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Geology of the Southern Apennines

E. PATACCA (*) & P. SCANDONE (*)

ABSTRACT

This paper aims to provide a concise description of the geology of the Southern Apennines especially useful for readers having scarce familiarity with this complex region. The text is divided into four parts:

– Brief introduction to the geology of the Southern Apennines in which the general outlines of the thrust belt-foredeep-foreland system are given together with a general description of the internal structural architecture of the mountain chain;
– Summary of the paleogeographic models existing in the geological literature and discussion of the basic criteria used for the palinspastic restoration of the Apennine depositional domains proposed in this paper;
– Synthetic description of the Apennine tectonic units and of the Neogene-Quaternary thrust-sheet-top deposits cropping out in the study area and discussion on the available structural and stratigraphic information constraining the time-space reconstruction of the tectonic deformation;
– Short illustration of the principal steps describing the kinematic evolution of the thrust belt-foredeep-foreland system from the early Miocene to the end of the early Pleistocene.

The enclosed simplified geological-structural map will help the reader to keep in mind without difficulties the key points of the regional framework. Selected references on the single tectonic unit or thrust-sheet-top deposit have been provided at the end of each paragraph, with the aim of assisting the reader who wanted to tackle the Apennine geological problems by navigating through the numerous controversies and internal inconsistencies of the current literature.

KEY WORDS: *Italy, Central Apennines, Southern Apennines, tectonic units, thrust-sheet-top deposits*.

RIASSUNTO

Geologia dell'Appennino Meridionale.

Questo lavoro ha lo scopo di fornire una succinta descrizione della geologia dell'Appennino meridionale rivolta sopratutto ad un lettore che abbia scarsa dimestichezza con l'area. Il lavoro è diviso in quattro parti:

– breve introduzione alla geologia dell'Appennino Meridionale nella quale viene fornito un quadro generale relativo agli elementi di primo ordine del sistema catena-avanfossa-avampaese e alla struttura interna della catena;
– rassegna dei modelli paleogeografici esistenti in letteratura e discussione dei criteri utilizzati per la ricostruzione palinspastica che viene qui proposta;
– descrizione sintetica delle unità tettoniche che formano la catena Sud-Appenninica e dei depositi che le ricoprono in discordanza; discussione sulle evidenze strutturali e sui dati stratigrafici disponibili per vincolare la ricostruzione spazio-temporale della deformazione tettonica;
– breve descrizione delle tappe più significative dell'evoluzione cinematica del sistema catena-avanfossa-avampaese dal Miocene inferiore alla fine del Pleistocene inferiore.

La carta geologica strutturale allegata dovrebbe aiutare il lettore a conservare il quadro regionale d'assieme, volutamente semplificato, durante la lettura della nota. Qualora il lettore volesse approfondire le sue conoscenze sulle problematiche dell'Appennino meridionale, è stata messa a disposizione, unità per unità, una bibliografia selezionata. Attraverso di essa il lettore potrà navigare all'interno delle numerose controversie e contraddizioni interne che rendono variegata la letteratura geologica italiana

TERMINI CHIAVE: *Italia, Appennino Centrale, Appennino Meridionale, unità tettoniche, depositi discordanti sulla catena.*

1. FOREWORD

This paper aims to provide a concise description of the geology of the Southern Apennines especially useful for readers having scarce familiarity with this complex region. The work is divided into four parts:

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– Synthetic description of the Apennine tectonic units and of the Neogene-Quaternary thrust-sheet-top deposits present in the study area and discussion on the available stratigraphic and structural information constraining the time-space reconstruction of the tectonic deformation;
– Description of the principal steps describing the kinematic evolution of the thrust belt-foredeep-foreland system from the early Miocene to the early Pleistocene.

Where possible, the surface geological data have been integrated with the subsurface information coming from extensive petroleum exploration in the area.

The enclosed simplified geological-structural map will help the reader to keep in mind without difficulties the key points of the regional framework. Selected references on the single tectonic unit or thrust-sheet-top deposit have been provided at the end of each paragraph, with the aim of assisting the reader who wanted to tackle the Apennine geological problems by navigating through the numerous controversies and internal inconsistencies of the current literature.

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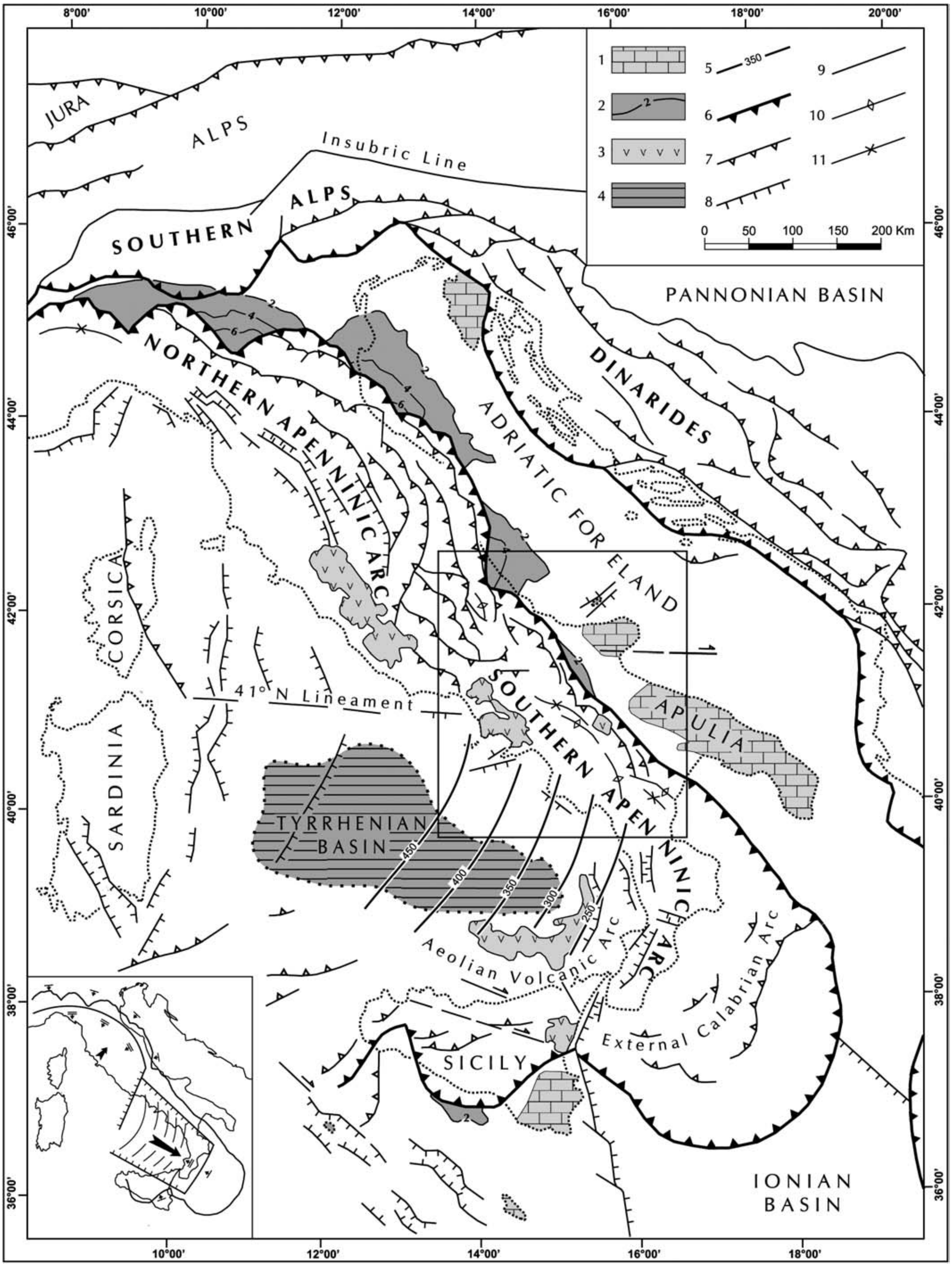

JURA
ALPS
Insubric Line
SOUTHERN ALPS
PANNONIAN BASIN
NORTHERN APENNINIC ARC
DINARIDES
ADRIATIC FORELAND
CORSICA
SARDINIA
41° N Lineament
APULIA
SOUTHERN APENNINIC ARC
TYRRHENIAN BASIN
Aeolian Volcanic Arc
External Calabrian Arc
SICILY
IONIAN BASIN
0 50 100 150 200 Km

Fig. 1

2. GEOLOGICAL FRAMEWORK OF THE SOUTHERN APENNINES

The area object of this paper is located in the northern part of the Southern Apenninic Arc, a segment of the mountain chain that extends from the Southern Abruzzi-Alto Molise region to Sicily through the Calabrian Arc (see fig. 1). Four first-order geological elements may be distinguished in this region (see PATACCA *et alii*, 1990 and references therein):

1) The Tyrrhenian area, characterized by oceanic crust and thinned continental crust, representing a back-arc extensional feature developed at the rear of the Apennine system in late- and post-Tortonian times. Intermediate and deep-focus earthquakes depict a relic lithospheric slab dipping towards the NE beneath the Aeolian calc-alkaline arc (ANDERSON & JACKSON, 1987; GIARDINI & VELONÀ, 1991);

2) The Southern Apennine mountain chain, formed by a deep-seated carbonate duplex system («Inner Apulia Platform» of the geological literature, see MOSTARDINI & MERLINI, 1986) tectonically overlain by a thick pile of NE-verging rootless nappes derived from basin and platform domains (MOSTARDINI & MERLINI, 1986; CELLO *et alii*, 1987, 1989; CASERO *et alii*, 1988, 1991; PATACCA & SCANDONE, 1989, 2001; PATACCA *et alii*, 1992a,b; ROURE *et alii*, 1991; MATTAVELLI *et alii*, 1993; ROURE & SASSI, 1995; LA BELLA *et alii*, 1996; LENTINI *et alii*, 1996, 2002; CORRADO *et alii*, 1997, 1998a,b; SPERANZA *et alii*, 1998: MONACO *et alii*, 1998; CELLO & MAZZOLI, 1999; DI BUCCI *et alii*, 1999; SCROCCA & TOZZI, 1999; MENARDI NOGUERA & REA, 2000; IMPROTA *et alii*, 2000; MAZZOLI *et alii*, 2000, 2001). The buried duplex system is composed of shallow-water and subordinate deeper-water Mesozoic-Tertiary carbonates stratigraphically covered by Pliocene terrigenous deposits. The Mesozoic carbonates, representing the main target of oil research in the Southern Apennines, have been extensively explored and carefully mapped over the whole study area (see NICOLAI C. & GAMBINI R., *Structural architecture of the Adria platform-and-basin system*, in this volume);

3) The Southern Apennine foredeep basin, corresponding to the youngest (Plio-Pleistocene) flexural depression developed at the front of the thrust belt. A description of the Plio-Pleistocene deposits filling the foredeep basin, accompanied by selected references, is provided in other pages of this volume (see PATACCA & SCANDONE, *Constraints on the interpretation of the CROP-04 seismic line derived from Plio-Pleistocene foredeep and thrust-sheet-top deposits*);

4) The Adriatic-Apulia foreland, constituted of Mesozoic-Tertiary carbonates and Triassic evaporites overlying a thick pile of mixed carbonate-siliciclastic Paleozoic deposits the top of which has been reached at a depth of 6112 m be the Puglia 1 well. A Precambrian (Baikalian-Panafrican) crystalline basement has been hypothesized under the whole Adriatic-Apulia foreland (VAI, 1994, 2001).

The enclosed simplified geological-structural map shows the areal distribution of the tectonic units in the Southern Apennines and their mutual geometric relationships. Our definition of «tectonic unit» roughly corresponds to the definition of «structural-stratigraphic unit» of IPPOLITO *et alii* (1975). A tectonic units is represented by a single thrust sheet or, more frequently, by a group of thrust sheets constituted of stratigraphic successions referable to the same paleogeographic realm, which have undergone a specific tectonic evolution different from the tectonic evolution recorded in the overlying and underlying thrust sheets. Every tectonic unit is separated from the underlying and overlying ones by first-order thrust surfaces (e.g. Triassic-Cretaceous deep-water deposits of the Lagonegro Units tectonically sandwiched between the Triassic-Miocene platform carbonates of the Alburno-Cervati plus Monti della Maddalena Units (hangingwall) and the lower Pliocene siliciclastic flysch deposits stratigraphically covering the Mesozoic-Tertiary carbonates of the Apulia Platform (footwall). Thrust surfaces delimitating tectonic units are usually represented, in the Southern Apennines, by long thrust flats displaying very low cutoff angles at the footwall. The only exception is represented by the Sannio Unit, the basal contact of which with the underlying Lagonegro Units corresponds to a detachment surface. We could obviously use the term «nappe» for most of the Apennine units. However, the term nappe could result ambiguous in a region where it has been used for indicating either thrust sheets having the same meaning as our tectonic units (e.g. Lagonegro, Molise and Sannio Nappes of SELLI, 1962) or piles of thrust sheets including different groups of tectonic units, which in certain times moved coherently as a single body towards the

Fig. 1 - Structural sketch of the Italian Peninsula and surrounding areas showing the partition of the Apennine mountain chain into two major arcs: the Northern Apenninic Arc and the Southern Apenninic Arc (after PATACCA *et alii*, 1993 with slight modifications). The box at the center delimitates the region mapped in pl. 1. In the lower left box, the present-day differential sinking of the foreland lithosphere in the Northern and Southern Apenninic Arcs has been schematized. Large arrows indicate the directions of the last orogenic transport. The length of the arrows is proportional to the rates of the flexure-hinge retreat in the sinking plate. Small arrows indicate the dip of the lower plate. 1) Mesozoic-Tertiary carbonates of the foreland areas. 2) Depth (in kilometers) of the base of the Pliocene-Pleistocene deposits in the Apennine and Sicily foredeep basins. 3) Major Quaternary volcanic edifices. 4) Tyrrhenian areas with Bouguer gravity anomalies exceeding 200 mgals, floored by oceanic crust or thinned continental crust. 5) Wadati-Benioff zone in the Southern Tyrrhenian area (depths in kilometers). 6) Front of the Maghrebides, Apennines, Southern Alps and Dinarides. 7) Other major thrusts, including the front of the Alps. 8) Normal faults. 9) High-angle faults, mostly strike-slip faults. 10) Anticline axis. 11) Syncline axis.

– *Schema strutturale della penisola italiana ed aree adiacenti mostrante la suddivisione della catena appenninica in due archi principali: l'Arco Appenninico Settentrionale e l'Arco Appenninico Meridionale (da* PATACCA et alii, *1993 con lievi modifiche). Il riquadro delimita l'area rappresentata nella carta geologico-strutturale di tav. 1. Nel riquadro in basso a sinistra è stata schematizzata la diversa struttura litosferica nei due archi appenninici. Le frecce grandi indicano la direzione dell'ultimo trasporto orogenico. La lunghezza delle frecce è proporzionale alla velocità di arretramento dell'asse di flessura della placca in subduzione. Le frecce piccole indicano l'immersione della placca inferiore. 1) Carbonati mesozoico-terziari delle aree di avampaese. 2) Profondità (in chilometri) della base dei depositi plio-pleistocenici nei bacini di avanfossa dell'Appennino e della Sicilia. 3) Principali edifici vulcanici quaternari. 4) Aree del Mar Tirreno con valori dell'anomalia di Bouguer superiori a 200 mgals, a crosta oceanica o continentale assottigliata. 5) Zona di Wadati-Benioff nell'area tirrenica meridionale (profondità in chilometri). 6) Fronte delle Maghrebidi, dell'Appennino, delle Alpi meridionali e delle Dinaridi. 7) Altri sovrascorrimenti principali. 8) Faglie normali. 9) Faglie ad alto angolo, sopratutto faglie trascorrenti. 10) Asse di anticlinale. 11) Asse di sinclinale.*

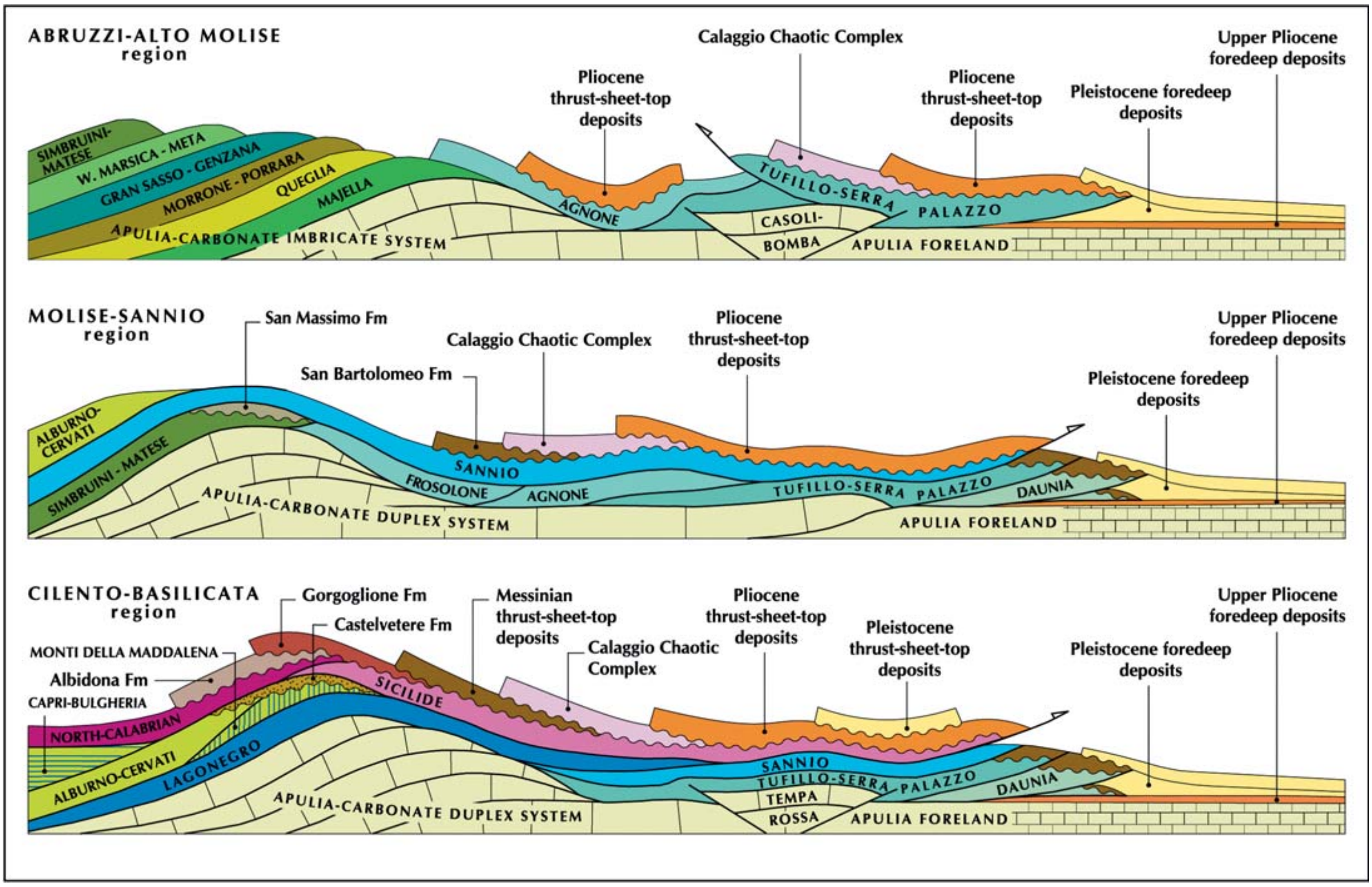


Fig. 2 - Schematic representation of the geometric relationships between the tectonic units of the Southern Apennines in correspondence to three transects cutting across the mountain chain in the Southern Abruzzi-Alto Molise, Molise-Sannio and Cilento-Basilicata regions.
– *Rappresentazione schematica dei rapporti geometrici tra le varie unità tettoniche dell'Appennino lungo tre transetti (Abruzzo meridionale-Alto Molise, Molise-Sannio e Cilento-Basilicata).*

foreland region (e.g. Metaponto Nappe *sensu* Ogniben, 1969).

A single tectonic unit is usually constituted of numerous lithostratigraphic units. In the enclosed map of plate 1, we have just separated within the single tectonic units the flysch deposits from the underlying pre-flysch deposits with the intent to outline the important change in the sedimentation that took place when a stable foreland segment was incorporated in the foredeep basin. We will see that the age of the siliciclastic flysch deposits in the different Apennine units is one of the most important criteria for reconstructing the time-space migration of the thrust belt-foredeep-foreland system.

3. GEOMETRICAL PATTERN OF THE APENNINE UNITS AND PALINSPASTIC RELOCATION OF THE CORRESPONDING DEPOSITIONAL DOMAINS

The geometrical relationships between the tectonic units present in the study region are schematized in fig. 2. We have chosen to illustrate the internal nappe geometry by means of three transects because some tectonic units are present only in specific sectors of the mountain chain. A representation by means of transects helps the reader to understand the major lateral variations in the structural configuration. Owing to the forward tectonic transport principally towards the NE, i.e. from the Tyrrhenian region towards the Adriatic-Apulia foreland, the geometric order of the Apennine units from the highest to the lowest ones roughly follows the arrangement of the corresponding paleogeographic domains from the SW towards the NE. However, the existence of important breaches that have modified the primary nappe geometry and the occurrence of important longitudinal changes in the internal structural architecture of the mountain chain make difficult to operate correlations between the northern and the southern portions of the study area (Abruzzi-Alto Molise and Sannio-Matese regions in the north; Campania-Lucania region in the south). These longitudinal structural variations, sometimes controlled by original paleogeographic variations, explain why a lot of different reconstructions coexist in the geological literature. The only agreement among these reconstructions is the identification of a more internal (western) basinal realm referable to the southern margin of the Tethys Ocean flanked by a more or less complex system of platform and basins. However, significant differences exist as concerns the number and the extent of the platforms and basins.

The simplest palinspastic restoration, quite popular among oil geologists, was proposed by Mostardini & Merlini (1986) who recognized six paleogeographic domains moving from west to the east: Tyrrhenian Basin, Apenninic Platform. Lagonegro-Molise Basin, Inner Apulia Platform, Apulia Basin and Outer Apulia Platform, the latter corresponding to the present foreland of the Southern Apennines (fig. 3). The principal differences between this paleogeographic model and a similar reconstruction proposed in the last sixties by OGNIBEN (1969) consist in the partition of the Apulia domain into two platforms separated by an intermediate basinal domain (Apulia Basin) from which the Daunia Unit should have derived. In the scheme of OGNIBEN (1969), on the contrary, the Daunia Unit («Ex-basal Complex») had been referred to the Lagonegro Basin. In addition, MOSTARDINI & MERLINI (1986) suggested a possible derivation of the Sicilide Unit from the Lagonegro Basin rather than from an internal depositional realm flanking the oceanic Tethys. This indication has been followed by PESCATORE and co-workers (PESCATORE, 1988, 1995; PESCATORE & TRAMUTOLI, 1980; PESCATORE *et alii*, 1988, 1992, 1996, 1999a) who have described in Basilicata questionable stratigraphic contacts between the lower Cretaceous Galestri Formation (attributed in this paper to the Lagonegro Unit II) and the Cretaceous-Paleogene Corleto Perticara Formation (here attributed to the Sicilide Unit).

A more articulated model, popular in the seventies, was proposed by D'ARGENIO *et alii* (1972, 1975) and IPPOLITO *et alii* (1975). According to this model (fig. 4), an intermediate platform (the Abruzzi-Campania Platform) separated the Lagonegro Basin from the Molise one. Greater paleogeographic complexities have been subsequently postulated by SGROSSO (1986, 1988, 1996, 1998) who has proposed a palinspastic restoration (fig. 5) according to which five platforms and five basins existed

Fig. 3 - The Southern Apennine depositional realms during Cretaceous-Paleogene times according to MOSTARDINI & MERLINI (1986).
– I domini deposizionali dell'Appennino meridionale nel Cretaceo-Paleogene secondo MOSTARDINI & MERLINI (1986).

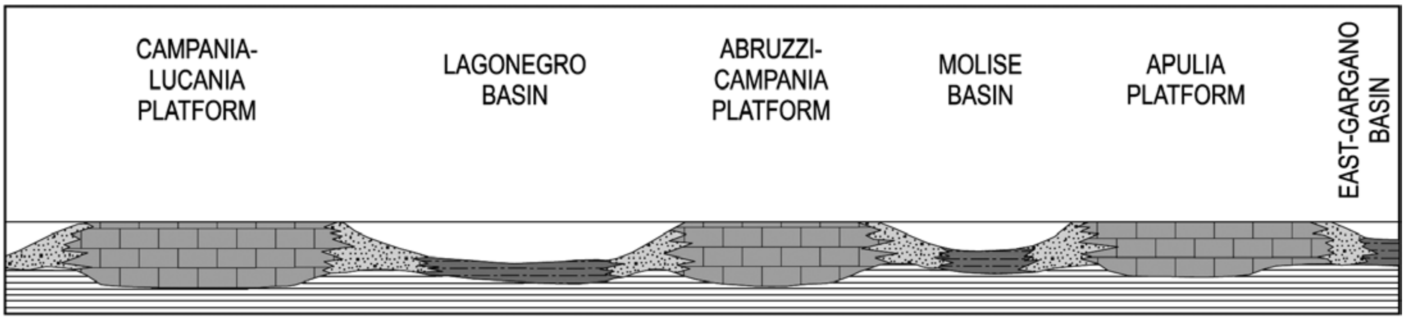


Fig. 4 - The Southern Apennine platform-and-basin system during Jurassic-Paleogene times according to D'ARGENIO *et alii* (1972) and IPPOLITO *et alii* (1975).
– Il sistema piattaforme-bacini nell'Appennino meridionale durante il Giurassico-Paleogene secondo D'ARGENIO et alii *(1972) e IPPOLITO* et alii *(1975).*

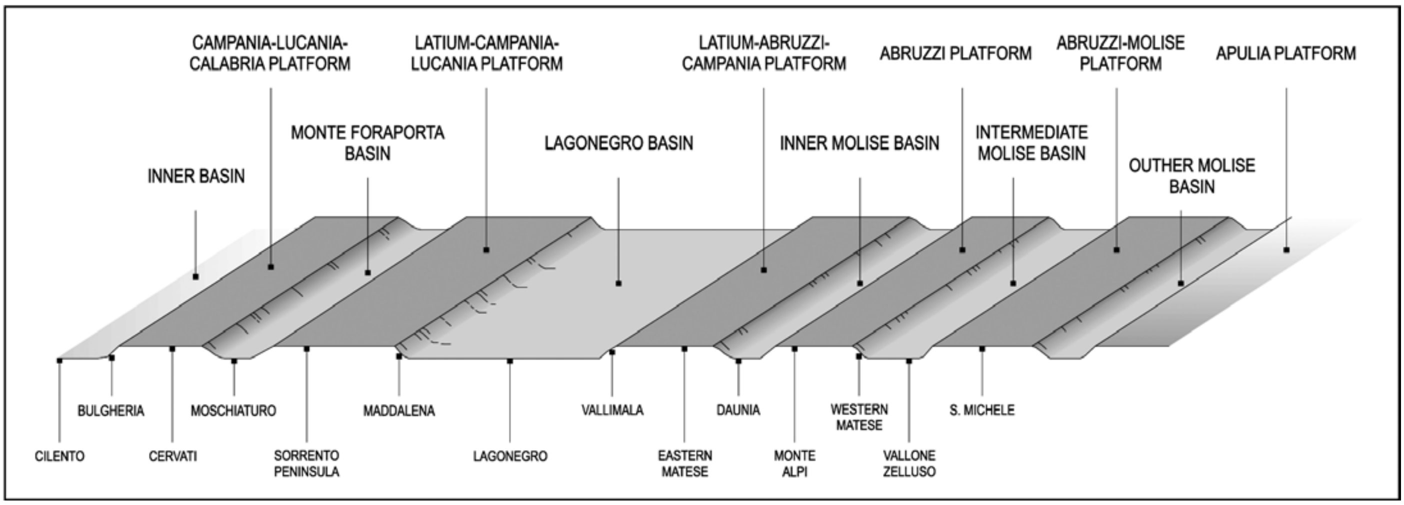


Fig. 5 - The Southern Apennine platform-and-basin system during Jurassic-Paleogene times according to SGROSSO (1998).
– Il sistema piattaforme-bacini nell'Appennino meridionale durante il Giurassico-Paleogene secondo SGROSSO (1998).

during Mesozoic and Paleogene times between the internal oceanic basin and the Apulia Platform (=Outer Apulia Platform of MOSTARDINI & MERLINI, 1986).

Finally, a completely different restoration, which revived old models of SELLI (1962) and SCANDONE (1967), was proposed by MARSELLA *et alii* (1992, 1995). According to these authors, the Lagonegro Units derived from an oceanic realm located west of the Apenninic Platform together with the Ligurian (=North-Calabrian), Sicilide and Molise Units.

With the exception of SGROSSO (1986, 1988, 1998), no author has made explicit the assumptions and postulates that existed behind the proposed palinspastic restoration. Consequently, a reader not familiar with the Apennine geology has no element to make a choice among so many different and mutually incompatible models. In our opinion, no cylindrical reconstruction can satisfy the available geological information. For instance, the simple scheme admitting an undifferentiated Lagonegro-Molise Basin between the Apenninic Platform and the Apulia Platform agrees with the general geological features of the Campania-Lucania region (southern part of the study area) but conflicts with a lot of geological evidence in the Sannio-Molise and southern Abruzzi regions (central and northern parts of the study area, respectively). The application of this model, in fact, would led to the paradox that during a forelandward thrust propagation platform domains belonging to the Apenninic Platform (e.g. Western Marsica platform domain), which were located west of the Lagonegro basin, were reached by the lower-plate flexure-hinge retreat and were incorporated in the Apennine foredeep basin in a time (early Messinian) in which more external (eastern) Lagonegro domains had already been incorporated in the thrust belt.

The palinspastic relocation of the Apennine depositional domains proposed in fig. 6 admits important longitudinal variations in the platform-and-basin areal distribution. The principal basic criteria and procedures we have followed for palinspastic restoration are:

– Definition of the geometrical relationships between the tectonic units forming the thrust belt. A long thrust flat separating two tectonic units with a low cutoff angle at the footwall suggests (suggests but does not prove, because important backthrusts cannot be excluded *a priori*) an internal (south-western) provenance of the upper unit. However, the original thrust geometries in the mountain chain have been largely modified by subsequent breaching processes (e.g. repeated imbrications of the Sicilide/Sannio tectonic couple in the Lucanian Apennines). In some cases, these tectonic complications make difficult the identification of the primary nappe geometry and this fact explains, for example, why an internal provenance of the Lagonegro Units has been affirmed by some authors;

– Identification and characterization of the facies in the single tectonic units following well defined isochrones. Basin analysis resulted a powerful tool for identifying important tectonic shortening indicated by the lack of facies necessarily present in the original depositional domain. In addition, basin analysis helped very much in the definition of the role of the paleotectonic activity in the time-space evolution of platform and basin systems;

– Definition of the age of incorporation of foreland domains in the foredeep basin. The age of the siliciclastic flysch deposits gets progressively younger moving from the internal (western) to the external (eastern) depositional domains because of the progressive flexure-hinge retreat of the lower plate. However, the possible occurrence of free boundaries *sensu* ROYDEN *et alii* (1987) accommodating differential flexure retreats in adjacent areas makes dangerous cylindrical extrapolations. In fact, paleogeographic realms occupying different positions in the foreland region (more internal in areas with low-rate flexure-hinge retreat and more external in areas with high-rate flexure-hinge retreat) may have been incorporated in the foredeep basin in the same time;

– Definition of the age of incorporation in the thrust belt of the different foreland domains. Due to the overall forward thrust propagation, the incorporation of foreland domains in the thrust belt gets younger moving from the internal to the external depositional realms. However, out-of-sequence processes can make difficult to discriminate between the first tectonic transport and subsequent ones. In addition, transpressional features related to the activity of strike-slip faults in the foreland region may be mistaken for compressional features related to the forward migration of the thrust front.

In the palinspastic restoration proposed in this paper, the provenance of the Sicilide Unit from a basinal realm located west of the Apenninic Platform is based on the geometrical relationships between the Sicilide and Alburno-Cervati Units. The Sicilide Unit systematically overlies the Alburno-Cervati and Monti della Maddalena Units in the whole study region wherever the carbonate massifs are exposed (e.g. synform between Monte Soprano and Monte Alburno, Sele Valley, eastern margin of Monte Marzano, High Agri Valley). A possible differentiation of the Sicilide Unit *Auct.* into an internal nappe derived from a western basinal realm and an external group related to the Lagonegro basin has been indicated in literature as a reasonable compromise for combining the tectonic evidence in the Cilento-Monte Marzano area with the stratigraphical relationships between the Galestri Formation and the Argille Varicolori plus Corleto Perticara formations described by PESCATORE and coworkers (Groppa d'Anzi Lagonegro Unit of PESCATORE *et alii*, 1988). However, there are no lithostratigraphic or biostratigraphic differences between the Sicilide sequences exposed in the Tyrrhenian areas of the mountain chain and those cropping out in Basilicata attributed to the Lagonegro Basin. In addition, the contacts between the Galestri Formation and the overlying Argille Varicolori plus Corleto Perticara formations described in geological literature as conformable stratigraphic contacts are, in our opinion, unquestionable tectonic contacts (tectonic truncations of the strata in the hangingwall and footwall; mechanical lamination of the rocks above and below the contact; different structural fabrics in the rocks forming the footwall and the hangingwall blocks; in some cases, overturned beds in the hangingwall).

The attribution of the Apennine carbonate thrust sheets present in the northern part of the study area to four different groups of tectonic units derives from their different geometric positions in the nappe pile and from the different times in which the corresponding depositional realms were incorporated in the foredeep basin and subsequently in the thrust belt. The first group includes the Capri-Bulgheria, Alburno-Cervati and Monti

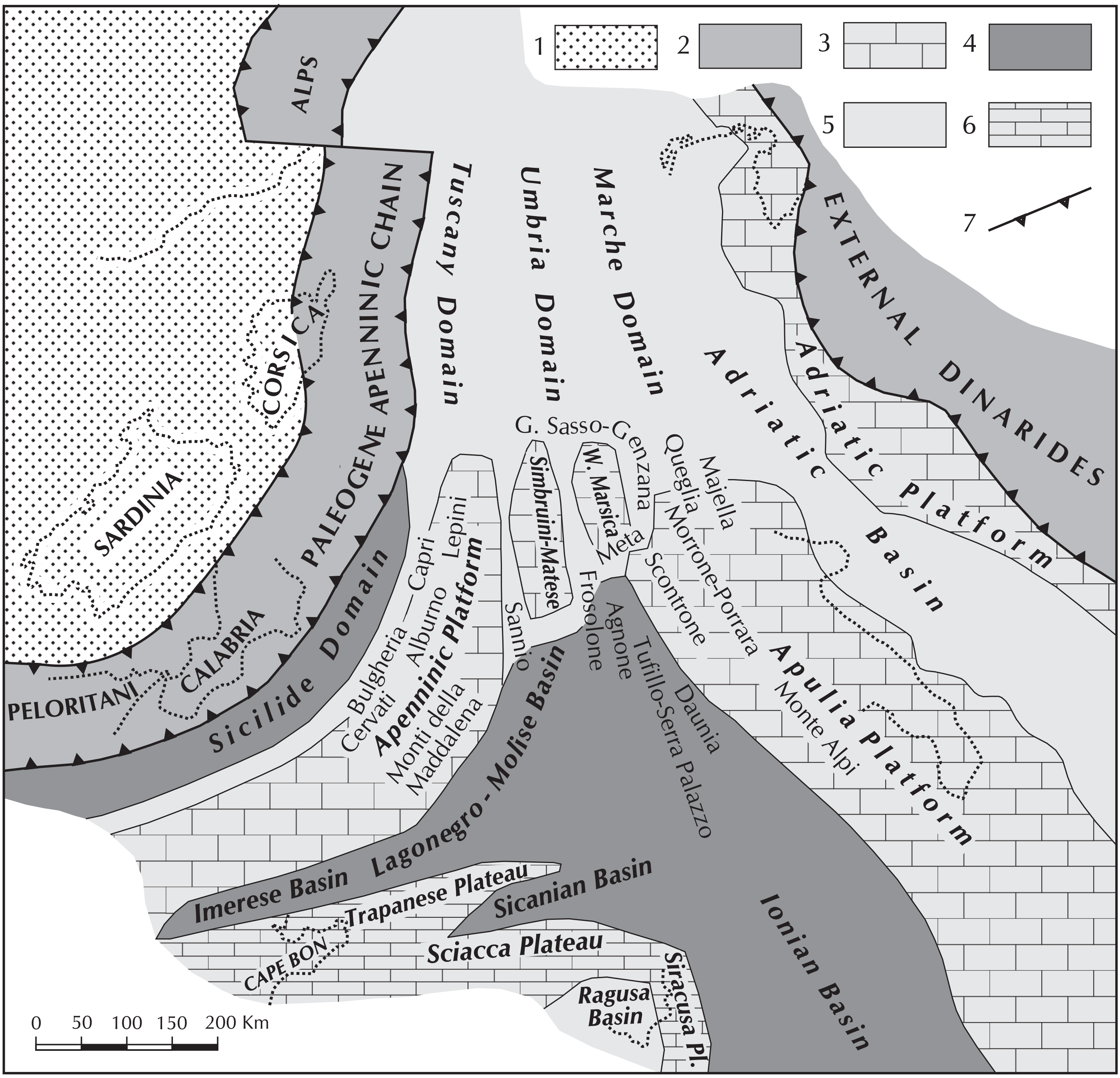


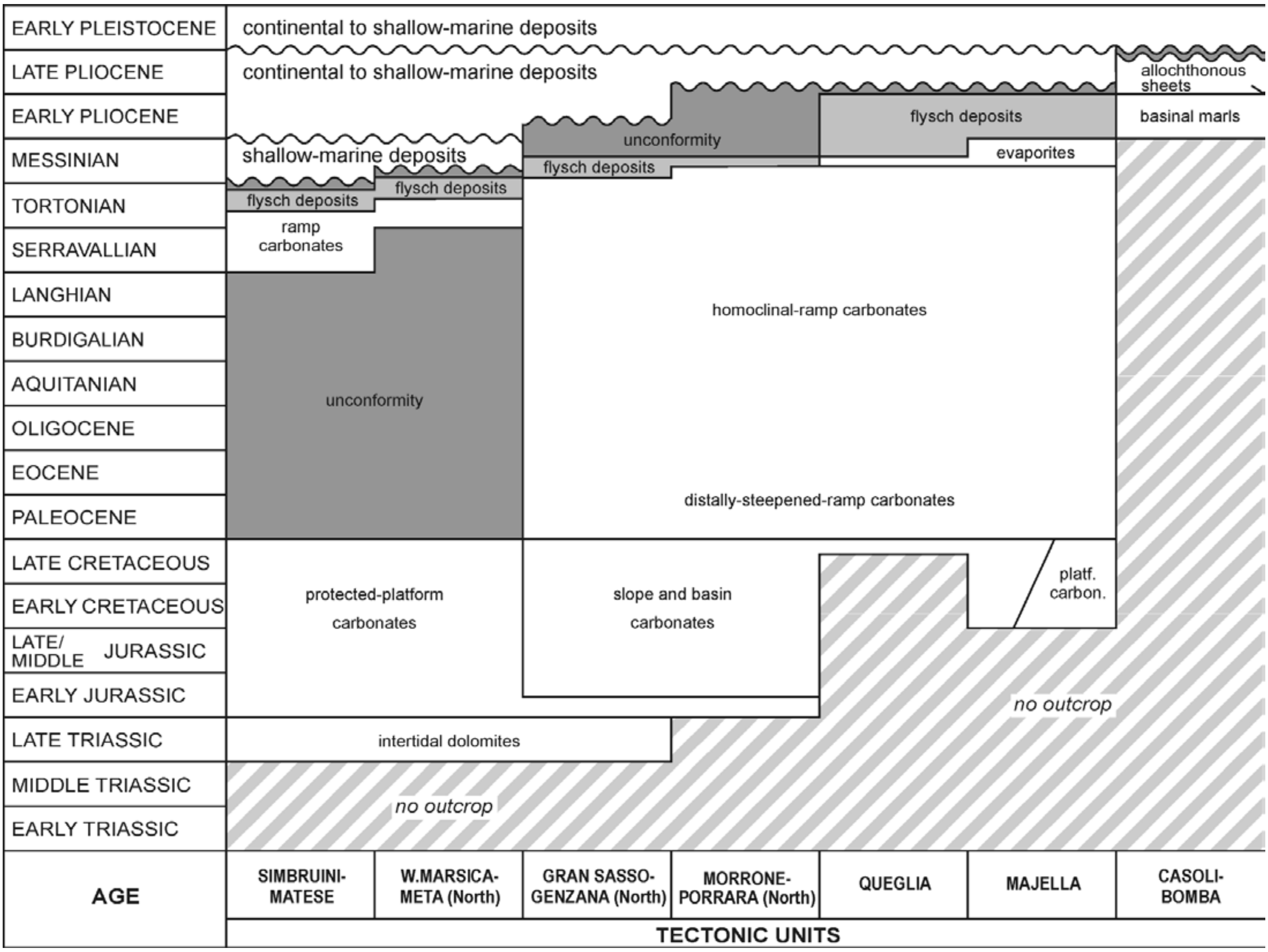
Fig. 6 - Palinspastic restoration of the Central Mediterranean region in the late Oligocene (about 30 Ma) showing the distribution of the Central and Southern Apennine platforms and basins before their incorporation in the mountain chain. 1) European foreland. 2) Paleogene mountain chains. 3-6) African foreland: 3) shallow-water carbonate platforms; 4) deeper-water basins floored by oceanic or thinned continental crust; 5) basinal areas with isolated structural highs; 6) wide pelagic plateaux. 7) Fronts of the orogenic belts.
– Ricostruzione palinspastica dell'area centro-mediterranea nell'Oligocene superiore (circa 30 milioni di anni fa) mostrante la distribuzione dei domini di piattaforma e bacino nell'Appennino Centrale e Meridionale prima della loro incorporazione in catena. 1) Avampaese europeo. 2) Catena paleogenica. 3-6) Avampaese africano: 3 carbonati di piattaforma di mare basso; 4) bacini profondi a crosta oceanica o continentale assottigliata; 5) aree bacinali con alti strutturali isolati; 6) plateaux pelagici. 7) Fronte di catena.

della Maddalena Units; the second and third groups are represented by the Simbruini-Matese Unit and by the Western Marsica-Meta Unit respectively; the fourth group includes the Morrone-Porrara and Majella Units, as well as platform carbonates present in the southernmost outcrops of the Gran Sasso-Genzana Unit. The existence of a deeper-water tongue that separated the Apenninic Platform from the Simbruini-Matese Platform providing a sort of connection between the Umbria domain and the Lagonegro-Molise Basin is suggested by the occurrence of Lagonegro-Sannio deposits tectonically sandwiched between the Alburno-Cervati and Simbruini-Matese Units. In the whole Campania-Lucania Apennines, the basinal deposits of the Sannio and Lagonegro Units are tectonically overlain by the carbonates of the Alburno-Cervati and Monti della Maddalena Units. In the Caserta-Benevento area, on the contrary, the Sannio Unit tectonically overlies the carbonates of

TABLE 1

– Major sedimentary characteristics and ages of the stratigraphic sequences representative of the tectonic units and of the thrust-sheet-top deposits cropping out in the Southern Abruzzi-Alto Molise region (see fig. 2). In tables 1-3, the age of the siliciclastic flysch deposits and the age of the unconformity at the base of the thrust-sheet-top deposits, becoming younger from the Tyrrhenian margin to the Adriatic margin of the mountain chain, reflect the time-space migration of the lower-plate flexure-hinge retreat and of the compressional deformation from the internal (southwestern) to the external (northeastern) paleogeographic domains.

