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**GEODYNAMIC EVOLUTION OF THE TYRRHENIAN SEA
NEW MULTICHANNEL SEISMIC REFLEXION DATA
(ODP Leg 107 sites survey)**

by

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Introduction. The present-day Western Mediterranean Sea results from successive openings of back-arc basins associated with the consumption of the former Mesogean ocean areas.

The Tyrrhenian Sea is the youngest of these basins. Its western margin is edged by the Corsica and Sardinia islands, the drifting of which, related to Europe, stopped 18 m.y. ago (REHAULT J. P., 1981). Its northeastern and southern margins are edged by two compressive systems, the Apenninic and the Northern Sicilian Chains, the backbones of which have mainly been built between the Burdigalian and the Tortonian times (i.e. from 18 m.y. to 10 m.y. ago) though more recent compressive events have occurred since then (AMODIO-MORELLI et al., 1976).

Both chains are linked in the east by the Tyrrhenian arc (so called Calabrian—Peloritan arc) which faces the Ionian sea, the only oceanic area of the foreland between the African continent and its Adriatic counterpart.

On the one hand, it is tempting to attribute the opening of the Tyrrhenian to the subduction of the oceanic lithosphere a relic of which the Ionian sea is. However, the occurrence of active margins without back-arc basins shows that the plunging of this slab into the asthenosphere is not sufficient for such a process. On the other hand, induction of a tensional state of stress in the Tyrrhenian area by a NNW/SSE shortening between Europe and Africa implies an anticlockwise rotation of the Adriatic foreland related to the African plate. However, the seismicity does not show any active plate boundary between them and no relevant observation support the hypothesis of such boundary in Neogene (HORVÁTH, 1984).

An attempt to conciliate both facts has already been published (MOUSSAT, 1983; MOUSSAT et al., 1985a, b). This model is discussed here in the light of the results of new multichannel seismic reflexion records carried out by IFREMER/IFP for the ODP (Leg 107) sites survey.

Structure of the Tyrrhenian basin (Fig. 1)

The area of maximum stretching (Moho depth shallower than 10 km) and volcanic activity lies in the east of the so called "Faille Centrale". This area is divided into two depressions tightly delineated by the 3000 meter isobath, the Central and Eastern basins, in the middle of which elongated tholeiitic volcanoes (Magnaghi, Vavilov and Marsili) form embryos of oceanic ridges (MOUSSAT, 1983; MOUSSAT et al., 1985b). According to a previous detailed fault mapping these deep basins (as well as the margins) are characterized by two sets of faults:

