

A PERMANENT SUBMARINE OBSERVATORY IN ALBORAN ISLAND AND THE LONG TERM OBS FOMAR NETWORK: News.

A. Pazos¹, J. Martín Davila¹, E. Buforn², M. J. García³, M. Bullón⁴ and ROA seismic group¹.

1 Sección de Geofísica, Real Observatorio de la Armada, Cecilio Pujazón s/n, 11.100 San Fernando, Spain. pazos@roa.es.
2 Dpto. Física de la Tierra, Universidad Complutense de Madrid, 28040 Madrid, Spain. ebufornp@fis.ucm.es.
3 Unidad de sistemas Básicos, AEMET, Delegación T. en Adalucía, Americo Vespucio, 3 bajo, isla Cartuja, 41092 Sevilla
4 Instituto Español de Oceanografía, Corazón de María 8, 28002 Madrid.

Abstract

The Eurasian-African plate boundary crosses the called "Ibero-Maghrebian" region, from the San Vicente Cape to Tunisia including the south Iberia, Alboran Sea, and northern of Morocco and Algeria. The low convergence rate produces a continuous moderate seismic activity of low magnitude and shallow depth, where the occurrence of large earthquakes is separated by long time intervals. In this region, there are also intermediate and very depth earthquakes. To study this complex area, the Royal Naval Observatory in San Fernando (ROA) and the Universidad Complutense de Madrid (UCM), with the collaboration of GeoForschungZentrum (GFZ), have deployed the Western Mediterranean Broad Band seismic network (WM), but with stations located in southern Spain and Northern Africa, surrounding the Alboran sea and the Gulf of Cádiz. Due to the fact of that many events are located at marine areas and the poor geographic azimuthal coverage at some zones provided by land stations, the WM network is complemented with a deployment of several broad band Ocean Bottom Seismometers (OBS) in the Gulf of Cádiz and the Alborán sea. A permanent Submarine Observatory was deployed in the vicinities of Alborán island (OBS Alborán) at the end of September 2009 and is linked to the island by a 2 km optic fiber cable. Also, a four long term temporal OBS's will be deployed nearby at the Gulf of Cádiz and Alborán sea (Red FOMAR), with the support of the Spanish Navy facilities.

Keywords: Western Mediterranean, marine, permanent OBS, long term OBS.

INTRODUCTION

The western part of the Eurasian and African plate boundary extends from the Azores islands through the Strait of Gibraltar to the northern parts of Algeria and Tunisia. In the oceanic part the boundary is well defined, following a line from Azores to the Gulf of Cádiz, but in the Iberian-Maghrebian region, the boundary is diffuse [1]. In this area, the plate boundary has a complex nature corresponding to the transition from the oceanic to the continental crust.

The low convergence velocity in this region, between 2 and 5 mm/y. [3], produces a moderate seismic activity, with earthquakes of low and moderate magnitude of mainly shallow depth (less than 30 Km.) and some earthquakes of intermediate depth (between 30 and 150 Km. of depth). Figure 1 shows the distribution of the seismicity in the Iberian-Maghrebian region for earthquakes of magnitude $m_b > 3.5$.

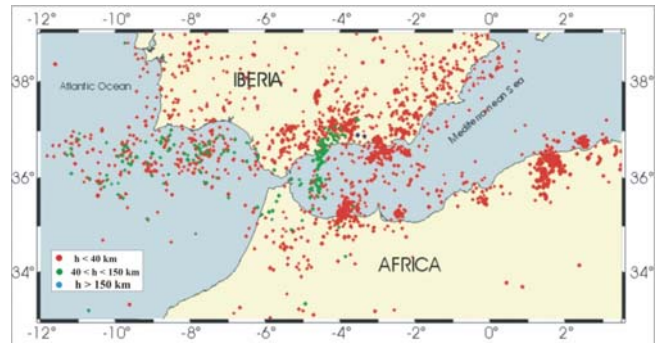


Fig. 1. Distribution of the earthquake epicenters for the period 1980-1999 ($m_b \geq 3.5$) taken from the IGN and the ROA catalogues. Data Base.

In the Gulf of Cádiz, large offshore earthquakes have occurred some of which have produced tsunamis, like the 1755 ($I_0=X$) Lisbon earthquake which generated a great tsunami, causing more than 1200 deaths in Spain alone [6]. The earthquake of February 28th of 1969 ($M_s=8.1$) occurred to the west of Cape of San Vicente also generated a small tsunami [5].

