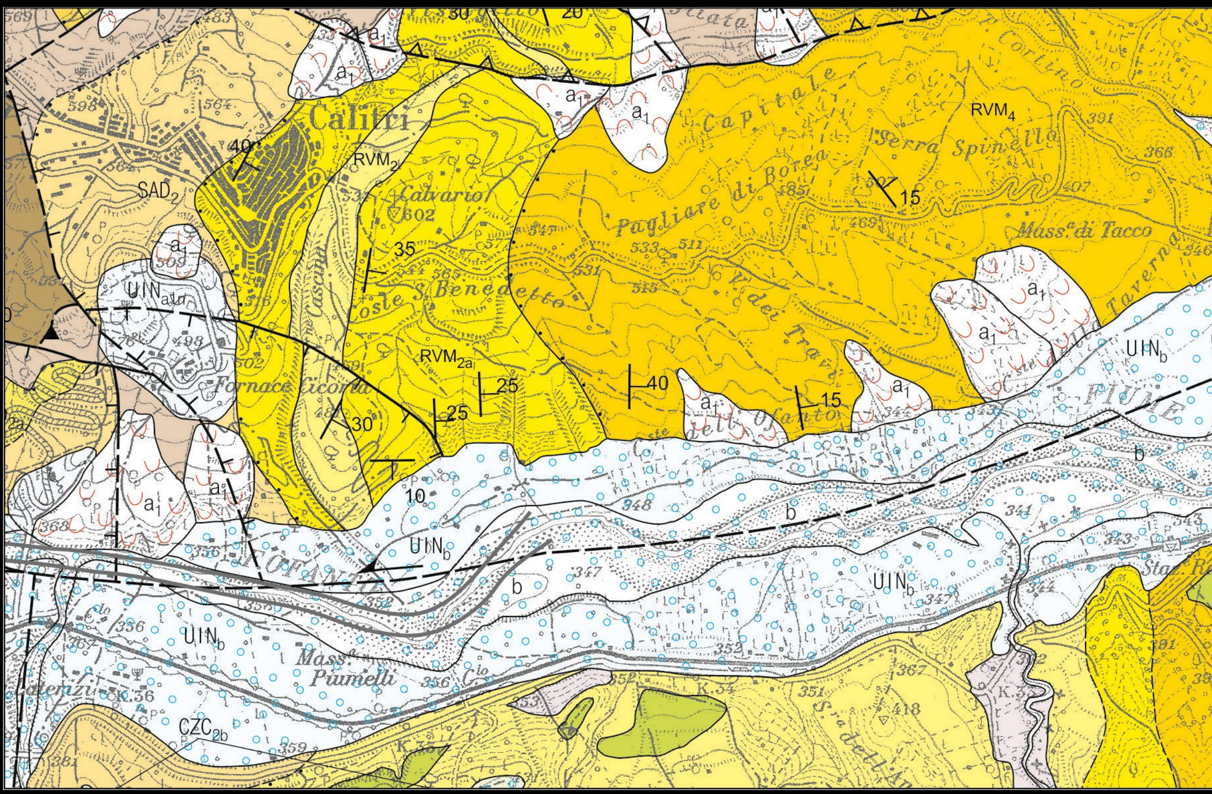
Geological Field Trips and Maps



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Geological map of the eastern sector of the Pliocene-Quaternary Ofanto Basin: an upgrade

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Cover page Figure A
Panoramic view of the Fronti di Ruvo area.

Cover page Figure B
Part of the geological map concerning the Calitri-Serra Spinello area.

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Abstract

The mapped area is located west of Monte Vulture volcano on the fold-and-thrust belt front of the southern Apennines chain and includes Pliocene to Quaternary marine and continental sediments of the Ofanto Basin. This basin, showing an E-W trend, traces a marked bend in the NW-SE regular orientation of the South-Apennines morphostructures. The geological map here presented was drawn on a topographic base of IGM at 1:25,000 scale, using CorelDRAW® Graphics Suite software. It contains a large portion of the field survey performed in the CARG Project (*geological cartography of Italy*) for the mapping of the Sheet 451 *"Melfi"* at the scale 1:50,000.

The Ofanto Basin is one of the best example of intra-chain basin with a rich record of tectonics-sedimentation interplay. The stratigraphic techniques here adopted vary in relation to the type of rocks, i.e. as a function of the presence of bedrock units, clastic covers, alluvial terraced deposits, or volcanic products. As a mater of fact, in the study area the bedrock is represented by tectonic units formed of continuous and concordant stratigraphic successions of different lithology, whereas the Pliocene-Quaternary deposits have been mapped using Unconformity-Boundary Stratigraphic Units (*UBSU*), in turn composed by several lithofacies.

The need of an upgrade of the geological map of the Ofanto Basin, edited in 2014, has been stimulated by a new stratigraphic pattern concerning a relevant issue of the sedimentary succession, i.e. the further subdivision of an original unconformity-bounded unit. In particular, sedimentological and biostratigraphic analyses performed on many stratigraphic logs have revealed local unconformities which allowed subdividing the Ruvo del Monte synthem in five new subsynthems. The ages of such subsynthems and their arrangement along the axis of the basin display a peculiar tectonically-controlled west to east migration pattern of sedimentation, driven by left-lateral transpression.

Keywords: Unconformity-bounded stratigraphic units (UBSU), tectono-sedimentary evolution, Pliocene-Quaternary, Ofanto Basin, southern Apennines (Italy).

Introduction

The Ofanto Basin (hereafter OB) extends along the homonymous river from the Monte Vulture Volcano to Lioni village, covering an area about 7 km wide and 45 km long (Fig. 1). It has been intensely deformed by sinsedimentary Pliocene-Quaternary folding and faulting (Giannadrea et al., 2014) and interpreted as a piggyback basin (Roure et al., 1991; Hippolyte et al., 1992, 1994; Patacca and Scandone, 2001) or as a more generic thrust-top basin (Casciello et al., 2013). Its deposits have been divided in two sedimentary cycles (Vezzani, 1968; Pescatore and Ortolani, 1973), whereas the official 1:50,000-scale geological maps – sheets 451 *"Melfi"* and 450 *"Sant'Angelo dei Lombardi"* (Servizio Geologico d'Italia, 2010 and 2016) – describe six Unconformity-Bounded Stratigraphic Units (hereafter UBSU, including both synthems and subsynthems) grouped in three supersynthems (named, from the oldest to the youngest: Aquilonia, Ariano Irpino and Fiumara di Atella).

The geological map of the eastern sector of the OB (Fig. 1a) was published at 1:25,000 scale as an attached map to the paper entitled "Pliocene to Quaternary evolution of the Ofanto Basin in southern Italy: an approach based on the unconformity-bounded stratigraphic units" (Giannandrea et al., 2014). In this paper, the Authors illustrate the step-by-step criteria which led to the recognition of the stratigraphic setting of the study area. An amount of about 3500 m-thick stratigraphic sections were analysed and stratigraphically correlated (Fig. 2). Such a synoptic stratigraphic scheme has shown local-scale unconformities (x_1, x_2, and x_3), not previously mapped, which allows further stratigraphic subdivisions of the Ruvo del Monte synthem. The limits among the new subsynthems coincide with the lithological boundaries already mapped at the scale 1:25,000 as lithofacies. We have recently performed a cartographic revision in the field, mapping the single unconformities inside the Ruvo del Monte synthem, which led to the institution of five subsynthems labelled as follows (from the bottom): Cairano, Calitri, Masseria Quaglietta, Serra Spinello, and Casalino. Consequently, we propose here an upgrade of the published geological map of the eastern sector of the OB – a best practice in the digital cartography era – for the new map shows a substantial difference with regard to the previous map, which highlights the presence of tectonic structures and implies some relevant remarks about the main deformational features of the area (cf. Figs. 1a and 1b).

Methods and techniques

Fieldwork and sedimentological analyses of stratigraphic sections (for a total thickness of ~3500 m) carried out in the whole basin area (Fig. 1 and 2) along the more significant outcrops (Giannandrea et al., 2014) have been here partly re-interpreted. The stratigraphic analysis has been mainly carried out through the recognition and description of discontinuity surfaces. Some second-order unconformity surfaces have been mapped and illustrated in details. Abrupt facies changes, lithological contacts and the geometric relationships among the major geological bodies have been used to recognize the discontinuities in the field. The stratigraphic subdivision of the units confined by such discontinuities has been based on the UBSU criteria (Chang, 1975; Salvador, 1987, 1994).

