CONSIGLIO NAZIONALE DELLE RICERCHE
Istituto di Scienze Marine - Bologna

CALAQUAKE-2014

Technical Report

Ionian Sea

(May 9 -26, 2014)

Luca Gasperini, Flavio Priore, Giulia Barbieri, Giovanni Barreca, Mirko Carlini, Vincenzo Cedro, Alessio Cesari, Enrico Dalpasso, Andrea Gallerani, Katja Lindhorst, Claudio Pastore, Francesco Urzì, Marco Venieri, Alina Polonia.

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- CNR Consiglio Nazionale Delle Ricerche www.cnr.it
- ISMAR Istituto di Scienze Marine www.bo.ismar.cnr.it
- SEG Soc. of Exploration Geophysicists www.seg.org
- XTF Extended Triton Format www.tritonelics.com
- IHO Int. Hydrographic Organization www.iho.org
- GPS-DGPS-RTK Global Positioning System samadhi.jpl.nasa.gov
- DTM Digital Terrain Model en.wikipedia.org
- SRTM Shuttle Radar Topogr.Mission www2.jpl.nasa.gov/srtm
- MBES MULTIBEAM ECHOSOUNDER SYSTEM
- SBP Sub Bottom Profiling
- PSU Practical Salinity Scale ioc.unesco.org
- XBT Expendable BathyTermograph www.sippican.com
- UTM Universal Transverse Mercator
- UTC Universal Time Coordinated
- WGS84 World Geodetic System 1984
- NMEA National Marine Electronics Association www.nmea.org
- SO.PRO.MAR. Societa' Promozione lavori Marittimi Fiumicino (Italy)
- SBE Sea Bird Electronics www.seabird.com
- BENTHOS Teledyne Benthos www.benthos.com
- SIS Sea Floor Inf. System www.kongsberg.com
- KONGSBERG Kongsberg Maritime www.kongsberg.com
- COMM-TECH Communication Technology www.comm-tec.com
- GMT Generic Mapping Tool gmt.soest.hawaii.edu/gmt
- GEOMAR: Helmholtz-Zentrum für Ozeanforschung Kiel
- COST-FLOWS PROJECT: Impact of Fluid Circulation in Old Oceanic Lithosphere on the Seismicity of Transform-Type Plate Boundaries: New Solutions for Early Seismic Monitoring og Major European Seismogenic Zones. COST ACTION: COST ES1301

Acronyms of Organizations, Manufacturers and Products

HOW TO READ THIS REPORT

Section 1 gives the introductory and background information, including some technological and scientific issues of the organization and execution of tasks, whereas section 2 summarizes the cruise operations. Section 3 provides the technical aspects that were involved in the data acquisition and processing. Section 4 and following discuss the initial results, the on-going data processing and usage, and give concluding remarks. Some data processing procedures that were used in the production of this report along with additional technical details and data are presented in the Appendix.

ACKNOWLEDGMENTS

Many people contributed to the success of the research cruise (CALAQUAKE-2014 *R/V Urania*). We are particularly indebted to the Captain Vincenzo Lubrano, the officers and crew members of *R/V Urania* for their professionalism and efforts in assuring the success of the cruise. The project was co-funded by Italian CNR and MIUR project: *Geodinamica attiva e recente dell'Arco Calabro e del complesso di accrezione nel Mar Ionio*, coordinated by Carmelo Monaco (University of Catania).

RIASSUNTO

Questa relazione contiene il resoconto tecnico della campagna di Geologia Marina denominata "CALAQUAKE-2014", effettuata tra il 9 e il 26 Maggio 2014 nel Mar Ionio. Durante la spedizione CALAQUAKE-2014 sono stati acquisiti dati di sismica a riflessione, morfobatimetria e magnetometria, e sono stati campionati i sedimenti marini utilizzando un carotiere a pistone. Sulle carote e' stato eseguito un campionamento geochimica e biologico allo scopo di analizzare le acque interstiziale e la componente microbiologica dei sedimenti. Scopo principale della campagna era studiare la geologia dell'Arco Calabro, il sistema di subduzione al largo della Sicilia Orientale e della Calabria, la sua struttura superficiale e il potenziale sismogenico delle numerose faglie attive che hanno causato terremoti e tsunami disastrosi nel recente e più remoto passato, come nel caso di Messina nel 1908 e del Golfo di Augusta nel 1693, o il catastrofico terremoto di Creta del 365 AD (M>8), che ha causato effetti in tutto il Mediterraneo e la deposizione di oltre 25 m di sedimenti nella piana abissale del Mar Ionio.

ABSTRACT

This is the technical report of the "CALAQUAKE-2014" oceanographic expedition, carried out during the period 9 to 26 May 2014 in the Ionian Sea. During CALAQUAKE-2014, seismic reflection, morphobathymetric and magnetometric data were collected, as well as well targeted sediment cores in key areas of the Ionian continental margin. A geochemical and biological sampling of the cores was performed in order to analyze pore water and sediment microbiology.

The main aim of the expedition was to study the geology of the Calabrian Arc, the subduction system off the coast of eastern Sicily and Calabria and its shallow structure, along with the seismogenic potential of the active faults. In fact, tis region was site of numerous devastating earthquakes/tsunamis in the recent past, such as in Messina (1908) and the Gulf of Augusta (1693), or the M>8, AD 365 Cretan earthquake, which caused a tsunami wave hitting the whole Eastern Mediterranean coasts and the deposition of a megabed up to 25 m thick in the Ionian abyssal plain.

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1. INTRODUCTION AND BACKGROUND

The Project CALAQUAKE (**CAL**abrian **A**rc subduction complex: active faults, historical earth**QUAKE**s and turbidites) is designed to carry out an integrated geological and geophysical study of the deformation processes and relationships between tectonics and sedimentation in key areas of the subduction complex, selected through the integrated analysis of available data. Our purpose is to carry out a multi-scale geological and geophysical study of this area, which has the potential to reveal if subduction is still active, to determine fault dynamics in different domains of the subduction complex, to define relationships between seismic shaking, mass and fluid flow and to address seismic and tsunami hazard in the Central Mediterranean region.

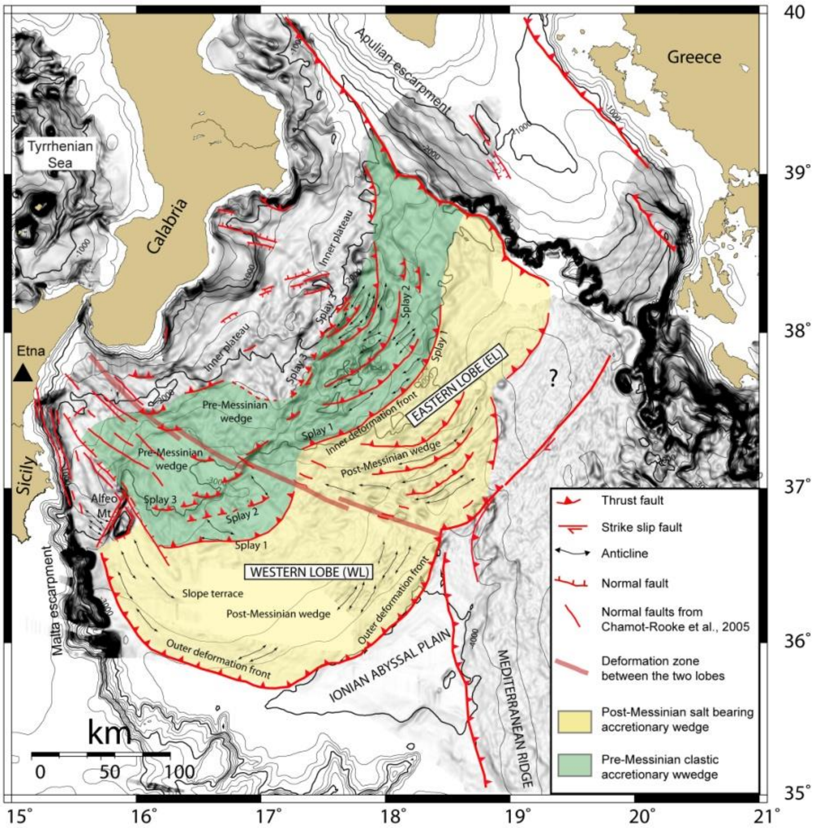

Figure 1. Morphostructural map of the Calabrian Arc (from Polonia et al., 2011).

