

## SUBMARINE TOPOBATHYMETRIC RELIEF MAP OF THE ALBORÁN SEA AND THE STRAIT OF GIBRALTAR



## HOW IS THE SEABED AND ITS GEOLOGY IN THE ALBORÁN SEA



PRESENTATION.....

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SUBMARINE MORPHOLOGY OF THE ALBORÁN SEA.....

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## **PRESENTATION**

### ***What the purpose of this map is and what it was made for***

This relief Topobathymetric Map of the Alborán Sea and the Strait of Gibraltar is a product meant for scientific dissemination and teaching. It has been made taking advantage of the result of several studies carried out by the Spanish Institute of Oceanography (IEO) on seabeds and their geology. It is, thus, a product derived from the IEO scientific and technological activity.

This map is the third one that shows our seabeds. It is within the framework of a dissemination campaign of marine sciences in general, and of their scientific and technological activity in particular, started by the IEO to contribute to the improvement of the Spanish society scientific culture and what the society knows about the Institute and its activities.

## PRESENTATION

It is a relief map of the seabeds, thermoformed in PVC. The map includes the topography of the terrestrial zone of the Alborán Sea; its dimensions are 960 x 680 mm. Information on roads and cities has been added to the terrestrial topography. Submarine morphology is presented encoded in colour to give the appearance of height and depth, depending on the case, thus achieving better visualisation. In order to be better understood and be more didactic, the map was made at two different scales. The horizontal scale is 1: 400,000 for the entire map; nevertheless, the vertical scale is 1: 75,000 for the submarine zone and 1: 100,000 for the terrestrial zone. That is, the submarine relief was exaggerated to stand out to the maximum, but without distortion, the relieves and forms that are meant to be known.

The maximum depth represented on the map is 1,996 meters, found in the Eastern Basin of the Alborán Sea, and the average depth on the map is 990 meters. Some bathymetric curves, as well as punctual depths, have been drawn in the submarine part so that the real depths in metres can be identified. Land toponymy was labelled according to the way displayed in the Spanish National Geographic Institute cartography. Submarine relieves have been labelled with the toponymy used in the charts from the Navy Hydrographical Institute, and some new names, given to morphological elements described for the first time. For more learned users, the map indicates the most relevant geological facts such as submarine canyon areas, active faults, areas affected by large landslides and submarine sedimentary avalanches. In the lower map banner, there is an outline of the division into physiographic provinces as well as some characteristic bathymetric profiles.

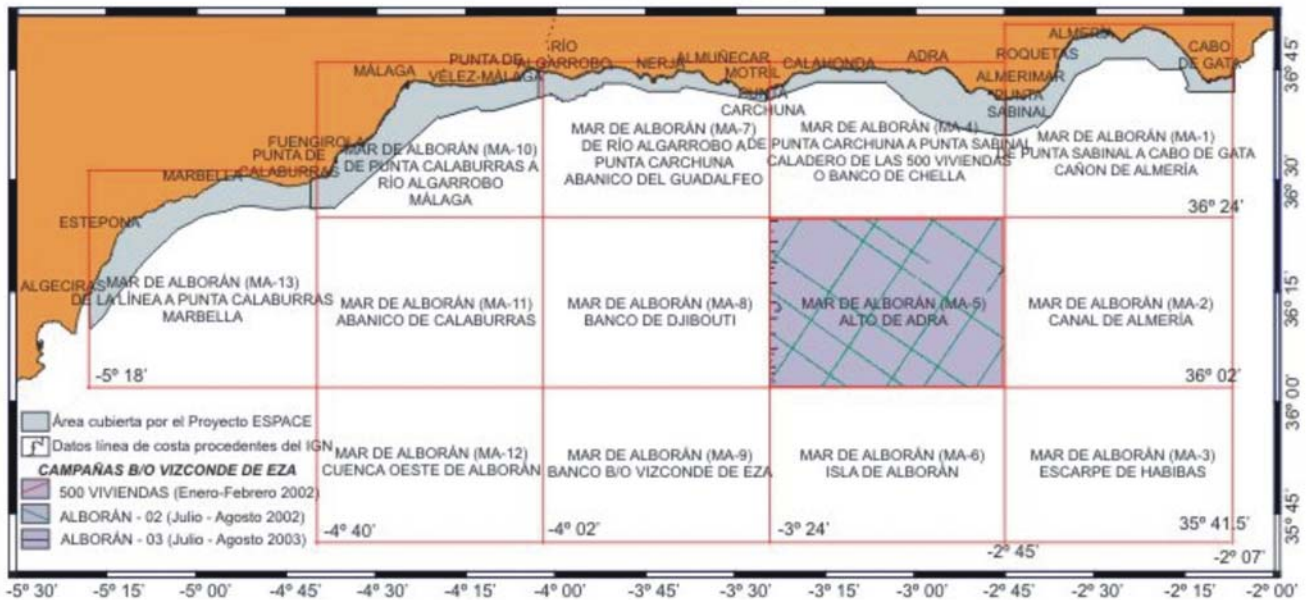
## PRESENTATION

### *How the map was made*

The land part comes from conventional cartography. The submarine one is based on data obtained with multi-beam echo sounders in oceanographic campaigns carried out between 2001 and 2003 on board of oceanographic vessel Vizconde de Eza (SGPM), in the framework of the Fishing Charts of the Mediterranean (CAPERMA), carried out by the Spanish Institute of Oceanography (IEO) and the Secretariat General of Maritime Fisheries (SGPM). Within the said programme various Fisheries Charts at 1:75,000 and 1:250,000 scales (see index Map) have already been published. ([http://www.mapa.es/es/pesca/pags/vizconde\\_web/mapas.htm](http://www.mapa.es/es/pesca/pags/vizconde_web/mapas.htm)).

The data collection was made with last generation technologies: multi-beam echo sounders, which provide very high accuracy in representing the submarine relief, high resolution seismic system, which provide information of the first meters under the seabed, and high accuracy navigation with the use of GPS in differential mode and supported by inertial navigation systems.

