Report on the gravimetric, magnetometric, bathymetric activities during Cruise PANSTR10 with R/V *Urania*: Panarea and Stromboli, Aeolian Islands, 2010-02-05 - 2010-02-15.

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SUMMARY
We present the shipboard activities and preliminary results of Cruise PANSTR10((2010-02-05 2010-02-15)) with R/V *Urania*. The cruise was scheduled to acquire high resolution magnetometric and gravimetric data on the Panarea and Stromboli volcanic edifices. In addition to this, swath bathymetry and CTD casts were obtained, and five OBS were launched N of Alicudi and on the lineament Stromboli-Marsili, aiming at collecting active and passive seismological data in the Aeolian and Calabrian Arcs.

Key words: Gravimetry – Magnetometry – Bathymetry – Tectonics – Volcanism – Aeolian Islands – Stromboli – Panarea – Tyrrhenian Sea

PREFACE

Section 1 gives the introductory and background information, including some technological and scientific issues of the organization and execution of tasks. Section 2 provides the technical aspects that were involved in the data acquisition and processing. Sections 3 and 4 discuss the initial results, the on-going data processing and usage, and give some concluding remarks. Cruise summary (table A1), Diary of operations (table A4), acronyms (table A) and 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.

1 INTRODUCTION AND SETTING

Since 2002, after the exhalative crisis of November 2nd ISMAR and INGV have been involved in studying Panarea volcanic complex (Anzidei et al. 2005; Cocchi et al. 2008). Cruise PANSTR10 was planned to fill the gap in high resolution gravimetric and magnetometric data, including also Stromboli.

The Aeolian volcanic back-arc (Fig. 1) comprise seven major islands (Alicudi, Filicudi, Salina, Lipari, Vulcano, Panarea and Stromboli), and several seamounts, and are formed by the convergence of the African and Eurasian plates and by the subduction and southeastward rollback of the Ionian lithosphere (Barberi et al. 1973; Doglioni

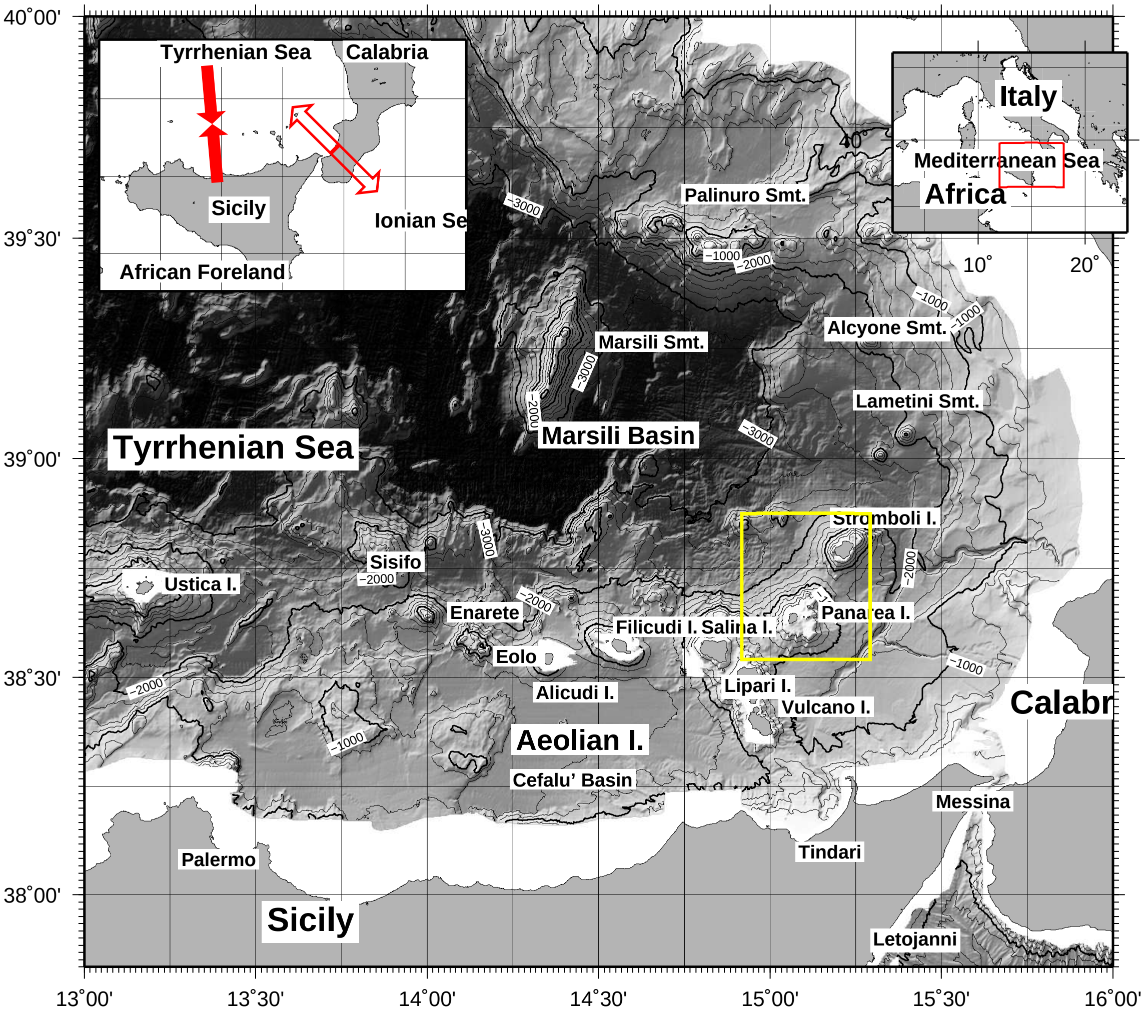

Figure 1. Morphology of the Southern Tyrrhenian Sea (bathymetric data from (Marani et al. 2004)). The yellow box indicates the location of the study area. The top left inset is a schematic structural sketch after Neri et al. (2003), D'Agostino & Selvaggi (2004), and Billi et al. (2006)

1991, 1994; Carminati et al. 1998; Argnani 2000). It can be subdivided into western, central and eastern sectors (De Astis et al. 2003), characterized by different structural and tectonic evolution, i.e. compression in the western sector, strike-slip faulting and extension in the central and eastern islands.

Panarea is the emergent portion of a submarine stratovolcano more than 2000 m high and 20-km-long across (Gabbianelli et al. 1993; Gamberi et al. 1997; Calanchi et al. 2002). To the east of Panarea, a group of islets (Basiluzzo, Dattilo, Panarelli, Lisca Bianca, Bottaro, Lisca Nera and Formiche) is present. Panarea is considered inactive, however Gamberi et al. (1997) have shown possible recent volcanic outcrops near Basiluzzo; present deformation patterns are likely connected to NE-SW trending faults (Lucchi et al. 2007).

The gas release of 2002-11-03 E of Panarea, a marine area known since historical times for fumarolic activities (Italiano & Nuccio 1991), generated sustained columns of bubbles from the seafloor to the surface. Several active spots were identified by divers and ROVs' and by repeated multibeam surveys (Anzidei et al. 2005; Esposito et al. 2006; Aliani et al. 2010). The most impressive one was just SW of Bottaro (PEG1, Fig. 2 and 3) with gas reaching the surface from 15 m depth, from an elliptic depression produced by the explosive collapse of the seafloor; a plume of sediments was present at the surface for days. Several authors discussed the phenomena in the light of volcanic surveillance and possible regional tectonic connections (Heinicke et al. 2009; Acocella et al. 2009; Walter et al. 2009).

Stromboli is a 45-km-long volcanic island in the northeastern-most part of the Aeolian arc. It lies on the thinned crust of the Southern Tyrrhenian continental margin, and deep focus seismicity shows hypocenters in the area of Stromboli at depths between 250 km and 300 km . The continental crust, on which the Aeolian Is-

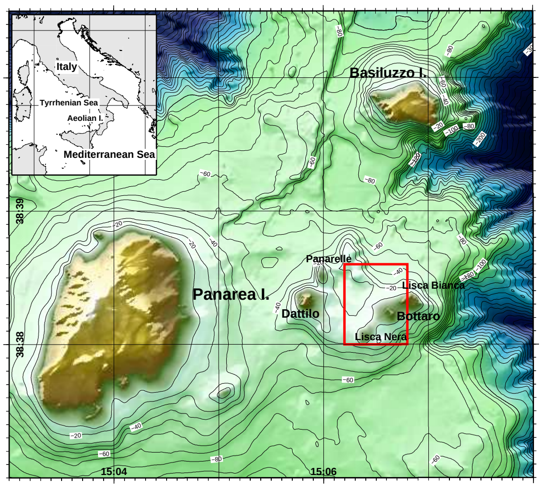

Figure 2. Panarea I. and Islets.

lands reside, thins out towards the center of the Tyrrhenian Basin and has a crustal thickness of about 18 km underneath the island (Morelli et al. 1975). A regional zone of crustal weakness controls the magmatic plumbing system and the volcano-tectonic evolution of the Stromboli-Panarea belt (Lanzafame & Rossi 1984; Zanchi & Francalanci 1989; Gabbianelli et al. 1993; Bosman et al. 2009).

