Project n. 037110

NEAREST

"Integrated observations from NEAR shore sourcES of Tsunamis: towards an early warning system"

Instrument: STREP

Thematic priority: 1.1.6.3 GOCE (GlObal Change and Ecosystems)

D7: Deployment cruise of broad band OBS and cruise report

Due date of deliverable: 12

Actual submission date: 12

Start date of project: 1/10/2006

Duration: 3 years

Organisation name of lead contractor for this deliverable: AWI

Project Co founded By the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a gruop specified by the Consortium (including Commission Services	
CO	Confidential, only for members of the Consortium (including Commission Services)	

1. INTRODUCTION: NEAREST PROJECT

NEAREST is an EU-funded project (GOCE, contract **n. 037110)** which is mainly addressed to the identification and characterisation of large potential tsunami sources located near shore in the Gulf of Cadiz (fig. 1) through the near real-time detection of signals by a multiparameter seafloor observatory GEOSTAR like.

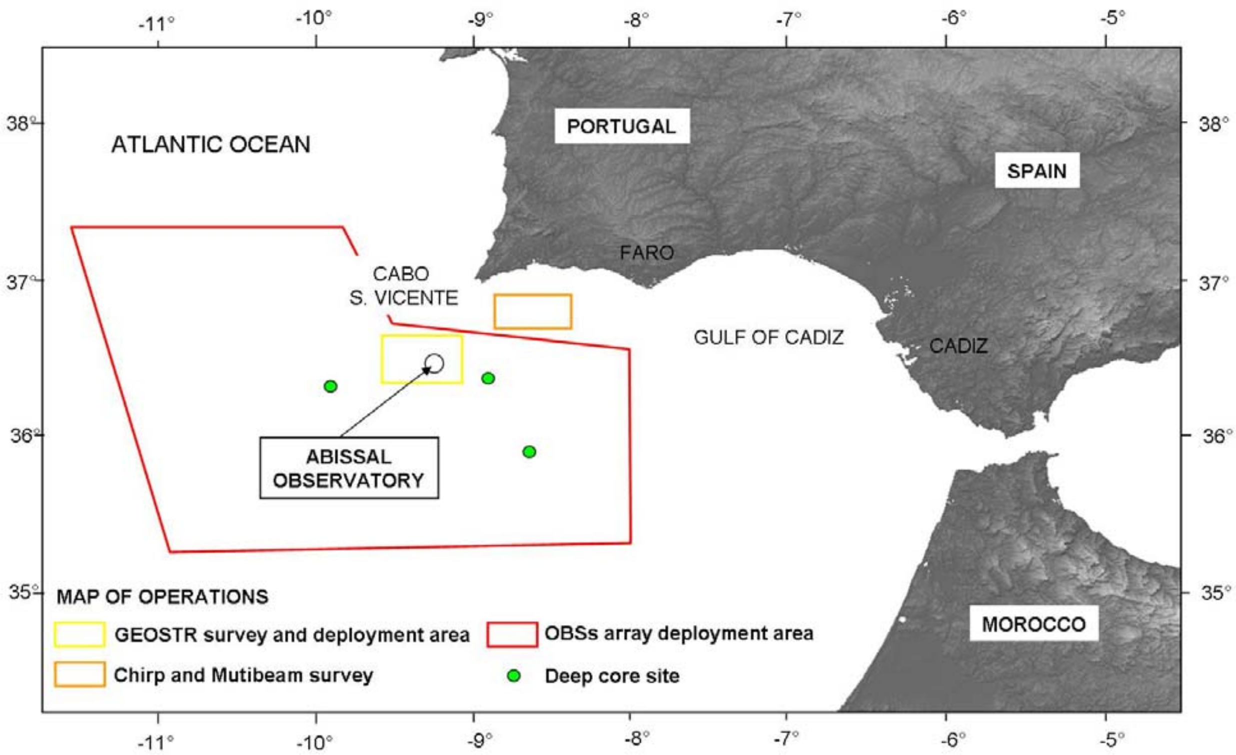

Fig. 1 - Working area

In this area, highly populated and prone to devastating earthquakes and tsunamis (e.g., 1755 Lisbon earthquake), a very good geological/geophysical knowledge has already been acquired in the last decade so it represent an excellent place in which test the near real-time detection of seismic signals.

The methodological approach will be based on the cross-checking of multiparameter time series, acquired on the seafloor by a long-term deep-sea station, equipped with real-time communication to an onshore main station, and by broad band Ocean Bottom Seismometers. All these data series also will be integrated with those coming from land seismic and tide gauge stations, actually active, to be used in a feasibility study for an Early Warning Systems (EWS) prototype in this peculiar area. The EWS will be based on reliable procedures to pass the needed parameters and information to the decision-makers (e.g., local civil protection authorities).

