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MAPPING GEOLOGY IN ITALY

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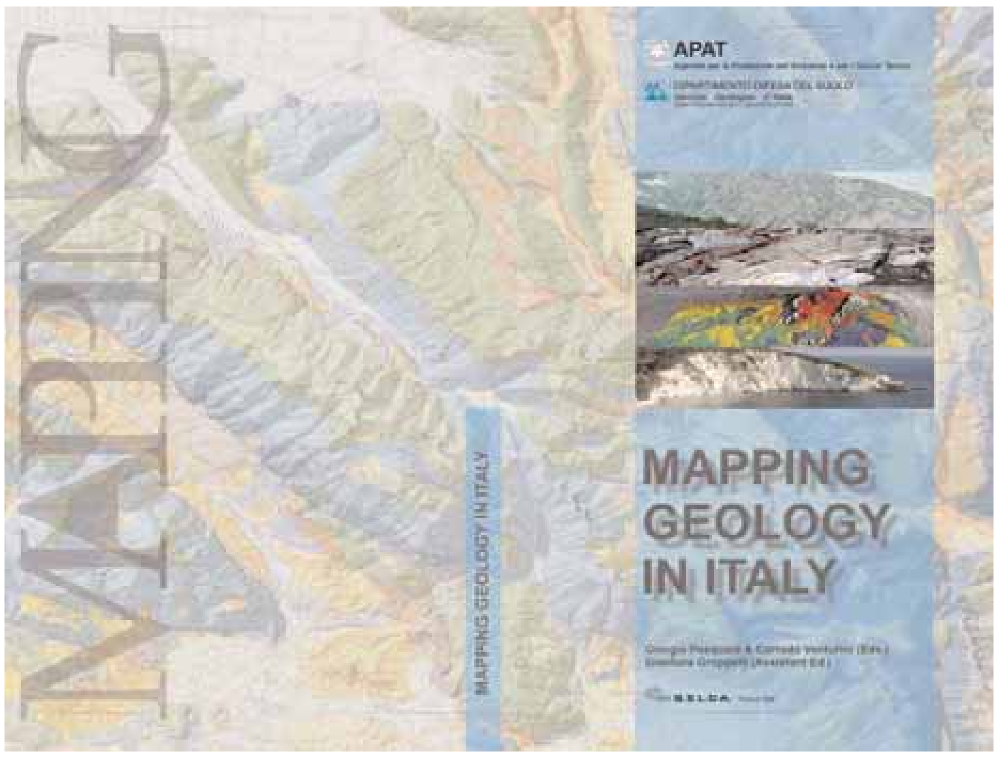

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ROMA - 2004

Dedicated to the overlasting memory
of Maddalena, and to our wives,
Lilia and Maria Pia, with love

INTRODUCTION

The volume is a collection of some of the most recent, geological and geomorphologic cartographic representations of key areas of the Italian territory and its evolution, illustrated by means of state-of-the-art methodologies, appropriate to each site-specific geological condition; it contains 38 contributions, centred on areas that are representative of the main geological aspects of the Italian territory.

The initial page of each contribution features a background image excerpted from a geographic Atlas of Italy dating back to the second half of the 19th Century; the back of the same page shows the geological/geomorphologic map on which the contribution is based: This in order to create an ideal connection between two representations of the territory, separated by more than 100 years of geological investigations.

The main purpose of the present work is to combine data, cartographic representations and evolutive interpetations, with the related research methodologies. Moreover, this volume is intended to foster dialogue between experts in the field of geological cartography, and serve as a didactic tool for Earth Science students and Earth scientists. We believe the above mentioned approach was agreed upon by all of the contributors of the present work, despite the inevitable differences in style and expression.

The first section of the volume provides a brief description of the geologic evolution of the Italian territory, and the final one contains a physical map of Italy where the location of the studied areas is indicated. Their cartographic representation is the ultimate synthesis of the methodologies adopted and described by the contributors.

The contributions that compose the present volume are arranged following thematic areas, starting from the ones dedicated to the Quaternary (marine geology, geomorphology, neotectonics and surface deposits analysis), to the ones related to recent and active volcanism, and then to stratigraphic, tectonic and kinematic topics related to the classic Apenninic Meso-Cenozoic successions. Finally, the deformative features of different Alpine basements are considered.

A special conclusive section is dedicated to the cartographic illustration of two geosite case studies, for which a graphical project targeted to the lay public has been elaborated.Italy represents a huge archive of geological conditions and events, which, during the last 500 million years, left their undeletable signature in a very limited crustal sector.

Stratigraphic and deformative evidences, sedimentary and magmatic events, rotations and traslations of lithospheric blocks, crustal stacking and doubling: A complicated geological evolution that is as compelling as a screenplay enriched with “coups de theatre” such as lithospheric extensions, oceanizations, passive margins turning into active margins, syn-sedimentary tectonic movements at different scales, A and B subduction processes, collisional events generating fold-nappe orogens and thrust-and-fold belts, migrating foreland basins, fast-spreading back-arc basins, superpositions of deformations related to different orogenetic processes, reactivations of palaeostructures and spectacular topographic inversions. Metamorphic processes, exhumations of the deep crust and magmatic processes linked to various geodynamic settings also played an important role in Italy’s geological evolution.

Italy’s geomorphologic setting is the result of a series of processes that, combined with ever-evolving geological conditions, contributed to the shaping of the peninsula: A complex intertwining of depositional and erosive features, both subaerial and submarine, originated by the Quaternary, glacial and post-glacial events that interacted, and interefered, with eustatic and isostatic movements, magmatic events and, last but not least, man-induced modifications of the territory.

All the above represents just a short summary of Italy’s geology and geomorphology, which have never ceased to charm both the experts and the lay public, attracted by a compelling geological tale, told by generations of Earth scientists.

Basic geological knowledge is best represented and conveyed through geological and geomorphologic, 2D, and state-of-the-art 3D maps.

Italians have always prided themselves on their cartographic production. It all started back at the beginning of Italy’s history as a unified country, when geological mapping studies were prompted by the need to represent landscape features, show the location of rivers and the distribution of mountainous areas, plan the siting of strategic communication and transportation infrastructures and individuate borders between countries for commercial and defense purposes.

The first evidences of cartographic activity in Italy date back to the Roman Imperial age, when a huge and marvellous road-map (redrawn from the original in the High Middle Ages and afterwards named “Tabula Peutingeriana”) was compelled. Since then, the process of collection and elaboration of data has continued uninterrupted to our day.

Two thousand years later, the Italian territory has still much to offer to the ones who are willing to unveil its mysteries and search for clues to its geological past.

A SHORT OUTLINE OF THE GEOLOGY OF ITALY

The geologic makeup of Italy is characterised by an extreme diversity of geologic features which, since ancient times, have drawn the attention of Earth scientists from all over the world. This peculiar geological setting is due to Italy's location in the middle of the Mediterranean Sea, where it was involved in the complex geodynamic processes derived from the long-lived, and ongoing, dynamic interaction between the European and African tectonic plates. These processes shaped the Italian peninsula, charcaterised by a series of orogenic and magmatic arcs, flanked by basins with different structural significance (Fig. 1).

The earliest evidence found in Italy's geologic record dates back to the tectonic processes related to the evolution of the Palaeozoic ocean known as Palaeotethys and its margins, which, troughout Europe, led to the Caledonian and Hercynian orogenies.

In fact, some metasedimentary successions in Sardinia and the Carnic Alps indicate a Caledonian age: In particular, Cambrian-Ordovician marine successions, mostly carbonatic and terrigenous, which accumulated on an epicontinental passive margin, are exposed in Sardinia, associated to basic and intermediate volcanics, probably erupted during a concomitant rifting phase.

The following, Hercynian palaeogeograhic and tectonic evolution is well documented in Italy, mainly in Sardinia, in the Alps and the Calabrian-Peloritan Arc.

The Sardinian basement, poorly affected by Alpine deformations, represents a classic example of Hercynian orogen, with a collisional belt characterised by significant crustal thickening, magmatism and metamorhism during the Carboniferous and the Devonian. The tectonic makeup of Hercynian Sardinia is composed of a stack of west-verging folds and thrusts, whose emplacement was followed by a prolonged phase of intrusion of huge calcalkaline plutonic bodies and extrusion of alkaline and peralkaline volcanics, related to the post-collisional extension of the mountain belt (Fig. 2).