1.1 REGIONAL TECTONIC SETTING

The Calabrian Arc (CA) is part of the eastward migrating Apennine subduction system and connects the NW trending Apennine with the E-W oriented Maghrebian thrust belt [*Patacca and Scandone*, 2004]. It is located above a 300 km wide subduction zone, dipping toward NW characterized by the presence of an active volcanic arc (the Aeolian Islands) and a well defined Wadati-Benioff zone [*Wortel and Spakman*, 2000], with earthquakes descending to nearly 500 km of depth [*Selvaggi and Chiarabba*, 1995]. The

Neogene and Quaternary evolution of the CA is controlled by the south-eastward retreat of the Apennine-Calabrian subduction zone, that caused rifting and lithospheric thinning culminating in the opening of the Tyrrhenian Sea starting from the upper Miocene [*Malinverno and Ryan*, 1986; *Jolivet and Faccenna*, 2000; *Faccenna et al*., 2001; *Sartori*, 2003]. Since that time, Calabria has migrated towards SE due to the rapid roll-back of the Ionian-Tyrrhenian slab and trench retreat [*Faccenna et al*., 2001; *Faccenna et al*., 2004]. Trench retreat was particularly fast over the Neogene and early Quaternary [*Patacca et al*., 1990] as indicated by high extension rates (50-70 mm/yr) recorded in the Vavilov (Neogene) and Marsili (Early Middle Pleistocene) oceanic seamounts [*Marani and Trua*, 2002; *Mattei et al*., 2002] and rapid migration of the trench [*Faccenna et al*., 2001]. On the other hand, vertical axis rotations responsible for the arcuate shape of the CA occurred during Miocene to Quaternary but were almost finished 1 Ma [*Mattei et al.*, 2007] as confirmed by GPS results showing no active back-arc extension in the Southern Tyrrhenian Sea [*D'Agostino et al*., 2008].

The external part of the arc (Figure 1) is represented by a subduction complex that reaches both the Ionian abyssal plain and the Mediterranean Ridge and is bordered by two major structural features, the Malta escarpment to the southwest and the Apulia escarpment to the northeast. The CA accretionary wedge developed due to the SE-NW Africa/Eurasia convergence, presently occurring at a very slow rate (5 mm/yr or even <5 mm/y), as reported by recent GPS studies [*Calais et al.*, 2003; *Reilinger et al*., 2006; *Serpelloni et al*., 2007; *D'Agostino et al*., 2008; *Devoti et al*., 2008]. On the other hand, geodetic investigations of crustal motion in the central Mediterranean have shown significant deviations from the direction of relative motion between the Eurasia and Africa plates [*D'Agostino and Selvaggi*, 2004; *Serpelloni et al*., 2007; *Devoti et al*., 2008; *D'Agotino et al*., 2008].

Despite the very slow modern-day plate convergence rates observed by GPS, subduction may still be active in the CA, and subduction rate will depend both on the convergence rate and the velocity of the subduction hinge [*Doglioni et al*., 2006; *Doglioni et al*., 2007]. GPS sites in Calabria (relative to Apulia) show systematic residuals directed towards the Ionian Sea, suggesting active crustal compression and an outward motion of the CA as a result of still active subduction that accounts for the shortening taken up in the accretionary wedge, eventually accommodated by long-term slip on the subduction interface [*Gutscher et al.*, 2006: *D'Agostino et al.*, 2008].

Previous studies have outlined the overall geometry of the subduction complex in the Ionian Sea through the analysis of crustal-scale seismic data [*Finetti* 1982, *Cernobori et al*., 1996; *Doglioni et al*., 1999, *Catalano et al*., 2001, *Finetti*, 2005], while geological field studies onland have described the inner continental basement rock assemblage made of a nappe pile of metamorphic rocks comprising Tertiary ophiolitic units overlain by a large sheet of pre-alpine continental-derived metamorphic basement with local remnants of Mesozoic-Cenozoic sedimentary cover [*Bonardi et al*., 2001; *Rossetti et al*., 2004]. During Oligocene-early Miocene, the metamorphic basement units were affected by crustal extension during Tortonian times [*Mattei et al*., 2007] while during Pleistocene it experienced high uplift rates, up to 1 mm/yr [*Westaway*,1993; *Gvirtzman and Nur*, 2001]. These latest tectonic phases affected the inner part of the CA and generated extensional fault systems both parallel and oblique to the coastline [*Del Ben et al*., 2008]. They are the major tectonic features of the inner portion of the CA, that dismember all the older tectonic lineaments.

The submerged portion of the CA consists of a north-westward thickening wedge of deformed sediments [*Finetti* 1982; *Cernobori et al*., 1996; *Minelli and Faccenna*, 2010] overlying, in the most external portion, north-westward dipping sediments and the basement. This is structurally consistent with the presence of a SE-verging accretionary wedge [*Cernobori et al*., 1996]. The wider portion of the slope, named “external CA” [*Rossi and Sartori*, 1981], hosts thrust systems, chaotic units and a province of mud volcanoes [*Praeg et al*., 2009; Panieri et al., 2013] that may indicate dewatering of the Calabrian prism due to compressional deformation.

1.2 PREVIOUS STUDIES: THE CALAMARE 2008 CRUISE

Results obtained through the analysis of the data collected during the previous Urania 2008 cruise (CALAMARE project: CALabrian Arc MARrine geophysical Experiment) constitutes the background of this proposal (*Polonia et al., 2011; Polonia et al., 2012*). The structure and evolution of the external Calabrian Arc (CA) subduction complex has been reconstructed through an integrated geophysical approach involving multi-channel and single-channel seismic data at different scales. Pre-stack depth migrated crustal-scale seismic profiles have been used to reconstruct the overall geometry of the subduction complex, i.e., depth of the basal detachment, geometry and structural style of different tectonic domains, and location and geometry of major faults. High-resolution multi-channel seismic (MCS) and sub-bottom CHIRP profiles acquired in key areas of the subduction complex, as well as multibeam data, integrate deep data and constrain the fine structure of the accretionary wedge as well as the activity of individual fault strands.

