The ROA and UCM OBS pool (FOMAR Network) and other OBS activities.

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Abstract: *The Royal Spanish Navy Observatory (ROA) started to deploy the the Western Mediterranean seismic broad band network in 1996, being the main goal to study the seismicity of the Ibero-Maghrebian region. This network has been growing continuously until now a day that it is composed by 15 broad band stations. In 2005, the ROA purpose two initiatives to improve the observation of the seismicity in this area, and both of them were funded by the MEC. The first one was to acquired a permanent cabled OBS, the ALBO project (RIOA05-23-002), being deployed in 50 m depth close to the Alboran island in 2009. And thanks to the second one, the FOMAR project (CGL2005-24194-E), the ROA acquired three long-term broad band OBS in 2010. Recently, the UCM acquired three new broad band OBS conforming the ROA/UCM OBS pool, called the FOMAR OBS pool. In this paper, the ALBO OBS and the FOMAR pool are described and also the first results obtained in the ROA experiment in the Gibraltar strait are shown.*

Keywords: *temporary OBS pool, Noise, OBS permanent, refraction profile.*

INTRODUCTION

The south of the Iberian Peninsula is located in a complex plate boundary between Eurasia and Africa corresponding to the transition from the oceanic to the continental crust [1 and 2]. The low convergence velocity in this region, between 2 and 5 mm/y. [4], 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 mb>3.5.

However, some very large earthquakes have been registered, especially in the Cape of San Vicente (SV)–Gulf of Cadiz (GC) area. The largest one, the 1755 Lisbon earthquake M w 8.5 [6] with a big associated tsunami, caused more than 15,000 casualties and very significant damage in the south-west of the Iberian Peninsula and in northwest Morocco. But this is not an isolated case; in the last 50 years, large earthquakes have occurred, such as GC 1964 (Ms 6.5) and SV 1969 (Ms 8.1) [5]. Earthquakes of smaller size in this area can also produce some damage and a considerable social alert because they are felt in a wide region, as it happened in the 2009 earthquake Mw 5.5 felt in a wide zone of the south-west of the Iberian Peninsula and as far as Madrid.

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 [3], and the Western Mediterranean (FDSN code: WM) seismic Network was established. A list of the stations is given in Table 1 and a map with their locations is shown in figure 2.

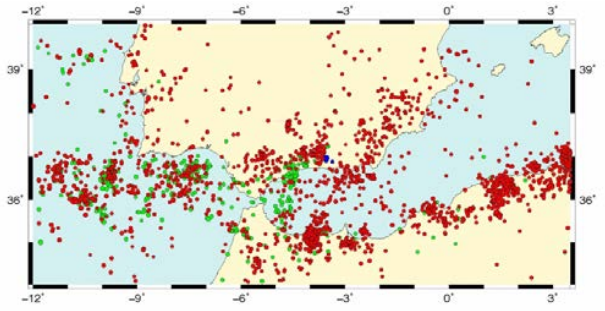

Fig. 1.- Seismicity of the Ibero-Maghrebian region since 1960 to 2014, and magnitude grater then 3.5 (IGN calaogue). Red dots: superficial earthquakes (h<40km); Green dots: intermediate earthquakes (40<h<150 km); and Blue dots: deep earthquakes (h>600km)

To improve the WM network, the ROA Geophysical Department applied for two initiatives in 2005. The first one, the ALBO project, for installing a permanent submarine observatory in the Alboran island; and the second, the FOMAR network project, to acquire three temporary long-term broad band OBS's. Both projects were funded by the Ministry of Education and Science (MEC).

