

for the future is an activity by which experts from developed countries can make a significant humanitarian contribution to those who need it.

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Fig. 3. Three-dimensional model for part of Dubai. The height of each building is estimated from its shadow. On the basis of this analysis, the numbers of buildings in each of four classes (single story, 2–5 stories, 6–10 stories, more than 10) have been counted. (Courtesy of Informap Inc., Dubai).

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New Gravity Map of the Western Galicia Margin: The Spanish Exclusive Economic Zone Project

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Since 1995, the most intensive mapping of the seafloor off the Spanish coast has been carried out in the framework of the Spanish Exclusive Economic Zone Project (ZEEE). The main objectives of this project are to obtain improved multibeam bathymetric cartography of the areas off Spanish coastlines, and to perform a geophysical survey, well-suited with a 10-knot navigation velocity (some techniques requires lower navigation velocity).

The geophysical survey includes gravity, geomagnetism, and low-penetration seismic techniques in order to infer the geological structure of the seafloor. Other oceanographic variables such as current, surface salinity, and temperature profiles, can be recorded without compromising this systematic survey effort.

The ZEEE Project has carried out its survey activities for one month every year. Data acquisition is achieved aboard the Spanish

R/V *Hesperides*. Until 1997, surveying efforts concentrated on the Balearic Sea and Valencia Gulf, both in the western Mediterranean Sea. Between 1998 and 2000, the ZEEE Project investigations were conducted offshore the Canary Archipelago. Since 2001, the third phase of the program has been focused on the West Galicia Margin in the northeastern Atlantic Ocean.

Survey results on the West Galicia Margin area are of interest for two key reasons. First, there is great scientific interest in the improvement of the knowledge of this non-volcanic rifting margin, since this margin offers good conditions for the study of the processes that take place in this type of geological context, because it is sediment-starved.

Second, the obtained results also have major socioeconomic repercussions because they can prove significant to defining the expansion of the Spanish shelf, beyond Spain's Economic Exclusive Zone distance of 200 nautical miles.

All of the gravity data acquired to date on this area have been stored as a database, with the aim of preparing gravity anomaly maps on a scale 1:200,000. The database and gravity

anomaly charts from the ZEEE Project will provide the most coherent and complete gravity perspective available for this area.

This article describes the efforts and accomplishments of the project to date.

The West Galicia Margin

The West Iberia non-volcanic margin and, in particular, the West Galicia Margin, have been the subject of different marine geology studies during the past few decades [e.g., Boillot *et al.*, 1988; Henning *et al.*, 2004]. These studies have increased the knowledge of the structures and evolution of the North Atlantic Ocean, especially during Mesozoic and Cenozoic times.

This margin was developed by the northward propagation of the Atlantic Ocean opening during Mesozoic times. During the Cenozoic, the convergence between the Eurasian and Iberian plates generated compressive features and the reactivation of Mesozoic extensional structures (i.e., normal margin-parallel faults) to the north of the Galicia Margin.

Consequently, some of the continental basement blocks were uplifted, leading to the formation of a region of submarine banks, the biggest of which is the Galicia Bank. These submarine banks form a sedimentary fence between the Galicia Interior Basin and the Iberia Abyssal Plain (Figure 1).

Between the submarine banks and the Iberia Abyssal Plain, the ocean-continent transition zone is defined as a narrow region, a few tens of kilometers wide, in which an abnormally

thin oceanic crust, underlain by a serpentinized peridotite body, is described. Westward, that peridotite bulk rises to the sea bottom as a basement high, which extends at least several tens of kilometers, parallel to the margin.

Because presumed synrift (i.e., contemporaneous with the rift episode) sediments are present on seismic profiles east of the peridotite ridge but are absent to the west, this high has been assumed to mark the ocean-continent boundary [Boillot *et al.*, 1989], although the process of its emplacement is still under discussion.

