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ALVEOLINA HORIZONS IN THE TRENTINARA FORMATION (SOUTHERN APENNINES, ITALY): STRATIGRAPHIC AND PALEOGEOGRAPHIC IMPLICATIONS

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Abstract. In late Paleocene-Eocene times, in the Tethyan area, the shallowest and most restricted carbonates deposited between the intertidal zone and the lower limit of the upper photic zones are characterized by *Spirolina*-dominated facies. This extremely shallow-water carbonate facies is recorded from the Cenomanian to the Miocene in the Tethyan realm with similar sedimentological characters and similar spiroliniform epiphytic taxa. All these taxa can be considered to reflect some kind of vicariance through time. In Southern Italy this peculiar facies is represented by the Trentinara Formation (Lower-Middle Eocene); in several stratigraphic sequences of this formation, three levels containing alveolinids were identified. The first is well known in the literature and allows us to assign the lowermost part of the formation to the lowermost Ypresian (bio-chronozone SBZ 6, *Alveolina ellipsoidalis* zone); the second is not age diagnostic because alveolinids are rare and poorly preserved; the third allows the age of the upper part of the Trentinara Formation to be established as Early Lutetian (bio-chronozone SBZ 13, *Alveolina stipes* zone). The exact age of the top of the formation is still unclear, but probably falls within the Lutetian-Priabonian interval. The geographic locations of the most significant shallow-water carbonates of Early-Middle Eocene age, cropping out in the southern Apennines, have led to a first attempt to map their distribution within the central gyre of the western Tethys.

Riassunto. Nell'intervallo stratigrafico compreso tra il Paleocene terminale e l'Eocene dell'area tetidea, una peculiare facies costituita da foraminiferi a guscio imperforato, principalmente *Spirolina*, caratterizza i depositi carbonatici di mare poco profondo a circolazione molto ristretta, compresi tra la zona intertidale ed il limite inferiore della zona fotica superiore. Nel dominio tetideo questa facies, caratterizzata da carbonati di acque estremamente basse, ricorre dal Cenomaniano al Miocene con caratteristiche sedimentologiche simili e con simili taxa epifitici spiroliniformi. Questi taxa, che nel tempo si susseguono, potrebbero essere intesi come specie vicarianti in ambienti analoghi. In Italia meridionale, questa peculiare facies è rappresentata dai calcari della Formazione di Trentinara (Eocene inferiore-medio). Lo studio di diverse sequenze stratigrafiche permette di identificare, nella Formazione di Trentinara, tre livelli contenenti alveoline. Il primo è ben conosciuto in letteratura e permette di definire l'età della parte più bassa della Formazione di Trentinara come Ypresiano basale (bio-cronozona SBZ 6, zona ad *Alveolina ellipsoidalis*); nel secondo le alveoline sono rare e mal conservate; il terzo permette di fissare l'età della parte superiore, ma non terminale, della Formazione di Trentinara come Luteziano inferiore (bio-cronozona SBZ 13, zona ad *Alveolina stipes*). L'esatta datazione del tetto della Formazione è ancora un problema aperto, anche se, in ogni caso esso rientra nell'intervallo Luteziano-Priaboniano. La localizzazione dei più significativi affioramenti carbonatici dell'Eocene inferiore e medio, affioranti in Appennino meridionale, ha permesso di effettuare un primo tentativo di modello di distribuzione di facies, appartenenti ai domini di piattaforma, per il settore centrale della Tetide occidentale.

Introduction

Although numerous studies have been made on the geology and paleontology of the Mesozoic carbonate sediments which constitute the so-called Apennine Platform (Ippolito et al. 1973), much less attention has been addressed to its Paleogene cover, often consisting of shallow-water carbonates and bearing characteristic foraminiferal faunas. The most significant succession is known as the Trentinara Formation (Selli 1962), where *Spirolina* assemblages dominate the microfacies ("cenozona a *Spirolina* spp." in Sartoni & Crescenti 1962).

More generally, the *Spirolina* Facies, cropping out in numerous areas of the Tethyan realm (Figs. 1A, 1B), represents extremely restricted shallow environments. Three major groups of foraminifers, spirolinids, rotaliids and conical-agglutinated foraminifera, occur in it. Their strict dependence on restricted shallow-water environments explains why they are preserved only epi-