In the Alpine belt, metamorphic basements display almost everywhere an Hercynian overprint and evidences of volcanic activity. It is possible to recognize polyphase metamorphic complexes, widely intruded by plutonic bodies whose chemical composition shows a temporal progression from peraluminous to calcalkaline and finally high-K calcalkaline character.

The Calabrian-Peloritan basements display various types of metamorphic sequences as well, from weakly metamorphosed to amphibolite, granulite and migmatite facies. Late Carboniferous to Permian granitoids of calcalkaline character occur.

Among the Hercynian segments of the Southern Alps, the succession exposed in the Carnic Alps deserves particular attention since, during the Carboniferous compressive phase, it was located in the external zone of the mountain belt.

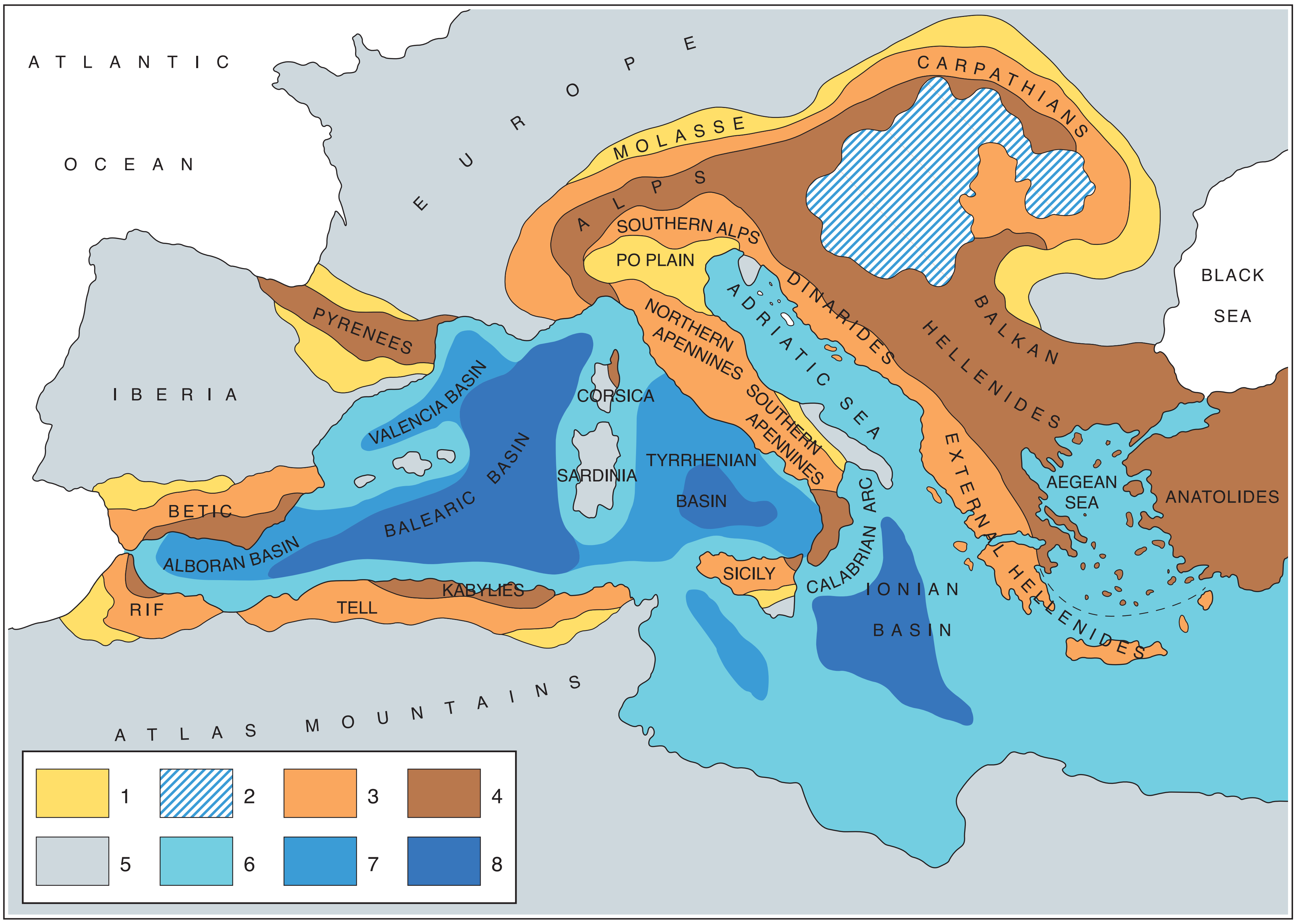


Fig. 1 - *The main geological and structural elements of the Mediterranean area. 1) Neogene foredeeps. 2) Pannonian back-arc basin. 3) Neogene thrust belts. 4) Cretaceous thrust belts. 5) Stable continental blocks. 6) Mediterranean continental crust. 7) Mediterranean thinned continental crust. 8) Oceanic crust.*

Therefore it displays non-metamorphic or archimetamorphic features, and contains a rich shallow-sea fauna of Late Ordovician to Middle Devonian age.
The Hercynian event ended with the settlement of a dextral transcurrence tectonic regime between Gondwana and Laurasia. In Italy, as well as in several areas of Southern Europe, Permian-Carboniferous transtensions originated pull-apart basins, often continental and less frequently marine (Carnic Alps), located in sectors of the Alps, Apennines and the Corsica-Sardinia block.
After the complex assembling of Pangea, the whole central ad southern Europe was subject to a continental rifting regime that, starting in the Early (-Late) Permian, led to the opening of a new Tethys Ocean between Gondwana and Laurasia.
The future realm of the Italian territory was then characterised by a portion of the Tethys, known as Ligurian-Piedmont Ocean, and by its margins. The Ligurian oceanic floor was composed of peridotites intruded by gabbros and covered by MORB tholeiites, radiolarites and pelagic limestones. The passive margins of the ocean were segmented into platforms and basins during most of the Mesozoic Era.
In the Southern Alps, evidences of this particular palaeogeographical setting are widepsread and spectacular, especially in the Dolomites and the Carnic and Giulian Alps. There the Permian-Carboniferous fluvial, lacustrine and marginal marine depositional regime gave way, in the Late Permian and Triassic, to the sedimentation of evaporitic and terrigenous shallow-sea deposits and the build-up of huge organogenic, carbonate bodies of Late Triassic age.
During this geologic time interval, a high subsidence rate, coupled with extensive and transtensive tectonic regime, caused the break-up of peritidal platforms, fragmented in isolated blocks, separated by deep basins infilled with terrogenous sediments and volcanic products. In Jurassic time, the effects of the extensional tectonic activity became more marked, and further affected the palaeogeographic articulation of the area.
In the central and southern Apennines, this kind of palaeogeographic conditions continued during the Cretaceous and most of the Tertiary: In fact, beside large carbonatic platforms such as the Lazio-Abruzzo and Campania-Lucania ones, spectacular slope-and by-pass margins developed, passing into deep pelagic basins like the Umbria-Marche and the Molise-Sannio ones.
An event which played a major role in shaping the present geologic setting of the Italian peninsula, is represented by the abrupt change in the relative motion between Europe and Africa; in late Cretaceous times, the two plates began converging towards each other, with minor extensional deformations, controlled by the same compressional regime.
This geodynamic reorganization led to the substitution of passive margins, whic had long represented key areas of the geologic evolution, with active margins. Along these converging margins, the Ligurian oceanic crust was almost completely consumed, with the exception of the Jonian area whose oceanic crust continued its northwestward suduction, also in Pliocene-Qaternary times, beneath the Calabrian Arc.

