

A revised stratigraphy of the Upper Cretaceous to Oligocene units from southeastern Salento (Apulia, southern Italy)

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KEY WORDS — *Stratigraphy, Upper Cretaceous-upper Oligocene, Foraminifers, Southeastern Salento, Apulia, Southern Italy.*

ABSTRACT — *A revised stratigraphy of the Late Cretaceous to Oligocene units of the southeastern Salento (Apulia, southern Italy) is proposed. In the study area this time interval is represented by six stratigraphic units:*

1 – The «Santa Cesarea Limestone»: the deposits referred to this unit are dated late Campanian on the basis of rudist assemblages and benthic foraminifers.

*2 – The «Ciolo Limestone»: this new unit is introduced to indicate upper Maastrichtian limestones containing larger foraminiferal assemblages attributable to the *Lepidorbitoides socialis* Zone and globotruncanids pointing to an age not older than the earliest Gansserina gansseri Zone.*

*3 – The «Torre Tiggiano Limestone»: this new term refers to limestones with alveolinids and nummulitids containing larger foraminiferal assemblages indicative of different Middle Eocene intervals as the lower Lutetian (*Alveolina stipes* Zone) and the upper Middle Eocene (*Alveolina elongata* Zone).*

4 – The «Torre Specchialaguardia Limestone» this unit is introduced to indicate coral limestones containing larger foraminiferal assemblages of Priabonian age (late Eocene).

*5 – The Castro Limestone: this term is used in a restricted sense indicating the upper Oligocene reef complex whose larger foraminiferal assemblages indicate the lower Chattian (*Cyclolypeus* Zone).*

*6 – The Porto Badisco Calcarene: the bioclastic deposits referred to this unit contain larger foraminiferal associations dated as upper Chattian (*Miogypsinoidea* Zone).*

The 4 Paleogene units are recognized as unconformity-bounded stratigraphic units on the basis of the stratigraphic relationships observed in the study area. The hypothesis that also the «Ciolo Limestone represents a UBSU is put forward on the basis of several arguments deduced from the stratigraphy of the Upper Cretaceous deposits of the Apulian Platform.

RIASSUNTO — [Nuovo schema stratigrafico per le unità del Cretacico Superiore-Oligocene del Salento sud-orientale (Puglia, Italia meridionale)] – *Viene proposto un nuovo schema stratigrafico per i depositi del Cretacico Superiore-Oligocene del Salento sud-orientale (Puglia). In tale schema vengono riconosciute 6 unità stratigrafiche:*

1 – «Calcare di Santa Cesarea»: i depositi riferiti a tale unità vengono datati Campaniano superiore sulla base delle associazioni a foraminiferi bentonici e a rudiste.

*2 – «Calcare del Ciolo»: questa nuova unità viene introdotta per indicare dei calcari del Maastrichtiano superiore nei quali sono state riconosciute associazioni a macroforaminiferi riferibili alla Zona a *Lepidorbitoides socialis* e globotruncanidi che indicano un'età non più antica della base della Zona a Gansserina gansseri.*

*3 – «Calcare di Torre Tiggiano»: questo nuovo termine viene introdotto per indicare calcari ad alveoline e nummuliti in cui sono state riconosciute associazioni a macroforaminiferi indicative di diversi intervalli dell'Eocene medio fra cui il Luteziano inferiore (Zona ad *Alveolina stipes*) e la parte alta dell'Eocene medio (Zona ad *Alveolina elongata*).*

4 – «Calcare di Torre Specchialaguardia»: questa unità viene introdotta per indicare calcari a coralli ed alghe rosse che contengono associazioni a macroforaminiferi di età Priaboniana.

*5 – Calcare di Castro: questo termine viene ristretto al complesso di scogliera dell'Oligocene superiore le cui associazioni a macroforaminiferi indicano il Cattiano inferiore (Zona a *Cyclolypeus*).*

*6 – Calcarene di Porto Badisco: i depositi riferiti a questa unità contengono associazioni a macroforaminiferi del Cattiano superiore (Zona a *Miogypsinoidea*).*

Sulla base delle relazioni stratigrafiche osservate nell'area studiata le 4 unità paleogeniche corrispondono ad altrettante unità stratigrafiche limitate da inconformità. L'ipotesi che anche il «Calcare del Ciolo» rappresenti un'unità stratigrafica limitata da inconformità viene proposta sulla base di considerazioni dedotte dalla stratigrafia del Cretacico Superiore della Piattaforma Apula.

INTRODUCTION

The stratigraphy of Upper Cretaceous and Paleogene deposits cropping out along the southeastern border of the Salento peninsula (Apulia, southern Italy) has been discussed in several papers since the beginning of last century. After some papers envisaging the direct superposition of Miocene deposits on Cretaceous limestones (Milano, 1815; Brocchi, 1821; Costa, 1857) the presence of Paleogene deposits was first reported by De Giorgi (1880, 1884). At the beginning of this century a quite bitter controversy arose about the occurrence and distribution of Eocene deposits (Dainelli, 1901, 1905; Baldacci, 1902; Di Stefano, 1906, 1908; Douvillè R., 1907a, 1907b). Later, the presence of Oligocene limestones was reported by Silvestri (1908, 1929), Principi (1940) and Lazzari & Moncharmont (1955).

In the 60's several papers were published, most of them related with the preparation of the new edition of the geological map (Luperto, 1962; Alvino, 1964; Largaiolli *et al.*, 1966; Nardin & Rossi, 1966; Martinis, 1967; Rossi, 1969). Luperto (1962) recognized, on the basis of the foraminiferal assemblages, the occurrence of three distinct units, respectively Late Cretaceous, Middle Eocene and Late Oligocene (Chattian) in age, separated by stratigraphic gaps. Largaiolli *et al.* (1966) and Nardin & Rossi (1966) proposed a stratigraphic scheme different from that of Luperto (1962) and identified two distinct stratigraphic units in the Upper Oligocene, indicated as Oligocene I and Oligocene II. Martinis (1967) introduced two formal lithostratigraphic units: the Melissano Limestone, Late Cretaceous in age, and the Castro Limestone, Paleocene to Oligocene in age. The stratigraphic scheme proposed by Martinis (1967) was used in Sheets 223 «S. Maria di Leuca» and 214 «Gallipoli» of the geological map of Italy at 1:100000 scale. Rossi (1969) formally distinguished the Porto Badisco Calcarene, a lithostratigraphic unit introduced by Alvino (1964), which corresponds to the Oligocene II of Largaiolli *et al.* (1966) and Nardin & Rossi (1966), from the Castro Limestone which corresponds to the Oligocene I of the last Authors. The latter scheme was used in Sheet 215 «Otranto» of the geological map of Italy at 1:100000 scale.

The most recent attempt of stratigraphic reconstruction is given by Bosellini F.R. & Russo (1992). These authors, applying the concepts of sequence stratigraphy, propose to subdivide the sedimentary succession into 4 depositional sequences, one in the Upper Cretaceous, corresponding to the Melissano Limestone of Martinis (1967), one of very late Mid-

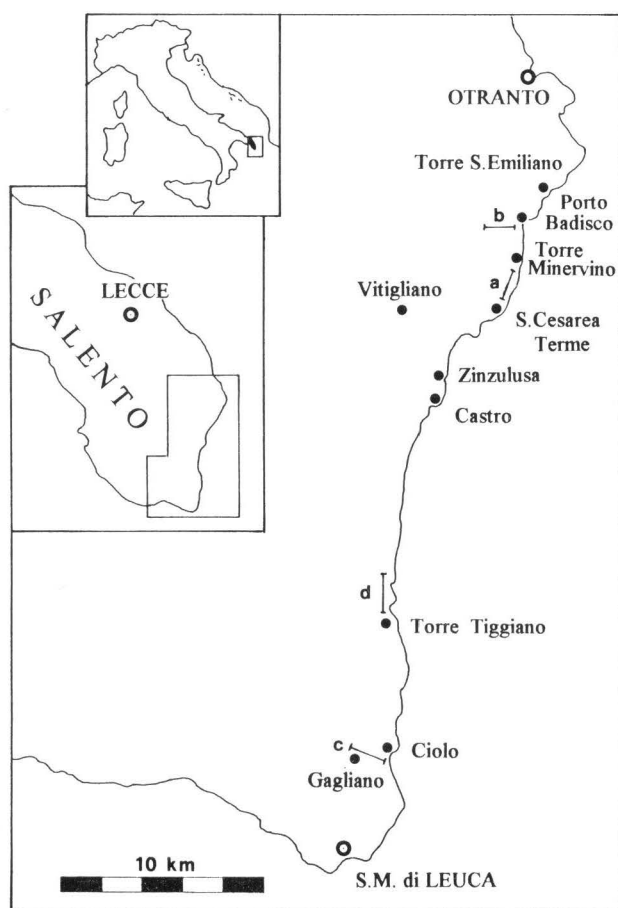
dle Eocene age, for which a formal name is not indicated, a middle Chattian sequence indicated as Castro Limestone and finally the Porto Badisco Calcarene, considered of very late Oligocene or very early Miocene age.

