2022 EAGE ANNUAL
83RD CONFERENCE & EXHIBITION
MADRID I SPAIN

MARIBNO AMPHIBIOUS PROJECT: ROLE OF THE INHERITED TECTONICS IN THE STRUCTURE OF THE NORTHWESTERN IBERIAN MARGIN

A. Muñoz-Martín[1,2], J. Granja-Bruña[1], M.Á. De la Fuente-Oliver[1], M. Druet[3], G. De Vicente[1,2], J. Gallastegui Suarez[4], A. Maestro[3]

[1] Complutense University of Madrid; [2] Instituto de Geociencias (IGEO CSIC-UCM); [3] Instituto Geológico y Minero de España; [4] Universidad de Oviedo

Summary

The northwestern margin of the Iberian Peninsula (western Bay of Biscay) is a unique place that can be considered as a natural laboratory to study the role of tectonic inheritance in the evolution of the extensional continental margins and their subsequent inversion. Because this scientific interest it is being carried out MARIBNO amphibious project, headed by the Complutense University of Madrid, for the acquisition of offshore-onshore geophysical-geological data. The project has three main objectives: 1) Study of the along- and across-strike crustal structure in the western end of the Cantabrian range and its adjacent continental margins (N-S trending Atlantic margin and E-W trending Cantabrian margin); 2) Study of the tectonic control of inherited Cretaceous rift structures during the Alpine compression (i.e., tectonic inversion); and 3) Mapping and characterization of the crustal domains, combining geological and geophysical criteria. The MARIBNO project is still underway (2019-2022). Data acquisition was completed up to 85%, but this large dataset is still being processed and preliminary interpreted. Acquired information will be complemented with onshore gravity and magnetic data and geological field mapping on seismic transects throughout the Cantabrian Mountains. Here we show the current development of the MARIBNO amphibious project and some preliminary data.

MARIBNO amphibious project: role of the inherited tectonics in the structure of the northwestern Iberian margin

Introduction

The northwestern margin of the Iberian Peninsula (western Bay of Biscay) is a unique place that gathers several outstanding geological features in a relatively reduced area. Here, a former hyperextended continental margin developed in proximity to a triple point, underwent a subsequent partial tectonic inversion yielding the present Cantabrian margin (Fig. 1). For all these reasons, the northwest area of Iberia can be considered as a natural laboratory to study the role of tectonic inheritance in the evolution of the extensional continental margins and their subsequent inversion. However, and largely due to the lack of interest from exploration companies, the northwestern margin of Iberia presented a great deficit of geophysical and geological information. Both scientific interest and the lack of information provided the main reasons for the MARIBNO amphibious project (see study area in Fig.1). This project is being carried out by a multidisciplinary geoscientific team, headed by the Complutense University of Madrid, for the acquisition of offshore-onshore geophysical and geological data. The project has three main objectives: 1) Study of the along- and across-strike crustal structure in the western end of the Cantabrian range and its adjacent continental margins (N-S trending Atlantic margin and E-W trending Cantabrian margin); 2) Study of the tectonic control of inherited Cretaceous rift structures during the Alpine compression (i.e., tectonic inversion); and 3) Mapping and characterization of the crustal domains, combining geological and geophysical criteria.

The MARIBNO project is still underway (2019-2022). In the endo of 2021 the data acquisition was completed up to 85%, but this large volume of information is still being processed and preliminary interpreted. Acquired information will be complemented and combined with the additional acquisition in 2022 of onshore gravity and magnetic data and the information from several geological field mapping studies on seismic transects throughout the Cantabrian Mountains. Here we show the current development of the MARIBNO amphibious project and some examples of preliminary data.

