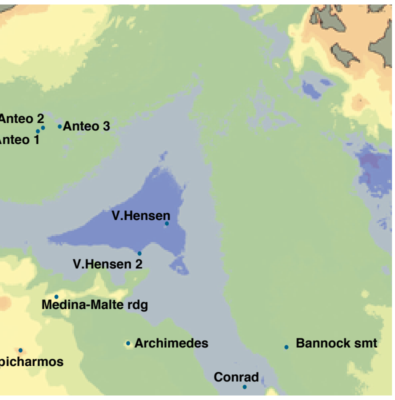
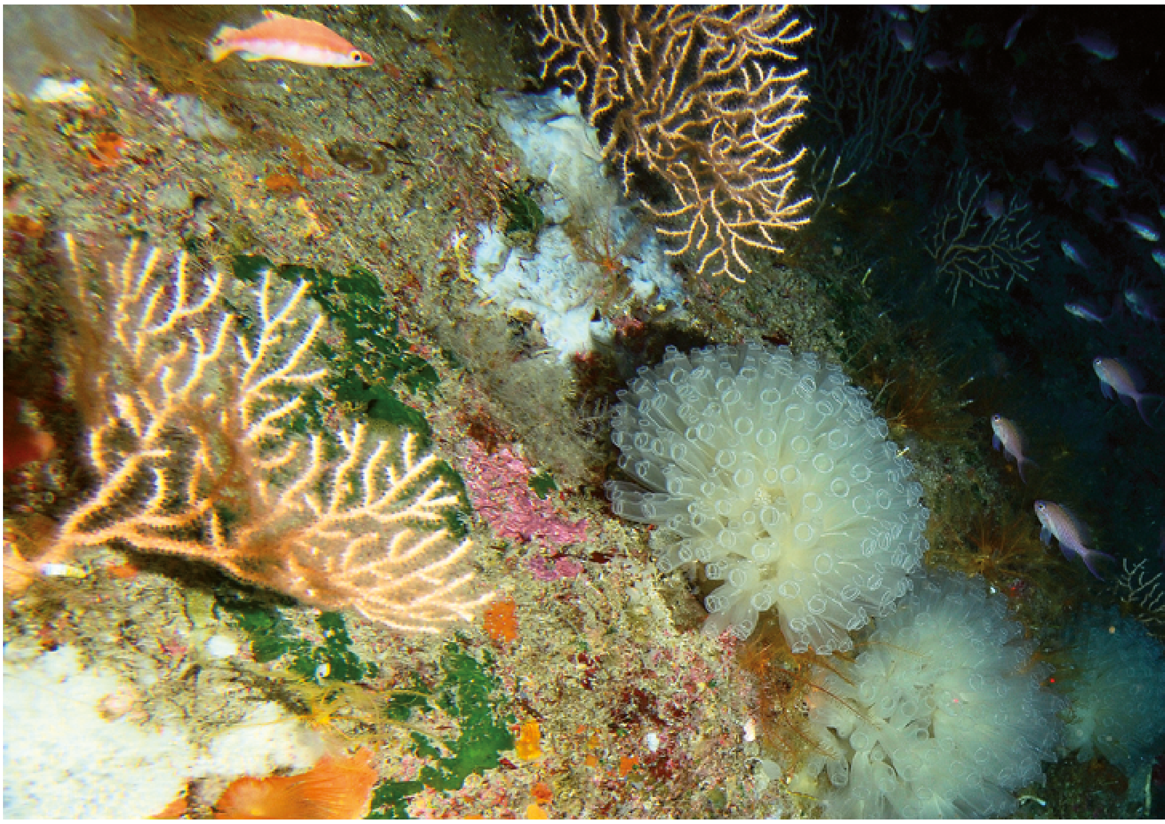
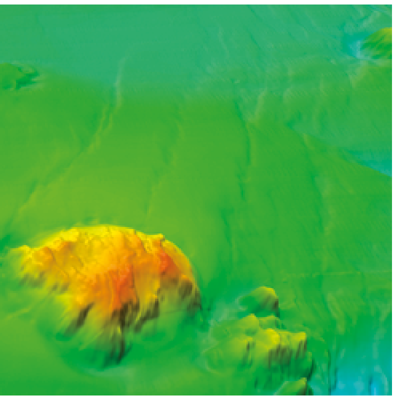
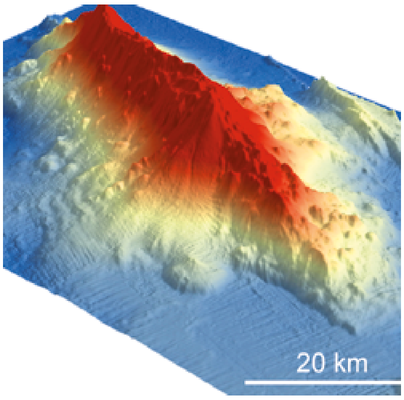
# Atlas of the Mediterranean Seamounts and Seamount-like Structures

Maurizio Würtz and Marzia Rovere (Editors)









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2015

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*“There is simply no such thing as an accurate map of the world, and there never will be.*
*The paradox is that we can never know the world without a map, nor definitively represent it with one.”*

Jerry Brotton, 2012. *A History of the World in twelve maps.* Penguin Books Ltd, UK.

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# Contents

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# Preface

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Starting a new project on Mediterranean seamounts named PROMETEOS (PROtection of the MEdiTErranean Open Seas: Contributing to the establishment of Marine Protected Areas over offshore seamounts and submarine canyons) and funded by MAVA, was a challenge for the experts involved. A previous project, led also by Pr. Maurizio Würtz, was concerning Mediterranean submarine canyons (Würtz, 2012: http://cmsdata.iucn.org/downloads/2012_035.pdf and was oriented on the preparation of articles by regional experts, based on their knowledge of specific canyons in different part of the Mediterranean.

Discussions at the start of the project showed that the existing knowledge on the Mediterranean seamounts was very scarce and that numerous seamounts and seamount-like structures were not even named, mapped or studied, even if they were known by fishermen for their impact on the aggregation of predators in their surroundings.

So, the decision was not to produce articles reviewing well-known seamounts, which could have been redundant with existing scientific publications, but to compile an Atlas of the Mediterranean seamounts. With the aim to produce an useful tool for future research planning as well as a reference for conservation and governance actions, this seamount Atlas contains detailed maps, drawn made by a GIS software according to a standard format, geographical locations and depth data, as well as, when available, other relevant information, morphological and geological descriptions, data about benthic communities and about the pelagic life around the seamount. Moreover, updated references of scientific publications or reports complete each section of the Atlas.

Based on a revised definition of seamounts and seamounts-like structures, the number of data sheets grew from less than one hundred up to more than the double, thus describing a total of 242 seamounts, banks, rises, highs, hills, spurs and other kind of sea floor elevations according to the standard nomenclature of the undersea features done by the International Hydrographic Organization. Therefore this Atlas represents an important step to a better understanding of the Mediterranean deep sea functioning and the importance of these underwater structures in the fisheries, being the main extractive activities in the offshore area.

The Atlas also summarizes the results of a specific research, which has been conducted in the field under the PROMETEOS project, in particular for the seamounts of the Tyrrhenian Sea and Sardinia Channel, bringing some new vision on the importance of the seamount and seamount-like structure effects in aggregating top pelagic predators.

At the end of this project, we could say that basic information has been gathered for the development of further work on the importance and influence of seamounts, their biodiversity, their habitat for predators and marine mammals and their impact on fisheries. Already other options for study of the seamounts in different part of the Mediterranean have been explored and could be developed in the near future, pending identification of funding sources.

The main remaining issue, as for the submarine canyons and the deep sea or offshore waters in general, is their protection from impacts, their conservation and their management. One of the main impacts is related to the damage done by trawlers, and those found at a depth of more than 1000m are protected by a decision of the General Fisheries Council for the Mediterranean (GFCM).

Other impacts include pollution coming in particular from the maritime traffic or accidents, but also from land based sources and underwater noise due to maritime traffic, military exercises, seismic exploration or mineral resources exploitation.

Recently, during the meeting organised in Malaga by the Convention on Biological Diversity (CBD) and the United Nations Environment Programme - Mediterranean Action Plan (UNEP-MAP) from 7 to 11 April 2014, large areas of the Mediterranean sea have been considered for being declared as Ecologically or Biologically Significant (marine) Areas (EBSAs), including canyons and seamounts, potentially leading to their consideration in the future as marine conservation or protection areas, based on their importance for different life stages of specific species.

This Atlas will certainly help, being a first step, but the road is still long until the declaration of a coherent and representative network of marine protected areas covering deep sea and offshore marine environment

Back to work, and all together, we can reach this target.

# Introducing the Mediterranean Seamount Atlas: general aspects

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Seamounts are relevant seafloor structures, which may have different origins and which feature all the world oceans and they may be defined as hotspots of biodiversity, greatly affecting the productivity of the offshore ecosystems and the distribution of pelagic top predators. Seamounts are generally not ecologically isolated or island-like systems, and they can have species assemblages similar to those found in adjacent deep-sea habitats, but can have a different structure in terms of the abundance or frequency of species, and more recent studies indicate that rates of endemism may not be high (McClain, 2007).

Seamounts span a broad depth range, are influenced by different oceanographic processes, are located in diverse geological settings, and therefore comprise heterogeneous habitat types, encompassing variable communities over large spatial scales. Seamounts are increasingly exploited by humans: fishing on seamounts is a widespread activity, as well as the exploration for seabed minerals and Rare Earth Elements (Hein *et al*., 2009; Hein *et al*., 2010), which poses future challenges for their conservation (Morato *et al*., 2010; Schlacher *et al*., 2014) ; gas and oil exploitation are additional emerging environmental issues affecting seamounts, especially in the central and eastern Mediterranean, also taking into account that the seamount communities are very slow to recover from impacts (Clark *et al*., 2010).

Scientists estimate their global number from a little more than a thousand (Wessel, 2001; Kitchingman and Lai, 2004; Etnoyer *et al*., 2010; Harris *et al*., 2014) to several ten of thousands (Yesson *et al*., 2011) to about two hundred thousands (Hillier and Watts, 2007) to about one million in the Pacific Ocean only (Carter *et al*., 2006) to 25 million globally (Wessel *et al*., 2010). The estimates based on satellite altimetry, to examine gravitational anomalies in the sea surface, can detected only features > 1500 m above the seafloor, so the smallest and deepest seamounts cannot be well resolved. Real bathymetric soundings from the publicly available cruises sample only a small fraction of the ocean floor, so that we are still far from having real numbers (Wessel *et al*., 2010). So a large a range of estimates depends from a variety of factors including not only the bathymetric database reference used but, first of all, from the definition of what the word “seamount” means.

Staudigel *et al.* (2010a) proposed a broad definition (see the chapter “Seamount definition”), which allows to include all elevations rising more than 100 m from the surrounding seafloor, but excluding those elevations rising within the continental shelf. Of course, this simple broad definition may be not shared by geologists, who prefer to call seamount an isolated conical volcanic feature taller than 1000 m above the seafloor and who take into account also aspects about the seamount origin, for which they use a set of terms which are also related to the structure types (i.e. bank, volcano, horst, rise, ridge, structural high, knoll etc.). On the other hand a broad and simple definition of the term seamount may be useful for biologists and ecologists, who are much more interested in the seamount effects both on the pelagic and benthic communities.

However, even if we were to adopt the definition done by Staudigel *et al.* (2010a), still remains unclear to what value of the ratio between the height and base extension we must refer in order to define a seafloor elevation as seamount, in fact from this ratio also depends the flank steepness, which allow us to separate a “true seamount” from a simple “sea bottom hump”, but also because the kind and the strength of the seamount effects on circulation also depend from its morphology and thus its effect on the biological component.

Another striking aspect about the seamount definition and the seamount type identification is how to estimate the seamount height. When one elevation, even of irregular shape, rises isolated on a flat seafloor it could be quite easy to compute its height, but in the case of steep profiles of the seafloor one seamount may have one side (or more) very deeper than the others, it can be not so easy to compute its height. It can be estimated from the deeper side, from the shallower one or we can estimate the mean of the variable bathymetry of the seamount base? A quite difficult task, not completely discussed up to now. In order to avoid this unsolved problem, we decided to use the deeper bathymetric ring (closed bathymetry line) around the seamount, by this way it is possible to assessing the depth of its base and thus to estimate the height (see the chapter “Making of the Atlas”).

Obviously some aspects about seamount definition remain unsolved, nevertheless, as the subject of this Atlas is to review the knowledge of the Mediterranean seamounts and seamount-like structures, we have taken into account any elevation which fits the above mentioned definition and that has been quoted by scientific and technical literature, by the official undersea feature name lists or known by fishermen, thus also including banks, reefs and other similar structures outside the continental shelf boundaries. We have to consider that the scale of the Mediterranean pelagic ecosystem is quite different from the oceanic one, as well as its geological history and the scale of the oceanographic processes in its two basins: the Levantine basin and the western Mediterranean, which were supposedly completely separated during the deep-basin desiccation phase (from 5.60 to 5.32 Ma) of the Messinian salinity crisis (Clauzon *et al.*, 1996; Krijgsman *et al.*, 1999) and isolated from the Atlantic Ocean.

In the Mediterranean, contrary to the oceans, even a very small hard outcrop may have huge effects on the pelagic fauna distribution or may host a unique benthic community, such as the deep-sea coral reef. Deep-sea coral communities are commonly associated with seamount and submarine canyons around the world, and so they are in the Mediterranean Sea, where they may be locally an important component of the deep sea ecology providing food and refuge for many associated species. Scientist distinguish two main types of deep-sea corals: the "white coral" community of *Lophelia pertusa* and *Madrepora oculata* and the "yellow" *Dendrophyllia cornigera.* The true extent of the deep-sea coral community in the Mediterranean Sea is poorly known and the relatively few verified records of live *L. pertusa* and *M. oculata* exhibit a scattered distribution pattern, mainly linked with seamounts and troughs, such as in the Strait of Sicily, where healthy deepwater coral banks have been recently recorded and described (Bussoletti *et al.*, 2010; Freiwald *et al.,* 2009; Martorelli *et al.,* 2011; Scembri *et al.,* 2007; Taviani *et al.,* 2011; Zibrowius and Taviani, 2005).

Several benthopelagic fish species aggregate for spawning or feeding over seamounts (Althaus *et al.*, 2009). Blackspot seabream (*Pagellus bogaraveo*) is one of the most common fish species living over the Mediterranean seamounts together with the congener species, Axillary seabream (*Pagellus acarne*), wreckfish (*Polyprion americanus*), blackfish (*Centrolophus niger*) and imperial blackfish (*Schedophilus ovalis*), whose populations in some seamounts have been severely depleted because of the strong pressure by the sport and commercial fishing.

Seamounts interact with currents and create flow complexities which depend upon current speed, water mass stratification and their morphology (see White and Mohn, 2004 for a complete review). Seamount effects on circulation include internal wave generation, eddy formation, local upwelling and closed circulation patterns called Taylor columns, which affect pelagic and benthic ecosystems over and around seamounts, even for significant distances downstream of the seamounts (Boehlert and Genin, 1987).

Seamount effect on the pelagic top predators such as tunas, swordfish and sharks has been described by Morato *et al.* (2008) and by Kaschner (2007). It was demonstrated that seamounts may attract pelagic visitors, which aggregate within variable distance (10-30 km) from the summit according to the seamount characteristics (e.g. peak depth, elevation, circulation, etc.), but also according to the species considered. This aspect is poorly investigated in the Mediterranean Sea, only recently an extensive survey (IUCN-Prometeos) was carried out in order to identify what species of cetacean is mostly affected by seamount. It was found that the striped dolphin (*Stenella coeruleoalba*) is a good indicator of the seamount effect, which influences the species distribution and abundance up to about 13 nm (Aissi *et al.*, 2013). It is also evident that not all the seamounts have similar effects, a great variability exists according to the seamount morphology, depth of the summit, but mainly according to the interactions of these seamount features with the local and basin circulation.

Many reviews (Morato and Pauly, 2004; Clark and Koslow, 2007; Clark *et al.*, 2010; Pitcher *et al.,* 2007; Freiwald *et al.,* 2009; Staudigel *et al.*, 2010b) demonstrate that seamounts are unique marine ecosystems, which support fragile habitats and vulnerable species of flora and fauna often under threats (both anthropogenic and natural). The role of seamounts in oceans primary productivity is still under discussion, but recent studies suggest that they can exert a trapping effect of organic matter and thus enhance the presence of microbial communities specifically on seamounts (e.g. Mendonça *et al.*, 2012). Also, the enhanced heterogeneity of seamount-hosted hydrothermal systems represents a dynamic range of habitats, providing for the growth of a remarkable diversity of microbes (Emerson and Moyer, 2010). Although hydrothermal venting occurs only at a small fraction of all seamounts, this particular setting hosts unknown microbial communities, that also have a potential for biotechnologies in the blue economy scheme (e.g. scavenging of valuable metals, new metabolites for the health and cosmetic industry). Furthermore, open questions remain about the role of seamounts in ocean acidification and global carbon cycle (Emerson and Moyer, 2010).

A number of on line tools, archives and reports are now available: Seamount Catalog; Seamounts Online (Stocks, 2009); CenSeam, global census of marine life on seamounts (Duffy, 2008; Stocks *et al.*, 2012); OASIS, Oceanic Seamounts: an Integrated Study; etc. These allow us to have a better idea about their geographic location and features on global scale. However, our knowledge of seamounts is far less comprehensive than for many other marine ecosystems and, even if the interest about their importance is growing, the need to protect these ecosystems is only just being recognized [Food and Agriculture Organisation (FAO) for fisheries; the International Seabed Authority (ISA) for mining; Parties to the Convention on Biological Diversity (CBD) and the United Nations General Assembly for conservation issues]. The fragility of seamount ecosystems, and the magnitude of threats posed to them, make an assessment of their management needs an urgent task (Alder and Wood, 2004). The Seamounts Online database estimates that less than 400 seamounts have been sampled in the world oceans, and of these less than 100 have been sampled in any detail. A key aim of marine scientists should be to increase the number of seamounts that have been sampled, and to ensure that they are sampled in sufficient detail to enable meaningful conclusions to be drawn (Duffy, 2008).

The above considerations are particularly true about the Mediterranean Sea, where our knowledge about seamounts is marked by large gaps, mainly on the eastern basin seamounts (Morato *et al.,* 2012), but also by an asymmetry between the amount of geological studies and the biological ones. The knowledge of the seamounts in the Mediterranean Sea chiefly comes from the two Deep Sea Drilling Program legs (13, 42 at www.deepseadrilling.org) and the three Ocean Drilling Program legs (107, 160, 161 at www-odp.tamu.edu) which drilled several sites in the Alborán Sea, the Western Mediterranean, the Tyrrhenian and Ionian Sea and the Eastern Mediterranean. After that, several other cruises, researches and European projects have followed and increased the base knowledge of the nature and structure of several Mediterranean seamounts. Yet, the majority of the structures remain completely unknown. The biological studies came afterwards and have been mainly carried out in order to investigate and describe the benthic habitat, while we dispose of very few documents about the pelagic life around and over Mediterranean seamounts. Just as an example, we don't have information about the seamount effect on the Deep Scattering Layer (DSL) in the Mediterranean and we don't know the distribution and migratory behaviour along the seamount flanks of the large number of mesopelagic organisms (myctophids, pasiphaeid shrimps, squids), whose biomass was never completely estimated. The most striking knowledge gap on the Mediterranean seamounts, however, without doubt concerns the benthic communities. If we consider the entire archive of the present Atlas, information on the benthic communities is available for only 47% of the seamounts and in the totality of these cases it is a partial one. The Tyrrhenian region (accounting for 65 seamounts) is a very representative case, in fact, a part for some scattered data mainly derived from indirect fishing bycatch observations or geologic surveys and mainly related to demersal fish, molluscs or crustacean species (Sabatini *et al.*, 2011), only one characterization of the sessile assemblages has been carried out so far in this area (Bo *et al.*, 2011).

Despite several of the Mediterranean benthic surveys revealed the existence of important communities of cold-water corals (Izquierdo *et al.,* 1996; Galil and Zibrowius, 1998; Gil *et al.*, 2010; Bo *et al.*, 2011; Freiwald *et al.*, 2011; Pardo *et al.,* 2011; Aguilar *et al.*, 2013), that are considered among the top priority Vulnerable Marine Ecosystems (VMEs), and highlighted a significant impact from fishing activities (Freiwald *et al.*, 2011; Lo Iacono *et al.,* 2012), no scientific effort has been addressed so far for a large-scale exploration of these structures. Suspension feeders, particularly deep-sea corals and sponges, in fact, usually dominate the hard-bottom habitats of seamounts. In particular, deep-sea corals are considered the most diverse invertebrate group on seamounts (Stocks, 2004) and usually dominate in quantitative terms (Genin *et al.*, 1992; Rogers, 1994). Corals play also an important functional role, by creating important refuge or nursery habitats for a rich associated fauna of invertebrates (especially crustaceans and echinoderms) and fish, some of which of commercial interest (Rogers *et al.*, 2007).

The most important habitat-forming coral taxa usually found on Mediterranean seamounts are alcyonaceans (as sea fans and soft corals and, at least for soft bottoms, sea pens), antipatharians (forming large forests up to 500 m depth) and scleractinians (such as *Dendrophyllia cornigera* or the well known white corals *Madrepora oculata*, *Lophelia pertusa* and *Desmophyllum dianthus* thriving at bathyal depths). These coral forests account for some of the most longevous species known in nature, such as the isidid alcyonacean *Isidella elongata* or the black coral *Leiopathes glaberrima*, characterized by slow growth rates and a centennial or millennial life span, representing unique biological archives of paleoceanographic data (Robinson *et al.*, 2014). Yet, despite their widely accepted ecological and paleogeographic importance, records of scleractinian corals on seamounts are patchy and simply not available for most of the global ocean (Tittensor *et al.*, 2009).