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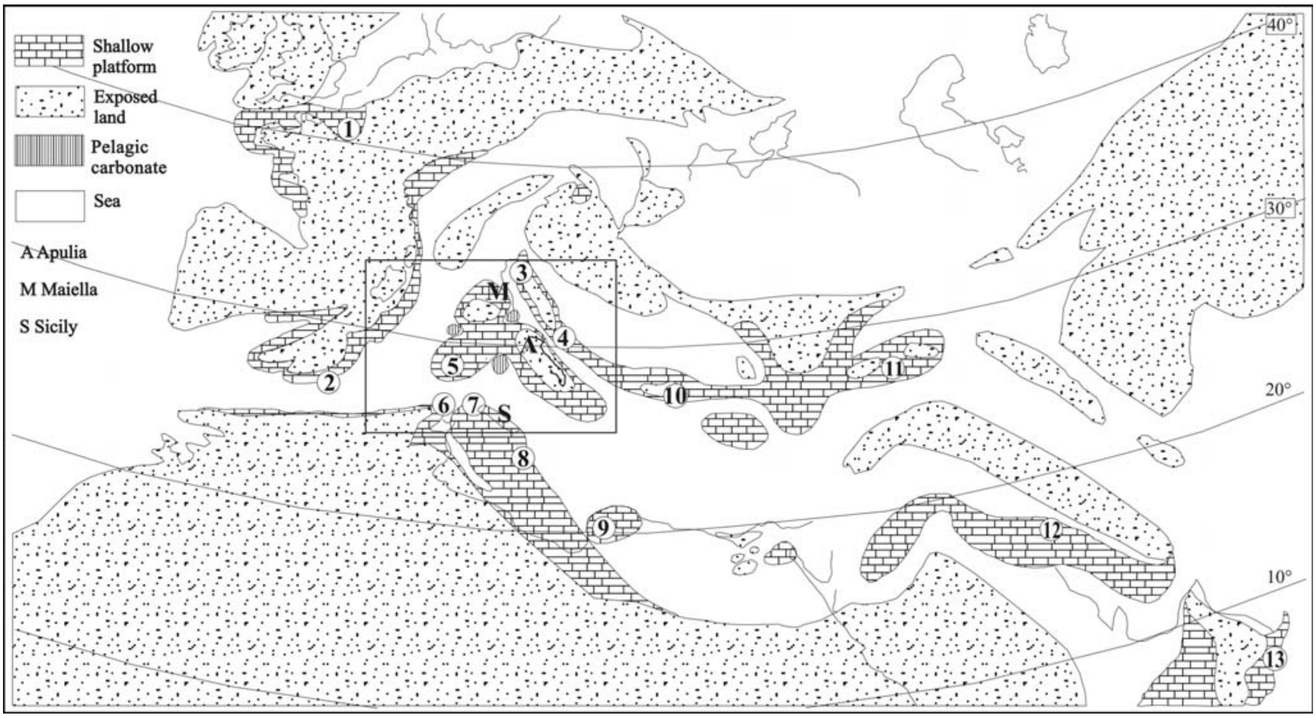


Fig. 1A - Paleogeography of the Lutetian Western Neotethys and its shallow carbonate realms; 1- France: Medoc (Poignant 1960, 1961), Paris Basin (Le Calvez 1949), Adour Basin (Sztràkos 1996); 2- Spain (Romero & Caus 1999); 3- Istrian Peninsula (Ćosović et al. 2004); 4- northern Dalmatia (Bignot 1972, 1975); Dinarids (Radoičić 1995); Croatia, central Adriatic area (Tari-Kovačić et al. 1998); Croatia, Pelješac Peninsula (Marjanac et al. 1998); 5- Italy: central and southern Apennines (present paper); 6- Northern Tunisia (Bonnefous & Bismuth 1982); 7- Lampione Islet (Bismuth & Bonnefous 1981); 8- Malta (Felix 1973); 9- Libya (Tedeschi & Papetti 1964, Lehmann et. al. 1967); 10- Greece (Fleury 1980, 1982, 1997); 11- Turkey (Sirel & Açar 1982; Sirel 2003); 12- Iraq-Iran (Henson 1950; Teherani-Khosrow 1978); 13- Oman (Bourdillon de Grissac 1988); A- Apulia, M- Maiella; MoB- Molise Basin; S- Sicily. (Map from Butterlin et al. 1993, modified).

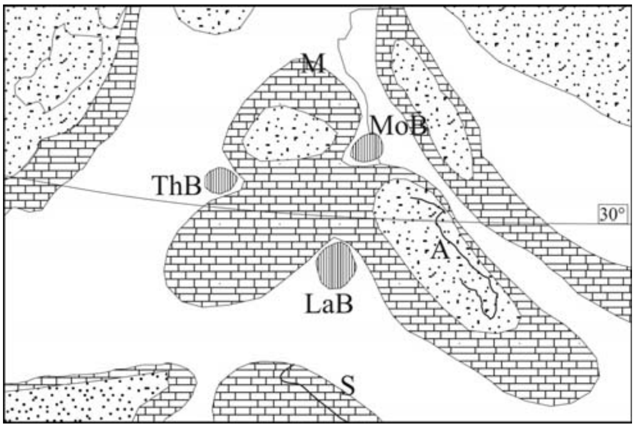


Fig. 1B - Detail of the investigated area. LaB- Lagonegro Basin; MoB- Molise Basin; ThB- Tyrrhenian Basin; A- Apulia, M- Maiella; S- Sicily. (Map from Butterlin et al. 1993, modified).

sodically in the fossil record, limiting their usefulness as biostratigraphic index fossils.

The Trentinara Formation (= *Spirolina* Facies auct.) consists of a very shallow-water succession, deposited in a shelf domain characterized by restricted water circulation. It contains stratigraphic gaps at various levels and crops out sparsely with modest thickness. The texture of these carbonates is characterized by wackestone, rarely packstone; episodes of brackish to fresh-water influx are testified by abundant and widespread levels with charophytes and smooth-shelled ostracods. Subaerial exposure is also documented by *Paronipora* (= *Microcodium*) (Barattolo & Parente 1991a; Vecchio 2003). Benthic porcelaneous foraminifers (mainly *Spirolina* but also occasionally alveolinids) dominate, but also lamellar foraminifers, such as rotaliids, and conical-agglutinated foraminifera occur.