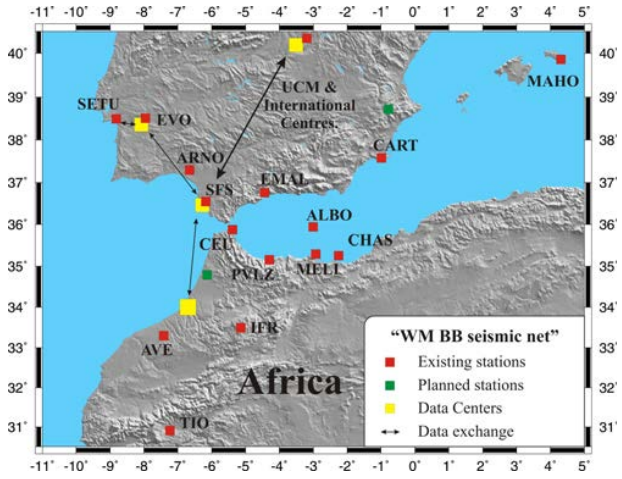

Fig. 2.- The seismic broad band Western Mediterranean (WM) network and ALBO permanent Observatory.

Code	Lat. (º)	Long. (º)	Digitiz.	State
AVE	33.2981	-7.4133	Q330HR	VSAT
CART	37.5758	-1.0012	Q330HR	VSAT
CEU	35.8789	-5.3731	PS6-24	Intranet
EMAL	36.7620	-4.4292	PS6-24	ADSL
EVO	38.5320	-8.0130	PS6-24	ADSL
IFR	33.5166	-5.1272	PS6-24	ADSL
MAHO	39.8959	+4.2665	Q330HR	VSAT
MELI	35.2938	-2.9350	Q4120	ADSL
PVLZ	35.1730	-4.3010	PS6-24	Intranet
SETU	38.5020	-8.9579	DM24	-------
SFS	36.4656	-6.2055	Q4120	VSAT
SFUC (1996-1998)	36.6370	-6.1750	Q680	CLOSED
TIO	30.9267	-7.1627	PS6-24	VSAT
ARNO	37.0988	-6.7321	Q330HR	ADSL
CHAS	35.1834	-2.4308	Q330HR	Intranet
UCM	40.3075	-3.2439	PS6-24	ADSL

Table 1. Location, digitizer type and state of the WM seismic stations.

In this work, the ALBO observatory and the FOMAR network are shown, and also the preliminary results of the deployment of the ROA/UCM OBS pool in the Gibraltar strait.

THE ALBORAN OBSERVATORY (ALBO)

The ALBO project (RIOA05-23-002) started on 2005 and was funded by the Ministry of Education and Science (MEC). Initially, the main goal 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 drove towards the new concept of the submarine Observatory with capability to deploy more submarine complementary instrumentation and including other on-land instruments.

The Alboran island is located in an strategic place, between the south-east Spanish coast and Morocco, close to the plate boundary, providing an excellent place to observe this important and complex seismic area., in especial the intermediate seismicity existing at the east of the Gibraltar Strait (see figure 1).

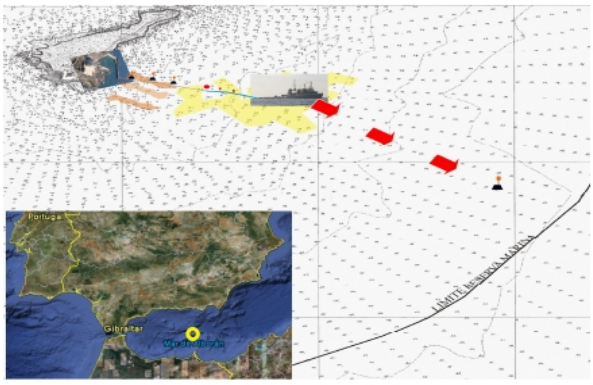

Fig. 3. Alboran island and the marine reserve. A scheme of the fiber optic cable deployment is shown.

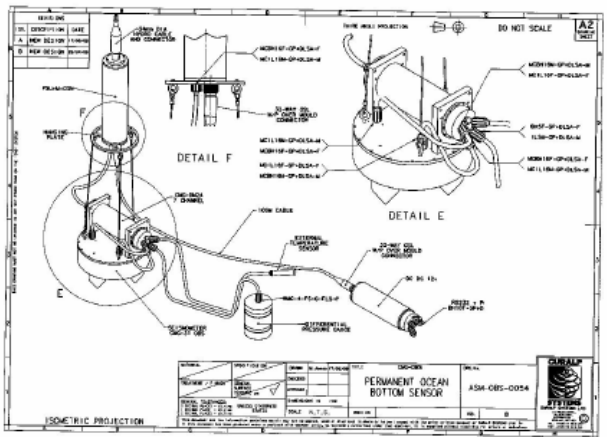

Fig. 4. Seismometer and accelerometer housing with the digitizer tube above and the pressure gauge. The switch tube at the right.

