CONSIGLIO NAZIONALE DELLE RICERCHE
ISTITUTO PER LA GEOLOGIA MARINA

GEOPHYSICAL STUDIES IN THE WESTERN IONIAN SEA AND IN THE MALTA ESCARPMENT AND AROUND THE AEOLIAN ISLANDS

REPORT ON MULTICHANNEL SEISMIC, SBP AND MAGNETIC INVESTIGATIONS DURING CRUISE MESC2001 WITH R/V URANIA

Bortoluzzi G., Argnani A.,
Accettella D., Bonazzi C., Carluccio S., Chierici F.,
Gasperini L., Romano S., Sacchetti F., Zitellini N.,
Frugoni F., Musacchio G., Nisi M.F., Nonnis O.,
Costa Pisani P.,
Scotto di Vettimo P., Guardati G.

IGM-CNR Technical Report N.71

Bologna, August 2001

IGM-CNR Cataloging-In-Publication data: IGM-CNR Technical Report N.71

GEOPHYSICAL STUDIES IN THE WESTERN IONIAN SEA AND IN THE MALTA ESCARPMENT AND AROUND THE AEOLIAN ISLANDS. REPORT ON MULTI-CHANNEL SEISMIC, SBP AND MAGNETIC INVESTIGATIONS DURING CRUISE MESC2001 WITH R/V URANIA

by Bortoluzzi G., Argnani A.,
Accettella D., Bonazzi C., Carluccio S., Chierici F.,
Gasperini L., Romano S., Sacchetti F., Zitellini N.,
Frugoni F., Musacchio G., Nisi M.F., Nonnis O.,
Costa Pisani P.,
Scotto di Vettimo P., Guardati G.

Includes bibliographical reference and index.

1. Ionian Sea 2. Thyrrhenian Sea 3. Malta Escarpment 4. Aeolian Islands 5. Multi-channel Seismic 6. CHIRP SBP 7. Magnetics 8. Neotectonics 9. Seismogenic Faults

Abstract - A summary of the methodologies, technical details and ship-board results of geophysical survey in the Western Ionian Sea (Malta Escarpment) and around the Aeolian I. is presented. During 18 days of work with R/V Urania a dense grid of MCS, SBP and magnetic lines was obtained.

Sommario - Vengono presentati le metodologie e l'insieme dei risultati ottenuti durante una campagna Multicanale , SBP e magnetometria nel Mar Ionio (scarpata di Malta) e nel M.Tirreno attorno alle Isole Eolie. Durante 18 giorni di lavoro in zona si e' ottenuto un denso grigliato di linee Multicanale, SBP e magnetometria.

Reproduced by IGM-CNR from camera-ready copy supplied by the authors.
Published in the WWW at doc.igm.bo.cnr.it or www.igm.bo.cnr.it
Available in PostScript® and PDF ® formats. Available also in RTF and LaTeX text and images, within the full production suite, upon request to the authors.

Production Notes - The document was edited with standard text editors, typeset with Leslie Lamport's LaTeX, translated to PostScript and PDF with dvips and ps2pdf and printed camera ready. The full production was done on a Linux box with GNU-GPLsoftware. Converted to HTML by Nikos Drakos's LaTeX2HTML and to PDF by Alladin Ghostscripts's ps2pdf. All 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.

ACRONYMS

ACRONYM	DESCRIPTION	URL-email
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
IGM	Istituto per la Geologia Marina CNR	www.igm.bo.cnr.it
GNDT	Italian group for protection from earthquakes	emidius.itim.mi.cnr.it/GNDT
INGV	Istituto Naz. Geofisica e Vulcanologia	www.ingv
ICRAM	Ist. Centrale Ricerca Ambiente Marittimo	www.icram.org
SO.PRO.MAR	Societa' Progetti Marittimi	sopromar@pronet.it
SEG	Soc. of Exploration Geophysicists	www.seg.org
IBCM	Int.Bathym.Chart of the Mediterranean	www.ngdc.noaa.gov/mgg/ibcm/
GMT	Generic Mapping Tool	gmt.soest.hawaii.edu/gmt
GPS-DGPS	Global Positioning System	samadhi.jpl.nasa.gov
MCS	Multi Channel Seismic	
SBP	Sub Bottom Profiling	

Table 1: Acronyms of Organizations, Manufacturers, Products

AUTHORSHIP

Giovanni Bortoluzzi compiled and finalized the main body of this report, other than being in charge of the technical aspect of the expedition, jointly with Luca Gasperini during the first leg. Andrea Argnani, as chief scientist, contributed to the geological and scientific background. All the participants to the cruise contributed to the achieved results with their work and discussion aboard. Nevio Zitellini, Claudia Bonazzi, Patrizia Costa Pisani and Daniela Accettella worked in team to process the seismic data that were all successfully migrated aboard. Luca Gasperini, Fabio Sacchetti, Stefano Carluccio and Stefania Romano carefully looked after the Chirp Sonar acquisition. Francesco Frugoni, Paolo Scotto di Vettimo and Giulio Guardati were in charge of the navigation. Gemma Musacchio, Marco Fulvio Nisi, Francesco Chierici, Ornella Nonnis and Nevio Zitellini followed the seismic acquisition. Paolo Scotto di Vettimo, Stefano Carluccio and Fabio Sacchetti installed and maintained the instruments and equipment.

HOW TO READ THIS REPORT

Section 1 gives the introductory and background information, together with some technological and scientific issues of the organization and execution tasks. Section 2 summarizes the cruise. Sections 3 provide the technical details of the data acquisition and processing, whereas section 4 discusses some results, the on-going data processing and usage, and gives some concluding remarks.

