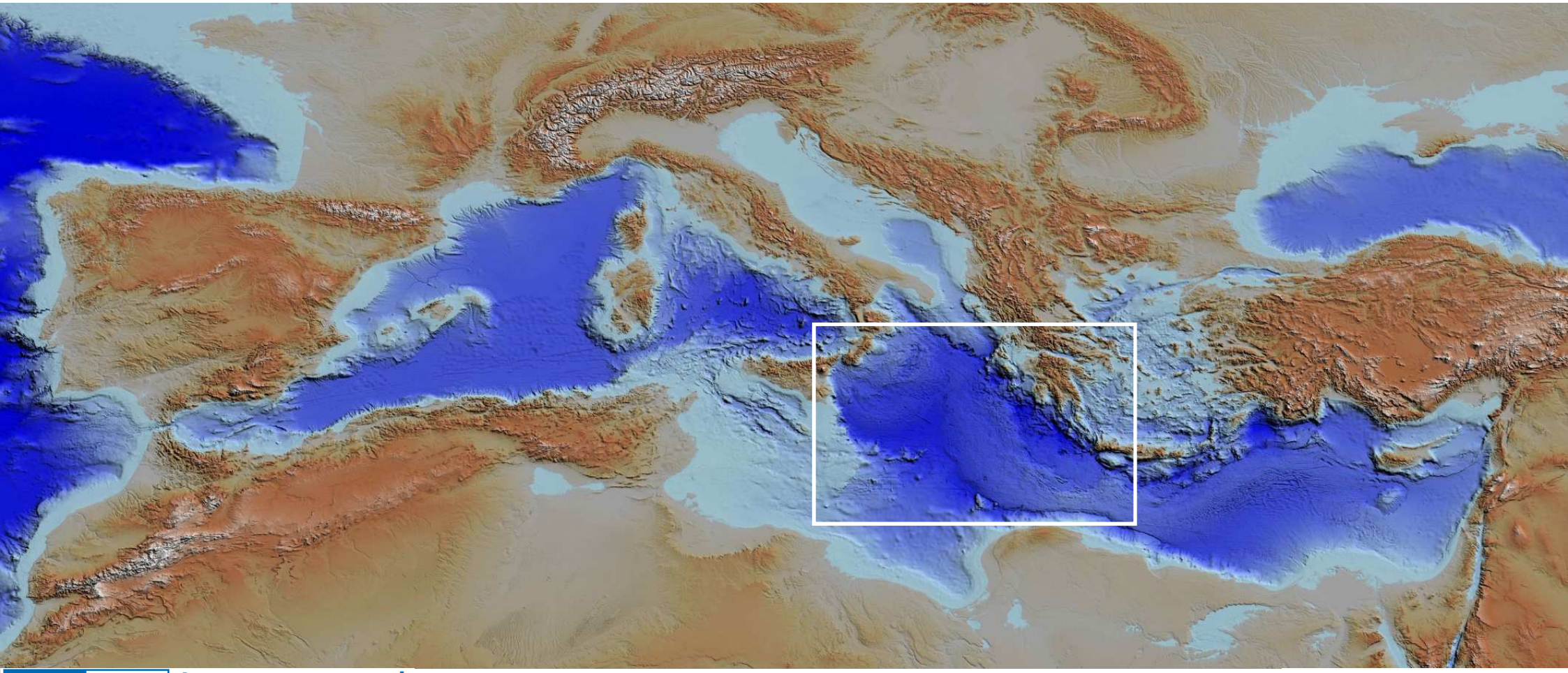
Testing subduction/megathrust activity in the eastern Mediterranean Sea using deep sea tsunamigenic turbidites



Intergovernmental Oceanographic Commission

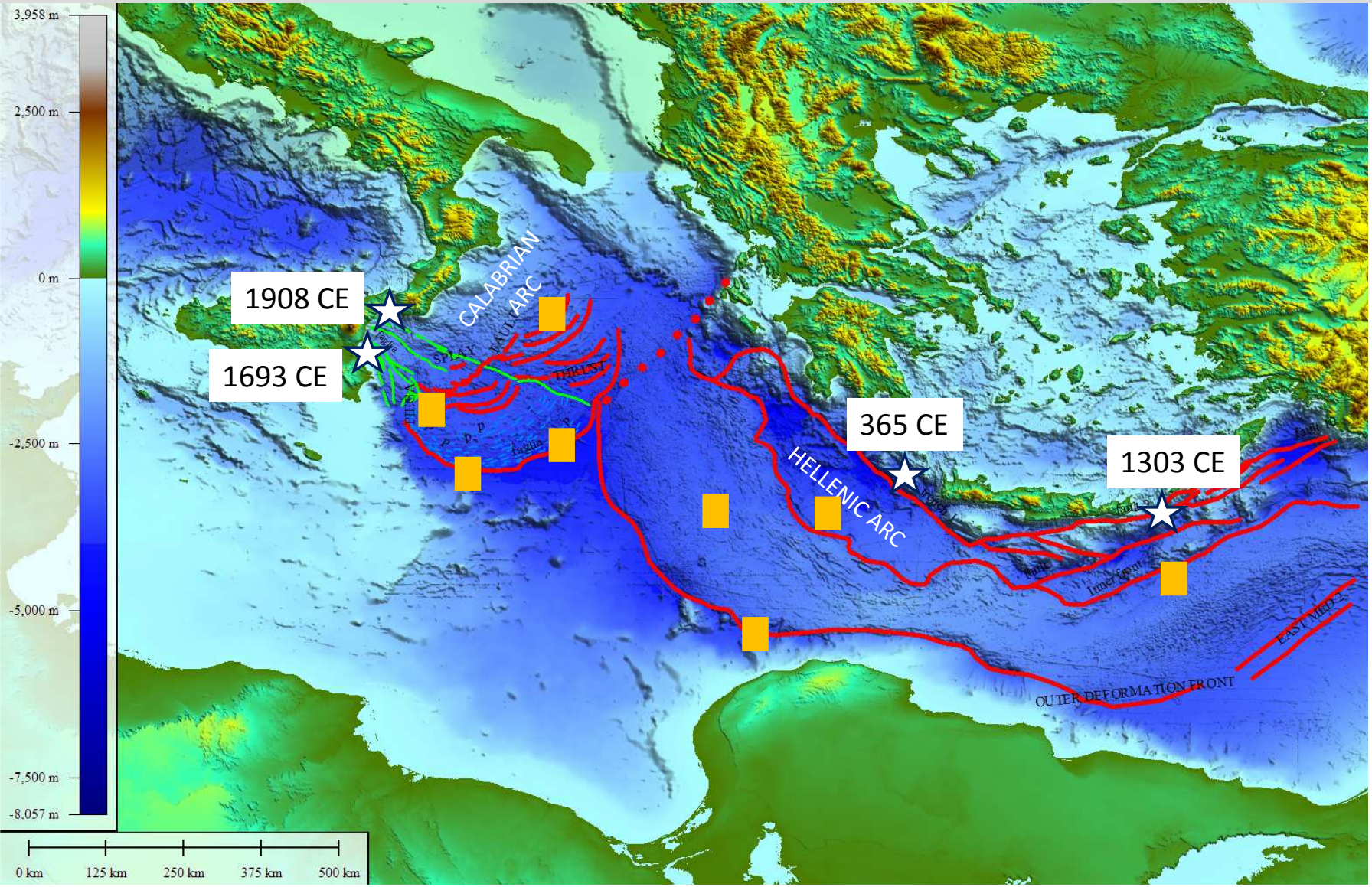
unesco

Alina Polonia - ISMAR-CNR

Institute of Marine Sciences - National Research Council

CNR ISMAR ISTITUTO DI SCIENZE MARINE

GEODYNAMIC AND TECTONIC SETTING – CALABRIAN AND HELLENIC ARCS

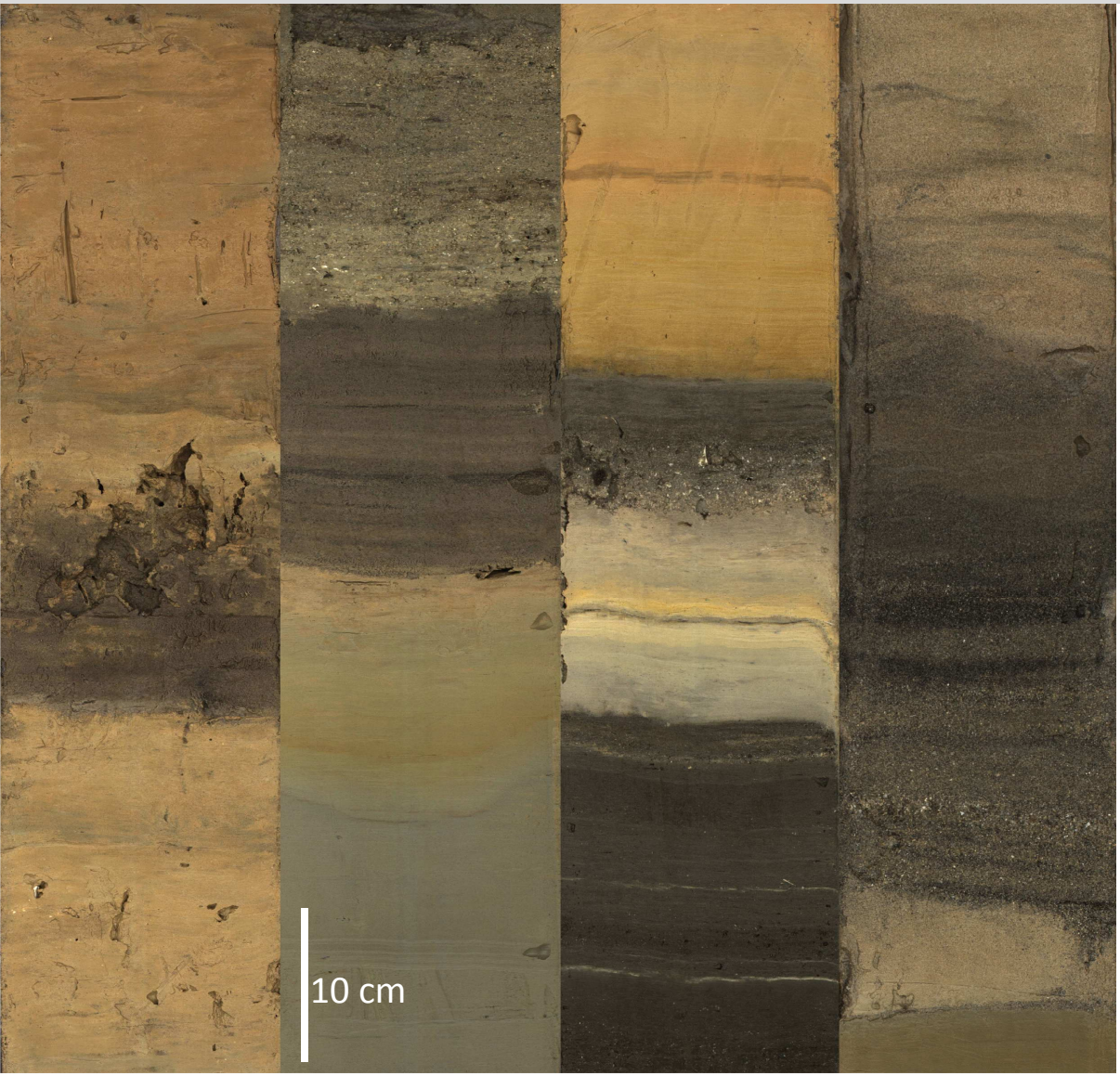


The Hellenic and Calabrian Subduction Systems host the largest seismogenic sources in the eastern Mediterranean region

