Proceedings of the 3rd IASME/WSEAS International Conference on Geology and Seismology (GES'09), pp.153-157

Multiparametric seafloor exploration: the Marsili Basin and Volcanic Seamount case (Tyrrhenian Sea, Italy)

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Abstract: - Exploration of ocean seafloor is of paramount importance for a better understanding of the geodynamic evolution of our Planet. The pilot experiment of ORION-GEOSTAR 3 EC project was the first long-term continuous geophysical and oceanographic experiment of an important seafloor area of Southern Tyrrhenian Sea, the Marsili abyssal plain. The latter hosts the Marsili Seamount which is Europe's one of the largest underwater volcano of Plio-Pleistocenic age. In spite of its dimensions, it is rather unknown about the present characteristics and activity. For this reason, we deployed a deep-sea observatory network, composed by two bottom observatories,, on the seafloor at the base of the seamount at 3320 m b.s.l., in the period December 2003-May 2005. Some of the instruments on board the observatory were: broad-band seismometers, hydrophones, gravity meter, two magnetometers (scalar and vectorial), 3D single-point current meter, ADCP, CTD, automatic pH analyser and off-line water sampler for laboratory analyses. The first successful scientific objective was to obtain long-term continuous recordings under a unique time reference. The data analysis shows that they are generally of good quality and really continuous (only a few gaps). As a first step we performed a classification of seismic waveforms, a first inversion of magnetic variational data, and a first analysis of gravity meter, chemical and oceanographic data. Analysis of individual time series has shown interesting results, i.e. depth of the magnetic Moho under the Marsili, attenuation of recorded seismic body waves and clues of hydrothermal circulation. We show examples of the preliminary data analysis together with first results and comparisons among data coming from different sensors.

Key-Words: Marsili Basin and Volcanic Seamount, Exploration with seafloor observatories, ORION-GEOSTAR 3 EC project

1 Introduction

Our Planet is a complex system where different macro-components, such as hydrosphere, geosphere, biosphere and atmosphere, interact on different spatial and time scales. In particular, oceans, covering more than 7/10 of the Earth surface, still remain largely unexplored and a variety of processes and interactions of different nature taking place inside them are poorly known. In the last decades of the previous century the extension of experimental observations on the seafloor has represented the actual challenge to start an innovative long-term and multidisciplinary investigation, improving the traditional periodic and episodic exploration campaigns. Study of the deep seafloor helps us: a) to understand submarine geodynamics, composing the complex dynamics of all structural elements of plate tectonics; b) to discover and reconstruct the climate change history and its effects on the ecosystems. The scientific discovery and achievement are strongly dependent on the availability, accessibility and novelty of the ocean technology and infrastructures. This requires continuous innovation in marine engineering and knowledge transfer from a wide range of technical disciplines such as robotics, communications, energy, to scientists, and then to policymakers [1].

Marine technology has strongly evolved over the past decades and has been offering new tools to achieve significant advances. As an example, deep-sea vehicles (ROVs, AUVs, crawlers, etc.) are now key tools for the exploration of the deep ocean realms as well as drill ships, which can provide long records into the past. Moreover, since development and research in industry run in parallel, the scientific community has benefited

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from a mature industrial supplier base and has been able to progress towards greater depths and higher reliability regarding new sensor systems for physical, chemical and oceanographic *in situ* measurements. In this regard, the recent development of long-term, multiparameter seafloor observatories has replied to a major challenge - the acquisition of long-term time series in deep sea waters – which in essence adds the fourth dimension to a 3D understanding of the phenomena. The fourth dimension, i.e. temporal variability, is critical for many processes on Earth, for instance the periodicity of fluid flow, rates of active tectonics, recurrence intervals of geo-hazards (e.g., earthquakes, tsunamis), and ecosystem life cycles.

Specifically, from the European Commission (EC) FP5 up to the present running FP7, the European scientific community has been involved in several important initiatives addressed to long-term observation and state-of-the-art deep-sea technology. Development of European seafloor observatories with multidisciplinary capabilities has been pioneered under the EC-funded GEOSTAR projects [2, 3, 4].

