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Tectono-stratigraphic setting of the Campania region (southern Italy)

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ABSTRACT

This paper furnishes a brief, but exhaustive, description of the tectonics and stratigraphy of the Campania region (southern Italy). The attached geological map (Main Map) at 1:250,000 scale should be considered as a first attempt to provide a more detailed geological cartography of the entire region, with respect to the available literature, in the light of scientific advances in stratigraphy and tectonics reached in the last years. The geological setting, proposed in this study, is the result of a review and reinterpretation of the current geological knowledge plus original surveys carried out in some key sectors of the area. We also include a schematic stratigraphic chart and three geological cross-sections illustrating the tectonic architecture in depth for the internal and external zones. The geodatabase was compiled in GIS format and subsequently imported in vector graphic software to allow a classical cartographic design.

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Southern Apennines; Ligurian Accretionary Complex; Apennine Platform; Lagonegro-Molise Basin; Apulian Platform; wedge-top basin

1. Introduction

The geological cartography is one of the main tools to understand the environment around us both in the terms of knowledge of the surface and subsurface for different theoretical and applicative scopes, amongst others the study and mitigation of the geological hazard, the exploitation of natural resources and the enhancement of geological heritage. In the light of these features, the Campania region is one of places in the world where a large variety of geological environments are present in a narrow, highly inhabited area. The goal of the paper is to provide a synthesis of the geological setting of this area through the description of the overall stratigraphy and the deep structure of the orogenic chain. Furthermore the paper is complemented by a geological map of the Campania region (Main Map) at 1:250,000 scale.

2. Methods

The Main Map, covering an about 14,000 km² area (Figures 1 and 2), results from a reinterpretation of the available geological cartography at 1:100,000 (Servizio Geologico d'Italia, 1963–1972) and 1:50,000 (ISPRA, 2017) scale of the Italian Geological Survey, with in addition geological data carried out during original surveys in some key sectors. The proposed geological setting, summarized in the stratigraphic chart (Figure 3), derives from decennial studies performed by different authors on different sectors of the southern Italy (e.g. Bonardi, D'Argenio, & Perrone,

1988; Bonardi, Amore, et al., 1988; Bonardi et al., 2009; Casero, 2004; Ciarcia, Mazzoli, Vitale, & Zattin, 2012; Critelli, 1999; D'Argenio, Pescatore, & Scandone, 1973, 1975; Menardi Noguera & Rea, 2000; Milia & Torrente, 2014, 2015; Milia, Iannace, Tesauro, & Torrente, 2017; Milia, Torrente, & Iannace, 2017; Milia, Valente, Cavuoto, & Torrente, 2017; Mostardini & Merlini, 1986; Patacca & Scandone, 2007; Patacca, Sartori, & Scandone, 1990; Pappone & Ferranti, 1995; Pescatore, Renda, Schiattarella, & Tramutoli, 1999; Pescatore, Di Nocera, Matano, & Pinto, 2000; Scandone, 1967, 1972; Scrocca et al., 2007; Selli, 1957, 1962; Sgrosso, 1998; Torrente, Civile, Martino, & Milia, 2000; Vitale & Ciarcia, 2013; Vitale, Ciarcia, & Tramparulo, 2013; Vitale, Amore, et al., 2017; Vitale, Tramparulo, et al., 2017). Three cross-sections (Figure 4), representative of the tectonic architecture for the internal and external zones, are presented. They were built integrating information about stratigraphy and structural setting of surface and subsurface. Well-logs and seismic profiles, provided by ViDEPI (2017) and CROP04 (Catalano, Monaco, Tortorici, Paltrinieri, & Steel, 2004; Mazzotti, Patacca, & Scandone, 2007; Menardi Noguera & Rea, 2000) projects, were used to reconstruct the geology of the orogenic wedge in depth.

3. Geological setting

Southern Apennines (Figure 1) are defined by the tectonic superposition of several thrust sheets made up of Meso-Cenozoic deep basin to shallow-water

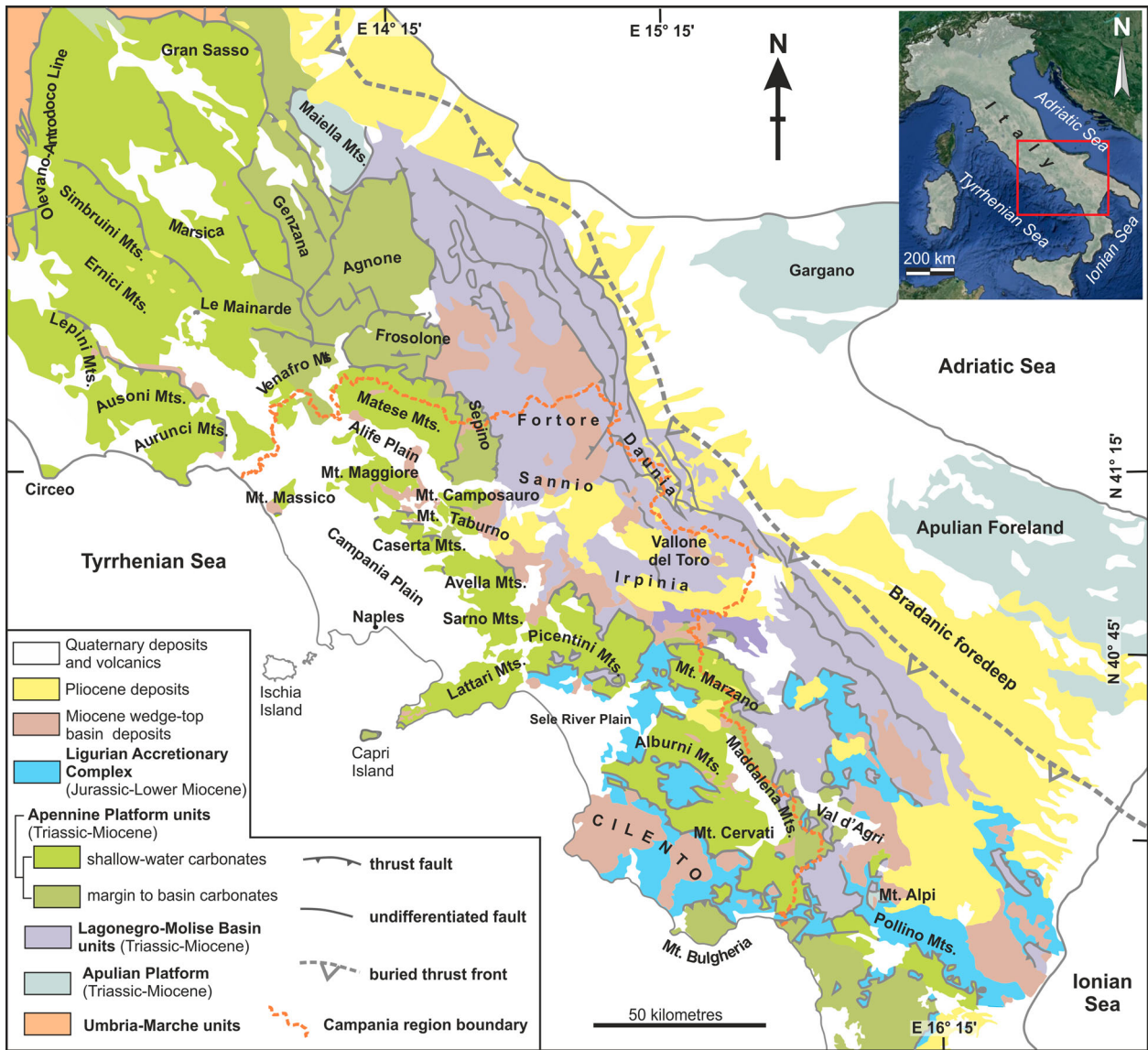


Figure 1. Schematic geological map of the southern Apennines (after Vitale, Amore, et al., 2017).

successions, dissected by several Quaternary structural depressions, especially along the Tyrrhenian Sea side. The allochthonous units, forming the orogenic structure, can be grouped in three main tectonic complexes: (i) Ligurian Accretionary Complex (LAC), (ii) Apennine Platform (AP) units and (iii) Lagonegro-Molise Basin (LMB) units. In the study area, the tectonic pile is unconformably covered by Mio-Pliocene wedge-top basin deposits and Quaternary post-orogenic sediments and volcanics. LAC occupies the highest tectonic positions, covering the AP units, in turn overthrusting the LMB units. The foreland is represented by the Apulian Platform not cropping out in the Campania region. As it is clear from many wells and seismic surveys carried out for the oil exploration (ViDEPI project) or for scientific purposes (CROP04 project), the LMB units form tectonic duplexes and imbricated slices overthrusting the buried Apulian carbonates.