ACNOWLEDGMENTS

Master Vincenzo Lubrano Lavadera, Officiers and Crew of R/V Urania are gratefully acknowledged for their extremely helpful and patient support during our operations. The crossing of the Lipari-Salina strait crowded with sails has been a remarkable masterpiece. Marco Ligi and Luca Masini are thanked for their help in preparing the Seismic Equipment. Angelo Magagnoli, Wladimiro Landuzzi, Patrizia Dall'Olio and Paolo Ferretti helped with the logistic.

Contents

List of Figures

List of Tables

1 INTRODUCTION AND GEOLOGICAL SETTING

The Cruise MESC 2001 is part of the IGM-CNR research project 'Hazard evaluation of submarine geological processes in the Italian seas: earthquakes, tsunamis and slides' funded by the Italian group for protection from earthquakes (GNDT). The areas investigated during the survey (Fig.1), from the Messina Strait to the Malta escarpment, and around the Aeolian Volcanic edifices present a record of seismicity that goes back to historical times with events that seriously affected people and manufacts in the adjacent coastal area.

Active faulting of regional extent are affecting the slope of eastern Sicily and the adjacent Ionian basin. However, the complexity of the tectonic system in the region is far from being fully resolved, mainly because of the lack of a properly spaced seismic survey.

Published maps of active faults affecting the slope of eastern Sicily and the adjacent Ionian basin are currently based on a seismic grid that is loosely spaced ([1],[2],[3],[4]) and, therefore, both direction and extent of faults are only weakly constrained. Because a good knowledge of the architecture of a fault system is a pre-requisite to evaluate its hazard potential, we planned and carried out a seismic survey aiming at more closely mapping the active fault system of eastern Sicily offshore. The survey was planned upon a 5 nm spaced grid of reflection seismic profiles covering the Malta Escarpment and adjacent Ionian Basin; only towards the deeper Ionian Basin plain, away from the Malta Escarpment, spacing was enlarged to c.a. 10 nm.

The main objective was to better define the architecture of the active fault system affecting the eastern slope of Sicily. Firstly, the direction and continuity of fault segments should be better defined in plan view. Secondly, small sedimentary basins showing growth strata geometries have been originated by extensional faulting. Analysis of stratal geometries should help estimating amount of throw and relative age of activity of fault segments. Finally, the high resolution Chirp sonar profiles, acquired together with seismic data, could bring information on the occurrence of large mass movements along the slope. Such processes may play a role in trigger or modulate tsunamis in a tectonically active environment. An additional seismic survey, of limited extent, was planned also to be carried out in the sea surrounding the islands of Vulcano, Lipari and Salina with the aim of mapping the regional tectonic features controlling the evolution of the line of volcanoes and, eventually, the stability of the individual edifices.

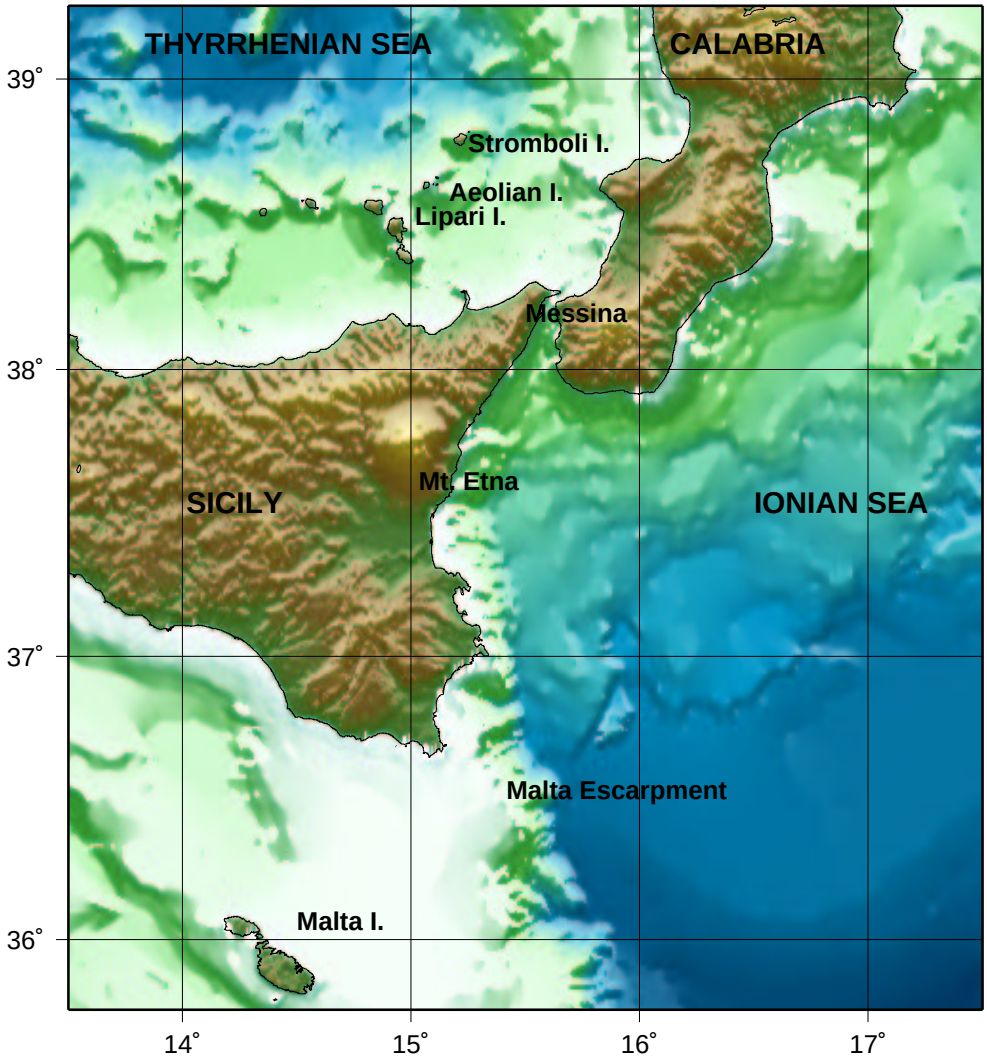

Figure 1: Work areas. Bathymetric data regridded from IBCM data ([7] [8].