– Caratteristiche principali ed età delle sequenze stratigrafiche rappresentative delle unità tettoniche e dei depositi discordanti sulla catena nell'Abruzzo meridionale e nell'Alto Molise (vedi fig. 2). Nelle tabb. 1-3 l'età dei depositi silicoclastici e l'età della base dei depositi discordanti che si ringiovaniscono andando dal margine tirrenico al margine adriatico della catena riflettono l'arretramento dell'asse di flessura della placca inferiore e la migrazione spazio-temporale del fronte di compressione dai domini più interni (sud-occidentali) a quelli più esterni (nord-orientali).

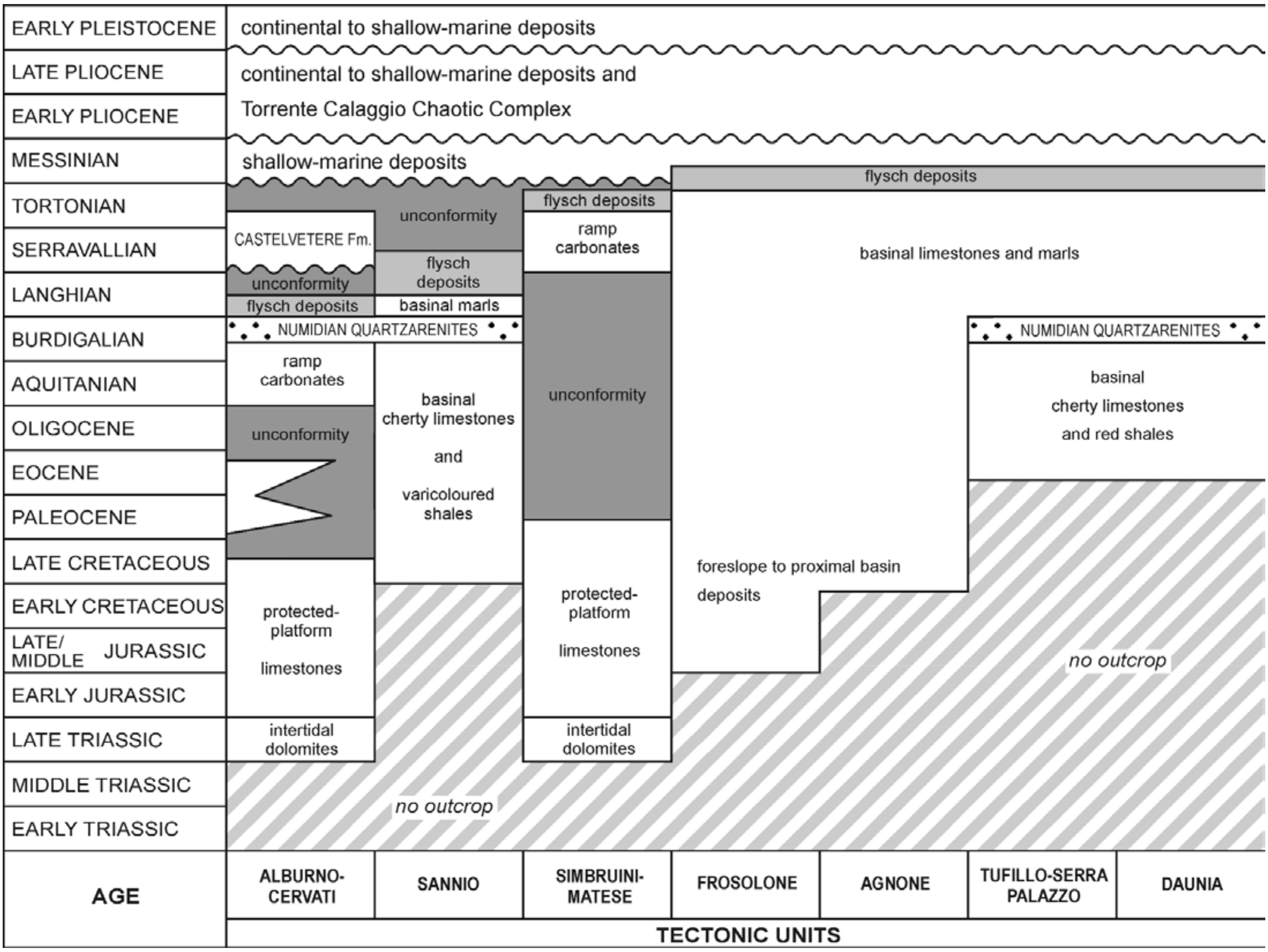


the Simbruini-Matese Unit. In addition, the Monte Taburno 1 well, located near the eastern foot of the Taburno-Camposauro massif, encountered at the base of a stratigraphic succession surely belonging to the Sannio Unit more than 1000 meters of Cretaceous shaly deposits referable to the Galestri Formation of the Lagonegro sequence. A lateral transition between the original outer margin of the Matese carbonate platform and the southwestern margin of the Frosolone basin is demonstrated by the wide spectrum of transitional facies preserved in the Western Matese area (CLERMONTÉ & PIRONON, 1979). The existence of a deeper-water tongue separating the Simbruini-Matese Platform from the Western Marsica one, suggested by the structural restoration of the Molise nappes, would justify the occurrence of ammonite-bearing Jurassic hemipelagic deposits in the Simbruini Mountains (ACCORDI *et alii*, 1988). The Simbruini-Matese carbonate had to be replaced towards the south by a deeper-water depositional realm, which was part of the wide Lagonegro-Molise Basin, but we do not know how far the platform facies extended. A transition between the Molise Basin and the Western Marsica Platform is supported by the facies of the Jurassic-Cretaceous deposits of the Mainarde Mountains. Finally, the original position of the Tufillo domain adjacent to the Agnone one is proved by the gradual transition of facies

TABLE 2

– Major sedimentary characteristics and ages of the stratigraphic sequences representative of the tectonic units and of the thrust-sheet-top deposits cropping out in the Molise-Sannio region (see fig. 2).

– *Caratteristiche principali ed età delle sequenze stratigrafiche rappresentative delle unità tettoniche e dei depositi discordanti sulla catena nel Molise e nel Sannio (vedi fig. 2).*



between the Miocene pre-flysch deposits of the Agnone and Tufillo sequences in the Sangro Valley.

Synthetic information on depositional characteristics and ages of the stratigraphic sequences representative of the thrust sheets and thrust-sheet-top deposits of the Southern Apennines is given in the synoptic schemes of tables 1-3 referring to the Southern Abruzzi-Alto Molise, Molise-Sannio and Cilento-Basilicata transects illustrated in fig. 2. In these schemes, the onset of the siliciclastic flysch deposits in the different tectonic units and the base of the thrust-sheet-top deposits getting younger from the Tyrrhenian to the Adriatic regions illustrate the eastward time/space migration of the thrust belt-foredeep-foreland system.

4. THE SOUTHERN APENNINE TECTONIC UNITS

This section contains a short description of all tectonic units forming the Southern Apennine mountain chain. Description starts from the most internal units that occupy the highest position in the tectonic edifice and are represented only in the southern part of the study area. At the end of each description, a few selected references will be provided aimed at helping the reader who wishes learn more about regional geology.

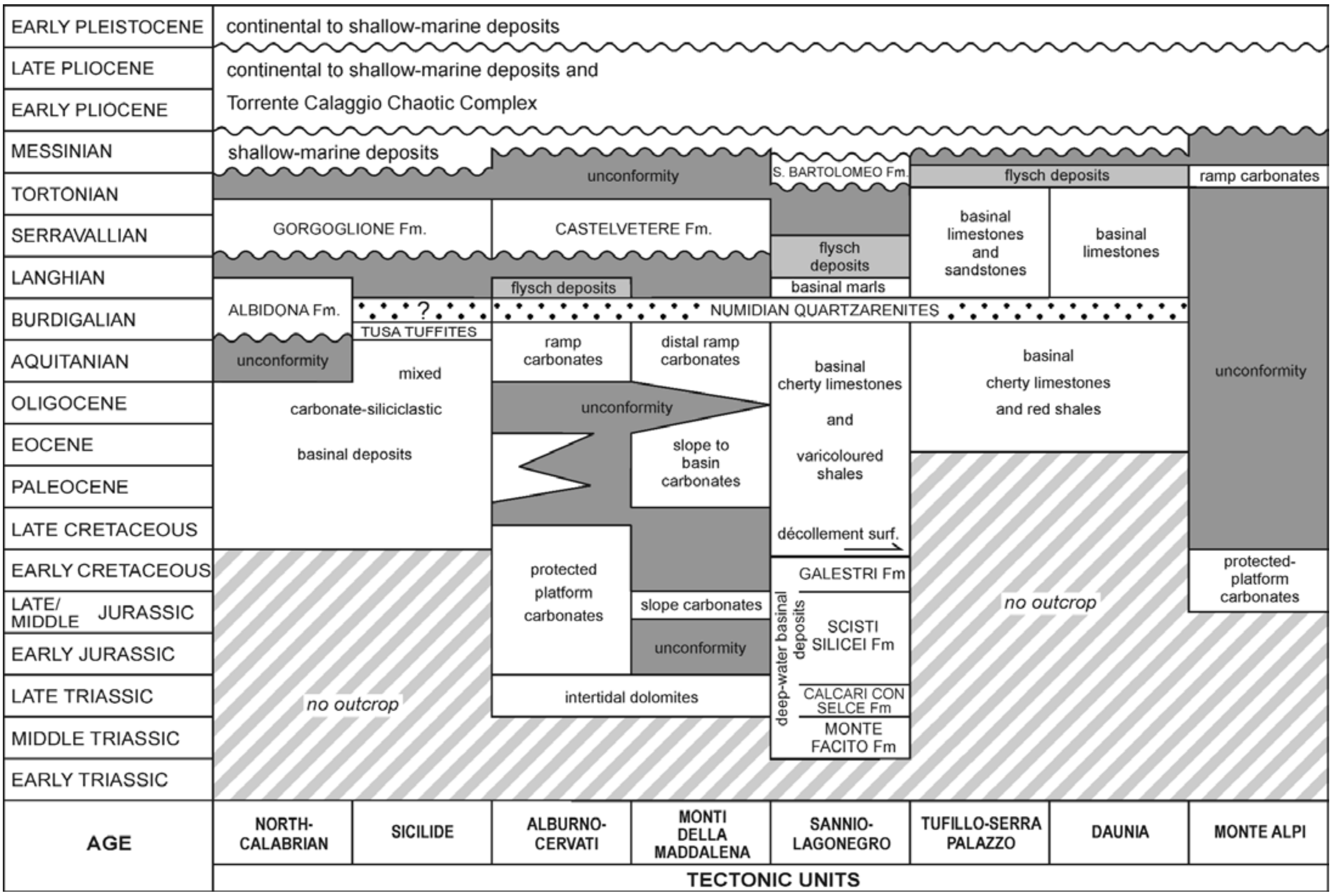
4.1. INTERNAL NAPPES

The term «internal nappes» is commonly used by Apennine geologists to indicate allochthonous sheets the original depositional realmof which was located somewhere west of the Apenninic Platform, The internal nappes include the ophiolite-bearing Ligurian Units, derived from basinal domains floored by the Tethyan oceanic crust, and the Sicilide Unit, derived from a more external basinal domain the basement of which was constituted of oceanic crust as in the Ligurian domain or, more probably, by a thinned continental crust.

TABLE 3

– Major sedimentary characteristics and ages of the stratigraphic sequences representative of the tectonic units and of the thrust-sheet-top deposits exposed in the Cilento-Basilicata region (see fig. 2).

– *Caratteristiche principali ed età delle sequenze stratigrafiche rappresentative delle unità tettoniche e dei depositi discordanti sulla catena nell'Appennino campano-lucano (vedi fig. 2).*



4.1.1. «Diorite-Kinzigite» and ophiolite-bearing units

Ophiolite-bearing nappes (Ligurian Complex of OGNIBEN, 1969), originated from the closure of the Jurassic Tethys Ocean, crop out only in the southernmost part of the study area associated with crystalline rocks («Diorite-Kinzigite» Unit *Auct*.) derived from a continental basement facing the oceanic realm. These units, occupying the highest position in the Apennine pile of nappes, are still badly defined in terms of internal geometry, stratigraphic successions and age of deformation. Consequently, different interpretations coexist in the current literature. In this paper, we refer to BONARDI *et alii* (1988) according to which the ophiolite-bearing nappes basically consist of three major units characterized by different age, structural fabric and metamorphism. The lower thrust sheet, called the Frido Unit, is composed of slightly metamorphosed shales, quartzarenites and subordinate limestones with lenticular bodies of mafic and ultramafic rocks. According to BONARDI *et alii* (1993), the age of the sequence ranges from the upper Jurassic to the upper Oligocene. The age of the metamorphism is probably lower Miocene, as in the Verbicaro and San Donato Units (see paragraphs 4.3.1 and 4.3.2 in the next pages). The Frido Unit is overlain by a tectonic melange (Episcopia-San Severino Melange) made up of metapelites including huge blocks of serpentinites, granulites, amphibolites, granitoids and marbles (SPADEA, 1982). A non-metamorphic unit averaging 1500 meters in thickness follows, called the North-Calabrian Unit. The sequence consists of pillow basalts overlain by upper Jurassic radiolarites, shales and quartzarenites (Timpa delle Murge Fm), black shales (Crete Nere Fm) and mixed calcareous-siliciclastic turbidites (Saraceno Fm). The age of the entire sequence ranges from the upper Jurassic to the lower Miocene (BONARDI *et alii*, 1988; DI STASO & GIARDINO, 2002). Since no evident gap has been recognized in the stratigraphic sequence of the North-Calabrian Unit, the aforementioned authors have supposed the local persistence of an undeformed segment of the Jurassic Tethys Ocean until the Oligocene-Miocene boundary at least. However, an ocean floor persistence through Cretaceous and Paleogene times cannot be considered as a fact because the stratigraphic continuity of the sedimentary sequence is poorly documented.

BONARDI *et alii* (1988) have recognized on top of the North-Calabrian nappes a fourth unit, informally called «Parasicilide» Unit because of close similarities with the

Sicilide Unit (see also Bonardi *et alii*, 1993), constituted of upper Cretaceous-upper Oligocene calcareous and siliciclastic turbidites. In our opinion, the bulk of the «Parasicilide» deposits can be referred to the Sicilide Unit *sensu stricto* (Corleto Perticara Fm) while a minor portion belongs to the North-Calabrian Crete Nere Formation.

Selected references: Bousquet, 1962; Selli, 1962; Ietto *et alii*, 1965; Vezzani, 1968a,b, 1969; Ogniben, 1969; Dietrich & Scandone, 1972; Haccard *et alii*, 1972; Amodio Morelli *et alii*, 1976; De Blasio *et alii*, 1978; Lanzafame *et alii*, 1978, 1979a,b; Spadea, 1982; Marcucci *et alii*, 1987; Knott, 1987, 1994; Bonardi *et alii*, 1988, 1993; Mauro & Schiattarella, 1988; Monaco *et alii*, 1991; Monaco, 1993; Monaco & Tortorici, 1995; Cirrincione & Monaco, 1996; Di Staso & Giardino, 2002.

4.1.2. Sicilide Unit

The Sicilide Unit, established in the Southern Apennines by Ogniben (1969) is widespread in the Basilicata region. The stratigraphic succession, reaching a thickness of 1500-2000 meters, consists of three major intervals:

1) Lower Varicolored Clay, made up of some hundred meters of gray-greenish and red shales with thin intercalations of siliceous calcilutites. A Cretaceous age has been merely inferred by the stratigraphic position since no diagnostic fossils have been recovered from this part of the sequence;

2) Corleto Perticara Formation. The Corleto Perticara Formation (*sensu* Selli, 1962) may be divided into two portions. The lower portion is characterized by white calcilutites containing planktonic foraminifers and cream siliciclastic calcarenites with sporadic intercalations of red marls and gray calcareous sandstones. The calcarenites contain sporadic reworked macroforaminifers. This part of the sequence corresponds to the Sant'Arcangelo member of the Varicolored Clays of the geological literature. The age ranges from a dubious late Cretaceous to the late Oligocene. The upper portion of the Corleto Perticara Formation, corresponding to the Corleto sandstones of the geological literature, consists of medium to coarse-grained gray calcareous sandstones with subordinate siliciclastic calcarenites containing *Lepidocyclina* and *Miogypsinoides*. The age of this sandy interval approximates the Oligocene-Miocene boundary. The thickness of the entire Corleto Perticara Formation exceeds 600 meters;

3) Upper Varicolored Clay and Tusa Tuffite. The Upper Varicolored Clay consists of red, green and gray-greenish shales and silty shales with intercalations of calcilutites and siliciclastic calcarenites; fine-grained green quartzarenites occur in the upper portion. The thickness exceeds 800 meters. The uppermost part of this interval contains variable amounts of volcaniclastic sandstones (Tusa Tuffite) that in some areas (e.g. Rotondella area) prevail over the other lithologies reaching a thickness of some hundred meters. The age of the entire interval 3 ranges from the Oligocene/Miocene boundary to the Burdigalian (N5-N6 foraminiferal zones, NN3 nannofossil zone).

Numidian quartzarenites and associated basinal limestones and marls cropping out between Potenza and Pietragalla (see Centamore *et alii*, 1971), attributed in the current geological literature to the Sicilide Unit, belong in reality to the Sannio Unit. Small outcrops of Numidian sandstones possibly belonging to the Sicilide Unit have been recognized in the Nova Siri area.

The Sicilide Unit tectonically overlies the Alburno-Cervati Unit (Cilento-Monte Marzano area), the Lagonegro Units (from the San Fele area to the High Agri Valley) and the Sannio Unit (from the Vulture area to the Sant'Arcangelo synform). Near Rotondella, the Sicilide Unit tectonically overlies the more external Tufillo-Serra Palazzo Unit. The contact between the Sicilide Unit and the underlying allochthonous sheets is systematically represented by a thrust flat showing low cutoff angles at the footwall and higher angles at the hangingwall. In the study area, the Sicilide Unit is unconformably covered, together with the North-Calabrian Unit, by the Gorgoglione Formation (see chapter 5 of this paper dedicated to the thrust-sheet-top deposits).

Between the Vulture Volcano and the Sant'Arcangelo depression, the thrust flat separating the Sicilide and Sannio nappes is cut across by upper Pliocene and Pleistocene breaches that have created an imbricated zone characterized by a remarkable telescopic shortening. In subsurface the breaching and the consequent imbrication are well documented in commercial boreholes (Tempa Rossa 1 and 2, Gorgoglione 1, Tempa d'Emma 1) that have encountered several repetitions of the Sicilide-Sannio tectonic couple.

Selected references: Selli, 1962; Ogniben, 1969; Centamore *et alii*, 1971; Lentini, 1979, 1991; Zuppetta *et alii*, 1984a; Pescatore *et alii*, 1988, 1992, 1999a,b; Fornelli *et alii*, 1989; Critelli *et alii*, 1990; Baruffini *et alii*, 2002.

4.2. Tectonic units derived from the Apenninic Platform

Tectonic units certainly derived from the Apenninic Platform (which is also indicated in the geological literature as the Campania-Lucania Platform or Inner Platform or Western Platform) form the bulk of the carbonate massifs in the Campania-Lucania Apennines. We have included in this group of units the carbonate sequences of the Lepini Mountains (see Cosentino *et alii*, 2002) exposed in the northern part of the study area. Four major units have been distinguished, known in the geological literature as the Capri-Bulgheria, Alburno-Cervati, Monti della Maddalena and Monte Croce Units (D'Argenio *et alii*, 1972, 1975; Ippolito *et alii*, 1975; Scandone, 1972). The Mesozoic carbonate sequences of the Alburno-Cervati Unit are indicative of a platform interior and subordinately (e.g. Monte Marzano area) of a platform-edge. The facies of the Capri-Bulgheria sequences are indicative of slope to basin environments, with basinal characters mostly developed in the Monte Bulgheria sequence. The Monti della Maddalena Unit is characterized by slope deposits with wide erosional/non-depositional hiatuses. The Mesozoic sequence of the Monte Croce Unit shows similarities with the Monti della Maddalena sequence.

As concerns the mutual geometric relationships, the primary contact between the Capri-Bulgheria and Alburno-Cervati Units is never exposed. The contact between the Alburno-Cervati and Monti della Maddalena Units, well exposed east of the Vallo di Diano depression, is represented by a thrust surface with low cutoff angles at the footwall and variable, in some cases significant, cutoff angles at the hangingwall. A good example of tectonic truncation of the beds at the hangingwall is exposed northeast and east of Arenabianca, not far from the southern termination of the Vallo di Diano Basin. Here, NNW-SSE trending sub-vertical Jurassic limestones of the Alburno-Cervati Unit are separated by east/north-east dipping Upper Triassic dolomites and dolomitic limestones of the Monti della Maddalena Unit by a thrust surface gently dipping towards the NNE.

4.2.1. *Capri-Bulgheria Unit*

This unit crops out only in the Capri Island and in the Monte Bulgheria-Capo Palinuro area.

In the Capri Island, the stratigraphic succession consists of shallow-water dolomites dubitatively attributed to the early Liassic stratigraphically overlain by slope to basin carbonate deposits ranging in age from the middle-late Liassic to the late Oligocene/early Miocene.

In the Monte Bulgheria-Capo Palinuro area, a middle Liassic to lower Miocene sequence of basinal carbonates 900-1000 meters thick overlies 500-600 meters of Upper Triassic-lower Liassic shallow-water dolomites and limestones. An interval of lower/middle Liassic resedimented calcirudites several tens of meters thick marks the transition from the shallow-water deposits to the basinal ones.

Jurassic basinal deposits cropping out near Salerno and in the Monti Mai area have been dubitatively attributed to the Capri Unit. However, their geometric relationships with the adjacent carbonates surely belonging to the Alburno-Cervati Unit have not been sufficiently investigated.

Selected references: Scarsella, 1961; Scandone *et alii*, 1963; Sgrosso, 1965, 1995; Torre, 1969; De Alfieri *et alii*, 1986; Barattolo & Pugliese, 1987; Pappone *et alii*, 1988; Castelluccio & Napolitano, 1989; Tozzi *et alii*, 1996.

4.2.2. *Alburno-Cervati Unit*

Carbonate deposits belonging to the Alburno-Cervati Unit are widespread in the whole Campania-Lucania Apennines and in the Pollino Mountain. Complete upper Triassic-upper Cretaceous sections are well exposed in the Pollino, Picentini and Marzano Mountains, as well as in the Sorrento Peninsula. Natural sections of the upper Cretaceous to Miocene portion of the sequence are available in the Monte Sottano, Monte Soprano-Monte Chianello and Monte Cervati areas, as well as in the Sapri-Lauria region. In all these sections, with the exception of the Monte Marzano area where Jurassic slope deposits and Cretaceous platform-edge deposits occur, the Jurassic to Paleocene stratigraphic succession is indicative of a platform-interior environment. The overlying lower Miocene deposits indicate a deepening-upward carbonate ramp.

A composite type-section representative of the carbonates of the Alburno-Cervati Unit, reaching a total thickness of about 4500 meters, is made up of the following intervals:

– Massive white dolomites (Carnian, 350-400 m) overlain by Raiblian lagoonal mudstones (100-150 m);

– Well-bedded gray dolomites (Norian, 600-650 m) with episodes of restricted circulation in the upper part of the interval («Scisti Ittiolitici» *Auct.*) grading upward into white stromatolitic dolomites (Norian, 600-800 m) and dolomitic limestones with large megalodonts (Rhaetian, 200-300 m);

– Sporadically dolomitized subtidal to intertidal limestones (Jurassic-upper Cretaceous, 1800-2000 m);

– Disconformable shelf-lagoon limestones (Trentinara Fm, Paleocene-Eocene, 50-100 m) and scattered nummulitic limestones with sporadic euxinic deposits rich in fish remains (Middle Eocene, a few meters) overlain by lateritic paleosoils mostly developed in the Monte Soprano-M. Chianello and Sapri areas. The latter mark a generalized gap spanning the late Eocene and the Oligocene;

– Disconformable shallow-water calcarenites characterized by open circulation on a deepening carbonate ramp (Cerchiara Fm and Roccadaspide Fm, Lower Miocene, 30 m). Near the top of the interval an important volcanic activity is recorded by tuffite deposits (Burdigalian);

– Hemipelagic marls rich in sponge spicules (a few meters) followed by Numidian quartzarenites and quartz-bearing calcarenites (Bifurto Fm, Upper Burdigalian, a few tens of meters). The hemipelagic marls indicate a subsidence not compensated by sedimentation that led to the drowning of the platform;

– Immature sandstones (Civita sandstones) conformably overlying the Numidian quartzarenites. The Civita sandstones, well exposed only in the southern part of the study region (Pollino area, where they reach a total thickness of a few hundred meters) mark the incorporation of the Alburno-Cervati depositional realm in the foredeep basin around the Burdigalian/Langhian boundary.

In the Monte Marzano area, shelf-lagoon Liassic limestones are disconformably overlain by middle-upper Jurassic resedimented calcirudites. The breccias, in turn, are stratigraphically overlain by lower Cretaceous shelf-edge limestones testifying to a progradation of the platform edge over slope deposits after a retrogradation episode caused by the activity of backstepping Jurassic faults. A generalized retrogradation of the platform likely related to an extensional faulting took place during the late Senonian. This important episode of platform-edge retreat is testified in the Monte Alburno and Monte Marzano areas by the occurrence of talus breccias and coarse-grained calcarenites («Calcari Pseudosaccaroidi» *Auct.*) disconformably overlying shelf-lagoon upper Cretaceous limestones.

Selected references: Selli, 1957, 1962; Sartoni & Crescenti, 1961; De Castro, 1962b, 1987, 1990; Scandone & Sgrosso, 1963; Pescatore, 1965a; Crescenti, 1966; Sgrosso, 1968; D'Argenio *et alii*, 1972, 1975, 1992; Boni, 1974; D'Argenio, 1974; Ippolito *et alii*, 1975; Bravi & Schiattarella, 1986, 1988; Perrone, 1987; Carannante *et alii*, 1988, 1998; Boni *et alii*, 1990; Pappone, 1990; Patacca *et alii*, 1990, 1992a; Castellano & Sgrosso, 1996.

4.2.3. *Monti della Maddalena Unit*

The Monti della Maddalena Unit, tectonically sandwiched between the Alburno-Cervati and the Lagonegro Units, forms the bulk of the carbonate massifs east of Vallo di Diano. West of the Sele Valley, the Monti della Maddalena Unit has not been recognized as yet though we suspect its existence in the Picentini Mountains (e.g. upper Triassic dolomites of Croci d'Acerno, see De Castro, 1990 and Costa Calda Unit of Pagliaro, 2001 in the Campagna tectonic window).

In the type-area, the stratigraphic sequence is represented by upper Triassic tidal-flat dolomites disconformably overlain by slope to basin carbonate resediments. The stratigraphic succession, the maximum thickness of which slightly exceeds 1000 meters, is represented by the following intervals:

– White dolomites with well preserved subtidal to intertidal sedimentary structures grading upwards to dolomitic limestones with large megalodonts (Norian-Rhaetian, 800-1000 m). Minor bioconstructions are locally present. Extensive paleokarst features indicate repeated emersion episodes;

– Discontinuous breccias with unsorted large clasts derived from the Rhaetian shallow-water dolomites. This breccia has been interpreted as the marker of a faulting episode responsible for the retrogradation of the platform edge around the Triassic/Jurassic boundary and for the establishment of a steep slope above a previous tidal-flat physiography;

– Talus breccias, debrites and calciturbidites (Jurassic-Eocene, 150-200 m) with intraformational truncation surfaces evidencing repeated erosional gaps;

– Outer-ramp carbonate deposits (lower Miocene, a few meters) grading upward into hemipelagic marls rich in sponge spicules and planktic forams (Burdigalian, a few tens of meters). The latter are stratigraphically overlain by Numidian quartzarenites and quartz-bearing calcarenites (upper Burdigalian, a few meters).

Selected references: SGROSSO, 1966; SCANDONE & BONARDI, 1968; D'ARGENIO *et alii*, 1972, 1975; SCANDONE, 1972; IPPOLITO *et alii*, 1975; MARSELLA & PAPPONE, 1986; PAPPONE, 1990; PATACCA *et alii*, 1992a; IANNACE & ZAMPARELLI, 2002.

4.2.4. *Monte Croce Unit*

The Monte Croce Unit crops out only in the Campagna tectonic window beneath deep-water deposits of the Lagonegro Units and the shallow-water carbonates of the Apenninic Platform. In the Acerno 1 well, located in correspondence to the northwestern border of the window, the Monte Croce Unit lies above a thick stack of Lagonegro thrust sheets which in turn tectonically cover the Apulia carbonates of the buried duplex system. In other pages of this volume (see PATACCA, *Stratigraphic analysis of selected wells along the CROP-04 transect. Southern Apennines, Italy*), the Monte Croce Unit has been interpreted as a tectonic repetition of the Monti della Maddalena Unit caused by a major breach cutting across the primary nappe geometry.

The stratigraphic sequence of the Monte Croce Unit is represented by the following intervals:

– Massive dolomitic breccias (about 250 m) with an ill-defined bedding in the upper part, interpreted as coarse-grained talus deposits. The clasts of the breccia are mostly represented by shallow-water carbonates, mostly upper Triassic dolomites and upper Jurassic limestones. The age of these breccias is badly defined but in any case not older than the upper Jurassic;

– Reddish calciturbidites rich in large foraminifers and subordinate calcirudites with minor intercalations of greenish marls (Paleogene, 15-20 m);

– Fine-grained to coarse-grained gray calciturbidites alternating with greenish marls, with occasional intercalations of breccias with clasts made up of Jurassic-Cretaceous platform carbonates (Aquitanian-Burdigalian, about 100 m). Near the top of the interval, a tuffite bed is accompanied by spicule-rich marls.

– Arkosic lithic sandstones with intercalations of calcareous breccias, alternating in the upper portion with calcilutites rich in planktonic foraminifers (Langhian-Serravallian *p.p.*, 100-150 m);

– Gray turbiditic sandstones with lens-shaped intercalations of resedimented calcirudites and pebbly mudstones containing granite boulders and blocks derived from the Sicilide Unit (Serravallian, about 100 m).

Selected references: SCANDONE *et alii*, 1967; SCANDONE & SGROSSO, 1974; TURCO, 1976; FERRANTI & PAPPONE, 1992.

4.3. TECTONIC UNITS OF UNCERTAIN PALEOGEOGRAPHIC DERIVATION

In this chapter we shall deal with four tectonic units – the Verbicaro, San Donato, Timpone Pallone and Monte Foraporta Units – the palinspastic relocation of which is still an unsolved problem though they have been usually referred to the Apenninic Platform. The Verbicaro and San Donato Units, both affected by low-grade metamorphism of Miocene age, are widely developed in the Calabrian Costal Range. The Timpone Pallone Unit crops out only in the Pollino area while the Monte Foraporta Unit is developed in the Lagonegro region.

BOUSQUET (1971) attributed to the same tectonic unit, called the Pollino-Campo Tenese Unit, the metamorphosed San Donato deposits and the non-metamorphosed Alburno-Cervati carbonate exposed in the Calabrian Coastal Range and in the Pollino area. This attribution was based on the supposed existence of lateral transitions between metamorphosed and non-metamorphosed Jurassic-Cretaceous limestones in the Calabrian Costal Range north of Papasidero and at Cozzo Vardo along the southwestern foot of the Pollino Mountain. In reality, a clear mechanical contact separates the two sequences in both regions, with the metamorphosed Triassic-Miocene deposits of the San Donato Unit systematically overlying the non-metamorphosed Triassic-Miocene deposits of the Alburno-Cervati Unit. The San Donato and Alburno-Cervati Units, in turn, are tectonically overlain by the Verbicaro Unit.

In the geological literature, the Verbicaro and San Donato Units have been referred to the Apenninic Platform and the Verbicaro Unit has been considered the southern continuation of the Capri-Bulgheria Unit (see, e.g., CNR-PROGETTO FINALIZZATO GEODINAMICA, 1991). However, the equivalence of these two units is just a conjecture and no real documentation exists. A correlation between the San Donato and the Lagonegro sequences has been proposed by IETTO & BARILLARO (1993), but stratigraphic inconsistencies in this correlation have been criticized by IANNACE *et alii* (1995). A paleogeographic derivation of the Verbicaro and San Donato Units from a microcontinent separating the Liguria-Piedmont Ocean form a West-Adriatic Ocean has been proposed by PERRONE (1996), but geological evidence supporting this attribution is quite poor. In conclusion, we prefer to consider the palinspastic relocation of the Verbicaro and San Donato Units an important open problem that requires additional future investigation.

The Timpone Pallone Unit has been dubitatively attributed to the Apenninic Platform (CNR-PROGETTO FINALIZZATO GEODINAMICA, 1991) because of its geometric position underneath the Alburno-Cervati Unit, easily explainable by admitting the existence of a breach across the Alburno-Cervati carbonates causing a tectonic repetition of the sequence. However, we cannot fully exclude that the Timpone Pallone window represents an emergence of the Apulia-carbonate duplex system, as it is the case of Monte Alpi.

Based on the geometrical position between the Alburno-Cervati and the Monti della Maddalena Units, the Monte Foraporta Unit has been supposed to have derived from a basinal domain located within the Apenninic Platform. This attribution, however, is not supported by the facies distribution of the Jurassic deposits in the Alburno-Cervati, Monte Foraporta and Monti della Maddalena sequences. Consequently, we consider the derivation of the Monte Foraporta Unit too an open problem.

4.3.1. *Verbicaro Unit*

The Verbicaro Unit crops out in the Calabria Coastal Range and along the southwestern margin of the Pollino Mountain. The sequence consists of upper Triassic-lower Liassic shallow-water dolomites and dolomitic limestones overlain by middle Liassic to lower Miocene slope to basin carbonate deposits. Erosional/non-depositional hiatuses are common features in the whole stratigraphic sequence. Where the amplitude of the stratigraphic gap is maximum, uppermost Cretaceous resedimented calcarenites and calcirudites lie in disconformity over upper Triassic shallow-water dolomites. An important Paleocene-Eocene mafic magmatic episode is recorded by widespread lava flows and dikes («limburgites» of QUITZOW, 1935). During the early Miocene (18-19 Ma according to K/Ar measurement results, PIERATTINI *et alii*, 1975) the Verbicaro sequence underwent a low-grade metamorphism with a HP/LT imprint increasing towards the south.

Selected references: SELLI, 1957; GRANDJACQUET & GRANDJACQUET, 1962; VALLARIO & DE' MEDICI, 1967; GRANDJACQUET, 1969; BOUSQUET & GRANDJACQUET, 1969; DAMIANI, 1970; GRANDJACQUET, 1971; PIERATTINI *et alii*, 1975; CLIMACO *et alii*, 1997.

4.3.2. *San Donato Unit*

The strong recrystallization related to the metamorphism (DIETRICH *et alii*, 1976) and the complex structural fabric resulting from repeated events of isoclinal folding (PIERATTINI, 1975) hamper an easy reconstruction of the San Donato stratigraphic sequence. The Triassic portion consists of some hundred meters of Anisian-Ladinian phyllites with lenticular intercalations of algal metalimestones followed by a thick pile (more than 1000 meters) of Ladinian-Carnian limestones and Norian-Rhaetian dolomites (IANNACE *et alii*, 1995). Very poor information is available on the Jurassic-Cretaceous portion of the sequence, made up of strongly foliated metalimestones with sporadic relics of the original sedimentary texture («calcaires plaquettès» of BOUSQUET, 1971). We do not know whether these metalimestones are representative of shallow-water deposits as the underlying Triassic dolomites or are part of a basinal sequence, as suggested by probable relics of graded bedding. The sequence ends with lower Miocene metacalcarenites with macroforaminifers followed by sandstones containing Numidian-type rounded quartz grains (PATACCA *et alii*, 1992a).

Selected references: BOUSQUET & DUBOIS, 1967; BOUSQUET & GRANDJACQUET, 1969; BOUSQUET, 1971; AMODIO MORELLI *et alii*, 1976; DIETRICH *et alii*, 1976; CNR-PROGETTO FINALIZZATO GEODINAMICA, 1991; IANNACE *et alii*, 1995 (with references therein).

4.3.3. *Timpone Pallone Unit*

The Timpone Pallone Unit crops out in a tectonic window exposed along the southwestern slope of the Pollino Mountain below upper Triassic dolomites of the Alburno-Cervati Unit. The stratigraphic sequence consists of some hundred meters of upper Cretaceous shallow-water limestones showing the same characteristics as the coeval terms of the Alburno-Cervati sequence.

Selected reference: BOUSQUET, 1971.

4.3.4. *Monte Foraporta Unit*

The Monte Foraporta Unit has been recognized and described only in the Lagonegro-Lauria area where it is represented by some hundred meters of upper Triassic(?)-Jurassic anoxic basinal deposits tectonically sandwiched between the Alburno-Cervati and the Monti della Maddalena Units. The stratigraphic sequence consists of Rhaetian(?)-lower Liassic resedimented dolorudites and dolarenites followed by middle Liassic cherty limestones, upper Liassic ammonitic marls and finally middle Jurassic limestones. Because of the geometrical position of the Monte Foraporta Unit, BONI *et alii* (1974) hypothesized the existence a local euxinic basin between the Alburno-Cervati and the Monti della Maddalena depositional realms. However, the facies distribution of the Jurassic carbonate deposits surely referable to the Apenninic Platform does not support this palinspastic reconstruction. Presently, the paleogeographic pertinence of the Monte Foraporta Unit remains an open problem in the Southern Apennine geology.

Selected references: BONI *et alii*, 1974; DE ALFIERI *et alii*, 1986.

4.4. TECTONIC UNITS DERIVED FROM THE LAGONEGRO-MOLISE BASIN

The Lagonegro, Sannio and Molise nappes, the latter including the Frosolone, Agnone, Tufillo-Serra Palazzo and Daunia Units, are here considered derived from a single, wide basin located between the Apenninic Platform and the Apulia Platform. Northwards this deep-marine basin had to be replaced by a system of platforms and basinal tongues (see fig. 6).

The Lagonegro Units consist of two first-order thrust sheets known in the geological literature as the Lagonegro Unit I and the Lagonegro Unit II. The primary Miocene geometry of the Lagonegro II/Lagonegro I tectonic couple was drastically modified during Pliocene times by breaching processes that produced thick antiformal stacks in the Lagonegro Unit II, as well as complex imbricate structures at the base of the thrust system. Presently, the Lagonegro Units overlie the buried Apulia-carbonate duplex system and are tectonically covered by the Alburno-Cervati, Monti della Maddalena, Sicilide and North-Calabrian Units, as well as by the Sannio Unit. In agreement with CARBONE *et alii* (1988) and CARBONE & LENTINI (1990), we believe that the Sannio Unit represents the detached Cretaceous-Miocene portion of the Lagonegro sequence that underwent a compressional tectonic history completely independent from that of the Lagonegro Units.