Southern Apennines result from the subduction of the Neo-Tethys oceanic lithosphere beneath the

Europa/AlKaPeCa plates (e.g. Carminati, Lustrino, & Doglioni, 2012; Cosentino, Cipollari, Marsili, & Scrocca, 2010; Vitale & Ciarcia, 2013 and reference therein) with the E-migration of the thrust front, as consequence of the downgoing slab-retreat (Malinverno & Ryan, 1986). The subduction started in the Paleocene/Eocene time (Rossetti et al., 2001) with different paroxysmal tectonic stages such as the Oligocene–Langhian and upper Serravallian–Tortonian fast thrust front migrations that caused the opening of Ligurian–Provençal and Tyrrhenian back-arc basins, respectively (Dewey, Helman, Turco, Hutton, & Knott, 1989; Faccenna, Becker, Lucente, Jolivet, & Rossetti, 2001; Milia & Torrente, 2014; Milia, Valente, et al., 2017). In the Aquitanian–Burdigalian interval, the orogenic pulses formed an incipient orogenic prism made up of oceanic to transitional successions (LAC; Ciarcia et al., 2012; Vitale & Ciarcia, 2013). Subsequently the thrust front eastward migrated, involving younger and younger foredeep basin deposits covering

the margin of the Adria plate. The Mio-Pliocene orogenic evolution was marked by the sedimentation of thick sequences of turbiditic calci- and siliciclastic deposits both in foredeep and wedge-top basins (e.g. Ascione, Ciarcia, Di Donato, Mazzoli, & Vitale, 2012), whose ages constraint and define the temporal sequence of the tectonic pulses (e.g. Vitale & Ciarcia, 2013), including several envelopment thrust faults that presently are the best-preserved compressional structures of the region (Vitale, Tramparulo, et al., 2017). During Pleistocene, extensional tectonics affected the Campania margin and the western flank of the southern Apennines producing several basins (Campania Plain, Sele River Plain, Salerno Gulf, Naples Gulf, Vallo di Diano and Auletta Valley; Figure 2) mainly controlled by NW–SE and NE–SW normal faults (Barchi, Amato, Cippitelli, Merlini, & Montone, 2007; Brancaccio et al., 1991; Ippolito, D’argenio, Pescatore, & Scandone, 1973; Mariani & Prato, 1988; Milia & Torrente, 1999, 2011, 2015; Milia, Torrente, Russo, & Zuppetta, 2003, Milia, Torrente, et al., 2017). Here several intermontane depressions were the location of thick lacustrine-marine deposits, often alternating and covered by volcanic rocks, especially in the Late Pleistocene–Holocene.

4. Stratigraphy

For the stratigraphy of each sedimentary unit refer to the scheme of Figure 3.

4.1. Ligurian Accretionary Complex

LAC includes the deep basin successions of Nord-Calabrese and Parasilide units, cropping out extensively in the southern sector of the Campania region (Figure 2).

4.1.1. Nord-Calabrese unit

The Nord-Calabrese unit, at least 1200 meters thick, is made of three formations: the uppermost Cretaceous–Middle Eocene Crete Nere Fm.; the Upper Eocene–lowermost Aquitanian Saraceno Fm. and lower Aquitanian–lowermost Burdigalian Sovereto Fm. The Crete Nere Fm. (CRN, Bonardi, Amore, et al., 1988) includes at base alternation of quartzarenites and argillites, covered by black shales, argillites and calciclastic turbidites. The Saraceno Fm. (SAR, Bonardi et al., 2009; Ciarcia et al., 2012; Vitale, Ciarcia, Mazzoli, & Zaghoul, 2011) is made of calciclastic, locally silicified turbidites upward passing to silici- and calciclastic turbidites with nodules of dark chert, arenaceous-marly turbidites with cherty nodules and breccias. The succession is capped by the Sovereto Fm. (SOV) consisting of thin-bedded sandstones and intercalations of pelites.

4.1.2. Parasilide unit

The Parasilide unit (Ciarcia et al., 2009a; Guerrero, Martin-Algarra, & Perrone, 1993; Vitale et al., 2011), up to 1000 meters thick, includes four formations. At base the uppermost Cretaceous–Middle Eocene Argille Scagliose Fm. (AS; Ciarcia et al., 2012) consists in three heteropic sequences: (i) micaceous sandstones, varicolored clays and grey and greenish cherty limestones; (ii) dark silicified argillites, marls and marly limestones and (iii) dark argillites, slates and marls. The succession upward passes to the Upper Eocene–Aquitanian p.p. Monte Sant’Arcangelo Fm. (FMS), made of marly limestones and secondarily calcarenites, silty marls and micaceous sandstones and Upper Oligocene–Aquitanian p.p. varicolored clays (AV, Argille Varicolori Fm.), partially heteropic with the upper part of FMS, comprising reddish, greyish and greenish clays, calcarenites and whitish marls. Finally the succession ends with Burdigalian p.p. Arenarie di Albanella Fm. (ALB; Critelli, de Capoa, le Pera, & Perrone, 1994) consisting of thick-bedded sandstones and whitish marls.

5. AP domain

5.1. Southern sector

5.1.1. Mt. Bulgheria and Roccagloriosa

The sedimentary succession exposed at Mt. Bulgheria, about 1800 meters thick, includes at base Norian–Hettangian p.p. shallow-water dolostones and limestones (DBa, Dolomia di Base Fm.), upward passing to Jurassic slope to basin cherty limestones, oolitic and Ellipsactinia limestones (GCS). These sediments are covered by uppermost Cretaceous–Paleocene upper slope calcarenites and calcirudites with Rudist fragments (CBI, Calcari Cristallini Fm.), Eocene–Burdigalian p.p. yellowish, reddish marly calcilutites with planktonic foraminifers, greenish and reddish marls (SCA, Scaglia Condensata Fm.). The succession upward passes to Burdigalian p.p. dark argillites, marly limestones and marls, silicified and quartz sandstones, calcarenites including Miogypsinids sp. (GIP, S. Giovanni a Piro Fm.). The Roccagloriosa succession, at least 450 meters thick, is formed only by uppermost Cretaceous–Paleocene upper slope Calcari Cristallini Fm. and Eocene–Burdigalian Scaglia Condensata Fm., covered by Langhian tobacco argillites with intercalated calcareous breccias, Numidian and arkosic sandstones (BIF, Bifurto Fm.).

5.1.2. Alburno, Cervati and Soprano Mts.

In the southern sector of the Campania region the most of carbonate ridges are made of a similar succession, with a thickness between 2000 and 2500 meters, formed at base by Norian–Hettangian p.p. dolostones (DBa), upward evolving to Jurassic–Lower Cretaceous limestones with Cladocropsis and Clypeina and

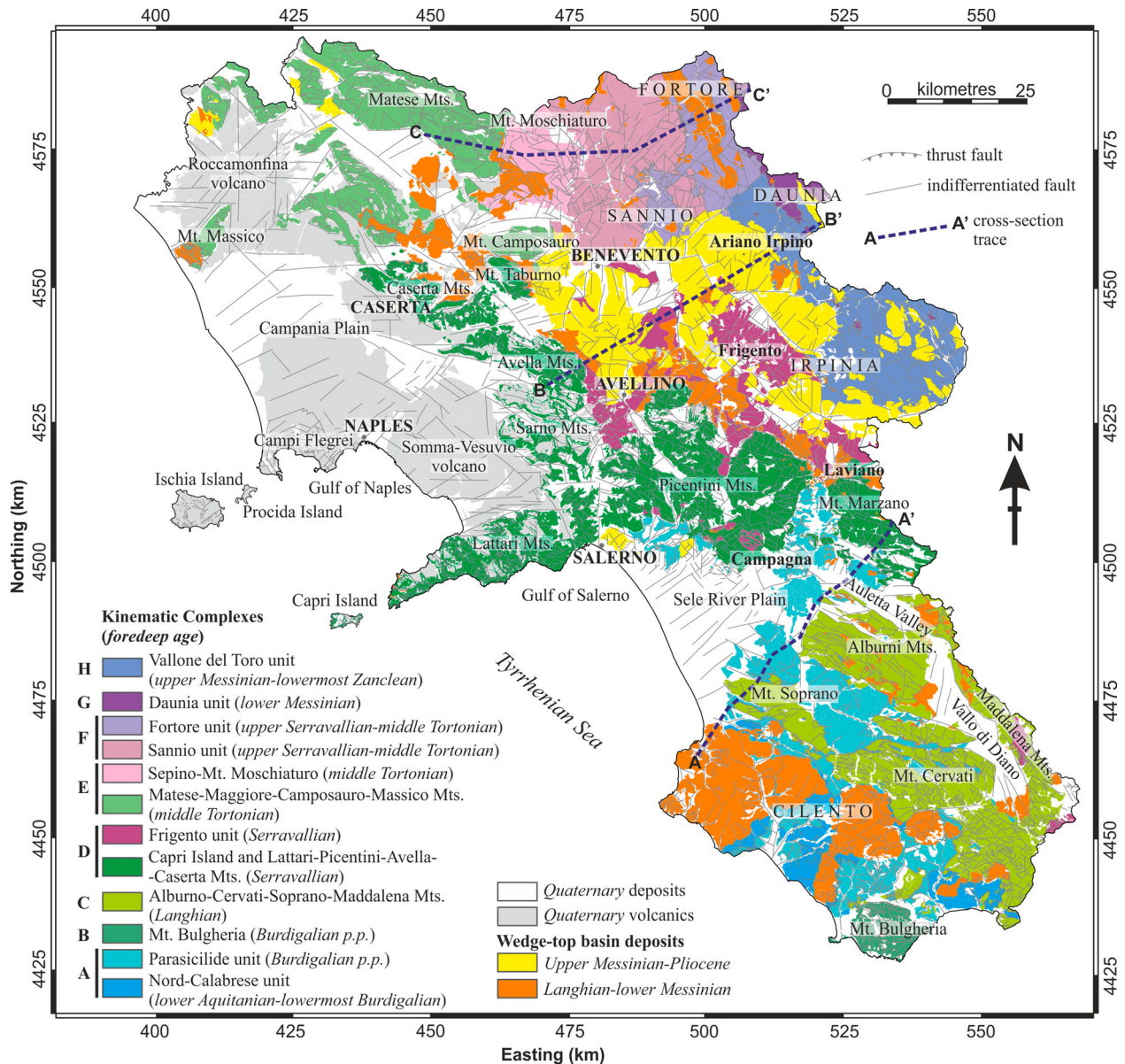


Figure 2. Kinematic complexes map of the Campania region.