2 CRUISE SUMMARY

SHIP: R/V URANIA
START: 2001-07-27 PORT: MESSINA
END: 2001-08-15 PORT: NAPOLI
SEA/OCEAN: Jonian Sea / Thyrrhenian Sea / Mediterranean Sea
LIMITS: NORTH 38:50 SOUTH: 36:00 WEST: 14:30 EAST: 16:30
OBJECTIVE: GEOPHYSICAL INVESTIGATIONS IN THE JONIAN SEA
COORDINATING BODIES: IGM CNR BOLOGNA (ITALY)
PARTICIPATING BODIES: INGV
CHIEF OF EXPEDITION: Andrea Argnani (IGM-CNR)
CONTACT: andrea.argnani@igm.bo.cnr.it
DISCIPLINES: MULTICHANNEL SEISMIC, CHIRP SBP, MAGNETICS
WORK DONE: 2500 KM MCS AND CHIRP-SBP, 1120 KM MAGNETICS, 2 CTD CASTS

LOCALIZATION:

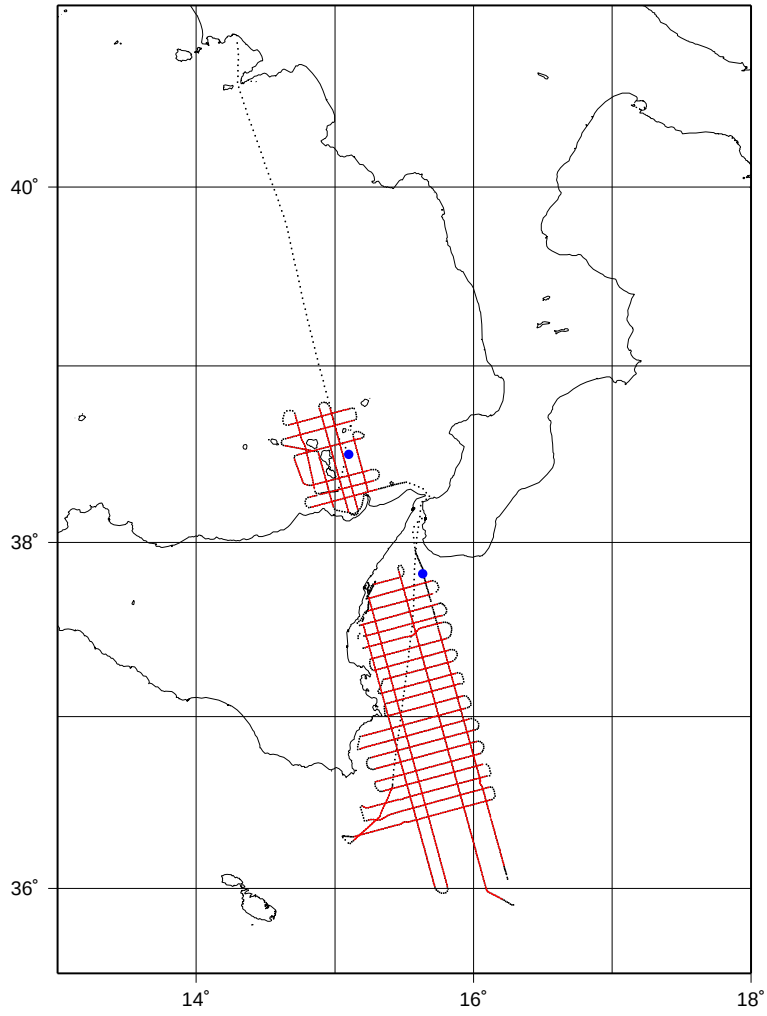

Figure 2: Ship tracks for MCS, SBP and magnetics, and CTD locations(blue dots).

