# Active deformation evidence in the offshore of western Calabria (southern Tyrrhenian Sea) from Ultra-High Resolution multichannel seismic reflection data: results from the Gulf of Santa Eufemia


Fabrizio Pepe[1], Mor Kanari[2], Pierfrancesco Burrato[3], Marta Corradino[1], Henrique Duarte[4], Luigi Ferranti[5], Carmelo Monaco[6], Marco Sacchi[7], and Gideon Tibor[2]

1. Dipartimento di Scienze della Terra e del Mare, Università di Palermo, Italy - 2. Israel Oceanographic & Limnological Research, Haifa, Israel - 3. Istituto Nazionale di Geofisica e Vulcanologia, Roma - Italy
4. Marine Department, Geosurveys – Geophysical Consultants Lda, Aveiro, Portugal - 5. Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università di Napoli "Federico II", Napoli, Italy
6. Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, Università degli Studi di Catania, Catania, Italy - 7. Consiglio Nazionale delle Ricerche - Istituto di Scienze Marine, Sede secondaria di Napoli, Napoli, Italy

fabrizio.pepe@unipa.it mor.kanari@ocean.org.il pierfrancesco.burrato@ingv.it



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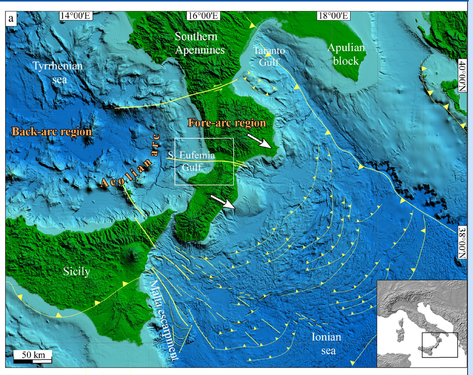
## Background and goals of the study

**Research theme.** An ultra-resolution, multichannel seismic reflection data set was collected on the coastal area around the Sant'Eufemia Gulf (Tyrrhenian side of the Calabrian Arc, Italy) during an oceanographic cruise organised in the frame of the "Earthquake Potential of Active Faults using offshore Geological and Morphological Indicators" (EPAF) project. The latter was founded by the Scientific and Technological Cooperation (Scientific Track 2017) between the Italian Ministry of Foreign Affairs and International Cooperation and the Ministry of Science, Technology and Space of the State of Israel. In this work, we provide preliminary results of the most technologically advanced ultra-high-resolution geophysical method used during this survey to reveal the 3D faulting pattern, the late Quaternary slip rate and the earthquake potential of the marine fault system located close to the densely populated west coast of Calabria.

**Goal of the Study.** The Gulf of Sant'Eufemia (southern Tyrrhenian Sea), which is part of the fore-arc of the Tyrrhenian-Ionian subduction system, is an area of high 'Seismogenic Faults' relevance. The Calabria 8 September 1905 earthquake is one the most powerful event occurred in Italy (at least in terms of recorded magnitude: Ml=7.9, Dunbar et al., 1992; Ms=7.47; Margottini et al., 1993; Gruppo di Lavoro CPTI 15, http://emidius.mi.ingv.it/CPTI15-DBMI15/, Rovida et al., 2015). Although early investigation (e.g. Cucci and Tertulliani 2010; Loreto et al., 2013; 2017) tentatively identified its causative fault, the regional processes active in the Sant'Eufemia Gulf, related to the oblique subduction of the Adriatic-Ionian plate, and the 3D pattern of active faults are still poorly understood and not completely reconstructed yet. This is not only due to the lack of seismic data acquired in the Sant'Eufemia Gulf, but also due to the lack of the technology necessary to acquire and process ultra-high-resolution multi-channel seismic data with decimetric resolution (comparable with outcrops) and penetration higher than 400-500 m. To solve the problem, we experimented acquiring ultra-high-resolution seismic data using innovative technologies for the offshore imaging of stratigraphy and structures with a horizontal and vertical resolution at decimetric scale.




Tectonic sketch map of the Central Mediterranean area showing the major structural domains with major tectonic boundaries draped. The white box indicates the investigated area.