We identified four main morpho-structural domains in the subduction complex related to different tectonic processes, such as frontal accretion, out-of-sequence thrusting, underplating and complex faulting (*Polonia et al., 2011*). Although shallow thrust-type seismicity along the CA is lacking, we identified active deformation of the shallowest sedimentary units at the wedge front and in the inner portions of the subduction complex. This implies that subduction could be active but aseismic or with a locked fault plane. These findings have consequences on seismic risk hazard, since we identified tectonic structures likely to have caused large earthquakes in the past and to be the source regions for future events (*Polonia et al., 2012*).

1.3 ACTIVE FAULTS IN THE SUBDUCTION COMPLEX

The CA (**Figure 1**) is part of the most active seismic belt in Italy, and is the last remaining segment of oceanic crust subduction. This region is characterized by a high earthquake hazard: it has been struck repeatedly by very strong historical earthquakes in 1169, 1542, 1624, 1693, 1783, 1905, 1908, often associated with destructive tsunami. The Messina earthquake/tsunami occurred in 1908, killed over 80,000 people.

If, on one hand, it is well known that the Calabrian Arc and, in particular, the Messina Straits region, is the locus of active deformation (*Argnani et al., 2009; Doglioni et al., 2012*) and destructive historical earthquakes and tsunamis (*CPTI Working Group, 2004, Tinti et al., 2004; Tinti, 2007*), knowledge of source parameters is relatively poor, particularly for seismogenic structures extending offshore.

The multiscale analysis of geophysical data integrated with analysis of onland geology and paleoseismology provided new insights to compile an inventory of first order active faults that may have produced past seismic events (*Polonia et al., 2011; Polonia et al., 2012; Polonia et al., 2014*). The proposed seismogneic faults include:

i) the NNW-SSE trending transtensive Alfeo-Etna fault system, crossing the Alfeo seamount and reaching the Etna volcano on its nortwestern tip;

ii) the out-of-sequence thrusts within the Calabrian Arc accretionary wedge (Polonia et al., 2011; Polonia et al., 2012), very similar to the seismogenic splays off Nankai (*Park et al., 2002; Moore et al., 2007*) and Sumatra (*Gulick et al., 2011*);

iii) the Ionian Fault system, crossing the Messina Straits region. This fault accommodates margin segmentation, the outward movement of Calabria relative to Sicily and divergence in the Messina Straits area. It is a lithospheric structure representing an incipient plate boundary in the central Mediterranean Sea (*Polonia et al., 2012; Polonia et al., 2014a; Polonia et al., in preparation*).

These faults which possibly connect onland to the Tindari-Novara fault system (*Billi et al., 2007; palano et al., 2012*) are likely to be source regions for future large magnitude events as they are long, deep and bound sectors of the margin characterized by different deformation and coupling rates on the plate interface. Moreover, the proposed active crustal faults, represent likely conduits for fluid within the accretionary wedge (*Panieri et al., 2013*).

We planned to analyse in detail the geometry, kinematics and evolution of these fault systems in key-areas of the subduction complex through an integrated geological and geophysical approach which involves the acquisition of multibeam swath bathymetry, single-channel seismic reflection profiles as well as well targeted sediment cores.

1.4 SEISMIC SHAKING AND MASS FLOWS

Active deformation in the Calabrian Arc is reflected in the high seismicity of this area (*Pondrelli et al., 2006; Neri et al., 2003; Neri et al., 2004; Presti et al., 2013*) which is part of the most active seismic belt of the Central Mediterranean region. It faces the highly populated regions of Southern Italy, that were struck repeatedly by large magnitude earthquakes in the recent past (*Valensise and Pantosti, 1982; Bottari et al.,* *1989; Jacques et al., 2001; Galli and Bosi, 2003; Jenny et al., 2006*), often associated with destructive tsunamis (*Piatanesi and Tinti, 1998; Tinti et al., 2004*).

For several major earthquakes in the region, like the 1908 (*Mulargia and Boschi, 1983; Bottari et al., 1986; Capuano et al., 1988; De Natale and Pingue, 1991; Amoruso et al., 2002; Michelini et al., 2005; Pino et al., 2009*) and 1693 (*Bianca et al., 1999; Sirovich and Pettenati, 1999; Monaco and Tortorici, 2000; Gutscher et al., 2006*) it has been suggested that seismogenic structures may have been entirely or partially located offshore.

Northeastern Sicily and southern Calabria, bear a similar historical record of destructive earthquakes and tsunamis (*Bottari et al., 1989; Piatanesi and Tinti, 1998; Boschi et al., 2000; Jacques et al., 2001; Galli and Bosi, 2003; Tinti et al., 2004; Jenny et al., 2006; CPTI working group, 2004*). The record of major seismic events in southern Calabria includes more than 25 earthquakes with M>6 occurred since 91 B.C. close to the Messina Strait region (*CPTI Working Group, 2004; Galli and Bosi, 2003; Galli et al., 2006*).

The integrated analysis of well-targeted sediment cores in the forarc basin and in the slope basins adjacent to the active faults have the potential to reconstruct the record of great earthquakes in the region. This technique has been successfully applied to the Cascadia arc, where great subduction earthquakes (M8 - M9) occur at intervals of roughly 300-1500 years. While earthquake catalogues in Southern Italy extend back 2000 years, it is important to be able to compare the sedimentary record (of earthquake triggered submarine landslides) to the historic seismic record and once the correlation is established to extend the paleoseismic catalog further back in time.

The multidisciplinary investigation of the effects of historical earthquakes in the Ionian Sea, on marine sedimentation through the analysis of the turbidite record (*Ryan and Heezen*, 1965; *Kastens, 1984; Polonia et al., 2013a; 2013b; 2014b*) suggests that major historical earthquakes recorded in the area (i.e. the 1908, 1693 and 1169 events) triggered mass flows and turbidite emplacement. The source for all the historical turbidites discovered in the deep basin, as inferred from their mineralogy, is the metamorphic basement outcropping in the Messina Straits region. These findings suggest that seismically/tsunami triggered turbidites represent more than 90% of sedimentation in the deep basin and this is related to the occurrence of frequent, medium scale, earthquakes in the working area. Marine sediments may thus be considered as seabed archives of paleo-earthquakes capable of reconstructing seismicity back in time, during several earthquake cycles (10,000-30,000 years).

Turbidite record will be analysed to determine which portions of the arc have experienced great earthquakes in the past, and whether the recurrence interval is regular or not, and how often catastrophic events occur.

2. Cruise summary

SHIP: *R/V Urania* Flag: Italy [IT] Call Sign: IQSU IMO: 9013220, MMSI: 247498000

START: 2014-05-09 PORT: Messina

END: 2014-05-26 PORT: Napoli

SEA/OCEAN: Ionian Sea

LIMITS: NORTH 38N SOUTH 35.4N: WEST:15.5E EAST: 18.9E

OBJECTIVE: structural geology, active faults, historical earthquakes in the Calabrian Arc (Ionian Sea)

COORDINATING BODIES: ISMAR-Bologna BOLOGNA (ITALY)

CHIEF OF EXPEDITION: Luca Gasperini (ISMAR-CNR) CONTACT: luca.gasperini@ismar.cnr.it

P.I: Alina Polonia (ISMAR-CNR) CONTACT: alina.polonia@ismar.cnr.it

DISCIPLINES: MARINE GEOLOGY, MARINE GEOPHYSICS, PHYSICAL OCEANOGRAPHY, CHEMICAL OCEANOGRAPHY,

WORK DONE: 850 KM_2 MULTIBEAM; 2300 KM SBP; 11 PISTON CORES, 1 GRAVITY CORE, 15 CTD CASTS.

