CNR – NATIONAL RESEARCH COUNCIL OF ITALY
EARTH AND ENVIRONMENT DEPARTMENT

ACQUISITION OF MULTICHANNEL SEISMIC REFLECTION PROFILES IN THE CENTRAL AND SOUTHERN TYRRHENIAN SEA

TIR10: R/V URANIA CRUISE REPORT, 2010-10-19, 2010-10-28

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ISMAR Bologna TECHNICAL REPORT

Bologna, November 2010

ISMAR-CNR Cataloging-In-Publication data: ISMAR Bologna TECHNICAL REPORT

TIR2010 R/V URANIA CRUISE REPORT, 2010-10-19, 2010-10-28: Acquisition Of Multichannel Seismic Reflection Profiles In The Central And Southern Tyrrhenian Sea.

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Incmludes bibliographical reference and index.
1. ultichannel Seismic Reflections 2. Active Faults 3. Seismic Hazard 4. Sesimic Oceanography 5. Central and Southern Tyrrhenian Sea

Abstract

summary of methodologies, technical details and ship-board results of the TIR2010 geophysical, geological and oceanographical survey in the Central and Southern Tyrrhenian Sea with *R/V Urania* is presented.

Sommario - Vengono presentati le metodologie e l'insieme dei risultati ottenuti durante la campagna TIR2010. E' stata utilizzata la nave da ricerca *R/V Urania* del CNR,

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Production Notes - The document was edited with standard text editors, typeset with L.Lamport's LaTeX, translated to PostScript with dvips and printed with an A4 laser printer. The full production was done on a Linux box with GNU-GPL software. Converted to HTML by N.Drakos's LaTeX2HTML and to PDF by Alladin Ghostscripts's ps2pdf. Most of the maps included were produced by Wessel and Smith's GMT package. Some drawings were produced by xfig (www.xfig.org). Non PostScript images were converted by John Bradley's xv or other public-domain packages, among them convert.

ACRONYM	DESCRIPTION	URL-email
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
DTA	Department Earth and Environment	www.dta.cnr.it
IGAG	Institute Environ. Geology and Geoengineering	www.igag.cnr.it
ISMAR	Istituto di Scienze Marine	www.bo.ismar.cnr.it
IAMC	Istituto per l'Ambiente Marino Costiero	http://www.iamc.cnr.it/IAMC/
IGG	Istituto di Geoscience e Georisorse	www.igg.cnr.it
INGV	Istituto naz. geofisica e Vulcanologia	www.ingv.it
UNIROMA1	Universitá di Roma La Sapienza	www.uniroma1.it
UNIBO	Universit'øf Bologna	www.unibo.it
UNIPI	Universitá of Pisa	www.unipi.it
CSIC	Consejo de Superior de Investigations Cientificas	http://www.csic.es
DURHAM	Durham University	http://www.dur.ac.uk
SEG	Soc. of Exploration Geophysicists	www.seg.org
XTF	Extended Triton Format	www.tritonelics.com
UNESCO	United Nations Scient. and cultural org.	www.unesco.org
IOC	Intergov. Oceanogr. Comm. of UNESCO	ioc.unesco.org
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
OBS	Ocean Bottom Seismometer	woodshole.er.usgs.gov/operations/obs
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
SERCEL	Sercel	www.sercel.com
COMM-TECH	Communication Technology	www.comm-tec.com
NEPTUNE	Simrad MBES Software	www.kongsberg-simrad.com
MB-SYSTEM	MB-SYSTEM	www.ldgo.columbia.edu/MB-System
GMT	Generic Mapping Tool	gmt.soest.hawaii.edu/gmt

Table 1: Acronyms of Organizations, Manufacturers and Products

ACKNOWLEDGMENTS

Many people contributed to the success of the research cruise (TIR10 *R/V Urania*). We are particularly indebted to the Captain Vincenzo Lubrano Lavadera, the officers and crew members of *R/V Urania* for their professionalism and efforts in assuring the success of the cruise. VTS of Messina is warmly acknowledged for support and cooperation. The project was funded by CNR Earth and Environment Department.

