CONSIGLIO NAZIONALE DELLE RICERCHE

BRUNO D'ARGENIO, TULLIO PESCATORE
& PAOLO SCANDONE

Structural pattern of the Campania-Lucania Apennines

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11 – Structural pattern of the Campania-Lucania Apennines

BRUNO D'ARGENIO, TULLIO PESCATORE & PAOLO SCANDONE
Istituto di Geologia e Geofisica, Università – Napoli

Riassunto – *Schema strutturale dell'Appennino Campano-Lucano.*

Nell'Italia meridionale si riconoscono tre elementi tettonici di primo ordine: ⟨1⟩ La *catena* appenninica s.s., costituita da una serie di coltri, di ricoprimento messe in posto essenzialmente durante il Miocene, il cui spessore raggiunge i 15.000 metri; ⟨2⟩ l'*avanfossa*, il cui substrato è costituito dal tetto dei carbonati dell'avampaese ribassato a gradinata, colmata da terreni pliocenici e quaternari il cui spessore supera i 3000 m e che hanno subito solo movimenti verticali; ⟨3⟩ l'*avampaese* costituito da una successione di carbonati neritici il cui spessore può superare i 6000 m. Questi depositi riposano su di un basamento non affiorante né incontrato in perforazioni.

Questi elementi tettonici sono costituiti da numerose unità stratigrafico-strutturali, di cui si descrivono le principali caratteristiche stratigrafiche e tettoniche. Dall'analisi delle facies di tali unità e dai loro attuali rapporti geometrici è possibile riconoscere, per le aree esterne, una corrispondenza tra unità o gruppi di unità stratigrafico-strutturali e unità paleogeografiche. Per le aree interne i dati relativi non consentono ancora di stabilire una soddisfacente corrispondenza.

Si sono riconosciute, dall'esterno verso l'interno, le seguenti unità paleogeografiche: Bacino est garganico; Piattaforma carbonatica apula; Bacino molisano; Piattaforma carbonatica abruzzese-campana; Bacino lagonegrese; Piattaforma carbonatica campano-lucana. L'evoluzione di queste aree è controllata, dal Trias medio all'Aquitaniano, da movimenti tettonici di tipo prevalentemente verticale. Tra il Langhiano e il Pliocene medio una serie di fasi tettoniche ha dislocato le unità paleogeografiche mesozoico-paleogeniche dando origine alle unità stratigrafico-strutturali esterne della catena. Dal Pliocene medio superiore iniziano infine le fasi orogenetiche s.s. che sollevano l'edificio sud-appenninico e gli conferiscono l'attuale fisionomia.

1 – Introduction.

This brief description of the Campano-Lucanian Apennines is the result of more than ten years of study by geologists of the University of Naples, as well as others from the Universities of Bari, Bologna, Catania, Paris, and Montpellier, and from the Geological Survey for the revision of the Geological Map of Italy carried out by G. Bonardi, E. Cocco, B. D'Argenio, P. De Castro, G. Guzzetta, A. Ietto, T. Pescatore, P. Scandone, I. Sgrosso, M. Torre and A. Vallario, working under the direction of F. Scarsella.

To the survey of the large Apennine region covered by the sheets of Isernia, Caserta, Benevento, Amalfi, Salerno, Vallo della Lucania, Lauria, Potenza, and Castrovillari were added stratigraphic and sedimentological field studies of the shelf carbonates and flysch which produced a growing series of contributions extending finally, to the whole Apennine chain in the area surveyed. Facies analysis and study of the present relations between the stratigraphic-structural units composing the chain make it possible now to present a unified picture of the paleotectonic, tectogenetic, and neotectonic evolution of the Southern Apennines, especially their external zones (Plate 1). The geologic history of the internal Apennine units, now being studied, is more difficult to understand and in several instances still no more than hypothetical.

Given its schematic character, this note will be limited to a summary description

of the successions which make up distinct stratigraphic-structural units and of the tectonic evolution of the region studied, leaving for later publications what has been said elsewhere in greater detail (D'ARGENIO, PESCATORE and SCANDONE, 1973; PESCATORE and ORTOLANI, 1973; SCANDONE, 1972).

2 – General.

The Campano-Lucanian Apennines form a tectonic structure with nappes which were produced and emplaced in the Cretaceous-Lower Pliocene interval, finally reaching an aggregate thickness of about 15,000 m (Plate 1). The tectonic phases which have affected the external zone of the Apennine region are naturally the most recent, and cover substantially the whole Miocene-Early Pliocene interval (25 to 5 m. y. B.P.). Enough is known of these tectonic episodes to reconstruct their development. Less clear, as mentioned above, are the pre-Langhian events which, over a period of at least 50 m.y., affected the internal zone.