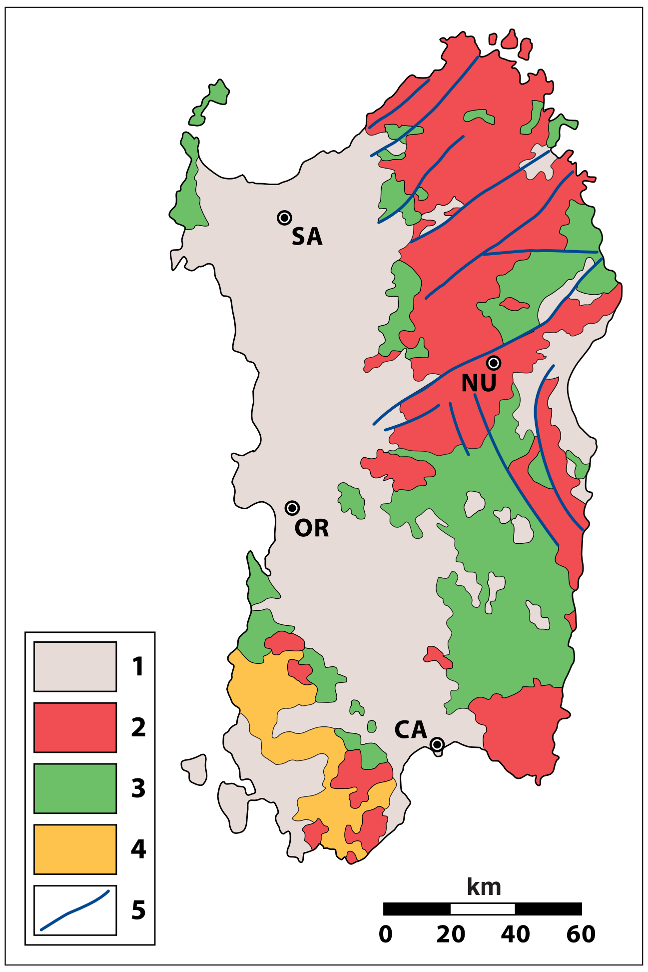


Fig. 2 - *The Hercynian orogenic belt in Sardinia.*
1) Post-Hercynian cover. 2) Intrusive complex. 3) Thrust belt. 4) External fold belt.
(After Servizio Geologico Nazionale*, 2001 - Mem. descrittive della Carta Geologica d'Italia, Vol. LX, modified).*

The above described processes led to the formation of the Alpine and Apennine collisional belts, bounded by foreland basins, and to the opening of the Tyrrhenian back-arc basin which was preceded by the eastward drifting and counterclockwise rotation of the Sardinia-Corsica block. The subsequent geodynamic evolution led to the further fragmentation of the African foreland, with the separation between the Adria and African plates and the rifting of the Sicilian Channel.
The Alps are composed of a stack of large tectonic nappes derived from the European and African continental margins and the Tethyan oceanic lithoshpere, thrust towards the W, NW and N, over the European foreland. South of a a major, lithospheric suture zone known as Insubric or Periadriatic Line, rise the Southern Alps, dominated by south- and southwest-verging thrust sheets, accreted toward the Adria plate (Fig. 3).
The Alps display a rough and steep topography with high erosion and denudation rates and are characterised by a basement reaching high-grade metamorphic facies at the surface, a process of convergence that continued even after the collisional event, the development of outer molasse basins deformed by compressional structures, rather than extensional ones.
The formation of the Alpine belt was extremely articulated, spanning the time between the late Cretaceous and the Neogene, and gave rise to a tectonic architecture that, altough extremely complex in detail, reflects the expected piling-up of the palaeogeographic units forming the European and African margins prior to their collision.
Within this architecture it is still possibile to recognize the cylindristic models of the first geologists who studied the Alpine belt, among whom Emile Argand and Rudolf Staub, whose remarkable intuitions date back to the beginning of the twentieth century. In spite of the impres-

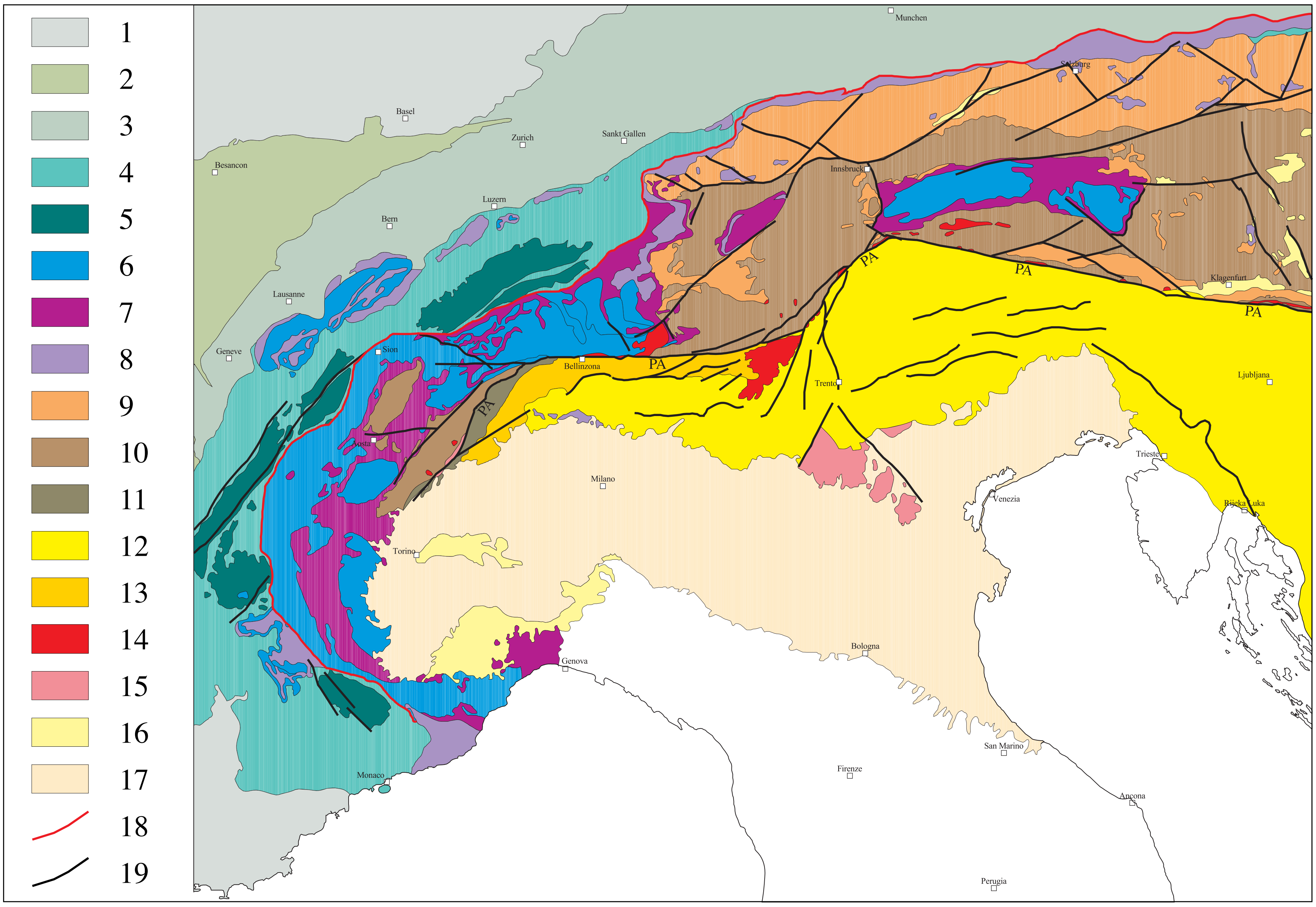


Fig. 3 - *Tectonic sketch-map of the Alps. 1) European foreland. 2) Jura fold belt. 3) Subalpine molasse. 4) Helvetic cover. 5) Helvetic basement. 6) Pennidic nappes. 7) Pennidic ophiolite-bearing nappes. 8) Pennidic Flysch nappes. 9) Austroalpine cover. 10) Austroalpine basement. 11) Ivrea-Verbano Zone. 12) Southalpine cover. 13) Southalpine basement. 14) Paleogene intrusives. 15) Paleogene volcanics. 16) Perialpine Oligo-Miocene basins. 17) Po plain. 18) Pennidic front. 19) Main regional faults (PA = Periadriatic Line). (After Bistacchi & Massironi, 2001 - In G. Pasquarè (Ed.): Tettonica recente e instabilità di versante nelle Alpi centrali, Cariplo-C.N.R., modified).*

sive amount of subduction and obduction processes, of the great lateral displacement of terrains and of the tight alternation of diverging and converging structures, the palinspastic reconstructions carried out during the last century mostly recognize the longitudinal persistence of several palaeogeographic realms along the entire Alpine belt. Again, despite the tectonic and metamorphic deformations which stemmed from the Alpine collision and affected the rock units derived from the previous palaeogeographic setting there is a general agreement on the main palaeogeographic-structural domains forming the Alps.