This brief paper gives some information about the seafloor mission performed under ORION-GEOSTAR 3 EC project in the Marsili Basin (Southern Tyrrhenian Sea), close to the Marsili Volcanic Seamount. In the following sections we will show examples of the preliminary data analysis together with first results and comparisons among the data coming from different sensors.

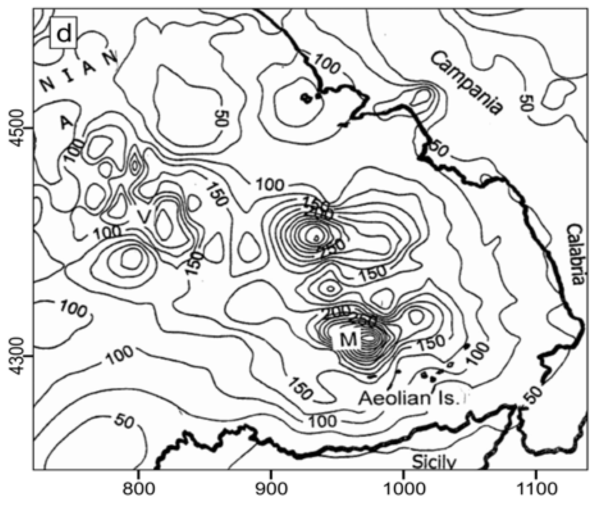

Fig. 1. Heat flow (mW/m^2) of the Southern Tyrrhenian Sea [6].

2 Marsili Basin and Volcanic Seamount pilot experiment

The Marsili Basin has developed in the last 2 Ma [5]. It is the most recent ocean crust floored basin presenting all the characteristics of oceanic back-arc spreading basin with high values of heat flow (Fig. 1; after [6]) and low values of Moho isobaths (Fig. 2; after [7]).

However it lacks the typical morphology of a spreading centre where new crust is produced. Instead, the central youngest part of the basin is occupied by the Marsili Volcanic Seamount, discovered in the 1920s, with a volume of 1400 km^3, an elevation of about 3000 m from the basement level of the basin and a strongly NNE-SSW elongated structure [8]. This volcanic structure is one of the largest European underwater volcanoes of Plio-Pleistocenic age and is a key to understanding the mechanisms driving the lithosphere formation and dynamics in the Tyrrhenian Sea. The Marsili Basin has been the objective of ship-based pioneer exploration from 1970s [9], however its geophysical characteristics and activity have remained mostly unknown so far (small square in Fig. 3 shows the area of interest). Marsili volcano, showing remarkable similarities to the mid-oceanic ridges, has been recently interpreted as a super-inflated spreading ridge [10, 11].

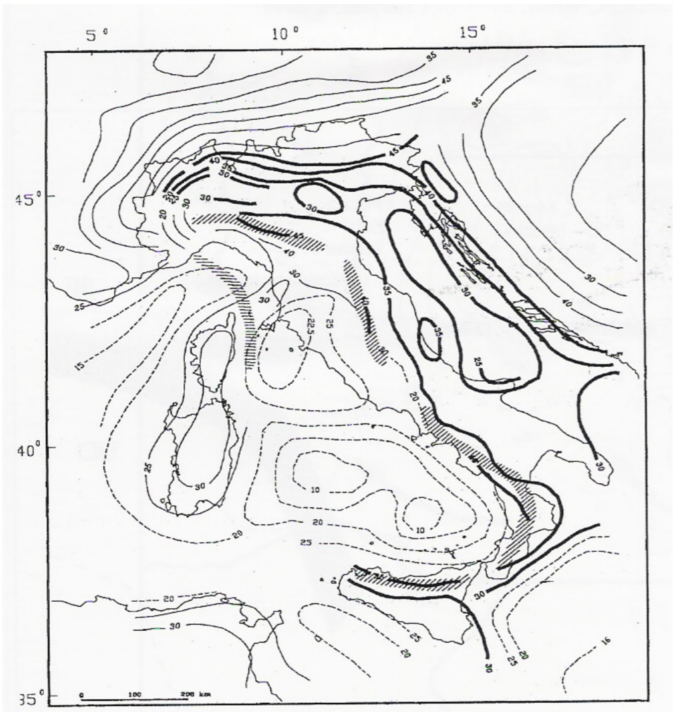

Fig. 2. Moho isobaths (km) of the Italy and surrounding seas [7].