The Miocene tectogenesis was followed by creation of the other two first-order structural elements which, together with the mountain chain, make up the southern part of the Italian peninsula, *viz* the Bradanic foredeep and the Puglian foreland. The Bradanic foredeep, whose floor is made of the uppermost carbonates of the Puglia foreland depressed stepwise, is filled with Pliocene and Quaternary formations which have undergone vertical displacement only. In these deposits are intercalated, by gravity sliding, allochthonous masses from the Apennine front. The maximum thickness of these formations filling the foredeep is more than 3,000 m.

Among the three primary structures of southern Italy: the south Apennine chain, the Bradanic foredeep and the Puglian foreland, it is possible to distinguish a series of stratigraphic-structural units. By these we mean large geologic bodies, integral or fragmented, corresponding wholly or partly to pre-existing paleogeographic units, and defined by their specific lithologic character, homogeneous large-scale mechanical behaviour, and their geometric relations with adjacent units. They may still be in stratigraphic contact with their original basement, or else have been moved from their initial location. Finally, they may have undergone more or less severe deformation or be only slightly formed.

Before describing the geologic events which have created the present structures, we shall briefly illustrate the different stratigraphic-structural units, beginning with the internal ones which took shape first and generally occupy more elevated positions in the Apennine structure, then proceeding to the external ones. The nomenclature and symbols are those of the general 1 : 1,000,000 map (Structural Model of Italy).

3 – Internal units.

3.1 – *Liguride Complex.*

9a Upper part, mainly Eocene: Flysch of Albidona and of S. Mauro (Southern Apennines).

9b² Liguride Succession of the Southern Apennines (Santa Venere, Pollica, Frido, Crete Nere, Saraceno).

In this complex we distinguish two units: the Frido and the Cilento.

3.1.1 – **Frido Unit.**

This name designates a terrigenous succession affected by low-grade metamorphism, usually at the base of the Cilento. It is the ' Ophiolitic Shale ' of earlier authors, and corresponds partly to the ' Argillophyllitic Flysch ' of IPPOLITO and LUCINI (1957), partly to the Santa Venere Formation of IETTO, PESCATORE and COCCO (1965), and partly to the Black Flysch of SCANDONE (1967). It outcrops in southern Lucania and northern Calabria, always above the limestone massifs of the Campano-Lucanian platform (see below) and beneath the Cilento Flysch or the crystalline rocks of the ' Diorite-Kinzigite ' Formation. The succession is, from the base upwards (VEZZANI, 1968):

⟨*a*⟩ Variegated shales, quartz conglomerates, calcirudites and graded calcarenites; some tens of m;

⟨*b*⟩ Lead-grey shales with graded quartzarenite and calcarenite intercalations; about 300 m;

⟨*c*⟩ Alternation of grey and greenish quartzarenites with grey shales; 250-300 m;

⟨*d*⟩ Graded calcarenites, calcisiltites, and grey shales; about 300 m;

⟨*e*⟩ Lead-grey shales with intercalations of fine-grained quartzarenites and calcisiltites; about 300 m.

On the basis of a fairly rich microfauna, the succession was attributed to the Neocomian - Albian interval by VEZZANI (1969) and OGNIBEN (1969). Its relationship with the Cilento Flysch is not clear: this may have been superimposed tectonically on the Frido or is possibly in discordant stratigraphic contact with it. In the southernmost part of the area the Frido Flysch occurs as a *mélange* containing blocks of ophiolites in varying grades of metamorphism, and of old crystalline rocks.

3.1.2 – **Cilento Unit.**

This is a thick, largely terrigeneous unit outcropping extensively from the Cilento to the Ionian slopes of the Pollino. Here are the oldest known flyschoid deposits of the Campano-Lucanian Apennines, their age extending from Albian (VEZZANI, 1968) to Oligocene (DONZELLI and CRESCENTI, 1962). The Cilento Unit corresponds variously to the ' Marly-Arenaceous Flysch ' of IPPOLITO and LUCINI (1957), the ' Cilento Nappes ' of SELLI (1962), the ' Cilento Flysch ' of IETTO, PESCATORE and COCCO (1965), and the ' Ligurian Complex ' of OGNIBEN (1969). It lies always on top of the Frido, at the same time covering tectonically the horizons of Monte Bulgheria-Verbicaro and Alburno-Cervati. It comprises the following formations, from the base upwards:

1) *Crete Nere Formation.* Marly calcarenites, argillites and silty clays, sandy limestones and graded quartzarenites, calcitutites (often siliceous, *pietra paesina*). There are rather marked lateral variations; the fauna is entirely pelagic and indicates a Cenomanian age; the thickness exceeds 1,000 m.