The recurrence of major earthquakes and associated tsunami in this region remains *unknown*

Marine sediments may provide information on the activity of the subduction thrust and crustal faults

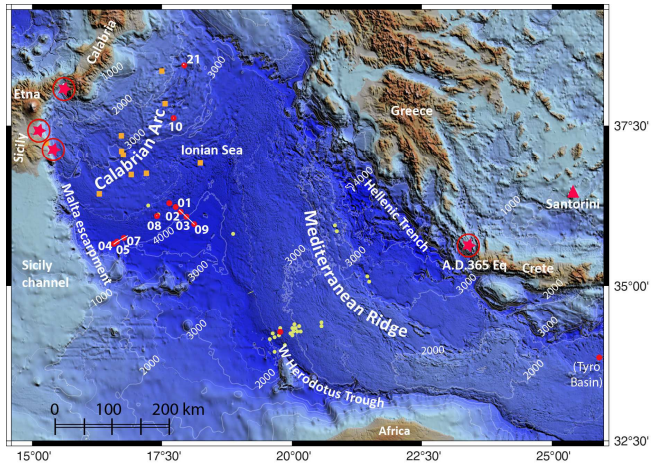
MARINE SEDIMENTS AS ARCHIVES OF PAST EARTHQUAKES AND TSUNAMIS

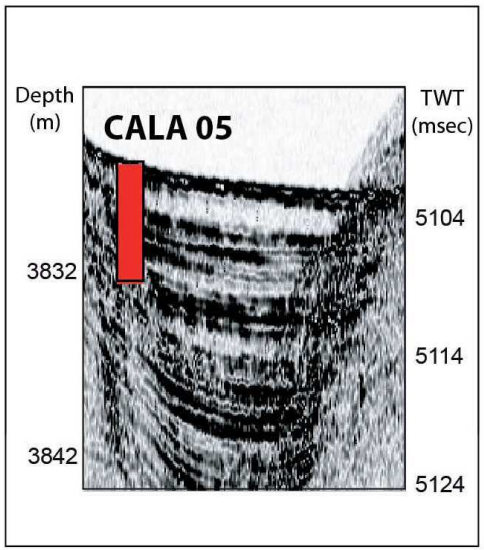


LEADING SCIENTIFIC QUESTIONS

- ❑ CAN WE RECONSTRUCT PAST TSUNAMI BASED ON THE SEDIMENTARY RECORD?
- ❑ WHAT MARINE SEDIMENT CAN TELL US ABOUT PAST CATASTROPHIC EVENTS? WHERE AND HOW OFTEN?
- ❑ IS IT POSSIBLE TO DISCRIMINATE BETWEEN CRUSTAL AND PLATE INTERFACE EQS FROM THE ANALYSES OF SEISMO-TURBIDITES?

DEEP SEA SEDIMENT ANALYSIS



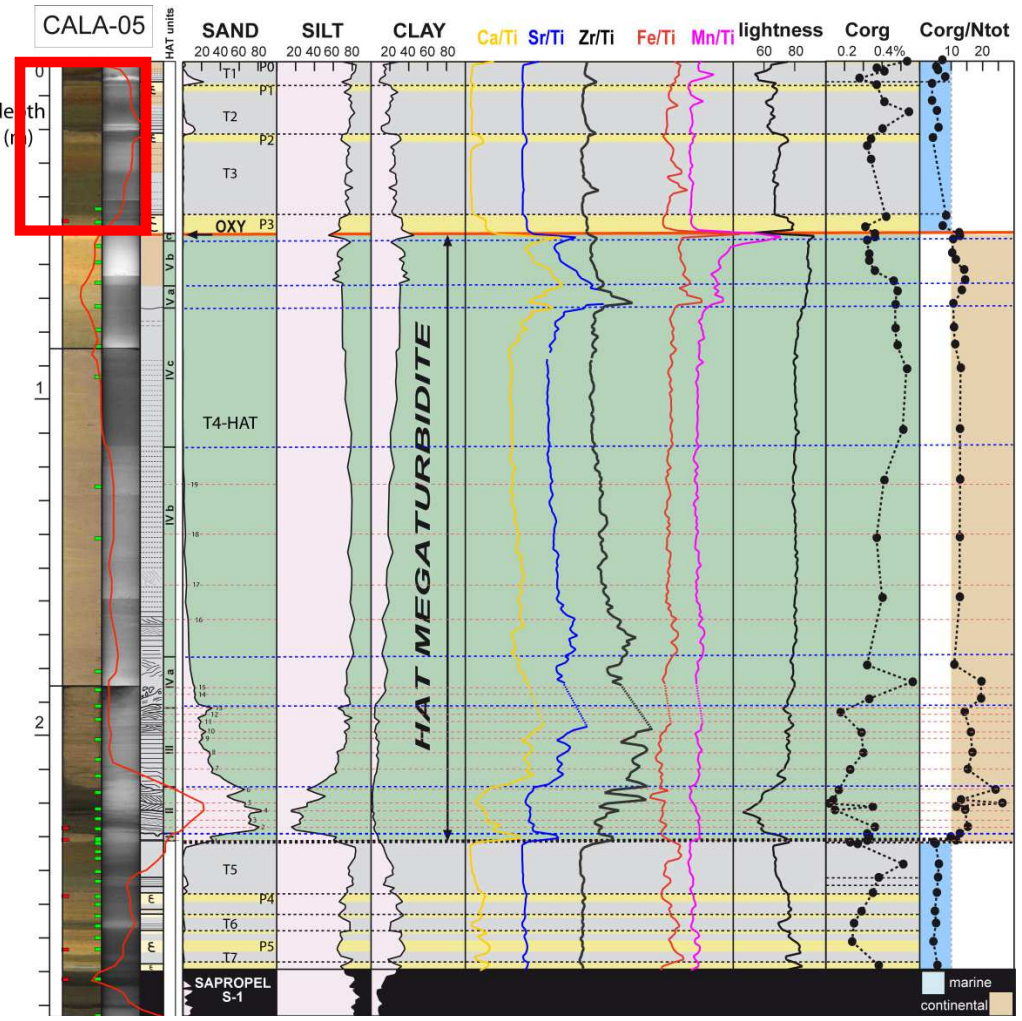


3 recent turbidites interbedded with pelagic sediments

Homogenite/Augias turbidite (HAT)

Turbidites interbedded with pelagic sediments

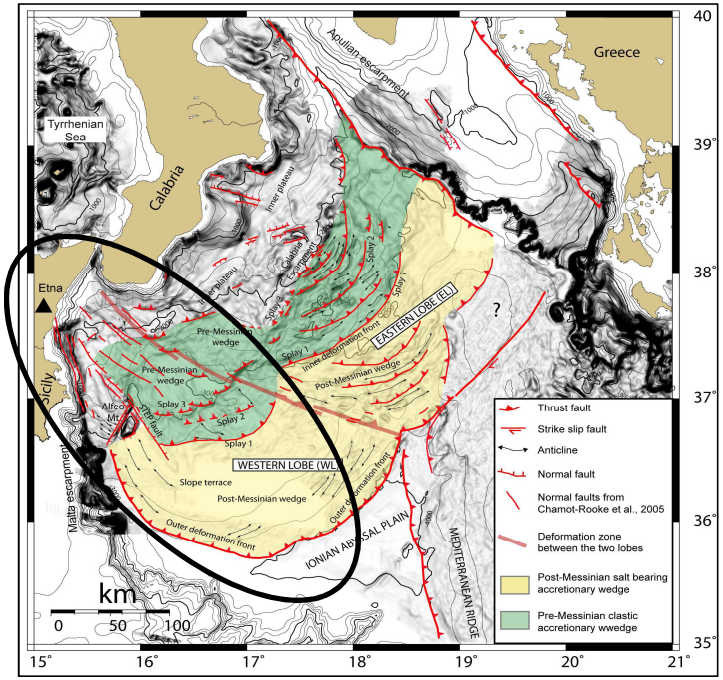
Sapropel S1 (6-10 kyr bp)