Very likely a better knowledge about these aspects would be very useful in order to understand the processes that regulate the Mediterranean ecosystem functioning, *i.e.* how such oligotrophic ecosystem has the capability to sustain large populations of benthic suspension-feeders, or of top predators like tunas, swordfish, whales, dolphins and sharks. As well as how the mechanisms of the Pelagic-Benthic Coupling are expressed over these deep structures; which is the connectivity among the deep benthic populations and the Atlantic deep fauna, how the mesoscale Mediterranean turbulences affect the distribution and composition of the seamount assemblages or also how are the communities structured over steep bathymetric gradients.

With the aim to give an idea of the updated knowledge about the seamounts, this Atlas reviews the main aspects of the very heterogeneous information about geology, benthic and pelagic habitats of 242 Mediterranean seamounts and seamount-like structures (only those which have a name). Considering that the GEBCO Gazetteer globally includes 2274 structures (an amount obtained as a result of adding the definitions: seamount, ridge, reef, bank, guyot, hill, knoll, rise, spur, seamount chain, seamount group), our number appears to be the result of a great effort and shows how much poor is still the knowledge about seamounts in the oceans. Giving even a simple glance to the Atlas pages, we can realize that too many seamounts still remain unknown, we hope that the evidence of these knowledge gaps drive more interest and resources toward the seamount as focal point of the Mediterranean ecosystem conservation.

## Seamount definition

The term seamount has been defined several times (Murray, 1941; Menard, 1964; Wessel, 2001; Schmidt and Schmincke, 2000; Pitcher *et al.,* 2007; International Hydrographic Organization, 2008; Wessel *et al.,* 2010), but there is no "generally accepted" definition. Most definitions serve the particular needs of a discipline or a specific paper. Inconsistencies are common among different publications and, most notably, differ from the recommendations of the International Hydrographic Organization (IHO) and the International Oceanographic Commission (IOC) (International Hydrographic Organization, 2008; Staudigel *et al.,* 2010a).

Indeed, seamounts can have a variety of shapes, but are generally conical with a circular, elliptical or more elongate base. Seamounts are most of the times volcanic in origin, an underwater volcano first creates a seamount which grows due to the active intense volcanism. Seamounts can be associated with seafloor 'hot-spots' (thinner areas of the earth's crust where magma can escape), where mantle plumes transport heat to the base of the lithosphere (Malamud and Turcotte, 1999). Seamounts are growing in almost every tectonic setting, they are produced near mid-ocean spreading ridges, in island-arc convergent settings, seamounts are found both on the subducting plate and the back arc basin in an ocean crust subduction system. They can also be formed along a volcanic passive continental margin, as in the case of the young Tyrrhenian Sea. Seamounts, often with a slope inclination of up to 60°, provide a striking contrast to the surrounding rather 'flat' abyssal plain. Their relief has profound effects on the surrounding oceanic circulation, with the formation of trapped waves, jets, eddies and closed circulations known as Taylor columns (Taylor, 1917 in Rogers, 1994).

There is a certain consensus in the scientific community to define a seamount as an isolated underwater feature of limited extent across the summit usually composed of hard substrate and with an elevation higher than 1000 m above the seafloor and this geological definition has been used in global studies of seamount distributions (e.g. Craig and Sandwell, 1988; Kitchingman and Lai, 2004; Kitchingman *et al.*, 2007; Harris *et al.*, 2014). However, Allain *et al.* (2006) have stressed that any elevation can have an impact on the surrounding ecosystem; for example, a very specific fauna was observed on a 12 m-high elevation feature in the North Atlantic (Bett, 2001). Thus, an operational definition of seamounts, which aims to be appropriate to benthic communities as well as pelagic fisheries ecology, might have to take into consideration underwater features less than 1000 m of elevation and of different shapes, such as terraces, ridges, banks, plateaus, etc., which are normally excluded from the formal definition of a seamount, but may still be relevant. In regards to the relevance of seamounts to pelagic ecology and fisheries, the summit depth appears to be as important as the elevation. The depth of the peak, the geomorphology and the geographic isolation of the seamount, the steepness of the slopes, as well as temperature, pressure, local hydrothermal emissions and hydrodynamism greatly influence the composition and the distribution of the benthic biocoenoses (Boehlert and Genin, 1987; Samadi *et al.*, 2007; Clark *et al.*, 2010). For example, the Tyrrhenian Vercelli and Palinuro Seamounts' peaks, by penetrating in the euphotic zone, allow the massive development of algae as observed also on numerous oceanic shallow water structures, often hosting dense kelp canopies (Bo *et al.*, 2011). The local hydrodynamic conditions, however, occurring along the flanks of a topographic elevation, play the most important role in determining the composition of the megabenthic assemblages (Genin *et al.*, 1986; Bo *et al.*, 2011) by generating different silting levels which may in turn influence settling rates and food availability.

As understanding of the geologic processes that form seamounts and their distribution has improved, the strict 1000 m relief limitation was relaxed and the geological literature now routinely applies the term 'seamount' to much smaller structures (down to a few tens of metres). Studies of seamount populations reveal that their size–frequency distributions are continuous with no obvious break. Thus, seamounts do not have a clear lower-size limit, making any size-based criteria for defining them arbitrary. Consequently, the term 'seamount' has been applied more generally to topographic 'hill' elevations regardless of size and relief (Epp and Smoot, 1989; Rogers, 1994; Pitcher *et al.,* 2007).

Nevertheless, until recently, the debate on the definition of the word seamount does not seem to be resolved. Harris *et al.* (2009) and Williams *et al.* (2009) have argued about the distinction between the term seamount. According to Harris *et al.* (2009) smaller features such as knolls, banks, or pinnacles may have a range of different geological origins and compositions and may not reflect clear ecological differences. Thus, consistent terminology and definitions are crucial when used in a comparative approach (e.g. to evaluate the methods and outcomes used during a Marine Protected Area planning phase). They also suggest that, although the specification of 1000 m elevation in the geological definition of a seamount might be arbitrary, the actual difference in the height of a feature above the surrounding seabed is likely to have important ecological implications. For example, seamounts act as obstacles to oceanic flow, causing local upwelling and eddy formation and lower-relief features such as knolls and pinnacles are unlikely to have the same oceanographic influence. Consequently, grouping seamounts and smaller features together is an example of false homogeneity.

On the other hand, Williams *et al.* (2009) have grouped seamounts, knolls, and pinnacles together, referring to them all as seamounts. According to these Authors, relief is not a generally applicable characteristic to biodiversity via mechanisms such as Taylor columns, because local-scale hydrodynamic processes are complex and depend on other factors, especially seamount depth and the effects of surface forcing. Conversely, more complex classifications (e.g. Rowden *et al.,* 2005) show that many other physical aspects contribute to an ecologically meaningful definition. For these reasons, Williams *et al.* (2009) used the term seamount in a generic sense. This follows convention from the US Board on Geographic Names, which pre-dates the 1000-m criterion of Menard (1964), and defines seamounts to include "submarine elevations of mountain form whose character and depth are such that the existing terms bank, shoal, pinnacle, etc. are not appropriate".

About this aspect, Pitcher *et al.* (2007) confirmed that the geological literature routinely applies the term seamount to much smaller structures (down to a few tens of metres), and noted that size-based criteria for defining seamounts are arbitrary. In a recent review of seamount characteristics, Wessel (2007) stated that "there are no geological reasons to separate smaller seamounts from their taller counterparts". However, the key question here is not which of several subjective geological classifications is correct, but instead which classification of geological information will be the most useful for describing and communicating patterns in biodiversity. This is the key area that needs to be emphasized and is the key area that will drive this area of science forward to contribute more effectively to national and international conservation efforts.

As there is no "generally accepted" definition and because seamount researchers begins to coalesce into one broad, multidisciplinary research community, Staudigel *et al.,* (2010a), stressed that it is important to: (1) have a simple definition that explains which features are included under the umbrella of seamount research and which are not, providing an essential condition for defining the seamount research community, and (2) respect and be aware of differences among disciplinary definitions, as they may stand in the way of consistently applying one disciplinary data set to another.

Geoscientists define seamounts as constructional features, so that formation processes are at the heart of their views and definition. Biologists define seamounts as habitats that are controlled by specific ocean environments, including the shape and summit depth of the feature studied. Staudigel *et al.* (2010a), in accordance with Schmidt and Schminke (2000), have combined these diverse perspectives under one inclusive umbrella definition that describes seamounts as: *any geographically isolated topographic feature on the seafloor taller than 100 m, including ones whose summit regions may temporarily emerge above sea level, but not including features that are located on continental shelves or that are part of other major landmasses.*

This definition is useful for the community of seamount scientists but it can be too broad to serve as an effective functional definition for many disciplinary studies.

As we explore the major differences among definitions of the term "seamount," several important issues play a role:

— *The inclusion of the temporarily emergent portions of seamounts* is relatively obvious for geologists who look at seamount construction over long time scales. Many large seamounts either have summit regions that currently breach sea level, or at some point they emerged as on oceanic island and are now entirely submerged. Hence, temporary emergence is part of the life cycle of many very large seamounts, even if it must be said that as soon as a seamount has reached a critical size, subsidence of the oceanic crust onto the mantle becomes the dominant process (Watts, 2001). The inclusion of emerged summits, however, is counter intuitive for a biologist. Biological communities on land are dramatically different from submerged communities and, hence, data from the emerged fractions of a seamount cannot be reasonably included into a focused marine biological study.

— There is much discussion about the *minimum size cut-off of a feature to warrant the use of the term seamount*. Menard (1964) originally suggested 1000 m as a minimum size, recognizing that under some circumstances, it is difficult to distinguish some smaller seamounts from seafloor roughness. The same 1000 m-height requirement is also included in the definition of the International Hydrographic Organization (IHO) and International Oceanographic Commission (International Hydrographic Organization, 2008). However, there are a large number of named seamounts that are much smaller than 1000 m and much of the current literature on the geology of seamounts proposes 100 m as a lower cut-off. This cut-off was chosen because features of this size can be recognized as individual volcanoes, in most cases. Smaller features may be called knolls, abyssal hills, abyssal peaks (International Hydrographic Organization, 2008), pinnacles, or pillars (Harris, 2007). It is also interesting to note that many smaller seamounts may be completely buried by sediments or digested into the oceanic lithosphere over geological time (Staudigel *et al.*, 2010c). Such buried seamounts cease to exist as a seafloor bathymetric features (like for example the case of the Bannock Seamount in the Ionian Sea) and, hence, they do not exist for oceanographers, biologists, and fisheries scientists. Yet, they may still present a significant gravity anomaly, so Wessel *et al.* (2010) include them in the seamount count and they remain significant features for geologists or geochemists who study their subduction and fluid flow.

— *Some seamount definitions also include aspects of their shape*, in particular, restricting their use to conical features, whereby flat-topped ("tablemount") seamounts are commonly called guyots. This morphological distinction is significant insofar as flat-topped seamounts are likely to once have been islands or coral reefs, while conical ones are likely to not to have breached the sea surface during their life cycle, because they do not show signs of erosion (Staudigel and Clague, 2010).

— In their original definition, *seamounts were defined based on their tectonic setting*, specifically, as features on the seafloor that are not part of mid-ocean ridges or subduction zones (Menard, 1964). This limitation to intraplate volcanoes pays tribute to the distinct magmatic processes that form volcanoes at mid-ocean ridges, arc volcanoes, and in intraplate settings. Wessel *et al.* (2010) restrict their use of the term seamount to intraplate features, excluding arc volcanoes in their seamount count.

Although the above examples are not meant to be comprehensive, they demonstrate that there are important nuances in the way the term seamount is used in different seamount science disciplines. Those differences have to be considered when correlating data from one discipline to another, and much care has to be applied when working in such an interdisciplinary context. Staudigel *et al.* (2010a) emphasized that their umbrella definition is useful in defining what seamount sciences are about, but it does not replace the definitions used by individual science disciplines.

Finally, since the term "seamount" is variably used by marine scientists (Staudigel *et al.,* 2010a), in this review the term seamount defines "any geographically isolated topographic feature on the seafloor taller than 100 m, including ones whose summit regions may temporarily emerge above sea level, but not including features that are located on continental shelves or that are part of other major landmasses" (Iyer *et al.*, 2012). But generically, any conical or steep volcanic feature is referred to as a seamount and these may be or may not be volcanically active.

## Making of the Atlas

The EMODnet gridded bathymetry of the Mediterranean seafloor with a grid spacing resolution of 450 m (1) has been used as reference for the seamount map drawing, shallower peak (summit) locations, summit and base depth estimations. The Mediterranean basins have been divided into the five regions, mostly according to the EMODnet subdivision and the official names of the sea regions provided in the GEBCO Gazetteer, with minor changes:

1. Alborán Sea
2. Western Mediterranean
3. Tyrrhenian Sea
4. Sardinia Channel - Strait of Sicily - Ionian Sea - Adriatic Sea
5. Eastern Mediterranean

As it has been already stressed, in this Atlas the term "Seamount" identifies an elevation rising at least 100 m from the surrounding seafloor, consequently it encompasses a wide set of underwater features, which are described and classified by the Intenational Hydrographic Organization (2013) as *Bank, Guyot, Hill, Knoll, Mound, Peak, Reef, Ridge, Rise, Seamount, Shoal, Spur,* and the more generic terms such as *High, Structural High, Dome* and *Volcano* (2).

The mud volcanoes, even if rising > 100 m from the seafloor, have been generally not considered; for example the new mud volcanoes discovered in the Tyrrhenian Sea by Rovere *et al.* (2014) have been omitted. The only exception has been made for the Granada Mud Volcano in the Alborán Sea. On the other hand, only elevations outside the legal continental shelf limits have been presented in the Atlas, very few exceptions were made, such as the Amendolara Bank in the northern Ionian Sea, due to their relevance and current state of knowledge. Sovereign rights over the continental shelves are conventionally fixed at 200 m water depth by the Convention on the Continental Shelf drawn up by the UNCLOS in 1958; because of this limit, some important elevations have been excluded from the list (e.g. El Babouche Bank on the northern Tunisian margin), also others that have geological relation to canyons and to erosional and depositional processes at the shelf edge have been left out (e.g. Haut-Fond du

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1 http://www.emodnet-hydrography.eu/content/content.asp?menu=0310019_000000

2 http://www.gebco.net/data_and_products/undersea_feature_names/

Mejean on the southern French margin[3]). It is worth mentioning that an homogeneous picture of the detailed bathymetry of the continental shelves is not available for the entire Mediterranean. The mapping of bathymetric depths < 200 m is indeed extremely time consuming and requires expensive marine technology, not equally owned and accessible among the 22 states overlooking the Mediterranean Sea. Also the resolution of 500 m, that we have adopted from the EMODNet compilation, is not sufficient for describing the morphological features that characterize the continental shelf. For the sake of homogeneity and consistency, we thus preferred to mapping exclusively those structures that are located downslope the continenatl shelf, with the exception of the shallow water sectors of the Sardinia Channel and the Strait of Sicily.

A great part of the seamount names have been obtained from scientific literature or from other official sources such as charts, maps and inventories by GEBCO ([4]). In some cases, it was retained the name commonly used by professional and sport fishermen for the well-known elevations, still officially nameless (e.g. “Occhiali Seamount”, Ligurian sea, in the Western Mediterranean Section). This probably proved to be one of the biggest tasks in making the Atlas, because the recommendations and the efforts to homogenize the “toponomy” of the oceans made by IOC and IHO are completely unattended by scientists and geographers, and confusion reigns in the undersea feature names realm. The same structure is often known with at least three different names, as is the case of the seamounts in the Balearic Promontory (*e.g.* Ausiás March, Ses Olives), where the structures can be referred to with their Catalan, Spanish and English names. Some degree of confusion may arise when the structures are addressed both with their national language name and the English translation (*e.g.* Kolumbo vs Columbo Volcano in the Aegean Sea).

Each seamount location has been identified by the geographic coordinates of its summit (or shallower peak), within the WGS84 system and handling the EMODnet grid data by Surfer 11 software. Coordinates are given following the international ISO 6709 standard representation of geographic point location [first horizontal coordinate (x), such as latitude, second horizontal coordinate (y), such as longitude]. The coordinates are expressed in decimal degrees with a precision of five decimals, because all the geographical software require nowadays this kind of input and we wanted to make the Atlas information as much easily accessible as possible.

Several geographic positions of the seamount summits are reported in the scientific literature or are available from the Author’s observations. In these cases the coordinates have been reported without modifications, even if the location doesn’t fit the EMODnet bathymetry.

The peak depth (m) has been estimated from EMODnet bathymetry at 10 m depth interval, when no official data were available. Swath bathymetry from multibeam echosounding surveys is now available for some large Mediterranean areas, in this case it was possible to obtain more reliable seamount summit depth data. When available from this kind of sources, the summit depth is reported as single value. In the EMODnet compilation, when no survey data are available in a certain region, the GEBCO (General Bathymetric Charts of the Oceans, www.gebco.net) data are used instead.

The seamount base depth (m) estimation may be controversial because the irregular morphology of the seamount and the seafloor inclination. Mostly the base depth has been estimated from the EMODnet bathymetry by considering value of the deepest closed bathymetry line (ring) around the seamount summit (Fig. 1). In this case, the base depth is reported as 10 m depth interval.

When available from scientific literature or from Author’s observations (i.e. swath bathymetry from multibeam systems) the depth of the seamount base has been reported as single value or a couple of values, indicating the shallower and the deeper values of the base depth.

Information about geology, benthic communities and pelagic habitat have been summarized taking into account the seamount origin, type and morphology, recent observations and data obtained from ROV surveys, bottom fish surveys, cetacean acoustic and visual surveys as well as information coming from professional and sport fishermen. Most of the pelagic habitat descriptions of the Tyrrhenian seamounts are obtained from the unpublished interim report of the IUCN-Med Prometeos project.

Some seamounts have an official name, but no data are available about its geology, in these cases it has been quoted the source from which it possible to find the seamount name (maps, charts, websites, etc.).

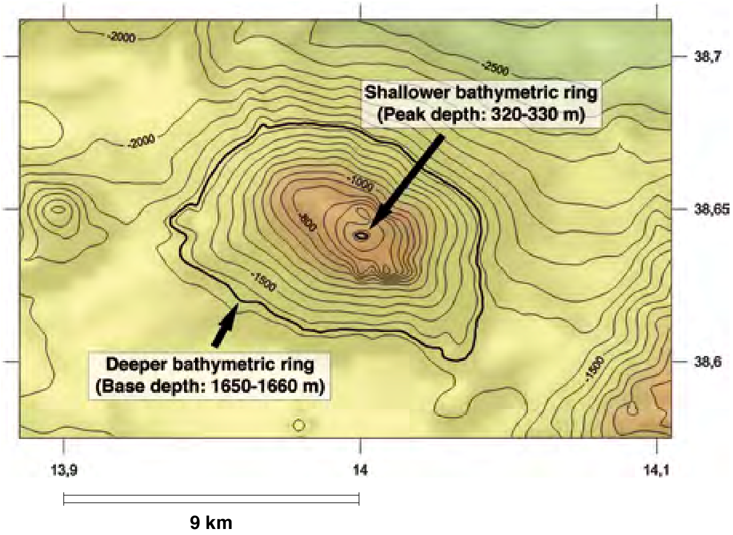

**Fig. 1:** Enarete Seamount, Tyrrhenian sea. Example of the peak and base depth estimation from the EMODnet bathymetry data by Surfer 11 software. Note the deeper bathymetry ring, which identifies the seamount base.

Scale bar. The length in km of a degree of longitude have been estimated for the mean latitude value of each seamount position (See the website: http://www.csgnetwork.com/degreelenllavcalc.html).