NEAREST, moreover, will search for sedimentological evidence tsunamis records to improve the knowledge on the recurrence time for extreme events and will try to measure the key parameters for the comprehension of the tsunami generation mechanisms.

Another aspect investigated by the project is the improvement of integrated numerical models for the building of more accurate scenarios of tsunami impact and the production of accurate inundation maps in selected areas of the Algarve (SW Portugal), highly hit by the 1755 tsunamis.

To realize all these aims a first NEAREST cruise was planned in august 2007 in order to deploy the abyssal multipurpose observatory and the array of ocean bottom seismometers (OBS).

1.1. GEOLOGICAL SETTING

The SW Iberian Margin is located at the eastern end of the Azores-Gibraltar-Fracture zone, wich is the Eurasia-Africa plate boundary in agreement with the plate-kinematic reconstructions (Olivet et al. 1996; Srivastava et al., 1990).

The area could be divided in two main morphotectonic domains (Tortella et al., 1997): the first between the Gorringe Bank and Cabo Sao Vicente to the west, and the Gulf of Cadiz, between the Cabo Sao Vicente and the Strait of Gibraltar to the east (fig. 2).

The first area is characterized by a complex and irregular topography, dominated by large seamounts, deep abyssal plains, and massive rises (e.g. Bergeron and Bonnin, 1991; Gràcia et al., 2003a, Terrinha et al., 2003; Zitellini et al., 2004) such as the Gorringe Bank. The second area is characterized by a smoother topography and by a prominent NE-SW trending positive free-air gravity anomaly (Dañobeitia et al., 1999; Gràcia et al., 2003b).

During the Triassic-Jurassic break-up of Pangea, the eastward drifting of Africa respect to Iberia led to the formation of a rift basins between the new continental margins; this divergent stage ended in early Late Cretaceous. Subsequent northwards migration of Africa with respect to Eurasia led to subduction of western Tethis toward East (Late Cretaceous-Paleogene) and final continental collision with the formation of the Betics-Rif mountains belts and the Gibraltar Arc (Miocene). The

Gibraltar Arc emplacement produced a number of allochthonous units identified from the Gulf of Cadiz to the Horseshoe Abyssal Plain (Bonnin et al., 1975; Torelli et al., 1994; Flinch et al., 1996; Maldonado et al., 1999; Gràcia et al., 2003b; Medialdea et al., 2004).

From Tertiary up to now the main compression direction has rotated anticlockwise, currently the latest GPS kinematic models (Nocquet et al., 2004), show a WNW-ESE main direction of the relative movements between the African and Iberian plates.