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1. INTRODUCTION AND BACKGROUNDS

The cruise TIR10, with the R/V Urania, during October 2010, provide, as the main purpose, new acquisitions of multichannel seismic profiles, to study the tectonic setting and the geodynamic evolution of three main structures whitin the Tyrrhenian Sea. The main areas of investigations are the Pontine Islands, the Messina Strait from the Southern Tyrrhenian Sea to the Southern Ionian Sea, and the Gulf og Naples. In the Tyrrhenian Sea an extensional to trans-extensional tectonic setting occurs, and a transition from the continental to the oceanic crust is observed from the Pontine Islands to the southwest sector.

These research activities contibute to the knowledge of the geodynamics and the evolution of the Tyrrhenian backarc basin, in cooperation with the **CROP** (CROsta Profonda) project, funded by the CNR to study the italian crust and its seas. Moreover, the areas of investigations can contribute to the definition and prevention of geological, seismic and volcanic hazard, because both the Pontine escarpment and Messina Strait are seismogenetic structures with an high-level tzunami generation, and the Campi Flegrei represent an high-risk area due to the number of inhabitans.

Different topics has to be examined during this research activity: 1) the characters of the transition from a continental to an oceanic crust, 2) the transfer zone between the Calabrian oceanic and the Sicilian continental subductions, 3) the complex volcanic district characterized by frequent explosive eruptions of Pontine Islands and Gulf of Naples.

Also, TIR10 includes measurements and data acquisitions in the fields of Oceanography and Seismic Oceanography, taking advantage of the high resolution surveying.

1.1. GEOLOGICAL SETTING

The Thyrrenian Sea is commonly considered as the back arc basin connected to the west-directed subduction of the Apennines chain. Here the tectonic regime is mainly extensional and trans-extensional and involves both continental and oceanic crust.

The Messina Strait is probably where the fault system responsible of the earthquake of 1908 and of the subsequent tsunami is located (Argnani et al., 2009). This structure can be described as a semi-graben characterized by a complex kinematics. If is formed by faults trending ENE-WSW in the northern part with a dip slip kinematics and by N-S and NNE-SSW faults in the south, with a trans-extensional direction of movement. This kinematic configuration can be deduced by the relative motion between the Sicilian structures in the west and the Calabrian arc in the east, resulting this latter more advanced due to the southeastward migration of the subduction arc. This two sector have in fact a different geodynamic behaviour: in the east of the strait the subduction hinge is progressively moving away from the upper plate, whereas in the western sector the same hinge approaches it (Devoti et al., 2008). Nevertheless, few evidences are available about the geometry and the position of the fault plane connected to the 1908 Messina earthquake. Growing geometries of Late Pleistocene deposits recognized in the area are not enough to reconstruct the geometry along strike of the main fault plane.

A definition of the length of the plane and of its dip, combined with a rheological profile can provide information in order to better define the seismic parameters of the seismogenic source and, also, the role of these fault system in the geodynamic setting of the area.

The Pontine islands escarpment is one of the most relevant morphological structure in the Tyrrhenian Sea, and, likely, of the Mediterranean area. It has a NW-SE direction, and is the boundary between the continental crust to the North-East and the supposed oceanic crust in the South-West. Its nature is almost unknown; is possible to hypotise the occurrence of a normal fault system that controls the escarpment, which should have a mainly trans-extensional kinematic. The very well development slope (from -200 to -3000 m meters in less than 10 km) suggests the occurrence of recent tectonic activity. Based on the length of this supposed fault zone (150-200 km) this structure could potentially generate earthquakes with very high magnitude, even if the occurrence of an high heat flow reduce the elastic thickness and the differential stress in the area.

Finally, the volcanic area of the Phylgrean Field , located at the northern boundary of the Campana Plain, is a tectonically depressed area along the Tyrrhenian margin of the Southern Apennines. The tectono-volcanic activity is very important and, consequently, this area has an elevated volcanic risk as it densely populated (Di Vito et al., 2008). A peculiar character of this activity is the bradisism, a periodicity of relative speed uplifting and slow subsidence episodes. The most recent crisis due to bradisism occurred in 1969-1972 [e.g., Corrado et al. (1977)] and in 1982-1984 [e.g. Natale et al. (1999)]. In the last decades the need to better define this processes associated to volcanic risk become progressively higher.