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[3] ftp://ftpaamp.aires-marines.fr/MEDSEACAN/Rapport_Final_MEDSEACAN.pdf

[4] http://www.geomapapp.org/database/GEBCO/GEBCO_gazetteer.htm

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# 1. Seamounts and Seamount-like Structures of the Alborán Sea

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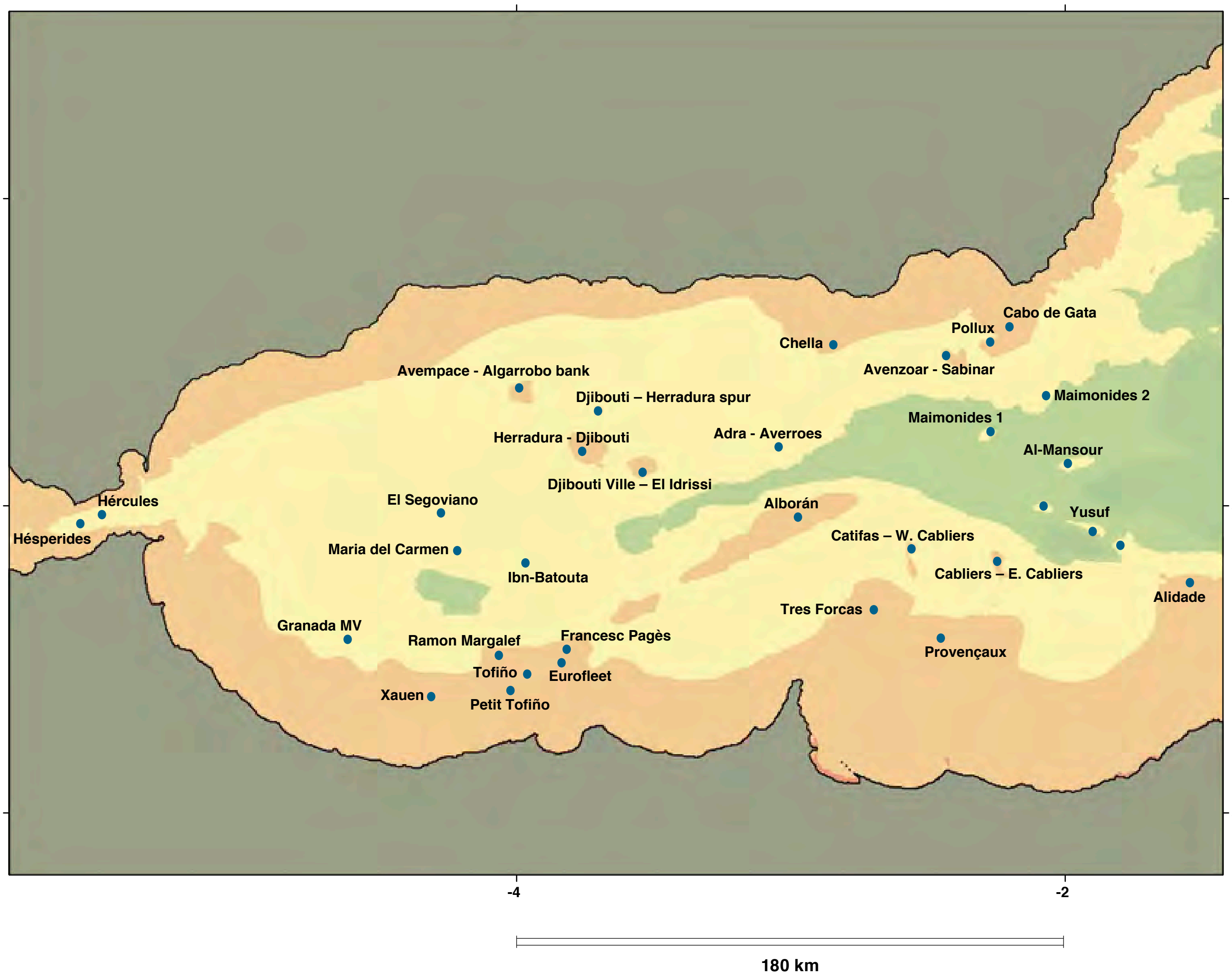
**Table 1: Seamounts and Seamount-like Structures of the Alborán Sea.**

| Seamout name | Lat. ° | Long. ° | ▲ Peak depth (m) | Base depth (m) | Page |
|---|---:|---:|---:|---:|---:|
| **Adra - Averroes Ridge** | 36.19175 | -3.04489 | 580-590 | 900-910 | 24 |
| **Al-Mansour High** | 36.14442 | -1.93284 | 1067 | 1831-1900 | 25 |
| **Alborán Ridge** | 35.96310 | -2.97440 | 30-40 | 590-600 | 26 |
| **Alidade Bank** | 35.74980 | -1.54550 | 280-290 | 390-400 | 27 |
| **Avempace - Algarrobo Bank** | 36.38370 | -3.99090 | 270 | 710 | 28 |
| **Avenzoar - Sabinar Bank** | 36.48890 | -2.43440 | 280 | 720 | 29 |
| **Cabliers - East Cabliers Bank** | 35.81910 | -2.24810 | 220-230 | 590-600 | 30 |
| **Cabo de Gata Spur** | 36.58270 | -2.20330 | 100 | 160 | 31 |
| **Catifas - West Cabliers Bank** | 35.85980 | -2.56050 | 350 | 1000 | 32 |
| **Chella Bank** | 36.52424 | -2.84548 | 70 | 700 | 33 |
| **Djibouti - Herradura Spur** | 36.30880 | -3.70330 | 430 | 740 | 35 |
| **Djibouti bank - Herradura Seamount** | 36.17720 | -3.76110 | 270 | 680-690 | 36 |
| **Djibouti Ville - El Idrissi Bank** | 36.10910 | -3.54080 | 230 | 640-650 | 37 |
| **El Segoviano Hill** | 35.97680 | -4.27597 | 1125 | 1309 | 38 |
| **Eurofleet Seamount** | 35.49242 | -3.82350 | 115 | 250-290 | 39 |
| **Francesc Pagès Seamount** | 35.53274 | -3.81764 | 96 | 500 | 40 |
| **Granada Mud Volcano** | 35.56513 | -4.61609 | 583 | 755 | 41 |
| **Hércules Seamount** | 35.97120 | -5.51190 | 450-460 | 640-650 | 42 |
| **Hésperides Seamount** | 35.94180 | -5.59080 | 460-470 | 630-640 | 43 |
| **Ibn-Batouta Bank** | 35.80678 | -3.96800 | 770 | 1296-1314 | 44 |
| **Maimonides Seamount 1** | 36.22885 | -2.28539 | 1450 | 1675-1910 | 45 |
| **Maimonides Seamount 2** | 36.34745 | -2.05960 | 1211 | 1370-1640 | 45 |
| **Maria del Carmen Hill** | 35.85394 | -4.21657 | 1006 | 1407 | 46 |
| **Petit Tofiño-Petit Xauen Seamount** | 35.40175 | -4.01581 | 98 | 350-400 | 50 |
| **Pollux Bank** | 36.53310 | -2.27370 | 300 | 600 | 47 |
| **Provençaux Bank** | 35.56909 | -2.45369 | 200-210 | 280-290 | 48 |
| **Ramon Margalef High** | 35.50325 | -4.04498 | 235 | 430-440 | 49 |
| **Tofiño Seamount** | 35.45921 | -3.94600 | 68 | 400 | 50 |
| **Tres Forcas Ridge** | 35.66150 | -2.69790 | 170-180 | 380-390 | 51 |
| **Xauen Bank** | 35.36959 | -4.32822 | 98 | 400-490 | 52 |
| **Yusuf Ridge 1** | 35.99910 | -2.07900 | 1180-1190 | 1580-1590 | 53 |
| **Yusuf Ridge 2** | 35.91638 | -1.89988 | 1400-1410 | 1560-1570 | 53 |
| **Yusuf Ridge 3** | 35.87130 | -1.79890 | 1000-1010 | 1230-1240 | 53 |

**Seamounts and Seamount-like Structures of the Alborán Sea: general map.**

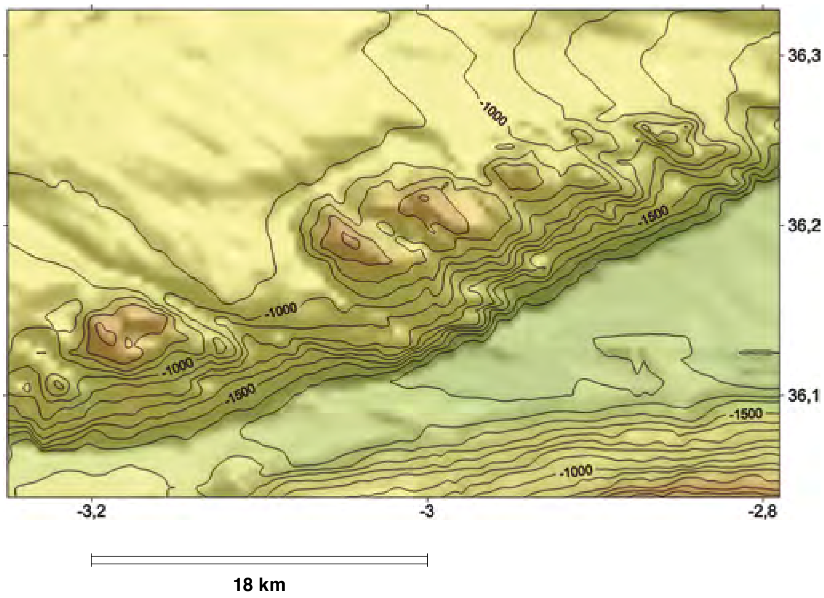


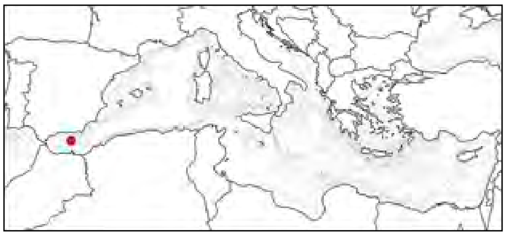
The Alborán Sea is a narrow basin surrounded by and developed on an orogenic belt that straddles the boundary between Africa and Europe, the Betic-Rif Chain. Like all other sea regions of the Mediterranean Sea, the Alborán Sea evolved in the general frame of slow convergence between Africa and Europe that commenced about 130 Ma, as a consequence of the opening of the North Atlantic Ocean, and is still active today along a complex plate boundary that encompasses and influences all of the Mediterranean region. The opening of the Alborán Sea started about 22 Ma by stretching of continental crust, but oceanization never occurred there and thinned continental crust now paves the basin. Between 15 and 12 Ma, other rifting episodes caused additional crustal thinning and triggered mud diapirism, as for example in the Granada Mud Volcano. When the rifting ended in the late Miocene, a N-S oriented contraction occurred involving folding and strike-slip faulting, then the Alborán basin collapsed and the surrounding areas were uplifted. Therefore most of the seamounts and banks that characterize the Alborán Sea are due to tectonic vertical movements and volcanism active during the continental stretching (Comas *et al.,* 1992). The opening of this sea region, analogously to what is supposed to have happened also in the Tyrrhenian Sea, was due to a slab roll back of the subducting oceanic crust of the ancient Tethys Ocean beneath Europe (Lonergan and White, 1997). Once the oceanic crust had been consumed, Africa and Europe collided and the mountain chains of Alps, Carpathians and Balkans were formed.

**STRUCTURE:**

## Adra - Averroes Ridge

▣ **Location:** 36.19175°N – 3.04489°W
▲ **Peak depth (m):** 580-590 ◮ **Base depth (m):** 900-910





**DESCRIPTION:**

### Geology

The Adra Ridge extends for 25 km with a NE-SW direction and it borders the Alborán channel. The top is situated at 580 m and rises 320 m from the sea bottom. The Alborán Basin and the structural highs were formed in an extensional backarc suite in the Late Oligocene and Miocene (Platt *et al.*, 2003), but it was the last compressive phase that produced a structural uplift of previous morphological highs.

### Life on and around the Seamount

No information about the Adra Ridge benthic communities has been found in the scientific literature.

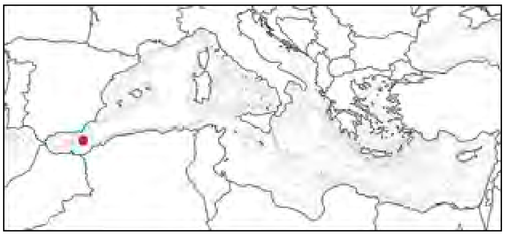
Cetaceans are very common in the Alborán Sea where high number of species occurs such as: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Ziphius cavirostris, Physeter macrocephalus (= P. catodon)* and *Balaenoptera physalus*. The area is also of importance for marine turtles (*Caretta caretta, Dermochelys coriacea*) and large pelagic fishes (*Thunnus thynnus*) because it is situated within their migratory pathway (Robles, 2007; IEO-CSIC-MAGRAMA *et al.*, 2012; Cañadas, 2014).

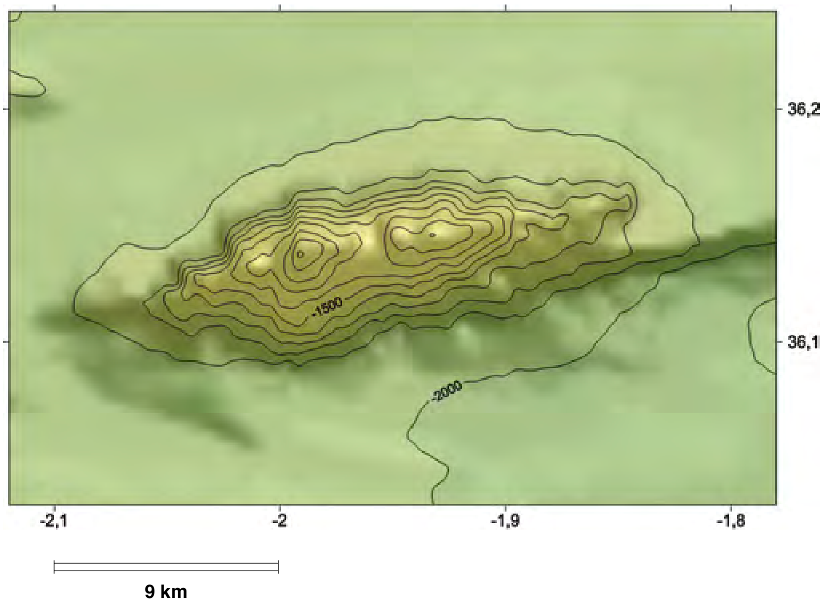
**STRUCTURE:**

# Al-Mansour Seamount

▣ **Location:** 36.14442°N – 1.93284°W

▲ **Peak depth (m):** 1067 **Base depth (m):** 1831-1900





**DESCRIPTION:**

## Geology

The Al-Mansour Seamount is an isolated structure in the Eastern Alborán Basin. Multibeam bathymetry shows it to be an ENE-WSW trending elliptical seamount, ~ 129.6 km-long, 7 to 2 km-wide, and with a basal of area of 98 km$^2$. A narrow and irregular summit with two major peaks caps the seamount, the western peak being the shallowest (976 m). Its flanks are quite similar in slope gradients and relief. The southern flank has an average gradient of 10° with a relief of 838 m; the northern flank is slightly steeper, with average of 16°, and it has a relief of 709 m.

The Al-Mansour Seamount is volcanic and Tortonian age rocks have been sampled from it (Duggen *et al.,* 2004; Gill *et al.,* 2004), as well as Miocene lavas, possibly thoelitic to andesitic in composition (Duggen, 2008). The seamount is bounded by normal faults (Martínez *et al.,* 2013) and its formation has favored the generation of two major troughs trending NE-SW to ENE-WSW in the Western Alborán Basin. The volcanic basement is partially overlain by a Plio-Quaternary cover of variable thickness (< 510 ms).

## Life on and around the Seamount

Deep water *Desmophyllum dianthus* corals have been found on this seamount (Schörder-Ritzrau *et al.,* 2003).

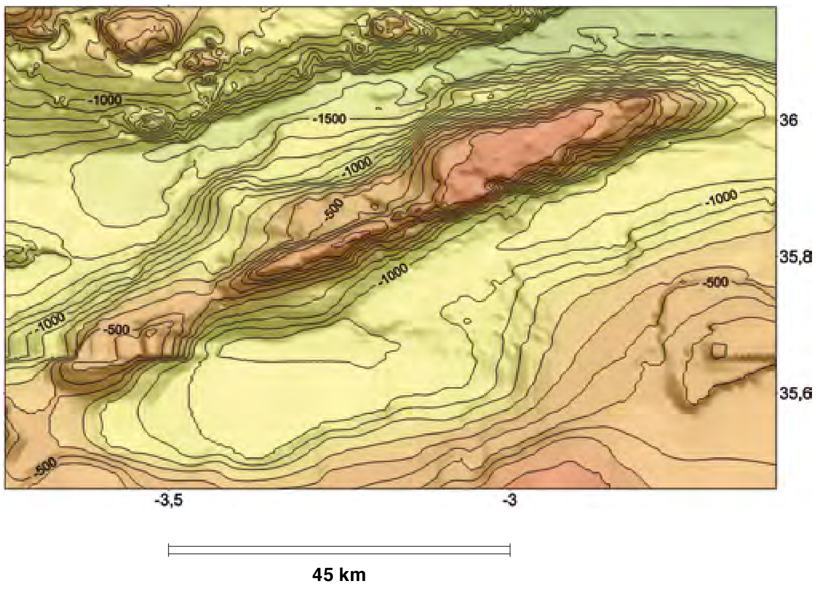
No information about the Al-Mansour Seamount pelagic communities has been found in the scientific literature.

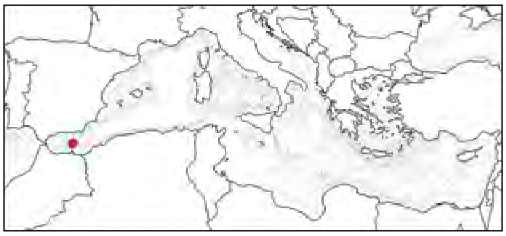
**STRUCTURE:**

## Alborán Ridge

▣ **Location:** 35.96310°N – 2.97440°W

▲ **Peak depth (m):** 30-40 ▲ **Base depth (m):** 590-600





**DESCRIPTION:**

### Geology

The Alborán Ridge crosses the Alborán Sea Basin and it extends for 100 km with an ENE-WSW direction. The top of the ridge is relatively flat (0.4-2°) but is very irregular and locally reaches 5°. It is dominated from 60 m water depth by the rhombohedral elevation of the Alborán Island, with numerous erosive terraces, ridges, depressions, tectonic scarps, as well as solitary and fields of sedimentary waves (Bárcenas *et al.,* 2004a, 2004b). Mass-transport deposits (from slides to turbidites) are developed on the southern flank (Vázquez *et al.,* 2010) and two NNW-SSE canyons are differentiated.

Others processes related to water mass dynamics include the presence of an isolated continental shelf characterised by carbonate sedimentation, particularly coralline algae and rodoliths (Milliman *et al.,* 1972; Bárcenas *et al.,* 2001) related to the Atlantic Water flow and sea level oscillations. On the Alborán Ridge, volcanism dates from 9.4 to 9.3 Ma, indicating that part of this high was an active volcanic edifice during the Late Miocene (Fernández Soler *et al.,* 2000; Duggen *et al.,* 2004; Duggen *et al.,* 2005). The Alborán Ridge was formed as a tectonic relief, uplifted by means of folding and laterally-compressive processes (Bourgois *et al.,* 1992; Woodside and Maldonado, 1992).

### Life on and around the Seamount

In the frame of the LIFE+INDEMARES project the fauna from the deep shelf of the Alborán Ridge was investigated using a combination of ROV surveys and collecting devices. They reveal that sponges are relevant or dominant benthic organism in three major habitats of the deep shelf: the rodolith beds (60-100 m), the rocky plains (80-120 m) and the isolated rocky outcrops surrounded by soft sediments. The rocky outcrops standing out from soft bottoms provided an optimal substrate for suspension feeders, often hosting a large variety of sponges, cnidarians, brachiopods, molluscs, sabellid tube worms, ascidians, etc. Large areas of the deep shelf were covered with soft bottom, particularly on the north side of the island. The substrate mostly consisted of coarse sand mixed with calcareous gravel, more rarely incorporating a low proportion of mud (Sitjá and Maldonado, 2014). Other investigations with ROV observations and box corer samples at the northern flank of the Alborán Ridge have revealed large benthic communities. The base of the ridge is dominated by polychaetes, benthic foraminifers and cerianthids as major elements. Areas with coral rubbles (*Dendrophyllia cornigera*, *Lophelia pertusa* and *Madrepora oculata*) covering soft sediment show scarce benthic life. Live *Lophelia* colonies appeared at 404 m depth attached to fossil corals. Hard substrate served as colonization ground for oysters (*Spondylus gussoni* and *Neopycnodonte zibrowii*) and sponges, crinoids, cidaroid urchins and squat lobsters. Near the shelf, the fossil maërl and rodololithes are predominant with bryozoans and mollusc facies. The fish and shark species were recorded: *Arctozenus risso*, *Helicolenus dactylopterus*, *Nezumia* sp., *Pagellus bogaraveo, Phycis blennoides, Trachyrincus scabrus* and *Scyliorhinus canicula*, *Scyliorhinus canicula* (Hebbeln *et al.,* 2009).

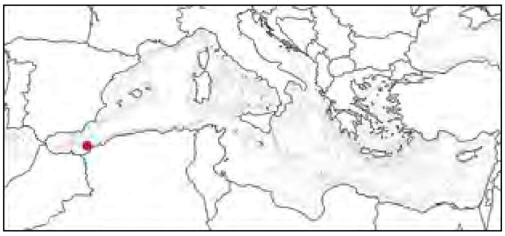
Cetaceans are very common in the Alborán Sea where high number of species occur such as: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Ziphius cavirostris, Physeter macrocephalus* (= *P. catodon*) and *Balaenoptera physalus.* The area is also of importance for marine turtles (*Caretta caretta, Dermochelys coriacea*) and large pelagic fishes (*Thunnus thynnus*) because it is situated within their migratory pathway (Robles, 2007; IEO-CSIC-MAGRAMA *et al.,* 2012; Cañadas, 2014).

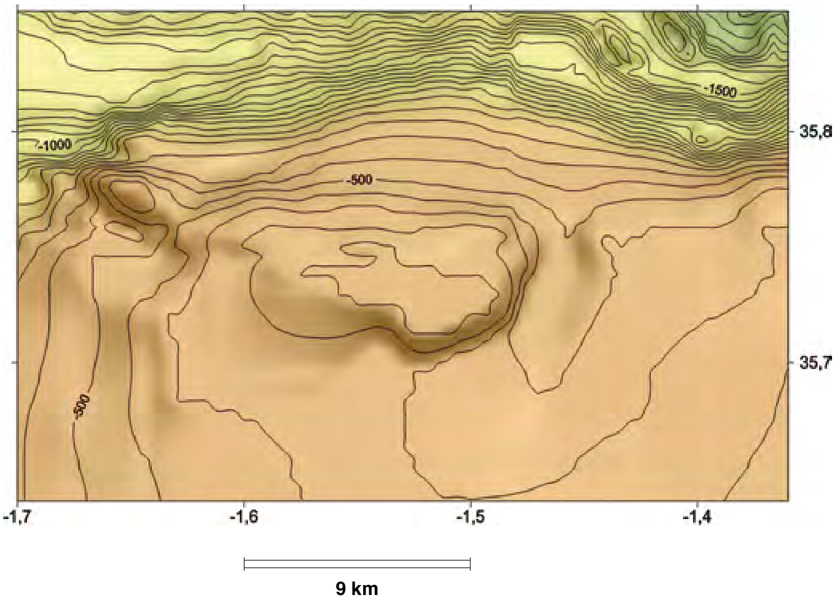
**STRUCTURE:**

## Alidade Bank

▣ **Location:** 35.74980°N – 1.54550°W

▲ **Peak depth (m):** 280-290 ⋀ **Base depth (m):** 390-400





**DESCRIPTION:**

### Geology

The Alidade Bank has an elongated shape and extends with a WNW-ESE direction. It is associated with magnetic anomalies induced by the volcanic materials (Galdeano *et al.,* 1974).