## MAPA ÍNDICE



*Cartographic plan of the Fisheries Charts on a 1:75,000 scale. Aside from these maps, a general map of the entire Alborán Sea on a 1:250,000 scale has been published.*

## **PRESENTATION / How the map was made**

The necessary information to make this map was obtained with oceanographic vessel Vizconde de Eza:

OCEANOGRAPHIC VESSEL VIZCONDE DE EZA, of the Secretariat General of Maritime Fisheries (Ministry of Agriculture, Fisheries and Food): its full length is 53 m and its gross tonnage is 1,400 t. It is mainly used in fishing and oceanography campaigns.



*FIGURE 1.- Oceanographic vessel Vizconde de Eza*

The multi-beam echo sounder sends off 131 sound beams ten times a second, which does a fan-type scanning of the various points located under the vessel and thus covering the entire seabed. This technology, along with the positioning systems based on a Global Positioning System (GPS), in differential mode, provides accuracy in the range of centimetres in the study of submarine morphology. The digital treatment of this information allows elaborating Digital Terrain Models (DTM), using the sounds of the echo sounders, comparable to an “aerial photograph” of the seabed.

The map production and thermoforming are made stemming from real digital data. First, a computer-generated mould or model is made out of solid material in three

dimensions (3D). Then, and by means of heat, the 3D colour map is superimposed on the PVC, which adapts to the three-dimensional mould above.

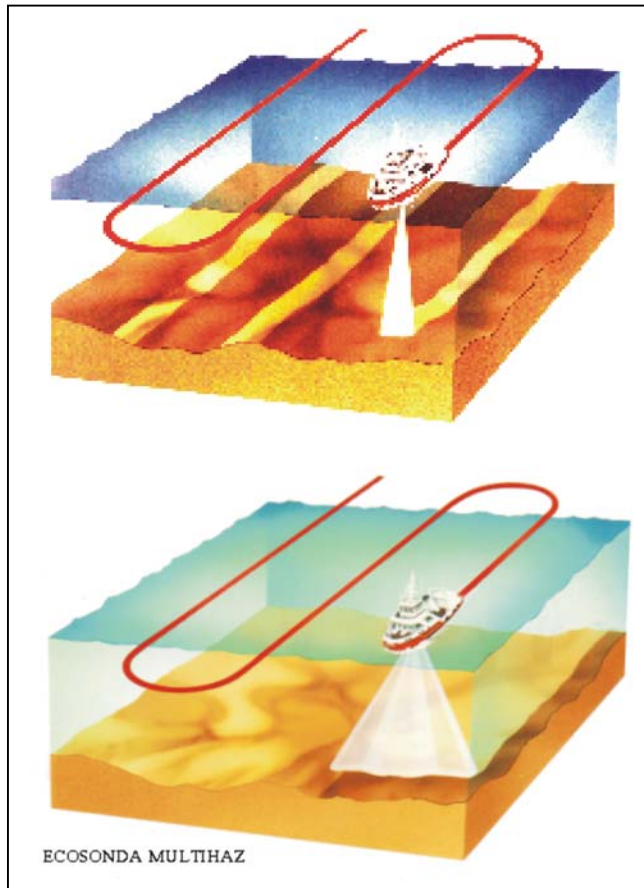


Figure 2.- The multi-beam echo-sounder running scheme (lower part) compared to the “classic” mono-beam echo sounder (upper part), indicating the area of the seabed covered by both kinds of echo sounders. The different coverage of both the mono and multi-beam echo sounders can be noticed; with the former, the entire seabed is “illuminated” with sound, whereas with the mono-beam there are uncovered areas between the vessel’s track lines. Moreover, echo sounder densities of several hundreds of points per square metre can be achieved, given the feature associated with the multi-beam echo sounders of a very high 131 beam shot rate.

## SUMBARINE MORPHOLOGY OF THE ALBORÁN SEA AND THE STRAIT OF GIBRALTAR

The origin of the Alborán Sea is related to the push northward of the African tectonic plate with the European plate.

This general movement of plates resulted in the opening of the Alborán Sea, either as an effect of an Alborán microplate movement against the area currently known as the Gibraltar Arch, or, according to other authors, as an effect of *roll-back* westward caused by a subduction zone in the Gulf of Cadiz.

In any case, this stage of enlargement ended in the Miocene (23 to 5 million years ago) and, since then, there is pressure in that area due to the African plate push northward and north-westward. This push has caused several things: first, the narrowing of the Alborán Sea in some hundred of kilometres; second, it provoked the closing of the Strait of Gibraltar in the Upper Miocene, which, in turn, caused the drying of the Mediterranean and the deposition of a very thick layer (thousands of meters) of salt and evaporites (gypsums) as a result of water evaporation for 600,000 years. During the Pliocene (5 to 1.6 million years), the connection Atlantic-Mediterranean through the Strait of Gibraltar was re-established, thus, the Mediterranean being filled again with water from the Atlantic. According to some authors, the Mediterranean took around 36 years to be filled again.

The present appearance of the Alborán seabed shows the effects of the said continuous pressure, thus causing a series of strike-slip fault with arm-shaped or x-shaped directions, as an answer to this push. These great faults, with direction NE-SW and NW-SE, can be seen in the present morphology of the Alborán seabed, for instance in the Serrata-Carboneras Fault or in the Yusuf Fault (figure 3).

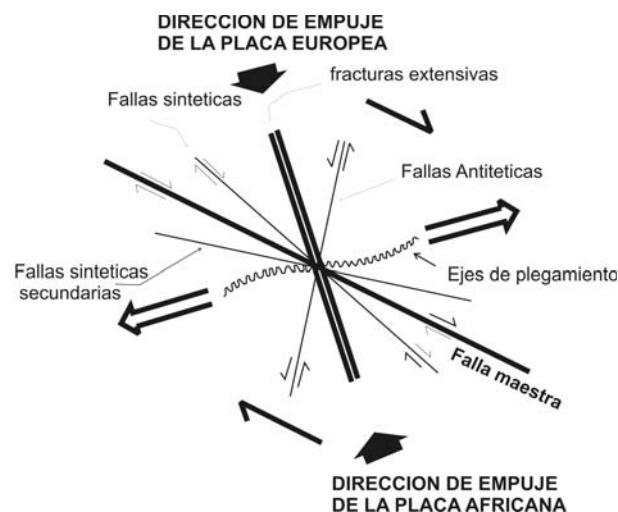


Figure 3.- Scheme of forces. The push of plates provokes faults and folds shown in this figure. The kind of force is known as "simple shear"

The final *touch* to the morphology of the Alborán Sea and its present coast is a result of the sea level oscillation during the quaternary, which, as a consequence of successive glaciations, caused rises and falls of the sea level, thus, provoking the insertion of submarine canyons that can be seen on the relief map as well as the erosion on the top part of some seamounts such as the Seco de Los Olivos or the Chella Bank seamount.