limestones with Requienids and Gastropods (**GCa**). The sedimentary pile continues, after minor emersion episodes locally marked by residual red clays, with Upper Cretaceous Rudist and Orbitolinid limestones and Radiolitid limestones (**CSa**).

After an uppermost Cretaceous–Paleocene stratigraphic gap, the succession upward passes to the lower middle Eocene shallow-water Trentinara Fm. (**TRN**) made at base of calcarenites with Alveolinids, nodular limestones and conglomerates with marly and clayey matrix, lenses of greenish, yellowish and pinkish marls and clays. In the Alburno Mts. locally calcarenites with macro-foraminifers, reddish and grey marls, and cherty marly limestones occur (**SCA**, Bravi & Schiattarella, 1988). After another gap, the sequence continues with Oligocene–Aquitanian lateritic red clay and Aquitanian p.p.–Burdigalian Cerchiara–Roccadaspide Fm. (**RCD**) consisting of calcarenites with glauconite with a base with

characteristic levels of ostreids and pectinids. Finally the succession ends with the Langhian Bifurto Fm.

5.1.3. Maddalena–Foraporta Mts.

The succession, exposed at Maddalena Mts., 1200–1400 meters thick, is made at base by shallow-water carbonates consisting in Norian–Hettangian p.p. dolostones (**DBa**) and Jurassic–Lower Cretaceous limestones and dolomitic limestones (**GCa**). The succession upward continues with uppermost Cretaceous–Paleocene Calcari Cristallini Fm. formed by upper slope calcirudites with macro-foraminifers. The Triassic–Paleocene sequence is heteropic with massive dolostones related to a late dolomitization process. The sedimentary pile ends with the Bifurto Fm. The Upper Triassic–Middle Jurassic Mt. Foraporta succession, about 500 meters thick, crops out only in the southeastern sector of the region (Figure 2). It includes well-bedded dark slope-basin limestones and dolomitic

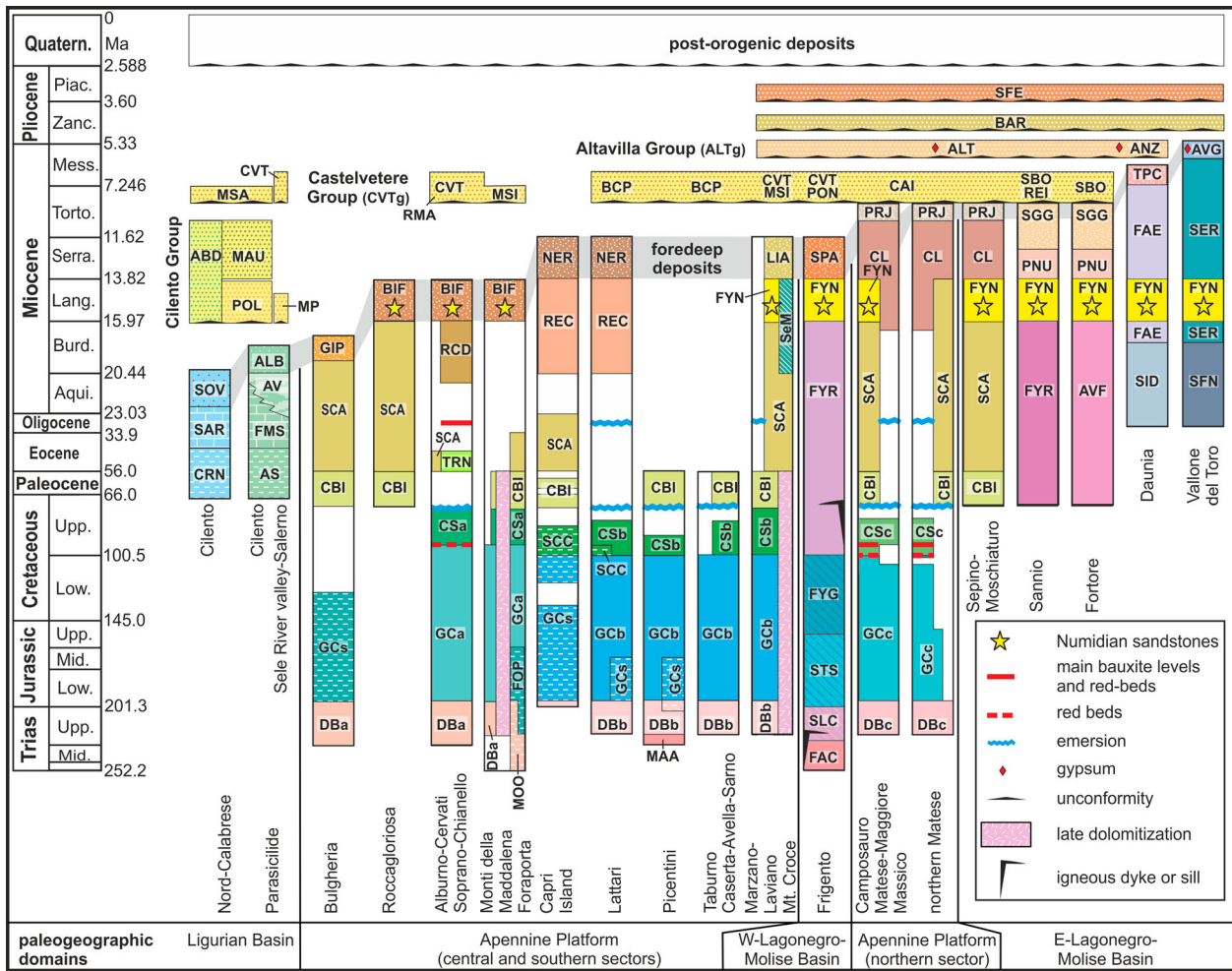


Figure 3. Stratigraphic chart showing the sedimentary successions exposed in the Campania region. For the Formation abbreviations, see the legend of the [Main Map](#).

limestones with intercalated yellowish marls, calcarenites and calcirudites with *Lithiotis*, ammonites, crinoids and echinids (**FOP**). Also these rocks laterally pass to late massive dolostones. Locally, at base, greenish and reddish argillites, with intercalation of sandstone and calcarenite layers and bodies of boundstones and dolomitic limestones, are present (**MOO**).

5.2. Central sector

5.2.1. Capri Island

The succession exposed in the Capri island, about 2000 meters thick, is characterized by Hettangian p.p. shallow-water dolostones (**DBb**), evolving to Jurassic–Lower Cretaceous margin to basin carbonates including limestones with *Lithiotis* and oolites, cherty limestones, laterally passing to limestones with *Ellipsactinia* (**GCs**). The succession is unconformably covered by Aptian–Cenomanian slope calcirudites with fragments of ostreid and rudists (**GCs**) and Turonian–Coniacian cherty limestones and marly limestones (**SCC**; Scaglia Rossa Fm.). The succession upward continues with Maastrichtian–Paleocene

slope Calcari Cristallini Fm., Eocene–Oligocene slope well-bedded yellowish cherty calcarenites and calcilutites (**SCA**; Scaglia Cinerea Detritica Fm.), Burdigalian–Serravallian calcarenites (**REC**, Recommone Fm.) and Serravallian sandstones (**NER**, Nerano Fm.).

5.2.2. Lattari, Picentini, Marzano, Sarno, Avella and Caserta Mts.

The carbonate successions, exposed northward of Alburno Mts. up to Caserta Mts. and exceeding 3000 meters in thickness, consist of similar shallow-water rocks made at base by Norian–Hettangian p.p. dolostones (**DBb**), Jurassic–Lower Cretaceous limestones and dolomitic limestones (**GCb**) with some lateral heteropies of slope to basin carbonates (**GCs**, Lattari and Picentini Mts.). Only in the Picentini Mts., Carnian dolostones and *Avicula* and *Myophoria* marls are present (**MAA**). The succession continues with Upper Cretaceous shallow-water limestones (**CSb**) with some slope conglomeratic bodies (**SCC**; Mt. Lattari; Iannace, Frijia, Galluccio, & Parente, 2014). In the Picentini, Caserta, Sarno, Avella and Marzano Mts., the sequence is locally covered by the Calcari Cristallini Fm. Only in the Lattari Mts., the Upper Cretaceous

carbonates upward pass to the Burdigalian–Langhian shallow-water Reconnome Fms. and finally to the Serravallian sandstones of the Nerano Fm.