### Life on and around the Seamount

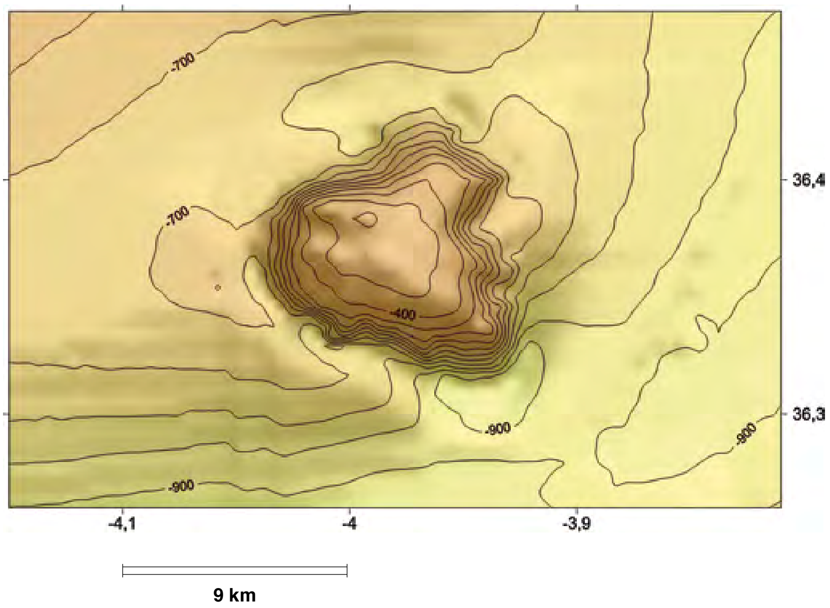
The Alidade Bank was known as fishing hot spot for groupers, spiny lobsters and other valuable commercial benthic species, unfortunately from early 'nineties, powerful and fast boats have started to fish by using new technologies, consequently in that undisturbed site, fishing collapsed in few years (Chalabi, 2012).

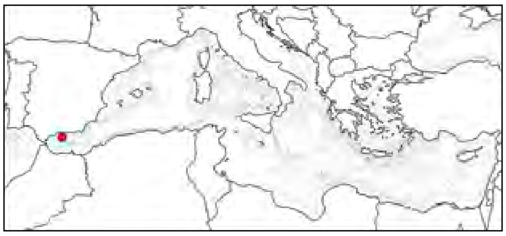
Several species of marine turtles and cetaceans have been documented as *Caretta caretta*, *Tursiops truncatus, Stenella coeruleoalba, Delphinus delphis, Ziphius cavirostris* and *Globicephala melas.* Also it is an important feeding area for locally breeding bird populations (Sergeant *et al.,* 1978; Marin *et al.,* 2012).

**STRUCTURE:**

# Avempace - Algarrobo Bank

**Location:** 36.38370°N – 3.99090°W
**Peak depth (m):** 270 **Base depth (m):** 710





**DESCRIPTION:**

## Geology

The Avempace Seamount shows a cone-truncated geometry with the top at 270 m water depth and a relief of 440 m. The top is relatively flat (0°-5°) and the flanks display high slope gradients of up to 53° and are crossed by gullies that are radially oriented relative to the summit. Scars affect the eastern and southern flanks of the seamount at depths of 300-500 m. It is surrounded by sedimentary features that have been interpreted in relation to the interference with bottom currents (Palomino *et al.,* 2011). The Alborán Basin and the structural highs were formed in an extensional backarc suite in the Late Oligocene and Miocene (Platt *et al.,* 2003), but it was the last compressive phase that produced a structural uplift of the previous morphological highs as the Avempace Seamount.

The Avempace Seamount was dredged during the 9th UNESCO/IOC cruise and one large boulder of gneissic rock was sampled, in addition to abundant coral fragments, serpulid and Mn crusts. The sample probably corresponds to a fallen block on the slope of the basement high, as is revealed by its shape and the occurrence of a complete cover of oxide crusts and biota colonization (Kenyon *et al.,* 2000).

## Life on and around the Seamount

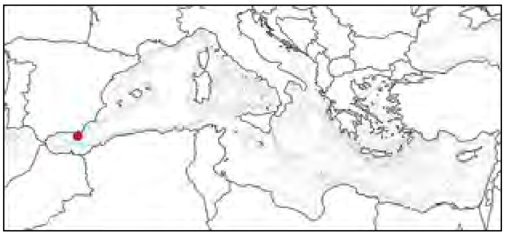
Outcropping ridges and superimposed biogenic structures composed of carbonate-rich sediments were found on the summit of the Avempace Seamount (Palomino *et al.,* 2011). During expeditions of the DEEPER project it was observed to be composed mostly of dead cold water corals *(Lophelia pertusa*, *Madrepora oculata*, *Desmophyllum* sp. and *Caryophyllia smithii)* and carbonate shelled benthic fauna (Gil *et al.,* 2009b). Surficial sediments were also composed of bioclastic glauconitic-rich muddy sand. Benthic and demersal species are quite diverse and are dominated by crinoids (*Leptometra phalangium*), followed by crustaceans (*Ebalia nux*, *Plesionika antigai*, *Lophogaster typicus*), molluscs (more than 150 spp. and dominated by *Limopsis aurita* and *Yoldiella philippiana*), fishes (*Gadiculus argenteus*, *Basthysolea profundicola, Hoplostethus mediterraneus*, *Galeus atlanticus, Galeus melastomus*), and echinoderms (echinoids and holothurians) (Gil *et al.,* 2009a, 2010; Gofas *et al.,* 2011; de Mol *et al.,* 2011).

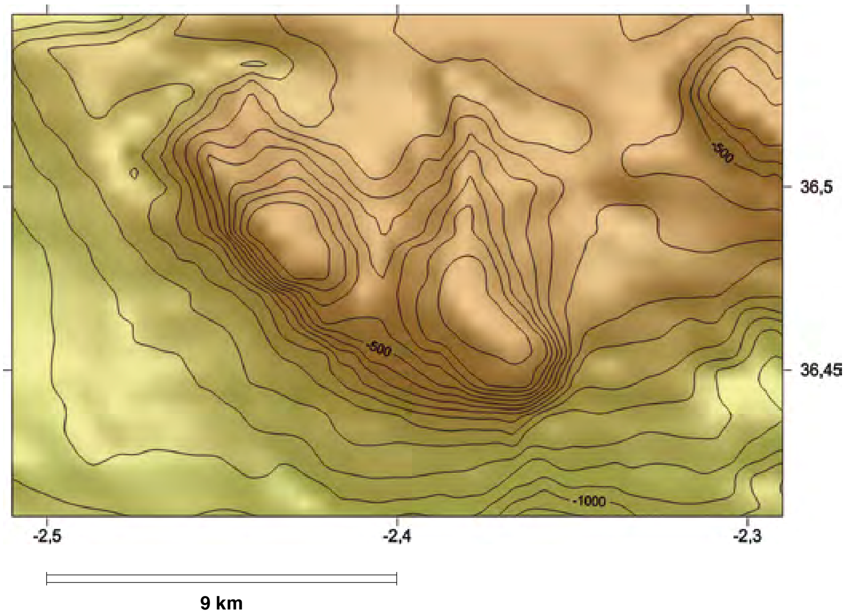
Cetaceans are very common in the Alborán Sea where high number of species occurs such as: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Ziphius cavirostris, Physeter macrocephalus (= P. catodon)* and *Balaenoptera physalus*. The area is also of importance for marine turtles (*Caretta caretta, Dermochelys coriacea*) and large pelagic fishes (*Thunnus thynnus*) because it is situated within their migratory pathway (Robles, 2007; IEO-CSIC-MAGRAMA *et al.,* 2012; Cañadas. 2014).

**STRUCTURE:**

# Avenzoar - Sabinar Bank

◘ **Location:** 36.48890°N – 2.43440°W
▲ **Peak depth (m):** 280 **Base depth (m):** 720





**DESCRIPTION:**

## Geology

The Sabinar Bank, also named “Avenzoar Bank”, is a flat-topped volcanic bank situated in the Eastern Alborán Sea, 4.5 km from the Almería Channel. It occurs along the upper slope of the Almeria Margin, showing a subcircular shape and developing within a depth range of 280-720 m (García *et al.,* 2006; Gràcia *et al.,* 2006; Lo Iacono *et al.,* 2008). The Sabinar Bank is the morphological expression of middle Miocene to Pleistocene calc-alkaline K-rich volcanic rocks, related to the subduction of the Tethys oceanic lithosphere into the mantle wedge beneath the Alborán tectonic block (Duggen *et al.,* 2004). The Bank displays two main morphological highs, from 280 to 400 m deep, oriented along a NNW-SSE direction, separated by a narrow N-S oriented 500 m-deep trough. The depth of the base ranges from 700 to 800 m. Its flanks, displaying an alternation of low and high acoustic backscatter values, reach a maximum gradient of 25°. Small scale landslides were observed along the southern foot of the Sabinar Bank (Estrada *et al.,* 1997; Lo Iacono *et al.,* 2008; Alonso *et al.,* 2014). The slide scar system, ranging in depth from 1000 m to 1300-1500 m, suggests dismantlement of the margin by retrogressive mass movements, probably promoted by friable lithology and by the steepness of the flanks of the volcanic high (Gràcia *et al.,* 2006; Lo Iacono *et al.,* 2008; Alonso *et al.,* 2014). The low acoustic seafloor backscatter values along the scar system and the presence of shallow semi-transparent seismic facies indicate that most of the scars are buried and draped by recent sediments (Lo Iacono *et al.,* 2008). On the Sabinar Bank tops are characterized by a smooth seafloor and show particularly low backscatter values. Diffused low backscatter facies observed on its top correspond to fine sediments, as evidenced by the groundtruthing seafloor samples and the seismic records acquired in the area (Lo Iacono *et al.,* 2008). The reason of draping sediments could be due to an increase in fine sediment deposition related to the reduced distance of the Almería Turbidite System (García *et al.,* 2008). Unconfined suspended sediments from the shallower sectors of the Almería Canyon could be moved toward the Sabinar Bank by currents flowing from W and NW directions.

## Life on and around the Seamount

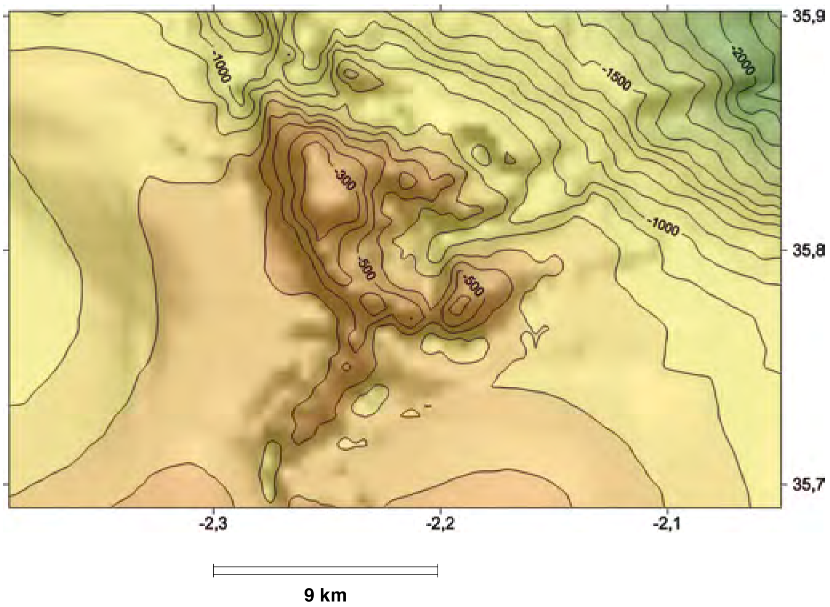
The Sabinar Bank is dominated by soft sediment benthic communitites, such as crinoids (*Leptometra phalangium*), shrimps (*Plesionika antigai, P. heterocarpus* and *P martia*), antozoans (*Cavernularia pusilla, Kophobelemnon stelliferum, Funiculina quadrangularis, Isidella elongata* and *Pennatula phosphorea*) and oloturians (*Parastichopus regalis* and *Mesothuria intestinalis*) (Pardo *et al.,* 2011). Dead reefs of *Dendrophyllia cornigera* have been also observed on the rocky areas of the Bank (Pardo *et al.,* 2011).

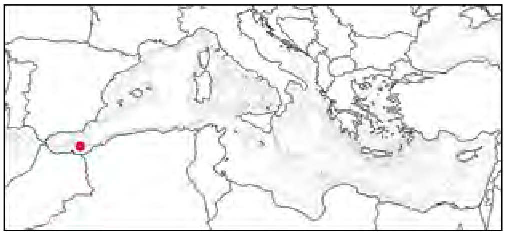
No information about the Sabinar Bank pelagic communities has been found in the scientific literature.

**STRUCTURE:**

## Cabliers - East Cabliers Bank

▣ **Location:** 35.81910°N – 2.24810°W
▲ **Peak depth (m):** 220-230 ⋀ **Base depth (m):** 590-600





**DESCRIPTION:**

### Geology

The Cabliers Bank appears on the Geomorphological Map of Spain, published by the Instituto Geológico y Minero de España (1). Although this structure has an official name, no geological information is available in the scientific literature.

### Life on and around the Seamount

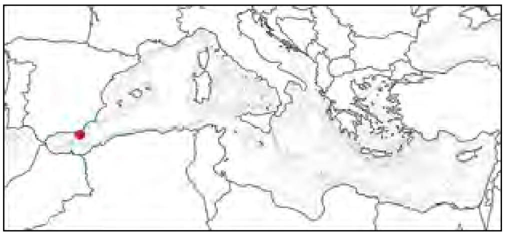
Cold-water corals such as *Desmophyllum dianthus*, *Stenocyathus vermiformis*, *Caryophyllia* sp. *Pourtalosmilia anthophyllites*, *Javania caileti*, *Anomocora fecunda*, and *Dendrophyllia* sp. together with the reef forming scleractinians *Lophelia pertusa* and *Madrepora oculata* (here present in exceptional abundance) have been reported on the Cabliers Bank (Aguilar *et al.*, 2013; OCEANA, 2014). Some fish species can be found in these reefs such as *Helicolenus dactylopterus*, *Coelorinchus caelorhincus*, *Pagellus bogaraveo* and *Conger conger*, as well as cephalopods (OCEANA, 2014). Hard-bottom gorgonian gardens and black coral forests as well as sponge grounds with the massive species *Asconema setubalense*, *Phakellia* sp., *Axinella* sp. and *Tenea muricata* were reported in the same ROV survey. Among the most interesting finding there are some rare cnidarians (*Anomocura fecunda*, *Anthomastus* sp., *Nidalia studeri*, *Dendrobrachia* sp., *Nicella granifera*, and *Sideractis glacialis*) (Aguilar *et al.*, 2013).

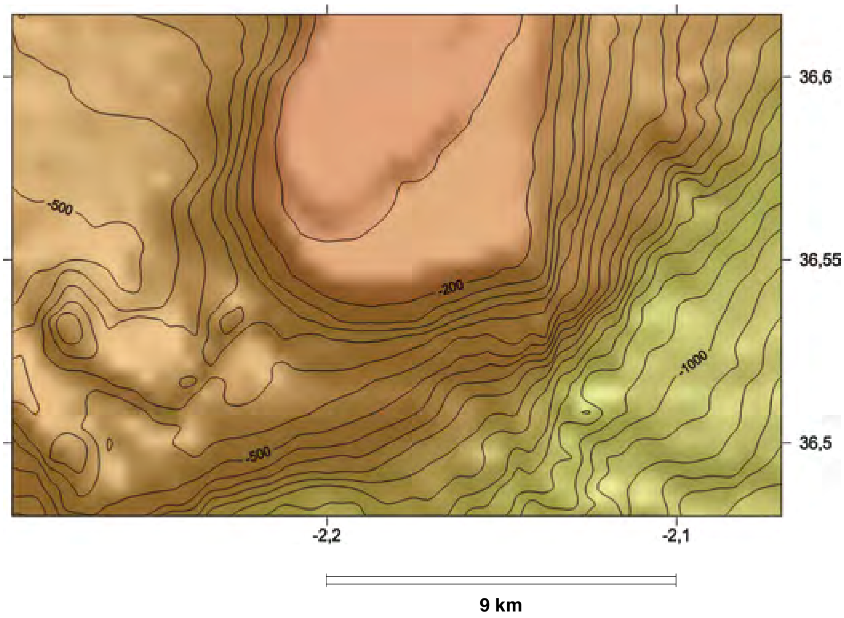
Various protected elasmobranches (*Oxynotus centrina*, *Centrophorus granulosus*, *Leucoraja circularis*, *Cetorhinus maximus*, *Squalus acanthias*) were observed on the Cabliers Banks (Aguilar *et al.*, 2013).

**STRUCTURE:**

# Cabo de Gata Spur

◘ **Location:** 36.58270°N – 2.20330°W
▲ **Peak depth (m):** 100 ⋀ **Base depth (m):** 160





**DESCRIPTION:**

### Geology

The Cabo de Gata Spur can be considered as the submerged geologic and morphologic prolongation of the De Gata Cape. It corresponds to a flat topped platform, 100-160 m in depth, developing along a N-S direction for a maximum length of 20 km and covering a surface of around 120 km$^2$ (Gràcia *et al.,* 2006; Lo Iacono *et al.,* 2008). Similarly to the surrounding volcanic banks (Pollux, Sabinar, Chella) it is composed of a Miocene to Pleistocene calc-alkaline through K-rich volcanic basement and is topped by thin carbonate platforms (Duggen *et al.*, 2004; Gràcia *et al.,* 2006). Some sectors of the spur are characterized by sub-horizontal terraces, observed at the depths of 120 and 150 m with maximum lengths of 4 km, probably formed in shallower environments during previous low stand sea level phases. The edge of the spur displays and abrupt morphology and is at depths between 150 and 160 m. The walls of the spur extend from the edge to depths of 400 m along the 9° steep western flank and 800 m along the 5° steep eastern flank. The western flank is characterized by linear rills and gullies, few meters incised and close to the more developed Gata Tributary Valley System (García *et al.,* 2006), whereas the eastern flank is characterized by wide slide scars at 300 m and 500-600 m.

### Life on and around the Seamount

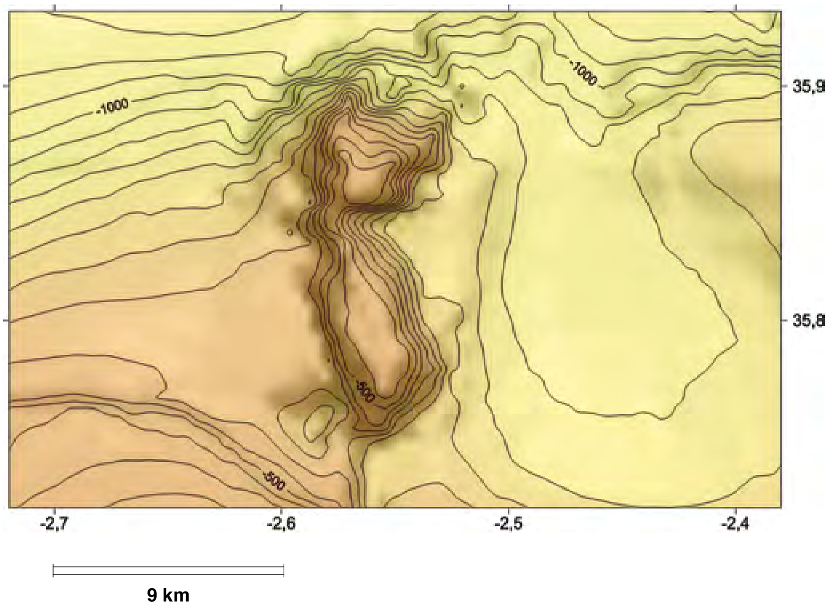
The Cabo de Gata Spur is the physical continuation of the Gata-Nijar natural continental and marine park, where extensive meadows of the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* have been mapped. The Gata-Nijar natural park is one of the potential areas proposed by the IUCN as Marine Protected Area in the Alborán Sea (IUCN, 2012).

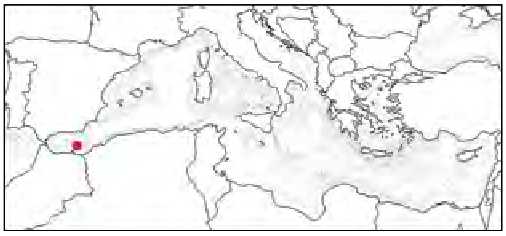
No information about the pelagic communities of the Cabo de Gata Spur has been found in the scientific literature.

**STRUCTURE:**

# Catifas - West Cabliers Bank

◘ **Location:** 35.85980°N – 2.56050°W
▲ **Peak depth (m):** 350 ⋀ **Base depth (m):** 1000





**DESCRIPTION:**

## Geology

The Catifas Bank, also named “West Cabliers Bank”, is the western element of the Cabliers Bank, consisting of two main volcanic outcrops, around 30 km far from them along a W-E direction (Ammar *et al.,* 2007). The Catifas displays its top at a depth of 350 m and its base at a depth ranging between 600 m along the southern side and over 1000 m along the northern side (Ballesteros *et al.,* 2008). The Bank, N-S oriented, is around 22 km-long and mainly composed of volcanic rocks, related to the evolution of the Alborán Arc during the late Miocene (Duggen *et al.,* 2004). The southernmost portion of the Catifas is connected to the Tres Forcas Ridge, which consists of calc-alkaline rocks of Tortonian age (9.8 Ma) (Hernandez and Bellon, 1985).