The present paper focuses on dating the Trentinara Formation by alveolinids found in horizons mainly at the base and in the upper part of the sedimentary sequence. As the rest of the foraminiferal assemblage (spirolinids, etc.) hardly contributes to the dating of the sediments, a systematic inventory of this group will be given elsewhere.

The Trentinara Formation *sensu stricto* occurs in Italy along the Tyrrhenian side of the southern Apennines from south of the Sele River (Campania region) to the Pollino massif (northern Calabria), but similar or equivalent facies are also observed more northward, up to the Aurunci Mts. (southern Latium). Whether they belong to the same tectonic unit as the Trentinara Formation is uncertain.

The Trentinara Formation varies in thickness from a few meters (e.g. Alburni Mts., Barattolo & Vecchio 2000a; Barattolo et al. 2000) up to 125 m (Capaccio Vecchio, Sartoni & Crescenti 1962). The strata usually consist of light brownish to dark gray wackestone-packstone, in beds generally 20-40 cm thick. They alternate with green clays sometimes containing calcareous nodules. This formation disconformably overlies Cretaceous (Campanian) shelf carbonates and is overlain unconformably by the Lower Miocene deposits of the Roccadaspide Formation (Barattolo & Parente 1991b). Towards the south, the latter formation is replaced by the Cerchiara Formation. Northward, the carbonates analogous to the Trentinara Formation are overlain by the Cusano Formation.

Trentinara Formation and analogous facies in the southern Apennines

Only few reports have dealt with the stratigraphy and micropaleontology of the Trentinara Formation, probably due to its modest outcrop area and thickness compared to those of the Mesozoic carbonate deposits in the region. Moreover, the outcrops are usually faulted and only a few of them show the whole succession. The name of the formation derives from the village of Trentinara in southern Campania (Cilento). Selli (1962) noticed the occurrence of these carbonates over autochthonous Mesozoic sediments of the Apennines from south of the Sele River (Campania) down to northern Calabria and Basilicata, while Sartoni & Crescenti (1962) referred the whole lithostratigraphic unit to the so called "*Spirolina* spp. cenozone" and distinguished two intervals. The lower one is rich in *Spirolina* and at the bottom sometimes shows an assemblage characterized by *Alveolina ellipsoidalis* Schwager and *Glomalveolina lepidula* (Schwager). The upper interval contains *Coskinolina* sp., *Periloculina raincourti* Schlumberger and "*Rhapydionina* sp.". The occurrence of *Alveolina subpyrenaica* Leymerie, *Alveolina ellipsoidalis* Schwager and *Glomalveolina lepidula* (Schwager) led Selli (1962) and Sartoni & Crescenti (1962) to include the base of the Trentinara Formation in the "Upper Paleocene", according to Hottinger & Schaub (1960). This was later confirmed by Hottinger (in Selli 1962). The upper part of the formation was supposedly Lower Eocene, because of the presence of *Coskinolina* sp. and *Periloculina raincourti* Schlumberger (Sartoni & Crescenti 1962). In our opinion, taxa figured as *Coskinolina* sp. (Sartoni & Crescenti 1962; pl. 40, fig. 2; pl. 41, fig. 2), *Coskinolina* cf. *liburnica* Stache (Sgrosso 1968; text-fig. 12) and *Coskinolina liburnica* Stache (Chiocchini & Mancinelli 1977, pl. 46, fig. 2) have to be ascribed to a new taxon. Also *Periloculina raincourti* Schlumberger, figured in Sartoni & Crescenti (1962), has to be referred to *Periloculina* (?) *decastroi* Vecchio & Barattolo (2006).

Facies analogous to the Trentinara Formation are recorded northward of the Sele River at Montagna di Bruno, in the Caserta district (Sgrosso 1963), Mai Mts., Salerno (Picentini Massif), and Aurunci Mts., Southern Latium (D'Argenio 1963; Chiocchini & Mancinelli 1977; Romano & Urgera 1995; Barattolo unpublished). In the sequences cropping out at Rotondo, Cianelli and the Concalunga Mts. (eastern part of the Aurunci Mt., southern Latium), Chiocchini & Mancinelli (1977) established their "*Spirolina* sp. biozone". In these localities, Paleogene limestones unconformably overlie Senonian carbonates and are, in their turn, overlain unconformably by Miocene limestones of the Cusano Formation (Selli 1957). These two authors ascribed the *Spirolina* sp. biozone to the Thanetian-Lutetian and specified that their biozone has the same stratigraphic extension as the so-called *Spirolina* spp. cenozone of Sartoni & Crescenti (1962).