A first-order open problem in the Campania-Lucania Apennine is represented by the occurrence of tectonic slices sandwiched between the Lagonegro Unit II and the

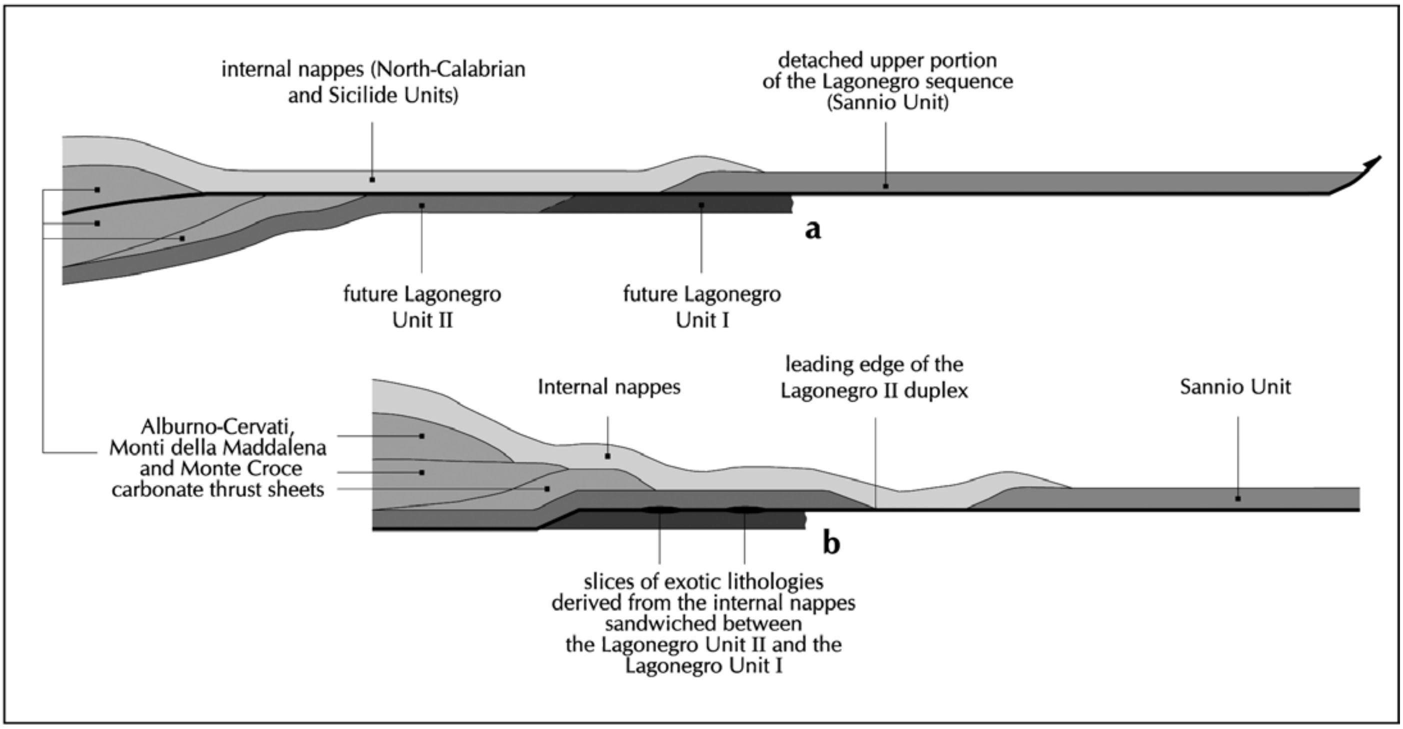


Fig. 7 - Possible mechanism explaining the occurrence of exotic rock materials tectonically sandwiched between the Lagonegro Unit I and the Lagonegro Unit II.
– Possibili meccanismi tettonici per spiegare la presenza di materiali rocciosi estranei tra l'Unità Lagonegrese I e l'Unità Lagonegrese II.

Lagonegro Unit I made up of exotic rock-materials. In the High Agri Valley area, the exotic lithologies consist of calcilutites, marls, siliciclastic calcarenites and subordinate sandstones referable to the Corleto Perticara Formation (Sicilide Unit). In the Lagonegro area, the tectonic slices include also metapelites and quartzites displaying close similarities with the most common lithologies of the Frido Unit. We have tried to explain the presence of exotic rock-materials between the two Lagonegro Units by reconstructing the following succession of tectonic events (see fig. 7):

– Tectonic transport of the internal nappes (North-Calabrian and Sicilide Units) in the Lagonegro domain and detachment of the upper portion of the Lagonegro sequence (future Sannio Unit, fig. 7a);

– Forward transport of the internal nappes on top of the Lagonegro Unit II while the latter moved over the future Lagonegro Unit I (fig. 7b). Relic slices of internal nappes had the possibility to be trapped in the shear zone at the base of the Lagonegro Unit II.

As regards the Molise nappes, there is a general agreement in the geological literature about the original position of the Frosolone basinal domain very close to the outer margin of the Matese Platform (CLERMONTÉ & PIRONON, 1979) and about the contiguity of the Frosolone and Agnone domains (CLERMONTÉ, 1977; PATACCA *et alii*, 1992b). The agreement extends to the original contiguity of the Tufillo-Serra Palazzo and Daunia basinal domains, but large disagreements exist on their original location. For example, MOSTARDINI & MERLINI (1986) assign to the Daunia domain a very external position, between the Inner Apulia Platform and the Outer Apulia Platform (Apulia Basin), while SGROSSO (1988b) relocates the same depositional domain in a basin (Inner Molise Basin) that occupied an internal position with respect to the Frosolone and Agnone domains (Intermediate Molise Basin). A detailed mapping of the Molise nappes in the Low Sangro Valley (IEZZI & SBRANA, 1991) has evidenced within the Agnone Unit a clear lateral transition from an Agnone-type stratigraphic sequence to a Tufillo-type succession. Consequently, in the palinspastic restoration of fig. 6 the Tufillo domain occupies a position adjacent to the Agnone domain. The facies of the Tufillo siliciclastic flysch deposits, more distal than the coeval terrigenous deposits of the Agnone sequence, agree with a more external position of the Tufillo domain.

4.4.1. Lagonegro Units

The Lagonegro Units are constituted of two major thrust sheets. The upper thrust sheet (Lagonegro Unit II) is constituted of middle Triassic to lower Cretaceous basinal marine deposits with abundant shallow-water-derived carbonate material. The lower thrust sheet (Lagonegro Unit I) is composed of upper Triassic-lower Cretaceous deep-water deposits displaying more distal characteristics than the coeval deposits of the Lagonegro Unit II.

In the upper thrust sheet (Lagonegro Unit II), the following intervals have been distinguished:

– Chaotic complex (Monte Facito Formation, middle Triassic, 700-800 meters) represented by gray, green and red silty shales and pebbly mudstones including huge slides of different lithologies, mostly represented by:

– massive algal limestone, locally draped by yellowish and pinkish hemipelagic limestones and marls rich in ammonites and pelagic pelecypods;

– yellowish silty marls rich in brachiopods and subordinate fine-grained gray sandstones showing well preserved ripple cross laminations;
– fine-grained red and green turbiditic quartzarenites;
– gray calcareous sandstones, calcirudites and oolite-bearing siliciclastic calcarenites with reworked fusulinids and other Permian-early Triassic forams;
– red radiolarian cherts;
– mafic pillow lavas.

The chaotic complex is stratigraphically overlain by a few meters of red pelagic clays and marls with *Daonella lommeli*.

– Close alternance of thin-bedded nodular calcilutites and red clays grading upwards into gray cherty limestones with shaly interbeds (Calcari con Selce Formation, Upper Triassic). A key horizon formed by thin volcaniclastic layers and associated vivid-green siliceous clays in the lower part of the formation represents a very useful key bed for stratigraphic correlations. The total thickness ranges from 400-450 meters in the northern areas (where the cherty limestones are strongly dolomitized) to about 200 meters in the southern areas (where dolomitization processes are usually absent). The uppermost portion of the Calcari con Selce Formation, regularly grading upward into the Scisti Silicei Formation, is characterized by the presence of dusky-red, green and black siliceous shales and by the sporadic occurrence of brown nodular cherts;
– Predominantly siliceous, radiolarian-rich deposits accumulated below the CCD (Scisti Silicei Formation, Rhaetian-Jurassic, 150-200 m), in which three intervals may be recognized:
– Well-bedded gray cherty limestones and dolomitic limestones with intercalations of greenish-gray and dark-gray to black siliceous shales (Rhaetian-?Toarcian);
– Variegated to prevalently red siliceous shales associated with calciturbidites and with centimetric red to green radiolarian cherts (lower-middle Jurassic);
– Thin-bedded red and green siliceous radiolarites with episodic intercalations of shelf-derived lime resediments (middle-upper Jurassic);
– Gray to dark-gray siliceous shales associated with well-bedded buff to off-white redeposited calcilutites and subordinate calcarenites rich in radiolarians (Galestri Formation, Neocomian-Aptian *p.p.*, 400 m).

In the Lagonegro Unit I the Monte Facito Formation is lacking. In addition, the few meters of pink to off-white condensed nodular limestones and marls rich in pelagic bivalves characterizing the lowermost portion of the Calcari con Selce Formation in the Lagonegro Unit II are laterally replaced in the Lagonegro I Unit by a thick package of dark-gray to dusky-red *Halobia*-bearing siliceous shales and subordinate thin-bedded gray cherty limestones (Sorgente Acero Member of the Calcari con Selce Formation). In subsurface sections, this unit a thickness of several hundred meters. The last important difference between the Lagonegro II and the Lagonegro I Units is made by the absence of dolomitization in the Calcari con Selce Formation of the Lagonegro Unit I and by the more distal depositional characteristics of the Scisti Silicei and Galestri Formations of the Lagonegro Unit I.

Selected references: Amodeo *et alii*, 1993, 1994; Brönniman *et alii*, 1971; Ciarapica *et alii*, 1990a,b,c; De Capoa Bonardi, 1969, 1984; De Castro, 1962a; De Wever & Miconnet, 1985; Donzelli & Crescenti, 1970; Luperto, 1962, 1965; Luperto Sinni, 1966; Marsella *et alii*, 1993; Miconnet, 1983, 1988; Mietto & Panzanelli Fratoni, 1990; Mietto *et alii*, 1991; Pasini, 1982; Ricchetti, 1961; Scandone, 1963, 1967, 1972; Wood, 1981.

4.4.2. Sannio Unit

The Sannio Unit extends in the Southern Apennines from the Alto Molise region (Trigno Valley) to southern Basilicata (Nocara Ridge). Complete sections are very well exposed at Monte Moschiaturo east of Matese (northern area) and in the Stigliano-Campomaggiore region (southern area). The stratigraphic sequence, reaching a total thickness of about 1500 m, is represented by following intervals:

– Varicolored shales with intercalations of fine-grained silicified calciturbidites, radiolarian cherts and subordinate black shales deposited in a deep basin beneath the CCD («Argille Varicolori» *p.p. Auct.*, 150-200 m). An Albian age is documented in the lower portion of the interval; Cenomanian and Turonian ages are documented in the upper portion;
– More or less silicified, fine-grained calciturbidites and subordinate resedimented calcirudites alternating with red and gray-greenish siliceous shales (Monte Coppe Formation, upper Cretaceous, 70-80 m);
– Lime debrites and calciturbidites with intercalations of red, green and yellowish marls and clays (Coste Chiavarine, Monte Calvello, Monaci and Morcone *p.p.* formations of Pescatore, 1965b; Monte Coppe *p.p.*, Monte la Defenza and Vagliardara-Crocelle-Cardeto *p.p.* formations of Pagliaro, 1998, Paleocene-lower Oligocene, 200-300 m);
– Carbonate ramp deposits represented by calcarenites and calcilutites grading upward into gray-greenish marls rich in sponge spicules, containing thin volcaniclastic beds (Morcone *p.p.* and Monte Moschiaturo formations of Pescatore, 1965b; upper portion of the Vagliardara-Crocelle-Cardeta Formation of Pagliaro, 1998, Aquitanian-Burdigalian, 80-100 m). The contact between this interval and the underlying one corresponds to an important disconformity with a depositional gap covering the entire late Oligocene;
– Numidian sandstones (Stigliano sandstones of the geological literature, Upper Burdigalian, more than 500 metres);
– Marls and subordinate siliciclastic calciturbidites grading upward into arkosic-lithic sandstones (Serra Cortina Formation, Langhian-Serravallian, a few hundred meters) locally including (e.g. Colobraro area) blocks of Mesozoic platform limestones.

In the northern part of the study area, the Sannio Unit tectonically overlies the Matese, Frosolone, Agnone and Tufillo-Serra Palazzo Units and is unconformably covered by the San Bartolomeo Formation. In Basilicata, the Sannio Unit overlies the Tufillo-Serra Palazzo Unit and is in turn tectonically covered by the Sicilide Unit.

The Sannio Nappe has been interpreted by Carbone *et alii* (1988) and Carbone & Lentini (1990) as the detached upper portion of the Lagonegro sequence. The attribution of the Sannio sequence to the Lagonegro Basin is supported by the following facts:

– The uppermost portion of the Galestri Formation in the Lagonegro Units reaches the Aptian while an Albian age is documented in the lowermost portion of the Argille Varicolori Formation of the Sannio Unit. Both the Galestri and Argille Varicolori Formations were deposited in a deep basin below the CCD in the absence of any siliciclastic supply;

– At the top of the Galestri Formation, fine-grained calciturbidites and radiolarian cherts identical to those occurring in the lowermost portion of the Sannio sequence are locally preserved (e.g. between Pergola and Brienza). These lithotypes are very different from the coeval deposits of the Sicilide sequence which systematically contain siliciclastic material;

– The incorporation of the Sannio domain in the foredeep basin (Serra Cortina siliciclastic flysch deposits) took place around the Langhian-Serravallian boundary, in agreement with an original position of the basin east of the Alburno-Cervati domain, which was reached by the flexural subsidence during late Burdigalian-Langhian times (Civita siliciclastic flysch deposits). In addition, the occurrence of shallow-water carbonate blocks in the Serra Cortina sandstones agrees with a possible derivation from the Alburno-Cervati or Monti della Maddalena domains, which were reached by the compressional deformation during the Langhian or around the Langhian-Serravallian boundary;

– The absence of lithologies referable to the Sannio Unit in the allochthonous sheets overlying the Alburno-Cervati and Monti della Maddalena units agrees with an original location of the Sannio basinal domain east of the Apenninic Platform.

Field evidence that apparently conflicts with the provenance of the Sannio Unit from the Lagonegro Basin exists in Irpinia north of the Picentini-Marzano mountains where resedimented limestones and siliceous shales surely belonging to the Sannio sequence tectonically overlie the Castelvetere Formation (e.g. Cresta del Gallo near Teora) or younger (Messinian) thrust-sheet-top deposits (e.g. Nusco). This fact may be explained by admitting moderate backthrusts during middle and upper Miocene times when the Sannio sequence had already been detached from its original substratum.

Selected references: SELLI, 1962; MANFREDINI, 1963; PESCATORE, 1965b; CRESCENTI, 1966; BOENZI *et alii*, 1968; OGNIBEN, 1969; CENTAMORE *et alii*, 1970, 1971; SCANDONE, 1972; PIERI & RAPISARDI, 1973; ORTOLANI *et alii*, 1975; DAZZARO & RAPISARDI, 1984, 1987; CARBONE *et alii*, 1987, 1988; DAZZARO *et alii*, 1988a; CARBONE & LENTINI, 1990; PATACCA *et alii*, 1992a; MOLISSO *et alii*, 1994; GALLICCHIO *et alii*, 1996; PAGLIARO, 1998; PESCATORE *et alii*, 1996, 2000; DI NOCERA *et alii*, 2001; MATANO & DI NOCERA, 2001; BASSO *et alii*, 2002.

4.4.3. Frosolone and Agnone Units

The Frosolone and Agnone Units, widespread in the Alto Molise region, extend from the northern margin of Matese to the Low Sangro Valley (Pennadomo area). It is not yet clear whether the Frosolone and Agnone allochthonous sheets are separated by a major thrust surface or they represent second-order thrust sheets belonging to the same first-order tectonic unit as is the case of the Montenero Val Cocchiara Unit of DI BUCCI & SCROCCA (1997). No doubt exists about the original contiguity of the Frosolone and Agnone depositional domains, which is attested by the gradual transition of facies between stratigraphic sections surely belonging to the Frosolone thrust sheet and stratigraphic sections referable to the Agnone one.

Well exposed sections representative of the Frosolone sedimentary sequence exist in the Monte Patalecchia and Montagnola di Frosolone areas. Additional stratigraphic information on the lowest portion of the sequence is provided by the Frosolone 2 well. The following lithologic intervals may be distinguished:

– Gray crystalline dolomites and cherty dolomites attributed in the composite log of Frosolone 2 to the upper Triassic-Jurassic. The upper portion of this interval crops out near Carpinone and Pesche, as well as at Monte Patalecchia. These carbonates, considered in the official geological map 1:100.000 as upper Triassic tidal-flat dolomites, consist in reality of dolomitized breccias containing unsorted blocks of Triassic and Jurassic shallow-water carbonates;

– Resedimented breccias grading upwards into cherty calciturbidites with intercalations of siliceous shales (100-150 m). In the upper part, the graded calcarenites contain benthic forams (*Orbitolina*) indicative of a Lower Cretaceous age;

– Silicified fine-grained calciturbidites and subordinate calcirudites with intercalations of shales (50-60 m), grading upward into Scaglia-like limestones containing variable amounts of shelf-derived resediments (Upper Cretaceous-Eocene, a few hundred meters);

– Gray, greenish and reddish marls with intercalations of calciturbidites (Oligocene-Lower Miocene, 40-50 m);

– Calcareous breccias and subordinate calcarenites (Langhian, a few meters), followed by hemipelagic limestones and marls rich in planktic forams (Serravallian-Tortonian, 150-200 m);

– Clays and silty clays with rare intercalations of fine-grained sandstones (upper Tortonian, 200-250 m) overlain by coarse-grained sandstones (Sant'Elena Sandstone, also called Frosolone Sandstone in the geological literature, uppermost Tortonian?-lower Messinian, several hundred meters).

It is interesting to remark that the Sant'Elena Sandstone, a typical siliciclastic flysch deposit conformably overlying the Tortonian fine-grained terrigenous deposits of the Frosolone sequence is laterally replaced by a thrust-sheet-top deposit unconformably overlying the Mesozoic carbonates of the Simbruini-Matese Unit. In the Matese and Monte Maggiore regions these unconformable terrigenous deposits are known in the geological literature as the San Massimo Sandstone or the Caiazzo Sandstone.

The contact between the Matese and the Frosolone Units is represented by a high-angle reverse fault well exposed in the Torrente Lorda area (see CLERMONTÉ & PIRONON, 1979; SCROCCA *et alii*, 1995; SCROCCA, 1996; DE CORSA *et alii*, 1998). Sedimentary features recognized along the northern slope of Matese have resulted crucial for understanding the tectonic evolution of the region. In the footwall of the high-angle fault bordering Matese, resedimented breccias (Cantalupo breccias in PATACCA *et alii*, 1992b) containing blocks of Matese-derived carbonates (Cretaceous rudistid limestones, Miocene *Lithothamnium* limestones and *Orbulina* marls) stratigraphically overlie Tortonian hemipelagic deposits of the Frosolone sequence. Locally (e.g. Castellone area, see also CIAMPO *et alii*, 1983 and SGROSSO, 1978), the Cantalupo breccias lie with an unconformity surface directly on the Matese carbonates, testifying to a backstepping of the active reverse faults. The Cantalupo breccias are stratigraphically overlain by uppermost Tortonian clays, silty clays and very fine-grained sandstones (Castelpizzuto Flysch in AMORE *et alii*, 1988c). Along the road San Massimo-Roccamandolfi, finally, upper Tortonian condensed mudstones unconformably overlie the Mesozoic Matese carbonates the top of which is lined by an evident hard-ground surface. Both the Castelpizzuto Flysch and the Mesozoic Matese carbonates (the latter capped by the thin veneer of condensed mudstones) are stratigraphically covered by the coarse-grained San Massimo/Sant'Elena sandstones. The described stratigraphic contact indicates a de-activation of the Matese front in the short time interval ranging from the deposition of the Cantalupo breccias plus Castelpizzuto Flysch and the deposition of the San Massimo-Sant'Elena sandstones. The fine-grained terrigenous deposits of the Castelpizzuto Flysch overlying the Cantalupo breccias, together with the condensed mudstones onlapping the Matese carbonates, have been attributed to the latemost Tortonian (*A. primus* nannofossil zone). The overlying San Massimo Sandstones yielded planktic forams indicative of the earliest Messinian. Note that very different ages have been given by SGROSSO (1996, 1998) who has attributed the San Massimo-Sant'Elena sandstones to the late Messinian on the base of a questionable occurrence of Messinian evaporites in the Agnone flysch deposits (see discussion in PATACCA *et alii*, 1992b) and of non-univocal geochemical data collected in the Northern Matese area.

As concerns the Agnone Unit, the pre-flysch deposits differ from those of the Frosolone sequence in two principal aspects:

– Due to the up-section geometry of the basal detachment trajectory, the dolomitic lower portion of the Frosolone sequence is lacking;

– The Cretaceous-Paleogene calcareous resediments of the Frosolone sequence are laterally substituted, together with the bulk of the Scaglia-like calcilutites, by red and green shales and radiolarian cherts containing sporadic intercalations of calcilutites and graded calcarenites («Argille Varicolori» *p.p. Auct.*). This lateral variation of facies is quite gradual through the Alto Molise region, though the end-members at Montagnola di Frosolone (south) and in the Low Sangro Valley (north) look very different.

Some differences exist also in the siliciclastic flysch deposits of the Frosolone and Agnone sequences. The upper Tortonian clays and silty clays with subordinate intercalations of fine-grained sandstones present at the base of the Sant'Elena Sandstone in the Frosolone sequence are lacking in the Agnone sequence where they are replaced by a few meters of mudstones. The monotonous Sant'Elena Sandstone, in addition, is laterally substituted by the Agnone Flysch in which three members (Verrino, Poggio-Villanelle and Sente members) have been distinguished (PATACCA *et alii*, 1992b), the upper one (Sente Member) reaching the *Turborotalia multiloba* planktic foram Zone.

The Frosolone Unit is supposed to overlie quite internal structures of the buried Apulia-carbonate duplex system, but no well has reached the substrate. The Agnone Unit lies over the Gran Sasso-Genzana Unit that in turn tectonically covers buried structures of the Apulia-carbonate duplex system occupying an external position with respect to the Majella Unit, Both the Frosolone and Agnone Units are tectonically overlain by the Sannio Nappe.

Selected references: SIGNORINI, 1961; SIGNORINI & DEVOTO, 1962; PESCATORE, 1965a; CRESCENTI, 1967; CLERMONTÉ 1977; SGROSSO, 1978; CLERMONTÉ & PIRONON, 1979; CIAMPO *et alii*, 1983; AMORE *et alii*, 1988c; CIVITELLI & CORDA, 1988; SGROSSO *et alii*, 1988; WHITEMAN, 1988; PATACCA *et alii*, 1990, 1992b; AMORE, 1992; DI BUCCI, 1993, 1995; SCROCCA *et alii*, 1995; SCROCCA, 1996; DI BUCCI & SCROCCA, 1997; DI LUZIO *et alii*, 1999; SCROCCA & TOZZI, 1999; ANTONUCCI *et alii*, 2000.

4.4.4. Tufillo-Serra Palazzo and Daunia Units

The Tufillo-Serra Palazzo and Daunia units crop out along the outer margin of the Apennines from Abruzzi to Basilicata.

A type-section of the Tufillo-Serra Palazzo Unit consists of the following intervals:

– Varicolored shales with subordinate intercalations of calciturbidites («Argille Varicolori» *p.p. Auct.*, Paleogene-lower Miocene, a few hundred meters);

– Hemipelagic marls and Numidian sandstones (upper Burdigalian). The thickness of the sandstones ranges from 300-400 meters in the south (Basilicata) to a few meters in the north (Abruzzi);

– Calciturbidites and hemipelagic foraminiferal limestones with thick intercalations of calcareous sandstones. The ratio of the carbonate material versus the siliciclastic detritus decreases from Abruzzi (Tufillo Formation in SELLI, 1962) to Basilicata (Serra Palazzo Formation in SELLI, 1962). The age of this interval is Langhian-Tortonian. The thickness exceeds 500 meters. Huge olistoliths of platform-derived Cretaceous limestones are known in the Tricarico area (LOJACONO & SBARRA, 1991b);

– Gray clays and silty clays with intercalations of fine-grained siliciclastic turbidites (Olmi Formation, uppermost Tortonian?-lower Messinian, some hundred meters).

The stratigraphic sequence of the Daunia Unit differs from the Serra Palazzo one in the following aspects:

– Minor content in Numidian sandstones, the total thickness of which does not exceed a few meters, also in the southern outcrops;

– Absence of sandstones in the post-Numidian interval basically constituted of hemipelagic foraminiferal limestones. The latter are associated, mostly in the lower part of the interval, with coarse-grained calciturbidites rich in platform-derived clasts;

– More distal characteristics of the uppermost Tortonian?-Messinian fine-grained siliciclastic deposits (Treste Formation).

In the Molise region, the Daunia Unit is unconformably overlain by Messinian evaporites. This unconformity indicates that the first compressional deformation of the Tufillo-Daunia depositional domain took place, at least in the northern part of the study area, during Messinian times before the salinity crisis.

In Basilicata, the Tufillo-Serra Palazzo Unit tectonically overlies the Daunia Unit and no gradual transition between the two sequences has been observed. In

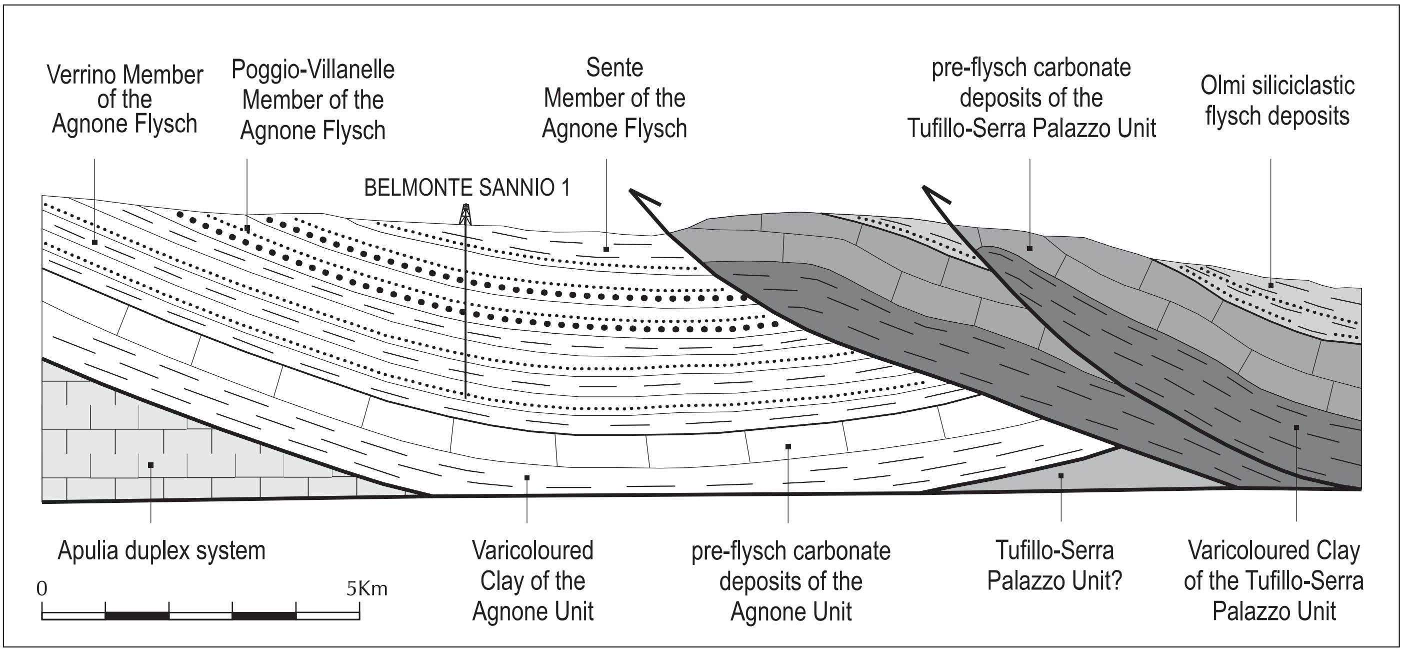


Fig. 8 - Schematic cross section showing the geometrical relationships between the Agnone and Tufillo-Serra Palazzo Units in the Castiglione Messer Marino-Schiavi d'Abruzzo area (Low Sangro Valley).
– *Sezione schematica mostrante rapporti geometrici tra l'Unità Agnone e l'Unità Tufillo-Serra Palazzo nell'area di Castiglione Messer Marino-Schiavi d'Abruzzo area (bassa Valle del Sangro).*

Molise, on the contrary, the Serra Palazzo and Daunia Units form an imbricate fan in which a gradual transition from the typical Tufillo-Serra Palazzo lithofacies to the Daunia ones is recognizable moving across the different thrust sheets. Consequently, the boundary between the two units is not so objectively defined as in Basilicata.

The Tufillo-Serra Palazzo and the Daunia Units lie over different thrust sheets of the Apulia Platform. The Tufillo-Serra Palazzo Unit, in turn, is tectonically overlain by the Sannio Nappe.

In the Low Sangro Valley-Schiavi d'Abruzzo area, the contact between the Tufillo-Serra Palazzo Unit and the Agnone Unit is represented by a backthrust structure featured by an eastward-dipping high-angle fault. The footwall of the fault is occupied by the siliciclastic flysch deposits of the Agnone Unit while the hangingwall block is formed by the Miocene carbonates of the Tufillo-Serra Palazzo Unit. Several good-quality seismic lines allow the reconstruction of the subsurface geometry, with the backthrust fault surface cutting across up-section the Agnone sedimentary sequence (fig. 8). The upsection cutoff geometry in the footwall of the thrust makes unrealistic a provenance of the Tufillo-Serra Palazzo and Daunia units from a realm located west of the Agnone depositional realm, as proposed by SGROSSO (1998). Alternative reconstructions according to which the Daunia depositional domain coincided with an Apulia Basin separating an «Inner Apulia Platform» from an «Outer Apulia Platform» (MOSTARDINI & MERLINI, 1986) conflicts with the geometric position of the Tufillo-Serra Palazzo Unit above quite internal units of the Apulia Platform, with the latemost Tortonian?-early Messinian age of the siliciclastic deposits of the Tufillo-Serra Palazzo and Daunia sequences and with the Messinian age of the first compressional deformation in the Daunia Unit testified by the unconformably overlying evaporites. A palinspastic restoration in which the Tufillo-Serra Palazzo and Daunia realms occupied the external portion of the Molise Basin entirely fits the available structural and stratigraphic information. This relocation gives also a logical explanation to the gradual transition of facies between the Miocene carbonate deposits of the Agnone sequence and the coeval deposits of the Tufillo-Serra Palazzo sequence observed in the Bomba-Pennadomo area (IEZZI & SBRANA, 1991), as well as to the occurrence of platform-derived (Apulia-derived) olistoliths in the Serra Palazzo Unit in Basilicata (LOJACONO & SBARRA, 1991b). The relocation of the Tufillo-Serra Palazzo and Daunia depositional realms in the Molise basin justifies the term «Molise nappes» introduced by SELLI, 1962 and applied by us to the Frosolone, Agnone, Tufillo-Serra Palazzo and Daunia Units.

Selected references: SELLI, 1962; CROSTELLA & VEZZANI, 1964; WEZEL, 1966; BOENZI *et alii*, 1968; CENTAMORE & VALLETTA, 1969; CROSTELLA & STROCCHI, 1969; CENTAMORE *et alii*, 1970, 1971; PALMENTOLA, 1970; PIERI & WALSH, 1973; RAPISARDI & WALSH, 1978; DAZZARO & RAPISARDI, 1984, 1987; DI NOCERA & TORRE, 1987; DAZZARO *et alii*, 1988a; MAIORANO, 1988; SANTO & SENATORE, 1988; SENATORE, 1988; RUSSO & SENATORE, 1989; LOJACONO & SBARRA, 1991a,b; PATACCA *et alii*, 1992a,b; SBARRA, 1993, 1994; BOIANO *et alii*, 1994; CRITELLI & LE PERA, 1995b; GALLICCHIO & MAIORANO, 1999; MATANO & DI NOCERA, 2001; BASSO *et alii*, 2002.

4.5. TECTONIC UNITS DERIVED FROM THE SIMBRUINI-MATESE PLATFORM

In the enclosed geological-structural map (plate 1), an undifferentiated Simbruini-Matese Unit, mostly composed of shallow-water carbonates, extends from the Simbruini-Ernici Mountains to Matese including the Eastern

Ausoni and Venafro mountains as well as the Monte Maggiore and Taburno-Camposauro massifs. In reality, this undifferentiated carbonate unit in reality consists of several thrust sheets affected by an important telescoping shortening as suggested by the distribution of the Mesozoic facies. The maximum structural complexity is reached in the Matese area where SGROSSO (1986, 1988) has attributed to two different carbonate platforms, separated by a basinal realm, the slope deposits of Western Matese and the shelf-lagoon/platform-edge deposits of Eastern Matese (see fig. 5). The considerable shortening postulated by this author was mainly based on the assumption that the two paleogeographic domains were incorporated in the foredeep basin in different times (Eastern Matese in the early Tortonian, see CIAMPO *et alii*, 1987 and Western Matese in the early Messinian, see AMORE *et alii*, 1988c). In reality, the Eastern Matese paleogeographic domain was incorporated in the foredeep basin during late Tortonian times (*Gd. obliquus extremus* foraminiferal zone, see PATACCA *et alii*, 1990, 1992b), not long before the Western Matese too was reached by the flexural subsidence (latemost Tortonian, *Amaurolithus primus* nannofossil zone). Consequently, we have considered the Western Matese and Eastern Matese deposits as derived from different areas of the same carbonate platform, though we do not exclude the existence of two distinct tectonic units separated by an important thrust as it is the case of the Alburno-Cervati and Monti della Maddalena Units both derived from the Apenninic Platform.

4.5.1. Simbruini-Matese Unit

The stratigraphic sequence of the Simbruini-Matese Unit consists of 2500-3000 meters of Triassic-Cretaceous shallow-platform carbonates disconformably overlain by Miocene inner-ramp shallow-water limestones grading upwards to outer-ramp hemipelagic marls and finally into siliciclastic flysch deposits. The Mesozoic facies are mostly indicative of tidal-flat and platform environments. Upper Cretaceous platform-edge facies are present in Eastern Matese. Upper Cretaceous-Paleogene slope deposits are widely represented in Western Matese and in the Venafro mountains. The geometrical relationships between the platform-interior/platform-edge carbonate deposits of Eastern Matese and the slope deposits of Western Matese have not been fully clarified as yet, so that we do not know whether the facies representative of the entire lateral transition original are still preserved or the primary depositional setting has been modified by the tectonic shortening.

A composite type-section representative of the bulk of the Simbruini-Matese Unit is described by the following intervals:

– White stromatolitic dolomites (Norian, 500-600 m) followed by limestones and dolomitic limestones with large megalodonts (Rhaetian, 200-300 m);

– Subtidal to intertidal limestones and subordinate dolomitic limestones (Jurassic-Upper Cretaceous, about 1500-1800 m). Bauxite deposits and widespread paleokarst features indicate important episodes of emersion during Cretaceous times (RUBERTI, 1992);

– Sporadic Paleocene and Eocene limestones (a few tens of meters);

– Disconformable *Lithothamnium* limestones (Cusano Formation, Burdigalian *p.p.*-Serravallian, a few tens of meters), indicative of a shallow ramp, grading upward into deep-ramp limestones and marls rich in *Orbulina universa* and other planktic forams (Longano Formation, Serravallian-upper Tortonian, a few tens of meters). The contact between the Cusano and Longano Formations is usually marked by an evident hard ground;

– Fine-grained immature sandstones and marls (Pietraroja Formation, upper Tortonian, 500-600 m) overlain by mudstones and subordinate channelized sandstones with olistostromes and slides of Sannio-derived materials (Torbido Formation, upper Tortonian, around 150 m). The occurrence of the exotic materials proves that the Sannio Unit, already affected by compressional deformation, formed in late Tortonian times the active margin of the mountain chain facing a foredeep basin floored by the flexured Matese Platform.

In Western Matese and in the Venafro mountains, Cretaceous-Paleogene slope sequences are widespread, characterized by resedimented calcareous breccias and calciturbidites with intraformational truncation surfaces evidencing repeated erosional gaps. These slope to proximal-basin deposits are stratigraphically overlain by hemipelagic limestones and marls representing the basinal equivalent of the Cusano and Longano formations of Eastern Matese.

The Simbruini-Matese Unit tectonically overlies the W. Marsica-Meta Unit (Valroveto area) in is in turn overlain by the Alburno-Cervati Unit along its southwestern margin and by the Sannio Unit along the eastern margin. The contact between the Simbruini-Matese Unit and the Alburno-Cervati carbonates is usually poorly exposed but has been well identified in the Caserta mountains (PESCATORE & SGROSSO, 1973). The contact with the Sannio Unit, on the contrary, is very well exposed all along the eastern margin of Matese, from Cerreto Sannita to Guardiaregia. In the Longano-Roccamandolfi area, the Simbruini-Matese Unit is separated from the Frosolone Unit by a high-angle thrust fault sealed by the lower Messinian San Massimo-Sant'Elena sandstones.

After from MOSTARDINI & MERLINI (1986), the Alburno-Cervati and the Simbruini-Matese Units have been often grouped into an undifferentiated tectonic unit called Western Platform of Apenninic Platform However, the attribution of the Alburno-Cervati and Matese carbonates to the same paleogeographic domain and to the same tectonic unit is contradicted by the following major geological evidence:

– The Alburno-Cervati depositional domain was incorporated in the Apennine foredeep basin around the Burdigalian/Langhian boundary whilst the Matese domain underwent flexural subsidence in late Tortonian times. This time difference exceeding 8 million years attests the more external position of the Matese realm;

– The Alburno-Cervati depositional domain was probably incorporated in the thrust belt around the Langhian/Serravallian boundary. In any case it is certain that the Alburno-Cervati and Monti della Maddalena Units were already deformed in Serravallian times when they were unconformably overlain by the Castelvetere sandstones. The Matese domain, on the contrary, underwent the first compressional deformation in latemost Tortonian times. This is still a significant time difference, which exceeds 5 million years.

An important open problem is whether in the north a tongue of the Lagonegro Basin separated the Apenninic and the Simbruini-Matese Platforms or the latter merged into a single paleogeographic domain. The existence of two platforms separated by the northern continuation of the Lagonegro Basin is supported by the following facts:

– From the Caserta to the Partenio mountains, the platform-interior Mesozoic carbonates of the Alburno-Cervati Unit are bordered by platform-edge and slope Jurassic to Upper Cretaceous deposits that directly face coeval shelf-lagoon carbonates belonging to the Simbruini-Matese Unit (D'ARGENIO & SCANDONE, 1969; SGROSSO, 1995). Unless improbable strike-slip faults parallel to the elongation of the mountain chain, the facies distribution suggests the existence of a basinal domain between the Alburno-Cervati and the Matese depositional realms, presently hidden in the subsurface;

– The Alburno-Cervati and Monti della Maddalena Units lie over the Lagonegro Units whilst the Simbruini-Matese Unit is overlain by the Sannio Unit which is considered derived from the Lagonegro Basin;

– In the Monte Taburno 1 well, located near Castelpoto a few kilometers ESE of Benevento, a section of limestone and shales referable to the Galestri Formation was drilled between 730 and 1992 meters. Seismic lines calibrated on the borehole show that these deposits surely derived from the Lagonegro Basin lie over the Camposauro carbonates, which belong to the Simbruini-Matese Unit.

At the state of the art, we do not know how far the Matese Platform extended southwards before being replaced by a deeper-water basinal domain.

Selected references: OGNIBEN, 1956; SELLI, 1957; SARTONI & CRESCENTI, 1961; CATENACCI *et alii*, 1962; PESCATORE & VALLARIO, 1963; SGROSSO, 1964; PESCATORE, 1965b; CRESCENTI, 1966; D'ARGENIO, 1967, 1974; SGROSSO & TORRE, 1968; IETTO, 1969; CRESCENTI & VIGHI, 1970; DEVOTO, 1970; PAROTTO, 1971; D'ARGENIO *et alii*, 1972, 1975; IPPOLITO *et alii*, 1975; CLERMONTÉ & PIRONON, 1979; ACCORDI *et alii*, 1982; CIAMPO *et alii*, 1983; DE CASTRO, 1987; AMORE *et alii*, 1988c; COMPAGNONI *et alii*, 1990; PATACCA *et alii*, 1990; 1992b; RUBERTI, 1992, 1997; CARANNANTE *et alii*, 1993, 1996; BUONOCUNTO *et alii*, 1994; LONGO *et alii*, 1994; SCROCCA *et alii*, 1995; ACCORDI & PALLINI, 1996; SCROCCA, 1996; DE CORSA *et alii*, 1998.