The first long-term continuous geophysical and oceanographic experiment dedicated to the study

ISSN: 1790-2769 ISBN:978-960-474-058-1

of the long-term activity of the Marsili seamount was carried out in the frame of the ORION-GEOSTAR 3 EC project (2002-2005), where a deep-sea observatory network, including two multi-sensors observatories, was deployed on the seafloor at the base of the seamount at 3320 m b.s.l., in two separate legs between December 2003 and May 2005 (seafloor location of the experiment: 39°29'12" N, 14°19'52" E;). Besides oceanographic sensors, geophysical instruments were installed on board the observatories: 3D broad-band seismometers, hydrophones, gravity-meter, two magnetometers (scalar and vectorial) (Fig. 4).

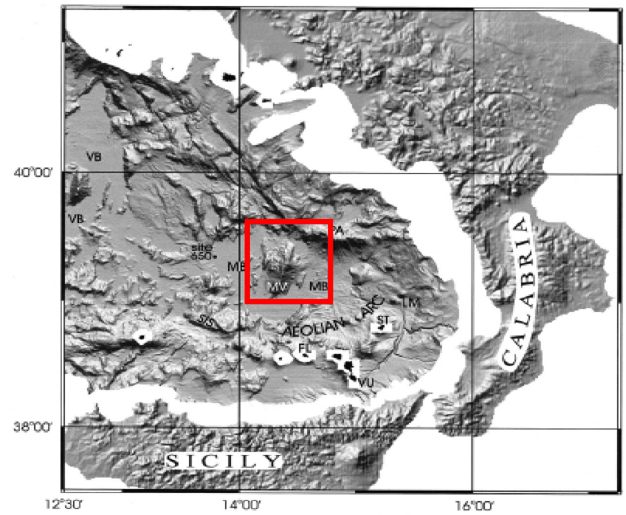

Fig. 3. Bathymetry of the Southern Tyrrhenian Basin; the Marsili Seamount is marked by the small square [8].

Given an overall duration of the seafloor monitoring of 477 days, this experiment has produced the first long multi-sensor time-series, for a total data amount of 28.5 Gbytes.

3 Seafloor data

The first successfully scientific objective was the acquisition of long multiparameter time-series under a unique time reference thanks to a centralised data acquisition and clock. The data quality check, which is always performed before the data analysis and elaboration,

shows that data are of good quality, and in general continuous with only a few gaps.

ORION-GEOSTAR 3 observatories included 3D broad-band seismometer with electrochemical transducer (PMD EP-300-DT, 0.0167 to 50 Hz bandwidth and 100 Hz sampling rate). The previously consolidated installation procedure for GEOSTAR-class observatories insures a good ground coupling of the sensor and signal to noise ratio, fundamental requirements to obtain high-quality seismic recordings [12].