At the east of the strait of Gibraltar large historical earthquakes have occurred (figure 2). For example, earthquakes of 1829 and 1884 on the Spanish coasts and the shocks of 1716, 1790, 1825, 1858 and 1891 in the Algeria coasts. More recently, we have the occurrence of the Asnam (1980, $M_s=7.1$), Boumerdes (2003, $M_w=7.1$), and Al Hoceima earthquakes (2004, $M_w=6.2$). The 2003 Boumerdes (Algeria) earthquake generated a small tsunami that reached the Spanish coasts, mainly, at the Balearic islands.

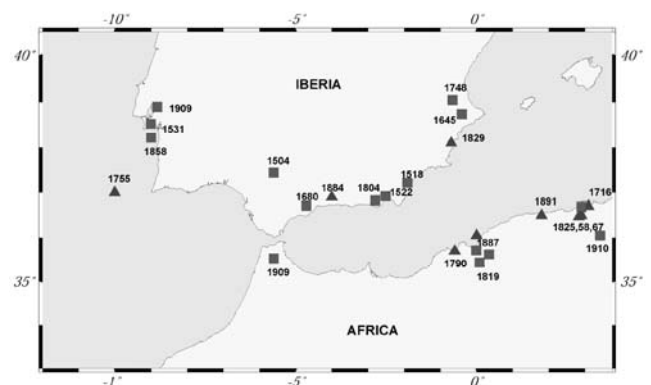


Fig. 2. Historical seismicity. Triangles: earthquakes with maximum intensity of X. Squares: earthquakes with maximum intensity of IX.

THE “WM” BROAD BAND NETWORK.

In order to study this complex area, the Real Observatorio de la Armada in San Fernando (ROA), together with the Universidad Complutense de Madrid (UCM), started to deploy, in 1996, their first broad band station (ROA/UCM) with the collaboration of the GeoForschungZentrum (GFZ) of Potsdam (Germany). Since then, several broad band stations were deployed in the south of Spain, including the Spanish North of Africa sites [2], and the Western Mediterranean (FDSN code: WM) seismic Network was established.

New partners has been incorporated to the WM Network: the Evora University (Portugal) has contributed to the network with one station in Evora and other in Setubal (SETU) and the Institut Scientifique of Rabat (Morocco) has installed 3 ROA/UCM stations in Morocco (AVE, IFR and TIO), recently the GFZ has also been incorporated as a partner. The WM Network is formed by twelve stations (see figure 3 and table 1) located in South of the Iberian Peninsula and in North Africa.. In the future the network will incorporate stations in Algeria (Oran), 4 stations more in South Portugal, and one in the vicinities of Madrid. A list of the stations is given in Table 1 and their location shown in figure 3.

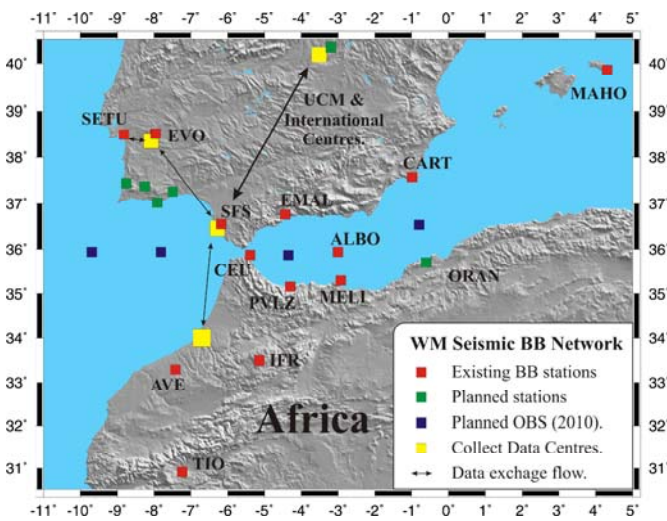


Fig. 3. Seismic BB Western Mediterranean Network, the permanent ALBO Submarine Observatory, and the future OBS FOMAR network.

The instrumentation of the stations of the WM network includes a Streckeisen STS-2 sensor (flat response from 100 seconds up to 100 Hz.), a high resolution acquisition system Quanterra or an EarthData digitizer (24 bits, high dynamic range), and a process Seiscomp system, based on an embedded PC with Linux [4]. The Málaga station (EMAL) has installed an EpiSensor accelerometer joint to the STS-2 sensor, so a six channels Earthdata digitizer is used. The Ceuta station (CEU) is powered by batteries and solar panels (now a days is being tested in a new site with intranet link and power).