4.6. TECTONIC UNITS DERIVED FROM THE WESTERN MARSICA PLATFORM

We have considered the W. Marsica-Meta Unit as the only tectonic unit derived from the Western Marsica Platform, in spite of the occurrence of important thrust sheets in the type area (see e.g. ANGELUCCI & PRATURLON, 1968). This choice is principally based on the internal coherency of the facies of the Mesozoic deposits that do not suggest important elisions by tectonic shortening, and on the age of the siliciclastic flysch deposits which is lower Messinian over the whole region. The boundaries between the W. Marsica-Meta Unit and the Gran Sasso-Genzana Unit mostly derive from VEZZANI & GHISETTI (1988).

4.6.1. W. Marsica-Meta Unit

The stratigraphic sequence of the W. Marsica-Meta Unit is represented by upper Triassic-upper Cretaceous shallow-water carbonates experiencing important episodes of subaerial exposure during Albian and Aptian times. The shallow-water carbonates, forming the bulk of the unit, grade southwards (Mainarde-Meta region) into slope and proximal-basin carbonate deposits (see facies distribution in ACCORDI *et alii*, 1988). Both shallow-water and deeper-water sequences end with upper Miocene carbonates upwards followed by siliciclastic flysch deposits. The lithologic characteristics of the carbonate deposits in the Western Marsica and Meta areas display close similarities with the type-sequences of Eastern Matese and Western Matese, respectively. Nevertheless, important differences concern the age of the siliciclastic flysch deposits and the age of the first compressional deformation. In the Western Marsica realm, foreland hemipelagic sedimentation persisted until the early Messinian (see COSENTINO *et alii*, 1997 and references therein) before turning into a terrigenous sedimentation. The Matese Unit, on the contrary, in the same time had already experienced incorporation in the Apennine thrust belt. Lower Messinian siliciclastic flysch deposits coeval with the siliciclastic flysch deposits of the W. Marsica-Meta Unit are developed in the Frosolone and Agnone Units. The occurrence of coeval siliciclastic flysch deposits logically implies a common foredeep basin. The latter had to be floored in the north by the Marsica Platform and in the south by the Molise Basin. In the Fucino area, upper Messinian («Lago-Mare») thrust-sheet-top deposits unconformably overlying deformed and eroded Cretaceous limestones (Le Vicenne conglomerates, COLACICCHI *et alii*, 1967) date the incorporation of the Marsica-Meta Unit in the Apennine thrust belt.

Selected references: MANFREDINI, 1963, 1965; PESCATORE, 1963, 1965; COLACICCHI & PRATURLON, 1965a,b; PARADISI & SIRNA, 1965; COLACICCHI, 1966; ACCORDI, 1966; CRESCENTI, 1969a,b; CRESCENTI *et alii*, 1969; NIJMAN, 1971; PAROTTO, 1971; PAROTTO & PRATURLON, 1975; PRATURLON & SIRNA, 1976; CHIOCCHINI & MANCINELLI, 1977; CARBONE, 1984; D'ANDREA & URGERA, 1986; ACCORDI *et alii*, 1988; CIARAPICA, 1990; DAMIANI *et alii*, 1992; PATACCA *et alii*, 1992b; MICCADEI, 1993; CHIOCCHINI *et alii*, 1994; CIPOLLARI, 1995; CIPOLLARI & COSENTINO, 1995; CIPOLLARI *et alii*, 1995; COSENTINO *et alii*, 1997; MICCADEI *et alii*, 1998; MILLI & MOSCATELLI, 2000; PIACENTINI, 2000.

4.7. TECTONIC UNITS DERIVED FROM THE GRAN SASSO-GENZANA PLUS MONTAGNA DEI FIORI BASINAL REALMS AND RELATED MARGINAL AREAS

We have distinguished in the geological-structural map of plate 1 only two major tectonic units, neglecting the numerous complex second-order thrust sheets documented in the area (see e.g. GHISETTI & VEZZANI, 1986a,b; CALAMITA *et alii*, 2002).

4.7.1. Gran Sasso-Genzana Unit

The Gran Sasso Unit, together with the underlying Montagna dei Fiori Unit, tectonically overlies the Queglia and the Morrone-Porrara Units. It is in turn tectonically covered by the W. Marsica-Meta, Simbruini-Matese and Molise Units.

In the type area, the stratigraphic sequence is represented by upper Triassic- lower Liassic shallow-water carbonates overlain by basinal deposits containing a variable amount of platform-derived resediments. The latter are conformably covered by lower Messinian siliciclastic flysch deposits. The pre-flysch basinal succession, displaying close similarities with the well-known Umbria-

Marche one, is represented by middle Liassic cherty limestones (Corniola Formation, 400-500 m) followed by ammonite-bearing marls (known in the Gran Sasso area as the Verde Ammonitico Formation) which are in turn overlain by hemipelagic limestones and marly limestones (upper Liassic-Digger, some tens of meters). The upper Jurassic-lower Cretaceous (Barremian) portion of the sequence is characterized in the whole basinal area by massive coarse-grained calcirudites overlain by the cherty limestones of the Maiolica Formation. Along the margins of the basin, these lithologies are laterally replaced by coral-hydrozoan reefs and subordinate high-energy bioclastic shoals (Terratta Formation, several hundreds of meters). After an episode of sediment starvation recorded in the northernmost part of the study area by siliceous green marls with subordinate fine-grained calciturbidites (Fucoid Marl), the deposition in the basinal domain is recorded by an essentially continuous succession of hemipelagic calcilutites containing variable amounts of coarse-grained resediments derived from the platform margins (Scaglia Formation). An important episode of downslope displacement of skeletal material and carbonate lithoclasts characterizes the late Albian-late Cenomanian portion of the stratigraphic sequence. Channelized bioclastic deposits on top of the pelagic calcilutites testify to a progradation of the basin-floor fan during the Maastrichtian. The Tertiary portion of the northernmost sections of the Gran Sasso-Genzana Unit is characterized by hemipelagic sequences more or less continuous from the Paleocene-Eocene (Scaglia Formation) to the early Messinian (Pteropod Marl) through the Oligocene and Miocene (Scaglia Cinerea, Bisciaro and Schlier Formations). In the marginal areas of the Gran Sasso-Genzana Unit, on the contrary, the huge volumes of carbonate material exported from the platform margins to the basin, combined with a decrease in the subsidence rate, caused a progressive progradation of the depositional slope apron and the establishment of a distally-steepened ramp.

A lateral transition between the Gran Sasso Genzana Basin and the northwestern margin of the Apulia Platform is preserved in a series of carbonate structures emerging from the lower Messinian siliciclastic flysch deposits south of Scontrone, between the High Sangro Valley and the High Volturno Valley. The preservation of the original depositional system has been possible thanks to the direction of the lateral transition parallel to the strike of the regional tectonic features which allowed the incorporation of different facies in the same thrust sheet without obliterating the stratal architecture. The margin of the Apulia Platform in this area is represented by Neocomian platform-interior carbonates (Morrone di Pacentro Formation) basinward replaced by coral-bearing platform-edge limestones (upper portion of the Terratta Formation), both disconformably overlain by the Tortonian-lower Messinian *Lithothamnium* Limestone which is in turn stratigraphically covered by siliciclastic flysch deposits stuffed with Molise-derived olistostromes and slides (Castelnuovo al Volturno Flysch). Resedimented gypsarenites and gypsrudited have been locally recognized in the Castelnuovo al Volturno Flysch. Gypsum beds are also present near Anversa degli Abruzzi, in terrigenous deposits at the top of the Montagna Grande sequence. In the early nineties, the occurrence of Messinian evaporites in Eastern Marsica was considered an anomaly conflicting with the available stratigraphic data that suggested a palinspastic position of the Genzana Basin in a foreland area reache by flexural subsidence in the Tortonian, a long time before the Messinian salinity crisis. In order to find a solution to this problem, PATACCA *et alii* (1992b) suggested a more external paleogeographic pertinence of the Montagna Grande sequence whilst CORRADO *et alii* (1996) envisaged tectonic relationships between the Montagna Grande carbonates and more external gypsum-bearing terrigenous deposits. The two sequences would have been drown close by chance via strike slip motion along a lateral fault. Actually, the Montagna Grande carbonates conformably grade upwards to the gypsum-bearing deposits, but the occurrence of resedimented evaporites in the siliciclastic deposits of the Gran Sasso-Genzana sequence is lo longer an anomaly. Consequently, the Montagna Grande «problem» has ceased to be a problem.

Selected references: ZAMPARELLI, 1963, 1966; COLACICCHI & PRATURLON, 1965a,b; COLACICCHI, 1967; CRESCENTI *et alii*, 1969; ADAMOLI *et alii*, 1978, 1982, 1990; CHIOCCHINI & MANCINELLI, 1978; CHIOCCHINI *et alii*, 1980, 1994; GHISETTI & VEZZANI, 1986a,b; 1988, 1990, 1991, 1997; ACCORDI *et alii*, 1988; BIGOZZI, 1990, 1994; GHISETTI *et alii*, 1990; DE LA PIERRE & BRUZZONE, 1991; BIGOZZI *et alii*, 1992; D'ANDREA, 1988; AMORE *et alii*, 1989; D'ANDREA *et alii*, 1992; PATACCA *et alii*, 1990, 1992b; DE LA PIERRE, 1994; DE LA PIERRE & CLARI, 1994; GHISETTI *et alii*, 1994; BARCHI & BIGOZZI, 1995; MICCADEI *et alii*, 1998; VAN KONIJNEMBURG *et alii*, 1999; PIACENTINI, 2000; PACE *et alii*, 2001; CALAMITA *et alii*, 2002.

4.7.2. *Montagna dei Fiori Unit*

The Montagna dei Fiori Unit, lying in the footwall of the Gran Sasso-Genzana Unit, tectonically overlies the Queglia Unit. The Mesozoic-Tertiary pre-flysch deposits show the characters of the most typical Umbria-Marche sequences. The flysch deposits (Laga Flysch) are represented by about 3000 meters of turbiditic sandstones the base of which post-dates the FCO of *Tb. multiloba* and pre-dates the salinity crisis. The salinity crisis is recorded in the middle part of the sequence by a horizon of gypsarenites several meters thick constituting a useful key bed. Near the top of the sequence, a second key bed is represented by a well dated (upper Messinian, 5.5 Ma) volcaniclastic layer that has been recognized along the Adriatic side of the Apennines in different tectonic units widespread from Romagna to Southern Abruzzi. We will se in the next pages that this horizon, together with the evaporites of the salinity crisis allowed us to operate close correlations between the Messinian deposits of the Montagna dei Fiori, Queglia and Majella Units.

Selected references: KOOPMAN, 1954; GIROTTI & PAROTTO, 1969; GIANNINI *et alii*, 1970; BROGINI, 1973; MUTTI *et alii*, 1978; PALTRINIERI *et alii*, 1982; CANTALAMESSA *et alii*, 1986b; CHIOCCHINI *et alii*, 1986; INVERNIZZI & RIDOLFI, 1992; VALLONI *et alii*, 2002.

4.8. TECTONIC UNITS DERIVED FROM THE APULIA PLATFORM

We have included in this group the Morrone-Porrara, Queglia, Majella and Casoli-Bomba Units, as well as the Monte Alpi Unit exposed in a small tectonic window east of Lagonegro which represents in the Southern Apennines the only element of the buried Apulia-carbonate duplex system that reaches the surface. The Monte Alpi Unit, dubitatively correlated by us with the Morrone-Porrara Unit, should not be confused with the Monte Alpi oilfield domain of fig. 6, which has been correlated, with the Majella domain. The Casoli-Bomba Unit has a southern counterpart in the Tempa Rossa-Rotondella thrust system located north and east of the Sant'Arcangelo depression. The Tempa Rossa-Rotondella thrust system, never reaching the surface, has been object of extensive petroleum exploration.

4.8.1. Morrone-Porrara Unit

The Morrone-Porrara Unit lies tectonically overlies the Queglia Unit and, in its southern termination, the Majella Unit. Northwards, it disappears beneath the lateral ramp of the Gran Sasso tectonic arc.

The Morrone-Porrara Unit has derived, as the more external Majella Unit, from a N-S trending basin-and-platform system in which the transition between Jurassic-Cretaceous platform-interior carbonates (Morrone di Pacentro area) and coeval basinal deposits (Morrone di Popoli area) is still preserved. Both shallow-water and deeper-water deposits are disconformably overlain by Miocene deepening-upward homoclinal-ramp carbonates followed by siliciclastic flysch deposits. The onset of the siliciclastic sedimentation took place during the Messinian, but the exact age has still to be defined. During the Messinian, the foredeep basin shifted from the Gran Sasso-Genzana domain (early Messinian before the salinity crisis) to the Queglia domain (late Messinian after 5.5 Ma, established by the age of a widespread well dated volcaniclastic horizon). Since the Morrone-Porrara domain occupied an intermediate position between the Gran Sasso-Genzana and the Queglia domains, the age of its incorporation in the foredeep basin would better constrain the reconstruction of the kinematic evolution of the area. The lower chronological boundary is limited by the occurrence of *Tb. multiloba* in the pre-flysch deposits. In addition, gypsum-bearing mudstones are reported in the geological literature (see GHISETTI *et alii*, 1994; MICCADEI & PAROTTO, 1998) but the relationships between these restricted deposits and the terrigenous flysch deposits are not fully clarified. At the base of the terrigenous deposits a tuffite bed is present, but we do not know whether this layer is the 5.5 Ma volcaniclastic layer or is an older horizon as the volcaniclastic bed observed at the base of the evaporites in the Queglia sequence. The fossil content does not solve the problem since it is represented in the lower portion of the flysch deposits by a planktic foram association of the *Gt. conomiozea* Zone, *Tb. multiloba* Subzone and in the upper portion only by sparse ostracods (*Cyprideis*, locally associated with rare *Candona*), which are not indicative of a specific time interval.

The Morrone Unit is unconformably overlain by Pliocene thrust-sheet-top deposits referable (CIPOLLARI, personal communication) to the MNN 16a Zone which corresponds to the *Gt. puncticulata p.p.* and *Gt. crassaformis p.p.* foraminiferal Zones These Pliocene deposits would seal the contact between the carbonates of the Morrone Unit and the underlying terrigenous deposits of the Queglia Unit establishing an upper boundary for the incorporation of both units in the Apennine mountain chain.

Selected references: BENEO, 1939; RAFFI & FORTI, 1959; CRESCENTI, 1969a,b; CRESCENTI *et alii*, 1969; ACCORDI *et alii*, 1982; BELLATALLA *et alii*, 1992; CARBONI *et alii*, 1992; D'ANDREA *et alii*, 1992; GIOVANNELLI, 1992; PATACCA *et alii*, 1992b; MICCADEI & PAROTTO, 1998.

4.8.2. Queglia Unit

The Queglia Unit extends with a N-S trend for about one hundred kilometers in length and 20-25 kilometers in width in the footwall of the Montagna dei Fiori, Gran Sasso-Genzana and Morrone-Porrara Units. Between the Morrone and Majella mountains, the Queglia Unit occupies a narrow structural corridor that becomes progressively narrower until it disappears beneath the Morrone-Porrara carbonates that in the Campo di Giove area lie directly over the Majella carbonates. In correspondence to the Pescara Valley, a gently folded thrust flat separates Messinian terrigenous deposits of the Queglia Unit from underlying lower Pliocene terrigenous deposits of the Majella Unit. From the northernmost to the southernmost outcrops, the Queglia Unit is structurally characterized by a tight system of N-S oriented folds, mainly reverse folds.

The sedimentary sequence of the Queglia Unit is represented by about 150 meters of Cretaceous-Paleogene basinal carbonates disconformably overlain by some tens of meters of Miocene open-ramp limestones followed by Messinian hemipelagic marls and evaporites. The latter are overlain in turn by a few tens of meters of mudstones containing in the upper portion a tuffite bed (5.5 Ma volcaniclastic horizon) followed by a thick pile of uppermost Messinian-lower Pliocene siliciclastic flysch deposits.

In the current literature there is a large disagreement about the tectonic pertinence of the deposits by us attributed to the Queglia Unit. For example, the siliciclastic flysch deposits entirely referred to the Queglia Unit in plate 1 have been mapped by GHISETTI *et alii* (1994) partly as Teramo Flysch (upper Messinian-lower Pliocene, Farindola Unit), partly as Cellino Formation (upper Messinian-lower Pliocene, Villadegna-Cellino Unit), partly as upper Messinian-lower Pliocene deposits of the Majella sequence (Alanno-Majella Unit) and partly, finally, as the Forca di Penne-La Queglia Flysch (upper Messinian-?lower Pliocene) attributed to a system of imbricates developed between the Gran Sasso plus Morrone and the Majella mountains. The same deposits have been mapped by BIGI *et alii* (1995) partly as Cellino Formation plus Torrente Cigno Clay (upper Messinian-lower Pliocene, Cellino Unit) and partly as post-evaporite Member of the Laga Formation (upper Messinian, Laga-Monte La Queglia Unit). A thoroughly discussion on this subject is out of the aims of this paper. We wish to emphasize the important shift of the foredeep basin between the early and the late Messinian recorded by the more internal Laga Flysch (Montagna dei Fiori Unit) and the more external flysch deposits of the Queglia Unit. The onset of the siliciclastic flysch deposits in the Laga foredeep basin dates back to the early Messinian after the FCO of *Tb. multiloba* (see CANTALAMESSA *et alii*, 1986b) and before the salinity crisis. The uppermost portion of the sequence (post-salinity crisis) does not reach the upper Messinian «Lago-Mare» episode since sedimentation stopped immediately after the 5.5 Ma volcaniclastic horizon. The onset of the Queglia siliciclastic flysch deposits, on the contrary, took place in late Messinian times after the 5.5 Ma volcaniclastic event and foredeep sedimentation persisted until the early Pliocene (*Gt. margaritae-Gt. puncticulata* concurrent range Zone). A channelized limestone-pebble conglomerate roughly marking the Messinian-Pliocene boundary forms a useful key bed at about 800 meters above the base of the siliciclastic flysch deposits well recognizable also in the subsurface. The same conglomerate key bed is present in the Majella Unit where it marks the base of the siliciclastic flysch deposits. In terms of structural features, the Majella conglomerate conformably follows the broad, long wave-length anticline depicted by the underlying Mesozoic-Tertiary carbonates whilst the Queglia conglomerate appears everywhere involved in a tight system of thrusts and short wave-length folds, frequently reverse folds, implying a very shallow décollement surface. In addition, the thick sequence of upper Messinian siliciclastic turbidites underlying the Queglia conglomerate are laterally replaced in the Majella sequence by a few meters of upper Messinian hemipelagic marls which were deposited in a foreland setting. In conclusion, all the available stratigraphic and structural data concur to include all the upper Messinian-lower Pliocene siliciclastic deposits of the external Abruzzi region into a single major tectonic unit, the Queglia Unit, which is internally organized into a system of folds and thrusts showing a high degree of structural complexity.

Selected references: CASNEDI, 1983; BIGI & DI BUCCI, 1987; CENTAMORE *et alii*, 1992; PATACCA *et alii*, 1992b; BIGI, 1993; GHISETTI *et alii*, 1994; BIGI *et alii*, 1995; CASCELLA & LIRER, 1998; VALLONI *et alii*, 2002.

4.8.3. *Majella Unit*

The Majella Unit has been identified as yet only in Abruzzi and in Basilicata in the subsurface of the High Agri Valley (Monte Alpi oil field). In Abruzzi, the Majella Unit is tectonically overlain by the Queglia Unit in the north and by the Molise nappes (Agnone and Tufillo-Serra Palazzo Units) in the south. The buried carbonate thrust sheets attributed to the Majella Unit in Basilicata are tectonically overlain by the Lagonegro Units. The subsurface identification of the Majella Unit between southern Abruzzi and Basilicata is still an open problem.

In Central Majella, the transition from the northern termination of the shallow-water Apulia Platform and a deeper-water basin referable to an external area of the Marche depositional domain is spectacularly exposed. As in many other areas of the Central Apennines, the platform-basin system was created by a Jurassic extensional tectonics responsible for the drowning of large portions of a widespread upper Triassic-lower Liassic shallow-water carbonate domain. The platform sequence is represented by Cretaceous shallow-water carbonates showing two major episodes of subaerial exposure in Aptian and Albian times. The basinal deposits are represented by the Fucoid Marl and the Scaglia Formation, the latter containing variable amounts of platform-derived carbonate resediments. Both platform and basinal deposits are overlain by uppermost Cretaceous to upper Miocene carbonate-ramp deposits organized in a series of backstepping sequences displaying progressively more distal facies moving towards the north separated by disconformity surfaces. The Messinian salinity crisis has been recorded by a shallowing-upward sequence of evaporites and evaporitic limestones overlain by about 10 meters of upper Messinian hemipelagic marls containing in the lower portion the 5.5 Ma volcaniclastic horizon. The upper Messinian marls are overlain in turn by a channelized limestone-pebble conglomerate with at the base a veneer of open-marine clays of the S*phaeroidinellopsis* acme Zone. The conglomerate is followed by about 500 meters of lower Pliocene siliciclastic flysch deposits. Coeval siliciclastic flysch deposits stratigraphically overlie Messinian carbonates and evaporites at the top of the Monte Alpi oil-field reservoir. The upper Messinian marls of the Majella sequence obviously represent the foreland equivalent and the coeval sandy turbidites in the Queglia sequence deposited in the adjacent foredeep basin. The shift of the foredeep basin from the Queglia to the Majella depositional domains was obviously less dramatic than the basin shift from the Laga (Montagna dei Fiori) to the Queglia domains. The top of the siliciclastic flysch deposits, in fact, has the same age (early Pliocene, *Gt. margaritae-Gt. puncticulata* concurrent range Zone) in the Queglia and Majella sequences in spite of the different age of the base, and this fact indicates a depocenter shift within the same foredeep basin rather than the creation of a new flexural depression. In the case of the Montagna dei Fiori and Queglia Units, on the contrary, the age of the uppermost portion of the Laga Flysch is slightly older than the base of the flysch deposits in the Queglia Unit, and this fact implies a considerable retreat of the flexure hinge around 5.5 Ma.

Selected references: BALLY 1954; CATENACCI & CHIOCCHINI, 1967; CRESCENTI, 1969a,b; CRESCENTI *et alii*, 1969; DONZELLI, 1969; CATENACCI, 1974; ACCORDI *et alii*, 1982; CATENACCI *et alii*, 1982; ACCARIE, 1988; PIGNATTI, 1990, 1994; VECSEI, 1991, 1998; BELLATALLA, 1992; PATACCA *et alii*, 1992b; EBERLI *et alii*, 1993; GHISETTI *et alii*, 1994; SANDERS, 1994, 1996; MUSSAVIAN & VECSEI, 1995; BERNOULLI *et alii*, 1996; MUTTI *et alii*, 1996; LAMPERT *et alii*, 1997; VECSEI & SANDERS, 1997, 1999; DANESE, 1998, 1999; VECSEI *et alii*, 1998; CRESCENTI *et alii*, 2002; MORSILLI *et alii*, 2002.

4.8.4. *Casoli-Bomba Unit*

The Casoli-Bomba Unit is represented in the subsurface by a NNW-SSE/N-S trending popup-like structure bounded by Adriatic-dipping and Tyrrhenian-dipping high-angle thrusts. This structure, the top of which reaches the surface in the Low Aventino Valley, has been recognized in seismic lines from the eastern margin of Majella to the Alto Molise region and has been explored by several commercial wells. In the Aventino Valley, only the Pliocene portion is exposed, tectonically overlain by the Molise nappes. The southward continuation of the Casoli-Bomba Unit is still an open problem. In Basilicata, a counterpart of the Casoli-Bomba Unit is represented by the Tempa Rossa-Rotondella thrust system that occupies an external position with respect to the major Southern Apennine duplex system (see structural map at the top of the Apulia carbonates in NICOLAI & GAMBINI, *Structural architecture of the Adria platform-and-basin system*, in this volume). Both in the Casoli-Bomba and Tempa Rossa-Rotondella structures the drilled sequence consists of Mesozoic-Tertiary carbonates (usually shallow-water carbonates) and Messinian evaporites disconformably overlain by Pliocene siliciclastic deposits referable to the *Gt. puncticulata zone*.

Selected references: CRESCENTI, 1975; CASNEDI *et alii*, 1981; PATACCA *et alii*, 1992b; D'ANDREA *et alii*, 1993.

4.8.5. *Monte Alpi Unit*

The Monte Alpi Unit, exposed in the homonymous mountain, represents in the Southern Apennines the only emergence of the buried Apulia-carbonate duplex system, the allochthonous sheets being locally represented by the

North-Calabrian and Lagonegro Units. The stratigraphic sequence consists of upper Jurassic-lower Cretaceous platform-interior limestones disconformably overlain by upper Miocene ramp carbonates yielding in the upper portion *Tb. multiloba*. Both Mesozoic and Miocene carbonates are unconformably overlain by a terrigenous sequence made up of polygenic conglomerates, shales and subordinate siliciclastic calcarenites. The clasts of the conglomerate are representative of all the tectonic units present in the Southern Apennines, from the metamorphic internal units to the external Molise Units. The matrix of the conglomerates is characterized by the occurrence of very-well rounded polycyclic quarts grains associated with feldspars and rock fragments. No indicative fossils have been found in the terrigenous deposits. However, the close similarities between the matrix of the conglomerates and the sandstones overlying the Apulia carbonates in the Monte Alpi oil field suggest an early Pliocene age. If this age attribution is correct, the depositional domain of the Monte Alpi Unit (in which the unconformable terrigenous sequence has the meaning of a thrust-sheet-top deposit) had to occupy a position slightly internal with respect to the depositional domain of the Monte Alpi oil field (in which the turbiditic sandstone sequence has the meaning of a foredeep deposit). We have correlated the foredeep basin of the Monte Alpi oil field depositional domain with the coeval foredeep basin of the Majella domain. We have also dubitatively correlated the Monte Alpi Unit with the more internal Morrone-Porrara Unit taking into the consideration the fact that the Monte Alpi Unit was already part of the mountain chain when a foredeep basin developed in the Monte Alpi oil field depositional domain.

Selected references: SARTONI & CRESCENTI, 1961; GRANDJACQUET, 1963; ORTOLANI & TORRE, 1971; SGROSSO, 1988a; TADDEI & SIANO, 1992.

5. THE SOUTHERN APENNINE THRUST-SHEET-TOP DEPOSITS

The term «thrust-sheet-top deposit» has been often used in the current literature as a synonym for «piggyback-basin deposit». In this paper, the term thrust-sheet-top deposit refers to every kind of sedimentary unit unconformably overlying a thrust sheets. We prefer to use the term piggyback-basin deposit dealing with a thrust-sheet-top deposit that formed on top of an active thrust sheet, i.e. in a basin located at the rear of a growing ridge (see original definition in ORI & FRIEND, 1984). The stratigraphic characters of the thrust-sheet-top deposits are closely controlled by the trajectories of the thrusts active during sedimentation. Therefore, thrust-sheet-top deposits are very useful not only for fixing an upper chronological boundary to the deformation of the underlying thrust sheet but also for reconstructing the synsedimentary tectonic setting. For example, a preliminary rough analysis of the stratigraphic sequence based on the presence or absence of growth strata allows us to discriminate sediments certainly deposited in the hangingwall of an active thrust from sediments probably deposited on a footwall block, respectively (see fig. 9).

In the following pages we will provide a synthetic description of the Apennine thrust-sheet-top deposits starting from the oldest depositional sequences unconformably overlying the most internal tectonic units.

5.1. CILENTO GROUP AND ALBIDONA FORMATION

The Cilento Group was established by AMORE *et alii* (1988b,d) as an unconformity-bounded unit stratigraphically overlying the North-Calabrian and Alburno-Cervati nappes. According to these authors, the Cilento Group represents a lower-middle Miocene synorogenic cycle post-dating the Burdigalian tectonic phase. The cycle would consist of three formations, the San Mauro, Torrente Bruca and Pollica Formations, the equivalent of which is represented in Basilicata and Northern Calabria by the Albidona Formation of SELLI (1962). In effects, the San Mauro and Torrente Bruca Formations entirely correspond to the Albidona Formation; the Pollica Formation crops out only in the Cilento region and has no counterpart in Basilicata and Northern Calabria.

In Cilento and in the type area, the Albidona Formation consists of at least 1500 meters of siliciclastic turbidites with intercalations of carbonate megaturbidites. The age of these deposits is controversial. In the type-area, the Albidona formation has been attributed to the Langhian by SELLI (1962) and subsequently to the Eocene by MOSTARDINI *et alii* (1966), OGNIBEN (1969), PAVAN & PIRINI (1963) and VEZZANI (1970), to the late Oligocene-early Burdigalian by ZUPPETTA *et alii* (1983), to the early-middle Burdigalian by BONARDI *et alii* (1985) and to the Eocene by BARUFFINI *et alii* (2000). In Cilento, the San Mauro Formation (equivalent of the Albidona Formation) has been attributed to the Eocene-Oligocene by COCCO & PESCATORE (1968), to the Eocene-early Miocene by COCCO (1971), to the Aquitanian by GUERRERA (1978), to the early/late Burdigalian-early Langhian by AMORE *et alii* (1988b) and to the Langhian-Tortonian by RUSSO *et alii* (1995).

The Eocene attribution of the Albidona Formation is obviously inconsistent with the Eocene and Oligocene ages documented in the underlying Saraceno Formation in the type-area (see DE BLASIO *et alii*, 1978 and BONARDI *et alii*, 1988). On the other hand, Oligocene macroforaminifers were already found in the San Mauro deposits (Cilento) by PRINCIPI (1940) sixty years ago. At the state of the art, the Burdigalian-Langhian age proposed by AMORE *et alii* (1988b,d) seems to be the most reliable attribution.

According to BONARDI *et alii* (1985) and LENTINI *et alii* (1987), the Albidona Formation unconformably overlies the Alburno-Cervati carbonates of Monte Raparo sealing the tectonic contact between the North Calabrian and the Alburno-Cervati Units, as well as the contact between the Alburno-Cervati Unit and the Lagonegro Units. In reality, the contact between the Albidona Formation and the underlying Monte Raparo carbonates, described as an unconformity surface, is a folded thrust-flat which separates the North-Calabrian Unit plus Albidona Formation from the underlying carbonates of the Alburno-Cervati Unit with an important cutoff angle at the hangingwall. The Monte Raparo carbonates form here a sort of small duplex between the North-Calabrian Unit plus Albidona Formation and the Lagonegro units. This geometrical configuration can be easily explained by interpreting the Monte Raparo carbonates as a decapitated out-of-sequence structure of Alburno-Cervati Unit sandwiched between the North-Calabrian Nappe plus Albidona and the Lagonegro Unit II transported over the Lagonegro Unit I.

As concerns the depositional setting of the Albidona Formation, COLELLA & ZUFFA (1988) have evidenced the

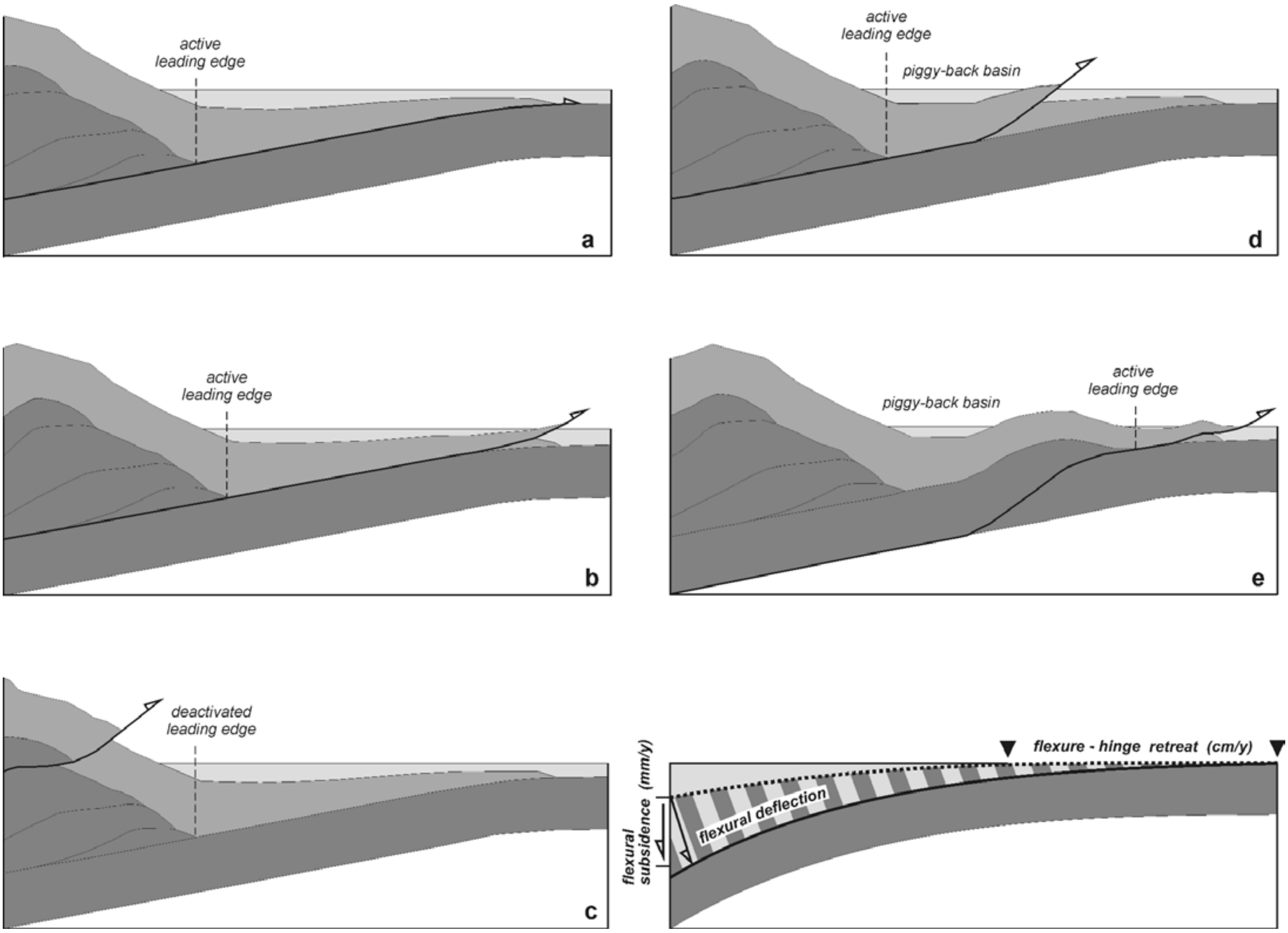


Fig. 9 - Schematic representation of active thrust trajectories controlling sedimentation on top of the Southern Apennine duplex system. – *Rappresentazione schematica delle traiettorie dei thrusts attivi che hanno controllato la sedimentazione sul dorso del sistema duplex dell'Appennino Meridionale.*

different provenance of the siliciclastic and carbonate materials, the former from the active western margin of the basin and the latter from the passive eastern margin. Considering that the Albidona basin was floored by the deformed North-Calabrian Unit, a tectonic activity of the western margin must be related to an out-of-sequence thrust propagation or to the nucleation of an important breach. The tectonic instability of the western margin of the Albidona basin is also confirmed by the occurrence of olistoliths of ophiolitic rocks associated with olistostromes of deep-marine deposits widespread from Cilento to Basilicata (DIETRICH & SCANDONE, 1972).

Selected references: SELLI, 1962; PAVAN & PIRINI, 1963; IETTO *et alii*, 1965; MOSTARDINI *et alii*, 1966; COCCO & PESCATORE, 1968; COLELLA & ZUFFA, 1988; VEZZANI, 1970; COCCO, 1971; DIETRICH & SCANDONE, 1972; GUERRERA, 1978; ZUPPETTA *et alii*, 1983; BONARDI *et alii*, 1985; CRITELLI, 1987, 1990; LENTINI *et alii*, 1987; AMORE *et alii*, 1988b, d; COLELLA & ZUFFA, 1988; CRISCI *et alii*, 1988; CRITELLI & LE PERA, 1990, 1991, 1994, 1995b; DI GIROLAMO *et alii*, 1992, 1994; RUSSO *et alii*, 1995.

5.2. GORGOGLIONE FORMATION

The Gorgoglione Formation was established by SELLI (1962) who interpreted this lithostratigraphic unit as a «neoautochthonous» deposit unconformably overlying the Albidona Formation and the Lucanian nappes (= Sicilide Nappe in this paper). The stratigraphic sequence of the Gorgoglione Formation consists of turbiditic sandstones and subordinate polygenic conglomerates reaching a thickness of about 1500 meters. A Langhian-early Tortonian age (BOENZI & CIARANFI, 1970; CIARANFI, 1971) is commonly reported in the geological literature.

Three turbidite systems have been recognized in the Gorgoglione sequence by BOIANO *et alii* (1994) and BOIANO (1997). The lower system is represented by pelitic-arenaceous deposits displaying no remarkable lateral variations of facies. According to these authors, a structural high divided the Gorgoglione basin into a northern sector and a southern sector during the deposition of the lower system The middle and upper systems, the former separated from the lower turbidite system by a disconformity surface, are represented mainly by turbiditic sandstones and subordinate conglomerates organized into thinning- and fining-upward megacycles. As concerns the tectonic evolution of the sedimentary basin, three principal stages have been recognized by BOIANO (1997) and BOIANO *et alii* (1994). The first stage was characterized by an open topography with the progradation of overbank pelitic deposits (lower turbidite system) the depositional geometry of which was influenced by the structural high separating the northern and southern sectors of the basin. The second stage (middle turbidite system and lower part of the upper system) was closely controlled by piggyback thrust propagation towards the foreland which caused a remarkable narrowing of the basin, as suggested by the NNW-SSE elongation of the turbidite bodies, in line with the paleocurrent mean direction. The third stage (upper portion of the upper turbidite system) was characterized by conditions of tectonic quiescence related to the far-field inward migration of the active thrusts (out-of-sequence thrust propagation). In effects, a drastic physiographic change had to occur between the lower and middle turbidite systems. The lower system might represent, in our opinion, a nappe sheet drape deposited on top of the Sicilide Unit during its forward displacement on a long thrust flat. The abrupt change in the sea-floor physiography passing from the lower turbidite system to the middle system can be related to a breach of the thrust toe producing a NNW-SSE elongated narrow basin.

The entire Gorgoglione synthem is currently considered, in the geological literature, as a piggyback-basin deposit (see PESCATORE & SENATORE, 1986 and subsequent literature). Piggyback basins develop in the hangingwall of active thrusts and are backward limited by inactive ridges. In the case of the Gorgoglione Formation, on the contrary, the stratigraphic signatures recognized by BOIANO (1997) and BOIANO *et alii* (1994) indicate that during the deposition of the middle and upper turbidite systems the basin had to be located in the footwall of the active thrusts (breaches or out-of-sequence thrusts), at the rear of an inactive ridge.

In the Cilento region, a conglomerate sequence is developed on top of the Albidona Formation. These conglomerates, known in the geological literature as the Monte Sacro Conglomerate (DE PIPPO & VALENTE, 1991), have been dubitatively considered a proximal facies of the Gorgoglione Formation.

Selected references: SELLI, 1962; BOENZI & CIARANFI, 1970; CIARANFI, 1971; COCCO *et alii*, 1972; LOIACONO, 1974, 1981, 1993; PESCATORE, 1978; COLELLA, 1979; PESCATORE *et alii*, 1980a,b; PESCATORE & SENATORE, 1986; LENTINI *et alii*, 1987; CRITELLI & LOIACONO, 1988; DE PIPPO & VALENTE, 1991; BOIANO, 1993, 1997; CATALANO *et alii*, 1993; BOIANO *et alii*, 1994.

5.3. CASTELVETERE FORMATION

The Castelvetere Formation (PESCATORE *et alii*, 1969) is represented by siliciclastic deposits, mostly disorganized coarse-grained sandstones and polygenic conglomerates, containing in the lower part olistoliths of platform-derived carbonates and in the upper part olistostromes and slides of Sicilide-derived materials. The depositional environment ranges from a shelf margin (e.g. Sorrento Peninsula), to the base of a slope (e.g. northeastern margin of the Partenio and Picentini mountains, northern margin of Monte Marzano). The outcrop distribution principally follows the outer margin of the Alburno-Cervati and Monti della Maddalena units. The most internal (SW) outcrops of the Castelvetere Formation are known in the Sorrento Peninsula and along the southern margin of the Alburni Mountains. The age of the Castelvetere Formation is Langhian-Tortonian according to PESCATORE *et alii* (1969), Serravallian-Tortonian according to SANTO & SGROSSO (1987) and Tortonian according to PATACCA *et alii* (1990). At the state of the art, a Serravallian-Tortonian *p.p.* age seems very likely. The Castelvetere Formation unconformably overlies the Mesozoic-Tertiary carbonates of the Alburno-Cervati and Monti della Maddalena units and is in turn tectonically overlain by the Sicilide Nappe. The maximum thickness exceeds 1500 meters.

The Castelvetere Formation has been usually interpreted as a wildflysch deposit accumulated in a foredeep basin inward limited by the active front of the Alburno-Cervati and Monti della Maddalena carbonates (see original definition in PESCATORE *et alii*, 1969). PESCATORE & SENATORE (1986) divided the Castelvetere Formation into two portion separated by an unconformity surface. The lower portion was interpreted as a foredeep deposit accumulated at the base of the slope of the Campania-Lucania Platform while the latter was collapsing towards the basin; the upper portion was interpreted as a piggyback-basin deposit unconformably overlying the platform carbonates and the allochthonous «Argille Varicolori» unit. The unconformity would testify to an important tectonic event during Burdigalian times. According this interpretation the lower portion of the Castelvetere Formation should be pre-Burdigalian, whilst microfossils indicate an age not older than the Serravallian (SANTO & SGROSSO, 1987). We did not recognize any regional unconformity or remarkable change in the depositional features between the lower portion of the Castelvetere Formation, everywhere portion stuffed with carbonate olistoliths, and the upper portion, stuffed with Sicilide-derived slides and olistostromes. Field evidence, in addition, including the evidence provided by PESCATORE *et alii* (1969), points to a syntectonic sedimentation of the Castelvetere Formation controlled by backstepping thrusts rather than by normal faults producing a collapse of the outer margin of the platform.