The Mt. Vesole succession (Cilento, Campania), very close to the village of Trentinara, is the type locality of *Praturlonella salernitana* Barattolo, 1978, a dasycladalean green alga which constantly occurs in the upper part of the Trentinara Formation. This mountain is also the type locality of *Dargenioella vesolei* De Castro, 1987, a porcellaneous foraminifer, which occurs in the lowermost part of the formation. In this formation, Barattolo & Parente (1991a) recognized three intervals, C1, C2 and C3, characterized by a rich association of *Alveolina* spp., *Clypeina* spp. and *Praturlonella salernitana* Barattolo, respectively. Barattolo & Vecchio (2000a, b), pointed out a further *Alveolina* spp. level in the upper part of the formation, Barattolo & Romano (2002) attributed the *Clypeina* spp. of the C2 interval to

Fig. 2 - Locations of the stratigraphic sequence discussed. CA: Castelcivita (Alburni Mts., Campania); CV: Capaccio Vecchio (Campania); SP: Serra Pastorella (Basilicata).

two new species (*Clypeina lucana* and *Clypeina bucuri*), while Vecchio & Barattolo (2006) established *Periloculina* (?) *decastroi* from uppermost Ypresian-lowermost Lutetian beds.

Selected Lithostratigraphic Sections

The present study is based on two stratigraphic sections (Serra Pastorella and Castelcivita) and on an isolated additional outcrop (Capaccio Vecchio) (Fig. 2). All of them belong to the Alburno-Cervati tectonic unit of the Apennine Platform (Ippolito et al. 1973).

The stratigraphic section of Serra Pastorella (Basilicata) is located 1.5 km ENE of Lauria (see Barattolo & Vecchio 2000b) in the locality "Pianicelli" from 750 to 680 m a.s.l., kilometric coordinates: Long. = 572.80 km; Lat. = 4433.88 km (datum WGS84, Projection NUTM33). The Castelcivita (Alburni Mountains, Campania) outcrop is located along the national road No. 488 from Controne to Castelcivita, between kilometers 12.150 and 12.700. The Capaccio Vecchio (Cilento, Campania) outcrop is located close to the Monastery of the Madonna del Granato, along the monocline of Monte Soprano, kilometric coordinates: Long. = 504.32 km; Lat. = 4477.48 km (datum WGS84, Projection NUTM33).

At Serra Pastorella, in the Basilicata region (SP in Fig. 3), one level rich in alveolinids occurs at the top of the sequence; another two levels containing rare alveolinids are also present in the middle part of the sequence. At Castelcivita (CA in Fig. 3) the carbonate succession, although rather thin (15 m), shows four horizons with alveolinids. One at its base, a second one in the middle part and two others at the top of the sequence. At Capaccio Vecchio the lowermost level is richer in alveolinids than at Castelcivita; this allows us to date the base of the C1 interval (Fig. 3). The uppermost levels in Serra Pastorella and Castelcivita are the richest in alveolinids, which allows us to date