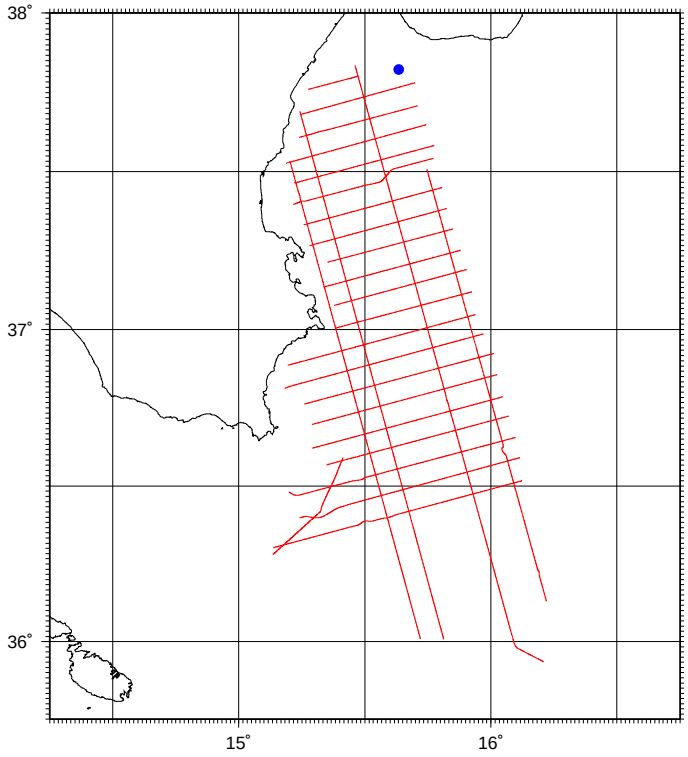

Figure 3: Ship tracks for MCS, SBP and magnetics, and CTD locations. Ionian Sea Survey Area.

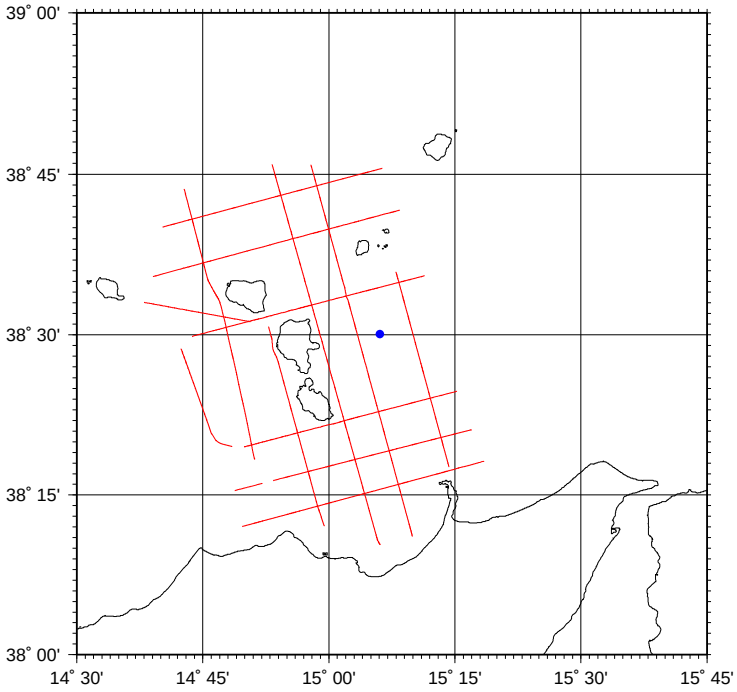

Figure 4: Ship tracks for MCS, SBP and magnetics, and CTD locations. Aeolian I. Survey Area.

SCIENTIFIC AND TECHNICAL PARTIES

NAME	ISTITUTE	POSITION	tel & email
Andrea Argnani	IGM-CNR	Chief of Expedition	andrea.argnani@igm.bo.cnr.it
Daniela Accettella	IGM-CNR		daniela.accettella@igm.bo.cnr.it
Claudia Bonazzi	IGM-CNR		claudia.bonazzi@igm.bo.cnr.it
Giovanni Bortoluzzi	IGM-CNR		gb@igm.bo.cnr.it
Stefano Carluccio	IGM-CNR		stefano.carluccio@igm.bo.cnr.it
Francesco Chierici	IGM-CNR		francesco.chierici@igm.bo.cnr.it
Luca Gasperini	IGM-CNR		lucag@igm.bo.cnr.it
Stefania Romano	IGM-CNR		stefania.romano@igm.bo.cnr.it
Fabio Sacchetti	IGM-CNR		
Nevio Zitellini	IGM-CNR		nevio.zitellini@igm.bo.cnr.it
Francesco Frugoni	INGV-RM		
Gemma Musacchio	INGV-MI		musacchio@mi.ingv.it
Marco Fulvio Nisi	ICRAM		
Ornella Nonnis	ICRAM		o.nonnis@katamail.com
Patrizia Costa Pisani	Univ. Roma		
Paolo Scotto di Vettimo	SOPROMAR	Onboard Sys.Engineer	paoloscotto@tin.it
Giulio Guardati	SOPROMAR		
IGM-CNR	Istituto Geologia Marina CNR	Via Gobetti 101, Bologna	www.igm.bo.cnr.it
INGV-RM	Ist.Naz.Geofisica e Vulcanologia	Via di Vigna Murata, 605 Roma	
INGV-MI	Ist.Naz.Geofisica e Vulcanologia	Via Bassanini,15 Milano	
ICRAM	Ist.Cent. Ric.Appl.Mare	Via di Casalotti, 300, Roma	www.icram.org
SO.PRO.MAR	Societa' Progetti Marittimi	Via Della Pesca, 11, Fiumicino	

Table 2: Scientific and technical parties

SUMMARY OF OPERATIONS

After the equipment mobilization that started 2001-07-27 11:00, ship left the port of Messina 2001-07-27 at 16:30. The seismic operation started 2001-07-28 in the morning with the deployment of the seismic streamer for weight balancing and of the seismic source. The first line was run 35 NM S of Messina with direction SSE. 2001-07-29 in the afternoon the streamer was recovered and partially oil-filled. After a port call to Riposto-Giarre 2001-08-02 for crew exchange, the operations in the Ionian Sea and in the Malta Escarpment stopped 2001-08-10 in the evening when ship left the area S of C.Passero heading to the Strait of Messina and to the Aeolian Islands.

