Mesozoic-Tertiary carbonate platforms in marginal areas (Mts. Prenestini, Central Apennines)

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ABSTRACT

In the carbonate Apennines, transitional zones play a leading role in any attempt to reconstruct the original relations between platforms and adjacent basins, and in general the geodynamic evolution of wide areas. They present however peculiar problems of geological mapping as usually represented by quite narrow zones where successions are highly variable in space and time. A detailed field mapping was carried out in the southern sector of the Prenestini Mts., where in a limited area Mesozoic and Tertiary transitional successions are well exposed. We tried to define here, using traditional methods of lithostratigraphic and facies analysis, integrated by methods and concepts of sequence stratigraphy, units and sub units that could be used in field mapping holding at the same time their specific environmental connotation. Field mapping, therefore, evidencing the areal distribution of the different lithologies characterized by a precise environmental meaning, gave a substantial contribution to the palaeoenvironmental reconstruction.

AIMS

Investigaion and mapping of carbonate platform margins, especially in tectonically disturbed areas like the Apennines, is a quite difficult task. The main purpose of the study was to elaborate, and to test in a suitable area, a methodological approach to define the lithostratigraphic units and subunits to be used in field mapping when the palaeoenvironmental reconstruction, and not the mere areal distribution of the lithofacies, is the crucial goal. A second aim was to test whether some important facies boundaries recognized by sequence stratigraphy mainly studying vertical successions in detail, could be really used for field mapping at a given scale.

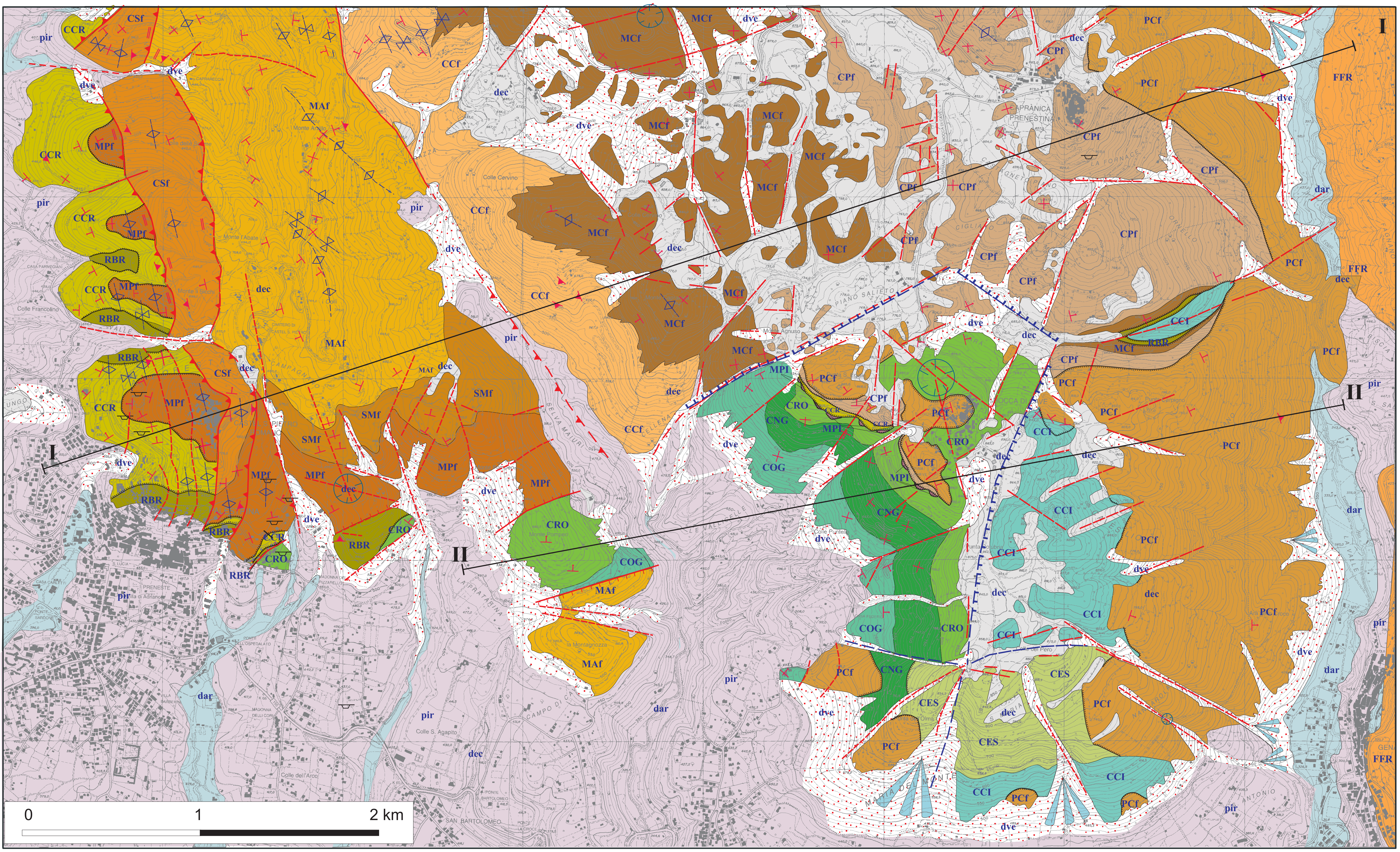
KEY-WORDS

Carbonate platform margin, carbonate ramp, facies analysis, sequence stratigraphy, synsedimentary tectonics, Prenestini Mts., Central Apennines.

RIASSUNTO

Nell'Appennino calcareo, le facies di transizione occupano una posizione strategica nella ricostruzione degli originari rapporti tra piattaforme carbonatiche e bacini adiacenti, ma presentano peculiari problemi di cartografia geologica in quanto arealmente ristrette e altamente variabili nel tempo e nello spazio. E' stata prescelta per lo studio la porzione meridionale dei M.ti Prenestini, ove in un'area limitata sono presenti e ben esposte situazioni di transizione di facies sia mesozoiche che terziarie. Qui si è tentato di definire, attraverso l'applicazione dei tradizionali metodi di analisi stratigrafica e analisi di facies, e la loro integrazione con i concetti e metodi della stratigrafia sequenziale, delle unità litostratigrafiche di vario rango che, utilizzate ai fini del rilevamento, fornissero anche una specifica connotazione ambientale. In tal modo il rilevamento di terreno, mettendo in evidenza la distribuzione areale delle differenti tipologie litologiche aventi un preciso significato ambientale, ha anche fornito un contributo sostanziale alla ricostruzione paleoambientale dell'area.

GEOLOGICAL MAP OF SOUTHERN SECTOR OF THE PRENESTINI MTS.



dve — **Talus, alluvial fans** *(Holocene)*
(dve) - Heterometric polygenic rudites, usually in a silty-sandy matrix.

dec — **Eluvial-colluvial deposits** *(Holocene)*
(dec) - Soils and palaeosoils, often associated with weathered pyroclastic deposits; " terre rosse" and doline floor sediments; reclamation fillings, anthropic terraces.

dar — **Alluvial deposits** *(Hol ocene)*
(dar) - Silty-sandy to pebbly sediments.

COLLI ALBANI VOLCANIC COMPLEX

pir — **Pyroclastic rocks and lavas** *(Pleistocene)*
(pir) - Prevailing pyroclastic deposits, with interbedded lavas of the central cone *Phase of the Tuscolano-Artemisio Edifice (0,50-0,35 Ma) (CNR, 1986).*

TERTIARY UNITS

FFR — **"Formazione di Frosinone"** *Auct. (Upper Tortonian p.p.)*
(FFR) - Medium to thin bedded silicoclastic sand/pelite association, locally with lenses of well cemented polygenic calcareous breccia ("Brecce di Genazzano").
Foredeep turbidites.

UAM — **"Marne a Orbulina"** *Auct.(Upper Tortonian p.p.)*
(UAM) Thin to medium bedded marly limestones and calcareous marls, passing upward into thin bedded, brown-gray or greenish marls and clayey marls, with intense bioturbation, rich in planktonic foraminifera (*Orbulina*). The base is marked by a centimetric level of phosphatic-glauconitic grainstone/packstone or rudstone.
Hemipelagites

GUADAGNOLO SUCCESSION

An overthrust probably with limited shortening juxtaposes the western and eastern parts of the Prenestini structure. Therefore, the stratigraphic units defined separately in the two parts, according to the prevalence of main facies associations along the two successions, are not in physical continuity and can be considered, age by age, to be substantially heteropical.

CALCAREOUS UNIT *(Langhian-Tortonian p.p.)*

PCf — **Punta Carpigno facies**
(PCf) Whitish or havana brown calcarenites and calcirudites (packstone, grainstone and rudstone), in thin to very thick beds, sometimes amalgamated and often showing the quite typical "lozenge" structure (combination of sets of oblique laminae and tectonic cleavage), rich in fragments of bivalves, echinoids, red algae and bryozoa (most abundant in the upper part). ("Calcari a Briozoi e Litotamni" *Auct.*).
Subtidal to intertidal deposits - (middle/inner carbonate ramp).

MARLY UNIT *(Langhian-Tortonian p.p.)*

MAf — **Monte Arzillo facies**
(MPf) Prevailing greyish/havana brown or yellowish marls or calcareous marls, associated with bioclastic calcarenites or calcirudites (packstone/grainstone or rudstone/floatstone). In the lower part frequent debris flow, slumping and carbonate turbidite occur. In the middle and upper part, bioclastic intercalations possibly related to storm deposits are quite common.
Subtidal to hemipelagic deposits - (outer carbonate ramp)

MARLY - CALCAREOUS UNITS *(Upper Aquitanian - Burdigalian)*

CPf — **Capranica Prenestina facies**
(CPf) - Thin to thick beds of interbedded grey to hazel marls or calcareous marls and havana brown calcarenites (bioclastic packstone/grainstone). Bioturbation is usually recognizable, more intense in the marly levels. Glauconitic horizons are also frequent, as well as isolated concentrations of shark teeth. Marly levels and calcarenites are arranged in sequences that coarsen upward, and calcarenites often show the typical "lozenge" structure (see above). Some marly levels up to 15-20 cm thick, with intense bioturbation and net or erosive upper boundary, followed by sequences coarsening upward or by beds of bioclastic rudstone/floatstone, are also present.
Tidal to subtidal deposits (middle/inner carbonate ramp)

MPf — **Monte Pompeo facies**
(MPf) This unit (Palestrina-Monte Pompeo) is similar to the Capranica Prenestina Unit (CPf), but is distinguished by a more significant pelitic fraction and the presence of graded bioclastic levels, sometimes with a basal lag and hummocky structures, testifying to a general moderate deepening of the depositional environment.
Tidal to subtidal deposits (middle carbonate ramp)

CSf — **Colle delle Scrime facies**
(CSf) Prevailing thin to thick bedded, sometimes finely laminated, yellowish/hazel marls, interbedded with calcarenites and calcirudites (bioclastic packstone/grainstone or rudstone/floatstone), deposited by grain flow/debris flow. Carbonate turbidites are also present in the lower part.
Hemipelagic deposits with bioclastic supply (outer carbonate ramp - slope)

