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The role of the strike-slip tectonics in the evolution of the Alboran Sea, Western Mediterranean

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ABSTRACT

The Alboran Basin is a Neogene extensional basin which originated and evolved since the early Miocene within a plate tectonic setting of convergence between Iberia and Africa. The basin has been identified as formed by crustal stretching and extensional tectonic from the early to the late Miocene. However, the current organization of the Alboran Sea basin has resulted mainly from post-Miocene contractional tectonics superimposed on earlier extensional structures. The present structural framework indicates that two sets of conjugate strike-slip systems (left-lateral faults with a NE-SW trending, and right-lateral faults with a NW-SE trending; being 120• -130• the angle between the two strands) accounted for a significant post-Messinian deformation of the Alboran Sea basin. The stress field evidenced by the wrench-tectonic structures is consistent with the latest Neogene to Present Africa-Eurasie roughly N-S convergence plate kinematics in the westernmost Mediterranean.

INTRODUCTION

The Alboran Sea basin, in the westernmost Mediterranean, is bounded by the Betic (Southern Spain) and the Rif (Morocco) Chains to the North and South respectively. The basin is located behind the Gibraltar Arc, which connects the internal zones of both chains to the West. To the East, the basin opens to the oceanic South Balearic Basin.

Available geological and geophysical data indicate that the basement beneath the Alboran Sea is continental. Beneath the sedimentary cover, the acoustic basement is heterogeneous and formed of either metamorphic or volcanic rocks. Metamorphic rocks of the Betic and Rif Chains have been recovered at the bottom of commercial wells offshore Spain and Morocco, and at Site 976 (ODP Leg 161, Comas, Zahn, Klaus, et al., 1996) in the West Alboran Basin. Results from Site 976 demonstrated that the basin is floored with metamorphic rocks from the Alpuj·rride Complex of the Alboran Crustal Domain. East of 4º W, most of the residual highs sampled by dredging and diving appear to consist of volcanic rocks. Notwithstanding, the nature of the true basement in the eastern Alboran Sea region is still unknown.

The Alboran Sea is 400 km long, 200 km wide, and has narrow shelf and slope physiography. It exhibits complex seafloor morphology, with several sub-basin, ridges, and seamounts. The Alboran Ridge and the Alboran Trough are the most prominent linear structures that extend more 180 km and trend NE-SW across the Alboran Sea, this linear structures allow to differentiate the Eastern, Western and South-western Alboran Basin.

The sedimentary cover of the basin is formed of up to 7 km thick sequences, early Miocene to Recent in age. Six seismostratigraphic units, from the Burdigalian to the Holocene, has been differentiated and described in many papers based on seismic lines interpretation and borehole data (Comas, Zahn, Klaus, et al., 1996; and references therein). In the central region of the Alboran Sea (outside the main sub-basins), most sediments above the acoustic, probably volcanic, basement are post-Miocene in age. Deposits of similar age and characteristics than those occurring in the marine realm are found in the intermontane basins on the outcropping Alboran Domain in the Betic and Rift Chains. A correlation between these onshore and offshore sediments is presented by RodrÌguez-Fern·ndez et al., 1999.

Alkaline and calcoalkaline volcanic and volcaniclastic rocks from early to late Miocene (Bellon et al., 1983; Hernandez et al., 1987) are intercalated within the sedimentary sequences of the basin, and some of them are cropping-out at the seafloor.

CONTRACTIVE DEFORMATION AND STRIKE-SLIP FAULTING

Onshore and offshore data indicate that the extensional evolution in the Alboran Basin was completed by the latest Tortonian. Since the Tortonian, a contractive tectonic reorganization resulted in conspicuous N-S shortening and E-W elongation of the former Miocene Alboran Basin. Thus, folding, inversion of previous extensional faults, and reverse and strike-slip faulting (Comas et al., 1992; Woodside and Maldonado, 1992; Watts et al., 1993; RodrÌguez-Fern·ndez and MartÌn-Penela, 1993) caused a serious contractive deformation in the whole region, namely significant basement uplifting and creation of new depocenters.

Significant morphology lineaments in the Alboran Sea basin and at its transition to the South Balearic Basin (e.g., the Palomares and Serrata-Carboneras shear-zones, and the Alboran Ridge) formed during the post-Tortonian deformation.

Many bathymetric depressions and post-Messinian depocenters in the Alboran Sea region (e.g., the Alboran Through, the Almería Canyon, and the Yusuf Basin) are very recent wrench-related structures. Strike-slip structures onshore are congruent with those known in areas surrounding the Alboran Sea (Hernandez et al., 1987; de LarouziËre et al., 1988; Montenat, 1990). Lamproites, shoshonitic lavas and alkali basalts, upper Miocene-Pliocene in age (Bellon et al., 1983) are contemporaneous with the contractional deformation of the basin.

The Serrata-Carboneras Fault-zone, which corresponds to a main NE-SW strike-slip shear-zone in the eastern Iberian margin, cuts across the southeastern Betic Chain and continues offshore in the AlmerÌa Gulf toward the Eastern Alboran Basin. Multichannel seismic profiles show two conjugate strike-slip fault systems in this region, trending in a NE-SW and NW-SE direction.