1.2. OCEANOGRAPHIC SETTING

The Tyrrhenian Sea exchanges water with the rest of the Mediterranean Sea through the Sardinia Channel,the Sicily Strait and the Corsica Channel, that represent morphologic constraints for the circulation of the intermediate and deep waters (Millot, 1987; Astraldi and Gasparini, 1994; Sparnocchia et al., 1999; Astraldi et al., 2001). The surface water (0-200 m) entering the Tyrrhenian Sea through the Sardinia Channel is the Modified Atlantic Water (MAW) from the Algerian Current (AC). The MAW is characterized by low salinity (on average less than 38 PSU), and flows cyclonically along the Italian coast. Through the Sicily Strait and deeper than 200 m down to about 700 m, the basin receives the Levantine Intermediate Water (LIW), which is marked by a subsurface temperature maximum and by a higher salinity (on average 38.8 PSU), and mixes with the surface MAW and deeper water masses. From about 700 m to the bottom the Tyrrhenian Deep Water (TDW) is present, being the result of the modification of the West Mediterranean Deep Water (WMDW) that crosses the Sardinia Channel. The circulation pattern in the Tyrrhenian Sea is normally characterized by two cyclonic gyres in the south and in the northern basins, and by the presence of cyclonic and anticyclonic eddies in the central basin. Interesting features in the TDW (Zodiatis and Gasparini, 1996) are the thermoaline 'staircase' formations.

The physical oceanographic objective of this survey was to conduct seismic oceanography [e.g. Buffet et al. (2009)], that is, the method of using multi-channel seismic (MCS) reflection profiling to image thermohaline finestructure in the ocean. In addition to the MCS profiling, a series of strategically located Expendable Bathythermograph (XBT) probes (which consist of a missile-shaped device with a thermocouple located at its nose cone) were launched. The XBT is attached to a pistol-shaped launching device that is connected to a personal computer. Once the probe is launched it falls under its own weight, while maintaining connection with the ship via a thin copper wire. As it falls, it records temperature variations in the ocean. It is capable of measuring vertical resolutions as small as 65 cm and temperature variations as small as $\pm 0.1^{\circ}$C, (Boyd and Linzell, 1993). Recently, the Mediterranean Occidental (MEDOC) survey (Ranero et al., 2010), found significant thermohaline staircases in the deeper parts of the Tyrrhenian basin (Figure 1)

Thermohaline staircases are regular, well-defined, step-like variations in vertical temperature and salinity gradients that form when temperature and salinity increase with depth and nearly compensate with density, (Kelley, 1984). Turbulent mixing can disrupt the regular step-like structures, so they are typically found in regions where the Prandtl number (the ratio of viscous to thermal diffusion rates) is near unity and turbulent mixing is unusually weak (Merryfield, 2000). Therefore, isopycnal (equal density) stratification is more static than in regions dominated by turbulence.

Figure 1 - Map of the lateral distribution of XBT profiles in the Tyrrhenian Sea. Three main water masses are identified: a) Modified Atlantic Water (pink), b) Levantine Water (green) and c) Western Mediterranean Deep Water (blue), which is characterized by staircase formation.

2. CRUISE SUMMARY

SHIP: *R/V Urania* Flag: Italy [IT] Call Sign: IQSU IMO: 9013220, MMSI: 247498000
START: 2010-10-19 PORT: Napoli
END: 2010-10-28 PORT: Napoli
SEA/OCEAN: Tyrrhenian Sea, Mediterranean Sea
LIMITS: NORTH 41:10.0 SOUTH: 37:50.0 WEST: 12:20.0 EAST: 16:00
OBJECTIVE: Multichannel line acquisition in the Tyrrhennian Sea
COORDINATING BODIES: IGAG ROME ISMAR BOLOGNA (ITALY)
CHIEF OF EXPEDITION: Marco Ligi (ISMAR-CNR)
CONTACT: Marco.Ligi@ismar.cnr.it
DISCIPLINES: MARINE GEOLOGY, MARINE GEOPHYSICS, SEISMIC OCEANOGRAPHY, PHYSICAL OCEANOGRAPHY
WORK DONE: 1006 KM MULTICHANNEL REFLECTION SEISMIC, ~100 KM^2 MULTIBEAM, ~1000 KM SBP, 1 CTD CASTS, 40 XBT Drops,