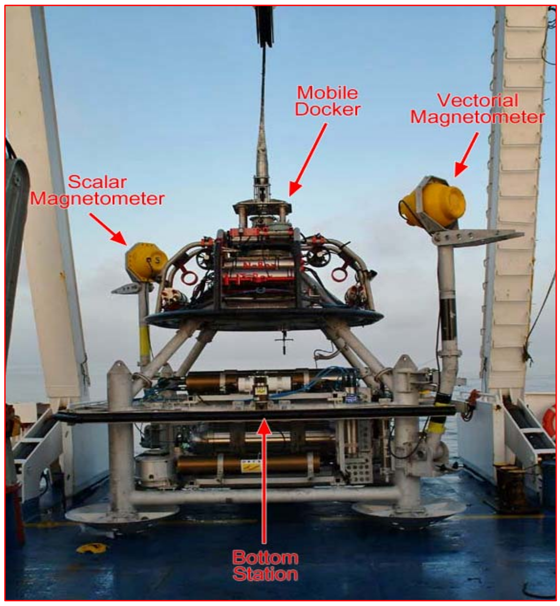

Fig. 4. One of the seafloor observatory, namely GEOSTAR, on the deck of the R/V Urania before the deployment; the observatories are deployed by means of a special vehicle, the Mobile Docker (MODUS) which is driven from a console on board of the ship [4]. All equipment is installed on GEOSTAR frame, except from the magnetometers that are mounted at the ends of two booms to minimize the signatures, on magnetic records, induced by the e.m. fields generated by the observatory electronics and GEOSTAR frame itself.

Noise analysis in the frequency domain was performed by calculating the Power Spectral Density (PSD) on data segments selected over the whole mission period, in absence of earthquake signals. The PSD was compared to Peterson's low/high noise models (LNM, HNM) which are average spectra computed for broadband seismological stations world-wide [13]. An example of background noise spectra of seafloor seismological recordings taken during the Marsili campaign is given in Fig. 5 where the corresponding seismogram is also reported (top left). The smaller box includes 2500 seconds of the three-component signal on which the spectrum was calculated. The frequency of 0.2 Hz, typical of oceanic microseismic noise, is well defined on all the seismic components.

An interesting aspect of the seismological analysis is represented by earthquakes only recorded by the seafloor seismometer. They represent about 25% of the total local seismicity recorded during the

ISSN: 1790-2769 ISBN:978-960-474-058-1

experiment [14]. Fig. 6 shows an example of an earthquake, occurred nearby one of the seafloor observatory as testified by the close P-S arrival times. In addition, the waveforms of some of the events recorded suggest that these might be associated to submarine landslides which have a duration of some tens of seconds, as we already noted in other Mediterranean areas [15]. Some attenuation of the body waves was also observed as possible indication of hydrothermal circulation underneath the Marsili volcano.

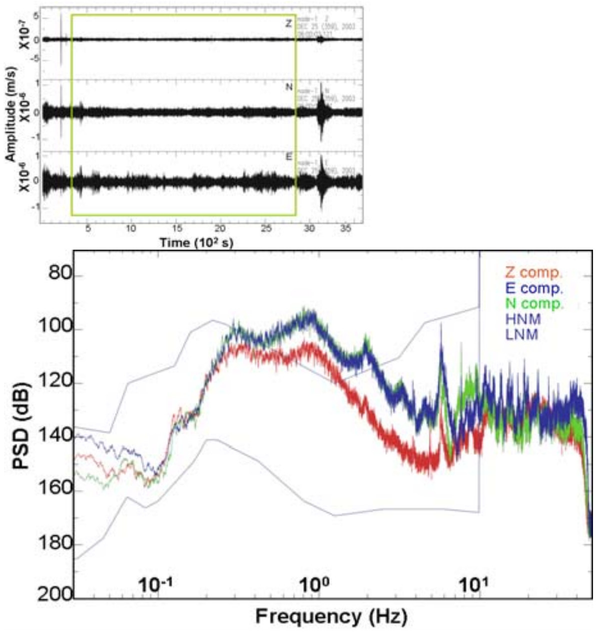

Fig. 5. Power Spectral Density of seafloor seismic recordings compared to the Peterson's noise models [13].