2) *Pollica-Saraceno Formation.* From the base upwards:

⟨*a*⟩ Sandstones: fine and medium-grained, with coarse grained intercalations;

⟨*b*⟩ Well-bedded coarse-grained sandstones alternating with conglomerates with abundant matrix. Intraformational slumps common in the upper part. The sandstones are lithic arkoses with predominantly siliceous cement, and in the area east of the Pollino (Saraceno Formation) there are calcarenite intercalations throughout. Thickness about 800 m; age between Cenomianian and Paleocene.

3) *S. Mauro-Albidona Formation:*

⟨*a*⟩ Alternation of greyish silty and argillaceous marls in beds up to 10 m thick and well-bedded sandstones. Thickness very variable, from 400 to 1,000 m, gradually giving way to:

⟨*b*⟩ Coarse sandstones and conglomerates with predominant matrix, about 1,000 m. In this formation are found olistostromes of Maestrichtian-Paleocene age. In some places (Monte Sacro) it is completely conglomeratic. The age is Paleocene to Oligocene.

The flysch type sequence of the Cilento was deposited in a basin supplied mainly with terrigenous material from crystalline rocks in an area whose vigorous tectonic activity is indicated by the intraformational slumps and olistostromes. Except for the basal pelitic sediments of the black shales, deposition was by turbidity currents *sensu lato*. From the Paleocene on ward, this basin also received clastic carbonate material from a shelf area.

3.2 – ***Sicilide Complex.***

10d Variegated Clay or Chaotic South-Apennine Complex; Molise-Sannitic Nappes; Tusa Tuffite.

These last, according to our interpretation, should for the most part be placed in the Irpinian Unit and the Lagonegro units described below. The Sicilide Complex (Variegated Clay, *sensu lato*) is a calcareous-argillaceous succession exposed in Lucania, and in Campania particularly to the east of the limestone massifs. Affected by several phases of tectonic activity it lies in Lucania above the formations of the Lagonegro basin, and in Campania covers either the Campano-Lucanian platform (Langhian phase) or the Abruzzo-Campania platform (Tortonian phase). It is composed, in the Campano-Lucanian Apennines, of the Variegated Clay, the Tusa Tuffite, and the internal Red Flysch.

The Variegated Clay, of Cretaceous or Eocene age, has been subdivided by OGNIBEN (1969):

1) Lower Member: red and green clays, slightly fissile; 500-800 m;

2) Middle Member: calcarenites, marly limestones and marls passing upward nto sandstones and clays with calcarenitic and marly intercalations; about 1,000 m;

3) Upper Member: red and green clays as n Lower Member; 500 m.

One of us (PESCATORE) finds the S. Mauro Formation (Cilento Unit) and the Middle Member of the Variegated Clay very similar in their sedimentary character. They are lithologically alike, and of the same age but show opposite provenances. The Liguride and Sicilide complexes could have been deposited in a single basin west of the Campano-Lucanian platform: the Liguride internally and the Sicilide externally.

4) Tusa Tuffite: alternation of tuffite, marl and limestone, 250-300 m thick; age Late Eocene to Oligocene. The tuffites have been described as ' phenoandesites' (OGNIBEN, 1969); recently WEZEL (1973) assigned the type section to the Lower Oligocene-Aquitanian.

4 – External units.

4.1 – *Internal carbonate platform or Panormide Complex.*

13g^2 Calcarenites in parallel transgression on 13g, passing into flysch (Cerchiara, Bifurto, Punta Lagno, etc.; Aquitanian-Serravallian).

13g^1 Neritic carbonate sediments (Middle Triassic to Paleocene), with local volcanic rocks of the limburgite cycle (Panormide Complex or Internal platform).

13g^1 Transition facies to pelagic environment (scarp and transition facies, reefs included).

Three stratigraphic-structural units are distinguishable in the formations making up the internal carbonate (Campano-Lucanian) platform:

Bulgheria-Verbicaro Unit;
Alburno-Cervati Unit;
Foraporta-Monti della Maddalena Unit.

4.1.1 – Bulgheria-Verbicaro Unit.