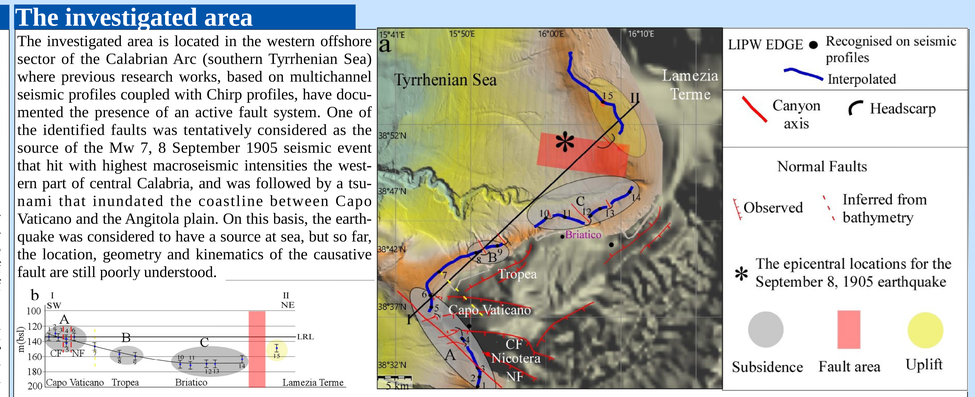
## The EPAF Project


The EPAF project aims to develop a new, multidisciplinary, method to identify and define the geometry of active faults in the offshore area, using the geophysical dataset, and to reconstruct the history of fault movements through radiocarbon dating of benchmarks identified on gravity core data.

The approach consists of an innovative combination of a geophysical dataset, algorithm, and sampling methodology. Primary data are 1) high-resolution geophysical data (seismic reflections, multibeam data and potential fields); 2) physical experimental investigation of paleo sea-level markers; 3) benchmarks recognized in gravity core data.

## The investigated area

The investigated area is located in the western offshore sector of the Calabrian Arc (southern Tyrrhenian Sea) where previous research works, based on multichannel seismic profiles coupled with Chirp profiles, have documented the presence of an active fault system. One of the identified faults was tentatively considered as the source of the Mw 7, 8 September 1905 seismic event that hit with highest macroseismic intensities the western part of central Calabria, and was followed by a tsunami that inundated the coastline between Capo Vaticano and the Angitola plain. On this basis, the earthquake was considered to have a source at sea, but so far, the location, geometry and kinematics of the causative fault are still poorly understood.

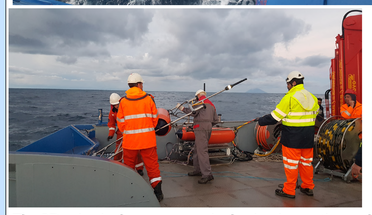






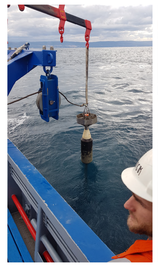
(a) Map of the position of the LIPWs formed in the offshore sector of the Capo Vaticano promontory during the LGM, (b) section oriented towards the NE of the depth of the LIPW. LRL, depositional equilibrium profile. The star indicates the epicentre of the earthquake that occurred on 8 September 1905.

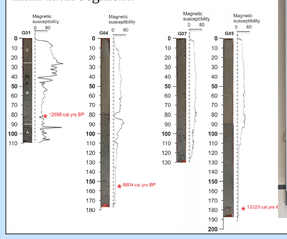
## The equipment

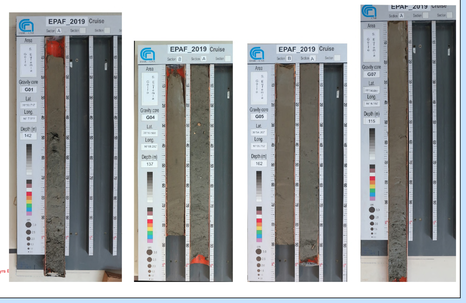


The 2D seismic data were acquired using innovative multi-tip sparker sources based on negative discharge technology, together with a dual-sources Sparker system and a HR 48-channel, slant streamers, with group spacing variable from 1 to 2 meters. The sampling rate was set at 10 kHz. An innovative designed differential GPS positioning system navigation system was used to perform all necessary computations to determining real-time positions of sources and receivers. The hardware components were produced by the Geo Marine Survey System B.V., The Netherlands (https://www.geomarinesurveysystems.com/). Data processing was performed by GeoSurvey (Portugal).