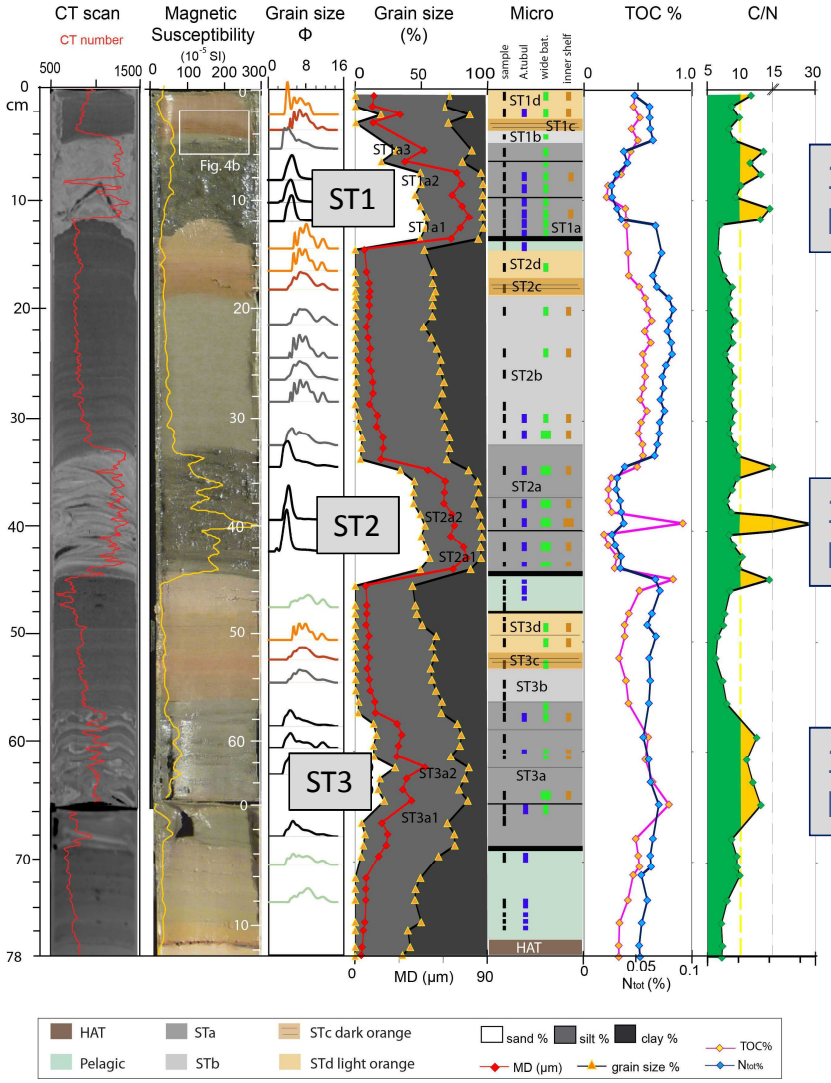


Modified from Polonia et al., 2013 SR

90% of sedimentation is represented by turbidite beds

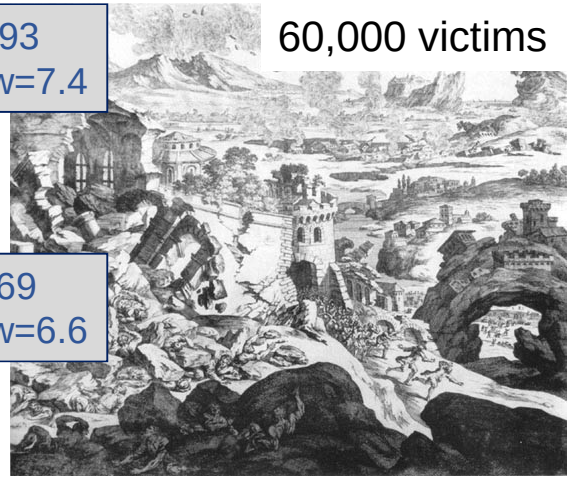
ACTIVITY OF CRUSTAL FAULTS IN THE CALABRIAN ARC





80,000 victims

1908
Mw=7.2



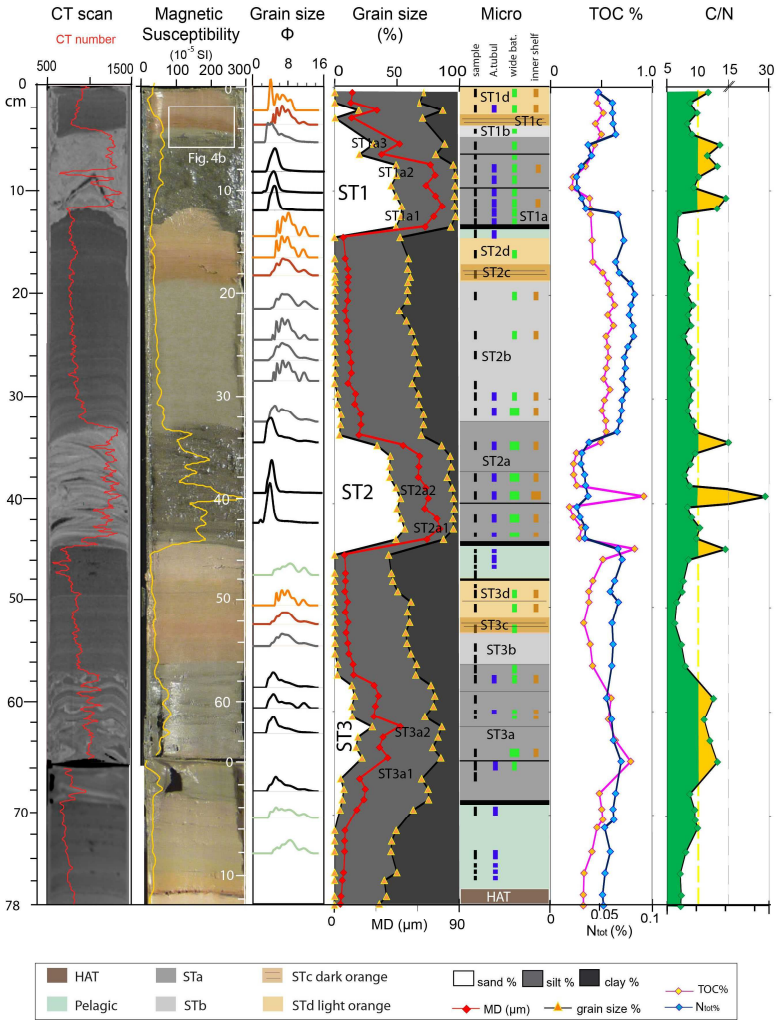
60,000 victims

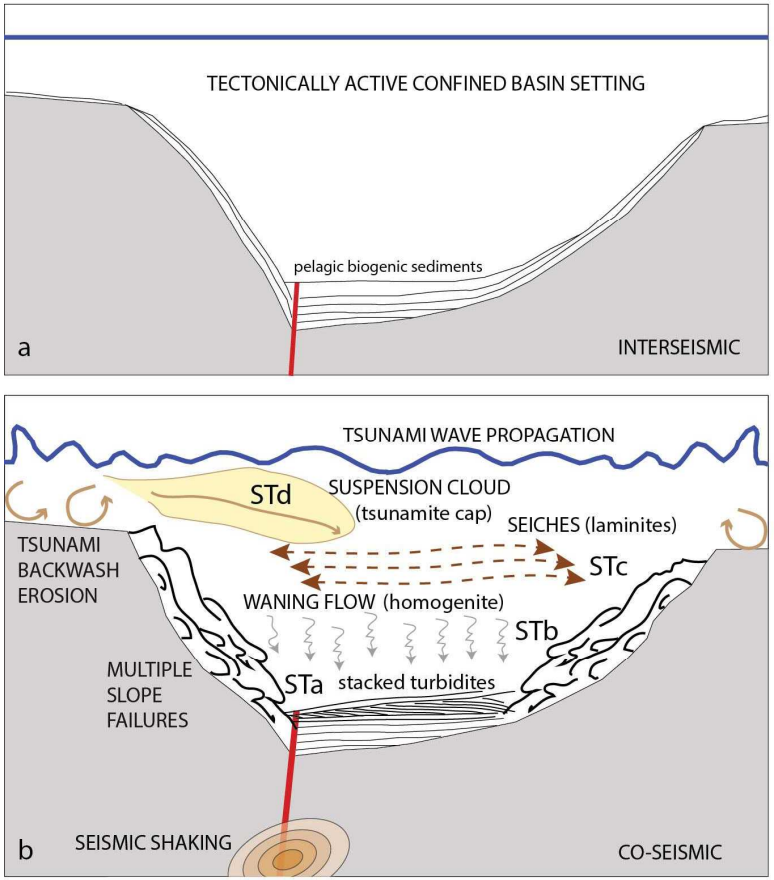
1693
Mw=7.4

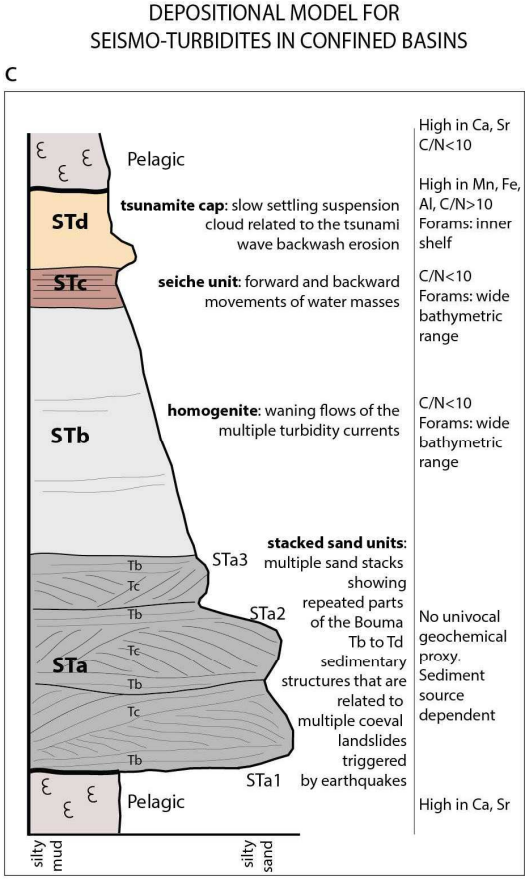
1169
Mw=6.6

Modified from Polonia et al., 2013 G-cubed

FROM SEDIMENT DEPOSITS TO SEDIMENTARY PROCESSES







Modified from Polonia et al., 2017 MG

MEDITERRANEAN SEA MEGATURBIDITES

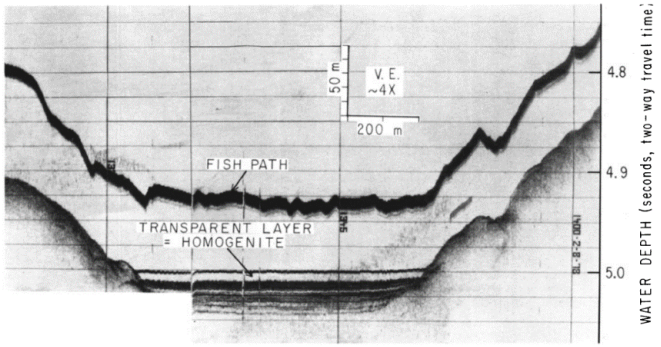
THE HOMOGENITE/AUGIAS TURBIDITE

The recentmost megaturbidite, **described for the first time in 1975 by Hieke** was named either:

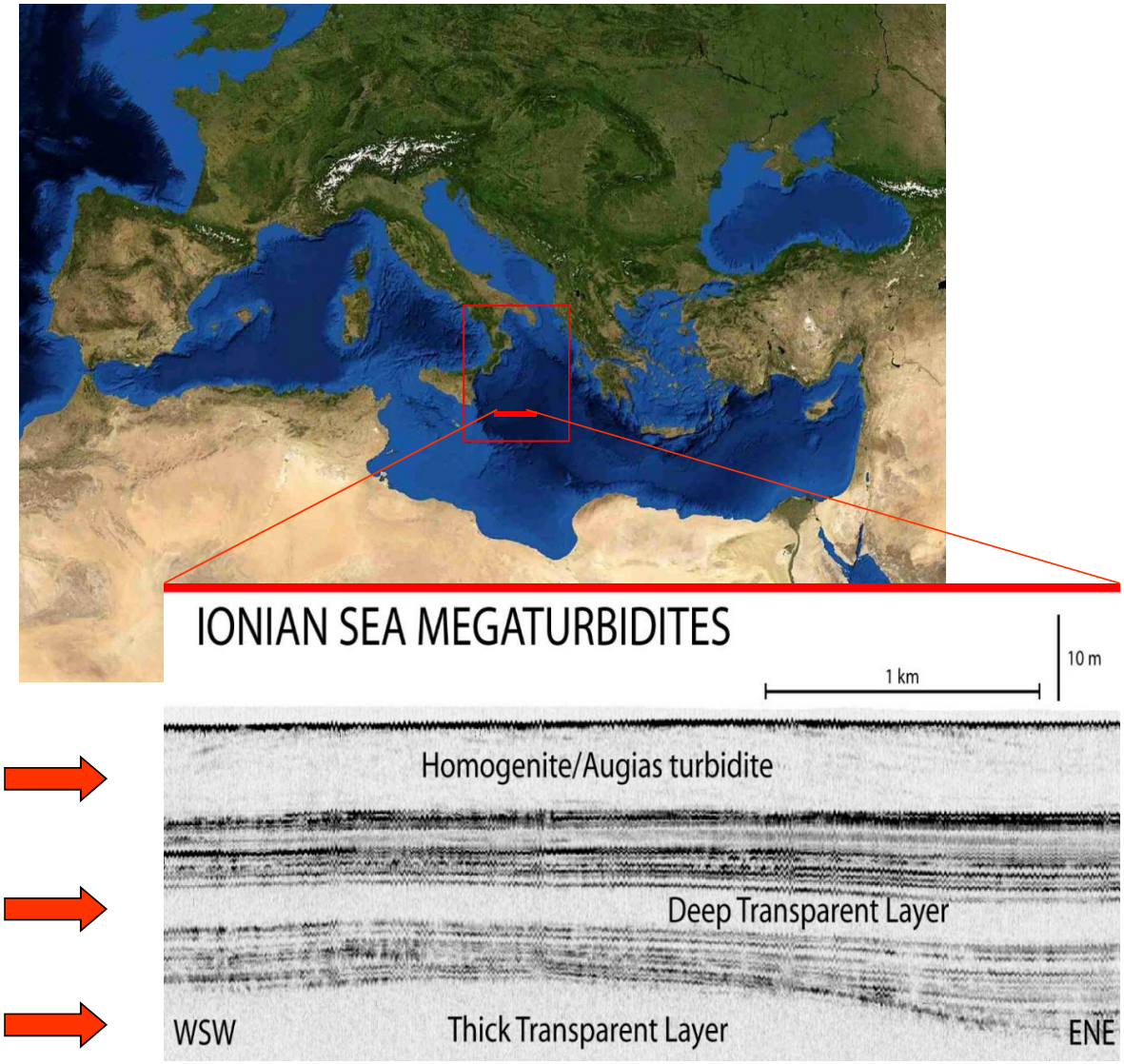
-“Homogenite” (Kastens and Cita, 1981);

- “Augias homogenite/turbidite” (Hieke, 1984).