5.2.3. Laviano and Mt. Croce

In the Laviano area, the Mt. Marzano Mesozoic carbonates evolve to Eocene–Aquitainian slope to basin deposits including cherty limestones, marls and argillites (**SCA**, Scaglia Rossa and Scaglia Cinerea type deposits), covered by the Burdigalian–Langhian Numidian sandstones (**FYN**, Flysch Numidico Fm.) and Serravallian calcarenites and sandstones of Laviano Fm. (**LIA**). The succession of Mt. Croce exposed only within the Campagna tectonic window shows a similar stratigraphic evolution of the Laviano succession; however, it is characterized by a thicker pile (Flysch della Vallimala, Fraschi and Fontana Porcellara Fms., [Scandone & Sgroso, 1974](#)) with a dominant calciclastic component. Furthermore the Maastrichtian–Aquitainian Scaglia upward passes to Burdigalian–Langhian bioclastic calcirudites and calcarenites (**SeM**, Serra della Manca Mb.).

5.3. Northern sector

5.3.1. Camposauro, Matese, Maggiore and Massico Mts.

The Triassic–Cretaceous part of the carbonate succession (**DBc**, **GCc** and **CSc**) forming the Camposauro–Matese–Maggiore–Massico Mts. is similar to that of the Alburno–Cervati–Avella–Caserta Mts. previously described, however, some important differences result especially in the Cretaceous part (**CSc**). In fact, these successions are characterized by the occurrence of some bauxitic levels within the Albian–Cenomanian rocks (e.g. [Boni, Reddy, Mondillo, Balassone, & Taylor, 2012](#)). Such as the most of the carbonate successions in the southern Apennines, the shallow-water uppermost Cretaceous is lacking, however, at the Mt. Camposauro ([Vitale, Amore, et al., 2017](#)), the Cenomanian limestones upward pass to Maastrichtian–Paleocene Calcari Cristallini Fm. containing fragment of rudists, Eocene–Aquitainian Scaglia Detritica Fm. (**SCA**), made of alternating argillites and calciclastic breccias and silicified varicolored argillites with blocks of partially silicified limestones with rudists. The succession continues with Langhian Numidian sandstones Fm. (**FYN**) and the Serravallian–lower Tortonian Longano Fm. consisting of marls, marly limestones and calcarenites with macro-foraminifers and finally the middle Tortonian Pietraraja Fm. (**PRJ**) comprising fine-bedded argillitic marls and sandstones. This is observed also for the succession cropping out in the northern sector of the Matese Mts., where the Triassic–Cretaceous sequence evolves to Paleogene–Langhian slope to basin Scaglia Detritica Fm. covered by the Longano and Pietraraja Fms. In the remnant areas, the

Cenomanian limestones upward pass to Burdigalian p.p.–Langhian Cusano Fm. made of shallow-water calcarenites and calcirudites with red algae, bryozoids, ostreids and pectinids and then to Longano and Pietraraja Fms. In the [Main Map](#), the Cusano and Longano Fms. have been joined in a single formation (**CL**). The thickness of the exposed succession exceeds the 2500 meters.

5.4. LMB units

5.4.1. Frigento unit

This unit is defined by a sedimentary succession, with a thickness ranging between 2500 and 4000 m, characterized at base with the Ladinian–Carnian Mt. Facito Fm. (**FAC**) consisting of slope to basin calcilutites, and fine-grained sandstones with intercalations of reefal bodies of marls and limestones with corals, sponges and brachiopods. The succession upward evolves to a deep basin sequence made of Carnian–Norian cherty limestones (Calcari con Selce Fm., **SLC**), Rhaetian–Jurassic radiolarites and reddish, greenish and violet silicified argillites (**STS**, Scisti Silicei Fm.) and Lower Cretaceous dark silicified argillites with intercalated calcilutites marly limestones and marls (**FYG**, Flysch Galestrino). The succession passes to slope to basin deposits of the Late Cretaceous to Burdigalian Flysch Rosso Fm. (**FYR**) consisting at base by calcarenites and calcirudites with nummulitids and alveolinids, marls, and greenish and reddish argillites upward passing to varicolored argillites. The FYR is covered by the Numidian Sandstone Fm., in turn underlying several hundreds of meters of post-Numidian basin deposits (**PNU**) and Serravallian marly–arenaceous turbidites of Serra Palazzo Fm. (**SPA**). Post-Numidian deposits, generally overlying the Langhian Numidian sandstones, occur in different LMB successions, with ages spanning between middle to late Miocene.

5.4.2. Sepino–Mt. Moschiatturo unit

This unit, exposed in the southeastern side of the Matese Mts ([Figure 2](#)), is characterized by a thick sequence of Paleocene calciclastic rocks formed by calcarenites and conglomerates frequently recrystallized (Calcari Cristallini Fm.) evolving to Eocene–Aquitainian Scaglia Detritica deposits (**SCA**) and locally to slope to basin deposits analogous to the FYR, largely occurring in the Sannio and Frigento units. Lenses of Numidian sandstones are present covered by post-Numidian marls and finally by middle Tortonian sediments similar to the Pietraraja Fm. The whole thickness is about 1000 m. The Morcone1 well ([ViDEPI, 2017](#)) indicates that these rocks tectonically cover the Matese Mts. succession and the upper Miocene deposits of Caiazzo Fm. (Castelvetere Group).

5.4.3. Sannio unit

This unit, exposed in the Sannio and Irpinia areas (Figure 2), is made of a ca. 2000-meter-thick succession including FYR and Numidian sandstone Fm. upward passing to post-Numidian deposits, consisting of marls with planktonic foraminifers, and finally to the upper Serravallian–middle Tortonian San Giorgio Fm. (SGG, Pescatore et al., 2008) made of silici- and calciclastic turbidites (Pescatore et al., 2000).

5.4.4. Fortore unit

This unit, exposed in the homonymous area, consists of a ca. 2000-meter-thick succession, formed at base by clays, varicolored argillites and marls with intercalations of calcilutites and calcarenites, locally with jaspers (AVF, partially corresponding to the Corleto–Perticara Fm., Pescatore et al., 2000) passing to volcanoclastic deposits (TUT; Tufiti di Tusa; Paola Doce Fm., Pescatore et al., 1999), Numidian sandstones Fm., post-Numidian deposits and the siliciclastic turbiditic sandstones and, subordinately, pelitic and conglomeratic layers of San Giorgio Fm.

5.4.5. Daunia unit

This unit is exposed only at boundary with the Puglia region, in the easternmost sector. The ca. 2000-meter-thick succession is made of a dominantly calciclastic rocks consisting at base of Upper Oligocene–middle Burdigalian clays, varicolored marls with intercalation of whitish calcilutites and calcarenites (SID; Monte Sidone Fm., Dazzaro et al., 1988) covered by upper Burdigalian–Tortonian bioclastic calcarenites and breccias, calcilutites and characteristic whitish marls (FAE; Flysch di Faeto) including the Numidian sandstones. The succession is capped by lower Messinian marly clays, clayey and silty marls with rare calcareous beds (TPC; Toppo Capuana Fm.)

5.4.6. Vallone del Toro unit

This unit is tectonically underlying the Fortore and Daunia units and consists of a ca. 2000-meter-thick Upper Oligocene–middle Burdigalian succession with a base of alternating calcarenites, reddish and greenish argillites and calcareous breccias (SFN; Serra Funaro Fm., Crostella & Vezzani, 1964), upward passing to upper Burdigalian–lower Messinian calcarenites (SER; Serroni Fm., Basso et al., 2002) including Numidian sandstones, and upper Messinian–lowermost Zanclean varicolored clays with gypsum and sulfur layers, olistholites of gypsum and channelized calcareous breccias and sandstones with gypsum (AVG, Mezzana di Forte Fm.).

5.5. Wedge-top basin deposits

Several unconformable sedimentary cycles of Miocene–Pliocene deposits occur above the allochthonous

prism (wedge-top or piggy-back basins), frequently sealing the tectonic contacts between the different thrust sheets (Bonardi et al., 2009; Patacca & Scandone, 2007; Vitale & Ciarcia, 2013). Generally these clastic deposits show sharp lateral and vertical facies variations including olistoliths and olistostromes. Five main cycle deposits are defined: (i) Cilento Group; (ii) Castelvetere Group; (iii) Altavilla Group; (iv) Baronia Fm. and finally (v) Sferracavallo Fm.