3. MATERIALS AND METODS

The research cruise was carried out with the 61 meter *R/V Urania* (**Figure 2**), owned and operated by SO.PRO.MAR. and on long-term lease to CNR. The ship is normally used for geological, geophysical and oceanographic work in the Mediterranean Sea and adjoining waters, including but not limited to, the Atlantic Ocean, the Red Sea, and the Black Sea. *R/V Urania* is equipped with DGPS and SEAPATH positioning system (satellite link by FUGRO), single-beam and multibeam bathymetry and integrated geophysical and oceanographic data acquisition systems, including ADCP, CHIRP SBP and other Sonar Equipment, other than water and sediment sampling. Additional equipment can be accommodated on the keel or towed.

Figure 2. The R/V Urania.

3.1 Navigation and Data Acquisition

The vessel was set for data acquisition and navigation with PDS-2000 software by RESON, interfaced to several sensors through a multiserial and Ethernet link; among such instruments, the DGPS (Fugro), the Atlas-Krupp Deso-25 single-beam echosunder, the MAHRS MRU and the meteorological station. Position and depth data were also distributed to the CTD data acquisition console.

POSITION	ACROSS	ALONG	HEIGHT
REFERENCE POINT	0.00	0.0	0.0
DGPS	1.64	14.30	14.18
MBEAM	0.00	14.36	-4.96
MAHRS	0.0	0.0	-3.40
ECHO SOUNDER 33	0.0	-1.85	-3.80
CHIRP	-1.00	11.80	-4.00
A-FRAME	6.5	-6.70	0.00
STERN	0.0	-30.60	0.00

Table 1. Instrumental Offsets of PDS2000 on Ship Urania (PDS2000). The GPS antenna (primary positioning system) is located on point DGPS.

A Kongsberg processor running the SIS software, collected the multibeam data, including a SEAPATH MRU, compass, and DGPS. An Anderaa Meteorological Station was also made available, at a rate of one measurement every 5 minutes.

CTD DATA

CTD casts were taken throughout the surveyed areas, for sound velocity analysis, and were used for real-time MBES acquisition and post-processing. Position of CTD stations is reported in **Table 2**. CTD casts were carried out once in a day just before the execution of gravity coring. In order to save time, and because oceanography was not in the objectives of the cruise, data acquisition was terminated once a stable velocity/depth function was reached. This happened most often below 600 m of water depth.
Together with sound velocity, data of conductibility, temperature and oxygen were collected.

CHIRP SBP

SBP data was acquired by the 16 transducers, hull mounted BENTHOS (DATASONICS)Mod.CAP-6600 CHIRP-II profiler, with operating frequencies ranging between 2 and 7 kHz. The pulse length was selected between 5 ms and 15 msec, while the trigger rates varied from 0.25 to 1.5 seconds, depending to water depth. Data were collected using the *multiping* techniques, *insonifying* the water column with several chirp-sonar pings. Digital data acquired by the *Communication Technology* SWANPRO software, were recorded in the XTF format on local disks and transferred on the network upon request. Backups were loaded on external HD. Navigation data were made available to the system as lat/long by NMEA sentences of the DGPS receiver at a rate of approximately 1 Hz or by the PDS2000's NMEA at 1Hz. The XTF data were then converted to SEG-Y using the SeisPrho software (*Gasperini and Stanghellini, 2009*), also employed for compiling BMP images of the seismic profiles onboard. **Figure 3** shows an example of CHIRP SBP profile collected.

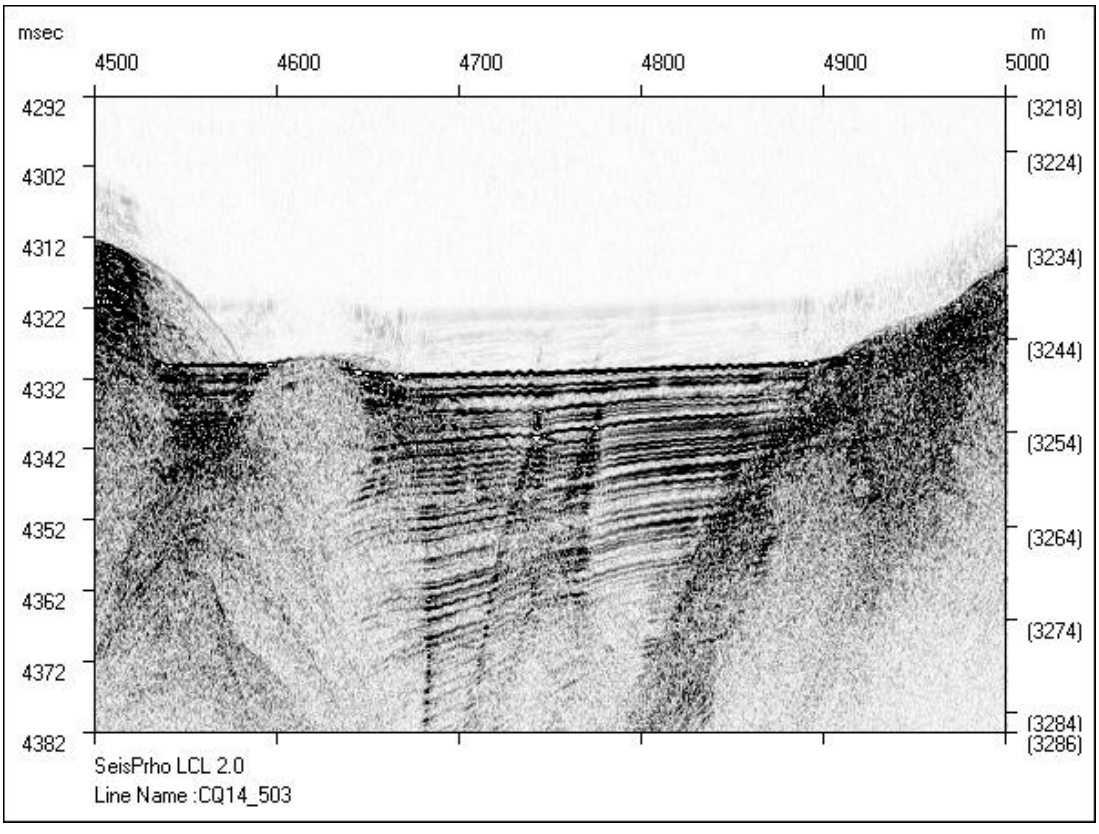

Figure 3. Example of CHIRP SBP profile collected during CALAQUAKE-2014.

Multibeam Echosounder (MBES) DATA

Swath bathymetry was collected using a SIMRAD EM®302 MBES. The EM-302 has the following technical specifications:

Operating frequency: 30 kHz
Depth range: 10-7000 m
Swath width: 5.5xDepth, to approx 8 km
Pulse forms: CW and FM chirp
Swath profiles per ping: 2
Motion compensation:
-Yaw ± 10 degrees
-Pitch ± 10 degrees
-Roll ± 15 degrees
Sounding pattern: Equi-distant /equiangular
Range sampling rate: 3.25 kHz (23 cm)
High resolution mode: High Density processing

Sidelobe suppression: > 25 dB
Suppression of sounding artefacts: 8 frequency coded transmit sectors
Beam focusing: On transmit and on reception
Beamforming method: Time delay
Gain control: Automatic
Swath width control: Manual or automatic, all soundings intact when reduced swath width
Seabed imagery/sidescan sonar image: Standard
Water column display: Standard
Mammal protection: Standard.