On the 3rd October 2009, the submarine instruments were deployed offshore (figure 3), in 46 meters depth water about 1500 meters away from the island, with the collaboration of the Spanish navy ships “Mar Caribe” and “Neptuno”, and the SEGEPESCA boats “Punta las Sirenas”, “Risco de Famara” and “Las Galeras”. Also others institutions have collaborated as UNBUDIZ (Spanish navy divers unit at Cadiz), UCM, among others.

The Alboran observatory has two components. On one hand, the on-land instrumentation composed by a permanent geodetic GPS, a meteorological station (in collaboration with the Spanish Meteorological Agency, AEMET), a tide gauge (in collaboration with the Spanish Navy Hydrographic Institute, IHM) and a radiometer in collaboration with the Granada University, UGR.

On other hand, the offshore part is linked with the island by a 2 km optic-fiber cable designed with a core of steel wire rope (3600 kg), a 2 multimode fiber optic lines (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 galvanized steel and a stainless steel wire braids, all covered by polyurethane bedding sheaths. The submarine system was designed at Güralp laboratories and is composed by two separated parts (see figure 4): 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. But also there are 4 available RS-232 channels connectors with power, linked by a 100 meters cable to the switch tube.

The seismic part (seismometer and accelerometer) is hosted in a titanium housing and is buried on the sea floor thanks to the collaboration of the deep divers (figure 5).

Since the installation, the offshore part has suffer several problems related with the power and also with the leveling of the seismometer, being necessary some reparation and modifications.

Now a days, the problem with the leveling of the masses of the seismometer is being solved at Guralp Laboratories.

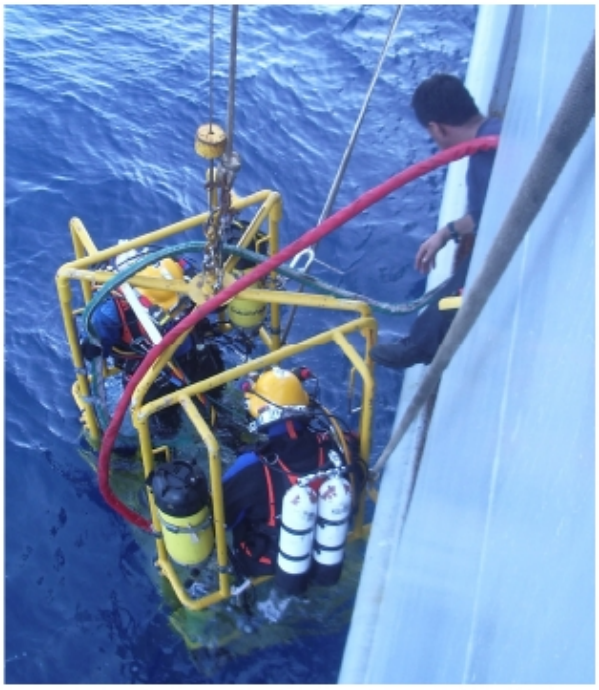

Fig. 5. Divers, on board of “Neptuno” ready to bury the seismic sensor.

THE LONG TERM FOMAR OBS POOL

The FOMAR project (CGL2005-24194-E) was funded by the MEC and the objective is to anchor long term Broad Band OBS's in the Alboran sea and the Gulf of Cadiz to improve the azimuthal coverage of the land stations of the Western Mediterranean Network. In 2010, the ROA acquired three LOBSTER OBS's (figure 6).