Other relevant morphological elements represented on the map have to do with volcanism (seamounts and guyots), or with the leak of seabed gases and fluids which provoke mud volcanoes and pockmarks.



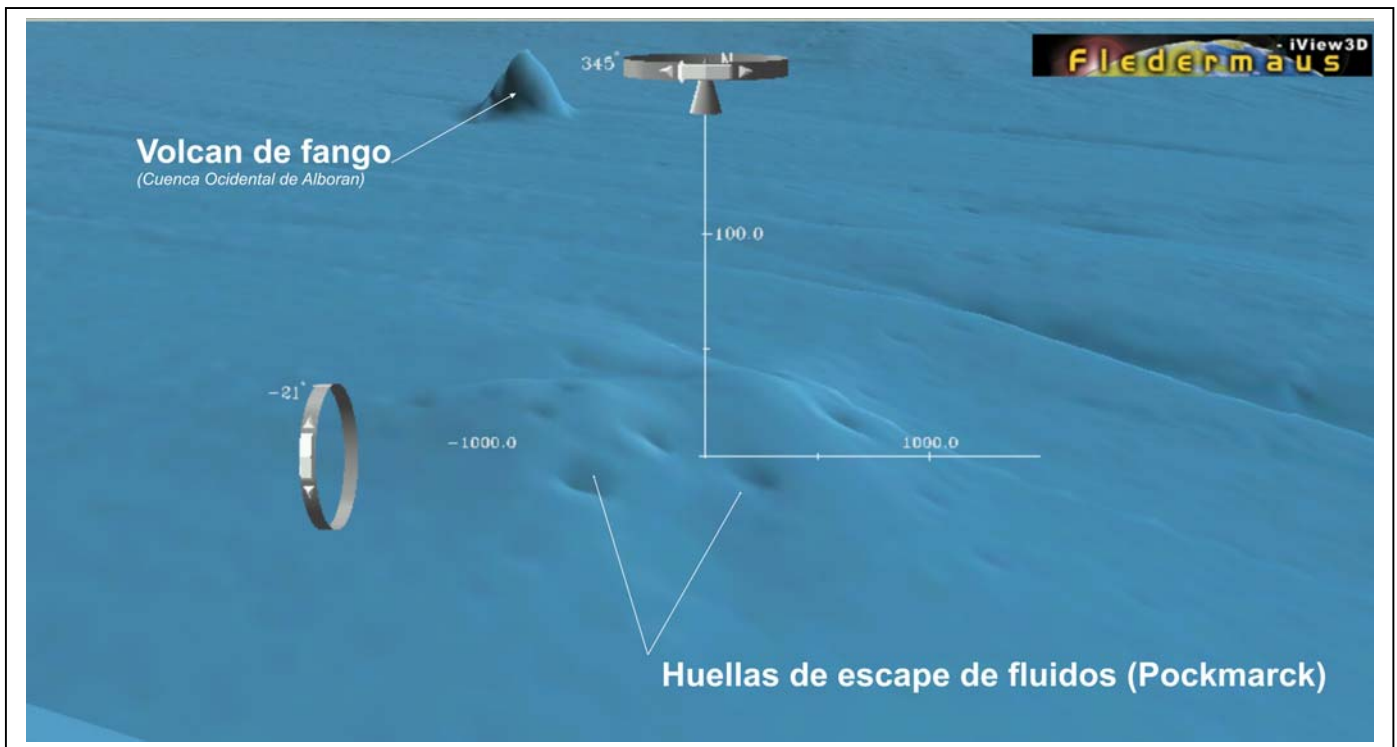


Figure 4.- Pockmarks in the foreground and a mud volcano in the background . Both phenomena are related to the leak of gases, liquids and fine sediments from the seabed (Western Basin of the Alborán).

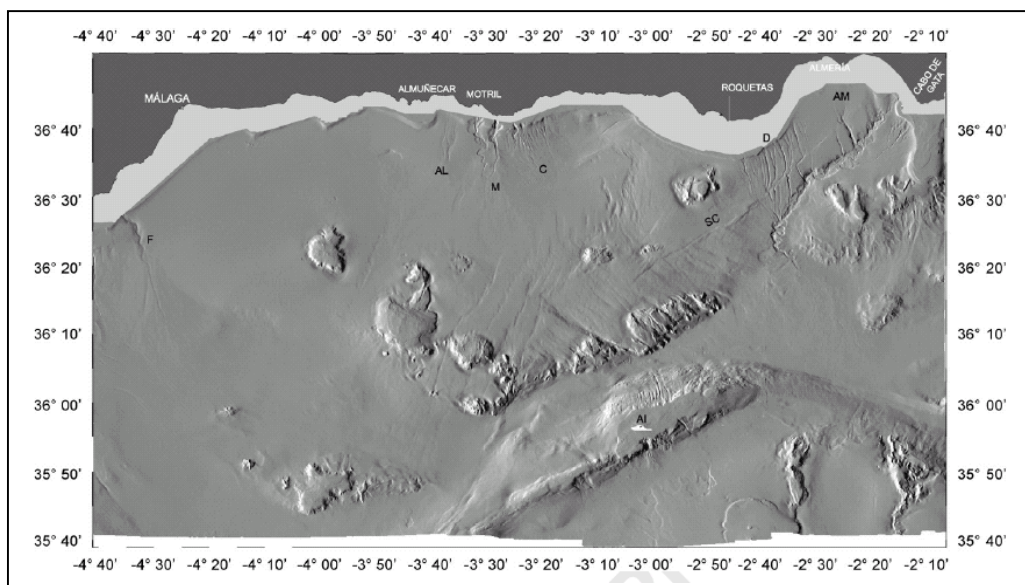


Figure 5.- Digital model of the Alborán seabeds. This image, built up from data of the multi-beam echo sounder, shows the seabed around the Alborán Sea with high resolution and in detail, and can be compared to an “aerial photo” of the seabed if water had been removed. The image has been “illuminated” in an artificial manner as if the sun came out from the left part of the image. The figure shows numerous seamounts, the Alborán Island (Al) and submarine canyons.