This unit is exposed at Capri and Monte Bulgheria, and in northern Calabria. Predominantly dolomitic in the lower part (Upper Triassic-Lower Lias), it becomes largely calcareous in the upper (Lias-Aquitanian). Limburgites occur locally in the Upper Cretaceous part of the section as lava flows (sometimes with pillows) and feeders. The succession is interrupted by frequent disconformities, indicating oscillations of sea level. The reef facies is fairly widespread (lower Lias and Upper Jurassic at Monte Bulgheria; Upper Jurassic at Capri and in northern Calabria), as are breccias formed by disintegration of nearby reefs. Farther out in the basin the succession is more nearly continuous, and the pelagic facies takes over (Monte Bulgheria). The calcarenitic and marly facies of the Upper Cretaceous and Paleogene joins this shelf area to the Sicilide basin.

4.1.2 – **Alburno-Cervati Unit.**

Exposed in Campania (Avella-Partenio, Monti Lattari, and Monti Picentini), in western Lucania (Monte Coccovello, Monti di Lauria) and in northern Calabria (Pollino and Catena Costiera Group, north of the Sangineto line). The succession, more than 4,000 m thick, is made up of shallow-water carbonates, mainly dolomitic in the lower part, mainly calcareous (back-reef facies) in the upper part. The age ranges from Upper Triassic to Upper Cretaceous.

⟨*a*⟩ Massive dolostones (250-300 m); blackish argillites and calcilutites with *Avicula* and *Myophoria* (150 m); well-bedded white and grey dolostones with stromatolites in the upper half; thickness more than 1,000 m. Towards the middle of this section there occurs locally a laminated horizon with ichthyolites. Age: Late Triassic.

⟨*b*⟩ Limestones and dolomitic limestones with megalodonts; limestones with *Palaeodasycladus* and *Orbitopsella;* about 800 m.

⟨*c*⟩ Oölitic and pseudo-oölitic limestones, calcilutites and calcarenites with *Cladocoropsis* and *Clypeina;* about 800 m. Age: Dogger-Malm.

⟨*d*⟩ Calcilutites and calcarenites with subordinate dolomitic limestones and dolostones. Diceratids in the lower part, rudists in the upper. The uppermost part of this section has intraformational conglomerates with matrix of greenish clay, and calcilutites and calcarenites with *Spirolina* and *Alveolina*. Thickness: 1,000 to 1,200 m; age: Cretaceous, Paleocene, and Early Eocene. Followed concordantly by:

⟨*e*⟩ Transgressive glauconitic calcarenites with *Miogypsina* (10-80 m); graded quartzarenites, clays, graded calcareous microbreccia with macroforaminifera (100 m). Aquitanian-Langhian.

The Alburno-Cervati Unit corresponds to the central zone of the Campano-Lucanian platform. It is tectonically superposed on the eastern sediments of this platform (Foraporta-Monti della Maddalena Unit) and on those of the Lagonegro-Irpinian basin, and covered by the Sicilide and Cilento units.

4.1.3 – **Monte Foraporta - Monti della Maddalena Unit.**

As mentioned above, this unit includes the sediments of the eastern margin of the Campano-Lucanian platform. The outer shelf and slope facies outcrop at Monti della Maddalena, and a proximal basin facies at Monte Foraporta. In the Monti della Maddalena region the succession consists of white dolostones (Upper Triassic); limestones, mainly of reef facies (Jurassic); calcarenites with rudist fragments and macroforaminifera (Upper Cretaceous-Lower Miocene), and clays, graded quartzarenites and microbreccias with macroforaminifera (Aquitanian-Langhian). At Monte Foraposta the order (disturbed by greater tectonic activity), from below upward, is:

⟨*a*⟩ White dolostones (Upper Triassic), about 100 m;

⟨*b*⟩ Grey and black ichthyolitic dolostones (Upper Triassic ?), about 100 m;

⟨*c*⟩ Grey and black calcitutites, marly limestones and yellow marls; intraformational conglomerates, calcitutites and graded calcarenites (middle Lias to Dogger, perhaps Malm. Thickness 300 m.

4.2 – ***Lagonegro Units.***

$14b^{2}_{d}$ Lagonegro Unit I; distal facies. *Calcari con selce*, *Scisti silicei*, *Galestri* (Upper Triassic to Lower Cretaceous).

$14b^{2}_{p}$ Lagonegro Unit II; proximal facies. Zone of tectonic doubling of the Lagonegro Units Monte Facito Formation; *Calcari con selce*, *Scisti silicei*, *Galestri* (Middle Triassic to Lower Cretaceous).

These are basin sediments with terrigenous, shallow-water facies in the lower part, bathyal pelagic in the middle, and clastic carbonate to terrigenous, more or less deep-sea sediments at the top. In the whole area of outcrop, which stretches from Monti Picentini to southern Lucania, there is a tectonic duplication of the Lagonegro Unit, each part presenting a more or less complete section.

