NEAREST (INTEGRATED OBSERVATIONS FROM NEAR SHORE SOURCES OF TSUNAMIS: TOWARDS AN EARLY WARNING SYSTEM)

http://nearest.bo.ismar.cnr.it

NEAREST 2008 Cruise Preliminary Report r/v Urania

1st Aug 2008 - 4th Sept 2008

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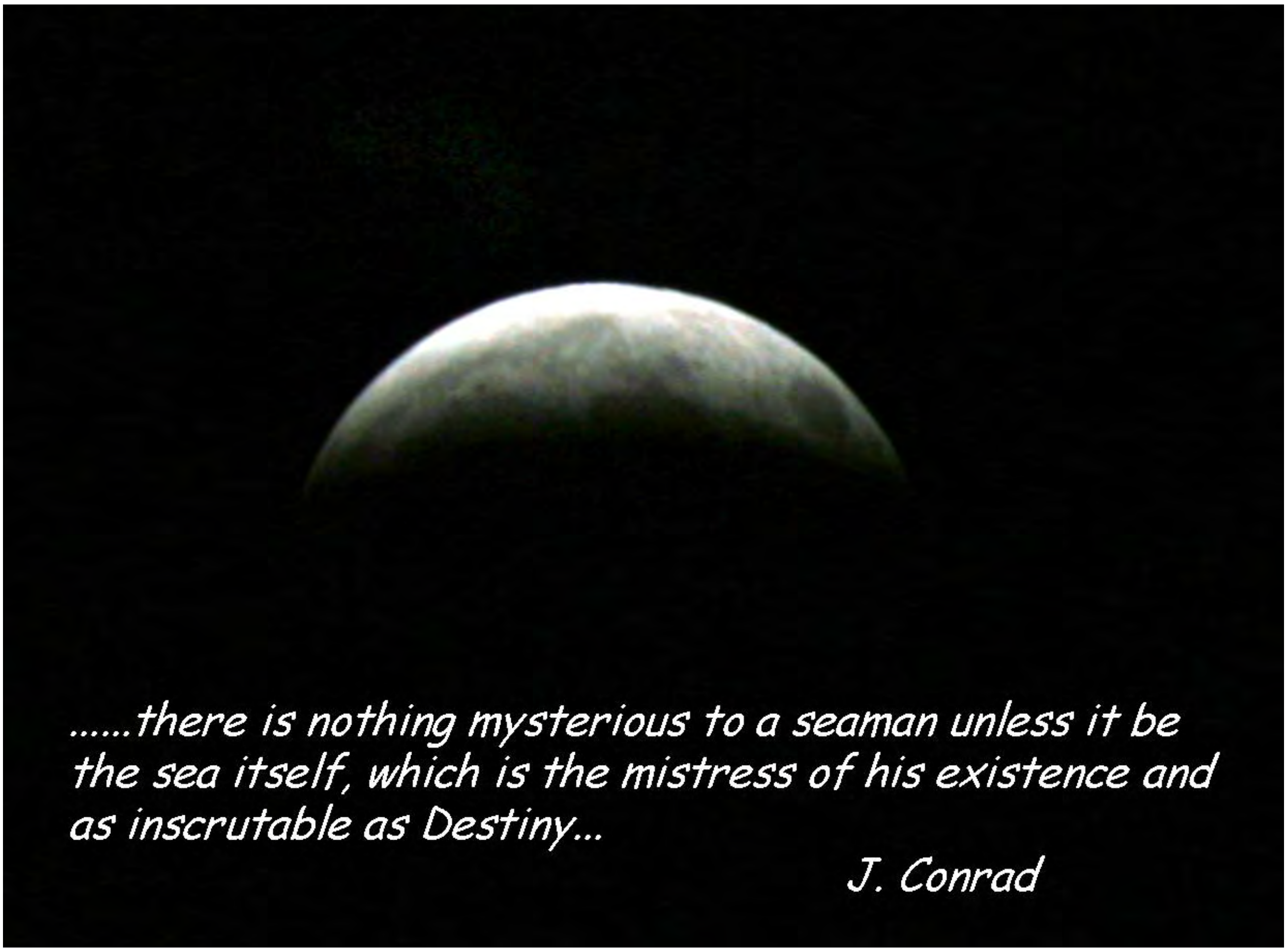

ISTITUTO DI SCIENZE MARINE - SEDE DI BOLOGNA

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Cover: Moon eclypse in the Atlantic (16-08-2008) by L.Innocenzi

Graphics and maps by : G. Carrara, F. D'Oriano

We want to thank the Master E. Gentile and the crew of RV Urania for their great and friendly support and professional handling of the instruments… and for the graffa's party!

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Summary of the operations

During the NEAREST 2008 Cruise were performed the following operations:

1) Recovery of 24 OBSs

2) Recovery of the seafloor multiparametric abyssal station

3) Recovery of the communication buoy's cable

4) the acquisition of multibeam bathymetric data offshore Morocco .

These operations were planned on behalf the European Project NEAREST designed to identify, characterize and monitor the large potential tsunami sources located near shore in the Gulf of Cadiz (SW Iberian Margin).

1. Introduction: NEAREST Project

NEAREST (Integrated observations from Near Shore Sources of Tsunamis: towards an early warning system) is carried out on behalf the EU Specific Programme “Integrating and Strengthening the European Research Area”, Sub-Priority 1.1.6.3, “Global Change and Ecosystems”, Call identifier: FP6-2005-GLOBAL-4 (OJ 2005 C 177/15, contract n. 037110) under the coordination of ISMAR (Institute of Marine Sciences, department of Bologna, Italy) and the partnership of nine European and one North African institutions (table 1).

1	Consiglio Nazionale delle Ricerche Istituto Scienze Marine, Dipartimento di Bologna	Italy	ISMAR
2	Fundação da Faculdade de Ciências da Universidade de Lisboa - Centro de Geofísica da Universidade de Lisboa	Portugal	FFCUL
3	Consejo Superior de Investigaciones Cientificas – Unitat de Tecnologia Marina - Centre Mediterrani d’Investigacions Marines i Ambientals	Spain	CSIC
4	Alfred-Wegener-Institute fur Polar-und Meeresforschung Geophysics section	Germany	AWI
5	Université de Bretagne Occidentale UMR 6358 Domaines Océaniques	France	UBO-UMR6358
6	Istituto Nazionale Geofisica e Vulcanologia Roma 2 section – Marine Unit RIDGE	Italy	INGV
7	Technische Fachhochschule Berlin - FB VIII - Maschinenbau, Verfahrens- und Umwelttechnik - AG Tiefseesysteme	Germany	TFH
8	Instituto Andaluz de Geofísica - Universidad De Granada	Spain	UGR
9	Instituto de Meteorologia Divisão de Sismologia	Portugal	IM
10	Centre National pour la Recherche Scientifique et Technique	Morocco	CNRST
11	XISTOS Développement S.A.	France	XISTOS

Table 1: List of participant institutions

NEAREST is a multidisciplinary project devoted to the study of the tsunami phenomena in its different aspects which can be summarized as follows: the identification and characterisation of the large potential tsunami sources located near shore in the Gulf of Cadiz; the improvement of near real-time detection of earthquake and tsunami signals by a multiparameter seafloor observatory (Geostar-like station) for the characterisation of the potential tsunamigenic sources to be used in the development of an Early Warning System (EWS) Prototype; the improvement of integrated numerical models enabling 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.

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. This region represent therefore an excellent place in which test the near real-time detection of seismic signals.

The methodological approach is be based on the cross-checking of multiparameter time series, acquired on the seafloor by 24 broad band Ocean Bottom Seismometers and by a long-term deep-sea station developed by the INGV partner upgrading the GEOSTAR technology. This abyssal station is equipped with real-time communication to an onshore main stations located in Portugal, Morocco and Spain. 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).

In addition, NEAREST 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. Among the different actions undertaken by NEAREST to accomplish the abovementioned tasks a cruise was carried out in august 2007, through the R/V Urania (see NEAREST 2007 cruise report available on http://nearest.bo.ismar.cnr.it/), in order to deploy the abyssal multipurpose observatory and the array of 24 ocean bottom seismometers (OBS). The main goal of the NEAREST 2008 campaign is to recover the instrument deployed at sea one year ago: the abyssal station, the buoy and the 24 OBS. Once completed these operations, we will carry out the completion of the swath bathymetric mapping of the continental slope South of Portimao (Portugal) and platform along the Moroccan coast, between Rabat and Tanger. The NEAREST 2008 campaign was organized in two legs. The first devoted to the recovery of the 24 OBS stations, the second for the recovery of the abyssal station, the sea bottom sampling and the swath bathymetry mapping.

1.1. Geological setting

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

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.1).

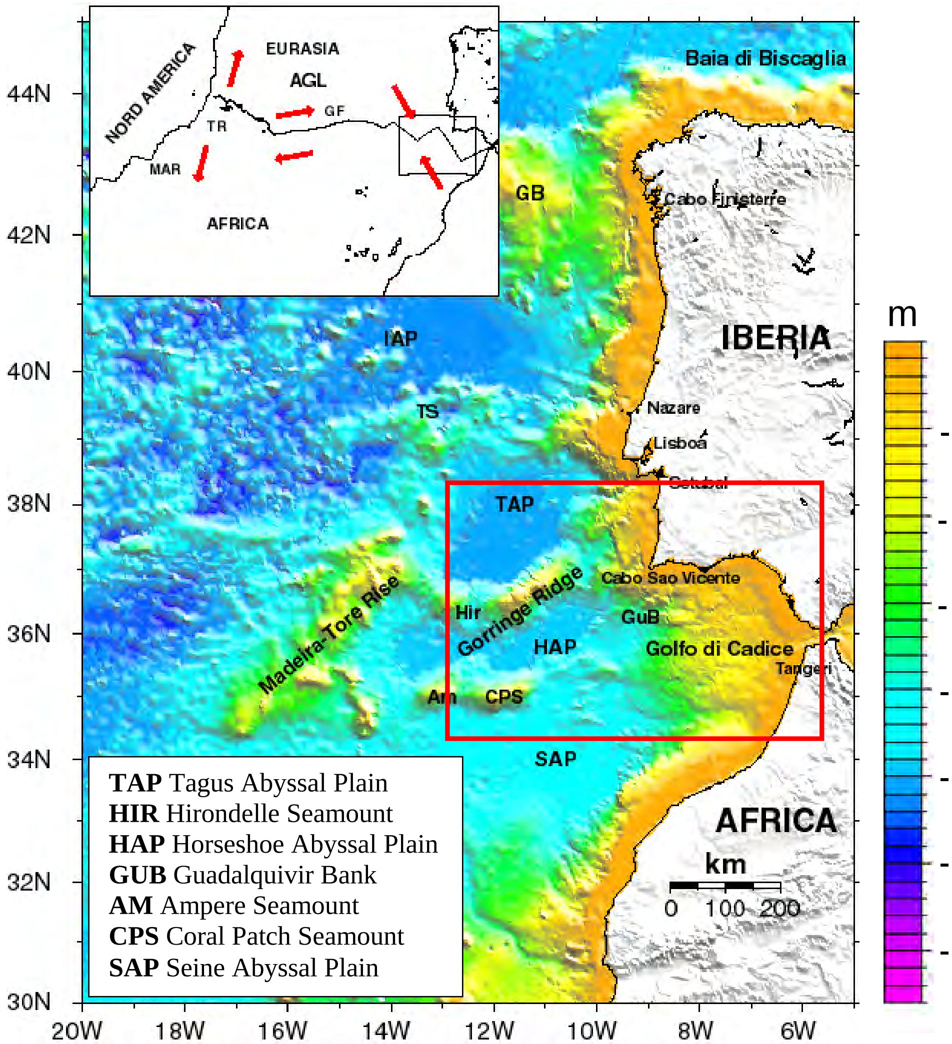

Fig. 1 – SW Iberian margin

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.

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.

2. NEAREST 2008 CRUISE

2.1 Objectives

The scientific survey was performed between 1th August and 4th September 2007 offshore Cabo Sao Vicente and in the Gulf of Cadiz, in Portuguese and Moroccan ZEE. The main goals of the cruise were the recovery of the whole instrumentation deployed during the previous cruise NEAREST 2007. The first leg was entirely dedicated to the recovery of the 24 oceanic bottom seismeters (OBS) while the second leg was devoted to the recovery of the abyssal station and the mooring cable. In addition sub-bottom profiles and multibeam data were collected. These data will improve either the geological than the geophysical knowledge of the tectonic architecture of the area where, it is hypothesized, is localized the source of the 1755 Lisbon Earthquake. The cruise was divided in two legs because the large volume of instruments to be recovered. The first leg took place from 1th of August until the 13th of August, the second leg from 14th of August until 28th of August 2008.

3. First Leg: OBS recovery

A passive seismic experiment was conducted in the Gulf of Cadiz during the last 12 months within the NEAREST project. Its aim is the detailed investigation of the local seismicity and the Earth structure in the source region of the Lisbon 1755 earthquake and tsunami.

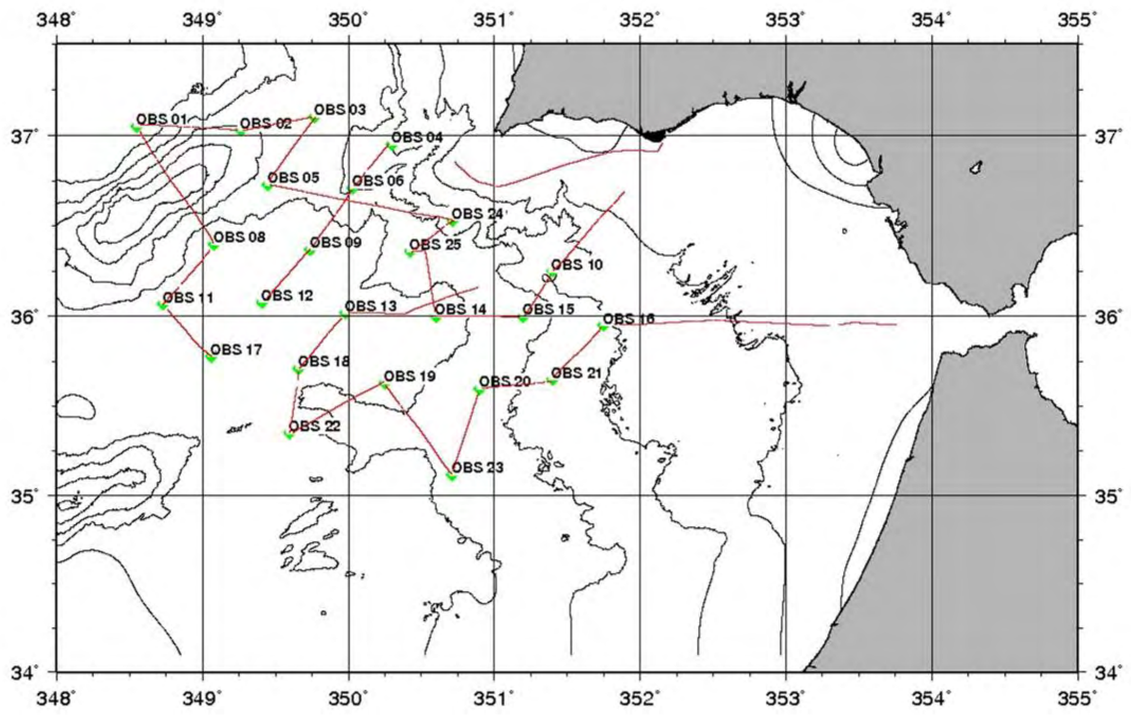

Figure 2. Locations of the recovered OBS during NEAREST-2008 cruise.

Tectonic structures, in the transition from the Azores fracture zone to the postulated subduction zone in the area of the Strait of Gibraltar, that have the potential to cause Tsunamis will be localized and characterized. For this purpose 24 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 were deployed between September 2007 and August 2008. During the cruise 24 of 24 instruments were recovered (fig. 2). Seismicity studies and passive seismic imaging techniques will be performed after the quality control of the data has been finished.

3.1 OBS technical description

24 DEPAS LOBSTER (**L**ongterm **O**cean **B**ottom **S**eismometer for **T**sunami and **E**arthquake **R**esearch, see figure 3) K/MT 510 manufactured by K.U.M. Umwelt- und Meerestechnik Kiel GmbH, Germany, were used during the experiment. They were equipped with a Güralp CMG-40T broadband seismometer incorporated in 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 was granted by 132 lithium power cells. Each sensor channel was sampled with 100 Hz, preamplifier gain of the hydrophone channel was 4 and 1 for the three seismometer components. The total disk space of the stations was 20 GB each. The clocks of the data loggers were synchronized by GPS time before deployment and after recovery of the instruments. The time difference during the recording period is corrected linearly. The seismometers are equipped with a cardanic levelling mechanism, which was initiated a few hours after settlement of the OBS at the seafloor, and then every 15 days.

Figure 3 - LOBSTER

3.2 Station recovery

Approaching to the deployment positions we tried to range the OBSs at the seafloor to get a better control on their positions (coordinates, depth). For shallow OBSs (2000 to 3000 m water depth) we stopped the ship at 1 nm of distance, whereas for the more deep OBSs we stopped already at 2 nm from their position. After enabling the release unit we carried out a full set of range measurements from each direction for the two first OBS on the track (OBS16 and 21; see table 2). For OBS 16 (~2070 m water depth) we got very clear answers from the release unit from all measurement positions, whereas for OBS21 we got an answer only at 3 of 4 points. However, for both OBSs we were able to estimate the position at seafloor using a small software script which was provided by the colleagues from University of Hamburg. After release of both stations with the release command, we continued with ranging of the rising OBS from the last measurement point. These measurements could be used to estimate the arrival time at surface and the average rise velocity (1.2 m/s). This rise velocity was used to calculate the rise time of all the remaining OBS. It was proved by recovery at surface when the depth of the OBS was well known from the bathymetry.

OBS 16	time [UTC]	latitude		longitude		range
06.08.2008	6.02	35°	56.951' N	08°	13.954' W	2650 m
						2655 m
		35°	56.939' N	08°	13.947' W	2655 m
	6.20	35°	57.982' N	08°	14.987' W	2574 m
						2574 m
		35°	57.975' N	08°	14.992' W	2573 m
	6.34	35°	56.980' N	08°	15.978' W	2443 m
						2441 m
		35°	56.975' N	08°	15.982' W	2442 m
	6.50	35°	55.977' N	08°	14.990' W	2921 m
						2925 m
		35°	55.968' N	08°	14.984' W	2923 m
	6.51	release				
	6.54					2866 m
	6.55	35°	55.910' N	08°	14.984' W	2863 m
	6.56					2820 m
	6.57	35°	55.850' N	08°	14.990' W	2805 m
	6.58					2801 m
	6.59					2772 m
	7.00	35°	55.833' N	08°	14.989' W	2777 m
	7.01					2758 m
	7.02	35°	55.772' N	08°	14.976' W	2754 m
	7.03	35°	55.741' N	08°	14.970' W	2751 m
	7.04	35°	55.725' N	08°	14.976' W	(3363 m)
	7.06	35°	55.714' N	08°	14.963' W	(2750 m)
	7.07	35°	55.674' N	08°	14.951' W	(2756 m)
result		35°	57.115' N	08°	15.078' W	2015 m w.d.

OBS 21	time [UTC]	latitude		longitude		range
	10.15.25	35°	39.965' N	08°	35.973' W	3446 m
	10.15.52					no answer
	10.16.24					no answer
	10.17.07					3437 m
	10.17.23					3432 m
	10.31.58	35°	38.992' N	08°	36.994' W	no answer
	10.32.25					no answer
	10.32.58					no answer
	10.33.31					no answer
	10.34.10					no answer
	10.49.01	35°	37.972' N	08°	36.040' W	2847 m
	10.49.18	35°	37.969' N	08°	36.039' W	no answer
	10.49.45	35°	37.962' N	08°	36.040' W	2850 m
	10.49.59	35°	37.957' N	08°	36.041' W	2852 m
	11.05.30	35°	38.924' N	08°	35.044' W	2902 m
	11.06.05					2895 m
	11.06.20	35°	38.903' N	08°	35.067' W	2893 m
	11.07.00	release				
	11.11.36	35°	38.818' N	08°	35.097' W	2570 m
	11.12.36	35°	38.810' N	08°	35.105' W	2496 m
	11.13.36	35°	38.811' N	08°	35.115' W	no answer
	11.14.36	35°	38.813' N	08°	35.124' W	no answer
result		35°	38.696' N	08°	36.114' W	2504 m w.d.

Table 2. Ranging of OBS-16 and OBS21.

Unfortunately, we were not able to locate the remaining OBS, not only because of the tied time table which became even more tied due to unplanned stop at Faro due to the need of desembaking one member of the team because injured and bad sea conditions. We had big problems to hear the answers from the release units even for station shallower than 3000 m water depth, which was already observed at the releaser test in 2007 during the deployment cruise. Possible causes might be a strong layering (stratification) of the water column or the noise of RV Urania itself. However, in all cases the release unit got the signals from deck unit (fig. 4), since we could release all OBS. Sometime after sending the release code we tried to get the range close to the expected recovery position to assure the successful release and rise of the OBS. In most cases we got answer starting from a distance of at about 3600 m from the rising OBS.

Unknown regular signals (one ping about every 10 seconds) were recorded as answers at the deck unit at stations OBS23 and later at OBS14 (Later on, disappeared at station OBS14 during the ranging measuraments).

Figure 4. Deck unit 8011M used to communicate with the release unit of the OBS.

After we were sure about the arrival of the OBS at surface the ship was positioned some hundreds meters away from the expected position of recovery against the waves (normally SSE of the stations). At the estimated time the OBS could be quickly located at the surface. In most cases this was done by eye, since the flag and the float units could be easily seen during the day. Only one flag was missing. The flash lights helped during the night; also the radio beacons worked well but were not needed to locate the OBS.

The recovery on deck was possible in most cases within 10 to15 min after the appearance of the OBS at the sea surface due to the good work of the bridge and the deck crew. During the recovery an entering hook and the backboard crane was used. The position of recovery at deck was taken to calculate the mean coordinate of the OBS at depth from deployment and recovery coordinates. In most cases the difference in coordinates between deployment and recovery is very small (table 3 and 4)

.

Figure 5. LOBSTER recovery.

OBS Nr.	release date	release time	recovery on	recovery on deck		
	[UTC]		surface	time	latitude	longitude
OBS 01	10.08.2008	14:21	15:35	15:55	37° 03.589' N	11° 26.719' W
OBS 02	10.08.2008	19:44	20:15	20:21	37° 01.461' N	10° 44.030' W
OBS 03	10.08.2008	22:58	23:54	23:59	37° 06.029' N	10° 13.676' W
OBS 04	09.08.2008	06:10	06:40	06:49	36° 57.212' N	09° 42.216' W
OBS 05	11.08.2008	03:01	03:44	03:52	36° 43.794' N	10° 33.195' W
OBS 06	09.08.2008	09:10	09:52	10:00	36° 42.417' N	09° 58.142' W
OBS 08	10.08.2008	07:17	08:22	08:30	36° 23.715' N	10° 55.338' W
OBS 09	09.08.2008	12:41	13:45	14:02	36° 22.401' N	10° 15.748' W
OBS 10	11.08.2008	23:50	00:18	00:24	36° 14.993' N	08° 36.162' W
OBS 11	10.08.2008	02:18	03:22	03:34	36° 03.723' N	11° 16.539' W
OBS 12	09.08.2008	16:35	17:40	17:50	36° 04.862' N	10° 35.382' W
OBS 13	07.08.2008	14:37	15:42	15:49	36° 01.383' N	10° 01.221' W
OBS 14	11.08.2008	16:53	17:52	18:00	36° 00.088' N	09° 24.038' W
OBS 15	11.08.2008	21:00	21:46	21:55	35° 59.824' N	08° 47.966' W
OBS 16	06.08.2008	06:51	07:22	07:35	35° 56.956' N	08° 15.060' W
OBS 17	09.08.2008	20:28	21:34	21:48	35° 46.696' N	10° 56.390' W
OBS 18	07.08.2008	10:44	11:50	12:03	35° 42.752' N	10° 20.279' W
OBS 19	07.08.2008	02:13	03:11	03:23	35° 38.103' N	09° 45.060' W
OBS 20	06.08.2008	14:58	15:47	15:55	35° 35.776' N	09° 05.943' W
OBS 21	06.08.2008	11:07	11:41	11:49	35° 38.470' N	08° 36.054' W
OBS 22	07.08.2008	07:17	08:15	08:22	35° 20.864' N	10° 24.200' W
OBS 23	06.08.2008	19:29	20:22	20:29	35° 07.063' N	09° 17.344' W
OBS 24	11.08.2008	10:22	11:00	11:08	36° 31.858' N	09° 16.849' W
OBS 25	11.08.2008	12:58	13:45	14:03	36° 21.498' N	09° 34.185' W

Table 3. Recovery parameters.