LOCALIZATION:

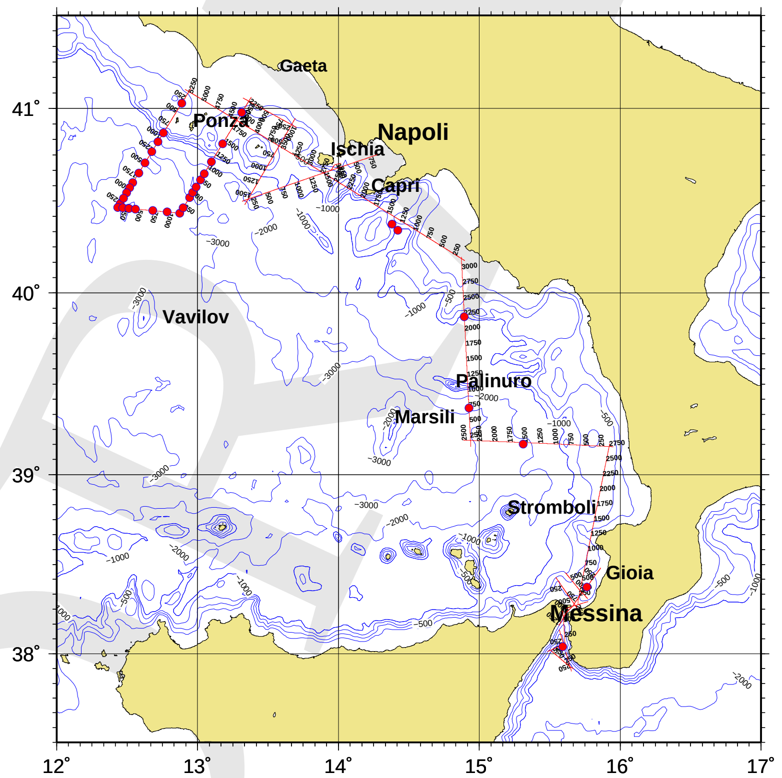

Figure 1: Ship tracks during Cruise TIR10. Red and blue circles are CTD and XBT drops, respectively

