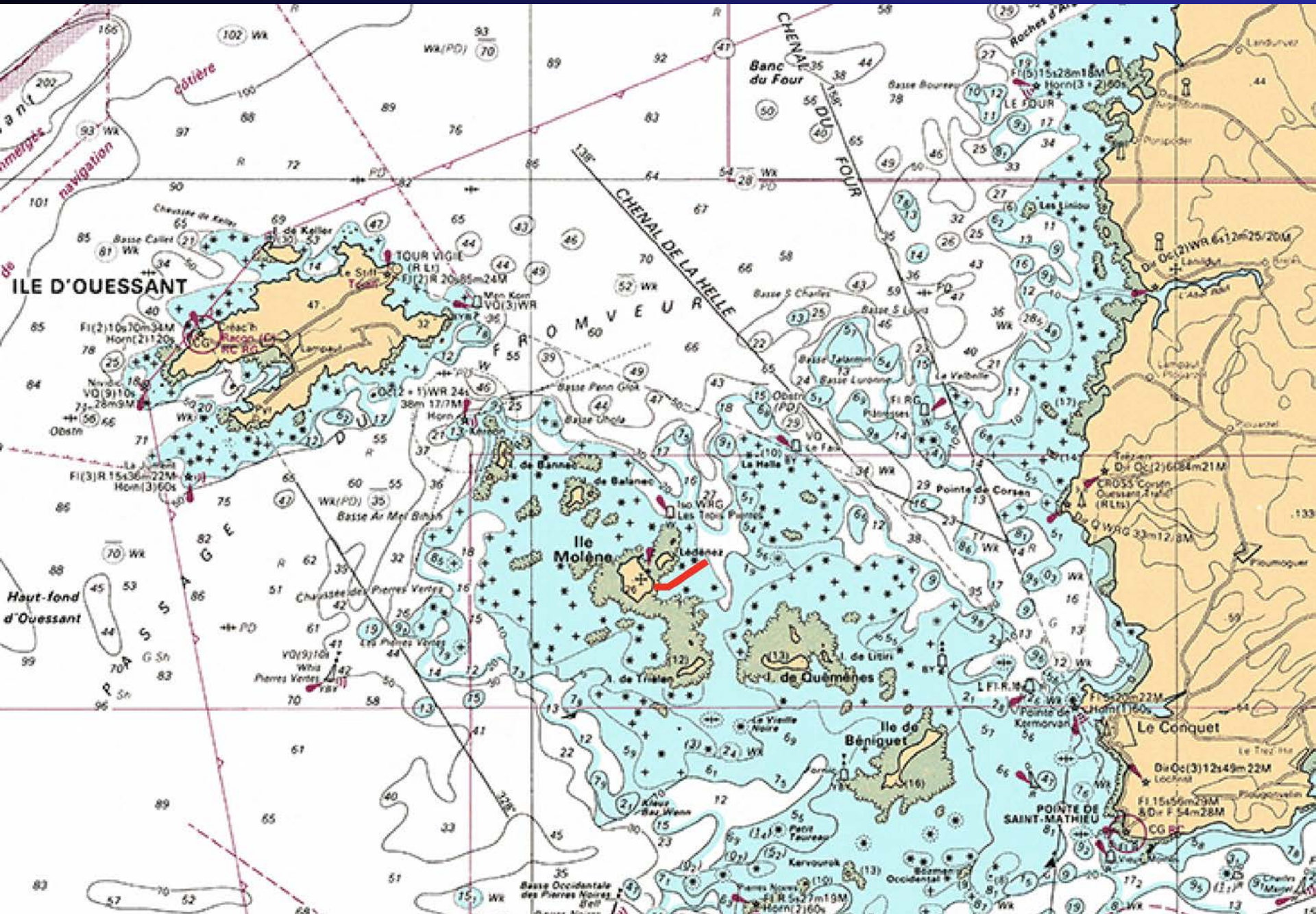
Molene EMSO station

performed 28 Jun 2017



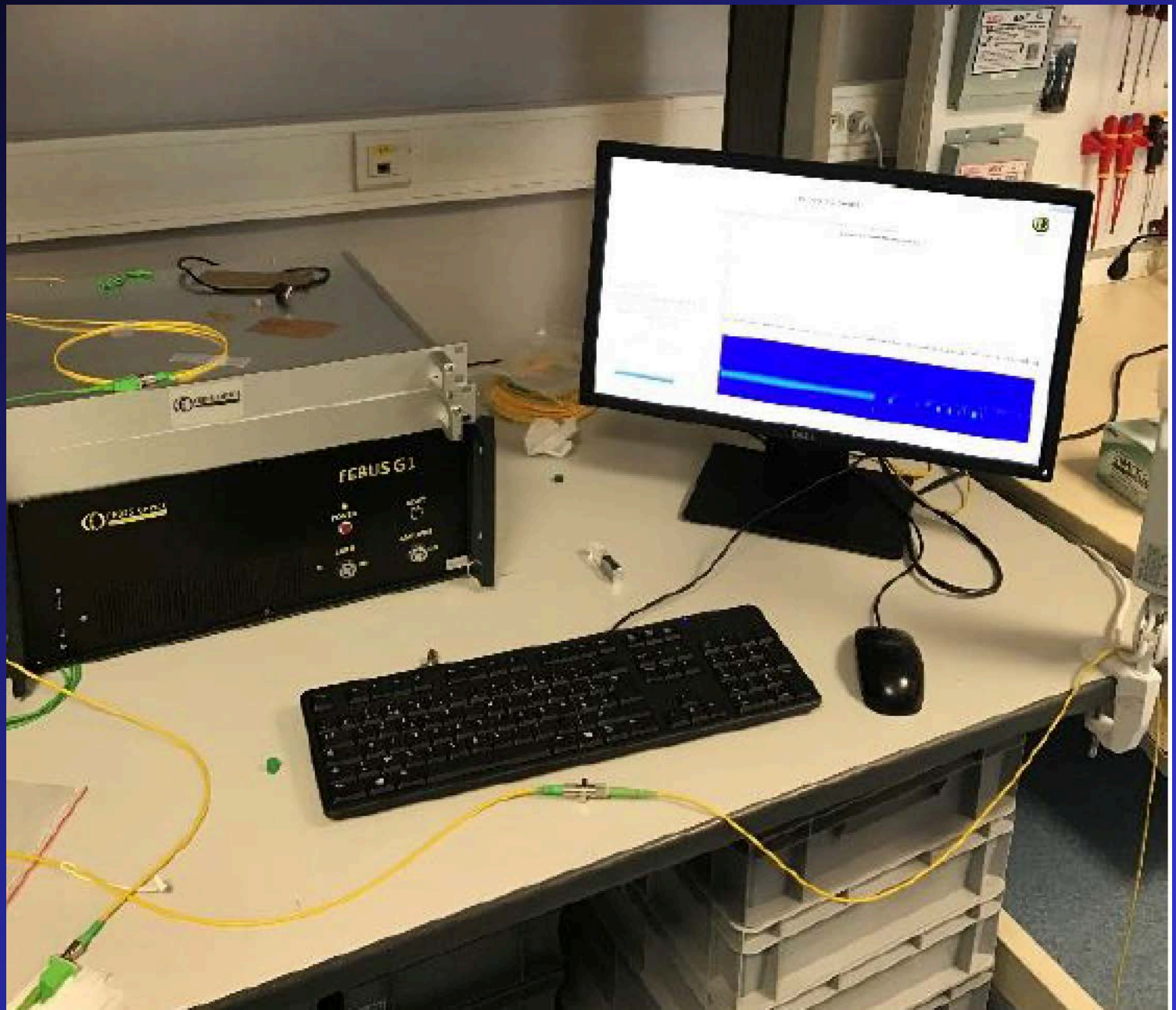