The seabed of the Alborán, represented in figure 5, show the existence of numerous seamounts which have a great biological richness, as, for example, the one of Avempace (Algarrobo bank on the 3D map). According to Dr. Juan Gil, PR of the DEEPER Project: “This seamount shows some features of great singularity. Several species, classified as being of special ecological relevance or subject to risks, particularly the seabed of *Leptometra* and the cold-water corals. The great accumulation of crinoids (as in the case of *Leptometra celtica*) are frequent in areas where the nutrition of epibiotonic suspensivorous organisms is favoured due to the seabed currents nature. Thanks to that, the exuberant activity of the habitat attracts many other species which use it as a zone for the lay and hatching. Their presence in massive quantities, as it has been shown in the DEEPER 0907 Campaign, can be favoured by the existence of a high geothermal gradient around the Djibouti Bank, which would define a geographic habitat of special interest controlled by functional hydrothermal emergences”.



Figure 6.- Fauna of seamount Avempace (Algarrobo Bank) the *Leptometra celtica* is remarkable.



Figure 7.- DEEPER 0907 Campaign: Coral remains (*Lophelia pertusa*) and broken stones from seamount Avempace

## **REPRESENTATION EXAMPLES FROM DIGITAL BATHYMETRY**

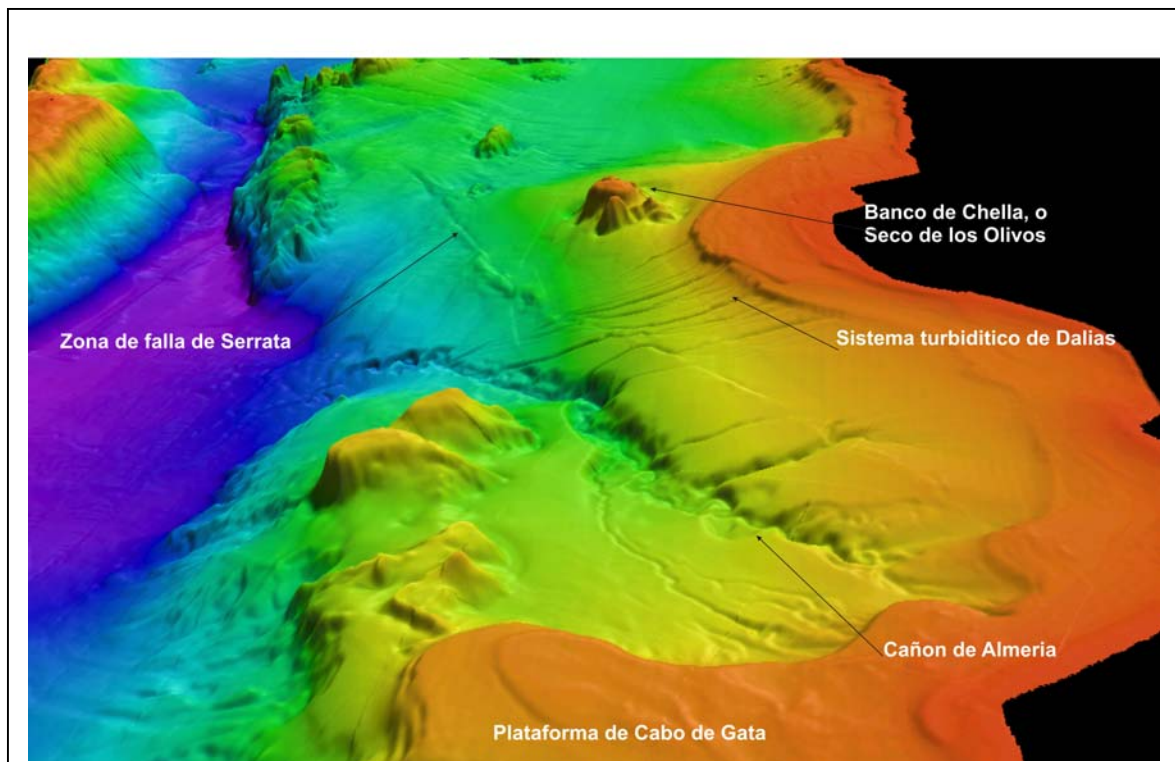
Next, some examples are briefly presented on scientific discoveries, made with the techniques and campaigns that allow obtaining the relief map as a dissemination tool.

### **SUBMARINE CANYONS**

The American geologist Francis Shepard was the one who studied submarine canyons and their origin more widely. After making different hypothesis about their formation, he finally concluded that submarine canyons do not respond to one single cause, but to several causes which can play a significant role in their origin and development: subaerial erosion, turbidity currents, faults, submarine landslides and remnant erosion are, among others, the factors which have influence on their genesis and evolution.

The origin of the Almería Canyon (figure 8), represented on the 3D map, resulted from the erosion during the sea level oscillations in the Quaternary. Then, it was developed in favour of the turbidity currents and the remnant erosion (García, M. et al. 2006).

In the case of this canyon, it can be observed that there are smaller canyons and gullies which lead to it (tributaries), as in the Dalías canyon system.

