High resolution mapping and seismic imaging in seismogenic zones: Application in SW Iberia and Almeria margin

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1.Introduction

The SW margin of the Iberian Peninsula hosts the present-day convergent boundary between the European and African Plates. Plate convergence is about 4 mm/yr and is accommodated over a wide and diffuse deformation zone (Sartori et al., 1994) characterized by a significant and widespread seismic activity (e.g. Buforn et al., 1995; Stich et al., 2005), source of the largest events in Western Europe, such as the 1755 Lisbon Earthquake and Tsunami (Mw 8.5) and 1969 Horseshoe Earthquake (Mw 7.0) (Baptista et al., 1998; Fukao et al., 1973; Stich et al., 2005).

Opposite, although the present-day crustal deformation of the Southeastern margin of the Iberian Peninsula (Almeria Margin) is also driven mainly by the NW-SE convergence (4-5 mm/yr) along the African Eurasian plate, the seismic activity is mainly characterized by low to moderate magnitude events. In particular, the continental margin south of Almeria, located at the NE Alboran Sea (Western Mediterranean) is an active area characterized by recent swarms of shallow moderate earthquakes (Mw 5.1 and 4.7), although large, destructive earthquakes may also occur, such as the historical Almeria Earthquake in 1522 (I > IX).

Since 1998, successive marine geophysical surveys based on multibeam, sidescan sonar, high-resolution and multichannel seismics and sampling have been carried out in the outer Gulf of Cadiz and the Southeastern margin of the Iberian margin.

In the SW margin of the Iberian peninsula, the data revealed several active west-verging thrusts (e.g. Marques de Pombal, Sao Vicente, and Horseshoe Faults) located <100 km offshore Portugal (e.g. Zitellini et al., 2001; Gràcia et al., 2003a, Terrinha et al., 2003). Folding and reverse faulting of the Quaternary units together with the swarm of surface seismicity along these structures suggest present-day tectonic activity (Gràcia et al., 2003b; Terrinha et al., 2003), which may pose a significant earthquake and tsunami hazard to the coasts of Portugal, Spain and Morocco. We focussed in the Marques de Pombal fault block, where we have identified numerous slope instabilities. We present the morphology and structure of slope failures and deposits, and discuss possible relationships with past large earthquake events.

In the Almeria Margin, a multidisciplinary dataset comprising high-resolution TOBI sidescan sonar, Simrad EM12S swath-bathymetry and backscatter, and TOPAS parametric echo-sounder was acquired onboard the Spanish RV Hesperides with the main objective of identifying active structures and potential sources of earthquakes in the frame of the HITS project. This high-resolution dataset, fully covering an area of 35 x 100 km and water depths ranging from 80 m to 1800 m, revealed with unprecedented detail the physiography and structure of the margin (Fig.1)

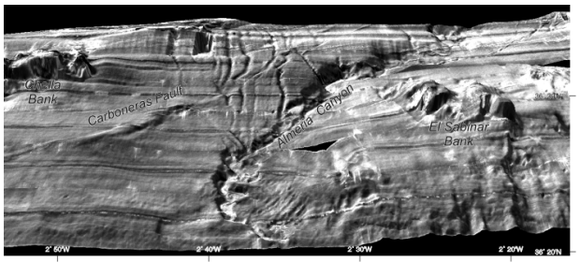

Fig. 1. High resolution TOBI sidescan sonar image showing the 60 km long submarine continuation of the Carboneras Fault, the Almeria Canyon and the Channel system.

2 Results and discussion

2.1 SW margin of the Iberian peninsula:

The marques de Pombal slides and deposits The Marques de Pombal fault (MP) block is a rectangular shaped monocline structure. The MP block is limited to the east by the Sao Vicente Canyon, and bounded to the west by a N20ºE-trending 50-km-long east-dipping thrust (Zitellini et al., 2001). Together with active faulting, gully-incised slope failures and submarine landslides are common in the MP block. Northward of the MP escarpment, we observe an amphitheatre-shaped headscarp at 2600m from where numerous deeply incised gullies drain towards the HITS basin, lying at 3850 m depth. On the high-resolution seismic reflection profiles, the basin is filled by a sequence of four transparent units corresponding to a piling of successive debris flows totalizing a thickness of 45 m. To the south of the MP escarpment, numerous slide scars and slope failures with retrogressive headscarps are observed. Lobes of debris flows slope down towards the Horseshoe Abyssal Plain at 4850 m depth.

The most prominent mass movement is located at the central part of the MP fault escarpment, where maximum slopes are up to 23º. We have identified a large area (~260 km^2) of high

backscatter corresponding to a complex submarine landslide. The source area is located at 2575 m and it is characterized by a discontinuous headscarp, which has up to 25m of maximum height, with several tension fractures in the surrounding sediments. Numerous tabular consolidated blocks, up to 1.6 km long, are detached from the head escarpment. The mid and toe areas of the landslide are formed by two individual flows: a translational slide to the north, and a debris flow to the south, reaching more than 3900 m depth, totalizing more than 1.3 km relief. The translational slide has a total affected area of 100.5 km^2 with a run out distance of 21.5 km. The debris flow includes a rafted block of up to 2.8 km, and has a distal depositional area with a slope <1º, showing a sharp turn to the north adapting to the topography. The debris flow comprises an area of 71.4 km^2 with a run out distance of 23.7 km. High-resolution seismic profiles across the toe of the translational slide reveal alternating transparent (landslide) and stratified (hemipelagic) units, suggesting cyclic activity of the MP faulting. The maximum thickness of the latest deposit is about 8 m, which may be related to the 1755 event.