5.5.1. Cilento Group

These slope to basin deposits unconformably cover the LAC units. The age of this succession ranges between the uppermost Burdigalian and the lowermost Tortonian. The Cilento Group includes the Pollica (POL) and San Mauro (MAU) Fms. (ISPRA, 2017). The former is formed by thin well-bedded arenaceous-pelitic turbidites (Arenarie di Cannicchio Mb.) upward followed by turbidites consisting of alternating sandstones, marls, clays and conglomeratic lenses. The succession upward passes to the San Mauro Fm. formed by siliciclastic and calciclastic (Fogliarina Auct.) turbidites. In the Mt. Centaurino, this deposit includes lenses of breccias of continental crystalline clasts and olistoliths of basalts and gabbros. In the southern sector of the Campania, the Cilento Group laterally passes to the Albidona Fm. (ABD; Bonardi, Ciampo, & Perrone, 1985) made of calcareous and marly-calcareous turbidites with intercalated arenaceous turbidites and sandy-conglomeratic debris. In the Sele River Valley, the Mt. Pruno Fm. (MP; Ciarcia et al., 2009a) is exposed, corresponding to the lower part of the Cilento Group. It consists of grey-greenish argillites with intercalated sandstones, calcarenites and marls.

5.5.2. Castelvetere Group

This sedimentary complex is formed by several, commonly with heteropic relationships, stratigraphic formations: Mt. Sacro, Mt. Siero, Vallone Ponticello, Reino, Breccie di Punta del Capo, Castelvetere, Caiazzo and S. Bartolomeo.

The upper Tortonian Mt. Sacro Fm. (MSA) covers the Cilento Group deposits. It is made of polygenic conglomerates, with dominant crystalline and subordinately carbonate clasts, embedded in a sandy matrix and coarse-grained quartz-feldspatic sandstones. The upper Tortonian Mt. Siero Fm. (MSI), unconformable on the AP carbonates includes calcirudites with calcareous and dolomite clasts embedded in a marly matrix, and secondarily clays and macro-foraminifer breccias. The Vallone Ponticello Fm. (PON) and Reino (REI) Fm. are exposed only in the Irpinia and Sannio sectors. They consist of upper Tortonian marly-arenaceous turbidites with intercalated calcirudites and calcarenites (Ciarcia, Torre, & Mitrano, 2009b; Pescatore et al., 2008). The upper Tortonian Breccie di Punta del Capo Fm. (BCP; D'Argenio et al., 2011; Vitale,

Tramparulo, et al., 2017) overlays the carbonates of Lattari and Avella Mts. It is formed by calcarenites and conglomerates including clasts of Cretaceous limestones, Recommone and Trentinara Fms., with intercalated sandstone lenses and carbonate olistoliths. Similar deposits, mainly characterized by calcareous conglomerates with rare arenaceous and crystalline clasts, are exposed in the Alburno Mts. (RMA; Ruditi dei Monti Alburni; Santo, 1996). The upper Tortonian–lower Messinian Castelvetero Fm. (CVT; Critelli & Le Pera, 1995; Pescatore, Sgrosso, & Torre, 1970), unconformable on the AP units, is made of a base of calcareous conglomerates embedded in an arenaceous matrix, upward passing to turbiditic sandstones with intercalations of clays, marls and conglomerates and olistostromes of the varicolored clays and AP carbonate olistoliths. In the northern sector of the Caserta Mts. and in the Fortore area, this deposit laterally passes to the Caiazzo and S. Bartolomeo Fms., respectively. The late Tortonian–early Messinian Caiazzo Fm. (CAI; Ogniben, 1956) unconformably covers the Camposauro–Matese–Maggiore–Massico Mts. and Sepino–Moschiatturo unit. It includes calcareous conglomerates at base upward evolving to arkosic–lithic sandstones, with calcareous cement and clay chips, locally with carbonate olistoliths and olistostromes of varicolored clays. In the Mt. Massico, this deposit hosts olistoliths and clasts of marbles (Di Girolamo, Sgrosso, De Genaro, & Giurazzi, 2000). The upper Tortonian–lower Messinian S. Bartolomeo Fm. (SBO; Crostella & Vezzani, 1964; Pescatore et al., 2000) is unconformable on the Fortore unit, consisting of turbiditic arkosic sandstones, clays and polygenic conglomerates frequently with millimeter up to few meters sized crystalline clasts.

5.5.3. Altavilla Group

It is formed by two upper Messinian–lowermost Pliocene formations both unconformable on the Castelvetero Group and Daunia unit: Altavilla (ALT; Ippolito et al., 1973) and Anzano (ANZ; Crostella & Vezzani, 1964). The Altavilla Fm. is formed by at base diatomites, evaporitic limestones, gypsum and sulfur levels, upward passing to conglomerates, sands, silty clays and clays, with intercalated varicolored clay lenses. The Anzano Fm. includes at base quartz-feldspatic sandstones and conglomerates and subordinate clays and silts. Levels of reworked gypsum, pelites with Pannonic-affinity ostracofaunas (Lago–Mare facies) and localized evaporites locally occur.

5.5.4. Baronía Fm.

The upper Zanclean Baronía Fm. (BAR; Ciarcia & Vitale, 2013) is a sedimentary succession covering the Altavilla Group and Vallone del Toro unit. It includes continental–transitional massive and bedded polygenic

conglomerates, yellowish shallow-water sands, silts and grey clays and localized arenaceous turbidites at base.

5.5.5. Sferracavallo Fm.

The Piacenzian Sferracavallo Fm. (SFE; Ciarcia, Di Nocera, Matano, & Torre, 2003) is formed by continental–transitional well-bedded polygenic conglomerates, sandstones with abundant mollusc shells, calcarenites and bioclastic calcirudites, silts and shallow-water grey–bluish clays.

5.6. Pleistocene–Recent deposits

Several Pleistocene intermontane and coastal structural depressions were formed as following the complex tectonic evolution of the eastern Tyrrhenian Sea side and Campania region (Milia & Torrente, 2014, 2015; Milia, Torrente, et al., 2017; Santangelo, Romano, Ascione, & Russo ermolli, 2017 and references therein). These basins were filled by marine, lacustrine, fluvial and volcanic sediments. In the Campania and Garigliano River Plain, sediments alternate with volcanic rocks produced by the Roccamonfina before and Campi Flegrei and Somma-Vesuvio after. The Pleistocene–Recent volcanic activity formed thick piles of pyroclastic and fallout deposits as well as volcanic edifices and calderas. The oldest exposed post-orogenic volcanic rocks are related to the activity of Roccamonfina volcano (630–50 ka; Conticelli et al., 2009 and references therein; De Rita & Giordano, 1996). The subsequent volcanic activity was characterized by different localizations of the eruptive vents: Ischia Island (150 ka–1302 AD; Meluso et al., 2014 and references therein), Campi Flegrei-Procida Island (80 ka–1538 AD; Torrente, Milia, Bellucci, & Rolandi, 2010; Isaia et al., 2015 and references therein) and finally Somma-Vesuvio volcano which activity started ca. 39 ka up to the last eruption of the 1944 AD (Cioni, Santacroce, & Sbrana, 1999 and references therein).

6. Geological cross-sections

The deep structure of the southern Apennines is a still debated issue. One of the most controversial topics is the role of thin- and thick-skinned tectonics during the Cenozoic orogenic evolution. Although geophysical surveys, such as the CROP04 project, provided us fundamental tools to shed light on this subject, tectonic interpretations have been various and often strongly contrasting (e.g. Butler et al., 2005; Catalano et al., 2004; Cippitelli, 2007; Menardi Noguera & Rea, 2000; Patacca & Scandone, 2007; Shiner, Beccacini, & Mazzoli, 2004; Scrocca et al., 2007; Vitale et al., 2012; Vitale & Ciarcia, 2013). We endorse the hypothesis of an alternating thin- and thick-skinned deformation with (i) the predominance of flat-dominated thrusts during the formation of the LAC and the imbrication of the