From the outer to the inner portions of the belt we recognize: The European foreland; the Helvetic domain, belonging to the deformed European margin; the Penninic domain, made up of the ophiolitic remains of the Tethyan ocean and its highly deformed and metamorphosed margins; the Austroalpine domain, derived from the northern margin of the African foreland, tightly compressed against the Penninic tectonic units and overthrusted on them; the Southalpine domain, composed of the deformed margin of the Adria plate, and backthrusted on it.

There's a general agreement on the recognition of the oldest Alpine orogenetic movements in the easternmost Austroalpine domain during early to middle Cretaceous. This orogenic phase produced also an eclogitic to Barrovian metamorphism, commonly ascribed to the closure of a Triassic Vardar Ocean and subsequent continental collision in the Balkanic and Carpathian area.

A widespread orogeny took place between the late Cretaceous and the Eocene. The orogenic process began with the subduction of Ligurian oceanic lithosphere beneath the African margin's accretionary wedge and ended with the Eocene collision between Adria and Europe. The resulting accretionary wedge is represented by the Penninic-Austroalpine core of the Alpine belt. The Penninic units include portions of the continental European lithosphere, fragments of the rifted European margin, as the Brianconnais realm basement nappes, ophiolitic bodies and related Flysch-like sequences and subduction melanges.

The Austroalpine units, mainly derived from the Adria passive continental margin, consist of a stack of cover and basement nappes overriding the Penninic ones, as clearly visible in the beautiful Engadine and Tauern tectonic windows. Based on metamorphic imprints and overprints it is possible to identify, within the Penninic and Austroalpine units, remnants of lithospheric slabs which were subducted to depths of at least 100 km and then rapidly exumed in conditions of high thermal gradient (Barrovian-type collisional metamorphism). This phase ended when the Penninic units of the outer European margin were involved in the subduction process, causing the commencement of a continent-continent collision.

During the Oligocene the subduction of the Euroean continental lithosphere continued, producing intense deformations in the thickened axial sector of the Alpine belt, its isostatic rise and subsequent topographic and morphologic uplift of the orogen.

The resulting, high erosion rate led to the deposition of huge volumes of turbiditic materials in the external Helvetic-Dauphinois domains. From the late Oligocene onwards this realm was affected by very intensive tectonic deformations with updoming of the European Variscan basement and decollement nappes in its sedimentary cover, wich reached the Alpine front with the Prealpine French-Swiss Klippens.

During this phase, a portion of the materials added to the accretionary prism was carried back and thrust toward the hinterland, forming the Southern Alps. This huge, southern Alpine orogenic prism, is composed of a Variscan metamorphic and plutonic basement and its Permo-Carboniferous and Mesozoic sedimentary cover, probably detached at the level of the Adriatic lower crust, nowadays exposed along the so-called Ivrea-Verbano Zone. The overthrusting of this fold-and-thrust belt on the Adriatic crust ended in the Messinian, and this testifies to the very recent age of the post-collisional crustal shortening in the Alps. Because of the southalpine orogeny the Alpine belt acquired the shape of a gigantic pop-up between the fore-thrusts and back-thrusts, with molasse basins on either side.

The diverging separation of the Southern Alps from the main Alpine belt was controlled by the activity of lithospheric faults such as the Periadriatic (Insubric) one, along which a former great dextral strike-slip movement was taken up by main vertical displacements that, in turn, produced the larger uplift of the axial sector of the belt with respect to the Southern Alpine one (Fig. 4).

At the same time, due to the laceration of the underlying, stretched European lithosphere, significant volumes of calcalkaline magmas are produced, with consequent emplacement of plutonic bodies along the Periadriatic Lineament. This magmatic activity can be ascribed to partial melting of the lithospheric mantle previously modified during the main Alpine subduction phases.

The Apennine mountain belt, despite its proximity to the Alps, displays topographic, morphologic, chronologic, structural and geodynamic features which are markedly different from those belonging to the Alpine model. Hoewever, the two orogens are connected, since the birth and evolution of the Apennines was the consequence and continuation of the same geodynamic process that originated the Alpine orogenic belt.

This connection is represented by the end of the Eoalpine collisional phase and the onset of new geodynamic processes in the western Mediterranean, such as the detachment of the Sardinian-Corsican microcontinent from the Iberia continental margin and the opening of the Balearic back-arc basin, the westward-dipping subduction of the Adria plate and the inception of the Apenninic accretionary prism along its western margin.

The geodynamic setting of the area, since the beginning of the Oligocene, was characterised by the progressive consumption of the Tethyan sea floor, the development of new back-arc basins among which (since Tortonian times) the Tyrrhenian one, which was an event of paramount importance in the geological history of the Apennines.

The Tyrrhenian sea was opened as a result of a southeastward rollback of subduction system near the margins of the Adriatic plate, provided that the subduction rollback exceeded the rate of convergence.

Moreover the Apenninic accretionary prism was characterised by different factors enabling a great horizontal mobility like the shalloiw depth of the Moho, the high heat flux in its inner portions, and the deep, rapidly prograding foreland basins. as a consequence of the above mentioned factors a thin-skinned thrusting developed with the progressive and rapid accretion of thrust sheets onto the Adriatic foreland in a regional subsidence regime, manteined by the presence of the back-arc extension during the whole Apenninic tectonic evolution.

The opening of the Tyrrhenian Basin was accompanied by rotational drifting toward the E and SE of the Apenninic accretionary prism, which acquired its sharp bending also because of the persistence of Tethyan oceanic crust in the Jonian basin.

Such process is attested by the presence of exotic fragments, of European and Alpine provenance within the palaeo-jonic melanges of the Calabrian arc, which connects the Apenninic belt and the Sicilian-Maghrebide belt.

The Apenninic accretionary prism was characterised by different factors enabling its great horizontal mobility like the shallow depth of the Moho, the high heat flux in its inner portions, and the deep, rapidly-prograding foreland basins. Due to the presence of predominant sedimentary materials within the prism, thin-skinned thrusting could develop with the progressive and rapid accretion of thrust sheets onto the Adriatic foreland in a regional subsidence regime, maintained by the presence of the wide Tyrrhenian back-arc basin during the whole Apenninic tectonic evolution.

A consequence of that is the limited participation of the cristalline basement in the build-up of the orogenic prism.

The final result of the geologic evolution of the Apennines is a thrust-and-fold belt, markedly convex toward the Adriatic and Apulian foreland, and characterised by remarkable geometric differences along the orogen’s longitudinal profile, which are due to the superposition of different deformation styles and variable rates of crustal shortening.

This segmentation is mainly controlled by transversal discontinuities, also associated with anticlokwise block rotations in response to possible geometric changes in the subduction process and in the rheologic behaviour of the involved crustal sectors.