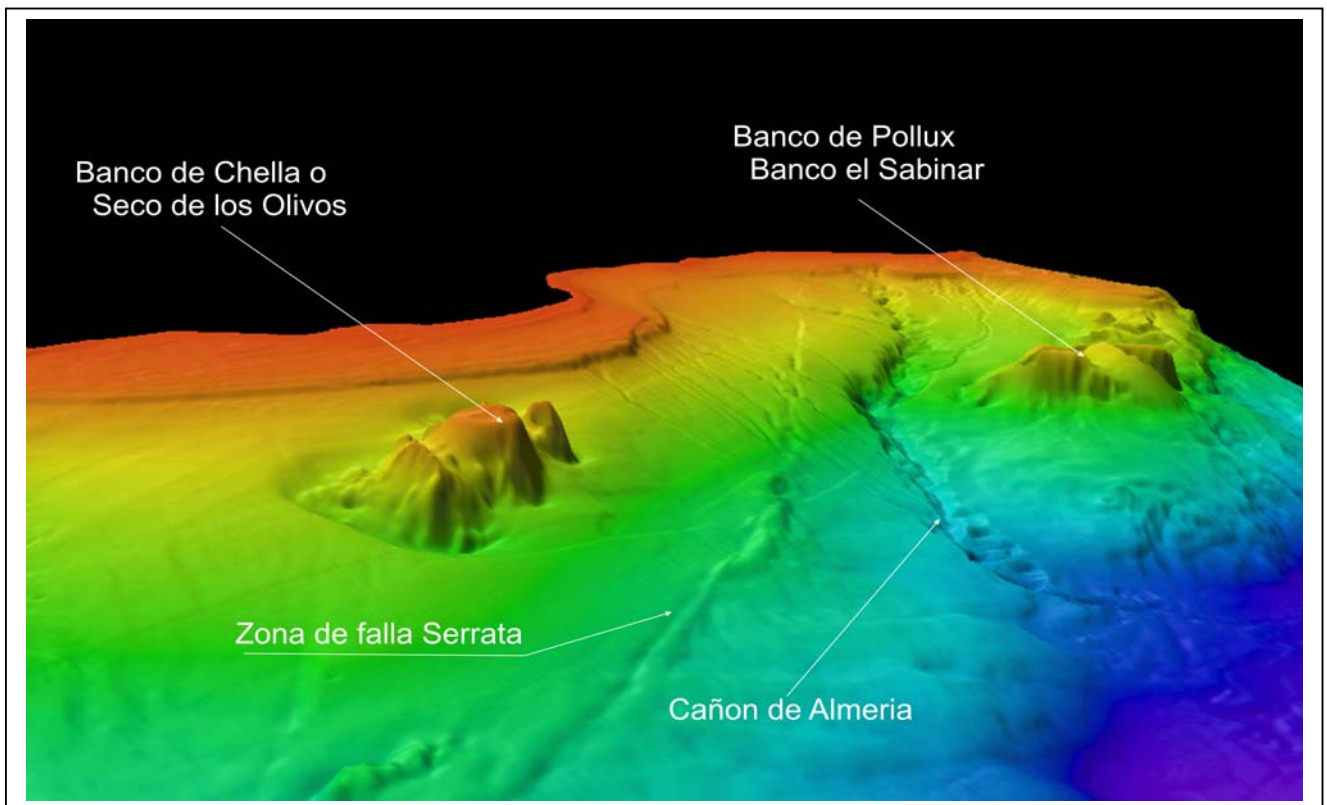


*Figure 8.- Almería Canyon seen from Cabo de Gata. It can be observed that the little tributary canyons of the turbidity system of Dalías are deviated by the Serrata-Carboneras Fault.*

## SEAMOUNTS. VOLCANIC EDIFICES

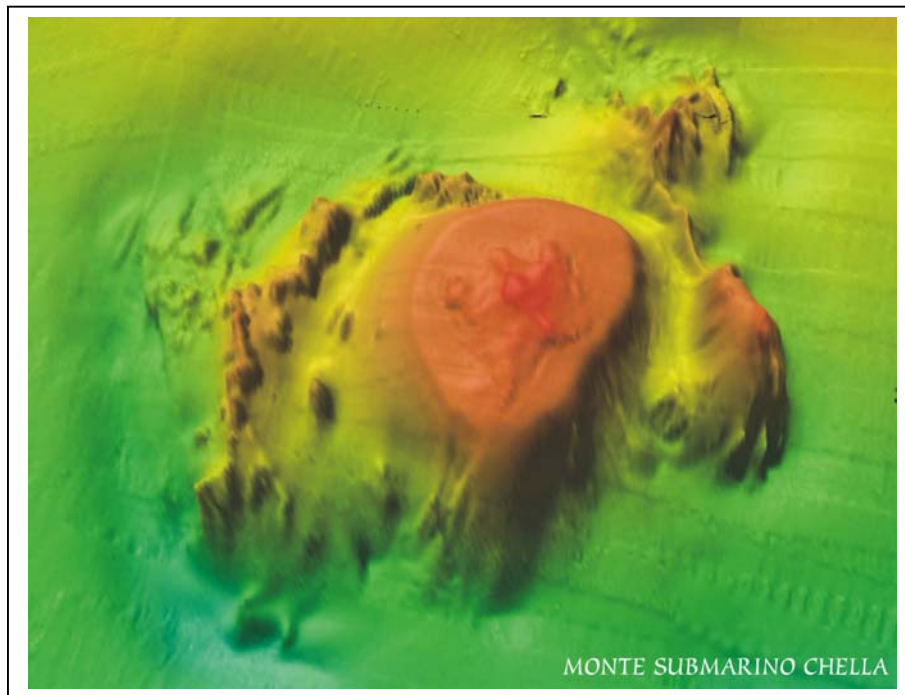
Most of the seamounts represented on this map are of volcanic nature (the continental crust under the Alborán Sea has become very thin). Others are made of metamorphic rocks belonging to the so-called Alborán domain, like Vizconde de Eza Bank.

The volcanic material, which is a component of many of these seamounts, is of calco-alkaline nature, as well as basalts and lavas of the Miocene and more modern periods.



*Figure 9.- On the first level, on the left, the Seco de Los Olivos or Chella Bank. At the end, two seamounts of volcanic nature can be observed: Pollux and Sabinar.*

The Chella Bank, also known as Seco de Los Olivos, is from the Neogene period, made of several peaks around its main body. Its flatted upper part, with a surface of 7.8 km<sup>2</sup>, is due to the Quaternary erosion as a result of the sea level falls during the glaciations. Over this surface, an irregular body which probably represents a later growth of carbonated material can be seen (figures 9 and 10).



**Figure 10.-** The Chella Bank, also known as *Seco de Los Olivos* can be taken as a “Guyot”. In its upper part, flatted by the quaternary erosion, rocks and carbonated growths of coral-producing nature were placed later. In the figure, numerous peaks and outcrops, which are also of volcanic nature, around the Bank can be seen.