Code	Lat /Long ($\pm 0.000.000$)	Digitiz.	State
AVE	33.2981 / -007.4133	PS6-24	RT
CART	37.5758 / -001.0012	Q4120	NRT
CEU	35.8789 / -005.3731	PS6-24	---
EMAL	36.7620 / -004.4292	PS6-24	RT
EVO	38.5320 / -008.0130	PS6-24	RT
IFR	33.5166 / -005.1272	PS6-24	RT
MAHO	39.8959 / -004.2665	Q4120	NRT
MELI	35.2938 / -002.9350	Q680	RT
PVLZ	35.1730 / -004.3010	PS6-24	---
SETU	38.502 / -8.9579	DM24	GPRS
SFS	36.4656 / -006.2055	Q4120	RT
SFUC (1996-1998)	36.6370 / -006.1750	Q680	Closed
TIO	30.9267 / -7.2617	PS6-24	---

Table 1. Location, digitizer type and state of the WM seismic stations: RT: real time station (internet link); NRT: near real time station (intranet).

The WM stations, except CEU and PVLZ, are linked in near-real time with ROA data center via modem (ppp protocol) or internet following the Seiscomp scheme [4].

THE PERMANENT ALBORAN SUBMARINE OBSERVATORY (ALBO).

The ALBO project (RIOA05-23-002) started on 2005 and was funded by the Ministry of Education and Science (MEC). Initially, the objective of this project was to deploy a broad band seismic OBS in the Alboran island surrounding linked by a cable to the island where a Navy intranet link and power is available. But new inputs have driven towards the new concept of the submarine Observatory. Finally on the 3rd October 2009 was deployed in 46 meters depth water about 1500 meters away from the dock of the island.

First Step: Authorizations.

The Alboran island and its surroundings have an special and restricted regulation (figure 4). The island is guarded by a permanent detachment of the Spanish Navy. Since 1997, the island and its surroundings, at the sea, were declared as marine reserve. In 2003, the Andalucía Government declared the island as a natural place. Finally, the lighthouse, where the land equipment is installed, depends of the Almería port authority.

Although the first conversations with the Navy authorities, Agriculture and Fishing Ministry (Marine Reserves department, “SEGEPECA”) and Andalucía Government (Environment Department) started along 2005, the finally authorization was received in January of 2008.

Previously, some “in situ” inspections had been done, and an inspection of the sea bed (where the cable should be deployed was carried out by divers of the Spanish Navy joint to the Alborán marine reserve personal).

Second step: planning and pre-installation.

After the visual inspection, some problems had been to solve:

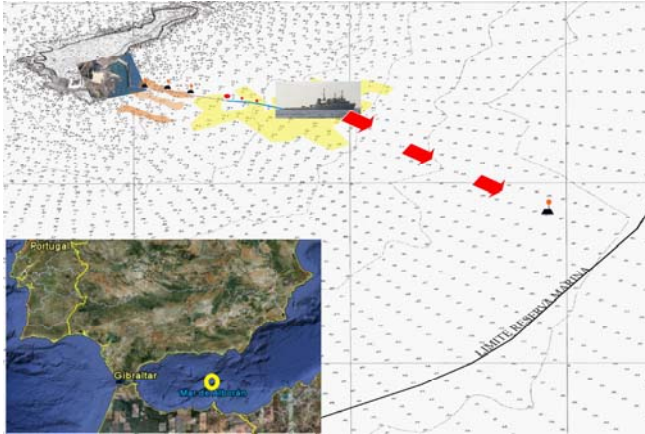


Fig. 4. Alborán island and the marine reserve. A scheme of the cable deployment manoeuvre is shown.

- Near the island (the first 450 meters) the sea bed is formed by rocks, so the cable needs to be well fixed.
- There are strong storms frequently.
- The cable is not flexible enough to go inside to the lighthouse within the existing conductions, so a more flexible optic fiber cable should be used in the last 30 meters and an optic junction box should be installed.

Other discussions were the cable protection, the manoeuvre for the deployment and Spanish Navy (available ships, divers, intranet link, ...) and SEGEPESCA facilities.

Near the coast, cables are usually protected by burial or using heavy and rigid tubes. But both techniques were unviable because they are too expensive and the environment impact is high. Therefore 25 concrete anchors were made at the ROA to provide more weight to the cable and fixed to the bottom along the most critical part (sea-land interface along 400 m length) and some metallic pieces to fix the cable along the wall of the dock (figure 5).