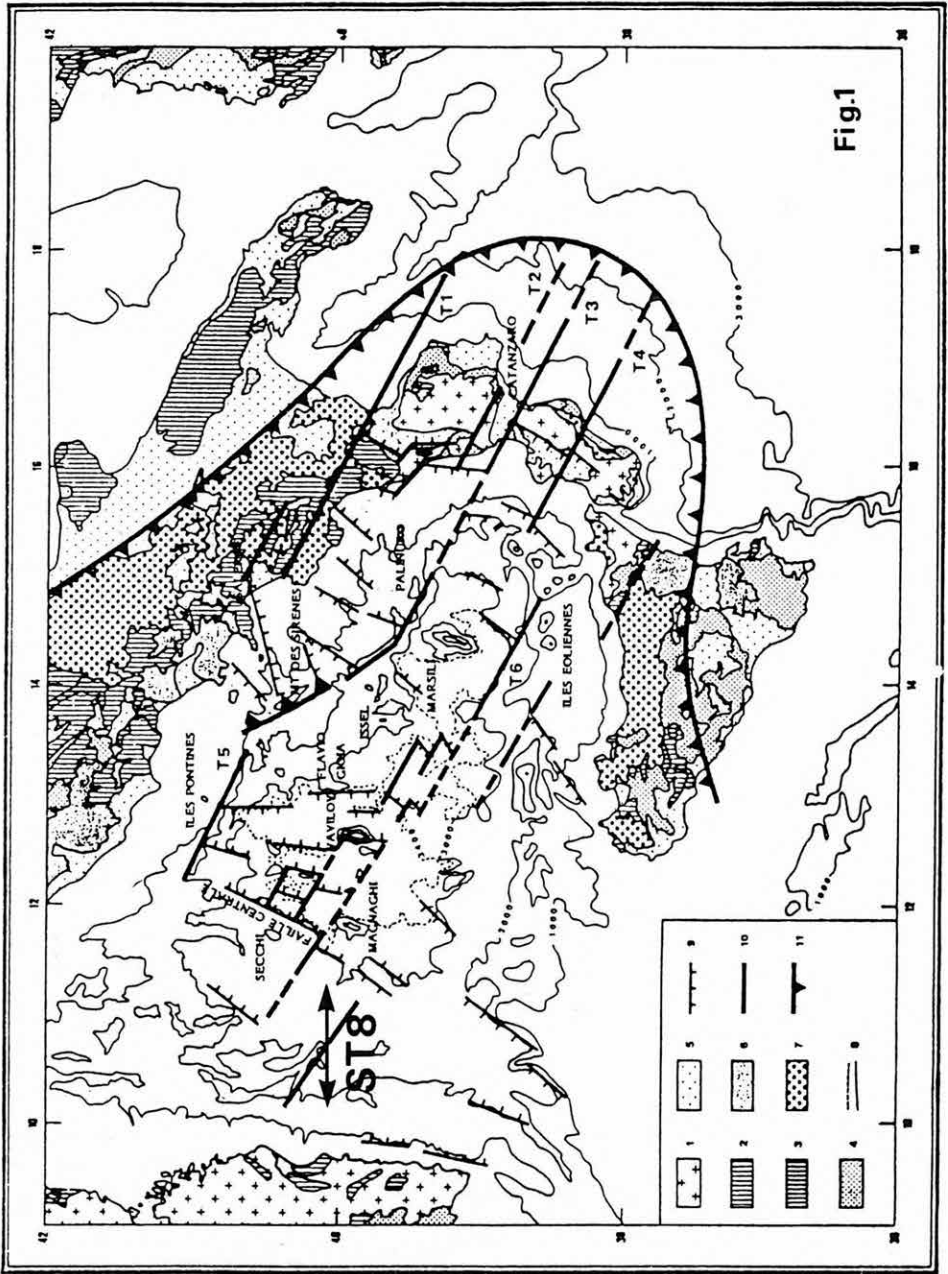


Fig. 1. Structural sketch map of the Tyrrhenian
ST8 location of seismic section of Fig. 2, 1 to 7 structural units, 8 isobaths, 9 main normal faults, 10 transform faults 11 thrust fault.

— a set of listric normal faults whose strike is N 30 E to NS. They form the walls of both rifts which tilted blocks of continental crust have slid down.

— a set of faults cutting more or less perpendicularly the tilted blocks, the offsets of which have generated numerous small closed half grabens. These faults form fracture zones, the direction of which lies in most cases approximately N 110 E/N 120 E, except the Siren seamount one, which is discussed later on (Fig. 1). Similar networks of faults have already been described on passive margins where the fractures oriented toward the ocean are considered as transcurrent faults whose strike is representative of the direction of opening—as transform faults are (LE PICHON and SIBUET, 1981).

The first contribution of the new seismic records lies in the fact that they corroborate the occurrence of such faults as well as the listric normal faults, although they do not enable to give us a better estimate of their mean direction. Nevertheless, the N 110—N 120 E direction of the opening of the Tyrrhenian is in agreement with the results of the tectonic analyses carried out in Calabria (MOUSSAT, 1983; MOUSSAT et al., 1985a).

Tectonics and sedimentation

Except the N 140 E Siren seamount, no obvious compressive feature has been described so far whereas evidences of extensional movements can be observed everywhere.

The *post-rift sediments* are of Pliocene and Quaternary age in the deep basins, the northern part of the central one excepted. In spite of this apparent break of the extensional movements in these areas (numerous normal faults with throw of the order of 100 ms d.t.t. are still active during Pliocene and Quaternary times), the rifting is likely to be still progressing since the end of Messinian time elsewhere.