These transversal discontinuities display N-S directed dextral transcurrent movements in the central Apennines, and NW-SE directed sinistral movements in Sicily. They control the differential accretion of the main thrusts fronts on the Padanian-Adriatic-Apulian foreland, the Jonian basin and the Hyblean platform. Among the most relevant transversal structures it is worth mentioning the Olevano-Antrodoco line (Fig. 7), that acts also as an out-of-sequence thrust where pelagic sediments overthrust the

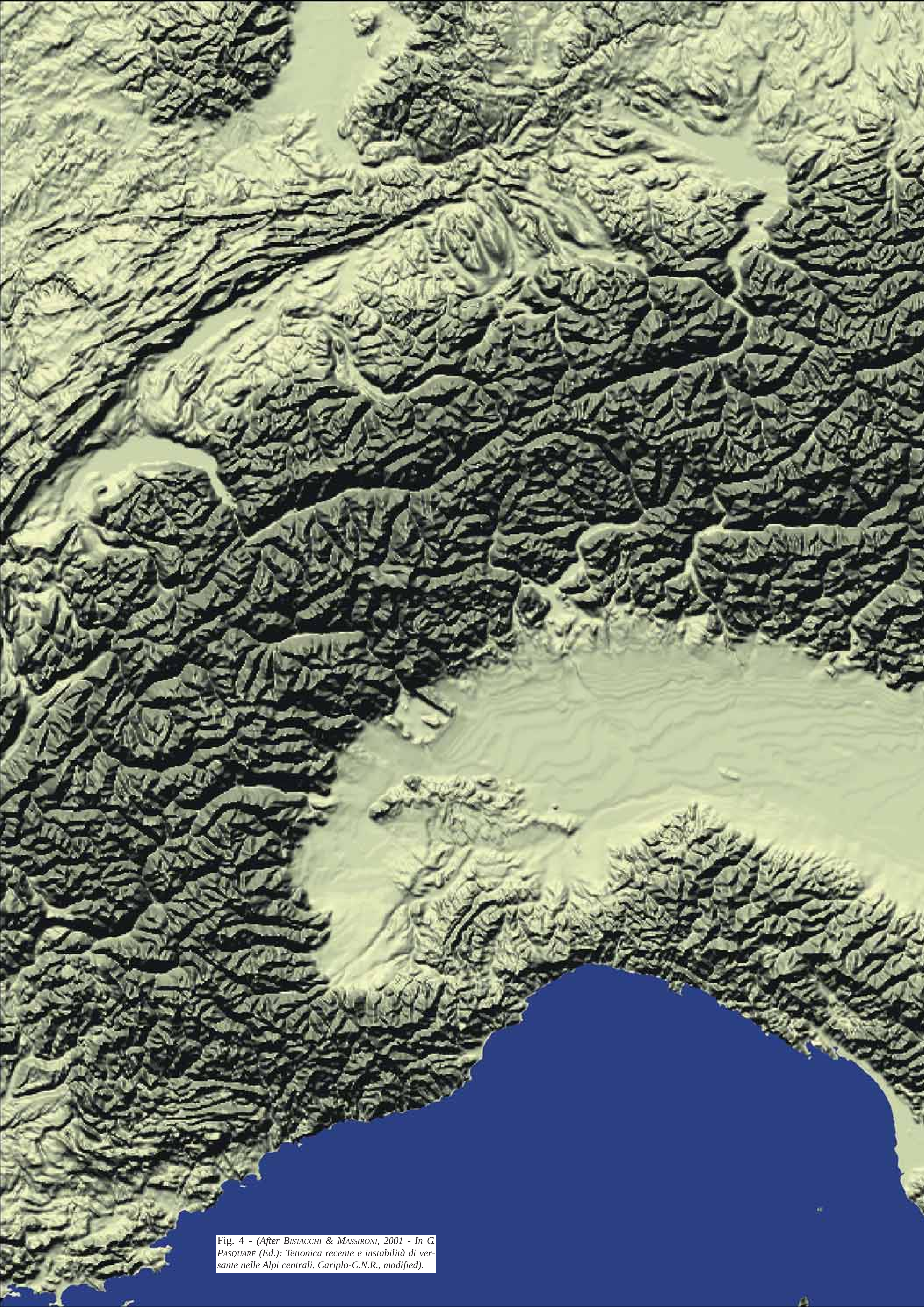
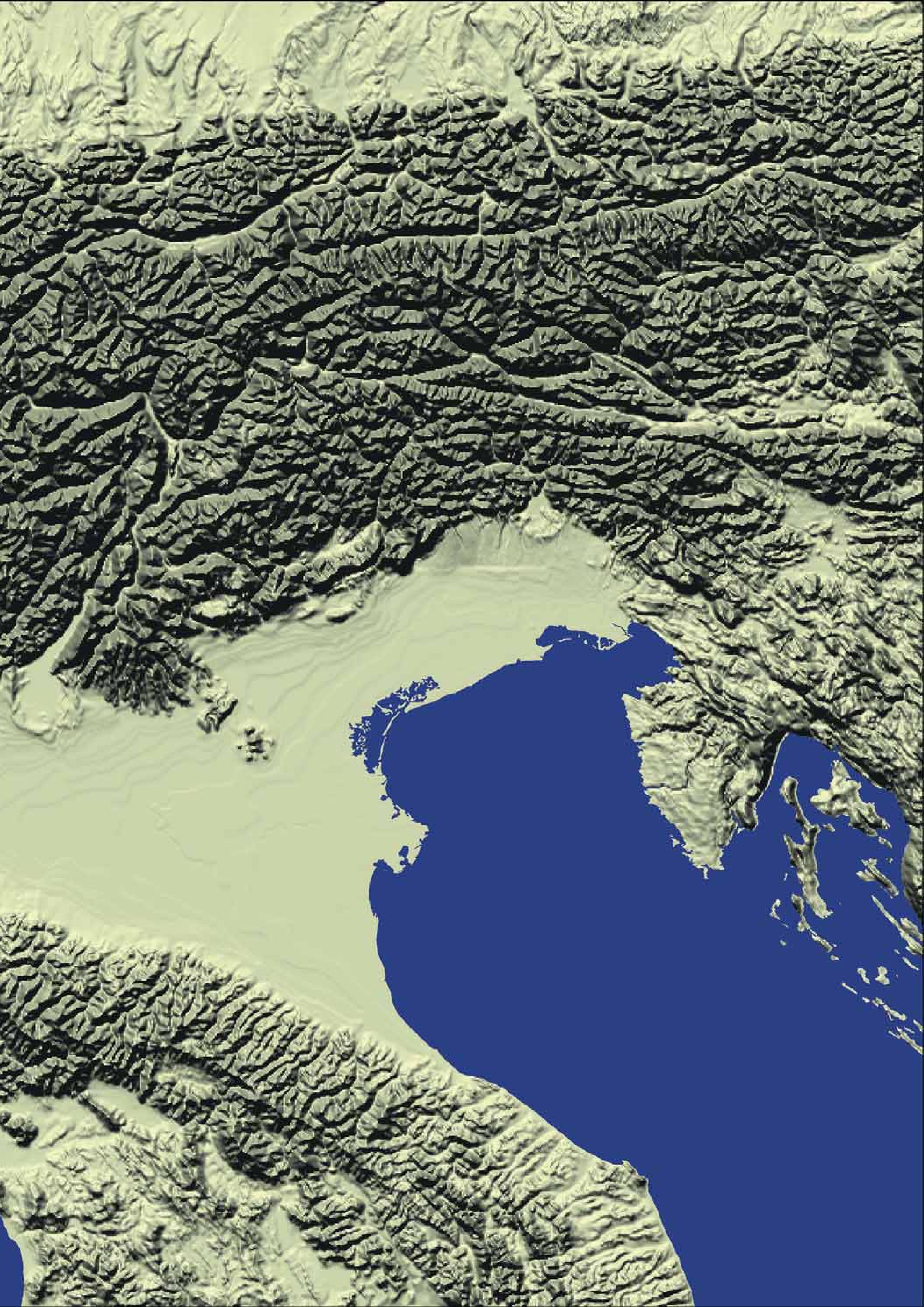


Fig. 4 - *(After Bistacchi & Massironi, 2001 - In G. Pasquarè (Ed.): Tettonica recente e instabilità di versante nelle Alpi centrali, Cariplo-C.N.R., modified).*



Apenninic carbonate platform.
In describing the geologic configuration of the Apenninic belt, two structural, palaeogeographic domains may be individuated:
- The Internal Domain, mainly composed of magmatic and sedimentary successions derived from the deformation of the Ligurian oceanic lithosphere during its descent underneath the Adriatic plate (coeval to the Cretaceous-Eocene Eoalpine phase), and exhumed during the successive formation of the Apenninic orogenic prism;
- The External Domain, represented by the rifted continental and passive margin sequences of the Adriatic and African platform, deformed at different crustal levels during the Oligocene-Pliocene collisional process. The resulting imbricate thrust systems were emplaced with Adriatic and African vergence, overriding the outermost foredeeps up to the Po-Apulian-Hyblean foreland.
The Internal Domain is represented by the Ligurian units, derived from the Tethyan Ocean. The most internal ones still preserve their ophiolitic substratum together with its volcanic and pelagic sedimentary cover. The external ones are represented by rocks originally covering the Ligurian oceanic crust, detached from their basement and transported laterally. They contain ophiolitic blocks and ophiolite-rich debris flows slided in the Ligurian basin during the late Cretaceous.
These Ligurian Units, devoid of any recognizable ophiolitic substratum, are widespread in the Southern Apennines and in Sicily. Within the deep-water sequences of Ligurian Units in Calabria and Basilicata, it is possible to observe also high-pressure subduction-related metamorphic imprints followed, during the subsequent uplifting, by a green-schist facies re-equilibration. Their exhumation occurred during the Miocene overthrusting of the Liguride accretionary wedge onto the continental margin of the Southern Tethys (Figs. 5 and 6).
During the Cretaceous and the Palaeogene, the Ligurian basin was infilled by thick turbiditic successions, both siliciclastic and carbonate, the latter mainly represented by the Helminthoid Flysch.
To the Internal Domain of the Apenninic-Maghrebide chain belongs also the so-called "Sicilide Complex", a non-ophiolitic, deep-sea succession of upper Cretaceous-lower Miocene, dominated by chaotic varicoloured shales.