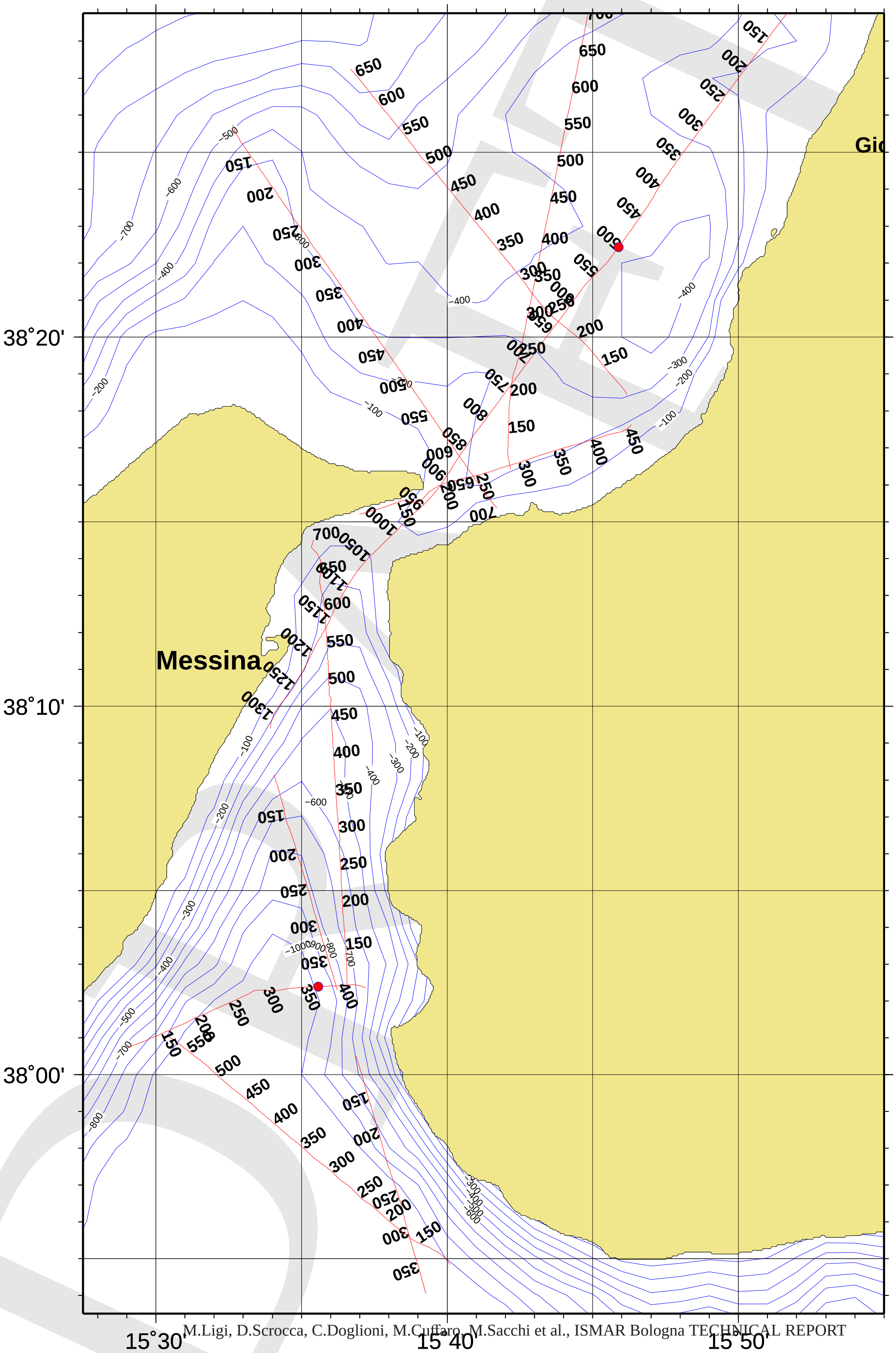

Figure 2: Ship tracks during cruise TIR10 , Strait of Messina Area. Red and blue circles are CTD and XBT drops, respectively.