In our work we refer to the Homogenite/Augias Turbidite as HAT.



Modified from Kastens and Cita, 1981, GSA Bull.

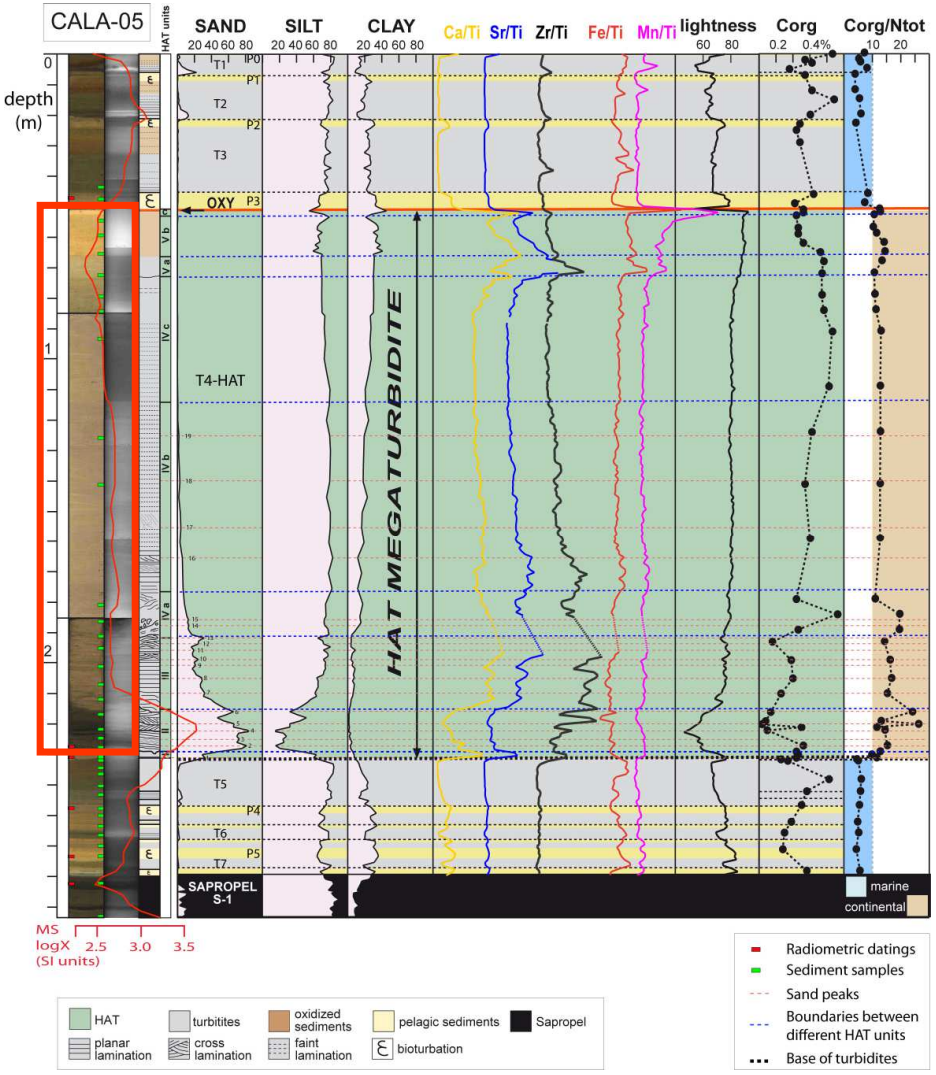


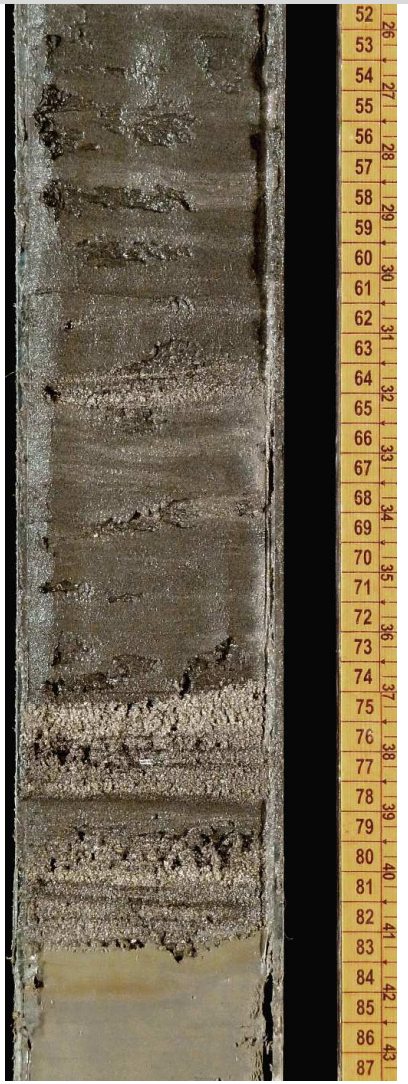
THE TSUNAMIGENIC MEGATURBIDITE

The HAT: a complex depositional sequence is displayed by X-ray images, grain-size distribution and composition.

The base of the megabed shows a sharp increase in sand content.

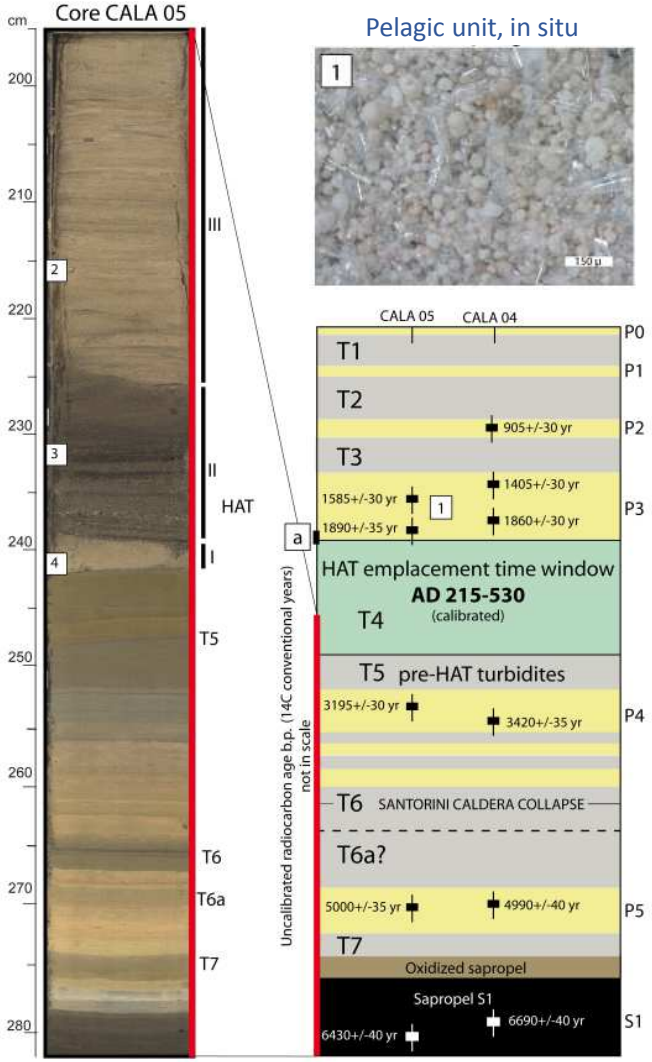
The sand consists of an heterogeneous mixture of detrital mineral grains and biogenic components from different bathymetric ranges.





Modified from Polonia et al., 2013 SR

RADIOMETRIC DATING – AGE OF THE TRIGGERING EVENT



TWO SEMI-INDEPENDENT RADIOMETRIC METHODS

1) The ages we obtained above the top of the turbidite were corrected by the time interval corresponding to the thickness of pelagic sedimentation separating the top of the HAT and the dated level.

2) We used sedimentation rate as defined by different dated samples in the same core. 1 cm of normal pelagic sedimentation in this core for example is 110±46 yr.

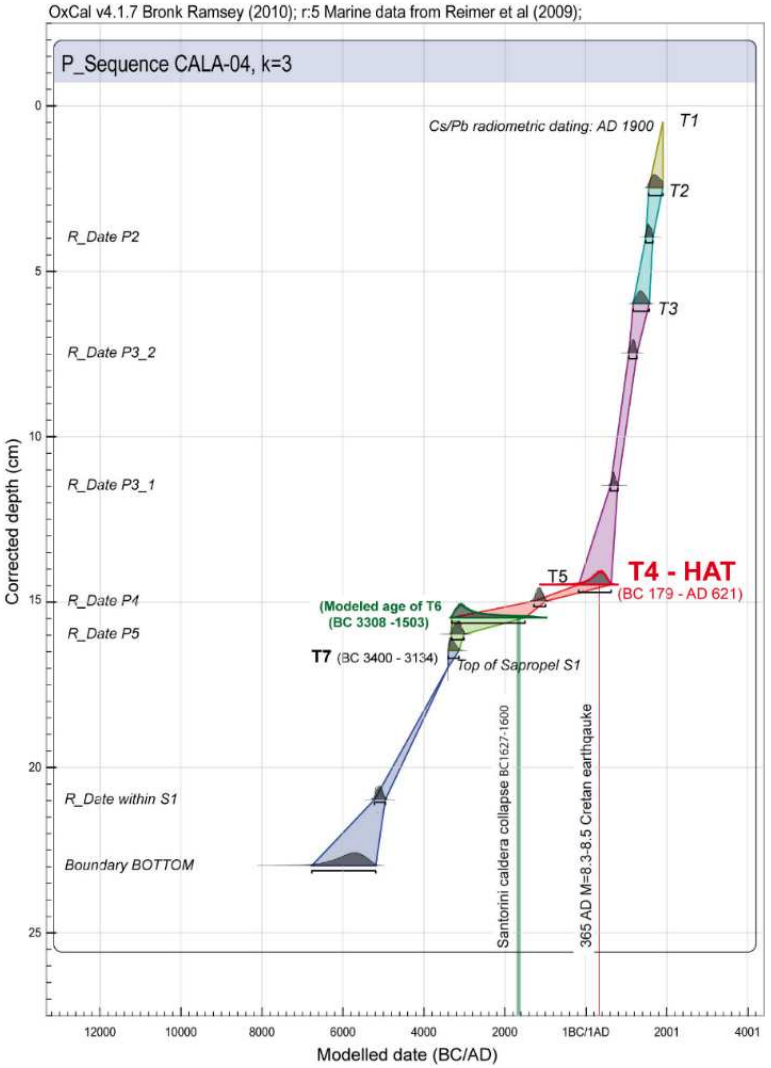
HAT emplacement time is confirmed by OxCal age model