Biostratigraphic data, published in Giannandrea et al. (2014), have been obtained from both calcareous

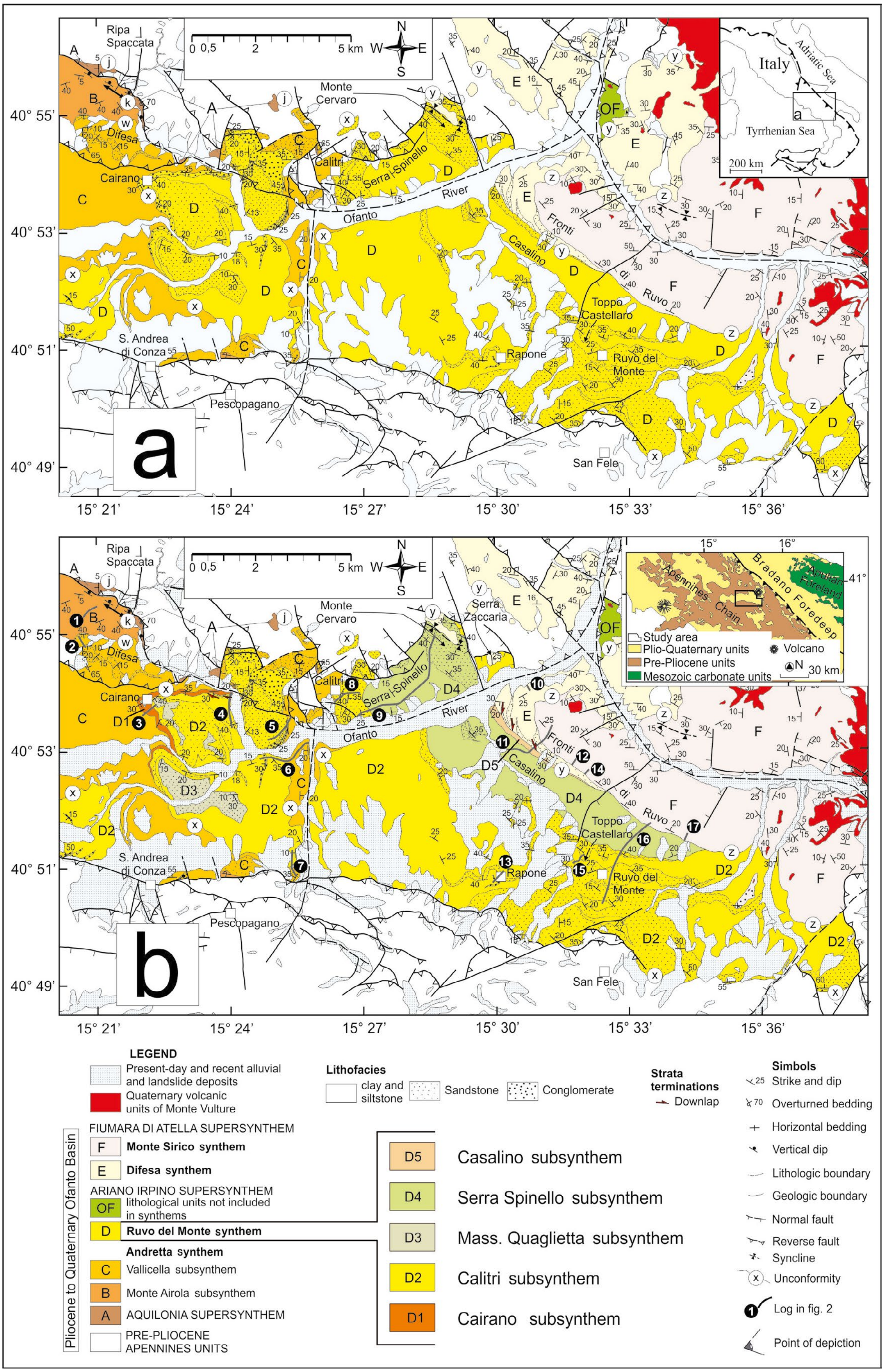

Fig. 1 – a) Geological map of the eastern sector of the Pliocene to Quaternary Ofanto Basin (modified, after Giannandrea et al., 2014); b) Upgrade of the Geological map of the eastern sector of the Pliocene to Quaternary Ofanto Basin, with locations of the segments in which we performed the sampling for biostratigraphic analysis and collected sedimentological data (shown in Fig. 2).

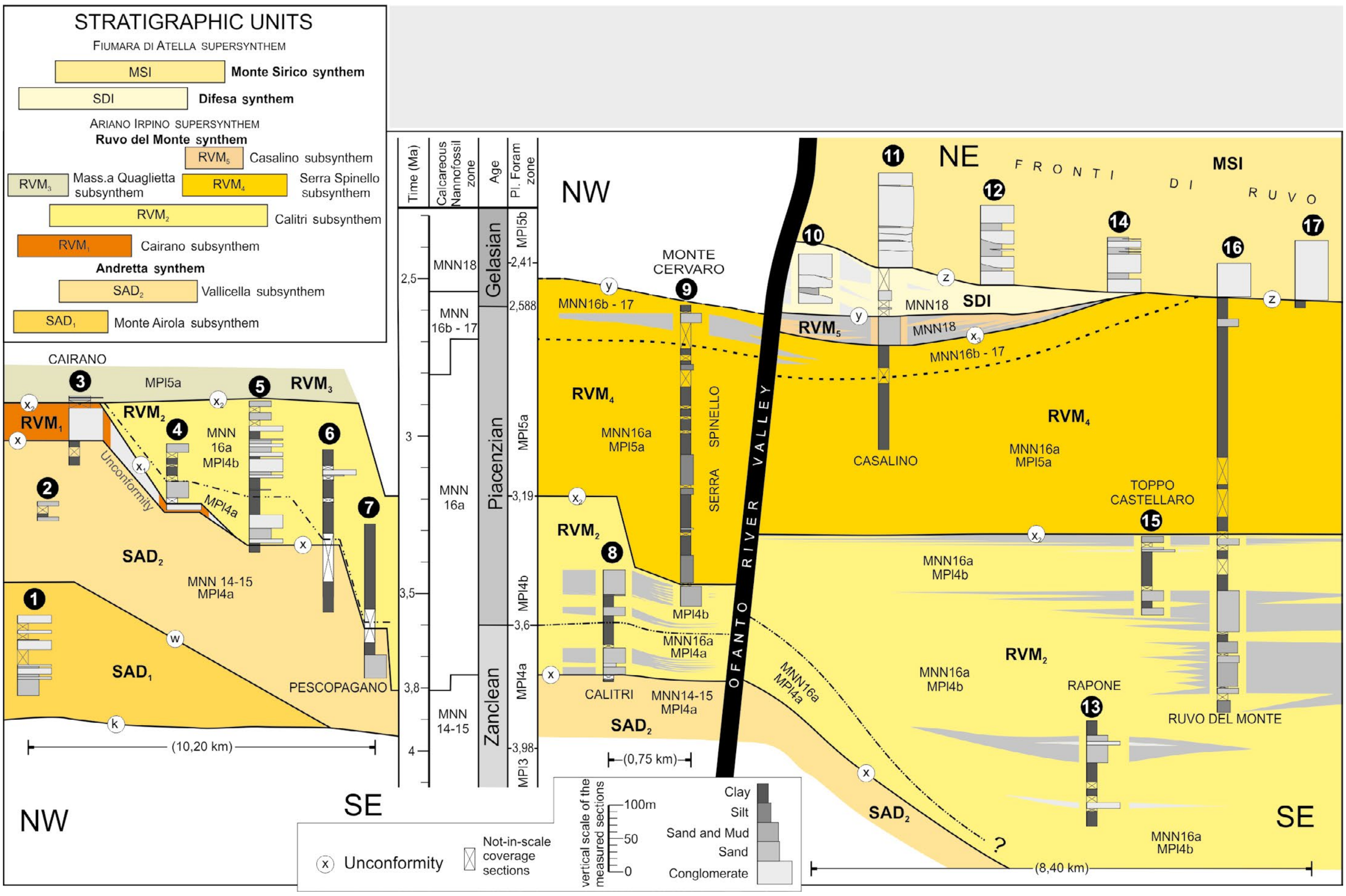

Fig. 2 – Stratigraphic correlation framework of the Ofanto Basin fill, showing logs from the study area (location in Fig. 1) and body geometries of the sandy and conglomerate deposits (modified after Giannandrea et al., 2014).

nannofossils and planktonic foraminifera. Unit names and codes corresponds to those of the Sheet N. 451 *"Melfi"*, scale 1: 50,000 (Servizio Geologico d'Italia, 2010).

The map was built on the types of the Italian *Istituto Geografico Militare* (1:25,000 scale), following authorization N. 6541, November 19, 2009; coordinates frame of the map is expressed in the official Italian national projection (Gauss-Boaga, international ellipsoid) and indicated at the apexes of the map sheet.