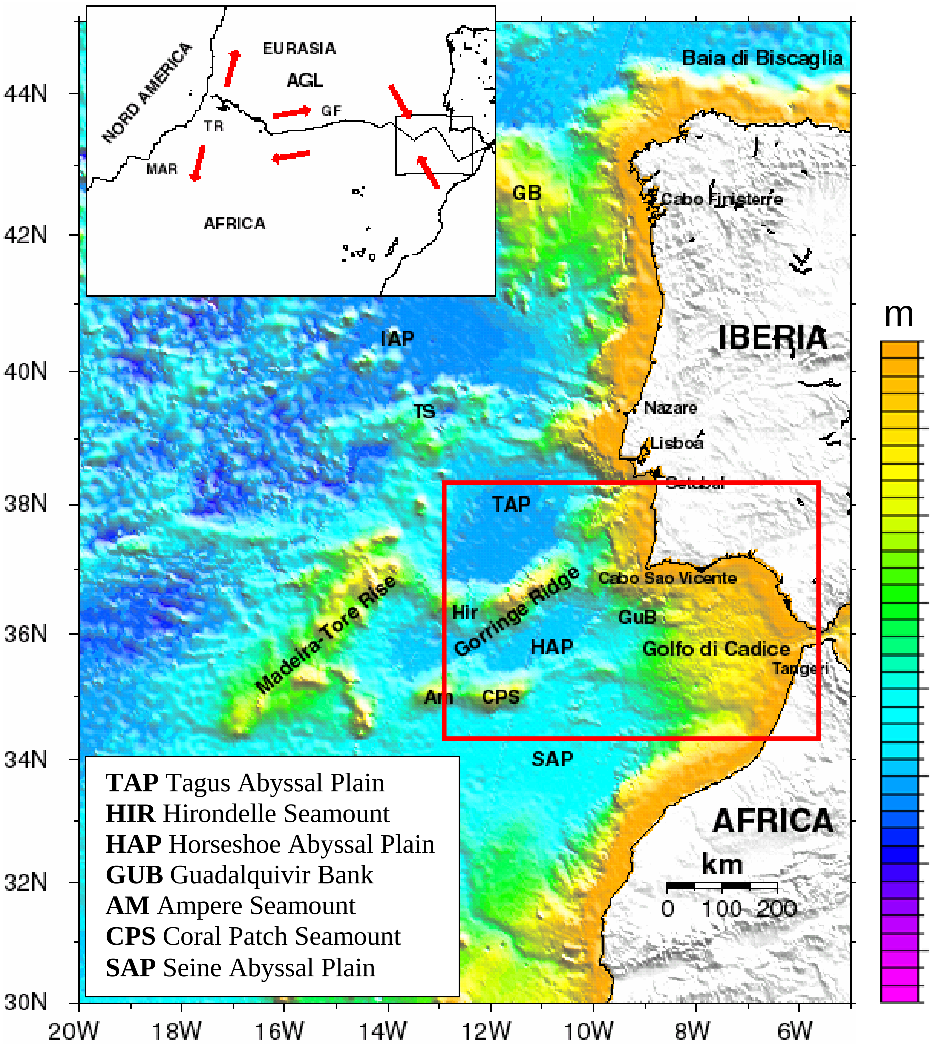

Fig. 2 – SW Iberian margin

Plate convergence of 4 mm/yr (Argus et al., 1989; Nocquet et al., 2004) is accommodated, in this area, over a wide and diffuse deformation zone (Sartori et al., 1994; Hayward et al., 1999)

characterized by significant and widespread seismic activity (e.g., Grimison and Chen, 1986). This tectonically active deformation zone was been source of the largest earthquakes that affected the East Atlantic cost since historical times (i.e. 1531, 1722, 1755, 1969) (Fukao, 1973, Martins and Mendes-Victor, 1990). The 1st of November 1755 occurred the most catastrofic of this event, the Lisbon Earthquake, this event was followed by a tsunami that struck the city and impact all the West Europe and Nord African cost. A moment magnitude >8.5 (MW) has been estimated for the Lisbon Earthquake (Martins and Mendes-Victor, 1990; Abe, 1989). The location of the tectonic structure that caused the earthquake end the tsunami has been debated during the last decades (e.g., Udías et al., 1976). After 15 years of geophysical investigation (Rifano-1992, Eu_Bigsets-1998, Parsifal-2000, Hits-2001, Voltaire-2002, Sismar-2003, ESF_Swim-2003) a series of regional tectonic active structures was described and showed to be the possible tsunamigenic tectonic sources, the Marquise de Pombal fault, the Horseshoe fault and the Portimao fault (e.g. Zitellini et al., 2001; Gràcia et al., 2003; Terrinha et al., 2003). This structures converge in a relatively small area located 100 miles offshore Cabo Sao Vicente, the SW culmination of Iberian peninsula that was choosen for the deployment of the seafloor observatory.

1.2. State of the Art for Tsunami Detection

The reason for developing a real-time, deep ocean tsunami measurement system was to foreseen the impact of tsunamis on coastal areas in time to save lives and protect property.

The first approach to Tsunami waves monitoring was a combination of tide gauges and seismometers. After that, in order to provide a much earlier warning of an approaching tsunami, NOAA (National Oceanic and Atmospheric Administration), developed the research project for Deep-ocean Assessment and Reporting of Tsunami (DART), using buoys in deep sea, acoustically linked to sea-floor pressure gauges. In turn, the buoys would relay the sensor data to a central land site by satellite radio links.

The first-generation DART was based on an automatic detection and reporting algorithm triggered by a threshold wave-height value. The DART II design incorporated two-way communications that enables tsunami data transmission on demand, independent of the automatic algorithm.

Each DART gage was designed to detect and report tsunamis on its own, without instructions from land. The tsunami detection algorithm developed in the gage's software works by firstly estimating the amplitudes of the pressure fluctuations within the tsunami frequency band and then testing these amplitudes against a threshold value. The amplitudes are computed by subtracting predicted pressures from the observations, in which the predictions closely match the tides and lower frequency fluctuations. The predictions are updated every 15 seconds, which is the sampling interval of the DART gages. The detection threshold was defined using statistical analysis on background oceanic noise. Based on past observations, a reasonable threshold for the North Pacific was fixed to 3 cm. When the amplitude exceeds the threshold, the gage goes into a rapid reporting mode to provide detailed information about the tsunami.

1.3 TSUNAMI MODELLING

The life of Tsunami can usually be divided in three phases: generation (source), propagation and inundation.