The Castelvetere Formation has been assembled, together with the Gorgoglione Formation and with the Burdigalian-Tortonian portion of the Serra Palazzo and Daunia sequences, into a group of thrust-sheet-top and foredeep deposits called Irpinian Units (see COCCO *et alii*, 1972; PESCATORE, 1978 and subsequent literature quoted in PESCATORE, *et alii*, 1996). According to these authors, the Irpinian Units would be representative of different portions of a single basinal domain (Irpinian Basin) that experienced an arkosic-lithic sedimentation after the Burdigalian tectonic phase. We fully agree with SGROSSO (1998) that the Irpinian Basin model is an obsolete paradigm based on correlations between non-coeval sedimentary sequences, which have been deposited in different times in basinal areas characterized by different tectonic settings

Among the Apennine geologists there is a sort of orally transmitted legend according to which the Castelvetere Formation unconformably overlies the Lagonegro Units. This story appears sometimes also in the scientific literature (e.g. PESCATORE *et alii*, 1996) though no documentation is provided. The reader should consider devoid of any reliability the existence of stratigraphic contacts between the Lagonegro Units and the Castelvetere Formation, the assumption of which would radically change the kinematic interpretation of the Southern Apennines.

Selected references: PESCATORE *et alii*, 1969, 1996; COCCO *et alii*, 1972, 1974; COCCO & PESCATORE, 1975; PESCATORE, 1978, 1984,

1988, 1995; PESCATORE & SENATORE, 1986; SANTO & SGROSSO, 1987; PESCATORE, 1978a,b, 1988, 1995; PATACCA *et alii*, 1990; CRITELLI & LE PERA, 1991, 1995a.

5.4. SAN BARTOLOMEO FORMATION, TOPPO CAPUANA FORMATION AND SAN MASSIMO SANDSTONE

The San Bartolomeo Formation lies in angular unconformity over the Sannio Unit and grades upwards into the Toppo Capuana Formation. The San Massimo Sandstone unconformably overlies the Matese Unit and is tectonically covered by the Sannio Unit. A type-section of the San Bartolomeo and Toppo Capuana Formations is represented by basinal sandstones and polygenic conglomerates exceeding 500 m in thickness (San Bartolomeo sandstones of the geological literature) overlain by pelitic-arenaceous turbiditic deposits reaching a thickness of about 200 metres (Toppo Capuana «marls» of the geological literature).

The San Bartolomeo and Toppo Capuana Formations were established by CROSTELLA & VEZZANI (1964) who attributed a Serravallian-Tortonian age to the San Bartolomeo Formation and a Tortonian age to the Toppo Capuana Formation. New micropaleontological investigations allowed us to attribute a latemost Tortonian?/early Messinian age to the San Bartolomeo sandstones and an early Messinian age to the overlying fine-grained deposits of the Toppo Capuana Formation. The *Turborotalia multiloba* planktic foram Zone is documented in the upper portion of the upper portion of the Toppo Capuana Formation. In the geological literature, the uppermost portion of the pre-flysch deposits of the Daunia sequence is often reported as the Toppo Capuana Marl. This terminology should be avoided since the same name applies in the type area to the uppermost, fine-grained portion of a terrigenous thrust-sheet-top deposit and in other areas to hemipelagic marls deposited in a very far foreland domain not yet incorporated in the foredeep basin.

The San Massimo Sandstone, representing the lateral equivalent of the Sant'Elena Sandstone of the Frosolone sequence, lies unconformably over the deformed Matese carbonates (SGROSSO, 1978). In more internal areas of the Apennine thrust belt, identical deposits occupying the same geometrical position as the San Massimo Sandstone are described in the geological literature with different names such as Caiazzo sandstones (OGNIBEN, 1956), Monte Cigno sandstones (PATACCA *et alii*, 1990) and Torrecuso Flysch (D'ARGENIO, 1967). All these names should be considered synonyms for San Massimo Sandstone. The age commonly attributed to these siliciclastic deposits in the current literature is early Messinian. However, a late Messinian age has been proposed by SGROSSO (1998).

In the Eastern Matese and Caserta mountains, the lowermost portion of the San Massimo Sandstone contains olistoliths of Mesozoic-Tertiary shallow-water limestones certainly derived from the Matese Unit. The occurrence of these olistoliths indicates an out-of-sequence propagation of the active thrusts after the deactivation of the Matese front.

Along the eastern margin of the Matese and Camposauro mountains, the San Massimo sandstones are tectonically overlain by the Sannio Unit which is in turn unconformably covered by the San Bartolomeo sandstones. Taking into consideration that the San Bartolomeo sandstones are roughly coeval with the San Massimo and Sant'Elena sandstones, we are obliged to admit that the bulk of the San Bartolomeo sandstones was accumulated behind the San Massimo Sandstone depositional domain and was afterwards passively transported by the Sannio Nappe when the latter overrode the Matese Unit. It is interesting to point out that the upper portion of the Toppo Capuana Formation (containing *Tb. multiloba*) is coeval with the upper portion of the Agnone flysch deposits (Sente Member). This fact implies that the Toppo Capuana Formation had to be deposited on top of the San Bartolomeo sandstones before the arrival of the Sannio nappe above the Agnone flysch. We think that the quite abrupt change in the sedimentary characteristics passing from the coarse-grained sandstones and conglomerates characterizing the whole San Bartolomeo Formation to the fine-grained deposits of the Toppo Capuana Formation corresponds to a change in the kinematic behaviour of the Sannio Nappe. We are inclined to think that the muddier sedimentation of the Toppo Capuana Formation took place during the large displacement of the Sannio Nappe on a long thrust flat. The stratal architecture of the San Bartolomeo deposits suggests a previous quite complex deformational history, with temporary episodes of telescopic shortening and with syn-transport tilt phenomena manifested by large-scale growth strata displaying in reflection seismic profiles spectacular progressive unconformities. Important breaching processes temporary interrupting the forward nappe transport are testified by the occurrence of Sannio-derived olistostromes intercalated in the turbiditic sandstones. In the geological literature, San Bartolomeo sandstone sections stuffed with slides of Sannio derived limestones and marls have been mistaken for a Paleocene-lower Eocene basinal sequence made up of alternating calcareous and siliciclastic turbidites (COCCO, 1972; PESCATORE *et alii*, 2000). The latter has been attributed to the Sicilide unit on the base of a vague resemblance with the Corleto Perticara Formation.

Selected references: CROSTELLA & VEZZANI, 1964; TORTORICI, 1975; LANZAFAME & TORTORICI, 1976; CIAMPO *et alii*, 1983; D'AZZARO & RAPISARDI, 1984, 1987, 1996; DI NOCERA & TORRE, 1987; D'AZZARO *et alii*, 1988a; DI NOCERA *et alii*, 1988, 1993b; RUSSO, 1988; PATACCA *et alii*, 1990; PAGLIARO, 1998; BOIANO, 2000; PESCATORE *et alii*, 2000.

5.5. UNDIFFERENTIATED MESSINIAN DEPOSITS

In the enclosed geological-structural map of plate 1 we have included in a single group of undifferentiated Messinian deposits small outcrops of pre-evaporite deposits exposed near Salerno, evaporite sequences cropping out along the Tyrrhenian margin of the Apennines (Gaeta), in Irpinia between Avellino and Benevento and in Molise along the outer margin of the mountain chain and scattered pre- to post-evaporite deposits cropping out in Calabria and scattered post-evaporite, as well as «Lago-Mare» deposits exposed in Irpinia and in the Latium-Abruzzi region. Very small outcrops (e.g. Sinni Valley, Low Sele Valley, Nusco-Lapio-Villamaina) have been omitted whilst other outcrops (e.g. outer margin of the Apennines, Fucino area) have been exaggerated because of their importance in fixing stratigraphical constraints for the time-space reconstruction- of the Apennine deformation.

The pre-evaporite deposits are usually represented by mudstones with subordinate sandstone intercalations. The thickness does not exceed 150-200 meters.

The evaporite deposits are represented by the well-known «Gessoso-Solfifera» Formation made up of marly clays and subordinate sandstones grading upwards into diatomites with fish remains that are in turn overlain by evaporites. The maximum thickness reaches 250-300 meters.

The «Gessoso-Solfifera» Formation is unconformably overlain by coarse-grained deposits, usually deltaic conglomerates and sandstones (e.g. Torrente Braneta Formation of the geological literature) associated with prodelta mudstones containing a Pannonian-type ostracod assemblage. The thickness reaches a few hundred meters.

In the Molise region, evaporite deposits unconformably overlying the Tufillo-Serra Palazzo and the Daunia Units prove the Messinian incorporation in the thrust belt of the corresponding depositional domains in a moment post-dating the FCO of *T. multiloba* zone present in the uppermost portion of the Tufillo-Serra Palazzo and Daunia sequences and pre-dating the salinity crisis.

Upper Messinian «Lago-Mare» deposits unconformably overlying the carbonates of the Western Marsica-Meta Unit near the Fucino Plain constrain within the Messinian the incorporation in the thrust belt of the Western Marsica-Meta domain.

Selected references on the pre-evaporite deposits: Coppa, 1967; De Castro Coppa *et alii*, 1969; Chiocchini *et alii*, 1971; Colalongo *et alii*, 1973; Ortolani *et alii*, 1979; Di Nocera *et alii*, 1981; Ortolani & Torre, 1981; Torre *et alii*, 1988.

Selected references on the evaporite deposits: Centamore & Valletta, 1969; De Castro Coppa *et alii*, 1969; Ciaranfi *et alii*, 1980; Di Nocera *et alii*, 1981; Dazzaro & Rapisardi, 1983; Di Nocera & Torre, 1987; Dazzaro *et alii*, 1988b; Basso *et alii*, 2001.

Selected references on the post-evaporite deposits: Colacicchi *et alii*, 1967; De Castro Coppa *et alii*, 1969; Devoto, 1969; D'Onofrio *et alii*, 1975; Di Nocera *et alii*, 1981; Ciampo *et alii*, 1986; Basso *et alii*, 1996; Patacca *et alii*, 1990; Cipollari *et alii*, 1999; Basso *et alii*, 2001

5.6. Torrente Calaggio Chaotic Complex

This unit, widespread in the whole study region, has been defined by Patacca *et alii* (1990) as a chaotic complex several hundred meters thick made up of olistostromes, slides and huge olistoliths with different composition and provenance set in a varicoloured clayey matrix. The unit overlies the Apenninic nappes and the pre-Pliocene thrust-sheet-top deposits and is stratigraphically covered by Pliocene clays with *Gt. puncticulata*. It is very probable that the Torrente Cerreto Unit established by Lentini (1979) in Basilicata corresponds to the Torrente Calaggio Chaotic Complex.

In the geological literature, the Torrente Calaggio Complex has been often mistaken for organized lithostratigraphic units of the Apenninic nappes (mostly «Argille Varicolori» and Numidian sandstones of the Sannio Nappe). Being the composition of the Torrente Calaggio Chaotic Complex usually controlled by the composition of the substratum, the attribution of the Torrente Calaggio Complex to a certain lithostratigraphic unit or to another obviously derives from the local abundance of representative lithotypes. In Basilicata, prevailing Sicilide-derived materials are associated with subordinate Sannio and Lagonegro-derived lithologies. In Irpinia, Baronia and in the Sannio-Molise region, the chaotic complex is principally made up of Sannio-derived materials locally associated with Lagonegro-derived lithologies and with scattered blocks of gypsum. Along the Apenninic margin between the Sangro and Biferno rivers, predominant varicoloured clays derived from the Molise nappes are associated with olistoliths of Messinian evaporites. Scattered masses of Cretaceous and Paleocene shallow-water limestones are widespread from Molise to Basilicata.

Portions of the Torrente Calaggio Chaotic Complex have been interpreted by Roure *et alii* (1991) as a tectonic melange. We disagree with this interpretation because the Torrente Calaggio Chaotic Complex never displays the tectonic structures indicative of high confining pressure (see HSÜ 1968) that should characterize a melange accretion by means of a «bulldozer» mechanism. On the other hand, it would be very hard to imagine conditions of high confining pressure in a complex that occupies a very high position in the tectonic edifice and is underlain and overlain by gently deformed thrust-sheet-top deposits. At the state of the art we think that the Torrente Calaggio Chaotic Complex may be the product of giant landslides that took place around the Messinian/Pliocene boundary. The chronological attribution of this catastrophic event, widespread over the whole Southern Apennines, is quite well constrained by the Pannonian-type ostracod assemblage present in the deposits of the underlying Braneta Formation (De Castro Coppa *et alii*, 1969) and by a foraminiferal assemblage indicative of the *Sphaeroidinellopsis* acme Zone in hemipelagic marls locally draping the chaotic complex (Ciampo *et alii*, 1986).

Selected reference: Patacca *et alii*, 1990, 1992b.

5.7. Undifferentiated Pliocene deposits

The greatest part of these deposits is represented by a quite complex depositional sequence (P_{1-2} thrust-related depositional sequence in Patacca & Scandone, 2001) the depositional characters of which strictly reflect the synsedimentary tectonic activity in the mountain chain. In addition, we have mapped in the same group minor outcrops of lower Pliocene terrigenous deposits scattered along the Tyrrhenian margin of the Apennines in Campania and Latium, as well as lower Pliocene terrigenous deposits unconformably overlying the Gran Sasso carbonates.

In the most complete sequences, three groups of deposits have been distinguished between southern Abruzzi and Basilicata, which correspond to well-defined systems tracts of a thrust-related depositional sequence.

The lower group is represented by some hundred meters of open-shelf foraminiferal mudstones grading upwards into shallow-marine sandstones (latemost Zanclean and early Piacenzian) interpreted as a muddy sheet drape deposited on top of the allochthonous sheets during their forward transport on a long flat fig. 9a and b).

The second group (Piacenzian) is represented by a fining-upward and deepening-upward succession of fan-delta coarse-grained deposits some hundred meters thick capped by prodelta and open-shelf mudstones (Caliandro cycle in Vezzani, 1966). Along the outer margin of the Apennines, this sequence is laterally replaced by marine-bar deposits grading upwards into open-shelf clays (Panni Formation in Crostella & Vezzani, 1964). The retrograding fan-delta/shelf system and the overlying transgressive system, which ends with a condensed section of open-marine mudstones, have been interpreted as the early and the late stages, respectively, of a backward-thrust-migration systems tract on top of the inactive toe of the Apenninic duplex (fig. 9c).

The third group of Pliocene thrust-sheet-top deposits is represented by a thick pile of fan-delta sandstones and conglomerates organized into a fining-upward lower sequence and a coarsening-upward upper sequence. In correspondence to the maximum-flooding episode at the top of the lower sequence the nannofossil associations and sporadic *Globorotalia inflata* indicate the late Pliocene (Gelasian). In some areas of the southern Apennines (e.g. Ofanto synform) these deltaic deposits form as a whole a wedge-shaped sedimentary body about 800 meters thick characterized by the widespread occurrence of growth strata and progressive internal unconformities. We have interpreted these deposits as the forward-thrust-migration systems tract in a piggyback basin located, in the case of the Ofanto basin, ahead of the active leading edge of the duplex system (fig. 9d). The position of the Ofanto basin ahead of the active leading edge obviously derives from regional information since discrimination between the tectonic setting of fig. 9d and the tectonic setting of fig. 9e is impossible only on the base of the stratigraphic signatures. In other pages of this volume we discuss the relationships between tectonics and sedimentation during the growth of important antiformal stacks in the Lagonegro Units ((PATACCA & SCANDONE, *Constraints on the interpretation of the CROP-04 seismic line derived from Plio-Pleistocene foredeep and thrust-sheet-top deposits*).

Selected references: CATENACCI & MOLINARI, 1965; VEZZANI, 1966, 1968c; FOLLADOR, 1967; CRESCENTI *et alii*, 1980; BALDUZZI *et alii*, 1982a,b; DI NOCERA *et alii*, 1983; GUERRERA & COCCION, 1984; CANTALAMESSA *et alii*, 1986a; CALDARA *et alii*, 1988, 1993; CASNEDI, 1988a,b; ORI *et alii*, 1991; AMORE *et alii*, 1996, 1998; BIGI *et alii*, 1997; CANTALAMESSA & DI CELMA, 1997; CIARCIA *et alii*, 1998; MATANO & STAITI, 1998; PATACCA & SCANDONE, 2001 and references therein.

5.8. UNDIFFERENTIATED PLEISTOCENE DEPOSITS

Lower Pleistocene deposits unconformably overlie the outer margin of the mountain chain and fill major intra-Apenninic structural depressions (e.g. Sant'Arcangelo basin). The older portion of these deposits (Craco Clay and Sant'Arcangelo Sandstone, Santernian) was deposited on top of the allochthonous sheets during their last transport towards the Apulia foreland. Younger deposit, basically represented by the Sub-Apenninic Clay (Emilian-Sicilian), are the upper portion of a thick sequence filling the Bradano Trough that transgressively covered the outer margin of the mountain chain after the de-activation if the nappe front. The Bradano Trough represents the youngest foredeep basin in the Southern Apennines. A more detailed documentation of the Bradano Trough deposits is available in PATACCA & SCANDONE (2001).

Along the Tyrrhenian margin of the mountain chain, Pleistocene terrigenous deposits are widely developed in the Sele, Volturno and Garigliano coastal plains where they reach considerable thicknesses (e.g. more than 3300 m in the Cancello 2 well drilled in the Volturno Plain). The sudden rapid accumulation of these terrigenous deposits, clearly related to the development of normal faults dissecting the Tyrrhenian margin of the mountain chain, is related to a major change of tectonic regime that took place around the early Pleistocene/middle Pleistocene boundary (see CINQUE *et alii*, 1993; HIPPOLITE *et alii*, 1994). Unfortunately, the beginning of the extensional tectonics setting is chronologically poorly defined and we do not know whether the lower portion of these deposits reaches the lower Pleistocene, as often reported in the geological literature dates, or it is confined within the middle Pleistocene, as we suppose.

Selected references: FOLLADOR, 1967; VEZZANI, 1967; IPPOLITO *et alii*, 1973; CRESCENTI *et alii*, 1980; BALDUZZI *et alii*, 1982a,b; CALDARA *et alii*, 1988, 1993; CASNEDI, 1988a,b; RUSSO, 1990 and references therein; MARINO, 1993, 1994; PIERI *et alii*, 1994, 1996; BIGI *et alii*, 1997; PATACCA & SCANDONE, 2001 and references therein; TROPEANO *et alii*, 2002; CIARCIA *et alii*, 2003.

6. THE TIME-SPACE EVOLUTION OF THE THRUST BELT-FOREDEEP-FORELAND SYSTEM IN THE SOUTHERN APENNINES

In this session, we will provide a tentative step-by-step reconstruction of the tectonic evolution of the Southern Apennines by using the available structural and stratigraphical information. In some cases, in which the incompleteness of the data makes it impossible to reach unequivocal conclusions, plausible solutions have been proposed, obviously making uncertainties explicit.

Late Burdigalian. The front of the mountain chain was located west of the Apenninic Platform that in this time began to experience flexural subsidence. The North-Calabrian Unit was already part of the tectonic wedge on top of which was deposited the Albidona Formation. In foreland domains, Numidian sands supplied by stable Africa were deposited in the Alburno-Cervati-Monti della Maddalena domains and in the Lagonegro Basin (Numidian sandstones of the Sannio, Tufillo-Serra Palazzo and Daunia sequences). The volumetric importance of the Numidian input decreases from south to north. It is probable that in late Burdigalian times the Sicilide domain was part of the foreland, but no sedimentary record younger than the Tusa Tuffite has been clearly documented.

Late Burdigalian/Early Langhian. After the Numidian-sand event, the Alburno-Cervati domain was incorporated in the Apennine foredeep basin (Civita sandstones, conformably overlying Numidian quartzarenites in the Pollino massif). In the mountain chain, the occurrence of huge olistostromes and olistoliths (the latter including ophiolites) in the upper portion of the Albidona Formation suggests breaching processes by out-of-sequence thrust propagation. It is very probable that the Sicilide domain was reached by the compressional deformation in this time and began to thrust over the western margin of the Apenninic Platform. The upper portion of the Civita sandstones is chronologically poorly defined, so that we do not know when exactly the foredeep sedimentation was interrupted by nappe transport. Fig. 10, referred to the Burdigalian-Langhian boundary, provides a palinspastic reconstruction of the Apenninic domains at that time.

Langhian-Serravallian. The migration of the foredeep basin from the Alburno-Cervati realm to the Lagonegro Basin marks the most important change in the tectonic setting. This shift is documented by the siliciclastic flysch deposits of the Sannio sequence (Serra Cortina sandstones). The occurrence of shallow-water carbonates included as blocks in the Serra Cortina sandstones and the occurrence of coarse-grained calcareous breccias intercalated in the coeval terrigenous deposits of the Monte Croce Unit (the latter containing also pebbles of

Numidian sandstones) suggest the incorporation in the thrust-belt of the Alburno-Cervati domain and Monti della Maddalena domains before the Langhian/Serravallian boundary. After the incorporation in the mountain chain of the Alburno-Cervati and Monti della Maddalena Units and before their forward transport above the Lagonegro domain, the Castelvetere sandstones began to be deposited on top of the carbonate units. The occurrence of thrust-sheet-top deposits stuffed with carbonate olistoliths quite far from the front of the carbonate massifs must be related to moments of out-of-sequence thrust propagation. Note that there is no agreement in the geological literature about the age of the Castelvetere Formation, which is given Serravallian-Tortonian in this paper and Tortonian-Messinian in SGROSSO, 1998).

Serravallian. In a still undefined moment of the Serravallian, the Alburno-Cervati and Monti della Maddalena Units began to thrust over the Lagonegro domain causing the detachment of the future Sannio nappe from its Triassic-Cretaceous substrate. In more internal areas of the thrust belt, the lower turbidite system of the Gorgoglione Formation was deposited on top of the Sicilide Unit.

Early Tortonian. Two steps may be recognized. During the first step, the middle and upper turbidite systems of the Gorgoglione Formation were deposited, with a generalized progradation and coarsening-upward in the upper part of the sedimentary sequence. The facies distribution of the Gorgoglione deposits shows active tectonics along the western margin of the basin related to an out-of-sequence migration of the active thrusts. During the second step, the internal nappes (Sicilide and North Calabrian Units plus Frido Melange) overrode the Alburno-Cervati and Monti della Maddalena Units. The progressive nappe advancing is recorded by the Sicilide-derived olistostromes widespread in the upper portion of the Castelvetere Formation.

Late Tortonian. In the late Tortonian the Simbruini-Matese Platform was reached by the flexural subsidence and was incorporated in the foredeep basin (Frosinone and Pietraroja siliciclastic flysch deposits in the Ernici-Simbruini and Matese mountains, respectively). In the thrust belt, the most important kinematic events are represented by the duplexing of the Lagonegro deposit, with consequent incorporation of slices of exotic rock-materials between the Lagonegro Unit II and the future Lagonegro Unit I, and by the forward transport of the Sannio Nappe. The position of Matese in front of the approaching Sannio nappe in this time (fig. 11) is indicated by the abundance of Sannio-derived olistostromes in the uppermost part of the Matese siliciclastic flysch deposits (Torbido Formation).

Late Tortonian/Early Messinian. In this time, the Matese depositional realm was incorporated in the thrust-belt while the foredeep basin shifted in the Frosolone domain. The thrust activity in correspondence to the Matese front is recorded by the Cantalupo breccias of the Frosolone sequence. A subsequent deactivation of the Matese front by out-of-sequence thrust migration is demonstrated by the deposition of the San Massimo Sandstone on top of the deformed Matese carbonates and by the occurrence of huge carbonate blocks in the terrigenous deposits from the Matese to the Caserta mountains.

Ahead of the inactive Matese front, the San Massimo sandstones (thrust-sheet-top deposits) were laterally replaced by the Sant'Elena sandstones (foredeep flysch deposits). Northwards, in the Western Marsica domain, siliciclastic flysch deposits equivalent of the Sant'Elena Sandstone were deposited in the same time on top of the

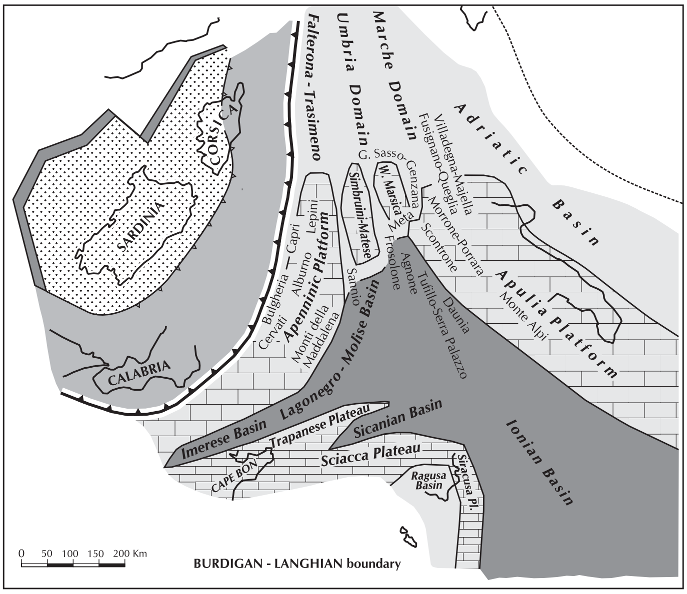


Fig. 10 - Palinspastic restoration of the Central-Southern Apennine domains in Langhian times when the Apenninic Platform was incorporated in the foredeep basin and immature turbidite sandstones were deposited on top of the Numidian quartzarenites.
– *Ricostruzione palinspastica dei domini centro- e sud-appenninici durante il Langhiano, quando la Piattaforma Appenninica fu incorporata nel bacino di avanfossa e arenarie torbiditiche immature furono deposte sulle quarzareniti numidiche.*

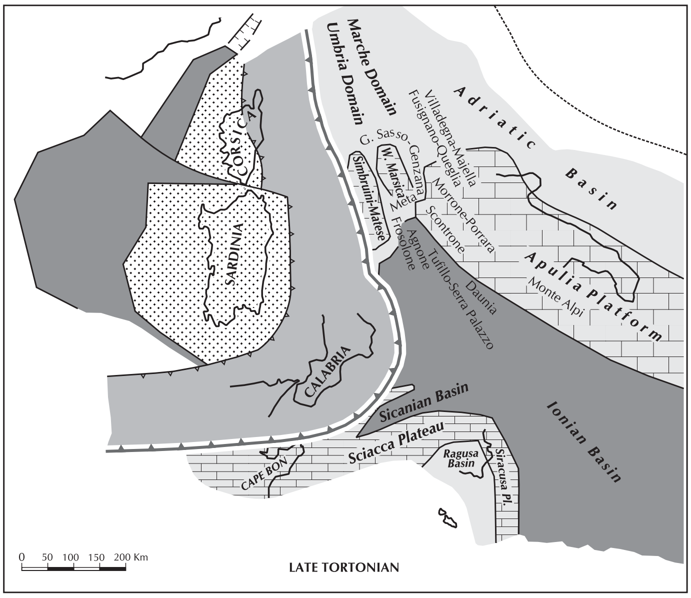


Fig. 11 - In late Tortonian times, flexural subsidence reached the Simbruini-Matese Platform and a foredeep basin developed in front of the deformed Alburno-Cervati and Monti della Maddalena Units. In Eastern Matese, the occurrence of Sannio-derived olistostromes in the upper Tortonian flysch deposits indicates that the Sannio domain had already been incorporated in the mountain chain.
– *Nel Tortoniano superiore la subsidenza flessurale raggiunse la Piattaforma Simbruini-Matese e un bacino di avanfossa si sviluppò al fronte delle Unità Alburno-Cervati e Maddalena coinvolte nella deformazione. La presenza di olistostromi di materiale sannitico nei depositi di flysch del Tortoniano superiore del Matese orientale indica che in quel tempo il dominio Sannio era già stato incorporato nella catena.*

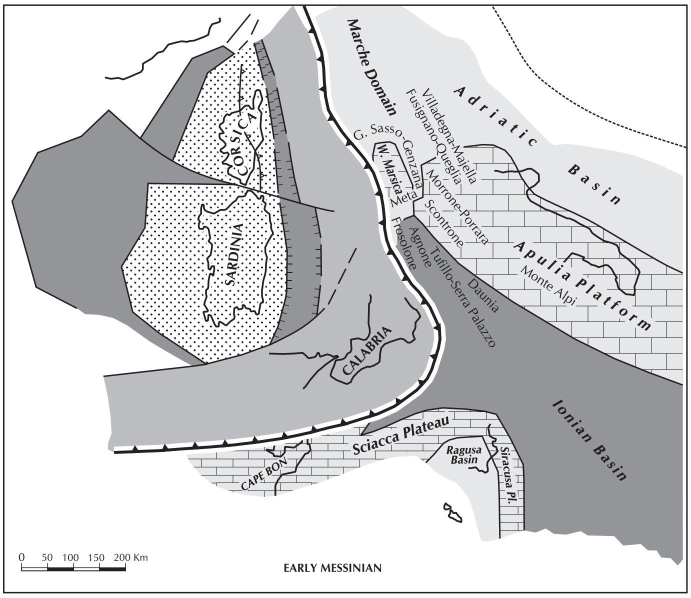


Fig. 12 - Around the end of the Tortonian, the Simbruini-Matese domain was incorporated in the mountain chain and the foreland flexure hinge shifted towards the W. Marsica Platform and towards the external areas of the Molise Basin. In early Messinian times, a continuous foredeep basin developed in the region, floored by platform pre-flysch deposits in the north and by basinal deposits in the south.
– Verso la fine del Tortoniano, il dominio Simbruini-Matese fu incorporato nella catena appenninica e l'asse di flessura della piastra di avampaese arretrò verso la Piattaforma della Marsica Occidentale e verso il Bacino Molisano dove si sviluppò un bacino di avanfossa nel Messiniano inferiore.

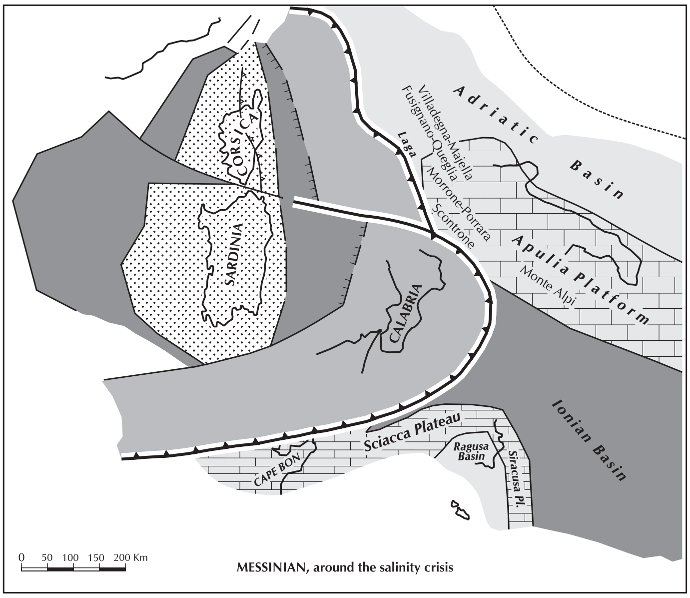


Fig. 13 - Still in Messinian times, after the FCO of *Tb. multiloba* and before the salinity crisis, the Gran Sasso-Genzana and the Montagna dei Fiori domains were incorporated in the foredeep basin. This moment is recorded n the Northern Abruzzi-Southern Marche region by the Laga Flysch deposits and in the Southern Abruzzi-Alto Molise region by a few outcrops of siliciclastic flysch deposits preserved in Eastern Marsica (Montagna Grande) and by the Castelnuovo al Volturno Flysch (Scontrone depositional realm). The Castelnuovo al Volturno Flysch marks the incorporation in the foredeep basin of the northwestern edge of the Apulian Platform.
– Durante il Messiniano dopo la FCO di Tb. multiloba *e prima della crisi di salinità, i domini Gran Sasso-Genzana e Montagna dei Fiori furono incorporati nel bacino di avanfossa. Questo momento è documentato dal Flysch della Laga nell'Abruzzo settentrionale-Marche meridionali, da piccoli affioramenti di depositi silicoclastici nella Marsica orientale (margine della Montagna Grande) e dal Flysch di Castelnuovo al Volturno nell'area di Scontrone-Alto Molise. Il depositi silicoclastici nella Marsica orientale (margine della Montagna Grande) e dal Flysch di Castelnuovo al Volturno marca l'incorporazione del margine nord-occidentale della Piattaforma Apula nel bacino di avanfossa.*

flexured platform. This coincidence implies that during early Messinian times a continuous foredeep basin developed from Abruzzi to Molise, floored by the Marsica-Meta platform-to-slope carbonates in the north and by the Molise basinal deposits in the south (fig. 12).

In more internal areas of the thrust belt, the San Bartolomeo sandstones were deposited on top of the Sannio Unit.

Early Messinian. The Sannio nappe overrode the southern margin of the Matese Unit in the early Messinian and advanced over the Frosolone and Agnone domains reaching the most internal areas of the Tufillo-Serra Palazzo domain after the FCO of *Tb. multiloba*. The Sannio Unit is limited westwards by a lateral ramp measuring about 80 km in length. Large-scale lateral ramps imply an abrupt longitudinal change in the thrust trajectories controlled by different shear stress conditions, likely related to abrupt lateral variations in the pore pressure gradients rather than to variations in the mechanical properties of the rock units. The Toppo Capuana fine-grained deposits, following the coarse-grained the San Bartolomeo sandstones, were probably deposited during the forward transport of the Sannio Nappe over a long thrust flat.

After the transport of the Sannio Unit over the Molise basinal domains, forward thrust propagation caused the incorporation in the mountain chain of the Frosolone, Agnone, Tufillo-Serra Palazzo and Daunia Units. The age of this compressional deformation is very well constrained by the occurrence of *Tb. multiloba* in the uppermost portion of the Agnone, Tufillo-Serra Palazzo and Daunia sequences and by the presence of evaporites on top the deformed Tufillo-Serra Palazzo and Daunia Units.

In the Central Apennines, the Western Marsica domain was probably reached in this time by the compression deformation. However, the stratigraphical constraints are not so decisive as in Molise because the earliest transgressive deposits date back to the late Messinian.

Messinian, around the salinity crisis. After the incorporation in the Apennine mountain chain of the Molise and (very probably) of the Western Marsica domains, a new foredeep basin established in correspondence to the Gran Sasso-Genzana depositional domain. The latter, in fact, was reached by the flexure-hinge retreat immediately after the first common occurrence of *Tb. multiloba* (fig. 13). This foredeep basin is documented by the Laga Flysch in Northern Abruzzi-Marche and by the Castelnuovo al Volturno Flysch in Southern Abruzzi. No documentation of a foredeep basin recording the salinity crisis exists in the Southern Apennines where no Messinian flysch deposits younger than the Olmi Formation of the Tufillo-Serra Palazzo Unit are known. We do not know whether this absence is related to a duplex configuration of the mountain chain that prevented the development of a foredeep basin (flexural depression occupied by the allochthonous sheets) or to a deep tectonic burial of Messinian flysch deposits in internal areas of the Apennines not reached by drilling. Thrust-sheet-top deposits referable to this time interval are represented by the «Gessoso-Solfifera» Formation, preserved in several structural depressions scattered through the Apennine mountain chain from Molise to Northern Calabria.

Late Messinian. A new important shift of the foredeep basin is documented in the northern part of the study area by the upper Messinian siliciclastic flysch deposits of the Queglia Unit. It is highly probable that the incorporation in the thrust belt of the Gran Sasso-Genzana and Montagna dei Fiori domains took place in late Messinian times. Unfortunately, the wide time interval between the age of the youngest portion of the Laga Flysch (Messinian post-salinity crisis and pre-«Lago-Mare» interval) and the age of the oldest thrust-sheet-top deposits unconformably overlying the Gran Sasso-Genzana Unit (upper portion of the *Gt. margaritae/Gt. puncticulata* concurrent range Zone) is too long for establishing a well-defined moment.

In the mountain chain, thrust-sheet-top deposits coeval with the foredeep ones are represented by the Torrente Braneta Formation and by the equivalent ostracod-bearing «Lago-Mare» deposits scattered in the Central Apennines. The Torrente Braneta Formation is overlain by the Torrente Calaggio Chaotic Complex, widespread over the whole study area. The mechanisms leading to generalized catastrophic landslides are still poorly understood but in any case do not appear controlled by the tectonic activity. It is possible that the marine flooding at the Miocene/Pliocene boundary may have caused in the mountain chain drastic changes in the hydrodynamic pattern, in particular in the pore pressure gradients, favouring generalized conditions of instability.

Early Pliocene, Zanclean. Progressive flexure-hinge retreat caused the incorporation in the foredeep basin of the Majella domain in the north and of the Monte Alpi domain in the south. We wish to recall that our Monte Alpi domain refers to the subsurface sections of the Monte Alpi oil field and not to the carbonates cropping out in the Monte Alpi tectonic window, which were probably incorporated in the Apennine thrust belt around the end of the Messinian. Subsequently, bur still in early Pliocene times before the last common occurrence of *Gt. margaritae* and after the first occurrence of Pseudoemiliana lacunosa, the Apenninic nappes reached the Majella and Monte Alpi depositional domains. The contact between the lower Pliocene siliciclastic flysch deposits of the Majella sequence and the allochthonous sheets is, represented by a sinistral lateral ramp very well exposed in the Aventino Valley. Moving towards the NW beyond the lateral ramp of the Molise Nappes, the Majella Unit is tectonically overlain by the Queglia Unit. The tectonic contact, well exposed in the Pescara Valley, appears as a thrust flat gently folded by the Majella anticline displaying no important cutoff angles at the footwall. In the hangingwall block, on the contrary, the terrigenous and pre-terrigenous deposits of the Queglia Unit are severely deformed in a tight system of N-S trending short wavelength folds, usually reverse folds. The age of the youngest siliciclastic flysch deposits of the Queglia Unit, reaching in the uppermost portion the *Gt. margaritae/Gt. puncticulata* concurrent range Zone, establish a lower chronological boundary for the incorporation of the Queglia domain in the Apennine mountain chain and for the transport of the Queglia Unit over the Majella domain. It is very likely that this transport was contemporaneous with the transport of the Molise Nappes over Majella, but no supporting evidence is available.

As in the case of the Sannio Unit, the Molise Units overlying the eastern flank of the Majella Anticline are limited westwards by a very long lateral ramp. Taking into consideration that the contact between the Simbruini-Matese Unit and the Frosolone Unit in the type area had been definitively sealed in early Messinian times, a palinspastic relocation of the Molise nappe front in late Messinian times implies an equal amount of backward translation of the Simbruini-Matese front. In addition, a 35° counterclockwise rotation of the Matese and Frosolone structures has been documented by Iorio *et alii* (1996) and Speranza *et alii* (1998). The position of the rotation pole was not defined, but its location in correspondence to the change in the strike of the Simbruini-Matese frontal thrust from a NW-SE direction to a W-E one (see plate 1) is very likely. If we smooth the rotation and then we move the Molise nappe front at the rear of the Gran Sasso Genzana Unit, roughly aligned with the front of the W. Marsica-Meta Unit, a wide space opens between the Simbruini-Matese front and Western Marsica which cannot be entirely re-accommodated by smoothing out the modest shortening between the W. Marsica-Meta Unit and the Gran Sasso-Genzana Unit. We think that this residual space was occupied by a branch of the Molise Basin. A continuation of the Frosolone realm towards the northwest following this deeper-water tongue would justify the local occurrence of ammonite-bearing Jurassic basinal deposits in the Simbruini Mountains (Damiani *et alii*, 1992). Such a reconstruction, in addition would give a logic explanation to an important thrust surface encountered by the Trevi 1 well at a depth of 3437 meters 14 kilometers behind the Simbruini thrust front. This thrust surface separates Mesozoic platform carbonates in the hangingwall from undefined Miocene limestones in the footwall. Finally, the occurrence of coarse-grained carbonate resediments in the Cretaceous-Paleogene Molise sequences between the Aventino and Sangro rivers could be better understood by admitting a carbonate clastic supply from the adjacent Western Marsica Platform rather than from the very distant Matese Platform.

Early Pliocene, late Zanclean. It is possible that the first deformation of Majella took place in this time interval, but data are insufficient for reconstructing a reliable tectonic history in this area. An important shift of the foredeep basin from the Monte Alpi domain to the Tempa Rossa and Rotondella depositional realms is documented in the Southern Apennines (see Patacca & Scandone, *Constraints on the interpretation of the CROP-04 seismic line derived from Plio-Pleistocene foredeep and thrust-sheet-top deposits*, in this volume). An analogous foredeep shift was expected in the northern area, between Majella and Casoli-Bomba, but no evidence has been found as yet.