The MB sonar head is positioned on the ship's keel using a V-shaped steel frame. A Sound Velocity probe at the keel 1m above the Sonar Head is interfaced directly to the MBES processor, thus providing the necessary real-time data for the beam-forming. CTD casts were used for input of the sound velocity profile to the system. All the function of the MBES are controlled by the Kongsberg software SIS (**Figure 4**), that provide quality control of the data and information for planning the survey.

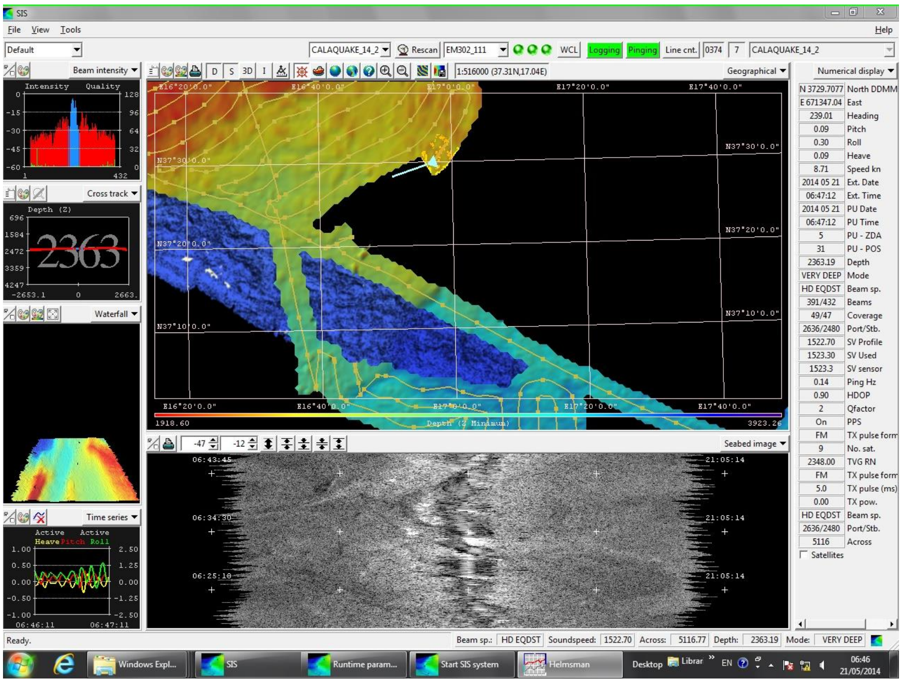

Figure 4. Control panel of SIS during data acquisition.

MAGNETIC DATA

During the entire cruise, excluding the coring and CTD station, a magnetometer SeaSpy (Marine Magnetics) with a of Layback:235m and a Cycling:1Hz.
Magnetic data were stored in ASCII files produced by the software Sealink, containing space separated fields with the following information:
/Date Time Field_Mag1 Gradient Longitude Latitude UTM_Easting UTM_Northing UTM_Zone.
Preliminary processing of the data ws carried out using the GMT package (**Figure 5**).

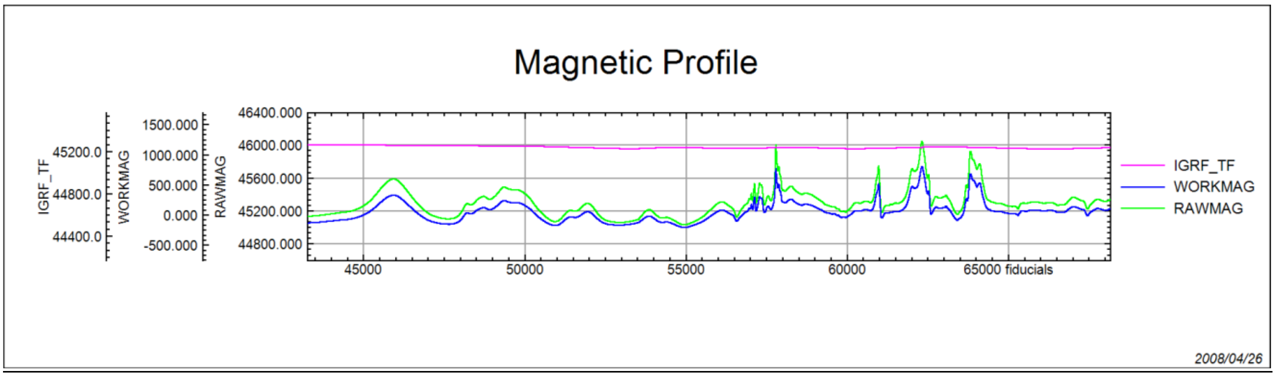

Figure 5. Example of processed magnetic profile.

SEDIMENT SAMPLING

Sediment samples were collected with a CP20 gravity corer (**Figure 6**). The corer was armed with a 1.2 T of weights and two 5 m-long pipes (10 m total length). A trigger was used to gather the maximum impact speed of the corer at the seafloor. Collected cores were cut onboard into 1 m-long segments and archived using the following labelling:

CQ14 (campaign name) + **core_number** (progressive core number) + **segment_number** (roman number)

