NEW INSIGHTS ON THE LIGURIAN SEA STRUCTURE AND EVOLUTION FROM A SYNTHESIS OF GEOPHYSICAL DATA

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Abstract

Using new multichannel seismic data (MALIS cruise, 1995), sampling and magnetic anomalies, we analyze the deep structures of the Oligocene-Miocene Ligurian basin and conjugate margins and describe the tectonic style of opening. We map the acoustic basement and propose new extents for the oceanic, transitional and continental domains. We find from seismic facies analysis that the previous Alpine crustal thickening likely contributed to spread the extension across NW Corsica, whereas farther south strain is localized at the foot of both margins. We identify probable tholeitic volcanics in the ocean and calc-alkaline volcanism becoming younger eastwards. Therefore, Apulian slab roll-back and inherited lithospheric inhomogeneities have strongly controlled the Ligurian basin evolution.

Key-words : Tectonics, Passive margins, Ligurian sea, Western Mediterranean

The Ligurian domain has received much less attention than other Mediterranean basins since the studies of the 80's which have provided the evolutionary scheme for Neogene basins [1, 2, 3]. This domain has undergone extension from Late Oligocene to lower Miocene within heterogeneous lithosphere, behind the Apulian subduction zone and at least partly within the Alpine orogen. Rifting occurred between -30 et -20 Ma and drifting until -15 Ma. The relative importance of tectonic forces acting during the evolution of the Liguria basin is unclear, since they depend on poorly controlled and complex, deep processes [4, 5, 6, 7, 8], as well as tectonic inheritance within the heterogeneous upper plate [9]. Furthermore, the age, nature and distribution of Neogene volcanic rocks, which have accompanied and postdated back-arc extension, are poorly constrained, and are not easily related to the various phases of back-arc evolution [10, 6, 11, 12]. In order to better identify the deep structures of this basin, its assymmetry, and the origin and importance of plutonism and volcanism which occurred before, during and after rifting, we have led a cruise (MALIS, 1995, N/O *NADIR*, IFREMER) which allowed us to collect a new set of 3300 km multichannel (96) seismic reflection lines and wide angle data recorded by land seismographs. After data processing, we have been able to recover acoustic energy from reflectors as deep 20 km below margins and 15 km in the deep basin [4]. Furthermore, dredging (MARCO cruise, 1995) et diving data (CYLICE cruise, 1997) have brought important constraints on the nature and age of rocks on the margins and the basin. We combine these data together with a new map of magnetic anomalies reduced to the pole, complementing another map recently published westwards [13]. To minimize problems arising from the salt layer and long-period multiple energy, we have used a tuned air-gun array ("single bubble" pulse method), and we have taken particular care during the processing phases with Geovecteur software^{TM} (*Compagnie Générale de Géophysique, France*).

We propose an updated map of the acoustic basement by using all profiles available in the region. Offshore, we identify the Hercynian basement and its sedimentary cover located in the Maures-Esterel Massif and in the western part of the Corsican margin, and the Alpine nappes on the NE parts of the Ligurian and Corsican margins. The correlation between the changes in syn-rift structural trends of the pre-rift acoustic basement with the change in the geology of the outcrops observed along the coast suggests that the pre-existing structures have influenced the mode of deformation of the acoustic basement during rifting. The morphology of the top of the acoustic basement and the deeper reflectors give insights on the width of the margins after rifting and on their detailed structure: we observe that the Ligurian margin is about 40-50 km wide from northeast to southwest, whereas the Corsican margin is generally wider (about 70-80 km width on NW and SW Corsica margins). No clear axial ridge is present near the centre of the basin.

We also propose new boundaries for the three domains recognised in the acoustic basement in the Ligurian basin: (1) *the continental thinned margins*: they are limited oceanwards by the slope break of the basement acoustic facies, and is structured in grabens and several half-grabens; (2) *the transitional domain:* along the Provençal-Ligurian margin, it is characterized by strong reflectors at the top of the acoustic basement gently deepening towards the continent; on the Corsican margin, it depicts typical facies of volcanic flows associated with large, circular magnetic anomalies; and (3) *the central domain:* although it was never drilled, the basin is assumed to be an oceanic type domain by most authors [14, 1, 10, 2, 3, 4], but with varying characteristics and shapes, since the crust is abnormaly thin [15] and magnetic anomalies are ambiguous [16, 4]: we base our interpretation of the atypical oceanic domain on the presence of a particular acoustic facies similar to the one identified in the Tyrrhenian sea [17]. Compared to previous studies [1, 10, 14], we therefore propose a slightly narrower oceanic domain in the northeastern half of the Ligurian Basin, with a wider NW Corsican margin.