The age of the oldest products has been determined to 100 ka for Stromboli Island and 250 ka for the Strombolicchio volcanic neck (Gillot & Keller 1993), remnant of an older eroded volcanic edifice (Okuma et al. 2009; Bosman et al. 2009). The evolution of Stromboli presented constructive and destructive phases; the last collapse of the NW flank, which probably occurred a few thousand years ago, generated a subaerial and submarine scar (Sciara del Fuoco'), where a submarine landslide and related tsunami occured 2002-12-29 during a large effusive phenomena (Chiocci et al. 2008b,a; Bosman et al. 2009).

Stromboli and Panarea were studied also by refraction and reflection seismic (Marsella et al. 2006; Castellano et al. 2008; Bortoluzzi et al. 2007). Within this context, an OBS was planned to be deployed and repeat the 2006 experiment (Paltrinieri et al. 2006) on the Marsili Seamount (Marani & Trua 2002; Cocchi et al. 2009; Caratori Tontini et al. 2010). Other 4 OBS were planned to be deployed N of Alicudi I. and on the lineament SE Stromboli NW Marsili looking forward to the forthcoming Refraction and Reflection Seismic Cruise with R/V Sarmiento de Gamboa and R/V Urania within the Spanish-German-Italian MEDOC project to study the Tyrrhenian Sea.

1.1 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 & 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

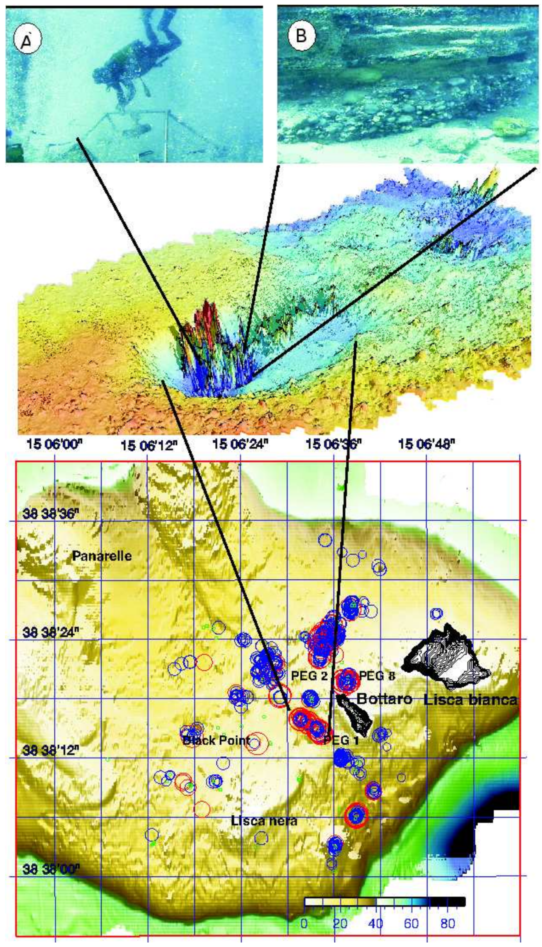

Figure 3. Gas emissions near Bottaro. Modified after (Aliani et al. 2010). Top panels show gas flowing SW of Bottaro. Bathymetry and gas locations from (Anzidei et al. 2005).

Figure 4. R/V *Urania*.

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 & Gasparini 1995) are the thermoaline 'staircase' formations.

2 MATERIALS AND METHODS

The research cruise was carried out with the 61 meter R/V *Urania* owned and operated by SO.PRO.MAR. and on long-term lease to CNR. 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 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, e.g. Side Scan Sonars.

2.1 NAVIGATION, CHIRP SBP, SWATH BATHYMETRY

The instrumental offsets are presented in Tables 1 and 2.

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. The sonar head is positioned on the ship's keel using a V-shaped steel frame. A Sound Velocity probe at the keel

POSITION	ACROSS	ALONG	HEIGHT
REF.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
DESO	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
MAGNETOM.	-5.50	-210	0.0
DGPSGRAV	0.0	-4.0	10.0
GRAV	-1.0	-1.0	0.0

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

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 normally 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 1 minutes, with (data sent in real time to an ISMAR's server

MULTIBEAM BATHYMETRY

The SIS (EM-710) was able to build real-time DTM at the resolution of 20 and 5 m during the acquisition of the entire surveyed areas. The data from these production DTMs were exported and used for planning and update of the SIS projects. The raw data were instead saved in the Kongsberg's .all format, for postprocessing with packages like NEPTUNE or MB-SYSTEM or other. The processed data will therefore be used for an up-to-date regional and local bathymetric compilations.

CHIRP SBP

A Teledyne Benthos CHIRP SBP system (16 hull-mounted transducers) was used. The data were

POSITION	ACROSS	ALONG	HEIGHT
REF. 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 2. Instrumental Offsets on Ship Urania (EM710). The DGPS antenna (primary positioning system) is located on point SEAPATH_GPS.

LON	LAT	STA	DATE TIME
1459.700	3832.517	01	06/02/2010 05.14.18
1504.836	3842.708	02	08/02/2010 08.39.02
1510.349	3854.976	03	09/02/2010 07.37.13
1421.908	3917.530	05	14/02/2010 13:41:14

Table 3. CTD Stations positions. Lat/lon data expressed as DDMM.xxxx. Time is UTC.

acquired by the SWANPRO software by Communication Technology, with direct interfacing to the DGPS, therefore actual positioning data have to be converted according to the offsets of Tab.**??**. The data were recorded in the XTF format and converted also into the SEG-Y format for processing with ISMAR's SEISPRHO package (Gasperini & Stanghellini 2009).

MAGNETOMETRY, GRAVIMETRY

A Seaspy by Marine Magnetics magnetometer was used. Sensor was towed at 180 m from stern, on the port side. Data acquisition was by Marine Magnetic's Sealink software. During the acquisition a DTM of the anomaly data (IGRF 2010 model) has been continuously updated, and served well for planning purposes. A Lacoste S-54 Model "Airsea System II" gravimeter was used. System was installed near center of gravity of ship. In Messina an absolute measurement was performed at the dock.

OBS

Five OBS designed by INGV-CNT-OBS (D'Anna et al. 2007, 2008; D'Alessandro et al. 2009) were deployed (Fig. 5). Table 4 shows the positions and date. Tables A5 and A6 in the Appendix show the instrumental characteristics and settings. Locations are in Fig. A2.

Figure 5. INGV OBS ready to launch. PANSTR10 .

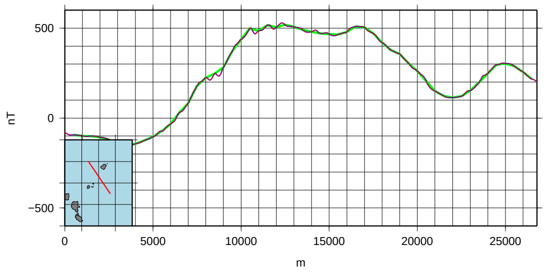

Figure 6. Profile obtained sampling the magnetic anomaly GMT grid (resolution 6ARCSEC) acquired during PANSTR10.

MAPPING AND MISCELLANEOUS

The datum was set to WGS84 and the UTM, zone 33N was chosen for navigation, display, and 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 & Smith 1998).

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

3 INITIAL RESULTS

GRAVIMETRY, MAGNETOMETRY AND BATHYMETRY

During PANSTR10 cruise, high-resolution gravimetric, magnetometric and morpho-bathymetric surveys were made principally on N-S tracks spaced 500 m , in the area of Panarea an Stromboli volcanoes an surroundings. Close to the islands detailed coverage of multibeam acquisitions were done, and around the Panarea submerged volcano data were acquired along N-S tracks spaced 250 m.

In particular, magnetic acquisitions were controlled for every runlines, by plotting preliminary results on a $\sim$ 180 m equispaced grid, to check goodness of results. Figures 6 and 7 show profiles obtained by sampling this grid, to verify the coverage of the data.

Multibeam swath bathymetry have been acquired along the magnetic and gravimetric runlines as well.