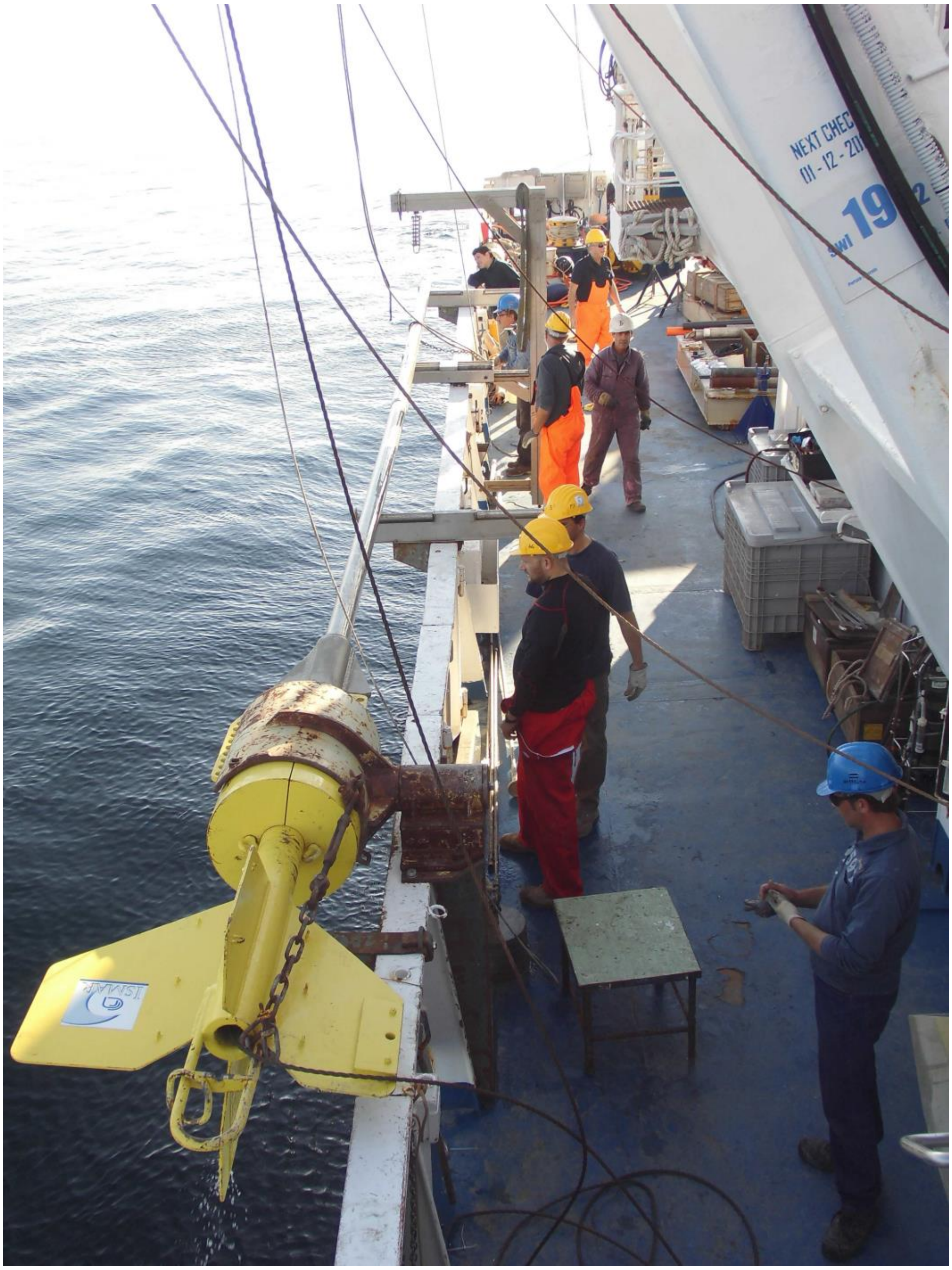

Figure 6. The CP20 piston corer armed before a coring.

MAGNETIC SUSCEPTIBILITY

Each of the collected core were logged for magnetic susceptibility onboard using a Bartington MS2. **Magnetic susceptibility** χ (latin: *susceptibilis* “receptive”) is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to an applied magnetic field (Wikipedia). We considered this measure onboard a first tool to guide pore-water sampling and stratigraphic correlation, since stratigraphi of the uppermost layer is fairly known in the region. Measures were taken each cm, and stored in Microsoft Excel CVS format, with 3 comma-separated columns containing:

depth; susceptivity; drift using a Laptop PC connected to the instrument trough a RS232/USB port, and a dedicated ISMAR-CNR software (**Figure 7**). At each core segment, the instrument drift was estimated with an empty sample, and added to the third column of the CVS acquisition file.

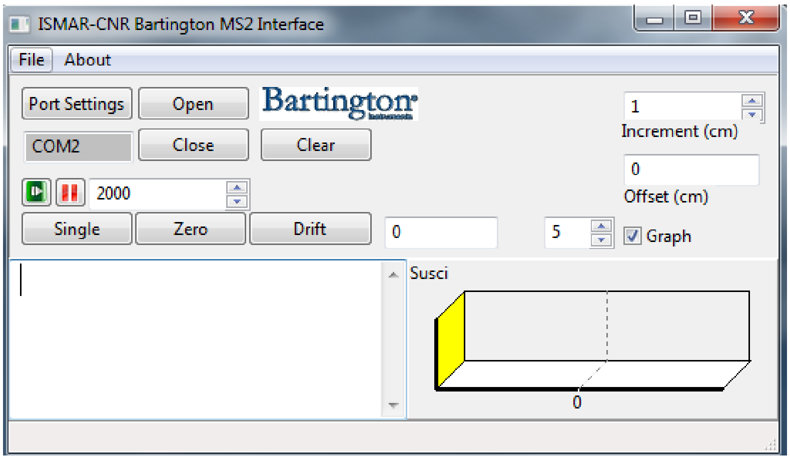

Figure 7. Main panel of magnetic susceptibility acquisition software

GEOCHEMICAL SAMPLING

Geochemical sampling for gas and pore water was carried out over all collected sediment cores. The analysis of gas and pore water will be performed in cooperation with GEOMAR (P.I. Christian Hensen) in the frame of the COST-FLOWS Project (Impact of Fluid Circulation in Old Oceanic Lithosphere on the Seismicity of Transform-Type Plate Boundaries: New Solutions for Early Seismic Monitoring of Major European Seismogenic Zones, COST Action: COST ES1301, Proponents: Marianne Nuzzo and Christian Hensen). Katja Lindhorst took part to the cruise in the frame of a STSM (Short Term Scientific Mission) approved and funded by COST-FLOWS Project.

Magnetic susceptibility profiles collected onboard on each core section were used to define sampling strategy.

-sediment sampling

Immediately collection, the cores were cut into sections. At the bottom of each section a sample for methane was taken using a 3 ml cut-off polypropylenes syringe. Before the closure of each section, a sample of sediment was also collected and stored in a glass bottle filled with 1.5 g NaCl and saturated NaCl water. The sample was sealed using a “Bördelkappenzange” to prevent loss of gas. An additional 3 ml of sediment sample was stored in a prepared plastic container for physical property analysis. A third sample was stored in a whirlpack to measure the absorption of gases within the sediment.

-Pore-water sampling

After magnetic susceptibility logs, small holes were drilled in the core liners to extract pore water. To this purpose we used 20 ml syringes (**Figure 8**). This procedure took very different time, depending on the type of sediment involved, ranging from some minutes to hours. For example, core CQ14-08 taken in vicinity to a deformation zone took several hours. Each sample was divided in three subsamples. First 2 ml were put in a 6 ml plastic container containing 20 µl of nitric acid (HNO_3); 1.8 ml were stored in Eppi cups; and finally, another 1.8 ml was put in a 2 ml glass bottle. All subsamples were stored in a plastic bags, one for each core station.

BIOLOGICAL SAMPLING

The bottom of each core segment was sampled for microbiological studies. Samples were collected in sterile vials, using sterile tools after scratching out the surficial part that has been in contact with the saw during cutting. Soon after collection samples were stored at -20 degrees centigrade. Analysis will include microbiological analysis of turbidite layer, to study microorganism colonization after catastrophic events.

MISCELLANEA

Georeferencing of the data was performed relative WGS84 datum, in UTM33N and 34N projections and time in UTC. Time zone was set to the UTC for the data acquisition. Positioning maps and bathymetric images were produced with GMT [Wessel and Smith (1995)] and Global Mapper. Multibeam data were pre-processed on board by CARIS software and ISMAR’s routines and scripts, using the SIS production DTMS, after conversion to the ASCII format. Bathymetric data were complemented by SRTM plus data available at the web page: topex.ucsd.edu/WWW_html/**srtm**30_**plus**.html. The computing center employed INTEL based PC running the GNU-Linux in addition to portable computer for data acquisition and personal processing. The Linux machines were used as data repositories using the SAMBA software, providing also network services like WWW, DHCP and NAT. Photographs and video were taken by digital cameras and video-camera by all participants.