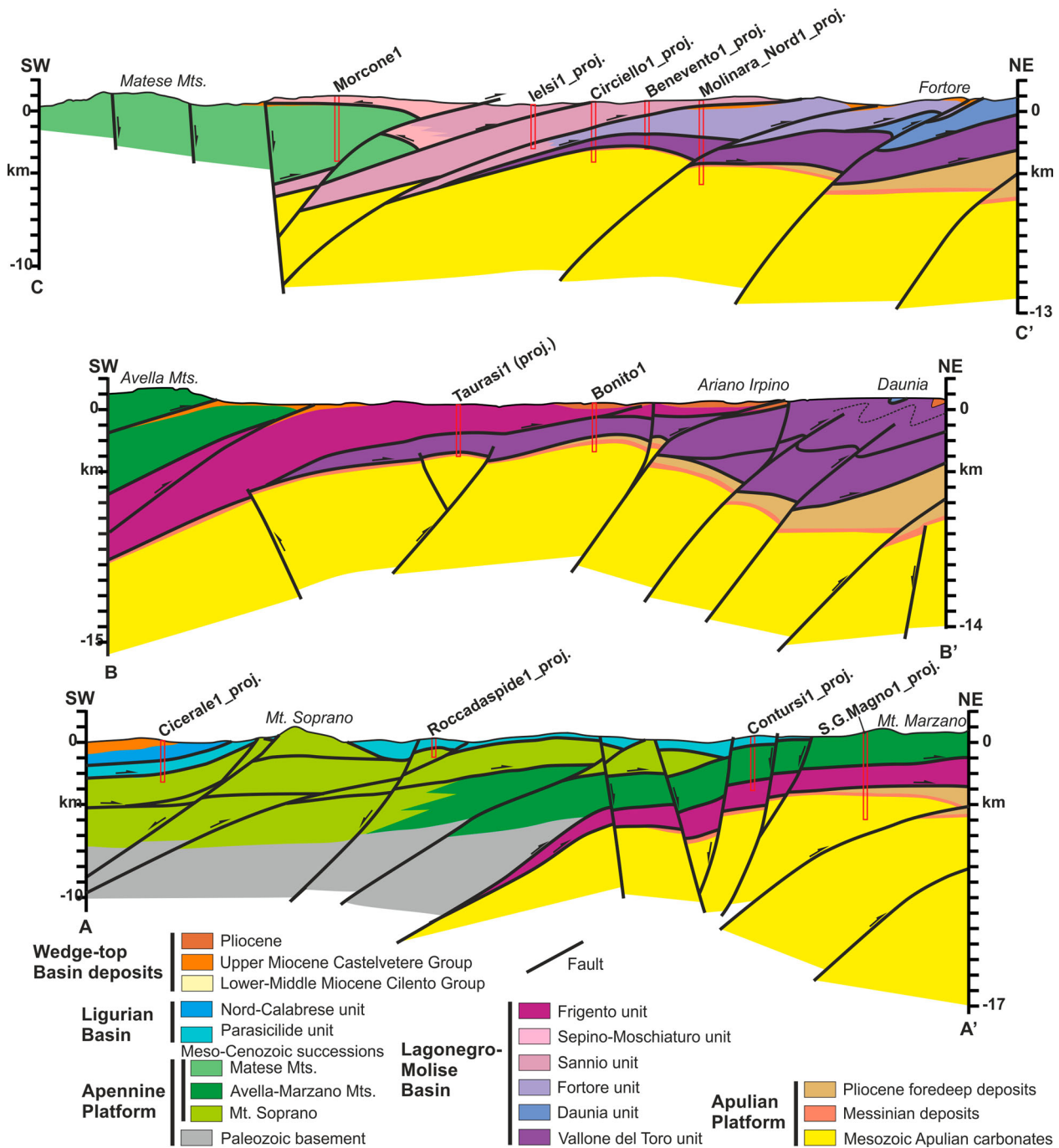


Figure 4. Geological cross-sections (traces are shown in Figure 2). The B–B’ section was modified from Ciarcia and Vitale (2013). For the stratigraphic setting, we used information from the well-logs of: Morcone_01bis_app, Ielsi_01, Circello_01; Benevento_01, Molinara_nord_01, Taurasi_01, Bonito_01, Cicerale_01, Roccadaspide_01, Contursi_01 and San Gregorio Magno_01 (VIDEPI, 2017).

LMB thrust sheets; (ii) the involvement of the Paleozoic basement during the overthrusting of the Apennine carbonates onto the LMB units and finally (iii) an important switch in the tectonic style occurred since the uppermost Miocene with the development of deep-seated thrust faults locally upward cross-cutting the allochthonous wedge as envelopment thrusts (e.g. Vitale, Tramparulo, et al., 2017).

In the light of this model, we built three sections (A–A’, B–B’ and C–C’; Figure 4) in three different sectors of the region (traces are shown in Figure 2). The A–A’ section comprises the inner units of the Apennine chain whereas the B–B’ and C–C’ sections illustrate

the structure of the external units. The section A–A’, corresponding to the Campania sector of the CROP04 seismic line and located the inner sector of the Apennine chain, shows the complete nappe pile of the southern Apennines formed, from top to bottom, by LAC, AP, Frigento (LMB) and buried Apulian units.

In the western side of the area, the main thrust between AP and LMB units involves the Paleozoic basement as well as late ramp-dominated thrust faults (thick-skinned deformation). The B–B’ section shows again the AP onto the LMB (Frigento) units with the interposition of upper Miocene deposits of the

Castelvetere Group. Once more ramp-dominated thrust faults cross-cut the Apulian carbonates and the allochthonous units, forming, in the easternmost side (Daunia sector), a highly deformed zone made up of NE-verging km-long anticlines that deform also the Pliocene wedge-top basin deposits. Finally the C–C' section shows the superposition of the Sepino–Mt. Moschiatturo unit (LMB) onto the Matese Mts. succession (AP) by means of a back thrust involving the deposits of Castelvetere Group. In turn the AP succession tectonically overlies a thrust sheet pile formed by Sannio, Fortore, Daunia and Vallone del Toro units (LMB). The thrust faults between Matese Mts., Sepino–Mt. Moschiatturo, Sannio and Fortore are all associated to deep-seated thrust faults deforming the buried carbonates of the Apulian Platform (thick-skinned tectonics). On the contrary the thrust faults separating the Fortore, Daunia and Vallone del Toro are associated to the late Tortonian–Messinian thin-skinned thrusting.

7. Conclusion

A geological map of the Campanian region is provided. It was made up using professional software and is geospatially referenced. The map and the proposed geological setting are the result of several years of geological research (starting from the geological map of Bonardi, D'Argenio, et al., 1988) and the old and new cartography delivered by the Italian Geological Survey. The integration between the map and the accompanying regional sections reveals the complex architecture of the southern Apennines thrust belt, characterized by an alternating thin- and thick-skinned tectonics, expressed by flat- and ramp-dominated thrust faults, respectively. A major switch in the structural style occurred since the uppermost Miocene, well-marked in the cross-sections where deep seated thrust faults in the buried Apulian carbonates, upward cross-cut the allochthonous wedge, frequently involving the upper Miocene–Pliocene wedge-top deposits.

Software

All available data, carried out from the literature and official cartography, were first processed to compile a geodatabase in GIS format (QGIS software). Subsequently, lines were imported in vector graphic software (CorelDraw X7) to allow a classical cartographic design.

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References

- Ascione, A., Ciarcia, S., Di Donato, V., Mazzoli, S., & Vitale, S. (2012). The Pliocene–Quaternary wedge-top basins of southern Italy: An expression of propagating lateral slab tear beneath the Apennines. *Basin Research*, 24, 456–474.
- Barchi, M., Amato, A., Cippitelli, G., Merlini, S., & Montone, P. (2007). Extensional tectonics and seismicity in the axial zone of the Southern Apennines. *Bollettino della Societa Geologica Italiana*, Spec. Issue 7, 47–56.
- Basso, C., Ciampo, G., Ciarcia, S., Di Nocera, S., Matano, F., & Torre, M. (2002). Geologia del settore irpino-dauno dell'Appennino meridionale: unità meso-cenozoiche e vincoli stratigrafici nell'evoluzione tettonica mio-pliocenica. *Studi Geologici Camerti*, 1, 7–27.
- 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. *Memorie della Societa Geologica Italiana*, 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. *Bollettino della Societa Geologica Italiana*, 104, 539–549.
- Bonardi, G., Ciarcia, S., Di Nocera, S., Matano, F., Sgrosso, I., & Torre, M. (2009). Carta delle principali unità cinematiche dell'Appennino meridionale. Nota illustrativa. *Italian Journal of Geosciences*, 128, 47–60. (scale 1:250,000, 1 sheet).
- Bonardi, G., D'Argenio, B., & Perrone, V. (1988). Carta geologica dell'Appennino meridionale. *Memorie della Societa Geologica Italiana*, 41, (1: 250,000 scale map).
- Boni, M., Reddy, S. M., Mondillo, N., Balassone, G., & Taylor, R. (2012). A distant magmatic source for Cretaceous karst bauxites of Southern Apennines (Italy), revealed through SHRIMP zircon age dating. *Terra Nova*, 24, 326–332.
- Brancaccio, L., Cinque, A., Romano, P., Roskopf, C., Russo, F., Santangelo, N., & Santo, A. (1991). - Geomorphology and neotectonic evolution of a sector of the tyrrhenian flank of the southern Apennines (region of Naples, Italy). *Zeitschrift für Geomorphologie*, 82(Suppl. Bd.), 47–58.
- Bravi, S., & Schiattarella, M. (1988). Stratigrafia dei livelli itticioliti eocenici dei Monti Alburni (Appennino Campano). *Memorie della Societa Geologica Italiana*, 41, 587–591.
- Butler, R. W. H., Mazzoli, S., Corrado, S., De Donatis, M., Di Bucci, D., Gambini, R., ... Zucconi, V. (2005). Applying thick-skinned tectonic models to the Apennine thrust belt of Italy – limitations and implications. In K. R.