MCf — **Monte Capranica facies**
(MCf) Towards north and west the Capranica Prenestina facies (CPf) passes into marly limestones and/or to grey/hazel calcareous marls, with intense bioturbation, associated with hazel/havana calcarenites or calcirudites (bioclastic packstone/grainstone or rudstone), sometimes in sequences coarsening upward, and more often in storm deposits.
Tidal to subtidal deposits (middle carbonate ramp)

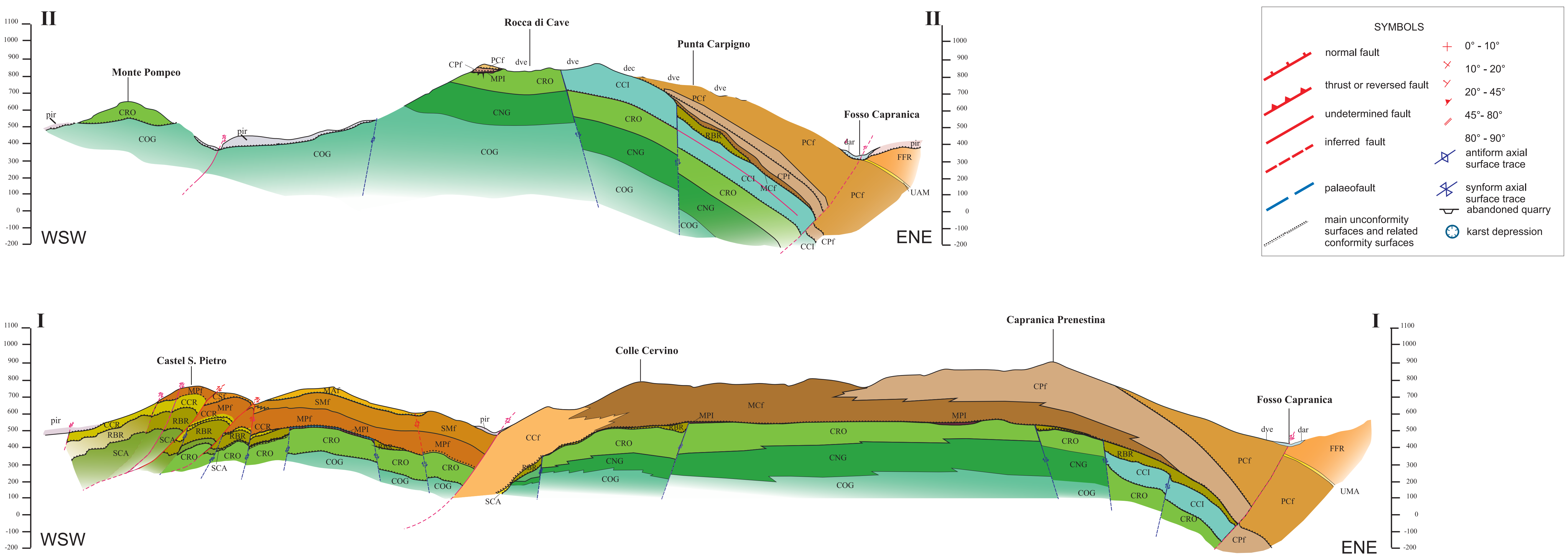


Fig. 1 - *Geological map and geological sections of the study area.*

SMf

Selva Maiuri- Campagnano facies
(SMf) Bioclastic calcarenites and calcirudites (packstone/grainstone and rudstone/floatstone), well stratified in medium to thick beds, rich in fragments of bryozoa, bivalves and red algae. Some levels are nearly entirely made of well sorted large foraminifers, deposited by storm events and grain flow/debris flow. Near Palestrina and Castel S.Pietro are present pelitic intercalations, more frequent and locally prevalent to the North, where reworked bioclastic grains, well sorted and rounded in more internal parts of the ramp, were resedimented within hemipelagites through slumping and other gravitational mechanisms.
Subtidal to hemipelagic deposits (outer carbonate ramp)

CCf

Colle Cervino facies
CCf) Thin to thick bedded, hazel grey or yellowish marls or calcareous marls, somewhere with intense bioturbation, interbedded with bioclastic calcarenites (packstone/grainstone) or calcirudites (rudstone/floatstone), deposited by storm events, grain flow, debris flow. Near Rocca di Cave calcarenitic alternations become more frequent, sporadically associated with marly limestones in coarsening upward facies associations. Breccias with prevailing clasts derived from the erosion of the Mesozoic platform succession are locally present here, while to the North are present conglomerates with polygenic clasts reworked from the "sabina" Meso-Cenozoic pelagic succession.
Subtidal to hemipelagic deposits (outer carbonate ramp, with local variations of the depositional profile)

DETRITAL-SKELETAL UNITS

CCR

Calcarenites and calcirudites with macroforaminifers (*Oligocene -Lower Aquitanian*)
(CCR) Medium to thick bedded, havana brown bioclastic packstone/grainstone and rudstone/floatstone, nearly exclusively made up of remains of large foraminifers ("brecciole", well exposed near Palestrina). Locally, in the basal part is present a level some ten meters thick of yellowish spongolitic marls (sometimes grey or with greenish glauconite), showing intense bioturbation and fine lamination, with chert and "brecciole" interbedded. In the Rocca di Cave area glauconitic, polygenic and heterometric conglomerates (rudstone/floatstone) are present; the clasts pertain to the "sabina" pelagic succession. More to the North the pelitic content increases and is locally prevalent, associated with interbedded breccias and/or pebbly mudstone.
Typical of this unit is the constant presence of conglomerates and of coarse bioclastic grains, well sorted and rounded during long and intense reworking along more inner parts of the ramp (or on the ancient carbonate platform), then carried away toward the slope during storm events and deposited by grain flow, debris flow and other gravitational mechanisms.
Resedimented coarse deposits interbedded with hemipelagites (outer carbonate ramp-slope)

SCD

"Detrital" Scaglia (*Paleocene? - Lower Aquitanian*)
(SCD) Pelagic deposits made up of marly wackestone/mudstone rich in sponge spicules, radiolarians and planktonic foraminifers, with frequent interbedding of detrital or detrital-skeletal matter in form of packstone/grainstone, "brecciole" with large foraminifers (usually Nummulites), channelized coarse deposits. Chert is present both as clast or in lenses and nodules. Beds vary from thin (pelagites) to very thick (detrital levels). Pelitic levels are discontinuous, with intense bioturbation or finely laminated. Detrital beds show quite variable texture and geometry; graded bedding is frequent, as well as lenticular geometry at medium scale. Outcropping only at Colle Corvia, some km north-west of the mapped area.)
Mixed deposits with prevailing detrital or detrital/skeletal matter carried along the ramp and resedimented in different ways within hemipelagites (slope)

RBR

Calcirudites and polygenic breccias (*Senonian -Eocene p.p.*)
(RBR) Whitish or hazel brown (sometimes polycrome) heterometric calcirudites and polygenic breccias (rudstone and floatstone) in a calcareous or calcareous-marly matrix, interbedded (especially in the lower part of the unit) with thin levels of greenish calcareous marls or with beds of bioclastic calcarenites, sometimes rich in macroforaminifers. Breccias and calcarenites are often chaotic and disorganized, in thick or very thick beds, sometimes in channelized bodies. The base of the unit is irregular, draping on a very articulated substratum of Mesozoic limestones.
Detrital or detrital-skeletal deposits transported along the ramp and resedimented, probably in presence of local variations of the depositional profile, through various flow mechanisms, interbedded with subordinate hemipelagites (transitional zone between outer ramp and slope)

PELAGIC MUDSTONE UNIT

MPI

Calcilutites with planktonic foraminifers (*Maastrichtian - Eocene*)
(MPI) Are grouped in this unit a number of lithotypes such as havana-pink to hazel mudstone/wackestone or marly mudstone/wackestone, rich in planktonic foraminifers, present with centimetric up to metric thickness in some condensed and/or lacunose successions. In the area around Rocca di Cave they are preserved at the top of the Cretaceous limestones as scattered residual pockets along paleokarst surfaces or in form of thin dykes.
Hemipelagites/pelagites (outer ramp to basin)

MESOZOIC UNITS

Remains of the ancient Mesozoic carbonate platform are preserved in the Rocca di Cave area, rimmed by banks and reefs passing toward NW (Colle Corvia) to slope/basin facies. The transition between the two realms is however not visible, owing to tectonic elision and Quaternary cover. North -West of Rocca di Cave the Mesozoic platform succession is closed by Upper Cenomanian - Turonian beds, to the South-East it includes the Senonian: the two sectors are divided by palaeofault systems. During Maastrichtian the likely combination of tectonics and eustatism is cause of sudden drowning also of the North-western Rocca di Cave area, testified by scattered small pockets of "Scaglia" with Globotruncanidae (MPI) preserved along submerged karst surfaces.

NORTH -WESTERN SECTOR

SCA

Scaglia (*Cenomanian - Senonian?*)
(SCA) White or pink marly mudstone/wackestone in fine to medium beds, sometimes densely interbedded with thin levels of chert, clay, or bioclastic finely laminated packstone/grainstone . Calciruddites and polygenic conglomerates (rudstone and floatstone), in medium to very thick beds, and heterogenous and heterometric breccias in lenticular bodies with graded bedding or chaotically arranged, are also present. Outcropping only at Colle Corvia, some km north-west of the mapped area.
Pelagites interbedded with coarse deposits resedimented through various flow mechanisms (outer slope - proximal basin)

CRO

Rudist and Orbitolina limestones (*Cenomanian p.p. - Turonian p.p.*)
(CRO) Whitish detrital and detrital/skeletal rudstones, locally boundstones, well stratified in medium to thick beds, rich in fragments of rudists (mainly radiolitids), corals and benthonic foraminifers (*Orbitolina*), passing upward to bioclastic packstone/grainstones and rudstones. Lithotypes differ in sorting, rounding, grain size, from well rounded and sorted grainstone/rudstone (probably beach deposits) to finer, more poorly sorted packstone (probably backreef sheltered environment).
This kind of deposits is typical of beaches, bars, sandy shoals along the platform rim in inter-reef zones. Granulometric features are linked to the energy level, while the fossil content is strictly related to the communities living in adjacent bottoms: benthonic foraminifers, corals, radiolitids, usually found in highly reworked and rounded fragments (open platform or patch reef deposits)