Detailed maps of the deposit centers of the successive sedimentary units observed on the seismic records as well as plots of the active faults at successive periods have shown that the main extensional movements have changed place through time: the more one goes further north of the rifts or the more one goes perpendicularly away from them, the younger they seem to be. Evidences of Pliocene, Quaternary and present active extensional faulting can be observed in the shallower areas of the Tyrrhenian margins. So, the *syn-rift sediments* are of early Pliocene age in the northern part of the central rift, whereas they are of Messinian and, at least, of late Tortonian age elsewhere in the deep basins. This last dating is based on field observations of the first extensional movements breaking up the backbone of the Apennines (AMODIO-MORELLI et al., 1976). However the opening of the Tyrrhenian Sea during the building of this chain is suggested by kinematic considerations (DEWEY and SENGÖR, 1979)—and a Middle to Upper Miocene age could be attributed to the sedimentary unit (B3) directly underlying the Messinian evaporites. However, no angular unconformity has been observed so far within this unit whereas effects of tectonic events weaker than the Middle Miocene one have been recorded by the sedimentation (unconformities of Messinian, Middle Pliocene and Middle Pleistocene (?) age). Thus this unit appears to be of upper Tortonian rather than Middle Miocene age. Few evidence of *prerifts sediments* underlying this unit have been reported (MOUSSAT, 1983; FABBRI et al., 1981). The sedimentary cover of the tilted blocks of the northern part of the central rift, on top of which the Pliocene deposits lie unconformably has been interpreted in such way (MOUSSAT, 1983). However, the upper Miocene sedimentary break observed in this area keeps us from determining its age.

Thus, the most important contribution of the new seismic records is backed up by the fact that they show the existence of thick sediments underlying the upper Tortonian

— Middle Miocene (?) ones (B3) (Fig. 2). They constitute the oldest sedimentary unit (B4) lying on the acoustic basement, observed so far in the bathyal plain.

This unit has been broken up by a drastic, probably distensive, tectonic event and then, recovered by prograding deposits of sediments coming from Sardinia. During this period of sedimentation, tilting of blocks down listric normal faults have occurred on the Sardinian margin. In spite of these facts, the variations of thickness of the lower sedimentary unit keep us from considering it as a pre-rift sedimentary sequence.

On the basis of kinematic considerations (8) as well as on the basis of field observations (REHAULT, 1981; AMODIO-MORELLI, 1976; CHERCHI et al., 1982), two hypotheses can be raised:

(a) The first rifting event is related to the opening of the Western Mediterranean, from late Oligocene (?) to Aquitanian—and is followed by the Tyrrhenian rifting s.s. starting (unconformity between B3 and B4) either in Middle Miocene time after the collision of Corsica and Sardinia against the Adriatic margin 18 m.y. ago or after the last of the main compressive events which give birth to the Apennines, i.e. in upper Tortonian time, 10 m.y. ago.

