THE CANARY ISLANDS TOPOBATHYMETRIC RELIEF MAP

THE CANARY ISLANDS: ASPECT OF THE SEA BED AND GEOLOGY

INSTITUTO ESPAÑOL DE OCEANOGRAFIA 1914

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

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

This map is one of the first actions of a dissemination campaign of marine sciences in general, and of their scientific and technological activity in particular, started by the IEO to contribute to the improvement of the Spanish society scientific culture and what society knows about the Institute and its activities.

What the map is like and what it shows

It is a relief map of the sea beds, thermoformed in PVC. The map includes the topography of the terrestrial zone of the Canary Islands; its dimensions are 831 x 394 mm. Information on roads and cities has been added to the terrestrial topography.

Submarine morphology is presented encoded in colour to give the appearance of height and depth, depending on the case, thus achieving better visualisation.

In order to be better understood and be more didactic, the map was made at two different scales. The horizontal scale is 1: 700,000 for the entire map; nevertheless, the vertical one is 1: 150,000, that is, the submarine relief was exaggerated to stand out to the maximum but without distortion the relieves and forms that are meant to be known. The maximum depth represented on the map is 4,500 metres.

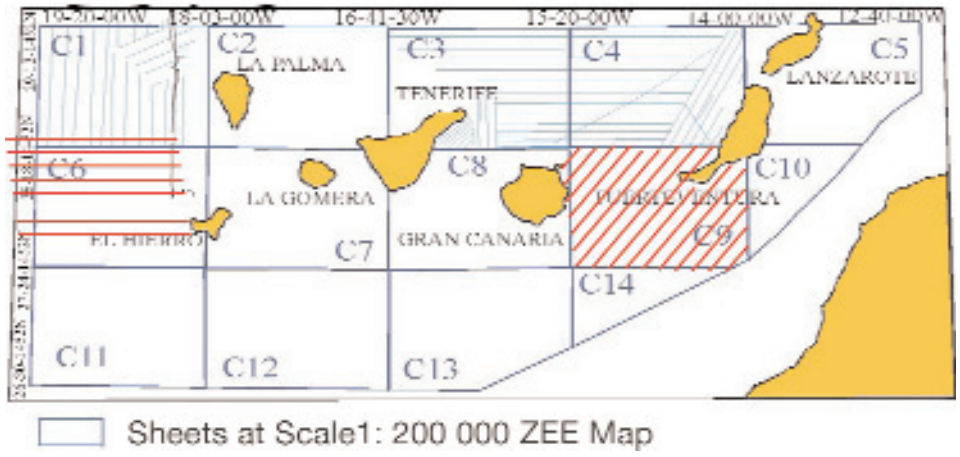
Some bathymetric curves have been drawn in the submarine part as well as punctual depths so that the real depths in metres can be identified.

Land toponymy was labelled according to the way displayed in the Spanish National Geographic Institute cartography. Submarine relieves have been labelled with the toponymy used in the charts from the Navy Hydrographic Institute.

For more learned users, the map indicates the most relevant geological facts such as submarine volcanism areas; faults, submarine canyons and areas affected by large landslides and submarine sedimentary avalanches. In the lower map banner, there is an outline of the division into physiographic provinces as well as some characteristic bathymetric profiles.

How the map was made

The land part comes from conventional cartography. The submarine one is based on data obtained with multi-beam echo sounders in oceanographic campaigns carried out between 1998 and 2002 on board of oceanographic vessels Hespérides & Vizconde de Eza, in the framework of the Spanish Exclusive Economic Zone programme (ZEE) (www.ieo.es/zee/). Magnetic and gravimetric maps have been published within the said programme. The data collection was made with last-generation technologies: multi-beam echo sounders, which provide very high accuracy in representing the submarine relief.



ZEE Programme sheets. The lines indicate the Oceanographic Vessel tracks to cover 100% of the sea bed.

The multi-beam echo sounder sends off 131 sound beams ten times a second, which does a fan-type scanning of the various points located under the vessel and thus covering the entire sea bed.

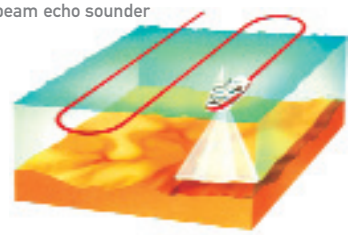
Oceanographic Vessel Hespérides. Hespérides docked at Santa Cruz de la Palma Harbour. ZEE-2000 Campaign.

