The Alboran Sea : a case of extensional basin developed on a collisional orogen

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The Alboran Sea and the surrounding mountain chains form the westernmost segment of the Alpine Mediterranean orogenic belts. Like other Mediterranean basins, the Neogene Alboran Sea basin developed behind an arc-shaped mountain belt (the Betic and Rifean chains and the Gibraltar Arc) and is settled on the site of an orogen generated by collisional stacking from the Late Cretaceous. The region straddles the boundary between two major plates - Europe and Africa - which converged during the Neogene.

The Gibraltar Arc resulted from a continent-continent collision that involved different crustal domains. During the collision, the Alboran Crustal Domain, hanging wall of the collisional suture and itself composed of nappe metamorphic complexes, thrusted westwards over the Iberian and African thinned continental crust producing shortening and crustal thickening in the Gibraltar Arc (BALANYA and GARCIA-DUENAS, 1988). During the Miocene, the migration of the arcuate mountain front was nearly coeval with the extension in the inner part of the arc that resulted in crustal attenuation and basinal spreading in the Alboran Domain. The Alboran Basin thus formed since the early Miocene whereas outside the arc thrusting processes continued.

The fact that the present continental crust beneath the Alboran Sea is about 14 km thick indicates that considerable thinning of the previous thickened crust, formed by the collisional stacking, must have happened. The Miocene crustal thinning of the Alboran Domain is related to large-scale extensional detachment faults recognized in the emergent Alboran basement at the Betic chain (GARCIA-DUENAS *et al.*, 1992).

MCS profiles in the Alboran Sea show thick sedimentary sequences (in places up to 7 km thick) filling grabens or half-grabens between basement highs. Seismic studies and commercial well data reveal four major seismostratigraphic units, early Miocene to Recent in age, overlying the metamorphic basement (JURADO and COMAS, 1992). The Miocene sedimentary fill beneath the sea can be correlated with large outcrops of coeval marine sediments on land (Betics and Rif). This indicate that the "Miocene Alboran Basin" occupied an area that extended beyond the present limits of the present Alboran Sea.

The structure of the Alboran Basin (Fig. 1) results from superimposed tectonic stages in basin evolution. Earlier structures correspond to extensional grabens from several rifting episodes (from latest Aquitanian to early Tortonian). Magmatic events and mud diapirism occurred outing rifting. Later structures testify to a post-rift N-S contraction, involving folding and strike-slip faulting, which conditioned present day sea-floor morphology. The last faulting episode took place in the Early Pliocene and was related to basin subsidence or collapse during the Pliocene-Quaternary. This episode shaped the present coastal line. The direction of extension during the rift processes was not congruent with the coeval relative motion of Europe and Africa plates (COMAS *et al.*, 1992).

Conflicting hypothesis for the origin of the Alboran Basin have been proposed, considering such processes as extension induced by mantle diapirism or convective removal of a collisional lithosphere root. Other models consider this basin as an equivalent to Pacific-type subduction zones. Nevertheless, these different explanations are poorly constrained by data regarding the extensional mechanism and kinematics which caused crustal thinning of the orogen and originated the Alboran Basin.

The attributes summarized above allow to consider the Alboran Basin as a suitable location to investigate extensional processes in an overall convergent tectonic setting.

This is the reason why an international workshop during the C.I.E.S.M. XXXI Congress and Plenary Assembly (Athens, 1988) to develop ODP drilling initiatives in the Mediterranean identified the Alboran Sea as one of the potential area to address "investigations of deformation processes at convergent plate boundaries". After years of intensive survey on this subject, an international consortium of scientists submitted to JOIDES Office a proposal (reference n° 323-Rev, COMAS *et al.*, 1991) including geodynamic and tectonic objectives in the Alboran Sea. The drilling target in the Alboran Basin satisfies one of the priority objectives of the TECP: to investigate the dynamics of the extension collapse of collisional ridges resulting in the formation of arc-shaped orogenic belts. Also, this target complies with a prerequisite underlined by the TECP: the accessibility to the basement. Actually, in the case of the Alboran basin the compression and extension deformation of its basement is well known from onland geology as it crops out extensively throughout Betic and Rifean chains.