4.2.1 – **Lower Lagonegro Unit.**

⟨*a*⟩ *Calcari con selce* (cherty limestones): grey calcilutites with bands and nodules of chert, 500 m. Fossils: *Halobia* spp.; *Posydonomia* spp.; occasional ammonites; radiolaria and sponge spicules. Upper Triassic.

⟨*b*⟩ *Scisti silicei* (siliceous shales): siliceous argillites and radiolarites, with very occasional limestone microbreccias; 70-80 m. Fossils: radiolaria; occasional foraminifera in the breccias. Jurassic.

⟨*c*⟩ *Galestri*: alternation of lead-grey siliceous argillites and more or less siliceous calcitutites, rich in iron and manganese; more than 400 m. Fossils: radiolaria and nanno-fossils. Lower Cretaceous.

⟨*d*⟩ Alternation of siliceous argillites, grey, red and green chert, and fine-grained, graded calcarenites; a few tens of m. Fossils: occasional *Globotruncana* and *Moncharmontia appenninica* in the middle part. Upper Cretaceous and perhaps Eocene.

4.2.2 – **Upper Lagonegro Unit.**

⟨*a*⟩ Monte Facito Formation: alternation of clays, marls, siltstones, and sandstones with occasional calcarenite horizons, polymict breccias and conglomerates (terrigenous member); 200 m. Fossils: *Spiriferina fragilis*, *Daonella* sp., occasional ammonites (terrigenous member); algae; corals; molluscs; brachiopods (organic member). Middle Triassic (Anisian-Ladinian).

⟨*b*⟩ *Calcari con selci:* calcilutites, dolomitic limestones, dolostones and subordinate intraformational conglomerates with bands and nodules of chert. 150 to about 250 m. Fossils: *Halobia* spp.; *Posidonomia* spp.; occasional ammonites; radiolaria and sponge spicules. In the graded breccias: *Dictyoconus cayeuxi, Protopeneroplis striata, Nautiloculina oolitica; Trocholina* spp. Jurassic.

⟨*c*⟩ *Scisti silicei:* radiolarites and siliceous argillites with intercalations of graded calcarenites and calcirudites; about 250 m. Jurassic.

⟨*d*⟩ *Galestri:* alternation of argillites, marls, and more or less siliceous calcilutites, with intercalations of graded breccia; more than 300 m. Fossils: radiolaria and sponge spicules; and in the graded breccias, *Protopeneroplis* spp., *Trocholina* spp., occasional calpionellids. Lower Cretaceous.

⟨*e*⟩ Cherts and siliceous argillites, calcirudites and graded calcarenites alternating with clays and red and greenish marls; limestone breccias, clays, and argillaceous quartz-arenites. About 250 m. Fossils: *Orbitoides media, Siderolites calcitrapoides* and *Globotruncana* in the lower part; nummulites and alveolinids in the middle, and *Miogypsina* in the upper part. Upper Cretaceous to Lower Miocene.

The geometric and facies relationships between the two Lagonegro units show that the sediments belonging to the eastern flank of the original basin have ridden over those of the central part, while the sediments belonging to the western flank are not exposed anywhere. The limestone-marl facies of the Upper Cretaceous-Miocene extends north as far as the Sannio hills, in places passing or appearing to pass into the sediments of the Irpinian units.

4.3 – *External carbonate (Abruzzo-Campania) platform.*

$13h^2$ Flysch (Pietraroia, M. Alpi) in stratigraphic succession of $13h^1$ (Tortonian, locally to Messinian).

$13h^1$ Neritic carbonates (Upper Triassic-Serravallian, generally with Paleogene hiatus («External platform»).

$13h^1_t$ Transitional facies to pelagic environment (scarp and transition facies, reefs included, at various levels; Lias-Paleogene).

The sediments belonging to the external (Abruzzo-Campania) platform are exposed in Campania in the mountains of the Matese, at Monte Maggiore and Camposauro, as well as in the tectonic window of Campania. In Lucania they are everywhere covered by the allochthon except where exposed in the tectonic window of Monte Alpi. Three stratigraphic-structural units have been distinguished:

Monte Croce Unit;
Matese-Monte Maggiore Unit;
West Matese Unit.

4.3.1 – Monte Croce Unit.

Exposed in the Campania tectonic window. The outcrop is many hundreds of m thick, and consists, from below upwards, of: white dolostones, sometimes with cherts

grey argillaceous limestones; white dolostones with cherts (Carnian-Norian). Massive limestones and breccias with ellipsactinids and corals (Malm) follow transgressively on the Triassic, and are succeeded in turn by a discomformable sequence of Eocene calcarenites with nummulites and alveolinids, and Aquitanian calcarenites passing into Tortonian marls and sandstones. These sediments can be interpreted as belonging to the margin of the Abruzzo-Campania platform.