Oceanographic Vessel Vizconde de Eza.

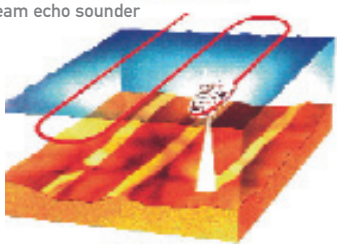
The necessary information to make this map was collected with two ships: OCEANOGRAPHIC VESSEL HESPÉRIDES, belonging to the Ministry of Education and Science, but operated by the Ministry of Defence, based in Cartagena; its full length is 82.50 m and its gross tonnage amounts to 2,709 t. It is mainly used in oceanography campaigns in Antarctica although it is used for other scientific purposes. OCEANOGRAPHIC VESSEL VIZCONDE DE EZA, belonging to the Secretariat General of Maritime Fisheries (Ministry of Agriculture, Fisheries and Food); its full length is 53 m and its gross tonnage amounts to 1,400 t. It is mainly used in fishing and oceanographic campaigns.

The multi-beam echo-sounder running scheme (above) compared to the "classic" mono-beam echo sounder (below), indicating the area of the sea bed covered by both kinds of echo sounders. The different coverage of both the mono and multi-beam echo sounders can be noticed; with the latter, the entire sea bed is "illuminated", whereas with the mono-beam there are uncovered areas between the vessel's track lines. Moreover, echo sounder densities of several hundreds of points per square metre can be achieved given the feature associated with the multi-beam echo sounders of a very high 131-beam shot rate.

Multi-beam echo sounder



Mono-beam echo sounder



This technology, along with the positioning systems based on a Global Positioning System (GPS) in differential mode, provides accuracy in the range of centimetres in the study of submarine morphology. The digital treatment of this information allows elaborating digital models of the land –using the sounds of the echo sounders– comparable to an "aerial photograph" of the sea bed.

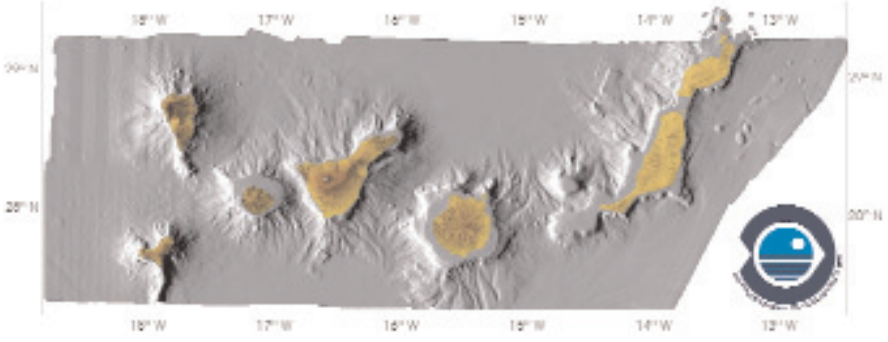
The map production and thermoforming are made stemming from real digital data. First a computer-generated mould or model is made out of solid material in three dimensions (3D). Then and by means of heat, the 3D colour map is superimposed on the PVC, which adapts to the three-dimensional mould above.

SUBMARINE MORPHOLOGY OF THE CANARY ISLANDS

The Canary Islands are volcanic ocean islands that show very special features as regards their genesis and submarine morphology. Concerning their origin, there has been a lot of speculation with several hypotheses, among which can be stated a specific origin in relation to a great fault coming from the Atlas, horsts, or the most generally accepted theory which links their origin to a "hot spot". The growth or genesis phases of ocean islands can be summarised into four:

1. - Seamount phase
2. - Shield growth phase (submarine and subaerial)
3. - Rest and deep erosion phase
4. - Post-erosive phase

Volcanism in the Canary Islands took place in several geological times, from the Cretaceous, represented in Fuerteventura Island, up to present time in the Western islands (La Palma & El Hierro). The most relevant feature of ocean islands from a morphological point of view is their permanent duality between "constructive" and "destructive" forces, which makes the island vertical growth process be regularly affected by landslide phenomena and rock and sediment avalanches. These balance the gravitational stability of volcanic buildings from time to time.