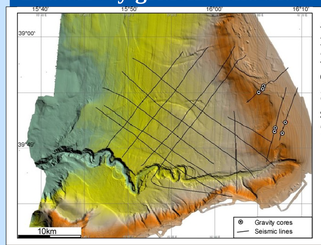
In addition to the seismic imaging, gravity core data were also collected for sedimentological analysis. Fossil samples were radiocarbon dated to obtain the age of the reflector, using the high-resolution mass spectrometry (AMS) technique at the Dating and Diagnostic Center (CEDAD) of the University of Salento. In particular, the LT19524A sample allowed to calibrate a reflector cut by the fault shown on Line NS01. The vertical offset of the reflector is 1.97 ms, which corresponds to 1.58 meters (assuming a propagation velocity of 1600 m/s). Therefore, the average long-term slip rate is 0.14 mm/year. This value represents a lower limit for the average long-term slip rate for the main fault segment.





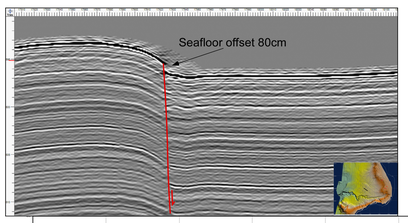



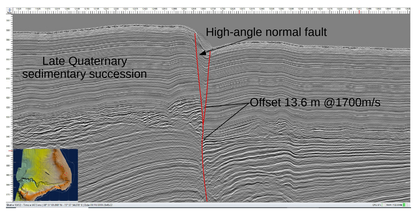

## The survey grid and the the Oceanographic Ship

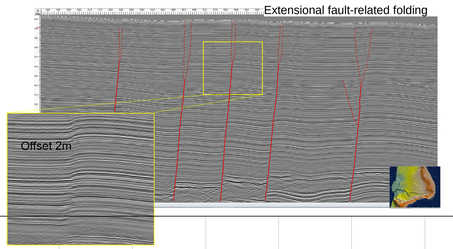


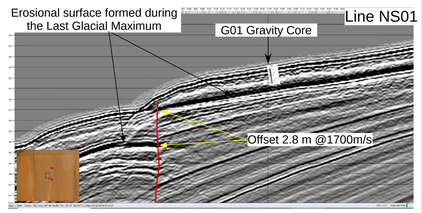

About 300 km of ultra high resolution (UHR) multichannel seismic profiles and eight gravity cores of 2 meters each were acquired in the Gulf of Sant'Eufemia, onboard the Atlante Oceanographic Ship.

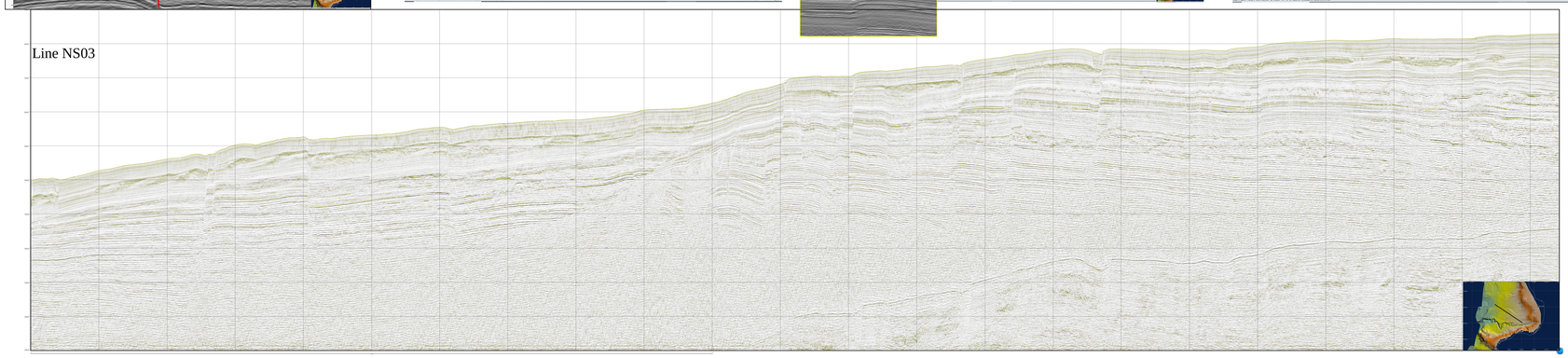
Seismic data were acquired both along the continental shelf and the upper slope, in water depths varying from 70 to more than 600 meters.