OBS Nr.	deployment			recovery			mean		water depth
	date (UTC)	lat [°]	lon [°]	date (UTC)	lat [°]	lon [°]	lat [°]	lon [°]	[m]
OBS 01	30.08.2007	37,050	-11,450	10.08.2008	37,060	-11,445	37,055	-11,448	5100
OBS 02	30.08.2077	37,026	-10,734	10.08.2008	37,024	-10,734	37,025	-10,734	2270
OBS 03	30.08.2007	37,100	-10,230	10.08.2008	37,100	-10,228	37,100	-10,229	3932
OBS 04	29.08.2007	36,950	-9,700	09.08.2008	36,954	-9,704	36,952	-9,702	1993
OBS 05	29.08.2007	36,730	-10,550	11.08.2008	36,730	-10,553	36,730	-10,552	3095
OBS 06	29.08.2007	36,710	-9,969	09.08.2008	36,707	-9,969	36,708	-9,969	2956
OBS 07	29.08.2007	36,365	-9,497	31.08.2007	36,366	-9,495	36,366	-9,496	3205
OBS 08	30.08.2007	36,400	-10,920	10.08.2008	36,395	-10,922	36,398	-10,921	4671
OBS 09	29.08.2007	36,370	-10,260	09.08.2008	36,373	-10,262	36,372	-10,261	4811
OBS 10	01.09.2007	36,250	-8,600	11.08.2008	36,250	-8,603	36,250	-8,601	2067
OBS 11	30.08.2007	36,069	-11,270	10.08.2008	36,062	-11,276	36,066	-11,273	4855
OBS 12	31.08.2007	36,080	-10,590	09.08.2008	36,081	-10,590	36,081	-10,590	4860
OBS 13	31.08.2007	36,020	-10,020	07.08.2008	36,023	-10,020	36,022	-10,020	4494
OBS 14	02.09.2007	36,000	-9,400	11.08.2008	36,001	-9,401	36,001	-9,400	2439
OBS 15	01.09.2007	36,000	-8,800	11.08.2008	35,997	-8,799	35,999	-8,800	3357
OBS 16	01.09.2007	35,950	-8,250	06.08.2008	35,949	-8,251	35,950	-8,251	2069
OBS 17	30.08.2007	35,780	-10,939	09.08.2008	35,778	-10,940	35,779	-10,939	4765
OBS 18	31.08.2007	35,710	-10,340	07.08.2008	35,713	-10,338	35,711	-10,339	4605
OBS 19	31.09.2007	35,630	-9,750	07.08.2008	35,635	-9,751	35,633	-9,751	4287
OBS 20	01.09.2007	35,600	-9,100	06.08.2008	35,596	-9,099	35,598	-9,100	3449
OBS 21	01.09.2007	35,650	-8,600	06.08.2008	35,641	-8,601	35,646	-8,600	2566
OBS 22	31.08.2007	35,350	-10,400	07.08.2008	35,348	-10,403	35,349	-10,402	4095
OBS 23	01.09.2007	35,117	-9,285	06.08.2008	35,118	-9,289	35,117	-9,287	3747
OBS 24	27.11.2007	36,532	-9,283	11.08.2008	36,531	-9,281	36,531	-9,282	2439
OBS 25	27.11.2007	36,361	-9,573	11.08.2008	36,358	-9,570	36,360	-9,571	3234

Table 4. Mean station coordinates.

Immediately after recovery of the OBS on deck we tried to manually stop the recording and synchronize the internal clock with GPS time signal using SENDCOM-3 interface. With only few exceptions, all stations stopped recording already before recovery due to the following reasons: “disk full” and “battery low”. The first cause was expected due to the length of the period of operation and the high sampling rate. All recorders of the 9 stations with full disks stopped recording properly and allowed a GPS synchronisation without any problems. The battery low at 9 stations was unexpected, since the capacity of the 132 Li cells was estimated to be enough for 12 month recording. The battery charge was so low (with only one exception), that even there was not enough power left to keep the clocks running (although there is a safety mode, which worked for one station). Therefore the recorder lost the synchronisation and we were not able to get the time shift of the internal clock.

After stopping the recording, the stations were cleaned and dismounted. All removable components were stored in boxes, the LOBSTER itself were stacked and stored onboard. With the exception of two stations (OBS16, OBS21) the stations were in very good conditions after recovery. These two stations showed corrosion at the power connectors of the recorder tube. Similar corrosion was maybe a cause of the failure of one power connector during the first deployment cruise in 2007. There was almost no cover with carbonates as it was observed before in the Mediterranean Sea.

3.3 Data handling

After cleaning, the recorder tube was taken off from the tube and connected to the Desktop PC by FireWire. Data retrieval from MCS recorders was performed using send2x software (*mcscopy*). Afterwards the raw data were decompressed into s2x format using *mcsread*. During this stage the time correction (if possible) was done. The final stage of first data conversion on the ship was the conversion into mseed format (*seedwrite*) to allow the very first quality check of the data. Two copies of the raw data were saved on external hard disks (less than 500 GB disk space), a third one on DL tapes. Furthermore, one copy of the uncompressed s2x-files (altogether more than 1 TB) and two copies of mseed data (500 GB) were save on external hard disks.

During checking some data we observed that maybe not all seismometers (at least components) levelled well. This will be checked together with other parameters (quality control) during the next weeks at AWI Institute. In all cases the hydrophone seems to work properly. We expect that there is no severe loss of data and therefore will not certainly hamper the analysis and interpretation of the data. We also hope that the timing problem of 9 stations (missing synchronization) could be solved with the use of the seismic signals itself.

OBS Nr.	Recorder SN	Start Recording (UTC)	Stop Recording (UTC)	data recorded	skew [μs]	comments
OBS 01	050919	30.08.2007 07:52:52	12.06.2008 21:59:37	16071096 kb	not synchronized	battery low, recorder off
OBS 02	050916	30.08.2007 03:47:35	22.05.2008 14:16:42	15305614 kb	not synchronized	battery low, recorder off
OBS 03	060741	29.08.2007 23:53:25	31.07.2008 16:10:57	18469887 kb	not synchronized	battery low, recorder off
OBS 04	050901	29.08.2007 22:10:32	25.06.2008 17:42:20	19513715 kb	+1456156	disk full, sleeping mode
OBS 05	050924	29.08.2007 16:59:04	23.06.2008 16:37:44	16570501 kb	not synchronized	battery low, recorder off
OBS 06	050910	29.08.2007 18:56:59	20.07.2008 07:14:42	19513715 kb	+1427375	disk full, sleeping mode
OBS 08	050923	30.08.2007 13:09:59	10.08.2008 08:37:04	18758201 kb	+494781	still recording, stop by END
OBS 09	050921	29.08.2007 14:02:56	29.04.2008 20:20:08	13172897 kb	not synchronized	battery low, recorder off
OBS 10	050912	01.09.2007 20:32:16	29.06.2008 16:07:25	19513716 kb	-116438	disk full, sleeping mode
OBS 11	050913	30.08.2007 18:03:02	02.05.2008 15:51:21	12288701 kb	+996218	batt. low, recording ended, sleeping mode
OBS 12	050915	30.08.2007 23:12:43	21.07.2008 09:09:57	19513715 kb	+280875	disk full, sleeping mode
OBS 13	050909	31.08.2007 10:52:51	14.07.2008 23:52:24	17458792 kb	not synchronized	battery low, recorder off
OBS 14	050926	02.09.2007 02:50:51	04.08.2008 15:34:01	19513715 kb	-3671407	disk full, sleeping mode
OBS 15	050917	01.09.2007 19:36:09	07.04.2008 06:54:36	19513715 kb	-80907	disk full, sleeping mode
OBS 16	050927	01.09.2007 10:40:59	07.07.2008 04:02:47	19513715 kb	-4257563	disk full, sleeping mode
OBS 17	050906	30.08.2007 21:24:09	28.05.2008 21:00:33	15023160 kb	not synchronized	battery low, recorder off
OBS 18	050905	31.08.2007 14:41:10	18.07.2008 03:13:29	19513716 kb	-2592782	disk full, sleeping mode
OBS 19	060743	31.08.2007 19:03:44	17.07.2008 17:03:37	19513716 kb	-3357407	disk full, sleeping mode
OBS 20	050907	01.09.2007 03:40:32	12.07.2008 10:31:17	19513716 kb	-3239282	disk full, sleeping mode
OBS 21	050928	01.09.2007 07:28:02	09.07.2008 06:01:13	19513715 kb	-2494594	disk full, sleeping mode
OBS 22	050925	31.08.2007 17:02:54	24.07.2008 17:54:03	17827192 kb	not synchronized	battery low, recorder off, no END mark
OBS 23	050918	31.08.2007 23:21:49	28.06.2008 21:03:08	16435417 kb	not synchronized	battery low, recorder off
OBS 24	050903	27.11.2007 03:21:27	11.08.2008 11:15:32	17422768 kb	+266562	still recording, stop by END
OBS 25	050904	24.11.2007 12:00:04	11.08.2008 14:09:54	16620292 kb	-70750	still recording, stop by END

Table 5. Recording parameters.

We want to thank the captain and the crew of RV Urania for their good and friendly support and professional handling of the instruments.

3.4 Preliminary evaluation of seismic data recorded by the NEAREST OBS's – Part II

3.4.1. Local seismicity recorded by the land station network

The first evaluation of the seismic data recorded by the NEAREST OBS network is provided by the comparison with the local and regional seismicity recorded by the land station network. Fernando Carrilho from IM (Instituto de Meteorologia) provided a list of all events recorded by his institute from the first day of recording, the 29th August 2007 till the 31st July 2008, the beginning of the cruise. In the study area, from 33.5ºN to 38.5ºN and from 14ºW to 5ºW, this dataset comprises 1893 seismic events that include also quarry blasts on land and some not well-located events. The epicentres are shown in fig. 6, together with the location of the NEAREST OBS network and known seismic stations operating in the area.

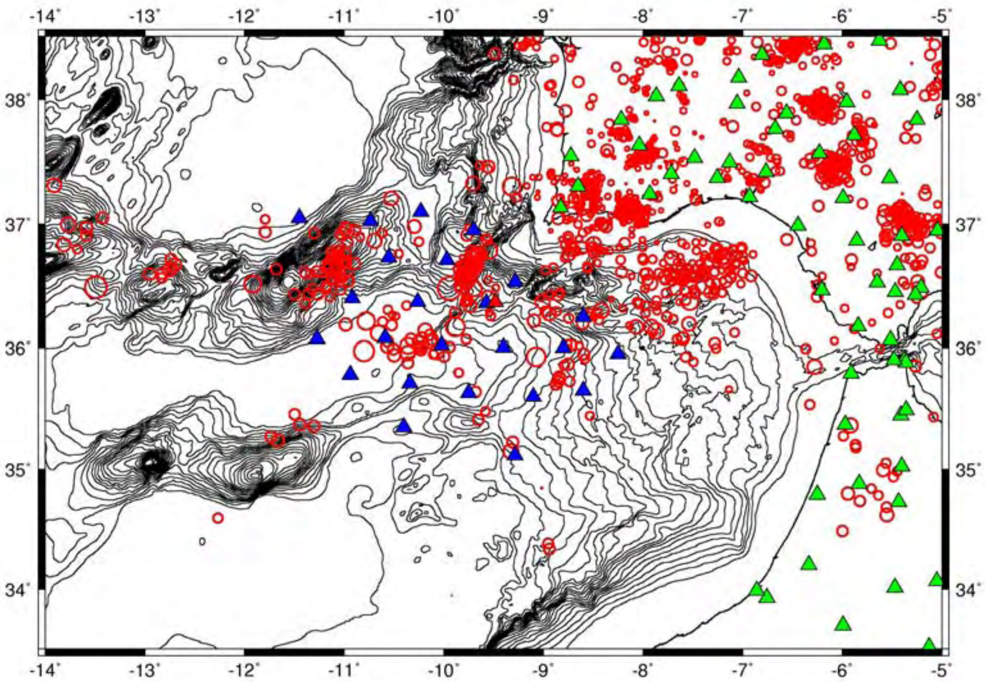

Figure 6 – Location of epicentres from the 1st day of operation of the NEAREST OBS network till the 31st July 2008, as provided by Fernando Carrilho (IM). Also shown are the known recording seismic stations operating on land

The recordings provided by the land stations will be very useful for the full exploitation of the NEAREST dataset, so that a list of the known seismic stations and their major characteristics is provided as an EXCEL file as Annex CD-SP1.

From the large dataset shown in fig. 6, we selected as first priority for the investigation of the NEAREST OBS network area all events that were at least at 75 km distance from the closest OBS. This dataset, shown in fig. 7, comprises 276 seismic events. Their magnitude (ML computed by IM) ranges from 0.5 to 4.7. The largest event was recorded the 11th January 2008. Another magnitude ML=4.1 was recorded the 10th May 2008. This dataset comprises a total of 15 earthquakes with magnitude ML≥3.0 The file comprising the full dataset provided by IM is given as an ascii file in annex CD-SP2.

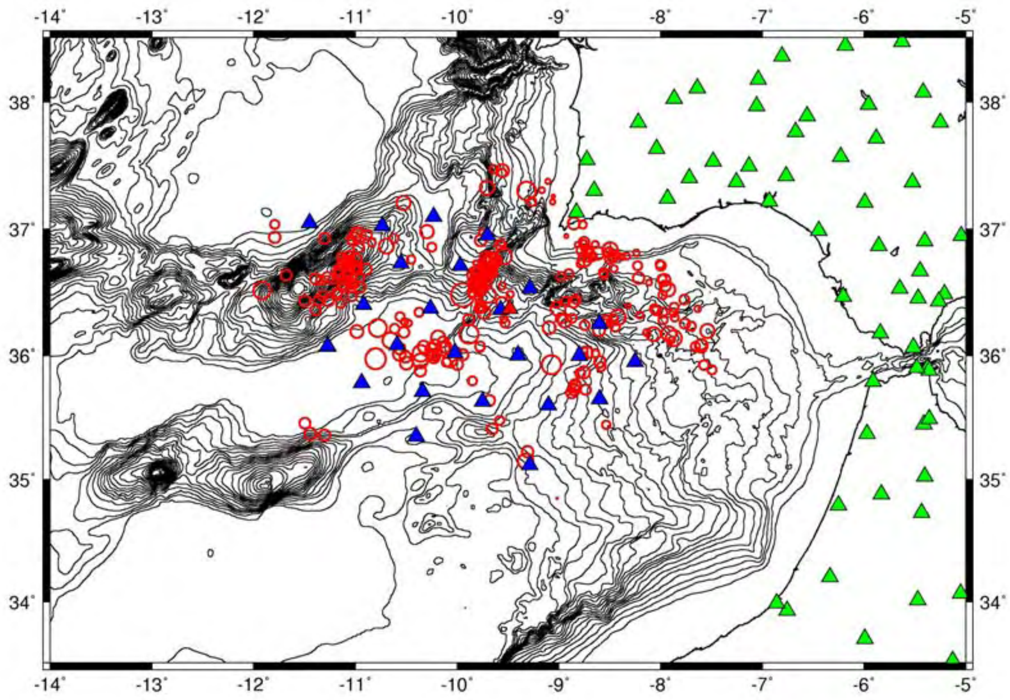

Fig. 7 – Location of 276 selected epicentres, which are closer than 75 km to the nearest OBS.

To assess the data quality recorded we screened all 257 events that should have been recorded by OBS18, considering the selected events set in fig7. The mini-seed data was converted to Nordic waveform data and the waveforms were examined using the SEISAN Seismic Analysis package (Havskov and Ottemöller, 2005). We classified the events as Very Good, when we have clear P and S readings and the polarity of the P phase can be seen without ambiguity, Good, when we have clear P and S phases, Fair, when we have clear S but P is doubtful, Unknown, when a small signal is seen but the phase cannot be clearly identified, and Null when no signal could be seen. The results of the screening are shown in the table below.

<table>
<tr><th>Quality</th><th colspan="3">Rating</th></tr>
<tr><td>Very Good</td><td>17%</td><td rowspan="2">52%</td><td rowspan="3">72%</td></tr>
<tr><td>Good</td><td>35%</td></tr>
<tr><td>Fair</td><td>20%</td><td></td></tr>
<tr><td>Unknown</td><td>7%</td><td rowspan="2">27%</td><td></td></tr>
<tr><td>Null</td><td>20%</td><td></td></tr>
</table>

We have 52% of events that are fully usable for location, 17% of which will also contribute for the determination of source mechanism using P-wave polarity. Only 27% are expected to be useless for location. We must say that these statistics may not represent a typical value. A preliminary screening on OBS16, on top of a thick sedimentary layer, showed less optimistic values. Considering that different instruments will have recorded different events with good quality, it may be expected that at least 2/3 of the 276 events recorded in the area by the land seismic network will be well relocated by the NEAREST OBS network.

3.4.2 Definition of an initial 1D velocity model for the location of earthquakes in the NEAREST deployment area

Using the data recorded and recovered onboard we proceed to try to locate some of the seismic events identified by the land network. In order to do this we must define an a priori velocity model for the study area.

The location of the events by the land network, computed at the Instituto de Meteorologia, uses a general velocity model that is accepted for all Iberia, onshore and offshore. This model, also provided by Fernando Carrilho, uses constant velocity layers and is presented in the table below:

Vp (km/s)	Depth (km)
6.10	0.0
6.40	11.0
6.90	24.0
8.20	31.0
8.50	90.0
Vp/Vs=1.75	

This velocity model seems not appropriate for the location of local earthquakes since it doesn't show a sedimentary layer and the crust is 31 km thick. In the absence of direct velocity measurements in the area of deployment of the NEAREST network, we have to rely on published works on the nearby areas (Gutscher et al., 2002), or on indirect inferences of velocity models (Gonzalez et al, 1996).

3.4.3 The work by Gonzalez et al., 1996

This work presents a velocity model along a profile that extends from SW Iberia to the Horseshoe Abyssal plain (figures 8 and 9).

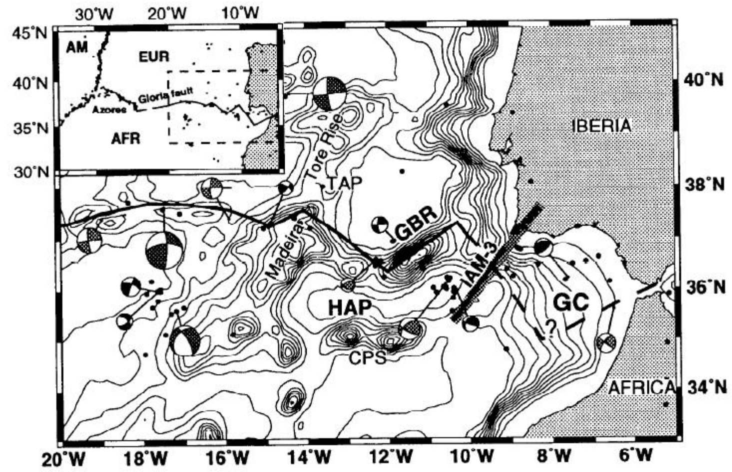

Fig. 8 – Location of the profile studied by Gonzalez et al. (1996), reproduced from their fig1.

The velocity model in Gonzalez et al. (1996) was obtained integrating information from the IAM-3 MCS line, wide-angle recordings on 10 land stations and gravity modelling. It does not provide a direct measure of the seismic velocities in the area but it should be considered as a good indication. Their final model is shown in fig.10.

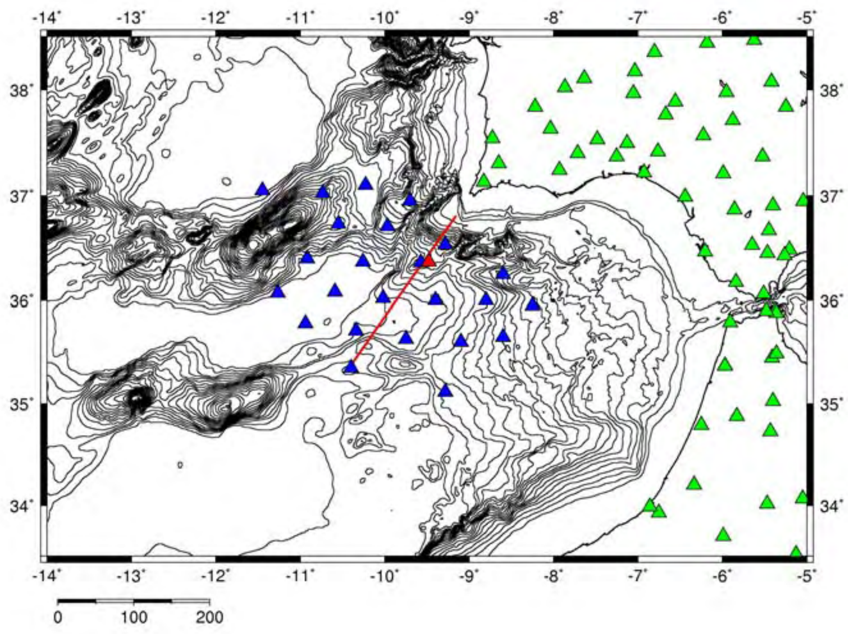

Fig. 9 – Location of the IAM-3 MCS profile used in the work by Gonzalez et al. (1996) and the NEAREST network.

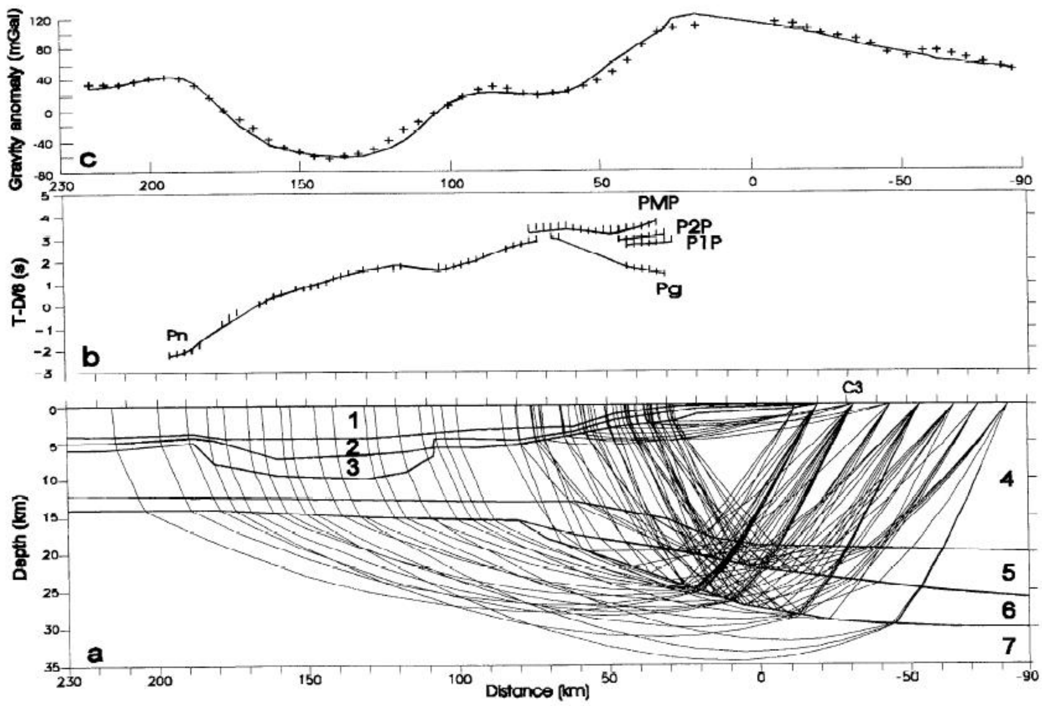

Fig.10 – Final velocity model derived by Gonzalez et al. (1996).

The layer characteristics described by Gonzalez at al. (1996) are presented in the table below:

Layer	Description	Vp (km/s)
1	Water	1.5
2	Upper sediments	2.2
3	Lower sediments	3.7
4	Upper crust	5.8 to 6.0
5	Middle crust	6.4
6	Lower crust	6.8 to 6.9
7	Upper mantle	7.8 to 7.9

We will consider as representative to our study area two velocity profiles extracted from Gonzalez et al. (1996) model, one at 90 km model distance, in thinned continental crust and a thinner sedimentary layer, and the second at 140 km model distance, in a zone of very thin crust (continental?) underlain by a thick sedimentary cover including the thick chaotic body of the Gulf of Cadiz.
The velocity models are presented in the table below:

@ 90 km		@ 140 km	
Vp (km/s)	Depth (km)	Vp (km/s)	Depth (km)
1.5	0.00	1.5	0.00
2.2	3.18	2.2	4.41
3.7	4.69	3.7	6.77
5.8 – 6.0	5.62	5.8 to 6.0	9.80
6.4	13.06	6.4	12.63
7.8 – 7.9	15.43	6.8 to 6.9	14.79

3.4.4 The work by Gutscher et al., 2002

In this paper Gutscher et al. present the results of refraction and wide-angle reflection modelling from coincident MCS and OBS recordings. The location of the profile studied is shown in fig. 11 (from the original paper). The relation between this profile and the NEAREST network is shown in fig.12.

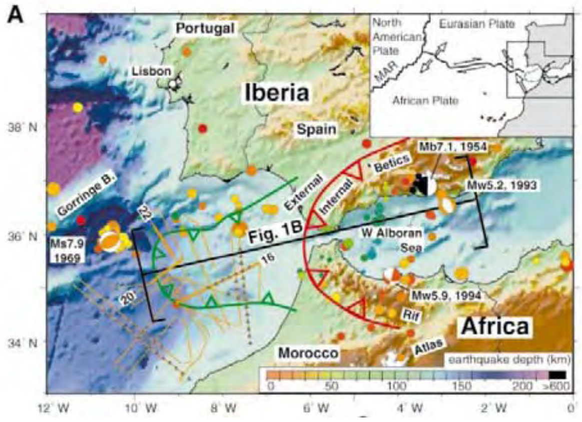

Fig. 11 – Location of the profile 16 investigated by Gutscher et al. (2002).
Here reproduced from their fig1.

We will consider as representative to our study area the 1D velocity profile that is inferred below the westernmost OBS, at 70 km model distance (fig. 13). In the work of Gutscher et al. two sedimentary layers are considered but only one single crustal layer.

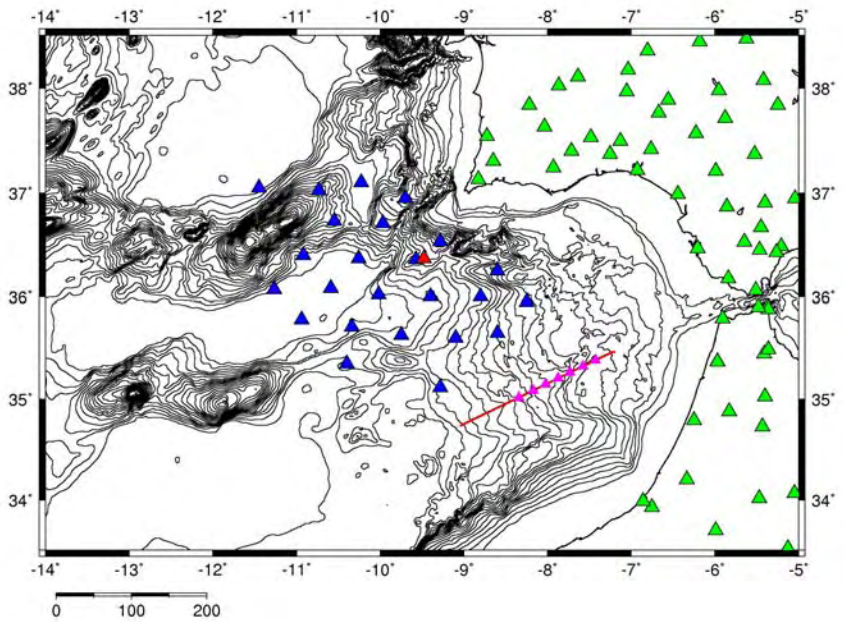

Fig. 12 – Location of the SISMAR-16 MCS profile and OBS's used in the work by Gutscher et al. (2002) and the NEAREST network.