CNG

Caprinid and Nerineid limestones (*Albian p.p. - Cenomanian p.p.*)
(CNG) Whitish/grey bioclastic wackestones and packstones, in thick to very thick beds, each passing upward to levels rich in nerineids and small gastropods. Lithotypes and sedimentary structures are varied. Banks and shoals repeatedly emerged, as witnessed by reddish horizons corresponding to coarse bioclastic grains, sometimes highly reworked and in sparry cement, with microkarst features and scattered internal sediments (laminated, barren pink mudstone). Lagoon mudstones or very fine bioclastic wackestones deposited between the emersion phases. In the upper part of the unit the bioclastic fraction becomes dominant, bedding is less regular, and locally splendid exposures of macrofossils occur (caprinids, radiolitids, corals). Then, sedimentation is again muddy and marked by reddish levels, pink internal sediments, shrinkage structures. The top is marked by a 2 m thick level of *Plesioptygmatis nobilis* and other gastropods. Macrofossil concentrations increase toward SE, carbonate mud fraction decreases at the same time, with evidence however of local restricted environments, witnessed by lenses of finely laminated pink mudstone/wackestone, barren or with ostracod fauna, by thin levels of conglomerates and breccias with black clasts, and by other peculiar features.
In the northwestern sector open sea was near but episodes of inner platform environment with mudstones, shrinkage structures, emersion evidences, are still recognizable. In the Rocca di Cave-Colle del Pero area, reefoid facies is best developed. More to Southeast, in the lower part of the unit prevail inner platform environments (both open and restricted), with muddy sediments alternating with reefoid deposits; in the upper one prevail shoals and organogenous banks, with evidence of sporadic emersions and local restricted environments (open lagoon - shelf-edge deposits)

COG

Ostracod and gastropod limestones (*Aptian - Albian p.p.*)
(COG) - White or hazel mudstones and wackestones, sometimes with shrinkage structures and bioturbation, in thick or very thick beds, with sporadic rudstones or floatstones interbedded. In the lower part macrofaunal content is poor, apart from local concentrations of small gastropods and fragments of requienids. Alternating bioclastic levels are made up of fragments of bivalves, gastropods, echinoids, corals and, in the upper part, also of radiolitids and brachiopods. *A lagoonal facies with muddy sediments in restricted platform environment is widespread in the lower part, maybe subject to temperature and salinity variations and to tidal cycles. On local hardened bottoms, monotypical associations of small gastropods occur. Hardened bottoms in fairly sheltered but not isolated lagoons are more frequent in the northwestern sector, where corals and rudists banks were able to settle. The top of the unit pertains to an inner platform poorly sheltered environment, subject to storm events and tidal currents (inner platform restricted lagoon deposits)*

SOUTH - EASTERN SECTOR

CES

Echinoid and stromatoporoid limestones (*Campanian-Maastrichtian*)
(CES) Bioclastic wackestone/packstones and floatstones in medium to thick beds, with echinoids, stromatoporoids (*Actinostromaria*) and planktonic foraminifers. Texture varies from bioclastic wackestone/packstone to very fine wackestone with planktonic foraminifers. Locally, large fossil fragments are scattered in a muddy matrix (floatstone). The bioclastic fraction is made up of biogenic remains coming from the near shelf-edge. Peculiar presence of tabular stromatoporoid colonies, often associated with levels rich in echinoid fragments. Pelagic influence is testified by planktonic foraminifers.
Open environments on sloping bottoms, below normal wave base (outer platform slope)

CCI

Hippuritid and coral limestones (*Turonian- Senonian*)
(CCI) The lower part of this heterogeneous unit is featured by the alternation of bioclastic wackestones, bioclastic breccias and mudstones rich in nerineids and acteonids, passing upwards to rudstones, floatstones, boundstones with colonial and noncolonial corals, hippuritids and radiolitids, interfingering with bioclastic packstone-grainstone and with mudstone-wackestone. Splendid associations of corals, rudistids and chetetids in living position are exposed in the upper part.
Within this unit are recognizable: sandy facies with nearly monotypical radiolitid associations, rare corals and sporadic caprinid remains, suggesting a backreef environment below normal wave base; hippuritid banks on slightly agitated bottoms in sheltered backreef areas; bioclastic sandy facies (from wackestone to grainstone/rudstone, with grain size, sorting and rounding according to hydrodynamical conditions) corresponding to beaches, bars, sandy shoals along the platform rim in inter-reef areas; reef facies with corals and rudists settled on hardened bottoms subject to wave action, passing to open platform environment (from restricted lagoon to open platform)

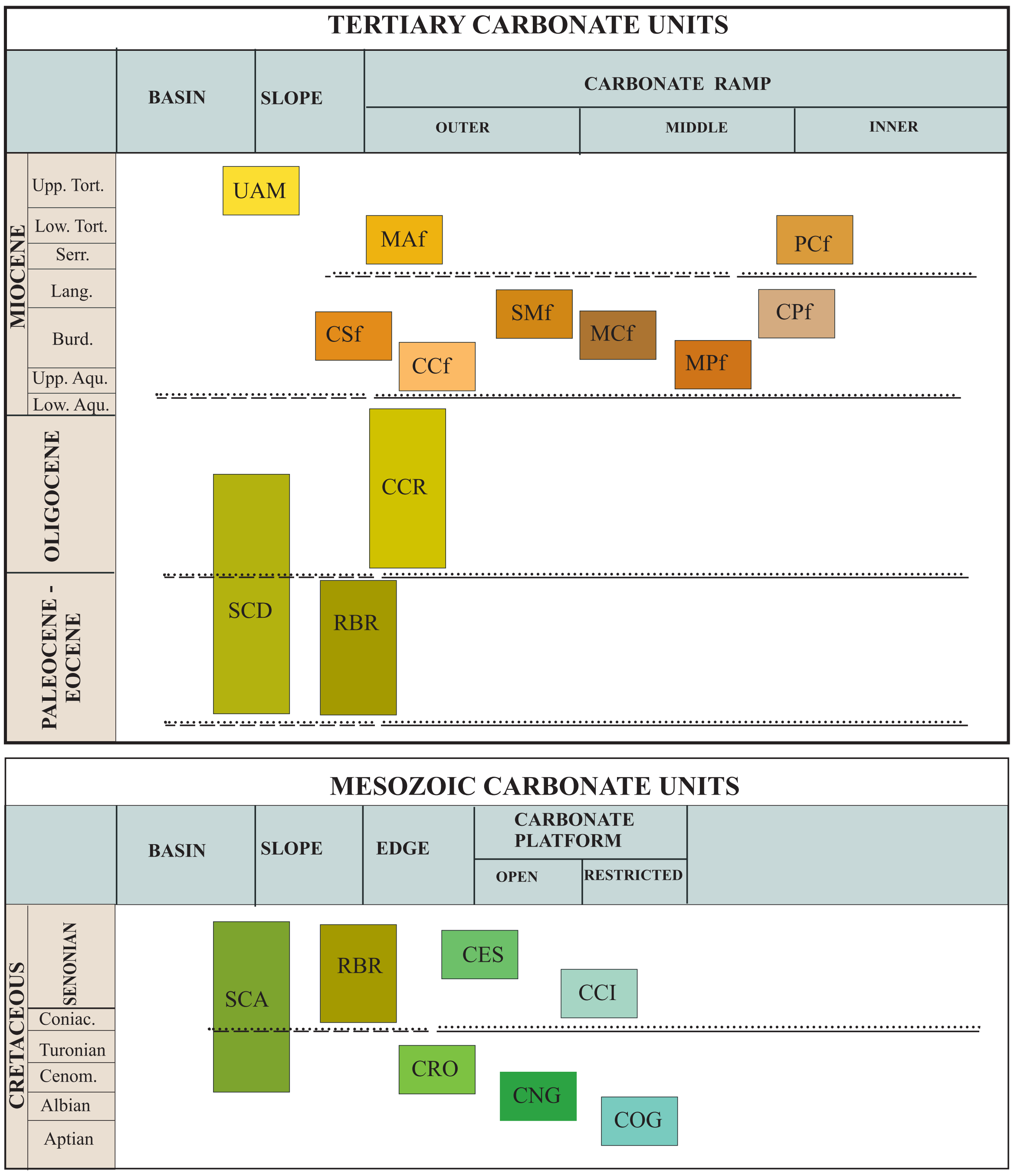


Fig. 2 - *Stratigraphic relations of the Tertiary and Mesozoic carbonate units outcropping in the southern Prenestini Mts.*

GEOLOGICAL SETTING

The central-southern Apennines are famous for their great exposures of carbonate rocks accumulated within the Mesozoic-Tertiary carbonate platform/basin system, developed along the Adria-Apulia passive margin. Remnants of the platforms, with traces of their original rims, and sometimes of the adjacent slopes, are preserved both in the external areas of the chain and in the foreland. A vast Apennine-Maghrebian platform (or possibly more platforms separated by shallow straits or small inter-platform basins) of the chain is now split into several tectonic units that form the core of the central-southern Apennine thrust belt. These carbonate structures comprise the main thrust sheets of the external Apennine, where they have strong morphological evidence. Carbonate platforms were surrounded by deeper waters, basins or pelagic platforms, somehow connected to each other.

To the west of the Latium-Abruzzi platform, where the investigated area is located, the Sabina Basin opened as a southward prolongation of the wide Umbria-Marches Basin, developed on a drowned lower-Jurassic carbonate platform. The successions of the Sabina Basin are characterized by the alternation of pelagic limestones, cherty limestones and marls with redeposited sediments derived from the nearby platform margin. The Sabina Basin was linked westwards to the Tuscan Basin.

The transitional sequences between platforms and basins along the chain are quite difficult to recognize and are generally obliterated by tectonic elision during transport. Platform margins are in fact the preferred site of decoupling and thrust initiation, and the transition from a platform to an adjacent basin is only exceptionally preserved and visible.

Carbonate platform/basin systems characterised the external areas of the Apennine-Maghrebian chain (and of other important sectors in the Mediterranean area) from the Late Triassic up to the end of the Cretaceous. Further away from cratons, these wide areas were sheltered from terrigenous feeding, while continuous subsidence, creating significant space accommodation, was balanced by high carbonate productivity. Therefore, very thick piles (measured in km) of pure limestones and dolomites of lagoonal and peritidal environment dominate the platform successions. Bioclastic or oolitic sands and biostromal to reefoid deposits characterize the platform margins, while adjacent slopes are documented by erosional escarpments and local canyons, by residemented, often turbiditic, skeletal and detrital-skeletal deposits, and by channelised breccias and megabreccias. Pelagic carbonates, marls and siliceous sediments characterize the basins.