The operation in the Aeolian Islands started 2001-08-10 early afternoon with the streamer and source deployment, up to 2001-08-14 early in the morning when the intrumentation was recovered and the ship headed to Naples, where it docked 18:30 Local Time.

2500 KM of MCS and SBP lines were run, having fired 25000 shots for each of the two GI-GUN employed. Shot quality have been always good except some hours before the end of the first leg. The streamer performed well except some dead channels and noisy channels. Some garbage and fishing materials were intercepted and captured without apparent damage. 1100 KM of magnetics lines were run, starting from 2001-08-04; no problem was encountered except when sailing around the Eolie Islands, where several quick recoveries were dictated by the heavy traffic around the ship.

3 MATERIALS AND METHODS

The cruise was conducted with CNR R/V Urania (Fig.5), a 63m long vessel operated by SO.PRO.MAR.

Figure 5: R/V Urania

3.1 POSITIONING AND NAVIGATION

The Positioning system NAVPRO V5.6 by Communication Technology (Cesena, Italy) was used. The instrumental offsets are presented in Fig. 6 and in Tab. 3. The integrated system used a Microtecnica Gyrocompasse and a Trimble 4000 Differential Locator, with a DGPS Satellite link by FUGRO. The datum was WGS84 and the Direct Mercator projection on 38.00'N and UTM 33 were chosen for navigation and display. Timing was set to UTC. The SBP-CHIRP workstation received the 'VESSEL(0,0)' positions by the NAVPRO serial output. These positions were therefore recorded on the SEGY trace headers. The speed of Sound for DEPTH 1 and 2 was set to 1500m/sec, with a transducer immersion of 3.5m. CTD measurements were made with the ship's Sea Bird Probe (Fig.7).

WHERE	ALONG	ACROSS	RANGE	BEARING
POS 1	4.80	1.40	5.0	16.26
VESSEL (POS 2)	0	0	0	0
ECHO SOUNDER 12	5.50	-1.85		
CHIRP	-5.50	-0.95	5.58	189.80
STERN	-46.6	-1.40	46.62	189.80
GI-GUN	-65.0	5.0		
FIRST ACTIVE	-177.5	0.0		
MAG	-230.0	-5.0		

Table 3: Instrumental Offsets on Ship Urania. Point (VESSEL,(0,0)) is located on the axis of the mast just behind the Command Bridge. The main GPS antenna (primary positioning system) is located on point POS1.

CRUISE MESC2001 27−JUL/16−AUG−2001 INSTRUMENTAL OFFSETS R/V URANIA

WHERE	ALONG	ACROSS	RANGE	BEARING
POS1	4.80	1.40	5.0	16.26
VESSEL	0	0	0	0
ECHO33	5.50	1.85	5.80	18.59
CHIRP	−5.50	−0.95	5.58	189.80
STERN	−46.6	−1.40	46.62	189.80
GI−GUN	−66.6	5.0		
FIRST ACT	−177.5	0.0		
MAG	−230.0	−5.0		