Finally, the existence on these seamounts of a wide variety of species, habitats and ecosystems, which are vulnerable to human action (fishing, trawling, civil constructions, diving, etc.) render these areas specially interesting to be considered as “Protected Marine Waters”. Due to the concentration of protected species that live in these areas and that function as true *islands* where a rich biodiversity has been conserved, the need to safeguard these areas has been claimed for years. Such is the case of the area known as *Placer de Las Bóvedas*, off the coast of San Pedro de Alcántara in Marbella. A place that has been very well conserved despite being in one of the most affected coasts of the peninsula and that the specialists consider to be among the best diving areas all around Spain.



**Figure 11.-** Red star (*Echinaster sepositus*) on maerl beds.



**Figure 12.-** Conger eel (*Conger conger*)

In connection to this, the NGO Océana carried out a campaign to research and assess the ecosystems and habitats of some areas of the Alborán Sea (figures 11 to 17), which showed the existence of a great variety of life kinds, from significant concentrations of corals and gorgonians to cetaceans, such as the mule dolphin and common pilot whale. However, threats were also found in these rich seabeds such as garbage, seabed trawling traces, which have harmed many places, and numerous lost fishing equipments, which, according to Océana's estimates, can be found every 50 meters.

Images of Seco de Los Olivos.

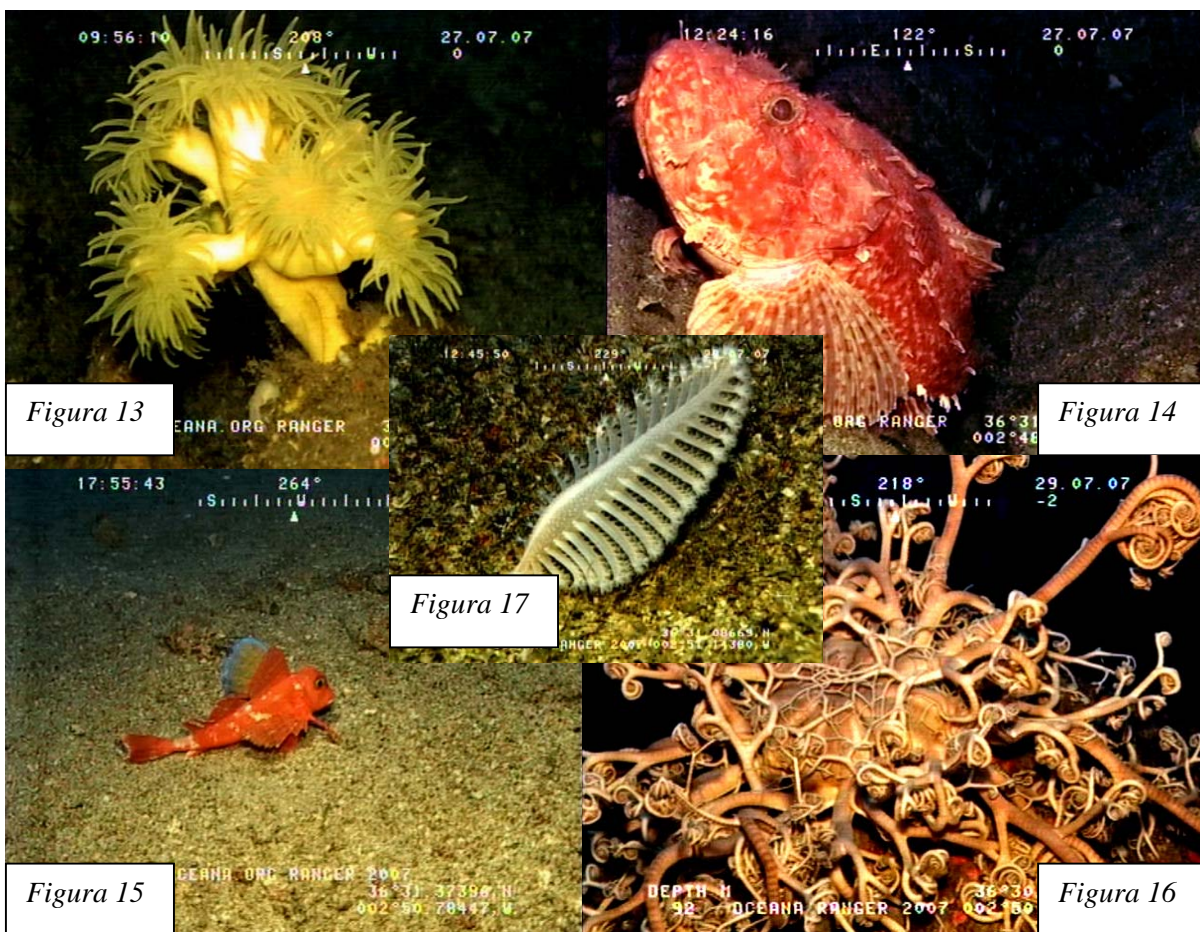


Figure 13 Yellow tree coral (*Dendrophyllia cornigera*)  
 Figure 14 Red scorpionfish (*Scorpaena scrofa*)  
 Figure 15 Streaked gurnard (*Trigloporus lastoviza*)  
 Figure 16 Basket star (*Astropartus mediterraneus*)  
 Figure 17 Sea feather (*Pennatularubra*)

## MORPHOTECTONICS. ACTIVE FAULTS

A fault is active when it deforms quaternary sediments, i.e., when it shows evidence of movement for the last 1.8 million years. Some active faults usually have associated earthquakes, which shows that they continue with activity .

Various kinds of faults are represented on the Topobathymetric map of the Alborán Sea: those indicates as “Faults” on the map correspond to graben or stretching fractures. Faults are made by applying tension in opposite directions on an area, thus, creating two face to face faults which shape a deep area or tectonic trough (figure 18).