Figure 8. Pore-water sampling

4. RESULTS

Major deformation zones of the Calabrian Arc subduction complex (**Figure 1**) were investigated during CALAQUAKE-2014 cruise, including (**Figure 9**): (i) the frontal part of the accretionary prism at the connection with the Mediterranean Ridge; (ii) the splay faults that separate the N and S part of the wedge; (iii) the deformation zone between the Eastern and Western lobes.

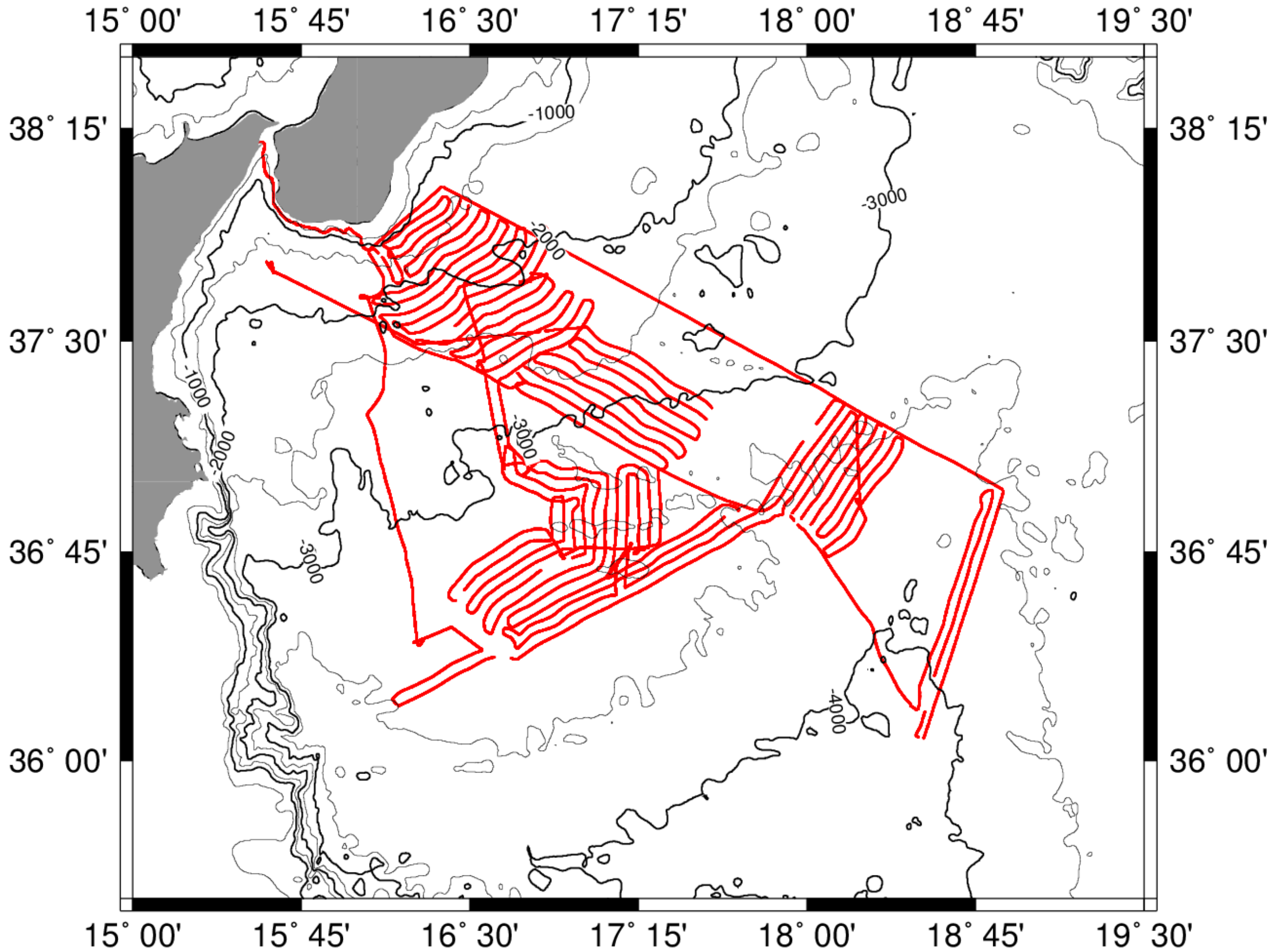

Figure 9. SBP and MBES tracks during CALAQUAKE-2014

Coring stations were executed without problems, although some location were critical due to the possible presence of coarse grained sediments or breccia. We collected 11 piston cores and 1 gravity core (**Table 3**) with several different configurations of the coring device (**Table 4**). The coring station were located in different domains of the Calabrian Arc (**Figure 10**), to address different scientific topics, such as the presence of seismoturbidites, accumulation rates in relationship with tectonic deformation, as well as fluid expulsion at tectonically controlled features, such as diapirs and mud volcanoes.

We faced some problems during magnetic data collection for two main reasons: 1) the tow-fish underwent a shark attack and was damaged; 2) the acquisition program failed to estimate correctly the UTM coordinates at the transition between UTM zone 33 and 34. These problems were solved fixing the transducer with rubber tape, and recalculating coordinates of each magnetic measure using interpolation with GPS time and logfiles of the main navigation system based on PDS software.