Preliminary tests with the BOTDR method on Molene Island



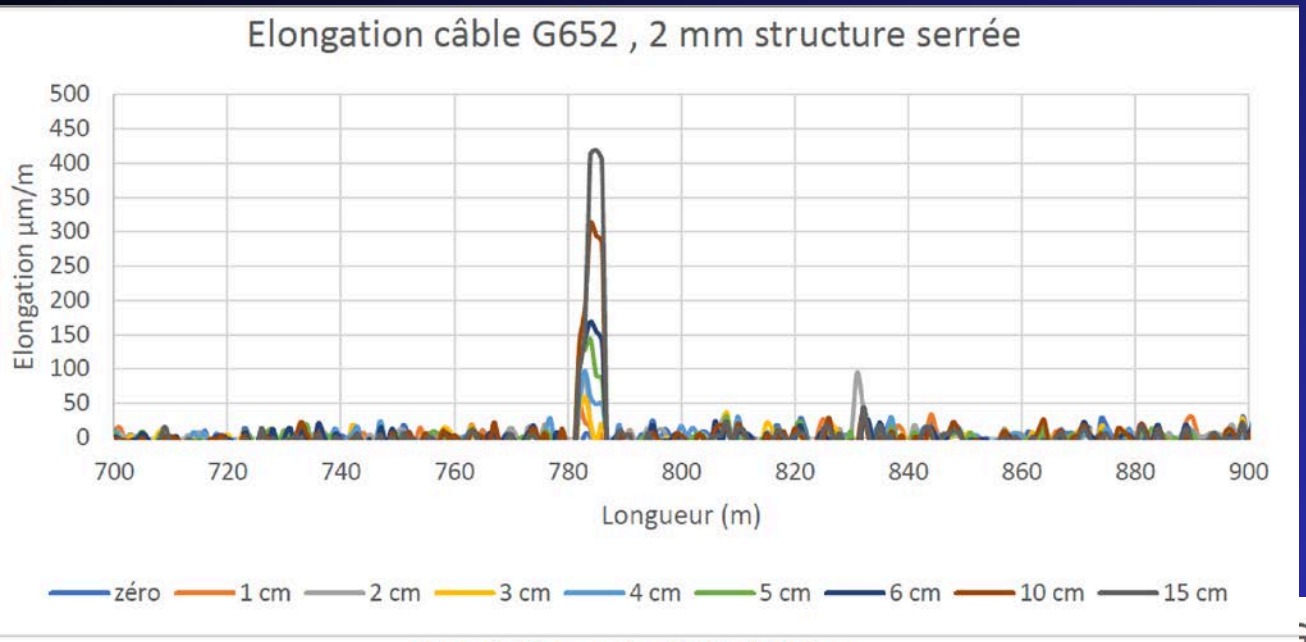
Preliminary tests with the BOTDR method on Molene cable