Environmental changes and syn sedimentary tectonics continuously influenced the evolution of the carbonate platforms of the Apennine-Maghrebian chain. Late break-up and drowning of portions of wider platforms characterize their history. In the central Apennines, for example, during the Cenomanian the break-up of the

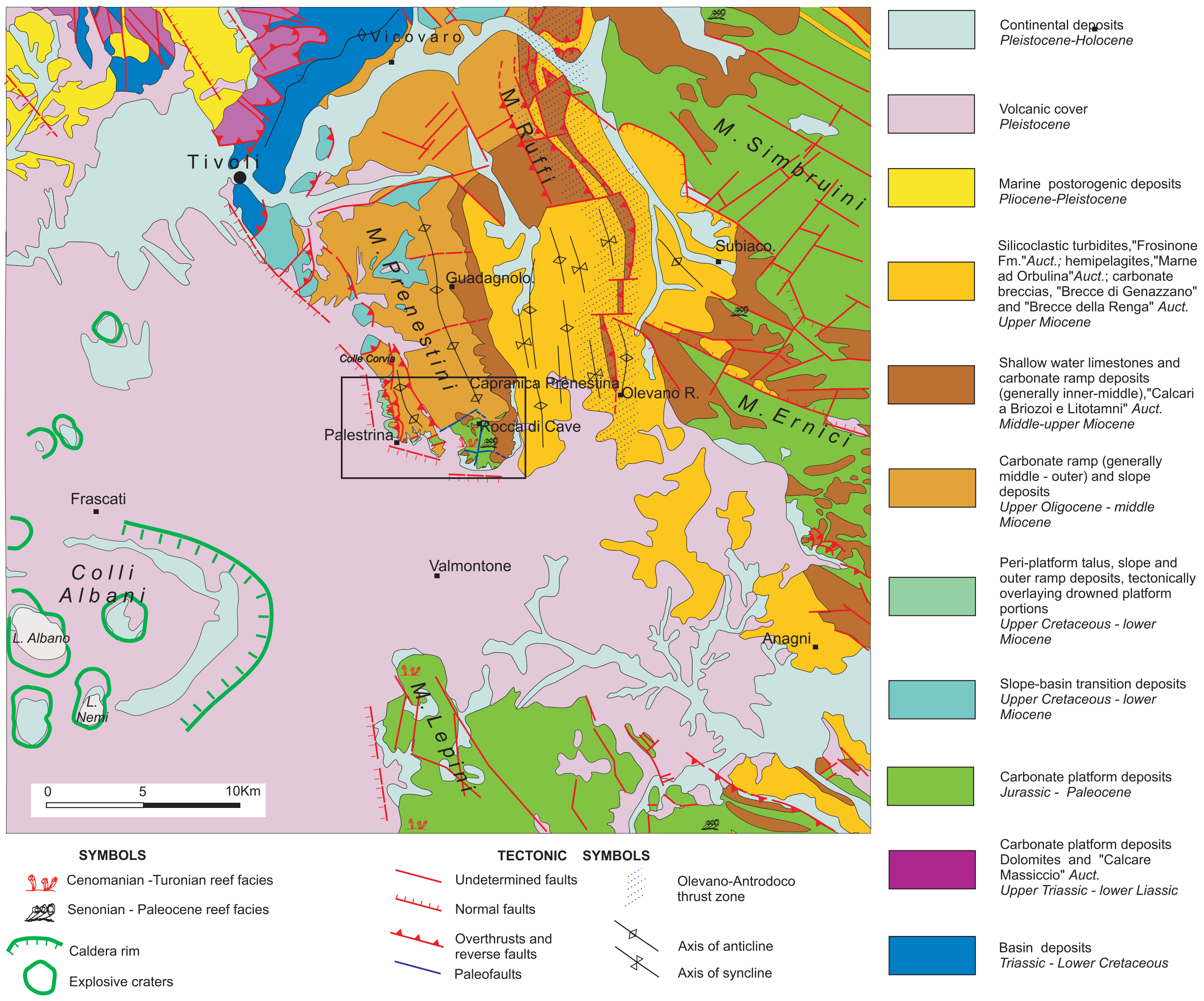
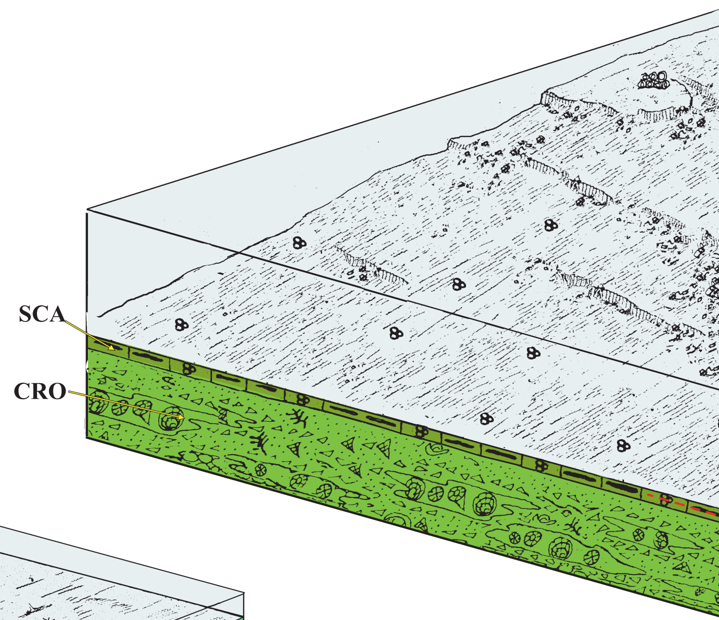
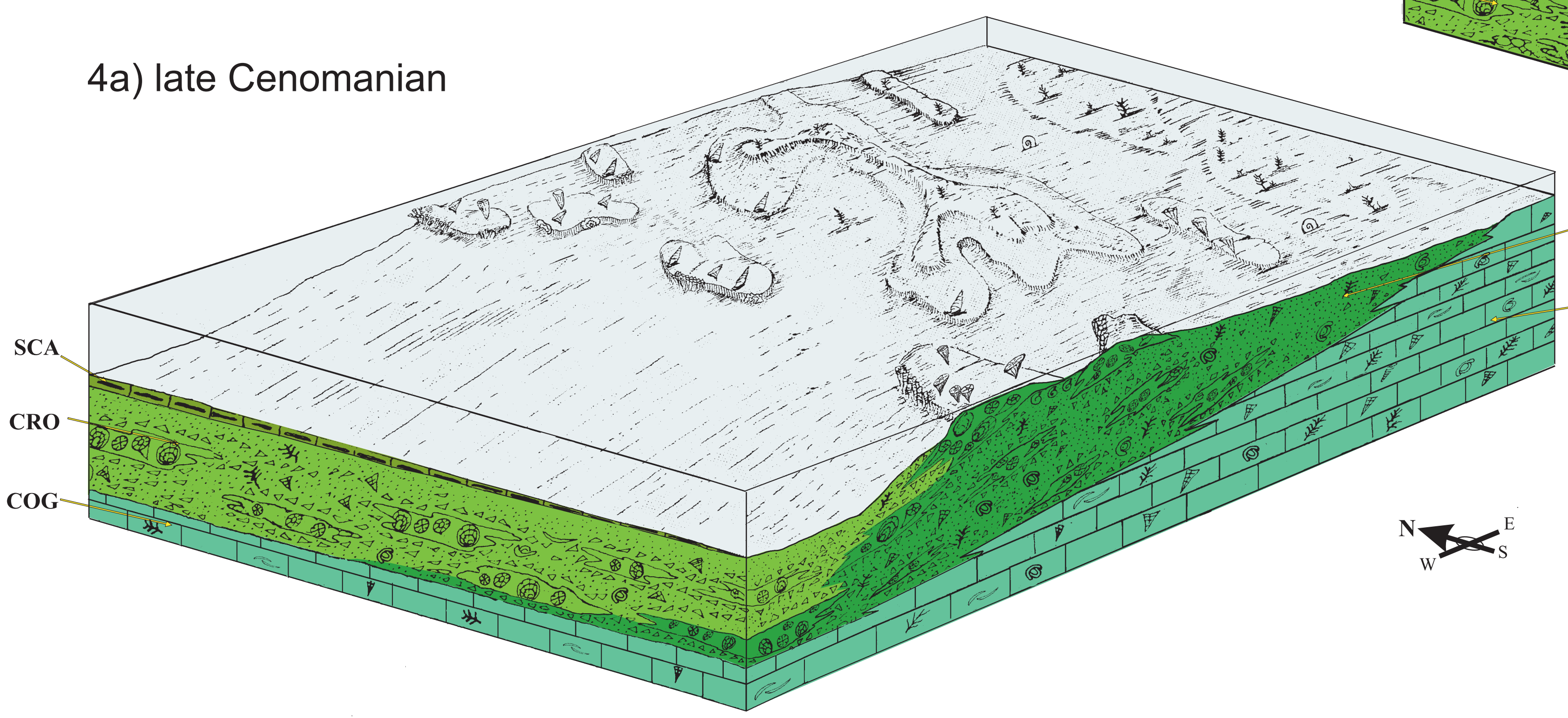