4.3.2 – **Matese-Monte Maggiore Unit.**

This succession begins with Upper Triassic dolostones. It shows a strong general resemblance in its Mesozoic part to that of the internal platform, from which it differs essentially in its smaller thickness (about 3,500 m) and by an extensive hiatus in the Middle Cretaceous, generally marked by bauxite deposits. The Cenozoic succession is different, however; the Paleocene is generally absent, and the Miocene transgression is a little more recent (Langhian, as opposed to Aquitanian-Langhian on the internal platform), and is characterized by calcarenitic and organogenic deposits, sometimes even Lithothamnium reefs, which pass upwards into a pelagic interval (Serravallian) followed by terrigenous sediments of Tortonian age.

The formations of the Matese-Maggiore Unit belong to the central part of the original Abruzzo-Campania platform.

4.3.3 – **Western Matese Unit.**

The sediments of the outer margin of the Abruzzo-Campania platform belong to this unit. The facies are those of outer shelf, slope or very proximal basin; and the succession, from below, is: white Upper Triassic dolostones; Jurassic intraformational conglomerates, and calcarenites and calcirudites with rudist fragments and macroforaminifera of Upper Cretaceous to Lower Miocene age. These are followed by Serravallian pelites and Tortonian marly sandstones.

4.4 – ***Molise-Sannio succession.***

This Cretaceous-Miocene section outcrops in the Frosolone area. The succession has been logged in AGIP Frosolone Well I north of the Matese (Pieri, 1966); it consists, from below upward, of the following:

⟨*a*⟩ Siliceous dolostone (Triassic-Lias);

⟨*b*⟩ Argillites and radiolarites with volcanic intercalations (Jurassic);

⟨*c*⟩ Calcarenites, calcirudites, calcilutites, and marl (Cretaceous-Paleogene); and calcarenites, siltstones and sandstones (Miocene).

Terrigenous sediments begin in the Upper Serravallian-Tortonian.

4.5 – ***Late orogenic Apennine Flysch.***

11 Flysch of Castelvetere, of Caiazzo, of S. Giorgio, of Gorgoglione.

14a Numidian flysch of Lucania and Serra Palazzo Flysch; Flysch of S. Bartolomeo and of (Daunia Flysch).

The late orogenic Apennine Flysch (Irpinian Unit) has extensive outcrops in Campania, Lucania, and Puglie, from the eastern margin of the limestone massifs to the Bradanic trough. It is a terrigenous and clastic-limestone deposit of Langhian to Tortonian age, tectonically superimposed on the Matese-Monte Maggiore or more external units, finally interfingering with the Pliocene sediments of the Bradanic trough. Three essential facies are recognizable:

1) *Sandy to conglomeratic.* Flysch of Castelvetere and sandstones of Caiazzo, typically occurring at the edge of the limestone massifs of Taburno, Partenio, and Monte Marzano. Lies unconformably on nappes of more internal provenance (Cilento Sicilide, Alburno-Cervati and Foraporta-Monti della Maddalena units), and contains olistostromes whose volume reaches a million cubic metres. Thickness more than 1,000 m.

2) *Sandy to pelitic.* Corresponds to the central zones of the original basin, and consists mainly of turbidites. Among these sandy to pelitic sequences, those (Gorgoglione and S. Giorgio formations, and Flysch of S. Bartolomeo) which lie unconformably on the nappes can be distinguished from those (part of the Serra Palazzo Formation) which are stratigraphically continuous with the deposits of the Lagonegro basin; the former lie to the west of the latter. The thickness of this facies reaches 2,000 m.

3) *Calcareous to marly.* This facies is found in the easternmost zones, at the edge of the Bradanic trough. The series is an alternation of calcareous turbidites and pelagic marls (part of the Serra Palazzo Formation; Faeto Flysch).

The Lagonegro basin, in which the Irpinian Units were laid down, originated in the Langhian tectonic phase: in fact, there is contemporary folding of the more internal units into nappes reaching as far as the western part of the basin. A new basin resulted whose western margin is represented by these nappes, and whose eastern margin was the Abruzzo-Campanian platform. The terrigenous material of the western and central facies came mainly from erosion of the nappes of the internal margin; the carbonatic one derived from the external margin of the platform. The Irpinian Unit ends with pelitic sediments of the Lower Tortonian.

5 – Late and post-tectogenic units.