Contents description

The attached map includes a large part of the OB, an elongated depression of the southern Apennines, roughly EW-directed and filled with Pliocene-Quaternary clastic deposits. In particular, this map displays the geology of the central and eastern portions of the basin, affected by significant tectonic deformations, and also a significant part of the bedrock units involved in the mountain building processes. Furthermore, volcanic products from the near Mt. Vulture, terraced alluvial sediments, both middle to upper Pleistocene in age, and Holocene waste deposits also occur.

The pre-Pliocene-Quaternary bedrock consists of clay, limestone, and sandstone, ranging in age from the Cretaceous to the Miocene, related to deep basinal or foredeep units (Sicilide, Lagonegro, and Irpinian) and – in minor amount – shallow-water carbonates of the Apenninic Platform.

Lithological descriptions, in stacking order (i.e from the south-west to the north-east), are reported in Table 2. Each tectonic unit includes a continuous stratigraphic succession featured by different lithology. Upper Miocene units unconformably lie on such tectonic units. These latter consist of Cerreta - Bosco di Pietra Palomba sandstones (middle-upper Serravallian), Castelvetere Formation (upper Tortonian - Messinian), and evaporiti di Monte Castello (Messinian), as reported in Table 3. The Cerreta – Bosco di Pietra Palomba sandstones crop-out north of the boundary of clastic units of the OB above the chaotic variegated clay of the Torrente Rifezze Tectonic sub-unit (see also the geological map - sheet N. 451 "Melfi", ISPRA website). The Castelvetere Formation outcrops along the southern side of the clastic units of the OB above the Sicilide, Apennines Platform, and Lagonegro tectonic units. The evaporite di Monte Castello formation, finally, crops out only in two small areas along the northern boundary of the OB.

Lithological descriptions of the Pliocene-Quaternary units related to the OB infill and to the Mt. Vulture volcanic products and correlated reworked sediments are reported in Table 1. Such units have been grouped in five supersynthems (named, from the oldest to the youngest, Aquilonia, Ariano Irpino, Fiumara di Atella, Monte Vulture, and Monticchio; cf. Giannandrea, 2004; Schiattarella et al., 2005; Giannandrea et al., 2006; Giannandrea, 2009; Labella et al., 2014; Schiattarella et al., 2016).

The Aquilonia supersynthem is an undifferentiated unit with several lithofacies, Zanclean p.p. in age; the Ariano Irpino supersynthem, Zanclean p.p. – Gelasian in age, has been divided into two synthems (Andretta and Ruvo del Monte), whereas the Fiumara di Atella includes Gelasian p.p. to Calabrian units of the Difesa and Monte Sirico synthems. In the eastern part of the OB, above the Monte Sirico synthem along the main fluvial channels, coeval middle to upper Pleistocene Vulture volcanic products and alluvial terraces sediments are present. These younger successions have been subdivided in further units bounded by unconformities, grouped into the Monte Vulture and Monticchio supersynthems.

The Monte Vulture supersynthem (ranging in age from 698±8 to 494±5 ka B.P., Villa and Buettner, 2009; Schiattarella et al., 2016) includes the Piani di Mesole e dell'Incoronata, Sant'Angelo, Foggianello, Barile, and Melfi synthems; the Monticchio supersynthem (ranging in age from 494±5 to 141±11 ka B.P., Villa and Buettner, 2009; Schiattarella et al., 2016) includes the Fosso dello Stroppito, Conza della Campania, Torrente Olivento, Caperroni, Valle dei Grigi - Fosso del Corbo and the Laghi di Monticchio synthems (*Tab. 1*).

Upper Pleistocene to Present alluvial and loose sediments (i.e. talus, landslide, and alluvial-colluvial deposits) have been mapped respectively in the recent to present-day floodplain and along the slopes where they mantled the Cretaceous to Pleistocene formations.

In the map here attached, a new cartographic representation regarding the Ruvo del Monte synthem (*Giannandrea et al., 2014; Schiattarella et al., 2016*) has been done. Stratigraphic log correlations performed on that synthem showed, in fact, three local unconformities (x_1, x_2, and x_3) that permitted a subdivision into five subsynthems (*Fig. 2*). They are now named: Cairano, Calitri, Masseria Quaglietta, Serra Spinello, and Casalino subsynthems. The lithological descriptions of the subsynthems derive largely from Giannandrea et al. (2014). Such a division led to a new outcome represented by the map here attached, which facilitates the comprehension of the interaction between tectonics and sedimentation. In Table 1 we report the new stratigraphic setting of this synthem.

In the frame of this revision, the oldest mapped unit is the **Cairano subsynthem**. It outcrops at the northern boundary of the OB, just in the Cairano Village area. It consists of two 50 m-thick unconformable stacked conglomerate bodies which have migrated southward during their sedimentation, interpreted as coarse-grained delta deposits (Giannandrea et al., 2014). This subsynthem directly lies on the prodelta clay of the Andretta synthem through a sharp contact (surface x). The Cairano subsynthem is overlapped by the **Calitri subsynthem** (surface x_1), also lying on the Andretta synthem clay and bedrock (surface $x+x_1$, i.e. the same discontinuity through the time). The Calitri subsynthem shows a large distribution and facies lateral variations (Fig. 1b). It mainly consists of massive and/or laminated grey-blue silty clays – cropping out in the central part of the basin – and, subordinately, by sandstones and conglomerate. These coarse-grained sediments have been deposited through two opposite entry points, in coincidence of Calitri (at north-west) and Ruvo del Monte (at south-east) villages. In the northern sector, the map displays the downlap strata geometry above the Cairano subsynthem (Fig. 1b, surface x_1). The age of this subsynthem is late Zanclean – Piacenzian (Fig. 2).

The **Masseria Quaglietta subsynthem** is unconformably placed on both the Cairano and Calitri subsynthems through the x_2 truncation surface (Figs. 1b and 2). It consists of medium-grained, horizontally-laminated yellowish sandstones, with scattered marine shells and intercalations of thin laminated silty clay sandstones, Piacenzian in age (Fig. 2).

The **Serra Spinello subsynthem** outcrops in the eastern portion of the basin between Serra Spinello, Casalino, and Toppo Castellaro localities (Fig. 1b). The basal boundary (surface x_2) separating the subsynthem from the underlying one appears as an unconformity in the Calitri area (Fig. 3), whereas the same contact is a paraconformity in the Ofanto River right side. The limit can be identified in the field as a lithological contrast (Fig. 2). In the left side of the Ofanto River (Serra Spinello locality) the unit consists of laminated grey to light blue silty-sandy clay (prodelta deposits, Giannandrea et al., 2014) organized in ENE-ward prograding bodies showing a progressive angular unconformity (Fig. 3). The beds attitude displays an anticlockwise rotation (Fig. 4)

TABLE 1

Lithological description of the Pliocene to Quaternary stratigraphic units of the Ofanto Basin, Vulture Volcano, and alluvial terraces of the Ofanto River valley (modified after Giannandrea et al., 2014); units codes correspond to those of the Italian Geological map at 1:50,000 scale, Sheet n. 451 "Melfi", Servizio Geologico d'Italia, (2010).

