Tectonic evolution of the Central Mediterranean area

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The structure of the Mediterranean region is the final result of a sequence of geodynamic events which may be roughly summarized in the following four principal stages :

— rifting and continental break-up of Pangea (Triassic to Early Jurassic);

— plate divergence and ocean-floor spreading in the Tethyan realm (Middle Jurassic to Early Cretaceous);

— plate convergence and continent-continent collision (Cretaceous to Eocene);

— progressive consumption of the original European and African continental margins (Eocene to Present).

According to plate tectonics theory, the Africa-Eurasia interaction may be described as a kinematic system dominated by the Atlantic ocean spreading (Smith, 1971). The successive positions of Eurasia and Africa, as well as the stress conditions along the plate boundaries at different times have been reconstructed in the Mediterranean region (Dewey *et al.*, 1973) following the interpretation of the Atlantic magnetic lineations given by Pitman and Talwani (1972). Such reconstructions fit quite well those obtained by regional geological studies, although remarkable discrepancies with palinspastic restorations appear, because of some oversimplifications inherent in the global tectonics interpretations. The subduction of continental lithosphere, for instance, is dogmatically excluded by the orthodox global tectonicians, while it is commonly admitted by many Alpine geologists in order to justify the deficit in the volumes of continental crust when we compare the present structures of the Mediterranean region with the original dimensions of the continental margins before the continent-continent collision (Laubscher, 1970). On the other hand, the complexity of the lithospheric structures (Panza *et al.*, 1980), the presence of post-collisional small ocean-type basins, the existence in some areas of fragmented and distorted deep-seated lithospheric slabs (Gasparini *et al.*, 1982) suggest that not only the crust-mantle system but also the lithosphere-asthenosphere system has been strongly modified by the Alpine tectonics during and after the Africa-Europe collision.

Monitoring regional plate kinematics in the Mediterranean region is an ambitious and fascinating aim for the future, and the reliability of the currently deployed measurement systems (VLBI, SLR, TLRS) suggests that very important results may be reached in some years. The success of such a project in the Mediterranean region is conditioned — here more than in other areas — by a careful site selection in order to obtain a network configuration suitable for the complexity of the kinematic system. The site selection, however, is closely dependent on the choice between two antithetic basic assumptions concerning the possible motions within the area :

(*a*) any detected change is significant in order to determine the motions between the European and African plates;

(*b*) detected changes do not necessarily follow slip vectors corresponding to the motions between « stable » Europe and Africa, since changes certainly result at least from rigid plate motions and from ductile deformations along the boundaries of rigid blocks.

We believe that the assumption (*a*) must definitively be rejected, because geological and geophysical evidences clearly show that « stable » Europe and Africa form only the boundaries of the Mediterranean system; the latter, in reality, includes « ductile » belts which originated from the deformation of both continental margins, and more rigid continental blocks originally belonging to the African and European plates, as well as small ocean-type basins generated in areas of severe lithospheric stretching.

A structural sketch of the Central Mediterranean region is shown in figure 1, where the present boundaries of « stable » Europe and Africa have been represented. At the surface, the northern boundary of « stable » Africa is marked by the South-Atlasic lineament, a long-