2.2 SE margin of the Iberian peninsula: The Carboneras Fault and the Almeria Canyon and Channel System

The SE margin of the Iberian Peninsula is dominated by the meandering Almeria Canyon and Channel system, confined between large topographic highs (Cabo de Gata Spur, Chella and El Sabinar Banks) composed by a Neogene volcanic basement and covered by carbonate platforms. Crossing the whole study area and deflecting a dense tributary drainage network, we have imaged the 60 km long submarine continuation of the Carboneras Fault, a major left-lateral fracture zone (Fig. 1), potential source of large earthquakes.

3.Conclusions

In the SW Iberian margin, the Marques de Pombal is one of the potential source of past large earthquake events. We imaged the morphology and structure of slope failures and deposits of this active tectonic block located 100 km offshore Portugal which is being dismantled by numerous slope failures: MP slides, HITS slides, and South-Pombal slides. The MP landslide is composed by a translational slide and a debris flow. Maximum run out distance is of 24 km. Even if the mass movement affects a considerable surface (260 km^2) it is laminar (estimated volume of 1.3 km^3), making unlikely that the slide triggered a subsequent tsunami, based on parameters defined by Harbitz (1992).

High-resolution seismic profiles suggest a cyclic activity of the MP fault. Assessment of seismic risk in SW Iberia is largely based on the relatively short period of instrumental (about 40 years) and historically recorded (few hundred years) earthquakes. Only a submarine paleoseismic approach may allow us to know the recent and past activity of these active faults and yield an earthquake recurrence rate. A good correlation between turbidites and historical and instrumental seismicity suggests that widespread turbidites may be considered as a paleoseismic indicator, to establish earthquake recurrence intervals of large magnitude Holocene events in the SW Iberian margin.

In the SE Iberian margin we have imaged and identified the main active structures and potencial sources of earthquakes of the Almeria margin. The detailed study of the Carboneras Fault Zone, potential source of large earthquakes, has implications for seismic hazard assessment models in the Iberian Peninsula, especially when considering large magnitude earthquakes and long recurrence intervals (10^3-10^4 years).

4.Ackowledgements

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Bathymetric map of the Gulf of Cadiz, NE Atlantic Ocean: The SWIM multibeam compilation

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1. Introduction

The Gulf of Cadiz, located at the convergent boundary between the European and African Plates, is characterized by a significant and widespread seismicity This area is also the source of the largest event occurred during historical times in Western Europe, the 1755 Lisbon Earthquake and Tsunami [1]. Since the 1990s the Gulf of Cadiz has been the subject of numerous geological and geophysical surveys, mainly based on multibeam, sidescan sonar, high-resolution and multichannel seismics, and sampling. The aim has been unravelling the complex geodynamic history of the Gulf of Cadiz, to characterize the deep structure, and to identify active tectonic sources in the region.
We focus on recently acquired multibeam data to present a new bathymetric compilation map.

2. Swath Bathymetric Data and Generation of a Digital Terrain Model (DTM)

The compilation of the deep multibeam bathymetric data in the Gulf of Cadiz include, as essential components, the 100 m grids acquired during the following cruises: TASYO-2000 PARSIFAL-2000, CADISAR-2001, HITS-2001, PICABIA-2003, MATESPRO-2004, CADISAR2-2004, DELILA-2004, DELSIS-2005, and SWIM2-2005.
Additional data on specific localities, has been provided by J.P. Henriet, G. De Alteriis teams, and SISMER database. The multibeam systems used to survey the seafloor are Simrad EM3000 and EM1000 for shallow areas, and Simrad EM300, EM12S, EM120 and Reson Seabat 8150 for intermediate to deep waters.

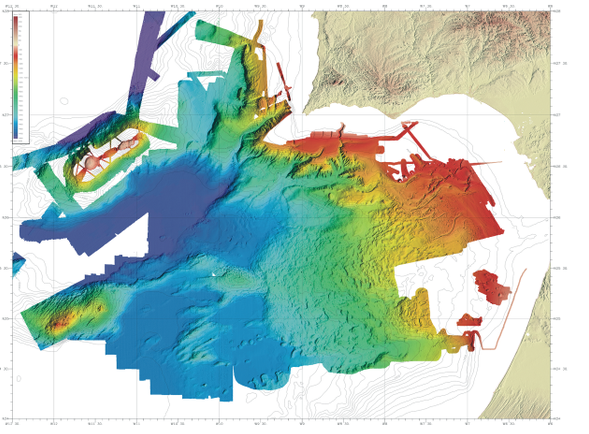

Figure 1. Bathymetric compilation map