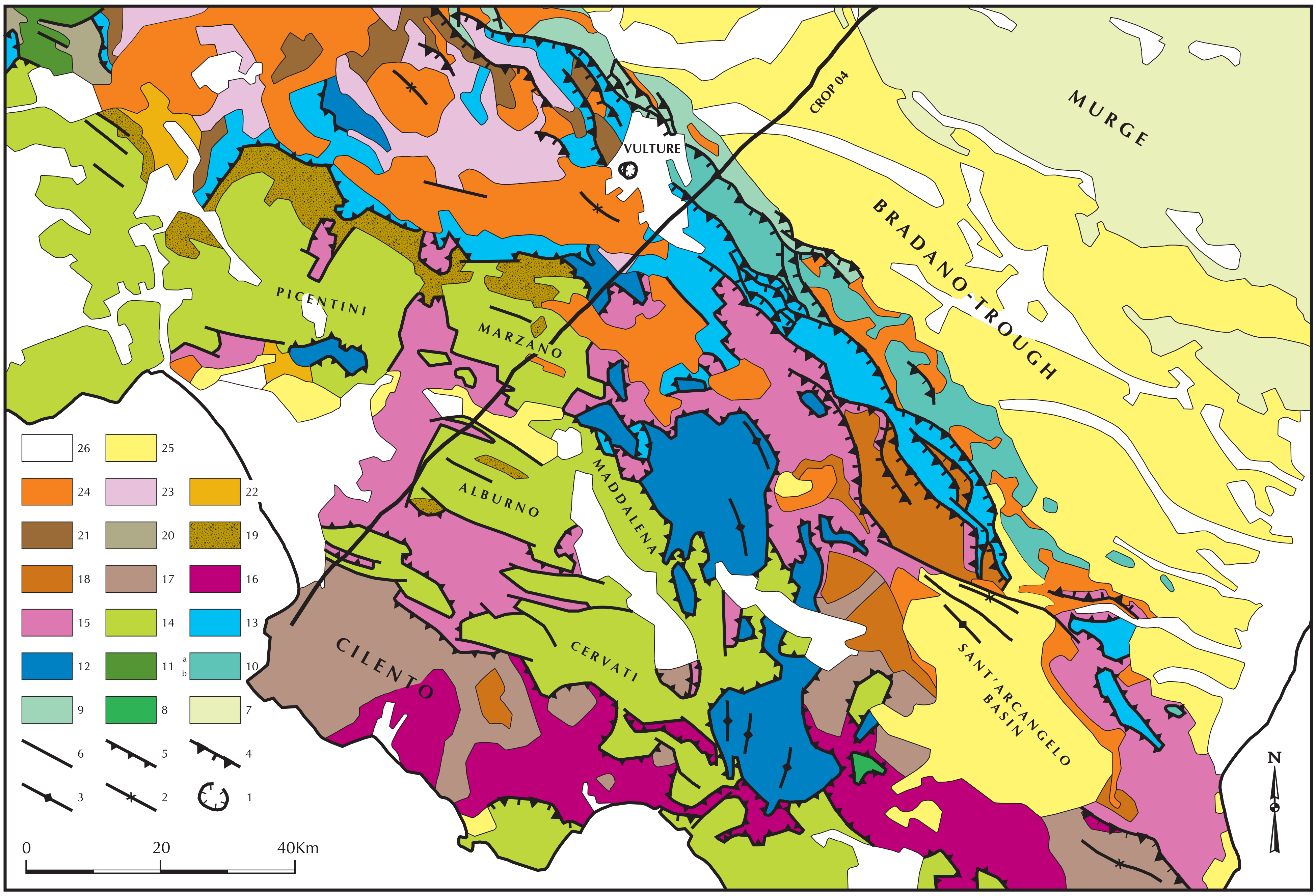


Fig. 5 - *Simplified geological map of the area visited on the field trip. The solid line shows the trace of the line CROP 04. 26) Continental and subordinate coastal deposits; volcanic rocks and volcaniclastic deposits (Holocene - Middle Pleistocene p.p.). 25) Terrigenous marine and paralic deposits filling the Bradano Trough and unconformable overlying the Apennine Units (Middle Pleistocene p.p. - Lower Pleistocene). 24) Pliocene thrust-top deposits. 23) Calaggio Chaotic Complex (upper Messinian - lower Pliocene). 22) Messinian - upper Tortonian thrust-top deposits (including the Braneta and Gessoso-Solfifera Formations). 21) Lower Messinian - upper Tortonian thrust-top deposits unconformably overlying the Sannio Unit (San Bartolomeo Formation). 20) Lower Messinian - upper Tortonian thrust-top deposits unconformably overlying the Matese Unit (San Massimo sandstone). 19) Middle Miocene thrust-top deposits unconformably overlying the Alburno-Cervati and Monti della Maddalena Units (Castelvetere Formation). 18) Middle Miocene thrust-top deposits unconformably overlying the Sicilide Unit (Gorgoglione Formation). 17) Lower Miocene thrust-top deposits unconformably overlying the North-Calabrian Unit (Albidona Formation). 16) North-Calabrian Unit (Palaeogene-Cretaceous). 15) Sicilide Unit (lower Miocene - Cretaceous). 14) Alburno-Cervati, Monti della Maddalena and minor Units derived from the Campania-Lucania carbonate platform (lower Miocene - Upper Triassic). 13) Sannio Unit (middle Miocene - lower Cretaceous). 12) Lagonegro Units (lower Cretaceous - Middle Triassic). 11) Matese Unit (upper Miocene - Upper Triassic). 10 Tufillo-Serra Palazzo Unit (upper Miocene - Palaeogene). 9) Daunia Unit (upper Miocene - Palaeogene). 8) Monte Alpi Unit (upper Miocene - Jurassic), including the overlying lower Pliocene thrust-top deposits (emergence of the Apulia - carbonate duplex system). 7) Cretaceous carbonates of the Murge foreland. 6) Faults, including normal faults and strike-slip faults. 5) Thrust flat. 4) Thrust ramp. 3) Anticline axis. 2) Syncline axis. 1) Caldera rim (Vulture Volcano). (After* Patacca *et alii, 2000 with slight modifications).*