HAT emplacement time window

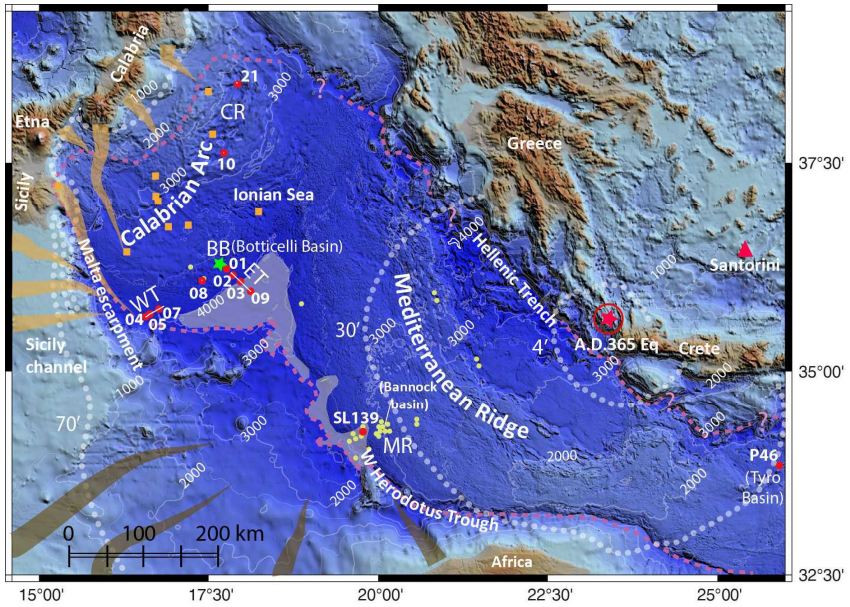
AD 215-530

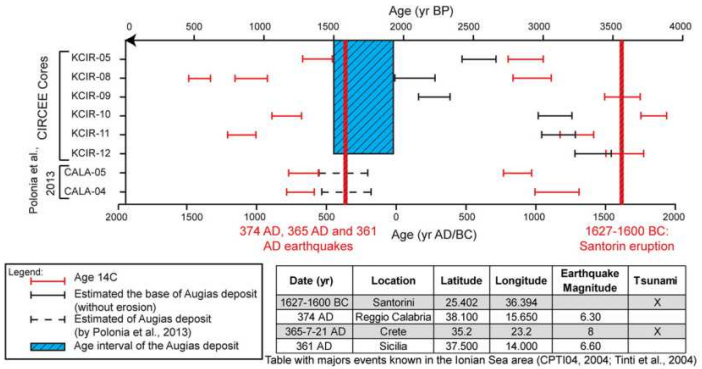
Modified from Polonia et al., 2013 SR

Yellow: pelagic sediments
Gray: turbidite beds
Green: HAT
Black: Sapropel S1



DATING RESULTS OVER AN AREA > 150.000 KM²

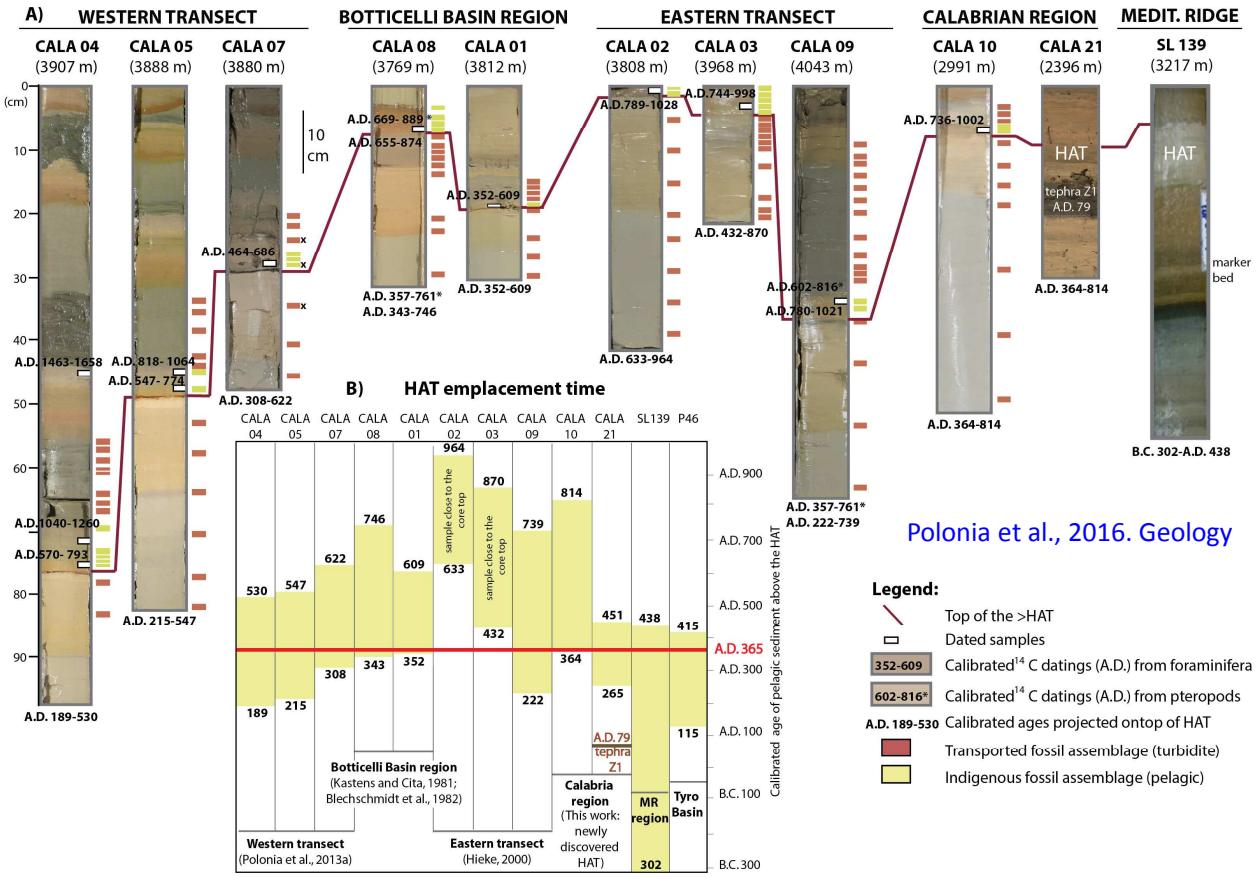




Date (yr)	Location	Latitude	Longitude	Earthquake Magnitude	Tsunami
1627-1600 BC	Santorini	25.402	36.394		X
374 AD	Reggio Calabria	38.100	15.650	6.30	
365-7-21 AD	Crete	35.2	23.2	8	X
361 AD	Sicilia	37.500	14.000	6.60	

Table with majors events known in the Ionian Sea area (CPTI04, 2004; Tinti et al., 2004)

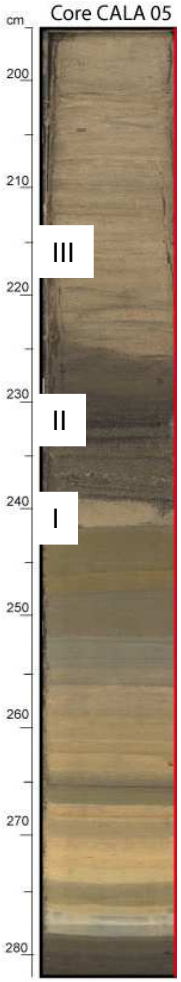
San Pedro et al., 2016. Marine Geology

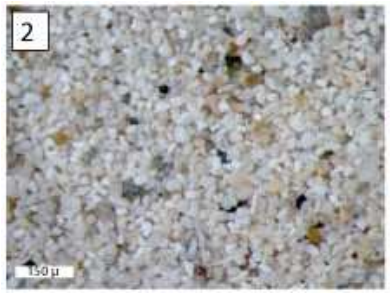


Polonia et al., 2016. Geology

The HAT triggering event took place in the time window AD 364-415 and was capable of initiating simultaneously sediment transport in widely separated sedimentary basins.

HAT: STACKED TURBIDITE





Unit III: Sicily Channel

The overall composition of this unit suggests that the material was displaced from the Malta escarpment and Sicily channel. Lower part is characterized by middle/lower bathyal biogenic components whereas the upper part by inner shelf elements

Unit II: Calabria

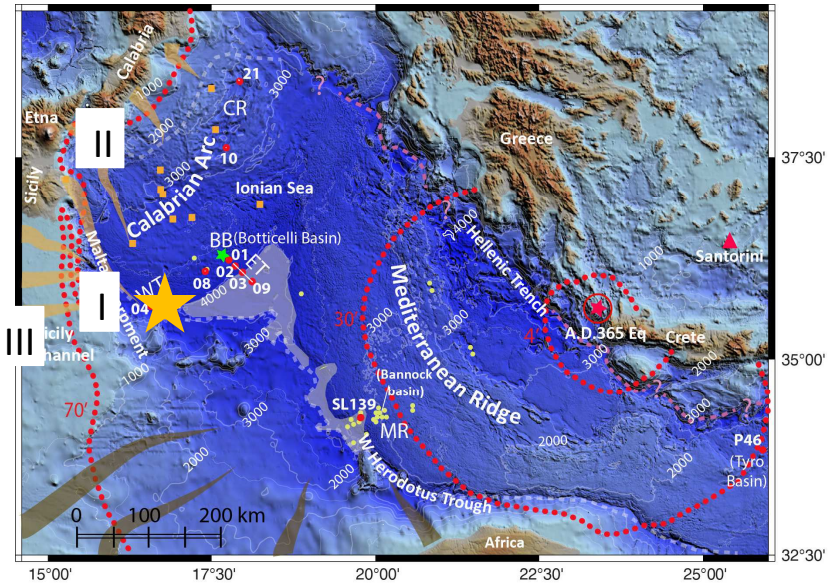
Sediment displaced from the southern Calabria and Northeastern Sicily. Material from the Malta escarpment (plagioclase and basaltic glass is a source indicator form Etna volcano) is still present. Fauna with bathymetric range from the inner shelf to middle/lower bathyal domains.

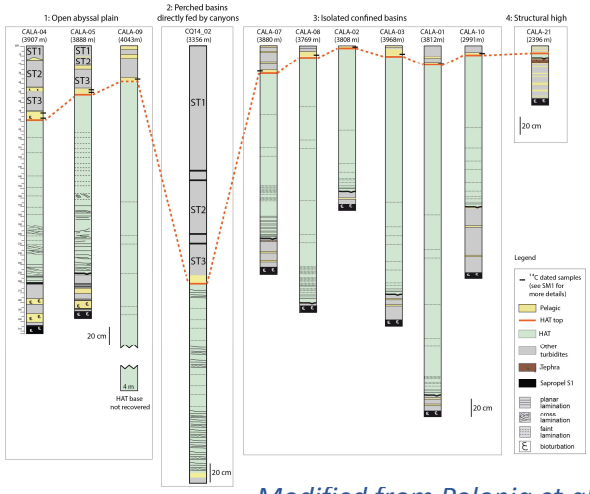
Unit I: Malta escarpment

Sediments displaced from the Malta escarpment Carbonates from the Hyblean plateau while clynopiroxene, amphibole, basaltic glass, feldspar, are indicators of the Etna volcano.

Polonia et al., 2013. Scientific Reports

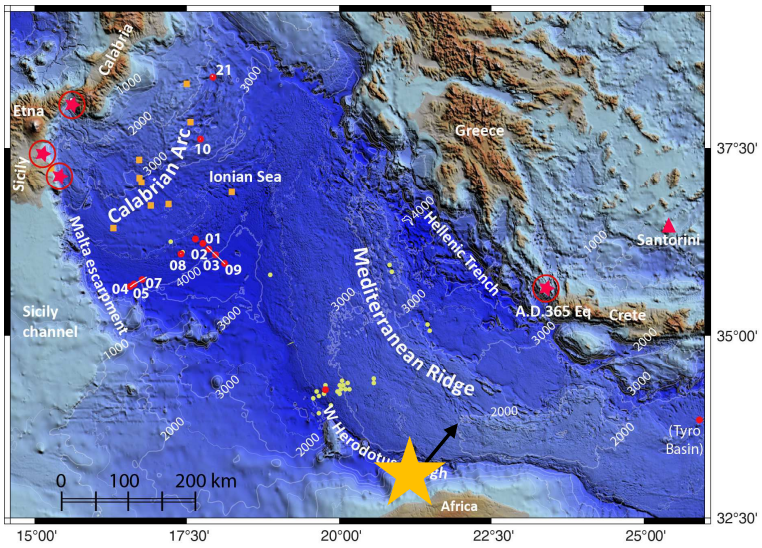
SEDIMENT SOURCE FROM ITALY



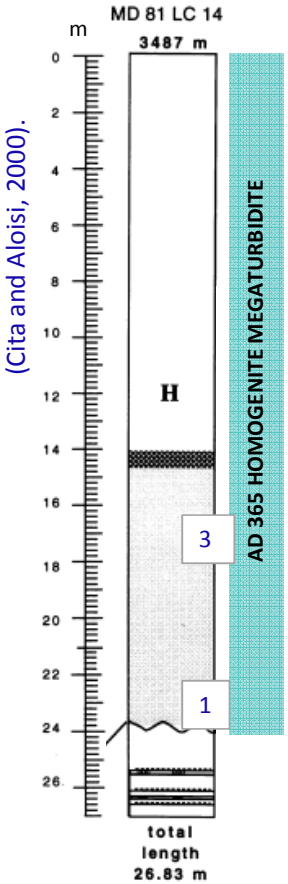


Modified from Polonia et al., 2022

HAT: STACKED TURBIDITE



Core western Herodotous Trough
Marion Dufresne Cruise 81, within MAST II Paleoflux Programme (Rothwell, 1995).