The ZEE Gravity Database and Charts

More than 250 track lines (for a total of >10,000 nautical miles) have been surveyed on the West Galicia Margin. Coverage of the surveyed lines is not uniform, with survey lines planned in order to obtain a full seafloor bathymetric coverage by the Simrad EM-12000 multibeam echo sounder used aboard the R/V *Hesperides*. Land gravity data from Spain's Instituto Geográfico Nacional database were used to avoid border errors near the coastline in the study area.

Ship gravity data were collected using a Bell Aerospace BGM-3 gravity system, with an automatic pitch and roll elimination. These data were merged with navigation information obtained by differential Global Positioning Systems integrated with the R/V *Hesperides*'s central navigation system, and the Eötvös effect (related to acquiring gravity measurements on moving platforms) was corrected. The offshore gravity data set was corrected for instrumental drift, and was tied into the land network through the Instituto Geográfico Nacional gravity bases of Cartagena (in south-eastern Spain) and Santander (in northwestern Spain).

Bouguer anomalies and sea bottom correction were calculated using a digital elevation model (DEM) with a 2-km grid size following the procedure of Carbó *et al.* [2004].

Regional Gravity Map

Bouguer anomaly maps with sea bottom terrain correction allow the interpretation, in terms of density and depth variations, of the bodies generating the anomalies below water slab. In that sense, the Bouguer anomaly map of the Western Galicia Margin allows the recognition of signatures in the crust, and also provides new information for future lithosphere structure studies on the area.

A Bouguer anomaly map of the Western Galicia Margin is shown in Figure 1. Bouguer anomaly values range from +20 milligal (mGal) near the coastline, to more than +370 mGal over the oceanic crust of the Iberia Abyssal Plain. To the north and the west of the study area, where the Bouguer anomaly values are higher, the transition takes place steeply through various elongated high gradient zones that are oriented NNW-SSE to N-S and NE-SW. These directions are coincident with those of the principal tectonic structures previously described on the margin [Malod *et al.*, 1993].

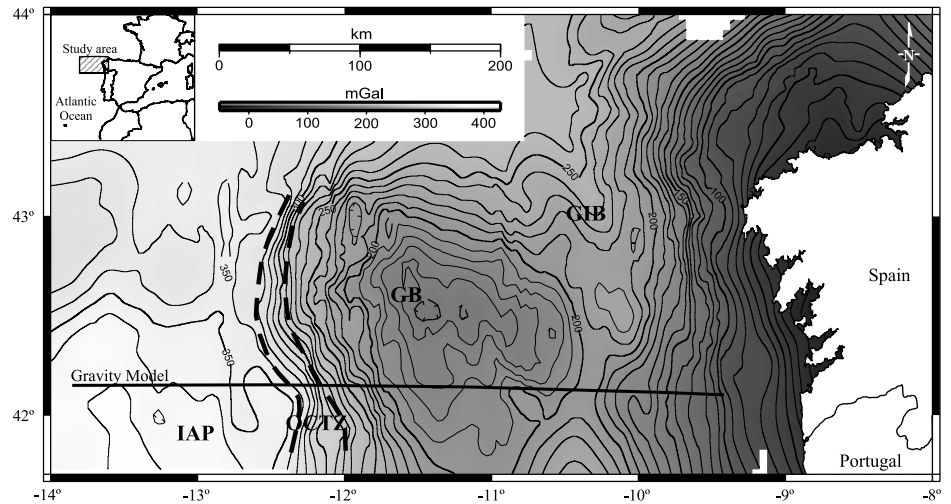


Fig. 1. Bouguer anomaly map of the Western Galicia Margin, with contours every 10 mGal. The location of the gravity model (Figure 2) is shown. The broken line marks the preliminary proposed limits of the ocean-continent transition zone (OCTZ). GIB = Interior Galicia Basin; GB = Galicia Bank; and IAP = Iberia Abyssal Plain.