## Life on and around the Seamount

Data on the benthic communities present in the Catifas Bank have been collected by the non-governmental organization OCEANA (Pardo *et al.,* 2011; Aguilar *et al.*, 2013; OCEANA, 2014). Video footage acquired during ROV dives in a depth range of 250-500 m showed large frameworks of dead cold-water corals *Lophelia pertusa* and *Madrepora oculata*, with few and small living colonies (Pardo *et al.,* 2011). The areas dominated by dead stony cold-water coral reefs are interrupted by large areas of muddy and detrital sediments, where the most commonly observed species are the glass sponge *Asconema setubalense*, the sponge *Acanthogorgia sp.*, the black corals *Parantipathes sp.* and (less common) *Antipathes dichotoma*, the solitary corals *Desmophyllum dianthus* and *Caryophyllia sp.*, the gorgonian *Callogorgia verticillata*, the cold-water coral *Dendrophyllia cornigera*, the echinoid *Cidaris cidaris*, the polychaete worm *Lanice conchilega* and the crinoid *Leptometra phalagium* (Pardo *et al.,* 2011; IUCN, 2012). Invertebrates such as spiny lobsters (*Palinurus mauritanicus*) and Norway lobsters (*Nephrops norvegicus*), echinoderms as *Cidaris cidaris*, cnidarians as *Kophobelemnon stelliferum* and *Isidella elongata* are abundant in detritic and muddy bottoms (OCEANA, 2014).

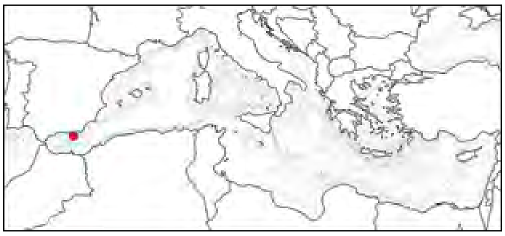
No information about the Catifas Bank pelagic communities has been found in the scientific literature.

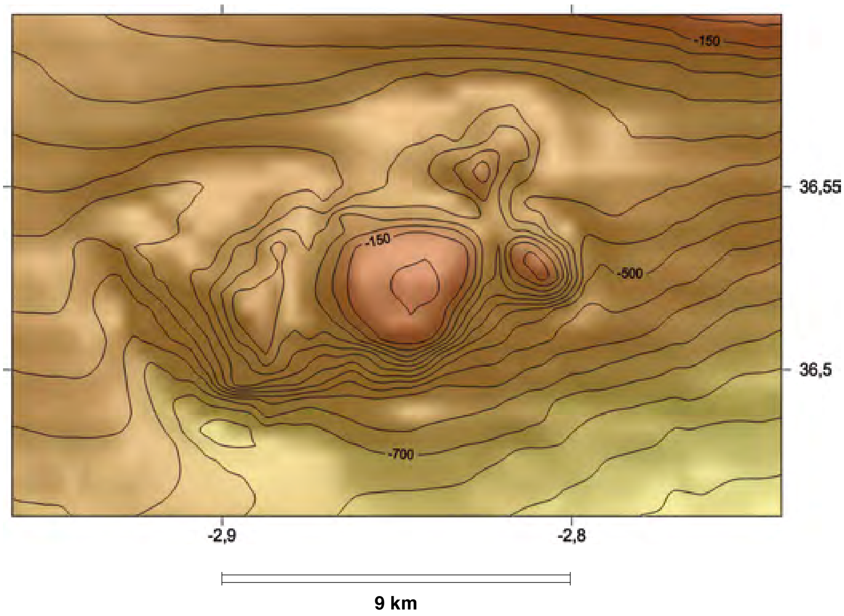
**STRUCTURE:**

# Chella - Seco de los Olivos Bank

**Location:** 36.52424°N – 2.84548°W

▲ **Peak depth (m):** 70 **Base depth (m):** 700





## DESCRIPTION:

### Geology

The Chella Bank, also named "Seco de los Olivos", is a flat-topped volcanic bank situated in the Eastern Alborán Sea. It occurs along the upper slope of the Almeria Margin, showing a subcircular shape and covering a surface area of 100 km$^2$ within a depth range of 70-700 m (Gràcia *et al.,* 2006; Lo Iacono *et al.,* 2008). The Chella Bank is the morphological expression of middle Miocene to Pleistocene calc-alkaline K-rich volcanic rocks, related to the subduction of the Tethys oceanic lithosphere into the mantle wedge beneath the Alborán tectonic block (Duggen *et al.,* 2004).

High-resolution swath bathymetric mapping reveals three main large-scale morphological features on Chella Bank: a flat sub-horizontal top and two main ridges, located to the west and to the east of the bank-top, previously named as AW (Afloramiento Oeste-West Volcanic Exposure) and ANE (Afloramiento Nor-Este-Northeast Volcanic Exposure), respectively (Muñoz *et al.,* 2008). The top of the bank is composed of an irregular central area showing a rough seafloor on a flat and sub-horizontal seafloor. Backscatter images of this sector alternate between highly reflective stripes, mainly present along the borders and correlated to rocky outcrops in the video images, and a central low reflective facies consisting of sandy deposits. These deposits have been interpreted as formed in coastal environments during previous sea level glacial maxima (Lo Iacono *et al.,* 2008, 2011). The western ridge of the Chella Bank covers a depth range of 160-620 m and is connected to the top of the Chella Bank by a 2 km-wide and 5 km-long saddle, striking NS (Lo Iacono *et al.,* 2012). The western ridge has up to 37 subcircular peaks and crests, with a depth range of 200-500 m, rising 15-40 m above the level of surrounding seafloor, 100-300 m in diameter (peaks) or 1-3.4 km-long (crests). These features are thought to be volcanic, although available data did not reveal their nature. The eastern ridge is composed of two main blocks, consisting of basaltic outcrops (Lo Iacono *et al.,* 2012), connected through a linear, slightly sinuous 2 km-long, NW-SE oriented structure. This linear structure rises up to 60 m above the level of surrounding seafloor and occurs in a water depth of 300 m. The base of the Chella Bank is partially surrounded by moats generated by strong bottom currents. The most incised moat, up to 600 m deep, is located at the southwestern base of the bank, showing higher backscatter values than those of the surrounding area, suggesting the active erosive action of those currents at the base of the bank.

### Life on and around the Seamount

The Chella Bank is one of the richest biodiversity features in Spanish waters (Aguilar *et al.*, 2008; OCEANA, 2011). Many marine species (more than 600) have been identified in the area, from fish (*Pagellus bogaraveo*, *Lophius piscatorius*, *Mullus surmuletus*, *Trachurus trachurus*, *Sardina pilchardus*, *Xiphias gladius*, *Solea solea*, etc.) to crustaceans (*Palinurus elephas*, *Palinurus mauritanicus*, *Aristeus* *antennatus*, *Nephrops norvegicus*) and cephalopods (*Eledone cirrhosa*, *Loligo vulgaris*, *Sepia officinalis*). Data acquired in the area showed the occurrence of an increased biodiversity. Macrobenthic communities such as coralligenous assemblages, gorgonian communities (*Callogorgia verticillata*, *Corallium rubrum*, *Viminella flagellum*, *Acanthogorgia armata*), black coral forests, small patches of living cold-water corals (*Madrepora oculata*, *Lophelia pertusa*, *Dendrophyllia cornigera*) and basket stars *(Astrospartus mediterraneus)* and several species of fishes dominate the top of the Bank (OCEANA, 2014). Hat-shaped glass sponges communities, probably *Asconema setubalense* and *Fakelia ventilabrum* are more frequent along the western and eastern ridges (Coiras *et al.,* 2011; Pardo *et al.,* 2011; IUCN, 2012; Lo Iacono *et al.,* 2012) and a report of the carnivorous sponge *Asbestopluma hypogea* was made by Aguilar *et al.* (2011) as well a the report of the stony coral *Anomocora fecunda* (Aguilar *et al.,* 2013), only known in the Macaronesian region and the Atlantic. The Chella Bank is subjected to intense bottom trawling and fishing-line activities due to the presence of many commercial fishery species on its top. Some of the benthic habitats of the area, such as cold-water corals, are endangered by the fishery activities and frequently appear in a poor state of conservation (Lo Iacono *et al.,* 2012). The Chella Bank was one of the study areas of the EU LIFE+ INDEMARES Project aiming to define potential sensitive environmental areas in the framework of the EU NATURA2000 network (www.indemares.es, www.oceana.org). Moreover, the bank has been proposed as potential Marine Protected Area by the IUCN (IUCN, 2012).

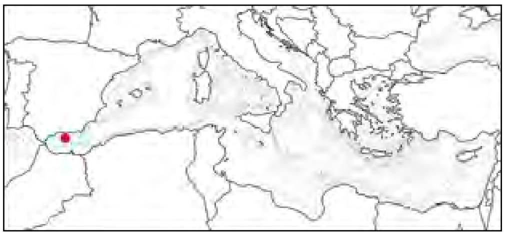
CTD transects collected along the Chella Bank show a strong increase of turbidity and chlorophyll values in the water column coinciding with the top of the Bank (Lo Iacono *et al.,* 2011). Derived geostrophic currents reach velocities of up to 60 cm/s. These values suggest an increase in nutrients and aliments through the water column, as clearly confirmed by the major occurrence of suspension feeder organisms such as cold-water corals and gorgonians along the top of the bank.

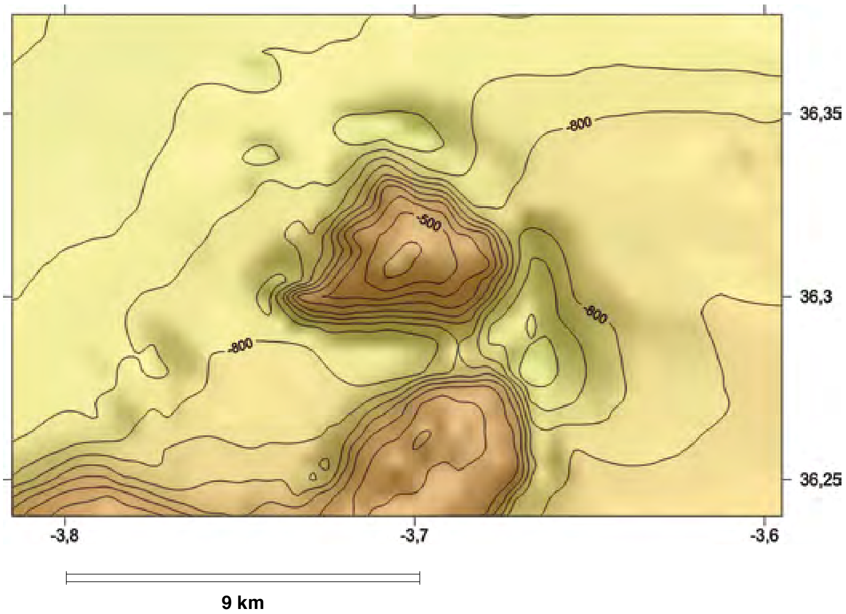
Several cetacean species such as Delphinus delphis, *Balaenoptera physalus, Globicephala melas* and *Stenella coeruleoalba* are common around the Chella bank, where also the less frequent minke whale *(Balaenoptera acutorostrata)* has been sighted as well as the loggerhead turtle *(Caretta caretta)* and, in deeper waters, the sixgill shark *(Hexanchus griseus)* (OCEANA, 2014).

**STRUCTURE:**

## Djibouti - Herradura Spur

◘ **Location:** 36.30880°N – 3.70330°W
▲ **Peak depth (m):** 430 **Base depth (m):** 740





**DESCRIPTION:**

### Geology

The Herradura Spur is pyramid-like in shape with the top at 430 m water depth and shows a relief of 310 m. It is surrounded by narrow conturitic channels and drifts (Palomino *et al.,* 2011). Also the Herradura Spur probably formed in response to the last Miocene compressive phase that produced a structural uplift of many structures in the Alborán Basin (Platt *et al.,* 2003).

### Life on and around the Seamount

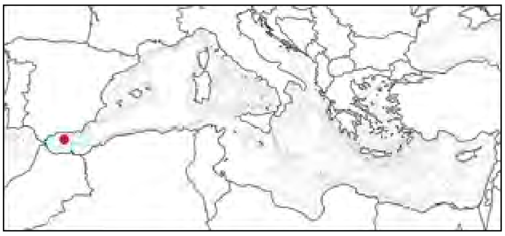
The seafloor of the Herradura Spur is represented by bioturbated mud, muddy sand and patches of rocky outcrops with coral habitats. Video observations and sediment samples collected during several oceanographic surveys show large number of coral fragments (*Dendrophyllia* sp., *Desmophyllium* sp., *Madrepora occulata* and *Lophelia pertusa*) and a variety of benthic species, including sponges, gorgonians, crustaceans, and molluscs (Gil *et al.,* 2009b; de Mol *et al.,* 2011).

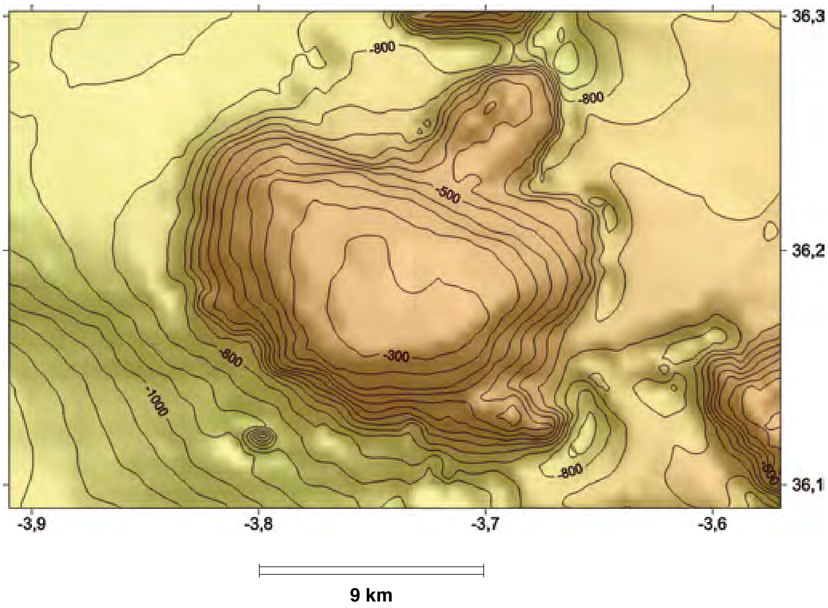
Cetaceans are very common in the Alborán Sea where high number of species occurs such as: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Ziphius cavirostris, Physeter macrocephalus (= P. catodon)* and *Balaenoptera physalus.* The area is also of importance for marine turtles (*Caretta caretta, Dermochelys coriacea*) and large pelagic fishes (*Thunnus thynnus*) because it is situated within their migratory pathway (Robles, 2007; IEO-CSIC-MAGRAMA *et al.,* 2012; Cañadas, 2014).

**STRUCTURE:**

# Djibouti Bank - Herradura Seamount

▣ **Location:** 36.17720°N – 3.76110°W
▲ **Peak depth (m):** 270 ⋀ **Base depth (m):** 680-690





**DESCRIPTION:**

## Geology

The Herradura Seamount is dome-like in shape with the top at 270 m water depth and a show a NE-SW prolongation of 7 km as a ridge. Its steep flanks (5-20°) are crossed by gullies with a radial orientation relative to the summit. Two minor sediments slides have been identified, at 300-800 m water depth on the southern flank, giving rise to mass movements towards the SE and SW (Palomino *et al.,* 2009). It is surrounded by narrow contouritic channels and drifts (Palomino *et al.,* 2011). The Alborán Basin and some highs were formed in an extensional backarc suite in the Late Oligocene and Miocene (Platt *et al.,* 2003), but some structures, as the Herradura Seamount, were formed during the last compressive phase that produced a structural uplift.

## Life on and around the Seamount

Outcropping ridges and superimposed biogenic structures composed of carbonate-rich sediments were found on the summit (Palomino *et al.,* 2011). During several oceanographic cruises it was observed to be composed mostly of dead cold water corals (*Lophelia pertusa*, *Madrepora oculata*, *Desmophyllum* sp. and *Caryophyllia smithi*) and carbonate shelled benthic fauna (Gil *et al.,* 2009b). Surficial sediments sampling and video transects reveal mud and muddy sand as the most prevalent sediments type in the summit and occur in local flat parts, near the base of the ridges (de Mol *et al.,* 2011). Benthic and demersal life is diverse and are dominated by crustaceans (*Plesionika antigai*, *Plesionika heterocarpus*, *Munida iris* and *Processa canaliculata*), fishes (*Hoplostethus mediterraneus*, *Gadiculus argenteus*, *Symphurus nigrescens*, *Bathysolea profundicola* and *Hymenoce phalusgracilis*), molluscs (*Clelande llamiliaris, Abralia veranyi* and *Sepia orbignyana*), crustaceans (*Parapenaeus longirostris*), echinoids (high abundance of *Leptometra phalangium)* poliqueta and cnidaris (*Alcyonum palmatum*) (Gil *et al.,* 2009a, Gofas *et al.,* 2011).

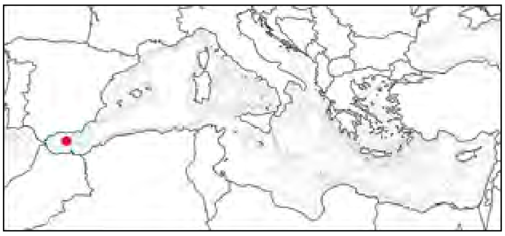
Cetaceans are very common in the Alborán Sea where a large number of species occur such as: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Ziphius cavirostris, Physeter macrocephalus (= P. catodon)* and *Balaenoptera physalus*. The area is also of importance for marine turtles (*Caretta caretta, Dermochelys coriacea*) and large pelagic fishes (*Thunnus thynnus*) because it is situated within their migratory pathway (Robles, 2007; IEO-CSIC-MAGRAMA *et al.,* 2012; Cañadas. 2014).

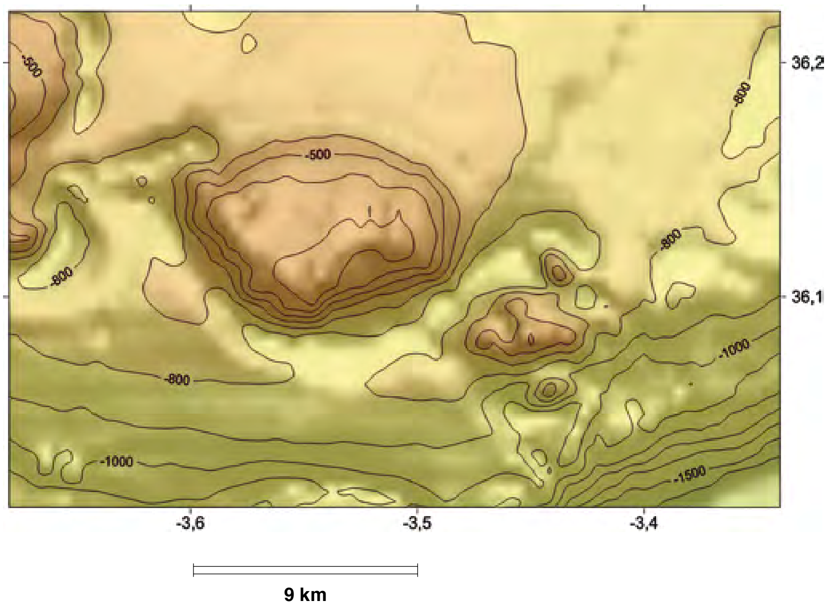
**STRUCTURE:**

## Djibouti Ville Seamount - El Idrissi Bank

▣ **Location:** 36.10910°N - 3.54080°W

▲ **Peak depth (m):** 230 ⋀ **Base depth (m):** 640-650





**DESCRIPTION:**

### Geology

The Djibouti Ville Seamount is round in shape and the top is located at 230 m water depth. It is surrounded by narrow contouritic channels and drifts (Palomino *et al.,* 2011). Dredging samples taken by Giermann *et al.* (1968) revealed its volcanic nature. It was sampled again during the 9th UNESCO/IOC cruise. In the dredging samples, pieces of volcanic rocks, abundant coral fragments, mud and Mn crusts were retrieved. Most of the volcanic samples are non vesicular, heavily altered andesites with a greenish, granular appearance due to the alteration of former pyroxene and plagioclase phenocrysts to a chlorite rich groundmass (Kenyon *et al.,* 2000).

### Life on and around the Seamount

The Djibouti Ville Seamount is dominated by outcropping hardground partly covered by a thin veneer of soft sediments. Conspicuous are fields of whitish sponges. Findings of cold-water corals comprised living *Dendrophyllia cornigera*, a living colony of *Madrepora oculata* and coral rubble. Oysters (*Neopycnodonte zibrowii*) colonising outcropping hardgrounds were observed among abundant fossil oysters. The top of the flank is dominated by extended fields with crinoids colonizing soft sediment, partly surrounded by coral rubble (Hebbeln *et al.,* 2009; Gil *et al.,* 2009a). Bottom-trawl fishing carried out on the Djibouti Ville Seamount (Gil *et al.,* 2009a) revealed 34 species of fishes including teleosts *(Epigonus denticulatus*, *Coelorinchus caelorhincus*, *Gadiculus argenteus* and *Gadicolus atlanticus)* and chondrichthyans *(Galeus melastomus*, *Scyliorhinus canicula*, *Raja clavata* and *Leucoraja naevus)*. Crustaceans were represented by 12 species where *Plesionika antigai* and *Plesionika heterocarpus* were the most abundant and 7 species of molluscs (mainly *Todarodes sagittatus)* and echinoids (mainly *Stichopus regalis* and *Holothuria forskali*) (Gil *et al.,* 2009a).