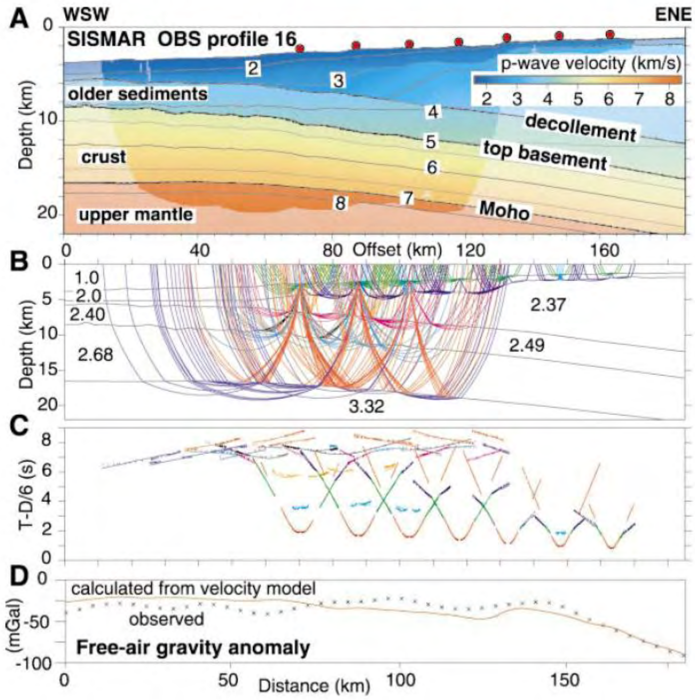

Fig. 13 – Final velocity model derived by Gutscher et al. (2002) reproduced from the original fig3.

The velocity profile inferred from the colour plot in Gutscher et al. (2002) work is shown in the table below:

Vp (km/s)	Depth (km)	Layer
1.5	0.00	Water
1.8 – 3.0	2.74	Upper sediments
3.7 – 4.2	6.87	Lower sediments
5.2 – 6.8	10.34	Crust
7.9 – 8.1	17.09	Upper mantle

3.4.5 Initial velocity model proposed

The models presented above are all shown in fig.14 as velocity-depth profiles. We may see that the models proposed by Gutscher et al. (2002) and the Gonzalez et al. (1996) @ 140 km model distance are very similar and so we propose that the initial velocity model for earthquake location in the area should be an average of both. The proposed model is indicated in pink in fig9 and the values are shown in the table below:

Vp (km/s)	Depth (km)	Layer
2.2	0.0	Upper sediments
3.8	6.5	Lower sediments
5.8	10.0	Upper crust
6.5	13.0	Lower crust
7.9	16.0	Upper mantle
8.1	20.0	
8.3	50.0	

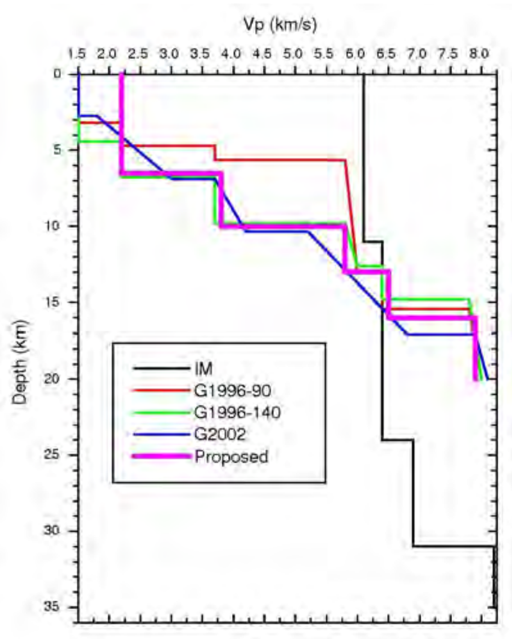

Fig. 14 – Synthesis of the velocity models presented: G2002 – Gutscher et al. (2002); IM – Instituto de Meteorologia; G1996-90 – Gonzalez et al. (1996) @90 km; G1996-140 – Gonzalez et al. (1996) @140 km. The proposed model is shown in pink.

3.4.6 Location of events using a small set of OBS data

Using the velocity model described in the previous paragraph and the deployment coordinates of the NEAREST OBS network, we used SEISAN to locate a few of the events that belonged to the list provided by IM. At the time of this exercise we had only data from 5 instruments, OBS16, OBS18, OBS19, OBS21 and OBS22 (this with uncertain absolute time). The waveforms and phase picks are shown in fig.15 for the event at 21/2/2008 20:39 with magnitude ML=2.6

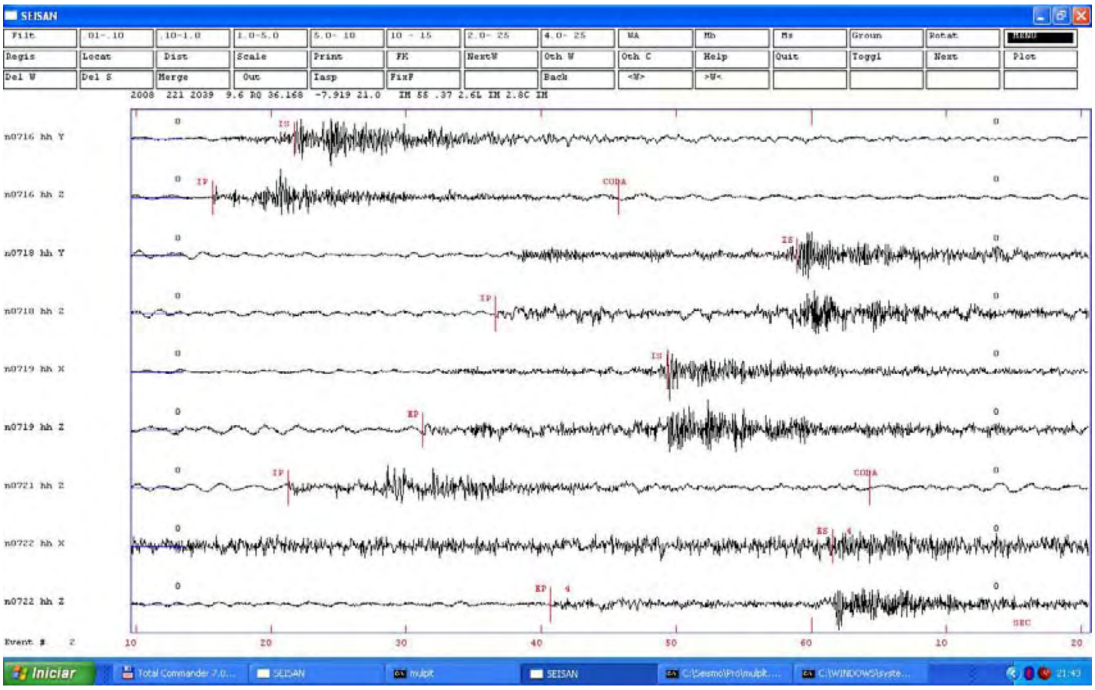

Fig. 15 – Waveforms and phase picks for 5 OBS's examined, event 20080221-20:39 ML=2.6.

The epicentre location of this event, using only OBS data, is shown in Fig11 as a red circle. When comparing this location to the original one provided by IM we see that, despite the poor distribution of the stations, the OBS location is pretty good.

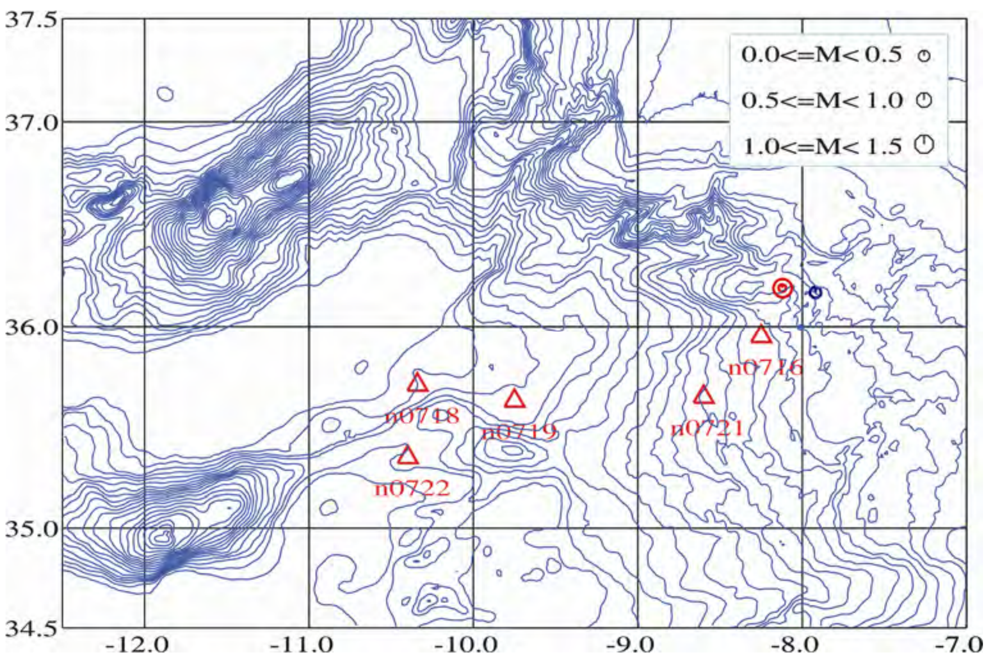

Fig. 16 – In red, epicentre obtained by the analysis of 5 OBS's, event 20080221-20:39 ML=2.6. In black we see the original location provided by IM.

3.4.7 Looking for local events not reported by the land stations

One of the added values of the NEAREST OBS network is the ability to detect and locate local events that cannot be identified and analysed by the land seismic network. The fully exploitation of the acquired dataset will imply a very long examination of the complete records for each station. To facilitate this task we propose the use of spectrogram images that summarize in a smaller single file all the information from the network over one day.

We present next the spectrogram analysis applied to the datasets comprising the recordings of 5 instruments, OBS16, OBS18, OBS19, OBS21 and OBS22. In fig. 17 we show a piece of spectrogram showing an earthquake that is well recorded on all 5 instruments. The horizontal scale is time, one tick per minute. The vertical scale is frequency, from 1 to 25 Hz. The colours display the spectral energy on each frequency bin red being the greatest. One earthquake is characterized in the spectrogram by a vertical alignment of energy. To facilitate the use of this utility, we include in the spectrogram one vertical green line for the time of one event that is already known. In this example the seismic land network already located this earthquake. When we have a vertical alignment without the green line then we have a completely new event. This is illustrated in fig. 18.

We see also in fig13 that not all the OBS's recorded the event and the amplitude varied from instrument to instrument. For the event identified in fig.18 we were able to pick P and S phases on 3 instruments and make a location. The waveforms and picks are shown in fig.19, while the location is shown in fig.20.

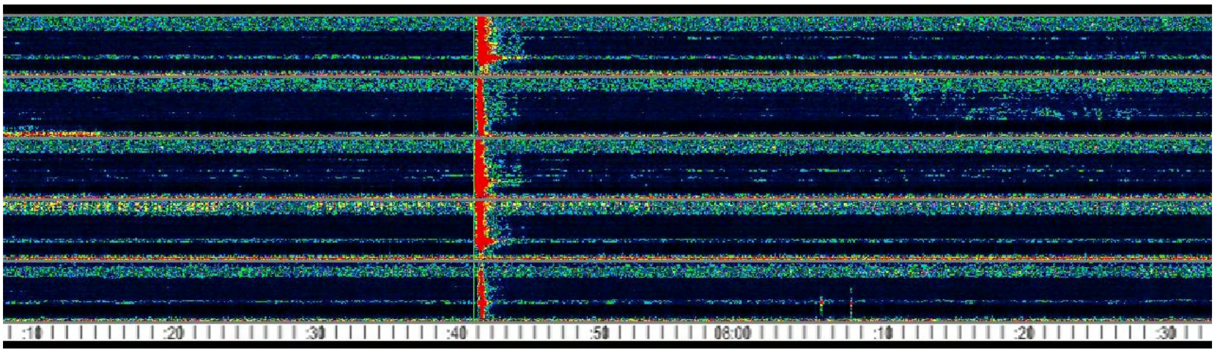

Fig. 17 – Example of 5-station spectrogram displaying one seismic event that was already in the land network event list.

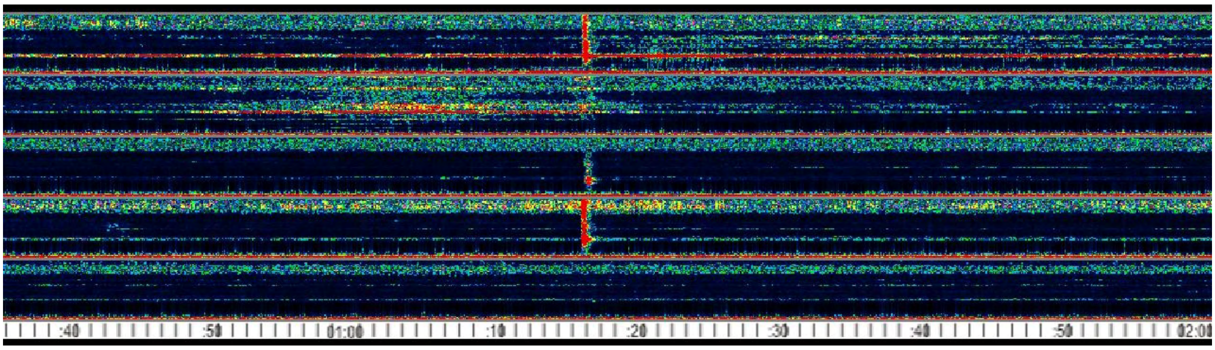

Fig. 18 – Example of 5-station spectrogram displaying one completely new seismic event.

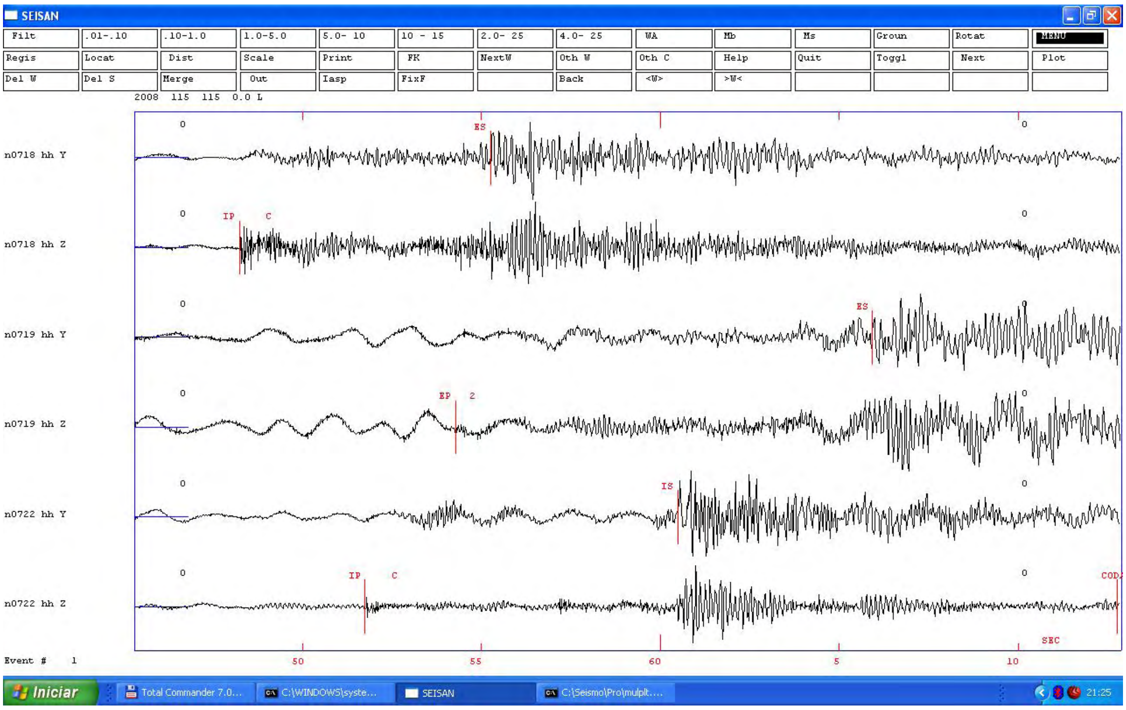

Fig. 19 – Waveforms and phase picks for the 3 OBS's examined for the new event identified 20080115-01:15.

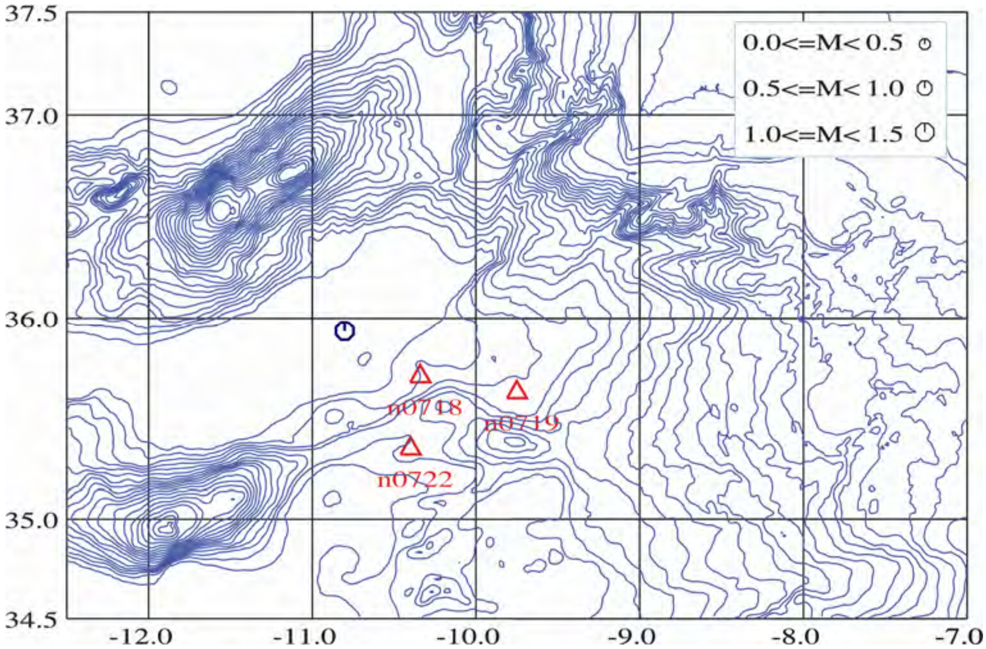

Fig. 20 – Epicentre location for the new event identified by 3 sensors from the NEAREST OBS network.

The new event is located in the Horseshoe Abyssal plain, in a area surrounded by other OBS's, meaning that a better location will be obtained using the complete dataset.
We performed the examination of 5-station spectrograms for 5 consecutive days. On average, for this dataset, we found a new event per day. However only one could be well located by the 5 instruments, all others lacked a sufficient number of phases. This preliminary evaluation gives a great expectation in relation to the full dataset. A significant number of new events, more than 100, are expected to have been recorded by the NEAREST OBS network.

3.3.8 Strange signals recorded at OBS21

We can use the spectrogram analysis also to single station signals, to investigate signals that are very local and are not recorded in other instruments. While doing the testing of this methodology we found that OBS21 reported a frequent signals without network significance. An example of spectrogram is shown in fig.21. We may not that, contrary to earthquakes, the signals on the seismometer have no correspondence in the hydrophone. This may indicate a very local source where the energy is not enough to make a good coupling of the surface movement to the water column. The waveforms that correspond to the spectrogram in fig16 are shown in fig.22.

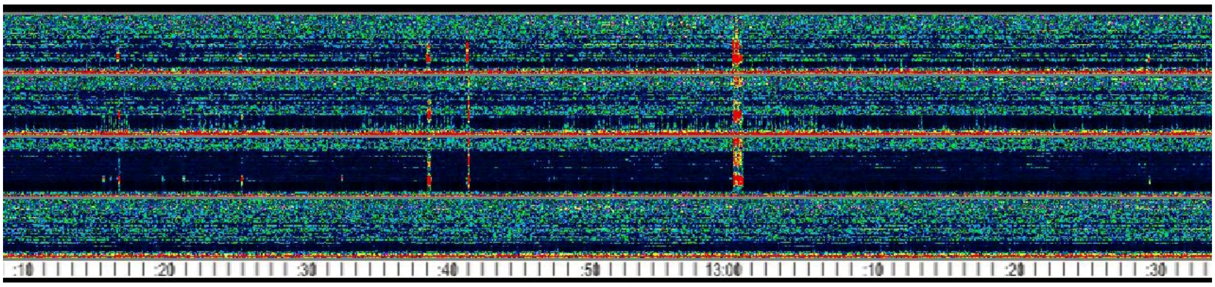

Fig. 21 – Example of 4-component spectrogram for OBS21 displaying a series of unique signals.

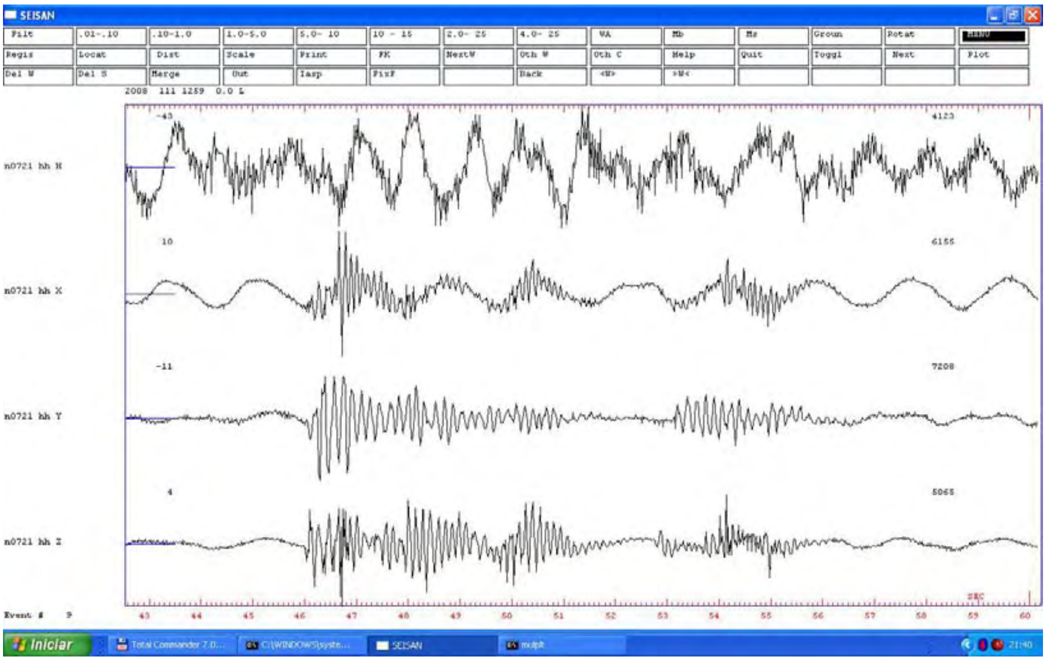

Fig. 22 – Waveforms of the local signals identified at OBS21.

Since the OBS21 is very close to one mud volcano (fig.23) Wolfram Geissler suggested that the activity recorded by the seismic sensor maybe related to the circulation of fluids in the area. This is one topic that should be investigated further while screening the complete dataset.

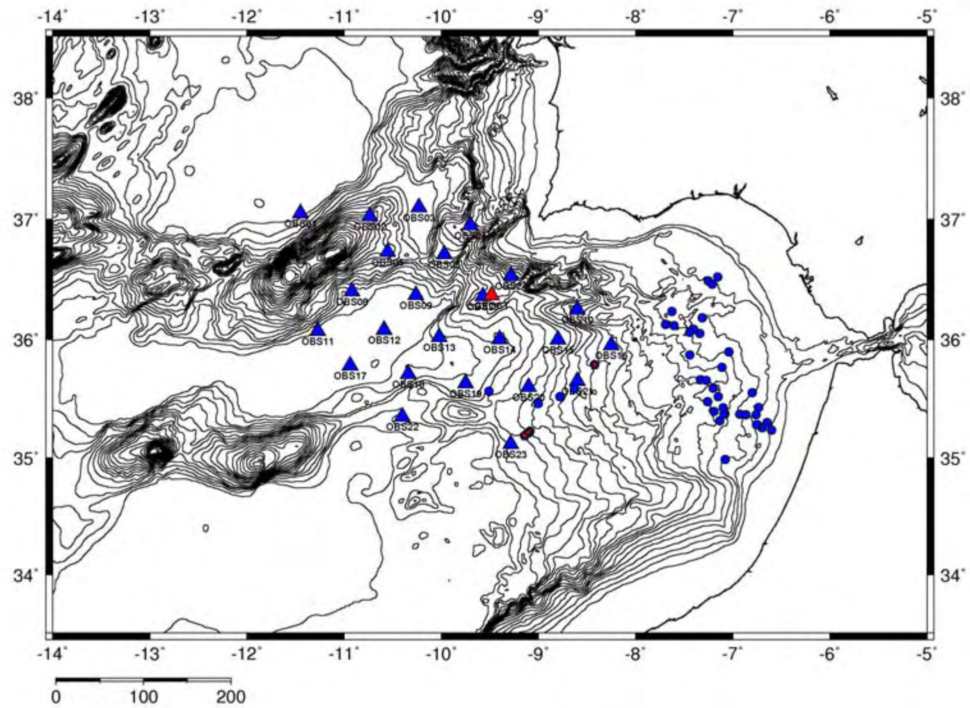

Fig. 23 – Relationship between the mud volcanoes in the Gulf of Cadiz and the NEAREST OBS network.

3.4.9 Wide angle recordings of the Moundforce cruise, August/September 2007

During the NEAREST deployment cruise in 2007 there was another cruise in the Gulf of Cadiz doing MCS acquisition with the R/V Atalante on behalf of the IGE (Madrid), PI Luis Somoza. There was some communication between the two expeditions and some of the MCS lines are located close to NEAREST OBS's, as is shown in fig.24. To assess the quality of the data recorded, we computed wide-angle seismic sections for OBS16 (N-S profile) and OBS18 (E-W) profile. The results are shown in fig.25 and 26, respectively.

