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Crustal structure of a young margin pair: New results across the Liguro–Provencal Basin from wide-angle seismic tomography

A. Gailler *, F. Klingelhoefer, J.-L. Olivet, D. Aslanian
and The Sardinia scientific party [1]
and Technical OBS team [2]

Ifremer, Department of Marine Geosciences, BP 70, Plouzané, France

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ABSTRACT

Tomographic inversion of two wide-angle seismic profiles acquired during the Sardinia cruise (2006) on the conjugate Gulf of Lions–West Sardinia margins pair offers insight into the deep structure of this young basin. It is the first combined conjugate margins study in this area based on deep seismic data. Modelling of the two conjugate profiles reveals that the conjugate margins are symmetric in term of crustal velocity structure, with a partitioning in three similar regions: (1) a zone of low crustal vertical velocity gradients and a crustal thickness of 18 to 10 km, interpreted to be thinned continental crust, (2) a transitional zone characterised by high lower crustal velocities, non-typical of continental or normal oceanic crust, and (3) a 4- to 5-km-thick crust showing vertical velocity gradients and relative velocity ranges typical of oceanic crust. This latter region is interpreted to be a thin oceanic crust resulting from a tectonic heritage and the possible influence of a cool slab back-arc basin. Although the three regions are found on both sides of the margin, they are asymmetric in terms of the width of these domains, wide and smooth along the Gulf of Lions margin, and narrow and abrupt along its conjugate Sardinia side. The width of Region 2 is larger on the Gulf of Lions side (~90 km) than on the Sardinia side (~40 km). Crustal thickness in Region 3 is about 1 km thinner on the Sardinia side than on its conjugate. In Region 1 the crustal thickness is lower on the Sardinia side at a given distance from the shelf break. The differences in width of Region 2 and in crustal thickness might be due to the origin as a back-arc basin of the NW-Mediterranean basin, with the final breakup located closer to the Western Sardinia margin, also probably linked to the complex tectonic history of the region. Our results do not support a simple shear mechanism of the opening of the basin along a lithospheric detachment fault.

1. Introduction

The conjugate margins of the Gulf of Lions and West Sardinia represent a unique natural laboratory to address fundamental questions on rifting (e.g., on crustal thinning, on the nature of the continent–ocean transition zone and on the style of rifting), because of their young age and accessibility. Although rifting in back-arc basins might differ in some points from cratonic rifting, the mechanics of actual fracturing of the continental crust remains similar. Back-arc basins are often more accessible structures, also characterised by a less complex geological history. Their study thus underlines their interest and importance in the understanding of the fundamental mechanisms of rifting.

The main difference between back-arc and cratonic rifting is the presence of a subducting slab in the mantle beneath the back-arc basin. Back-arc basins are supposed to be underlain by a hotter than normal mantle material (Currie and Hyndman, 2006), which produces the arc volcanism. However a range of back-arc basins shows unusually deep and thin crust, as well as an absence of volcanism, contrary to what would be predicted for high mantle temperatures (Louden, 1980). Deep seismic data can provide insight in the deep structure of these margins and help explain these anomalous features.

The Liguro–Provencal basin reveals a structure and evolution corresponding to a rifted margins pair formed by the rupture and rotation of the Corso–Sardinian micro-continent with respect to the Ibero–European plate from the Oligocene (Le Pichon et al., 1971). It probably opened in response to two factors: (i) the Gulf of Lions was clearly connected to the intra-European rift system, and (ii) the basin, once opened, was situated in a back-arc position (Auzende et al., 1973; Boccaletti and Guazzone, 1974) which evolved and rotated in response to a SE rollback of the slab of the African plate subducting beneath the European plate during an extensional phase (Rehault et al., 1984; Jolivet et al., 2006). The opening resulted in the emplacement of an

* Corresponding author. Now at: Institut Universitaire Européen de la mer (IUEM), UMR Domaines Océaniques, Université de Bretagne Occidentale (UBO), Plouzané, France.
E-mail address: gailler@univ-brest.fr (A. Gailler).

[1] A. Afilhado, F. Bache, M.-O. Beslier, E. Cosquer, A. Deschamp, L. Droz, C. Gorini, M. Moulin, H. Nouzé, J. Oudet, V. Pascucci, J. Perrot, M. Rabineau, J.-P. Réhault.
[2] L. Allano, J. Bégot, J. Crozon, P. Fernagu, E. Labahn, P. Pelleau, E. Théreau.

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oceanic crust, starting in the Late Aquitanian (24 Ma to 22 Ma) (Burrus, 1984; Gorini et al., 1993) and active until the Tortonian (15 Ma) (Gattacceca et al., 2007). Until now, deep seismic data were acquired along the Gulf of Lions margin only, and the extent of the oceanic type igneous crust in the basin toward the Sardinia margin was estimated from potential field data (i.e., magnetic data; Bayer et al., 1973; Gueguen, 1995). Five domains were identified from a combination with existing reflection and wide-angle seismic data.