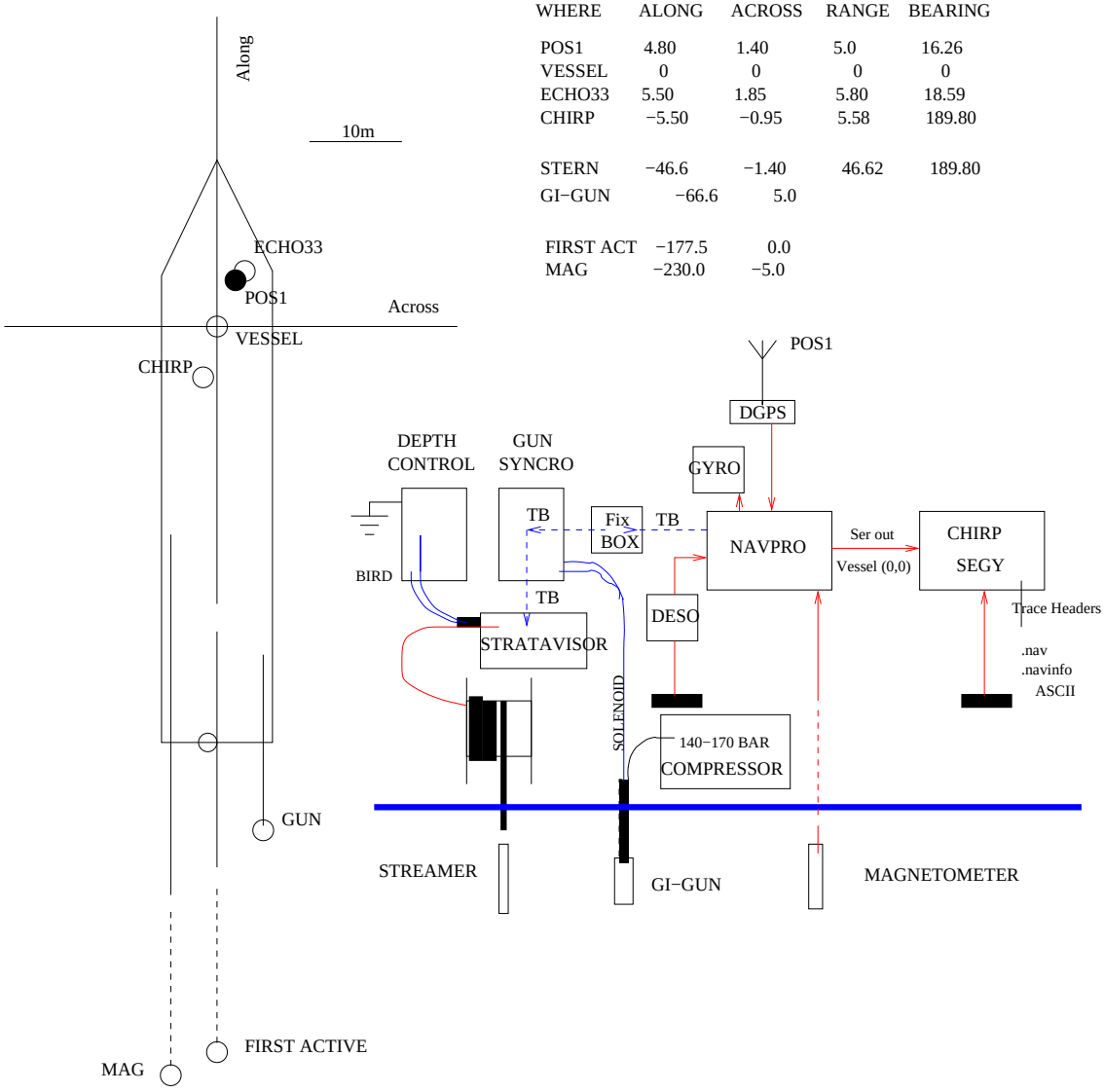

Figure 6: Instrumental Offsets on R/V Urania

Figure 7: The SEA BIRD SBE CTD probe.

SOUND VELOCITY ANALYSIS

During the MCS acquisition we performed some CTD measurements. The position of the stations are shown in Figs. 3 and 4 and in Table 4.

STATION	DATE	LAT	LON	DEPTH
STAZ1	2001-07-28	3749.320	1538.040	1634.0
STAZ2	2001-08-14	3830.080	1505.050	1093.0

Table 4: MESC 2001 CTD Locations.

The data are presented in Figs. 8 and 9. The SV profiles will be used for bathymetric post-processing.

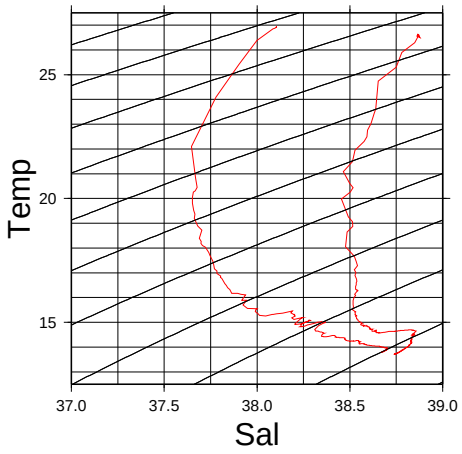

Figure 8: T/S diagram of the whole data sample.

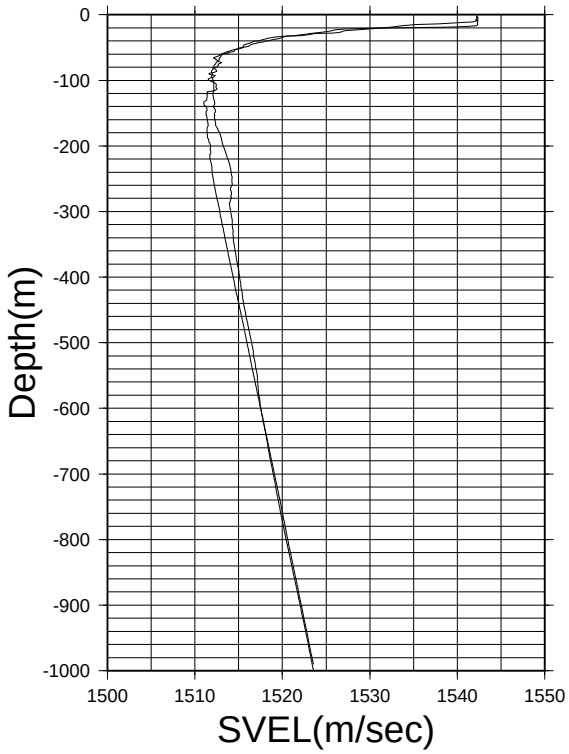

Figure 9: Sound Velocity Profiles of the whole data sample.

3.2 CHIRP SBP

SBP data was acquired by the 16 transducers, hull mounted DATASONICS Mod.CAP-6600 CHIRP-II profiler, with operating frequencies ranging 2-7 KHz. The analog sections were printed in real time on an 22" EPC recorder. The digital data were recorded in the SEG-Y format on MO removable disks and backup on HD.

The navigation data were made available to the system by NAVPRO as VESSEL (0,0) at a rate of aproximately 0.5hz. The data were recovered from the SEG-Y trace data files with an appropriate software. For the sake of achieving the maximum accuracies, the data must be converted to the CHIRP position (see Tab.3).

3.3 MULTICHANNEL SEISMIC

We employed high resolution Multichannel Seismic (Fig. 10) using the GI-GUN (Fig.12) (in the 105+105 c.i. Harmonic configuration) pneumatic sources by SODERA/SSI, powered by a 2500 L/Min, electrically driven, Mod. I28 air compressor by BAUER. The pressure to the gun was set to 175 Bar (2500 psi), actually ranging from 165 to 185 Bars. The seismic data were collected by a MOD.29500 TELEDYNE 48 channel streamer (Fig.11) and digitized and recorded on DDS-1 and DDS-2 DAT tapes by a GEOMETRICS's STRATAVISOR seismograph in the SEG-D 8048 Revision.0 format, with Sampling rate of 1 msec and Record Lenghts varying from 8 to 12 secs .