OBS

Four INGV designed OBS were deployed on the lineament Stromboli-Marsili; one of these was deployed on top on the Marsili Smt., to monitor the seismic and volcanic activity. The other OBS was deployed N of the Alicudi I., aiming at obtaining earthquake data for improving quality of focal solutions in the Western Eolian Sector. All the five OBS were also deployed for the MEDOC seismic shooting operations (120 L, 90 s interval), that occured April-May 2010 with the spanish R/V

LON LAT	UTM33	OBS	DATE TIME
1527.006 3840.008	539157 4279898	A4	2010-02-05T18.07.34
1420.089 3852.996	442306 4304032	A2	2010-02-06T00.36.41
1447.115 3901.971	481413 4320443	A5	2010-02-14T09.42.02
1423.601 3916.401	447672 4347287	A7	2010-02-14T14.33.46
1359.991 3929.997	414008 4372737	A6	2010-02-14T17.50.17

Table 4. OBS launch positions. Lat/lon data expressed as DDMM.xxxx. Time is UTC.

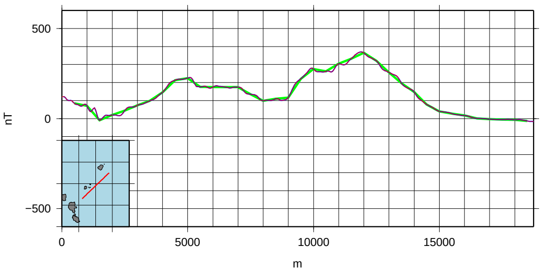

Figure 7. Profile obtained sampling the magnetic anomaly GMT grid (resolution 6ARCSEC) acquired during PANSTR10.

Sarmiento de Gamboa (Ranero, Zitellini et al., cruise report in preparation).

During shooting of E-W transect Sardinia to Italy at 40N , the INGV stations located in Lipari, Ustica and Alicudi and were able to receive signals, therefore we may be confident that the OBS's were illuminated as well by the shots (Figs. A5, A6 and A7 in the Appendix C).

Among the others OBS A7 (Fig. A4 was dropped on the depression (∼ 785-790 m) just SSW of the summit of the Marsili Smt., ∼ 60 m to the NNE of the deployment of the MRS06 cruise also Paltrinieri et al. (2006)).

CTD data

Figure A3 shows the CTD data collected during cruise PANSTR10.

4 CONCLUSIONS

During the 11 days of cruise PANSTR10, including transits and port calls, we obtained:

- high-resolution gravimetric and magnetometric coverage (500 and 250 m resolution, ∼ 2000 Km) around Panarea and Stromboli I.,
- high-resolution morpho-bathymetric coverage,
- deployment of 5 OBS.

Analysis of the data collected during the expedition is under process, and will continue during the forthcoming several months. The PANSTR10 scientific cruise contributes to the knowledge of the structural setting of the Eastern Aeolian arc, and could provide constraints to understand the evolution and the tectonic processes in the area.

The OBS deployed will be useful for detection of surface and deep earthquake in the Southern Tyrrhenian Sea; alonwith the INGV's National Network on Sicily and on continent they were also hearing during the refraction and multichannel reflection seismic operations in the Thyrrenian Sea on April-May 2010, during wich the spanish R/V Sarmiento De Gamboa, cooperated by R/V Urania, shooted and provided data for Deep Crustal Profiles.

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

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REFERENCES

Acocella, V., Neri, M., & Walter, T. R., 2009. Structural features of Panarea volcano in the frame of the Aeolian Arc (Italy): Implications for the 2002-2003 unrest, *J. Geodyn.*, **47**(5), 288–292.

Aliani, S., G.Bortoluzzi, Caramanna, G., & Raffa, F., 2010. Seawater dynamics and environmental settings after november 2002 gas eruption off Bottaro (Panarea, Aeolian Islands, Mediterranean Sea), *Cont. Shelf Res.*, **in press**.

Anzidei, M., Esposito, A., Bortoluzzi, G., & Degiosa, F., 2005. The high resolution map of the exhalative area of Panarea (Aeolian Is., Italy), *Ann. Geophys.*, **48**(6), 899–921.

Argnani, A., 2000. The Southern Tyrrhenian Subduction System: Recent Evolution and Neotectonic Implications, *Ann. Geophys.*, **43**(3), 585–607.

Astraldi, M. & Gasparini, G. P., 1994. The seasonal Characteristics of the Circulation in the Tyrrhenian Sea, in *Seasonal and Interannual Variability of the Western Mediterranean Sea*, vol. 46, pp. 115–134, ed. La Viollette, P. E., Am. Geophys. Union.

Astraldi, M., Gasparini, G., Gervasio, L., & Salusti, E., 2001. Dense Water Dynamics along the Strait of Sicily (Mediterranean Sea), *J. Phys. Oceanogr.*, **31**(12), 3457–3475.

Barberi, F., Gasparini, P., Innocenti, F., & Villari, L., 1973. Volcanism of the Southern Tyrrhenian Sea and its geodynamic implications, *J. Geophys. Res.*, **78**(23), 5221–5232.

Billi, A., Barberi, G., Faccenna, C., Neri, G., Pepe, F., & Sulli, A., 2006. Tectonics and seismicity of the Tindari Fault System, southern Italy: Crustal deformations at the transition between ongoing contractional and extensional domains located above the edge of a subducting slab, *Tectonics*, **25**(TC2006).

Bortoluzzi, G., Ligi, M., Cuffaro, M., D'Oriano, F., Ferrante, V., Partescano, E., Redini, F., Remia, A., Riminucci, F., Romagnoli, C., Casalbore, D., D'Anna, G., Mangano, G., Speciale, S., Manni, M., Platania, P., Rapisarda, S., Caratori Tontini, F., Cocchi, L., Sgroi, T., Brancatelli, G., & Meton, G., 2007. Rapporto preliminare sulle indagini di sismica a riflessione e rifrazione, morfobatimetriche e magnetometriche nel complesso dell'isola di Panarea (Eolie, Tirreno Meridionale). Crociera Pana_07 Con La N/O Urania (01/09-Agosto-2007), Tech. rep., ISMAR-Bologna.

Bosman, A., Chiocci, F., & Romagnoli, C., 2009. Morpho-structural setting of Stromboli volcano revealed by high-resolution bathymetry and backscatter data of its submarine portions, *Bull. Volcanol.*, **71**(9), 1007–1019.

Calanchi, N., Peccerillo, A., Tranne, C., Lucchini, F., Rossi, P. L., Kempton, P., Barbieri, W., & Woo, T. W., 2002. Petrology and geochemistry of volcanic rocks from the island of Panarea: implications for mantle evolution beneath the Aeolian island arc (Southern Tyrrhenian sea), *J. Volcanol. Geoth. Res.*, **115**(3-4), 367–395.

Caratori Tontini, F., Cocchi, L., Muccini, F., Carmisciano, C., Marani, M., Bonatti, E., Ligi, M., & Boschi, E., 2010. Potential-field modeling of collapse-prone submarine volcanoes in the southern Tyrrhenian Sea (Italy), *Geophys. Res. Lett.*, **37**, L03305,.

Carminati, E., Wortel, M. J. R., Spakman, W., & Sabadini, R., 1998. The role of slab detachment processes in the opening of the western-central Mediterranean basins: some geological and geophysical evidence, *Earth Planet. Sc. Lett.*, **160**(3-4), 651–665.

Castellano, M., Augusti, V., De Cesare, W., Favali, P., Frugoni, F., Montuori, C., T.Sgroi, De Gori, P., Govoni, A., Moretti, M., Patane', D., Cocina, O., Zuccarello, L., Marsella, E., Aiello, G., Di Fiore, V., Ligi, M. ., Bortoluzzi, G., Ferrante, V., Marchetti, E., Lacanna, G., & Ulivieri, G., 2008. Seismic tomography experiment at italy's stromboli volcano, *EOS Transaction*, **89**(30).

Chiocci, F. L., Romagnoli, C., & Bosman, A., 2008a. Morphologic resilience and depositional processes due to the rapid evolution of the submerged Sciara del Fuoco (Stromboli Island) after the December 2002 submarine slide and tsunami, *Geomorphology*, **100**(3-4), 356–365.

Chiocci, F. L., Romagnoli, C., Tommasi, P., & Bosman, A., 2008b. The stromboli 2002 tsunamigenic submarine slide: characteristics and possible failure mechanisms, *J. Geophys. Res.*, **113**, B10102.

Cocchi, L., Caratori Tontini, F., Carmisciano, C., Stefanelli, P., Anzidei, M., Esposito, A., Del Negro, C., Greco, F., & Napoli, R., 2008. Looking inside the Panarea Island (Aeolian Archipelago, Italy) by gravity and magnetic data, *Ann. Geophys.*, **51**(1), 25–38.