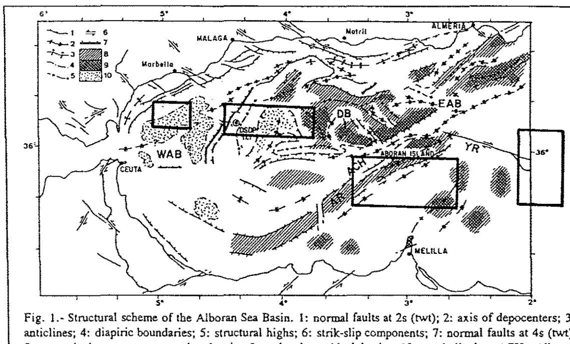

Fig. 1.- Structural scheme of the Alboran Sea Basin. 1: normal faults at 2s (twt); 2: axis of depocenters; 3: anticlines; 4: diapiric boundaries; 5: structural highs; 6: strik-slip components; 7: normal faults at 4s (twt); 8: acoustic basement presumed volcanic; 9: volcanic residual banks; 10: mud diapirs. ACH: Alboran Channel. AR: Alboran Ridge. DB: Djibouti Bank. EAB: Eastern Alboran Basin. WAB: Western Alboran Basin. YR: Yusuf Ridge. Squares: suitable drillsite-areas.

For tectonic purposes, deep drilling results in the Alboran Basin can provide accurate information on timing of extension-and-compression deformation and synchronous basin formation, rate and amount of subsidence, nature of the basin floor, role of volcanism, and interference between rifting and contractionneotectonic processes in the evolution of a young basin. Drilling here can clanfy the lithosphere defonnation mode, vital to the development of geodynamic models not only for this region but also for equivalent settings in nascent back-arc basins.

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Proposal for deep drillings in the Mediterranean Sea (Rhone Deep-Sea Fan and Var Ridge)

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The general aim of this drilling project is devoted to deep turbiditic sedimentation related to external forcing mechanisms such as sea-level changes, tectonics and climate.

We shall present here, among the main objectives of this project, those that concern the improvement of sequence stratigraphy model [1, 2] in deep-water settings; many of which are not universally recognized and usually are poorly documented.

The Rhone Fan in the Gulf of Lions [3] and the Var Fan on the Ligurian Margin [4](2), two of the main turbiditic systems of the northern Mediterranean margin, offer a unique opportunity to precise the relative influences of sea-level changes and regional tectonics on basinal sedimentation. These fans have in common several characteristics: their construction follows the same main eustatic event (Messinian salinity crisis), they were fed by common terrigeneous sources (the Alps) and they are both of Plio-Quaternary age. The main differences between them concern the nature of sedimentary input (probably much coarser in the Var system than in the Rhone Fan), and the physiographic and local tectonic conditions prevailing during their constructions. These differences resulted in contrasting modes of fan growth:

- The **Rhone Fan** can be considered as "typical" and relatively simple example of a turbiditic system. During its history, the prevailing physiographic characteristics of the Gulf of Lions margin were not different from those of today, and were very close to the general sequential model (broad shelf, well expressed shelf-break). Moreover, subsidence of the margin is known to have been relatively low and costant since earliest Pliocene, varying from about 26 m/100,000 years on the outer shelf to about 33 m/100,000 years in the basin 151

These analogies in the background conditions (physiography, subsidence) of the Gulf of Lions and of the sequential model, together with the relative simplicity of the sedimentary evolution of the Rhone Fan, make the Gulf of Lions and Rhone Fan good potential areas to test the general concepts of the sequential model of margin construction.

However, the sedimentary evolution of this fan shows some specificities that are not predictable by the model. Our observations indicate in particular (a) the existence of significant turbiditic sedimentation during relative rises of sea-level and sea-level highstands (*e.g.:* deposition of the sandy "neofan" during the Holocene highstand [6], and probable active channelized basin sedimentation during the lower Pliocene sea-level rise [3]), and (b) mass-movement prcesses at the end of lowstand channel/levee deposition, that is to say during the subsequent rises of sea-level [3].

It appears thus that the determination of the exact timing of deposition of this types of sediments is essential and will be considered as another objective for the proposed drilling.

- In contrast, the **Var System** must be regarded as a "atypical" turbiditic system. The main interest of this system lies in the specific physiographic conditions and the local tectonic activity that resulted in the overgrowth of a single levee (the "Var Ridge" southern levee). These conditions were, among others: absence of a shelf, which prevented accumulation during highstands, continuity between the Var River and the Var Canyon leading to the permanent feeding of the basin by the fluvial input, tectonic control of feeding axes leading to the stability of depocenters.

These specificities design the Var system as a good target for improving the general model.

Comparison between drilling results in the Rhone Fan, where sealevel changes are likely to be the main controlling factor of sedimentation, and in the Var System, where local tectonics played a greater role, is expected to highligh significant information on the relative influence of these two factors.

(1)Other institutions are likely to partecipate in the further elaboration of this proposal, still in preparation; it will be presented in the framework of an open discussion during which other objectives should be defined.

(2)The results concerning a comparative study of architecture and growth-pattern of both the Rhone Fan and Var Ridge will be presented during the section on "Deep sea depositional systems".

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