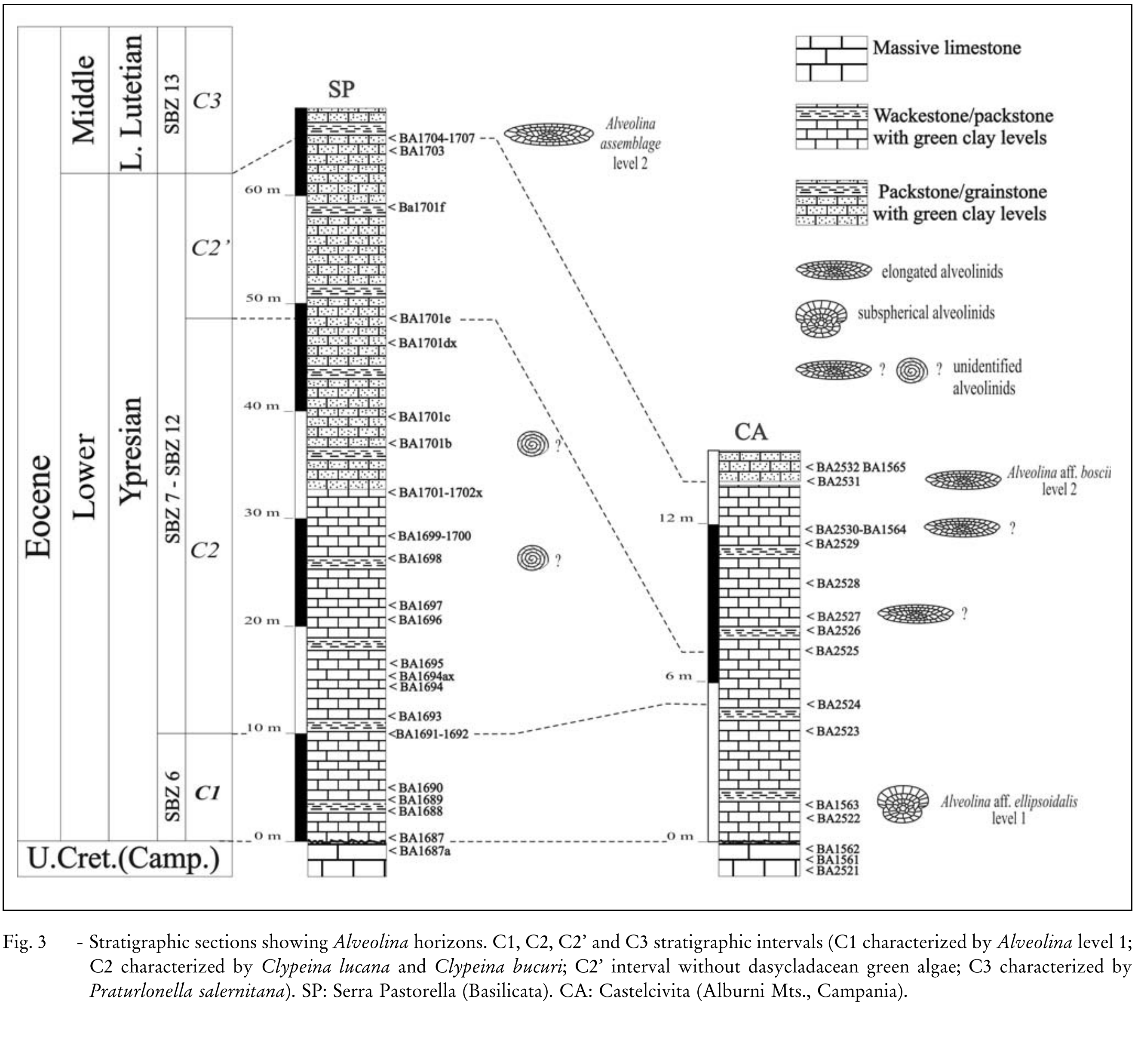


Fig. 3 - Stratigraphic sections showing *Alveolina* horizons. C1, C2, C2' and C3 stratigraphic intervals (C1 characterized by *Alveolina* level 1; C2 characterized by *Clypeina lucana* and *Clypeina bucuri*; C2' interval without dasycladacean green algae; C3 characterized by *Praturlonella salernitana*). SP: Serra Pastorella (Basilicata). CA: Castelcivita (Alburni Mts., Campania).

the base of the C3 interval. The intermediate levels contain rare alveolinids, which do not permit a specific identification.

Dating the Trentinara Formation

Taking into account the data from Barattolo & Parente (1991a) and Barattolo & Vecchio (2000b), the Trentinara Formation is here subdivided from the base to the top into four intervals: C1, C2, C2' and C3. C1 is characterized by a rich association of *Alveolina ellipsoidalis* and *Glomalveolina lepidula*. The first appearance of dasycladalean green algae such as *Clypeina bucuri* and *C. lucana* is used for correlation within the Trentinara Formation and for defining the C1/C2 boundary (Barattolo & Parente 1991a). Their disappearance and the first appearance of *Praturlonella salernitana* is used to define the lower and the upper limit of the C2' intervals, respectively. C2' corresponds to an additional unit distinguished in the present paper, while C3 is defined by the occurrence of *Praturlonella salernitana*. The biostratigraphic subdivision based on dasyclads has proved to be useful for intraformational correlation, but it is hardly used with other shallow water facies, probably because these algae characterised extremely restricted facies.

Instead, alveolinids allow an accurate dating. Two *Alveolina* levels were used for a bio-chronostratigraphic dating. The first level (*Alveolina* level 1) is at the base of the succession in the lower part of C1. The second level (*Alveolina* level 2) is in the upper portion of the succession at the very beginning of C3.

The age of the formation is given here taking into account the shallow benthic standard zonation SBZ (Serra-Kiel et al. 1998). The occurrence of *Alveolina ellipsoidalis* Schwager, 1883, (Pl. 1, fig. 1) in the Capaccio Vecchio succession (*Alveolina* level 1) defines the lower limit of the Trentinara Formation as corresponding to SBZ 6. The other components confirm this age: *Glomalveolina lepidula* (Schwager, 1883), *G. periloculinoides* (Silvestri, 1939), *Alveolina* cf. *varians* Hottinger, 1960, *A. decipiens* Schwager, 1883, *A.* cf. *aragonensis* Hottinger, 1960, *A.* cf. *subpyrenaica* Leymerie, 1846. *Spirolina* sp., miliolids, *Redmondina* sp., rotaliids, chrysalidinids, nodophthalmidids, textulariids, *Praturlonella* aff. *salernitana*, *Thaumatoporella* sp., charophytes, gastropods and bivalves are also present. The level containing *Alveolina* aff. *ellipsoidalis* (Pl. 1, fig. 6) cropping out at Castelcivita seems to correspond to the *Alveolina* level 1 cropping out at Capaccio Vecchio. The *Alveolina* level 2 at Lauria contains *Alveolina stipes* Hottinger, 1960, (Pl. 3, fig. 7), which is restricted to SBZ 13 (Lower Lutetian). All other alveolinid taxa, identified as *Glomalveolina delicatissima* (Smout, 1954), *Alveolina* cf. *croatica* Drobne, 1977, *A. hottingeri* Drobne, 1977, *A. levantina* Hottinger, 1960, *A.* cf. *stipes* Hottinger, 1960, *A. boscii* (Defrance in Bronn, 1825), *A.* cf. *tenuis* Hottinger, 1960, confirm this stratigraphic attribution. *Spirolina* sp., *Dendritina dusemburyi* Henson, 1950, *Orbitolites* sp., miliolids, nubeculariids, textulariids, *Gyroidinella* sp., *Gypsina* sp., new genera and species of rotaliids and imperforated conical foraminifera, *Thaumatoporella* sp., *Praturlonella salernitana* and bivalves are also present. The occurrence of *Alveolina* aff. *boscii* (Pl. 2, fig. 5) at Castelcivita also suggests SBZ 13 zone. New genera of rotaliids, *Fabiania* sp., *Orbitolites* sp., *Spirolina* sp., miliolids, and textulariids, are also present. According to Serra-Kiel et al. (1998) the SBZ 6 zone is correlated with the middle part of the P5