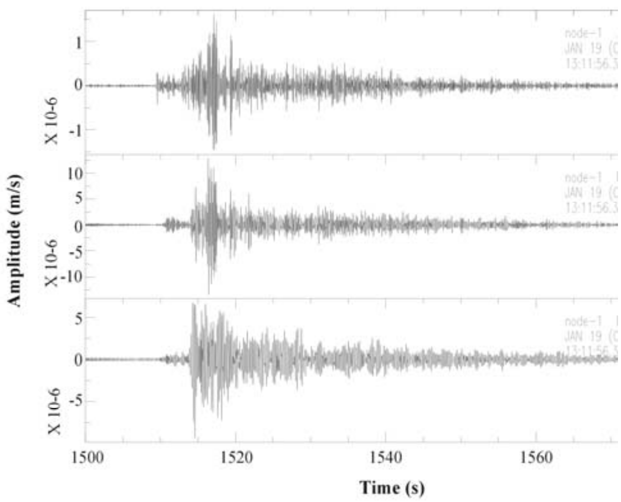

Fig. 6. Example of very local earthquake recorded by one of the ORION-GEOSTAR 3 seismometer at seafloor.

The vectorial magnetometer, being a sophisticated compass, provided precise information about the exact orientation of the benthic station also useful for the correct orientation of the seismological recordings. From a more scientific viewpoint, the study of the time variation of magnetic data allowed to estimate conductivity structure underneath the area of observations [16, 17, 18]. This estimation confirmed the low values of both Moho and lithosphere depths as deduced by seismic data analysis [7].

Fig. 7 shows some examples of geomagnetic records: magnetometers are so sensitive that some smallish spikes are visible, due to the activation of the geochemical package placed in the central frame of the benthic station. Functioning deterioration of this package caused later on larger disturbances on the geomagnetic data: this was an important clue to recognise the precise origin of the problem.

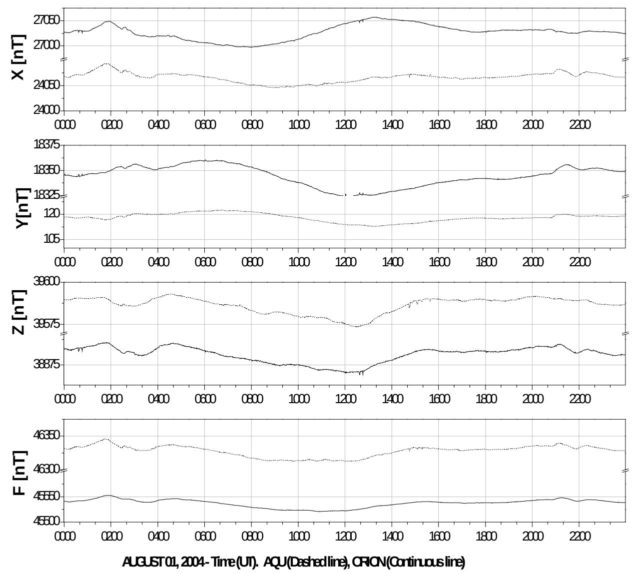

Fig. 7. Example of X, Y, Z, F seafloor magnetic field recordings (bold line) and comparison with data from L'Aquila Observatory (light line) [18].

4 Conclusions

The ORION-GEOSTAR 3 deep seafloor experiment was performed from Dec. 2003 to May 2005 and successfully acquired an enormous amount of data. From first data analyses, we found interesting geophysical and oceanographic time variations occurring around Marsili Volcanic Seamount. In particular, magnetic data allow to estimate some conductivity structure at different depths under the Marsili and gravimetric data show relevant signal patterns at low frequency; seismic data show some local activity with recurring seismic signals. Significant correlations between

ISSN: 1790-2769 ISBN:978-960-474-058-1

recorded time series could be related to activity and structure of the Marsili volcano: for instance the attenuation of the body waves could be an indicator for the possible existence of a hydrothermal circuit. This article is a starting point for the ambitious endeavour of describing the present state of the Marsili Volcanic Seamount.

Acknowledgements
Other institutions contributed to ORION-GEOSTAR 3: Tecnomare S.p.A. and ISMAR-CNR (Italy); TUB, TFH and IFM-GEOMAR (Germany); IFREMER and ORCA (now SERCEL) (France). Thanks to the Captains and the crew of the R/V Urania. Thanks are also due to European Commission that funded the project.

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