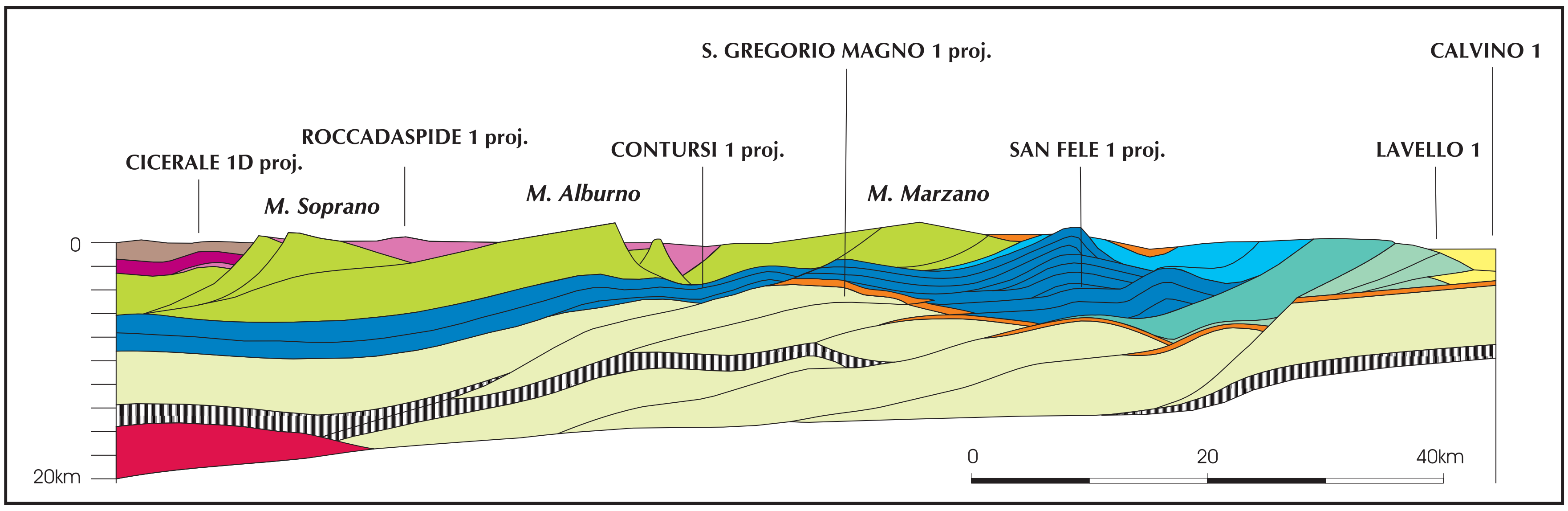


Fig. 6 - *Interpreted line drawing of the line CROP 04. Colours as in Fig. 5 ,with the exception of the North-Calabrian Unit, the Sicilide Unit and the Albidona Formation that have been grouped. (After* Patacca & Scandone*, 2004. Geological transect across the Southern Apennines along the seismic line CROP 04. 32nd Intern. Geol.Congr., Field Trip Guidebook vol. 1, P2).*

The Ligurian Units were covered, after their main deformation phase, by piggy-back basins filled by marine and transitional clastic and evaporitic sediments of Oligocene-Pliocene age, designed as Epi-Liguride sequences.

The External Domain is characterised by sedimentary sequences of peritidal carbonate platform, pelagic carbonate platform and pelagic basin, derived from the fragmentation of the Adriatic continental margin between the Triassic and the early Cretaceous, which was concomitant with the rifting and opening of the Ligurian Tethys. The transitional areas between platforms and basins represent a very clear example of the Mesozoic rifting evolution and of the subsequent contractional tectonic inversion, becoming the preferred sites of the main changes in the structural style and of along-strike kinematics (Fig. 7).

Following the onset of plate convergence along the Apenninic margin, and beginning in Oligocene time, in front of the external units a series of deep foreland basins originated, infilled with deep-water turbidite systems, entirely deposited by turbidity currents and related gravity flows (Fig. 8).

Within the External Domain, the deformation style is different in the southern and the northern sectors of the belt: The structure of the northern sector, characterised, at its back, by a limited thinning of the Tyrrhenian crust, may be explained in terms of a thick-skinned or inversion tectonic model that implies a certain degree of basement deformation and requires limited crustal shortening. The structure of the southern sector, characterised, at its back, by neoformation of Tyrrhenian oceanic crust, is best explained in terms of a thin-skinned model with detachment of the sedimentary cover from the basement and a larger tectonic tranport of the allochtonous sheets.

The opening of the back-arc Tyrrhenian basin during the Neogene caused the development of widespread extensional structures also along the inner sector of the belt. Such effects continued

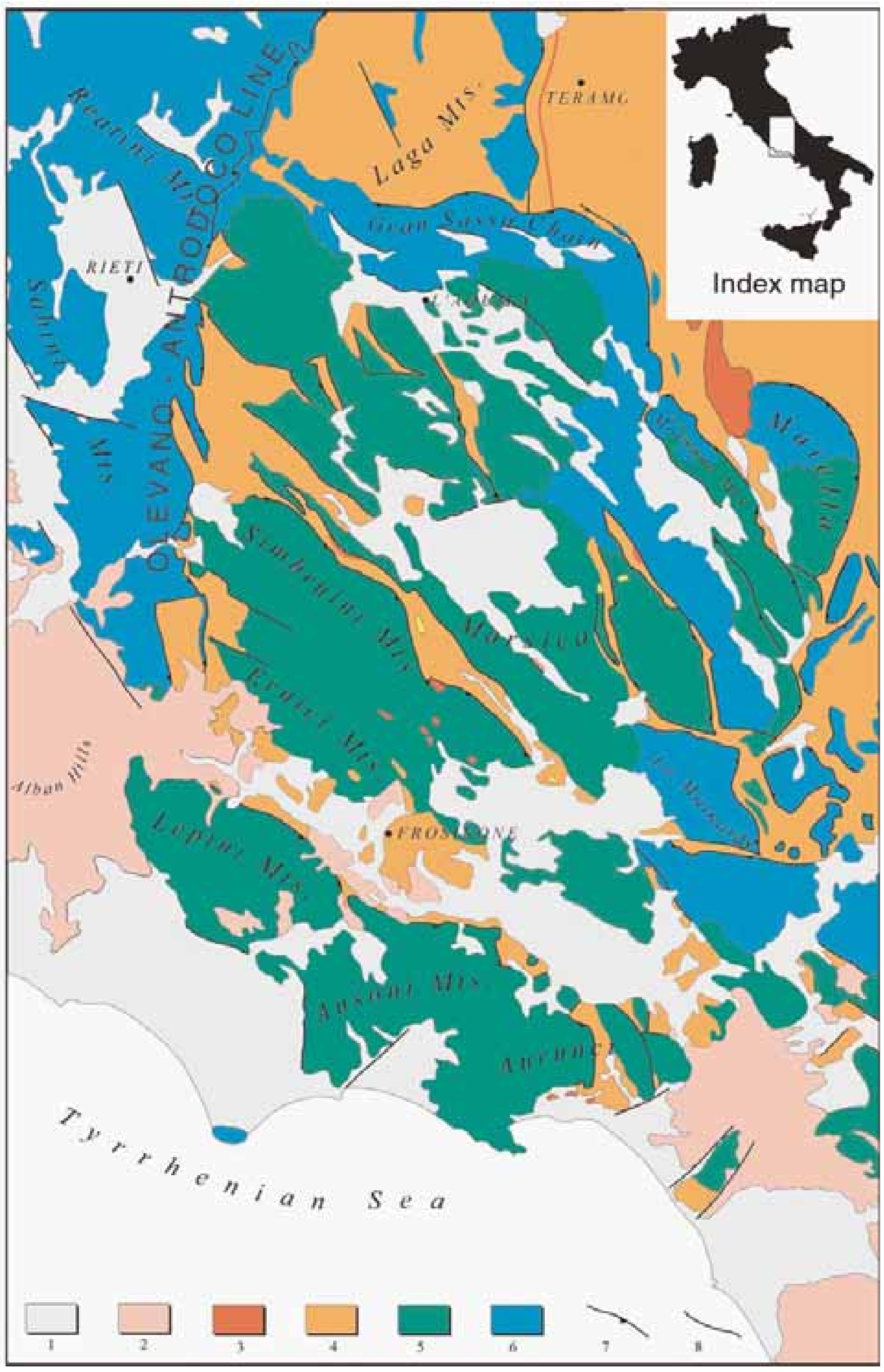


Fig. 7 - *Structural map of the Central Apennines. 1) Pliocene-Quaternary marine and continental deposits. 2) Pleistocene volcanic rocks. 3) Messinian evaporites. 4) Neogene foredeep siliciclastic deposits. 5) Meso - Cenozoic shallow-water limestones. 6) Meso - Cenozoic deep-water limestones. 7) Thrust. 8) Fault. (After* Cosentino *et alii, 2002 - Boll. Soc. Geol. It., Vol. spec. n.1, parte I, modified).*