In the present paper a revised stratigraphy of the Upper Cretaceous to upper Oligocene deposits cropping out along the coast of southeastern Salento is proposed. Six distinct stratigraphic units are recognized: «Santa Cesarea Limestone» (late Campanian), «Ciolo Limestone» (late Maastrichtian), «Torre Tiggiano Limestone» (Middle Eocene), «Torre Specchialaguardia Limestone» (Priabonian), Castro Limestone (*sensu* Bosellini F.R. & Russo, 1992) (early Chattian), Porto Badisco Calcarene (late Chattian). The 4 Paleogene units are recognized as UBSUs (Unconformity-Bounded Stratigraphic Units; NACSN, 1983; ISSC, 1987) on the basis of the stratigraphic relationships observed in the study area. The hypothesis that also the «Ciolo Limestone» represents a UBSU is put forward on the basis of several arguments deduced from the stratigraphy of the Upper Cretaceous deposits of the Apulian Platform.

UPPER CRETACEOUS

In the geological literature on southeastern Salento as well as in the geological maps at 1:100000 scale all the Upper Cretaceous deposits are grouped in a single stratigraphic unit, the Melissano Limestone. The age indicated by Martinis (1967) for this formation is Turonian-Senonian. Later some small outcrops in the area of Poggiardo and along the coast north of S. Cesarea Terme, attributed to this formation, were dated as early Maastrichtian (late Campanian?) based on benthic foraminifers (De Castro, 1990), as late Campanian-early Maastrichtian based on rudist assemblages (Cestari & Sirna, 1989) and as late Campanian based on ammonoids (Giudici & Pallini, 1994). The type section of the Melissano Limestone has been recently reinvestigated by Reina & Luperto Sinni (1993a) who indicated a Campanian age based on the presence of *Murciella cuvillieri*.

In the present paper we recognize two distinct stratigraphic units in the Upper Cretaceous of southeastern Salento: the «Santa Cesarea Limestone» and the «Ciolo Limestone». Both these units are clearly distinguishable from the typical deposits of the Melissano Limestone, outcropping in the type section of Melissano and along the coastal road west of S. Maria di Leuca and represented by well



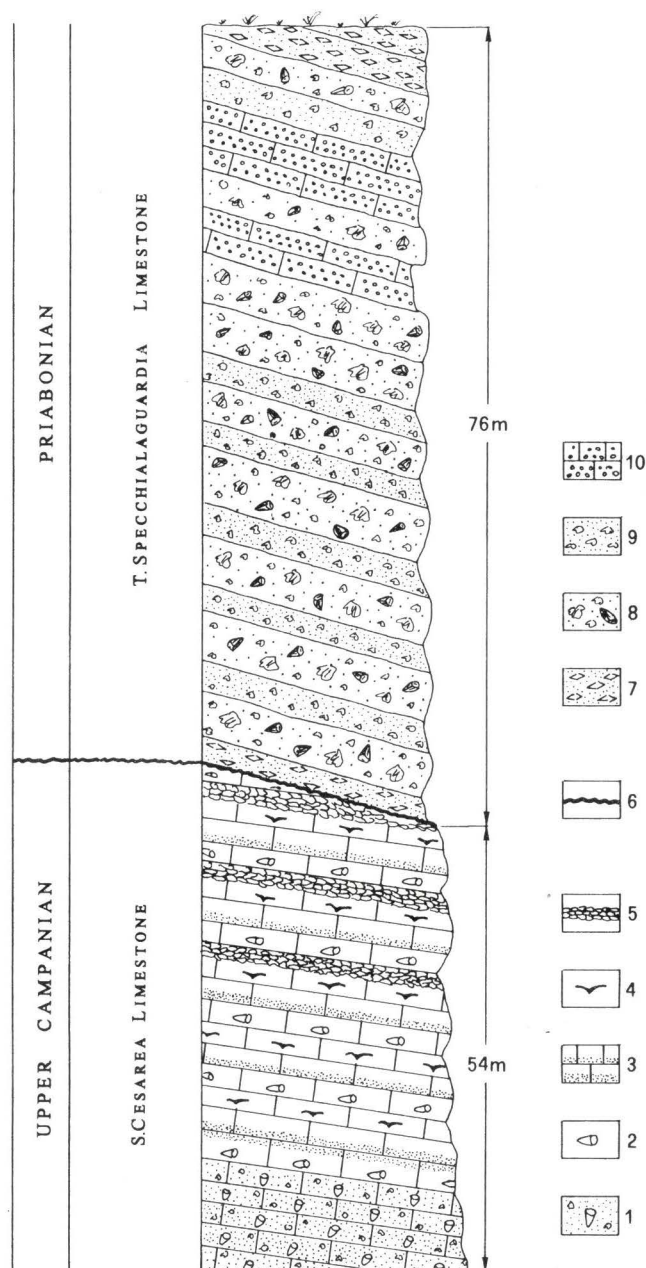
Text-fig. 1 - Geographical setting of the study area with location of stratigraphic sections. a: S.Cesarea Terme; b: Porto Badisco cove; c: Ciolo inlet; d: Torre Tiggiano.

bedded calcareous and dolomitic mudstones of inner platform environment.

«SANTA CESAREA LIMESTONE»
(UPPER CAMPANIAN)

This unit crops out widely along the coast between S.Cesarea Terme and Porto Badisco; smaller outcrops have been observed in some quarries in the zone of Poggiardo. The maximum thickness measured in the roadcut north of S.Cesarea Terme is about 54m; at Porto Badisco Upper Cretaceous limestones do not exceed 10m in thickness.

In the section north of S. Cesarea (text-fig.2) this unit is dominated at the base by massive bioclastic grainstones and rudstones with abundant rudist and echinoderm debris, rare fragments of coral colonies and micritic intraclasts. Moving upwards



Text-fig. 2 - Stratigraphic section measured along the road SS 173 north of S.Cesarea Terme. 1 - bioclastic grainstone/rudstone with coarse rudist debris; 2 - rudstone/floatstone with rudist whole shells and fragments; 3 - foraminiferal packstone/wackestone; 4 - laminated mudstone with birdseyes and mud-cracks; 5 - loferitic breccias; 6 - unconformity; 7 - larger foraminiferal grainstone with discocyclinids and nummulitids; 8 - rudstone/floatstone with coarse coral debris; 9 - coarse grainstone/packstone with benthic foraminifers and red algae; 10 - wackestone with globigerinids and red algae.

in the sequence these coarse bioclastic lithotypes become rarer and are substituted by cm-thick levels, often in lenses, consisting of rudstones and floatstones very rich in rudistid shells and fragments. These levels are separated by thick beds of mud-supported limestones. The different lithotypes are often organized in meter-scale cycles with at the base the rudist floatstones and rudstones followed by foraminiferal packstones and wackestones, bioturbated mudstones and laminated mudstones with birdseyes and mudcracks. Sometimes the cycles are capped by loferitic breccias with large lithoclasts of laminated mudstones in a muddy matrix.

In the area of Porto Badisco (text-fig.5) this unit is represented by spectacular monospecific assemblages of radiolitids in life position followed by mudstones and wackestones with benthic foraminifers and rudist debris.

The fossil association of the «Santa Cesarea Limestone» is dominated by rudists and benthic foraminifers. The rudist assemblages of the area north of S.Cesarea Terme have been described by Cestari & Sirna (1989), whereas those of the quarries in the area of Poggiardo have been investigated by several workers (Tavani, 1958; Campobasso & Morolla, 1975; Sladic-Trifunovic & Campobasso, 1980; Sladic-Trifunovic, 1989; Cestari & Sirna, 1989; Laviano & Sirna, 1993). They have been dated as Maastrichtian by Sladic-Trifunovic & Campobasso (1980), and late Campanian to early Maastrichtian by Cestari & Sirna (1989). These rudist assemblages have been identified by Sladic-Trifunovic (1989) as the so called «*Pyronaea*-

Pseudopolyconites fauna», typical of the upper Senonian of the Apulian plate. The chronostratigraphic value of this fauna has been widely debated in the literature (see Sladic-Trifunovic, 1989 and Gusic & Jelaska, 1990). Summing up the main elements of the controversy Sladic-Trifunovic (1989) attributes this fauna to the Maastrichtian, on the basis of considerations on the phylogenetic development in the genus *Pyronaea*, whereas Gusic & Jelaska (1990) extend to the upper Campanian the stratigraphic range of some species previously believed to be confined to the Maastrichtian (i.e. *Pyronaea milovanovici*, *Joufia reticulata*, *Colveraia variabilis* and *Vaccinites ultimus*). According to the latter it is impossible to differentiate the upper Campanian from the lower Maastrichtian on the basis of rudist assemblages whereas a greater stratigraphic detail may be attained on the basis of benthic foraminifers and especially orbitoids and siderolitids.