The crustal structure imaged on MCS lines depicts strong changes between conjugate margins, in good agreement with the morphological segmentation. On the Ligurian margin, offshore the Maures Massif, the top of the acoustic basement is underlined by a strong reflector which forms a nearly E-W trending fault sub-parallel to the structural pattern observed onshore in the Maures Massif, therefore suggesting that both onshore and offshore fault networks were inherited from the same tectonic history and would have been reactivated during the Oligocene opening of the Ligurian basin. This geometry is comparable to the one observed in the Gulf of Lions [10, 17] where it is interpreted as a décollement associated with the reactivated Pyrenean thrusts. On the Corsican margin, near the NW Cap Corse, the top of the acoustic basement is underlined by strong reflectors gently dipping towards the continent and sole into a group of strong reflectors, sub-horizontal and sub-parallel, between 6-7 s TWT. By analogy with onland features [18, 19], we interpret shallow reflectors as thrusted units related to the Alpine orogenesis and deeper reflectors as a shear zone within the Alpine nappes, reactivated as normal faults during Oligocene time.

Finally, we have performed a systematic identification of volcanic or volcanoclastic bodies in the basin and the margins. In the Gulf of Genova, we note high seismic velocities at the base of the crust, located under and around the Monte Doria volcano, and also along the Ligurian margin from the Gulf of Lions to the Gulf of Genova, and only locally on the Corsican margin. This layer 2-3 km is of controversial origin [14, 10, 20], and we have no way to answer. A new map of magnetic anomalies reduced to the pole shows that volcanism identified on seismic profiles correlates well with the largest positive magnetic anomalies. The two types of magnetic signatures are thought to represent : (1) volcanic flows sourced from nearby lava centers located in the deep basin, trending parallel to the basin axis: we can hypothesize that this volcanism has a tholeitic affinity and overlies mantle rocks, since both types of rocks have been identified in the Tyrrhenian sea [21]; and (2) magmatic fields on the margins and in the transitional domain, striking NW-SE or NE-SW, for which recent datings suggest different volcanic phases of 21-18 Ma, 16-15 Ma and 12-11 Ma which migrated from the the Ligurian margin to the Corsican margin. We propose that this space-time migration is driven by the roll-back of the Apulian subduction zone towards the E-SE [2, 3], in a way similar to what is described in the Tyrrhenian Sea [2, 5, 22], and that part of the Alpine (Apenninic) frontal wedge has collapsed during this process. Magmatic fields on the margins and in the transitional domains are therefore likely to be related to the subduction setting, whereas the spread volcanic signature in the deep basin is probably related to drifting.

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Introduction

La distribution bathymétrique des espèces d'ostracodes en Méditerranée occidentale et en mer d'Alboran était déjà entamée (1, 2, 3, 4, 5). Dans le but de compléter l'établissement de cette distribution, l'étude de l'ostracofaune des sédiments superficiels prélevés en plusieurs points de la marge méditerranéenne marocaine (partie occidentale) a été réalisée. Cette marge, située dans la partie méridionale de la mer d'Alboran, s'étend du détroit de Gibraltar à l'Ouest à 4°30' de longitude à l'Est (Fig. 1). Sur le plan hydrodynamique, les eaux superficielles, d'origine atlantique, circulent en permanence d'Ouest vers l'Est et donnent naissance à un ou deux gyres anticycloniques de part et d'autre du Cap des trois Fourches (6). Dans le sens inverse, les eaux méditerranéennes profondes longent la pente continentale marocaine en direction du détroit de Gibraltar (6).

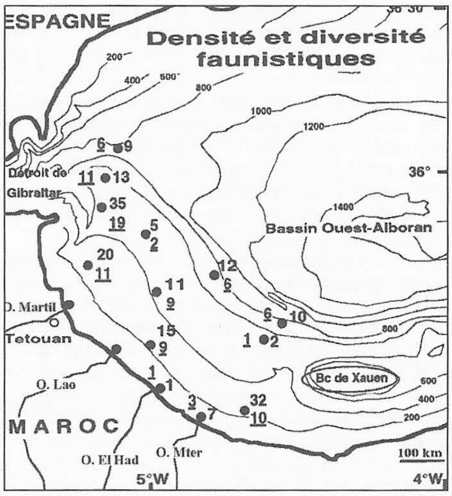

Fig. 1 Distribution de la densité et de la diversité (chiffres soulignés) faunistiques dans les dépôts superficiels.

Matériels et méthodes

Les échantillons étudiés proviennent de la partie supérieure (0 - 2 cm) de carottes de type "Kullenberg" prélevés lors de la campagne océanographique Albosed II-1986 (Fig. 1), à bord du *N/O Catherine Laurence* (CNRS - France). Les échantillons ont été traités sur 20 g de sédiment brut et tamisés sur 125 μm. Les paramètres analytiques de la microfaune d'ostracodes pris en compte sont d'ordre qualitatif et quantitatif.

Résultats et discussions

La microfaune autochtone d'ostracodes montre une densité et une diversité faunistiques relativement faibles avec environ 23 espèces et 19 genres (Fig. 1 et 2). Elle caractérise l'étage circalittoral sur le haut de la pente continentale et l'étage strictement épibathyal sur le plateau marginal et la pente qui lui est adjacente (Fig. 3 et 4). Au niveau des embouchures des Oueds, l'absence de cette microfaune serait due à l'instabilité du fond marin, à la forte turbidité du milieu soumis à l'importance des apports détritiques terrigènes par les différents émissaires continentaux, le développement d'un milieu réducteur et à l'importance des apports en métaux lourds due aux rejets industriels des villes côtières et surtout de la ville de Tétouan (1, 2, 4, 7).