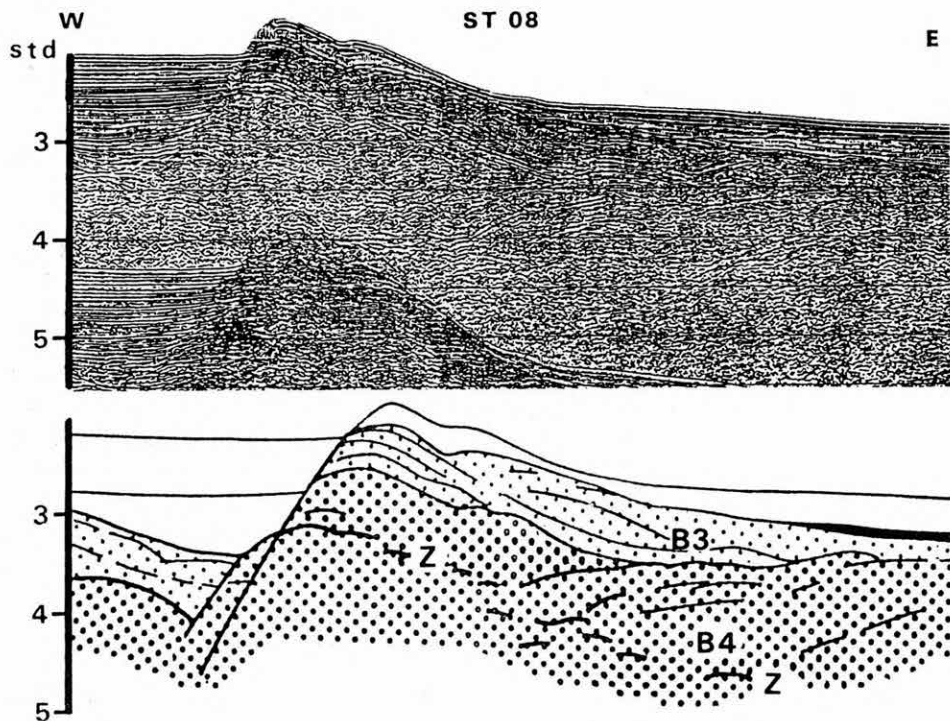


Fig. 2. Seismic section (location on Fig. 1)

Unit 1: Plio-Quaternary—in white, unit 2: Messinian—in black, unit B3: Middle (?) to Upper Tortonian—thin dots, unit B4: Late Oligocene to Lower Miocene (?)—thick dots. See text for discussion Z: unconformity of unit B4 on the acoustic basement—thick dots too

(b) The first rifting event started only after the continental collision of Corsica—Sardinia against the Adriatic margin 18 m.y. ago. Then, it has been followed by a second phasis of extension (unconformity between B3 and B4) which started 10 m.y. ago.

Geodynamic

According to these observations, the Tyrrhenian sea has undergone a continuous stretching, at least from Tortonian to present time. However regional angular unconformities related to accelerations of the subsidence in Messinian, Middle Pliocene and Middle Pleistocene (?) (FABBRI et al., 1981) show that this stretching was not uniform through time. These accelerations appear correlated with compressive events in the Apennines and Sicilian chains as well as with accelerated motions of the part of the arc, free of continental foreland (MOUSSAT, 1983; MOUSSAT et al., 1985a). Thus the shortening between Europe and Africa is involved in the process of opening of the Tyrrhenian Sea.

However, the hypothesis of a stretching induced by the squeeze of the Tyrrhenian area is not supported by the direction of movements observed along the ESE—WSW fracture zones afore mentioned.

On the one hand, dextral movements are expected to exist along such faults on the Sicilian margin, from the southward thickening of the continental crust as well as from the EW “en échelon” directed folds of Middle Pliocene in Sicily. On the other hand, besides the northward thickening of the continental crust, the Campanian margin bears evidence of sinistral shear along such fracture zones:

(a) the opening of the pull-apart basin of Salerno (N 70 E) related to the thrust fault of the Siren seamount along the N 140 E segment of the fracture zone which runs from the northern end of the central rift to the southern ends of the tectonic troughs of the northern margin;

(b) the field observations of sinistral strike-slips along such faults in Calabria, e.g. along the SE extension of the fracture zone which bounds the northern end of the Salerno basin (MOUSSAT, 1983; MOUSSAT et al., 1985a, b). Such strike-slips of opposite directions, on both sides of the Tyrrhenian basin imply that the arc is dragged by a force oriented toward the subduction zone rather than pushed by a force which squeezes its back arc area. The existence of such drag force is supported by the stresses analysis of the tectonic events affecting Calabria from Tortonian time to present (MOUSSAT, 1983; MOUSSAT et al., 1985a).

This force results from the continental collision which lock the African plate and its Adriatic promontory against Europe. Due to the low rate of convergence between these plates, the high density of the oceanic or thinned continental lithosphere makes the slab sink and shrink southeastward away from the overlying plate which is spreading out toward the subduction zone in a sort of gravity flowage. The successive riftings of the Tyrrhenian basin seem related to the same process, involving however continental collisions of second order (e.g. Corsica—Sardina/Adria collision) which lock the ends of the successive arcs, while transform faults allow the rest of them to move toward the subduction zone.

Besides, an additional drag force contributes episodically to the accelerations of the motion of the arc when the shortening seems to increase quickly between Europe and Africa. This is probably due to a force which acts on the subducted plate rather than on the overlying one, and which makes the slab shrink faster.

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