The Serrata-Carboneras Fault-zone corresponds with a N45E directed, 60 km long and 15 km wide, left-lateral major wrench zone. Within this zone, the master strike-slip fault downthrow the basement to the NW, bounding a depocenter in which Messinian sediments occur on the basement top. Pliocene-to-Holocene sediments, sealing the fault, are thicker in the hanging wall and evidence coeval faulting activity. Seismic profiles, imaging the morphology of the fault and its relationship with the overlying sediments, indicate that the basement high corresponds to a contractional fault block (*sense* Harding, 1980). Other subordinate faults, paralleling the master fault within the wrench zone, show negative flower morphology, branch upward, and become simplified at deep. Pliocene to Holocene sediments are also strongly faulted and faulting affects the sea-floor, thus evidencing that the tectonic activity has continued till Present.

The NW-SE conjugate (105• -120• angles between the two strands) right-lateral fault system is present in a broader zone around the Serrata-Carboneras wrench-zone, and single faults have minor continuity. Onshore these faults appear as normal faults with some dextral displacement affecting Pliocene and Pleistocene sediments. These faults set are still actives at Present as shown by some focal earthquake mechanisms computed in the region, being responsible of the coastal morphology at places. The stress field of this right-lateral system is provided by the present-day seismicity, which show a N-S to N-20E compression with a horizontal position for the P axes at present.

The volcanic Alboran Ridge, which aligns with the Jebha Fault, represents a positive, antiformal flower-structure related to a left-lateral strike-slip system that extends along more than 120 km to the Xauen Bank (comprising folded sediments). Seismic images indicate a zone of Pleistocene-to-Holocene deformation (post M-unconformity) and tilting imaged as a series of folds and faults extending from the southern flank of the Alboran Ridge to the adjacent basin floor. At the southern flank of the Ridge, the attitude of the Pliocene-to-Holocene syntectonic sediments suggests that folds developed above a near-vertical reverse fault, and the northern flank of the Ridge shows comparable fault-related uplifting of syntectonic Pliocene to Holocene sediments. The late Pliocene-to-Pleistocene uplift of the Ridge was not accompanied by nearby volcanic activity, indicating that volcanism was not active at these times (Comas et al., 1999). The Alboran Ridge clearly evidences the existence of Post-Messinian compressional structures in the Alboran Basin.

In the southeastern Alboran Sea, the Yusuf right-lateral fault (Mauffret et al., 1987) represents the NW-SE trending right-lateral strike-slip system. The Yusuf Basin, containing sediments up to 2000 m thick, is bounded by the Yusuf Fault to the northeast. The Yusuf Fault, with an apparent vertical throw of > 2 km, is interpreted as being the master-fault of the system. The rhomboid-shaped Yusuf Basin is a negative flower-structure (pull-apart-type basin), and the adjacent Yusuf Ridge (900 m high) has been interpreted as a positive flower-structure within the Yusuf strike-slip system. The fault that limits the Yusuf Ridge to the northeast was active before or during the early Pliocene, but not later on. The fault forming the southern escarpment of the Yusuf Ridge (the Yusuf Fault), however, was active till the Present, as demonstrated by the considerable uplifting of the Pleistocene-Holocene sequences near the top of the southwest flank of the ridge (Comas et al., 1999).

Directions of compressional events during the post-extensional contractive deformation of the Alboran Basin are indicated by east-northeast - west-southwest trending folds and sinistral northeast-southwest and north-northeast - south-southwest and dextral west-northwest - east-southeast strike-slip conjugate fault systems (120• -130• angles between the two strands). NNW-SSE to N-S stress field produces left-lateral movement in the NE-SW fault system, and a right-lateral movement in the NW-SE one. Folds of N70-80E direction are also consistent with the same stress field.

CONCLUSIONS

Since the late Tortonian a contractive reorganization of the Alboran Basin was conditioned by folding, conjugate strike-slip faulting, and tectonic inversion of previous extensional structures. This deformation affected the whole Alboran region; i.e., the emerged remnants of the former Alboran Miocene basin, outcropping now in the Betic and Rif Chains, and the present Alboran Sea basin.

Strike-slip (wrench) tectonics seems to be accounted for significant post-Messinian deformation of the basin. The conjugate strike-slip fault systems gave way to both transtensive conditions that originated new depocenters, and transpressive situations producing local uplifting (positive flower-structures) by oblique-reverse strike-slip faults and folds. Most of these faults are now active, leading to distribute seismicity in the region. The focal mechanisms of earthquakes and moderate teleseisms document the present-day state of stress in the basin, quite variable from one site to another, in accordance with the distinct types of deformation now occurring in the region. The contractional deformation of the Alboran Basin is consistent with the N-NW/N current convergence of Eurasia and African plates, and correspond to the still active distributed-deformation of the plate boundary in the westernmost Mediterranean.

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