Latemost Zanclean-late Pliocene. A significant forward nappe transport is documented in the whole Southern Apennines around the Zanclean-Piacenzian boundary. In the Abruzzi-Molise region, the Molise Nappes thrust over the Casoli-Bomba domain, the latter not yet reached by compressional deformation. In Basilicata, the allochthonous sheets reached the Tempa Rossa and Rotondella domains. During transport, muddy thrust-sheet-top deposits were laid down on top of the advancing nappes. A generalized deactivation of the nappe front around 3.30

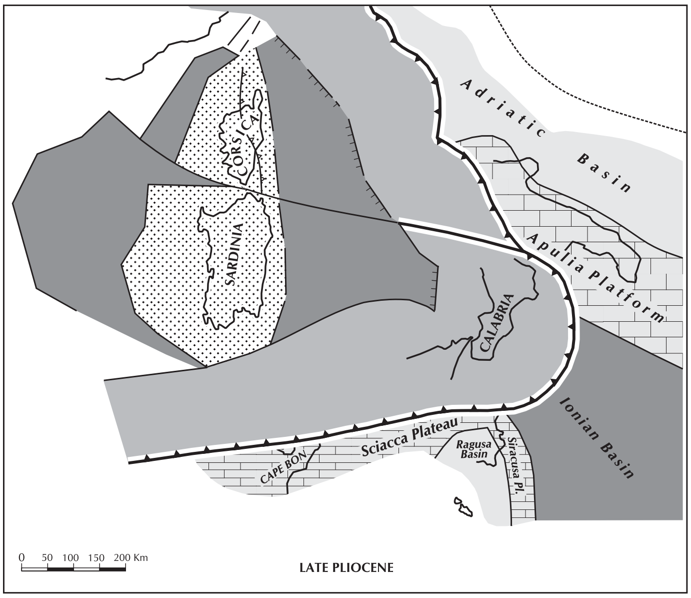


Fig. 14 - During the late Pliocene, a continuous foredeep basin developed in front of the Apennine mountain chain from the Po Valley to Southern Basilicata. In the Southern Apennines, the southern part of this basin is known in the geological literature as the Bradano Trough. The Bradano Trough experienced flexural subsidence until the Early Pleistocene-Middle Pleistocene boundary when a sudden drastic change in the tectonic regime took place and the mountain chain began to undergo a generalized uplift together with the previous foredeep depression.

– Durante il Pliocene superiore un bacino di avanfossa si sviluppò ininterrottamente al fronte della catena appenninica dalla Val Padana alla Basilicata. La parte meridionale di questo bacino è conosciuta come Fossa Bradanica. La Fossa Bradanica fu soggetta a subsidenza flessurale fino al limite Pleistocene inferiore-Pleistocene medio quando si verificò un brusco cambiamento di regime tettonico e la catena cominciò a sollevarsi assieme all'antistante bacino di avanfossa.

Ma, accompanied by a generalized out-of-sequence migration of the active thrusts, led to the sedimentation on top of the Apenninic nappes of retrograding shelf deposits followed by prograding fan-delta/shallow-marine deposits. In concomitance with the deactivation of the nappe front, a new foredeep basin developed along the Apennine margin documented by *Gt. crassaformis* and *Gt. inflata* turbidites widespread in the subsurface from Abruzzi to Basilicata (fig. 14). During the Gelasian, important compressional features developed in the buried Apulia-carbonate duplex system and in the overlying allochthonous sheets, which caused the growth of huge antiformal stacks both in the deep-seated Apulia carbonates and in the Apenninic nappes.

The Majella Mountain is a ramp anticline that depicts an arc-shaped feature with a strike direction changing from NNW-SSE in the north, to N-S in the central part and finally to NNE-SSW in the south. It is possible that the arc structure was created in late Pliocene times, in concomitance with the aforementioned compressional tectonics affecting the Apulia carbonates, but the stratigraphical constraints are quite poor. In addition, the subsurface extent of the Majella Unit towards the south is a first-order open problem.

Early Pleistocene. During Santernian times, the Apenninic thrust sheets underwent the last forward tectonic transport. As in the Pliocene, a muddy sheet drape was deposited on top of the advancing nappes. One again, flexural subsidence shifted towards the NE and a new foredeep basin developed ahead the nappe front. After the last nappe transport towards the foreland, important compressional features formed in the Apulia carbonates, documented by the Casoli-Bomba thrust system in the north and by the Tempa Rossa-Rotondella thrust system in the south. Around 0.65 Ma, flexural subsidence suddenly ceased in the whole Southern Apennines east of the Ortona-Roccamonfina alignment and a generalized uplift began in the mountain chain and in the Bradano Trough.

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REFERENCES

ACCARIE H. (1988) - *Dynamique sédimentaire et structurale au passage plate-forme/bassin. Les faciès carbonatés crétacés et tertiaires du Massif de la Maiella (Abruzzes, Italie)*. Ecole des Mines de Paris, Mém. Sci. de la Terre, **5**, 162 pp.

ACCORDI B. (1966) - *La componente traslativa nella tettonica dell'Appennino Laziale-Abruzzese*. Geologica Rom., **5**, 355-406.

ACCORDI G., CARBONE F., CIVITELLI G., CORDA L., DE RITA D., ESU D., FUNICIELLO R., KOTSAKIS T., MARIOTTI G. & SPOSATO A. Eds. (1988) - *Note illustrative alla carta delle litofacies del Lazio-Abruzzo ed aree limitrofe.* C.N.R., Quaderni de «La Ricerca Scientifica», **114** (P.F. Geodinamica, Monografie Finali, **5**), 223 pp.

ACCORDI G. & CARBONE F. (1988) - *Sequenze carbonatiche meso-cenozoiche*. In ACCORDI G. & CARBONE F. Eds., *Lithofacies map of Latium-Abruzzi and neighbouring areas.* C.N.R., Quaderni de La Ricerca Scientifica, **114** (P.F. Geodinamica, Monografie Finali, **5**), 11-92.

ACCORDI G., CARBONE F., SIRNA G., CATALANO G. & REALI S. (1982) - *Sedimentary events and rudist assemblages of Maiella Mt. (Central Italy): paleobiogeographic implications*. Geologica Rom., **26**, 135-147.

ACCORDI G. & PALLINI G. (1996) - *Early Cenomanian, Mantelli zone, ammonite assemblage, from a carbonate shelf edge sequence (Matese, Central Apennines).* Palaeopelagos, **6**, 273-280.

ADAMOLI L., BERTINI T., CHIOCCHINI M., DEIANA G., MANCINELLI A., PIERUCCINI U. & ROMANO A. (1978) - *Ricerche geologiche sul Mesozoico del Gran Sasso d'Italia (Abruzzo).* II. *Evoluzione tettonico-sedimentaria dal Trias superiore al Cretaceo inferiore dell'area compresa tra il Corno Grande e S. Stefano di Sessanio (F. 140 Teramo).* Studi Geol. Camerti, **4**, 7-18.

ADAMOLI L., BERTINI T., CHIOCCHINI M., DEIANA G., MANCINELLI A., PIERUCCINI U. & ROMANO A. (1982) - *Ricerche geologiche sul Gran Sasso d'Italia (Abruzzo). V. Evoluzione tettonico-sedimentaria dal Trias superiore al Cretaceo inferiore dell'area compresa tra M. Camicia ed Ofena (F. 140 Teramo).* Studi Geol. Camerti, **7**, 89-95.

ADAMOLI L., BIGOZZI A., CIARAPICA G., CIRILLI S., PASSERI L., ROMANO A., DURANTI F. & VENTURI F. (1990) - *Upper Triassic bituminous facies and Hettangian pelagic facies in the Gran Sasso range*. Boll. Soc. Geol. Ital., **109**, 219-230.

AMODEO F., BAUMGARTNER P.O. & D'ARGENIO B. (1994) - *Late Triassic to Jurassic stratigraphy and the sedimentary evolution of the Lagonegro domain (Lucania, Southern Italy*). I.A.S. 15th Meeting (Ischia, 13-15 April 1994), Abstracts, 20-21.

AMODEO F., MOLISSO F., KOZUR H., MARSELLA E. & D'ARGENIO B. (1993) - *Age of transitional beds from «Cherty Limestones» (calcari con selce) to «radiolarites» (scisti silicei) in the Lagonegro Domain (Southern Italy). First evidence of Rhaetian conodonts in peninsular Italy*. Boll. Serv. Geol. Ital., **110**, 3-22.

AMODIO-MORELLI L., BONARDI G., COLONNA V., DIETRICH D., GIUNTA G., IPPOLITO F., LIGUORI V., LORENZONI S., PAGLIONICO A., PERRONE V., PICCARRETA G., RUSSO M., SCANDONE P., ZANETTIN-LORENZONI E. & ZUPPETTA A. (1976) - *L'Arco calabro-pelori-*

tano nell'orogene appenninico-maghrebide. Mem. Soc. Geol. Ital., **17**, 1-60.

AMORE O. (1992) - *Studi biostratigrafici dei sedimenti miocenici del bacino molisano: nannoplancton calcareo*. Consorzio Univ. Napoli-Palermo, III Ciclo - Sede consorziata Napoli, Dottorato di Ricerca in Geologia del Sedimentario, Dissertazione Finale, Tipolitografica Sud, 95 pp.

AMORE O., ARUTA G., CIAMPO G., NAPOLITANO P., REA G., RUGGIERO E. & SGROSSO I. (1989) - *Ricerche stratigrafiche sui sedimenti miocenici connessi con i rilievi carbonatici di M. San Michele e M. La Rocca (Abruzzo-Molise)*. Conf. Sci. Annu. sulle Attività di Ricerca dei Dipartimenti (Napoli, 13-14-15 Dic. 1989), Litogr. A. De Frede, Napoli, 8-9.

AMORE O., BASSO C., CIARCIA S., DI NOCERA S., MATANO F., TORRE M., CIAMPO G., DI DONATO V., ESPOSITO P. & STAITI D. (1998a) - *Nuovi dati stratigrafici sul Pliocene affiorante tra il fiume Ufita e il torrente Cervaro (Irpinia, Appennino meridionale*). Boll. Soc. Geol. Ital., **117**, 455-466.

AMORE O., BONARDI G., CIAMPO G., DE CAPOA P., PERRONE V. & SGROSSO I. (1988b) - *Relazioni tra «Flysch interni» e domini appenninici: reinterpretazione delle formazioni di Pollica, San Mauro e Albidona e il problema dell'evoluzione inframiocenica delle zone esterne appenniniche*. Mem. Soc. Geol. Ital., **41**, 285-297.

AMORE O., CIAMPO G., DI DONATO V., ESPOSITO E., SANTINI U. & STAITI D. (1996) - *Biostratigraphy and evolution of the Plio-Pleistocene Calvello Basin (Potenza, Italy)*. Mem. Soc. Geol. Ital., **51**, 1153-1163.

AMORE O., CIAMPO G., RUGGIERO E., SANTO A. & SGROSSO I. (1988c) - *La successione miocenica del Matese nord-occidentale: nuovi dati biostratigrafici e conseguenti ipotesi paleogeografiche*. Mem. Soc. Geol. Ital., **41**, 311-319.

AMORE F.O., IACCARINO G. & PERRONE V. (1988d) - *Segnalazione di Nannoflore mioceniche nella successione di Monte Centaurino (Cilento orientale): problemi di correlazione tra la formazione di San Mauro e la formazione di Albidona*. Boll. Soc. Geol. Ital., **107**, 219-226.

ANDERSON H. & JACKSON J. (1987) - *The deep seismicity of the Tyrrhenian Sea*. Geophys. Journ. R. Astron. Soc., **91**, 613-637.

ANGELUCCI A. & PRATURLON A. (1968) - *Raddoppio tettonico della serie meso-cenozoica nelle gole di Celano a nord del Fucino (Appennino centrale)*. Geologica Rom., **7**, 431-446.

ANTONUCCI A., DE CORSA S., DI LUZIO E., LENCI F., SANSONNE P., SCROCCA D. & TOZZI M. (2000) - *La Montagnola di Frosolone ed il Matese settentrionale: nuovi dati sulla geologia molisana*. Boll. Soc. Geol. Ital., **119**, 637-654.

BALDUZZI A., CASNEDI R., CRESCENTI U., MOSTARDINI F. & TONNA M. (1982a) - *Il Plio-Pleistocene del sottosuolo del Bacino Lucano (Avanfossa Appenninica)*. Geologica Rom., **21**, 89-111.

BALDUZZI A., CASNEDI R., CRESCENTI U. & TONNA M. (1982b) - *Il Plio-Pleistocene del sottosuolo del Bacino Pugliese (Avanfossa Appenninica)*. Geologica Rom., **21**, 1-28.

BALLY A. (1954) - *Geologische Untersuchungen in den SE-Abruzzen*. Bühler Buchdruck, Zürich, 291 pp.

BARATTOLO F. & PUGLIESE A. (1987) - *Il Mesozoico dell'isola di Capri*. Quad. Accad. Pontaniana, **8**, 172 pp.

BARCHI M. & BIGOZZI A. (1995) - *Ipotesi sulla geometria e la genesi dei bacini euxinici del Trias superiore in Appennino Centrale*. Studi Geol. Camerti, Vol. Spec. 1995/2, 53-62.

BARUFFINI L., LOTTAROLI F. & TORRICELLI S. (2002) - *Integrated high resolution stratigraphy of the lower Oliocene Tusa Tuffite Formation in the Calabro Lucano area and Sicily (Southern Italy)*. Riv. Ital. Paleont. Stratigr., **108** (3), 457-478.

BARUFFINI L., LOTTAROLI F., TORRICELLI S. & LAZZARI D. (2000) - *Stratigraphic revision of the Albidona Formation in the type locality (Calabria, Southern Italy)*. Riv. Ital. Paleont. Stratigr., **106** (1), 73-98.

BASSO C., CIAMPO G., CIARCIA S., DI NOCERA S., MATANO F. & TORRE M. (2002) - *Geologia del settore irpino-dauno dell'Appennino meridionale: implicazioni sui domini paleogeografici delle unità bacinali meso-cenozoiche e nuovi vincoli stratigrafici nell'evoluzione tettonica mio-pliocenica del settore esterno della catena*. Studi Geol. Camerti, n.s., **2**, 7-27.

BASSO C., DI NOCERA S., MATANO F. & TORRE M. (1996) - *Successioni sedimentarie del Messiniano superiore e del Pliocene inferiore-medio in Irpinia settentrionale*. Boll. Soc. Geol. Ital., **115**, 701-715.

BELLATALLA M. (1992) - *Caratterizzazione stratigrafica dei depositi miocenici e pliocenici della Maiella*. Univ. degli Studi di Pisa, Dottorato di Ricerca in Scienze della Terra, Dissertazione Finale, 166 pp.

BELLATALLA M., GIOVANNELLI A. & MARIOTTI G. (1992) - *Catena del M. Morrone, M. Pizzalto e M. Porrara: elementi e considerazioni per una loro interpretazione*. Quinto Simp. di Ecologia e Paleoecologia delle Comunità Bentoniche (Roma, 28-30 sett. 1992), libro-guida delle escursioni, 121-126.

BENEO E. (1939) - *Sezioni geologiche attraverso la montagna del Morrone (Appennino abruzzese)*. Boll. R. Uff. Geol. Ital., **64**, 1-29.

BERNOULLI D., ANSELMETTI F.S., EBERLI G.P., MUTTI M., PIGNATTI J.S., SANDERS D.G.K. & VECSEI A. (1996) - *Montagna della Maiella: the sedimentary and sequential evolution of a Bahamian-type carbonate platform of the south-tethyan continental margin*. Mem. Soc. Geol. Ital., **51**, 7-12.

BIGI S. (1993) - *Caratterizzazione geologico-strutturale della zona esterna dell'Appennino abruzzese tra il Gran Sasso d'Italia e la Maiella*. Univ. degli Studi di Camerino, in di Ricerca Tettonica e Geologia Strutturale, V Ciclo, Dissertazione Finale, 98 pp.

BIGI S., CALAMITA F. & CENTAMORE E. (1995) - *Caratteristiche geologico-strutturali dell'area abruzzese ad oriente del Gran Sasso*. Studi Geol. Camerti, Vol. Spec. 1995/2, 67-76.

BIGI S., CANTALAMESSA G., CENTAMORE E., DIDASKALOU P., MICARELLI A., NISIO S., PENNESI T. & POTETTI M. (1997) - *The Periadriatic Basin (Marche-Abruzzi sector, Central Italy) during the Plio-Pleistocene*. G. Geol., 3ª, **59** (1-2), 245-259.

BIGI S. & DI BUCCI D. (1987) - *Rilevamento geologico delle strutture di Monte Picca e di Monte La Queglia, Appennino abruzzese*. Geologica Rom., **26**, 413-418.

BIGOZZI A. (1990) - *Cyclic stratigraphy of the Upper Triassic-Lower Liassic sequence of Corno Grande (Central Apennines)*. Mem. Soc. Geol. Ital., **45**, 709-721.

BIGOZZI A. (1994) - *Storia evolutiva ed inquadramento sequenziale dell'area del Gran Sasso nell'intervallo Trias superiore-Lias inferiore*. Atti Tic. Sci. Terra, S. Spec., **2**, 73-95.

BIGOZZI A., CIARAPICA G., CIRILLI S. & PASSERI L. (1992) - *Eteropie di facies nel Trias superiore e nel Lias inferiore del Gran Sasso*. In: TOZZI M., CAVINATO G.P. & PAROTTO M. Eds., «Studi preliminari all'acquisizione dati del profilo CROP 11 Civitavecchia-Vasto», AGIP-CNR-ENEL, Studi Geol. Camerti, Vol. Spec., 1991-2, 115-118.

BOENZI F., CIARANFI N. & PIERI P. (1968) - *Osservazioni geologiche nei dintorni di Accettura e di Oliveto Lucano. (Tav. 200 III NE, IV SE e IV NE)*. Mem. Soc. Geol. Ital., **7**, 379-392.

BOENZI F. & CIARANFI N. (1970) - *Stratigrafia di dettaglio del «Flysch di Gorgoglione» (Lucania)*. Mem. Soc. Geol. Ital., **9**, 65-79.

BOIANO U. (1993) - *Le facies torbiditiche grossolane del Flysch di Gorgoglione (Miocene, Appennino lucano): caratteri deposizionali ed ipotesi sulla formazione degli strati amalgamati*. G. Geol., **55**, 179-187.

BOIANO U. (1997) - *Anatomy of a siliciclastic turbidite basin: the Gorgoglione Flysch, Upper Miocene, southern Italy: physical stratigraphy, sedimentology and sequence-stratigraphic framework*. Sediment. Geol., **107**, 231-262.

BOIANO U. (2000) - *La formazione torbiditica di San Bartolomeo (Appennino meridionale): revisione litostratigrafica, analisi sedimentologica ed implicazioni sui caratteri dei bacini legati a prismi di accrezione*. Boll. Soc. Geol. Ital., **119**, 39-62.

BOIANO U., CRITELLI S., LOJACONO F., PESCATORE T. & SBARRA R. (1994) - *Le successioni terrigene esterne dell'Appennino Lucano*. Guida alle escursioni Congr. Soc. Geol. Ital., Bari 1994, Quad. Bibl. Prov. Matera, **15**, 157-203.

BONARDI G., AMORE F.O., CIAMPO G., DE CAPOA P., MICONNET P. & PERRONE V. (1988) - *Il complesso liguride auct.: stato delle conoscenze e problemi aperti sulla sua evoluzione pre-appenninica ed i suoi rapporti con l'Arco Calabro*. Mem. Soc. Geol. Ital., **41**, 17-35.

BONARDI G., CIAMPO G. & PERRONE V. (1985) - *La formazione di Albidona nell'Appennino calabro-lucano: ulteriori dati stratigrafici e relazioni con le unità esterne appenniniche*. Boll. Soc. Geol. Ital., **104**, 539-549.

BONARDI G., DE CAPOA P., FIORETTI B. & PERRONE V. (1993) - *L'âge des métacalcaires de l'Unité du Frido (région calabro-lucanienne, Italie) et ses implications géodynamiques*. C.R. Acad. Sci. Paris, s. 2, **317**, 955-962.

BONI M. (1974) - *Le argille rosse continentali del passaggio Paleocene-Miocene nella piattaforma carbonatica campano-lucana*. Boll. Soc. Geol. Ital., **93**, 1059-1094.

BONI M., IANNACE A., KÖSTER J. & PARENTE M. (1990) - *Anoxis facies in the Upper Triassic of Picentini Mountains (Southern Apennines, Italy)*. Boll. Soc. Geol. Ital., **109**, 171-185.

BONI M., IPPOLITO F., SCANDONE P. & ZAMPARELLI TORRE V. (1974) - *L'unità del Monte Foraporta nel Lagonegrese (Appennino Meridionale)*. Boll. Soc. Geol. Ital., **93**, 469-512.

BOUSQUET J.C. (1962) - *Age de la série des Diabases-Porphyrites (roches vertes du flysch calabro-lucanien; Italie Méridionale)*. Bull. Soc. Géol. France, s. 7, **4**, 712-718.

BOUSQUET J.C. (1971) - *La tectonique tangentielle des series calcareo-dolomitiques du nord est de l'Apennin calabro-lucanien (Italie Méridionale)*. Geologica Rom., **10**, 23-52.

BOUSQUET J.C. & DUBOIS R. (1967) - *Découverte de niveaux anisiens et caractères du métamorphisme alpin dans la région de Lungro (Calabre)*. C.R. Acad. Sci. Paris, s.D, **264**, 204-207.

BOUSQUET J.C. & GRANDJACQUET C. (1969) - *Structure de l'Apennin Calabro-Lucanien (Italie Méridionale)*. C.R. Acad. Sci. Paris, s. D, **268**, 13-16.

BRAVI S. & SCHIATTARELLA M. (1986) - *Segnalazione di livelli ittiolitici eocenici a Cyclopoma gigas AGASSIZ ai Monti Alburni (Appennino Campano)*. Boll. Soc. Natur. Napoli, **95**, 255-279.

BRAVI S. & SCHIATTARELLA M. (1988) - *Segnalazione di livelli ittiolitici eocenici dei Monti Alburni (Appennino Campano)*. Mem. Soc. Geol. Ital., **41**, 587-591.

BROGINI A.L. (1973) - *Studio stratigrafico e micropaleontologico del Cretaceo inferiore della Montagna dei Fiori (Ascoli Piceno-Teramo)*. Atti Soc. Tosc. Sci. Nat., Mem., s. A, **80**, 79-105.

BRÖNNIMAN P., DURAND DELGA M. & GRANDJACQUET C. (1971) - *Présence simultanée de Protopeneroplis striata* WEYNSCHENK *et de calpionelles néocomiennes dans le «flysch galestrino» de Lucanie (Italie Méridionale)*. Rev. Micropaléont., **14**, 96-101.

BUONOCUNTO F.P., D'ARGENIO B., FERRERI V. & RASPINI A. (1994) - *Microstratigraphy of highly organized carbonate platform deposits of Cretaceous age. The case of Serra Sbregavitelli (Matese, central Apennines)*. G. Geol., s. 3ª, **56** (2), 179-192.

CALAMITA F., SCISCIANI V., ADAMOLI L., BEN M'BAREK M. & PELOROSSO M. (2002) - *Il sistema a thrust del Gran Sasso d'Italia (Appennino Centrale)*. Studi Geol. Camerti, n.s., **1**, 19-32

CALDARA M., CIARANFI N. & MARINO M. (1993) - *I depositi plio-pleistocenici di avanfossa al bordo dell'Appennino meridionale tra Oliveto Lucano e Garaguso (Basilicata)*. Boll. Soc. Geol. Ital., **112**, 893-908.

CALDARA M., LOJACONO F., MORLOTTI E., PIERI P. & SABATO L. (1988) - *I depositi plio-pleistocenici della parte nord del bacino di S. Arcangelo (Appennino lucano): caratteri geologici e paleoambientali*. Mem. Soc. Geol. Ital., **41**, 391-410.

CANTALAMESSA G., CENTAMORE E., CHIOCCHINI U., COLALONGO M.L., MICARELLI A., NANNI T., PASINI G., POTETTI M., RICCI LUCCHI F., CRISTALLINI C. & DI LORITO L. (1986a) - *Stratigrafia. Il Plio-Pleistocene delle Marche.* In: CENTAMORE E. & DEIANA G. Eds., «La Geologia delle Marche», Numero Speciale 73° Congr. Soc. Geol. Ital. (Roma 30 sett.-4 ott. 1986), Studi Geol. Camerti, 61-81.

CANTALAMESSA G., CENTAMORE E., CHIOCCHINI U., MICARELLI A., POTETTI M. & DI LORITO L. (1986b) - *Stratigrafia. Il Miocene delle Marche.* In: CENTAMORE E. & DEIANA G. Eds., «La Geologia delle Marche», Numero Speciale 73° Congr. Soc. Geol. Ital. (Roma 30 sett.-4 ott. 1986), Studi Geol. Camerti, 35-55.

CANTALAMESSA G. & DI CELMA C. (1997) - *I depositi pliocenici dell'unità di Ariano (Monti della Baronia, Appennino meridionale*). Studi Geol. Camerti, **14**, 89-101.

CARANNANTE G., GRAZIANO R., RUBERTI D. & SIMONE L. (1996) - *Upper Cretaceous temperate-type open shelves from Northern (Sardinia) and Southern (Apennines-Apulia) Mesozoic Tethyan margins*. In JAMES N.P. & CLARKE J. Eds., «Cool water carbonates», Spec. Publ. Soc. Econ. Paleont. Mineral., **56**, 309-325.

CARANNANTE G., MATARAZZO R., PAPPONE G., SEVERI C. & SIMONE L. (1988) - *Le calcareniti mioceniche della formazione di Roccadaspide (Appennino campano-lucano)*. Mem. Soc. Geol. Ital., **41**, 775-789.

CARANNANTE G., RUBERTI D. & SIRNA G. (1998) - *Senonian rudist limestones in the Sorrento peninsula sequences (Southern Italy)*. Geobios, **22**, 47-68.

CARANNANTE G., RUBERTI D. & SIMONE L. (1993) - *Rudists and related sediments in Late Cretaceous open shelf settings. A case history from Matese Area (Central-Southern Apennines, Italy)*. G. Geol., s. 3ª, **55** (1), 21-36.

CARBONE F. (1984) - *Evoluzione tettonico-sedimentaria delle unità carbonatiche centroappenniniche durante il Meso-Cenozoico*. CNR, Cent. Studi Geol. Italia Centrale, 1984, 34 pp.

CARBONE S., CATALANO S., LENTINI F. & MONACO C. (1988) - *Le unità stratigrafico-strutturali dell'Alta Val d'Agri (Appennino lucano) nel quadro dell'evoluzione del sistema catena-avanfossa*. Mem. Soc. Geol. Ital., **41**, 331-341.

CARBONE S. & LENTINI F. (1990) - *Migrazione neogenica del sistema catena-avampaese nell'Appennino meridionale: problematiche paleogeografiche e strutturali*. Riv. Ital. Paleont. Stratigr., **96**(2-3), 271-296.

CARBONI M.G., CIVITELLI G., CORDA L., ESU D., MATTEUCCI R. & PALAGI I. (1992) - *Evoluzione delle facies e delle comunità bentoniche dal continentale al marino nel Miocene superiore della valle del fiume Aventino*. Quinto Simp. di Ecologia e Paleoecologia delle Comunità Bentoniche (Roma, 28-30 sett. 1992), libro-guida delle escursioni, 110-119.

CASCELLA A. & LIRER F. (1998) - *Upper Miocene pre-terrigenous deposits of the Queglia Unit (Abruzzo, Central Apennines, Italy): biotratigraphic data*. Atti Soc. Tosc. Sci. Nat., Mem., s. A, **105**, 137-149.

CASERO P., ROURE F., ENDIGNOUX L., MORETTI I., MÜLLER C., SAGE L. & VIALLY R. (1988) - *Neogene geodynamic evolution of the Southern Apennines.* Mem. Soc. Geol. Ital., **41**, 109-120.

CASERO P., ROURE F. & VIALLY R. (1991) - *Tectonic framework and petroleum potential of the southern Apennines.* In SPENCER A.M. Ed., *Generation, accumulation, and production of Europe's hydrocarbons*, Spec. Publ. European Assoc. Petroleum Geosci., **1**, 381-387.

CASNEDI R. (1983) - *Hydrocarbon-Bearing Submarine Fan System of Cellino Formation, Central Italy*. Bull. Amer. Assoc. Petroleum Geol., **67**, 359-370.

CASNEDI R. (1988a) - *La fossa bradanica: origine, sedimentazione e migrazione*. Mem. Soc. Geol. Ital., **41**, 439-448.

CASNEDI R. (1988b) - *Subsurface basin analysis of fault-controlled turbidite system in Bradano trough, Southern Adriatic foredeep, Italy*. Bull. Amer. Assoc. Petroleum Geol., **72** (11), 1370-1380.

CASTELLANO M.C. & SGROSSO I. (1996) - *Età e significato dei depositi miocenici della formazione di M. Sierio e possibile evoluzione cinematica dell'Unità Monti della Maddalena nell'Appennino campano-lucano.* Mem. Soc. Geol. Ital., **51**, 239-249.

CASTELLUCCIO C. & NAPOLITANO P. (1989) - *Nuovi dati sulla struttura dell'Isola di Capri*. Rend. Soc. Geol. Ital., **12**, 25-28.

CATALANO S., CARBONE S. & LENTINI F. (1993) - *Il Flysch di Gorgoglione nell'ambito dell'evoluzione dell'Appennino lucano*. G. Geol., s. 3ª, **55** (1), 165-178.

CATENACCI V. (1974) - *Note illustrative della carta geologica d'Italia alla scala 1:100.000 - Foglio 147 Lanciano.* Serv. Geol. d'Italia, 87 pp., Nuove Tecnica Grafica, Roma.

CATENACCI E. & CHIOCCHINI M. (1967) - *Osservazioni stratigrafiche sul versante occidentale del Monte Amaro (Montagna della Maiella, Appennino abruzzese).* Boll. Soc. Geol. Ital., **86**, 423-444.

CATENACCI E., DE CASTRO P. & SGROSSO I. (1962) - *Complessi guida del Mesozoico calcareo-dolomitico nella zona orientale del Massiccio del Matese*. Mem. Soc. Geol. Ital., **4**, 21 pp.

CATENACCI V., MATTEUCCI R. & SCHIAVINOTTO F. (1982) - *La superficie di trasgressione alla base dei «calcari a Briozoi e Litotamni» nella Maiella meridionale.* Geologica Rom., **21**, 559-575.

CATENACCI E. & MOLINARI V. (1965) - *Sull'età dei conglomerati di Minturno (Lazio meridionale).* Boll. Serv. Geol. Ital., **86**, 17 pp.

CELLO G. & MAZZOLI S. (1999) - *Apennine tectonics in southern Italy: a review*. Journ. Geodynamics, **27**, 191-211.

CELLO G., PALTRINIERI W. & TORTORICI L. (1987) - *Caratterizzazione strutturale delle zone esterne dell'Appennino molisano*. Mem. Soc. Geol. Ital., **38**, 155-161.

CELLO G., TORTORICI L., MARTINI N. & PALTRINIERI W. (1989) - *Structural styles in the frontal zones of the Southern Apennines, Italy: an example from the Molise district*. Tectonics, **8** (4), 753-768.

CENTAMORE E., ADAMOLI L., BERTI D., BIGI G., BIGI S., CASNEDI R., CANTALAMESSA G., FUMANTI F., MORELLI C., MICARELLI A., RIDOLFI M. & SALVUCCI R. (1992) - *Carta geologica dei bacini della Laga e del Cellino e dei rilievi carbonatici circostanti*. S.EL.CA, Firenze.

CENTAMORE E., CHIOCCHINI U., JACOBACCI A., LANARI G. & SANTAGATI G. (1970) - *Geologia della zona nord-occidentale del F° 187 «Melfi»*. Boll. Serv. Geol. Ital., **91**, 113-148.

CENTAMORE E., CHIOCCHINI U. & MORETTI A. (1971) - *Geologia della zona tra Acerenza e Avigliano (provincia di Potenza)*. Studi Geol. Camerti, **1**, 97-122.

CENTAMORE E. & VALLETTA M. (1969) *Contributo alla conoscenza geologica dell'Appennino Molisano*. Boll. Serv. Geol. Ital., **89**, 53-64.

CHERCHI A., RUBERTI D. & SIRNA G. (1991) - *Osservazioni biostratigrafiche sul Cretaceo del Matese centro-settentrionale (Italia Centrale)*. Boll. Serv. Geol. Ital., **110**, 91-110.

CHIOCCHINI M., FARINACCI A., MANCINELLI A., MOLINARI V. & POTETTI, M. (1994) - *Biostratigrafia a foraminiferi, dasicladali e calpionelle delle successioni carbonatiche mesozoiche dell'Appennino centrale (Italia)*. Studi Geol. Camerti, Vol. Spec. 1994, 9-128.

CHIOCCHINI M., LOSEGO I., MANCINELLI A. & ROMANO A. (1980) - *Ricerche geologiche sul Gran Sasso d'Italia (Abruzzo)*. IV. *Evoluzione paleogeografica, durante il Giurassico superiore ed il Cretaceo inferiore, del margine della piattaforma carbonatica nell'area tra Barisciano e Castel del Monte*. Studi Geol. Camerti, **6**, 55-80.

CHIOCCHINI M. & MANCINELLI A. (1977) - *Microbiostratigrafia del Mesozoico in facies di piattaforma carbonatica dei Monti Aurunci (Lazio meridionale)*. Studi Geol. Camerti, **3**, 109-152.

CHIOCCHINI M. & MANCINELLI A. (1978) - *Ricerche geologiche sul Mesozoico del Gran Sasso d'Italia (Abruzzo)*. III. *Correlazioni microbiostratigrafiche tra facies di margine della piattaforma carbonatica e facies pelagiche del Giurassico e Cretaceo inferiore*. Studi Geol. Camerti, **4**, 19-36.

CHIOCCHINI U., CIPRIANI N., DI GIACOMO G., GIACCHETTA D. & MACRÌ F. (1987) - *Petrografia delle arenarie torbiditiche messiniane del bacino della Laga*. G. Geol., s. 3, **49**, 59-71.

CHIOCCHINI U., CONATO V. & VALLETTA M. (1971) - *I sedimenti miocenici e pliocenici tra il T. Fiumarella e l'alta Valle del F. Ofanto (Campania)*. Nota I. *Stratigrafia*. Boll. Serv. Geol. Ital., **92**, 87-108.

CIAMPO G., SGROSSO I. & RUGGIERO TADDEI E. (1983) - *Età e modalità della messa in posto del massiccio del Matese nel bacino molisano*. Boll. Soc. Geol. Ital., **102**, 573-580.

CIAMPO G., SGROSSO I. & RUGGIERO TADDEI E. (1986) - *Il limite Miocene-Pliocene nella sezione di Torrente Braneta (Irpinia)*. Boll. Soc. Geol. Ital., **105**, 35-40.

CIAMPO G., SGROSSO I. & RUGGIERO TADDEI E. (1987) - *L'inizio della sedimentazione terrigena nel Matese, nei monti del Casertano e nei monti di Suio*. Boll. Soc. Geol. Ital., **106**, 323-330.

CIARANFI N. (1971) - *Flysch di Gorgoglione*. Boll. Serv. Geol. Ital., Suppl., **92**, 101-114.

CIARANFI N., DAZZARO L., PIERI P. & RAPISARDI L. (1980) - *I depositi del Miocene superiore al confine molisano-abruzzese*. Boll. Soc. Geol. Ital., **99**, 103-118.

CIARAPICA G. (1990) - *Central and Northern Apennines during the Triassic: a review*. Boll. Soc. Geol. Ital., **109**, 39-50.

CIARAPICA G., CIRILLI S., MARTINI R., PANZANELLI-FRATONI R., ZANINETTI L. & SALVINI-BONNARD G. (1990a) - *Reworked foraminifera in the Triassic Monte Facito formation Auctt., Lagonegro basin (southern Apennines, Italy)*. Boll. Soc. Geol. Ital., **109**, 143-149.

CIARAPICA G., CIRILLI S., MARTINI R., RETTORI R., SALVINI BONNARD G. & ZANINETTI L. (1990b) - *Carbonate buildups and associated facies in the Monte Facito formation (Southern Apennines)*. Boll. Soc. Geol. Ital., **109**, 151-164.

CIARAPICA G., CIRILLI S., PANZANELLI FRATONI R., PASSERI L. & ZANINETTI L. (1990c) - *The Monte Facito formation (southern Apennines)*. Boll. Soc. Geol. Ital., **109**, 135-142.

CIARAPICA G. & PASSERI L. (2000) - *Le facies del Triassico inferiore e medio (fm. di Monte Facito Auctt.) nelle aree di Sasso di Castalda e di Moliterno*. Boll. Soc. Geol. Ital., **119**, 339-378.

CIARCIA S., DI NOCERA S., MATANO F. & TORRE M. (2003) - *Evoluzione tettono-sedimentaria e paleogeografica dei depocentri «wedge-top» nell'ambito del «foreland basin system» pliocenico dell'Appennino meridionale (settore Irpino-Dauno)*. Boll. Soc. Geo. Ital., **122**, 117-137.

CIARCIA S., DI NOCERA S. & TORRE M. (1998) - *Sistemi di fan delta al margine orientale del bacino di Ariano (Pliocene inferiore, Appennino apulo-campano)*. Boll. Soc. Geol. Ital., **117**, 807-819.

CINQUE A., PATACCA E., SCANDONE P. & TOZZI M. (1993) - *Quaternary kinematic evolution of the Southern Apennines. Relationships between surface geological features and deep lithospheric structures*. Spec. Issue on the Workshop: «Modes of crustal deformation: from the brittle upper crust through detachments to the ductile lower crust» (Erice, 18-24 November 1991), Ann. Geofis., **36**, 249-260.

CIPOLLARI P. (1995) - *Modalità e tempi di propagazione del sistema catena-avanfossa nella zona di incontro tra Appennino settentrionale e Appennino centrale*. Univ. degli Studi di Roma «La Sapienza», Dottorato in Scienze della Terra (VII ciclo), Dissertazione Finale, 229 pp.

CIPOLLARI P. & COSENTINO D. (1995) - *Miocene unconformities in the Central Apennines: geodynamic significance and sedimentary basin evolution*. Tectonophysics, **252**, 375-389.

CIPOLLARI P. & COSENTINO D. (1999) - *Cronostratigrafia dei depositi neogenici del settore ernico-simbruino, Appennino centrale*. Boll. Soc. Geol. Ital., **118**, 439-459.

CIPOLLARI P., COSENTINO D., ESU D., GIROTTI O., GLIOZZI E. & PRATURLON A. (1999) - *Thrust-top lacustrine-lagoonal basin development in accretionary wedges: late messinian (Lago-Mare) episode in the central Apennines (Italy)*. Palaeogeogr. Palaeclimatol. Palaeoecol., **151**, 149-166.

CIPOLLARI P., COSENTINO D. & PAROTTO M. (1995) - *Modello cinematico-strutturale dell'Italia centrale*. Studi Geol. Camerti, Vol. Spec. **1995/2**, 135-143.

CIRRINCIONE R. & MONACO C. (1996) - *Evoluzione tettono-metamorfica dell'Unità del Frido (Appennino meridionale): nuovi dati microstrutturali*. Mem. Soc. Geol. Ital., **51**, 83-92.

CIVITELLI G. & CORDA L. (1988) - *Successioni flyschoidi e complessi alloctoni*. In: ACCORDI G. *et alii* Eds., «Lithofacies map of Latium-Abruzzi and neighbouring areas». C.N.R., Quaderni de La Ricerca Scientifica, **114** (P.F. Geodinamica, Monografie Finali, **5**), 93-168.

CLERMONTÉ J. (1977) - *La bordure abruzzaise sud-orientale et le haut Molise: histoire sédimentaire et tectonique comparée*. Riv. Ital. Paleont. Stratigr., **83**, 21-102.

CLERMONTÉ J. & PIRONON B. (1979) - *La plate-forme campano-abruzzaise de la Meta au Matese (Italie méridionale): différenciations au Paléogene et au Miocène, structures, relations avec les formations molisanes*. Bull. Soc. Geol. France, s. 7, **21**, 737-743.

CLIMACO A., BONI M., IANNACE A. & ZAMPARELLI V. (1997) - *Platform margins, microbial/serpulids bioconstructions and slope-to-basin sediments in the Upper Triassic of the «Verbicaro Unit» (Lucania and Calabria, Southern Italy)*. Facies, **36**, 37-56.

CNR-PROGETTO FINALIZZATO GEODINAMICA (1991) - S*tructural Model of Italy 1:500.000 and Gravity Map.* Quad. Ric. Sci., **3** (114), S.EL.CA., Firenze.

COCCO E. (1971) - *Note illustrative della Carta Geologica d'Italia alla scala 1:100.000. F. 209 Vallo della Lucania*. Serv. Geol. Ital., Roma, 45 pp.

COCCO E. (1972) - *Torbiditi calcaree ed arenacee nelle argille variegate dei Monti del Sannio (Campania)*. Mem. Soc. Geol. Ital., **11**, 145-159.

COCCO E., CRAVERO E., ORTOLANI F., PESCATORE T., RUSSO M., SGROSSO I. & TORRE M. (1972) - *Les faciès sedimentaires miocènes du Bassin Irpinien (Italie Meridionale)*. Atti Accad. Pontan., **21**, 13 pp.

