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Main Recent Deformation and Seismotectonics in the Central Mediterranean Region

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EXTENDED ABSTRACT

Late Neogene-Quaternary tectonics in the Central Mediterranean region has been entirely controlled by the Africa-Adria-Europe plate interaction and by the passive subduction of the south-western margin of Adria. Presently the western, northern and eastern boundaries of Adria are outlined by first-order geological features (Apennines, Alps and Dinarides); the southern boundary, on the contrary, is still undefined and its location is controversial.

The reconstruction of the Neogene-Quaternary relative motion of Adria *versus* Europe is well constrained by the geometrical configuration of the Insubric indenter and by the geometry of the young thrust systems in the Southern Alps, Dinarides and Hellenides. The major structural features of these areas may be simultaneously justified by a counterclockwise rotation of Adria around a pole located in the Western Mediterranean Sea not far from the Corsica coast. The slip vectors obtained by such a rotation pole satisfactorily account for the overall kinematic processes along the external margin of Adria during Neogene-Quaternary times:

- maximal compression across W-E/NW-SE frontal ramps and dextral strike-slip motion/transpression along NS/NNE-SSW lateral/oblique ramps in the Southern Dinarides and Western Hellenides ;
- dextral strike-slip motion between Istria and the Northern Dinarides along faults oriented NW-SE;
- maximal compression across ENE-WSW frontal ramps in the Southern Alps from Friuli to Garda;
- Adria indentation in the Western Alps with maximal compression across N-S fronts.

Note that in such a scheme a considerable dextral strike-slip motion is kinematically required along the northern edge of Adria between Lago Maggiore and Garda.

Passing from the Alps to the Apennines, we observe a drastic change of the structural features related to a drastic change of the plate interaction. Adria, in fact, represents the upper plate in the Alps and the lower plate in the Apennines. Europe, on the contrary, represents the lower plate in the Western Alps, that is in a segment of the collisional system which corresponds to a neutral arc, and the upper plate in the Apennines, that is a subduction segment where back-arc basins have progressively opened. Therefore, the boundary between the Alps and the Apennines is defined by a transform fault zone which has accommodated the opposite lithospheric sinking.

Due to the relative motion of Adria around the above mentioned pole, no convergence processes may be invoked in order to explain the Neogene-Quaternary evolution of the Apennines. Here, in fact, the orogenic transport has followed directions which in the areas of maximal shortening, that is at the apex of the two major arcs, paradoxically make angles of about 90° with the Adria slip vectors. In addition, the average magnitudes of the vectors indicative of the post-Tortonian orogenic transport (about 2.5 cm/year in the Northern Apenninic Arc and 5.5 cm/year in the Southern Apenninic Arc) largely exceed the magnitude of the Adria slip vectors (less than 1 cm/year). Palinspastic restorations of the Tyrrhenian-Apennine system show that the amount of convergence (Northern Apennines) or divergence (Central and Southern Apennines) are negligible whilst the flexure retreat of the sinking lithosphere roughly equals the arc-trench migration and the back-arc spreading. Thus, the Apenninic evolution must have been entirely controlled by passive subduction processes, that is by processes in which no significant contribution to the slab sinking has been supplied by plate convergence.

Presently, the Apenninic mountain chain appears to be divided into two major arcs separated by an important N-S tectonic lineament (Maiella-Roccamonfina Line) which plays the role of dextral lateral ramp of the Northern Arc.

In the Northern Apenninic Arc, where subduction processes seem to be still active, we can recognize:

- a Padan-Adriatic compressional belt outlined by the front of the thrust sheets and by the emergence of out-of-sequence ramps;
- an intermediate belt, classically assumed as an extensional belt related to the Tyrrhenian rift but recently interpreted as the passive roof of an eastward-migrating asthenospheric wedge;
- a Tyrrhenian extensional belt marked by a widespread Pliocene-Quaternary volcanism. This internal belt actually corresponds to the portion of the mountain chain recently incorporated in the back-arc system.

The Southern Apenninic Arc exhibits structural features comparable to those recognized in the north. Nevertheless, in the whole region from the Maiella-Roccamonfina Line to the Taranto Gulf foreland flexure retreat and active thrust propagation have ceased since Middle Pleistocene times and the entire mountain chain-foredeep system has undergone a gentle tilting towards NE accompanied by rapid uplift and by severe block-faulting. This dramatic change of geodynamic behaviour has been related to a lithosphere rebound due to the detachment of the subducted slab in the area. Several geological evidences show that in the Calabrian Arc flexure retreat and orogenic transport have continued during the Apenninic uplift. Nevertheless, considering the regular uplift of Late Pleistocene marine terraces in Calabria we cannot exclude a detachment of the subducted slab also in this region. The southern boundary of the Calabrian Arc is well defined in North Sicily by a dextral shear zone which represents the southern rail of the eastward-escaped Calabrian Arc.