Cocchi, L., Caratori Tontini, F., Muccini, F., Marani, M. P., Bortoluzzi, G., & Carmisciano, C., 2009. Chronology of the transition from a spreading ridge to an accretional seamount in the Marsili backarc basin (Tyrrhenian Sea), *Terra Nova*, **21**(5), 369–374.

D'Agostino, N. & Selvaggi, G., 2004. Crustal motion along the Eurasia-Nubia plate boundary in the Calabrian Arc and Sicily and active extension in the Messina Straits from GPS measurements, *J. Geophys. Res.*, **109**, B11402.

D'Alessandro, A., D'Anna, G., Luzio, D., & Mangano, G., 2009. he INGV's new OBS/H: Analysis of the signals recorded at the Marsili submarine volcano, *J. Volcanol. Geotherm. Res.*, **183**, 17–29.

D'Anna, G., Mangano, G., D'Alessandro, A., & Amato, A., 2007. The new INGV broadband OBS/H: test results on submarine volcano Marsili and future developments, *EGU, Geophysical Research Abstracts*, **9**, 06583.

D'Anna, G., Mangano, G., D'Alessandro, A., D'Anna, R., Passafiume, G., & Speciale, S., 2008. First long time OBS campaign in the Ionian Sea, Tech. rep., INGV.

De Astis, G., Ventura, G., & Vilardo, G., 2003. Geodynamic significance of the Aeolian volcanism (Southern Tyrrhenian Sea, Italy) in light of structural, seismological, and geochemical data, *Tectonics*, **22**(4), 1040.

Doglioni, C., 1991. A proposal kinematic modelling for W-dipping subductions - possible applications to the Tyrrhenian-Apennine systems, *Terra Nova*, **3**, 423–434.

Doglioni, C., 1994. Foredeeps versus subduction zones, *Geology*, **22**(3), 271–274.

Esposito, A., Giordano, G., & Anzidei, M., 2006. The 2002-2003 submarine gas eruption at Panarea volcano Aeolian Islands, Italy: volcanology of the seafloor and implications for the hazard scenario, *Mar. Geol.*, **227**, 119–134.

Gabbianelli, G., Romagnoli, C., Rossi, P., & Calanchi, N., 1993. Marine geology of the Panarea-Stromboli area (Aeolian Archipelago, Southeastern Tyrrhenian Sea), *Acta Vulcanol.*, **3**, 11–20.

Gamberi, F., Marani, M., & Savelli, C., 1997. Tectonic, volcanic and hydrothermal featues of a submarine portion of the Aeolian arc (Tyrrhenian Sea), *Mar. Geol.*, **140**, 167–181.

Gasperini, L. & Stanghellini, G., 2009. SEISPRHO: an interactive computer program for processing and interpretation of high-resolution seismic reflection profiles, *Comp. Geosci.*, **37**(7), 1497–1507.

Gillot, P. Y. & Keller, J., 1993. Radiochronological dating of Stromboli, *Acta Vulc.*, **3**, 69–77.

Heinicke, J., Italiano, F., Maugeri, R., Merkel, B., Pohl, T., Schipek, M., & Braun, T., 2009. Evidence of tectonic control on active arc volcanism: The Panarea-Stromboli tectonic link inferred by submarine hydrothermal vents monitoring (Aeolian arc, Italy), *Geophys. Res. Lett.*, **36**, L04301.

Italiano, F. & Nuccio, P. M., 1991. Geochemical investigations of submarine exhalations to the east of Panarea, Aeolian Islands, Italy, *J. Volcanol. Geoth. Res.*, **46**, 125–141.

Lanzafame, G. & Rossi, P. L., 1984. Evidenze di attivita' tettonica recente a Panarea (Eolie): implicazioni vulcanologiche, *Geol. Romana*, **23**, 131–139.

Lucchi, F., Tranne, C. A., Calanchi, N., & Rossi, P., 2007. Late Quaternary deformation history of the volcanic edifice of Panarea, Aeolian Arc, *Bull. Volcanol.*, **69**, 239–257.

Marani, M. P. & Trua, T., 2002. Thermal constriction and slab tearing at the origin of a superinflated spreading ridge: Marsili volcano (Tyrrhenian Sea), *J. Geophys. Res.*, **107**(B9), 2188.

Marani, M. P., Gamberi, F., Bortoluzzi, G., Carrara, G., Ligi, M., & Penitenti, D., 2004. Tyrrhenian sea bathymetry, in *From seafloor to deep mantle: architecture of the Tyrrhenian backarc basin*, vol. 44 of **Mem. Descr. Carta Geologica d'Italia**, eds Marani, M. P., Gamberi, F., & Bonatti, E., APAT.

Marsella, E., Favali, P., Castellano, M., Aiello, G., Bortoluzzi, G., Di Fiore, V., Ligi, M., Sgroi, T., Frugoni, F., Patane', D., Passaro, S., Ruggieri, S., Ferrante, V., Scotto Di Vettimo, P., Iavarone, M., Mangano, G., Augusti, V., Ciampi, M., De Cesare, W., Rocca, M. L., Di Prima, S., Rapisarda, S., Zuccarello, L., Platania, R., Contrafatto, D., Moretti, M., Govoni, A., Speciale, S., Marchetti, E., Lacanna, G., Ulivieri, G., Genco, R., Ilinskyi, D., & Rinke, N. R., 2006. The Stromboli Geophysical Experiment. Preliminary Report on Wide Angle Refraction Seismics and Morphobathymetry of Stromboli Island (Southern Tyrrhenian Sea, Italy) based on Integrated Offshore-Onshore Data Acquisition (Cruise Str06 R/V Urania), Tech. Rep. 102, ISMAR-CNR, projects.bo.ismar.cnr.it/CRUISE_REPORTS/2006/MRS06_REP.

Millot, C., 1987. Circulation in the Western Mediterranean, *Oceanol. Acta*, **10**(2), 143–149.

Morelli, C., Pisani, M., & Gantar, C., 1975. Geophysical anomalies and tectonics in the Strait of Sicily and of the Ionian Sea, *Boll. Geofis. Teor. Appl.*, **XVII**(67), 211–249.

Neri, G., Barberi, G., Orecchio, B., & Mostaccio, A., 2003. Seismic strain and seismogenic stress regimes in the crust of the southern Tyrrhenian region, *Earth Planet. Sc. Lett.*, **213**, 97–112.

Okuma, S., Stotter, C., Supper, R., Nakatsuka, T., Furukawa, R., & Motschka, K., 2009. Aeromagnetic constraints on the subsurface structure of Stromboli Volcano, Aeolian Islands, Italy, *Tectonophysics*, **478**(1–2), 19–33.

Paltrinieri, D., Signanini, P., Viezzoli, C., Bortoluzzi, G., Di Sabatino, B., Madonna, R., Rainone, M. L., Caratori Tontini, F., Cocchi, L., D'Anna, F. M. G., Mangano, G., Cuoco, E., Calcara, M., Ferrante, V., Redini, F., Rovere, M., Rusi, S., Marino, A., Caso, C., Vitale, S., Iezzi, B., Tropea, F., & Siena, P., 2006. Report on The Morphobathymetric,Magnetometric, Gravimetric, Ctd Water and Bottom Sampling investigations during Cruise MRS06 aboard R/V Universitatis, Tech. rep., ISMAR-CNR, projects.bo.ismar.cnr.it/CRUISE_REPORTS/2006/.

Sparnocchia, S., Gasparini, G. P., Astraldi, M., Borghini, M., & Pistek, P., 1999. Dynamics and mixing of the Eastern Mediterranean Outflow in the Tyrrhenian Basin, *J. Marine Systems*, **20**(1–4), 301–317.

Walter, T. R., Wang, R., Acocella, V., Neri, M., Grosser, H., & Zschau, J., 2009. Simultaneous magma and gas eruptions at three volcanoes in southern Italy: an earthquake trigger?, *Geology*, **37**(3), 251–254.

Wessel, P. & Smith, W. H. F., 1998. New, improved version of generic mapping tools released, *EOS Trans. Amer. Geophys. U.*, **79**(47), 579.

Zanchi, A. & Francalanci, L., 1989. Analisi geologico-strutturale dell'isola di Stromboli: alcune considerazioni preliminari, *Boll. Gruppo Naz. Vulcanol.*, **2**, 1027–1044.

Zodiatis, G. & Gasparini, G. P., 1995. Thermoaline staircase formations in the Tyrrhenian sea, *Deep Sea Research*, **43**(5), 655–678.

