ADVANCED MULTICHANNEL SEISMIC REFLECTION PROCESSING TECHNIQUES APPLIED TO IMPROVE IMAGING OF ACTIVE FAULTS FROM THE ALBORAN SEA

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Abstract: Along the Alboran Basin (Western Mediterranean) is located the diffuse plate boundary between Iberia and Africa. This wide deformation zone is controlled by the NW-SE convergence of these two plates. Deformation is accommodated by a large number of faults, where are placed offshore and onshore. The Alboran basin has a complex evolution, and the processes which led to the basin formation in the early Miocene are still under discussion. It is an active zone, so it involves a seismic and tsunamigenic hazard for the region. With the objective of improve the knowledge of this area, the TOPOMED-GASSIS cruise took place in October 2011. During this cruise, a deep penetration dataset was acquired using new instruments that allow the imaging of the basin at a crustal scale. The result is a series of multichannel seismic profiles with unprecedented quality in the region, which permit to use state of the art processing and imaging techniques to obtain the deep tectonic structure of the plate boundary and also a good resolution in the sedimentary infill of the basin. Moreover, we carried out Pre-Stack Depth Migration algorithms to selected profiles, in order to show the real geometry of the structures in depth and also to obtain the fault parameters.

Key words: Alboran Basin, multichannel seismic reflection, advanced processing techniques, seismic hazards.

The Alboran Basin of the Western Mediterranean is located between the Iberian Peninsula and Africa (Figure 1). In this area runs the diffuse plate boundary between Iberia and Africa. This limit corresponds to a wide deformation zone, controlled by the NW-SE convergence (4.5 – 5.6 mm/yr) between the African and Eurasian plates (Booth Rea et al., 2007; Nocquet, 2012). Deformation here is distributed over a large number of faults offshore with structures that continue onshore (Sanz de Galdeano et al., 1990; Andeweg and Cloetingh, 2001).

The Alboran basin has a complex geological evolution. It is a back arc basin mainly formed during the Miocene by extensive processes in a plate convergent setting (e.g. Comas et al., 1999; Gelabert et al., 2002; Rosenbaum et al., 2002; Faccena et al., 2004; Booth Rea et al., 2007). However, the evolution and processes which led to the basin formation and current deformation are still under discussion.

It is an active zone, where instrumentally recorded shallow earthquakes from low to moderate magnitude (Mw < 5.5) occur. However, historical records evidence that large earthquakes have also been generated by some of these -poorly known- structures (Mw ≥ 8.0 and MSK Intensity X-XI) (Gracia et al., 2006, 2012; Zitellini et al., 2009; Bartolome et al., 2012). These events with large recurrence periods (> 1000 years), involve seismic and tsunamigenic hazard for the region that cannot be characterized only with the instrumental records (< 100 years). So, to analyze the seismic hazard of this area is necessary to study the active faults, although they may not show present-day seismic activity.

With the aim of improve the knowledge of the sedimentary and tectonic processes going on in the Alboran basin, the TOPOMED-GASSIS cruise took place in October 2011. The main goal of the TOPOMED-GASSIS cruise was to characterize the crustal and upper mantle structure of the Gibraltar Arc and to link recent (post-Tortonian) tectonics and vertical movements with the deep lithospheric structure. To accomplish this goal, it was used for the first time the new deep multichannel seismic equipment of the RV Sarmiento de Gamboa for acquisition of the seismic survey. It was used two high volume G-gun arrays (2000 psi / 2500 psi) and up to 6 km long Sercel multichannel digital streamer (408 / 480 active channels) towed behind the vessel at a survey speed of 4.5-5 knots. The resulting profiles allow to image with unprecedented resolution and penetration the structures, basins and margins. A total of 2564 km of deep multichannel seismic data had been obtained during this cruise (Figure 1).
The result is a regional dataset of very high quality, which permit to use state of the art processing and imaging techniques to obtain the deep tectonic structure of the plate boundary. A complete processing sequence (Figure 2) has been used in order to increase the signal to noise ratio. The result are high-quality sections for interpretation (see Figure 3) through frequency preservation, effective multiple attenuation and velocity analysis.

The main steps in this flow (Figure 2) are the deconvolution, the multiple attenuation and the velocity analysis. Two predictive deconvolution had been applied, first a Wiener deconvolution in Tau – P domain, and second a Surface Consistent deconvolution. In that way, we attenuate short period multiple reverberations, such peg leg multiples and the source bubble signature, and reduce noise. Also two demultiples techniques had been used: (i) the Surface Related multiple elimination (SRME), which works on a multiple prediction model to remove surface related multiples from the original dataset; and (ii) the radon demultiple, which was applied in order to attenuate far-offset residual multiples not removed by SRME process. Doing this processing to the data, we have clearer velocity picking semblance panel, which is fundamental to obtain an accurate velocity distribution and therefore, a good stack. The final image is a time-migrated section (Figure 3).

These images allow us to identify the structures (such as faults) and also the sedimentary infill of the basin (Figure 3c and Figure 4).
In order to obtain the real geometry of the structures in depth, we have performed a Pre-stack Depth Migration (PSDM) to few selected seismic profiles running across key tectonic structures. Due to the complexity of the Alboran Basin, we have focused our study in three main zones represented by one seismic profile each: (i) the Yusuf left-lateral fault zone in the Eastern Alboran Basin, which corresponds to a lithospheric boundary between two different crustal domains, (ii) the Alboran Ridge zone, the largest convergent structure in the basin, and (iii) the Western Alboran Basin, a narrow and deep sedimentary basin where mud diapirism processes take place. The objectives of this study are to characterize these fault areas, to identify active structures and obtain its seismogenic potential, and to study mud diapirism and fluid-flow related processes.
The quality of this seismic data allows us to characterize the sedimentary infill of the basin, and determine the shallow and deep characteristics of active fault systems (Figure 3). They are especially interesting to image the depth structure. For this reason, the detailed analysis of this dataset is a great opportunity to relate the regional processes that led to the basin formation and active tectonics with the lithosphere dynamics. Also, the MCS profiles in depth (km) will depict the real geometry of the structures in the Messinian surface; B: Acoustic basement.

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References


Figure 4: Time migration section (figure 3c) with geological interpretation. Three sedimentary units are identified: Ia: Quaternary – Upper Pliocene, with continuous parallel reflectors, Ib: Lower Pliocene, with a more transparent character, II: Top of the Messinian surface; B: Acoustic basement.