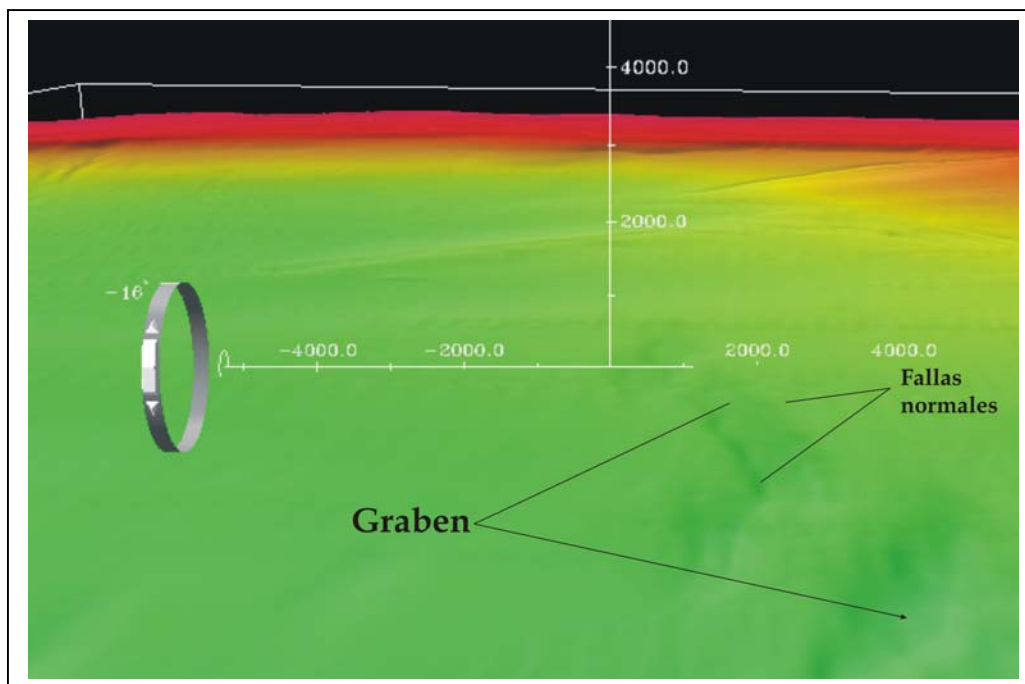
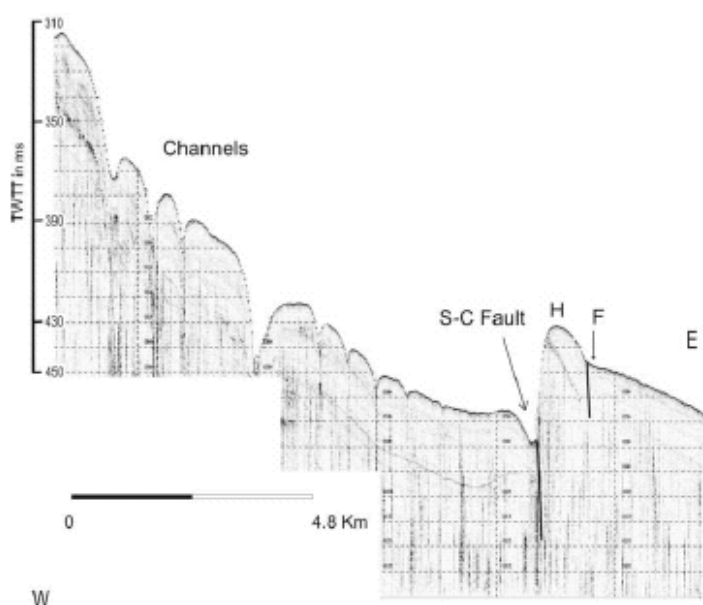


Figure 18.- Stretching faults shaping grabens on the continental margin off Adra.

The other faults on the Map correspond to great fracture zones of a *Strike-slip* type such as the Serrata-Carboneras or Yusuf Fault on the African margin.

The study of these fault areas is carried out with seismic systems which, with a higher or lower penetration under the seabed, allow us to see a profile in a vertical position of the seabed which can be up to some thousand meters deep. This technique is based on the measure of propagation times of an medium to low frequencies wave front, generated artificially by a source (string of air canyons). The signal is represented by the various layers of the subsoil, characterized by speed and density contrasts, registered through a streamer made by a series of hydrophones which drag behind the vessel a few metres under the water surface. The result is a profile of the sub-bottom up to some kilometres deep, where we are able to determine the structure and geometry of the various geological layers.

In figure 19, we present a low penetration profile under the seabed, although with high resolution, obtained with TOPAS 018 parametric echo sounders of Oceanographic Vessel Vizconde de Eza. The Serrata-Carboneras Fault (SC) is clearly appreciated and the gap or movement of the two lips or fault areas



*Figure 19- High resolution (low penetration) transversal profile of the Serrata-Carboneras Fault. The seabed displacement, as an effect of the present movement of the fault, can be noticed (CARPEMA Project).*

In figure 20, we can observe a reflection seismic profile transverse to the Carboneras Fault; this profile is of higher penetration than the one in figure 19. According to Eulalia Gracia, IMPULS Project Principal Researcher: “The profile showed by this figure was obtained during the IMPULS-2006 marine geophysical campaign on board of Oceanographic Vessel Hespérides on the margin of Almeria, SE of the Iberian Peninsula (E. Gracia, UTM-CSIC). The purpose of this project was to research on



active tectonics and paleoseismicity of the Carboneras Fault area, which is the southern ending of the shear area of the eastern Betics. This fault penetrates in the continental platform and slope of the Alborán Sea with a minimum length of 100 km, and it is characterized by sinistral transpressional movement (see glossary) between 18 and 25 km from the Miocene to the present. Despite its small instrumental seismicity, the seismic potential of the Carboneras Fault needs to be fenced in, having into consideration that it is one of the largest active faults described in the Iberian Peninsula, which is comparable to faults that have provoked Mw 7.4 earthquakes (Gràcia et al., 2006).

The innovations of the works done on the Margin of Almería are based on a sea-earth integration of paleoseismological data, which will allow determining the dynamics and past activity of active faults more accurately, and establish their seismic parameters (geometry, movement rate, maximum magnitude, recurrence period, time passed from the last earthquake). These parameters are essential in order to advise on the sort of seismic dangerousness of the Iberian Peninsula, especially for high magnitude earthquakes and long recurrence periods (104 years)”.