As already mentioned, the major open problem in the area is represented by the still undefined Africa-Adria boundary. South Sicily and the Pelagian Block are usually considered to represent the northern edge of the Africa plate which has moved in recent times from SE towards NW with a rate not exceeding 1 cm/year. If we accept this axiom we are also obliged to admit a lot of extension in the Ionian Sea between the Malta and Apulia escarpments during Neogene-Quaternary times. Geological/geophysical evidences make unrealistic a significant spreading of the Ionian Sea during Tertiary times, so that we have tentatively considered South Sicily as a part of Adria.

Palinspastic restorations of the Central Mediterranean region at different times from the Late Oligocene to the Early/Middle Pleistocene allowed us to reconstruct step-by-step the kinematic evolution of the area. The results of the kinematic analysis have been largely used, together with the available information on the present-day crustal/lithospheric structures, for a regional seismotectonic investigation. Input data obviously include the historical and present-day regional seismicity. The seismotectonic investigation has been planned and carried out in the frame of the scientific activities of Gruppo Nazionale per la Difesa dai Terremoti, with the contribution of several University and CNR researchers, too many to be quoted here. Principal aim of the study was the elaboration of a map of the seismic source zones in Italy and surrounding areas as a tool for hazard evaluations. Seismic source zones represent the surface projection of active fault systems characterized by consistent kinematic behaviour (that is major faults and associated synthetic and antithetic faults), able to generate earthquakes.

The proposed seismic zonation gives a quite satisfactory explanation of the earthquake distribution, as well as of the magnitude of the events and the fault mechanisms. Grouping the seismic zones according to their kinematic behaviour, we can distinguish:

- seismic source zones bordering the Adria northern margin (Western Hellenides, Dinarides, Southern Alps and Western Alps) with different expected earthquake fault-planes controlled by the trajectories of the Adria slip vectors:
    - thrust mechanisms in correspondence of W-E/WNE-ESE longitudinal fronts and dextral strike-slip/transpression mechanisms in correspondence of lateral/oblique ramps in the Western Hellenides and Southern Dinarides;

- dextral strike-slip and transpression mechanisms in correspondence of faults reactivating previous frontal/oblique ramps between Istria and the Northern Dinarides;
- thrust mechanisms in correspondence of ENE-WSW frontal ramps and both dextral and sinistral strike-slip mechanisms in correspondence of lateral ramps in the Eastern Southern Alps;
- W-E/WNW-ESE dextral strike-slip mechanisms in the Western Southern Alps;
- thrust mechanisms in correspondence of N-S fronts in the Western Alps;

- seismic source zones along the subducting south-western margin of Adria (Northern Apennines). In the Northern Apenninic Arc three longitudinal seismic belts may be recognized:
  - Adriatic belt, with expected thrust and subordinate strike-slip mechanisms. P axes are supposed horizontal and directed SW-NE;
  - intermediate belt, with major earthquakes released by tension faults dipping both towards the Adriatic and the Tyrrhenian seas. Due to the structural and kinematic complexity of the area, minor earthquakes with strike-slip or thrust mechanisms are possible;
  - Tyrrhenian belt, characterized by tensional regime with high heat flow and low-energy shallow earthquakes;
- seismic source zones related to the recent uplift and block-faulting of the Southern Apennines. We have already emphasized the drastic change of geodynamic regime which took place in the Southern Apennines since Middle Pleistocene times. Seismic source zones mostly follow a narrow belt characterized by NW-SE tension faults dipping both towards Apulia and the Tyrrhenian Sea. Some of these faults correspond to a re-activation of Pliocene-Quaternary thrusts. Minor earthquakes with strike-slip fault mechanisms should represent breakages along transfer fault segments;
- seismic source zones of the Calabrian Arc. It is still matter of debate whether the well-known Wadati-Benioff zone of the Southern Tyrrhenian Sea is still attached to the Ionian foreland lithosphere or is detached. In the first case the Sibari Plain and the North-Sicily shear zone would represent the surface expression of lithospheric tear faults and would act at shallow depths as lateral ramps of the thrust system. Fault plane solutions of earthquakes located in North-eastern Sicily showing dextral strike-slip motion would support this interpretation; nevertheless, the absence in the Ionian Sea of a seismic belt with thrust mechanisms and the existence along the Tyrrhenian coast of uplifted marine terraces attributed to the Upper Pleistocene favour the idea that the Calabrian Arc has undergone in recent times the same change of geodynamic regime experienced by the Southern Apennines;
- seismic source zones in the rigid foreland related to strike-slip faults (Western Sicily, Adriatic) or to dip-slip faults, the latter including tear faults in correspondence of the

flexure hinge of the foreland (South-eastern Sicily and Malta Escarpment, south-western margin of Gargano).

The proposed zonation represents the state of the art of Gruppo Nazionale per la Difesa dai Terremoti. Future research will be addressed to recognize and characterize the single active structures responsible for medium/high energy events in order to improve the results of the hazard evaluations by separating the big earthquakes, related to finite segments of major faults, from the small earthquakes considered as minor breakages randomly distributed within polygons corresponding to low-potential seismic source zones.