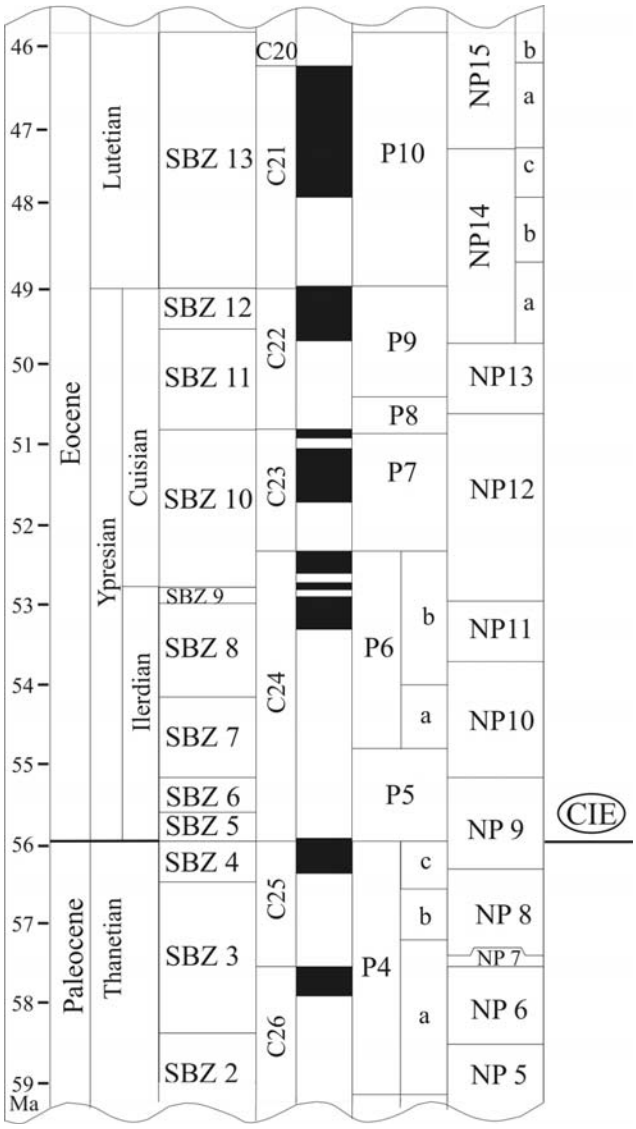


Fig. 4 - Chronostratigraphic correlation chart through the Paleocene-Eocene interval. Zonation of planktonic foraminifera (P) from Berggren et al. (1995), of calcareous nannoplankton (NP) from Martini (1971), and Shallow Benthic Zones (SBZ) from Serra-Kiel et al. (1998). Carbon isotope excursion (CIE) from Pujalte et al. (2003).

calcareous plankton zone, and to the upper part of the NP 9 nannoplankton zone.

In the definition of the Paleocene-Eocene boundary (Gebel Dababiya section, Egypt: Ouda 2003; Depuis 2004), SBZ 6 falls above this boundary (Fig. 4). Thus the base of the Trentinara Formation can be placed in the lowermost Ypresian (i.e. Ilerdian, lowermost Eocene). The SBZ 13 zone, defined by the total range zone of *Alveolina stipes* Hottinger, can be correlated directly to the transgressive base of the Lutetian stratotype in the Paris Basin (Hottinger 1960). Consequently, the *Alveolina* level 2 has to be dated as Early Lutetian (early Middle Eocene). According to Serra-Kiel et al. (1998), the SBZ 13 zone is correlated with the P10 plankton zone, equivalent to the upper part of the NP 14 and lower part of the NP 15 nannoplankton zones (Fig. 4). The intermediate *Alveolina* levels show only rare specimens which cannot be determined at species level; therefore a more accurate dating within the C1-C2' interval is not possible, at the moment. Also the age of the upper part of the Trentinara Fm. (upper part of C3 interval) is not well constrained. In several places, e.g. Serra Pastorella, the C3 interval is greatly reduced (a few meters instead of 35 m and more, e.g. Roccadaspide) or lacking altogether. Therefore it is assumed that, at least at Serra Pastorella, only the lower part of the C3 interval is preserved (Fig. 5). However, this interval is not younger than Priabonian because of the occurrence of *Praturlonella salernitana*, an alga recorded in beds not younger than Priabonian. In fact, this alga occurs in the upper part of the Tunisian Halk el Menzel Formation cropping out at Lampione Islet. This formation has been dated, by correlation with bore hole No. 2 Halk el Menzel, as Late Eocene because of the presence of *Nummulites fabianii* Prever in Fabiani, 1905, *Nummulites bouillei* de la Harpe, 1879, and *Nummulites incrassatus* de la Harpe, 1879 (Bonnefous & Bismuth 1982). This allows us to correlate the two formations and deduce for *Praturlonella salernitana* a range reaching the Late Eocene (Barattolo & Parente 1991a). Therefore the upper limit of the C3 interval falls somewere within the Early Lutetian-Priabonian time span.