COCCO E., CRAVERO E., ORTOLANI F., PESCATORE T., RUSSO M., TORRE M. & COPPOLA L. (1974) - *Le unità irpine nell'area a nord* *di Monte Marzano; Appennino Meridionale*. Mem. Soc. Geol. Ital., **18**, 607-654.

Cocco E. & Pescatore T. (1968) - *Scivolamenti gravitativi (olistostromi) nel flysch del Cilento (Campania)*. Boll. Soc. Natur. Napoli, **77**, 51-91.

Colacicchi R. (1966) - *Le caratteristiche della facies abruzzese alla luce delle moderne indagini geologiche*. Mem. Soc. Geol. Ital., **5**, 1-18.

Colacicchi R. (1967) - *Geologia della Marsica orientale*. Geologica Rom., **6**, 189-316.

Colacicchi R., Devoto G. & Praturlon A. (1967) - *Depositi messiniani oligoalini al bordo orientale del Fucino e descrizione di Tyrrhenocythere ruggierii Devoto, nuova specie di Ostracode*. Boll. Soc. Geol. Ital., **86**, 21-37.

Colacicchi R. & Praturlon A. (1965a) - *Il problema delle facies nel Giurese della Marsica nord-orientale*. Boll. Soc. Geol. Ital., **84**, 55-86.

Colacicchi R. & Praturlon A. (1965b) - *Stratigraphical and paleogeographical investigations on the Mesozoic shelf-edge facies in eastern Marsica (central Apennines, Italy)*. Geologica Rom., **4**, 89-118.

Colalongo M.L., Pasini G. & Carobene L. (1973) - *Su alcune sezioni neogeniche presso la costa tirrenica tra Salerno e Livorno*. G. Geol., s. 2, **39**, 101-103.

Colella A. (1979) - *Medium-scale tractive bedforms and structures in Gorgoglione flysch (lower Miocene; southern Apennines, Italy)*. Boll. Soc. Natur. Napoli, **98**, 483-494.

Colella A. & Zuffa G.G. (1988) - *Megastrati carbonatici e silicoclastici della formazione di Albidona (Miocene, Appennino meridionale): implicazioni paleogeografiche*. Mem. Soc. Geol. Ital., **41**, 791-807.

Compagnoni B., Galluzzo F. & Santantonio M. (1990) - *Le Brecce della Renga (Monti Simbruini): un esempio di sedimentazione controllata dalla tettonica*. Mem. Descr. Carta Geol. d'It., **38**, 59-76.

Coppa M.G. (1967) - *La microfauna delle argille mioceniche dei dintorni di Salerno*. Boll. Soc. Natur. Napoli, **76**, 3-75.

Corrado S., Di Bucci D., Naso G. & Butler R.W.H. (1997) - *Thrusting and strike-slip tectonics in the Alto Molise region (Italy): implications for the Neogene-Quaternary evolution of the Central Apennine orogenic system*. Journ. Geol. Soc. London, **154**, 679-688.

Corrado S., Di Bucci D., Naso G. & Damiani A.V. (1998a) - *Rapporti tra le grandi unità stratigrafico-strutturali dell'Alto Molise (Appennino Centrale)*. Boll. Soc. Geol. Ital., **117**, 761-776.

Corrado S., Di Bucci D., Naso G. & Faccenna C. (1998b) - *Influence of palaeogeography on thrust system geometries: an analogue modelling approach for the Abruzzi-Molise (Italy) case history*. Tectonophysics, **296**, 437-453.

Corrado S., Miccadei E., Parotto M. & Salvini F. (1996) - *Evoluzione tettonica del settore di Montagna Grande (Appennino Centrale): il contributo di nuovi dati geometrici, cinematici e paleogeotermici*. Boll. Soc. Geol. Ital., **115**, 325-338.

Cosentino D., Carboni M.G., Cipollari P., Di Bella L., Florindo F., Laurenzi M.A. & Sagnotti L. (1997) - *Integrated stratigraphy of the Tortonian/Messinian boundary: the Pietrasecca composite section (central Apennines, Italy)*. Eclogae. Geol. Helv., **90**, 229-244.

Cosentino D., Cipollari P., Di Donato V., Sgrosso I. & Sgrosso M. (2001) - *The Volsci Range in the kinematic evolution of the northern and southern Apennine orogenic system*. Boll. Soc. Geol. Ital., Vol. Spec. **1**, 209-218.

Crescenti U. (1966) - *Osservazioni sulla stratigrafia dell'Appennino meridionale alla luce delle recenti ricerche micropaleontologiche*. Boll. Soc. Geol. Ital., **85**, 541-579.

Crescenti U. (1967) - *Sulla biostratigrafia del Miocene medio del Molise occidentale*. Boll. Soc. Geol. Ital., **86**, 345-366.

Crescenti U. (1969a) - *Stratigrafia della serie calcarea dal Lias al Miocene nella regione marchigiano-abruzzese* (Parte I. *Descrizione delle serie stratigrafiche*). Mem. Soc. Geol. Ital., **8**, 155-204.

Crescenti U. (1969b) - *Biostratigrafia delle facies mesozoiche dell'Appennino centrale: correlazioni*. Geologica Rom., **8**, 15-40.

Crescenti U. (1975) - *Sul substrato pre-pliocenico dell'avanfossa appenninica dalle Marche allo Ionio*. Boll. Soc. Geol. Ital., **94**, 583-634.

Crescenti U., Biondi R., Raffi I. & Rusciadelli G. (2002) - *The S. Nicolao section (Montagna della Majella): a reference section for the Miocene-Pliocene boundary in the Abruzzi area*. Boll. Soc. Geol. Ital., Vol. Spec. **1**, 509-516.

Crescenti U., Crostella A., Donzelli G. & Raffi G. (1969) - *Stratigrafia della serie calcarea dal Lias al Miocene nella regione marchigiano-abruzzese.* (Parte II. *Litostratigrafia, Biostratigrafia, Paleogeografia)*. Mem. Soc. Geol. Ital., **8**, 343-420.

Crescenti U., D'Amato C., Balduzzi A. & Tonna M. (1980) - *Il Plio-Pleistocene del sottosuolo abruzzese-marchigiano tra Ascoli Piceno e Pescara*. Geologica Rom., **19**, 63-84.

Crescenti U. & Vighi L. (1970) - *Risultati delle ricerche eseguite sulle formazioni bauxitiche cretaciche del Casertano e del Matese, in Campania*. Mem. Soc. Geol. Ital., **9**, 401-434.

Crisci G.M., Critelli S. & De Rosa R. (1988) - *Vulcanismo sinsedimentario nella successione terrigena della formazione di San Mauro (Miocene inferiore, Unità del Cilento), Appennino meridionale*. Mineral. Petrogr. Acta, **31**, 159-178.

Critelli S. (1987) - *Petrologia delle areniti della formazione di San Mauro (Eocene superiore-Oligocene superiore, Bacino del Cilento), Appennino meridionale*. Mem. Soc. Geol. Ital., **38**, 601-619.

Critelli S. (1990) - *Detrital modes and provenance of the Cilento turbidite basin (Southern Apennines, Italy)*. 13th Int. Sedimentological Congress of the Int. Assoc. Sediment. (Nottingham, England, 26-31 August 1990), 54-56.

Critelli S., De Rosa R., Sonnino M. & Zuffa G.G. (1990) - *Significato dei depositi vulcanoclastici della formazione delle Tufiti di Tusa (Miocene inferiore, Lucania meridionale)*. Boll. Soc. Geol. Ital., **109**, 743-762.

Critelli S. & Le Pera E. (1995a) - *La formazione di Castelvetere nell'evoluzione petrostratigrafica dell'avanfossa del Tortoniano-Messiniano dell'Appennino meridionale*. Boll. Soc. Geol. Ital., **114** (3), 615-634.

Critelli S. & Le Pera E. (1995b) - *Tectonic evolution of the Southern Apennines thrust-belt (Italy) as reflected in modal compositions of Cenozoic sandstone*. Journ. Geol., **103**, 95-105.

Critelli S. & Le Pera E. (1990) - *Composizione e provenienza delle areniti delle formazioni del Torrente Bruca (Gruppo del Cilento) e di Monte Sacro (Cilento, Appennino meridionale)*. G. Geol., s. 3, **52**, 121-133.

Critelli S. & Le Pera E. (1991) - *Composizione e provenienza delle areniti delle formazioni del Torrente Bruca (Gruppo del Cilento) e di Monte Sacro (Cilento, Appennino meridionale)*. G. Geol., s. 3, **52**, 121-133.

Critelli S. & Le Pera E. (1994) - *Detrital modes and provenance of Miocene sandstones and modern sands of the Southern Apennines thrust-top basins (Italy*). J. Sediment. Res., **A64** (4), 824-835.

Critelli S. & Le Pera E. (1995b) - *Tectonic evolution of the Southern Apennines thrust-belt (Italy) as reflected in modal compositions of cenozoic sandstone*. Journ. Geol., **103**, 95-105.

Critelli S. & Lojacono F. (1988) - *Provenienza e dispersione dei sedimenti nel Flysch di Gorgoglione (Langhiano-Tortoniano, Appennino lucano): implicazioni sull'evoluzione delle mode detritiche arenacee nell'Orogene sudappenninico*. Mem. Soc. Geol. Ital., **41**, 809-826.

Crostella A. & Strocchi M. (1969) - *Geologia e geofisica della zona di Tricarico (Lucania)*. Boll. Soc. Geol. Ital., **88**, 217-234.

Crostella A. & Vezzani L. (1964) - *La geologia dell'Appennino foggiano*. Boll. Soc. Geol. Ital., **83**, 121-141.

Damiani A.V. (1970) - *Osservazioni geologiche in alcune tavolette del F° 220 nella Calabria nord-occidentale.* Parte I. *Stratigrafia.* Boll. Soc. Geol. Ital., **89**, 65-80.

Damiani A.V., Catenacci V., Molinari V. & Pichezzi R.M. (1992) - *Lito-biofacies del Triassico superiore-Dogger nei Monti Simbruini e nei Monti Ernici (Lazio*). In: Tozzi M., Cavinato G.P. & Parotto M. Eds., «Studi preliminari all'acquisizione dati del profilo CROP 11 Civitavecchia-Vasto», AGIP-CNR-ENEL, Studi Geol. Camerti, Vol. Spec., 1991-2, 181-186.

Damiani A.V., Chiocchini M., Colacicchi R., Mariotti G., Parotto M., Passeri L. & Praturlon A. (1992) - *Elementi litostrati-*

grafici per una sintesi delle facies carbonatiche meso-cenozoiche dell'Appennino centrale. In: TOZZI M., CAVINATO G.P. & PAROTTO M. Eds., «Studi preliminari all'acquisizione dati del profilo CROP 11 Civitavecchia-Vasto», AGIP-CNR-ENEL, Studi Geol. Camerti, Vol. Spec., 1991-2, 187-213.

D'ANDREA M. (1988) - *Evoluzione paleogeografica di un settore del margine sudorientale della piattaforma laziale-abruzzese durante il Mesozoico*. Univ. degli Studi di Perugia, Dottorato di Ricerca, Dissertaziopne Finale.

D'ANDREA M., MICCADEI E. & PRATURLON A. (1992) - *Rapporti tra il margine orientale della piattaforma laziale-abruzzese ed il margine occidentale della piattaforma Morrone-Pizzalto-Rotella*. In: TOZZI M., CAVINATO G.P. & PAROTTO M. Eds., «Studi preliminari all'acquisizione dati del profilo CROP 11 Civitavecchia-Vasto», AGIP-CNR-ENEL, Studi Geol. Camerti, Vol. Spec., 1991-2, 389-395.

D'ANDREA M. & URGERA A. (1986) - *Correlazioni stratigrafiche ed alcune considerazioni paleogeografiche sul Mesozoico dei Monti della Meta (Appennino centro-meridionale)*. Mem. Soc. Geol. Ital., **35**, 27-32.

D'ANDREA S., PASI R., BERTOZZI G. & DATTILO P. (1993) - *Geological model, advanced methods help unlock oil in Italy's Apennines*. Oil and Gas Journ., Aug. 1993, 53-57.

DANESE E. (1998) - *Evoluzione stratigrafica della Maiella meridionale tra il Maastrichtiano e il Messiniano*. Univ. degli Studi di Pisa, Dottorato di Ricerca in Scienze della Terra, Dissertazione Finale, 78 pp.

DANESE E. (1999) - *Upper Miocene carbonate ramp deposits from the southernmost part of Maiella Mountain (Abruzzo, Central Italy)*. Facies, **41**, 41-54.

D'ARGENIO B. (1967) - *Geologia del gruppo del Taburno-Camposauro (Appennino campano)*. Atti Accad. Sci. Fis. Mat. Napoli, s. 3, **6**, 35-218.

D'ARGENIO B. (1974) - *Le piattaforme carbonatiche periadriatiche. Una rassegna di problemi nel quadro geodinamico mesozoico dell'area mediterranea*. Mem. Soc. Geol. Ital., **13**, 137-159.

D'ARGENIO B., FERRERI V. & RASPINI A. (1992) - *A CM-scale study of shallow water cretaceous deposits formed under high frequency eustatic regime Monti di Sarno (Southern Italy). A sedimentologic approach to microstratigraphy*. Boll. Soc. Geol. Ital., **111**, 399-407.

D'ARGENIO B. & PESCATORE T. (1962) - *Stratigrafia del Mesozoico nel gruppo del Monte Maggiore (Caserta)*. Boll. Soc. Natur. Napoli, **71**, 55-61.

D'ARGENIO B., PESCATORE T. & SCANDONE P. (1972) - *Schema geologico dell'Appennino Meridionale (Campania e Lucania)*. Atti del Conv. Moderne vedute sulla geologia dell'Appennino (Roma 16-18 Febbraio 1972), Accad. Naz. Lincei, Quad., **183**, 49-72.

D'ARGENIO B., PESCATORE T. & SCANDONE P. (1975) - *Structural pattern of the Campania-Lucania Apennines*. Quad. Ric. Sci., **90**, 313-327.

D'ARGENIO B. & SCANDONE P. (1969) *Jurassic facies pattern in the Southern Apennines (Campania-Lucania)*. Ann. Geol. Inst. Publ. Hung., **54**, 383-396.

DAZZARO L., DI NOCERA S., PESCATORE T., RAPISARDI L., ROMEO M., RUSSO B., SENATORE M.R. & TORRE M. (1988a) - *Geologia del margine della catena appenninica tra il F. Fortore ed il T. Calaggio (Monti della Daunia-Appennino Meridionale)*. Mem. Soc. Geol. Ital., **41**, 411-422.

DAZZARO L., IANNONE A., MORESI M., RAPISARDI L. & ROMEO M. (1988b) - *Stratigrafia, sedimentologia e geochimica delle successioni messiniane dell'Irpinia al confine con la Puglia*. Mem. Soc. Geol. Ital., **41**, 841-859.

DAZZARO L. & RAPISARDI L. (1983) - *La successione evaporitica di M. Gessara, presso Scampitella (Appennino meridionale)*. Boll. Soc. Geol. Ital., **102**, 191-200.

DAZZARO L. & RAPISARDI L. (1984) - *Nuovi dati stratigrafici, tettonici e paleogeografici della parte settentrionale dell'Appennino Dauno*. Boll. Soc. Geol. Ital., **103**, 51-58.

DAZZARO L. & RAPISARDI L. (1987) - *Osservazioni geologiche sull'Appennino dauno*. Mem. Soc. Geol. Ital., **38**, 241-246.

DAZZARO L. & RAPISARDI L. (1996) - *Schema geologico del margine appenninico tra il F. Fortore e il F. Ofanto*. Mem. Soc. Geol. Ital., **51**, 143-147.

DE ALFIERI A., GUZZI R., SACCHI M., D'ARGENIO B., PERRONE V. & ZAMPARELLI V. (1986) - *Monte Foraporta unit: a minor element of southern Apennine nappe pile. Stratigraphic and tectonic study*. Rend. Soc. Geol. Ital., **9**, 171-178.

DE BLASIO I., LIMA A.M., PERRONE V. & RUSSO M. (1978) - *Studio petrografico e biostratigrafico di una sezione della Formazione del Saraceno nell'area tipo (Calabria nord-orientale)*. Riv. Ital. Paleont. Stratigr., **84**, 947-972.

DE CAPOA BONARDI P. (1969) - *Le Daonelle e le Halobie della serie calcareo-silico-marnosa della Lucania (Appennino Meridonale) Studio paleontologico e biostratigrafico*. Mem. Soc. Natur. Napoli, suppl. Boll., **78**, 1-130.

DE CAPOA BONARDI P. (1984) - *Halobia zones in the pelagic Late Triassic sequences of the Central Mediterranean area (Greece, Yugoslavia, southern Apennines, Sicily)*. Boll. Soc. Paleont. Ital., **23**, 91-102.

DE CASTRO P. (1962a) - *Sulla presenza del Lias negli «Scisti Silicei» di Giffoni Vallepiana nel Salernitano*. Boll. Serv. Geol. Ital., **83**, 3-32.

DE CASTRO P. (1962b) - *Il Giura-Lias dei Monti Lattari e dei rilievi ad ovest della Valle dell'Irno e della Piana di Montoro*. Boll. Soc. Natur. Napoli, **71**, 3-34.

DE CASTRO P. (1987) - *Le facies di piattaforma carbonatica del Giurassico italiano: diffusione areale e lineamenti biostratigrafici*. Boll. Soc. Paleont. Ital., **26** (3), 309-325.

DE CASTRO P. (1990) - *Studies on the triassic carbonates of the Salerno province (southern Italy): the Croci d'Acerno sequence*. Boll. Soc. Geol. Ital., **109**, 187-217.

DE CASTRO COPPA M.G., MONTCHARMONT ZEI M., PESCATORE T., SGROSSO I. & TORRE M. (1969) - *Depositi miocenici e pliocenici ad est del Partenio e del Taburno (Campania)*. Atti Accad. Gioenia Sci. Nat. Catania, s. 7, **1**, 479-512.

DE CORSA S., SCROCCA D. & TOZZI M. (1998) - *Geologia dell'anticlinale del Matese e implicazioni per la tettonica dell'Appennino molisano*. Boll. Soc. Geol. Ital., **117**, 419-441.

DE LA PIERRE F. (1994) - *Stratigrafia della successione cretacico-paleogenica affiorante tra la Valle del Velino e la Valle dell'Aterno (Appennino Centrale)*. Atti Tic. Sci. Terra, s. spec., **2**, 119-130.

DE LA PIERRE F. & BRUZZONE B. (1991) - *Analisi sedimentologica e biostratigrafica di alcune sezioni paleogeniche della catena del Gran Sasso*. Boll. Soc. Geol. Ital., **110**, 25-34.

DE LA PIERRE F. & CLARI P. (1994) - *Discontinuità stratigrafiche ed evoluzione tettonico-sedimentaria paleogenica della catena del Gran Sasso d'Italia*. Atti Tic. Sci. Terra, s. spec., **2**, 97-117.

DE PIPPO T. & VALENTE A. (1991) - *Osservazioni sedimentologiche preliminari sui «Conglomerati di Monte Sacro» (Campania)*. Boll. Soc. Geol. Ital., **110**, 47-51.

DEVOTO G. (1969) - *Alcune considerazioni sul Miocene terminale laziale-abruzzese*. Atti Accad. Gioenia Sci. Nat. Catania, s. 7, **1**, Suppl. Sci. Geol., 17-24.

DEVOTO G. (1970) - *Sguardo geologico dei Monti Simbruini (Lazio nord-orientale)*. Geologica Rom., **9**, 127-136.

DE WEVER P. & MICONNET P. (1985) - *Datations directes des radiolarites du bassin du Lagonegro (Lucanie, Italie méridionale). Implications et consequences*. Rev. Españ. Micropaleont., **17**, 373-402.

DI BUCCI D. (1993) - *Rapporti tra piattaforme carbonatiche e «alloctono» nell'area Alto Aventino-Sangro e relativo quadro geodinamico*. Univ. degli Studi di Roma «La Sapienza», Dottorato di Ricerca in Scienze della Terra-V Ciclo, Dissertazione Finale, 298 pp.

DI BUCCI D. (1995) - *Rapporti tra piattaforme carbonatiche e «alloctono» lungo la media Valle del Sangro*. Boll. Soc. Geol. Ital., **114**, 443-463.

DI BUCCI D., CORRADO S., NASO G., PAROTTO M. & PRATURLON A. (1999) - *Evoluzione tettonica neogenico-quaternaria dell'area molisana*. Boll. Soc. Geol. Ital., **118**, 13-30.

DI BUCCI D. & SCROCCA D. (1997) - *Assetto tettonico dell'alto Molise (Appennino Centrale): considerazioni stratigrafiche e strutturali sull'Unità di Montenero Val Cocchiara*. Boll. Soc. Geol. Ital., **116**, 221-236.

DIETRICH D., LORENZONI S., SCANDONE P., ZANETTIN-LORENZONI E. & DI PIERRO M. (1976) - *Contribution to the knowledge of the tectonic units of Calabria. Relationships between composition of K-white micas and metamorphic evolution*. Boll. Soc. Geol. Ital., **95**, 193-217.

DIETRICH D. & SCANDONE P. (1972) - *The position of the basic and ultrabasic rocks in the tectonic units of the southern Apennines.* Atti Accad. Pontaniana, **21**, 15 pp.

DI GIROLAMO P., MORRA V. & GALDI V. (1994) - *Metabasiti (MORB e WPB) nei sedimenti delle unità del Cilento e di Lagonegro (Appennino meridionale, Italia): affinità petrogenetiche ed implicazioni geodinamiche*. Boll. Soc. Geol. Ital., **113**, 233-242.

DI GIROLAMO P., MORRA V. & PERRONE V. (1992) - *Ophiolitic olistoliths in Middle Miocene turbidites (Cilento Group) at Mt. Centaurino (Southern Apennines, Italy).* Ofioliti, **17**, 199-217.

DI LUZIO E., PANICCIA D., PITZIANTI P., SANSONNE P. & TOZZI M. (1999) - *Evoluzione tettonica dell'Alto Molise*. Boll. Soc. Geol. Ital., **118**, 287-315.

DI NOCERA S., MATANO F. & TORRE M. (2001) - *Le unità sannitiche Auct. (Appennino centro-meridionale): rassegna delle correnti interpretazioni stratigrafiche e paleogeografiche e nuova ipotesi interpretativa con l'introduzione dell'unità di Frigento.* Studi Geol. Camerti, n.s., **1**, 87-102.

DI NOCERA S., ORTOLANI F., TORRE M. & RUSSO B. (1981) - *Evoluzione sedimentaria e cenni di paleogeografia del Tortoniano-Messiniano dell'Irpinia occidentale*. Boll. Soc. Natur. Napoli, **90**, 131-166.

DI NOCERA S., PAGANO C., RUSSO B. & TORRE M. (1988) - *Successioni del bacino irpino nei dintorni di Celenza Valfortore (Appennino Dauno)*. Mem. Soc. Geol. Ital., **41**, 423-430.

DI NOCERA S., RUSSO B. & TORRE M. (1983) - *I depositi marini del ciclo Pliocene inferiore-medio nei dintorni di Vietri di Potenza*. Rend. Accad. Sci. Fis. Mat. Soc. Naz. Sci. Lett. Arti Napoli, s. 4, **60**, 87-105.

DI NOCERA S. & TORRE M. (1987) - *Geologia dell'area compresa tra Deliceto e Scampitella (Appennino foggiano).* Boll. Soc. Geol. Ital., **106**, 351-364.

DI NOCERA S., TORRE M. & VITI P. (1993b) - *Le arenarie di Caiazzo nell'evoluzione tortoniano-messiniana dell'Appennino campano*. Atti Tic. Sci. Terra, **36**, 165-182.

DI STASO A. & GIARDINO S. (2002) - *New integrate biostratigraphic data about the Saraceno formation (North-Calabrian Unit; Southern Apennines).* Boll. Soc. Geo. Ital., Vol. Spec. **1**, 517-526.

D'ONOFRIO S., GIANNELLI L., IACCARINO S., MORLOTTI E., ROMEO M., SALVATORINI G., SAMPÒ M. & SPROVIERI R. (1975) - *Planktonic foraminifera of the upper Miocene from some italian sections and the problem of the lower boundary of the Messinian*. Boll. Soc. Paleont. Ital., **14**, 177-196.

DONZELLI G. (1969) - *Studio geologico della Maiella*. A cura di U. CRESCENTI, Tip. Di Virgilio, Chieti, 1997, 49 pp.

DONZELLI G. & CRESCENTI U. (1970) - *Segnalazione di una microbiofacies permiana; probabilmente rimaneggiata, nella formazione di M. Facito (Lucania occidentale)*. Boll. Soc. Natur. Napoli, **79**, 19 pp.

EBERLI G.P., BERNOULLI D., SANDERS D. & VECSEI A. (1993) - *From aggradation to progradation: the Maiella platform, Abruzzi, Italy.* In: SIMO T., SCOTT R.W. & MASSE J.P. Eds., «Cretaceous Carbonate Platforms», Mem. Amer. Assoc. Petroleum Geol., **56**, 213-232.

FERRANTI L. & PAPPONE G. (1992) - *Nuovi dati sui rapporti tettonici tra i terreni lagonegresi e quelli della piattaforma carbonatica campano-lucana nei dintorni di Campagna (Salerno-Appennino meridionale).* Rend. Accad. Sci. Fis. Mat. Soc. Naz. Sci. Lett. Arti Napoli, s. 4, **59**, anno 131, 103-119.

FOLLADOR U. (1967) - *Il Pliocene ed il Pleistocene dell'Italia centro-meridionale, versante adriatico. Biostratigrafia*. Boll. Soc. Geol. Ital., **86**, 565-584.

FORNELLI A., LOSITO R., GUAGLIARDI A. & MASSENZIO A. (1989) - *Provenienza delle Arenarie di Corleto*. G. Geol., s. 3, **51**, 63-79.

GALLICCHIO S. & MAIORANO P. (1999) - *Revised stratigraphy of the Serra Palazzo formation, a Miocene foredeep turbidite succession of the Southern Apennines (Italy).* Riv. Ital. Paleont. Stratigr., **105** (2), 287-302.

GALLICCHIO S., MARCUCCI M., PIERI P., PREMOLI SILVA I., SABATO L. & SALVINI G. (1996) - *Stratigraphical data from a Cretaceous claystones sequence of the «Argille Varicolori» in the Southern Apennines (Basilicata, Italy).* Palaeopelagos, **6**, 261-272.

GHISETTI F., FOLLADOR U., CASNEDI R. & VEZZANI L. (1994) - *Assetto tettonico delle zone esterne dell'Appennino abruzzese: elementi di analisi stratigrafico-strutturali*. Atti Tic. Sci. Terra, S. Spec. **2**, 5-43.

GHISETTI F. & VEZZANI L. (1986a) - *Assetto geometrico ed evoluzione strutturale della catena del Gran Sasso tra Vado di Siella e Vado di Corno*. Boll. Soc. Geol. Ital., **105**, 131-171.

GHISETTI F. & VEZZANI L. (1986b) - *Carta geologica del Gruppo M. Siella-M. Camicia-M. Prena-M. Brancastello (Gran Sasso d'Italia, Abruzzo), 1:25.000.* S.EL.CA, Firenze.

GHISETTI F. & VEZZANI L. (1988) - *Rapporti strutturali tra il fronte del Gran Sasso ed il flysch della Laga (Appennino centrale).* Mem. Soc. Geol. Ital., **41**, 1171-1178.

GHISETTI F. & VEZZANI L. (1990) - *Stili strutturali nei sistemi di sovrascorrimento della Catena del Gran Sasso (Appennino centrale).* In: BOCCALETTI M., DEIANA G. & PAPANI G. Eds., Atti del Convegno «Neogene Thrust Tectonics. Esempi da Alpi meridionali, Appennino e Sicilia» (Parma, 8-9 giugno 1990), Studi Geol. Camerti, Vol. Spec. 1990, 37-50.

GHISETTI F. & VEZZANI L. (1991) - *Thrust belt development in the central Apennines (Italy): northward polarity of thrusting and out-of-sequence deformations in the Gran Sasso chain*. Tectonics, **10**, 904-919.

GHISETTI F. & VEZZANI L. (1997) - *Interfering paths of deformation and development of arcs in the fold-and-thrust belt of the central Apennines (Italy).* Tectonics, **16** (3), 523-536.

GHISETTI F., VEZZANI L., BIGOZZI A., BLUMETTI A.M., BRUZZONE B., CELLINI M., CENTAMORE E., CLARI P.A., DE LA PIERRE F., FOLLADOR U., FREZZOTTI M., GIRAUDI C., PITTORI C. & RIDOLFI M. (1990) - *Carta Geologica del Gran Sasso d'Italia (da Vado di Corno a Passo delleCapannelle), 1:25.000*. S.E.L.CA., Firenze.

GIANNINI E., LAZZAROTTO A. & ZAMPI M. (1970) - *Studio stratigrafico e micropaleontologico del Giurassico della Montagna dei Fiori (Ascoli Piceno-Teramo).* Mem. Soc. Geol. Ital., **9**, 29-53.

GIARDINI D. & VELONÀ M. (1991) - *The deep seismicity of the Tyrrhenian Sea*. Terra Nova, **3**, 57-64.

GIOVANNELLI A. (1992) - *Le unità carbonatiche circostanti la pianura di Sulmona (AQ). Stratigrafia, analisi di facies e paleogeografia.* Università degli Studi di Roma «La Sapienza», Dottorato di Ricerca, Dissertazione finale.

GIROTTI O. & PAROTTO M. (1969) - *Il Mio-Pliocene di Ascoli Piceno*. Atti Accad. Gioenia Sci. Nat. Catania, s. 7, **1**, 127-174.

GRANDJACQUET C. (1963) - *Schéme structural de l'Apennin campano-lucanien (Italie).* Rev. Géogr. Phys. Géol. Dyn., s. 2, **5**, 185-202.

GRANDJACQUET C. (1969) - *Les phases tectoniques et le métamorphisme tertiaire de la Calabre du Nord et de la Campanie du Sud (Italie).* C.R. Acad. Sci. Paris, s. D, **269**, 1819-1822.

GRANDJACQUET C. (1971) - *Les séries transgressives d'age oligo-miocène inférieur de l'Apenninn méridional; conséquences tectoniques et paléogeographiques*. Bull. Soc. Géol. France, **13**, 315-320.

GRANDJACQUET C. & GRANDJACQUET M.J. (1962) - *Géologie de la zone de Diamante-Verbicaro (Calabre).* Geologica Rom., **1**, 297-312.

GUERRERA F. (1978) - *Stratigrafia e sedimentologia dei livelli «tripolacei» del Miocene inferiore-medio appenninico*. Boll. Soc. Geol. Ital., **99**, 233-262.

GUERRERA F. & COCCIONI R. (1984) - *Caratteristiche sedimentologiche e micropaleontologiche di successioni «tripolacee» plioceniche dell'Appennino lucano*. Boll. Soc. Geol. Ital., **103**, 205-223.

HACCARD D., LORENZ C. & GRANDJACQUET C. (1972) - *Essai sur l'evolution tectogénetique de la liaison Alpes-Apennins (de la Ligurie à la Calabrie).* Mem. Soc. Geol. Ital., **11**, 309-341.

HIPPOLYTE J.C., ANGELIER J. & ROURE F. (1994) - *A major geodynamic change revealed by Quaternary stress patterns in the Southern Apennines (Italy).* Tectonophysics, **230**, 199-210.

IANNACE A., BONI M. & ZAMPARELLI V. (1995) - *The middle-upper Triassic of the San Donato Unit Auct. (Northern Calabria): stratigraphy, paleogeography and tectonic implications.* Riv. Ital. Paleont. Stratigr., **101** (3), 301-324.

IANNACE A. & ZAMPARELLI V. (2002) - *Upper Triassic platform margi n biofacies and the paleogeography of Southern Apennines*. Palaeogeogr. Palaeclimatol. Palaeoecol., **179**, 1-18.

IETTO A. (1969) - *Assetto strutturale e ricostruzione paleogeografica del Matese occidentale (Appennino meridionale).* Mem. Soc. Natur. Napoli, Suppl., **78**, 441-471.

IETTO A. & BARILARO A.M. (1993) - *L'Unità di San Donato quale margine deformato Cretacico-Paleogene del bacino di Lagonegro (Appennino Meridionale-Arco Calabro)*. Boll. Soc. Geol. Ital., **112**, 1-20.

IETTO A., PESCATORE T. & COCCO E. (1965) - *Il flysch mesozoico-terziario del Cilento occidentale*. Boll. Soc. Natur. Napoli, **74**, 396-402.

IEZZI T. & SBRANA A. (1991) - *Studio geologico delle «Falde molisane» nell'area compresa tra i paesi di Villa Santa Maria e Roccascalegna*. Tesi di Laurea inedita, Università di Pisa, Facoltà di Scienze Matematiche Fisiche e Naturali, Corso di Laurea in Scienze Geologiche, Anno Accad. 1990-1991, 135 pp.

IMPROTA L., IANNACCONE G., CAPUANO P., ZOLLO A. & SCANDONE P. (2000) - *Inferences on the upper crustal structure of Southern Apennines (Italy) from seismic refraction investigations and subsurface data*. Tectonophysics, **317** (3-4), 273-297.

INVERNIZZI C. & RIDOLFI M. (1992) - *Analisi geologico-strutturale nelle formazioni oligo-mioceniche dell'area della Montagna dei Fiori (Marche meridionali)*. Studi Geol. Camerti, **12**, 79-91.

IORIO M., NARDI G., PIERATTINI D. & TARLING D.H. (1996) - *Paleomagnetic evidence for block rotaion in the Matese Mountains, Southern Apennine, Italy*. In: MORRIS A. & TARLING D.H. Eds., «Paleomagnetic and Tectonics of the Mediterranean Region». Geol. Soc. London, Special Publ., **105**, 133-139.

IPPOLITO F., D'ARGENIO B., PESCATORE T. & SCANDONE P. (1975) - *Structural-stratigraphic units and tectonic framework of Southern Apennines.* In SQUYRES C. Ed., Geology of Italy, Earth Sci. Soc. Lybian Arab Republ., 317-328.

IPPOLITO F., ORTOLANI F. & RUSSO M. (1973) - *Struttura marginale tirrenica dell'Appennino campano: reinterpretazione di dati di antiche ricerche di idrocarburi*. Mem. Soc. Geol. Ital., **12**, 227-250.

KNOTT S.D. (1987) - *The Liguride complex of southern Italy - a Cretaceous to Paleogene accretionary wedge*. Tectonophysics, **142**, 217-226.

KNOTT S.D. (1994) - *Structure, kinematics and metamorphism in the Liguride Complex, southern Apennines, Italy*. Journ. Struct. Geol., **16** (8), 1107-1120.

KOOPMAN A. (1954) - *Detachment Tectonics in the Central Apennines, Italy.* Geologica Ultraiect., **30**, 155 pp.

LA BELLA G., BERTELLI L. & SAVINI L. (1996) - *Monte Alpi 3D, a challenging 3D survey in the Apenninic Range, Southern Italy.* First Break, **14** (7), 285-294.

LAMPERT S.A., LOWRIE W., HIRT A.M., BERNOULLI D. & MUTTI M. (1997) - *Magnetic and sequence stratigraphy of redeposited Upper Cretaceous limestones in the Montagna della Maiella, Abruzzi, Italy*. Earth and Planet. Sci. Lett., **150**, 79-93.

LANZAFAME G., SPADEA P. & TORTORICI L. (1978) - *Provenienza ed evoluzione dei flysch cretaceo-eocenici della regione calabro-lucana. II. Relazioni tra ofioliti e flysch calabro-lucano*. Ofioliti, **3**, 189-210.

LANZAFAME G., SPADEA P. & TORTORICI L. (1979a) - *Mesozoic ophiolites of Northern Calabria and Lucanian Apennine (Southern Italy)*. Ofioliti, **4**, 173-182

LANZAFAME G., SPADEA P. & TORTORICI L. (1979b) - *Relazioni stratigrafiche tra ofioliti e Formazione del Frido nella Calabria settentrionale e nell'Appennino lucano.* Ofioliti, **4**, 178-182.

LANZAFAME G. & TORTORICI L. (1976) - *Osservazioni geologiche sul medio e basso bacino del F. Biferno (Molise, Italia centro-meridionale).* Geologica Rom., **15**, 199-222.

LENTINI F. (1979) - *Le Unità Sicilidi della Val d'Agri (Appennino lucano)*. Geologica Rom., **18**, 1979, 215-224.

LENTINI F. Ed. (1991) - *Carta geologica del Bacino del Fiume Agri*. Regione Basilicata-Dipartimento Assetto del Territorio, S.EL.CA., Firenze.

LENTINI F., CARBONE S., CATALANO S. & MONACO C. (1987) - *Confronti sedimentologico-petrografici e posizione strutturale dei flysch di Albidona e di Gorgoglione nella media val d'Agri (Appennino lucano).* Mem. Soc. Geol. Ital., **38**, 259-273.

LENTINI F., CARBONE S., DI STEFANO A. & GUARNIERI P. (2002) - *Stratigraphical and structural constraints in the Lucanian Apennines (southern Italy): tools for reconstructing the geological evolution.* Journ. Geodynamics, **34**, 141-158.

LENTINI F., CATALANO S. & CARBONE S. (1996) - *The external thrust system in Southern Italy: a target for petroleum exploration.* Petroleum Geosci., **2**, 333-342.

LOJACONO F. (1974) - *Osservazioni sulle direzioni delle paleocorrenti nel Flysch di Gorgoglione (Lucania)*. Boll. Soc. Geol. Ital., **93**, 1127-1155.

LOJACONO F. (1981) - *Contributo alla ricostruzione paleogeografica del bacino di sedimentazione del flysch di Gorgoglione (Lucania)*. Boll. Soc. Geol. Ital., **100**, 193-211.

LOJACONO F. (1993) - *Geometrie e caratteri deposizionali dei corpi arenacei nella successione stratigrafica del flysch di Gorgoglione (Miocene superiore, Appennino meridionale)*. Boll. Soc. Geol. Ital., **112**, 909-922.

LOJACONO F. & SBARRA R. (1991a) - *Caratteri sedimentologici della formazione di Serra Palazzo nei dintorni di Tricarico (Basilicata)*. Mem. Soc. Geol. Ital., **47**, 157-166.

LOJACONO F. & SBARRA R. (1991b) - *Carbonate olistoliths in a foredeep succession, southern Apennines (Miocene)*. G. Geol., s. 3ª, **53** (2), 227-233.

LONGO G., D'ARGENIO B., FERRERI V. & IORIO M. (1994) - *Fourier evidence for high frequency astronomical cycles recorded in lower Cretaceous carbonate platform strata, Monte Maggiore, Southern Apennines, Italy*. Spec. Publ. Int. Assoc. Sedimentol., **19**, 77-85.

LUPERTO E. (1962) - *Faune mesozoiche di Pignola (Potenza)*. Palaeontographia Ital., **57**, 1-9.

LUPERTO E. (1965) - *Foraminiferi del «Calcare di Abriola» (Potenza)*. Boll. Soc. Paleont. Ital., **4** (2), 161-207.

LUPERTO SINNI E. (1966) - *Presenza di foraminiferi giurassici nei calcari con selce di S. Fele*. Boll. Soc. Geol. Ital., **85**, 275-285.

MAIORANO P. (1998) - *Miocene quantitative calcareous nannofossil biostratigraphy from southern Apennines foredeep deposits and mediterranean DSDP Site 372*. Riv. Ital. Paleont. Stratigr., **104** (3), 391-416.

MANFREDINI M. (1963) - *Osservazioni geologiche sul bordo interno della depressione molisano-sannitica (Italia meridionale)*. Mem. Soc. Geol. Ital., **4**, 15 pp.

MANFREDINI M. (1965) - *Sui rapporti tra facies abruzzese e facies umbra nell'Appennino centro meridionale*. Boll. Serv. Geol. Ital., **86**, 87-112.

MARCUCCI M., CONTI M. & SPADEA P. (1987) - *Radiolarian association in cherts from Timpa delle Murge (Lucanian Apennine, Italy)*, Ofioliti, **12**, 411-414.

MARINO M. (1993) - *Biostratigrafia integrata a nannofossili calcarei e foraminiferi planctonici di alcune successioni terrigene plio-pleistoceniche di avanfossa (Bacino di Sant'Arcangelo e margine appenninico della Fossa bradanica-Italia meridionale)*. Univ. degli Studi di Bari, Dottorato di Ricerca in Scienze della Terra. Ciclo di Studi 1989-1992, Dissertazione Finale, 125 pp.

MARINO M. (1994) - *Biostratigrafia integrata a nannofossili calcarei e foraminiferi planctonici di alcune successioni terrigene pliocenico-superiori del Bacino di Sant'Arcangelo (Appennino Meridionale)*. Boll. Soc. Geol. Ital., **113**, 329-354.

MARSELLA E., BALLY A.W., CIPPITELLI G., D'ARGENIO B. & PAPPONE G. (1995) - *Tectonic history of the Lagonegro Domain and Southern Apennine thrust belt evolution*. Tectonophysics, **252**, 307-330.

MARSELLA E., KOZUR H. & D'ARGENIO B. (1993) - *Monte Facito Formation (Scythian-Middle Carnian). A deposit of the ancestral Lagonegro basin in the Southern Apennines*. Boll. Serv. Geol. Ital., **110**, 225-248.

MARSELLA E. & PAPPONE G. (1986) - *Sediment gravity flows on a Mesozoic carbonate slope. Monti della Maddalena (Southern Apennines)*. Rend. Soc. Geol. Ital., **9**, 219-224.