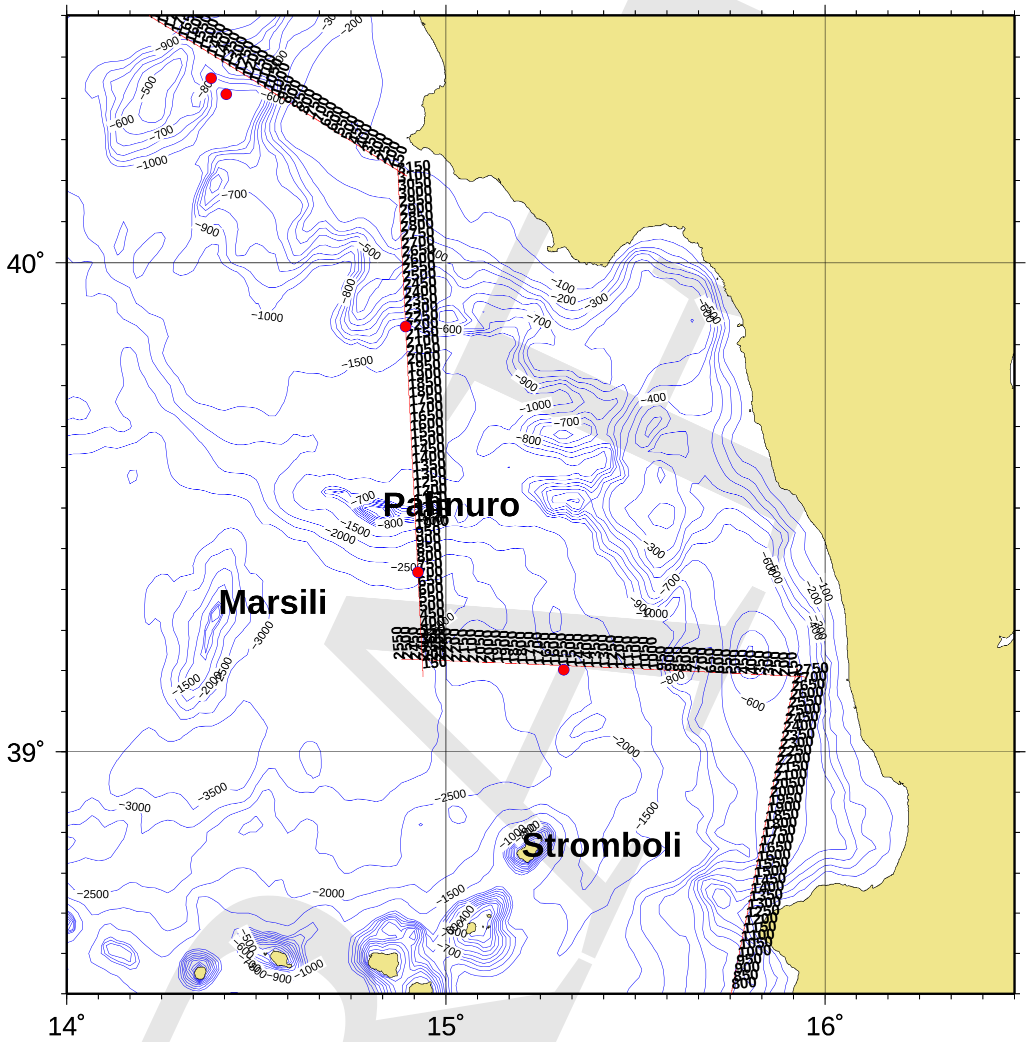

Figure 3: Ship tracks during cruise TIR10 , SE Tyrrhenian Sea. Red and blue circles are CTD and XBT drops, respectively.

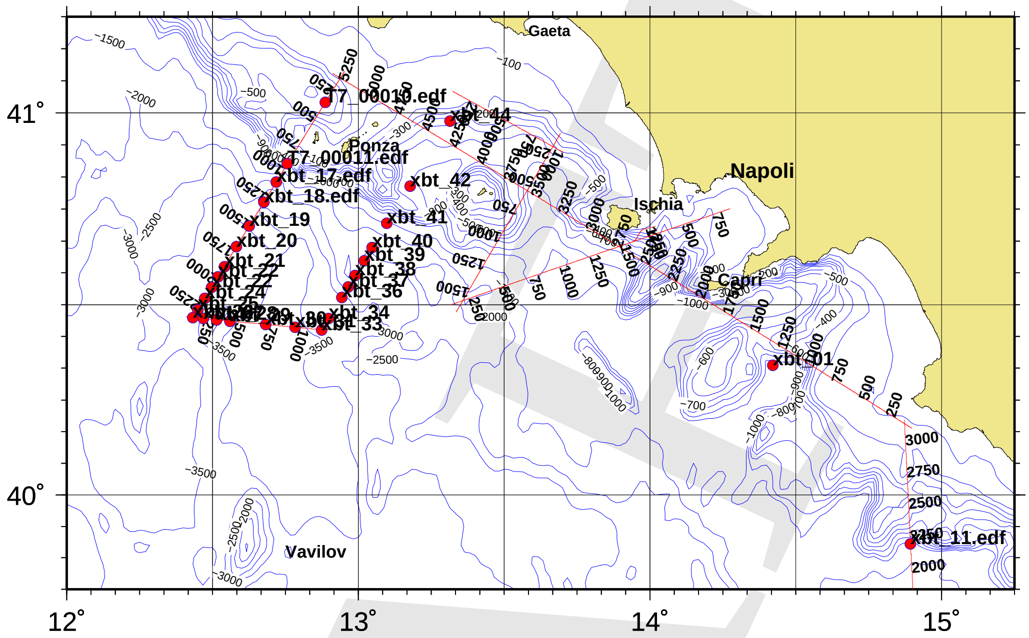

Figure 4: Ship tracks during cruise TIR10 , Pontine I. Area. Red and blue circles are CTD and XBT drops, respectively.

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T

Table 2: Scientific and technical parties

3. MATERIALS AND METHODS

The research cruise was carried out with the 61 meter *R/V Urania* (Fig.5), owned and operated by SO.PRO.MAR. and on long-term lease to CNR. The ship is normally used for geological, geophysical and oceanographical 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 oceanographical 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 5: *R/V Urania*.