Among the benthic foraminifers occurring in the «Santa Cesarea Limestone» the most common taxa are *Raadshoovenia salentina* (pl.1, fig.3), *Murciella cuvillieri* (pl.1, fig.4), *Accordiella conica* (pl.1, fig.2), *Moncharmontia apenninica* (pl.1, fig.1), *Dicyclina schlumbergeri*, *Pseudocyclammina* sp. (pl.1, fig.5), *Cuneolina* sp. and *Rotalia* sp., in association with miliolids, textulariids and rare pfenderinids.

The most significant species from a chronostratigraphic point of view is *Raadshoovenia salentina*. The problem of the stratigraphic value of this species has been lengthily discussed by De Castro (1988, 1990). Its occurrence in the area of Poggiardo

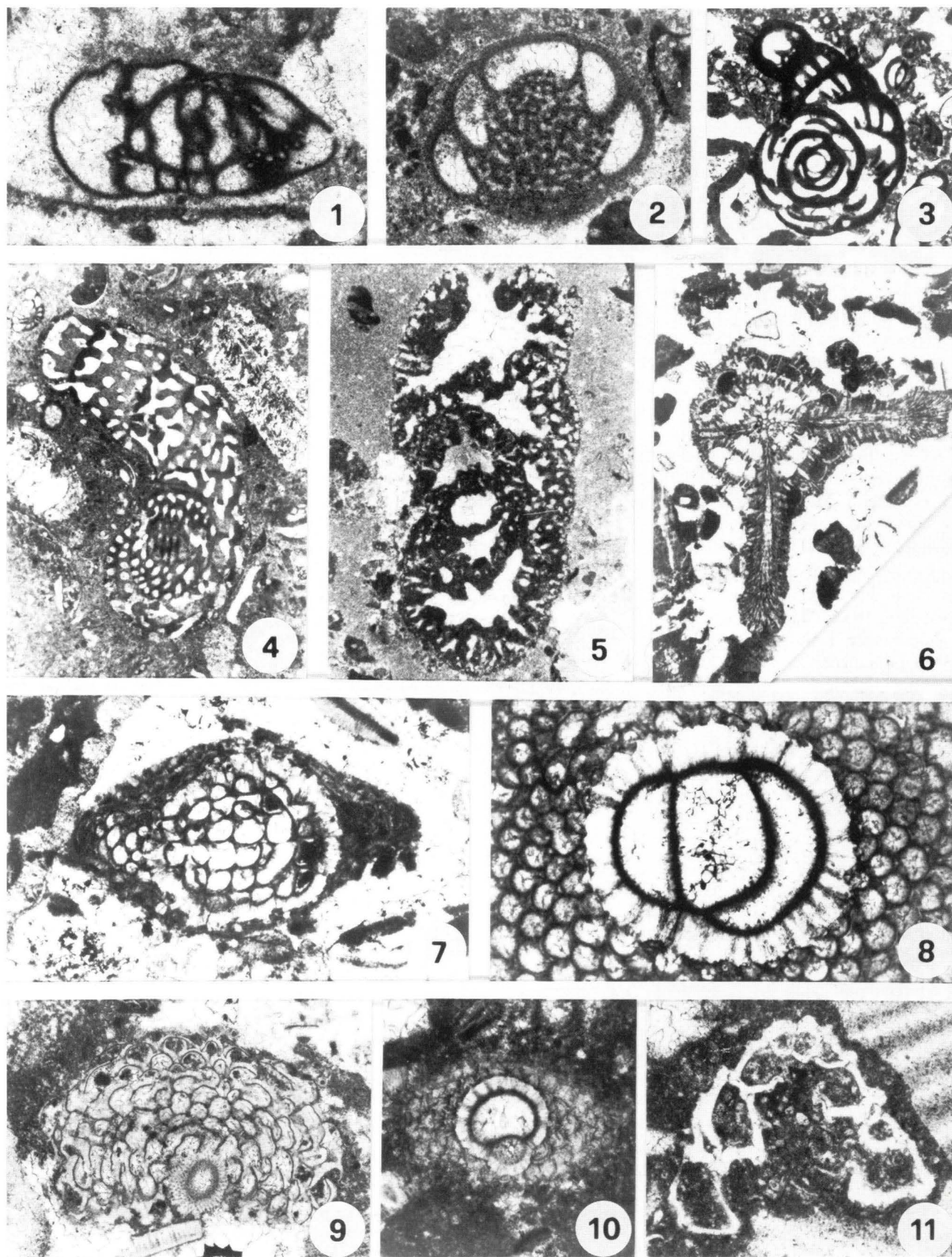
EXPLANATION OF PLATE 1

Figs. 1-5: Foraminifers of the «Santa Cesarea Limestone», upper Campanian.

- 1 - *Moncharmontia apenninica* DE CASTRO, tangential section. Quarry NW of Vitigliano; thin section A.8158.1, 60x.
- 2 - *Accordiella conica* FARINACCI, longitudinal section. Roadcut north of S.Cesarea Terme; thin section A.8300.1, 60x.
- 3 - *Raadshoovenia salentina* (PAPETTI & TEDESCHI), A form, transversal section. Quarry NW of Vitigliano; thin section A.8158, 30x.
- 4 - *Murciella cuvillieri* FOURCADE, oblique section. Surroundings of Vitigliano; thin section A.8157, 30x.
- 5 - *Pseudocyclammina* sp., oblique section. Roadcut north of S.Cesarea Terme; thin section A.8300.1, 30x.

Figs. 6-11: Foraminifers of the «Ciolo Limestone», upper Maastrichtian.

- 6 - *Siderolites calcitrapoides* LAMARCK, equatorial section. Southern side of Ciolo inlet; thin section A.8407.11, 15x.
- 7 - *Orbitoides gensacica* (LEYMERIE), A form; axial section through the nepiont of a juvenile specimen. Quarry between Castro Marina and S.Cesarea Terme; thin section A.8338.13, 30x.
- 8 - *Orbitoides apiculata* SCHLUMBERGER, A form; detail of the nepiont in equatorial section. Southern side of Ciolo inlet; thin section C.1.8, 60x.
- 9 - *Omphalocyclus macroporus* (LAMARCK), A form; subequatorial (slightly tangential) section. Southern side of Ciolo inlet; thin section A.8407.52, 30x.
- 10 - *Lepidorbitoides socialis* (LEYMERIE), A form; equatorial section through the nepiont of a juvenile specimen. Southern side of Ciolo inlet; thin section A.8407.55, 60x.
- 11 - *Contusotruncana contusa* (CUSHMAN), axial section. Southern side of Ciolo inlet; thin section A.8696a.6, 60x.



together with *Pseudosiderolites vidali* and the evolutionary stage showed by the specimens of *Orbitoides* (indicated as *Orbitoides media?* by De Castro, 1990) points to a late Campanian age. Therefore, taking into account the chronostratigraphic value of these taxa (Baumfalk, 1986; Bilotte, 1984; Drooger & De Klerk, 1985; Neumann, 1985, 1986, 1993) and following the indications of Gusic & Jelaska (1990) on the age of the «*Pironaea-Pseudopolyconites* fauna», the «Santa Cesarea Limestone» is assigned to the late Campanian.

The lower boundary of this unit has been never observed in the study area whereas its upper boundary is always marked by an angular unconformity associated with a more or less extended stratigraphic gap. Along the coast between S.Cesarea Terme and Torre Minervino Priabonian limestones (see below) lies unconformably on the Upper Cretaceous limestones. In the Porto Badisco cove the «Santa Cesarea Limestone» is truncated by a sharp angular unconformity underlying the Castro Limestone and the Porto Badisco Calcarene.

«CIOLO LIMESTONE» (UPPER MAASTRICHTIAN)

This unit crops out in the Ciolo inlet (Gagliano del Capo) and along the surrounding coast. Other outcrops of more limited thickness and extension can be found more to the north, close to Torre Tiggiano, along the coast between Castro Marina and S.Cesarea Terme at Porto Romanelli, and in some quarries in the surroundings of Vitigliano. The maximum thickness, measured along the southern cliff of the Ciolo inlet, is about 50m. In this section (text-fig.3), already investigated by Guerricchio & Zezza (1972), Bosellini F.R. & Russo (1992) and Bosellini A. (1993), the «Ciolo Limestone» is made at the base by coarse bioclastic grainstones with larger foraminifers and rudist debris alternating with floatstones-rudstones with coarse rudist debris and subordinate coral debris in a matrix of fine bioclastic packstones-grainstones. In the upper part of the sequence algal-foraminiferal wackestones with rudist debris alternate with coarse bioclastic grainstones with larger foraminifers and rudist debris.

The fossil content of this unit is dominated by rudists and larger foraminifers. The rudists have received little attention compared to those occurring in the «Santa Cesarea Limestone»; the only papers dealing specifically with rudists from the Ciolo inlet are those by Dainelli (1901, 1905). The presence in the «Ciolo Limestone» of *Hippurites cornucopiae* (Sirna G., personal communication, 1993) appears

interesting since this species had been never reported from the Apulian platform.