The group interval was of 12.5m for a total active length of 600m. The 150m tow leader and two 50 m stretch sections made up the streamer to a total length of 850m. The seismic source was fired by IGM's gun-control equipment [10](Fig. 13), that introduced a fixed delay of 10 msec from the Time Break, where the Injector delay was of 47.5 msec. Shot distances were of 50 m, thus achieving coverages of 600%. The Time Break was provide by

the Seismic Module in the NAVPRO Navigation System Software, with the 'DISTANCE FROM PREVIOUS SHOT' setting, in order to maximize the survey flexibility allowing the 'SHOT NOW' capability when on route. This was particularly important when dealing with high traffic or fishing activities that forced last minute deviations from the planned route. The depth of the source ranged between 5 and 6 m. The streamer was kept at 10-12 m depth with SYNTRON RCL-2 cable-levelers, using a Teledyne Mod. 28951 Depth Control System.

The data were processed onboard using the DISCO/FOCUS packages by PARADIGM, up to the time-migration of the sections, using a standard processing sequence.

Figure 10: The Seismic System deployed.

Figure 11: The TELEDYNE streamer. See also the RCL-2 cable leveler.

Figure 12: The SODERA/SSI GI-GUN.

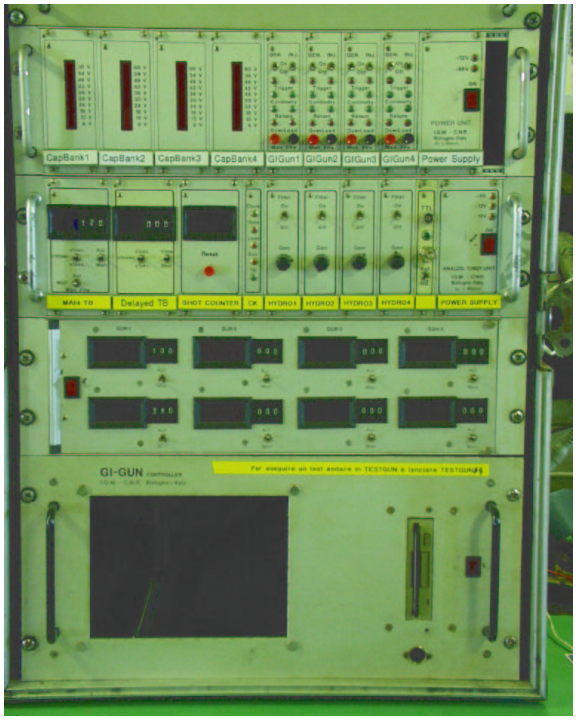

Figure 13: The IGM Gun Synchronizer [10].

3.4 MAGNETICS

On some of the lines in the Ionian Sea and in the totality of the lines on the Aeolian Islands we towed a "handheld" (Fig.14) Mod. GSM-19D magnetometer by GEM Systems. The data were directly interfaced to NAVPRO, therefore being available on the navigation files with the POS1 position (see Tab. 3 for the offsets).

Figure 14: The Mod. GSM-19D magnetometer by GEM

The data must be corrected with the M.Etna and L'Aquila Observatory data, filtered and the local anomalies computed with the IGRF-2000 model, as shown by [5].

A very crude and preliminary map of the data acquired in the Ionian Sea can be seen in Fig.15, where the raw data have simply been corrected for position and de-trended by a 3d-order surface to obtain the regional anomalies.

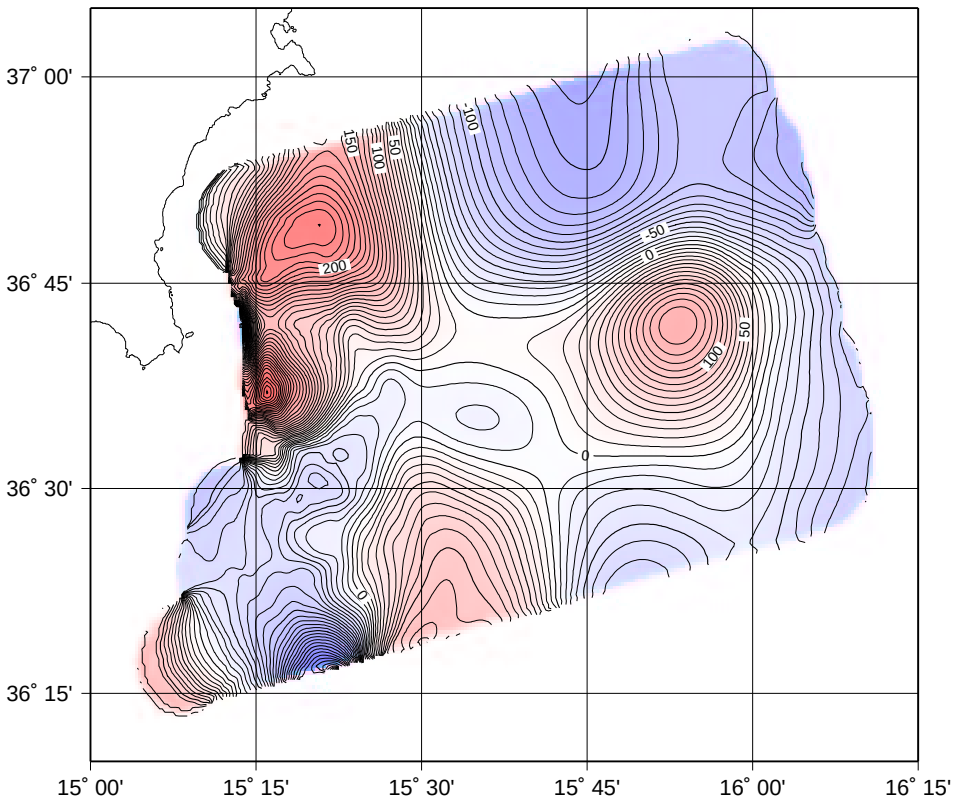

Figure 15: Raw magnetic data de-trended (3d-order).