Using different models to generate the initial displacemment of the seafloor and long waves or shallow water models to decribe tsunami propagation and to calculate the inundation, tsunami modelling has proved to be an important tool to evaluate the impact of tsunami waves in coasts and to assess the candidate sources for historical tsunamis in the possible tsunamigenic zones along the studies area.

However several authors investigated the tsunami sources in the SW of Iberia and Gulf of Cadiz, Fukao (1973), Johnston (1996), Baptista (1998,2003), Zitellini (1999) and Gutscher(2003), in the purpose to explain observable data for historical tsunamis (the great Lisbon earthquake and tsunami of 1755 with estimate magnitude 8.5-9), or to confirm instrumental records for recent tsunamis (the 1969 Horseshoe fault (HSF) earthquake MW 7.9).

The present study led in this area consists to use tsunami modelling to determine the impact of waves in the different coasts and, afterward, evaluate tsunami risk and vulnerability. Modelling was performed with COMCOT code, from Cornell University (Liu et al., 1994). The simulation domain covers the eastern part of the Atlantic Ocean offshore Morocco and the Gulf of Cadiz, from the most prone tsunami generation area. Three nested grid layers of different resolution (0.008º, 0.002º and 0.0005º) are incorporated to obtain a good description of bathymetric and topographic effects near shore. Results of the numerical simulations are discussed in terms of wave heights, flow depth and maximum velocity.

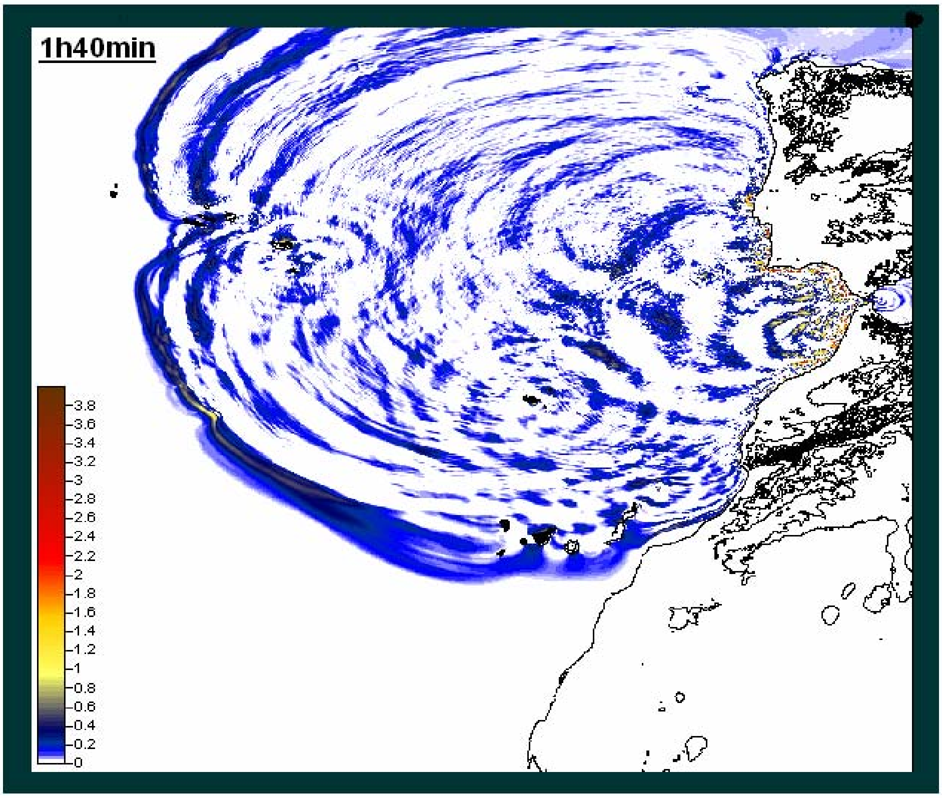

Fig:3 - Modelling of tsunami propagation for the 1755 tsunami for the source proposed by Zitellini et al. (1999) and Baptista et al. (2003)

2. NEAREST 2007 SECOND LEG: OBS DEPLOYMENT

Tectonic structures in the transition from the Azores fracture zone to the postulated subduction zone in the area of the Strait of Gibraltar will be localized and characterized that have the potential to cause Tsunamis. For this purpose we deployed 22 broadband ocean bottom seismometers (OBS) from the German DEPAS instrument pool coordinated by the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven and the GeoForschungsZentrum, Potsdam. Seismicity studies and passive seismic imaging techniques will be performed after 12 months recording, when the OBS have been recovered. During the transfer among the OBSs Chirp and Multibeam data were collected. Despite the project to build an array of 24 OBSs, cause technical problems during the second leg, it was possible to deploy only 22 of them. The last 2 are scheduled to be deployed as soon as possible.