Among the larger foraminifers the most diagnostic taxa are *Orbitoides apiculata* (pl.1, fig.8), *Orbitoides gensacica* (pl.1, fig.7), *Lepidorbitoides socialis* (pl.1, fig. 10), *Omphalocyclus macroporus* (pl.1, fig.9) and *Siderolites calcitrapoides* (pl.1, fig. 6) in association with *Planorbulina cretae*, *Rotalia* sp. and *Acervulina* sp. This assemblage is indicative of a Maastrichtian age (*Orbitoides apiculata* Zone of Van Hinte, 1976) and most probably of a late Maastrichtian (*Lepidorbitoides socialis* Zone of Van Gorsel, 1978). Rare specimens of globotruncanids and heterohelics, observed in the algal-foraminiferal wackestones from the upper part of the sequence at the Ciolo inlet, allow to confirm this age assignment. In particular, the presence of *Contusotruncana contusa* (pl.1, fig.11) indicates an age not older than the base of the *Gansserina gansseri* Zone of Caron (1985).

The lower boundary of «Ciolo Limestone» has been never observed in the study area; the upper boundary is always represented by an unconformity associated with a stratigraphic gap embracing at least the whole Paleocene and the Lower Eocene. In the section of the Ciolo inlet the upper Maastrichtian limestones are truncated by the upper Oligocene Castro Limestone; these two units are separated by an evident angular unconformity (see pl.31, fig.1 in Bosellini & Russo, 1992). Immediately north of the Ciolo inlet a thin level of Middle Eocene limestones occur in between these two units (see Guerricchio & Zezza, 1972 and Bosellini A., 1993). In the roadcut north of Torre Tiggiano (see text-fig.4) an unconformity marked by a clear erosional surface separates the «Ciolo Limestone» from Middle Eocene limestones. Along the coast between Castro Marina and S.Cesarea a clear angular unconformity is visible between the upper Maastrichtian limestones and the Castro Limestone (see also pl.34, fig.1 in Bosellini F.R. & Russo, 1992). In the quarries in the surroundings of Vitigliano the «Ciolo Limestone» is usually capped by the Andrano Calcarene (Upper Miocene) but sometimes a thin level of upper Oligocene limestones occurs in between these two units.

PALEOGENE

The Paleogene deposits cropping out along the southeastern coast of the Salento Peninsula have been referred in the geological maps to two distinct lithostratigraphic units: the Castro Limestone (Martinis, 1967) and the Porto Badisco Calcarene

(Alvino 1964). A more articulated stratigraphic reconstruction has been recently proposed by Bosellini F.R. & Russo (1992) who observed the presence of a Middle Eocene depositional sequence, locally interposed between the Upper Cretaceous limestones and the Upper Oligocene reef complex. In this paper it is proposed a still more articulated stratigraphy recognizing in the Paleogene of southeastern Salento at least 4 distinct UBSUs. The name of «Torre Tiggiano Limestone» is here informally proposed for the Middle Eocene unit; the name of «Torre Specchialaguardia Limestone» is introduced for a Priabonian UBSU not recognized or included in the Castro Limestone by previous authors; the name of Castro Limestone is used (in agreement with Bosellini F.R. & Russo, 1992), in a more restricted sense than that introduced by Martinis (1967), and indicates the Upper Oligocene reef complex; the name of Porto Badisco Calcarene is kept for the upper Chattian UBSU overlying the Castro Limestone.

«TORRE TIGGIANO LIMESTONE»
(MIDDLE EOCENE)

This unit is represented by thin and small outcrops of Middle Eocene limestones. The maximum thickness, about 7.5m, has been measured in the roadcut north of Torre Tiggiano (text-fig.4). Other small outcrops referable to this unit have been observed about two km north of Novaglie, north of the Ciolo inlet at Le Fogge (see also Guerricchio & Zezza, 1972; Bosellini F.R. & Russo, 1992; Bosellini A., 1993). More to the north Middle Eocene limestones are present in a roadcut west of S.Cesarea Terme on the road to Vitigliano (see pl.31, fig.3 in Bosellini F.R. & Russo, 1992 and Bosellini F.R. et al., 1993) and along the coast between S.Cesarea Terme and Torre Minervino.

In the section of Torre Tiggiano (text-fig.4) this unit is represented by about 70 cm of packstones-wackestones with alveolinids, peneroplids and dasycladaleans, followed by about 5.50m of laminated bioclastic grainstones with alveolinids and nummulitids (pl.2, fig.1). In the upper part of the sequence, about 1m below the angular unconformity separating this unit from the following one, it is present a sharp erosional surface followed by a level (about 10–20cm thick) of coarse bioclastic debris consisting of pelecypod and gastropod shells and fragments of coral colonies. The sequence ends with bioclastic packstones and grainstones with alveolinids and nummulitids.

Among the foraminifers the most significant

taxa occurring in this section are *Alveolina callosa*, *Alveolina tenuis*, *Assilina spira abrardi* (pl.2, fig.2), *Orbitolites* sp. (pl.2, fig.3), *Nummulites* spp. in association with *Acervulina linearis*, *Asterigerina rotula*, *Valvulina* sp., *Sphaerogypsina* sp., *Gyroidinella* sp., miliolids, peneroplids and rare discocyclinids. The uppermost level is characterized by a different foraminiferal assemblage with *Nummulites* sp., *Fabiania cassis* (pl.2, fig.4), *Alveolina* ex gr. *cosinensis* and discocyclinids. The presence of *Alveolina callosa* and *Alveolina tenuis* points to the early Lutetian (*Alveolina stipes* Zone of Hottinger, 1960); this age assignment is confirmed by the presence of *Assilina spira abrardi* (Schaub, 1981). A different age might be assigned to the uppermost level characterized by a different foraminiferal assemblage. It is worth recalling that a very late Middle Eocene age has been indicated by Bosellini F.R. & Russo (1992) for the limestones with alveolinids and nummulitids cropping out north of the Ciolo inlet whereas the small outcrop in the roadcut west of S.Cesarea may be assigned to the *Alveolina elongata* Zone of Hottinger (1960), corresponding to the Bartonian *sensu* Cavelier & Pomerol (1986), for the presence of *Alveolina fusiformis*. In conclusion the limestones with alveolinids and nummulitids, here indicated as «Torre Tiggiano Limestone», contain foraminiferal assemblages indicative of different Middle Eocene time intervals from the early Middle Eocene of the Torre Tiggiano section to the late Middle Eocene of Ciolo and S.Cesarea. Since a continuous succession embracing the whole Middle Eocene has never been observed in the studied area we can not rule out the possibility that in southern Salento the Middle Eocene is represented by two units separated by a small hiatus.

Both the lower and the upper boundary of this unit are represented by distinct unconformities. The lower boundary is always characterized by a clear erosional surface usually without a distinct angular unconformity. On the contrary a clear angular unconformity is always associated to the upper boundary. At Torre Tiggiano this unit is overlain by the Priabonian coral limestones («Torre Specchialaguardia Limestone»; see below) whereas near the Ciolo inlet and at S.Cesarea Terme it is overlain by the upper Oligocene Castro Limestone.

«TORRE SPECCHIALAGUARDIA LIMESTONE»
(PRIABONIAN)

This unit crops out in the roadcut north of Torre Tiggiano and along the coast between S.Ce-

sarea Terme and Porto Badisco. In the roadcut north of S.Cesarea (text-fig.2) the Priabonian sequence is about 76 m thick and is represented by: a) about 3m of larger foraminiferal grainstones; b) about 50 m of bioclastic limestones very rich in corals and red algae. The most frequent lithotypes are rudstones and floatstones with coarse coral debris in a matrix of algal-foraminiferal packstones-wackestones, alternating with coarse grainstones and packstones with benthic foraminifers and red algae and fine coral debris; c) the third interval, about 23 m thick, is characterized by wackestones with globigerinids and red algae alternating with grainstones and very rare rudstones with coral debris. At the top of the sequence there is a level, about 3 m thick, of coarse grainstones very rich in larger foraminifers.

At Torre Tiggiano (text-fig. 4) this unit is represented by about 14m of coral and red algae limestones mainly consisting of floatstones and rudstones with coarse coral debris and for-algal nodules in a matrix of packstones-wackestones with benthic foraminifers and red algae.

Foraminiferal assemblages of the «Torre Specchialaguardia Limestone» are represented by discocyclinids (*Asterocyclina priabonensis* pl.2, fig.7), small nummulitids, *Fabiania cassis* (pl.2, fig.6), *Halcyardia* sp. (pl.3, fig.4), and *Asterigerina rotula* at the base of the sequence sampled in the roadcut north of S.Cesarea; in the foraminiferal grainstones at the top of this sequence discocyclinids are associated with *Heterostegina gracilis* (pl. 3, fig.2), *Operculina* ex gr. *gomezi* (pl.3, fig.3) and *Spiroclypeus* sp. Both in the section of Torre Tiggiano and in the interval b) of the section north of S.Cesarea larger foraminifers are rather rare and the most common taxa are *Chapmanina gassinensis* (pl.2, fig.5), *Sphaerogypsina globulus*, *Planorbolina bronniman-*

ni, *Gyroidinella* ? *magna*, *Asterigerina rotula*, miliolids and peneroplids. In the for-algal nodules encrusting foraminifers are represented by victoriellids and acervulinids (*Acervulina linearis*).