Fig. 3 - *Regional geological setting and location of the study area.*

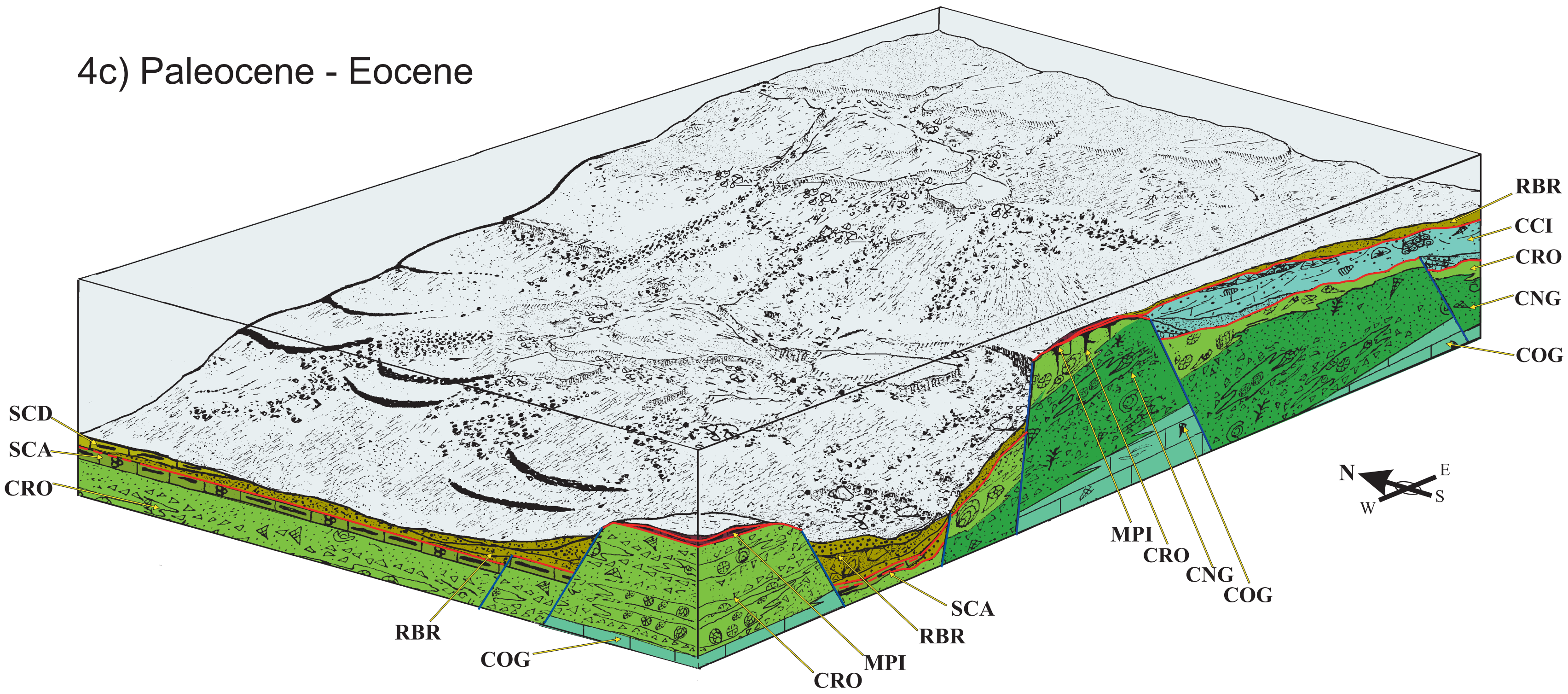
4b) Senonian

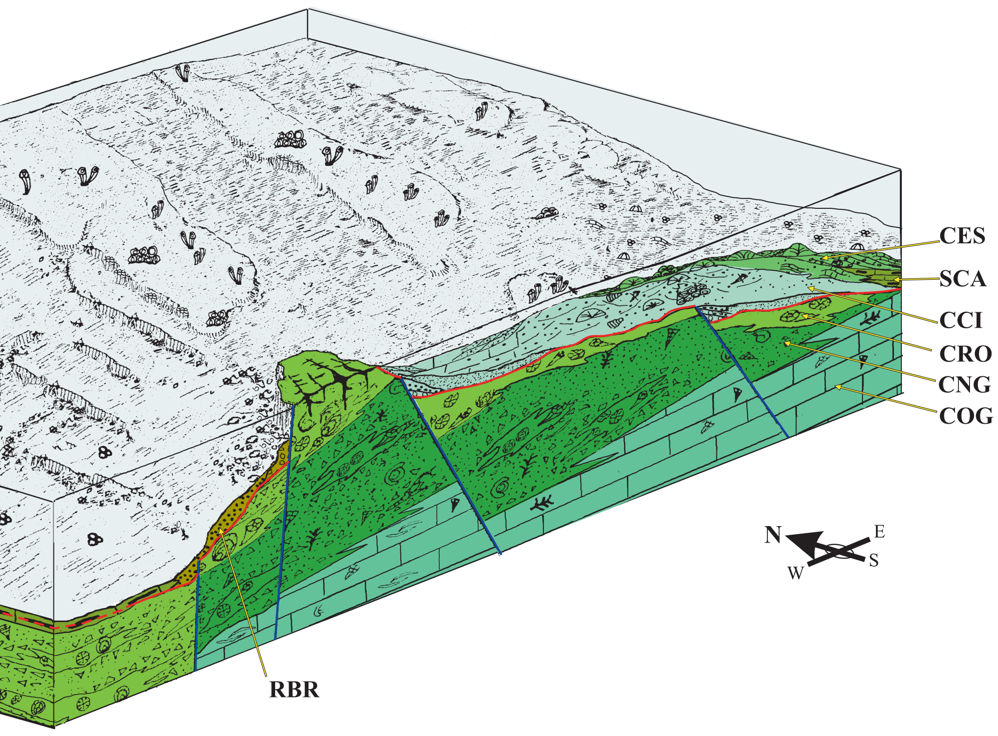


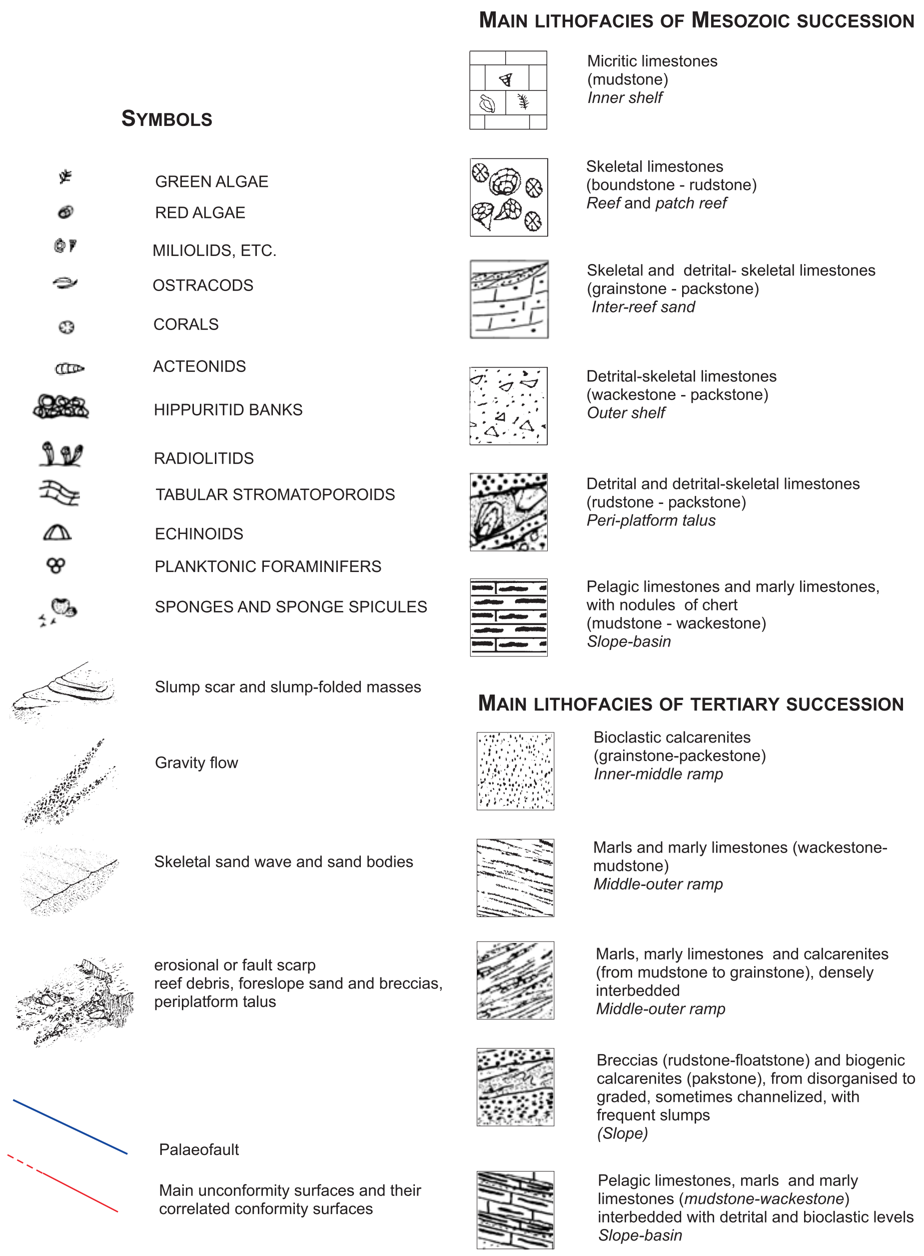
4a) late Cenomanian



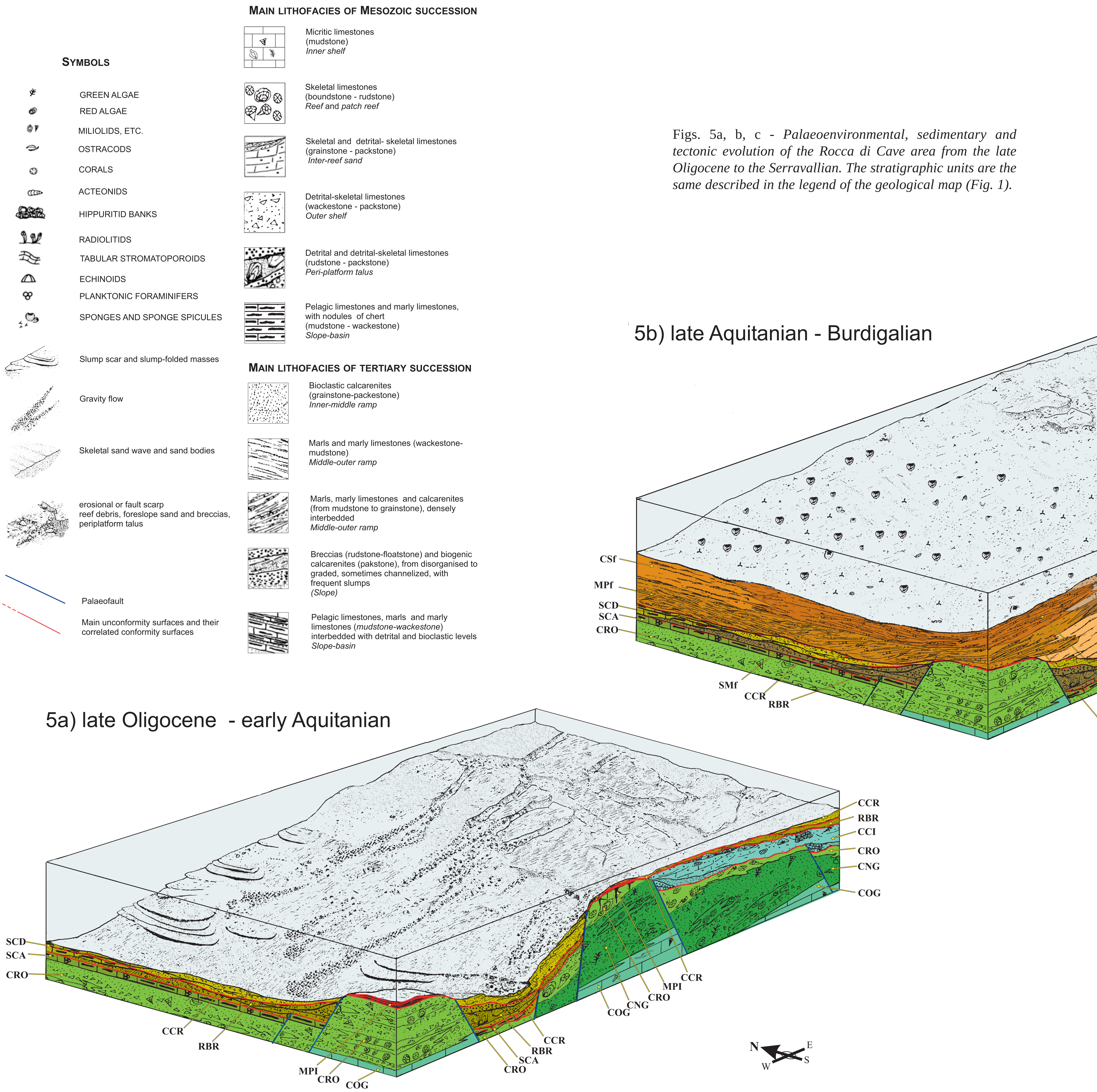
former Bahamian-type platforms gave rise to new prolific, tectonically-controlled margins, reducing the inner platform areas. Besides, the bauxite levels at this time also testify to the occurrence of emersion episodes. At a later stage, the palaeogeography of the area was dominated by wide carbonate banks and ramps, linking emerged portions of ancient platforms to the surrounding basins.
At the end of the Cretaceous, the whole Apennine Platform(s) emerged ("Palaeogene hiatus"). Only a few limited Eocene-Oligocene carbonate ramps persisted here and there along the margins.
Later on, starting in the early-middle Miocene, carbonate shallow-water sedimentation again completely unconformably or paraconformably covered the emerged Mesozoic limestones ("Miocene transgression"). This was the final act in the history of the carbonate realm. Miocene limestones were overlain everywhere by late Miocene silicoclastic turbidites, as this part of the future Apennines was involved in the evolution of a post-collisional orogenic system. Following the tectonic evolution of the chain, foredeep deposits replaced a sedimentary model that had lasted for nearly two hundred millions years.
The structural setting of the tectonic units is similar to other post-collisional belts, and consists of basement and cover thrust-sheets developed in an ensialic context. Extensional tectonics and generalized uplift characterised mid Pliocene-Pleistocene times.
The western boundary of the central Apennines is sharp along the well-known Olevano-Antrodoco-Sibillini line, an out-of-sequence N-S trending overthrust of early Pliocene age causing the western structures to overlap the eastern structures in an oblique direction with respect to the regional orogenic system (Castellarin, Colacicchi & Praturlon, 1978; Cipollari & Cosentino, 1991; Corrado, 1995). The area investigated (Fig. 1) is located a few km to the west of this tectonic line (Fig. 3).
The Prenestini Mts. are a NNW-SSE trending, eastward verging anticline (Maxia, 1954 a,b). Near the western side of this structure some overthrusts of uncertain importance are present.
The palaeogeographic reconstruction of the southern sector reveals that in pre-orogenic times, at least since the late Cenomanian, the area was a persistent structural high affected by syn sedimentary tensional tectonics (Negretti, 1956-57; Carbone, Praturlon & Sirna, 1971; Carbone & Sirna, 1981; Civitelli, Corda & Mariotti, 1986).