2.1 OBS DEPLOYMENT

24 DEPAS LOBSTER (**L**ongterm **O**cean **B**ottom **S**eismometer for **T**sunami and **E**arthquake **R**esearch, see Fig 4 and 5) K/MT 510 manufactured by K.U.M. Umwelt- und Meerestechnik Kiel GmbH, Germany, are used during the experiment. They are equipped with a Güralp CMG-40T broadband seismometer incorporated in a titanium pressure housing, a hydrophone, and a GEOLON MCS (**M**arine **C**ompact **S**eismocorder) data logger from SEND GmbH Hamburg, Germany. The electric power supply for the recorder and the seismometer is granted by 132 lithium power cells. Each sensor channel is sampled with 100 Hz, preamplifier gain of the hydrophone channel is 4 and 1 for the three seismometer components. The total disk space of the stations is 20 GB. Depending on the local seismic activity and active seismic surveys in the region the disk space can cover a recording time of 11 to 12 months. The clock of the data loggers were synchronized by GPS time before deployment and will be synchronized again after recovery of the instruments. The time difference during the recording period will then be corrected linearly. The seismometers are equipped with a cardanic levelling mechanism, which will be initiated a few hours after deployment, when the OBS is located on the seafloor, and then every 15 days (see Fig 5).

Fig 4 – OBSs on board

Fig 5 - Photograph of the LOBSTER (adapted from the LOBSTER manual).

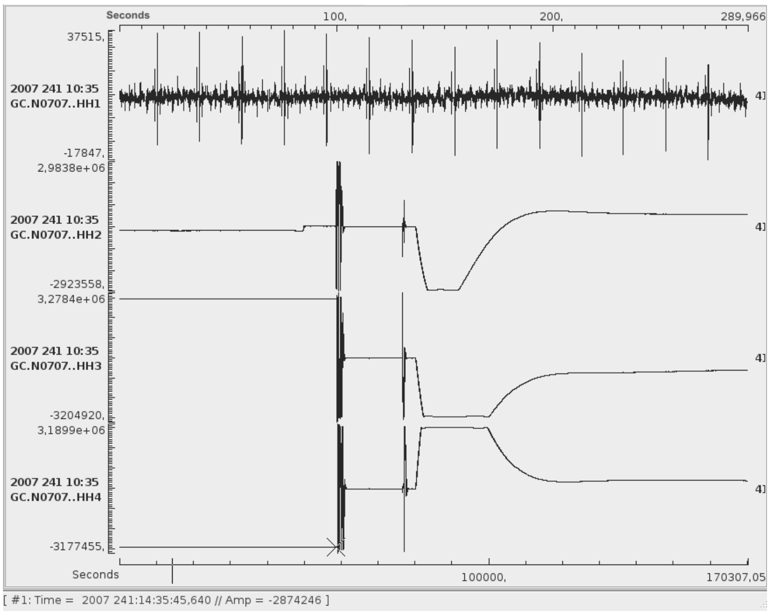

Fig 6 - Seismogram example of first levelling of OBS07 on the seafloor 4 hours after recording started. The uppermost trace is the hydrophone channel, where shooting signals of the RV Atalante can be seen. Below are the three seismometer channels. The time scale on top belongs to the time window showed; the time scale on the bottom shows gives the position of the time window within the whole recording interval.

2.2 Release test

The KUMQUAT release unit is the most important part of the OBS for a secure recovery. To proof the proper operation of the release units under deployment conditions in the deep sea we performed two release tests with 13 release units, each. The releasers were brought down to 3500 m depth using the geological winch of R/V Urania. Then the acoustic release code of each release unit was send three times. Due to the noisy conditions beneath the vessel not all acoustic responses from the release units could be received by the deck unit. After recovery onboard all release hooks were open confirming the proper operation of the release units at the average operation depth.