- McClay (Ed.), Thrust tectonics and hydrocarbon systems, *AAPG memoir*, 82, (pp. 647–667).
- Carminati, E., Lustrino, M., & Doglioni, C. (2012). Geodynamic evolution of the central and western Mediterranean: Tectonics vs. Igneous petrology constraints. *Tectonophysics*, 579, 173–192.
- Casero, P. (2004). Structural setting of petroleum exploration plays in Italy. In U. Crescenti, S. d’Offizi, S. Merlino, & L. Sacchi (Eds.), *Geology of Italy. Special publication of the Italian geological society for the IGC 32nd*. (pp. 189–199). Florence.
- Catalano, S., Monaco, C., Tortorici, L., Paltrinieri, W., & Steel, N. (2004). Neogene–Quaternary tectonic evolution of the southern Apennines. *Tectonics*, 23, TC2003.
- 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). *Bollettino della Società Geologica Italiana*, 122, 117–137.
- Ciarcia, S., Mazzoli, S., Vitale, S., & Zattin, M. (2012). On the tectonic evolution of the Ligurian accretionary complex in southern Italy. *Geological Society of America Bulletin*, 124, 463–483.
- Ciarcia, S., Torre, M., & Mitrano, T. (2009b). Stratigrafia della Formazione del Ponticello (Miocene Superiore, Appennino campano). *Bollettino della Società Geologica Italiana*, 128, 715–721.
- Ciarcia, S., & Vitale, S. (2013). Sedimentology, stratigraphy and tectonics of evolving wedge-top depozone: Ariano Basin, southern Apennines, Italy. *Sedimentary Geology*, 290, 27–46.
- Ciarcia, S., Vitale, S., Di Staso, A., Iannace, A., Mazzoli, S., & Torre, M. (2009a). Stratigraphy and tectonics of an internal unit of the Southern Apennines: Implications for the geodynamic evolution of the peri-Tyrrhenian mountain belt. *Terra Nova*, 21, 88–96.
- Cioni, R., Santacroce, R., & Sbrana, A. (1999). Pyroclastic deposits as a guide for reconstructing the multi-stage evolution of the Somma-Vesuvius Caldera. *Bulletin of Volcanology*, 61, 207–222.
- Cippitelli, G. (2007). The CROP-04 seismic profile. Interpretation and structural setting of the Agropoli-Barletta Geotraverse. *Bollettino della Società Geologica Italiana*, 7, 267–281.
- Coticelli, S., Marchionni, S., Rosa, D., Giordano, G., Boari, E., & Avanzinelli, R. (2009). Shoshonite and sub-alkaline magmas from an ultrapotassic volcano: Sr–Nd–Pb isotope data on the roccamonfina volcanic rocks, Roman Magmatic Province, southern Italy. *Contributions to Mineralogy and Petrology*, 157, 41–63.
- Cosentino, D., Cipollari, P., Marsili, P., & Scrocca, D. (2010). Geology of the central Apennines: A regional review. The geology of Italy: Tectonics and life along plate margins. In M. Beltrando, A. Peccerillo, M. Mattei, S. Coticelli, & C. Doglioni (Eds.), *Journal of the virtual explorer* (p. 36). Retrieved from <http://dx.doi.org/10.3809/jvirtex.2010.00223> (paper 12)
- Critelli, S. (1999). The interplay of lithospheric flexure and thrust accommodation in forming stratigraphic sequences in the southern Apennines foreland basin system, Italy. *Memorie dell’Accademia Nazionale dei Lincei*, 10, 257–326.
- Critelli, S., de Capoa, P., le Pera, E., & Perrone, E. (1994). Stratigrafia e petrografia delle Arenarie di Albanella (valle del Calore, Appennino campano). *Bollettino della Società Geologica Italiana*, 113, 451–463.
- Critelli, S., & Le Pera, E. (1995). La Formazione di Castelveteve nell’evoluzione petrostratigrafica dell’avanfossa del Tortoniano-Messiniano dell’Appennino meridionale. *Bollettino della Società Geologica Italiana*, 114, 615–634.
- Crostella, A., & Vezzani, L. (1964). La geologia dell’Appennino foggiano. *Bollettino della Società Geologica Italiana*, 83, 121–142.
- D’Argenio, B., Barattolo, F., Budillon, F., Cesarano, M., Donadio, C., Pappone, G., ... Putignano, M. L. (2011). Note illustrative della Carta Geologica d’Italia alla scala 1:25,000, sez. I NE Isola di Capri. Retrieved from www.isprambiente.gov.it/Media/carg/note_illustrative/484_Isola_di_Capri.pdf
- D’Argenio, B., Pescatore, T., & Scandone, P. (1973). Schema geologicodell’Appennino meridionale (Campania e Lucania). *Atti del Conv. Moderne vedute sulla geologia dell’Appennino. Acc. Nazion. Lincei*, 182, 49–72.
- D’Argenio, B., Pescatore, T., & Scandone, P. (1975). Structural pattern of the Campania–Lucania Apennines. In L. Ogniben, M. Parotto, & A. Praturlon (Eds.), *Structural model of Italy, Quaderni de «La ricerca scientifica»*, 90 (pp. 313–327). Roma: C.N.R.
- Dazzaro, L., Di Nocera, S., Pescatore, T., Rapisardi, L., Romeo, M., Russo, B., ... Torre, M. (1988). Geologia del margine della catena appenninica tra il F. Fortore ed il T. Calaggio (Monti della Daunia – App. Merid.). *Memorie della Società Geologica Italiana*, 41, 411–422.
- De Rita, D., & Giordano, G. (1996). Volcanological and structural evolution of roccamonfina volcano (southern Italy). In W. J. Mc Guire, A. P. Jones, & J. Neuberg (Eds.), *Volcano instability on the earth and other planets*, 110 (pp. 209–224). London: Geological Society.
- Dewey, J. F., Helman, M. L., Turco, E., Hutton, D. H. W., & Knott, S. D. (1989). Kinematics of the western Mediterranean. In M. P. Coward, D. Dietrich, & R. G. Park (Eds.), *Alpine tectonics* (pp. 265–283). London: Geological Society. Special Publications, 45.
- Di Girolamo, P., Sgrosso, I., De Gennaro, R., & Giurazzi, S. (2000). Metamorphic rocks in Campania (southern Italy): the ‘Mondragone marbles’. Petrological and geological study. *Bollettino della Società Geologica Italiana*, 119, 761–766.
- Faccenna, C., Becker, T. W., Lucente, F. P., Jolivet, L., & Rossetti, F. (2001). History of subduction and back-arc extension in the central Mediterranean. *Geophysical Journal International*, 145, 809–820.
- Guerrera, F., Martin-Algarra, A., & Perrone, V. (1993). Late Oligocene–Miocene syn-late-orogenic successions in western and central Mediterranean chains from the betic Cordillera to the southern Apennines. *Terra Nova*, 5, 525–544.
- Iannace, A., Frijia, G., Galluccio, L., & Parente, M. (2014). Facies and early dolomitization in upper Albian shallow-water carbonates of the southern Apennines (Italy): paleotectonic and paleoclimatic implications. *Facies*, 60, 169–194.
- Ippolito, F., D’argenio, B., Pescatore, T., & Scandone, P. (1973). Unità stratigrafico-strutturali e schema tettonico dell’Appennino meridionale. *Trad. from «The guide-book of Italy»*, 134–155. *Petroleum Exploration Society of Libia. Ist. Geol. Geof. Univ., pubbl. n.s.*, 15, Napoli.
- Isaia, R., Vitale, S., Di Giuseppe, M. G., Iannuzzi, E., Tramparulo, F. D. A., & Troiano, A. (2015). Stratigraphy, structure and volcano-tectonic evolution of Solfatara maar-diatreme (Campi Flegrei, Italy). *Geological Society of America Bulletin*, 127, 1485–1504.