3.1. NAVIGATION AND DATA ACQUISITION

The vessel was set-up for data acquisition and navigation with PDS-2000 software by RESON, interfacing by a multiserial and Ethernet link several instruments, among them the DGPS (Fugro), the Atlas-Krupp Deso-25 single-beam echosunder, the MAHRS MRU and the meteorological station.

The position and depth data were also distributed to the CTD data acquisition console. A Kongsberg processor running the SIS software, collected the multibeam data, including a SEAPATH MRU, compass, and DGPS. The MBES was the 70kHz, 400 1x2°, 150°aperture EM-710 (2000 m range) model by Kongsberg, with sonar head 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 beamforming. CTD casts were used for input of the sound velocity profile to the system. An Anderaa Meteorological Station was also made available, at a rate of one measurement every 5 minutes.

POSITION	ACROSS	ALONG	HEIGHT
REFERENCE POINT	0.00	0.00	0.00
DGPS	1.64	14.30	14.18
MBEAM	0.00	14.36	-4.96
MAHRS	0.00	0.0	-3.40
ECHO SOUNDER 33	5.50	-1.85	-3.80
CHIRP	-1.0	11.80	-4.00
A-FRAME	6.5	-6.70	0.0
STERN	0.00	-30.60	0.00

Table 3: Instrumental Offsets of PDS2000 on Ship Urania (PDS2000). The GPS antenna (primary positioning system) is located on point DGPS.

POSITION	ACROSS	ALONG	HEIGHT
REFERENCE POINT	0.00	0.00	0.00
SEAPATH_GPS	-4.039	0.163	-18.211
MRU	-0.341	-1.342	-1.596
MBEAM_TX	0.0936	10.2964	5.0623
MBEAM_RX	-0.0031	11.0144	5.0600
SEALEVEL	0	0	-0.0875

Table 4: Instrumental Offsets on Ship Urania (EM710). The DGPS antenna (primary positioning system) is located on point SEAPATH_GPS.

3.2. MULTICHANNEL REFLECTION SEISMIC DATA

All the relevant information for the acquisition is presented in the Appendix **??**.

The seismic source was set as a tuned array of three SERCEL's GI-GUN, configured in harmonic mode, two 45+45 and one 75+75 in^3, towed from the starboard and port sites, respectively. The compressed air was delivered at 120-140 Bar by an electrical Mod. I25 Bauer compressor, 2500 L/m.

The array was fired and synchronized by ISMAR's 8 PORTS GUN SYNCHRONIZER (Masini and Ligi, 1995). The RS-232 firing pulse, converted to TTL or Contact Closure by an external circuit, was provided by the PDS-2000 navigation system on programmed distances of 37.5m along the planned routes.

The seismic recording equipment employed (by Sercel) is summarized here below: Seal Recording System (Sys 5), NAS drives, Esqc QA, FSK/Digimain bird controller (??? CONTROLLARE ???), 96 channel Digital Streamer, 8 actives, 2 head stretches, 50 m tow leader, passive tail buoy, Digicourse cable levelers.

IMPORTANT NOTE: A fixed delay of 10ms was applied to the TB for the gun synchronization, plus 10-11 ms accounting for the opening of valves and shuttles, i.e. actual shot time is espected to appear some 20 ms after TB.

Figure 6: The EEL streamer (Sercel 96 channels digital) and DIGICOURSE Cable Levelers.

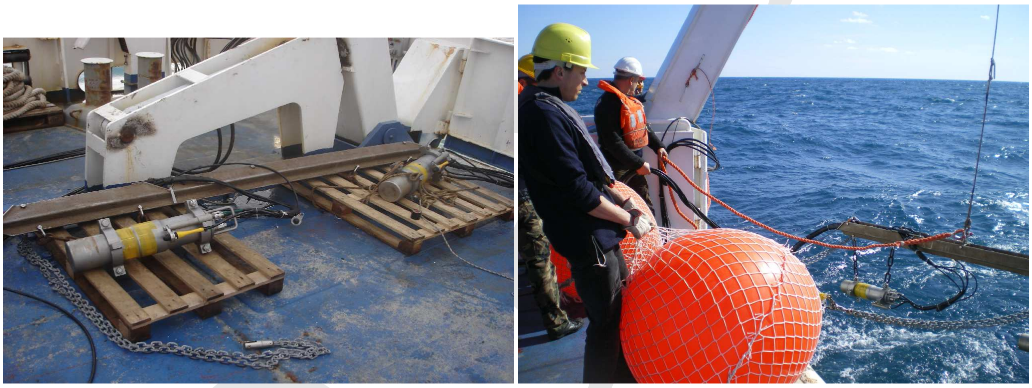

Figure 7: GI-GUN array.