On the basis of larger foraminiferal assemblages this unit can be dated as Priabonian (late Eocene); in particular *Asterocyclina priabonensis* is typical of middle and upper Priabonian (Less, 1987), whereas *Heterostegina gracilis* should indicate the upper Priabonian (Herb, 1978).

The lower boundary of the «Torre Specchialaguardia Limestone» may be observed at Torre Tiggiano, where an angular unconformity, associated to a clear erosional surface, separates this unit from the underlying Middle Eocene limestones, and north of S.Cesarea where an angular unconformity separates the Priabonian limestones from the underlying «Santa Cesarea Limestone». The upper boundary can be observed at Torre Tiggiano, where a stratigraphic gap separates the upper Oligocene Castro Limestone from the underlying Priabonian limestones, and south of the Porto Badisco cove, where an angular unconformity separates the «Torre Specchialaguardia Limestone» from the Castro Limestone and the Porto Badisco Calcarene.

CASTRO LIMESTONE (LOWER CHATTIAN)

This unit crops out widely along the coast between the Ciolo inlet and S.Cesarea Terme. More to the north it is present between Torre Minervino and the Porto Badisco cove. Some outcrops, a few meters thick, may be found more inward, near Vitigliano. The thickness of this unit ranges from 12m in the Ciolo section (text-fig.3) and at Torre Tiggiano (text-fig.4) to no more than 9m at Porto Badisco (text-fig.5); a much thicker section may be

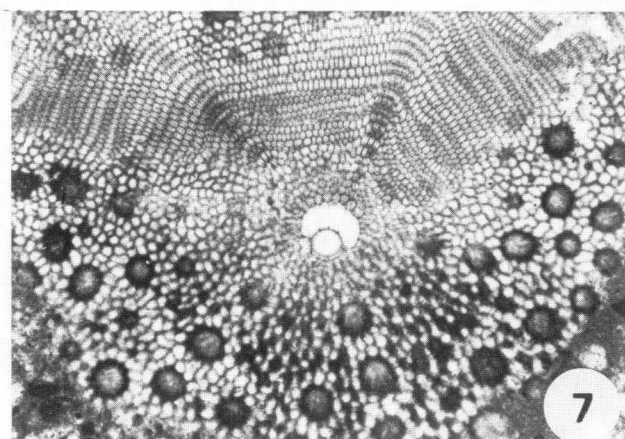
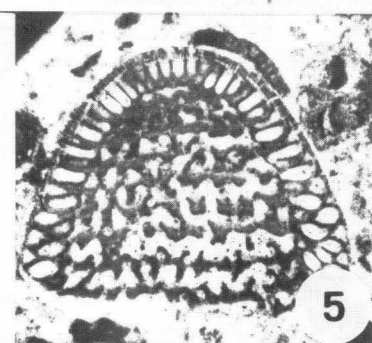
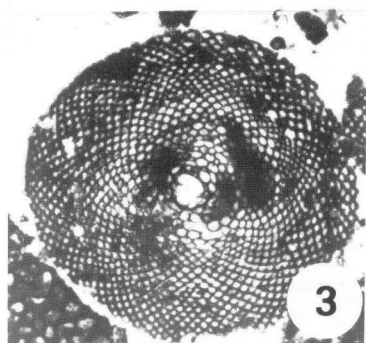
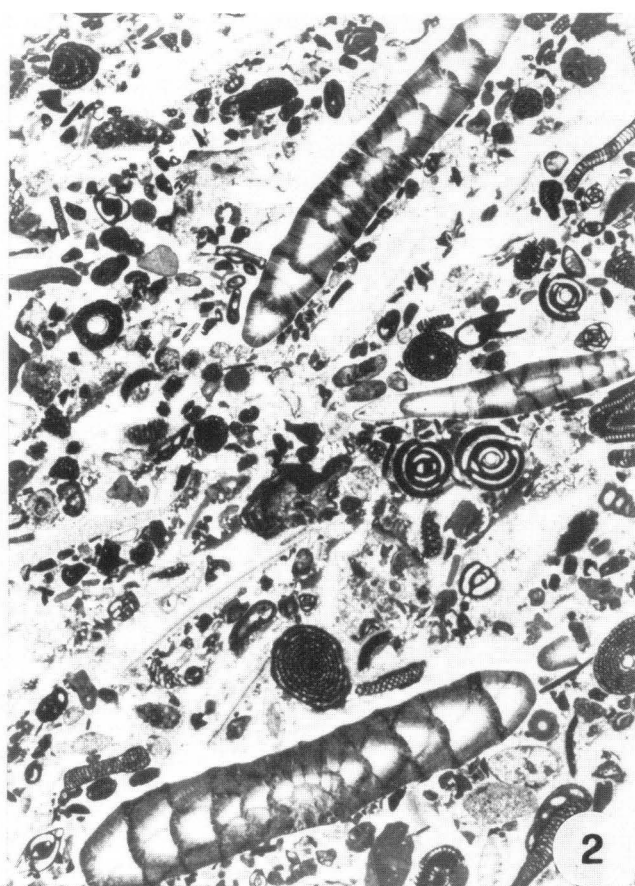
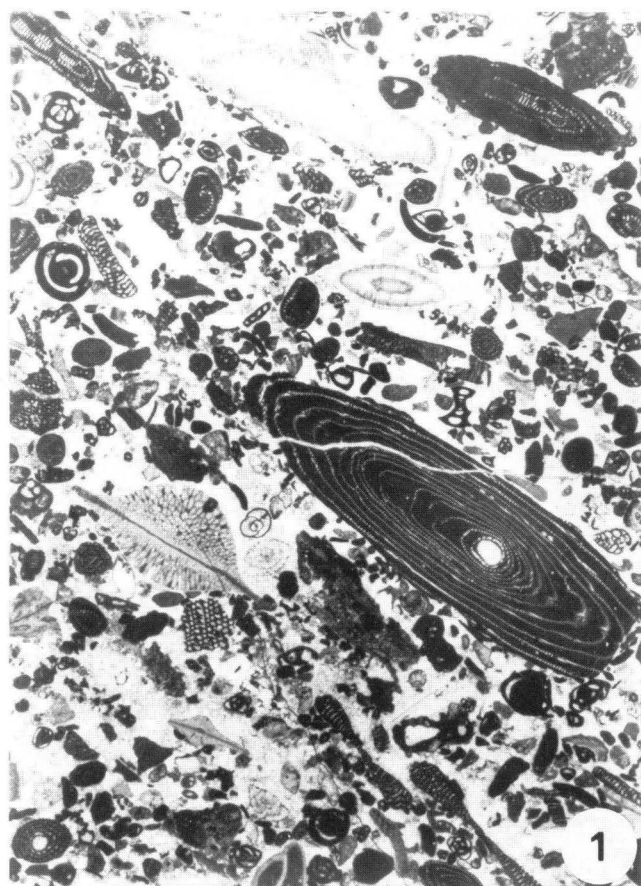
EXPLANATION OF PLATE 2

Figs. 1-4: Foraminifers of the «Torre Tiggiano Limestone», Middle Eocene. Roadcut north of Torre Tiggiano.

- 1 - Foraminiferal grainstone with alveolinids, nummulitids, discocyclinids, *Orbitolites* sp. and miliolids. Thin section A.8455.10, 7.5x.
- 2 - foraminiferal grainstone with *assilina spira abrardi* SCHAUB, *Orbitolites* sp., *Nummulites* and miliolids. Thin section A.8455.12, 7.5x.
- 3 - *Orbitolites* sp., A form; equatorial section. Thin section A.8453a.3, 15x.
- 4 - *Fabiania cassis* (OPPENHEIM), slightly oblique longitudinal section. Thin section A.8461.1, 15x.

Figs. 5-7: Foraminifers of the «Torre Specchialaguardia Limestone», Priabonian.

- 5 - *Chapmanina gassinensis* SILVESTRI, tangential section. Roadcut north of Torre Tiggiano; thin section A.8465.7, 30x.
- 6 - *Fabiania cassis* (OPPENHEIM), slightly oblique longitudinal section. Roadcut north of S.Cesarea Terme; thin section A.8560.2, 25x.
- 7 - *Asterocyclina priabonensis* GÜMBEL, A form; transversal oblique section through the nepiont. Roadcut north of S.Cesarea Terme; thin section A.8560.2, 30x.



observed along the southern cliff of the Zinzulusa cove (at least 80m).