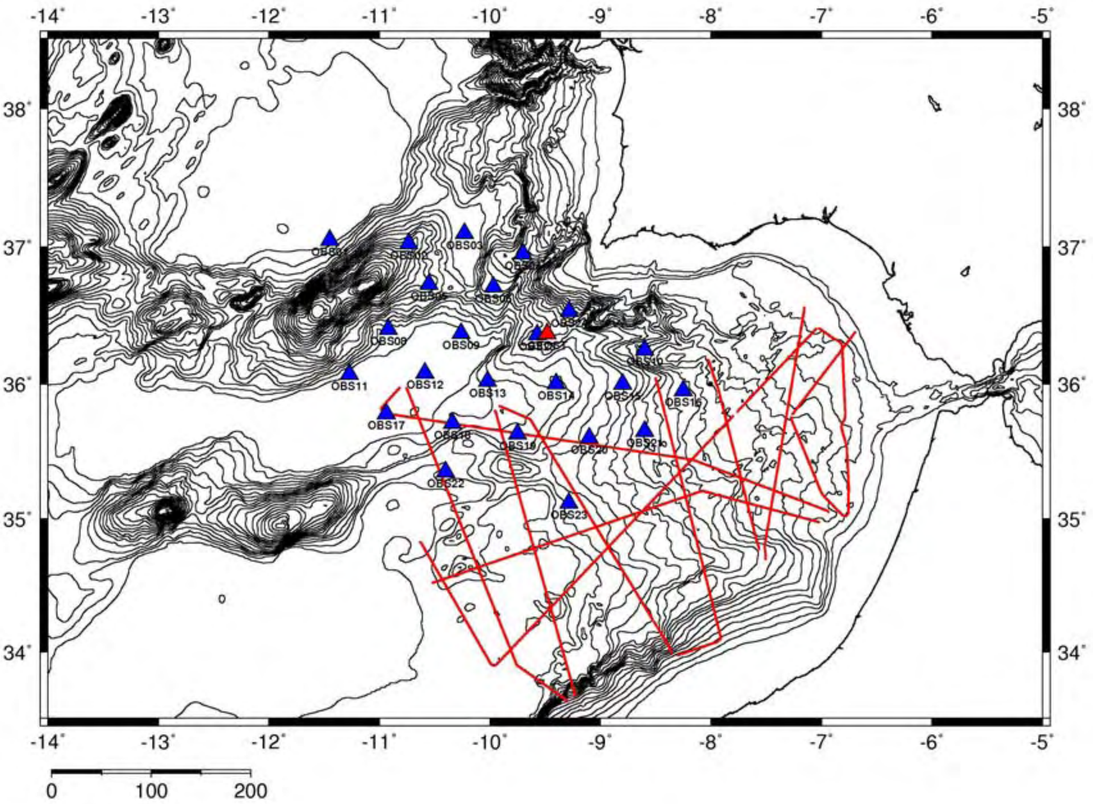

Fig. 24 – Location of the shots for MCS acquisition during the Moundforce cruise, August/September 2007.

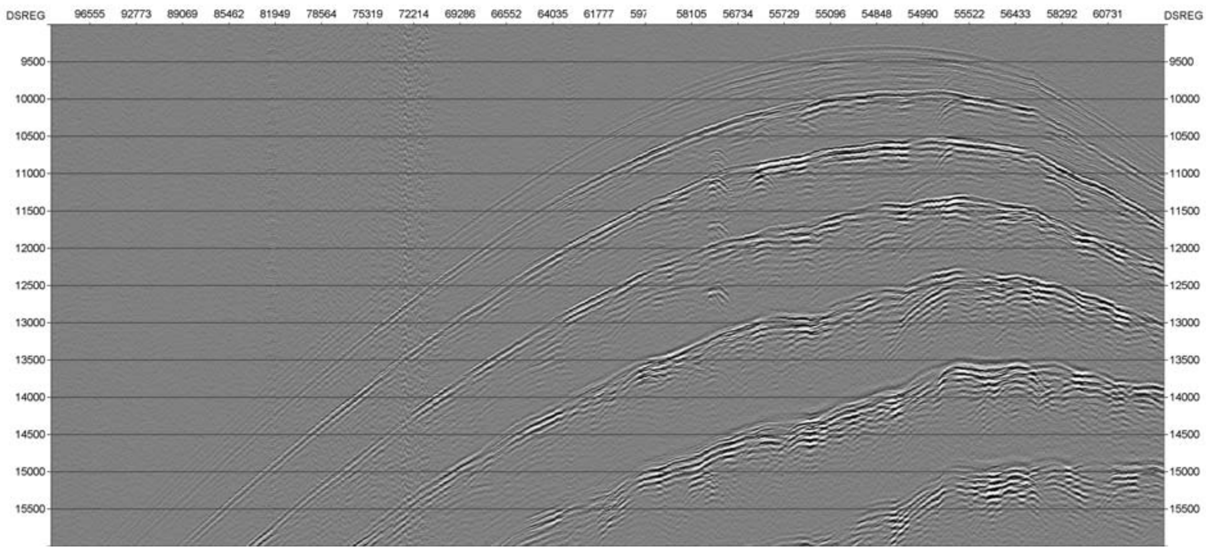

Fig. 25 – Wide-angle record section for OBS16 recording the closest N-S Moundforce profile. Reducing velocity is 2 km/s.

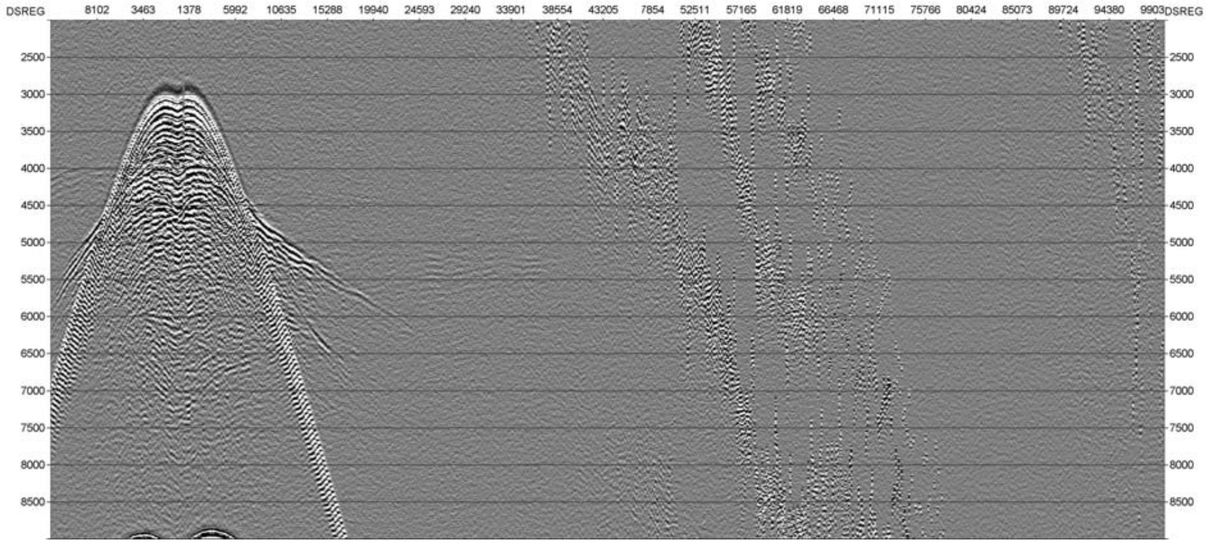

Fig. 26 – Wide-angle record section for OBS18 recording the W-E Moundforce profile. Reducing velocity is 6 km/s.

We may see that the OBS16, locate on top of the accretionary wedge, over a thick pile of sediments, did not record any crustal phase while OBS18, located in a more favourable geological environment, recorded some week crustal arrivals and a week PMP phase reflected in the crust-mantle boundary.

It is recommended that the seg-y files from the recorded Moundforce profiles are prepared and distributed to the interested partners as part of the data delivery package from the NEAREST OBS survey. Furthermore it is recommended that the Moundforce research group be contacted to foster the future investigation of joint MCS and wide-angle profiles.

3.4.9 Delays recorded on P-wave teleseismic events

The LOBSTER sensors recorded teleseismic events that can be used, for example, on P-wave tomography to investigate the mantle structure. One example of a record of a teleseismic event, Z-component, on OBS16, OBS18, OBS19, OBS21 and OBS22 is shown in fig.27.

If we compare the observed travel-times with theoretical ones computed from an average earth velocity model, we see that each stations shows a delay. This delay is systematic on several records and maybe related to the deep structure of the earth. But to be sure of this, a correction must be applied to the arrival times that takes into account the thickness of the sediments and crust below the seismic station. Fortunately a number of MCS profiles are available in the Gulf of Cadiz that can be used to make this correction properly (fig.28).

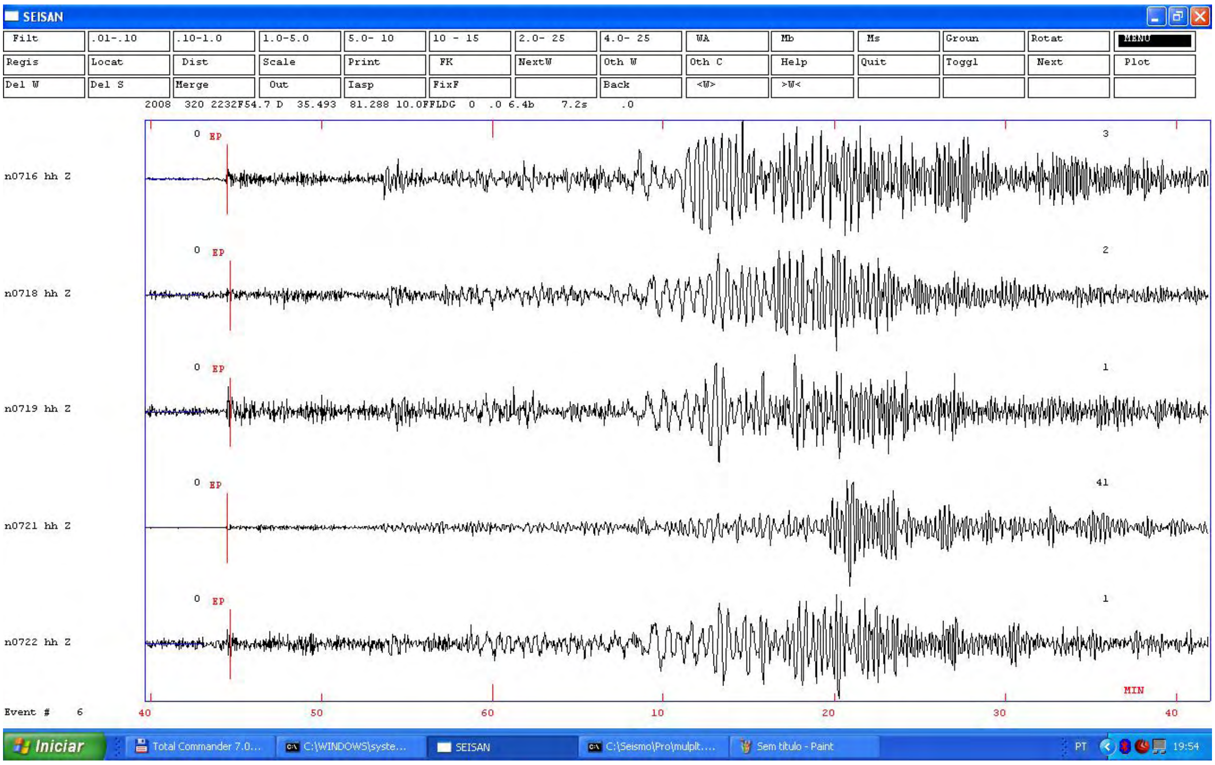

Fig. 27 – Recordings of a teleseismic event on 5 OBS's, vertical component.

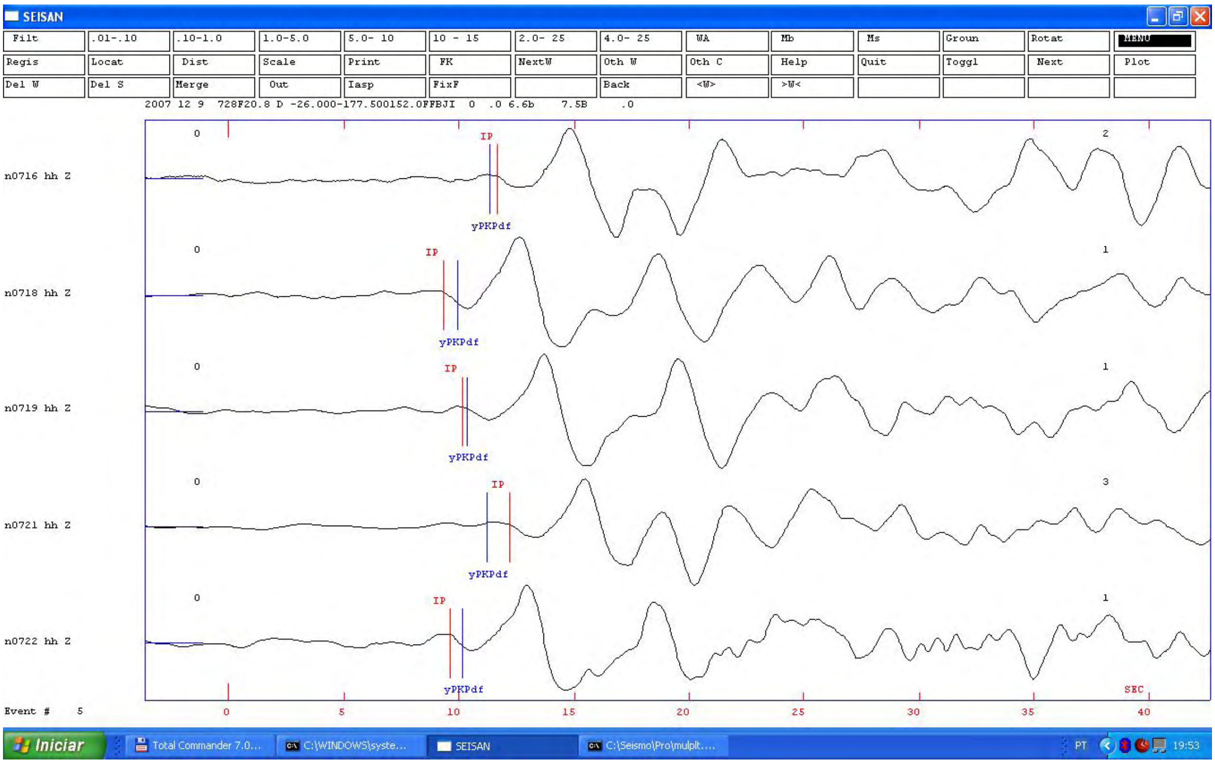

Fig. 28 – comparison of P-wave arrivals and theoretical travel-times.

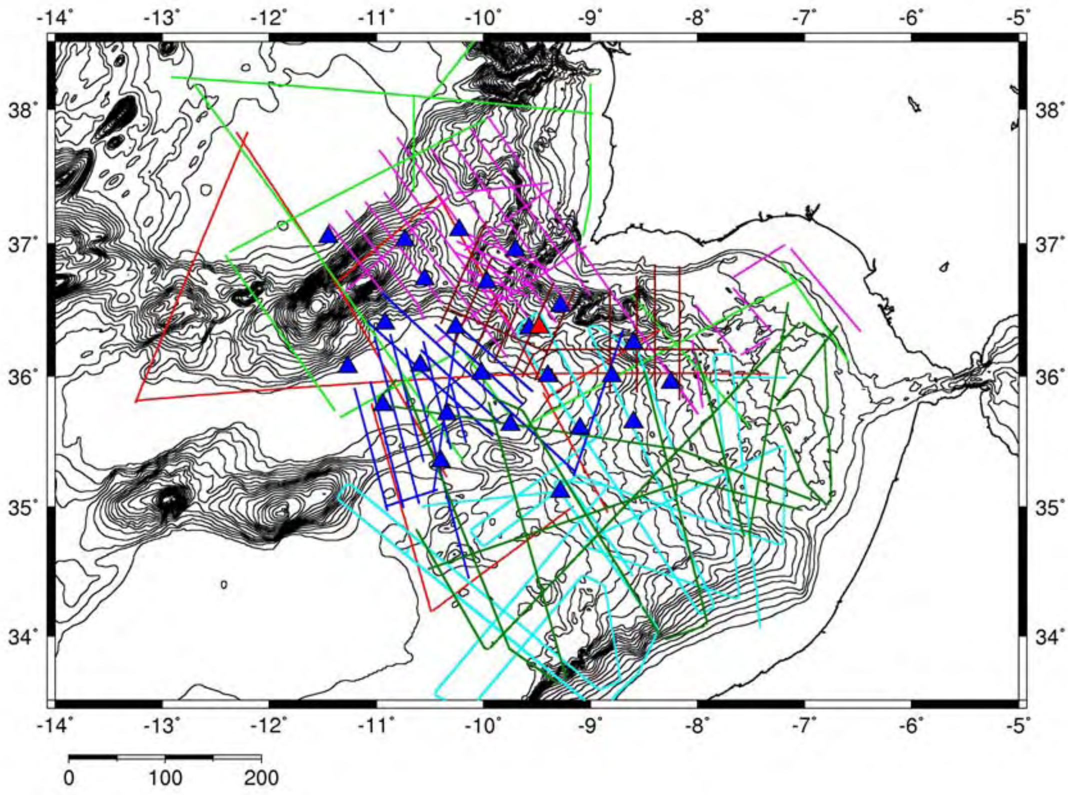

Fig. 29 – Available MCS profiles in the Gulf of Cadiz that can be used for correcting arrival times of teleseismic events.

3.4.10. Long term recording of pressure at the sea bottom

Wolfram Geissler reported some questions regarding the recording of the hydrophone data, suspecting that the very broad range of the sensor was clipped at the low frequencies by the data acquisition system. Also, some very low frequency fluctuations were observed on some of the data files. To illustrate these questions we show in fig.30 one daylong recording of pressure data for 5 instruments.

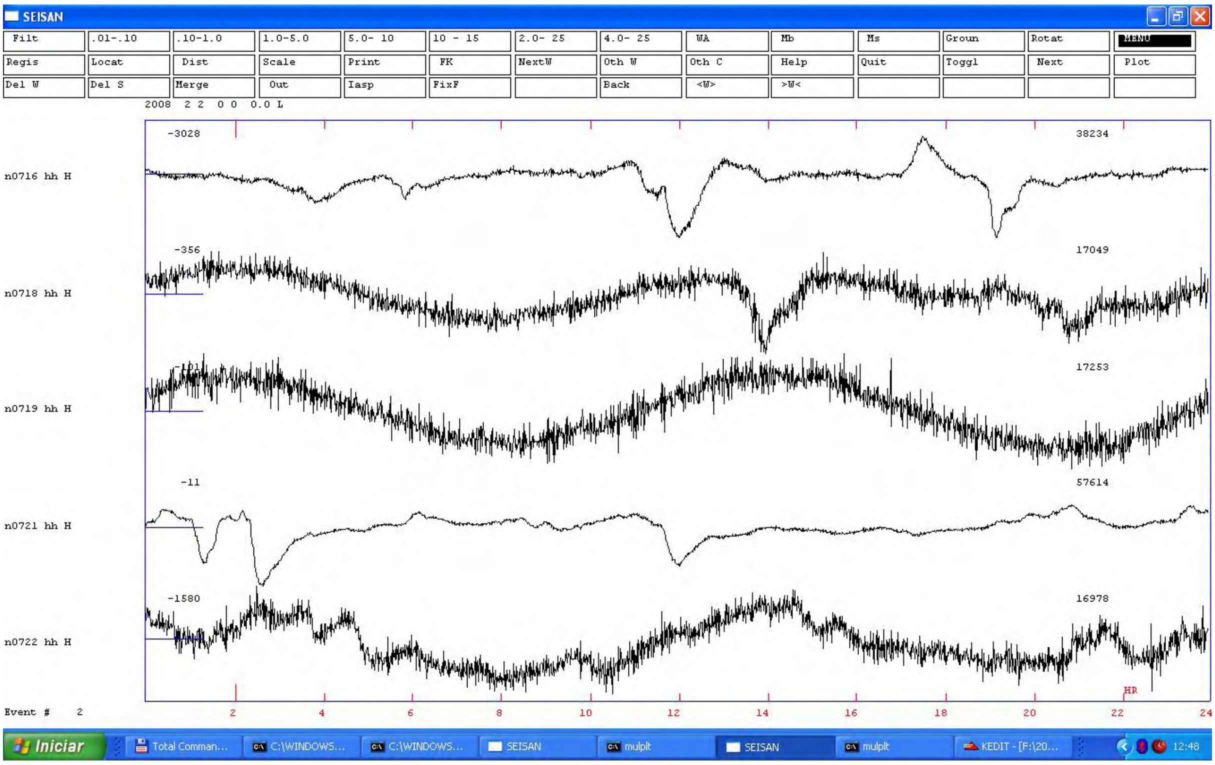

Fig. 30 – One day recording of pressure data on 5 instruments.

We may see that 3 of the sensors recorded one low-frequency sinusoidal fluctuation that could be due to tidal effects, showing that these instruments recorded all the frequency spectrum of the signal. Two other sensors record some faster fluctuations that seem to propagate from one instrument to the other. These fluctuations maybe due to atmospheric pressure variations. This could be confirmed by correlating the records with atmospheric pressure measured on land stations. Variations between instruments will have to be checked with all the dataset available.

4. SECOND LEG: Geostar and mooring cable recovery

The main target of this leg was the recovery of the abyssal station and the mooring cable. The buoy was already recovered on 20 October 2007 after a failure of the mooring cable (see bouy operation report Oct. 17-21; Nov 23-27, 2007 available on the NEAREST web site http://nearest.bo.ismar.cnr.it/). Additional targets of the second leg were the completion of the swath bathymetric mapping of the continental slope along the Maroccan margin, between Rabat and Tanger. In addition a CTD survey was performed on the GEOSTAR site.

4.1 Technical description of the Geophysical seafloor observatory and instruments

The Geostar system is a single-frame autonomous seafloor observatory able to collect multiparameter data with a unique time reference for long-term investigations.

The technology of this observatory derives from the synergy among research institutes and industries starting from 1995 to develop seafloor systems able to operate from shallow water up to deep sea.

During these years, a fleet of observatories has been built on behalf the funding support of European Commission (i.e. GEOSTAR; GEOSTAR-2; SN-1;ORION-GEOSTAR-3; ASSEM etc.), bringing more and more improvements at the main technology of benthic observatories. These systems satisfy the main conditions of seafloor observatories: multidisciplinary, long-term monitoring, unique time reference, autonomy, and development of (near) real-time communication system for warning of local events.

The last generation of Geostar seafloor observatory, planned in the framework of NEAREST project, is equipped with:

a) geophysical and oceanographic sensor package
b) central acquisition, control unit (central clock)
c) data processing unit
d) local memory storage
e) acoustic communication system

All of these characteristics are required to be able to acquire scientific multiparametric data, to detect real-time events (seismic and water pressure) and to communicate possible warning messages.

The observatory is constituted by three main sub-systems:

a) Bottom station constituting the monitoring system (fig.31)
b) MODUS vehicle that allows deployment and recovery procedures (fig.32)
c) Buoy system representing the communication system

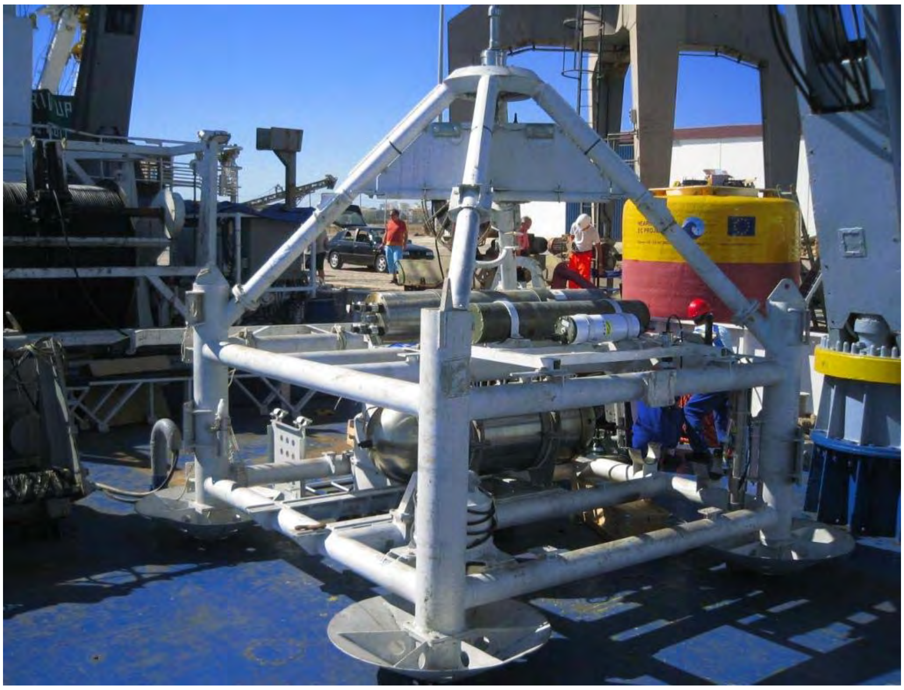

Fig. 31 - GEOSTAR abyssal multiparameter station

The Bottom station consists in a marine aluminum frame hosting instrumental sensor packages (see table 6), compass controlling heading, pitch and roll of the observatory during the deployment, lithium batteries for power supply, echosounder to determine the distance between Geostar and bottom surface during the deployment, electronic for data acquisition, hard disks for data storage, underwater part of acoustic communication system.

Sensor	Sampling rate	Acquisition
3-comp. broad band Seismometer	100 Hz	Continuous
3-comp. Accelerometer	100 Hz	Continuous
Hydrophone	100 Hz	Continuous
Pressure sensor	1 smp/15 sec	Continuous
Gravity meter	1Hz	Continuous
CTD & Transmissometer	1 smp/min	Continuous
ADCP	1 smp/ hour	Continuous
3 comp. Currentmeter	5 Hz	Continuous

Table 6: GEOSTAR main sensors

The acquisition data is entirely controlled by a central unit (DACS: Data Acquisition and Control System) that prepares and updates the hourly data messages, performs the TDA algorithm and transmit data messages on request; also it is able to send in real-time warning messages of detected events towards the surface communication system (buoy).

DACS manages a wide set of data having quite different sampling rate (from 100 Hz to 1 sample/15 sec), tagging each datum according to a unique time reference set by a central high-precision clock.

