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TECTONIC EVOLUTION OF THE OUTER MARGIN OF THE APENNINES AND RELATED FOREDEEP SYSTEM

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Abstract

The deformational history of the Apennines may be roughly divided in two parts, separated by the early rift-processes of the Tyrrhenian basin. Plate-tectonics supplies a good model for interpreting the first part of this history, which is entirely dominated by plate-convergence from middle Cretaceous to late Oligocene times, with continent-continent collision at the Eocene and consequent subduction of the western margin of the Adriatic Promontory beneath the Iberian microplate. The succession of these events is described by the Cretaceous-Paleogene building up of the Ligurian, Calabrian and Silicide nappes, as well as by the Oligocene calc-alkaline magmatism of Western Sardinia. At the Oligocene-Miocene boundary Corsica-Sardinia began counterclockwise rotation and the Provence basin opened in the wake. Subduction of the western margin of the Adriatic Promontory beneath the Corsica-Sardinia block still continued during and after this rotation, producing severe compression in the Apennines and widespread calc-alkaline volcanic activity in Western Sardinia. Regional metamorphism and piling up of nappes with considerable crustal shortening and orogenic transport towards the Adriatic foreland mainly occurred during Burdigalian and Tortonian times.

A drastic change in the history happened in late Tortonian times, when rifting occurred along the western margin of the Tuscan Apennines and in the present Northern and Western Tyrrhenian Sea. The nappe building was dissected by tension faults; subsiding basins strictly controlled by synsedimentary tectonics developed on foundered segments of the Apenninic mountain chain; the last calc-alkaline activity ceased at all in Western Sardinia. The Tyrrhenian basin started opening. We can express only hypotheses on the causes of such a drastic change when the eastern

border of the Corsica-Sardinia block abruptly transformed from an active margin into a passive one. Paradoxally, crustal shortening continued at the eastern margin of the Apennines during the opening of the Tyrrhenian Sea, with a time-space migration of the compression fronts towards the Po-Adriatic-Ionian foreland, closely pursued by the distension fronts. If the cause of the Tyrrhenian rifting was a divergence of the Adriatic Promontory from Corsica-Sardinia, then we should expect sink areas located at the outer margin of the moving block, that is along the front of the Dinarides and of the Eastern Southern Alps. Perhaps some recent compressional features recognized in these areas might be related to a late Tertiary counterclockwise rotation of the Adriatic Promontory, but what is really surprising is that the most severe compression actually occurred along the inner margin of the Adriatic Promontory, from the Po Plain to the Ionian Sea. No available model of the post-Tortonian Apennine evolution provides a convincing explanation of this fact.

Aim of our research was first of all to obtain a good geometrical definition of the present-day structural arrangement of the thrust belt-foredeep-foreland system; in the second place our investigation was addressed to establish the timing of the deformation and the space distribution of the compressional fronts; lastly we operated palinspastic restorations by filtering the different compressive events. After the geometrical and kinematical analysis we tried, of course, some speculations on the deep sources of the recognized deformational processes. A tentative model was finally elaborated, which interpretes the folding and the thrusting along the outer margin of the mountain chain, the time-space migration of the thrust belt-foredeep-foreland system and the rifting of the Tyrrhenian area as different products of a unique, major geodynamic process.

Figure 1 shows the main structural elements of the Italian Peninsula and surrounding areas, with major emphasis for the Pliocene-Quaternary features. Surface structures (fold axes, thrusts and faults), as well as the base-of-Pliocene surface clearly draw two major Apenninic arcs, convex towards the foreland, underlined too by the trend of the negative Bouguer anomalies. The two arcs are linked by a major tranversal accident,

known in the geological literature as "Maiella-Roccamonfina line". Cros= sing this fault zone the strikes of the tectonic structures abruptly chan= ge from the N-S to the E-W direction. In details, the northern Appenninic arc consists of several second-order arc-shaped segments (Monferrato, Emilia, Ferrara, Romagna-Marche and Adriatic folds) which mostly developed by counterclockwise rotation of the advancing thrust sheets and dextral displacement at the eastern edges by N-S trending tear faults. Also the southern Apenninic arc consists of several minor segments (Molise-Sannio, Irpinia-Lucania and Calabria-Peloritani segments) showing different struc= tural pattern and, sometimes, different ages and amounts of deformation. It is importan to underline that such a complex structural arrangement is the result of several compressive events which did not produce a cylin= drical deformation. The main recognized compressional events happened in late Messinian times (after the salinity crisis), during the early Pliocene (near the boundary between the G. margaritae and the G. puncticu= lata zones), during the middle Pliocene (within the G. gr. crassaformis zone), during the late Pliocene (within the G. inflata zone) and finally during Pleistocene times. We believe that compressional processes are still acting today.