The OBS’s were manufactured by KUM (Kiel, Germany) and the batteries, the data logger and also the broad band seismometer are settled in titanium pressure tubes. The main characteristics are:

- 335 kg (without anchor) aprox.
- 6000 m operation depth.
- Recorder: GEOLON-MCS.
- Releaser: K/MT 562 KUMQUAT, titanium.
- Hydrophone: HTI-04-PCA/ULF.
- Seismometer: CMG-40T (in a titanium pressure tube).
- Positioning:
  Radio Beacon Novatech RF700-A1, 7300m.
  Flasher Novatech ST400-A, 7300m.
  Signal Flag.

A first deployment was carried out in November 2011 at the SW of the San Vicente Cape as a part of the ALERTES project activities, using the Navy patrol boats facilities. Although a one year period was initially planned, with maintenances every 6 months, unfortunately, a six-month deployment was carried out for two OBS and a year deployment for the third, due to a failure within the acoustic release system. After recovering the OBS, the seismic data shown a sensor leveling malfunction. This problems were corrected in KUM laboratories along 2012 and 2013.

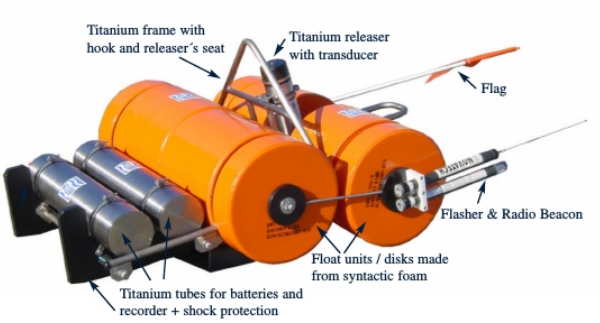

Fig. 6. LOBSTER OBS showing the main parts.

Recently, the UCM acquired three new broad band OBS through the UCM excellence campus, being ROA one of its members. These three OBS's have the same characteristics that ROA ones except the seismometer that is a Trillium 120.

These six OBS's, managed by the ROA, conforming the ROA/UCM Obs pool called the FOMAR pool.

GIBRALTAR STRAIT EXPERIMENT

In the frame of the ALERTES-RIM project and with the collaboration with SECEGSA, three OBS's were deployed (20/01/2014) in the surrounding of the Gibraltar strait (figure 7) during 8 moths, and also 4 broad band stations were installed in the Cadiz province and two more in north Morocco. In table 2 the locations and the depths are shown.

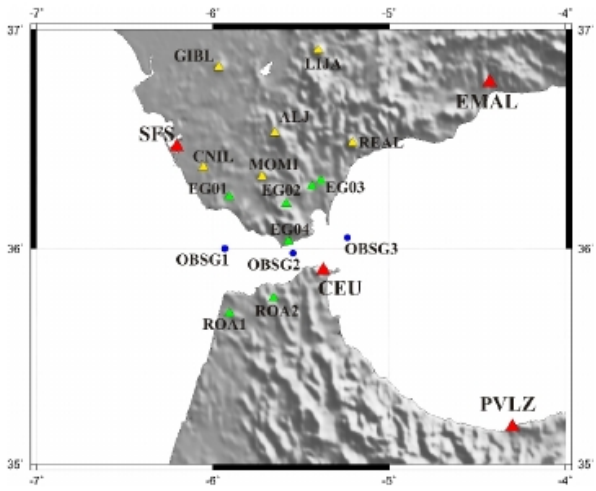

Fig. 7. Seismic broad band WM stations (red), short period stations (yellow), temporay broad band stations (green) and the deployed OBS's (blue).

The OBS's were anchored using the patrol boat “MEDAS” on 24th January 2014, and they were recovered on 18th September with the navy ship “VIGIA”. Also, the three new OBS's, with Trillium 120 seismometers, were anchored at the same positions for two months.

Finally, on 14th November 2014, these new OBS's were recovered using the navy facilities (“TAGOMAGO”). Also the temporary stations were removed, finishing this campaign.

	Lat. (º)	Long. (º)	Depth (m)
OBSG1	35.9978	-5.9430	188
OBSG2	35.9802	-5.5468	639
OBSG3	36.0495	-5.2328	861

Table 2. OBS Location and depth.