Fig. 32 – The Modus Module

MODUS (MObile Docker for Underwater Sciences) is used within NEAREST project to recover the GEOSTAR station that has been deployed during the first campaign of the project in late August 2007, Fig. 33.

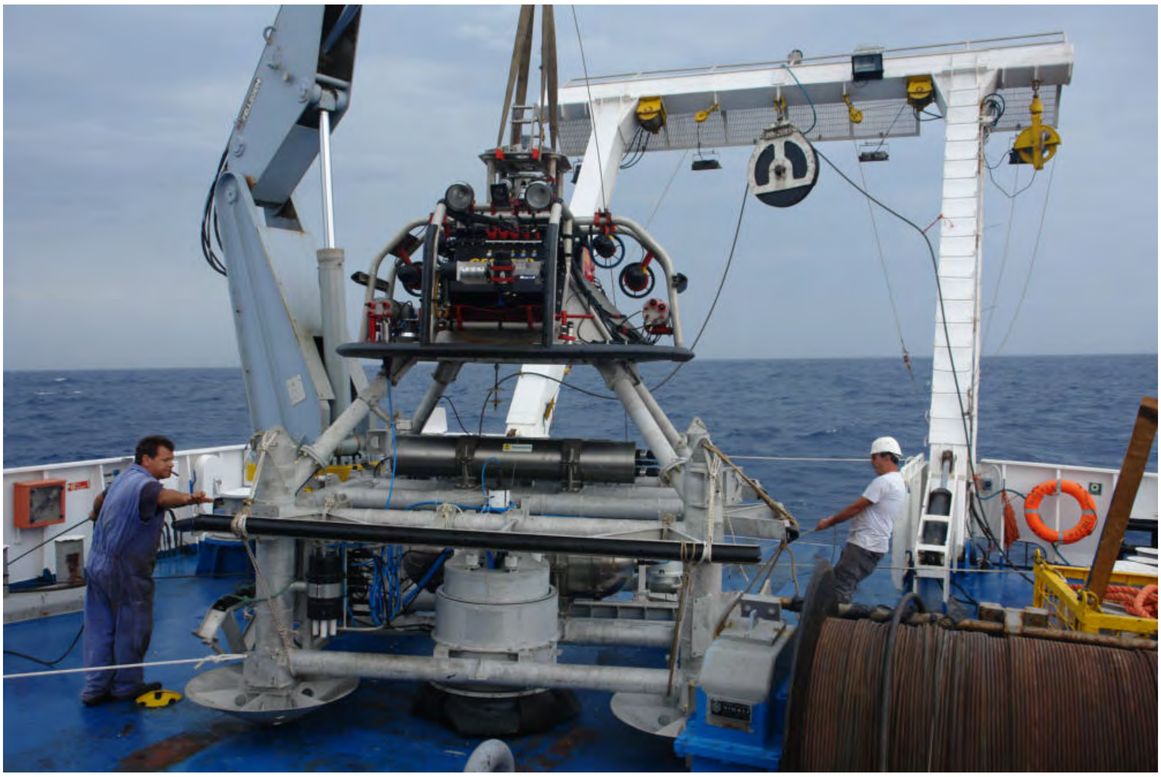

Fig. 33 -MODUS and the GEOSTAR station before the deployment 2007-08-25

The general concept is shown in Fig. 34. MODUS is connected to an umbilical providing the needed power and the glass fibres for the exchange of data for controls, video signals, sonar signals and other sensors and tools. Moreover, the umbilical carries the entire load of MODUS (8000 N in water) plus its payload, such us the GEOSTAR station (15000 N in water) and the force induced by its own weight (17900 N / km). A controlled SONAR head, with the ability to detect objects of the size of the station in a distance of 150 – 200 m, helps to find the station after the deployment of MODUS down a distance of about 30-50 m above the sea bottom. Thrusters allow to operate MODUS and to approach the station or to turn it for a scan of the surroundings.

The set up of MODUS took place on the URANIA while being in the harbour of Faro. Starting on 2008-08-13 and ending on 2008-08-14. For the set up Haiko deVries from TU Berlin came to assist and cross check the electronics and controls. Refer to Fig. 35 for the interior control equipment and Fig. 36 for MODUS itself in its ready-to-go-position at the stern URANIA.

Fig. 34 -MODUS approaching a deep-sea station (CAD-visualization)

Fig. 35 - MODUS control units and video monitors in the URANIA lab

Fig. 36 - MODUS in the harbour of FARO – Cais Comercial 2008-08-13

4.2 GEOSTAR Recovery operations

The Urania vessel reached the operational area on August 15, at about 18:00 (fig.37). The sea state was not considered calm enough to start the operation for the recovery of the abyssal station. Based on the weather forecast, it was decided to wait for the following day before to start the operations. During the night five CDT stations were performed around the location of the abyssal station (see chapter 6).

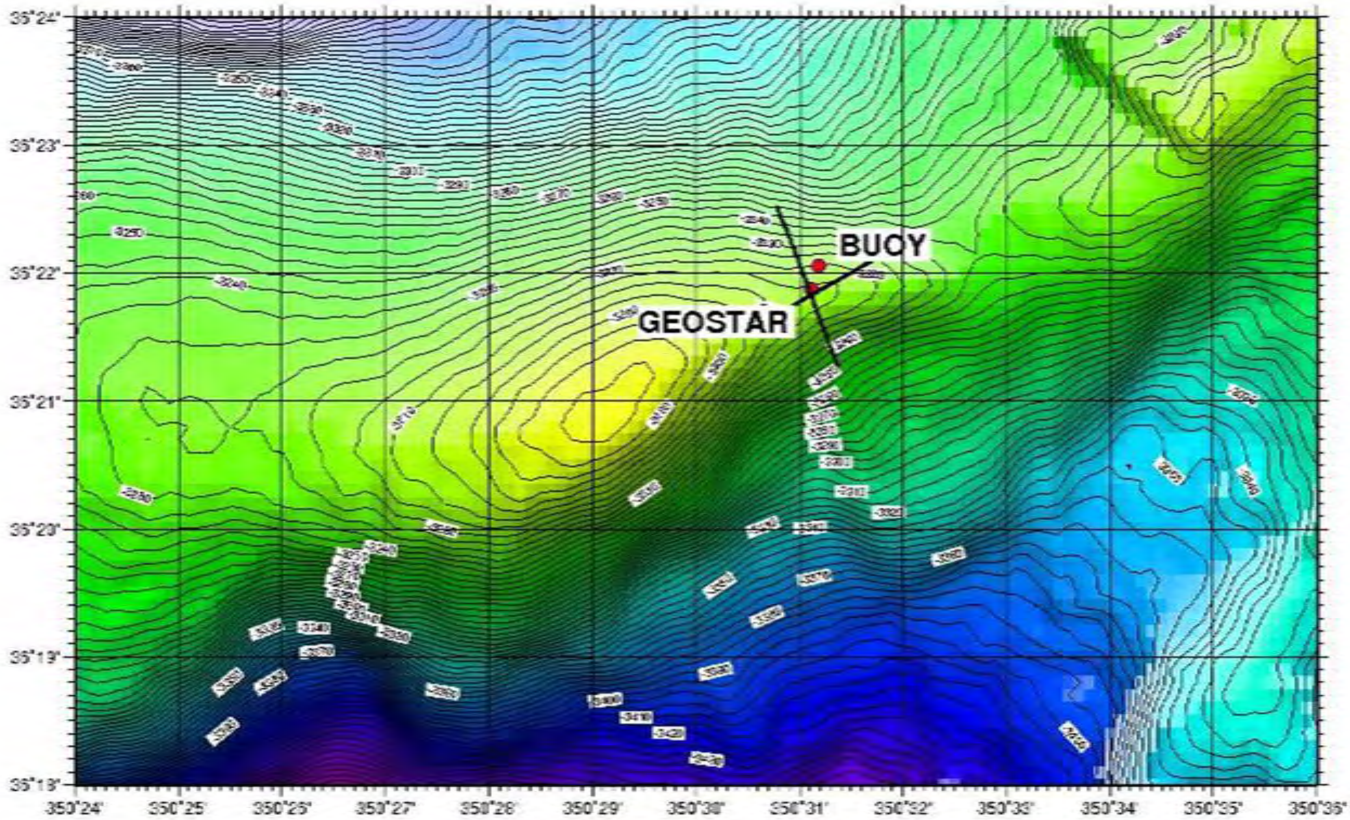

Fig. 37 - GEOSTAR and buoy site deployment locations. The official GEOSTAR and Buoy anchorage coordinates are respectively : 36°21.887'N 9°28.874'W and 36°22.056 N - 009°28.88 W.

On August 16, at 12:00 the sea conditions were considered good enough to start the recovery of the abyssal station. The mean wind was 15 knots from NW and the mean wave high was 1,5 meters. The recovery operations started at 14:58 local time.

No special occurrence until a water depth of about 2900 m at 16:44. NEXUS (the telemetry unit responsible for the entire data communication from and to MODUS) indicated problems by the flickering of the ERROR LED on the surface unit. This means an increase of dB-loss. The ERROR LED starts to operate to warn the users in advance, so before real data losses occur. At 2923 m the sonar showed virtual fish, a clear indication of transmission problems. During a stop for check at the winch the system did not recover. Constant increase of warnings from the control unit, less and less stabile at -3096m. Random flow of data, indication of the distance to the sea floor, but no control of the thrusters (which is the safety mode, to protect the high voltage parts from damage, if meaningless data arrive). Sea bottom visible, because the video system is still operation at 17:12 and 3136 m. 17:31 - Change of glass fibres on the ship side (winch outlet and control rack) did not have any effect at all. Video signals always fully operational.

Return to the surface	2008-08-16	17:32	
System recovers step by step	2008-08-16	18:02	ERRORs occur only rarely
System fully recovered	2008-08-16	18:27	ERROR free, fully operational
System on board	2008-08-16	19:04	END of dive

The system check afterwards gave no indication of damage on the fibre lines. ODTR measurements have been conducted for this. The results showed the same situation as before the dive. In consequence there is no increase of dB-loss because of damage due to operational procedures during this dive. Nevertheless, a signal attenuation occurred, this likely to the increase of tension in the cable and eventual to the bending at the termination with the loose bending restrictor Fig.38, which only can be assumed but not confirmed.

Fig. 38 - Termination and the bending restrictor before the Nearest recovery in August 2008

Before diving again all FO-connectors were cleaned and reconnected.

At 19.44 (UTC) the vessel arrived on the GEOSTAR deployment site and the first operation planned was the acoustic interrogation of the seafloor observatory through ATS-V acoustic modem. First of all, the acoustic link with the underwater modem (ATS-V-USS) was checked in order to request the GEOSTAR station status. All the communication attempts with the underwater acoustic failed.

The day after (2008-08-17) we tryed again the recovery starting at 09:00 local time and we record the first errors at a depth of 2600 m (09:28) followed by increase of data loss, while going deeper. Here the operative scheduling:

Complete loss of Sonar	2008-08-17	09:59	2899 m		
Altimeter random operation	2008-08-17	10:09	3000 m	**Seafloor contact**	
Distance to the sea floor 10 m	2008-08-17	10:15	3155 m		
Video remains, rest is “lost”	2008-08-17	10:15	3155 m		

Search for GEOSTAR begins with the positioning of the vessel only, unable to move or turn MODUS, as the thrusters are non operational because of the failure of data transmission.

GEOSTAR on video	2008-08-17	10:43	3153 m		
GEOSTAR lost	2008-08-17	10:55	3153 m		

Master is tuning in for the search

GEOSTAR on video	2008-08-17	11:20	3153 m		

Master improves positioning significantly, so we remain close to the station.

Station so close	2008-08-17	11:36	3153 m		Fig. 39
Station closer	2008-08-17	11:39	3153 m		Fig. 40
Docking	2008-08-17	11:40	3153 m		Fig. 41
Return to the surface	2008-08-17	11:41			
System recovers step by step	2008-08-17	12:22	2070 m	ERRORs flicker	
System fully recovered	2008-08-17	12:44	1300 m	ERROR free, fully operational	
System on board	2008-08-17	13:23	END of dive		Fig. 42

Fig. 39 - GEOSTAR station – top view from the vertical orientated stern camera

Fig. 40- GEOSTAR station –view from the cone camera 45°

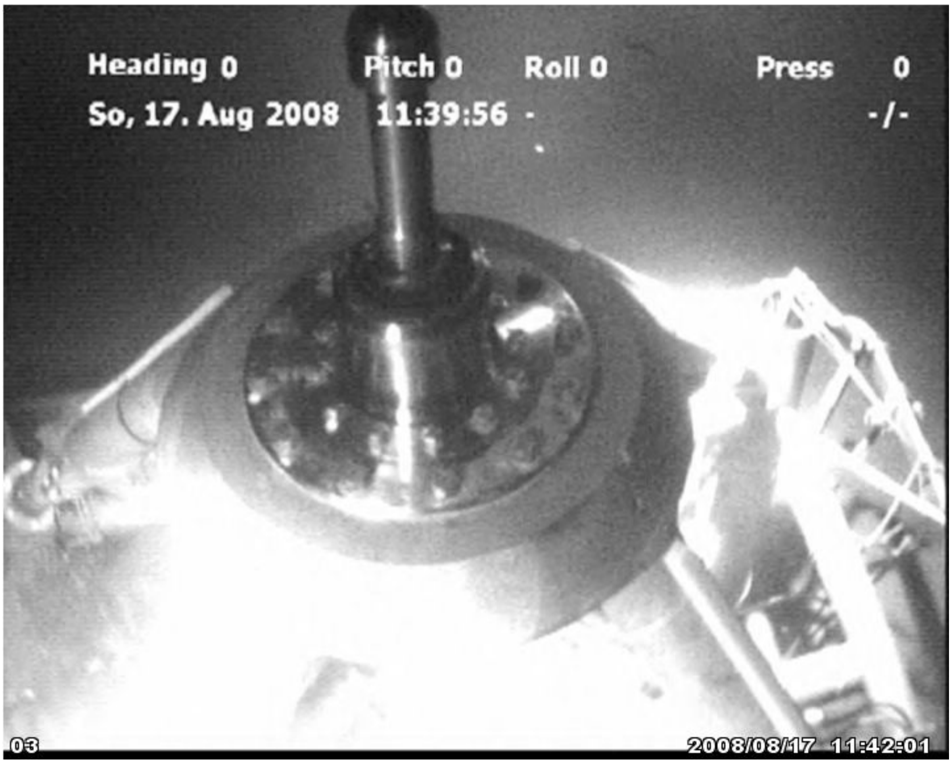

Fig. 41 GEOSTAR station, docking pin –view from the cone camera 45°

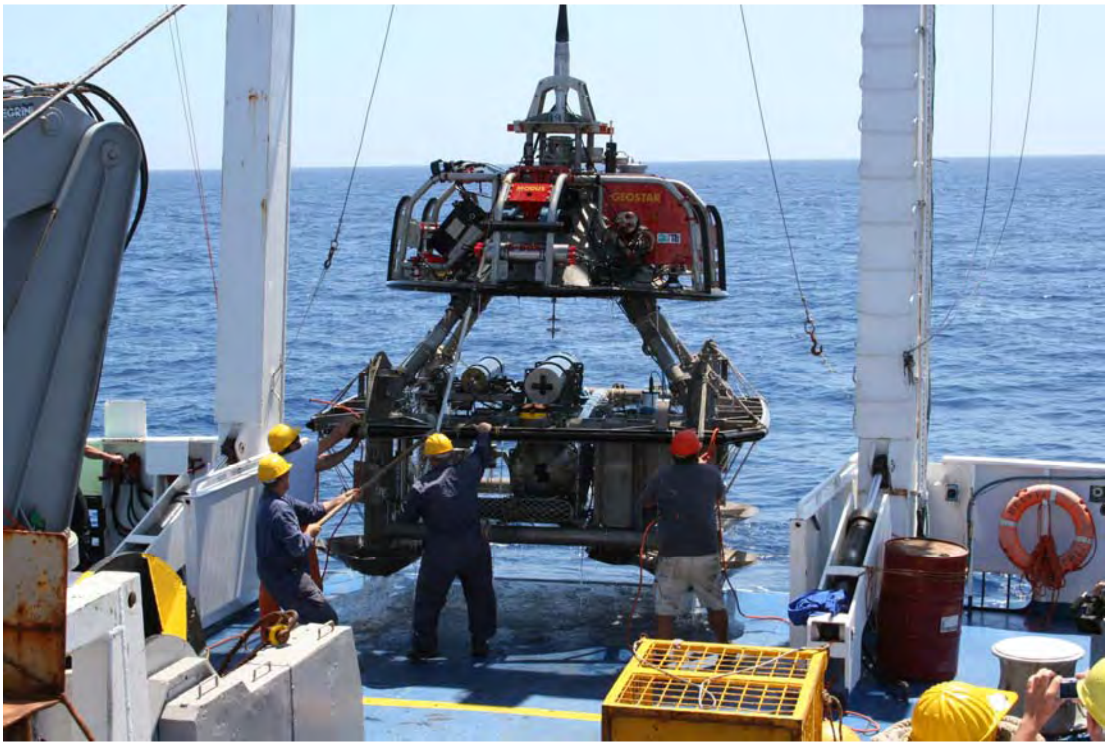

Fig. 42 MODUS and GEOSTAR station after the recovery 2008-08-17

During the deployment we had a smart collision that can be verified on the video documentation, which caused a nice bump on the cone, Figs. 43 and 45.

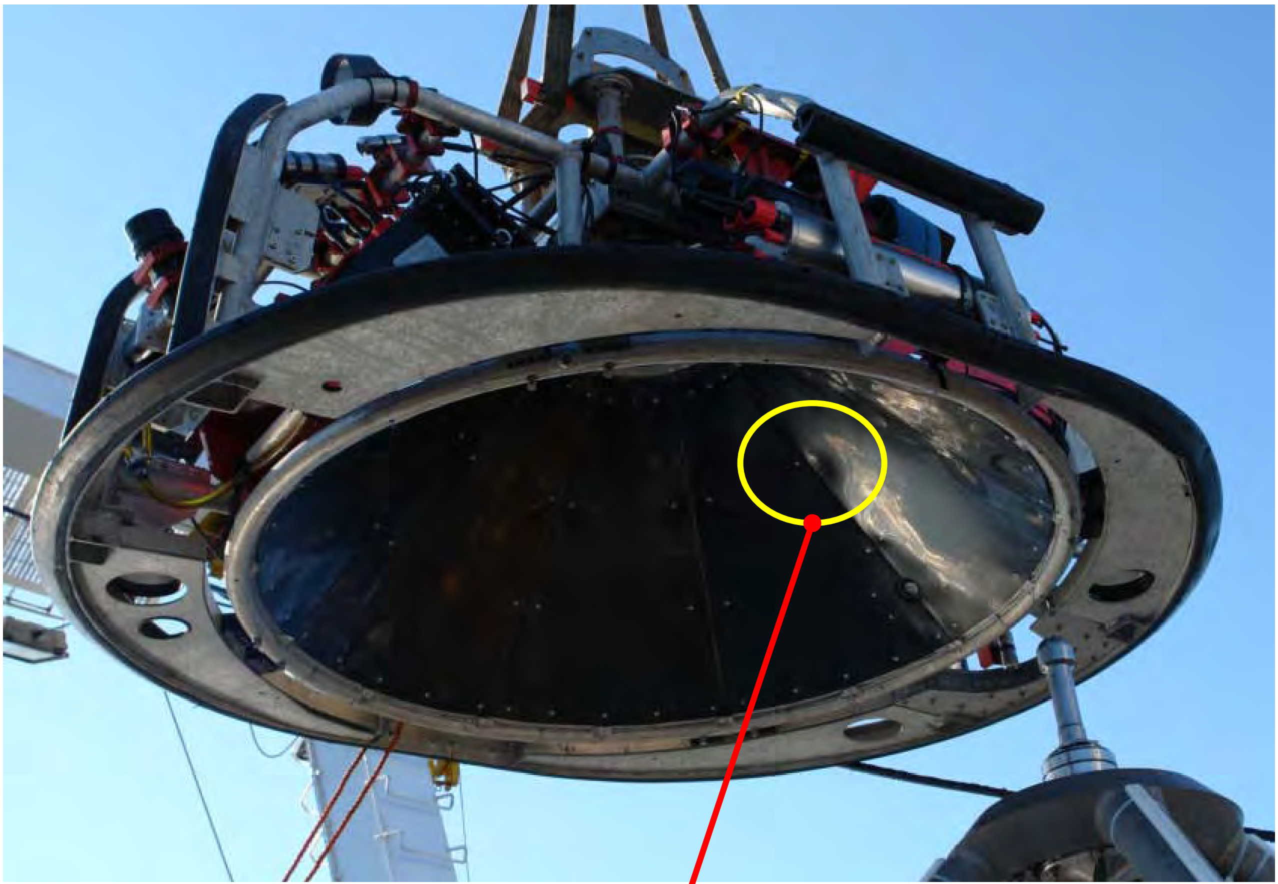

Fig. 43 - View into the inner area of the docking cone of MODUS with the traces of docking

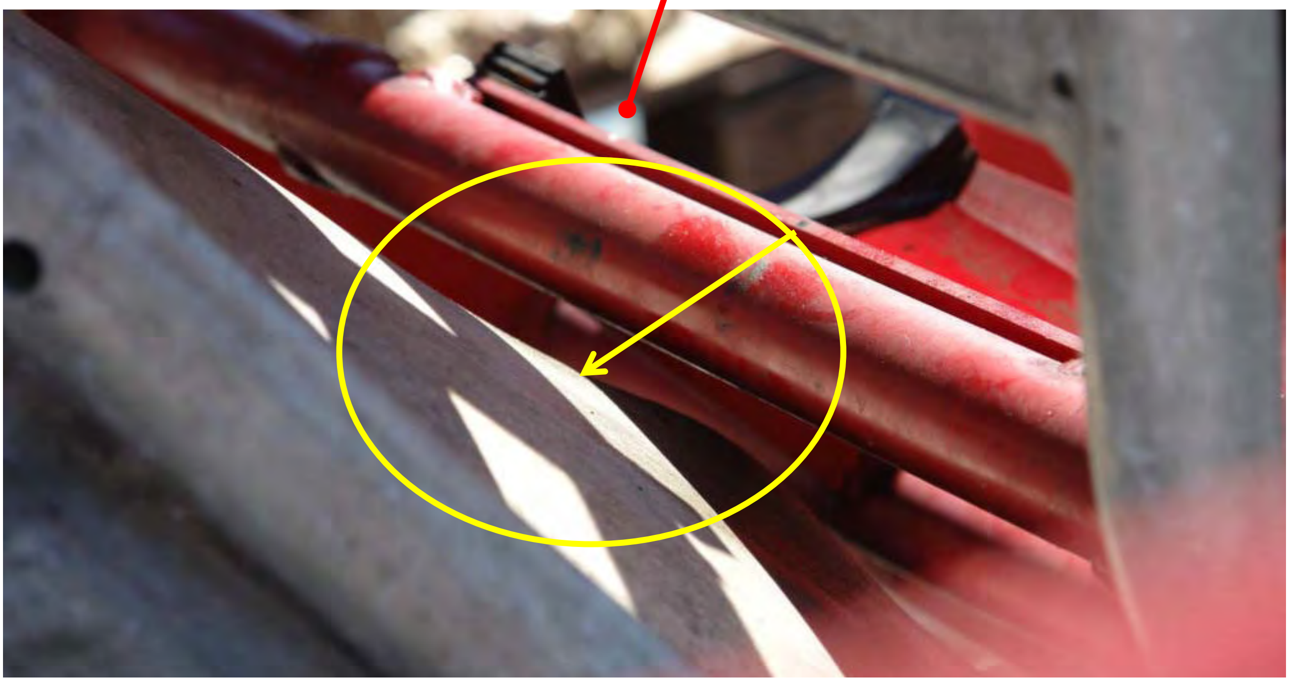

Fig. 44- View into the outer area of the docking cone of MODUS with the traces of docking

The repetition of the errors of the data transmission during the deployment can not be explained explicitly. The facts are the following:

- MODUS system is fully operational before the deployments
- MODUS system is fully operational after the deployments
- Transmission errors at the depth of 2900 m and 2600 m under “normal” conditions. This means no special see conditions, such as strong waves or other occurrences. Both values are related to MODUS by itself without station.
- Video uplink is operational, at full depth 3200 m, but the rest of the system not
- Recovery of the data transmission without any error indication at 1600 m (with station) and 1630 m (without station). This indicates rather a pressure than a load dependent behaviour. But this can not be proven without conducting a series of tests of the entire system at full depth, which is time consuming and not feasible during Leg 2, due to other obligations.
- Obviously there is a hysteresis in the entire system, as the reoccurrence of the signal takes place at a lower depth as the loss. The cause of the difference seems to disappear while MODUS is on deck, or it is a real hysteresis loop for unknown reason.

4.2.1 Check of MODUS after recovering

Processing the log files from the deployment cruise in August 2007 provides the following chart, Fig. 45. No indication of data losses or any other special occurrences. Pull (decreases after deployment of the station- DEP), pitch comes to a more or less constant value (usually there is a small gap between the station and MODUS, so slight changes are likely), acceleration is constant. After releasing the station [REL] and lifting the data start to change with faster changes induced by the surface waves → vessel → umbilical → MODUS. These data are consistent.

During the recovery dive different effects could be monitored as shown in the graph, Fig. 46. Pull is constantly running as these signals come from the sheave of the winch directly to the onboard computer of MODUS. Pitch and acceleration are interrupted frequently. The deeper it goes the more data are lost. Significant and surprising is that in a period of lower pull (less amplitude overlay) the signals more or less disappear completely and reappear with higher pull amplitudes. Nevertheless, the transmission is interrupted in the end completely as already described above. The entire data set and the cable will be investigated carefully after our return.