APPENDIX A: CRUISE SUMMARY

SHIP	R/V *Urania*
START	2010-02-05 PORT: Messina
END	2010-02-15 PORT: Napoli
SEA/OCEAN	Aeolian Islands, Tyrrhenian Sea, Mediterranean Sea
LIMITS	NORTH 39:30 SOUTH: 38:00 WEST: 14:00 EAST: 16:00
OBJECTIVE	GRAVIMETRIC BATHYMETRIC MAPPING
COORDINATING BODIES	ISMAR-CNR
CHIEF OF EXPEDITION	Mr. Giovanni Bortoluzzi
CONTACT	G.Bortoluzzi at ismar.cnr.it
DISCIPLINES	GEOPHYSICS
WORK DONE	2410 KM GRAVIMETRY, ∼2000 KM MAGNETOMETRY, ∼560 KM^2 MULTIBEAM, ∼1000 KM SBP, 5 CTD CASTS, 5 OBS DROPS

Table A1. Cruise Summary.

ACRONYM	DESCRIPTION	URL-email
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
INGV	Ist.Nazionale Geofisica e Vulcanologia	www.ingv.it
ISMAR	Istituto di Scienze Marine	www.ismar.cnr.it
ISMAR-BO	ISMAR, Bologna	www.bo.ismar.cnr.it
IIM	Ist.Idrografico Marina	
PDS-2000	RESON	www.reson.com/sw1738.asp
SBE	Sea Bird Electronics	www.seabird.com
SIPPICAN	Sippican Corp.	www.sippican.com
BENTHOS	Teledyne Benthos	www.benthos.com
SWAN-PRO	Communication Technology	www.comm-tec.com
GMT	Generic Mapping Tool	gmt.soest.hawaii.edu/gmt
MBES	Multibeam Echosounder System	
SBP	Sub Bottom Profiling	
SVP	Sound Velocity Profile	
CTD	Conductivity/Temperature/Depth	
MAW	Modified Atlantic Water	
LSW	Levantine Surface Water	
LIW	Levantine Intermediate Water	
CIW	Cretan Intermediate Water	
CDW	Cretan Deep Water (Involved recently in EMDW. Sometimes referred as CSOW).	
LDW	Levantine Deep Water (Formed in NW Levantine Basin).	
EMDW	Eastern Mediterranean Deep Water (Kept for historical reasons).	
EOW	Eastern Mediterranean Overflow Water (Sometimes called AIW or tEMDW at the Sicily channel).	
TDW	Tyrrhenian Deep Water	
WMDW	West Mediterranean Deep Water	
GPS-DGPS-RTK	Global Positioning System	samadhi.jpl.nasa.gov
DTM	Digital Terrain Model	en.wikipedia.org

Table A2. Acronyms of Organizations, Manufacturers and Products

PARTICIPANTS	ORGANIZATION	EXPERTISE	tel & email & www
Giovanni Bortoluzzi	ISMAR,Bologna		G.Bortoluzzi@ismar.cnr.it
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Veronica Rossi	UNIROMA		veronica_red@hotmail.it
Marco Cuffaro	UNIROMA		marco.cuffaro@uniroma1.it
Ilaria Cattafi	IIM		ilaria.cattafi@marina.difesa.it

Table A3. Scientific and technical parties

DATE	OPERATIONS
2010-02-05	Imbarco personale e materiale. Partenza dal porto di Messina ore 15.30 UTC, trasferimento area di operazione ed acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona A. Rilascio OBS A4 ore 18.07 UTC.
2010-02-06	Rilascio OBS A2 ore 00.36 UTC, acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona B. Calata CTD 01 ore 05.14 UTC. Fonda Lipari (sotto monastero) ore 16.45 UTC per avverse condimeteo.
2010-02-07	Partenza da Lipari ore 17.00 UTC, acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona C.
2010-02-08	Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona D. Calata CTD 02 ore 08.40UTC.
2010-02-09	Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona E. Calata CTD 03 ore 07.39 UTC.
2010-02-10	Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona F. Fonda Lipari (sotto monastero) ore 15.18 UTC per avverse condimeteo.
2010-02-11	Partenza da Lipari ore 19.12 UTC. Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona G.
2010-02-12	Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona H. Fonda Lipari ore 12.10 UTC per avverse condimeteo.
2010-02-13	Partenza da Lipari ore 11.55 UTC. Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona I. Calata CTD 04 ore 16.57 UTC.
2010-02-14	Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona L. Rilascio OBS
2010-02-15	Acquisizione dati Sub-Bottom, Sismici, Gravimetrici e Magnetometrici zona M. Ingresso porto di Napoli ore 08:00 UTC. Sbarco personale e materiale.

Table A4. Diary of Operations

APPENDIX B: OBS CHARACTERISTICS AND DEPLOYMENT

APPENDIX C: CRUISE MEDOC2010 SHOTS: DATA RECEIVED BY INGV'S STATIONS

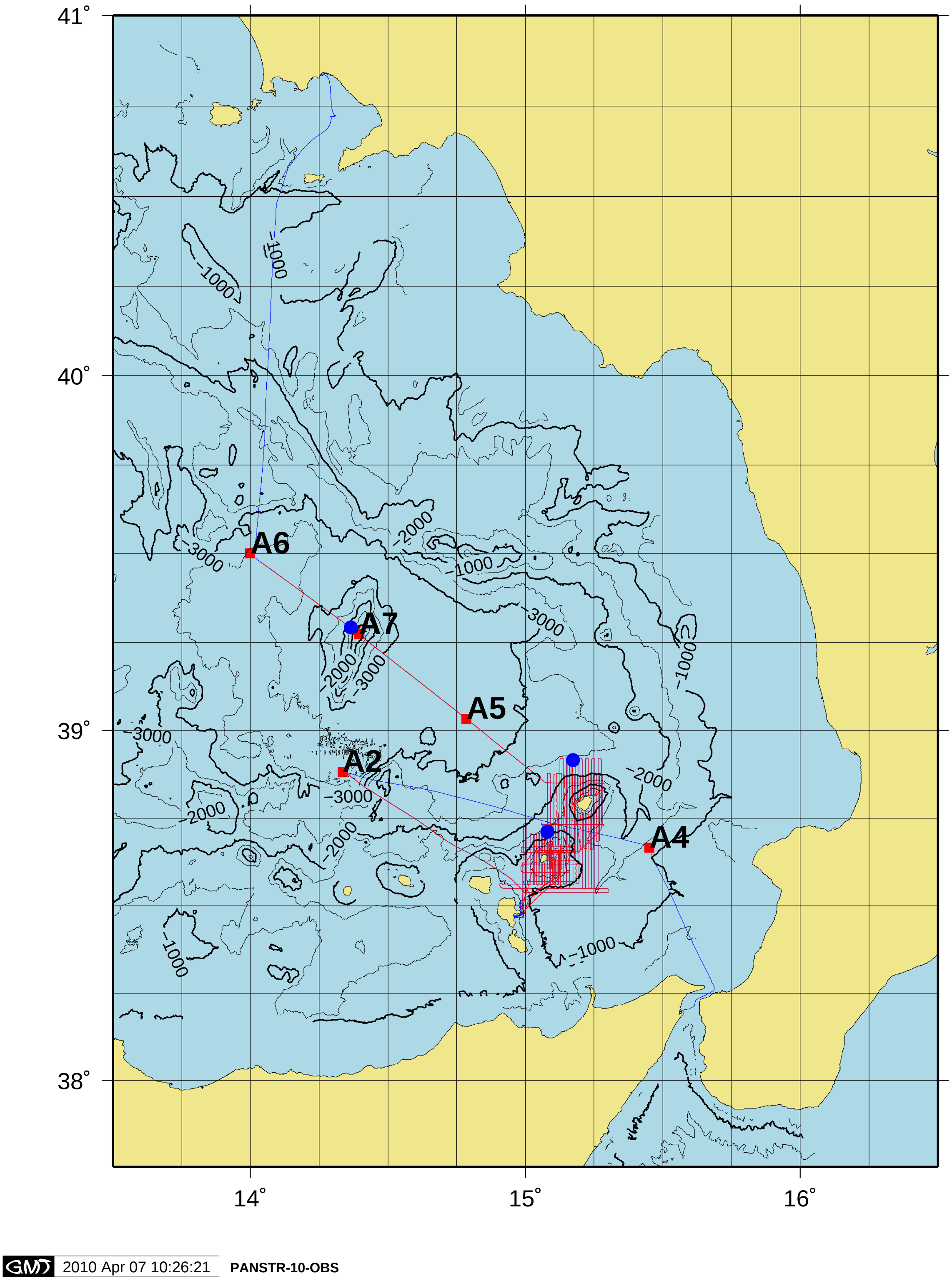

Figure A1. Rotte durante la PANSTR10, R/V *Urania*, inclusi i transiti.