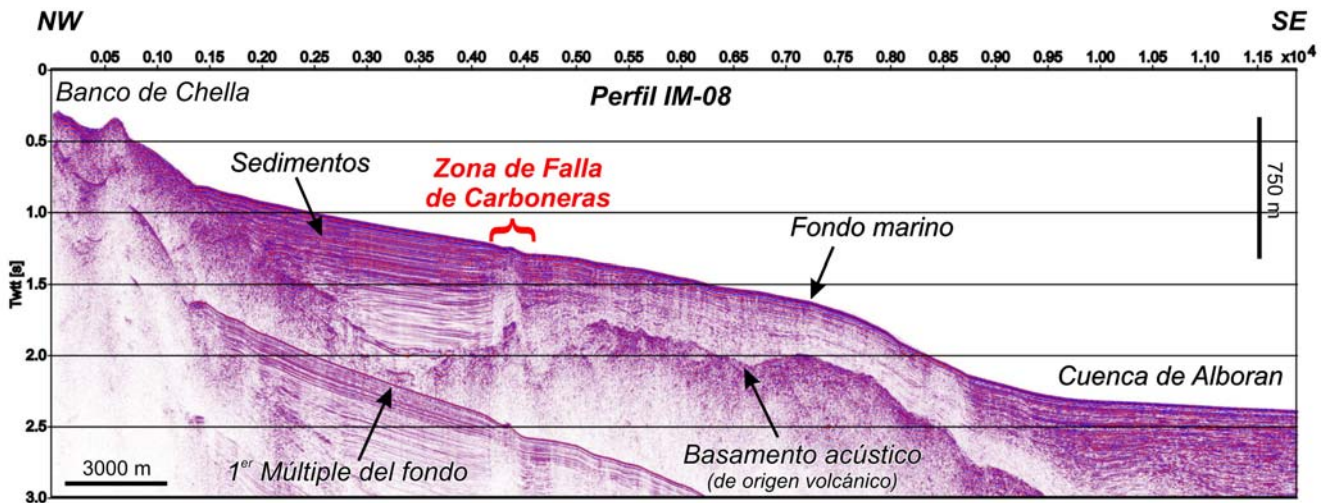


Figure 20.- In the area of the Carboneras Fault, it can be observed a distortion and discontinuity area of the reflectors up to the seabed surface, where a positive relief can be noticed. At the bottom of the IM-08 Profile, we can observe the acoustic basement, of volcanic origin, where acoustic waves cannot penetrate easily any further. The seafloor multiple corresponds to a profile “repetition” due to the double reflection of the sounds on the water surface.

## **SOME QUESTIONS AND THEIR ANSWERS**

### **Why some villages, roads, beaches are included and not simply topography?**

What is meant is that anybody, and, above all, students of nearby areas, can perfectly spot their cities, towns and villages, and can relate them to submarine forms. They are clear reference points close to the user.

### **Does the seabed really look like this?**

Yes, it is exactly like this. The map is based on data obtained from multi-beam echo sounders and GPS-D installed on oceanographic vessels. Multi-beam echo sounders identify 100% of the seabed with an accuracy of under a metre. The GPS-D (satellite global positioning system in differential mode) can spot the vessel with metric accuracy. All in all, it must be taken into account that the vertical scale has been exaggerated to highlight submarine relieves.

### **What is the course line?**

It is the path followed by a vessel.

### **What is a bathymetric profile?**

It is the profile of the seabed depths, following a specific line.

### **What is a physiographic province?**

They are areas of the seabed showing the same features regarding their physical geography (part of the geography that deals with the configuration of lands and seas).

### **What are submarine canyons?**

They are deep valleys open on the continental slope, which go from the continental edge up to the deep marine environment.

### **What are turbidity systems?**

It is the group of submarine gullies, canyons and channels which facilitate the transport of sediments from the continental platform to the great ocean floors.

**What are turbidites?**

They are sediments which have been initially placed near the edge of the continental platform which, after falling along the continental slope through submarine canyons and valleys, have been placed again in the deep marine environment, resulting in a very characteristic kind of material (sands and mud).

**What are the sediment gravity flows?**

It is the movement and displacement downhill of sediments due to gravity action. This process usually generates turbidity systems and leaves scars or scarps on the top of the movement.

**What is a guyot?**

It is a flat-topped seamount as a result of sea erosion. Many guyots are of volcanic nature. The name guyot comes from the Swiss-American geologist Arnold Henri Guyot (1807-1884).

**What is a fault?**

It is the contact surface between two blocks that move in differential mode one with respect to the other. They can expand spatially along hundreds of kilometres and through several million years in terms of time. An active fault is the one that has undergone displacement in the last two million years or on which seismic activity can be noticed.

**What is a strike-slip fault?**

These faults are vertical and the movement of blocks is horizontal, they are typical of *transforming limits of tectonic plates*. There are two kinds of strike-slip faults depending on their movement: dextral strike-slip fault and sinistral strike-slip fault. Dextral strike-slip faults are those which blocks' relative movement is toward the right, whereas the movement in the sinistral strike-slip faults is the opposite. They are also known as transversal faults. On our map, we have large faults of this kind such as the one of Serrata-Carboneras (left) or Yusuf (right).

**Sinistral transpressional movement**

Relative movement of a fault's lip from the other in a sinistral strike-slip faults and which, in addition, presents certain pressure between its blocks. In the case of Carboneras Fault, some authors estimate that this relative movement is between 18 and 35 km.

**What is a mud volcano?**

They are submarine shapes similar to volcanoes'; however, their origin is the result of the fluid emission (gases and liquids), rich in mud, and they have been noticed in marine and aerial environments alike. The scientific interest in mud volcanoes is greater every day due to the processes associated to this phenomenon, as the greenhouse gas emissions to the atmosphere or the energy production for extreme ecosystems. The gases that drag mud are usually: methane, carbon dioxide and nitrogen, with very saline water or fluids coming from the petroleum.

## IN ORDER TO KNOW MORE

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He has participated in 20 oceanographic campaigns developing the tasks to obtain and process of multi-beam bathymetry and reflection seismology, marine geology sampling and technical assistance with SIG.

Most of these campaigns were aimed at the charting of habitat. He also participated in the shooting and sampling of the benthos in deep waters using unmanned Submarines ROV for this purpose.

He recently presented his DEA (Advanced Studies Diploma) entitled “Marine geophysics techniques applied to the Study of the Serrata-Carboneras Fault Area”, at the Universidad Complutense de Madrid (UCM).

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