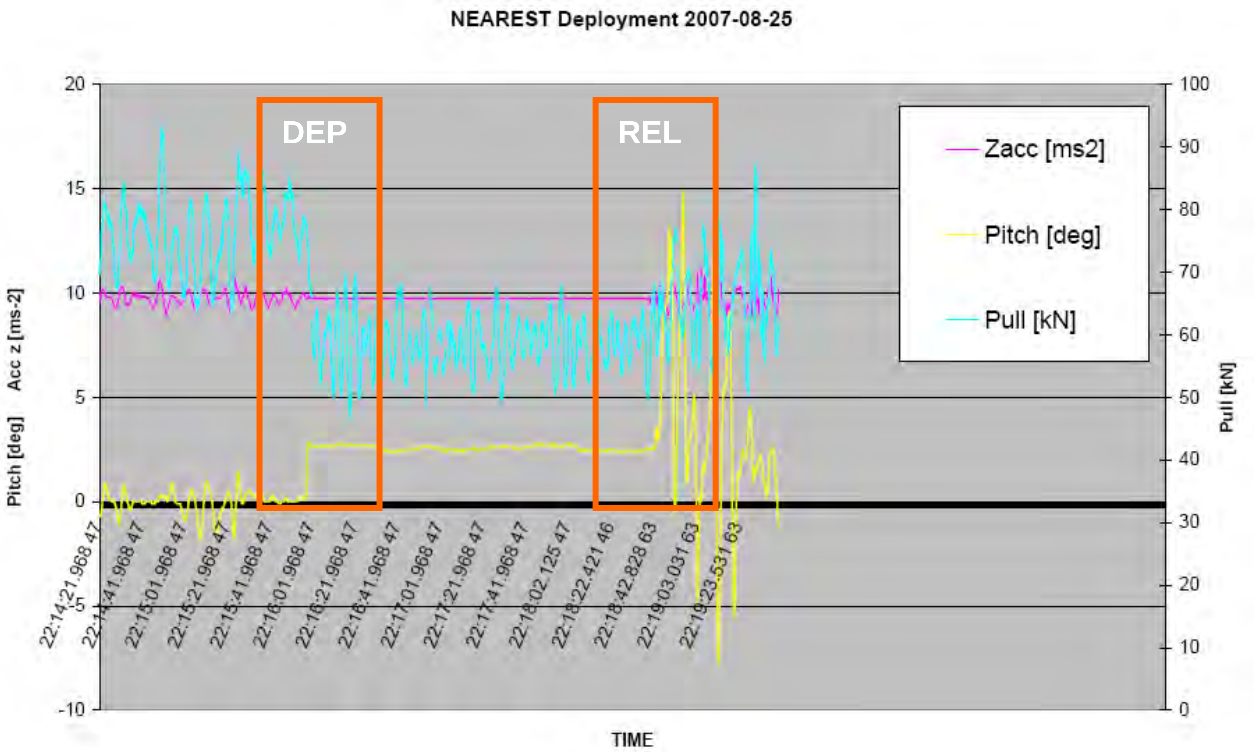

Fig. 45 - Vertical acceleration, pitch and pull at the winch during the deployment of GEOSTAR 08/07

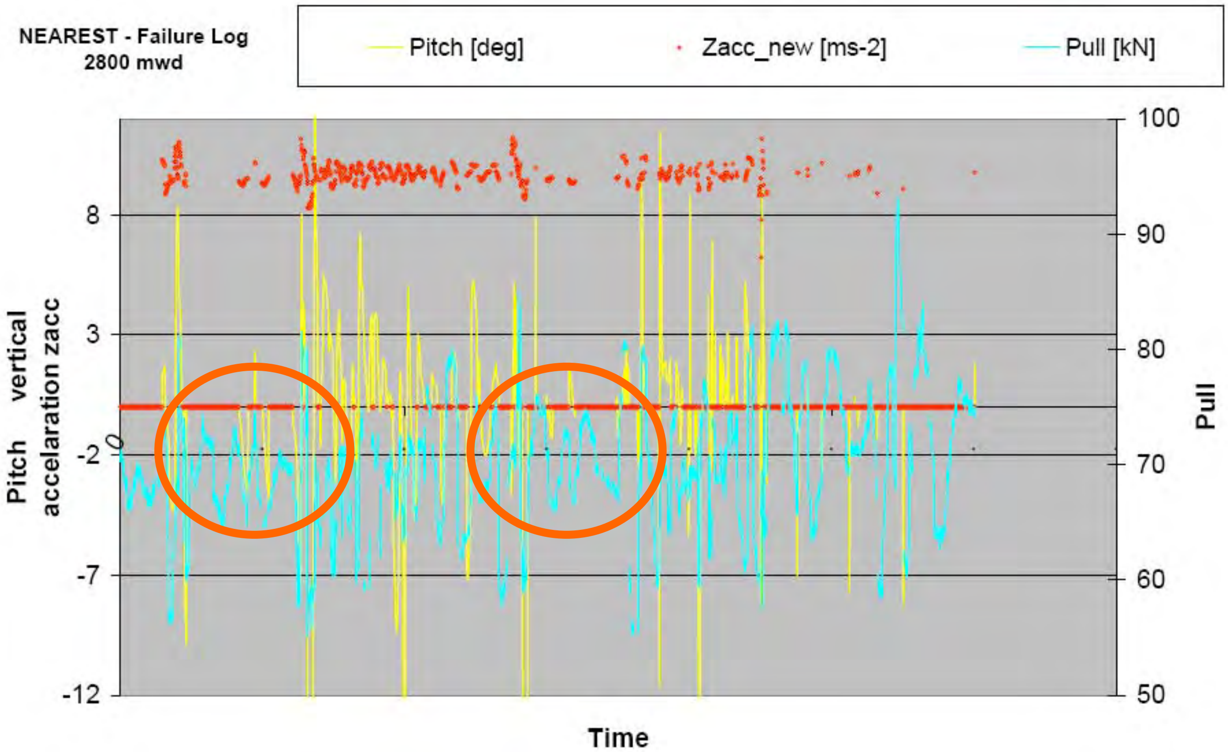

Fig. 46 - Vertical acceleration, pitch and pull at the winch during the recovery of GEOSTAR 08/08

4.2.2 GEOSTAR acoustic check after recovery

On 08/18/2008 after recovery, GEOSTAR was washed and a second series of “Head-to-Head” acoustic tests (consisting in direct contact between the surface and underwater transducers) were performed on the deck in order to check the acoustic functionalities and get STATUS and DATA messages from GEOSTAR DACS (Data Acquisition and Control System). By means of the *HMI-NEAREST* program, the UPLOAD ALL command was given in order to get settings and parameters of the underwater acoustic modem (fig. 47). In this case, the link was successful and the system replied correctly.

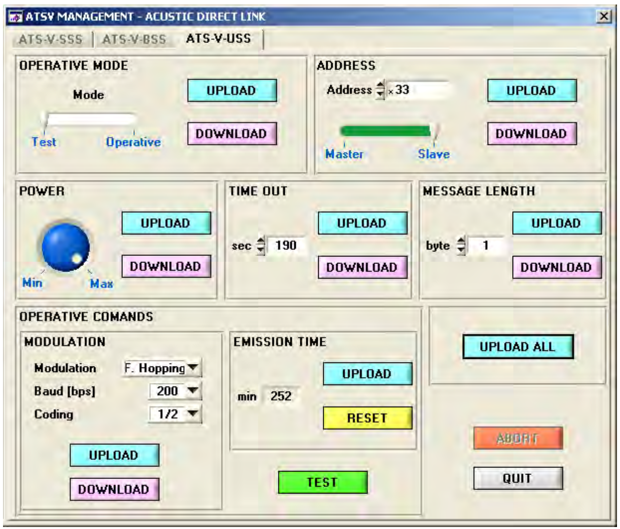

Fig.47: sketch of acoustic system parameters and settings showing a normal status of ATS-V-USS

Then, the DACS STATUS command was sent to GEOSTAR through *HMI-NEAREST* program in order to obtain information of the general status of the station as shown in the fig.48:

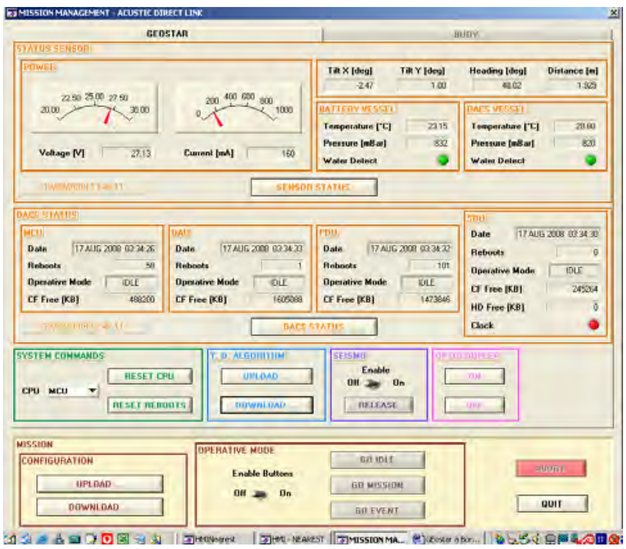

Fig. 48: Sketch of general status of GEOSTAR

The most relevant anomaly was a delay of about 34h with respect to the current one.
In order to understand the reasons of this delay, a complete check was performed (see next paragraph).
On 08/19/2008 a Direct Serial Link and Log File Download was carried out in order to gather more information, Log File were downloaded by a direct cable link to GEOSTAR. A request of DACS STATUS was sent to confirm the correct functionality of the system that suddenly replied (fig.49).

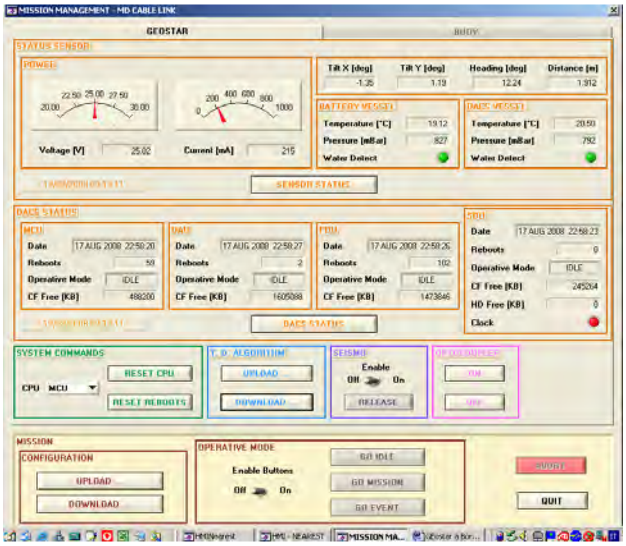

Fig. 49 – sketch of GEOSTAR DACS STATUS

A decrease in the Voltage (2 Volts less in comparison with previous DACS STATUS request) was noted. This fact could suggest a not-normal general status of the battery package, probably caused by the low temperature (~2 °C) in the Atlantic seafloor. The following table 7 shows a list of requests of STATUS and EVENT DATA LOG file directly downloaded via serial link port in order to better investigate the functionality of GEOSTAR during the deployment period.

Requested Date	**Result**	**Requested Date**	**Result**
16 Oct 2007	Files Found	16 Mar 2008	Files Found
16 Nov 2007	"	16 Apr 2008	"
16 Dec 2007	"	16 May 2008	"
16 Jan 2008	"	16 Jun 2008	"
16 Feb 2008	"	16 Jun 2008	"
	Check Date	**Result**	
	1 Aug 2008	Files Not Found	

Table 7. List of requests of STATUS and EVENT DATA LOG

The system shutdown was scheduled for July 27th 2008 and the result of these interrogations shows that before the 27th of July the files are present while on August 1st 2008 are not as expected.

Successively it was decided to disassembly the *Orca* Rubidium clock in order to quantify its status and drift.

At 16.55 (UTC), the power cable was removed from the DACS vessel and a voltage of 28.35 V was measured. After that, the DACS was taken off the vessel. The drift measurement was done before the programmed clock inter-calibration, in order to avoid the complete discharge of two 9V safety batteries caused by high power request during this operation. A direct link via serial port allowed a date-time request: the answer was August, 19th 20:15:21, the current time. Then, the drift was measured linking the clock to the GPS antenna, and a drift of 184 ms over almost 1 year was found. The clock behaved as expected based on the experience made in previous experiments. The following figure (fig.50) shows the display of the oscilloscope used to measure.

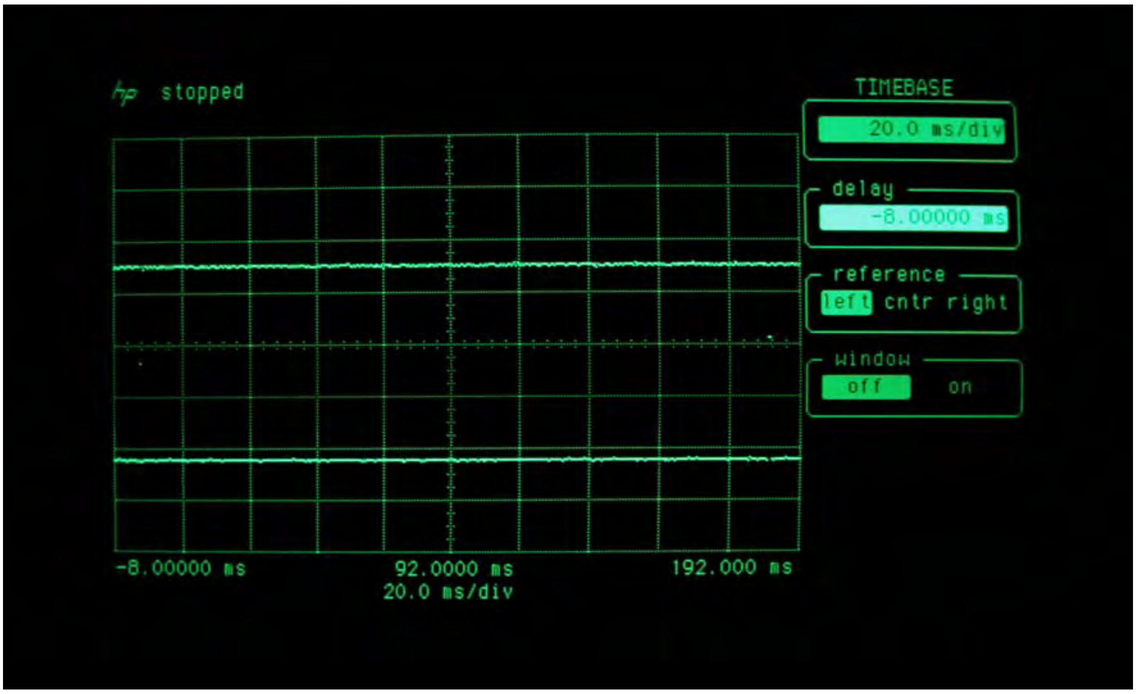

Fig. 50: Drift measured through the oscilloscope

At the end of the drift measurement, the inter-calibration of the clock ended and the clock was powered by an external supply in order to assure a stable voltage.

After the drift measurement, the three Flash Cards in the DACS were temporarily removed to backup the data:

- MCU (Master Control Unit): 4 MB;
- DAU (Data Acquisition Unit): 2.35 GB;

- SDU (Seismometer Data Unit): 257 MB.

Although the environmental low temperature produced a decreasing of the battery efficiency, the system was able to acquire correctly until July 5th. We have to underline that, for safety reasons, a shutdown of the system was programmed by July 27th. A further analysis on the hard disk showed a 44 GB of memory load.

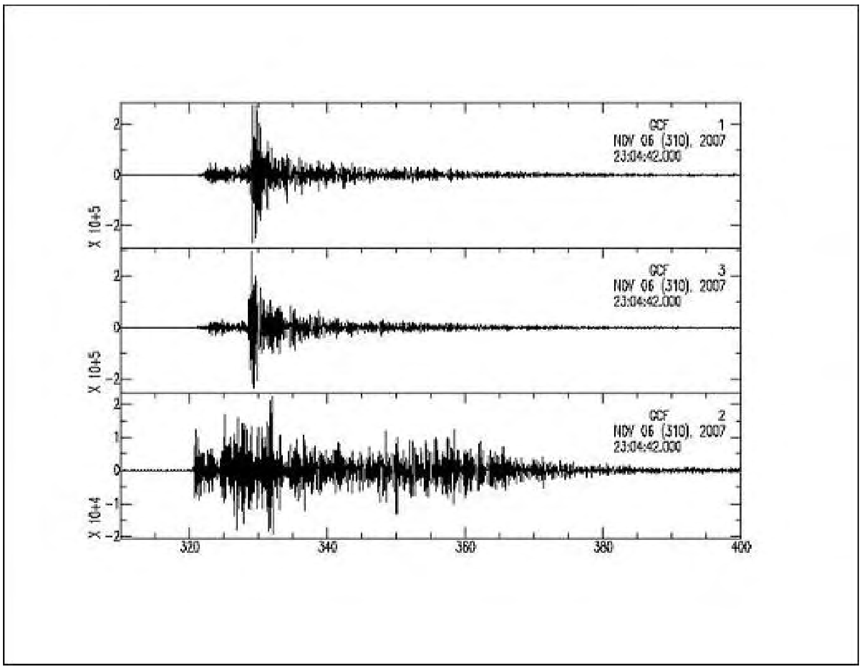

Fig 51 - Example of seismic events acquired by GEOSTAR.

4.3 Mooring cable recovery

The mooring scheme deployed in the previous NEAREST2007 cruise is shown in the following figure:

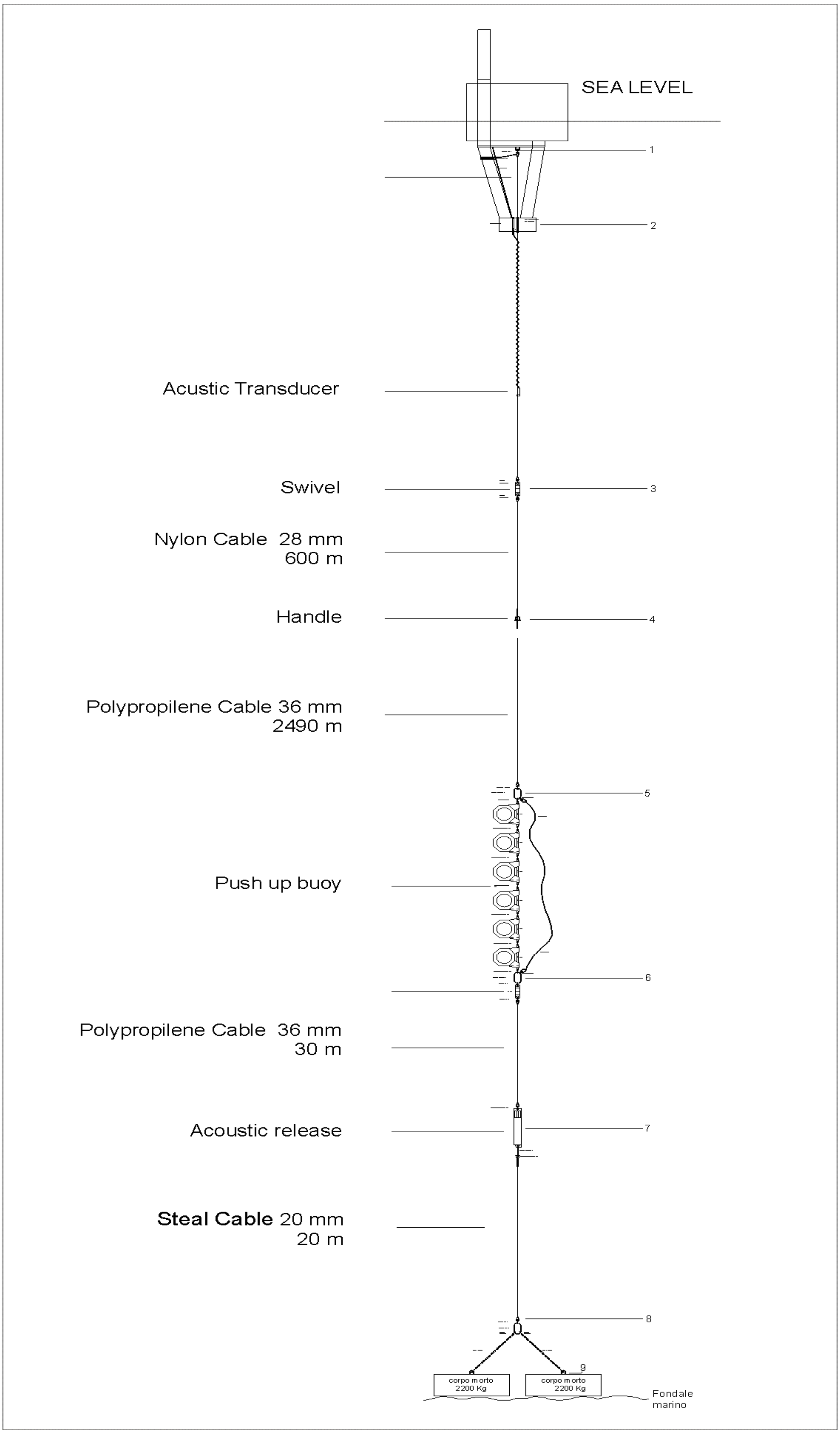

Fig 52 – Mooring configuration

The mooring of the buoy failed on October 19th 2007 due to the breaking of the stainless steel cable located just beyond the floating body, and the buoy started drifting in open ocean. The mooring line was lost on the seafloor including the acoustic transducer which is expected to lie on the seafloor in the nearby of the observatory.

The recovery operations were performed in 21 of August 2008 when the weather conditions permitted the work in the area (fig. 53). Approaching the position of 36°22.056 N - 009°28.88 W, on a water depth of 3225 mt a first tentative to communicate with the acoustic releaser was carried out without success. Only after one hour the system started to answer, then the release signal was sent. After 70 minutes the releaser was at 170 mt below sea level. At that point the Master of Urania decided to grab the cable, using a 12 mm steel cable of 7500 m length. This was an emergency action due to bad sea conditions and the risk to twist the mooring cable around the propeller. With that action the following instruments were recovered:

n. 1 acoustic release,

n. 6 buoys Nautilus

about 1000 mt of polypropilene cable

n. 1 swivel

the remaining components of the mooring were lost.

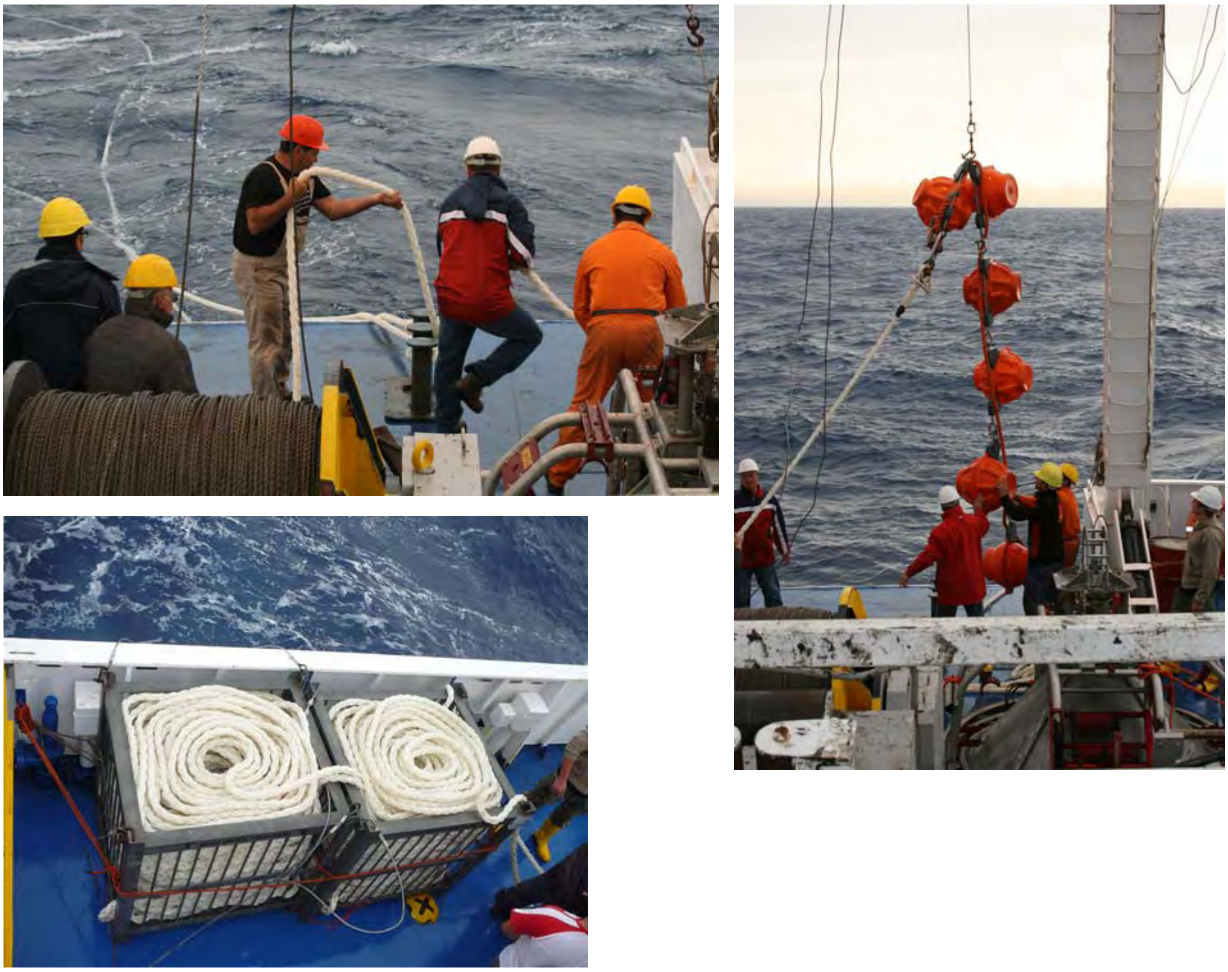

Fig. 53: Mooring recovery

5. CTD Survey

In order to characterise, from oceanographyc point of view, the deployment site of GEOSTAR an hydrological survey is necessary to define a microscale dynamic of the water masses involved in the Cadiz Gulf area.

5.1 Area description

The Gulf of Cadiz area plays a crucial role being involved in the Mediterranean Water (MW) outflow that, flowing parallel to the topography, reaches its density equilibrium after the 7°W and it separates in two cores located at different depth: UMW (Upper Mediterranean Water) centred at 700-800 m depth and LMW (Lower Mediterranean Water) located at 1100-1200 m depth (Freitas et al., 2002; Ambar and Howe, 1979). Generally, literature refers to the Mediterranean Outflow Water (MOW) as a deep countercurrent flowing in a region between 9°30 W and 8° 30W south of Cape St. Vincent (Ambar and Howe,1979) as well as it refers to the formation of meddy at around 36°N, 9°54°W (Rhein,1993; Baringer 1997; Serra 2002).

The only CTD cast (fig.54) performed during the past cruise (august 2007) on the site of GEOSTAR deployment, showed the main water masses involved in the water column above station at time of deployment.