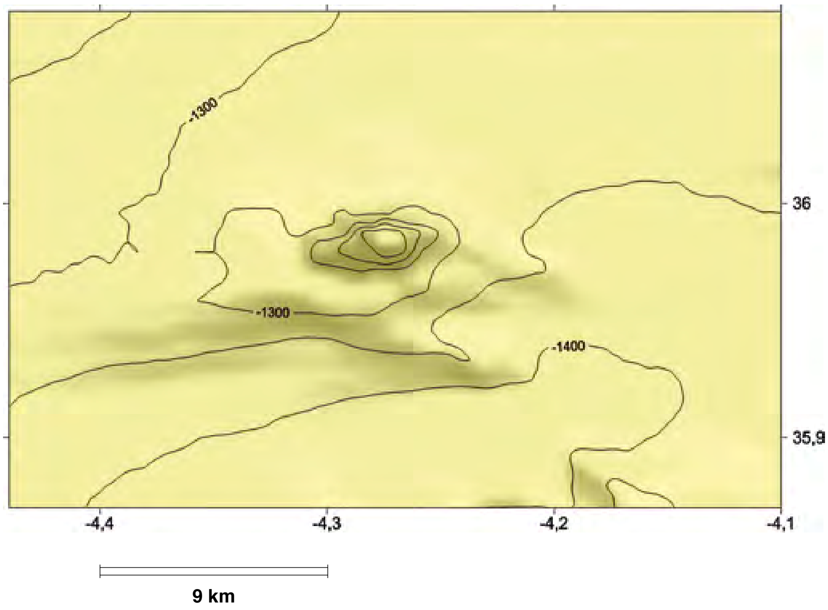
Cetaceans are very common in the Alborán Sea where high number of species occurs such as: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Ziphius cavirostris, Physeter macrocephalus (= P. catodon)* and *Balaenoptera physalus*. The area is also of importance for marine turtles (*Caretta caretta, Dermochelys coriacea*) and large pelagic fishes (*Thunnus thynnus*) because it is situated within their migratory pathway (Robles, 2007; IEO-CSIC-MAGRAMA *et al.,* 2012; Cañadas, 2014).

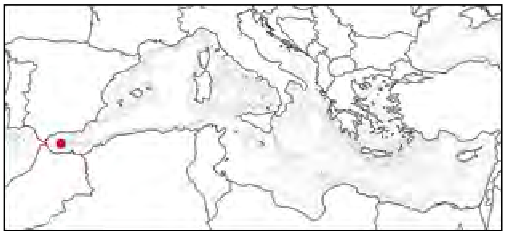
**STRUCTURE:**

# El Segoviano Hill

◘ **Location:** 35.97680°N – 4.27597°W

▲ **Peak depth (m):** 1125 **Base depth (m):** 1309





**DESCRIPTION:**

## Geology

The El Segoviano Hill extends E-W along the Western Alborán Basin, and it is about 6 km-long and 3 km-wide with a basal area of 12 km$^2$. Multibeam bathymetry reveals a 184 m-high elongated edifice characterised by a relatively flat summit area and steep slopes, with an average dip of 10-12°. The northern and western flanks have a complex geometry with small ridges, up to 20-62 m of relief, and a maximum gradient of 17°. The hill is defined as a plutonic outcrop, intruding Pliocene-Quaternary contouritic deposits (Ercilla *et al.,* 2012; Juan *et al.,* 2012). The outcrop corresponds to the Middle to Late Miocene igneous rocks that make up most of the ridges and seamounts located in the Alborán Sea (Duggen *et al.,* 2004). Its origin is related to Neogene volcanism linked to post-collisional extension occurring along the European and African margins of the western Mediterranean (Wilson and Bianchini, 1999).

## Life on and around the Seamount

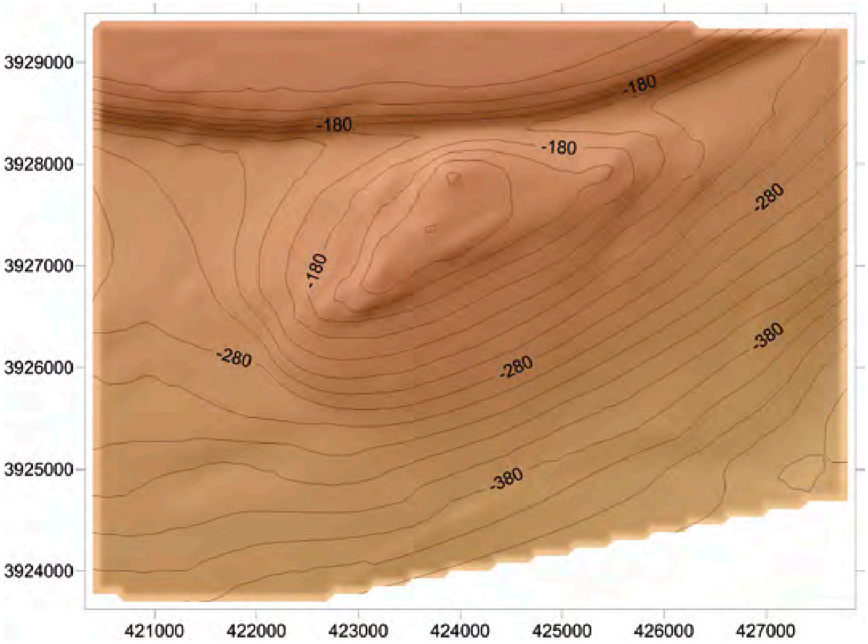
No information about the El Segoviano Hill benthic and pelagic communities has been found in the scientific literature.

**STRUCTURE:**

## Eurofleet Seamount

◘ **Location:** 35.49242°N – 3.82350°W

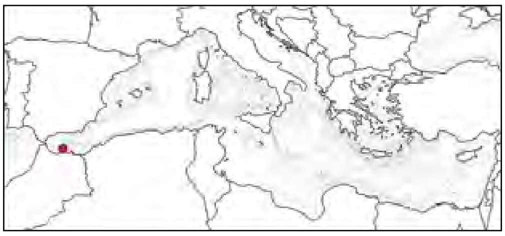
▲ **Peak depth (m):** 115 **Base depth (m):** 250-290



**DESCRIPTION:**

### Geology

The Eurofleet Seamount is located in the southern Alborán Sea, offshore Morocco, south of the Francesc Pagès High. Like the Francesc Pagès High, sometimes referred to Tofino Bank in the literature, the Eurofleet Seamount is located in the south-western prolongation of the Alborán Ridge and in the north-eastern prolongation of the Xuaen and Tofiño Banks. This seamount was mapped in detail using swath-bathymetry and named during the Eurofleet cruise SARAS (d´Acremont *et al.,* 2012). The seamount is characterized by a linear NE-SW elongated summit area (125 m water depth) with sediment wave features in the western part of the 115 m water depth peak. The northern, western, and southern flanks are steeper than the eastern flank with an average slope of 6° while the eastern flank has an average slope of 4°. No age or geochemistry data are available for the rocks forming the seamount.



The Eurofleet Seamount, like the Francesc Pagès Seamount, is offset from the Alborán Ridge (Ammar *et al.,* 2007; Martínez-García *et al.,* 2011) and is part of the Tofiño Bank formed by the compression and uplift of Miocene to Plio-Quaternary sedimentary layers related to Tortonian convergence (Bourgois *et al.,* 1992; Chalouan *et al.,* 1997).

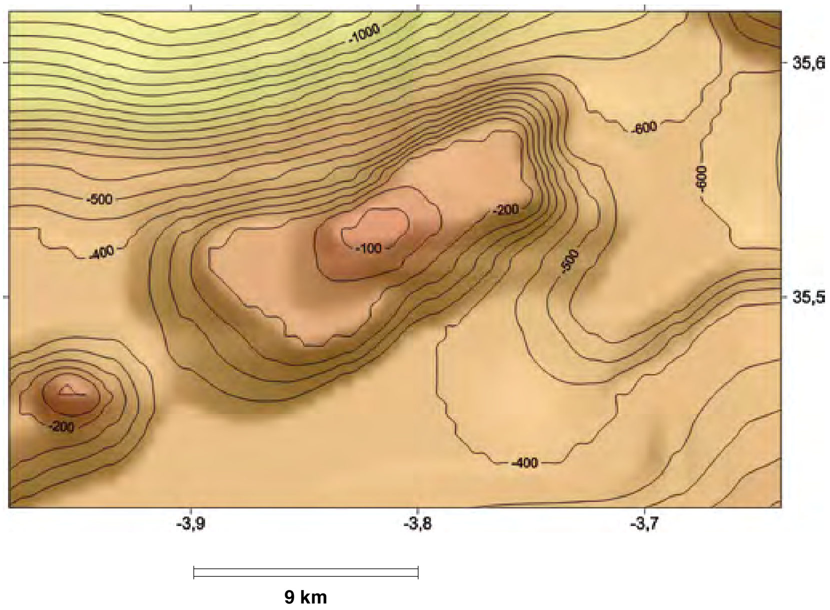
### Life on and around the Seamount

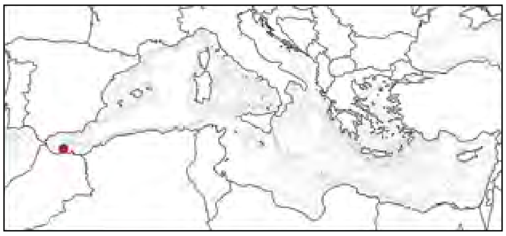
No information about the Eurofleet Seamount benthic and pelagic communities has been found in the scientific literature.

**STRUCTURE:**

# Francesc Pagès Seamount

◘ **Location:** 35.53274°N - 3.81764°W
▲ **Peak depth (m):** 96 ⋀ **Base depth (m):** 500





**DESCRIPTION:**

## Geology

The Francesc Pagès Seamount is located in the Western Alborán Basin, at the Morocco continental margin. It has an elliptical plan view morphology with a NE-SW trend and is 22 km-long and 8.2 km-wide with a basal area of 180 km$^2$. The Francesc Pagès is a relatively flat topped seamount with curvi-linear features resembling terraces and subcircular features resembling bioconstruction mini-mounds (24 m of relief). The northern flank is gentler showing an average seafloor gradient of 9° and has a relief of < 244 m. The southern flank is steeper (~ 16° average) and has a shorter relief (< 350 m). This seamount was mapped in detail with a multibeam system during EUROFLEET SARAS cruise, locating the peak coordinates at 35.704294ºN - 3.77659474ºW (d'Acremont *et al.*, 2012).

The Francesc Pagès Seamount connects with the Alborán Ridge toward the east, and together represent the morphological boundary separating the Western and Eastern Alborán Basins. Also, this seamount bounds the southern side of the Western Alborán Basin. The Francesc Pagès Seamount is an anticline formed since the Tortonian tectonic inversion of the Western Alborán Basin (Gensous *et al.,* 1986; Bourgois *et al.,* 1992). The northern and southern flanks are limited by steep reverse faults of opposite vergence (Bourgois *et al.,* 1992). The top is an abraded surface affected by the action of bottom currents related to the Western Mediterranean Deep Water and Atlantic Water and their vertical variations during the glacioeustatic changes. Also the top is eroded by shallow-water and subaereal processes during the Quaternary sea-level falls and lowstand stages. The flanks of the seamount are partially covered by Plio-Quaternary contourite and mass-transport deposits (Ercilla *et al.,* 2012; Juan *et al.,* 2012).

## Life on and around the Seamount

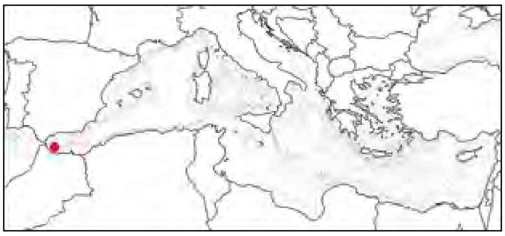
No information about the benthic and pelagic communities of the Francesc Pagès Seamount has been found in the scientific literature.

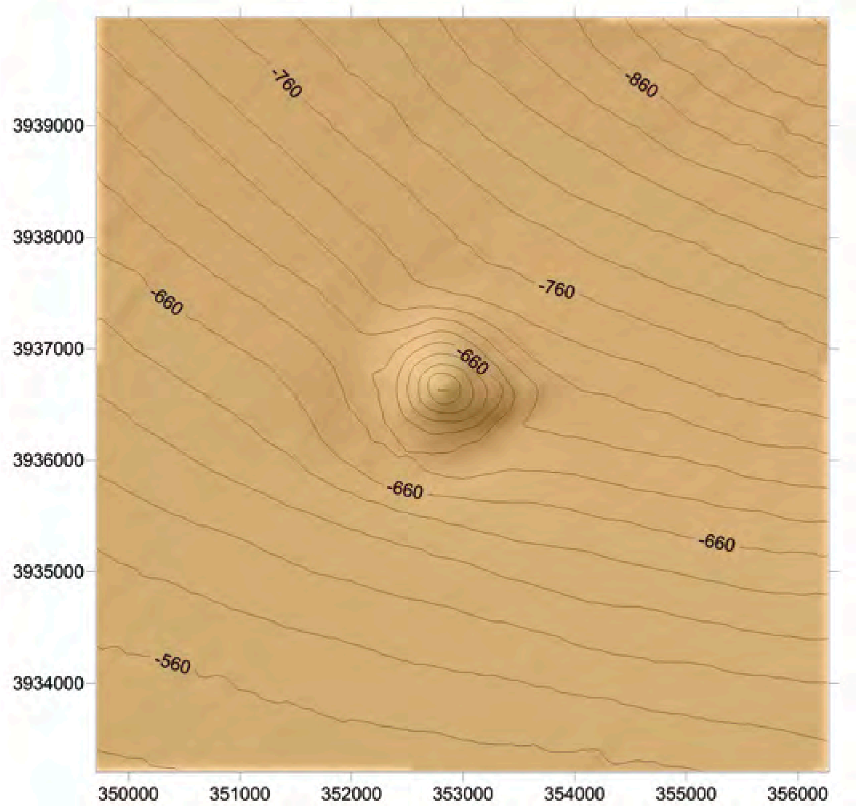
**STRUCTURE:**

## Granada Mud Volcano

▣ **Location:** 35.56513°N – 4.61609°W

▲ **Peak depth (m):** 583 **Base depth (m):** 755





### DESCRIPTION:

### Geology

The Granada Mud Volcano is an isolated circular cone-shaped edifice, with a basal area of 2.3 km$^2$, located in the Ceuta Drift, SW Alborán Sea. Multibeam bathymetry reveals a 172 m-high, 1700 m-wide single convex edifice characterized by a narrow summit. The flanks are quite similar, with steep slopes (10-13°) and reliefs of 100 m for the southern flank and 172 m for the northern flank. Towards the SW the cone is surrounded by a 785 m-wide and 30 m-deep moat. The Granada Mud Volcano is part of a set of structures, including the constructional edifice (the mud volcano itself) and a feeder complex that connects the volcano to its source stratigraphic unit (Somoza *et al.,* 2012). The mud breccias sampled from the Granada Mud Volcano contain blocks and clasts from sedimentary rocks that have been interpreted as being sourced from an Aquitanian-Burdigalian aged stratigraphic unit (Sautkin *et al.,* 2003; Gennari *et al.,* 2009). Hydrocarbons associated to the volcanic activity migrate from pre-Messinian units and are basically thermogenic in origin (Poludetkina and Kozlova, 2003; Blinova *et al.,* 2011). Pelagic marls drape the Granada Mud Volcano suggesting its inactivity or a latent period (Comas *et al.,* 2003; Sautkin *et al.,* 2003).

### Life on and around the Seamount

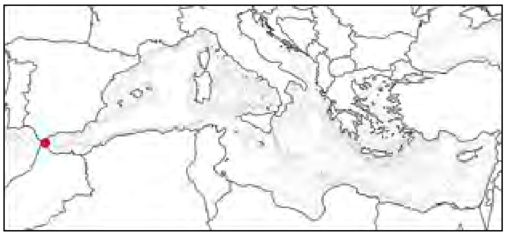
Hydrozoa and cold-water coral fragments were sampled on the Dhaka and Maya mud volcanoes, in the same province of the Granada Mud Volcano. (Margreth *et al.,* 2009).

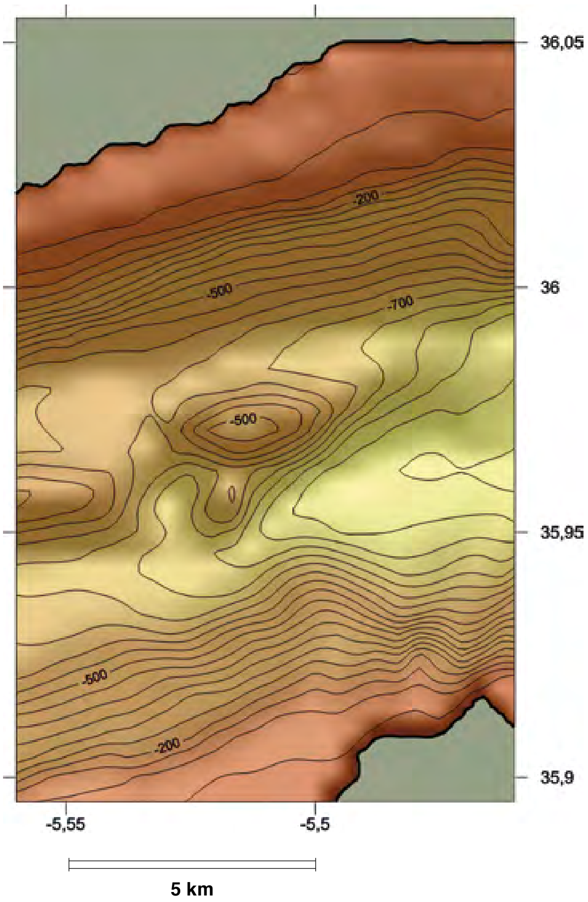
No information about the pelagic communities of the Granada Mud Volcano has been found in the scientific literature.

**STRUCTURE:**

# Hércules Seamount

◘ **Location:** 35.97120°N – 5.51190°W
▲ **Peak depth (m):** 450-460 ⋀ **Base depth (m):** 640-650





**DESCRIPTION:**

### Geology

The Hércules Seamount is located in a central ridge at the narrowest zone of the Strait of Gibraltar. This ridge consists of two seamounts, and Hércules occupies the eastern side (Sanz *et al.,* 1991). It is slightly elongated as an ENE-WSW direction and has a peak lying at 450 m water depth. It is 3.5 km-long and 1.5 km-wide. The constituting materials most probably belong to flysch series similar to those which outcrop on the Spanish and Moroccan coasts (Blanc, 2002). There are two possible interpretations about their origin: the central ridge as a detached panel from the northern flank of the northern channel, east of Tarifa; or an enhancement of relief by differential erosion of homogeneous hard rock units among the regional rock background.

### Life on and around the Seamount

The seafloor of the Hércules Seamount is covered by coral mounds and hard grounds highly lithified named lithoherm. Over a structure comprised of dead coral fragments that can be tens meters thick, are developed colonies of living corals (*Madrepora oculata*, *Lophelia pertusa*, *Dendrophyllia cornigera*, *Caryophyllia cyathus*, *Desmophyllum cristagalli*) and other benthic organisms as bryozoans, cirripeds, ophiuroids, etc. that are adapted to hard grounds of high energy (Izquierdo *et al.,* 1996).

Due to the location between the Atlantic and the Mediterranean, this is a strategic place for migratory species, such as bluefin tuna *(Thunnus thynnus)* that migrate from the Atlantic into the Mediterranean through the Strait of Gibraltar for spawning, as well as for the marine turtles *(Caretta caretta*, *Dermochelys coriacea* and *Chelonia mydas)* (Camiñas, 2005). Six species of cetaceans occur regularly within the Strait of Gibraltar: *Delphinus delphis*, *Stenella coeruleoalba*, *Tursiops truncatus*, *Globicephala melas*, *Physeter macrocephalus* (= *P. catodon*), *Orcinus orca* (de Stephanis *et al.,* 2008).