Figure 8: Tail buoy and shot.

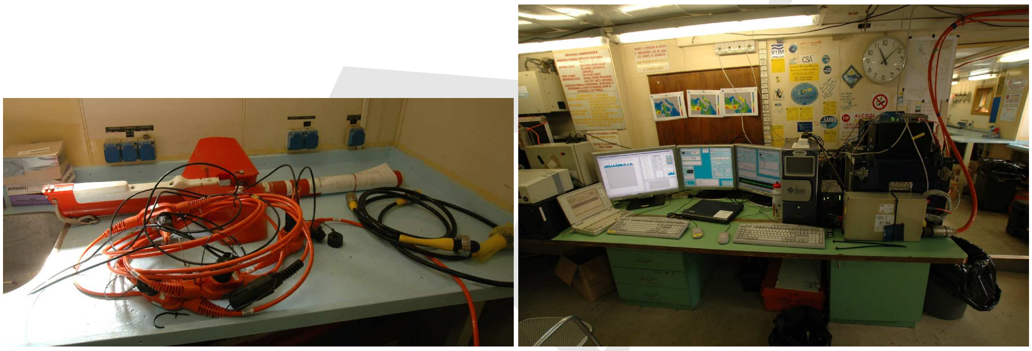

Figure 9: Birds and Seismic Recording Acquisition.

3.3. CTD AND XBT DATA

CTD casts were taken throughout the surveyed areas, for sound velocity analysis, and were used for real-time MBES acquisition and post-processing. On the way along seismic profiling, several T7 and T5 XBT launches data were collected by a Sippican Mod. MK21 profiler.

The position of the XBT and CTD stations are reported in Table **??** and can be viewed in Fig.**??**, respectively.

3.4. 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 mantained at 20 ms while the trigger rates varied from 0.25 to 1 seconds according to water depth. 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 HD and DVD. The navigation data was made available to the system as lat/long by NMEA sentences of the DGPS receiver at a rate of aproximately 1 Hz or by the PDS200's NMEA at 1Hz. The XTF data were then converted to SEG-Y by the Triton-Elics's Xtf2Seg software. This latter data were then input to the ISMAR's SEISPRO software (Gasperini and Stanghellini, 2009) for data processing and display. Since the SEG-Y converted positions were found to be truncated, the accurate position data were recovered from the XTF headers by routines developed at ISMAR, and re-input to SEISPRO. The operation was also useful to check data integrity, other than for producing the navigation map and database.

3.5. MISCELLANEOUS

The WGS84 datum, the UTM33N projection and UTC were chosen for navigation and display, and for data acquisition. The time zone was set to the UTC for the instrumental data acquisition. The positioning maps and bathymetric images were produced with GMT (Wessel and Smith, 1995) and Globalmapper. The multibeam data were pre processed on board by the GMT software and ISMAR's routines and scripts, using the SIS production DTMS, after conversion to the ASCII format.

Bathymetric data were complemented by the ISMAR's DTM of Tyrrhenian Sea (Marani et al., 2004).

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 alse network services like WWW, DHCP and NAT.

Photographs and video were taken by digital cameras and video-camera by all participants.

4. CONCLUDING REMARKS AND FUTURE WORKS

Main targets of TIR10 cruise have been reached. Post cruise processing will be necessary to provide higher quality seismic images, useful to find geological constrains for tectonic evolution of the central and southern Tyrrhenian domain.

A comparison of the interpretation of the obtained data with the previous CROP–CNR data base, contribuites to collect further areas to be investigated, in order to define the geometry of potential seismogenic zones.

Analysis of the data collected during the expedition is under process, and will continue during the forthcoming several months.

No problems were encountered regarding neither the people nor the environment during the cruise.

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