After a first surface water layer, an upper layer (300-400 m depth) of warm and fresh water (NACW North Atlantic Central Water) occupies a thickness of around 100 m. At around 800 m depth the profile shows an increase of salinity and temperature referring to the Mediterranean Water (MW) influence, which persist until 1200-1300 m depth. At the bottom the presence of colder and fresher water masses highlights a North Atlantic Deep Water (NADW) contribution.

Although a seasonal monitoring of the water column is lacking, the aim of the hydrological programme here proposed is focused on a better definition of the water masses involved in this area, in order to be able to compare and

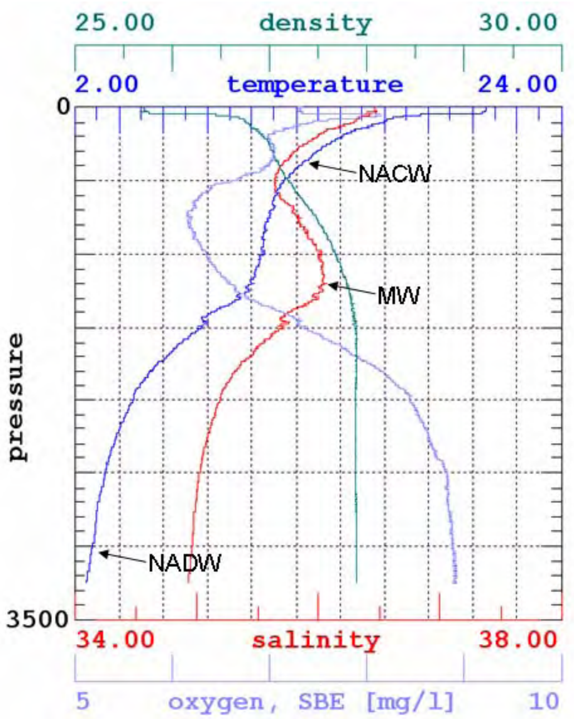

Fig.54: CTD profile performed during the NEAREST 2007 cruise

eventually to correlate the signals collected at the seafloor through GEOSTAR at least during the summer period.

5.2 Sampling and Methods

During the NEAREST 2008 cruise only 8 CTD stations, of 13 CTD planned, centred on GEOSTAR deployment site, were performed (fig.55) because of unfavourable weather conditions.

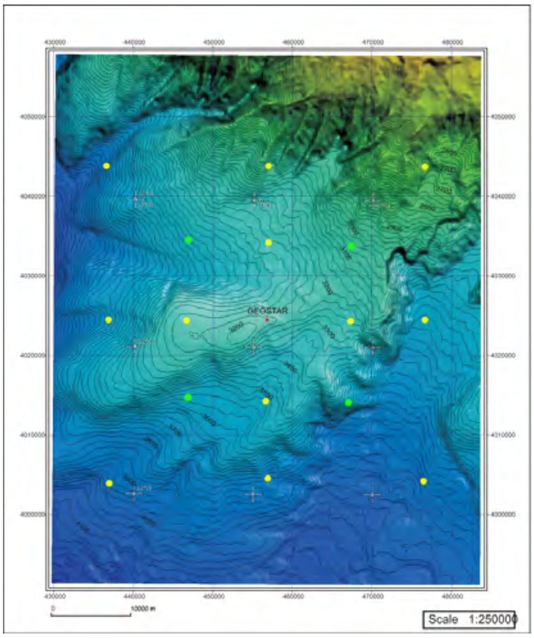

Fig.55: Area of the oceanographic survey around GEOSTAR site.

Considering the topographic limits around the deployment site of GEOSTAR, the main idea was to survey an area of about 30 km^2 in order to detect the water masses generated in the Portimao Canyon region and flowing southward (Serra, 2002), which also should be recorded in their deeper parts by the observatory and to recognise possible Mediterranean Water influences in the intermediate depth (fig.56).

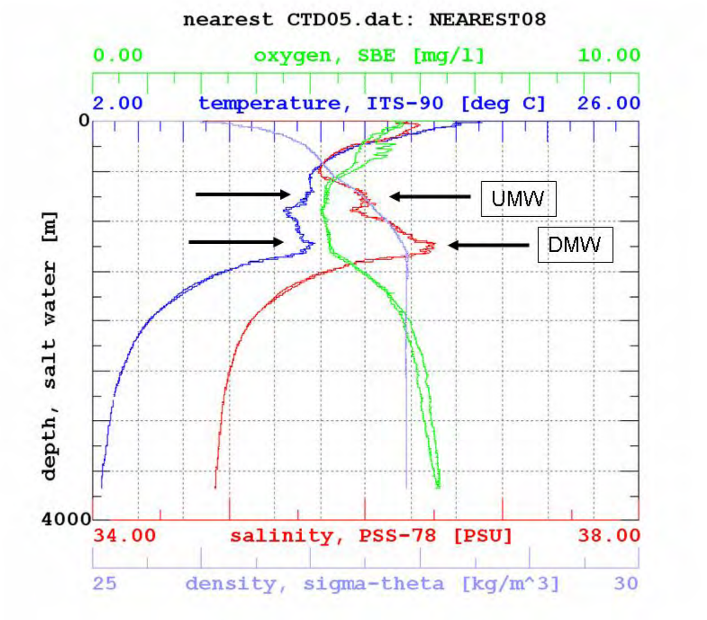

Fig.56: A sketch of CTD_05 cast showing two well defined core of Mediterranean water (Upper MW and Deep MW)

Compared with the CTD profile of past year, the new cast present an oxygen curve with lower average values attributable to calibration problem of the probe (fig.57) solvable during the post-processing phase.

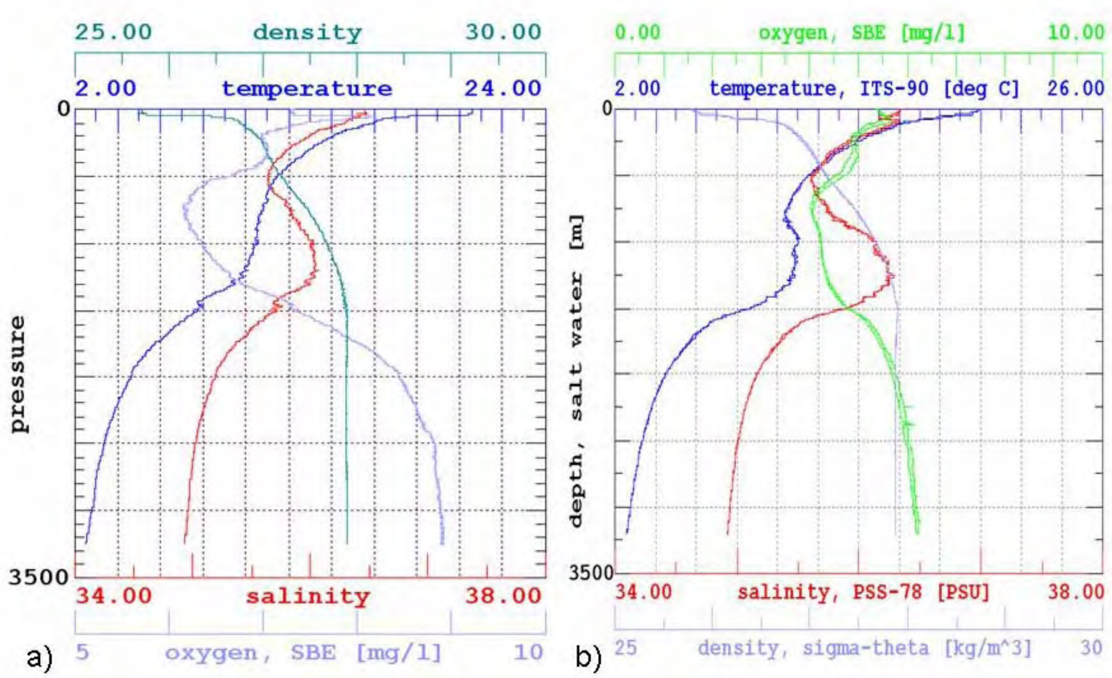

Fig.57: CTD_Geostar profile of NEAREST 2007 (a) and NEAREST 2008 (b)

The CTD_GEOSTAR station was repeated to provide a new more reference to align the long dataset of GEOSTAR observatory.

To collect these data, a on board CTD 911 plus was used. Also, salinity samples were collected for each station through Niskin bottle fired at 4 different depth (bottom, 2500 m, 1500 m and 500 m) in order to align the curves measured through instrumental measurements with analytical results.

The following table (table 8) resumes all CTD stations performed during the NEAREST '08 cruise:

Station	Coordinates		Depth	Date
	Latitude	Longitude		
CTD_07	36°21.895'N	09°22.234'W	3226	15/08/2008
CTD_04	36°27.221'N	09°28.858'W	3250	15/08/2008
CTD_06	36°21.850'N	09°35.603'W	3217	15/08/2008
CTD_09	36°16.480'N	09°28.872'W	3493	15/08/2008
CTD_12	36°11.102'N	09°15.458'W	3858	16/08/2008
CTD_08	36°21.871'N	09°15.588'W	3577	16/08/2008
CTD_GEOSTAR	36°22.047'N	09°27.560'W	3237	27/08/2008
CTD_05	36°21.985'N	09°42.239'W	3738	27/08/2008

Table 8. CTD stations

6. Multibeam and chirp survey

Two multibeam and chirp surveys were performed during the cruise. The first one is located off Portimao (South Portugal) and has been planned to join the previous 2007 Urania survey and the bathymetric survey performed by the portuguese partners inside the NEAREST project. These data are needed for the tsunami impact modelling on the coast foreseen by the Work Pakage n. 7 of the project itself.

The second survey was performed close to Morocco with the main goal to map the SWIM Faults along side the Moroccan margin and to map their continuation toward the mainland. This is an important implication in mapping Tsunami's source locations because, if prooved, the shear associated to this lineament will become an important constrain on the present day Europe/Africa plate boundary and consequently on the tsunamigenic potential of this structure.

6.1 Portimao survey map

The survey south the Algarve coasts consists in two portion: one really south of the Portimao coasts and the other one south of Faro as shown in the following figures.

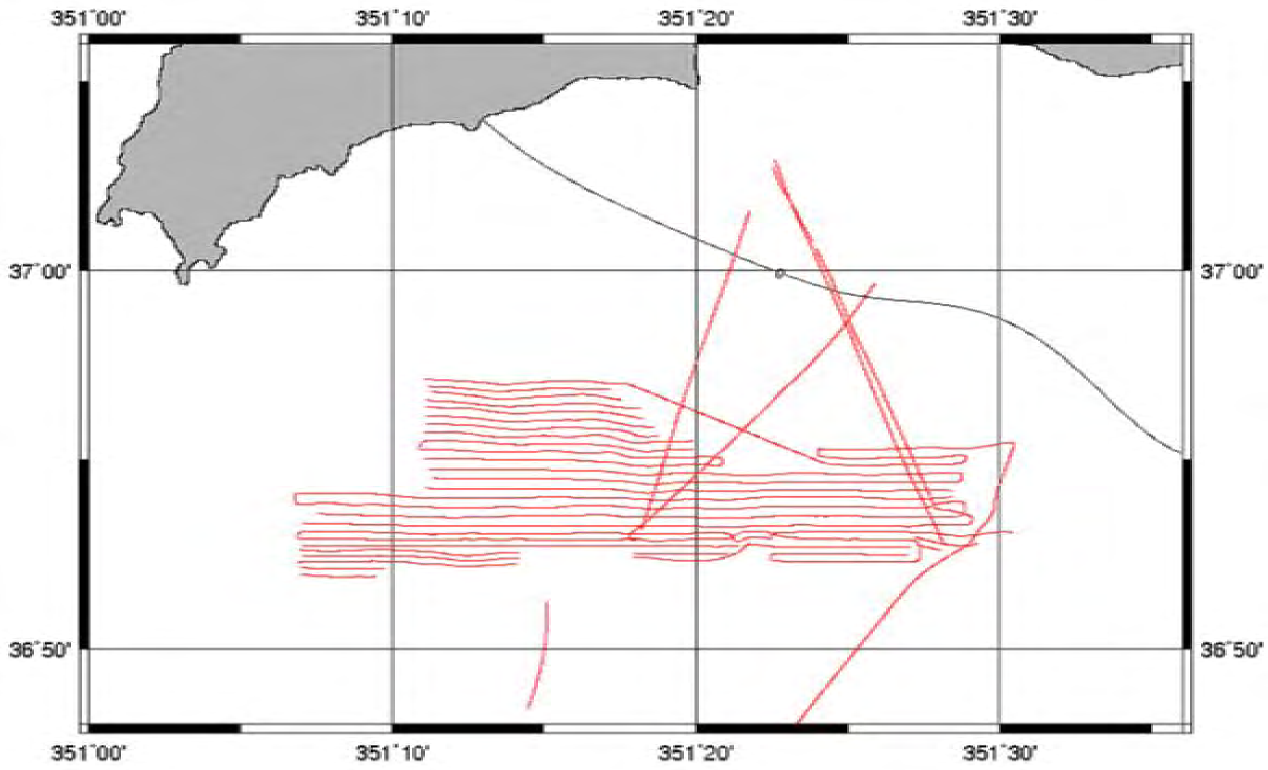

Fig 58 – Multibeam and chirp survey South of Portimao: navigation tracks.

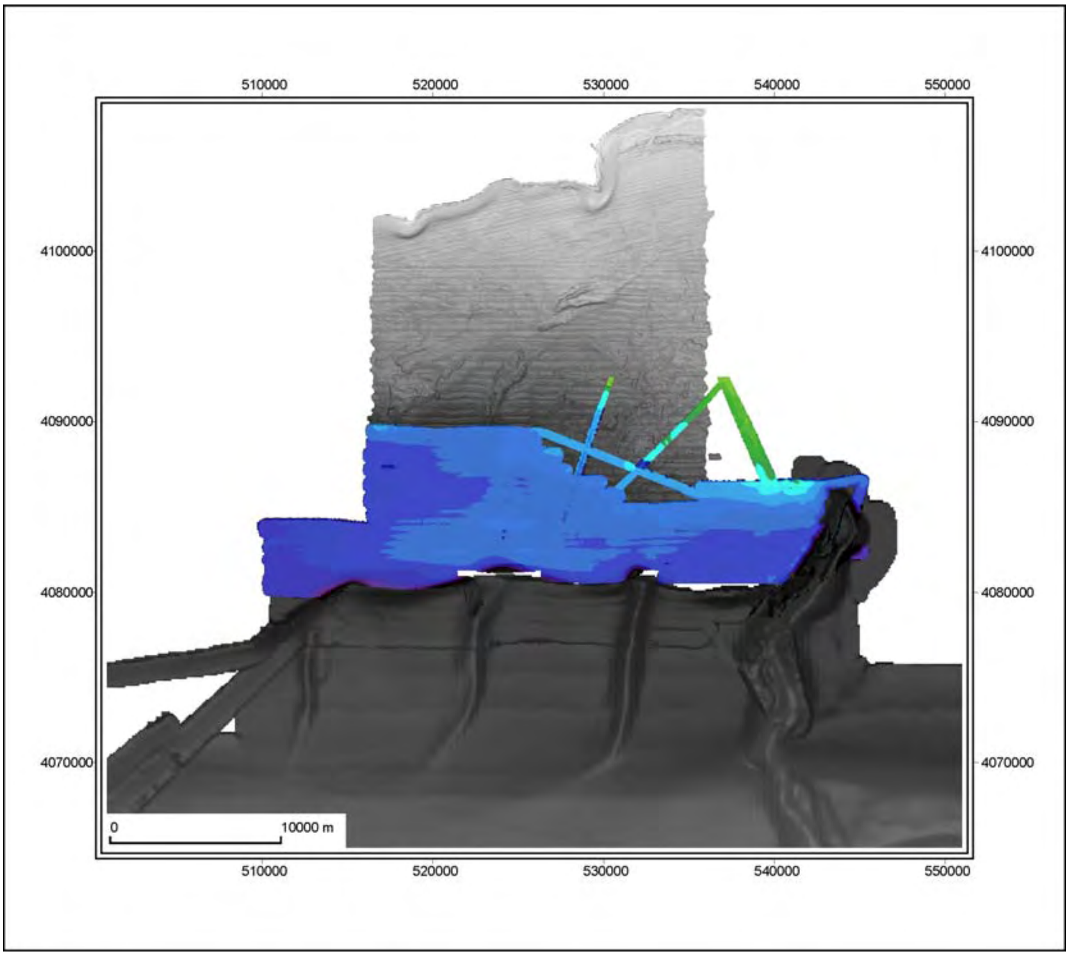

Fig 59 – South Portimao shaded relief

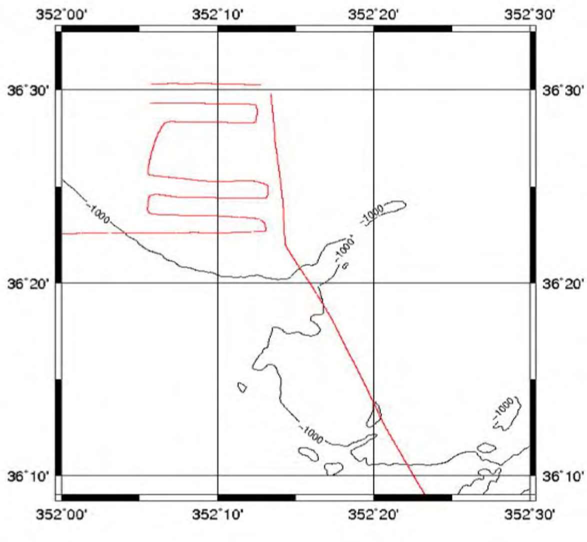

Fig 60 – Multibeam and chirp survey South of Faro: navigation tracks

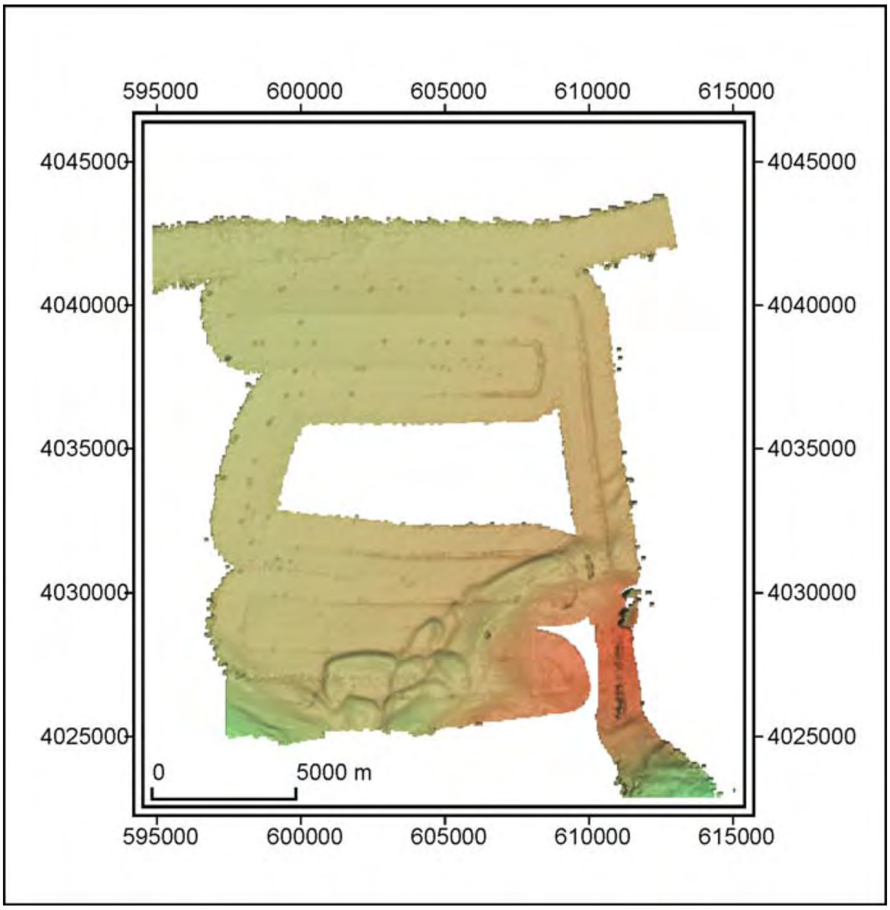

Fig 61 – South Faro multibeam data shaded relief

6.2 Moroccan survey map

The Moroccan Survey was performed near the Moroccan coasts between Rabat and Tanger.