Stratigraphic units							Biostratigraphic and radiometric (Ma) age after Schiattarella et al. (2016), Villa and Buettner (2009), and Giannandrea et al. (2006)
Supersynthem	synthem	subsynthem	Unconformity boundaries	Units code	Description of lithology and deposits interpretation	Thick (m)	
Monticchio	Laghi di Monticchio		Upper: Present topographic surface Lower: Erosion surface	LGM	This synthem includes volcanic products from several vents, constituted of ash and lapilli with clinoform and wave structures by surge or characterized by massive texture, with abundant sedimentary and ultramafic (wherlites and dunites; Jones et al., 2000) lithics. Carbonatitic and melilitic tuffisite lapilli are often present in the juvenile fraction (Stoppa et al., 2008 and bibliography derein).	4-7	0,141±11
	Conza della Campania	Caperroni	Upper: Erosion surface Lower: Erosion surface	CZC_2	Clast and mud-supported red sand and gravels; to the top, thin-laminated clay and silt (alluvial deposits), locally associated to travertine and eluvial-colluvial deposits.	~1	
		Sant'Andrea di Conza	Upper: Erosion surface Lower: Erosion surface	CZC_1	Clast-supported conglomerate with lens-shaped beds of brown-red sand (alluvial deposits), and strongly deformed red, grey, and green clays with isolated angular clasts and blocks of calcarenite, 1-2 m in diameter size (landslide deposits).	1-2 / 5-6	
	Fosso dello Stroppito	Vallone Spaccatornese	Upper: Erosion surface Lower: Erosion surface	SFS_3	Massive clast-supported conglomerate with dark red sandy matrix (alluvial deposits), locally, travertine and conglomerate.	Few	
		Ponte Giulio	Upper: Erosion surface Lower: Erosion surface	SFS_2	Massive or cross-bedded matrix-supported conglomerate (alluvial deposits), locally, travertine with scattered pebbles.	Few	
		Piano di Carda	Upper: Erosion surface Lower: Erosion surface	SFS_1	Clast-supported conglomerate, with dark red sandy-clayed matrix and lens-shaped beds of cross bedded sand (alluvial deposits).	Few	
Vulture	Barile		Upper: Erosion surface – palaeosol (Marker M18) Lower: Volcano-tectonic – erosion surface	SBL	This unit includes heteropic volcanic and epiclastic (alluvial and lacustrine) deposits. The volcanic deposits are rappresented by pyroclastic flows, fall deposits and interbedded lava flows (foidites, tephro-foidites, tephrites and basanites; Hieke Merlin, 1967; De Fino et al., 1982 e 1986). The pyroclastic flow deposits consist of massive or cross-bedded ash associated to layers of ash with accretionarry lapilli and centimetric pumices (tephrites and foidites; La Volpe & Principe, 1994; De Fino et al. 1982). The lacustrine deposits consist of massive or laminated ashes and pelitic sediments, whereas the alluvial ones are formed by massive and cross-bedded ashes and lapilli.		0,673±19 to <0,610
	Foggianello		Upper: Epiclastic sediments – formation of a volcanic caldera Lower: Erosive surface	FGG	Ash and lapilli, both of pyroclastc flow and pyroclastic fall, with trachite-phonolite (according to De Fino et al., 1982), trachite-andesite, and basaltic trachy-andesite composition. In the distal areas and at the base of the volcanic succession, this unit shows oblique-layered and cross-bedded sandy conglomerate (alluvial deposits).	Some tens	base of the unit 698±8
	Piani di Mesole e dell'Incoronata		Upper: Erosive surface Lower: Erosive surface	PMI	Brown clast-supported alluvial conglomerate, locally outcropping upon the terraced surfaces of Piani di Mesole and dell'Incoronata localities.	2	Middle Pleistocene
Fiumara di Atella	Monte Sirico		Upper: Erosive surface Lower (z): Unconformity	MSI	Massive clast-supported dark-brown conglomerate, with parallel and oblique layers and thin-bedded yellowish sand, silt, and clay. with rare remains of plants and disarticulated bones of sub-aerial vertebrates (alluvial and lacustrine deposits).	250	Gelasian - Calabrian
	Difesa		Upper (z): Erosive surface - unconformity Lower (y): Unconformity – downlap surface	SDI	Clast-supported dark-brown conglomerates, characterized by both massive and cross-bedding textures, with rare metric lens of thin-laminated yellowish sand, silt, and clay; these conglomerates laterally pass (toward south-east) to horizontally thin-laminated yellowish sand, silt, and clay with abundant fossil content (fragments of marine bivalves) (marine fan-delta deposits).	400	Gelasian; biozone: MNN18 (Rio et al., 1990)
Ariano Irpino	Ruvo del Monte	Casalino	Upper (y): Downlap surface Lower(x_3): Paraconformity	RVM_5	Amalgamated layers (60 - 70 cm thick) of fine-grained sandstones, yellowish in colour, with trough cross-beds, lag deposit of shells, and in the upper part of the unit, centimetric intercalations of thin laminated silty clays (delta front deposits).	40	Gelasian; Biozones: MNN18 (Rio et al., 1990).
		Serra Spinello	Upper (x_3): Paraconformity Lower(x_2): Unconformity; paraconformity.	RVM_4	Laminated grey to light blue silty-sandy clay (prodelta and continental platform deposits). In the upper part of the unit (Monte Cervaro locatity) a sandy body, composed of planar cross-stratified 3-5 m thick beds with common alignments of shells at the base of the foresets (shoreface deposits).	900	Piacenzian-Gelasian; Biozones: MNN16a, MNN16b/17 (Rio et al., 1990); MPL5a (Cita, 1975; emended).
		Masseria Quaglietta	Upper: Present topographic surface Lower(x_2): Erosive surfaces	RVM_3	Medium-grained, horizontally laminated yellowish sandstones, with scattered marine shells and intercalations of thin laminated silty clay sandstones. In Cairano locality a bed intercalation (60 cm thick) of rounded, matrix-supported, poorly- moderate sorted (max clast sizes: 10 cm), structureless conglomerate, with erosional base (Shallow marine environment maybe within 50 m).	30	Piacenzian; Biozones: MPL5a (Cita, 1975; emended).
		Calitri	Upper (x_2): Erosive surface; unconformity; paraconformity Lower (x; x_1): Erosive surface; downlap surface; erosive surface.	RVM_2	Grey - light blue silty clay, massive and/or laminated (prodelta and continental platform deposits); in a minor amount, coarse to fine-grained massive and graded sand with plano-parallel or cross lamination and interbedded thin laminated silt and clay (delta front deposits), and clast-supported massive and with concave cross-bedding conglomerate. Sands and clay contain well-preserved marine bivalves, present in fragments as well. The sands prevail at the base of the succession, in heteropic relationship with the clay, whereas the conglomerate is present just in the lower part of the unit and in rare lens-shaped metric bodies interbedded in the sands and clay.	600	Upper Zanclean – Piacenzian; Biozones: MNN16a (Rio et al., 1990); MPl4a to MPl5b (Cita, 1975; emended).
		Cairano	Upper (x_1): Erosive surface - downlap surface Lower(x): Abrupt contact – erosional truncation	RVM_1	Include two bodies (up to 50 m thick and ~3 km laterally continuous). Each body consists, for 16,70 thick, of massive clast-supported conglomerate, with large-scale planar cross-stratification and intercalations of massive or laminated silty sandstone with marine macrofossils, overlain by 32 m of massive clast-supported conglomerates in horizontal amalgamated beds (coarse-grained delta deposits).	100	Upper Zanclean
	Andretta	Vallicella	Upper (x): Abrupt contact Lower (w): Abrupt contact	SAD_2	Massive and laminated grey – light blue silty clay (prodelta and/or continental platform deposits), with lens-shaped decimetric bodies of laminated fine to coarse-grained sand (delta front deposits).	several hundreds	Zanclean; Biozones: MNN14-15, MNN16a (Rio et al., 1990); MPL3/MPL4a (Cita, 1975; emended).
		Monte Airola	Upper (w): Abrupt contact Lower (k): unconformity	SAD_1	Dark brown clast-supported coarse conglomerate, with both horizontal and oblique beds, and interbedded banks of sand, silt and clay with thin lamination (alluvial fan and alluvial plain deposits)	100	
Aqulonia			Upper (k): unconformity Lower (j): Erosive surface - Angular unconformity	AQ	Coarse, clast-supported conglomerates, brownish in colour, with both horizontal and oblique beds and thin laminated sandy-silty beds (alluvial plain deposits).	100	Zanclean; Biozone: MNN13 (Rio et al., 1990)

TABLE 2

Lithological description of the bedrock units (after Giannandrea et al., 2014); units codes correspond to those of the Italian Geological map at 1:50,000 scale, Sheet n. 451 “Melfi”, Servizio Geologico d’Italia, (2010).