5.1 – ***Postorogenic series.***

2a *Gessoso-solfifera* Formation *sensu lato*, Tortonian and Messinian molasse.

1 Continental and marine sediments, almost every-where later than Middle Pliocene (Holocene and Pleistocene sediments in general; Upper Pliocene-Calabrian marine cycle, Villafranchian, etc.).

5.1.1 – **Altavilla Unit.**

These sediments were deposited in fairly ample basins which developed after the early Tortonian tectonic phase. They are predominantly clastic and of Tortonian to Pliocene age; evaporites are sometimes present at the base (*Formazione Gessoso-Solfifera* = Gypsiferous and Sulphur-bearing Formation). The whole succession is several hundred m thick, the facies varying from littoral to bathyal. This unit has undergone *décollement* in the Middle Pliocene, as a result of which it occurs in the nappes reaching into the sediments of the Bradanic trough.

5.1.2 – **Ariano Unit.**

This unit outcrops extensively in the region of Benevento, Panni, and Ariano Irpino; in the upper valley of the Ofanto, and in the area around Potenza, Calvello, and S. Arcangelo. It lies everywhere discordantly on its substratum, and consists mainly of neritic and terrigeous sediments laid down in intra-Apennine basins. Two sedimentary cycles can be distinguished: Middle Pliocene and Plio-Pleistocene. The sediments of the former are folded along the eastern margin of the Apennine chain, while those of the latter are always undisturbed and subhorizontal.

5.1.3 – **Bradano Unit.**

The Bradanic trough developed after the Middle Pliocene tectonic phase. Its western margin is the Apennine front, and to the east it is bounded by the Murgian foreland which, deepening stepwise towards the Apennines, also forms parts of its floor. The Bradano Unit is terrigenous with neritic to pelagic facies, and up to 3,000 m thick. Hiatuses occur near the Apennine margin, but farther to the east the series is continuous.

5.2 – ***External units.***

15b Mesozoic-Cenozoic neritic carbonate sediments (Apulia, etc.), locally with volcanic rocks.

5.2.1 – **Apulia Unit.**

The Apennine foreland in southern Italy was represented by this unit following the Middle Pliocene tectonic phase. It is a Mesozoic (Upper Triassic to Upper Cretaceous) carbonate shelf series resembling in some respects the Alburno-Cervati and Matese-Monte Maggiore units, covered concordantly by transgressive organogenic calcarenites of the Serravallian. Its thickness can exceed 6,000 m (Pozzo Ugento in the Salento Murge).

6 – **Paleotectonics.**

Th paleotectonic evolution of the external zones in the area studied is characterized by epeirogenic movements from the Middle Triassic to the Aquitanian (Plate 1), The oldest formations found (Anisian) are terrigenous shelf sediments with local volcanic horizons (metamorphosed Triassic of Lungro and Acquaformosa in northern Calabria; Monte Facito Formation). The Lagonegro basin developed in the Carnian, between the Campania-Lucania and Abruzzo-Campania platforms. There is insufficient evidence to say shether the Molisano basin, too, was already outlined in the Triassic.

All the external paleogeographic units were differentiated by the Early Jurassic, following the Rhaetian-Liassic extensional phase, and they kept their individuality until Early Miocene time. From west to east they are:

- Campania-Lucania carbonate platform;
- Lagonegro basin;
- Abruzzo-Campania carbonate platform;
- Molise basin;
- Apulia platform.

During the Jurassic, sedimentation always balanced subsidence of the platforms, maintaining a shallow-water facies. In the basins subsidence exceeded sedimentation, so that the facies are those of a gradually deepening sea. Platforms and basins are often separated by steep escarpments due to contemporaneous faulting, which began in the Rhaetian-Liassic tectonic phase and continued throughout the Mesozoic and Early Tertiary.

The Cretaceous history of the Campania-Lucania platform is not unlike that of the Jurassic. The basin evidently became shallower; for the sediments, unlike those of the Jurassic, were deposited above the compensation level for calcite. Substantial uplift of the Abruzzo-Campania platform and part of the Apulia platform in the Middle Cretaceous caused a general emergence of these areas which is recorded by a bauxite horizon.

The main phase of tectonic activity was in the upper Senonian and effected both of the south-Apennine platforms. The faults limiting the back-reef and outer shelf zones were suddenly reactivated, and new faults also appeared. The central areas of the platforms emerged while the margins rapidly deepened, gathering, where the steep slopes permitted, clastic sediments (calcirudites and calcarenites with rudist fragments) derived from erosion of the emergent zones. The platforms emerged completely in the Middle Eocene, together with much of their thresholds; and sedimentation continued in the basins with alternations of clastic carbonate and pelagic materials.