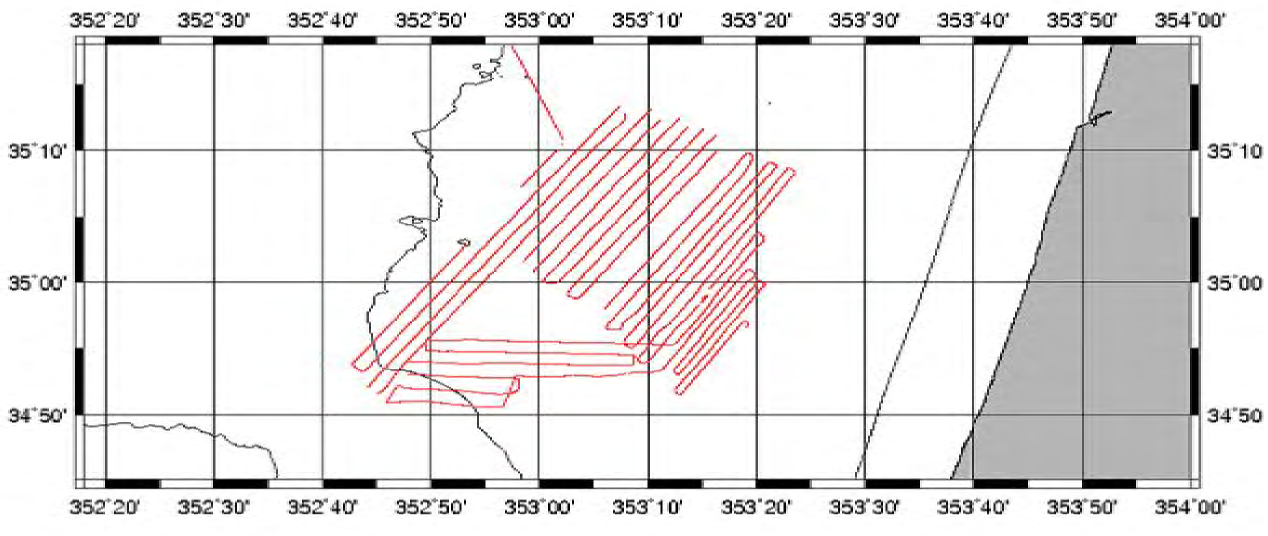

Fig**.** 62 – Multibeam and chirp survey off Morocco: navigation tracks

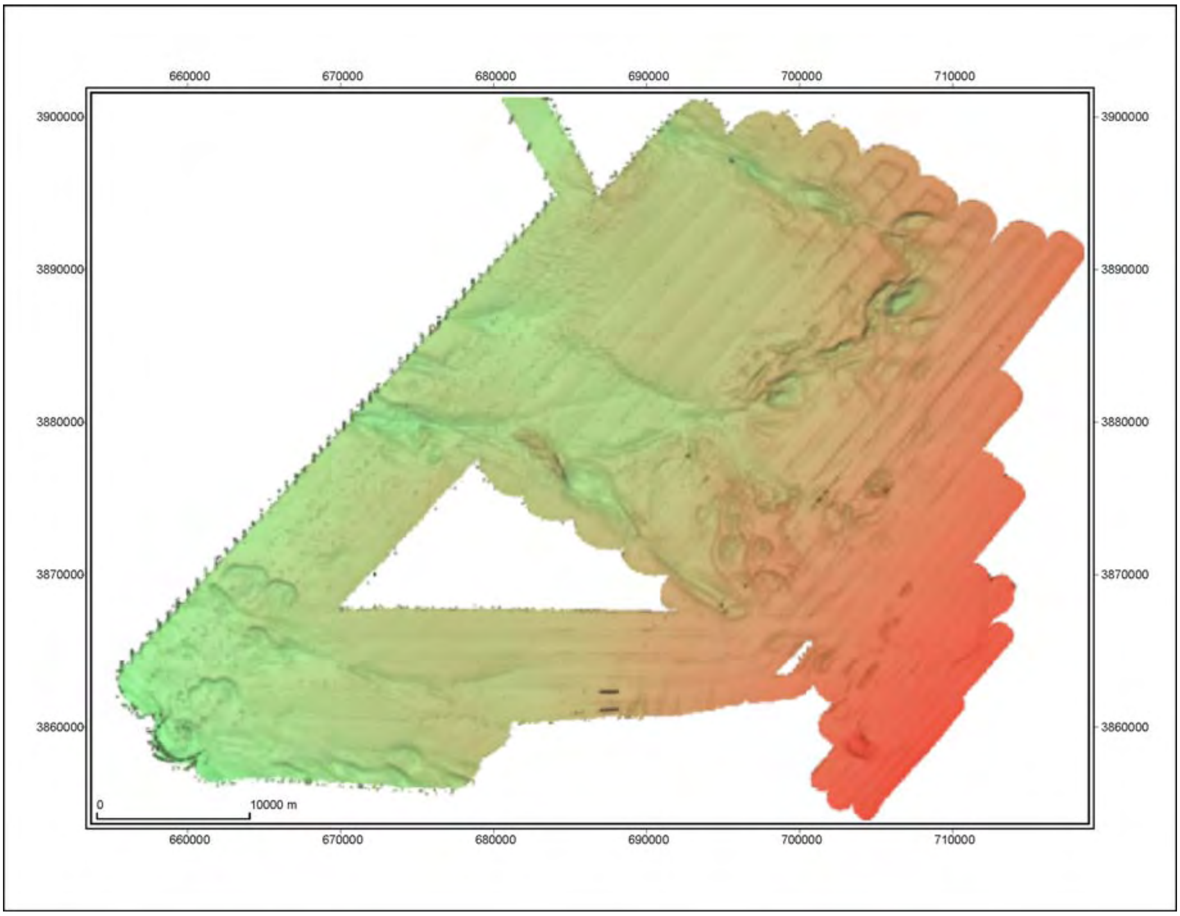

Fig 63 – Off Morocco shaded relief

6.3 Chirp data example

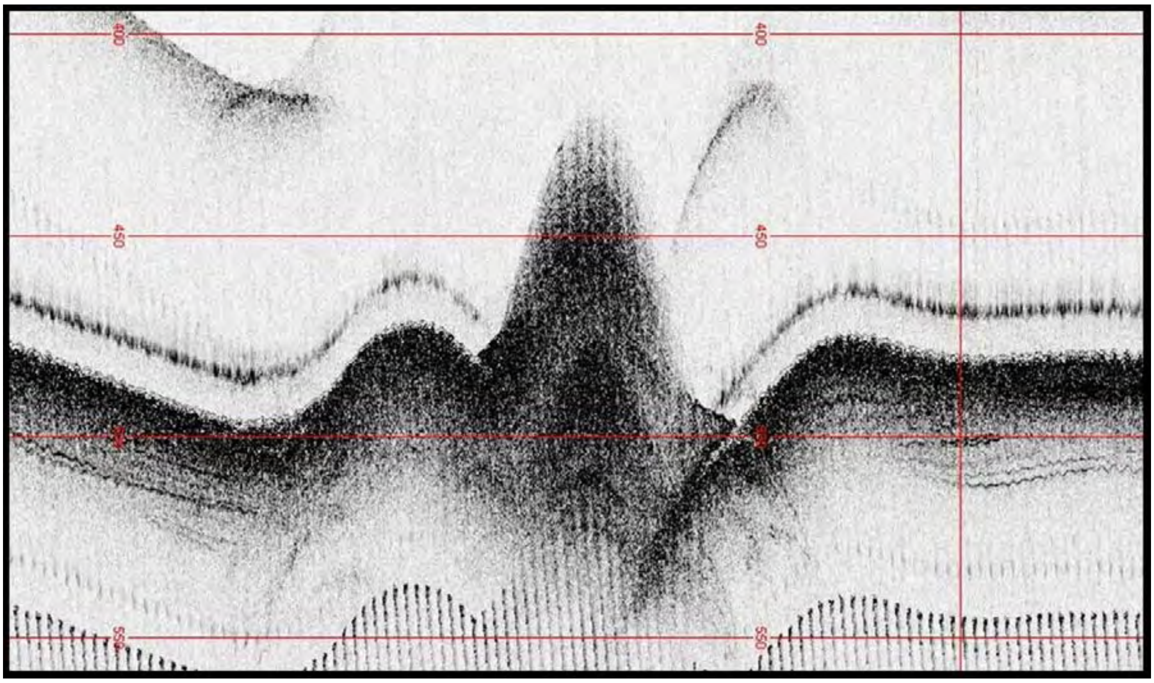

Fig 64 Example of fluid escape along a chirp line located off moroccan coasts

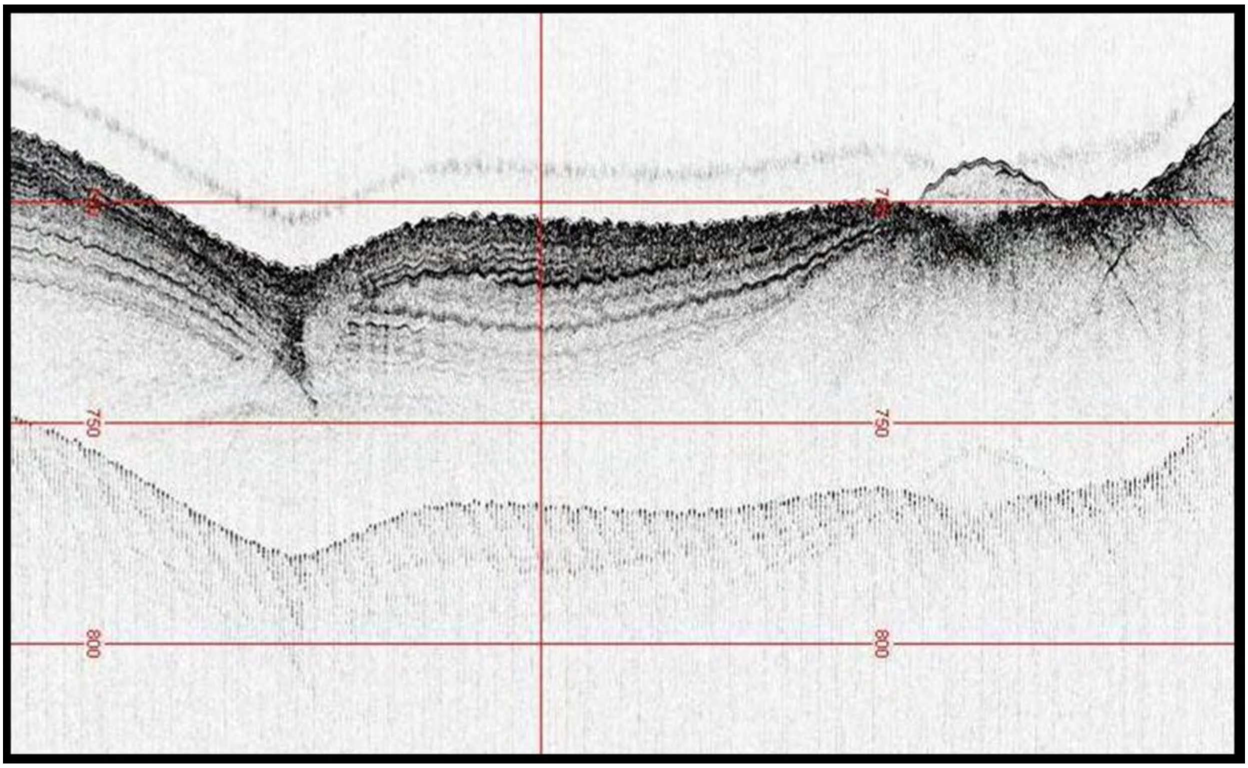

Fig 65 Example of faulting of the seabed along a chirp line located off moroccan coasts

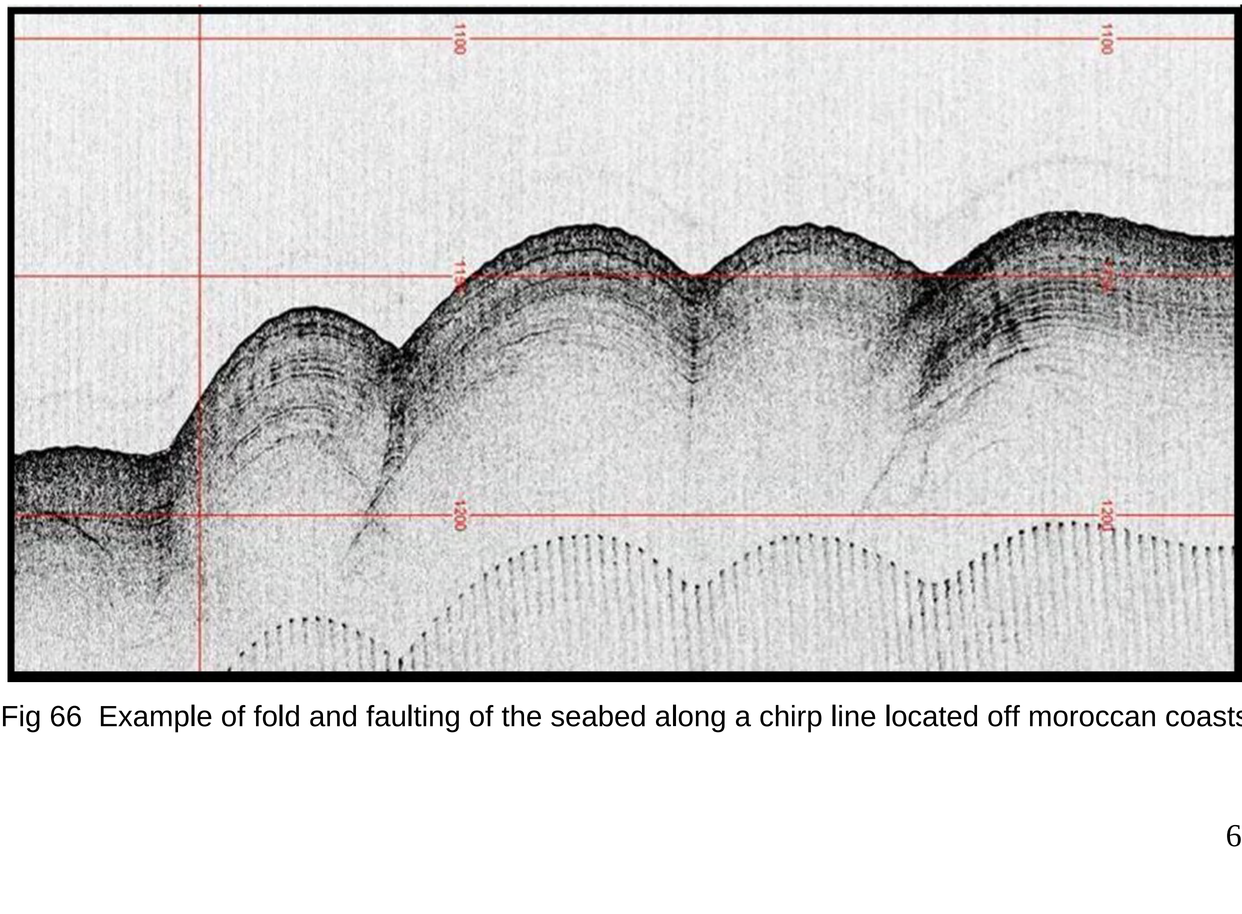

Fig 66 Example of fold and faulting of the seabed along a chirp line located off moroccan coasts

7. Instruments

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. The Ship is normally used for geological, geophysical and oceanographical work in the Mediterranean Sea and adjoining waters, including but not limited to, the Atlantic Ocean, the Red Sea, and the Black Sea.

R/V Urania is equipped with DGPS positioning system (satellite link by FUGRO), singlebeam 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, like Side Scan Sonars.

7.1 Chirp

Factory	Benthos
Model	Chirp II
Installation	Hull mounted
Number of transducers	16
Transducers type	AT 471
Signal generator / DSP	CAP-6600 Chirp II Workstation
DSP Sonar Signal Processing	16 bit A/D, continuous FFT
Operating sweep frequency	2 – 7 kHz
Ping rate	Variable, operator selectable (max 12 ping/sec)
Sweep Length	Variable, operator selectable
Multiping option	yes
Gain	Automatic gain control
Bottom tracking	Interactive
Navigation / Annotation	NMEA 0183
Data format	SEG Y
Printer	Alden
Acquisition software	SwanPRO / ChirpScan II
Processing software	SeisPRO / SwanPRO
Location controller / recorder	Recording room (room # 525)

Table 9 – Chirp II instrument parameters

7.2 Multibeam

Model	RESON 8160
Operating frequency:	50KHz
Swath angle:	150°
Operating Depth:	5 - 5000mt
Beam number:	126
Vertical resolution:	1.4cm with range until 750m 2.9cm with range between 1000m and 1500m 8.6cm with range between 1500m and 2500m

Table 10 – Multibeam instrument parameters

7.3 CTD

The CTD probe SeaBird 9Plus measures conductivity, temperature, pressure and parameters from up to eight auxiliary sensors at 24 scans per second.

The main housing contains the acquisition electronics, telemetry circuitry and pressure sensor while temperature and conductivity sensors are modular units. It's operating max depth is 6800m. During Nearest_2007 cruise the CTD SBE 9Plus was used in full configuration with an Altimeter, Oxygen sensor, Salinity, Transmissometer.

8. Daily report of the cruise

01-08-2008

Docked in Palermo. Embarkment scientific ISMAR – AWI – CUM – IM / CGUL-IDL Carrara Gabriela, Riminucci Francesco, Cuffaro Marco, Salocchi Aura, D'Oriano Filippo, Manzoni Sonia, Unglert K., Matias Luis, Doormann U., Feld C., Romsdorf M., Veneruso Mariacira, Labahnn E., Geissler W.

01-08-2008

11:00 Embarkment scientific instrumentation and equipments ISMAR, INGV – TFH and AWI – CUM. Departure from Palermo at 20:30.

02-08-2008

Transfer.

Settings of Chirp sub-bottom profiler and multibeam.

03-08-2008

Transfer.

04-08-2008

Transfer.

05-08-2008

Transfer. Pass through Gibraltar.
Start of Chirp sub-bottom e multibeam recording.

06-08-2008
Gulf of Cadiz. Recovery of OBS’s 16-21-20-23
Acquiring of chirp and multibeam data.

07-07-2008
Gulf of Cadiz. Recovery of OBS’s 19-22-18-13
Acquiring of chirp and multibeam data.
Romsdorf M. broke his hand falling down to the stears.

08-08-2008
Anchored near Faro.
07:30 UTC landing of Romsdorf M. and Feld C.

09-08-2008
Gulf of Cadiz. Recovery of OBS’s 4-6-9-12-17.

10-08-2008
Gulf of Cadiz. Recovery of OBS’s 08-01-02.

11-08-2008
Gulf of Cadiz. Recovery of OBS’s 03-05-24-25-14-15.

12-08-2008
Gulf of Cadiz. Recovery of OBS’s 10
End of OBS’s recovery

13-08-2008
Docked in Faro harbour.
Landing of AWI, KUM, ISMAR researchers
Landed: Riminucci Francesco, Cuffaro Marco, Salocchi Aura, Manzoni Sonia, Matias Luis, Doormann U., Feld C., Labahnn E., Geissler W.
Embark INGV, ISMAR, TFH researchers: Zitellini Nevio, Chierici Francesco, Favali Paolo, Lo Bue Nadia, Innocenzi Luigi, Cianchini Gianfranco, Gerber Hans, Langner Wilfred, Wolter Reinhard.

14-08-2008
Docked in Faro harbour.

15-08-2008
Sail from Faro. CTD’s casts near Geostar’s site: CTD 07-04.

16-08-2008
Gulf of Cadiz. CTD’s casts near Geostar’s site: CTD 06-09-12.
First attempt to recover Geostar failed caused by problem to the fiber connection of the MODUS.

17-08-2008
Gulf of Cadiz. CTD cast 08.
Recovery of GEOSTAR abyssal station.

Start of bathymetric survey South of Portimao.

18-08-2008
Gulf of Cadiz. Bathymetric survey South of Portimao.
Roadstead near Portimao to work on Geostar's instruments.

19-08-2008
Gulf of Cadiz. Bathymetric survey South of Portimao.
CTD-SVP cast for the setting the multibeam.

20-08-2008
Gulf of Cadiz. Bathymetric survey South of Portimao.

21-08-2008
Gulf of Cadiz. Bathymetric survey South of Portimao.
Recovery of the Geostar Buoy's mooring.

22-08-2008
Gulf of Cadiz. Bathymetric survey South of Faro.
Transfer and start the bathymetric survey offshore Morocco.

23-08-2008
Gulf of Cadiz. Bathymetric survey East of Morocco.

24-08-2008
Gulf of Cadiz. Bathymetric survey East of Morocco.
CTD-SVP cast for the settings of the multibeam.

25-08-2008
Gulf of Cadiz. Bathymetric survey East of Morocco.
Transfer to southern Portugal Sea.

26-08-2008
Gulf of Cadiz, south Portugal Calibration of the multibeam needed to correct a small tilt problem.

27-08-2008
Gulf of Cadiz. CTD's casts near Geostar site. CTD geostar-05.
Transfer to Faro.

28-08-2008
Demob of instruments. END OF THE CRUISE

9. References

Abe, K., 1989. Size of great earthquakes of 1837-1974 inferred from tsunami data. Journal of Geophysical Research, v. 84, p. 1561-1568.

Ambar I. and Howe M. R. (1979). *Observations of the Mediterranean outflow. The deep circulation in the vicinity of the Gulf of Cadiz*. Deep-Sea Res. II, 26A,555-568.

Argus, D.F., Gordon, R.G., DeMets, C. and Stein, S., 1989. Closure of the Africa-Eurasia-North America plate motion circuit and tectonics of the Gloria Fault: Journal of Geophysical Research. Solid Earth and Planets, v. 94, p. 5585-5602.

Baptista, M.A., Miranda, J.M., Chierici, F. and Zitellini, N., 2003. New study of the 1755 earthquake source based on multi-channel seismic survey data and tsunami modelling. Natural Hazards and Earth System Sciences, v. 3, p. 333-340.

Baptista, M.A., Miranda, P.M.A., Miranda, J.M. and Mendes Victor, L., 1998. Constraints on source of the 1755 Lisbon tsunami inferred from numerical modelling of historical data on the source of the 1775 Lisbon tsunami: Journal of Geodynamics, v. 25, p. 159-174.

Baringer M.O., Price J.F., (1997). *Mixing and Spreading of the Mediterranean Outflow.* J. of Phys. Oceanogr., 27, 1678-1692.

Bergeron, A. and Bonnin, J., 1991. The deep structure of Gorringe Bank (NE Atlantic) and its surrounding area. Geophysical Journal International, v. 105, p. 491-502.

Bonnin, J., Olivet, J.L. and Auzende, J.M., 1975. Structure en nappe à l'ouest de Gibraltar. C. R. Acad. Sci. Paris, v. 280, p. 559-562.

Danobeitia, J.J., Bartolome, R., Checa, A., Maldonado, A. and Slootweg, A.P., 1999. An interpretation of a prominent magnetic anomaly near the boundary between the Eurasian and African plates (Gulf of Cadiz, SW margin of Iberia). Marine Geology, v. 155, p. 45-62.

Flinch, J.F., Bally, A.W. and Wu, S., 1996. Emplacement of a passive-margin evaporitic allochthon in the Betic Cordillera of Spain. Geology, v. 24, p. 67-70.

Freitas P.S., Abrantes F., (2002). Suspended particulate matter in the Mediterranean water at the Gulf of Cadiz and off the southwest coast of the Iberian Peninsula. Deep-Sea Res. II, 49,4245-4261.

Fukao, Y., 1973. Thrust faulting at a lithospheric plate boundary; the Portugal earthquake of 1969. Earth and Planetary Science Letters, v. 18, p. 205-216.

González, A., Torné, M., Córdoba, D., Vidal, N., Matias, L.M. e Díaz, J., 1996. Crustal thinning in the Southwestern Iberia margin, Geophys. Res. Lett., 23, nº18, 2477-2480.

Gracia, E., Danobeitia, J., Verges, J. and Bartolome, R., 2003a. Crustal architecture and tectonic evolution of the Gulf of Cadiz, SW Iberia, at the convergence of the Eurasian and African plates. Tectonics, v. 22, p. 1033.

Gracia, E., Danobeitia, J., Verges, J., Zitellini, N., Rovere, M., Accetella, D., Ribeiro, A., Cabral, J., Matias, L., Bartolome, R., Farran, M., Casas, D., Maldonado, A., Pazos, A., Cordoba, D. and Roset, X., 2003b. Mapping active faults offshore Portugal (36 degrees N-38 degrees N); implications for seismic hazard assessment along the Southwest Iberian margin. Geology, v. 31, p. 83-86.

Grimison, N.L., Chen, W.P., 1986. The Azores-Gibraltar plate boundary: Focal mechanisms, depths of earthquakes and their tectonic implications. Journal of Geophysical Research, v. 91, p. 2029-2047.

Gutscher, M.-A., J. Malod, J.-P. Rehault, I. Contrucci, F. Klingelhoefer, L. Mendes-Victor, W. Spakman, 2002. Evidence for active subduction beneath Gibraltar, Geology, 30(12), p.1071–1074.

Gutscher, M.-A., Baptista, M.A. and Miranda, J.M., 2006. The Gibraltar Arc seismogenic zone (part 2): constraints on a shallow east dipping fault plane source for the 1755 Lisbon earthquake provided by fault parameters and tsunami modelling and seismic intensity. Tectonophysics, v. 426, p. 153-166.

Gutscher, M.-A., Malod, J., Rehault, J.P., Contrucci, I., Klingelhoefer, F., Mendes-Victor, L., Spakman, W., 2002. Evidence for active subduction beneath Gibraltar. Geology, v. 30, p. 1071-1074.

Havskov, J. and Ottemöller, Lars (editors), 2005. SEISAN: The Earthquake Analysis Software for Windows, Solaris, Linux and Macosx, Version 8.1, 259pp.

Hayward, N., Watts, A.B., Westbrook, G.K. and Collier, J.S., 1999. A seismic reflection and GLORIA study of compressional deformation in the Gorringe Bank region, eastern North Atlantic. Geophysical Journal International, v. 138, p. 831-850.

Johnson, J.M., Satake, K., Holdahl, S.R., Sauber, J., 1996. The 1964 Prince William Sound earthquake: joint inversion of tsunami and geodetic data. Journal of Geophysical Research, v. 101, p. 14,965–14,991.

Johnston, A., 1996. Seismic moment assessment of earthquakes in stable continental regions – III. New Madrid, 1811-1812, Charleston 1886 and Lisbon 1755. Geophysical Journal International. V. 126, p. 314-344.

Magagnoli, A. and Mengoli, M., 1995. Carotiere a gravità “SW-104”. Rapporto Tecnico N.27, IGM-CNR, Bologna.

Maldonado, A., Somoza, L. and Pallares, L., 1999. The Betic orogen and the Iberian-African boundary in the Gulf of Cadiz; geological evolution (central North Atlantic). Marine Geology, v. 155, p. 9-43.

Martins, I. and Mendes Victor, L.A., 1990. Contribucão para o estudo da sismicidade de Portugal continental. Universidade de Lisboa, Instituto Geofisico do Infante D. Luìs, publicacion 18, p. 67.

Medialdea, T., Vegas, R., Somoza, L., Vazquez, J.T., Maldonado, A., Diaz del Rio, V., Maestro, A., Cordoba, D. and Fernandez-Puga, M.C., 2004. Structure and evolution of the Olistostrome complex of the Gibraltar Arc in the Gulf of Cadiz, estearn Central Atlantic: evidence from two long seismic cross section. Marine Geology, v. 209, p. 173-198.

Nocquet, J.M. and Calais, E., 2004. Geodetic measurements of crustal deformation in the western Mediterranean and Europe. Pure and Applied Geophysics, v. 161, p. 661-681.

Olivet, J.L., 1996. La Cinématique de la Plaque Ibérique. Bull. CentresRech. Explor. — Prod. Elf Aquitaine v. 20, p. 131–195.

Rhein M., Hinrichsen H.H.,(1993). Modification of Mediterranean Water in the Gulf of Cadiz, studied with hydrographic, nutrient and chlorofluoromethane data. Deep-Sea Res. II, 40,267-291.

Serra N., Ambar I., (2002). Eddy generation in the Mediterranean undercurrent. Deep-Sea Res. II, 49, 4225-4243.

Sartori, R., Torelli, L., Zitellini, N., Peis, D. and Lodolo, E., 1994. Eastern segment of the Azores-Gibraltar line (central-eastern Atlantic); an oceanic plate boundary with diffuse compressional deformation. Geology, v. 22, p. 555-558.

Srivastava, S.P., Roest, W.R., Kovacs, L.C., Oakey, G., Levesque, S., Verhoef, J. and Macnab, R., 1990. Motion of Iberia since the Late Jurassic; results from detailed aeromagnetic measurements in the Newfoundland Basin. Tectonophysics, v. 184, p. 229-260.

Terrinha, P., Pinheiro, L.M., Henriet, J.P., Matias, L., Ivanov, M.K., Monteiro, J.H., Akhmetzhanov, A., Volkonskaya, A., Cunha, T., Shaskin, P. and Rovere, M., 2003. Tsunamigenic-seismogenic structures, neotectonics, sedimentary processes and slope instability on the Southwest Portuguese Margin. Marine Geology, v. 195, p. 55-73.

Torelli, L., Sartori, R. and Zitellini, N., 1997. The giant chaotic body in the Atlantic Ocean off Gibraltar; new results from a deep seismic reflection survey. Marine and Petroleum Geology, v. 14, p. 125-138.

Tortella, D., Torne, M. and Perez Estaun, A., 1997. Geodynamic evolution of the eastern segment of the Azores-Gibraltar Zone; the Gorringe Bank and the Gulf of Cadiz Region. Marine Geophysical Researches, v. 19, p. 211-230.

Udias, A., Lopez Arroyo, A. and Mezcua, J., 1976. Seismotectonic of the Azores-Alboran region: Tectonophysics, v. 31, p. 259-289.

Zitellini, N., Chierici, F., Sartori, R. and Torelli L., 1999. The tectonic source of the 1755 Lisbon earthquake and tsunami. Annali di Geofisica, v. 42, p. 49-55.

Zitellini, N., Mendes, L.A., Cordoba, D., Danobeitia, J., Nicolich, R., Pellis, G., Ribeiro, A., Sartoi, R., Torelli, L., Bartolome, R., Bortoluzzi, G., Calafato, A., Carrilho, F., Casoni, L., Chierici, F., Corela, C., Correggiari, A., Della Vedova, B., Gracia, E., Jornet, P., Landuzzi, M., Ligi, M., Magagnoli, A., Marozzi, G., Matias, L., Penitenti, D., Rodriguez, P., Rovere, M., Terrinha, P., Vigliotti, L. and Ruiz, A.Z., 2001. Source of 1755 Lisbon earthquake and tsunami investigated. Eos, Transactions, American Geophysical Union, v. 82, p. 285.

Zitellini, N., Rovere, M., Terrinha, P., Chierici, F., Matias, L. and Team, B., 2004. Neogene through Quaternary Tectonic reactivation of SW Iberian Passive Margin. Pure and applied Geophysics, v. 161, p. 565-585.

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Mastronardi Luigi	Bosum
Sano Gian	Seaman
Cirillo Carlo	Seaman
Mannarino Giuseppe	Seaman
Stragapete Giovanni	Cook
Pizzonia Leonardo	Steward
Maggio Antonio	Y.D.Boy
Merola Diego	Y.D.Boy
De Lauro Tommaso	Y.D.Boy
Cannavò Giovanni	Galley Boy
De Simone Troncone Paolo	Y.D.Boy

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AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung	Bremerhaven, Germany
K.U.M.	Umwelt – und Meerestechnik Kiel GmbH	Wischhofstrasse 1-3, Gebaeude D5, 24148 Kiel, Germany
FFCUL	Fundação da Faculdade de Ciências da Universidade de Lisboa	Lisboa, Portugal
INETI		Lisboa, Portugal
CSIC	Consejo Superior de Investigaciones Científicas-Unitat de Tecnologia Marina,	Barcelona, Spain
DESA	Geodynamique et valorisation des marges oceaniques, Université Mohamed V, Faculté des Sciences	Rabat-Agdal,Maroc

Fig. 67 – First Leg NEAREST Team

Fig. 68 – Second Leg NEAREST Team