Digital model of the seabed of the Canary archipelago. This image, built up from data of the multi-beam echo sounder, shows the seabed around the Canary Islands with high resolution and in detail, and can be compared to an "aerial photo" of the ocean bed if water had been removed. The image has been lit in an artificial manner as if the sun came out from the left part of the image. The figure shows insular platforms, submarine canyons, areas and avalanche scars and submarine volcanoes, as well as rising diapirs on the east of Lanzarote and Fuerteventura Islands.

REPRESENTATION EXAMPLES FROM DIGITAL BATHYMETRY

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

Submarine landslides and debris avalanches

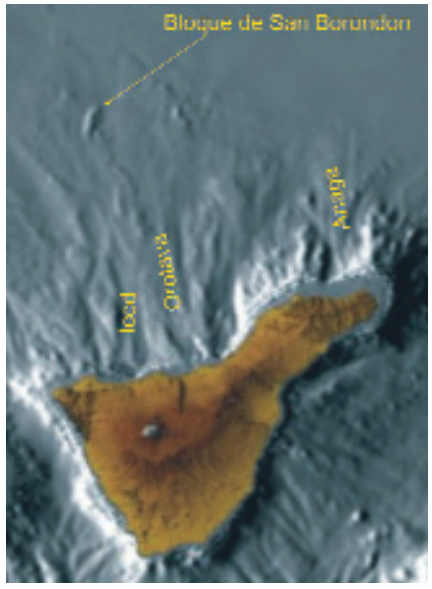
The displacements that take place as a result of the collapse of volcanic buildings can be of several kinds: landslides, debris avalanches, debris fluxes and turbidity currents, classified this way according to the kind of sediments and rocks that make them up.

Avalanches show a large extension and can transport rock blocks of kilometric magnitudes.

The information study obtained from the north coastline of Tenerife Island indicates that large debris avalanches have taken place, as the ones in Orotava and Icod. Within these large avalanches of sediments and rocks, a rocky block of kilometric size has been mapped (8 km x 3 km) located over 80 km off the present Tenerife shoreline where it comes from, and which has been labelled as "San Borondón Island" (in provenance from a Canary legend).

Just on this north façade of the insular coastline in Tenerife, the volume of sediments and slid rocks has been put at over 1,200 km^3.

Marks, scars and deposits associated with landslides and avalanches similar to the ones of North Tenerife have been mapped and identified in the rest of the islands.

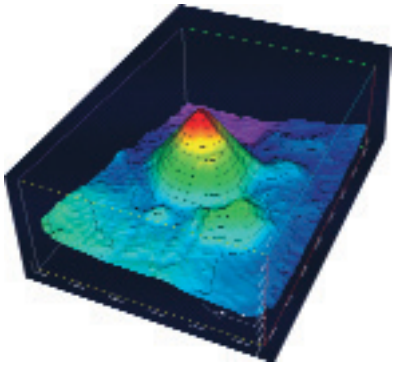


Aspect of the submarine avalanche at La Orotava, north of Tenerife Island, where the large rocky block called "San Borondón" can be spotted.

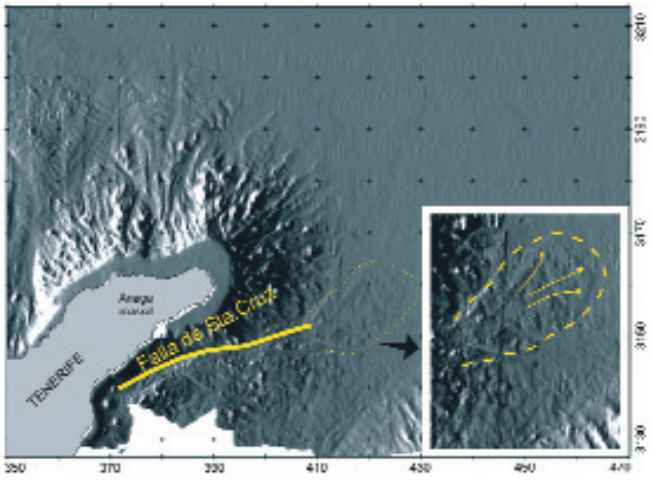
REPRESENTATION EXAMPLES FROM DIGITAL BATHYMETRY

Volcanic structures: Rift & volcanic buildings

The seabed that surrounds the Canary Islands spots the morphological existence of volcanic ridges and a large number of isolated volcanic buildings. Ridges are clearly identifiable in more modern islands: El Hierro and La Palma. In like manner, volcanic buildings are found in larger numbers round these western islands, even if other somehow isolated can be identified, such as Enmedio Volcano, located between Tenerife and Gran Canaria Islands.