- ISPRA. (2017). Geological maps of Italy, scale 1:50,000. Sheets 405, 407, 419, 431, 432, 433, 446–447, 448, 449, 450, 451, 464, 465, 466, 467, 468, 484, 485, 486, 489, 502, 503, 504, 505, 519, 520, 521. Retrieved from <http://www.isprambiente.gov.it/Media/carg/campania.html>
- Malinverno, A., & Ryan, W. B. F. (1986). Extension in the tyrrhenian Sea and shortening in the Apennines as result of arc migration driven by sinking of the lithosphere. *Tectonics*, 5, 227–245.
- Mariani, M., & Prato, R. (1988). I bacini neogenici costieri del margine tirrenico: approccio sismicostratigrafico. *Memorie della Società Geologica Italiana*, 41, 519–531.
- Mazzotti, A., Patacca, E., & Scandone, P. (eds.) (2007). Results of the CROP project Sub-project CROP-04 Southern Apennines (Italy). *Bollettino della Società Geologica Italiana*, 7, 314.
- Melluso, L., Morra, V., Guarino, V., de Gennaro, R., Franciosi, L., & Grifa, C. (2014). The crystallization of shoshonitic to peralkaline trachyphonolitic magmas in a H₂O–Cl–F-rich environment at ischia (Italy), with implications for the feeder system of the Campania plain volcanoes. *Lithos*, 210–211, 242–259.
- Menardi Noguera, A., & Rea, G. (2000). Deep structure of the Campanian–Lucanian Arc (southern Apennines). *Tectonophysics*, 324, 239–265.
- Milia, A., Iannace, P., Tesauro, M., & Torrente, M. M. (2017). Upper plate deformation as marker for the Northern STEP fault of the Ionian slab (Tyrrhenian Sea, central Mediterranean). *Tectonophysics*, v. 710-711, 127–148. doi:10.1016/j.tecto.2016.08.017
- Milia, A., & Torrente, M. M. (1999). Tectonics and stratigraphic architecture of a pery-Tyrrhenian half-graben (Bay of Naples, Italy). *Tectonophysics*, 315, 297–314.
- Milia, A., & Torrente, M. M. (2011). The possible role of extensional faults in localizing magmatic activity: A crustal model for the Campanian volcanic zone (Eastern Tyrrhenian Sea, Italy). *Journal of the Geological Society*, 168, 471–484.
- Milia, A., & Torrente, M. M. (2014). Early-stage rifting of the southern Tyrrhenian region: The Calabria–Sardinia breakup. *Journal of Geodynamics*, 81, 17–29. doi:10.1016/j.jog.2014.06.001
- Milia, A., & Torrente, M. M. (2015). Tectono-stratigraphic signature of a rapid multistage subsiding rift basin in the Tyrrhenian–Apennine hinge zone (Italy): A possible interaction of upper plate with subducting slab. *Journal of Geodynamics*, v. 86, 42–60.
- Milia, A., Torrente, M. M., & Iannace, P. (2017). Pliocene–Quaternary orogenic systems in central Mediterranean: The Apulia–Southern Apennines–Tyrrhenian Sea example. *Tectonics*. doi:10.1002/2017TC004571
- Milia, A., Torrente, M. M., Russo, M., & Zuppetta, A. (2003). Tectonics and crustal structure of the Campania continental margin: Relationships with volcanism. *Mineralogy and Petrology*, 79, 33–47.
- Milia, A., Valente, A., Cavuoto, G., & Torrente, M. M. (2017). Miocene progressive forearc extension in the central Mediterranean. *Tectonophysics*, 710-711, 232–248.
- Mostardini, F., & Merlini, S. (1986). Appennino centro-meridionale: Sezioni geologiche e proposta di modello strutturale. *Memorie Della Società Geologica Italiana*, 35, 177–202.
- Ogniben, L. (1956). Flysch miocenico autoctono e parautoctono e argille scagliose alloctone nella zona di caiazzo (caserta). *Bollettino Della Società Geologica Italiana*, 75, 169–179.
- Pappone, G., & Ferranti, L. (1995). Thrust tectonics in the picentini mountains, southern Apennines, Italy. *Tectonophysics*, 252, 331–348.
- Patacca, E., Sartori, R., & Scandone, P. (1990). Tyrrhenian basin and Apenninic arcs: kinematic relations since Late Tortonian times. *Memorie della Società Geologica Italiana*, 45, 425–451.
- Patacca, E., & Scandone, P. (2007). Results of the CROP project, sub-project CROP-04. *Bollettino Della Società Geologica Italiana*, 7, 75–119.
- Pescatore, T., Di Nocera, S., Matano, F., Pinto, F., Quarantiello, R., Amore, O., ... Martino, C. (2008). Geologia del settore centrale dei Monti del Sannio: nuovi dati stratigrafici e strutturali. *Memorie Descrittive Carta Geologica d'Italia*, 77, 77–95.
- 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). *Bollettino della Società Geologica Italiana*, 119, 587–601. (scale 1:50000, 1 sheet).
- Pescatore, T., Renda, P., Schiattarella, M., & Tramutoli, M. (1999). Stratigraphic and structural relationships between Meso-Cenozoic Lagonegro basin and coeval carbonate platforms in southern Apennines, Italy. *Tectonophysics*, 315, 269–286.
- Pescatore, T., Sgrosso, I., & Torre, M. (1970). Lineamenti di tettonica e sedimentazione nel Miocene dell'Appennino campano-lucano. *Memorie Società Naturalisti in Napoli*, 78, 337–408.
- Rossetti, F., Faccenna, C., Goffé, B., Monié, P., Argentieri, A., Funicello, R., & Mattei, M. (2001). Alpine structural and metamorphic signature of the sila piccola massif nappe stack (Calabria, Italy): insights for the tectonic evolution of the Calabrian Arc. *Tectonics*, 20, 112–133.
- Santangelo, N., Romano, P., Ascione, A., & Russo ermolli, E. (2017). Quaternary evolution of the Southern Apennines coastal plains: A review. *Geologica Carpathica*, 68, 43–56.
- Santo, A. (1996). Le ruditi dei Monti Alburni nel quadro dell'evoluzione altomiocenica dell'Appennino campano. *Bollettino della Società Geologica Italiana*, 115, 519–528.
- Scandone, P. (1967). Studi di geologia lucana: La serie calcareo-silico-marnosa ed i suoi rapporti con l'Appennino calcareo. *Bollettino della Società dei Naturalisti in Napoli*, 76, 301–469.
- Scandone, P. (1972). Studi di geologia lucana: Carta dei terreni della serie calcareo-silico-marnosa e note illustrative. *Bollettino della Società dei Naturalisti in Napoli*, 81, 225–300.
- Scandone, P., & Sgrosso, I. (1974). La successione miocenica dell'alta Vallimala nella finestra tettonica di Campagna (Monti Picentini). *Bollettino della Società Geologica Italiana*, 93, 1043–1047.
- Scrocca, D., Sciamanna, S., Di Luzio, E., Tozzi, M., Nicolai, C., & Gambini, R. (2007). Structural setting along the CROP-04 deep seismic profile (Southern Apennines–Italy). *Bollettino della Società Geologica Italiana*, 7, 283–296.
- Selli, R. (1957). Sulla trasgressione del Miocene nell'Italia meridionale. *Giornale Geologia*, 26, 1–54.
- Selli, R. (1962). Il Paleogene nel quadro della geologia dell'Italia Meridionale. *Memorie della Società Geologica Italiana*, 3, 733–789.
- Servizio Geologico d'Italia. (1963–1972). Geological maps of Italy, scale 1:100,000, sheets 160, 161, 162, 163, 171, 172, 173, 174, 175, 183–184, 185, 186, 187, 196, 197, 198, 199, 209, 210. Retrieved from http://193.206.192.231/carta_geologica_italia/default.htm

- Sgrosso, I. (1998). Possibile evoluzione cinematica miocenica nell'orogene centro-sud appenninico. *Bollettino della Società Geologica Italiana*, 117, 679–724.
- Shiner, P., Beccacini, A., & Mazzoli, S. (2004). Thin-skinned versus thick-skinned structural models for Apulian carbonate reservoirs: Constraints from the Val D'Agri fields. *Marine and Petroleum Geology*, 21, 805–827.
- Torrente, M. M., Civile, D., Martino, C., & Milia, A. (2000). Assetto strutturale ed evoluzione tettonica dell'area del Monte Vesole – Monte Chianello (Cilento, Appennino meridionale). *Bollettino Della Società Geologica Italiana*, 119, 733–747.
- Torrente, M. M., Milia, A., Bellucci, F., & Rolandi, G. (2010). Extensional tectonics in the Campania volcanic zone (eastern Tyrrhenian Sea, Italy): New insights into the relationship between faulting and ignimbrite eruptions. *Italian Journal of Geosciences*, 129, 297–315.
- ViDEPI. (2017). Retrieved from <http://unmig.sviluppoeconomico.gov.it/videpi/pozzi/pozzi.asp>
- Vitale, S., Amore, O. F., Ciarcia, S., Fedele, L., Grifa, C., Prinzi, E. P. ... Tramparulo, F. D. A. (2017). Structural, stratigraphic and petrological clues for a Cretaceous–Paleocene abortive rift in the southern Adria domain (southern Apennines, Italy). *Geological Journal*. doi:10.1002/gj.2919
- Vitale, S., & Ciarcia, S. (2013). Tectono-stratigraphic and kinematic evolution of the southern Apennines/Calabria–Peloritani Terrane system (Italy). *Tectonophysics*, 583, 164–182.
- Vitale, S., Ciarcia, S., Mazzoli, S., & Zaghoul, M. N. (2011). Tectonic evolution of the 'Liguride' accretionary wedge in the Cilento area, southern Italy: a record of early Apennine geodynamics. *Journal of Geodynamics*, 51, 25–36.
- Vitale, S., Ciarcia, S., & Tramparulo, F. D. A. (2013). Deformation and stratigraphic evolution of the Ligurian Accretionary Complex in the southern Apennines (Italy). *Journal of Geodynamics*, 66, 120–133.
- Vitale, S., Dati, F., Mazzoli, S., Ciarcia, S., Guerriero, V., & Iannace, A. (2012). Modes and timing of fracture network development in poly-deformed carbonate reservoir analogues. *Mt. Chianello, southern Italy*. *Journal of Structural Geology*, 37, 223–235.
- Vitale, S., Tramparulo, F. D. A., Ciarcia, S., Amore, F. O., Prinzi, E. P., & Laiena, F. (2017). The northward tectonic transport in the southern Apennines: Examples from the Capri Island and western Sorrento Peninsula (Italy). *International Journal of Earth Sciences*, 106, 97–113.