Lithology, facies distribution and coral assemblages of the Castro Limestone have been recently described by Bosellini F.R. & Russo (1992): this unit represents a fringing reef complex showing a well preserved zonation from 'back reef' through reef flat and reef front to fore reef.

Foraminiferal assemblages of the Castro Limestone are dominated by lepidocyclinids and small rotraliids. The most frequent species are *Lepidocyclina* (*Eulepidina*) *dilatata*, *Lepidocyclina* (*Nephrolepidina*) *praemarginata* (pl.3, fig.6), *Neorotalia viennoti*, *Operculina complanata*, *Spir-o-clypeus* sp., *Heterostegina* sp. and *Austrotrillina* sp. (pl.3, fig.5). The presence of globigerinids has been reported by Bosellini F.R. & Russo (1992) in the distal fore reef facies from Zinzulusa and by Bosellini A. (1993) in the Ciolo inlet.

On the basis of the larger foraminiferal association, and in particular on the evolutionary stage shown by the populations of *Nephrolepidina*, the Castro Limestone can be attributed to the *Cyclo-clypeus* Zone of Drooger & Laagland (1986) that would correspond to the lower Chattian in the more recent scheme of Laagland (1990).

The Castro Limestone as here accepted is a lower Chattian UBSU; its lower boundary is almost always associated to a well marked angular unconformity: in the Ciolo inlet the subhorizontal beds of the Castro Limestone truncates the tilted upper Maastrichtian «Ciolo Limestone»; at Torre Tiggiano the lower unconformity is associated to a narrower stratigraphic gap separating the Castro Limestone from the «Torre Specchialaguardia Limestone»; between Castro and S.Cesarea this unit overlies unconformably the Maastrichtian

limestones; in the roadcut west of S.Cesarea a clear angular unconformity separates Middle Eocene limestones, referred to the «Torre Tiggiano Limestone», from the Castro Limestone; at Porto Badisco an angular unconformity truncates the underlying upper Campanian «Santa Cesarea Limestone».

At Porto Badisco and in the zone of the Ciolo inlet the upper boundary of the Castro Limestone is a disconformity associated to a sharp erosional surface, followed by a rhodolitic level that represents the base of the Porto Badisco Calcarene. On the road Vignacastri-S.Cesarea Terme the upper boundary of this unit is marked by a sharp erosional surface showing traces of bioerosion by boring organisms; in this outcrop the rhodolitic level, that usually represents the base of the Porto Badisco Calcarene, is missing. Where the Porto Badisco Calcarene is not preserved at all the upper boundary of the Castro Limestone is marked by an angular unconformity associated with a wider stratigraphic gap separating the Upper Oligocene deposits from the Upper Miocene Andrano Calcarene (Torre Tiggiano) or from the Pleistocene Salento Calcarene (Castro Marina, Porto Miggiano).

PORTO BADISCO CALCARENITE (UPPER CHATTIAN)

This unit was once believed to be present only in the area of Porto Badisco; actually, as already pointed out by Bosellini F.R. and Russo (1992), it represents a distinct UBSU cropping out as far south as the Ciolo inlet. Maximum thickness may be estimated to about 80m in the zone of Porto Badisco considering that the base of this unit is at about sea level in the Porto Badisco cove and the

EXPLANATION OF PLATE 3

Figs. 1-4: Foraminifers of the «Torre Specchialaguardia Limestone», Priabonian. Roadcut north of S.Cesarea Terme.

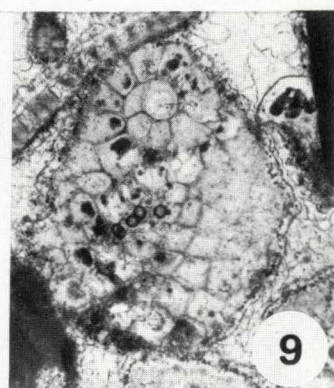
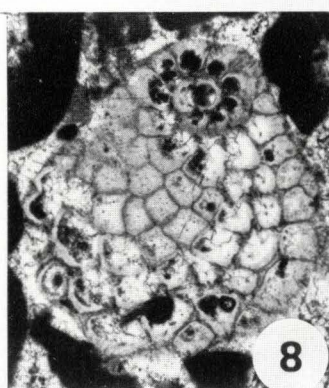
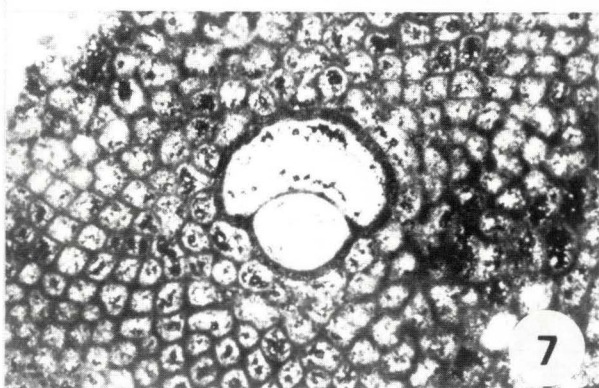
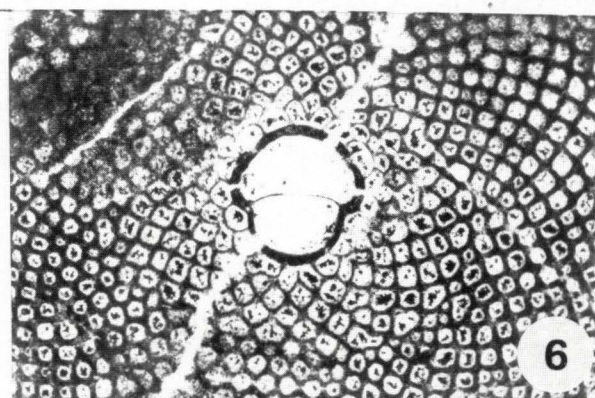
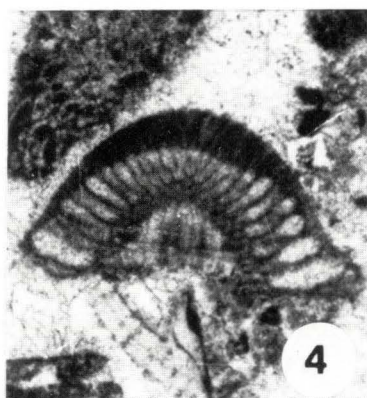
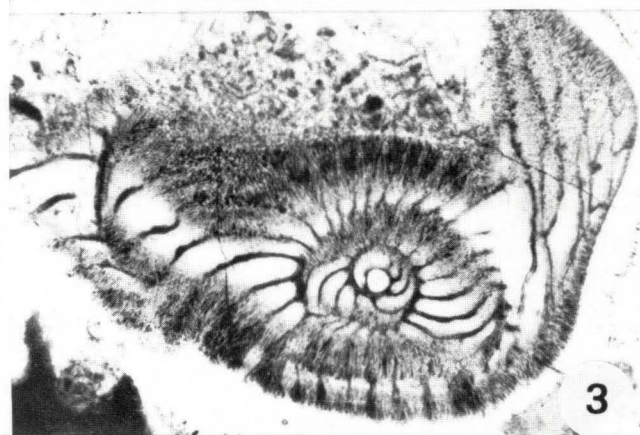
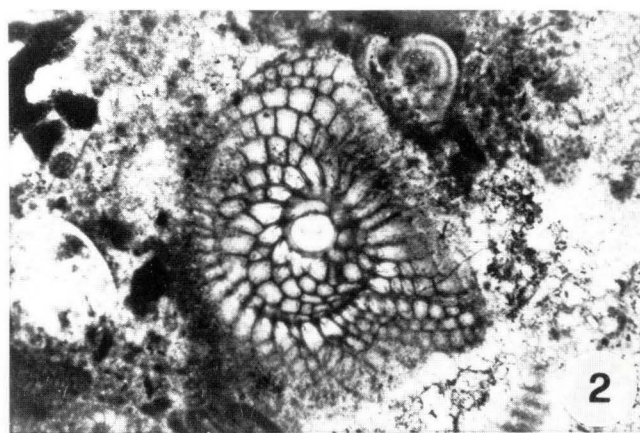
- 1 - Foraminiferal grainstone with discocyclinids, coral debris and red algae. Thin section A.8560.1, 7.5x.
- 2 - *Heterostegina gracilis* HERB, A form; fragment of a transversal section. Thin section A.8591.2, 30x.
- 3 - *Operculina* ex gr. *gomezi*, A form; oblique section. Thin section A.8591.2, 30x.
- 4 - *Halkyardia* sp., axial section. Thin section A.8560.1, 60x.