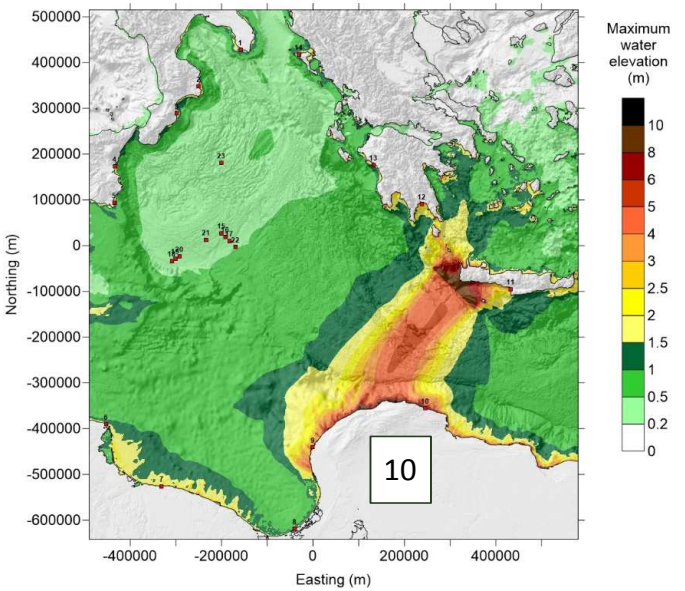


(Cita and Aloisi, 2000).

The sediment core recovered very coarse bioclastic sand overlain by **9 m of silty sand and 15 m of structureless mud**

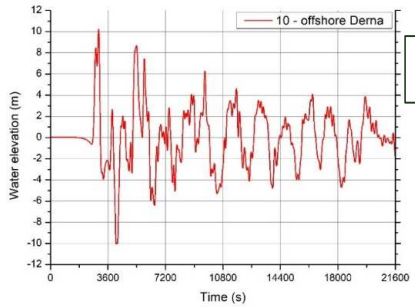
SEDIMENT SOURCE FROM AFRICA

TSUNAMI MAXIMUM WATER AMPLITUDE



UBO-TSUFD code (Tinti & Tonini, 2013)
Linear shallow water equations - Minimum depth = 10 m
Pure reflection along the coastal boundaries
Bottom friction = 0.025
Tsunami propagation simulated for 6 hours

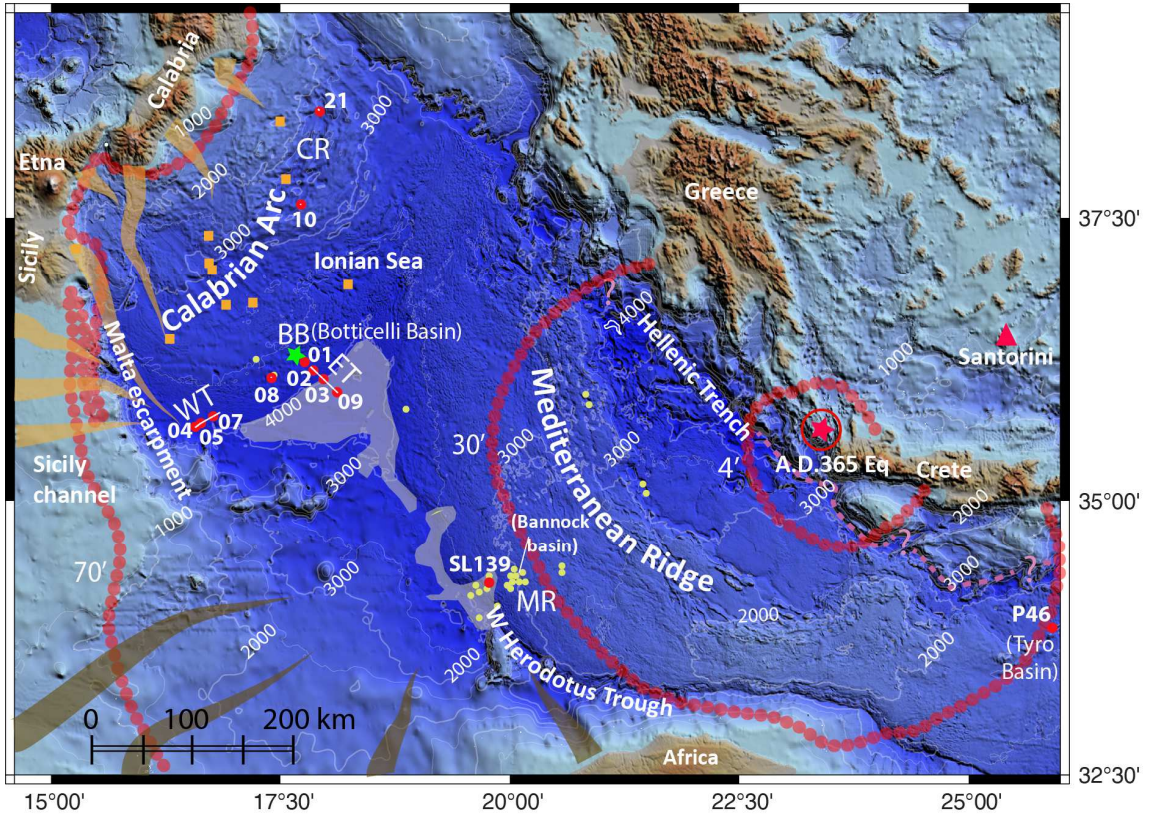
Virtual tide gauge offshore Sirte



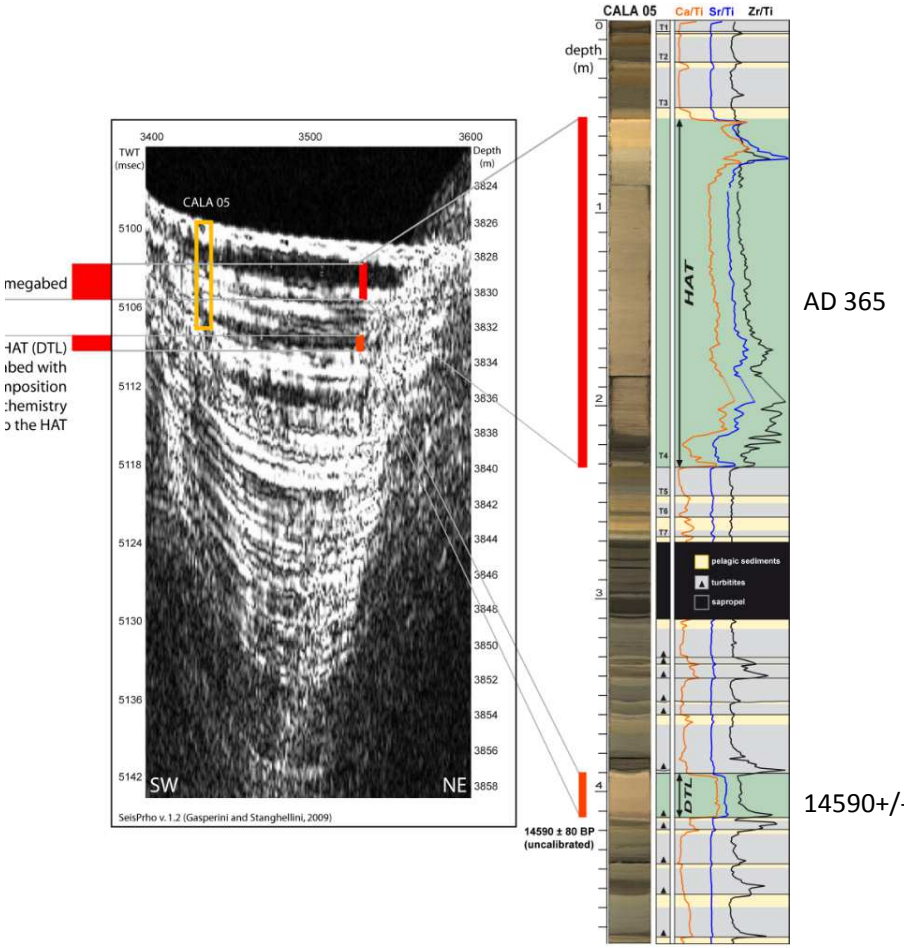
Armigliato et al., in preparation
(Tsunami source from Lorito et al., 2008)

TRIGGERING MECHANISM - MEGATSUNAMI

Seismic shaking from the Crete earthquake, although exceptional, was probably unable to trigger mass movements 600-800 km from the epicentre. When the tsunami hit the Malta escarpment, it propagated on the shallow continental sheves triggering gigantic turbidity currents that transported shallow water detritus to the abyssal plain along a front 1000 km long from Calabria to Africa.