Tectono-stratigraphic units							Biostratigraphic age
Tectonic Unit	Tectonic Sub-Unit	Formation	Member	Units code	Description of lithology and deposits interpretation	Thick (m)	
Sicilide		Monte Sant’Arcangelo		FMS	Fine to coarse-grained calcarenite and whitish calcilutite, stratified in 1 to 20 cm beds, with white nodular chert and intercalations of red and light grey clay and marly clay.	Some tens	Cretaceous-Eocene (Carbone et al., 1991)
		Argille variegate inferiori		AVF	Red, green, grey clay and marly clay, with intercalations of thin beds of calcarenite.	Few tens	Lower Cretaceous (Schiattarella et al., 2016)
Piattaforma Appenninica	Monte Marzano – Monti della Maddalena	Calcari bio-litoclastici con rudiste		CBI_a	Lithofacies of the pseudo-saccharoidal limestone: crystalline limestone laterally passing to white coarse-grained detrital limestone, slightly re-crystallized, with fragments of corals.	150	Maastrichtian-Paleocene (Schiattarella et al., 2016)
		Calcari a *Palaeodasycladus*		CPL	Whitish fine-grained calcarenite, oolitic limestone and dolomitic limestone with *Orbitopsella* praecursor and *Palaeodasycladus mediterraneus*; to the top, light brown oolitic limestone, locally rich of rests of sparitic bivalves, are present.	100	Lower Jurassic (Schiattarella et al., 2016)
Monte Arioso		Flysch Rosso	Calcareous marls	FYR	laminated grey, brown, and reddish marly clays with intercalation of centimetric beds of calcarenite are present (pelagic and turbidite deposits).		Lower Cretaceous p.p. – Oligocene? (Pescatore et al., 1999)
			Calcareous clastic	FYR_a	Massive and graded calcareous breccia, organized in beds and banks with clasts reaching at maximum the width of 15 cm in cui, sometimes represented by fragments of rudists. Thin layers of laminated grey shale (turbidite deposits) are interbedded with the breccia.	50	
			Cherty	FYR_1	Thin beds of black and red chert and brownish and red marly clay with intercalation of calcarenite and massive calcareous microrudite with white and light orange chert beds; at the base of the succession, an about 8 m thick red, green, and grey marly clayey thin-layered sequence is present (turbidite and pelagic sediments).	30	Albian – lower Turonian (Gallicchio et al., 1996)
		Flysch Galestrino		FYG	Light-grey and greenish shale with intercalations of 10 to 60 cm thick beds of marls and marly limestone; the base of the formation is constituted of about 3 m of thin-bedded chert and grey shale (pelagic sediments).	400	Lower Cretaceous (Scandone, 1972)
		Scisti Silicei	Chert	STS_d	Red and green chert, well-bedded in 2 to 10 cm thick layers (pelagic sediments), with rare intercalations of 40 to 60 cm thick beds of coarse-grained calcarenite (turbidites).	193	Jurassic (Scandone, 1972)
			Calcareous	STS_e	calcareous microrudite, calcarenite and grey shale, stratified in beds and banks which can reach a thickness of 4 m (turbidite deposits).	54	
		Calcari con selce		SLC_d	Grey and white dolostone with rare nodular chert in the upper portion of the succession (pelagic sediments).	50	Upper Triassic (Miconnet, 1988)
Groppa d’Anzi	Torrente Rifezze	Argille variegate	Calcareous marls	AV_b	Whitish calcareous marls, associated to 3-4 cm thick beds of calcisiltite with nodular chert, marly limestone, and calcarenite (pelagic sediments and, in minor amount, turbidite deposits). It is intercalated to the Argille variegate (AV).	40	Lower-middle Eocene (Schiattarella et al., 2016)
			Variegated clay	AV	Red, green, and grey clay and marly clay, with a chaotic attitude and/or affected by intense deformation, with olistoliths and intercalations of quartz- and arkosic sandstone beds in the upper part of the succession.	Few hundreds	Lower Cretaceous – Lower Miocene (Schiattarella et al., 2016)
	Sassano – Monte Mattina	Serra Palazzo	Vallone Forluso	PAA_2	Thin alternations of light yellow lithic sandstone, thin laminated grey silt, and dark grey silty clay, with thin intercalations of calcarenite (turbidite deposits).	20-30	Langhian (Gallicchio and Maiorano, 1999)
		Flysch Numidico		FYN	Coarse-grained quartzarenite, organized in 8-9 m thick banks and 30 to 80 cm thick beds, with decimetric interbedded layers of clayey marls (turbidite deposits)	Max 300	
		Paolo Doce	Sandstone with calcarenite	PDO_a	Fine- to coarse-grained bedded, massive, graded, and laminated sandstone (Ta-c and Tb-c Bouma-type sequences), with intercalations of fine-grained calcarenite (Tc-e Bouma sequence), silt, marls and thin-laminated marly clay (turbidite deposits and pelagic sediments)	80	Aquitanian-Burdigalian (Schiattarella et al., 2016)
			Calcareous marls	PDO	Medium- and fine-grained calcarenite with intercalations of marly limestone, marls and calcisiltite in 10 to 40 cm thick beds.	475	Upper Oligocene – Lower Miocene (Schiattarella et al., 2016)
		Flysch Rosso	Calcareous clastic	FYR_a	Calcareous breccia and medium- to fine-grained calcarenite with nodular chert and thin beds of red shale and chert (pelagic and turbidite deposits)	25	Middle Eocene (Schiattarella et al., 2016)
			Calcareous marls	FYR	Grey, brown, and red laminated marly clay, with intercalations of both massive and graded calcarenite in decimetric beds (pelagic and turbidite deposits)		Lower Cretaceous – Oligocene (Pescatore et al., 1999; Scandone 1967, 1972)
			Cherty	FYR_1	1 to 10 cm thick beds of black and red chert, with frequent intercalations of brownish and red marly clay (pelagic sediments).	10	Albian – lower Turonian (Gallicchio et al., 1996)
		Flysch Galestrino		FYG	Intensely deformed thin-bedded succession of light-grey and greenish shale, marls and marly limestone (pelagic sediments).	Some tens	Lower Cretaceous (Scandone 1967, 1972)
San Chirico		Serra Palazzo	Rotondella	PAA_1	4-8 cm thick beds of withish calcisiltite, with ondulate laminae and millimetric interlayers of calcareous marls; at several stratigraphic levels, medium- to fine-grained calcarenite in max 30 cm thick beds (pelagic and turbidite deposits)		Upper Burdigalian – Serravallian (Maiorano, 1998; Gallicchio and Maiorano, 1999)
			Vallone Forluso	PAA_2	Light yellow lithic sandstone, thin-bedded grey silt, and grey silty clay, with intercalations of gray calcarenite in centimetric beds (turbidite deposits)	Some tens	
		Flysch Numidico		FYN	Coarse to medium-grained quartz-sandstone, organized in banks and decimetric beds, with thin layers of grey-greenish silty clay and marls.	200	Lower Miocene (Schiattarella et al., 2016)

TABLE 3

Lithological description of the Miocene units unconformably lying on the bedrock units (after Giannandrea et al., 2014); units codes correspond to those of the geological map at 1:50,000 scale Sheet n. 451 "Melfi" Servizio Geologico d'Italia, (2010).

Stratigraphic units							Biostratigraphic age after Schiattarella et al., (2016)
Formation	Member	Unconformity boundaries		Units code	Description of lithology and deposits interpretation	Thick (m)	
Monte Castello evaporites		Upper	Erosive surface	GSC	Gypsrudite, nodular and laminated gyps with interbedded silt (evaporite deposits, partly reworked).	7	Messinian
		Lower	Unconformity				
Castelvetere	Marly clay silston, with olistoliths	Upper	Erosive surface	CVT_2	Thin beds of silt and marly clay with isolated decametric blocks of mudstone of the Apennines Platform and bodies of chaotic variegated clay.	90	Upper Tortonian – Lower Messinian
		Lower	Continuous and concordant				
	Sandstone with conglomerate	Upper	Continuous and concordant	CVT_1	Coarse to medium-grained light brown sandstone, with maximum 1 cm large clasts, organized in amalgamate and normal-graded beds with plano-parallel laminae; at different stratigraphic levels, 1 to 6 m thick lens-shaped bodies of graded polygenic conglomerate are present, showing clasts with maximum width of 5 cm (turbidite deposits).	160	
		Lower	Angular unconformity				
Cerreta - Bosco di Pietra Palomba sandstones		Upper	Erosive surface - unconformity	ACP	Yellowish sandstone in 10 to 50 cm thick beds, showing Ta-b, Tb-c and Ta-c Bouma sequences, with intercalations of thin-bedded grey clay and marly clay (turbidite deposits).	20-30	Middle – Upper Serravallian
		Lower	Unconformity				