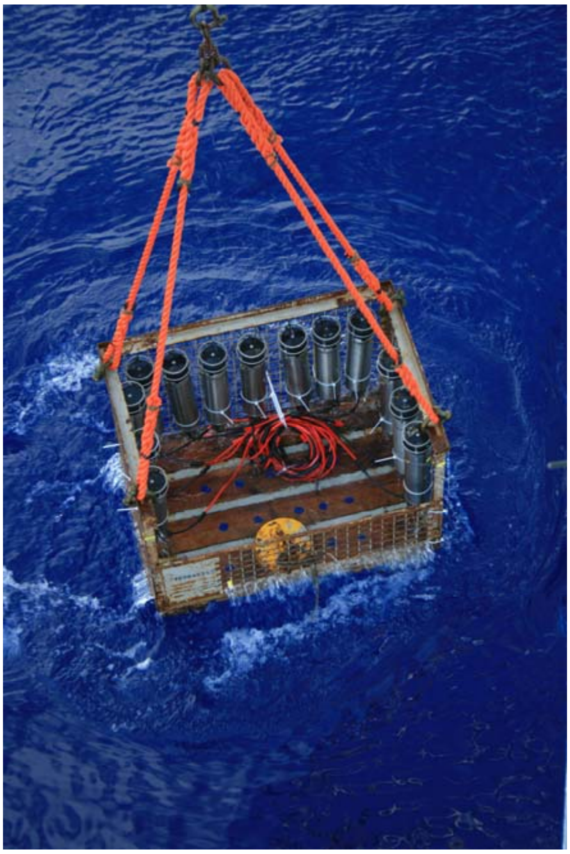

Fig 7 - Photograph of the releaser test configuration.
Parameters of test 1: 29.08.2007, 02:00 UTC
36°21.977'N 09°44.975'W, 3500 m depth
all tested 13 releaser units released
test 2: 29.08.2007, 06:30 UTC
36.21.684' N 09°44.711'W, 3500 m depth
all tested 13 releaser units released

2.3 STATIONS DEPLOYMENT

During the cruise 22 of 24 instruments were deployed (Figure 8, table 4). Unfortunately, the power connector of one recorder pressure tube was damaged. Therefore the 24th OBS could not be deployed. The remaining anchor was used to conduct a test measurement with OBS07 close to the position of the GEOSTAR observatory. OBS07 was successfully recovered after 2 days. This station was planned to be re-deployed at the end of the cruise. During deployment of OBS14 another problem occurred, because the head buoy became trapped below the OBS that could prevent its recovery. To save the OBS we released it from its anchor before it reached the ground.

OBS14 was re-deployed with the last available anchor. Finally, the OBSs n. 7 and 24 remain onboard at the end of the cruise. We will try to deploy them in the near future by another vessel.