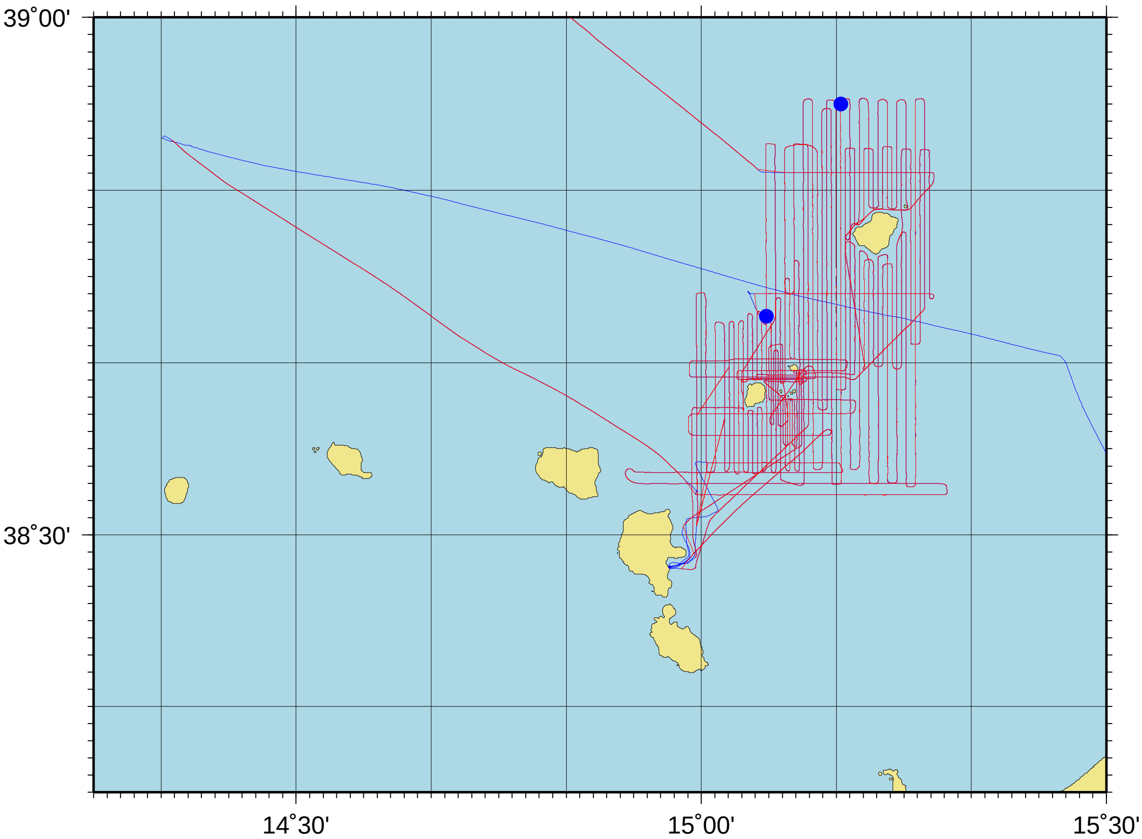

Figure A2. Rotte durante la PANSTR10, R/V *Urania*. I pallini blu sono le stazioni CTD. I quadrati rossi sono gli OBS.

Seismic sensor gimballed	Guralp CMG40T-OBS, 3C seismometer with a flat response between 60s and 100Hz, housed in a 16 cm of diameter spherical casing (6000m depth rated) and installed on a levelling platform with an operational tilt range of ±120°
Pressure sensor	Cox-Webb Differential Pressure Gauge 500s-2 Hz; gain 1 mV/Pa at 1 Hz on OBS A2, A4, A5, A6 HTI-04-PCA/ULF Hydrophone 100s-8KHz; sensitivity: -195 dB re: 1V/μPa (18V/bar) on OBS A7
Temperature logger	On OBS A7, a Tinytag ACS-0001-PK was installed. The deep water data logger kit contains a compact 16-bit data logger with a capacity of 16,000 readings, housed within a stainless steel canister designed to withstand depths up to 10km
Digitizer	SEND Geolon MLS 21 bits digitizer, 4 channels (3 for the seismometer and 1 for the hydrophone or DPG). Sampling rate up to 200 sps
Clock	Seascan Precision Time base. Time base drift <0.05 ppm
Storage Capacity	12 PCMCIA slots, up to 24 GB with 2GB flash cards.
Battery Packs	2 Primary Lithium-Thionyl Chloride battery packs of 14,4 V and 350 Ah
weight	450/36,5 Kg in air/water
Electronic canister	ERGAL canister (7075 T6 aluminium alloy), with hard anodizing.
Release system	IXSEA AR861S-MR and C980102 ORE-Offshore acoustic release system.
Emergency localization system	ELSACOM Guardian Sentinel, to transmit the OBS positions every 3 hours for more than one month, if it comes back on the sea surface.
OBS dimensions	1200x800x1500 mm

Table A5. OBS Characteristics.

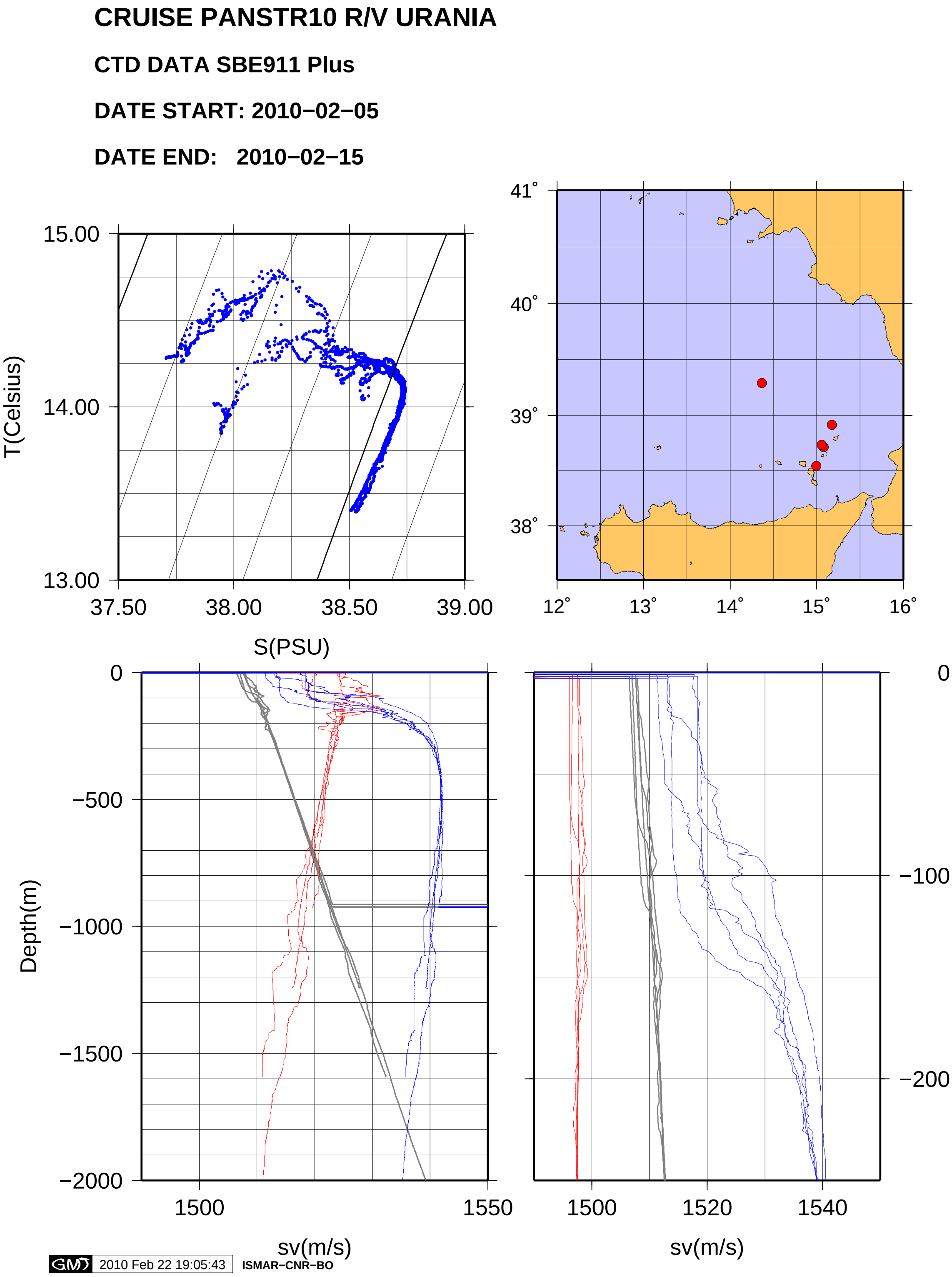

Figure A3. Dati CTD, crociera PANSTR10, R/V *Urania*. Notare le formazioni 'staircase' di Zodiatis & Gasparini (1995).