During this period, more than 140 earthquakes were recorded and located, improving the map of the seismicity of this area (figure 8).

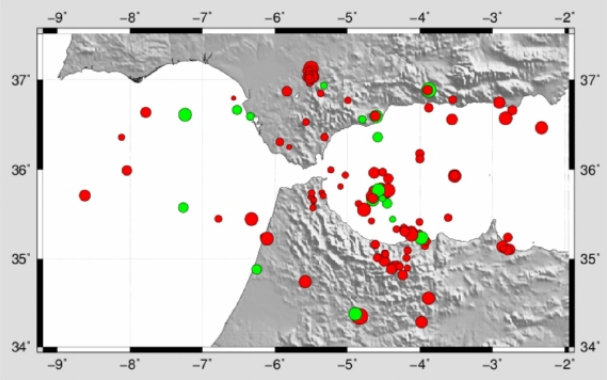

Fig. 8. Earthquakes recorded during the Gibraltar Strait campaign.

The OBS's worked correctly, recording the signals from the sensors (the seismometer and the hydrophone), and the leveling problem was tested. But they shown a high noise level due to the low depth (less than 1000 meters). In figure 9 a recorded earthquake is shown.

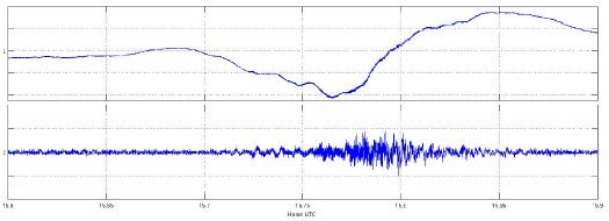

Fig. 9.Vertical component of the OBSG1 for the earthquake 09/08/2014 15:45:49.9 UTC, magnitude 3.6, at the NE of Torres de Alcala (Morocco). On the top, unfiltered data, and in the bottom the filtered one.

On the first week of September 2015 a new experiment in the frame of the AERTES-RIM project will be carried out, and the six OBS's will be deployed for eight months at SW of the San Vicente Cape conforming an hexagonal array (figure 10).

CONCLUSION

The ROA manages the broad band seismic Western Mediterranean network deployed around the Gulf of Cadiz and the Alboran sea, composed by 15 stations deployed in the Iberia Peninsula, North Africa Spanish places and also in Morocco.

This network has been complemented with the permanent ALBO OBS deployed in 2009 in 40 meters depth at 1500m of the Alboran island.

Finally, now a days, the FOMAR OBS pool is composed by 6 long term LOBSTER OBS's with broad band seismometers and hydrophones. This OBS's were tested during the Gibraltar Strait campaign and they will deployed (array configuration) during the first week of September at SW of the San Vicente Cape.

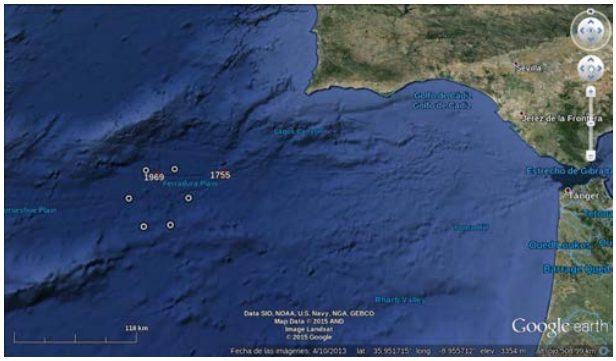

Fig. 10. Planned locations for the deployment of the OBS's in September 2015.

ACKNOWLEDGEMENTS

This work has been partly funded by the MEC through the projects RIOA05-23-002 (ALBO), CGL2005-24194-E (FOMAR network), ALERT-ES project (CGL2010-19803-C03) and ALERTES-RIM (CGL2013-45724-C3-3-R).

We thank the Spanish Navy for the support, especially to AMARDIZ, COMBUDIZ, Mar Caribe, Neptuno, CBA,... and also to SEGEPESCA and SECEGSA for the support and collaboration.

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