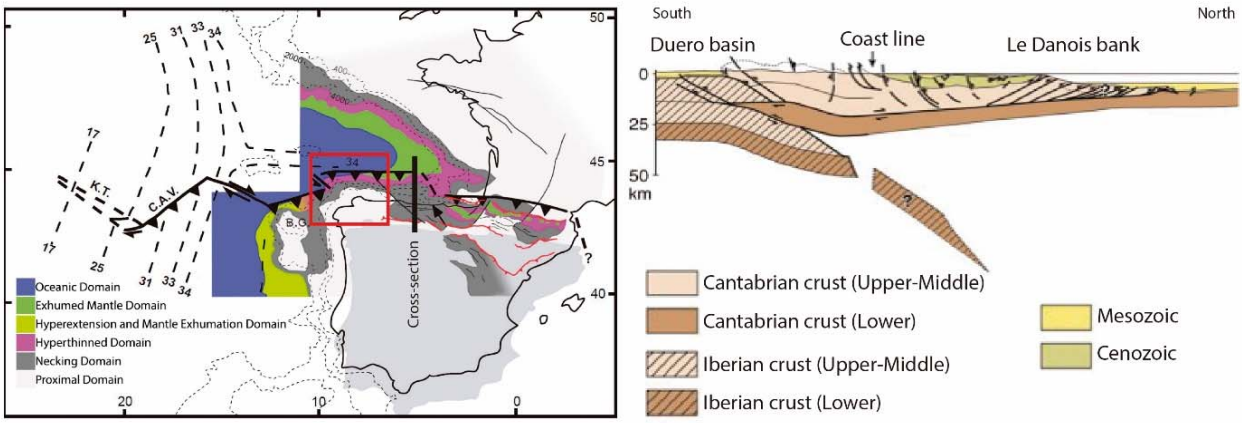

Figure 1 *Left) Scketched map showing the convergent-trancurrent northern boundary of the Iberian plate during the Eocene and magnetic anomalies in the NE Atlantic. Modified from Grimaud et al. (1982) and Gallastegui (2000), and including the crustal domains defined by Tugend et al. (2014) and Druet et al. (2018). Red inset shows the study area. The shaded region show the position of Iberia in the Isocron 33 and its motion between the Paleocene and Eocene is indicated with an arrow. B.G: Galicia bank. K.T.: King's Trough; C.A.V.: Azores-Vizcaya ridge. Isobaths en meters. Rigth) Schematic NS crustal cross-section of the Cantabrian margin (modified from Gallastegui 2000).*

Tectonic setting

The complex crustal structure of the northern Iberian margin is the result of the tectonic inheritance and the diverse geodynamical processes that have taken place over time (Fig. 1). These processes started with the collapse of the Variscan orogen in the Permian and the subsequent development of a rift stage

in the Lower Jurassic, yielding the opening of the Central Atlantic, where the oceanic crust begins to form, and continues with the northward propagation of the Central-Atlantic ridge. Between the Upper Jurassic and the Albian took place the individualization of Iberia, which separates from Eurasia by means a counterclockwise rotation. Later, the Iberian microplate progressively moves towards the southeast causing the opening of the Bay of Biscay from west to east, giving rise to the formation of the Cantabrian and Armorican margins. The opening of the Bay of Biscay and the creation of oceanic crust continues in time until the beginning of the Campanian (Gallastegui 2000). From the Upper Cretaceous, a NW-SE convergence between the Iberian and European plates begins, which gives rise to the formation of the Pyrenees and the Cantabrian Mountains until the Miocene (Roest and Srivastrava 1991). The partial closure of the Bay of Biscay occurs between the Paleocene - Eocene due to the beginning of subduction in the margin (Le Pichon et al. 1971). During convergence, the Iberian plate is subducted below the European in the east (Gallastegui 2000). This polarity, as the deformation progresses westwards, inhibits the development of subduction along the N Iberian margin in the study area.

The stacking of all these structures and tectonic regimes have yielded a complex and irregular development of the crustal domains along and across the margin, with an apparent consumption of the exhumed mantle domain during the tectonic inversion NW of Iberia. This complex evolution is reflected in the asymmetry of the tectonic domains and the development of the continental shelf in the North and South of the Bay of Biscay (e.g., Tugend et al. 2014 and Druet et al. 2018).

Data and methods

The aims of the MARIBNO amphibious project are intended to be achieved through the integration and combined interpretation of new geophysical and geological information recorded offshore and onshore. Amphibious research requires a precise coordination of the research working group and the use of a wide range of instruments and systems. Offshore facilities are managed by the Marine Technology Unit (UTM) and onshore instruments by the LABSIS-GEO3BCN, both belonging to the Superior Council of Scientific Investigations (CSIC), and to a lesser extent by the Complutense University of Madrid (UCM: gravimeter and magnetic gradiometer). The project addresses geological-geophysical aims at crustal scale using tested research techniques widely used by the scientific community. Offshore and onshore data acquisition are being carrying out under the authorization of the Spanish Government regulations and then guarantying minimum impact for the natural environment.