About the manoeuvre, it was determined to the kind of available ship (minimal speed, free space at the stern,...), but also the end of the cable in the drum. Finally, the cable was placed on the stern of the "MAR CARIBE" (figure 6, a patrol boat of the Navy) and the idea was to drive the cable from the sea to the land.

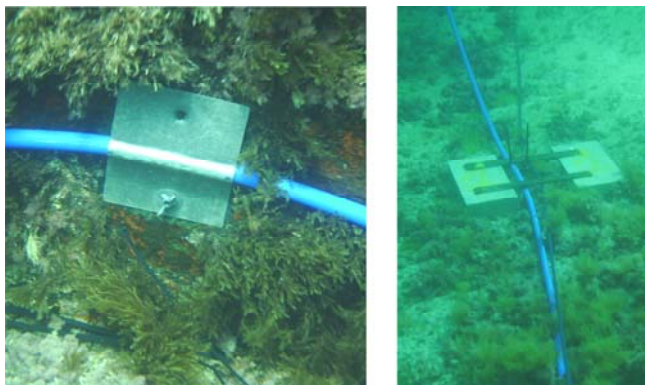


Fig. 5. Concrete anchors (right) and metallic pieces (left) to fix the cable at the bottom and to the dock wall.



Fig. 6. Stern of the "Mar Caribe" patrol boat, of the Spanish navy, with the cable ready for the deployment and the guide to drive the cable toward the Alborán island.

Previously to the deployment, divers, from the divers of Cádiz Unit of the Navy, placed the anchors along the first 400 meters away from the dock and marked them with buoys and a rope guide at the bottom. Also on land, the way for the cable was prepared from the dock (the sea-land interface) to the lighthouse.

Third step: the deployment.

Due to the seismometer should be buried at the bottom, about 50 meters depth, a special Spanish navy ship ("NEPTUNO") was needed in order to provide safety to the divers. But, this ship wasn't available at the same time that the "Mar Caribe" was in zone. So, the deployment was realized in two steps: the cable deployment and the system installation.

On the morning of the 1st October 2009, the "Mar Caribe" anchored at 700 yards at the East of the dock to deploy the cable. First a 1 km rope guide was carried out from the ship to the dock, and then the cable was recovered until the lighthouse in the island. In this part of the deployment, the cable shipped on surface thanks the buoys attached (fig 6). The rest of the cable, about 800 metres, was sunk directly (with buoys) until the final position; previously, the first part of the cable was sunk along the foreseen way (in figure 4 a scheme is shown). The sea end of the cable was water protected and two buoys in the end and 100 meters before were attached to mark the exact position.

Along the 2nd October, the navy ship "Neptuno" arrived to the work area and anchored near the marked position and fixing the ship over the exact position to recover the end of the cable. After connect the equipments and tested (on 3rd October) the sensors were buried at 35° 55' 54".72 N 003° 01' 07".98 W in 46 meters depth by divers (see figure 7). Also, the land equipments were installed and all connectors were done. Because some software problems, the intranet connection didn't work in this first step of the installation.

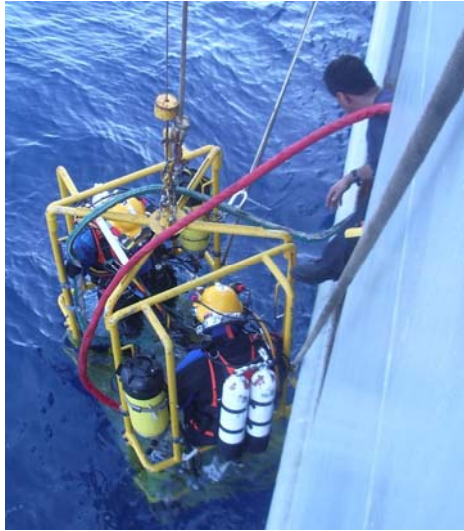


Fig. 7. Divers, on board of "Neptuno" ready to bury the seismic sensor.

The Instrumentation and the cable characteristics.

The 2 km. submarine cable was designed with a core of steel wire rope (3600 kg), a 2 multimode fibre optic cables (one for the seismic and pressure instrumentation, and the other one for additional instruments), four 1 mm conductors for power (one pair for Güralp system and the other one for additional systems), and a tinned copper, a galvanised steel and a stainless steel wire braids, all covered by polyurethane bedding sheaths.

The endings were made in Güralp system. In the land ending a fibre optic connector box was attached to joint with the optic fibre flexible cable to the lighthouse. At the sea ending, a converter tube is managed the communication, converting the TCP/IP to RS-232.