OBS Serial Number	A4
Lon Lat Time	1527.0056075 3840.0078879 05/02/2010 18.07.34
Synchronization time	05/02/2010 14:51:00
Seismometer release	06/02/2010 00:30:00
Start recording	05/02/2010 16:23:20
Levelling	Every 30 days and after 12 hours from start recording
Sampling Freq.	100 Hz
OBS Serial Number	A2
Lon Lat Time	1420.0891942 3852.9956644 06/02/2010 00.36.41
Synchronization time	05/02/2010 20:57:00
Seismometer release	06/02/2010 06:00:00
Start recording	05/02/2010 22:46:11
Levelling	Every 30 days and after 12 hours from start recording
Sampling Freq.	100 Hz
OBS Serial Number	A5
Lon Lat Time	1447.1151862 3901.9706885 14/02/2010 09.42.02 GPST 094238
Synchronization time	14/02/2010 08:29:00
Seismometer release	14/02/2010 14:30:00
Start recording	14/02/2010 08:33:00
Levelling	Every 30 days and after 12 hours from start recording
Sampling Freq.	100 Hz
OBS Serial Number	A7
Lon Lat	1423.6013304 3916.4010778 14/02/2010 14.33.46)143410GPS
Synchronization time	14/02/2010 13:50:00
Seismometer release	14/02/2010 19:50:00
Start recording	14/02/2010 13:53:25
Levelling	Every 30 days and after 12 hours from start recording
Sampling Freq.	100 Hz
OBS Serial Number	A6
Lon Lat	1359.9912974 3929.9972205 (14/02/2010 17.50.17)175049GPS
Synchronization time	14/02/2010 16:03:00
Seismometer release	15/02/2010 00:00:00
Start recording	14/02/2010 16:06:52
Levelling	Every 30 days and after 12 hours from start recording
Sampling Freq.	100 Hz

Table A6. OBS deployment data and Digitizer settings.

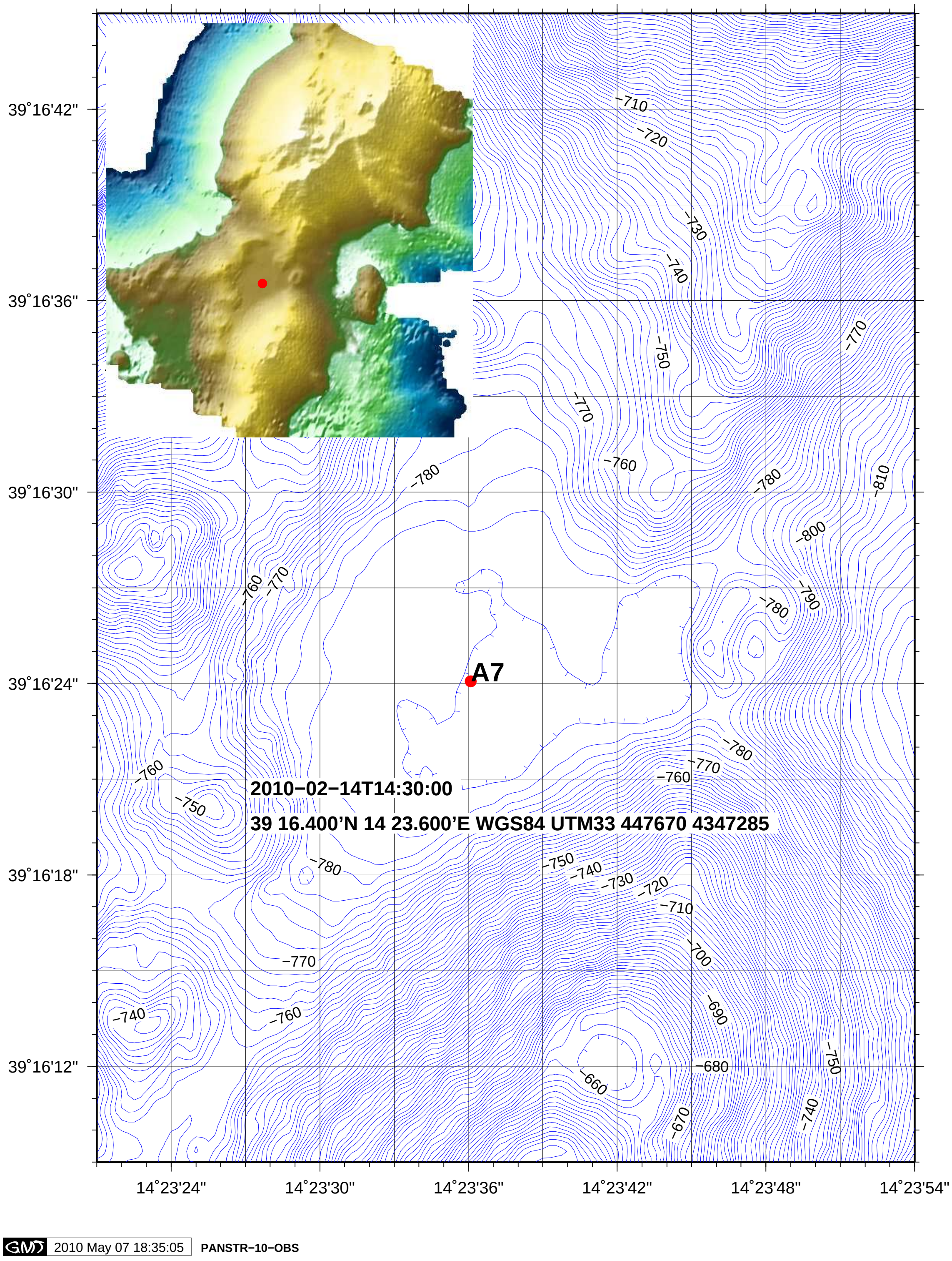

Figure A4. Deployment site of A7 OBS, Marsili Smt. PANSTR10 .