4 PRELIMINARY RESULTS AND CONCLUSIONS

Fig. 3 and 4 show the pattern of the MCS, SBP and Magnetic lines that were run in the Ionian Sea and around the Aeolian Islands.

The data were processed onboard, obtaining the time-migration of all the sections.

Seismic profiles acquired along the slope of eastern Sicily are of pretty good quality and show a number of features of interest. Extensional faults, often cutting the sea floor, have been well imaged, particularly on the E-W-trending profiles. Some of these faults are linked to the slope of the Malta Escarpment, whereas others are located further to the east. Half grabens filled by sediments with growth strata geometries are typically associated to the faults. At a preliminary inspection of seismic profiles these extensional faults seem to be located mainly in the northern side of the survey. It is not clear yet if they die out south-ward or are transferred to the east of the grid of profiles. As a side aspect which has relevance to the regional geology of the area, the extent of the Calabrian Arc accretionary wedge and the way it interferes with the Malta Escarpment have also been rather well imaged. The Malta Escarpment itself appears quite clearly on seismic profiles, and often reflections that are in continuity with the escarpment can be followed eastwards for 20- 30 km, under a sedimentary pile of variable thickness. In the southern part of the survey, where water depth was deeper, the quality of seismic images was a little degraded, with reduced penetration. Besides the greater water depth this degrading of the image is related to the nature of the geological units encountered; in fact, the sedimentary cover of the Calabrian Arc accretionary wedge is greatly reduced, leaving a tectonised unit close to or at the sea floor.

Seismic profiles acquired around the Aeolian Islands are not as good as those of the first survey, quality wise. The shallowness of water, steep slopes and abundance of volcanic rocks contribute to lower the quality of seismic data. However, some interesting features have been imaged along the volcanic ridge, particularly south of Vulcano, where steep faults cutting the substrate of the sedimentary cover has been detected. The side slopes of volcanic edifices have also been well imaged.

CONCLUSIONS

During the 18 days of operation we collected 38 MCS profiles in two separate surveys, 25 along the slope of eastern Sicily and 13 around the Aeolian Island, for a total of 2500 KM. Chirp sonar profiling were performed all the way through along with seismic acquisition, whereas magnetic data were collected in the southern part of the Ionian survey and in the Aeolian I. survey (1120 KM). Seismic profiles were all successfully processed aboard up to time migration.

Favourable weather conditions allowed us to work continuously during the cruise, limiting also the noise due to sea roughness, and the amount and quality of the data collected are a good premise for the fulfillment of our research goals.

The magnetic data are of good quality and might provide further insights into the tectonics of the surveyed areas.

Bibliography

[1] Cernobori L., Hirn A., McBride J.H., Nicolich R., Petronio L., Romanelli M. & STREAMERS/PROFILES Working Groups , *Crustal image of the Ionian basin and its Calabrian margins*, Tectonophysics 264, 175-189,1996.

[2] Hirn A., Nicolich R., Gallart J., Laigle M., Cernobori L. & ETNASEIS Scientific Group, *Roots of Etna volcano in faults of great earthquakes*, Earth Plan. Sci. Lett., 148, 171-191, 1997.

[3] Bianca M., Monaco C., Tortorici L. and Cernobori L., *Quaternary normal faulting in southeastern Sicily (Italy): a seismic source for the 1693 large earthquake*, Geoph. J. Intern., 139, 370-394,1999.

[4] Nicolich R., Laigle M., Hirn A., Cernobori L., and Gallart J., *Crustal structure of the Ionian margin of Sicily: Etna volcano in the frame of regional evolution*, Tectonoph., 329, 121-139, 2000.

[5] Bortoluzzi G. and 19 others, *Swath Bathymetry and geophysical survey of the Tyrrhenian Sea. Report on bathymetric, magnetic and gravimetric investigations during Cruises TIR96 and TIR99*, IGM Technical Report n. 52, 2000.

[6] URL: topex.ucsd.edu/marine_topo/text/topo.html

[7] Morelli C., Valchuck S., *The Int.Bathym.Chart of Medit.(I.B.C.M.)*, IBCM Supporting Vol, Ch.1, IOC, Unesco, 1997. (URL: www.ngdc.noaa.gov/mgg/ibcm/ibcm.html).

[8] GEBCO-97, *The second release of the GEBCO Digital Atlas. BODC*, on behalf of the IHO and the IOC (URL: www.ngdc.noaa.gov/mgg/gebco/gebco.html), 1997.

[9] Navigator Professional V5.56, Communication Technology, Piazza Guidazzi 3, Cesena, see also URL: www.comm-tec.com.

[10] Masini L. and Ligi M., *Sistema di controllo e sincronizzazione cannoni sismici ad aria compressa*, Rapporto Tecnico IGM N.37, 126pp, 1995.

[11] Wessel P. and Smith W.H.F., *New version of the Generic Mapping Tool released*, EOS Trans. AGU, p.329, 1995, see also URL: gmt.soest.hawaii.edu.