A 500-km-long reflection seismic profile (ECORS-CROP) in the Western Mediterranean Basin, between the Gulf of Lions and the west Sardinia margins showed the existence of a prominent landward dipping reflector located in the crust at the SE limit of the continental slope and called the T-reflector (de Voogd et al., 1991). The modelling of 30 expanding spread profiles (ESP) in the Liguro–Provencal basin imaged a 20–40 km wide zone of high crustal velocities south-eastward of this reflector (Le Douaran et al., 1984; Pascal et al., 1993; Contrucci et al., 2001) (Fig. 1). These high velocities could be the expression of extremely thinned and possibly broken up continental crust underplated and intruded by partial melt, or represent serpentinized peridotite material exhumed during the initial opening of the basin (Pascal et al., 1993). Based on these findings an opening along a lithospheric detachment fault (possibly represented by the T-reflector) has been proposed for the basin with the Sardinia margin representing the upper crustal plate, with exhumation of the mantle or lower crustal material occurring on the Gulf of Lions side (Mauffret et al., 1995; Séranne, 1999). But the lack of deep crustal seismic data from the Sardinia margin has until now prevented testing of this hypothesis and assessment of this asymmetry in depth. The existence of a high-velocity zone has been imaged in the Ligurian sea NW of Corsica (Contrucci et al., 2001) and punctually via ESP study in the Gulf of Lions area (Pascal et al., 1993).

Wide-angle seismic data can be used to quantify the continental crustal thickness, determine the degree of symmetry of rift structures and hence address fundamental questions concerning the mechanisms of rifting (e.g., simple shear: McKenzie, 1978; pure shear: Wernicke, 1985; mixed opening: Whitmarsh et al., 2001; Lavier and Manatschal, 2006). The main aims of the Sardinia wide-angle seismic cruise were to image continuously the deep crustal structure of the

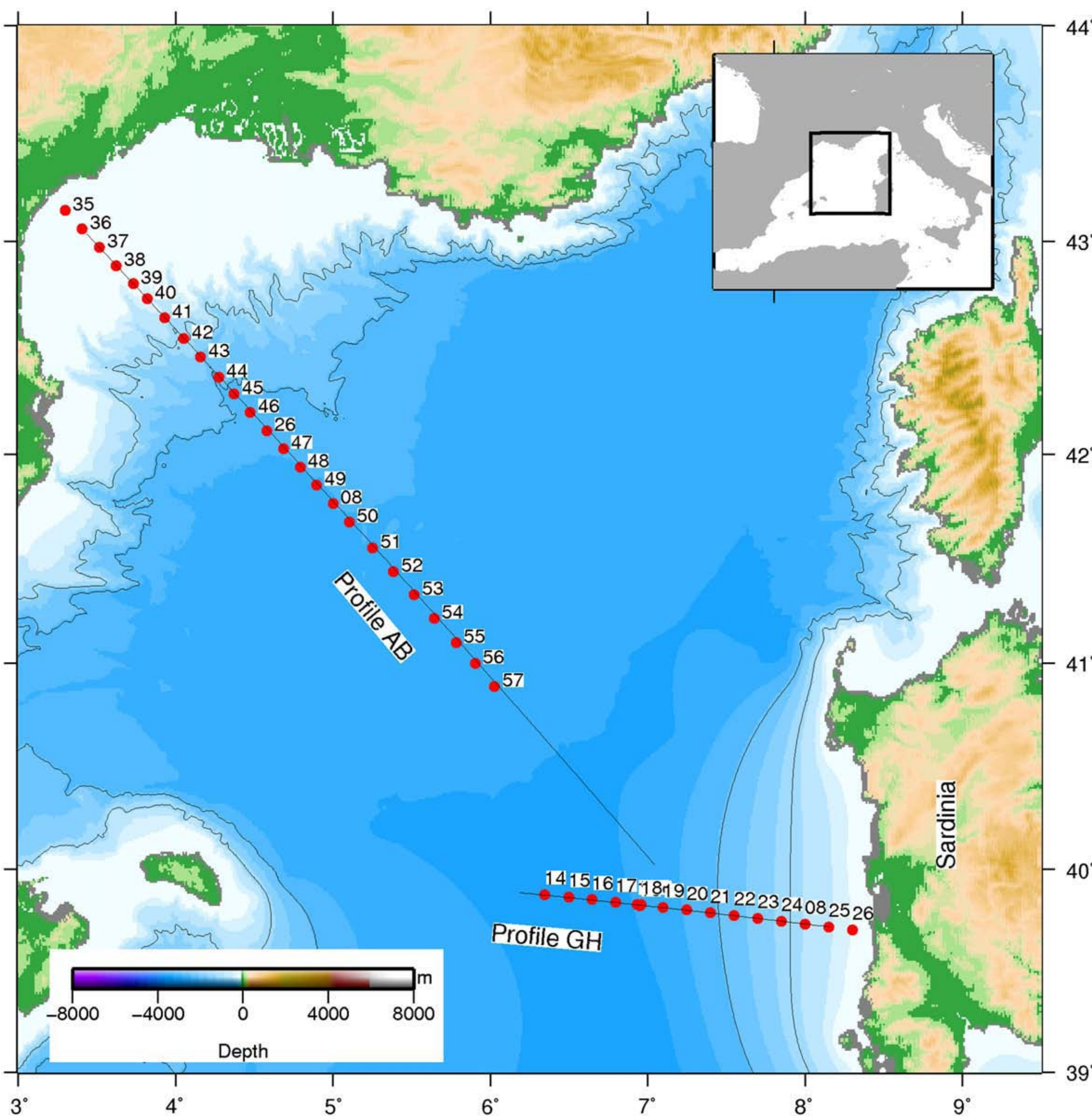

Fig. 1. Seafloor bathymetry of the study area (Loubrieu et al., 2008; Smith and Sandwell, 1997). Red circles mark position of seafloor instruments and black lines the shot profiles. Yellow triangles represent existing ESP locations. Inset shows location of the study area.