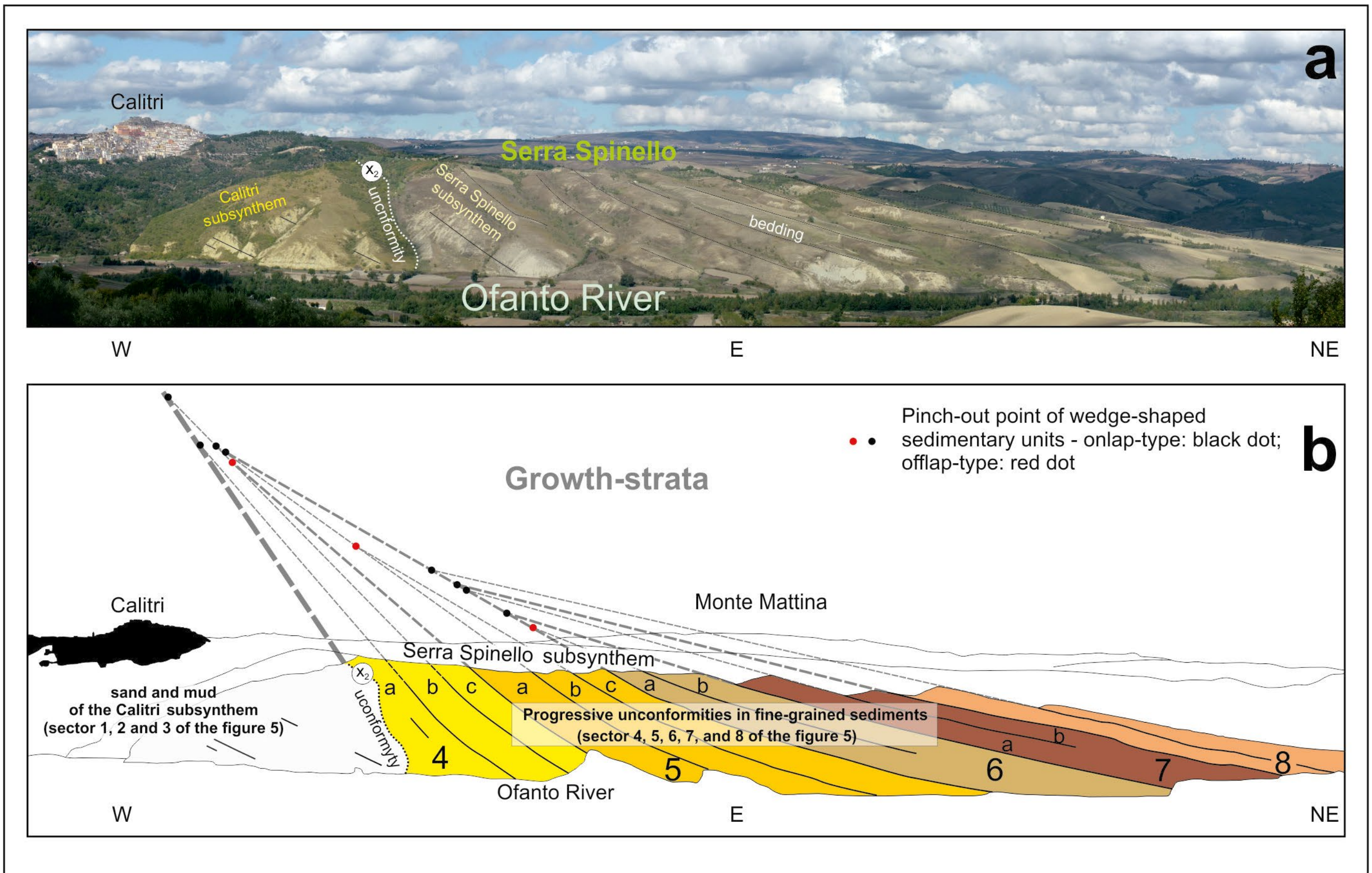

Fig. 3 – a) Panoramic view and b) line drawing showing ENE-ward progressive unconformity developed on the top of the unconformity (x2) between the Calitri and Serra Spinello subsynthems. In b, onlap and offlap-type unconformities are shown in the prolongation of the growth-strata.

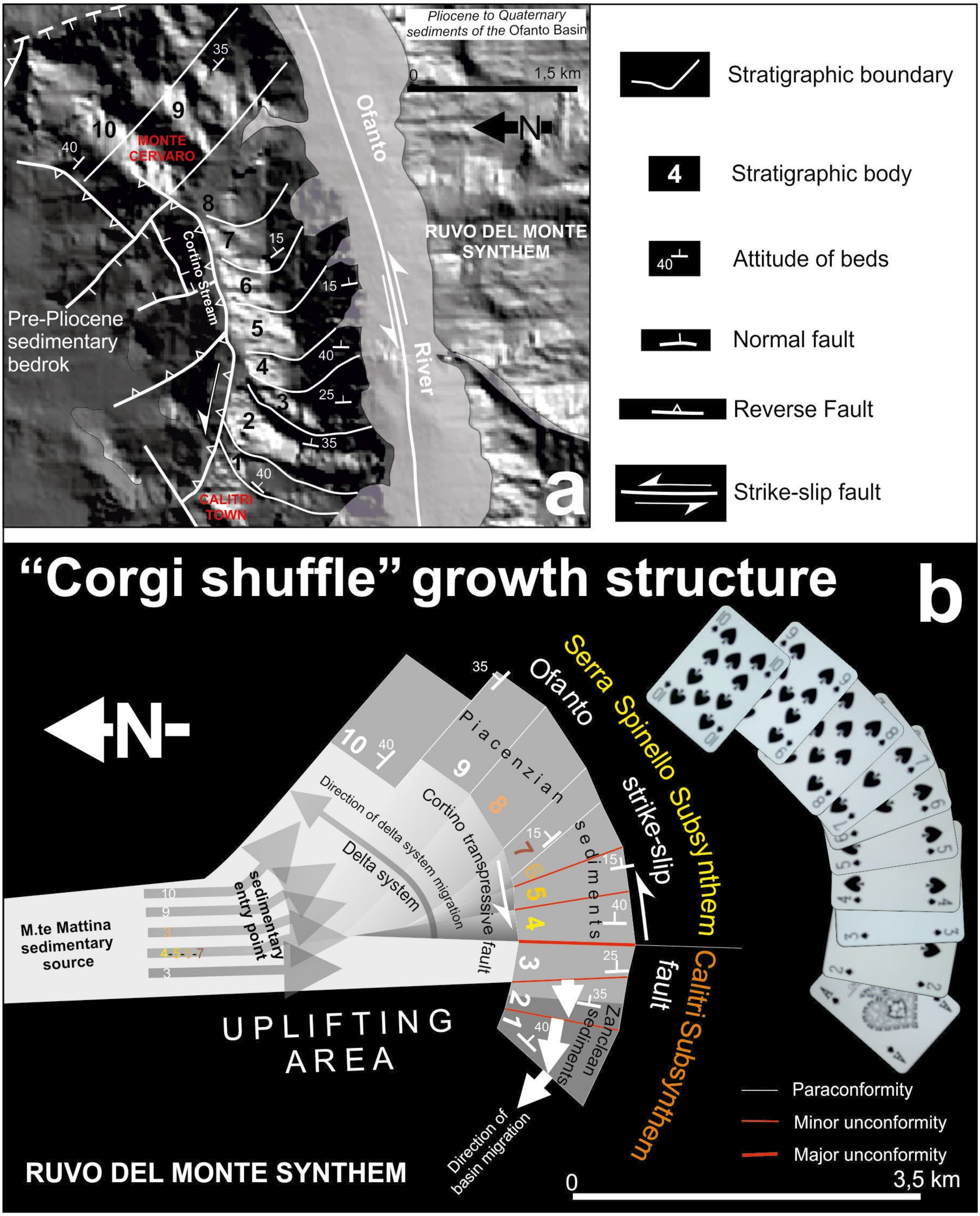

Fig. 4 – a) Plan-view sketch of the Serra Spinello growth structure (modified after Giannandrea et al., 2014) and b) geometric interpretation of the anticlockwise rotation of the beds attitude of ten sedimentary bodies. The progressive unconformities and the attitude of the single sedimentary bodies are the result of an E-W oriented left-lateral strike-slip motion.