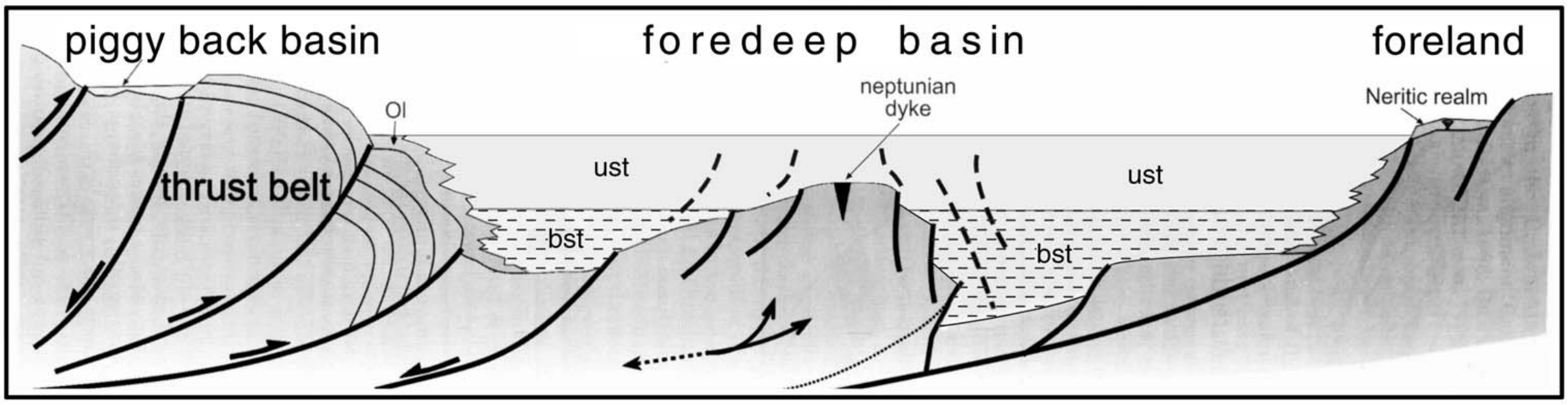


Fig. 8 - *Schematic relationships between the Apenninic thrust belt and its foreland during the foredeep stage. Ol) Olistostromes or megabreccias. bst) Basal massive siliciclastic turbidites. ust) Upper pelitic siliciclastic turbidites.* (After CENTAMORE et alii, 2002 - Boll. Soc. Geol. It., Vol. spec. n. 1, parte I, modified).

also during the Pleistocene with the formation of wide intermountain basins in the central and northern Apennines, while in the southern Apennines the extension processes caused the opening of peri-Tyrrhenian basins, subject to strong structural control.

Extensional tectonics favoured the onset of widespread volcanism in the Tyrrhenian peninsular and insular areas, whose magmas reflect the above illustrated geologic evolution (Fig. 9). Among the evidences of the relationship between magmatism and tectonics in the area, there is the distribution of calcalkaline subduction-related magmatism, marked by a continuous migration toward the east and south-east that follows the Corsican-Sardinian and Apenninic blocks in their anticlockwise rotation.

In the northern Tyrrhenian and Tuscany, calcalkaline magmatism migrated southeastward between the late Miocene and the Quaternary, down to the Aeolian archipelago, today an important site of volcanic activity.

Since Middle Pleistocene times, in Latium, Campania and, to a lesser extent, in Umbria and Basilicata, there has been a large diffusion of potassic and ultrapotassic volcanoes, some of which (in Campania) are still active today. These volcanoes' genetic interpretation has been the topic of intense debate, but today it seems that the prevailing opinion among publishers is that these magmas were generated in a mantle contaminated by fluids possibly derived from the downgoing slab, i.e. in subduction-related environment.

Several calcalkaline volcanic centres were active in Sardinia in Oligocene-Miocene times; today a few seamounts active in the central-southern Tyrrhenian display a similar calcalkaline composition.

In Sardinia, in the central-southern Tyrrhenian, in Sicily and the Sicily Channel, several volcanic centers, among which Mt. Etna Volcano, during the Pliocene and the Quaternary erupted Na-alkaline and transitional products bearing typical intraplate geochemical signatures.

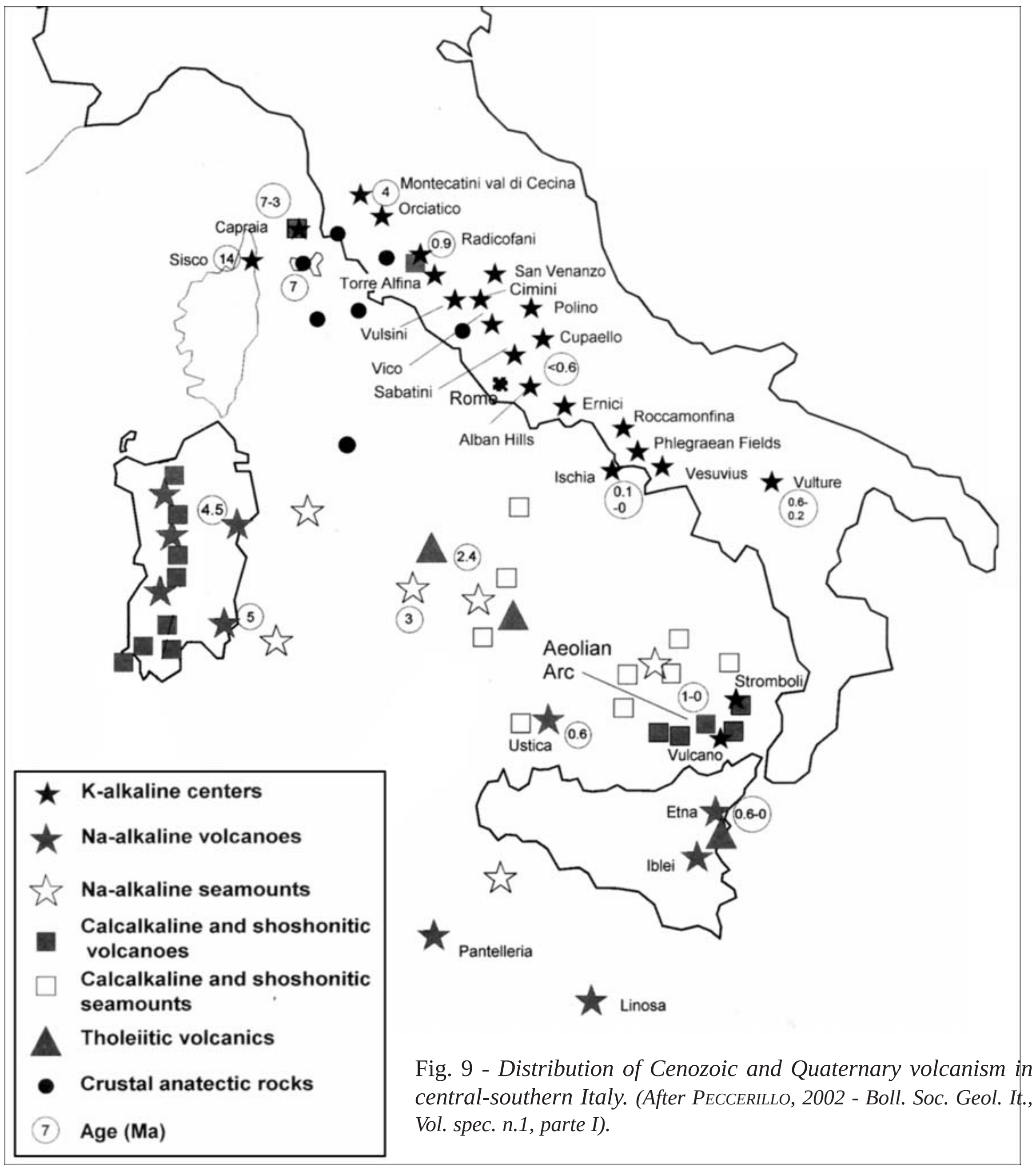


Fig. 9 - *Distribution of Cenozoic and Quaternary volcanism in central-southern Italy.* (After PECCERILLO, 2002 - Boll. Soc. Geol. It., Vol. spec. n.1, parte I).