Figs. 4a, b, c - *Palaeoenvironmental, sedimentary and tectonic evolution of the Rocca di Cave area from late Cenomanian to Eocene. The stratigraphic units are the same described in the legend of the geological map (Fig. 1).*

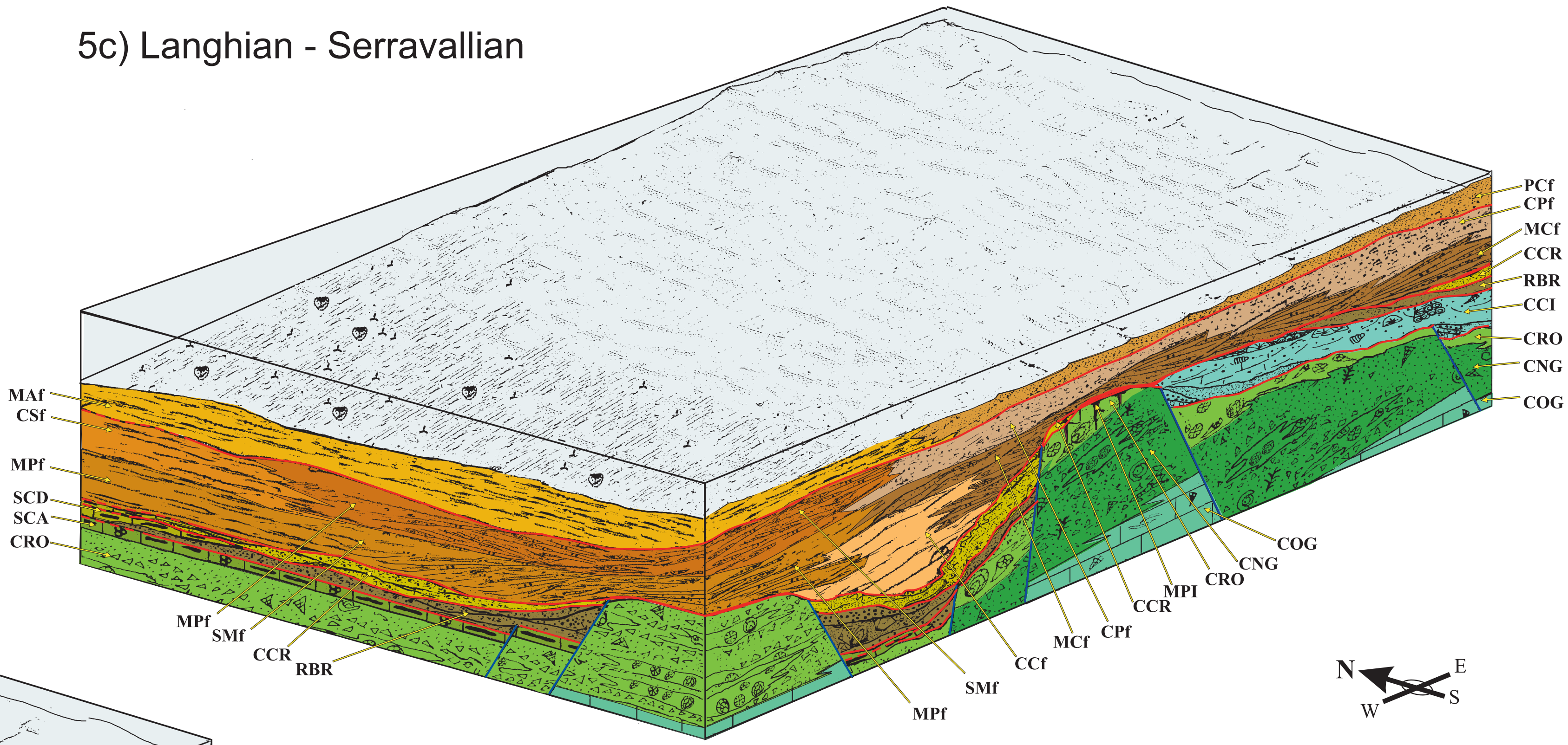


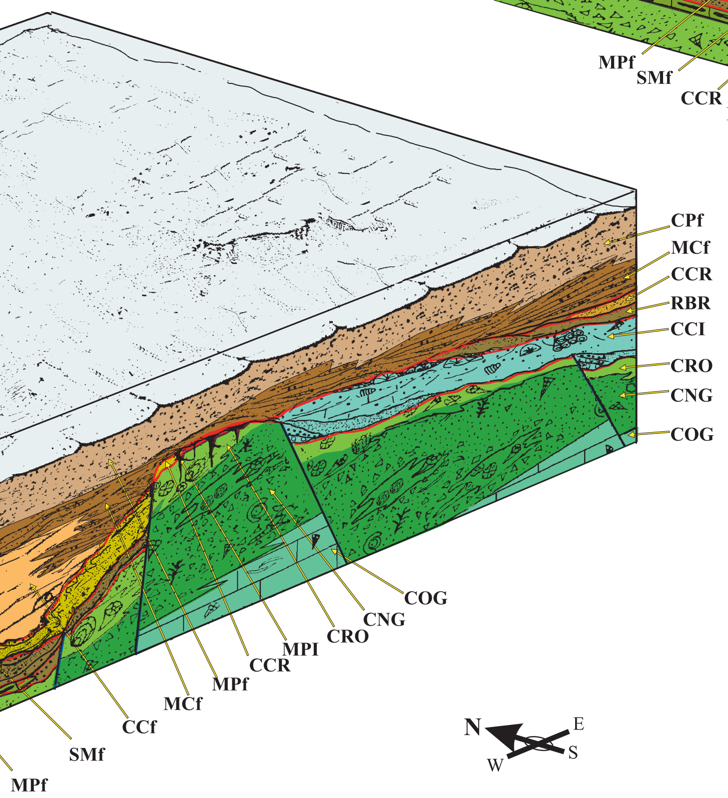
Figs. 5a, b, c - *Palaeoenvironmental, sedimentary and tectonic evolution of the Rocca di Cave area from the late Oligocene to the Serravallian. The stratigraphic units are the same described in the legend of the geological map (Fig. 1).*

Fig. 6 - *Nerinea bank: this high energy facies appears frequently in the Rocca di Cave sector* (CNG unit). *Gastropods are worn but unbroken and are embedded in detrital-skeletal matter. Subtidal shoals are suggested as the most likely environment.*

PALAEOGEOGRAPHIC EVOLUTION FROM THE LOWER CRETACEOUS TO THE SERRAVALLIAN

Shelf-edge limestones of Aptian-Senonian age, renowned for their splendid macrofauna (Fig. 6), are the oldest sediments of the area, outcropping around Rocca di Cave. Here during the Aptian-late Cenomanian (Fig. 4a) skeletal and detrital-skeletal shelf-edge facies migrated towards the SE, overlapping lagoonal micritic sediments. To the NW, in the Colle Corvia sector, shelf-edge facies pass to slope facies ("Scaglia" with bioclastic sediments interbedded). In the eastern sector of the Rocca di Cave





area, sedimentation was continuous up to the Senonian, while the western sector was subjected to uplift and karst during the late Cenomanian-Turonian, due to a system of tensional palaeofaults (Fig. 4b). The areal distribution of the Senonian facies suggests that in this time-interval the Rocca di Cave sector was a partially-emerged structural high, connected through wide shoals to the main carbonate platform (further east). During the Maastrichtian, it is likely that a combination of eustatism and tectonics caused a general drowning of the whole area, testified in the western sector of Rocca di Cave by small lenses of pelagic limestone (MPI) interbedded between Cenomanian and Miocene sediments (Figs. 4c and 5a).

Mesozoic and Cenozoic successions are coupled together through a number of unconformity surfaces tending to close up and merge (Fig. 7b) in the Rocca di Cave - Palestrina sector (where gaps in sequences are quite common), while passing to the corresponding conformity surfaces toward NW (Colle Corvia sector). Here the Cenozoic succession is continuous and thicker, up to 600-700 m, while in the intermediate area it shows thickness, age and facies extremely variable in response to factors including: relative location with respect to pelagic basin and platform; geometry of the top surface of the Mesozoic substratum, split by an intense synsedimentary tectonics; and interaction among eustatism, tectonics, subsidence and rate of carbonate supply.