There was a general transgression on the Campania-Lucania platform in the Early Miocene. The sediments, at first carbonates, became terrigenous and flyschoid in the Langhian; analogous terrigenous sediments also occur in the uppermost part of the Lagonegro succession. Tectogenesis had already started in the external zones

(Campania-Lucania platform and Lagonegro basin). On the Abruzzo-Campania platform the transgression took place in the Langhian, with deposition first of carbonates thes, in the Serravallian and Tortonian, a terrigenous fiyschoid sequence. Similar terrigenous sediments are also present in the upper part of the Molise Series (Frosolone). Even in these outlying zones, the beginning of terrigenous sedimentation coincides with the onset of tectogenesis.

7 – Tectogenesis.

The external zones of the Campania-Lucania Apennines were deformed by a series of tectonic phases between the Langhian and the Middle Pliocene. Among these can be distinguished:

– a Langhian phase, which affected the inner part of the external zones;

– a Serravallian phase, in reality a temporal and spatial extension of the Lanhian phase;

– a Tortonian phase, which formed the Apennine chain, and

– several phases from Messinian to Middle Pliocene, which brought the chain to its present situation above the foreland sediments.

During the first of these phases, a series of nappes from the interior (Sicilide, Cilento, and Frido units) rode up on the Campania-Lucania platform, which itself was breaking up and riding over the sediments of the Lagonegro basin. In this last, moreover, the sediments of the internal (western) flank overrode those of the axial part. While all this was going on, the nappes which had ridden up on the platform advanced still farther and came to rest on the Lagonegro sediments. Following the Langhian phase, a new basin (the Irpino basin) developed in place of the former Lagonegro basin. Its boundaries were the Abruzzo-Campania platform to the east, and the nappes of the Langhian phase to the west.

Further horizontal movements occurred in the Serravallian, especially of the Sicilide Unit in the northern part of the area studied and of the Campano-Lucanian platform sediments in the southern part. Meanwhile, between late Langhian and early Serravallian times, there was a great concordant transgression on the Abruzzo-Campania platform. The sediments, at first calcarenites and organogenic limestones, became terrigenous (mainly turbidites) in the lower Tortonian. At this point the next important tectogenic phase is in evidence: the Lagonegro and Irpinia units travelled over the area of flysch deposition bording the Abruzzo-Campania platform and partly outdistanced it. At the same time the Abruzzo-Campania platform became detached from its substratum and moved onto the sediments of the Molise basin. The imbricate structures and overthusts of the Campania-Lucania and Abruzzo-Campania platforms belong to this Tortonian phase.

Between late Tortonian and Early Pliocene time several basins formed on the advancing nappes or at their margins; in them were deposited the sediments of the Altavilla Unit. This interval was marked by several minor tectonic events, and was succeeded in the Middle Pliocene by an important phase of regional dimensions which

moved the whole pile of nappes towards the Apulia platform. The latter was lowered stepwise on its internal side, forming the Bradanic trough and assuming, as a whole, the role of the southern Apennine foreland.

The Apennine front thus lies largely on Lower to Middle Pliocene sediments and is covered unconformably by the Upper Pliocene-Calabrian. The Bradanic trough on the other hand, unaffected by orogenic transport, has a continuous sedimentary record from Middle Pliocene to Calabrian, disturbed only by olistostromes which slid down from the front of the chain.

8 - **Neotectonics.**

The orogenic movements which gave the southern Apennines their present shape began in the Late Pliocene after the tectonic phases just described. There are two main systems of Plio-Quaternary dislocations, one striking NW-SE (Apennine), the other SW-NE (anti-Apennine). These are well seen along the Tyrrhenian margin of the Apennines, where they divide the coastal plains (Volturno, Garigaliano, Sele) from the high coastal areas (Sorrento peninsula, Cilento). They also formed the Plio-Pleistocene intra-Apennine basins (Ariano Irpino, S. Arcangelo, etc.), which extend northward as far as a transverse tectonic lineament which runs from the south flank of the Gargano Mountains to the Phlegrean Fields. Plio-Quaternary deformation further affected the Bradanic substratum, differentiating the Murge hills from the Bradanic trough. In the latter the Apennine uplift brought a final eastward advance of the nappes, confirmed by the numerous oil wells drilled in the area.

Also related to this final tectonic activity are the volcanic phenomena of Campania and the Vulture. The Phlegrean Fields and Ischia are located on the transverse Gargano lineament mentioned above; the Vulture lies on a fault-line joining the mouths of the Sele and the Ofanto, at its intersection with the marginal faults of the Bradanic trough.

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