The whole system (made in titanium houses) was designed at Güralp laboratories system and is composed by two separated parts (see figure 8): the Güralp instrumentation is composed by a 7 channels CMG-DM24 digitizer, a CMG-3T seismometer (360 sec to 100 Hz response), 3C accelerometer, a temperature sensor and a differential pressure gauge. All these instrumentation are linked to the land by one of the optic fibre. The other fibre (after a 4 RS-232 channels conversion) and power are connected by a 100 metres cable to the switch tube, where four connectors are available with RS-232 and power.

Now a days, the seismic part (seismometer and accelerometer) is buried, and the pressure gauge is connected to the Güralp digitizer. Data are being recorded at the lighthouse on land, and soon, a intranet link with ROA will be available for real time link.

A currentmeter (from the Instituto Oceanográfico Español, IEO) is going to be installed and a magnetometer is planned for the future.

The ALBO observatory is open to any proposal to deploy new instrumentation since the switch tube and data can be linked in real time.

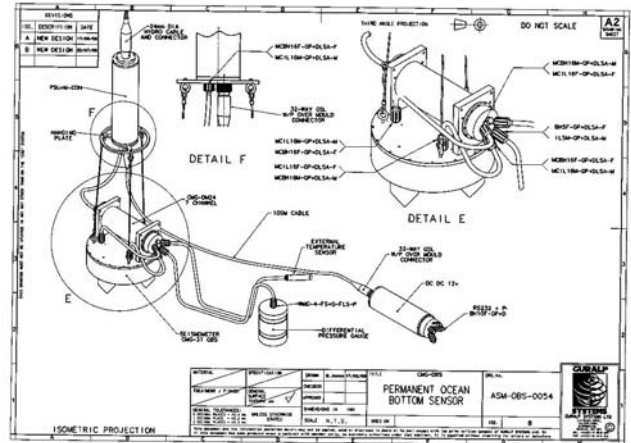


Fig. 8. Seismometer and accelerometer housing with the digitizer tube above and the pressure gauge. The switch tube at the right.

THE LONG TERM FOMAR NETWORK.

The FOMAR project (CGL2005-24194-E) is funded by the MEC and the objective is to anchor four long term BB OBS in the Alboran sea and the Gulf of Cadiz (see figure 3) to improve the azimuthal coverage of the land stations.

The OBS's were manufactured by KUM and batteries, the data logger and also the broad band seismometer are settled in titanium pressure tubes This type of OBS has an acoustic system that provides communication for commands and release.

Now a days, the OBS's are in the factory because a problem with the levelling of the sensor was detected. The deployment is planned for 2010 with the navy ships.

ACKNOWLEDGEMENTS

This work has been partly funded by the MEC through the projects CGL2006-10311-C03-02 (RISTE), RIOA05-23-002 (ALBO) and CGL2005-24194-E (FOMAR network). We thank the Spanish Navy for the support, especially to AMARDIZ, COMBUDIZ, Mar Caribe, Neptuno, CBA,... and also to SEGEPESCA for the support and collaboration.

REFERENCES

- [1] Buforn, E.; Udías, A; and Colombás, M.A. (1988), Seismicity, Source Mechanisms and Seismotectonics of the Azores-Gibraltar Plate Boundary, *Tectonophysics*, 152, 89-118.
- [2] Buforn, E.; Udías, A.; Matín Davila, J.; Hanka, W.; and Pazos, A. (2002), Broadband station network ROA/UCM/GFZ in south Spain and northern Africa, *Seismological Research Letters*, 73, 2, 173-176.
- [3] Gárate, J.; Martín Davila, J.; y Berrocoso, M. (2004), Series temporales para las estaciones GPS del Observatorio de la Armada en San Fernando, *Resúmenes, 4ª Asamblea Hispano-Portuguesa de Geodesia y Geofísica, Figueira da Foz, Portugal*, 501-502.
- [4] Heinloo, A. (2004), SeisComP 2.1 Manual. GFZ, Potsdam. <ftp://ftp.gfz-potsdam.de/pub/home/st/GEOFON/software/SeisComP/seiscomp-2.1.pdf>.
- [5] López Arroyo, A.; and Udías, A. (1972), Aftershocks sequence and focal parameters of the Feb 28, 1969 earthquakes of the Azores-Gibraltar fracture zone, *Bulletin of the Seismological Society of America*, 62, 699-719
- [6] Martínez Solares, J.M. (2001), Los efectos en España del terremoto de Lisboa (1 de Noviembre de 1755), *Instituto Geográfico Nacional, Monografía Nº 19*, 756 pp.