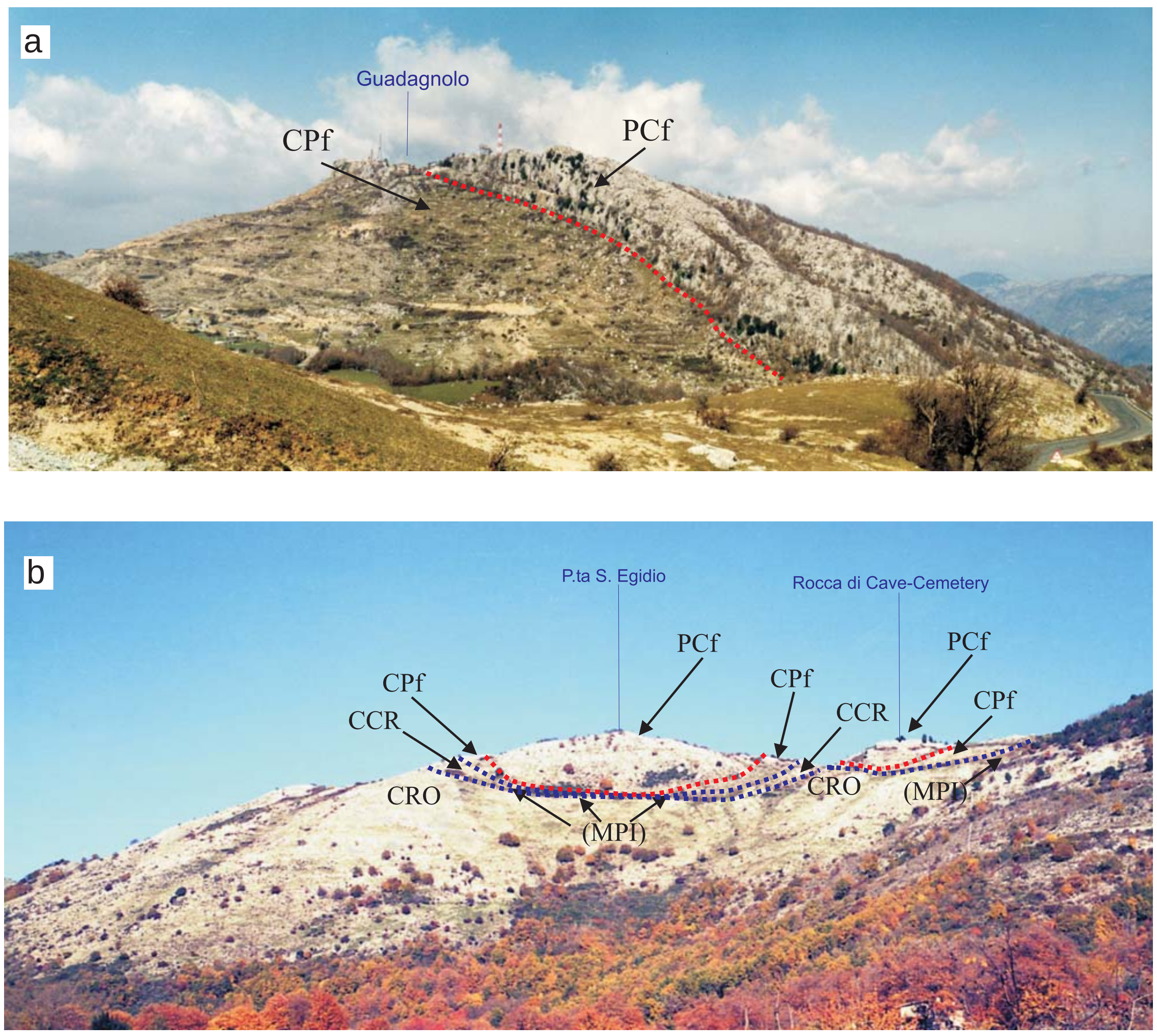


Fig. 7 - *Example of mappable unconformity surface (red dots) which can be followed, physically, over wide areas.*
a - *Rupe di Guadagnolo (NE sector of Prenestini Mts., about 7 km NNW of Rocca di Cave sector). Langhian-Tortonian Calcareous Unit* (PCf) *lying on Upper Aquitanian-Burdigalian Marly Calcareous Unit* (CPf). *The Marly Calcareous Units generally display a clear, wedge-shaped geometry toward SSE and tend to pinch-out onto Mesozoic Units. The marked unconformity surface between* PCf *and* CPf *merges into a complex system of unconformity surfaces in the Rocca di Cave sector (Fig. 7b);*
b - *Punta S. Egidio (Rocca di Cave W sector). The Marly Calcareous Units are strongly reduced in thickness and tend to disappear, while the Calcareous Unit (PCf) is directly lying on the Mesozoic Units (CRO), with interbedded lenses of Maastrichtian-Eocene Pelagic Mudstones Unit (MPI). With blue dots are marked the main unconformity surfaces between the Guadagnolo Succession and the Mesozoic Units. With red dots is marked the same unconformity surface of Fig. 7a;*
c - *Detail of the facies contrast between calcarenites and marls that generally marks the unconformity surface of Figs. 7a, b.*

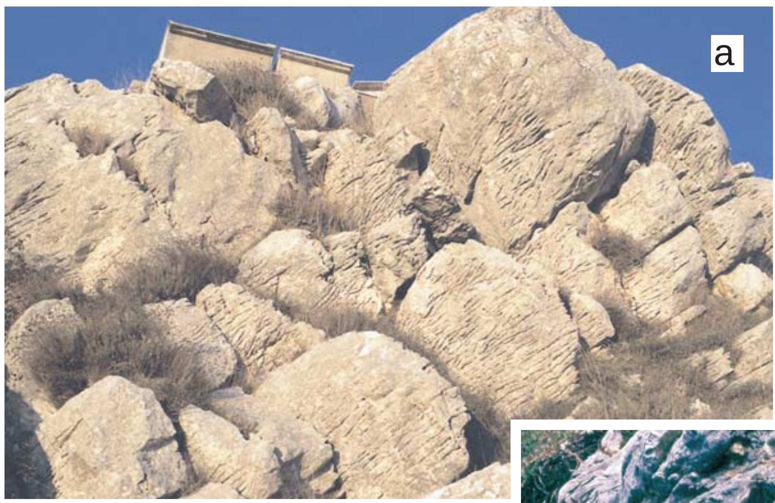


Fig. 8 - *Example of "lozenge structures", mainly controlled by sedimentary factors (Fig. 8a, where tabular and cross beddings are evident) and locally by superimposed tectonic elements (Fig. 8b, where fracture cleavage and stylolites array tend to mask the sedimentary structures).*

The base of the Tertiary succession crops out mainly in the Rocca di Cave - Palestrina sector with outer ramp - slope facies, passing toward NW (northern side of Colle Corvia) to more basinal sediments. These are marls and marly limestones interbedded with reworked sediments, mainly rudstone and floatstone made up of heterometric, sometimes decimetric, Mesozoic clasts, in carbonate or marly matrix. This time-interval was characterised by intense erosion coupled with slumps and accumulation of abundant detrital matter along the outer ramp (Fig. 4c).

The presence of shoals between the Rocca di Cave area and the main platform to the East (present Mt. Scalambra, Affilani Mts.) could have played a fundamental role in the facies distribution of the Tertiary succession. Indeed, favourable conditions existed cyclically for the reworking, rounding and sorting of the clasts found in conglomerates.

At the same time, shoals were a prolific area for large foraminifers and other benthonic organisms. During the Oligocene-early Aquitanian, the detrital supply originated from the erosion of the Mesozoic platform gradually decreased or ceased entirely. At the same time, the massive supply of reworked macroforaminifers and other detrital-skeletal matter greatly increased (Fig. 5a). Bioclastic sedimentation prevailed in the southern sector, with middle-outer ramp facies, while it alternated with emipelagic sedimentation and outer ramp-slope facies in the northern sector. On a global scale, this time-interval included a cycle displaying a general transgressive trend. The Miocene part of the succession was in fact characterised by prevailing emipelagic marly-spongolitic deposits rich in glauconite.

Facies analysis and sequence stratigraphy of Upper Aquitanian - Burdigalian sediments (Fig. 5b) evidenced five third-order sequences and a high-frequency cyclicity (MADONNA, 1995; CIVITELLI *et alii*, 1996a, b; BARBIERI *et alii*, 2003), which can be correlated with the subdivisions of HAQ *et alii*, 1988; ABREU *et alii*, 1998; and HARDENBOL *et alii*, 1998.

This thick pile of calcareous-marly deposits has been ascribed to a middle-inner to outer ramp environment, mainly influenced and controlled by storms and tidal currents.

An important unconformity surface (Figs. 7a-c) dated 16,5 Ma (MADONNA, 1995; BARBIERI *et alii*, 2003) marks the transition to the Langhian - Serravallian deposits (Fig. 5c) characterised by nearly homogeneous environmental conditions.

In the Rocca di Cave sector, and along the eastern side of the whole structure, there are dominant bioclastic and biogenic, fine-grained to coarse calcarenites, with characteristic "lozenge structures" (Figs. 8a, b), interpreted as representative of the innermost part of the local ramp (probably external in relation to the production zone during high-stand phases). These are in heteropy with the *Calcare a Briozoi e Litotamni Fm. Auct.*, unconformably lying on the Mesozoic platform to the east and widely outcropping in Latium-Abruzzi (Fig. 3). In the western sector, the same time interval is represented by a thick marly-calcareous succession, interpreted as outer ramp - slope facies, where hemipelagic deposits are interbedded with bioclastic calcarenites and calcirudites.

Carbonate ramp sedimentation ended during the Tortonian. A discontinuous conglomeratic-glauconitic level marks the transition to the emipelagic deposits of the *Marne ad Orbulina* Fm., followed abruptly upward by the silicoclastic turbidites of the Upper Tortonian *Arenarie di Frosinone Fm.*

The palaeogeographic reconstructions shown in Figs. 4 and 5 aim to synthesize new field data and previous works, and in particular are drawn according to CARBONE *et alii* (1971), CARBONE *et alii*. (1979) and CIVITELLI *et alii* (1986).