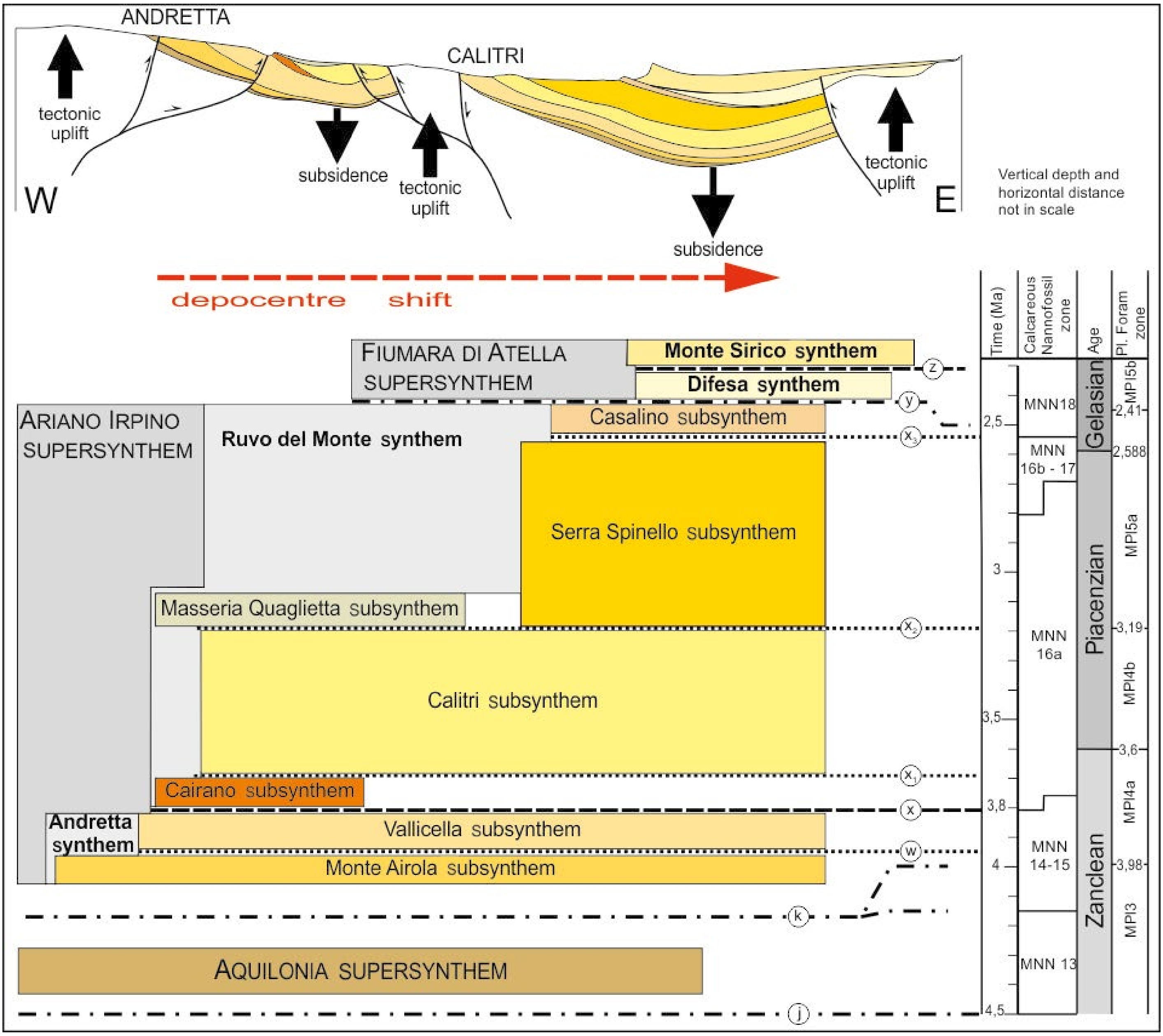

Fig. 5 – Tectono-stratigraphic scheme of the Pliocene-Quaternary Ofanto Basin evolution (calcareous nannofossil and planktonic foraminifera biostratigraphic zones after Giannandrea et al., 2014 and Schiattarella et al., 2016).

from the roughly meridian strike (near Calitri town) to the N50°W strike (Monte Cervaro). At the top of the fine-grained rock succession (Monte Cervaro locality), a coarse-grained sandstone body is present (shoreface deposits, Giannandrea et al., 2014). In the right side of the Ofanto River (Toppo Castellaro area, Fig. 1b) the unit shows about 385 m-thick of grey-blue, massive or laminated silty clay (continental platform deposits, Giannandrea et al., 2014). The maximum thickness of the subsynthem is ~900 m. The age of this stratigraphic succession (from west to east and from the bottom to the top), on the base of the calcareous nannofossil assemblages, can be referred to the Piacenzian-Gelasian (Fig. 2).

At the top of the Serra Spinello subsynthem, the **Casalino subsynthem** crops out only in the right side of the Ofanto River. It is made of a 45 m-thick lens-shaped sandy body (Figs. 1b and 2), whose deposits are interpreted as delta front (Giannandrea et al., 2014). At the base, the subsynthem paraconformably lies on the silty clay platform deposits (surface x_3). The age of this subsynthem is Gelasian (Fig. 2).

The newly mapped subsynthems stress the presence of an EW-directed tectonic structure along the Ofanto River,

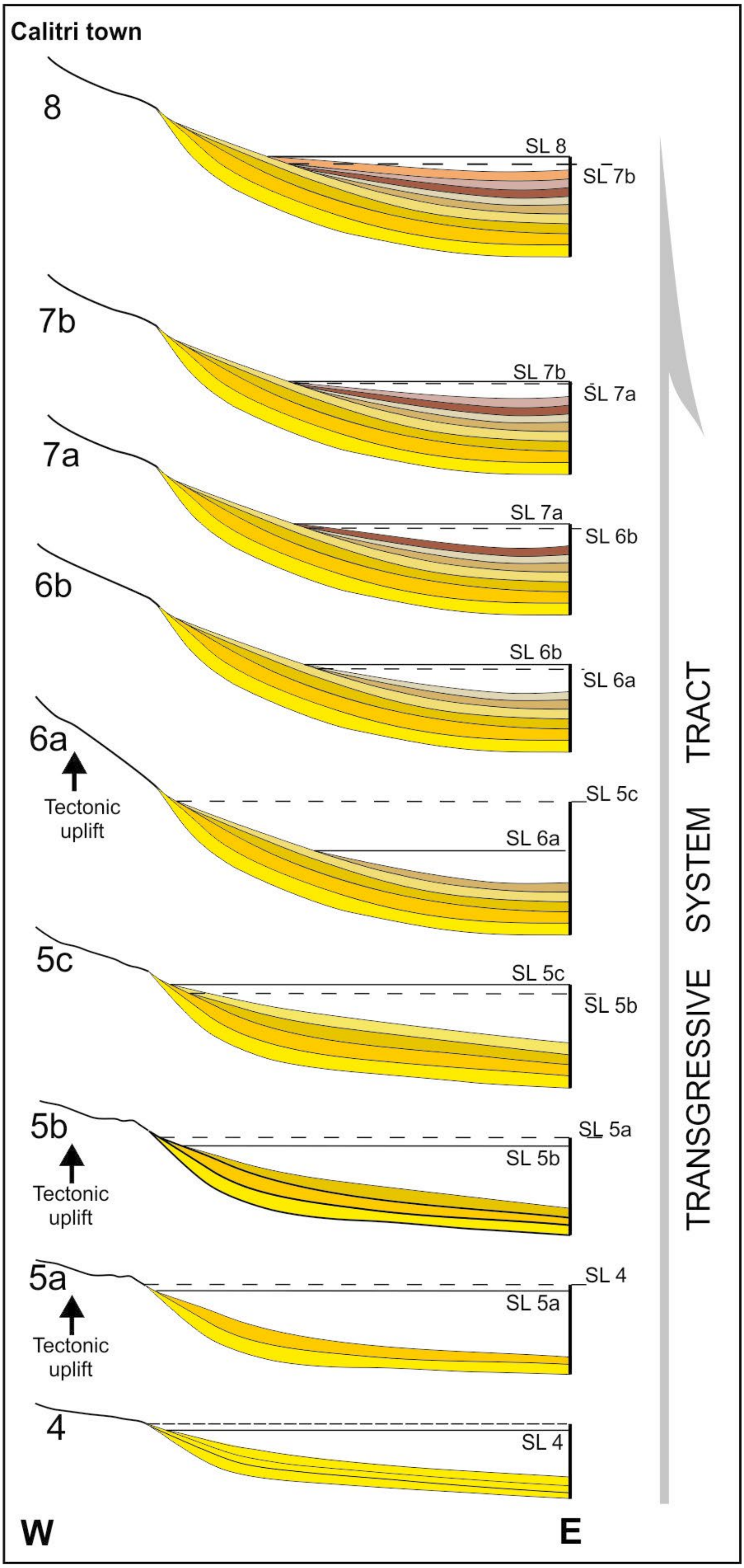

Fig. 6 – Evolutionary model of the Ofanto Basin during the Serra Spinello subsynthem sedimentation (cf. figure 3b), showing nine main sedimentary stages during a general transgressive system tract. In the stages 5a, 5b, and 6a, a coeval tectonic uplift due to the activity of the Calitri back-thrust overprints the sedimentary pattern.

responsible for a sinsedimentary activity, previously interpreted on the basis of more generic clues.