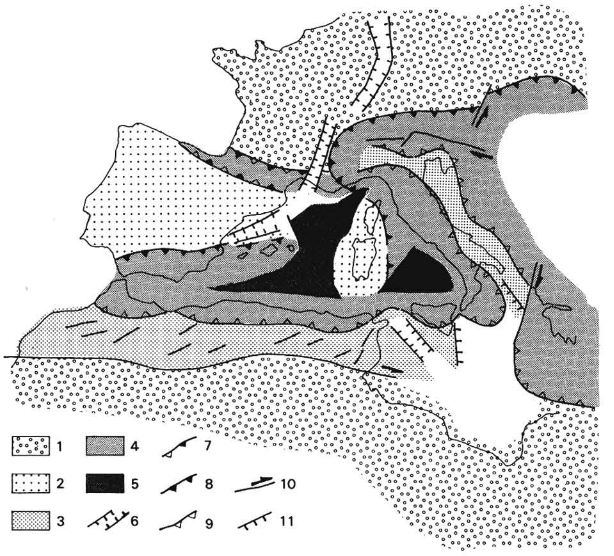

Figure 1
Structural sketch of the Central Mediterranean region. 1 = rigid plates (« stable » Europe and Africa) ; 2 = rigid microplates originally belonging to the European plate (Ibèria and Corsica-Sardinia) ; 3 = « metastable » areas originally belonging to the African plate ; 4 = « ductile » Alpine orogenic belts ; 5 = post-collisional ocean-type basins ; 6 = continental rifts ; 7 = fronts of the Pyrenees ; 8 = front of the Europe-verging orogenic system ; 9 = front of the Africa-verging orogenic system ; 10 = main transcurrent faults ; 11 = Malta and Apulia escarpments.

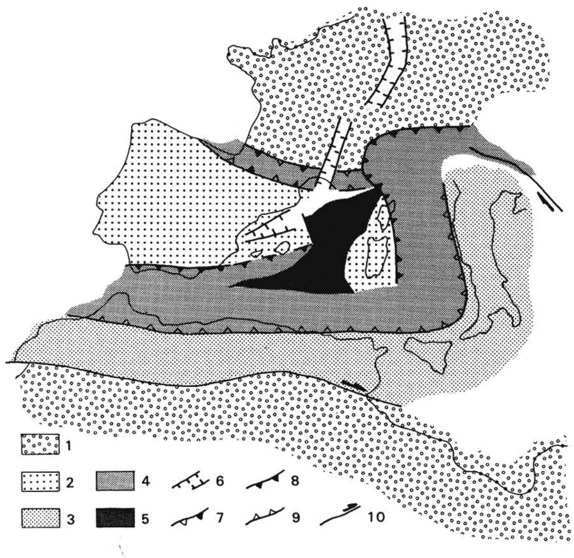

Figure 3
Palinspastic sketch of the Central Mediterranean region during Early Miocene times. 1 = rigid plates (« stable » Africa and Europe) ; 2 = rigid microplates (Iberia and Corsica-Sardinia) originally belonging to the European plate ; 3 = « metastable » areas of the African continental margin separated from the African rigid plate by the South-Atlasic fault system ; 4 = « ductile » Alpine orogenic belts ; 5 = Western Mediterranean basin ; 6 = continental rifts ; 7 = fronts of the Pyrenees ; 8 = front of the Europe-verging orogenic system ; 9 = front of the Africa-verging orogenic system ; 10 = main transcurrent faults.

lived structure which during Tertiary (and Quaternary ?) times played the role of a transcurrent fault system with dextral motion. The Atlas region is a fold belt characterized by « en echelon » anticlines trending ENE-WSW and by WNW-ESE dextral strike-slip faults and NNE-SSW sinistral antithetic faults. The general structural pattern is coherent with horizontal *P* axes acting according to the WNW-ESE direction. The eastern continuation of the South-Atlasic lineament towards the Ionian Sea and the Sirte Gulf is unknown. The nature and the kinematic role of the Ionian Sea, on the other hand, represent one of the main open problems in the Mediterranean region (Scandone *et al.*, 1981). Further investigations in this area (mainly reflection seismic profiling) might provide in the future a better understanding of the kinematic relationships between the Central and the Eastern Mediterranean regions.

The Po-Adriatic area is a relic of the ancient « African promontory » almost consumed by crustal shortening during the Alpine compression. Structurally, the region represented during Tertiary times a convergence zone of orogenic transport (Apennines, Southern Alps, Dinarides) and presently plays the role of a foreland of the last Apenninic thrusts.

The southern boundary of « stable » Europe is given by the northern fronts of the Alps and Pyrenees. Iberia with the Balearic Islands and Corsica-Sardinia represent rigid microplates originally belonging to the European plate. Iberia, together with Corsica and Sardinia, separated from « stable » Europe during Cretaceous times; the Corsica-Sardinia block moved away from Iberia during uppermost Oligocene-lowermost Miocene times. The Western Mediterranean basin opened in the wake of Corsica-Sardinia.