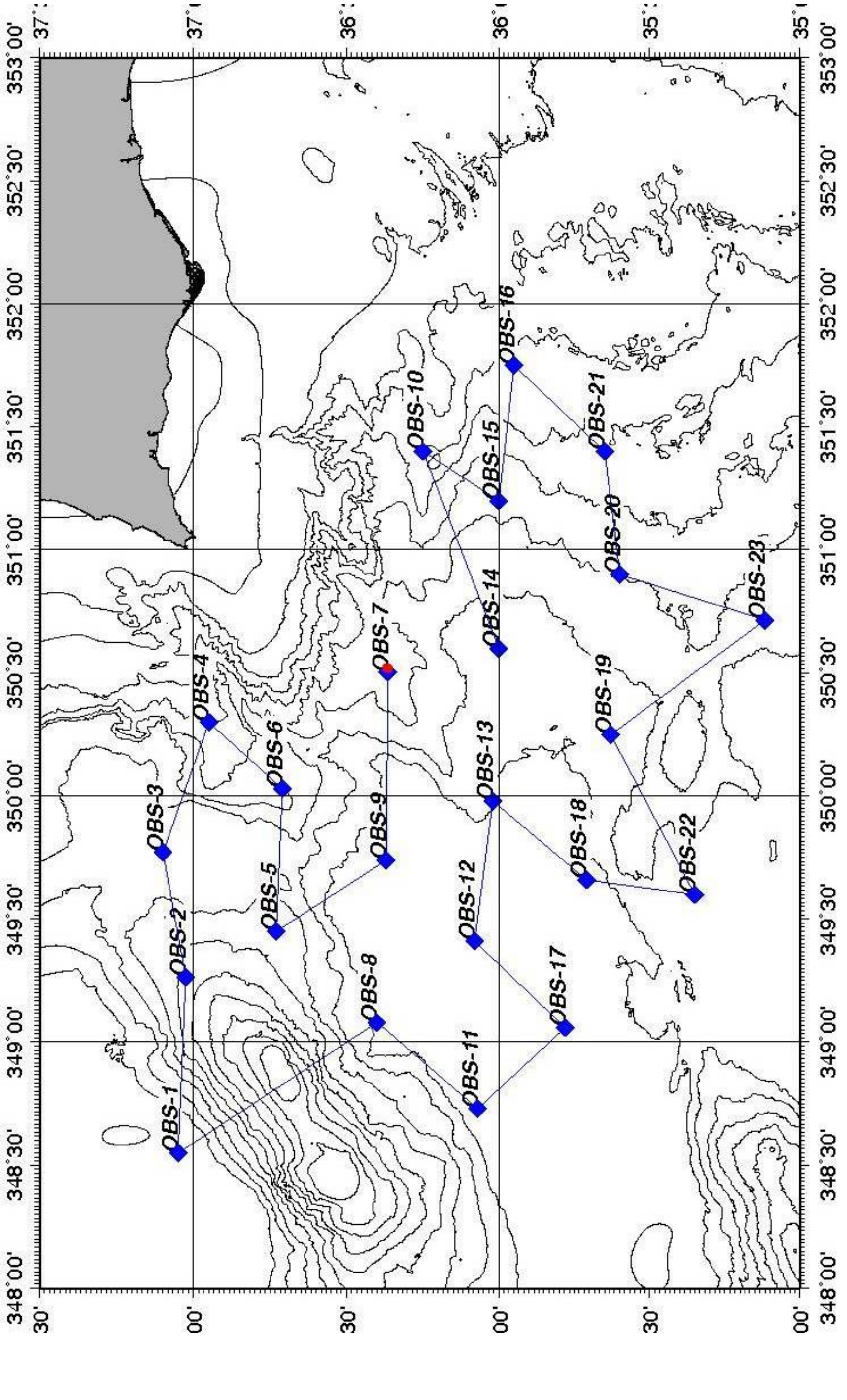

Fig 8.- Locations of the deployed OBS.

OBS	date (UTC)	time (UTC)	latitude	longitude	water depth
OBS 01	30.08.2007	10:26 h	37° 3.023' N	11° 26.997' W	4800 m
OBS 02	30.08.2077	06:42 h	37° 1.535' N	10° 44.061' W	2269 m
OBS 03	30.08.2007	03:13 h	37° 6.029' N	10° 13.796' W	3935 m
OBS 04	29.08.2007	23:00 h	36° 56.998' N	9° 42.008' W	1980 m
OBS 05	29.08.2007	17:52 h	36° 43.809' N	10° 33.002' W	3095 m
OBS 06	29.08.2007	20:44 h	36° 42.585' N	9° 58.161' W	2948 m
OBS 07*	29.08.2007	11:04 h	36° 21.902' N	9° 29.812' W	3205 m
OBS 08	30.08.2007	16:43 h	36° 23.997' N	10° 55.191' W	4668 m
OBS 09	29.08.2007	14:59 h	36° 22.199' N	10° 15.607' W	4811 m
OBS 10	01.09.2007	22:02 h	36° 14.974' N	8° 35.993' W	2061 m
OBS 11	30.08.2007	19:39 h	36° 4.154' N	11° 16.224' W	4858 m
OBS 12	31.08.2007	01:23 h	36° 4.787' N	10° 35.401' W	4858 m
OBS 13	31.08.2007	13:28 h	36° 1.208' N	10° 1.218' W	4500 m
OBS 14	02.09.2007	04:11 h	36° 0.010' N	9° 24.008' W	4209 m
OBS 15	01.09.2007	19:54 h	35° 59.988' N	8° 48.008' W	3360 m
OBS 16	01.09.2007	12:45 h	35° 56.990' N	8° 14.974' W	2061 m
OBS 17	30.08.2007	22:30 h	35° 46.783' N	10° 56.335' W	4764 m
OBS 18	31.08.2007	16:09 h	35° 42.593' N	10° 20.418' W	4605 m
OBS 19	31.09.2007	22:57 h	35° 37.796' N	9° 45.024' W	4394 m
OBS 20	01.09.2007	06:45 h	35° 35.987' N	9° 6.011' W	3442 m
OBS 21	01.09.2007	09:39 h	35° 38.984' N	8° 35.997' W	2575 m
OBS 22	31.08.2007	18:39 h	35° 21.009' N	10° 24.015' W	4101 m
OBS 23	01.09.2007	3:19 h	35° 7.009' N	9° 17.108' W	4745 m
OBS24	not deployed yet				
OBS07	Recovered and not re-deployed				

Table 1. OBS deployment parameters.

2.4 TEST MEASUREMENT: OBS07 CLOSE TO GEOSTAR SITE

To test the operation of the seismic acquisition system of the GEOSTAR observatory OBS07 was deployed close to the GEOSTAR position for only 2 days to allow parallel recording of the seismic activity. The deployment on August 29th and the recovery on August 31st 2007 (Fig 9, table 2) was conducted without any problems. Levelling of the seismometer was performed 4 hours after recording started and again one day later. The sample rate was 100 Hz, preamplifier gain was 4 for the hydrophone, and 2 for the seismometer channels. The instrument operated without any errors. About 134 MB were recorded. Data retrieval from MCS recorders was performed using send2x software. However, airgun signals from an active seismic survey of Spanish scientists onboard the French R/V Atalante performed during that time (Fig 6) dominated the recorded signals. Nevertheless, two small local earthquakes could be detected. One from August 31st 2007 is shown in figure 12.