3D outline of the Enmedio Volcano soil, located between Tenerife and Grand Canaria Islands. It is 2,500 m deep, and the volcano rises some 500 m over the seabed.



Digital model of the Sta. Cruz Fault soil. A sediment area in the shape of a fan can be noticed in its final part. The proposed fault has yielded the engagement of a submarine canyon.

Morphotectonics

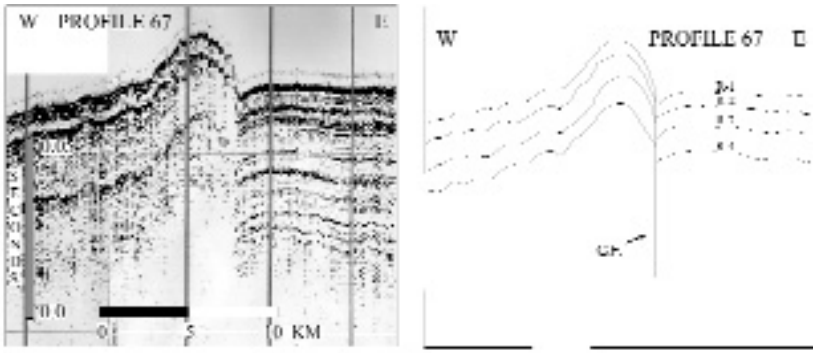
The morphological effects of tectonics on the Canary seabed have become evident from morphology studies of the seabed, supported by seismic reflection studies that provide us with information about the structure of the sea subsoil. The existence of two long faults can be stood out because of their specific interest:

- Santa Cruz Fault, which borders on and cuts the submerged part of the Anaga massif, 50 km long and which changes its direction from SW- NE to E-W.

REPRESENTATION EXAMPLES FROM DIGITAL BATHYMETRY

* Guayotá Fault, to be found 80 km NW off the Anaga massif, and has been identified from very high-resolution seismic profiles (Topas 018). It has been identified in 7 parallel profiles in E-W direction, separated 10 km between one another; therefore, the minimum length for this fault is 60 km.

Guayotá Fault (from a Canary legend, "evil god shut up in Echeyde") affects the Holocene higher sediments (> 100m) by pushing its acoustic reflectors between 25 and 30 m, and may have a morphological expression on the seabed, which accounts for a classification as an active fault.



High resolution seismic profile on Guayotá Fault. The profile shows a vertical cut under the sea floor and underground. It can be noticed the break of the reflectors (geological levels), moved away 25 m due to the fault.
GT = Guayotá Fault.

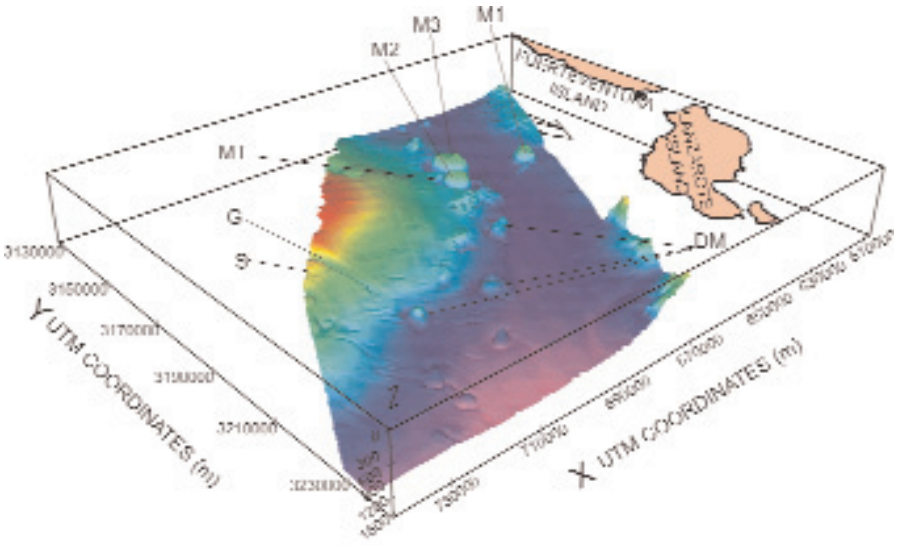
Diapirs and saline tectonics

In the Canary Channel (Channel between Fuerteventura and Lanzarote and the African coast), mounds in a circular or elliptical shape have been spotted on the seabed with relieves between 75 and 375 m on the surrounding seabed, and diameters between 4 and 8 km at their base. These mounds are partially surrounded at their base by furrows or erosive channels with depths ranging between 25 and 75 m deep.