The Messinian tectonic phase is well described in Romagna, where uppermost Messinian continental deposits conformably overlain by lowermost Pliocene marine deposits stratigraphically cover the Messinian evaporites in angular unconformity. Messinian compression is also well known in the Latium-Abruzzi region where Mesozoic carbonates overthrust deep-sea terrigenous sediments of early Messinian age and are unconforma= bly overlain by late Messinian lacustrine deposits. It is not yet clari= fied whether the Messinian or the lower Pliocene tectonics was responsible for the main thrust of the Sibillini mountains ("Anzio-Ancona line"). An impressive example of the Messinian orogenic transport is in Molise, where allochthonous sheets, already piled up in the Tortonian Apenninic chain, tectonically overlie lower Messinian sediments of the Molise units and are unconformably overlain by upper Messinian terrigenous deposits. The Abruzzi-Marche region, finally, offer a wonderful reading of the Mes=

sinian tectonism, with an evident time-space migration of the foredeep basin system from early Messinian times before the salinity crisis (Laga) to Late Messinian times before (Civitella del Tronto-Vomano) and after (south-eastern margin of Gran Sasso) the deposition of the calc-alkaline tuffite key bed.

The lower Pliocene tectonic phase is well documented by surface and subsurface data in the whole northern Apenninic arc. The lowermost Plio= cene deposits (which are always conformable, when they are present, with the uppermost Messinian ones) are often lacking and G. puncticulata sedi= ments overlie older units in angular unconformity. The most spectacular example of the lower Pliocene compression is represented in the Abruzzi region by the front of the Southern Gran Sasso-Morrone-Porrara mountains overthrusting the Maiella unit. A thick sequence of Messinian-lower Plio= cene deep-sea terrigenous sediments was involved in the deformation. Un= conformable deposits of lower Pliocene age (G. puncticulata zone) allow to date precisely the main compressional event. In the southern Apenninic arc the lower Pliocene tectonic phase was responsible for the first oroge= nic transport of the Molise units which overrode and overtook the Morrone-Porrara unit, reaching Maiella. Also in the southern Apenninic arc this compressional phase is well dated by the age of the youngest involved deposits (G. margaritae zone) and of the oldest unconformable deposits (G. puncticulata zone).

The "middle Pliocene transgression" is a widespread, well described event in the whole Apennines. In effects, this "transgression" (G. crassa= formis subzone) everywhere followed a severe compressional phase which occurred in the upper part of the G. aemiliana subzone. In the northern Apenninic arc, this phase was responsible for the major structural set= ting of the minor arcs along the outer border of the Northern Apennines and for the generation of the Adriatic folds from Romagna to Abruzzi. This compression was also responsible for the implacement of the Maiella and Casoli units. In the southern Apenninic arc, this tectonic event, documented by angular unconformity at the base of the G. crassaformis deposits, produced a considerable displacement of the allochthonous sheets towards the foreland.

Subsurface exploration clearly demonstrates in the whole Apennines a quite severe late Pliocene compressional phase which occurred within the G. inflata zone. In the northern arc, this event is well documented both along the front of the Apennines (e.g. Busseto, Collecchio) and in the most external Ferrara folds. In the Adriatic Sea, the upper Pliocene compression reactivated structures already formed in the middle Pliocene and created the most external Adriatic folds. From Abruzzi to the Taranto Gulf, this tectonic phase is well documented in subsurface by the overthrust of the allochthonous sheets on the G. inflata deposits stratigraphically covering the Apulia foreland, as well as by folding of the Apulia carbonates; at the surface this compression is witnessed by emerging ramps along the outer margin of the Southern Apennines with the upper Pliocene deposits of the "intra-Apenninic basins" involved in the orogenic transport. This deformation is sutured by unconformable upper Pliocene and, more often, lower Pleistocene deposits.

Finally, evidences of younger compression, acting at least up to middle Pleistocene times, have been found along the Padan margin of the northern arc and along the Ionian margin of the southern one.

The total amount of the post-Tortonian shortening exceeds, according the most conservative estimates, 100 kilometres. Where is the source area and where is, today, the original basement of the thin-skinned thrust sheets? Deep-focus earthquakes in the Southern Tyrrhenian area reveal the existence of a peculiar Benioff-zone which has been related to a relic slab of the Adriatic-Ionian subducted litosphere. In effects, the slab measures more than 650 kilometers in length, and if we assume a subduction rate of about 2 cm/y as average, we realize that the subduction process had to start at least 30 MY ago, that is long time before the opening of the Tyrrhenian Sea. We can, therefore, reasonably assume that the deep portion of the slab represents the lithosphere remnant from which were detached the Apenninic nappes piled up before late Tortonian times, and the shallow portion represents the lithosphere remnant of the post-Tortonian thrust sheets. No deep-focus earthquakes have been recorded in the Northern Apennines, but analysis of seismic-wave propagation indicates the existence of deep-seated lithospheric roots also in this region. Accepting the subduction as the most reliable process for shortening and mountain building, we suggest that lithosphere decoupling along the former Tortonian plate-margin and gravitational sinking of the Po-Adriatic-Ionian lithosphere may be the possible sources for the Tyrrhenian rifting and mantle upwelling, for the thin-skinned tectonics along the flexure of the down-going lithosphere and for the time-space migration of the thrust belt-foredeep-foreland system. Following such a model, the two Apenninic arcs (fig. 2) originated by differential sinking of the Padan-Adriatic, Apulian and Ionian foreland segments, with maximal convexity of the arcs and maximal orogenic transport in correspondence to the maximal retreat of the foundering lithosphere.