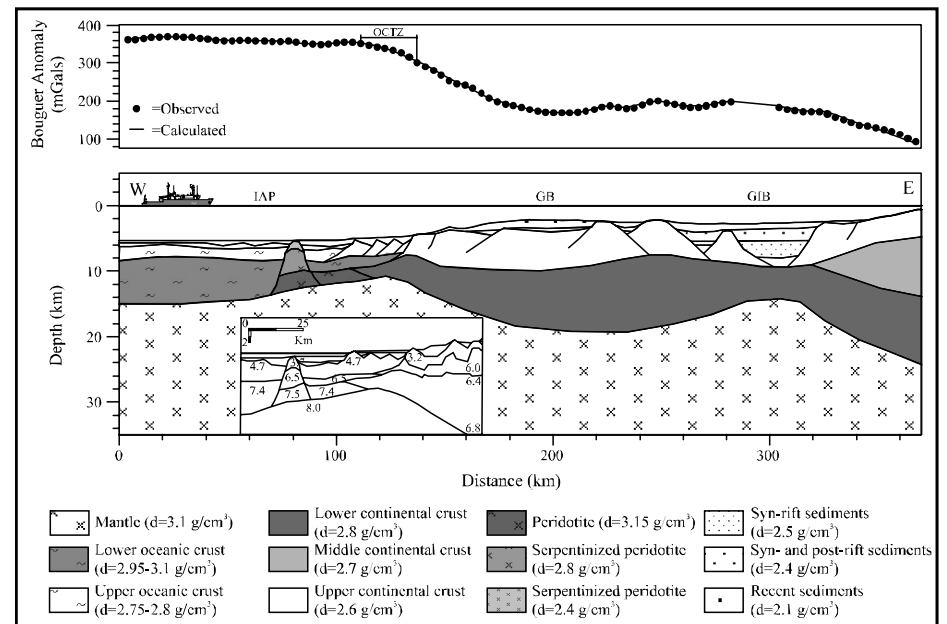


Fig. 2. Two-and-a-half dimensional gravity model of the southern West Galicia Margin (located in Figure 1). The seismic model (modified from Sibuet *et al.* [1995]) is drawn at the same scale of the gravity model (seismic velocities in km/s). The ocean-continent transition zone (OCTZ) is defined by the high gradient in the Bouguer anomaly profile.

A great minimum in the Bouguer anomaly values can be distinguished on the area of the Galicia Bank, related to the continental character and high thickness of the crust in this region. Eastward from this low, a relative maximum axis, oriented NNW-SSE, is observed over the Galicia Interior Basin zone. This axis is associated with the extreme stretching of the continental crust in this area, where the Moho surface is present at a minimum depth of 14 km, approximately, including the water slab [Pérez-Gussinyé *et al.*, 2003].

Over the Iberia Abyssal Plain are some high-frequency and low-amplitude aligned gravity highs, whose locations agree with those of the peridotite ridge described on the margin [Whitmarsh *et al.*, 1993]. The ocean-continent

transition zone is identified here as a zone with a Bouguer anomaly gradient of nearly 2.5 mGal/km (Figure 1).

Forward Modeling

A W-E profile (Figures 1 and 2) has been selected, which is perpendicular to the direction of the main structures and high gravity gradient zones described on the margin. This profile allows a reconstruction of the crust at the West Galicia Margin.

Gravity models have been executed in 2+1/2D (a two-dimensional model in which a third dimension, the perpendicular prolongation of the bodies, has been taken into account during its construction) [Campbell, 1983], using

Bouguer anomaly values and assuming a lateral extent of at least 50 km for cortical bodies and a variable lateral extent for sedimentary bodies such as semigraben (i.e., asymmetric, fault-bounded, extensional basin).

Thirteen different materials have been considered on the basis of refraction data from Sibuet *et al.* [1995]. Density-seismic velocity correspondence, shown in Figure 2, is derived from empirical relations [Ludwig *et al.*, 1970].