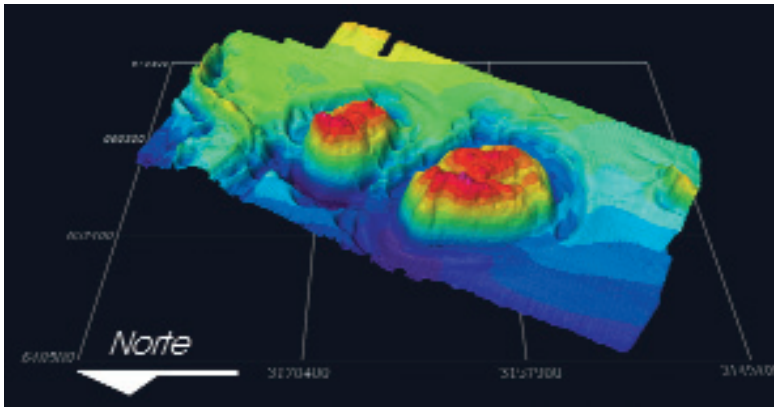
The location of Fuerteventura and Lanzarote Islands on the so-called Canary Ridge seems to

REPRESENTATION EXAMPLES FROM DIGITAL BATHYMETRY

correspond to the wall limit between the ocean crust and the continental crust. The presence of these mounds on the Canary Channel is attributed to the outcrop of evaporitic diapirs, corresponding to materials from the Triassic-Jurassic age on the African coastline and which extends offs hore towards the west, which includes the Canary Island Channel.



A 3D outline of the Canary Channel, situated between Fuerteventura, Lanzarote and the African continent. DM, M2 & M3 are diapirs. M1 is a volcanic building. The colour scale shows the seabed depth.



A detail of diapirs M2 and M3 in Hieabove figure. Erosive channels can be noticed at their bases of up to 75 metres deep. These channels can be originated by very dense water loaded with salts coming from the dissolving of diapirs.

SOME QUESTIONS AND THEIR ANSWERS

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

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

Does the seabed really look like this?

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

What is a bathymetric profile?

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

What is a physiographic province?

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

What is the Hot Spot theory?

It is a theory proposed by Canadian geologist J. Tuzo Wilson, based on the existence of (fixed) magma outflows or mantle plumes from the earth mantle which, on reaching the tectonic plates (crust) that moves along the fixed mantle plume called “hot spot”, create successive chained volcanoes whose age varies according to the movement on the plate. On these volcano chains, only the ones that happen to be on the “hot spot” at that moment will be active and will be the youngest ones.

Why so many submarine avalanches and landslides take place on the Canary margins?

Submarine avalanches and landslides on ocean islands are a widespread feature of these islands as a result of their so-quick growth process. Islands rise from the ocean bed and quickly grow

SOME QUESTIONS AND THEIR ANSWERS TO KNOW MORE

vertically until, due to their tall height and the intrusion of a large number of dikes, part of them becomes unstable and push away the material they are made of under the form of avalanches and of sediment and rock landslides by the effect of gravity.

What is a fault?

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

What are evaporitic diapirs?

A diapir is an anticline fold originated by the extrusive outflow of plastic materials (clays, salts and plasters) from the depths. This low-density and high-plasticity saline mass drills the overlaying strata on its way upwards and expands over them yielding a dome-like structure. The represented ones in the Canary Island Channel rise over the surrounding seabed some hundred meters.

IN ORDER TO KNOW MORE

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He was a guest researcher at Woods Hole Oceanographic Institution (USA) between 1978 and 1980 and has taken part in over 70 oceanographic campaigns.
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He has been an honorific professor of the Geodynamics Department of the Geological Sciences Faculty at the Complutense University of Madrid (UCM) since 1991, where he is the coordinator and co-director of the Course on Oceanographic Research Techniques Applied to Geological Engineering and to the Environment.