In September-October of 2021 it was carried out a geophysical cruise aboard the BO Sarmiento de Gamboa (CSIC). Data acquisition lasted 30 days and was divided in two cruise legs (Fig. 2): WAS Leg (Wide-Angle Seismic) and MCS Leg (Multi-Channel Seismic). The WAS Leg consisted in the acquisition of wide-angle seismic data along 3 transects with simultaneous offshore-onshore recording in 3 component short-period instruments (ocean bottom seismometers, OBS; land stations, LS): Transect WAS-1 (~320 km) was recorded in 14 OBS and 11 LS, Transect WAS-2 (~260 km) was recorded in 12 OBS and 10 LS, and Transect WAS-3 (~255 km) was recorded in 9 OBS and 12 LS. During the cruise, the UTM provided 14 OBS (LCheapo 4x4 by Scripps Institution of Oceanography) that were deployed three times, along each seismic transect. The onshore setup consisted in one single deployment with 33 LS (Spidernano with Geospace GeoMiniseis 2Hz sensor provided by the LABSIS-GEO3BCN-CSIC) that were divided in the three seismic transects. The active seismic signal was generated each 90 seconds (i.e., shot interval) by two GGUN-II arrays with a total volume of 4660 ci and submerged 15 m. The MCS leg consisted in the acquisition of 2D multi-channel seismic reflection data along 14 transects (~1500 km) recorded on a digital streamer with a 12.5 m channel-interval (Fig. 3). During the cruise, we used several streamer configurations depending on the chase boat availability and sea weather conditions: 480 channels (~6 km), 240 channels (~3 km) and 168 channels (~1.5 km). The active seismic signal was generated each 37.5 m (i.e., shot interval) by one GGUN-II array with a total volume of 1960 ci and submerged 7 m.

During both legs, a continuous marine acquisition of swath bathymetry, gravity, geomagnetics and ultra-high resolution seismic data also were carried out. The seafloor was sounded between 50 and 5000

m of water depth by means the hull-mounted multibeam Hydrosweep ATLAS DS echo-sounder system. Gravity data were acquired with the hull-mounted Lacoste and Romberg Air-Sea II marine gravimeter and linked to the Spanish absolute gravity network (National Geographical Service) by means a portable Scintrex CG-5 gravimeter. Geomagnetic data were acquired with a SeaSpy marine magnetometer that was towed 200 m behind the research vessel. Ultra-high resolution seismic data were acquired with the hull-mounted ATLAS PARASOUND P-35.