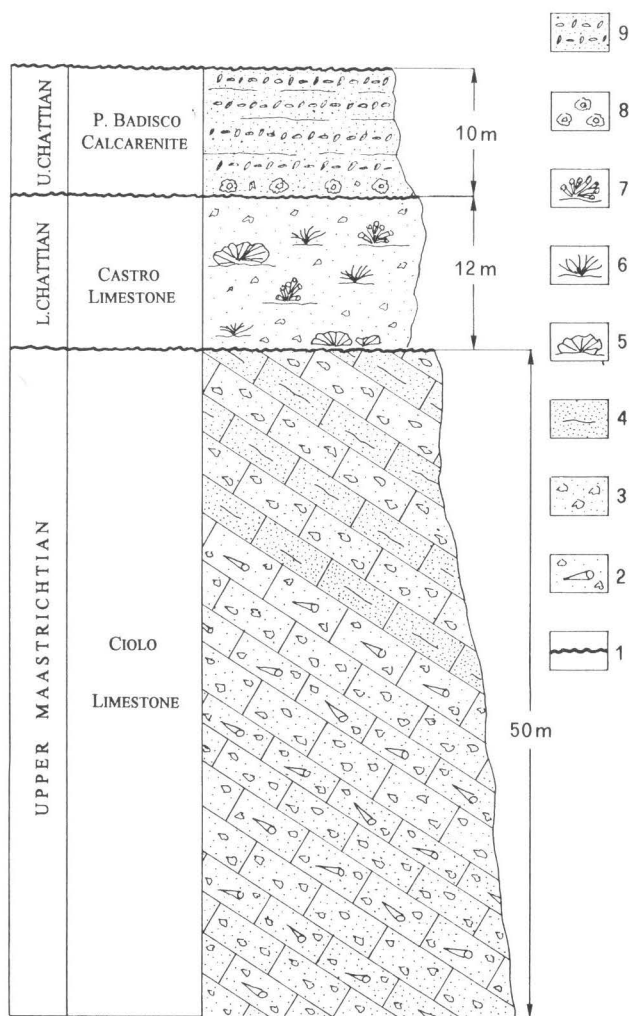
Figs. 5-6: Foraminifers of the Castro Limestone, lower Chattian.

- 5 - *Austrotrillina* sp., A form; transversal section. Northern side of Porto Badisco cove; thin section PBX, 30x.
- 6 - *Lepidocyclina* (*Nephrolepidina*) *praemarginata* LEMOINE & R.DOUVILLE', A form; equatorial section. Roadcut east of Vitigliano, on the road to Cerignano; thin section V2.20, 60x.

Figs. 7-9: Foraminifers of the Porto Badisco Calcarene, upper Chattian.

- 7 - *Lepidocyclina* (*Nephrolepidina*) *morgani* LEMOINE & R. DOUVILLE', A form; equatorial section. Porto Badisco cove; thin section PB.15.1.12, 60x.
- 8-9 - *Miogypsina* (*Miogypsinoides*) ex. interc. *complanata-formosensis*, equatorial sections. Roadcut south of Porto Badisco; thin sections A.8429.2 and A.8430.2 respectively, 30x.



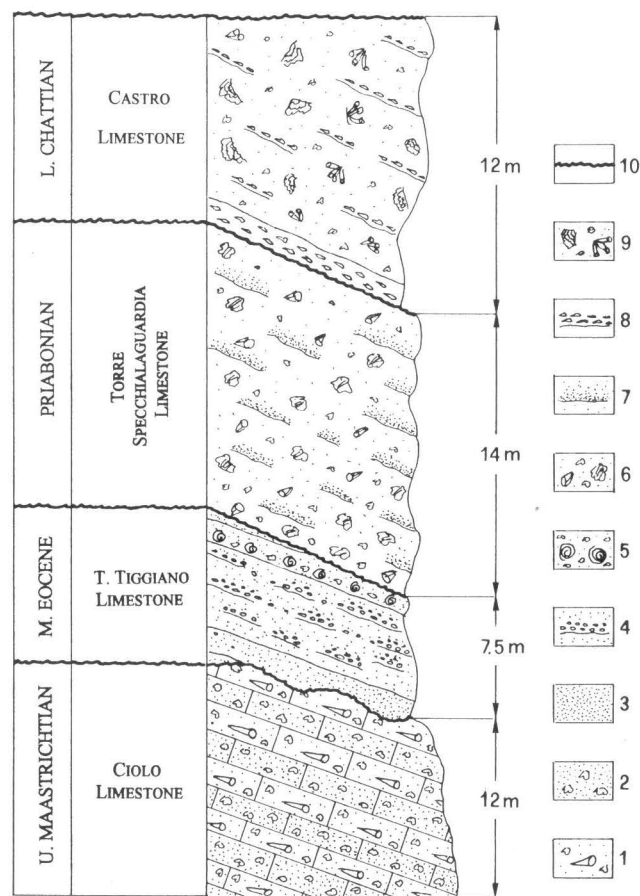


Text-fig. 3 - Stratigraphic section measured along the southern cliff of the Ciolo inlet. 1 - unconformity; 2 - floatstone/rudstone with coarse rudist debris; 3 - larger foraminiferal grainstone with orbitoids and siderolitids; 4 - algal-foraminiferal grainstone with dasycladaceans, orbitoids and rare globotruncanids; 5, 6, 7 - coral colonies in growth position; 8 - rhodolites; 9 - poorly cemented, coarse bioclastic calcarenite with larger foraminifers (mainly lepidocyclinids) and red algae.

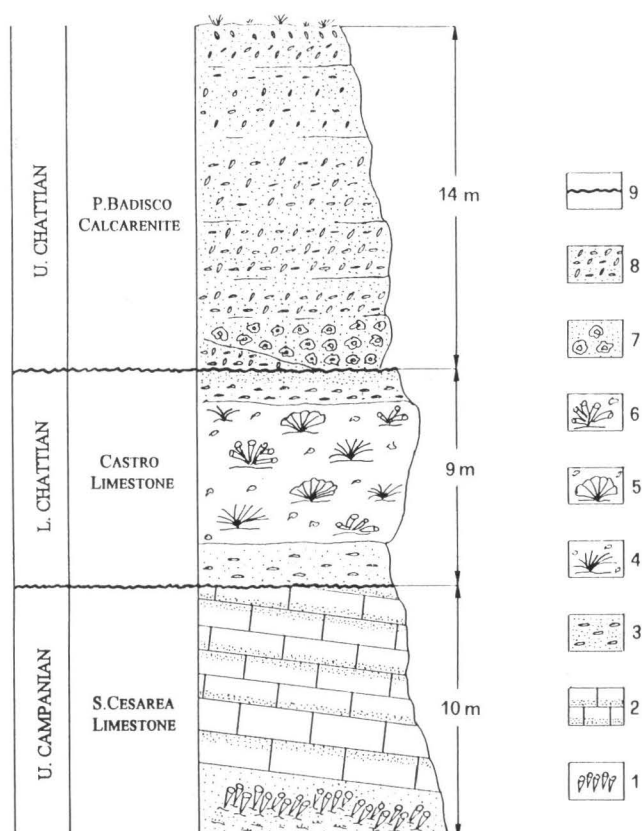
uppermost levels crop out west of Torre Minervino at about 80m above sea level; in the Ciolo inlet the thickness does not exceed 10m (text-fig.3).

At Porto Badisco (text-fig.5) this unit is characterized at the base by the presence of a lens-shaped rhodolitic body with a maximum thickness of about 1.5m. Above the rhodolites the sequence continues with poorly cemented coarse bioclastic calcarenites consisting of benthic foraminifers

(mainly lepidocyclinids and small rotaliids), red algae, echinid spines and debris, rare pelecypods and bryozoans. Moving up sequence along the road to Torre Minervino, more massive lithotypes occur consisting of well cemented grainstones with larger foraminifers and red algae. In the uppermost levels it is worth noting first the sparse occurrence of *Microcodium* auct. (= *Paronipora penicillata*; see Cherchi & Schroeder, 1988) and, finally, the presence of true *Microcodium* limestones.



Text-fig. 4 - Stratigraphic section measured along the road SS 173 north of Torre Tiggiano. 1 - floatstone/rudstone with coarse rudist debris; 2 - larger foraminiferal grainstone with orbitoids and siderolitids; 3 - packstone-wackestone with alveolinids, peneroplids and dasycladaceans; 4 - laminated bioclastic grainstone with alveolinids and nummulitids; 5 - coarse bioclastic debris (mainly pelecypod and gastropod shells and fragments of coral colonies); 6 - floatstone/rudstone with coarse coral debris and for-algal nodules; 7 - packstone/wackestone with benthic foraminifers and red algae; 8 - larger foraminiferal grainstone with lepidocyclinids; 9 - floatstone with large coral colonies not in growth position; 10 - unconformity.



Text-fig. 5 - Stratigraphic section measured along the northern side of the Porto Badisco cove. 1 - monospecific assemblages of radiolitics in life-position; 2 - mudstone/wackestone with benthic foraminifers and fine-grained rudist debris; 3 - larger foraminiferal grainstone/packstone with lepidocyclinids; 4, 5, 6 - coral colonies in growth position; 7 - rhodolites; 8 - poorly cemented coarse bioclastic calcarenite with larger foraminifers (mainly lepidocyclinids) and red algae; 9 - unconformity.