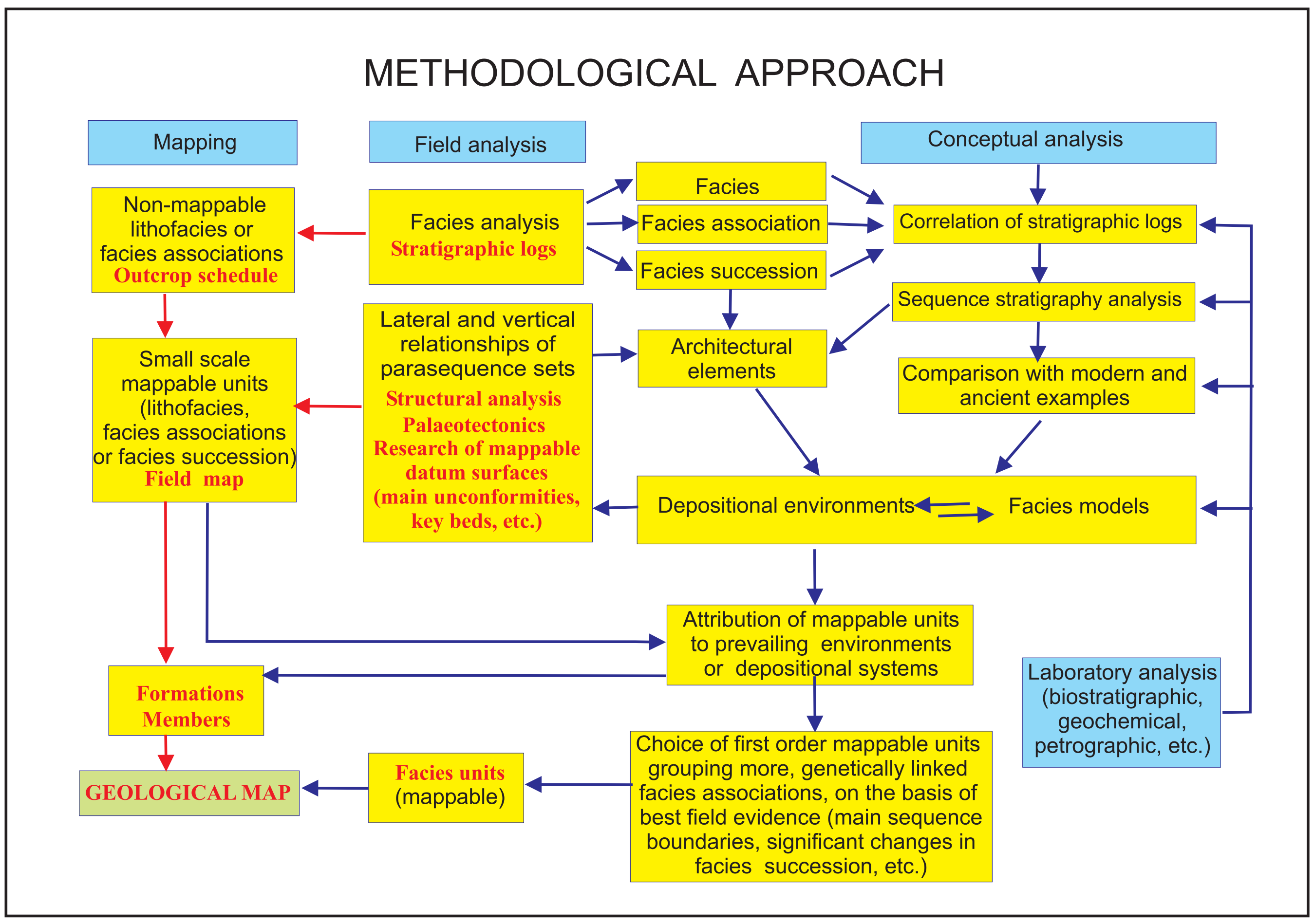
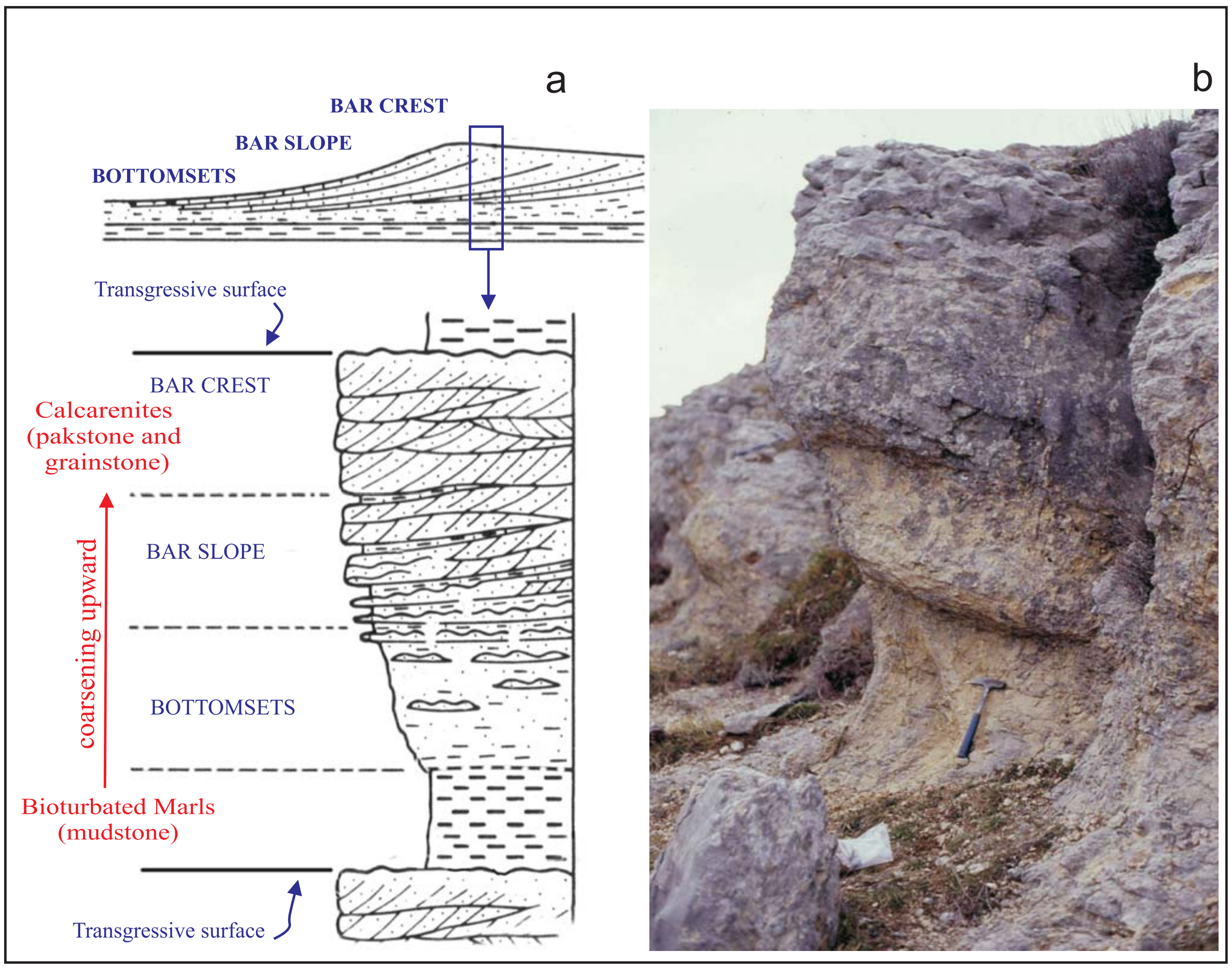


Fig. 9 - *Scheme of the methodological approach adopted in this work to identify the units mapped in Fig. 1. Two paths are indicated, both starting from the preliminary field analysis. One (red arrows) is the usual methodology followed to define traditional mappable units (formations, members, etc.). The second (blue arrows) is the path followed to pick out significant and mappable facies units that can contribute to geological mapping, especially when it is specifically aimed at a palaeoenvironmental and palaeogeographical reconstruction, as in the case at hand.*
*Both (informal) lithostratigraphic units and a number of mappable facies units are therefore present in the legend of Fig. 1 (original mapping scale 1:10,000). For all units, a reconstruction was attempted of the characteristics of the depositional environment within a complex platform-basin system, extremely variable through time (Figs. 4 and 5). These reconstructions, that show the palaeogeographic evolution of the whole succession from the Cenomanian to the Serravallian, are inevitably rather static. A more dynamic analysis of specific intervals highlights a complex tectonic-eustatic cyclicity, and the organization of high-frequency depositional sequences (*BARBIERI et alii*, 2003).*



Figs. 10a, b - *Example of facies association (non mappable) in the* CPf *Unit (Monte Manno section, Fig. 10b), interpreted (Fig. 10a) as subtidal bar, prograding in a transgressive setting (sketch after* MUTTI et alii, *1985 modified). The main transgressive surfaces are marked by abrupt changes in lithology, horizon of bioturbation, presence of glauconite, abrupt deepening in depositional environment etc.*

METHODOLOGICAL PROBLEMS IN FIELD MAPPING

The main units to be adopted in field mapping were determined using traditional methodologies of lithostratigraphic and facies analysis integrated with methodologies and concepts of sequence stratigraphy (Fig. 9). The aim was to identify units that could be used in field mapping but that at the same time would maintain a specific environmental connotation (associations of genetically connected facies). This task was performed by looking for suitable environmental models, variable in geological time, and developing them and checking that they would be coherent with the facies associations and depositional features characteristic of the different, mainly lithostratigraphic, units defined. Within the latter, many informal facies units (sensu CASTER, 1934; TEICHERT, 1958; N.A.S.C., 1983) have been distinguished on the basis of the prevailing facies association.

One of the main problems encountered (Fig. 9) regarded the definition of the position and meaning of non-mappable lithofacies or facies associations (single or elementary depositional units, such as, for example, that shown in Figs. 10a, b) within small-scale mappable units (such as that shown in Fig. 11) and finally of criteria for their grouping into informal facies units, formations and members that could be placed within a generally coherent environmental model (Figs. 4 and 5).

The palaeogeography has been extremely variable in time and space since the Late Cretaceous, especially in the Rocca di Cave sector. Therefore, more facies models, dynamically linked together, were needed. Moreover, sedimentation was affected by high-frequency events, often causing abrupt, significant but usually non-mappable changes within the sequences. This explains why the main units identified were defined on the basis of the prevalence of a given facies association rather than its exclusive presence.

This is particularly true for the Tertiary Guadagnolo succession, which could be ascribed in general to a carbonate ramp environment affected by active subsidence, synsedimentary tectonics, slumps and slides, and intermittent grain flow. Therefore, preference was given to a subdivision of ramp environments (AHR, 1973) according to hydrodynamical features, rather than to emphasizing the geometry of the depositional profile. Four main sectors were recognized: inner ramp, mid-ramp, outer ramp and basin (WRIGHT, 1986; BURCHETTE *et alii*, 1990; BURCHETTE & WRIGHT, 1992).

Inadequate biostratigraphic indications were another problem. Sedimentation was in fact affected from the late Cretaceous to the early Miocene by repeated erosional and reworking phases.

During the Langhian-Serravallian, this activity decreased. Unfortunately, sediments of this time-interval turned out to be of quite poor biostratigraphic resolution. Better results were obtained using geochemical methodologies, mainly ^{87}Sr /^{86}Sr chronology (BARBIERI *et alii*, 2003), that achieve the best stratigraphic resolution for the early and middle Miocene (HODELL *et alii*, 1991).

Nevertheless, the main problem remained as to

Fig. 11 - *Example of lithofacies succession (mappable) in the* CPf *Unit (Monte Cerella section). Recurrence of shallowing-coarsening upward depositional units. The basic facies association is characterised by a limited number of lithofacies (mainly marls and calcarenites).*

the definition of units clearly characterised from a genetic point of view, and that could be described as far as possible in an "objective" way. Attempts were made to organize field information so that the genetic connotation ("deductive" datum) would result from the sum of a number of "objective" data, such as a detailed description of those "lithological" or "geometrical" elements (granulometry, texture, composition, gradation, sorting, bioturbation, bed thickness, cross bedding, lamination, type of contacts, morphology of depositional surfaces…..) whose vertical and lateral distribution and association are used as a rule to define and identify facies, facies associations, depositional elements etc. Finally, the units thus defined were opportunely combined together in relation to the chosen cartographic scale and adopted for field mapping and legend.
For these mappable units (particularly those of the Guadagnolo succession) the informal term "facies" ("magnafacies" *sensu* CASTER, 1934, lithological unit representative of a depositional environment, named by a geographical locality) was adopted. Minor, non-mappable subdivisions are contained within these units ("parvafacies" *sensu* CASTER, 1934). Some of these are graphically sketched in Figs. 4 and 5.

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