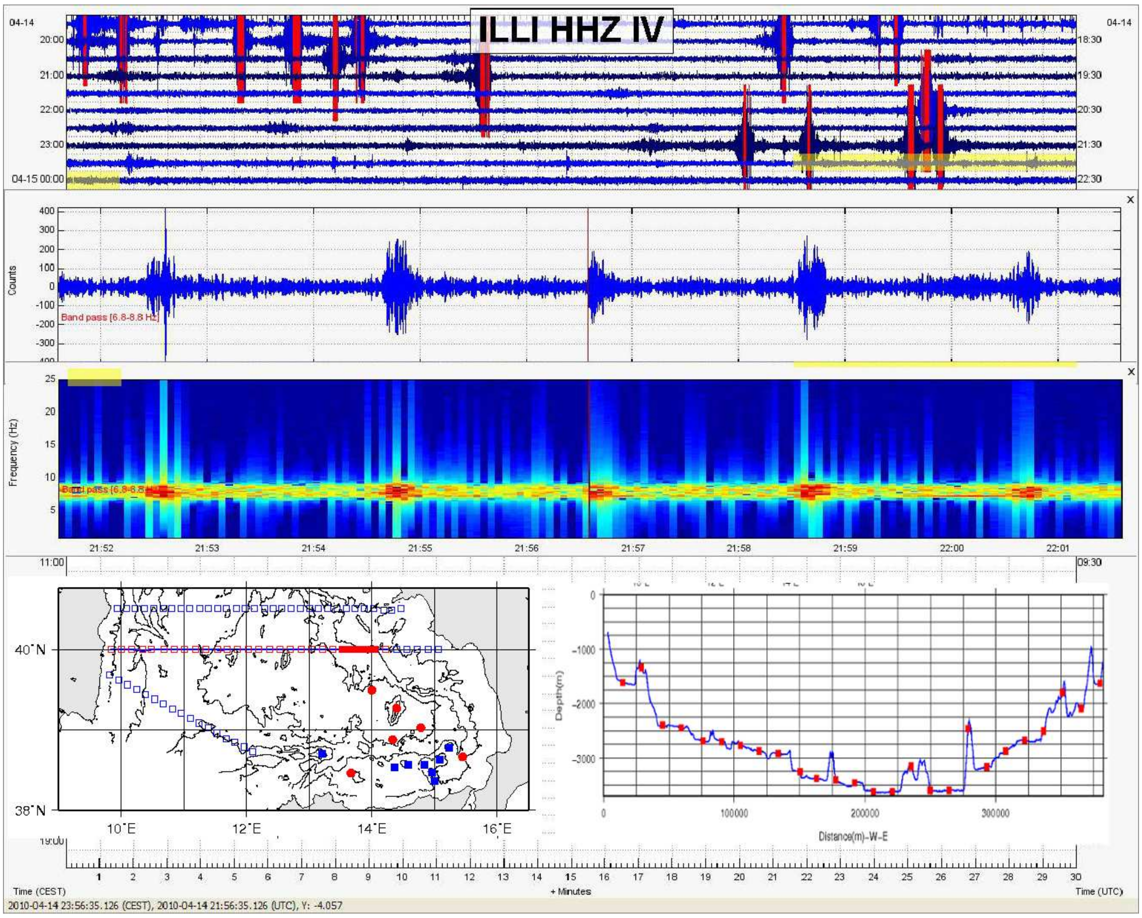

Figure A5. Lipari Station data, 2010-04-14 21:52, INGV National Seismological Network. Shots from R/V Sarmiento de Gamboa, cruise MEDOC10. Bottom Panel shows the R/V Sarmiento de Gamboa navigation (left, thick red line represents the shots from 2010-04-14 19:50 to 23:50) and (right) the OBS deployed along the line by R/V Urania

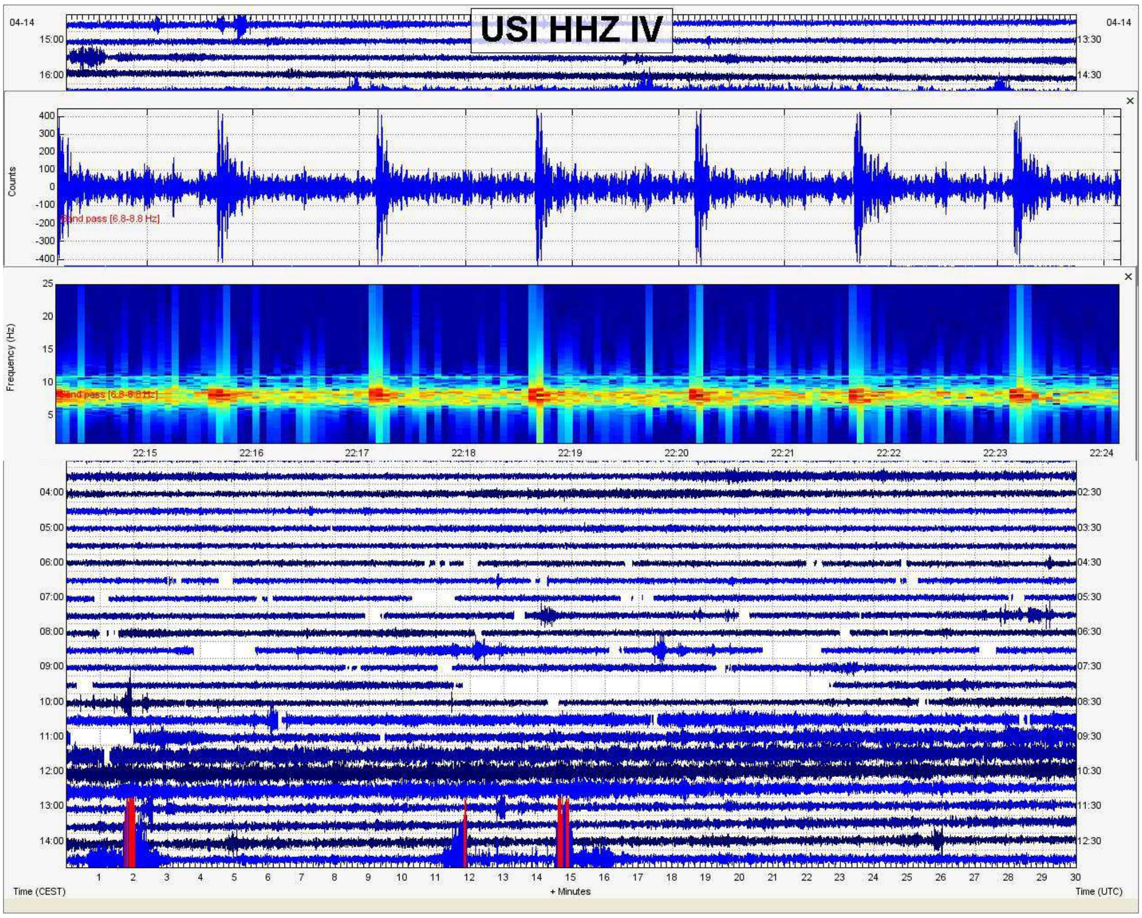

Figure A6. Ustica Station data, 2010-04-14 22:15,INGV National Seismological Network. Shots from R/V Sarmiento de Gamboa, cruise MEDOC10.

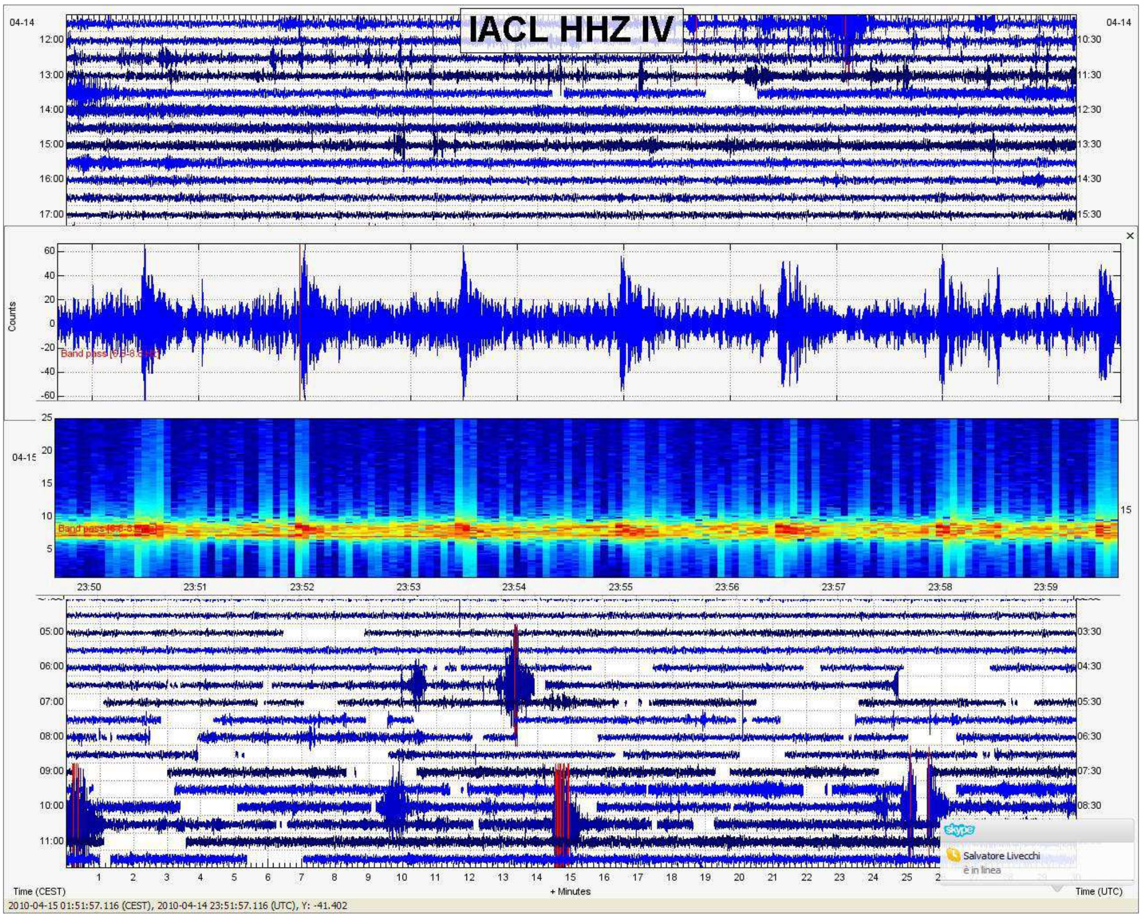

Figure A7. Alicudi Station data 2010-04-14 23:50, INGV National Seismological Network. Shots from R/V Sarmiento de Gamboa, cruise MEDOC10.