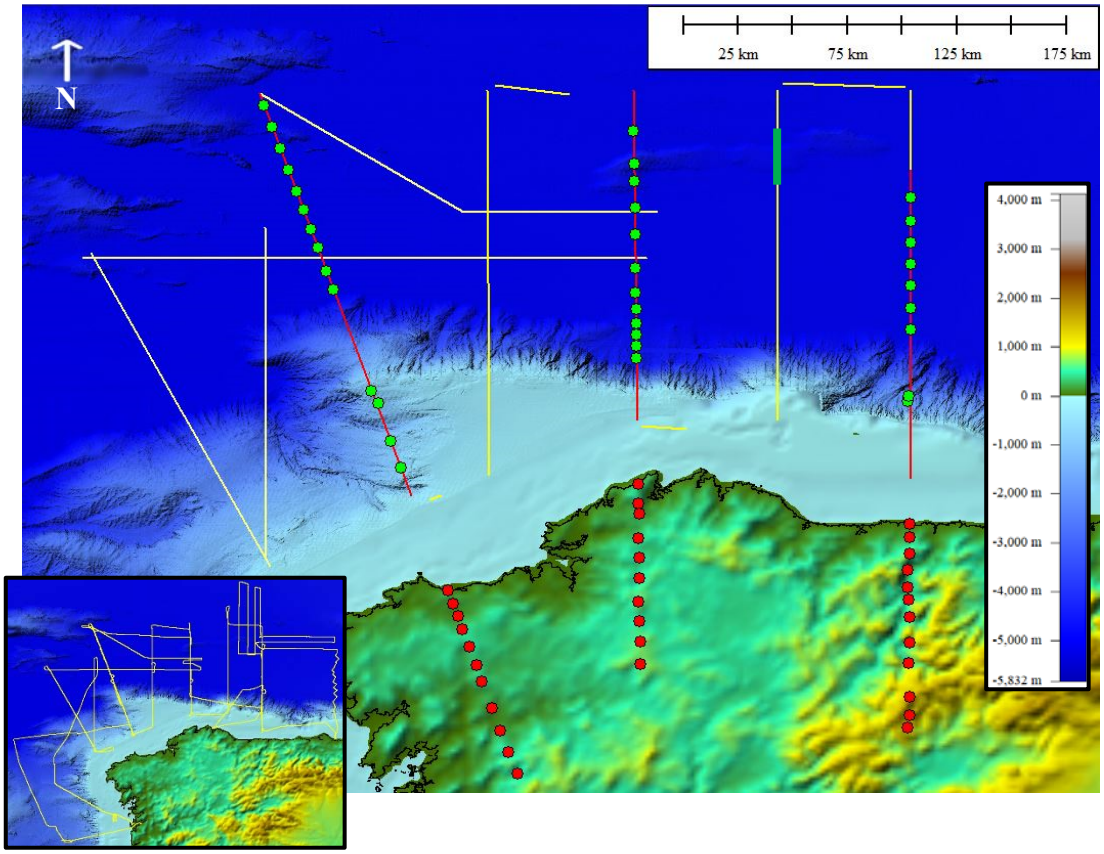

Figure 2 *Survey plan carried out in September-October of 2021. Background is a GEBCO30 elevation model. Red lines show the shooting lines during the WAS Leg. Green circles show the OBS position. Red circles show the LS position. Yellow lines show the seismic acquisition in the MCS Leg. The inset shows the navigation lines of the MARINO cruise. Green line shows the location of Figure 3.*

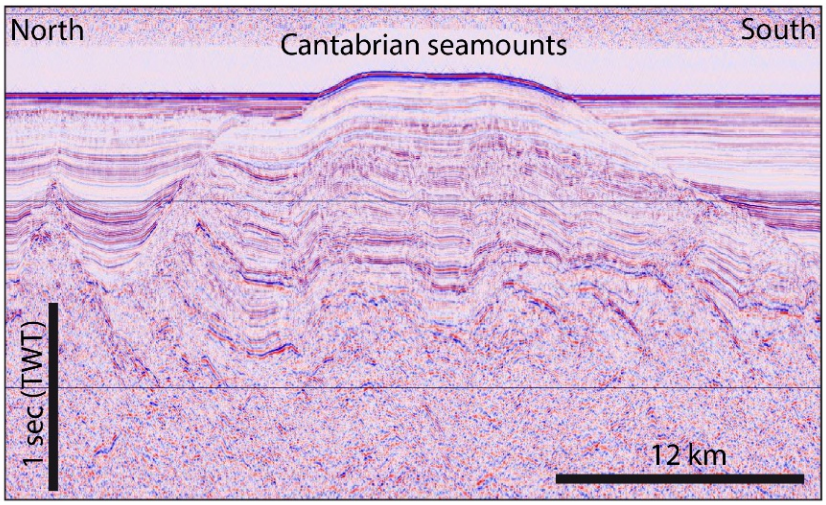

Figure 3 *Example of a 2D MCS profile showing tectonic inversion structures in the inner region of the Bay of Biscay. Data comes from an onboard migrated brute stack. See location in Figure 2.*

Conclusions

The MARIBNO amphibious project has completed the 85% of the planed data acquisition. This information includes 835 km of wide-angle seismic, 1500 km of multi-channel seismic, 4180 km of gravity data, 2530 km of geomagnetic data and 4030 km of ultra-high resolution seismic data. The project is still in progress and the acquired information will be complemented and combined with the additional acquisition in 2022 of onshore gravity and magnetic data and with the information from several geological field mapping studies on seismic transects throughout the Cantabrian Mountains. The large volume of new acquired data will fill an anomalous gap of information in the study of the Iberian margins. The interpretation of new data will provide valuable insights of the crustal structure in the western end of the Cantabrian margin and for extension in the geodynamic evolution of the Bay of Biscay.