Red dots: tsunami wave front at 4, 30 and 70 min after the earthquake, modified from Shaw et al. (2008)



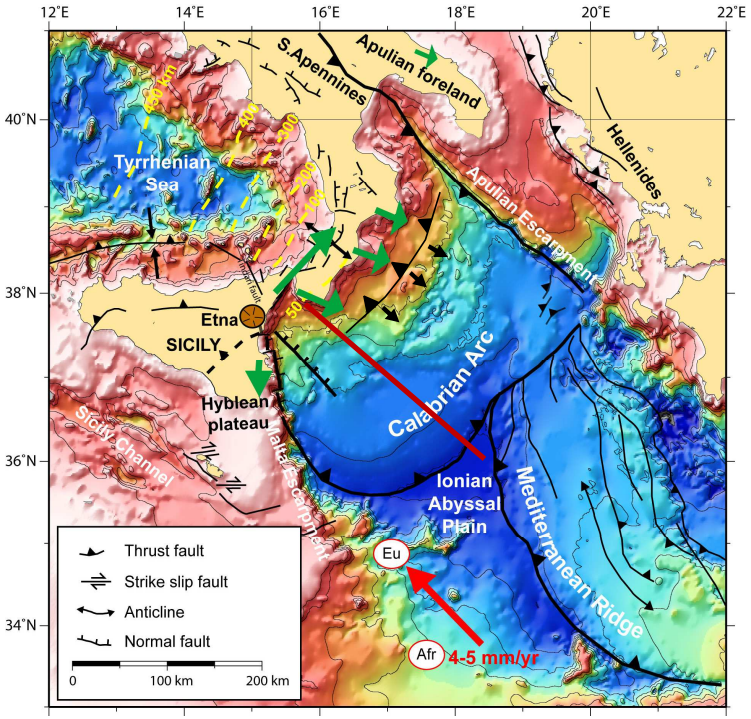
AD 365

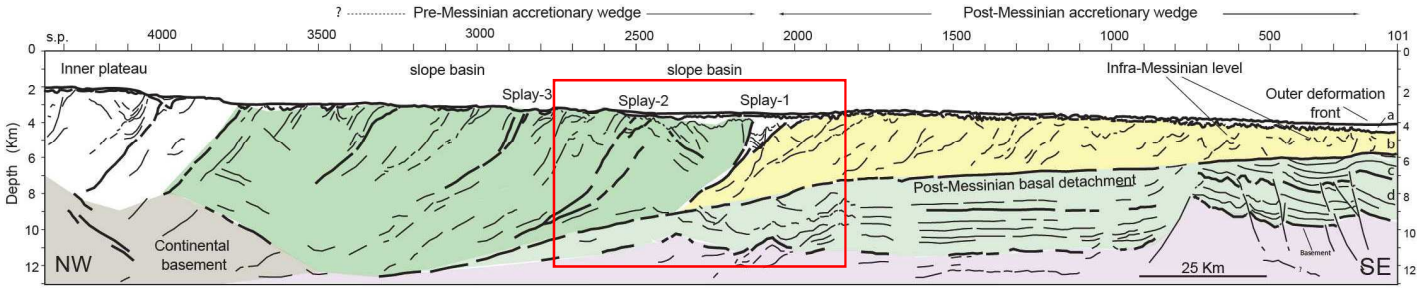
14590+/-80BP

Polonia et al., 2013. Scientific Reports

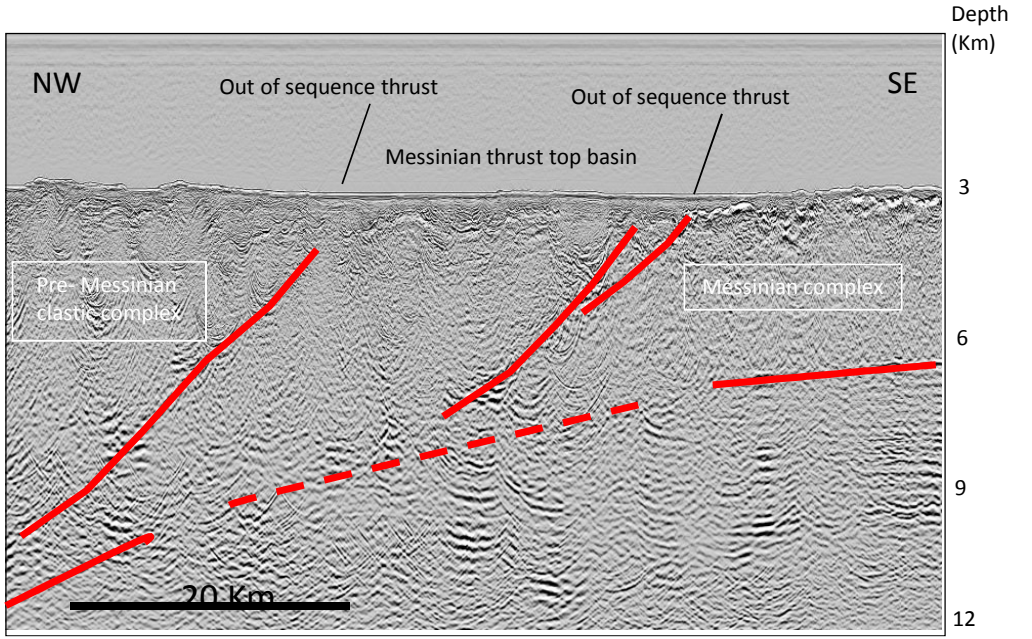
TSUNAMI SOURCES IN THE EASTERN MEDITERRANEAN

WHAT ABOUT THE CALABRIAN ARC SUBDUCTION THRUST?

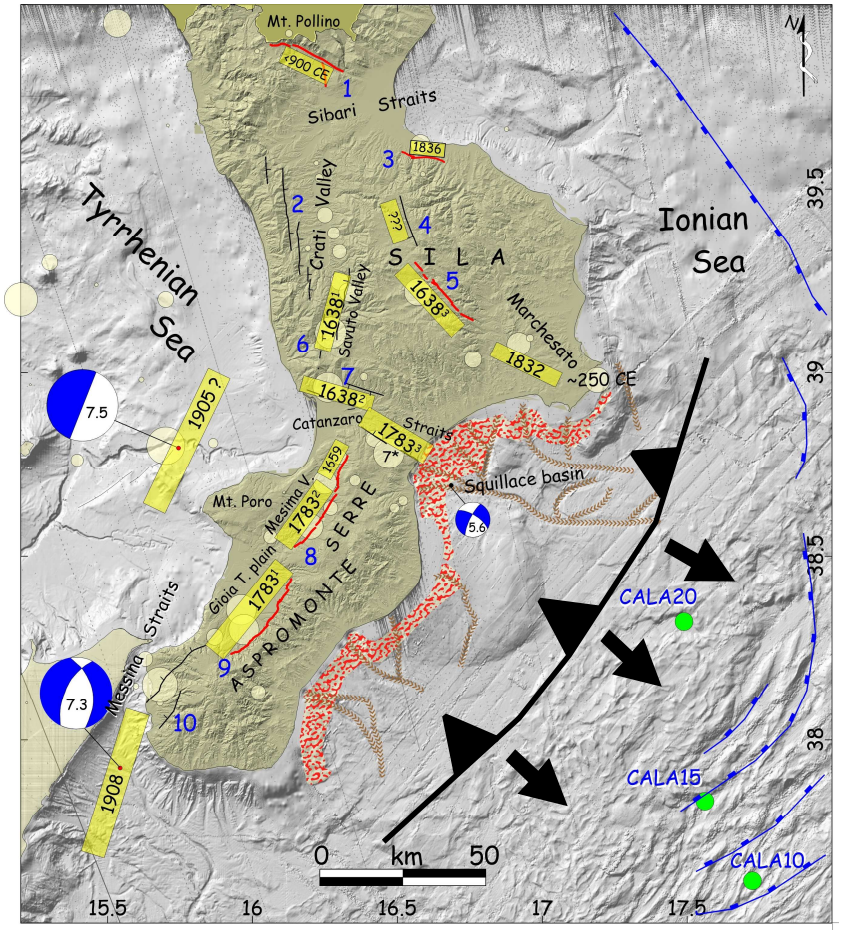




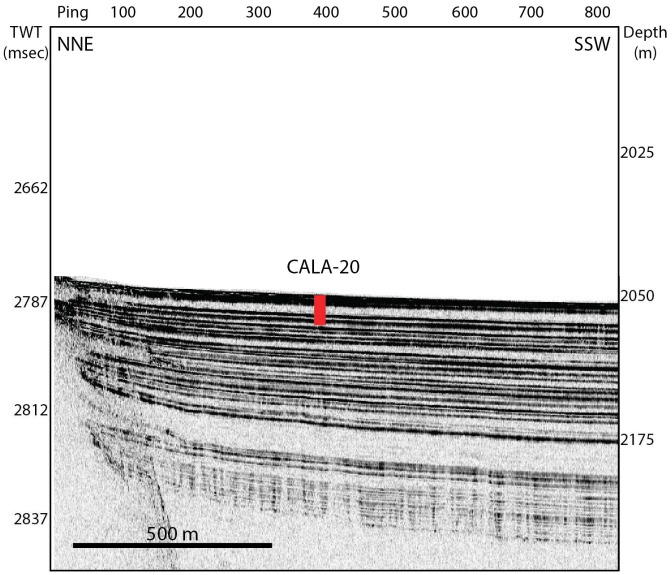
Modified from Polonia et al., 2011; 2016

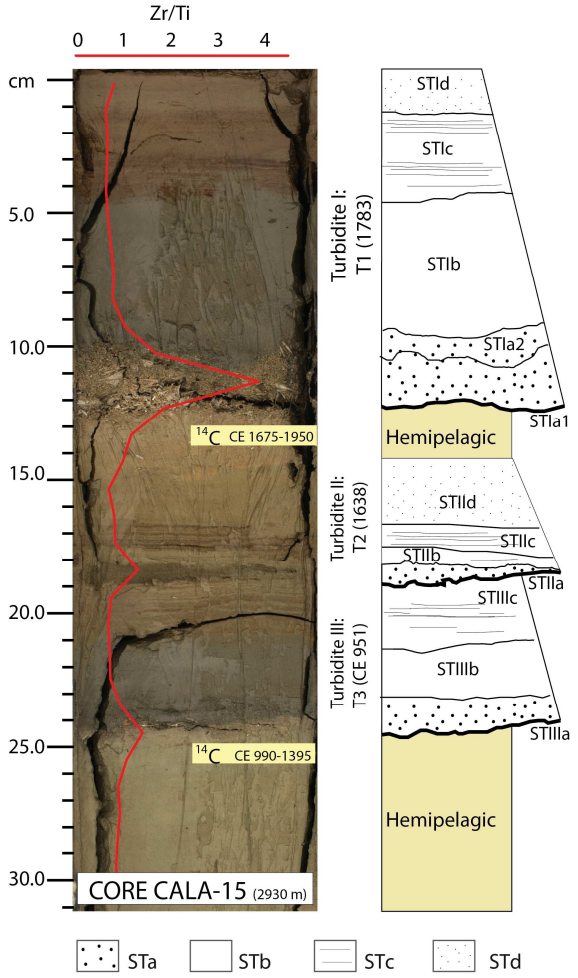


IS THE SUBUDCTION THRUST STILL ACTIVE?