MARSELLA E., PAPPONE G., D'ARGENIO B., CIPPITELLI G. & BALLY A.W. (1992) - *L'origine interna dei terreni lagonegresi e l'assetto tettonico dell'Appennino meridionale*. Rend. Accad. Sci. Fis. Mat. Soc. Naz. Sci. Lett. Arti Napoli, s. 4, **59**, anno 131, 73-101.

MATANO F. & DI NOCERA S. (2001) - *Geologia del settore centrale dell'Irpinia (Appennino Meridionale): nuovi dati e interpretazioni*. Boll. Soc. Geol. Ital., **120**, 3-14.

MATANO F. & STAITI D. (1998) - *Studio stratigrafico della successione pliocenica affiorante nel settore meridionale della Baronia (Unità di Ariano, Appennino campano).* Boll. Soc. Geol. Ital., **117**, 357-367.

MATTAVELLI L., PIERI M. & GROPPI G. (1993) - *Petroleum exploration in Italy: a review.* Marine Petroleum Geol., **10**, 410-425.

MAURO A. & SCHIATTARELLA M. (1988) - *L'Unità silentina di base: assetto strutturale, metamorfismo e significato tettonico nel quadro geologico dell'Appennino meridionale.* Mem. Soc. Geol. Ital., **41**, 1201-1213.

MAZZOLI S., BARKHAM S., CELLO G., GAMBINI R., MATTIONI L., SHINER P. & TONDI E. (2001) - *Reconstruction of continental margin architecture deformed by the contraction of the Lagonegro Basin, southern Apennines, Italy.* Journ. Geol. Soc. London, **158**, 309-319.

MAZZOLI S., CORRADO S., DE DONATIS M., SCROCCA D., BUTLER R.W.H., DI BUCCI D., NASO G., NICOLAI C. & ZUCCONI V. (2000) - *Time and space variability of «thin skinned» and «thick-skinned» thrust tectonics in the Apennines (Italy).* Rend. Fis. Accad. Lincei, **11** (9), 5-39.

MENARDI-NOGUERA A. & REA G. (2000) - *Deep structure of the Campanian-Lucanian Arc (Southern Apennine, Italy).* Tectonophysics, **324**, 239-265.

MICCADEI E. (1993) - *Geologia dell'area Alto Sagittario-Alto Sangro (Abruzzo, Appennino Centrale).* Geologica Rom., **29**, 463-481.

MICCADEI E. & PAROTTO M. (1998) - *Assetto geologico delle dorsali Rotella-Pizzalto-Porrara (Appennino abruzzese orientale).* Geologica Rom., **34**, 87-113.

MICCADEI E., PAROTTO M. & PIACENTINI T. (1998) - *Assetto geologico-strutturale dei monti della Conca Subequana (Appennino Abruzzese, Italia centrale).* Geologica Rom., **34**, 31-50.

MICONNET P. (1983) - *La région de Lagonegro (Italie meridionale): évolution géologique d'un bassin dans son cadre alpin.* Thèse 3e cycle, Univ. Science et Techniques de Lille, n. 1083, 185 pp.

MICONNET P. (1988) - *Evolution mesozoique du secteur de Lagonegro.* Mem. Soc. Geol. Ital., **41**, 321-330.

MIETTO P. & PANZANELLI FRATONI R. (1990) - *Conodonts from the Monte Facito formation and from the base of the Monte Sirino formation (Lagonegro sequence).* Boll. Soc. Geol. Ital., **109**, 165-169.

MIETTO P., PANZANELLI FRATONI R. & PERRI M.C. (1991) - *Spathian and aegean conodonts from the Capelluzzo calcarenites of the Monte Facito Group (Lagonegro sequence-Southern Apennines).* Mem. Sci. Geol. (già Mem. Ist. Geol. Mineral. Univ. Padova), **43**, 305-317.

MILLI S. & MOSCATELLI M. (2000) - *Facies analysis and physical stratigraphy of the Messinian turbiditic complex in the Valle del Salto and Val di Varri (Central Apennines).* G. Geol., **62**, 57-77.

MOLISSO F., LUTERBACHER H.P. & D'ARGENIO B. (1994) - *Stratigraphy of «Flysch Rosso» formation (Lagonegro Basin, Southern Apennines). Preliminary data from a sedimentological and biostratigraphical study.* IAS 1994, 291-293.

MONACO C. (1993) - *Le unità liguridi nel confine calabro-lucano (Appennino meridionale): revisione dei dati esistenti, nuovi dati ed interpretazione.* Boll. Soc. Geol. Ital., **112**, 751-769.

MONACO C., TANSI C., TORTORICI L., DE FRANCESCO A.M. & MORTEN L. (1991) - *Analisi geologico-strutturale dell'Unità del Frido al confine Calabro-Lucano (Appennino meridionale).* Mem. Soc. Geol. Ital., **47**, 341-353.

MONACO C. & TORTORICI L. (1995) - *Tectonic role of ophiolite-bearing terranes in the development of the Southern Apennines orogenic belt.* Terra Nova, **7**, 153-160.

MONACO C., TORTORICI L. & PALTRINIERI W. (1998) - *Structural evolution of the Lucanian Apennines, southern Italy.* Journ. Struct. Geol., **20**, 617-638.

MORSILLI M., RUSCIADELLI G. & BOSELLINI A. (2002) - *Large-scale gravity-driven structures: control on margin architecture and related deposits of a Cretaceous Carbonate Platform (Montagna della Majella, central Apennines, Italy).* Boll. Soc. Geol. Ital., **1**, 619-628.

MOSTARDINI F. & MERLINI S. (1986) - *Appennino centro-meridionale. Sezioni geologiche e proposta di modello strutturale.* Mem. Soc. Geol. Ital., **35**, 177-202.

MOSTARDINI F., PIERI M. & PIRINI C. (1966) - *Stratigrafia del Foglio 212 Montalbano Ionico.* Boll. Serv. Geol. Ital., **86**, 57-153.

MOUSSAVIAN E. & VECSEI A. (1995) - *Paleocene reef sediments from the Maiella carbonate platform, Italy.* Facies, **32**, 213-222.

MUTTI E., NILSEN T.H. & RICCI LUCCHI F. (1978) - *Outer fan depositional lobes of the Laga Formation (Upper Miocene and lower Pliocene), East-Central Italy.* In: STANLEY D.J. & KELLING G. Eds., «Sedimentation in submarine canyons, fans, and trenches», Dowden, Hutchinson & Ross, Stroudsburg, Pennsylvania, 211-223.

MUTTI M., BERNOULLI D., EBERLI G.P. & VECSEI A. (1996) - *Depositional geometries and facies associations in an upper Cretaceous prograding carbonate platform margin (Orfento supersequence, Maiella, Italy).* Journ. Sediment. Res., **66** (4), 749-765.

NIJMAN W. (1971) - *Tectonics of the Velino-Sirente area, Abruzzi, central Italy. Modification of compressional structures by subsequent dilatation and collapse.* Proc. (K.) Nederl. Akad. Wetensch., s. B, **74**, 156-184.

OGNIBEN L. (1956) - *Flysch miocenico autoctono e parautoctono ed argille scagliose alloctone nella zona di Caiazzo (Caserta).* Boll. Soc. Geol. Ital., **75**, 169-179.

OGNIBEN L. (1969) - *Schema introduttivo alla geologia del confine calabro-lucano.* Mem. Soc. Geol. Ital., **8**, 453-763.

ORI G. & FRIEND P.F. (1984) *Sedimentary basins formed and carried piggyback on active thrust sheets.* Geology, **12**, 475-478.

ORI G.G., SERAFINI G., VISENTIN C., RICCI LUCCHI F., CASNEDI R., COLALONGO M.L. & MOSNA S. (1991) - *The Pliocene-Pleistocene adriatic foredeep (Marche and Abruzzo, Italy): an integrated approach to surface and subsurface geology.* 3rd E.A.P.G. Conference, «Adriatic Foredeep Field Trip», Guide Book (Florence, May 26th-30th, 1991), 85 pp.

ORTOLANI F., NARCISO G. & SANZÒ A. (1975) - *Prime considerazioni sulla presenza del flysch numidico nell'Appennino sannita.* Boll. Soc. Natur. Napoli, **84**, 31-44.

ORTOLANI F. & TORRE M. (1971) - *Il Monte Alpi (Lucania) nella paleogeografia dell'Appennino meridionale.* Boll. Soc. Geol. Ital., **90**, 213-248.

ORTOLANI F. & TORRE M. (1981) - *Guida all'escursione nell'area interessata dal terremoto del 23 novembre 1980.* Rend. Soc. Geol. Ital., **4,** 173-214.

ORTOLANI F., TORRE M., RUSSO B. & DI NOCERA S. (1979) - *Depositi altomiocenici del bordo settentrionale della piana del Sele (Campania).* Boll. Soc. Geol. Ital., **98**, 3-14.

PACE B., DI MATTEO P., BONCIO P. & LAVECCHIA G. (2001) - *Considerazioni sull'evoluzione geologica della Marsica Sud-Orientale (Abruzzo, Appennino centrale) sulla base di un'analisi integrata di dati stratigrafici e strutturali.* Boll. Soc. Geol. Ital., **120**, 139-150.

PAGLIARO S. (1991) - *Geology of the Campagna tectonic window (Picentini Mts, Salerno).* Progetto CROP, Workshop Sottoprogetto CROP-04-Appennino Meridionale, Pisa 20-21 dicembre 2001, Riassunti, 23-24.

PAGLIARO S. (1998) - *Geologia dei monti del Sannio: stratigrafia dell'unità Sannio e rapporti con il massiccio del Matese.* Univ. degli Studi di Pisa, Dottorato di Ricerca in Scienze della Terra, Dissertazione Finale, 138 pp.

PALMENTOLA G. (1970) - *Nuovi dati e considerazioni sulla Formazione di Serra Palazzo in Lucania.* Mem. Soc. Geol. Ital., **9**, 81-90.

PALTRINIERI W., ZANCHINI G., MARTINI N. & ROCCIA L. (1982) - *Evoluzione del bacino torbiditico marchigiano-abruzzese a partire dal Messiniano in base a lineazioni profonde.* Mem. Soc. Geol. Ital., **24**, 233-242.

PAPPONE G. (1990) - *Facies di piattaforma carbonatica mesozoico-paleogeniche al confine campano-lucano. Evoluzione stratigrafica di un sistema di piattaforma carbonatica-scarpata-bacino.* Consorzio tra le Università degli Studi di Napoli e di Palermo - II ciclo - sede consorziata di Napoli, Dottorato di Ricerca in Geologia del Sedimentario, Dissertazione Finale, Tipolit. De Frede-Napoli, 112 pp.

PAPPONE G., SACCHI M. & ZAMPARELLI V. (1988) - *Studio comparato di alcune successioni di scarpata carbonatica dell'Appennino campano-lucano.* Atti 74° Congr. Naz. Soc. Geol. Ital. «L'Appennino campano-lucano nel quadro geologico dell'Italia meridionale» (Sorrento 13-17 sett. 1988), Extended Abstracts, **A**, 441-444.

PARADISI A. & SIRNA G. (1965) - *Osservazioni geologiche e paleontologiche sulla struttura compresa tra la Vallelonga e la Valle del Sangro (Marsica occidentale).* Geologica Rom., **4**, 145-160.

PAROTTO M. (1971) - *Stratigraphy and tectonics of the Eastern Simbruini and Western Marsica Ranges (Central Apennines-Italy)*. Atti Acc. Naz. Lincei, s. 8, **10**, 9-170.

PAROTTO M. & PRATURLON A. (1975) - *Geological summary of the Central Apennines*. In: OGNIBEN L., PAROTTO M. & PRATURLON A., Eds., «Structural Model of Italy», Quad. Ric. Sci., **90**, 257-311.

PASINI M. (1982) - *Fusulinidi permiani nel Trias medio dell'Appennino meridionale (Formazione di M. Facito)*. Mem. Soc. Geol. Ital., **24**, 169-182.

PATACCA E., SARTORI R. & SCANDONE P. (1990) - *Tyrrhenian basin and Apenninic arcs: kinematic relations since Late Tortonian times*. Mem. Soc. Geol. Ital., **45**, 425-451.

PATACCA E., SARTORI R. & SCANDONE P. (1993) - *Tyrrhenian basin and Apennines. Kinematic evolution and related dynamic constraints*. In BOSCHI E., MANTOVANI E. & MORELLI A. Eds., Recent Evolution and Seismicity of the Mediterranean Region, Kluwer Academic Publ., 161-171.

PATACCA E. & SCANDONE P. (1989) - *Post-Tortonian mountain building in the Apennines. The role of the passive sinking of a relic lithospheric slab.* In BORIANI A., BONAFEDE M., PICCARDO G.B. & VAI G.B. Eds., The lithosphere in Italy. Advances in Earth Science Research. It. Nat. Comm. Int. Lith. Progr., Mid-term Conf. (Rome, 5-6 May 1987), Atti Conv. Lincei, **80**, 157-176.

PATACCA E. & SCANDONE P. (2001) - *Late thrust propagation and sedimentary response in the thrust belt-foredeep system of the Southern Apennines (Pliocene-Pleistocene)*. In VAI G.B. & MARTINI I.P. Eds., Anatomy of an Orogen: The Apennines and Adjacent Mediterranean Basins. Kluwer Academic Publ., 401-440.

PATACCA E., SCANDONE P., BELLATALLA M., PERILLI N. & SANTINI U. (1992a) - *The Numidian-sand event in the Southern Apennines*. Mem. Sci. Geol. già Mem. Ist. Geol. Mineral. Univ. Padova, all. **43**, 297-337.

PATACCA E., SCANDONE P., BELLATALLA M., PERILLI N. & SANTINI U. (1992b) - *La zona di giunzione tra l'arco appenninico settentrionale e l'arco appenninico meridionale nell'Abruzzo e nel Molise*. In: TOZZI M., CAVINATO G.P. & PAROTTO M. Eds., «Studi preliminari all'acquisizione dati del profilo CROP 11 Civitavecchia-Vasto», AGIP-CNR-ENEL. Studi Geol. Camerti, Vol. Spec. 1991-2, 417-441.

PAVAN G. & PIRINI C. (1963) - *Microfossili cretacici ed eocenici nella zona di Monte Falapato*. Mem. Soc. Geol. Ital., **4**, 1105-1134.

PERRONE V. (1987) - *I depositi miocenici della dorsale di Monte Soprano (Appennino Campano): segnalazione di vulcanismo andesitico e nuova interpretazione*. Boll. Soc. Geol. Ital., **106**, 3-12.

PERRONE V. (1996) - *Une nouvelle hypothèse sur la position paléogéographique et l'évolution tectonique des Unités de Verbicaro et de San Donato (région Calabro-Lucanienne; Italie): implications sur la limite Alpes-Apennin en Calabre.* C.R. Acad. Sci. Paris, **322**, 877-884.

PESCATORE T. (1963) - *Rapporti tra depressione molisano-sannitica e Appennino calcareo*. Boll. Soc. Natur. Napoli, **72**, 213-227.

PESCATORE T. (1965a) - *La facies di transizione nel gruppo di Monte Marzano*. Boll. Soc. Natur. Napoli, **64**, 149-158.

PESCATORE T. (1965b) - *Ricerche geologiche sulla depressione molisano-sannitica*. Atti Accad. Sci. Fis. Mat. Napoli, s. 3, **5**, 101-145.

PESCATORE T. (1978a) - *Evoluzione tettonica del bacino irpino (Italia Meridionale) durante il Miocene*. Boll. Soc. Geol. Ital., **97**, 1978, 783-805.

PESCATORE T. (1978b) - *The irpinids: a model of tectonically controlled fan and base of slope sedimentation in Southern Italy*. In: STANLEY, D.J. & KELLING G. Eds., «Sedimentation in submarine canyons, fans and trenches», Dowden, Hutchinson & Ross, Stroudsbourg Pa., 325-339.

PESCATORE T. (1984) - *Evolution of a flysch basin during continental collision: Irpinian Basin, Southern Italy*. BOCCALETTI M., GELATI R., RICCI LUCCHI F. Eds., Proc. Interim. Colloq. on «Paleogeography and Geodynamics of the Perityrrhenian area» (Firenze, oct. 15-17, 1984), G. Geol., s. 3a, **48**, 121-127.

PESCATORE T. (1988) - *La sedimentazione miocenica nell'Appennino Campano-Lucano*. Mem. Soc. Geol. Ital., **41**, 37-46.

PESCATORE T. (1995b) - *La sedimentazione miocenica nell'Appennino Lucano*. In BONARDI G., DE VIVO B., GASPARINI P. & VALLARIO A. Eds., Cinquanta anni di attività didattica e scientifica del Prof. Felice Ippolito, Liguori Ed. - Napoli, 337-345.

PESCATORE T., DI NOCERA S., MATANO F. & PINTO F. (2000) - *L'unità del Fortore nel quadro della geologia del settore orientale dei Monti del Sannio (Appennino meridionale).* Boll. Soc. Geol. Ital., **119**, 587-601.

PESCATORE T., PINTO F., RENDA P., SENATORE M.R., TRAMUTOLI M. & VALENTE A. (1996) - *Avanfosse mioceniche dell'Appennino meridionale (Italia)*. Rend. Accad. Sci. Fis. Mat. Napoli, **63**, 85-121.

PESCATORE T., POZZUOLI A., STANZIONE D., TORRE M., HUERTAS F. & LINARES J. (1980°) - *Caratteri mineralogici e geochimici dei sedimenti pelitici del flysch di Gorgoglione (Lucania, Appennino meridionale)*. Period. Mineral., **49**, 293-330.

PESCATORE T., RENDA P., SCHIATTARELLA M. & TRAMUTOLI M. (1999a) - *Stratigraphic and structural relationships between Meso-Cenozoic Lagonegro basin and coeval carbonate platforms in southern Apennines, Italy*. Tectonophysics, **315**, 269-286.

PESCATORE T., RENDA P. & TRAMUTOLI M. (1988) - *Rapporti tra le unità lagonegresi e le unità sicilidi nella media Valle del Basento, Lucania (Appennino meridionale)*. Mem. Soc. Geol. Ital., **41**, 353-361.

PESCATORE T., RENDA P. & TRAMUTOLI M. (1992) - *«Tufiti di Tusa» e flysch numidico nella Lucania centrale (Appennino meridionale)*. Rend. Accad. Sci. Fis. Mat., Soc. Naz. Sci. Lett. Arti Napoli, s. 4, **59**, 57-72.

PESCATORE T., RENDA P. & TRAMUTOLI M. (1999b) - *Carta geologica della Lucania centrale (Appennino meridionale)*. Stabilimento L. Salomone, Roma.

PESCATORE T., SALVATI G. & TRAMUTOLI M. (1980b) - *Regressive depositional cycles in the Gorgoglione flysch, Irpinids (southern Italy)*. Geologica Rom., **19**, 51-61.

PESCATORE T. & SENATORE M.R. (1986) - *A comparison between a present-day (Taranto Gulf) and a Miocene (Irpinian Basin) foredeep of the Southern Apennines (Italy)*. Spec. Publs Int. Ass. Sediment., **8**, 169-182.

PESCATORE T. & SGROSSO I. (1973) - *I rapporti tra la piattaforma campano-lucana e la piattaforma abruzzese-campana nel Casertano*. Boll. Soc. Geol. Ital., **92**, 925-938.

PESCATORE T., SGROSSO I. & TORRE M. (1969) - *Lineamenti di tettonica e sedimentazione nel Miocene dell'Appennino campano-lucano*. Mem. Soc. Natur. Napoli, Suppl., **78**, 337-408.

PESCATORE T. & TRAMUTOLI M. (1980) - *I rapporti tra i depositi del bacino di Lagonegro e del bacino irpino nella media valle del Basento (Lucania)*. Rend. Accad. Sci. Fis. Mat. Soc. Naz. Sci. Let. Arti Napoli, s. IV, **47**, 19-41.

PESCATORE T. & VALLARIO A. (1963) - *La serie mesozoica nel gruppo del Monte Maggiore (Caserta)*. Mem. Soc. Geol. Ital., **4**, 11 pp.

PIACENTINI T. (2000) - *Evoluzione neogenico-quaternaria dell'area tra la Marsica nordorientale e la regione Peligna (Abruzzo): analisi paleogeografica e caratterizzazione strutturale*. Univ. degli Studi di Roma 3, Dottorato di Ricerca in Geodinamica, Dissertazione Finale, 277 pp.

PIERATTINI D. (1975) - *Primi risultati di una analisi strutturale della unità Pollino-Campotenese nella Calabria settentrionale*. Boll. Soc. Natur. Napoli, **84**, 359-372

PIERATTINI D., SCANDONE P. & CORTINI M. (1975) - *Età di messa in posto ed età di metamorfismo delle «limburgiti» nord calabresi.* Boll. Soc. Geol. Ital., **94**, 367-376.

PIERI P. & RAPISARDI L. (1973) - *Su alcune grovacche vulcaniche dell'Appennino dauno.* Boll. Soc. Natur. Napoli, **82**, 191-210.

PIERI P., SABATO L., LOJACONO F. & MARINO M. (1994) - *Il bacino di piggyback di Sant'Arcangelo: evoluzione tettonico-sedimentaria*. Boll. Soc. Geol. Ital., **113**, 465-481.

PIERI P., SABATO L. & TROPEANO M. (1996) - *Significato geodinamico dei caratteri deposizionali e strutturali della Fossa Bradanica nel Pleistocene*. Mem. Soc. Geol. Ital., **51**, 501-515.

PIERI P. & WALSH N. (1973) - *Osservazioni stratigrafiche sulla formazione di Serra Palazzo nell'ambito del F° 187 «Melfi»*. Boll. Soc. Natur. Napoli, **82**, 171-190.

PIGNATTI J. (1990) - *Il Paleogene della Maiella con particolare riferimento ai macroforaminiferi nel quadro delle piattaforme periadriatiche*. Univ. Consorziate Modena, Bologna, Firenze, Roma, Dottorato di Ricerca Paleontologia (III ciclo), Dissertazione Finale, 447 pp.

PIGNATTI J.S. (1994) - *Biostratigrafia dei macroforaminiferi del Paleogene della Maiella nel quadro delle piattaforme periadriatiche*. Studi di Geol. Camerti, Vol. Spec. 1994, 359-404.

PRATURLON A (1968) - *Note illustrative della Carta Geologica d'Italia alla scala 1:100.000 - Foglio 152 Sora.* Serv. Geol. d'Italia, 76 pp., Poligrafica & Cartevalori, Ercolano (Napoli).

PRATURLON A. & SIRNA G. (1976) - *Ulteriori dati sul margine cenomaniano della piattaforma carbonatica laziale-abruzzese*. Geologica Rom., **15**, 83-111.

PRINCIPI P. (1940) - *Sulla estensione dell'Oligocene nell'Appennino meridionale*. Boll. Soc. Geol. Ital., **59**, 167-204.

QUITZOW H.W. (1935) - *Der Deckenbau des Kalabrischen Massivs und seiner Randgebiete*. Abh. Ges. Wiss. Göttingen, Math. Phys. Kl., **3** (13), 63-179.

RAFFI G. & FORTI A. (1959) - *Micropaleontological and stratigraphical investigations in «Montagna del Morrone» (Abruzzi - Italy).* Rev. Micropaléont., **2**, 8-20.

RICCHETTI G. (1961) - *Geologia del nucleo mesozoico di Pignola e Abriola (Potenza)*. Boll. Soc. Geol. Ital., **80**, 247-268.

ROYDEN L., PATACCA E. & SCANDONE P. (1987) - *Segmentation and configuration of subducted lithosphere in Italy: an important control on thrust-belt and foredeep-basin evolution*. Geology, **15**, 714-717.

ROURE F., CASERO P. & VIALLY R. (1991) - *Growth processes and melange formation in the southern Apennines accretionary wedge*. Earth and Planet. Sci. Lett., **102**, 395-412.

ROURE F. & SASSI W. (1995) - *Kinematics of deformation and petroleum system appraisal in Neogene foreland fold-and-thrust belts.* Petr. Geosci., **1**, 253-269.

RUBERTI D. (1992) - *Le lacune stratigrafiche nel Cretacico del Matese centro-settentrionale*. Boll. Soc. Geol. Ital., **111**, 283-289.

RUBERTI D. (1997) - *Facies analysis of an Upper Cretaceous high-energy rudist-dominated carbonate ramp (Matese Mountains, central-southern Italy): subtidal and peritidal cycles*. Sediment. Geol., **113**, 81-110.

RUSSO B. (1988) - *Le microfaune a Foraminiferi delle «Marne Argillose del Toppo Capuana» nella località tipo (Appennino foggiano).* Boll. Soc. Geol. Ital., **107**, 503-512.

RUSSO B. & SENATORE M.R. (1989) - *Ricerche sull'Unità Dauna: biostratigrafia e sedimentologia della successione di Monte Sidone nell'Appennino Dauno (Appennino meridionale).* Atti Accad. Peloritana dei Pericolanti, **67**, 79-97.

RUSSO F. (1990) - *I sedimenti quaternari della Piana del Sele. Studio geologico e geomorfologico*. Consorzio Univv. degli Studi di Napoli e di Palermo. Sede consorziata di Napoli, Dottorato di Ricerca in Geologia del Sedimentario (II ciclo), Dissertazione Finale, Tipolit. De Frede - Napoli, 1990, 168 pp.

RUSSO M. ZUPPETTA A. & GUIDA A. (1995) - *Alcune precisazioni stratigrafiche sul Flysch del Cilento (Appennino meridionale).* Boll. Soc. Geol. Ital., **114**, 353-359.

SANDERS D. (1994) - *Carbonate platform growth and erosion: the Cretaceous to Tertiary of Montagna della Maiella, Italy*. Ph.D. thesis n. 10800, ETH Zürich, 107 pp.

SANDERS D. (1996) - *Rudist biostromes on the margin of an isolated carbonate platform: the Upper Cretaceous of Montagna della Maiella, Italy*. Eclogae Geol. Helv., **89** (2), 845-871.

SANTO A. & SENATORE M.R. (1988) - *La successione stratigrafica dell'Unità Dauna a Monte Sidone (Castelluccio Valmaggiore-Foggia).* Mem. Soc. Geol. Ital., **41**, 431-438.

SANTO A. & SGROSSO I. (1987) - *Alcune precisazioni sulle trasgressioni mioceniche nell'Appennino centro-meridionale*. Mem. Soc. Geol. Ital., **38**, 225-240.

SARTONI S. & CRESCENTI U. (1961) - *Ricerche biostratigrafiche nel Mesozoico dell'Appennino meridionale*. G. Geol., s. 2, **29**, 161-302.

SBARRA R. (1993) - *Lithostratigraphic and sedimentologic features of the Serra Palazzo Formation (Miocene of Southern Apennines).* G. Geol., s. 3ª, **55** (1), 189-199.

SBARRA R. (1994) - *La sedimentazione torbiditica nella avanfossa medio-miocenica dell'Appennino meridionale*. Università degli Studi di Bari, Dottorato di Ricerca in Scienze della Terra. Curriculum Geologia del Sedimentario, Dissertazione Finale, 175 pp.

SCANDONE P. (1963) - *Stratigrafia degli scisti silicei della Lucania*. Mem. Soc. Geol. Ital., **4**, 9 pp.

SCANDONE P. (1967) - *Studi di geologia lucana: la serie calcareo-silico-marnosa e i suoi rapporti con l'Appennino Calcareo*. Boll. Soc. Natur. Napoli, **76**, 301-469.

SCANDONE P. (1972) - *Studi di geologia lucana: carta dei terreni della serie calcareo-silico-marnosa e note illustrative*. Boll. Soc. Natur. Napoli, **81**, 225-300.

SCANDONE P. & BONARDI G. (1968) - *Synsedimentary tectonics controlling deposition of Mesozoic and Tertiary carbonatic sequences of areas surrounding Vallo di Diano (Southern Apennines)*. Mem. Soc. Geol. Ital., **7**, 1-10.

SCANDONE P. & SGROSSO I. (1963) - *Il Mesozoico nel gruppo montuoso dell'Acellica (M. Picentini-Salerno)*. Mem. Soc. Geol. Ital., **4**, 1-8.

SCANDONE P. & SGROSSO I. (1974) - *La successione miocenica dell'Alta Vallimala nella finestra tettonica di Campagna (Monti Picentini).* Boll. Soc. Geol. Ital., **93**, 1043-1047.

SCANDONE P., SGROSSO I. & BRUNO F. (1963) - *Appunti di geologia sul Monte Bulgheria (Salerno)*. Boll. Soc. Natur. Napoli, **72**, 19-27.

SCANDONE P., SGROSSO I. & VALLARIO A. (1967) - *Finestra tettonica nella serie calcareo-silico-marnosa lucana presso Campagna (Monti Picentini, Salerno).* Boll. Soc. Natur. Napoli, **76**, 247-254.

SCARSELLA F. (1961) - *Sulla presenza del Lias nell'Isola di Capri*. Rend. Accad. Sci. Lett. Arti Napoli, s. 4, **28**, 391-394.

SCROCCA D. (1996) - *La zona d'interferenza tra le strutture dell'Appennino centrale e meridionale: assetto tettonico ed evoluzione del sistema di sovrascorrimenti.* Università degli Studi di Roma «La Sapienza», Dottorato di Ricerca in Scienze della Terra, Dissertazione Finale, 268 pp.

SCROCCA D. & TOZZI M. (1999) - *Tettonogenesi mio-pliocenica dell'Appennino molisano.* Boll. Soc. Geol. Ital., **118**, 255-286.

SCROCCA D., TOZZI M. & PAROTTO M. (1995) - *Assetto strutturale del settore compreso tra il Matese, le Mainarde e l'unità di Frosolone. Implicazioni per l'evoluzione neogenica del sistema di sovrascorrimenti nell'Appennino centro-meridionale*. Studi Geol. Camerti, Vol. Spec. 1995/2, 407-418.

SELLI R. (1957) - *Sulla trasgressione del Miocene nell'Italia meridionale*. G. Geol., s. 2, **26**, 1-54.

SELLI R. (1962) - *Il Paleogene nel quadro della geologia dell'Italia Meridionale*. Mem. Soc. Geol. Ital., **3**, 733-789.

SENATORE M.R. (1988) - *Comparazione tra i depositi plio-pleistocenici del bacino di Gallipoli (Golfo di Taranto) e la successione miocenica del flysch di Faeto (unità irpine, Monti della Daunia): confronto tra l'avanfossa attuale e quella miocenica dell'Appennino meridionale (Italia).* Consorzio Univ. Napoli e Palermo, Sede consorziata Napoli, Dottorato in Geologia del Sedimentario, Dissertazione Finale, 317 pp.

SGROSSO I. (1964) - *La serie stratigrafica di Serra delle Macchietelle in relazione ad alcune caratteristiche della tettonica del Matese*. Boll. Soc. Natur. Napoli, **73**, 186-194.

SGROSSO I. (1965) - *Variazioni di facies nel Lias dei Monti Mai (Salerno)*. Boll. Soc. Natur. Napoli, **74**, 403-419.

SGROSSO I. (1966) - *Tentativo di ricostruzione paleogeografica nella zona di Vietri di Potenza con particolare riguardo alla trasgressione miocenica*. Boll. Soc. Natur. Napoli, **75**, 463-495.

SGROSSO I. (1968) - *Note biostratigrafiche sul M. Vesole (Cilento).* Boll. Soc. Natur. Napoli, **77**, 159-180.

SGROSSO I. (1978) - *Contatto stratigrafico tra le arenarie di Frosolone e i calcari mesozoici del Matese*. Rend. Soc. Geol. Ital., **1**, 19-20.

SGROSSO I. (1986) - *Criteri ed elementi per una ricostruzione paleogeografica delle zone esterne dell'Appennino centro-meridionale*. Mem. Soc. Geol. Ital., **35**, 203-219.

SGROSSO I. (1988) - *Nuovi elementi per un più articolato modello paleogeografico nell'Appennino centro meridionale*. Mem. Soc. Geol. Ital., **41**, 225-242.

SGROSSO I. (1995) - *Facies marginali in piattaforma carbonatica nel Mesozoico dell'Appennino Campano-Lucano*. In BONARDI G., DE VIVO B., GASPARINI P. & VALLARIO A. Eds., *Cinquanta anni di attività didattica e scientifica del Prof. Felice Ippolito, Liguori Ed.*, Napoli, 369-374.

SGROSSO I. (1996) - *I rapporti tra i depositi del massiccio del Matese e quelli del bacino molisano*. Mem. Soc. Geol. Ital., **51**, 263-272.

SGROSSO I. (1988a) - *Nuovi dati biostratigrafici sul Miocene del M. Alpi (Lucania) e conseguenti ipotesi paleogeografiche*. Mem. Soc. Geol. Ital., **41**, 343-351.

SGROSSO I. (1998b) - *Possibile evoluzione cinematica miocenica nell'Orogene centro-sud-appenninico*. Boll. Soc. Geol. Ital., **117**, 679-724.

SGROSSO I., AMORE F.O. & RUGGIERO TADDEI E. (1988) - *L'inizio della sedimentazione terrigena nel bacino molisano*. Boll. Soc. Geol. Ital., **107**, 73-79.

SGROSSO I. & TORRE M. (1968) - *Su alcuni affioramenti terziari dei dintorni di Monteroduni (Matese*). Boll. Soc. Natur. Napoli, **77**, 131-158.

SIGNORINI R. (1961) - *Osservazioni geologiche nell'Alto Molise*. Boll. Soc. Geol. Ital., **80**, 215-224.

SIGNORINI R. & DEVOTO G. (1962) - *Il Paleogene nell'Alto Molise*. Mem. Soc. Geol. Ital., **3**, 461-511.

SPADEA P. (1982) - *Continental rocks associated with ophiolites in Lucanian Apennines. Southern Italy*. Ofioliti, **7**, 501-522

SPERANZA F., MATTEI M., NASO G., DI BUCCI D. & CORRADO S. (1998) - *Neogene-Quaternary evolution of the central Apennine orogenic system (Italy): a structural and palaeomagnetic approach in the Molise region.* Tectonophysics, **299**, 143-157.

TADDEI A. & SIANO M.G. (1992) - *Analisi biostratigrafica e considerazioni paleoecologiche sulla successione neogenica del Monte Alpi (Lucania).* Boll. Soc. Geol. Ital., **111**, 255-272.

TORRE M. (1969) - *Studio biostratigrafico del Paleogene del M. Bulgheria*. Boll. Soc. Natur. Napoli, **78**, 355-364.

TORRE M., DI NOCERA S. & ORTOLANI F. (1988) - *Evoluzione post-tortoniana dell'Appennino meridionale*. Mem. Soc. Geol. Ital., **41**, 47-56.

TORTORICI L. (1975) - *Osservazioni geologiche sul flysch di S. Bartolomeo nell'area compresa tra il Fiume Trigno e Benevento (Italia meridionale).* Boll. Soc. Geol. Ital., **94**, 1791-1809.

TOZZI M., MENCONI A. & SCIAMANNA S. (1996) - *Studio strutturale del monte Bulgheria (Cilento meridionale) e sue implicazioni per la tettogenesi dell'Appennino campano.* Boll. Soc. Geol. Ital., **115**, 249-278.

TROPEANO M., SABATO L. & PIERI P. (2002) - *The Quaternary «Post-turbidite» sedimentationin the South-Apennine Foredeep (Bradanic Trough-Southern Italy).* Boll. Soc. Geol. Ital. Vol. Spec. **1**, 449-454.

TURCO E. (1976) - *La finestra tettonica di Campagna (M. Picentini, Salerno).* Boll. Soc. Natur. Napoli, **85**, 639-651.

VAI G.B. (1994) - *Crustal evolution and basement elements in the Italian area: Paleogeography and characterization*. BolI. Geof. Teor. AppI., **36** (141-144), 411-434.

VAI G.B. (2001) - *Basement and early (pre-Alpine) history.* In VAI G.B. & MARTINI I.P. Eds., Anatomy of an Orogen: The Apennines and Adjacent Mediterranean Basins. Kluwer Academic Publ., 121-150.

VALLARIO A. & DE' MEDICI G.B. (1967) - *Contributo alla conoscenza stratigrafica della Calabria Settentrionale.* I. *La serie del Colle Trodo.* Boll. Soc. Geol. Ital., **86**, 233-252.

VALLONI R., CIPRIANI R. & MORELLI C. (2002) - *Petrostratigraphic record of the Apennine foredeep basins, Italy.* Boll. Soc. Geol. Ital., Vol. Spec. **1**, 455-465.

VAN KONIJNEMBURG J.H., BERNOULLI D. & MUTTI M. (1999) - *Stratigraphic architecture of a lower Cretaceous-lower Tertiary carbonate base-of-slope succession: Gran Sasso d'Italia (Central Apennines, Itally).* SEPM, Spec. Publ., **63**, 291-315.

VECSEI A. (1991) - *Aggradation und Progradation eines Karbonatplattform-Randes: Kreide bis Mittleres Tertiär der Montagna della Maiella, Abruzzen*. Mitteilungen aus dem Geologischen Institut der Eidgenössischen Technischen Hochschule und der Universität Zürich, Neue Folge, nr. 294.

VECSEI A. (1998) - *Bioclastic sediment lobes on a supply dominated Upper Cretaceous carbonate platform margin, Montagna della Maiella, Italy*. Sedimentology, **45**, 473-487.

VECSEI A. & SANDERS D.G.K. (1997) - *Sea-level highstand and lowstand shedding related to shelf margin aggradation and emersion, Upper Eocene-Oligocene of Maiella carbonate platform, Italy*. Sediment. Geol., **112**, 219-234.

VECSEI A. & SANDERS G.K.D. (1999) - *Facies analysis and sequence stratigraphy of a Miocene warm-temperate carbonate ramp, Montagna della Maiella, Italy*. Sediment. Geol., **123**, 103-127.

VECSEI A., SANDERS D., BERNOULLI D., EBERLI G.P. & PIGNATTI J.S. (1998) - *Cretaceous to Miocene sequence stratigraphy and evolution of the Maiella carbonate platform margin, Italy.* In: «Mesozoic and Cenozoic Sequence Stratigraphy of European Basins», Spec. Publ. Soc. Econ. Paleont. Mineral., **60**, 53-74.

VEZZANI L. (1966) - *La sezione stratigrafica di Caliandro nel Pliocene medio-inferiore della Val d'Agri (Lucania).* Riv. Ital. Paleont. Stratigr., **72**, 191-229.

VEZZANI L. (1967) *Il bacino plio-pleistocenico di S. Arcangelo (Lucania).* Atti Accad. Gioenia Sci. Nat. Catania, **18**, Suppl. Sci. Geol., 207-227.

VEZZANI L. (1968a) - *Distribuzione, facies e stratigrafia della Formazione del Saraceno (Albiano-Daniano) nell'area compresa tra il Mare Ionio e il Torrente Frido*. Geologica Rom., **7**, 229-275.

VEZZANI L. (1968b) - *Studio stratigrafico della Formazione delle Crete Nere (Apriano-Albiano) al confine calabro-lucano*. Atti Accad. Gioenia Sci. Nat. Catania, s. 6, **20**, 189-222.

VEZZANI L. (1968c) - *Stratigrafia dei terreni infra-mesopliocenici di Ruvo del Monte (Potenza).* Boll. Accad. Gioenia Sci. Nat. Catania, **9**, 507-545.

VEZZANI L. (1969) - *La formazione del Frido (Neocomiano-Aptiano) tra il Pollino ed il Sinni (Lucania).* Geologica Rom., **8**, 129-176.

VEZZANI L. (1970) - Il flysch di Albidona nell'area del confine tra Calabria e Lucania. Geologica Rom., **9**, 101-126.

VEZZANI L. & GHISETTI F. (1988) - *Carta geologica dell'Abruzzo*. S.EL.CA., Firenze.

WEZEL F.C. (1966) - *La «Cenozona a Globorotalia fohsi» nel flysch esterno della Lucania*. Riv. Ital. Paleont. Stratigr., **72**, 1269-1296.

WHITEMAN M.I. (1988) - *The development of the former Molise Basin margin in the Isernia-Campobasso region.* Atti 74° Congr. Naz. Soc. Geol. Ital.: «L'Appennino campano-lucano nel quadro geologico dell'Italia meridionale» (Sorrento 13-17 sett. 1988), Extended Abstracts **A**, 521-528.

WOOD A.W. (1981) - *Extensional tectonics and the birth of the Lagonegro Basin (Southern Italian Apennines).* N. Jb. Geol. Paläont. Abh., **161**, 93-131.

ZAMPARELLI V. (1963) - *La successione stratigrafica dal Giurassico superiore al Cretaceo medio nel versante meridionale di Pizzo Cefalone (Gran Sasso d'Italia).* Boll. Soc. Natur. Napoli, **72**, 161-167.

ZAMPARELLI V. (1966) - *Le microfacies cretaceo-eoceniche nella serie di Rio Arno (Gran Sasso d'Italia).* Boll. Soc. Geol. Ital., **75**, 553-560.

ZUPPETTA A., RUSSO M. & TURCO E. (1984a) - *Alcune osservazioni sulle «Tufiti di Tusa» nell'area compresa tra la Valsinni e Rocca Imperiale (confine calabro-lucano)*. Boll. Soc. Geol. Ital., **103**, 623-627.

ZUPPETTA A., RUSSO M., TURCO E. & GALLO L. (1983) - *Età e significato della Formazione di Albidona in Appennino Meridionale*. Boll. Soc. Geol. Ital., **103**, 159-170.

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