In the cut of the road to Gagliano and in the Ciolo inlet (see Bosellini F.R. & Russo, 1992 and Bosellini A., 1993) the Porto Badisco Calcarene is represented by a more continuous, thinner rhodolitic level (max 50 cm) followed by bioclastic grainstones and packstones with benthic foraminifers and red algae.

The most significant species in the foraminiferal assemblage of Porto Badisco Calcarene are *Lepidocyclina* (*Eulepidina*) *dilatata*, *Lepidocyclina* (*Nephrolepidina*) *morgani* (pl.3, fig.7), *Operculina complanata*, *Heterostegina assilinoidea*, *Neorotalia viennoti*, *Spiroclipeus* sp.. In the upper levels of this unit, sampled along the road to Torre Minervino, this assemblage occurs along with *Miogypsina* (*Miogypsinoidea*) ex. interc. *complanata-formosensis*

(pl.3, figs.8-9). For the presence of this taxon along with *Lepidocyclina* (*Nephrolepidina*) *morgani* the Porto Badisco Calcarene can be attributed to the *Miogypsinoidea* Zone of Drooger & Laagland (1986), corresponding to the upper Chattian.

The lower boundary of the Porto Badisco Calcarene at Porto Badisco and at Ciolo corresponds to an erosional surface, followed by a rhodolitic level, separating this unit from the underlying Castro Limestone. South of the Porto Badisco cove the upper Oligocene calcarenites rest with a sharp angular unconformity on the upper Campanian «Santa Cesarea Limestone». The upper boundary, observed in the Ciolo inlet, on the road to Gagliano and west of the Porto Badisco cove, corresponds to an unconformity followed by the well known middle Miocene «Aturia level».

DISCUSSION AND CONCLUSIONS.

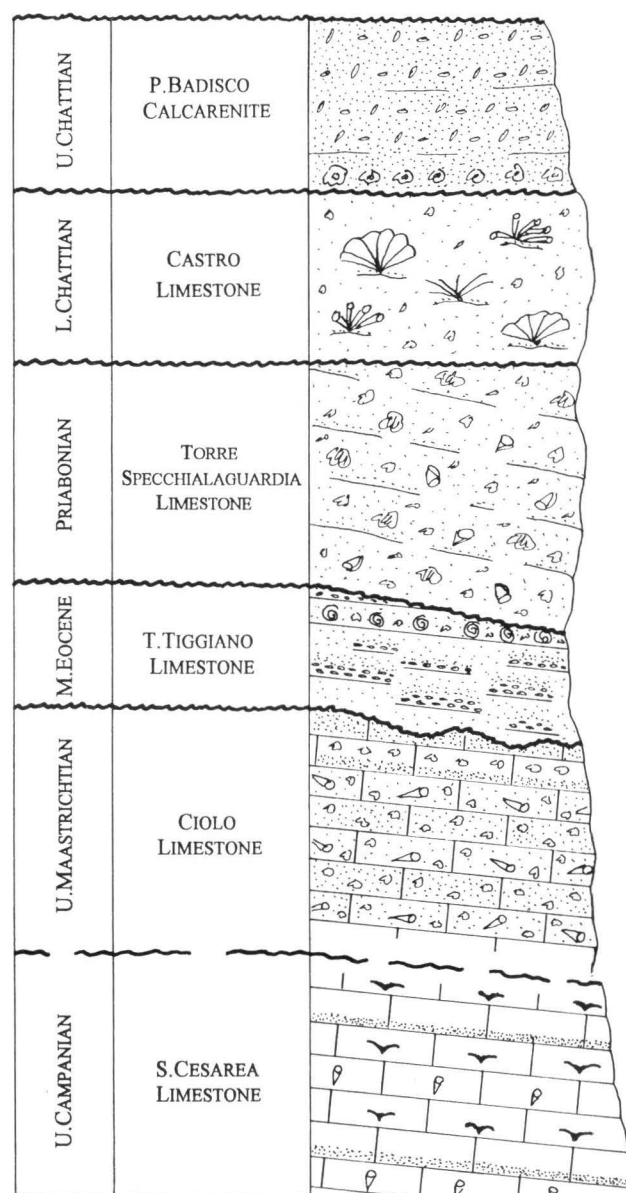
In the revised stratigraphic scheme here presented 6 distinct stratigraphic units are recognized in the Upper Cretaceous to upper Oligocene deposits of southeastern Salento. Moreover in the present paper it has been documented the presence of at least 4 UBSUs in the Paleogene of southeastern Salento: «Torre Tiggiano Limestone» (Middle Eocene), «Torre Specchialaguardia Limestone» (Priabonian), Castro Limestone (lower Chattian) and Porto Badisco Calcarene (upper Chattian). As discussed above the possibility that Middle Eocene deposits represent more than one unit can not be ruled out. Upper Paleocene microfaunas reported by previous authors (Hottinger, 1960, Martinis, 1967) have not been found in the study area but the presence of coeval deposits could have passed undetected especially if they were represented by very small and thin patchy outcrops.

As to the stratigraphic relationships between the Paleogene units it must be noted that: 1) a deeply eroded surface associated with a stratigraphic gap enclosing the whole Paleocene and the lower Eocene separates the Maastrichtian «Ciolo Limestone» from the Middle Eocene «Torre Tiggiano Limestone»; 2) an angular unconformity is always present between Upper Cretaceous-Middle Eocene deposits and younger units; 3) upper Oligocene units are clearly seen to rest with an angular unconformity on the Priabonian «Torre Specchialaguardia Limestone» south of Porto Badisco and at Torre S.Emiliano; 4) a sharp erosional surface is always present between the Castro Limestone and the Porto Badisco Calcarene but an angular unconformity has never been observed between these two units.

Moreover the Porto Badisco Calcarene has never been found overlying fore reef facies of the Castro Limestone, contrary to what indicated in fig.2 of Bosellini F.R. & Russo (1992).

The stratigraphic relationships between the two units recognized in the Upper Cretaceous deposits of Southeastern Salento, the «Santa Cesarea Limestone» and the «Ciolo Limestone», are more problematic. In fact the boundary between these two units has been never observed in the study area but several arguments, mainly deduced from the knowledges on the stratigraphy of the Upper Cretaceous in the Apulian Platform, suggest that this boundary might correspond to a regional unconformity associated to a hiatus separating upper Campanian from upper Maastrichtian deposits: a) a complete Upper Cretaceous sequence including the upper Maastrichtian with orbitoids or with *Rhapydionina liburnica* has been never documented from the Apulian Platform (Reina & Luperto, 1993b); b) the stratigraphy of the Rosaria Mare well (De Dominicis & Mazzoldi, 1989; Aiello, 1992), showing Maastrichtian Scaglia above Senonian carbonate platform facies (*Accordiella conica* zone), again suggests the existence of a hiatus in the terminal Cretaceous; c) a stratigraphic gap separating beds with *Raadshoovenia salentina* from upper Maastrichtian levels with larger foraminifers has been already suggested by Ricchetti *et al.* (1992, fig. 3); d) an early Maastrichtian unconformity has been hypothesized by Pieri & Laviano (1989) for the Upper Cretaceous deposits of the Ostuni area. On this basis we put forward the hypothesis that also the Upper Maastrichtian deposits here indicated as the «Ciolo Limestone» represent a UBSU.

A composite stratigraphic column for the Upper Cretaceous-upper Oligocene of southeastern Salento is shown in text-fig.6. Comparing this composite column with those measured along the coast between Gagliano and Porto Badisco (text-figs. 2-5) it results that a complete sequence comprising all the stratigraphic units has never been observed in the field: some units show remarkable thickness variations and may even be totally missing in some sectors of the coast. This is true not only for Middle Eocene deposits («Torre Tiggiano Limestone»), whose maximum thickness does not exceeds 7.5m, but also for the Priabonian unit («Torre Specchialaguardia Limestone»), reaching the maximum thickness north of S.Cesarea Terme (text-fig.2) but missing in the Porto Badisco cove (text-fig.5) and in the Ciolo inlet (text-fig.3). The same may be said for the «Ciolo Limestone», missing along the coast between S.Cesarea and Porto Badisco. This complex situation could be probably explained extending to



Text-fig. 6 - Composite stratigraphic section of the Upper Cretaceous to Oligocene units of southeastern Salento. All the unconformities bounding the Paleogene units have been observed in the study area; the hypothesis of an unconformity separating the «S.Cesarea Limestone» from the «Ciolo Limestone» is put forward on the basis of several arguments deduced from the stratigraphy of the Upper Cretaceous deposits of the Apulian Platform (see text).

the whole coast of southeastern Salento the hypothesis put forward by Bosellini A. (1993) for the sequence outcropping east of Gagliano. Large scale collapses occurring at different times along the platform margin could have determined an articulated morphology that in turn would have interfered with

eustatic oscillations and subsidence in determining the complex stratigraphic situation observed in the study area.

ACKNOWLEDGEMENTS

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