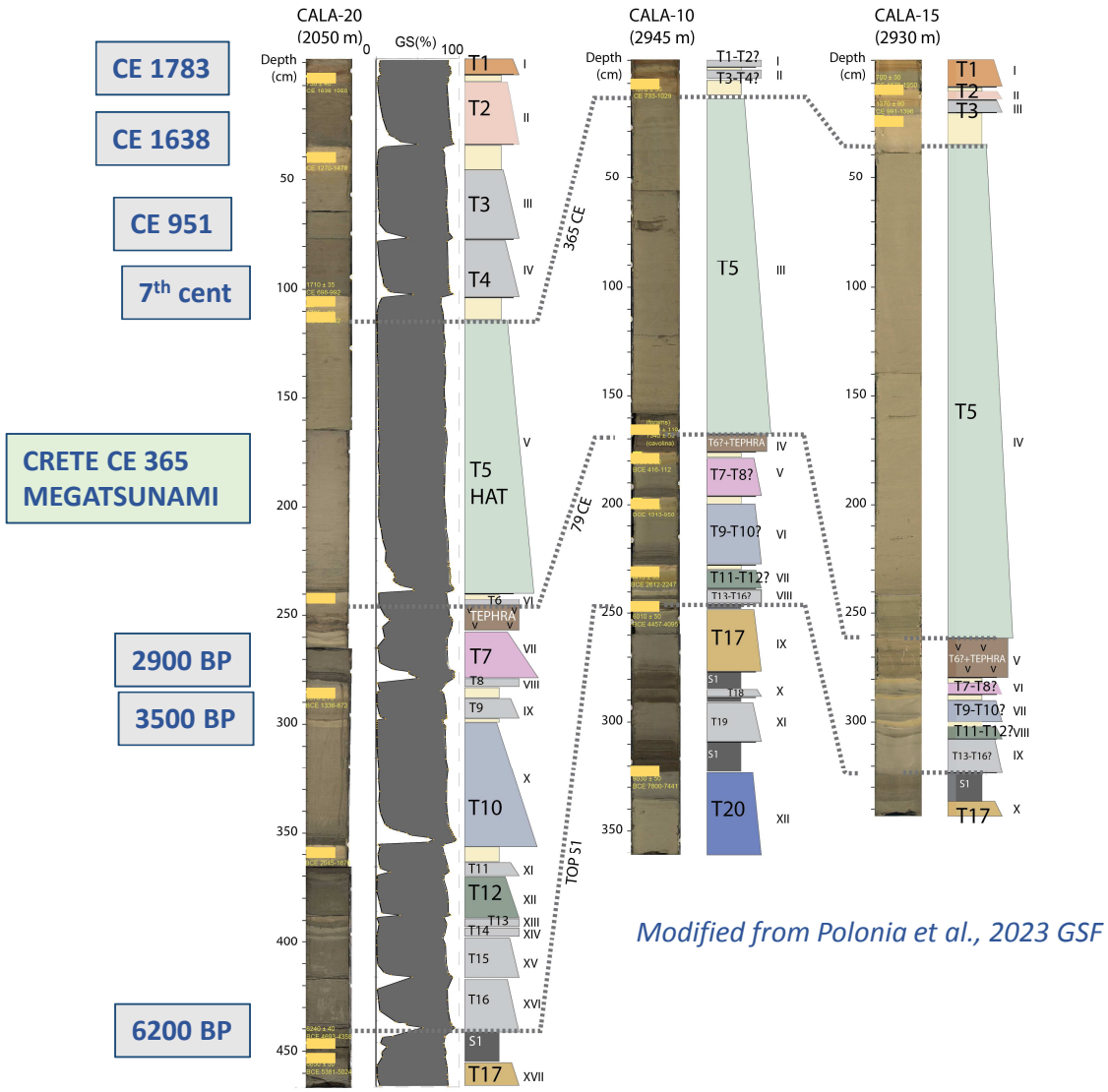


LITTLE IS KNOWN ABOUT THE ACTIVITY OF THE SUBDUCTION THRUST AND SPLAY FAULTS OFFSHORE CALABRIA WHERE TOMOGRAPHIC DATA SHOW A CONTINUOUS SLAB
BUT NO THRUST-TYPE EARTHQUAKES ARE RECORDED:
1) SUBDUCTION IS CEASED
2) LONG RECURRENCE TIME – RARE EVENTS





CORRELATION BETWEEN TURBIDITES AND EARTHQUAKES



Modified from Polonia et al., 2023 GSF

The core records 10 kyrs of sedimentation.

We have identified 20 events during the **Holocene**.

- The uppermost four seismo-turbidites (**T1-T4**) can be correlated with historical **events in Calabria.**
- **T5** correlates well with the far field **CE 365 Crete event**.
- Some older turbidites are large thickness sedimentary events (**T7, T10, T12, T17, T20**) that are likely candidates connected to **submarine faults activity, including the plate interface**.

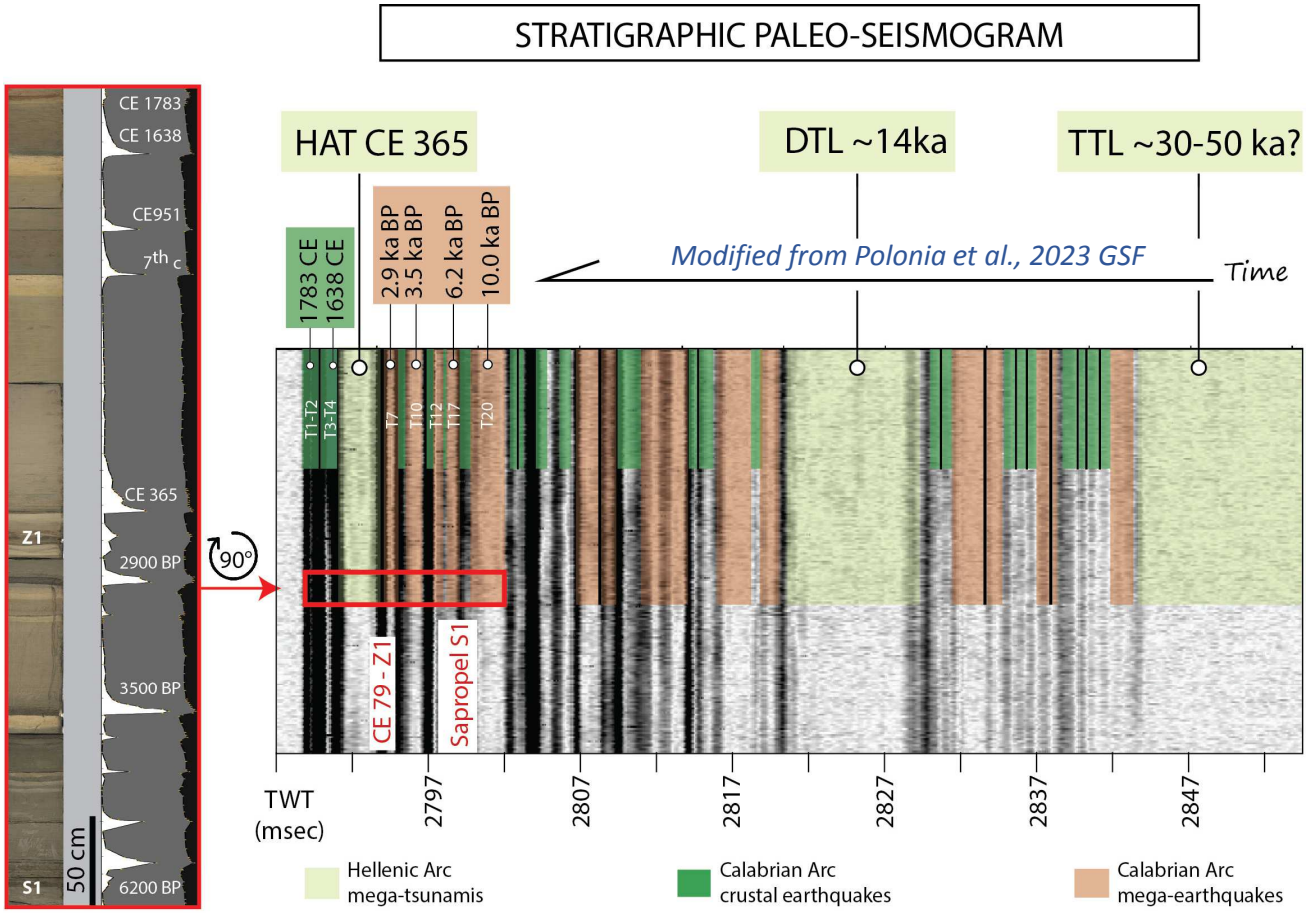
~2.9ka BP
~3.5ka BP
~6.1 ka BP
~10ka BP

RESEDIMENTED DEPOSITS FOR LONGER TIME INTERVALS (30-50 KA)

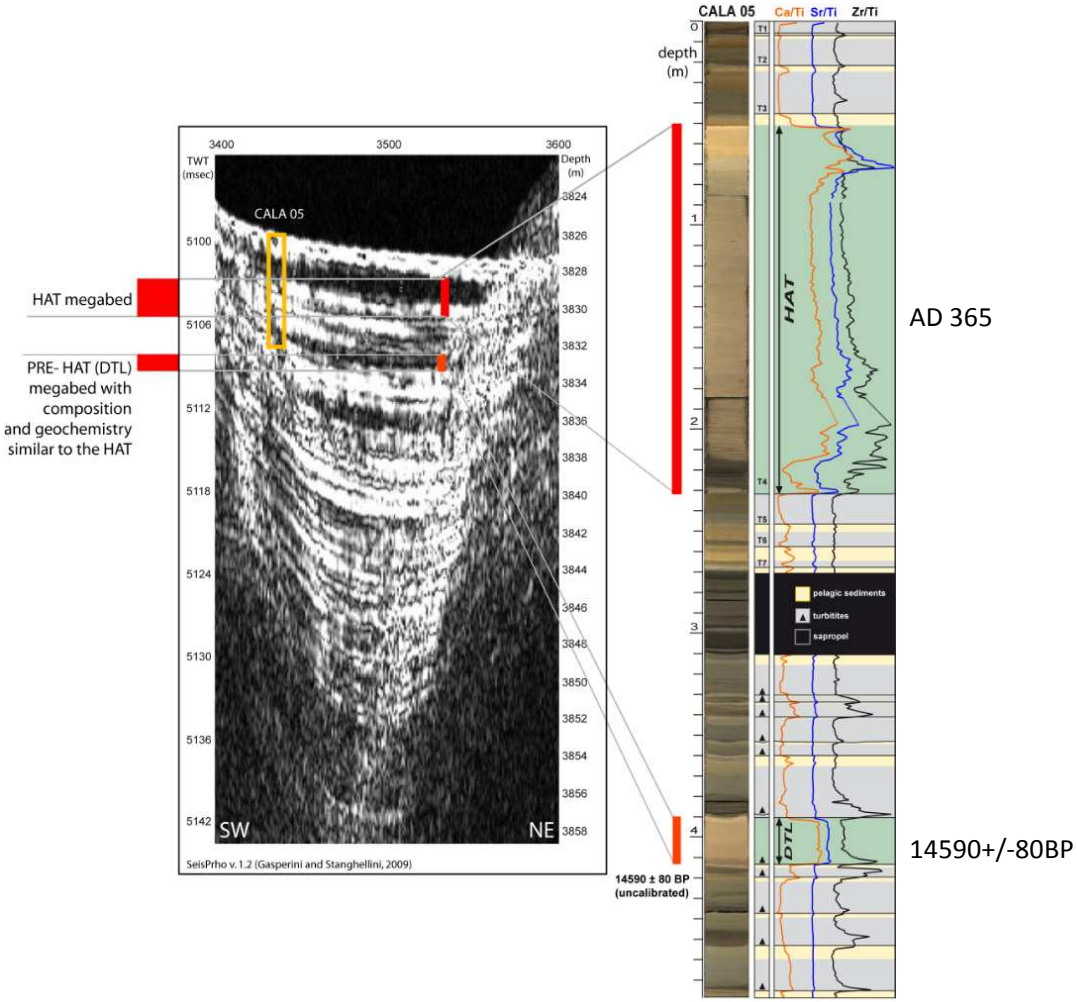
1- Thin seismo-turbidites record the activity of **crustal structures including faults onshore**.

2- Thick turbidites (megaturbidites with limited spatial extent and thickness) are interpreted as **subduction-type events in the Calabrian Arc => they recur every 2-3 Ka**
the last megabed was deposited about 2.9 ka => need for a careful assessment of the seismic hazard

3- Very thick resedimented units (megaturbidites) => **Hellenic Arc seismic events that have produced trans-Mediterranean tsunamis (CE365, 14Ka, 40-50 ka)**.



CORE STRATIGRAPHY AND GEOPHYSICAL DATA



SUMMARY OF RESULTS

CRETE-TYPE EVENTS:

- **365 CE Crete mega-earthquake** triggered a trans-Mediterranean tsunami that produced giant submarine slope failures along a front 1500 km long from Italy to northern Africa.
- ***5-10 Ka**? Work in progress…*
- **14 Ka**
- ***15-30 Ka: other mega-turbidites???** Work in progress…*
- **30-50 Ka another major event**

THE CALABRIAN ARC SUBDUCTION THRUST:

It might activate every 2-3 ka. The last megaturbidite is dated 2.9 Ka. This calls for a careful seismic and tsunami hazard assessment.

GIANT PISTON CORES ARE NECESSARY FOR BETTER DEFINING REPEAT TIME OF RARE CATASTROPHIC EVENTS BOTH ALONG THE HELLENIC AND CALABRIAN ARCS

Thank-you for your attention!