Fig 9 - Recovery of OBS07 at the sea surface.

	first release		on surface		on deck		coordinates		
station	date (UTC)	time (UTC)	date (UTC)	time (UTC)	date (UTC)	time (UTC)	latitude	longitude	water depth
OBS07	31.08.2007	08:52 h	31.08.2007	09:32 h	31.08.2007	09:54 h	36° 21.959' N	9° 29.724' W	3207 m

Table 2. Recovery parameters of OBS07 close to the GEOSTAR site.

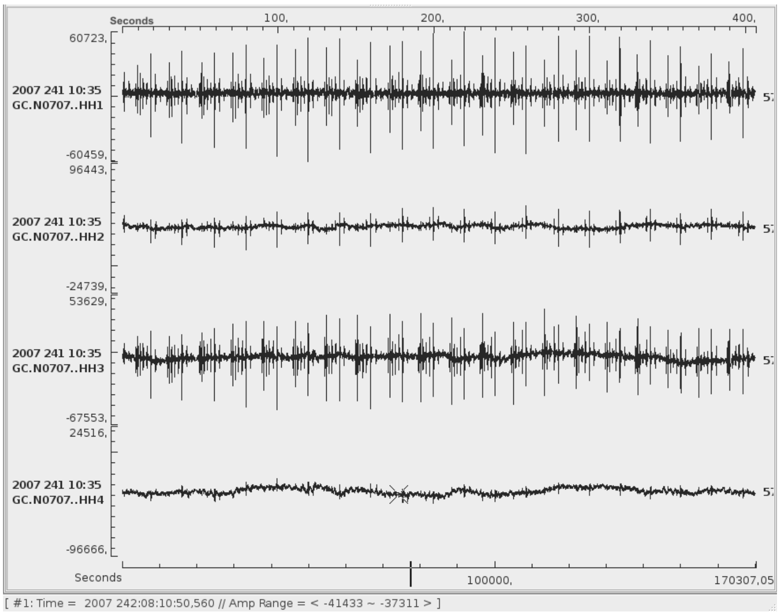

Fig 10 - Record example of OBS07. The data is dominated by strong airgun signals from a seismic survey of RV Atalante. The prominent signal on the three seismometer channels (bottom) is the S wavelet of the earthquake.

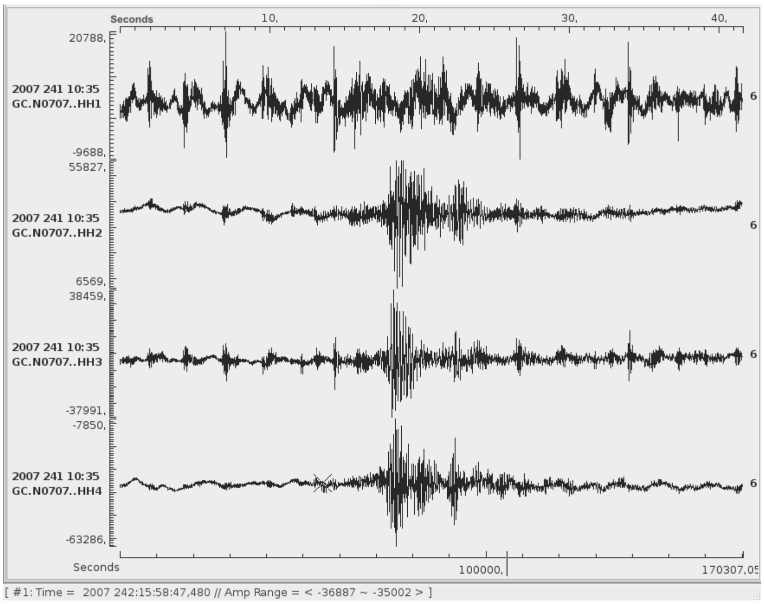

Fig 12 - Example of a local seismic event recorded by OBS07 on August 31st 2007.

URANIA 2007 SECOND LEG: Scientific and technical personnell

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Corcione Procolo G.	Mechanic
Mastronardi Luigi	Boatswain
Martiradonna Nicola	Seaman
Sano Gian	Seaman
Zimmitti Sebastiano	Cook
Pizzonia Leonardo	Steward
De Lauro Tommaso	Y.D.Boy
Cannavò Giovanni	Galley Boy
De Simone Troncone Paolo	Y.D.Boy