Two distorted and discontinuous orogenic systems having opposite vergence cross the whole Mediterranean region : the Europe-verging system (Betic Cordilleras, Alps, Carpatho-Balkan Arc) and the Africa-verging system (Maghreb, Apennines, Southern Alps,

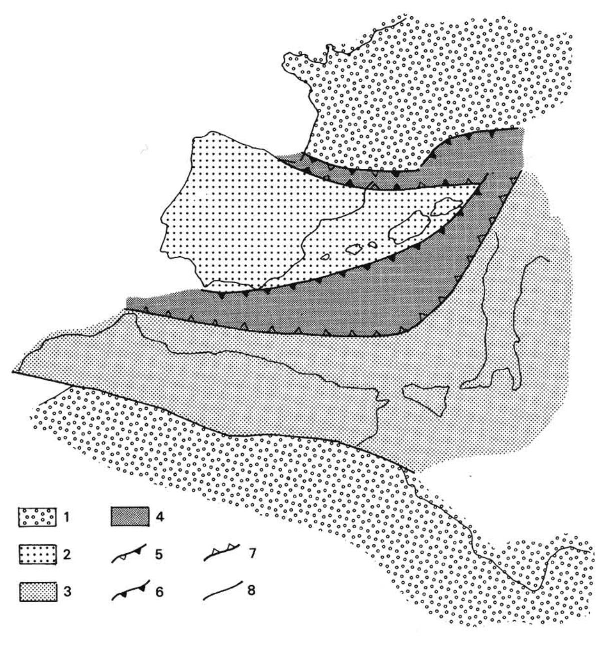

Figure 2
Palinspastic sketch of the Central Mediterranean region during Eocene times. 1 = rigid plates (« stable » Africa and Europe) ; 2 = rigid microplate (Iberia-Corsica-Sardinia block) broken off the European plate ; 3 = « metastable » areas of the African continental margin separated from the African rigid plate by the South-Atlasic fault system ; 4 = « ductile » orogenic belts ; 5 = fronts of the Pyrenees ; 6 = front of the Europe-verging orogenic system ; 7 = front of the Africa-verging orogenic system ; 8 = main transcurrent faults.

Dinarides, Hellenides). The Pyrenees belong to another orogenic system related to the interaction between the Iberian microplate and « stable » Europe.

The present configuration of the Mediterranean region described in figure 1 results from a complex geodynamic history which cannot be understood in terms of pure continent-continent collision. During Eocene times, after the Africa-Europe collision, a continuous orogenic belt separated « stable » Africa from the Iberian and European plates (fig. 2). Anticlockwise rotations of rigid blocks (Corsica-Sardinia), « ductile » distortions of the orogenic belt and right-lateral motion of North Africa and Southern Sicily along the South-Atlasic fault accompanied the opening of the Western Mediterranean basin (Early Miocene, fig. 3). Further right-lateral motions of the Atlasic-Sicily region and anticlockwise rotations of the Apennines led to the opening of the Tyrrhenian basin (Middle-Upper Miocene). Presently, the Africa-Europe convergence is likely to be still acting in the Central Mediterranean region, but other geodynamic processes also occur, including passive subduction of residual lithospheric slabs (e.g. the Calabrian Arc) and active spreading within young ocean-type basins (South-Eastern Tyrrhenian Sea), which should induce considerable motions.

In conclusion, we can distinguish in the Mediterranean system rigid plates (« stable » Europe and Africa), rigid microplates (Iberia and Corsica-Sardinia, probably forming today a unique kinematic block), metastable belts (Atlasic region, Southern Sicily and Pelagian Islands, Apulia, all of which underwent differential motions with respect to « stable » Africa and have been affected by minor ductile deformation) and finally « ductile » orogenic belts, split up and distorted in oroclinal zones. Future observing plans must take into account such regional constraints, in order to interpret correctly detected changes and to discriminate those values which can really be considered as indicative of rigid plate motions.

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