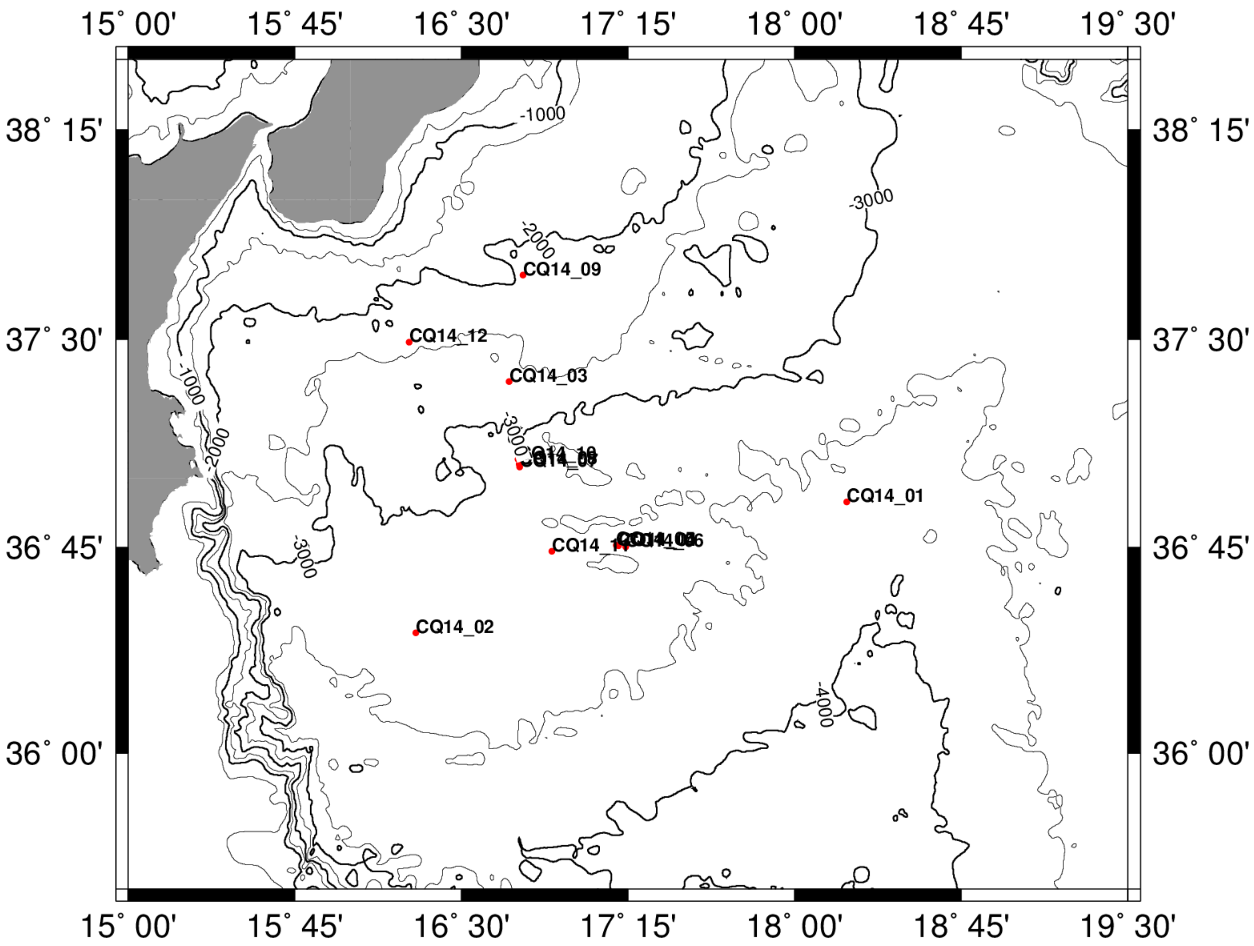

Figura 10. Location of the 11 Piston and 1 gravity cores collected during CALAQUAKE-2014

5. CONLUDING REMARKS AND FUTURE WORKS

During CALAQUAKE-2014, main scientific objectives were obtained. The new morphobathymetric and seismic reflection data, collected in key areas, will be used to characterize the surficial effects of tectonic deformation and gravitative processes, which are intimately connected in such a dynamic geological features. Magnetic data will be used in comparison with previously collected deep penetrating seismi reflection profiles do detect first order geodynamic boundaries.
However, the Calabrian Arc, despite its importance as a major structural domain in the Mediterranean area, and its seismogenic potential that create high hazard for the Souther Italy territory, is still only partially covered by high-resolution marine geological and geophysical data. For this reason, and to complete the work started with CALAQUAKE-2014, we will propose a new cruise for 2015.

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Station	Date	Time (UTC)	Lon	Lat	Depth (m)
CTD_01	09/05/2104	21:49:31	16°22.45'E	38 02.76 N	1338
CTD_02	10/05/2014	13:24:20	18°52.53'E	36°58.18'N	3494
CTD_03	11/05/2014	13:36:29	18°14.86'E	37 14.77 N	3330
CTD_04	12/05/2014	12:46:55	18°14.14'E	36°54.80'N	3791
CTD_05	13/05/2014	14:43:35	16°17.62'E	36°26.28'N	3354
CTD_06	14/05/2104	13:12:22	16°27.61'E	37 59.40 N	1540
CTD_07	15/05/2014	12:53:31	16°42.90'E	37°20.96'N	2756
CTD_08	16/05/2014	10:53:06	17°12.45'E	36°45.34'N	3463
CTD_09	17/05/2014	07:11:05	17°06.50'E	36°39.23'N	3421
CTD_10	18/05/2104	08:57:28	16°45.75'E	37 02.40 N	3481
CTD_11	19/05/2104	08:54:30	16°39.17'E	37 02.49 N	3481
CTD_12	20/05/2014	12:13:52	16°46.62'E	37°42.80'N	2256
CTD_13	21/05/2014	11:31:32	16°45.35'E	37°04.07'N	3104

Table 2. CTD stations carried out during CALAQUAKE-2014.

NAME	LON(ddmm.)E	LAT(ddmm.) N	Depth	Heading	Penet.(m)	Recover (m)
CQ14_01	1814.146828	3654.80146	3793	258	10	8.4
CQ14_02	1617.627214	3626.28346	3356	185	7	6.7
CQ14_03	1642.950897	3720.962858	2752	247	10	7.16
CQ14_04	1712.448302	3645.354277	3473	327	10	7.6
CQ14_05	1711.786741	3645.430651	3472	280	10	8.05
CQ14_06	1714.433312	3645.140663	3417	271	10	7.76
CQ14_07	1645.723147	3702.436100	3465	144	10.2	7.44
CQ14_08	1645.538338	3703.041039	3310	102	7.8	7.22
CQ14_09	1646.693486	3743.850847	2273	106	8	5.54
CQ14_10	1645.349874	3704.085527	3090	237	10	7.8
CQ14_11	1654.430564	3644.133826	3333	283	10	8.38
CQ14_12	1615.945932	3729.404166	2257	322	3.5	2.14

Table 3. Cores collected during CALAQUAKE-2014, location, penetration, etc.

ID	Max Load	Config Carot.	Testata kg	L. cavo sgancio	Alt. Caduta	Imbando	Penetraz.	Recupero	Recupero %	Spine attive n°	Spine semi-attive n°	Note	data
CALAQUAKE-2014													
CQ14_01	8357	CP10	1250	16.15	3.55	5	10	8.4	84	4	4	imbando di 1,6m, 4 spine attive uscire, 4 passive mosse in su (pistone ha fatto da	12-mag
CQ14_02	7044	CP10	1250	16.15	3.55	4	7	6.7	95.71429	4	4	3 spine attive uscite, diverse spine passive mosse	13-mag
CQ14_03	7794	CP10	1250	16.15	3.55	4.5	10	7.16	71.6	4	4	4 spine attive uscite, 4 semiattive mosse, diverse spine passive mosse	15-mag
CQ14_04	7366	CP10	1250	16.15	3.55	4.5	10	7.6	76	4	4	4 spine attive uscite, 4 semiattive mosse, diverse spine passive mosse 5	16-mag
CQ14_05	8357	CP10	1250	16.15	3.55	4.5	10	8.05	80.5	4	4	3 spine attive uscite, 1 semiattive mosse, diverse spine passive mosse 5	17-mag
CQ14_06	8035	CP10	1250	16.15	3.55	4.5	10	7.76	77.6	4	4	4 spine attive uscite, diverse spine passive mosse 5	17-mag
CQ14_07	8544	CP10	1250	16.15	3.55	4.5	10.2	7.44	72.94118	4	4	4 spine attive uscite, 4 semiattive mosse	18-mag
CQ14_08	8973	CP10	1250	16.15	3.55	4.5	7.8	7.22	92.5641	4	4	4 spine attive uscite, 4 semiattive mosse	18-mag
CQ14_09	7901	CP10	1250	16.15	3.55	4.5	8	5.54	69.25	4	4	4 spine attive uscite, 4 semiattive mosse	20-mag
CQ14_10	7800	CP10	1250	16.15	3.55	4	10	7.78	77.8	4	4	4 spine attive uscite, 4 semiattive mosse, 3 passive mosse	21-mag
CQ14_11	7500	CP10	1250	16.15	3.55	4	10	8.38	83.8	4	4	4 spine attive uscite, 4 semiattive mosse, 3 passive mosse	22-mag
CQ14_12	8100	GC1.2	1200	11	3	14	3.5	2.14	61.14286			gravità	24-mag

Table 4. Technical details of device employed at each coring station.