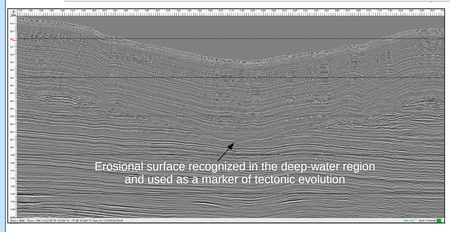



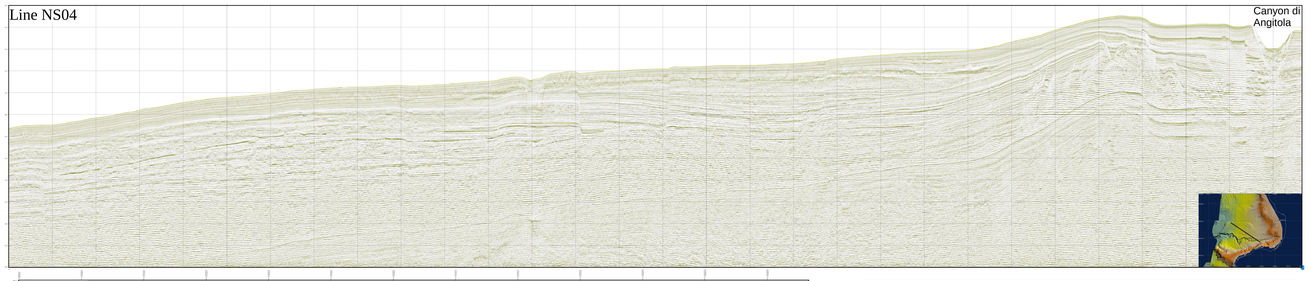



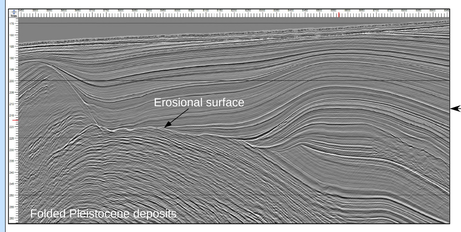



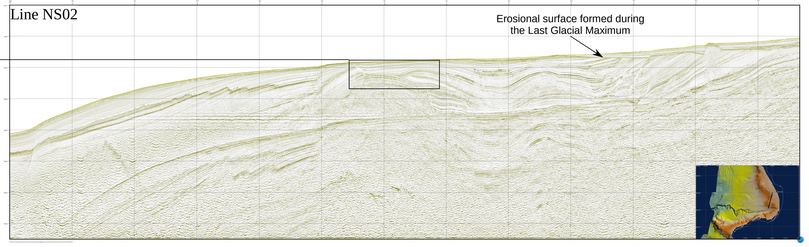



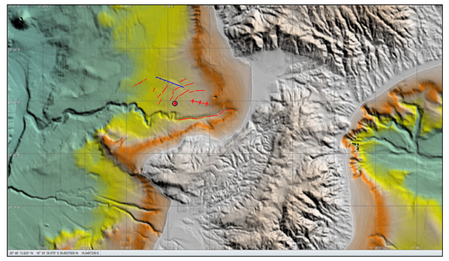




**Implications of our work for future seismic reflection data acquisition** The resolution of the seismic profiles obtained from this experiment is remarkable high respect to previously acquired seismic data for both scientific and industrial purposes. Therefore, the developed methodology may represent a standard for the acquisition of ultra-high-resolution multichannel seismic data aimed at recent to active tectonics studies.



Preliminary structural map of the Sant'Eufemia Gulf. The Calabria 8 September 1905 earthquake fall within this fault system, here named Santa Eufemia fault system.

## Preliminary results

The newly acquired and processed high-resolution seismic data show a vertical decimetric resolution and, therefore, suitable for identifying faults active during the Late Pleistocene-Holocene. It should be noted that the resolution of the seismic profiles obtained from this experiment is the highest respect to all previously acquired seismic data for both scientific and industrial purposes.

The seismic profiles demonstrate active faulting in many places. Active faults are identified by offsetting the strata up to the seafloor. These offset strata, and the geological structure of active faulting in the Sant'Eufemia basin are currently under interpretation. We include here several examples of the high-resolution data which was acquired in the geophysical survey of this study.