Also in Greece (Klokova Mt., Gavrovo-Tripolitza Zone), the occurrence of *Praturlonella salernitana* has been pointed out (Barattolo, unpublished) in Bartonian-Priabonian Trentinara Fm.-like limestones.

Paleoecological interpretation

A schematic section of a shelf edge showing a Lower-Middle Eocene distribution of facies is given in Fig. 6A, based on the model by Sartorio & Venturini (1988). Other facies recorded, for instance on the Adriatic Platform, have not been found on the Apennine platform: in particular, the transitional facies from the photic to the aphotic zone represented, according to the light and water energy conditions, by the deep-water discocyclinid assemblage (Hottinger 1981, 1983, 1997; Leutenegger 1984; Reiss & Hottinger 1984; Ćosović et

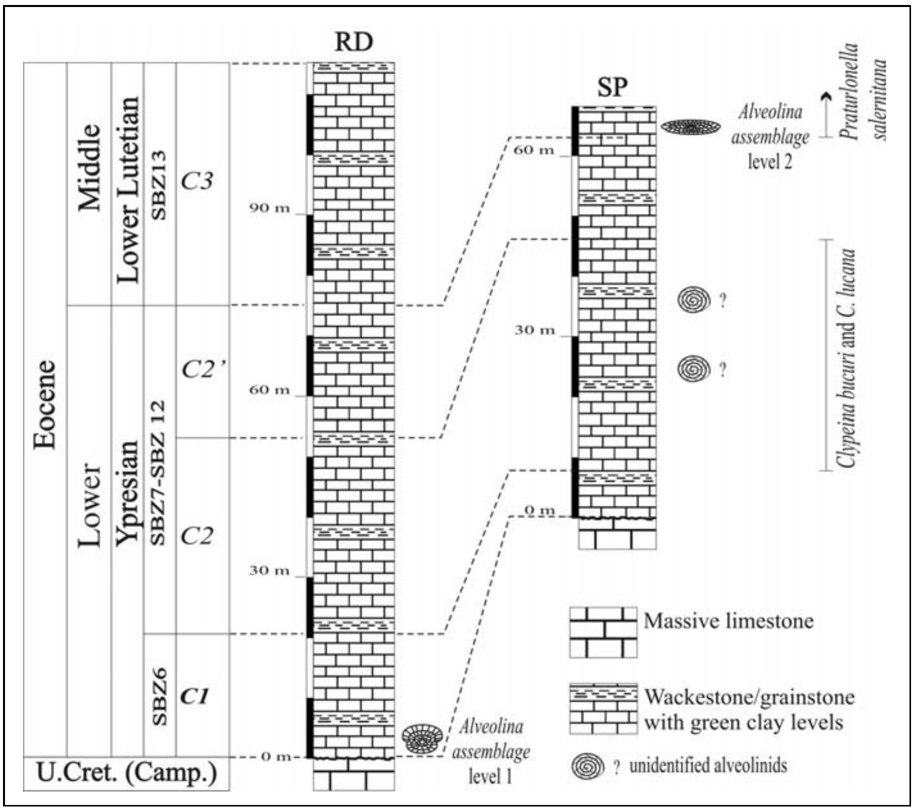


Fig. 5 - Correlation of the intervals containing dasycladacean green algae in the Roccadaspide and Serra Pastorella successions.

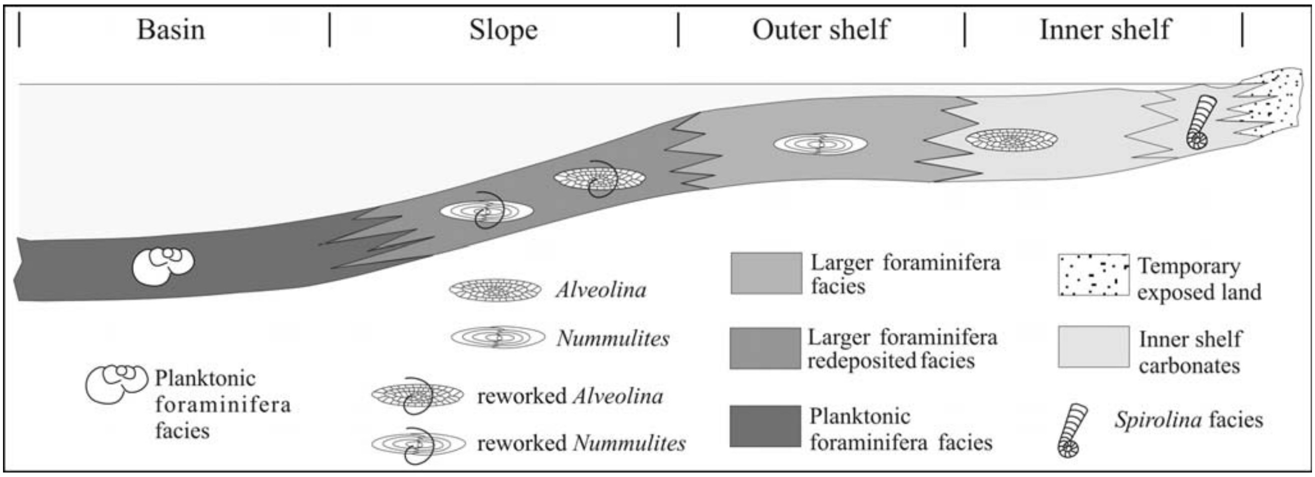


Fig. 6A - Schemating Lower-Middle Eocene shallow-water facies distribution.

al. 2004). In the southern Apennines, they are never recorded *in situ* and therefore do not appear on the map (Fig. 6B).