Acknowledgements

The MARIBNO amphibious project is founded by the Spanish Ministry of Science (PGC2018-095999-B-I00). M.A De la Fuente-Oliver is supported by a PhD. grant from the Spanish Ministry of Education (FPU19/03377). We are indebted to the crew and technicians of the R/V Sarmiento de Gamboa for their professional help at sea. The professional work of the technicians of the Unidad de Tecnología Marina (UTM-CSIC) and the LABSIS-GEO3BCN-CSIC is greatly appreciated.

MARIBNO working group: Univ. Complutense de Madrid (Muñoz-Martín, A., Granja-Bruña, J.L. De la Fuente-Oliver, M.A., De Vicente, G., Benito Sáez, A., Castillo García, I., Gamisel Muzás, A., Gorosábel-Araus, J.M., Granado, C., Liaño Velasco, S., Muñoz-Cemillán, A., Pertuz Domínguez, A., Prieto Rodríguez, N., Real Malats, L., Rebollada Merino, M.T., Rodríguez Ortega, A., Rodríguez-Zurrunero, A., Villabona Díaz, J.C.), Instituto Geológico y Minero de España (Druet, M., Maestro, A., Bohoyo, F., Fernández-Sáez, F.), Univ. Nacional de Educación a Distancia (Antón, L.), Univ. Rey Juan Carlos (Martín, S.), Real Instituto y Observatorio de la Armada (Pazos García, A., Catalán, M., Cabieces, R., Fiz Barrena, J., Peña García, J.A.). Repsol Exploración S.A. (Olaiz, A.J.), Inst. Ciencias del Mar (ICM-CSIC) (Carbonell, R.), Inst. Español de Oceanografía (Gómez-Ballesteros, M., Díez García, I., Tello, M.O.), Geociencias Barcelona-CSIC (GEO3BCN-CSIC) (Gómez de la Peña, L.), Univ. de Oviedo (Gallastegui Suarez, J., Díaz González, A., Gallastegui Vega, J., Olivar Castaño, A., Pedreira, D., Alonso, J.L.), Inst. Hidrográfico de la Marina (Espinosa, S., Martín León, H.)

References

Druet, M., Muñoz-Martín, A., Granja-Bruña, J.L., Carbó, A., Acosta, J., Llanes, P., and Ercilla, G. (2018). Crustal Structure and Continent-Ocean Boundary Along the Galicia Continental Margin (NW Iberia): Insights from combined gravity and seismic interpretation. *Tectonics*, 37(5), 1576–1604. https://doi.org/10.1029/2017TC004903

Gallastegui, J. (2000). Estructura cortical de la cordillera y margen continental cantábricos: Perfiles ESCIN-N. *Trabajos de Geología* (Vol. 29).

Grimaud, S., Boillot, G., Collette, B.J., Mauffret, A., Miles, P.R., and Roberts, D.B. (1982). Western extension of the Iberian-European plate boundary during the Early Cenozoic (Pyrenean) convergence: A new model. *Marine Geology*, 45(1–2), 63–77. https://doi.org/10.1016/0025-3227(82)90180-3

Le Pichon, X., Bonnin, J.C., Francheteau, J. y Sibuet, J.C. (1971): Une hypothèse d'évolution tectonique du Golfe de Gascogne. In: Histoire structurale du Golfe de Gascogne (J. Debysier, X. Le Pichon y M. Montadert, Eds.). *Technip, París*: VI.11.1-VI.11.44

Roest, W.R., and Srivastava, S.P. (1991). Kinematics of the plate boundaries between Eurasia, Iberia, and Africa in the North Atlantic from the Late Cretaceous to the present. *Geology*, 19(6), 613. https://doi.org/10.1130/0091-7613(1991)0192.3.CO;2

Tugend, J., Manatschal, G., Kusznir, N.J., Masini, E., Mohn, G., and Thinon, I. (2014). Formation and deformation of hyperextended rift systems: Insights from rift domain mapping in the Bay of Biscay-Pyrenees. *Tectonics*, 33(7), 1239–1276. https://doi.org/10.1002/2014TC003529