To constrain some cortical features, data were used from the seismic refraction profile interpretation by Sibuet *et al.* [1995], as well as from the seismic reflection profiles from Murillas *et al.* [1990]. The model has first been adjusted in zones with major seismic control and relatively few uncertainties (the ocean-continent transition zone and Galicia Interior Basin), and then extended toward those areas where seismic data are scarce.

The gravity profile shows a discontinuous increase from values close to +200 mGal eastward to even more than +350 mGal in the west (Figure 2). A relative maximum is related to the extremely stretched continental crust of the Galicia Interior Basin, whereas a relative minimum is identified over the Galicia Bank where the continental crust is thicker.

The profile presents a zone of strong gradient from kilometer +120 to +160 that has been related to the transition between continental and oceanic crust. Bouguer anomaly values become nearly plane toward the west following a relatively constant guideline over +340 mGal, being indicative values of "normal" oceanic crust as suggested by the gravity models.

Bouguer anomaly values become nearly plane toward the west following a relatively constant guideline over +340 mGal, being indicative values of "normal" oceanic crust as suggested by the gravity models. To go beyond Bouguer anomaly values of +340 mGal with a constant guideline, can be established as a

criterion to define the "normal" oceanic crust. Carrying out new models, similar to the one presented here, it is possible to delimit the ocean-continent boundary as preliminarily proposed in Figure 1. This location of the boundary from gravity data is a few tens of kilometers eastward from that previously established on the peridotite ridge according to a sedimentary criterion [Boillot *et al.*, 1989].

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NEWS

New Vegetation Index Data Set Available to Monitor Global Change

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A consistent, 2-decade or longer vegetation record is needed to detect trends in global land cover and climate change. With the longest record starting in 1981, vegetation data from the Advanced Very High Resolution Radiometer (AVHRR) have played a key role in detecting changes in vegetation caused by global temperature increases.

NASA's Global Inventory Modeling and Mapping Studies (GIMMS) group has recently produced a new global vegetation data set at 8-km resolution from 1981 to 2004. Maximizing

the length, stability, and quality of the AVHRR data set, the GIMMS Normalized Difference Vegetation Index (NDVI) data will enable new Earth science conclusions and continuous monitoring of vegetation dynamics during the next decade.

Since the first demonstrations of the capability of the AVHRR to measure Earth surface conditions [Tucker *et al.*, 1985], there has been intense interest in using the continuous record to monitor Earth surface conditions at a regional to global scale. Spectral vegetation indices are the most widely used of any of the products derived from the AVHRR instruments [Cracknell, 2001], a development not anticipated by the designers of the AVHRR instruments.

Using AVHRR data, Myrneni *et al.* [1997] showed evidence of a lengthening of the growing season at northern latitudes. Recently, Nemani *et al.* [2003] showed that changes in the climate caused a net primary production increase of 6% in the northern latitudes (3.4 petagrams (Pg) of carbon over 18 years). However, these and other authors have had to resort to ad hoc corrections and to adopt various vicarious calibration strategies in order to use the data.

NDVI from the AVHRR record suffers from some significant limitations, including the use of outdated and inadequate calibration, partial atmospheric correction, and small signal-to-noise ratios [Tucker *et al.*, 2004].

AVHRR has significantly more problems in correcting for atmospheric effects than the newer sensors (e.g., SeaWiFS: Sea-Viewing Wide Field-of-view Sensor, and MODIS: Moderate-Resolution Imaging Spectroradiometer) designed to measure vegetation dynamics due to wide spectral bands. The AVHRR sensor also has the additional problem of incorporating data from seven different AVHRR instruments on six U.S. National Oceanic and Atmospheric Administration polar orbiting meteorological satellites that suffer from orbital drift [Cracknell, 1997; Kidwell, 1998, 2000].

The GIMMS data set removes the effects of these issues with a correction using Empirical Mode Decomposition (EMD) designed for non-parametric and non-stationary data [Pinzon *et al.*, 2004]. These corrections result in a stable time series appropriate for trend analysis (Figure 1).

The GIMMS data set integrates the most recent AVHRR instruments (NOAA 16 and 17) into