Preliminary BOTDR tests on a fiberoptic cable in the lab

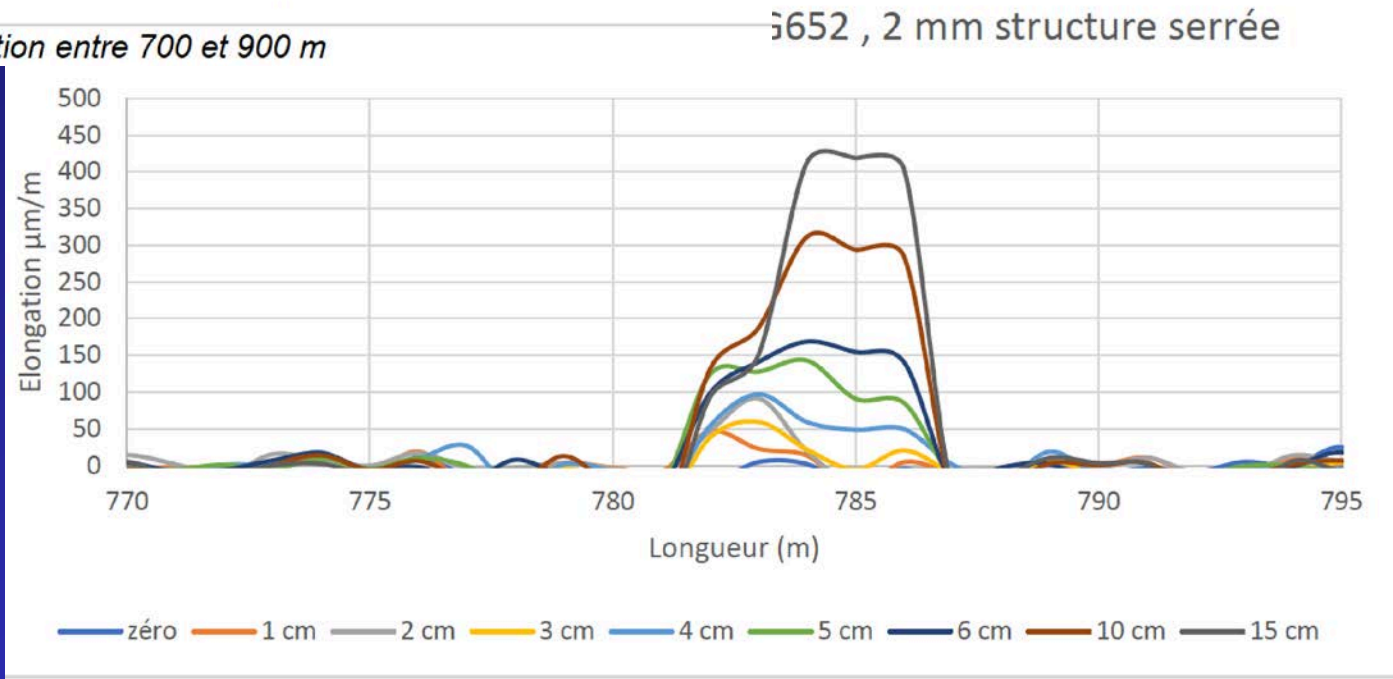


Preliminary BOTDR tests on a fiberoptic cable in the lab

Preliminary BOTDR tests on a fiberoptic cable in the lab

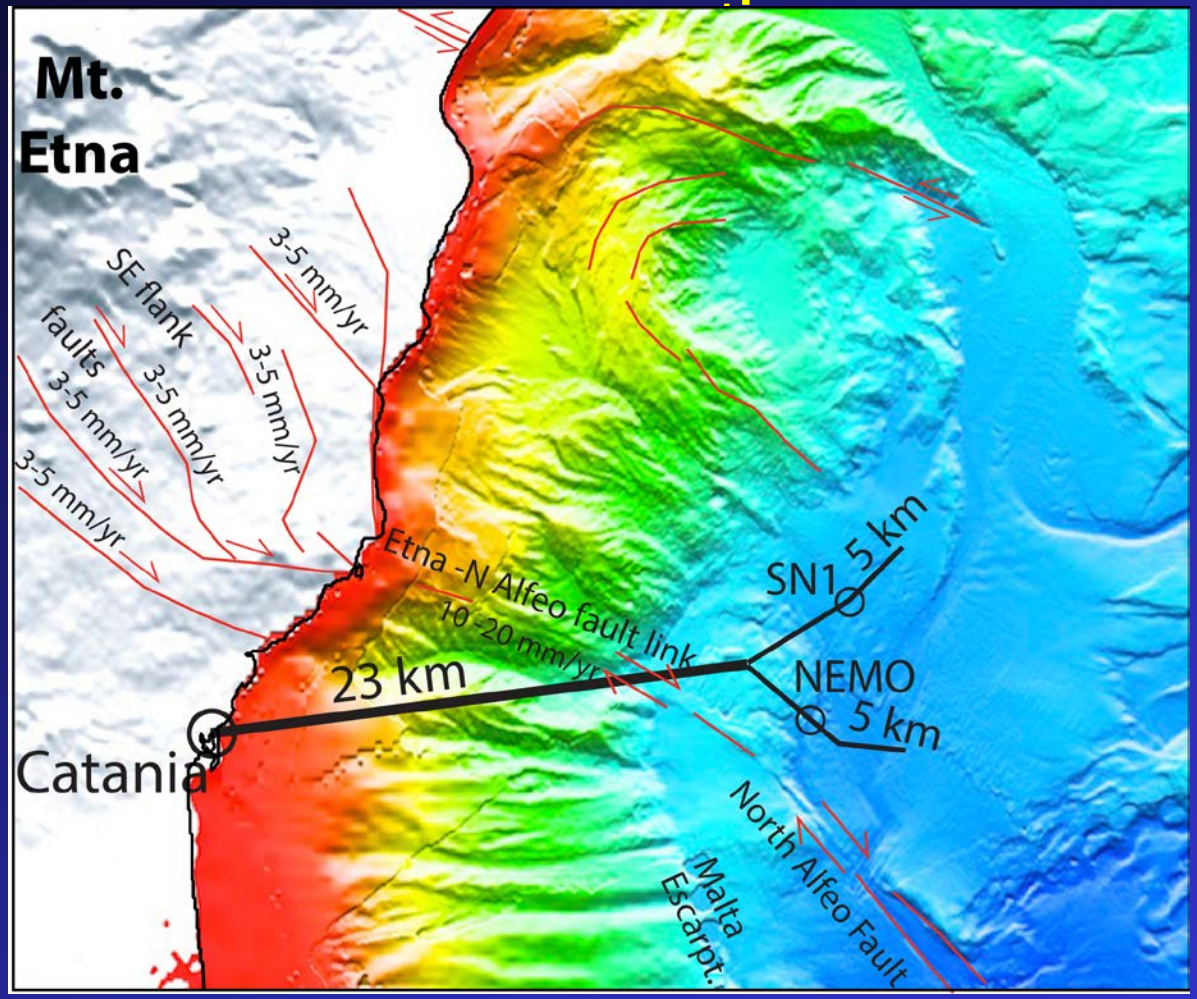


Acquisition entre 700 et 900 m



Acquisition entre 770 m et 795 m

Active tectonics and destructive historical earthquakes in E Sicily/Calabria: results of recent marine surveys and the FOCUS project, a novel approach for studying submarine faults with fiber



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