**STRUCTURE:**

# Hésperides Seamount

◘ **Location:** 35.94180°N – 5.59080°W

▲ **Peak depth (m):** 460-470 ⋀ **Base depth (m):** 630-640

## DESCRIPTION:

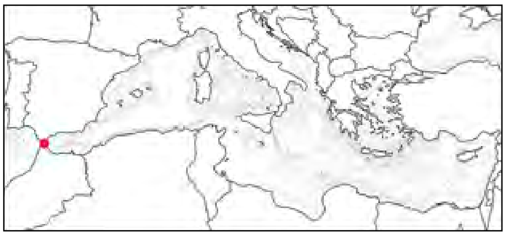
### Geology

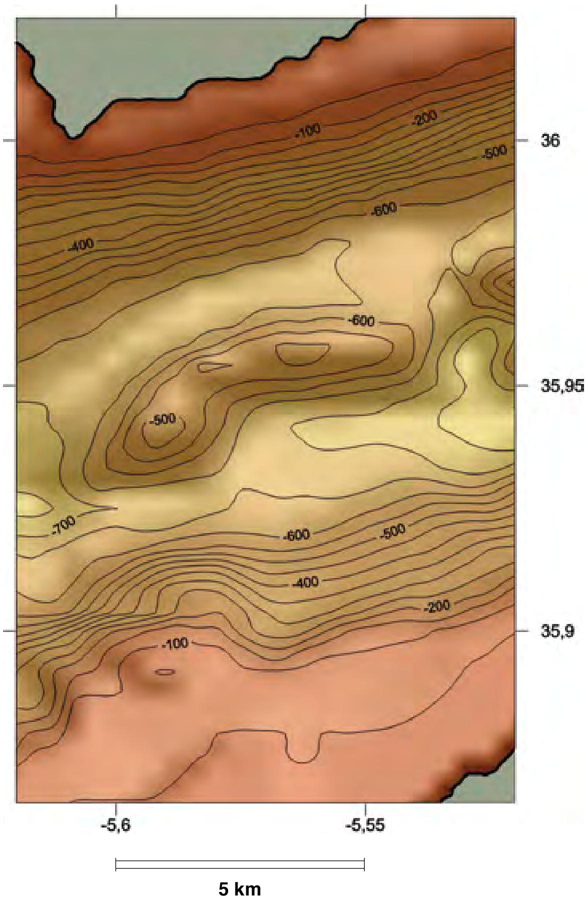
The Hésperides Seamount is situated in a central ridge at the narrowest zone of the Strait of Gibraltar. This ridge consists of two seamounts, and Hésperides occupies the western side (Sanz *et al.,* 1991). It is elongated in a NE-SW direction to the west and E-W to the east and has three peaks at 460, 485 and 480 m water depth. It is 6 km-long and 1.5 km-wide. The constituting materials are most probably belonging to flysch series similar to those which outcrop on the Spanish and Moroccan coasts (Blanc, 2002). Here are two possible interpretations about their origin: the central ridge as a detached panel from the northern flank of the northern channel, east of Tarifa; or an enhancement of relief by differential erosion of homogeneous hard rock units among the regional rock background.

### Life on and around the Seamount

The seafloor of the Hésperides Seamount is covered by coral mounds and hard grounds highly lithified named lithoherm. Over a structure constituted by dead coral fragments that can be tens meters thick, are developed colonies of living corals (*Madrepora oculata*, *Lophelia pertusa*, *Dendrophyllua cornigera*, *Caryophyllia cyathus*, *Desmophyllum cristagalli*) and other benthic organisms as bryozoans, cirripeds, ophiuroids, etc. that are adapted to hard grounds of high energy (Izquierdo *et al.,* 1996).

Due to the location between the Atlantic and the Mediterranean, this is a strategic place for migratory species, such as bluefin tuna *(Thunnus thynnus)* that migrate from the Atlantic into the Mediterranean through the Strait of Gibraltar for spawning, as well as for the marine turtles *(Caretta caretta*, *Dermochelys coriacea* and *Chelonia mydas)* (Camiñas, 2005). Six species of cetaceans occur regularly within the Strait of Gibraltar *Delphinus delphis*, *Stenella coeruleoalba*, *Tursiops truncatus*, *Globicephala melas*, *Physeter macrocephalus (= P. catodon)*, *Orcinus orca* (de Stephanis *et al.,* 2008).

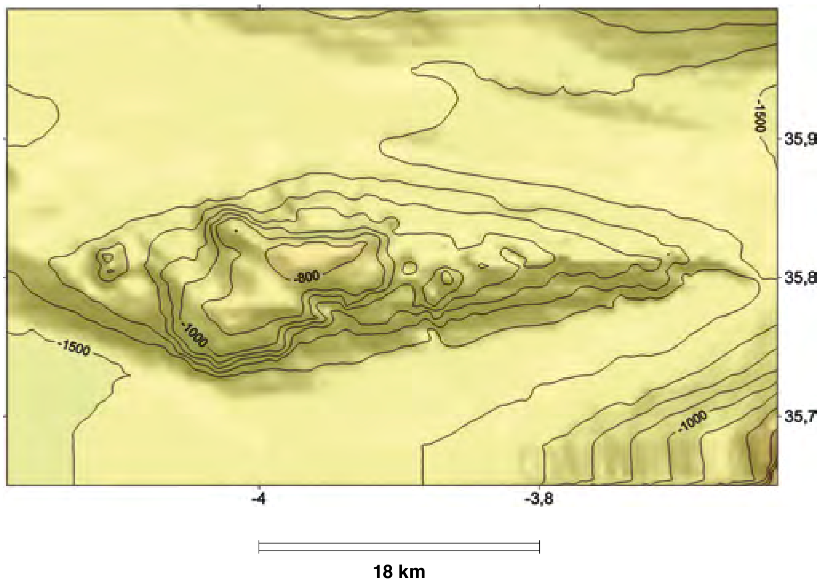


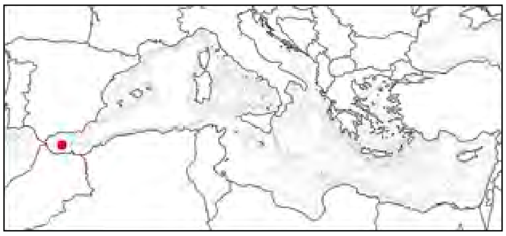


**STRUCTURE:**

# Ibn-Batouta Bank

▣ **Location:** 35.80678°N – 3.96800°W
▲ **Peak depth (m):** 770 ⋀ **Base depth (m):** 1296-1314





**DESCRIPTION:**

### Geology

The Ibn-Batouta Bank is located in the Western Alborán Basin. It is E-W trending structure with an irregular trapezoidal morphology comprising a main ~ 15 km-long edifice, bounded to the east by a relatively small spur and to the west by a linear ridge (~ 15 km-long). The seamount is 39 km-long and 12.6 km-wide with a basal area of 481 km$^2$. The top of the main edifice is almost flat having an undulated surface with small ridges up to 58 m high and three small isolated depressions (< 360 m). The morphology of the flanks is quite similar; the southern flank, with a relief of ~ 552 m, has a seafloor gradient between 5° and 7°. The northern flank displays gradients from 4° to 8.8° and a 506 m relief.

The Ibn-Batouta Bank has an igneous basement as suggested by the plutonic rocks, specifically gabbros, dredged from its basement (Duggen *et al.,* 2008). The top (~ 130 ms) and lower part of the flanks (~ 560 ms) are predominantly covered by Pliocene and Quaternary plastered drift deposits (Ercilla *et al.,* 2012; Juan *et al.,* 2012). The plutonic basement mainly outcrops in the upper part of the northern and southern flanks. Their genesis is related to Alborán Basin extension, which was accompanied by widespread Neogene volcanism, concentrated in, but not confined to, a SW-NE trending zone extending from Morocco to SE Spain.

### Life on and around the Seamount

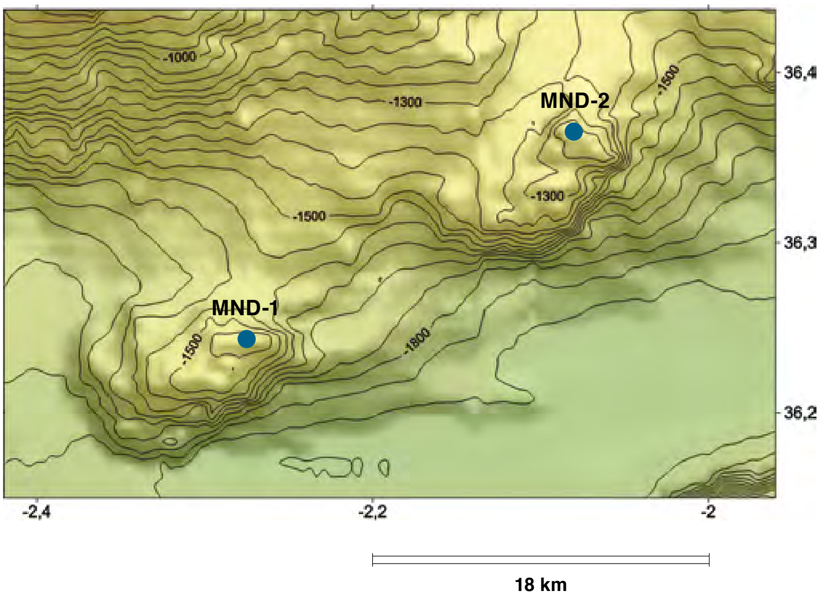
No information about the Ibn-Batouta Bank benthic and pelagic communities has been found in the scientific literature.

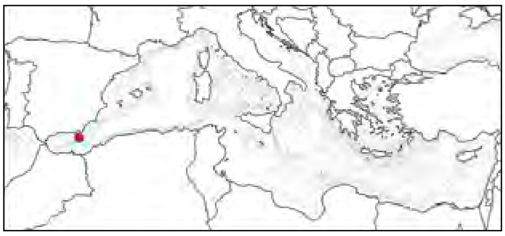
**STRUCTURE:**

# Maimonides Seamounts (MND-1 and MND-2)

MND-1 ◘ **Location:** 36.22885°N – 2.28539°W
▲ **Peak depth (m):** 1450 **Base depth (m):** 1675-1910

MND-2 ◘ **Location:** 36.34745°N – 2.05960°W
▲ **Peak depth (m):** 1211 **Base depth (m):** 1370-1640





**DESCRIPTION:**

## Geology

The Maimonides Seamount 1 is located in the easternmost sector of the Alborán Sea, at the base of the slope. It displays a slightly NE-SW trend and is ~ 15.4 km-long, 11 km-wide and has a basal area of 165 km$^2$. The summit of the seamount is an irregular surface, with small negative reliefs (~ 80 m). The flanks are asymmetric, and can be divided into two distinct flanks, northwestern and southeastern. The southeastern flank is steeper, with average gradients of 7°, and higher, with a relief of ~ 420 m. This flank is dominated by irregular-shaped ridges resembling rills and gullies and related deposits. The northwestern flank is smoother, gentler, with an average gradient of 3°, and is not so high (~215 m). Both flanks are affected by slides and mass transport deposits (Alonso *et al.,* 2014).

The Maimonides Seamount 1 is a volcanic seamount covered almost entirely by Plio-Quaternary cover (300 ms). This cover is relatively thinner on the southern flank, where it is locally lacking. Maimonides Seamount 1 and Maimonides Seamount 2 form the Maimonides Ridge. This ridge, together with the Alborán Ridge and the Al-Mansour Seamount, represent the NE-SW and NNE-SSW trending axis of the main volcanic seamounts (Gierman *et al.,* 1968; Auzende *et al.,* 1975). The genesis of the Maimonides Ridge is related to extension in the Alborán Basin which was accompanied by widespread Neogene volcanism, concentrated in, but not confined to, a SW-NE trending zone extending from Morocco to SE Spain. The compressional nature of the western part of the Maimonides Ridge, where Maimonides Seamount 1 is located, has been defined by Woodside and Maldonado (1992). Folding in some of the sediments on either side of the back-tilted block forming the bank further suggests compression, with uplift of the southern part of the bank rather than down-faulting of the northern part (as would be expected if, e.g., this were an extensional feature). The sediment to the south of the bank is both south-tilted and slightly up-faulted to the north against the rising bank.

The Maimonides Seamount 2 is located in the north-eastern sector of the Alborán Basin. This seamount forms a separate edifice in the Maimonides Ridge, separated from the Maimonides Seamount 1 by 15 km. In plan-view, the Maimonides Seamount 2 is 11.5 km-long and 5.7 km-wide with a basal area of 64 km$^2$ and elliptical geometry. The summit is defined by an irregular surface with circular to linear reliefs (< 60 m), and a significant spur to the northwest. The flanks are asymmetrical: the southeastern flank is steeper (~ 15°), has a relief of 360 m and the seafloor is relatively smooth; the northwestern flank is gentler with average gradients of ~ 8°, shorter (200 m-high) and its seafloor is irregular with linear and sinuous reliefs resembling gravitational features (erosive and depositional). Separating the two Maimonides Seamounts there is a low saddle infilled by Plio-Quaternary deposits affected by gravitational deposits.

The Maimonides Seamount 2 is a volcanic seamount, whose top and northwestern flank are almost entirely covered by Plio-Quaternary sediments (200 ms). Volcanic basement outcrops in the northwestern spur of the top and southeastern flank.

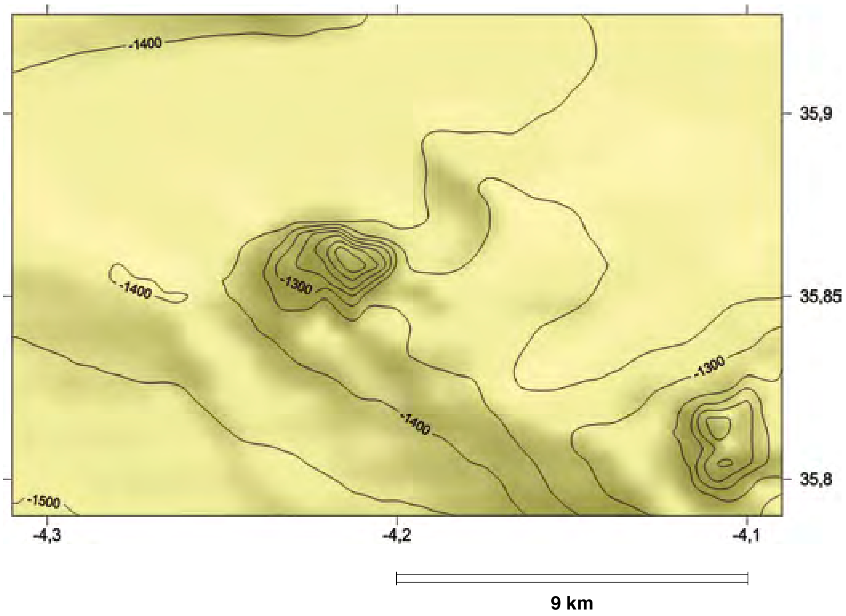
## Life on and around the Seamount

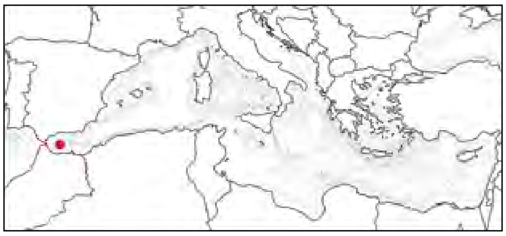
No information about the benthic and pelagic communities of the Maimonides Seamounts has been found in the scientific literature.

**STRUCTURE:**

## Maria Del Carmen Hill

◘ **Location:** 35.85394°N – 4.21657°W
▲ **Peak depth (m):** 1006 **Base depth (m):** 1407





**DESCRIPTION:**

### Geology

The Maria del Carmen Hill extends E-W along the Western Alborán Basin, it is 3.8 km-long and 3 km-wide, with a basal area of 8.6 km$^2$. Multibeam bathymetry reveals a 401 m-high elongated edifice characterised by a 3.5 km-long E-WNW crest line. The northern flank is the steepest, with a maximum dip of 44°. The southern flank has a complex geometry with SW-NE ridges, up to 110 m of relief, and a maximum gradient of 26°.

The hill is defined as a plutonic outcrop with no evident sedimentary cover, intruding Pliocene-Quaternary contouritic deposits (Ercilla *et al.,* 2012; Juan *et al.,* 2012). The outcrop corresponds to the Middle to Late Miocene igneous rocks that make up most of the ridges and seamounts in the Alborán Sea (Duggen *et al.,* 2004). Its origin is related to Neogene volcanism linked to post-collisional extension along the European and African margins of the western Mediterranean (Wilson and Bianchini, 1999).

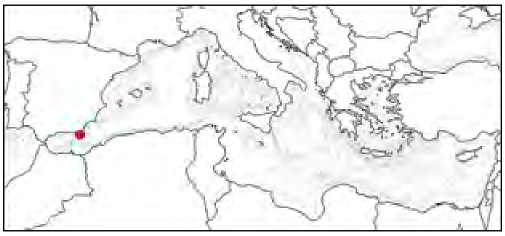
### Life on and around the Seamount

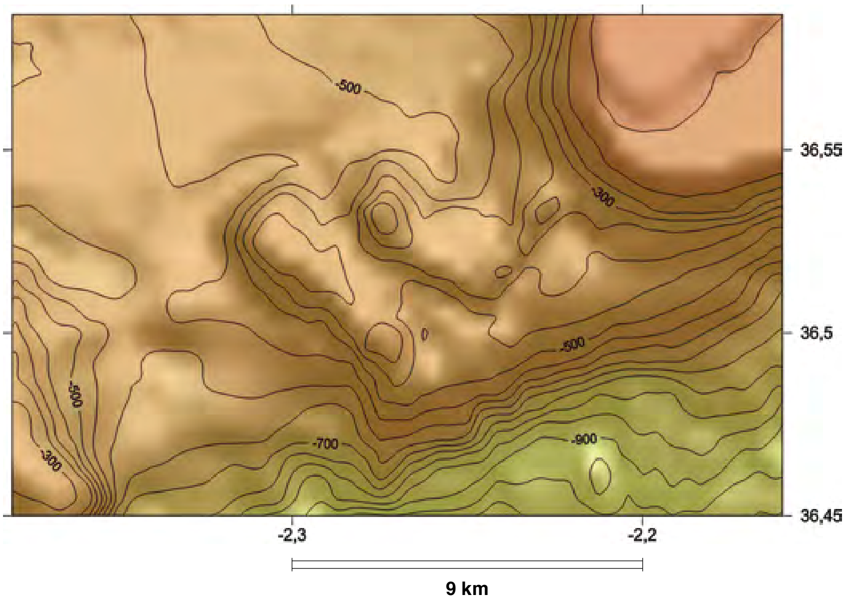
No information about the benthic and pelagic communities of the Maria del Carmen Hill has been found in the scientific literature.

**STRUCTURE:**

## Pollux Bank

▣ **Location:** 36.53310°N – 2.27370°W
▲ **Peak depth (m):** 300 **Base depth (m):** 600





**DESCRIPTION:**

### Geology

The Pollux Bank corresponds to a rough volcanic bank situated in the Eastern Alborán Sea, 13 km from the Almería Channel and about 20 km from the Cape de Gata (Lo Iacono *et al.,* 2008). As in the case of the Chella and Sabinar Banks, the Pollux Bank has been generated in relation to the middle Miocene to Pleistocene calc-alkaline K-rich volcanism occurred in this margin (Duggen *et al.,* 2004). The Pollux Bank has a smaller extension compared to the close Sabinar and Chella Banks and displays an irregular morphology, composed of several isolated highs and ridges, mainly oriented NW-SE and NE-SW, up to 60 m-high and 3 km-long (Lo Iacono *et al.,* 2008). Up to 200 m-high deeply carved scars along the southern flank of the bank suggest the persistence of mass failure processes in the area (Gràcia *et al.,* 2006; Alonso *et al.,* 2014), likely due to the increased steepness of the volcanic bedrock. Small and large-scale mass transport deposits (50 ms-thick and 17 km-long) affect the Plio-Quaternary deposits at the base of the Pollux Bank, at a maximum depth of 1700 m (Alonso *et al.,* 2014). The oldest of these deposits is dated around 1.65 kyr BP (Alonso *et al.,* 2014). Geophysical data acquired in the area show alternating high and low acoustic backscatter facies, suggesting that the bank is partially draped by fine sediments, likely owing to the sediment delivery of the close Almeria Channel system (Garcia *et al.,* 2006; Lo Iacono *et al.,* 2008).

### Life on and around the Seamount

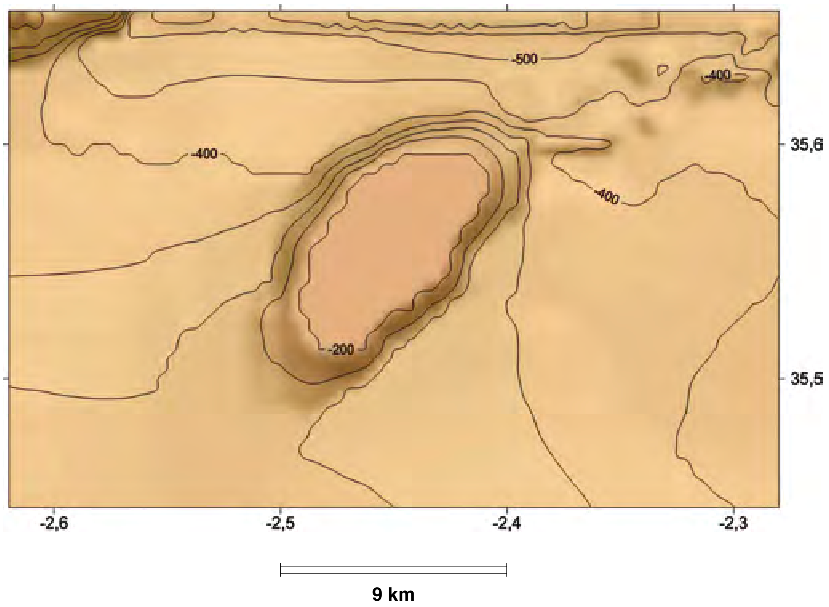
The Pollux Bank has been sampled during the CO-BAS Cruise (Taviani *et al.,* 2004) revealing the occurrence of "subfossil" cold-water coral reefs mainly composed of *Madrepora oculata* and *Lophelia pertusa*.

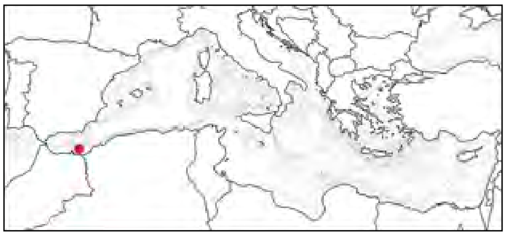
No information about the Pollux Bank pelagic communities has been found in the scientific literature.