Discussion and conclusions

The Pliocene-Quaternary OB infill has in the past been mapped with lithostratigraphic criteria (Vezzani, 1968; Servizio Geologico d'Italia, 1970a, and 1970b; Casciello et al., 2013) or of UBSU criteria (Servizio Geologico d'Italia, 2010 and 2016; Giannandrea et al., 2014).
In the official maps at 1:100,000 scale (Servizio Geologico d'Italia, 1970a, and 1970b) the OB succession has been subdivided into three lower-middle Pliocene informal formations made of clays, sands and conglomerates with roughly defined stratigraphic relationships. In the UBSU-based geological maps, many more stratigraphic units have been distinguished and grouped in the Aquilonia, Ariano Irpino, and Fiumara di Atella supersynthems. In this case, single lithofacies and discontinuities have been accurately mapped in order to ensure the maximum accuracy. The ranking of the unconformities has been established on the basis of regional comparison and correlations with other Pliocene-Quaternary sediments cropping out in other contiguous basins. Minor local unconformities not mapped in Giannandrea et al. (2014), for they were not physically correlated in the field, have been later used to upgrade the map here attached thank to a further elaboration of our scheme of Figure 2. More precisely, the extrapolation of such surfaces allowed us to separate the Ruvo del Monte synthem in five new subsynthem. The ages of these units (Cairano, Calitri, Masseria Quaglietta, Serra Spinello, and Casalino subsynthems) and the arrangement of their outcrop areas (Figs. 1b and 2) showed that the sedimentation was de-activated first to the west of the basin and their progressive eastward depocentre migration can be detected (Fig. 5).
The overlap pattern of the prodelta fine-grained sedimentary bodies constituting the Serra Spinello hill, as detected both from their planimetric view (Fig. 4a) and 3D reconstruction of their geometrical features (*Figs. 1 and 3*), suggests the presence of an EW-directed tectonic system along the Ofanto River, responsible for the sinsedimentary anticlockwise rotation of those bodies. Such an architecture resembles a kind of *"Corgi shuffle"* structure (Fig. 4b), as a result of complex kinematic interactions among high-angle faults and back-thrusts (Figs. 1, 4 and 5). The coupling of the tectonic uplift of the zone to the north of Calitri town, induced by back-thrusting, with the ENE-directed migration of the sedimentary entry point have produced the described pattern, together with the total cannibalization of the proximal deltaic facies, indeed scarcely present in that area.
In few words, the effects of the kinematics of the Ofanto and Cortino sub-parallel faults along the northern side of the basin (Serra Spinello area) are more appreciable in the new release of the map, showing a dominant left-lateral motion, also featured by transpressional components, which caused an anticlockwise rotation of the bed attitude up to 80° (Fig. 4). The upgraded interpretation of the growth-strata structure represented in figure 3b allowed reconstructing several evolutionary stages due to the interplay between tectonic uplift and sea-level variations (Fig. 6) during the Piacenzian.
The correct and accurate recognition of unconformity surfaces, supported by sedimentological and biostratigraphic analyses performed on many stratigraphic logs, can really improve the final cartographic product as in the case of the OB, filled by recurrent rock types (conglomerate, sandstone, and clay) with lateral facies variations and different entry points. In this sense, the UBSU-based geological maps should be considered as conservative data sets that can be upgraded and/or heavily renewed, depending on the quantity and quality of data.

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Reference

Casciello E., Esestime P., Cesarano M., Pappone G., Snidero M., Vergés J. *(2013)* - Lower plate geometry controlling the development of a thrust-top basin: the tectonosedimentary evolution of the Ofanto basin *(Southern Apennines)*. Journal of the Geological Society, London, **170**, 147 –158.

Chang K.H. *(1975)* - Unconformity-bounded stratigraphic units. Geol. Soc. Am. Bull., **86**, 1544-1552.

Cita M.B. *(1975)* - Studi sul Pliocene e gli strati di passaggio dal Miocene al Pliocene, VII. Planktonic foraminiferal biozonation of the Mediterranean Pliocene deep sea record: a revision. Riv. It. Paleont. Strat., **81**, 427-544.

Giannandrea P. *(2004)* - I depositi terrazzati affioranti nell'alta valle del Fiume Ofanto (*Foglio n. 451 "Melfi", Appennino campano-lucano*). Il Quaternario, ***17*** *(2/2), 511-521*.

Giannandrea P. *(2009)* - Evoluzione sedimentaria della successione alluvionale e lacustre quaternaria del Bacino di Venosa (*Italia meridionale*). Il Quaternario, **22** (2), *269-290*.

Giannandrea P., La Volpe L., Principe C., Schiattarella M. *(2006)* - Unità stratigrafiche a limiti inconformi e storia evolutiva del vulcano medio-pleistocenico di Monte Vulture (*Appennino meridionale, Italia*). Boll. Soc. Geol. It., **125**, 67-92 (*with attached geological map at scale 1:25.000*).

Giannandrea, P. Marino M., Romeo M., Schiattarella, M. *(2014)* - Pliocene to Quaternary evolution of the Ofanto Basin in southern Italy: an approach based on the unconformity-bounded stratigraphic units. Ital. J. Geosci. (Boll. Soc. Geol. It.), **133** (1), 27-44. Doi: 10.3301/IJG.2013.11 including a geological map at 1: 25,000 scale: Geological map of the Ofanto Basin (eastern sector). LAC, Firenze.

Harrison J.M. *(1963)* - Nature and significance of geologic maps: in The fabric of geology. Albritton C.C., editor; Freeman Cooper & Co, 374p.

Hippolyte J.C., Angelier J., Roure F. *(1992)* - Paleostress analyses and fold-and-thrust belt kinematics in the Southern Apennines. In: F. Roure, N Ellouz, V.S. Shein & I.I. Skvortsov (Eds.): "Geodinamic Evolution of Sedimentary Basins". International Symposium, 157-169.

Hippolyte J.C., Angelier J., Roure F., Casero P. *(1994)* - Piggyback basin development and thrust belt evoution: structural and palaeostress analyses of Plio-Quaternary basins in the Southern Apennines. Journ. Struct. Geol., **16**, 159-173.

Kupfer D.K. *(1964)* - Linear and Curvate Mountains (*abstr.*): Geol. Soc. America Sp. Paper 82, Abstract for 1964 (1965), p. 302.

Labella R., Capolongo D., Giannandrea P., Giano S.I., Schiattarella M. *(2014)* - Morphometric analysis of fluvial network and age constraints of terraced surfaces of the Ofanto basin, Southern Italy. Rend. Fis. Acc. Lincei, **25** (2), 253-263. DOI 10.1007/s12210-014-0321-1---ISSN: 2037-4631 (Print) 1720-0776 (Online)

Patacca E., Scandone P. *(2001)* - Late thrust propagation and sedimentary response in the thrust-belt-forepeep system of the Southern Apennines (*Pliocene-Pl*eistocene). In: G.B. Vai and I.P. Martini (Eds.): "Anatomy of an Orogen: the Apennines and Adjacent Mediterranean Basins". Kluwer Academic Publishers, 401-440.

Pescatore T., Ortolani F. *(1973)* - Schema tettonico dell'Appennino campano-lucano. Boll. Soc. Geol. It., **92**, 453-472.

Rio D., Raffi I., Villa G. *(1990)* - Pliocene-Pleistocene distribution patterns in the Western Mediterranean. In Kasten K.A., Mascle J. *et al.* (1990). Proceeding of ODP, Scientific Results, **107**, 513-533.

Roure F., Casero P., Vially R. *(1991)* - Growth processes and melange formation in the southern Apennines acretionary wedge. Earth and Planetary Science Letters, **102**, 395-412.

Salvador A. *(1987)* - Unconformity-bounded stratigraphic units. Geological Society American Bulletin, **98**, 232-237.

Salvador A. (Ed.) *(1994)* - International stratigraphic guide. International Union of Geological Sciences, Trondheim, Norway, and Geological Society of America, Boulder, 214 pp.

Schiattarella M., Beneduce P., Di Leo P., Giano S.I., Giannandrea P., Principe C. *(2005)* - Assetto strutturale ed evoluzione morfotettonica quaternaria del vulcano del Monte Vulture *(Appennino Lucano)*. Boll. Soc. Geol. It., **124**, 543-562.

Schiattarella M., Giannandrea P., Principe C., La Volpe L. *(2016)* - Note Illustrative della Carta Geologica d'Italia alla scala 1:50.000 - Foglio 451 Melfi. ISPRA, Servizio Geologico d'Italia, 122 pp., Litografia Artistica Cartografica, Firenze, online.

Servizio Geologico d'Italia *(1970a)* - Carta Geologica d'Italia alla scala 1:100.000, F. 186 *"Sant'Angelo dei Lombardi"*, ISPRA, Roma.

Servizio Geologico d'Italia *(1970b)* - Carta Geologica d'Italia alla scala 1:100.000, F. 187 *"Melfi"*, ISPRA, Roma.

Servizio Geologico d'Italia *(2010)* - Carta Geologica d'Italia alla scala 1:50.000, F. 451 *"Melfi"*, ISPRA, Roma.

Servizio Geologico d'Italia *(2016)* - Carta Geologica d'Italia alla scala 1:50.000, F. 186 *"Sant'Angelo dei Lombardi"*, ISPRA, Roma.

Vezzani L. *(1968)* - Stratigrafia di terreni infra-mesopliocenici di Ruvo del Monte (*Potenza*). Boll. Acc. Gioenia Sc. Nat. Catania, **9**, 3-41.

Villa I.M., Buettner A. *(2009)* - Chronostratigraphy of Monte Vulture volcano (*southern Italy*): secondary mineral microtextures and ^{39}Ar-^{40}Ar systematics. Bulletin of Volcanology, **71**, 1195-1208.

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