Didascalia delle illustrazioni

Figure 1. Major structural elements of the Italian Peninsula and surrounding areas

1 Foredeep basinal areas where the Pliocene-Quaternary deposits overlying the Po-Adriatic crust exceed 4.000 metres in thickness

2 Major overthrusts in the Apennines; compression fronts in the Alps, Southern Alps and Dinarides

3 Front of the "plastic nappes" in the southern Apenninic arc

4 Upper Pliocene-Quaternary folds in the Adriatic foreland

5 Faults (mainly strike-slip faults)

6 Normal faults

7 Quaternary subaerial volcanoes

8 Isobaths of the subducted Ionian lithosphere

9 Maximal (positive and negative) Bouguer gravity anomalies

Figure 2. Differential sinking of the Po-Adriatic-Ionian lithosphere. White arrows indicate the present-day direction of the orogenic transport at shallow depths. Small arrows describe the sinking of the lithosphere in the northern and southern Apenninic arcs. In the Southern Tyrrhenian Sea, the Ionian lithosphere dips nearly vertical to a depth of about 250 kilometers

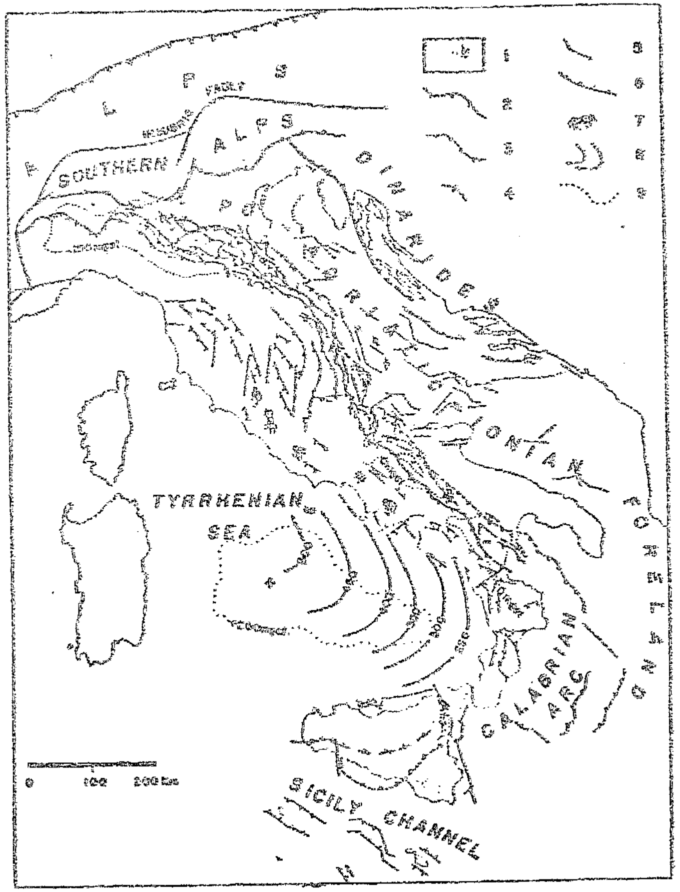

Fig. 1

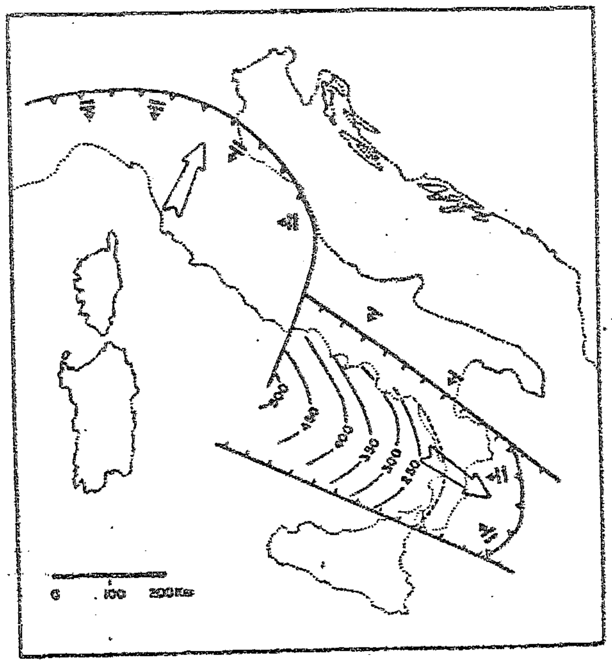

Fig. 2