## STRUCTURE:

# Provençaux Bank

▣ **Location:** 35.56909°N – 2.45369°W
▲ **Peak depth (m):** 200-210 ▲ **Base depth (m):** 280-290





## DESCRIPTION:

### Geology

The Provençaux Bank is located in the northeastern Moroccan shelf between 200 and 290 m water depth and displays a shape slightly elongated in the SW-NE direction. The summit is very flat and it is 12 km-long and 7 km-wide. The group formed by Pytheas-Cabliers-Provençaux Banks has been interpreted as a caldera filled by more than 1000 meters of sediment (Gierman *et al.,* 1968) the distance between the banks is longer than the largest calderas and therefore, the caldera hypothesis is unlikely. The origin is volcanic and probably of Messinian-Tortonian (Miocene) age (Ammar *et al.,* 2007). Metamorphic rocks with amphibole have been dredged in the Provencal Bank (Olivet *et al.,* 1972). Attach to the south of the bank there are three ridges that have elongated shapes, a mean width of 175 m and heights up to 50 m.

### Life on and around the Seamount

Two box corer samples at the summit of the bank reveal that the platform is made up of hard substrates only covered by a thin veneer of soft sediments with sandy sediment composed of foraminifera and dark glauconitic grains underneath the soft sediment layer. The benthic fauna comprises mainly gastropods, bivalves, echinoids and crustaceans. Video observations along the ridges at the base of the bank reveal a fossil coral framework colonised by a diverse associated fauna comprising sponges, soft corals, echinoderms and many other benthic organisms as well as scarce and patchly distributed live colonies of *Lophelia pertusa* and *Madrepora oculata* (Comas *et al.,* 2009; Hebbeln *et al.,* 2009; Fink *et al.,* 2013).

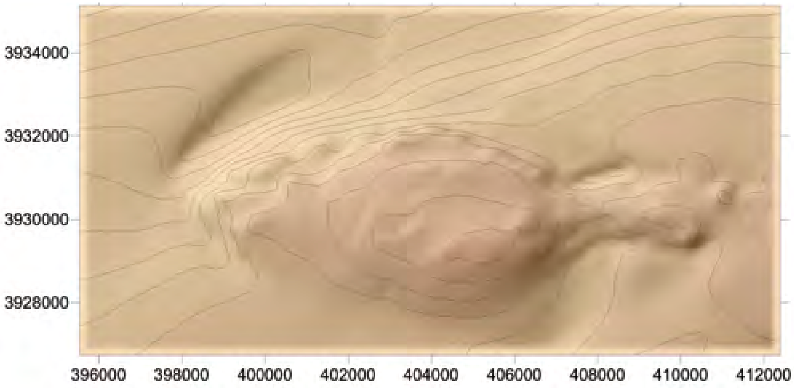
No information about the Provençaux Bank pelagic communities has been found in the scientific literature.

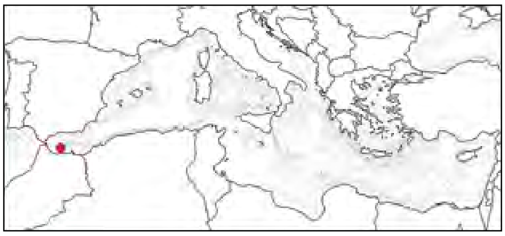
**STRUCTURE:**

# Ramon Margalef High

◘ **Location:** 35.50325°N – 4.04498°W

▲ **Peak depth (m):** 235 **Base depth (m):** 430-440





**DESCRIPTION:**

## Geology

The Ramon Margalef High is located in the southern Alborán Sea, offshore Morocco. This high is oriented E-W and is about 13 km-long. Two sectors can be identified. The larger western sector is ellipsoidal in shape and up to 4 km-wide, 9 km-long and has reliefs up to 235 m water depth. Stiff-layers are eroded and exposed at the top of the high. The eastern sector is smaller and deeper, ellipsoidal in shape, up to 2 km-wide, 5 km-long and has reliefs up to 310 m water depth. This High was mapped using swath-bathymetry and named during the EUROFLEET SARAS cruise (d´Acremont *et al.,* 2012). Surrounding the Ramon Margalef High, a 60 m-high depression is due to bottom water currents.

No age or geochemistry data are available but its location on the northern deformation front of the Xauen and Tofiño Banks suggests that this high is part of these banks. They are interpreted as formed by the compression and uplift of Miocene to Plio-quaternary sedimentary layers, related to Tortonian convergence (Bourgois *et al.,* 1992; Morley, 1993; Chalouan *et al.,* 1997; Ammar *et al.,* 2007). From seismic reflection and bathymetric data, the Ramon Margalef High shows signs of both past and present tectonic deformation with quaternary unconformities, E-W syn-sedimentary thrust faults associated on the flanks to mass-movement deposits (mostly slides and mass flow deposits), and contourites (d'Acremont *et al.,* 2013; Ercilla *et al.,* 2012).

## Life on and around the Seamount

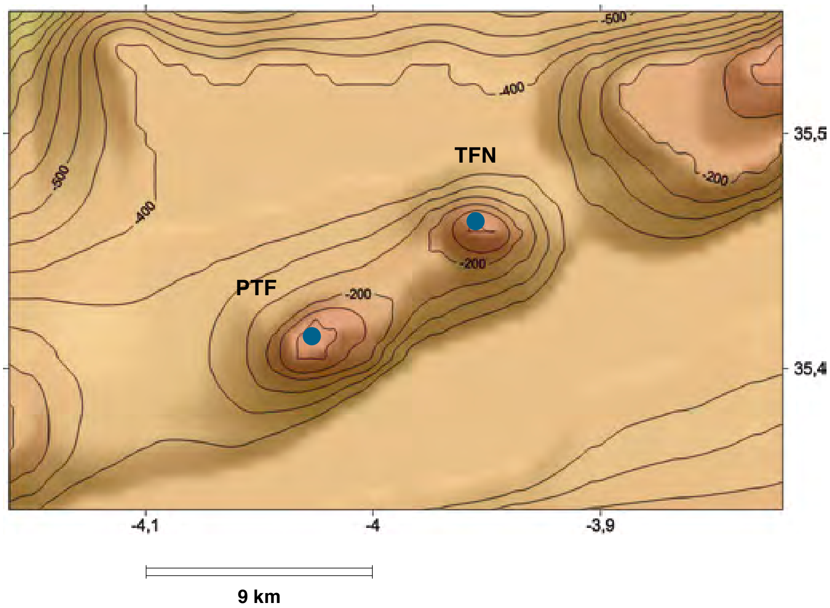
No information about the benthic and pelagic communities of the Ramon Margalef High has been found in the scientific literature.

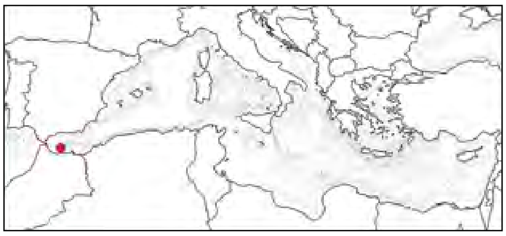
**STRUCTURE:**

# Tofiño Seamount and Petit Tofiño (Petit Xauen) Seamount

TFN ◘ **Location:** 35.45921°N – 3.94600°W
▲ **Peak depth (m):** 68 ⋀ **Base depth (m):** 400

**PTF** ◘ **Location:** 35.40175°N – 4.01581°W
▲ **Peak depth (m):** 98 ⋀ **Base depth (m):** 350-400





**DESCRIPTION:**

## Geology

The Tofiño Seamount is located in the southern Alborán Sea, offshore Morocco. This seamount is sub-circular with a diameter of 4 km. The eastern and western flanks are steeper than the northern and southern flanks with an average dip of 18° for the easter and wester flanks, 10° for the northern flank, and 5° for the southern flank. The summit lies at 68 m water depth and is located in the western part of the wide flat abraded general summit zone (115 m water depth). Sediment wave features and palaeo-shorelines characterize the morphology of the western part of the summit. This seamount was mapped in detail using integrated swath-bathymetry and box corers during the EUROFLEET SARAS cruise (d´Acremont *et al.,* 2012).

This seamount is part of the Tofiño Bank located in between the Xauen Bank and the Alborán Ridge that corresponds to a fold and thrust belt deforming the sedimentary cover (Bourgois *et al.,* 1992; Mauffret *et al.,* 2007; Ammar *et al.,* 2007;). West of this seamount, the Xauen Bank has been drilled by the El Jebha well (Morley, 1993; Chalouan *et al.,* 1997). The well has crossed sedimentary layers from early Miocene to Plio-Quaternary in age. Seismic reflection profiles show that the bank is formed by several E-W to ENE-WSW folds and thrusts (Bourgois *et al.,* 1992; Ammar *et al.,* 2007) cut off by a Quaternary erosional surface (Gensous *et al.,* 1986; d'Acremont *et al.,* 2011). It has been suggested that the Miocene layers were originally deposited in the thick West Alborán Basin then uplifted by compression (Ammar *et al.,* 2007; d'Acremont *et al.,* 2013).

The Petit Tofiño Seamount is located in the Western Alborán Basin on the Morocco margin. It is approximately 6 km-long, 4.7 km-wide and has a ~ 28 $km^2$ basal area; it trends NE-SW and is elliptical in plan-view. The flanks are smooth: the northern flank has a gentle slope averaging approximately 9°, with a relief of < 244 m; the southern flank is steeper (~16°) and has a relief of < 350 m. The summit is a flat-lying surface characterised by linear to sinuous, pointed, sub-circular mounds. This seamount was mapped in detail using integrated geophysical methods and named during the recent EUROFLEET SARAS cruise(d´Acremont *et al.,* 2012). The Petit Tofiño connects northwards with the Tofiño Seamount and southwards with the Xauen Bank. These have the same orientation as the Francesc Pagès Seamount and Alborán Ridge, and together comprise the main morphological barrier dividing the Western and Eastern Alborán Basins. The Petit Tofiño Seamount is an anticline formed since the Tortonian tectonic inversion of the Western Alborán Basin (Gensous *et al.,* 1986; Bourgois *et al.,* 1992). It is limited by a steep reverse fault on the southern flank, and on the land and seaward sides by synform structures (Bourgois *et al.,* 1992). Highly deformed Miocene deposits outcrop and Plio-Quaternary deposits have been identified at the foot of the flanks as contourite deposits predominantly formed by the Western Mediterranean Deep Water (Ercilla *et al.,* 2012; Juan *et al.,* 2012).

## Life on and around the Seamount

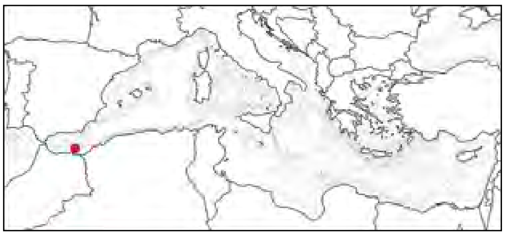
No information about the benthic and pelagic communities of the Tofiño and Petit Tofiño Seamounts has been found in the scientific literature.

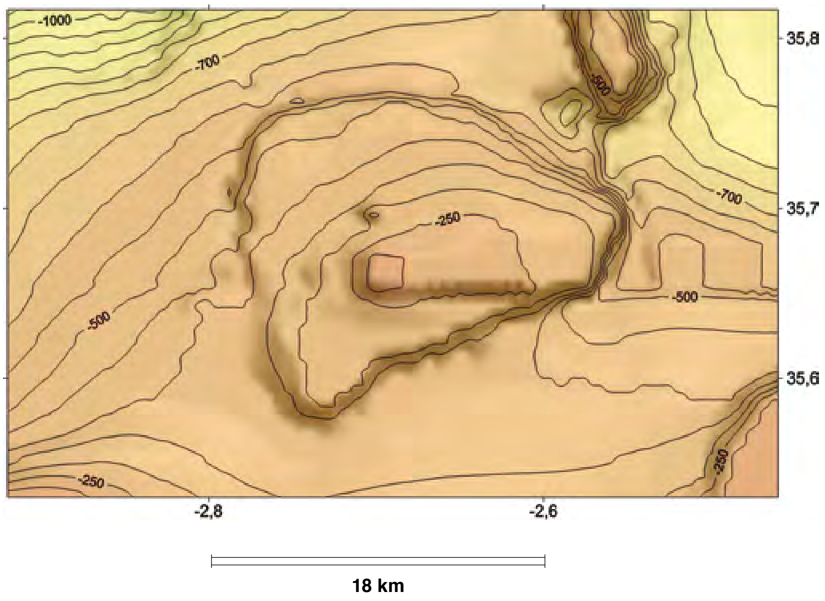
**STRUCTURE:**

# Tres Forcas Ridge

◘ **Location:** 35,66150°N – 2.69790°W

▲ **Peak depth (m):** 170-180 ⋀ **Base depth (m):** 380-390





**DESCRIPTION:**

## Geology

The Tres Forcas Ridge is a tabular seamount that rises more than 200 m from the sea bottom. It displays a very flat top, interrupted by the presence of single peaks on the central part of the summit with heights of 50 m and 30 m. It is surrounded by 25 m-deep depressions that correspond to contouritic channels. It is a high with a mixed origin, both structural and volcanic (Vázquez, 2001).

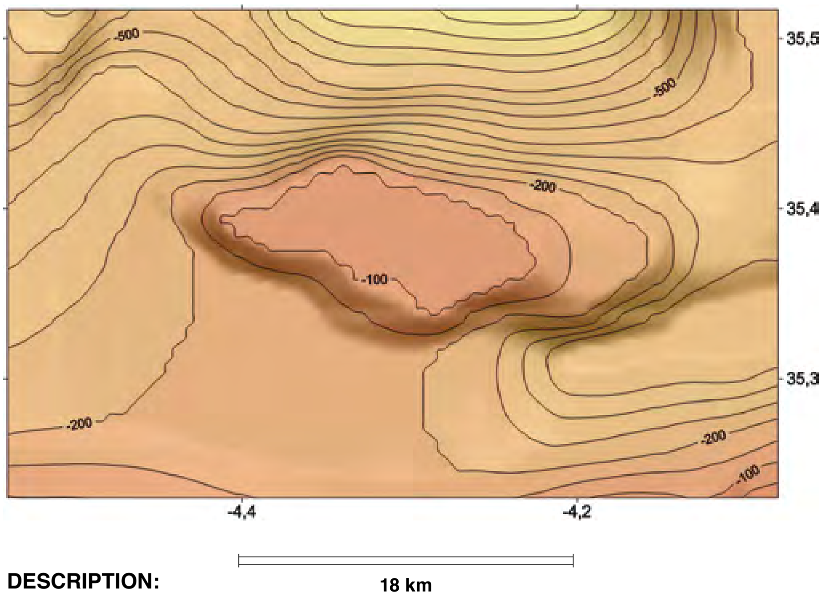
## Life on and around the Seamount

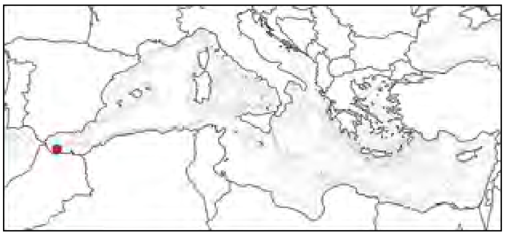
No information about the benthic and pelagic communities of the Tres Forcas Ridge has been found in the scientific literature.

**STRUCTURE:**

# Xauen Bank

**Location:** 35.36959°N – 4.32822°N
**Peak depth (m):** 98 **Base depth (m):** 400-490





**DESCRIPTION:**

## Geology

The Xauen Bank is located in the Western Alborán Basin on the Morocco margin. Multibeam bathymetry shows that in plan-view it has E-W elliptical geometry. It is 28 km-long and 12.1 km-wide, and has an important basal area (338 km$^2$). The summit is defined by a flat surface. Its flanks are similar in both slope gradients and relief. The southern flank displays up to 7° of slope gradient with relief of up to 462 m, bounded by a channel about 2 km-wide. The northern flank displays up to 8° of slope gradient and relief of up to 516 m.

This seamount has been mapped by two recent cruises (MARLBORO and EUROFLEETS SARAS in 2012) (d'Acremont, 2011; d'Acremont *et al.,* 2012). Morphological and seismic analysis of this seamount was carried out recently by d'Acremont *et al.* (2013), Ercilla *et al.* (2012) and Juan *et al.* (2012). These studies reveal that the Xauen Bank displays a variety of morphological features and deposits, including a prograding wedge on the top, mass flow deposits, bioconstructions, sharp scarps, a contouritic channel and moat, and drift deposits. The seismic profiles reveal that this seamount has a high degree of internal complexity comprising folded structures intruded by a magma channel. The directions of the different fold axes change from west to east, marking a different accommodation approximation of the Eurasian-African plates (d'Acremont, 2011).

The Xauen Bank is formed by early Miocene and Plio-Quaternary deposits (with an average of 159 ms) uplifted by compression with an estimated shortening of 3.5 km since the Messinian (0.65 mm/yr). The well-described El Jebha borehole was drilled into this bank (Morley, 1993; Chalouan *et al.,* 1997). The Messinian (213 m below seafloor) to basal Tortonian (1962 m below sea floor) sediments are claystones, turbiditic sandstones and volcanic clasts. From 1962 m to 2696 m the Serravallian and Langhian layers are composed of bathyal claystones with rare thin turbiditic sandstone intercalations. Early Miocene microfaunas observed at the base of the well may be reworked (Chalouan *et al.,* 1997). The sedimentary layers drilled on the Xauen Bank were originally deposited in the very deep West Alborán Basin then uplifted by the compression on the bank. The shortening is evaluated to be 3.5 km with two main E-W trending anticlines. The erosion cuts (1.6 km) the top of the folds. The uplift measured from their top the Messinian of the deep basin is estimated to 3.8 km (Ammar *et al*., 2007). The Xauen Bank is separated from the West Alborán Basin by a convergent thrust system located to the north of the bank, whereas the eastern and western flanks are limited by abrupt NW-SE scarps that are probably right-lateral strike-slip faults. The folds of the Xauen Bank have been confused with mud diapirs (Morley, 1993). The Xauen Bank comprises a nose of deformed deep basin sediments but the limit of the basin in line with the Jebha Fault can be observed on the northwest side of the bank (Ammar *et al.,* 2007).

Three tectonic compressional events have been defined in this area (Chalouan *et al.,* 1997). The two first events, late Tortonian and early Pliocene in age with NNE compression, affected the northern and western of the Xauen Bank. The third occurred between the Quaternary and Pliocene, with a compressional stress N150°E to N-S, and affected the northern Moroccan margin, forming a syncline south of the banks and uplifting the banks with a northern vergence of the folds and thrusts that limit the banks to the north. It has been suggested (Chalouan *et al.,* 1997) that the E-W to ESE-WNW folds are controlled by a deep Jebha Fault located beneath the bank.

## Life on and around the Seamount

No information about the benthic and pelagic communities of the has been found in the scientific literature.

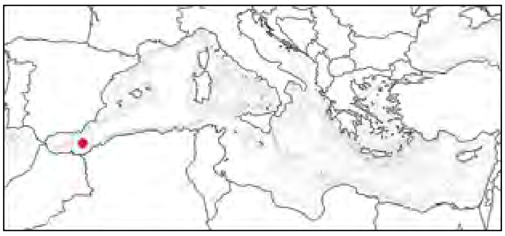
**STRUCTURE:**

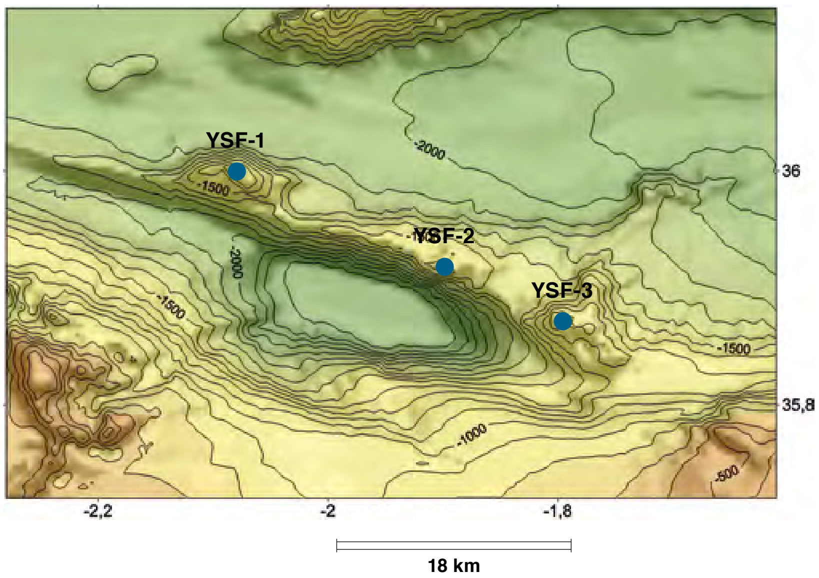
## Yusuf Ridge 1, Yusuf Ridge 2 and Yusuf Ridge 3

YSF-1 ▣ **Location:** 35.99910°N – 2.07900°W
▲ **Peak depth (m):** 1180-1190 ◭ **Base depth (m):** 1580-1590

YSF-2 ▣ **Location:** 35.91638°N - 1.89988°W
▲ **Peak depth (m):** 1400-1410 ◭ **Base depth (m):** 1560-1570

YSF-3 ▣ **Location:** 35.87130°N – 1.79890°W
▲ **Peak depth (m):** 1000-1010 ◭ **Base depth (m):** 1230-1240





**DESCRIPTION:**

### Geology

The Yusuf Ridge appears on the Geomorphological Map of Spain, published by the Instituto Geológico y Minero de España (1) and it is quoted by Díaz-del-Río *et al.* (2009). Although this structure has an official name, no geological information is available in the scientific literature.

### Life on and around the Seamount

No information about the benthic and pelagic communities of the Yusuf Ridge has been found in the scientific literature.

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