The location of the most significant Lower-Middle Eocene carbonates of shelf facies cropping out in the southern Apennines, allows us to propose a tentative shallow-water facies distribution (Fig. 6B). The Early-Middle Eocene paleogeographic framework is assumed to be roughly similar to that supposed by Ciarapica & Passeri (1998) for the Upper Oligocene. The reconstruction is highly approximate because some assemblages are autochthonous, but others are found reworked. Thus we can suppose the distribution of the Trentinara Fm. and the "Temporary exposed areas" is under-estimated, while that of "Larger foraminifera facies" and "Planktonic foraminifera facies" may be considerably over-estimated, because not indicative of the original areas.

Lower-Middle Eocene shelf facies: a tentative distribution

There is not yet a general consensus on the pre-orogenic paleogeography of Southern Italy. Several different models have been proposed in the last decades. One of them postulates, since the Late Triassic and throughout the Mesozoic, two carbonate platforms called Apenninic Platform to the west and Apulian Platform to the east, respectively, separated by the deep Molise-Lagonegro Basin (Pescatore 1965, 1988; Ogniben 1969; Casero et al. 1988; Mostardini & Merlini 1988; Pescatore et al. 1999; additional references in Sgrosso 1988, and in D'Argenio 1988). Ciarapica & Passeri (1998) generally agree with the above model, but they propose a complex of small carbonate platforms, detached from the continent and separated by more or less deep seaways (like the modern Bahamas, the Maldives or the Dahlak Ids.). A second model (Scandone 1972; Ippolito et al. 1973; D'Argenio et al. 1973; Amodio-Morelli et al. 1976), assumes three carbonate platforms arranged from west to east, the Campano-Lucana, Abruzzese-Campana and Apulo-Garganica, respectively. They are separated by two distinct basins, the Lagonegro Basin and the Molise Basin. In the most complex model (Sgrosso 1983, 1988) six carbonate platforms are distinguished.

Only a few papers (Ietto 1969; Pescatore 1962, 1963; Scandone et al. 1964; Scandone & Bonardi 1968; Sgrosso 1966; Sgrosso & Torre 1967) provide some paleoenvironmental information about Paleogene sediments, but no attempt has been ever made to place major facies into a paleogeographic context.

The Lutetian paleogeographic reconstruction, here adopted as a basis to locate the paleogeographic units, is that proposed by Butterlin et al. (1993) and Ciarapica & Passeri (1998): the Apulian platform had emerged to a large extent whereas the Mesozoic part of the Apennine Platform merged into a single one, exhibiting a trilobate outline (Fig. 1B). This Apennine Platform was in part subaerially exposed. To the west it was delimited by the Tyrrhenian Basin, to the east by the Lagonegro Basin (Fig. 1B) and to the northeast by the Molise Basin (MoB, in Butterlin et al. 1993).

After the Cenomanian-Turonian emersion, according to Ciarapica & Passeri (1998), the Apennine carbonate platform started again to export a great quantity of sediments far away from the margin and to prograde toward the basins. The numerous and more or less wide stratigraphic gaps recorded in the Upper Cretaceous-Miocene carbonate platform must be related to their low rate of subsidence, even with local emersions.

Within this general trend, there are two main difficulties in developing a coherent model: 1) the widespread reworking of the larger foraminifera fauna, preventing its exact location within the shallow carbonate domain; 2) the lateral shortening, displacement and thrust of the platform facies. In the present paper, a first

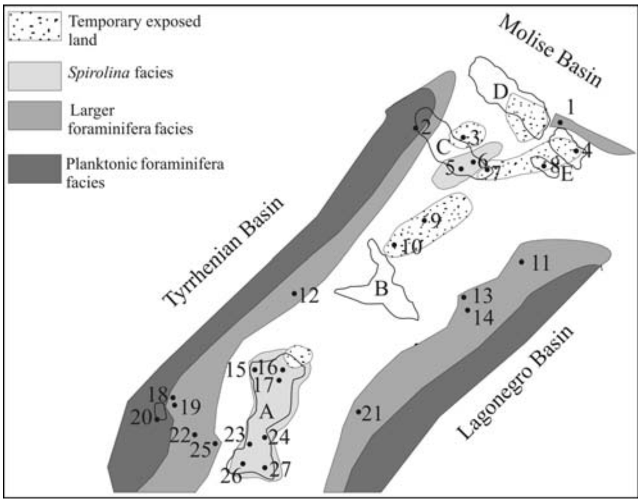


Fig. 6B - Locations of the most significant Lower-Middle Eocene shallow carbonate deposits in the southern Apennines, with a tentative distribution map of shallow-water facies. Only Eocene outcrops lying on the Mesozoic platform are considered. The paleogeographic scheme used is that proposed for the Upper Oligocene by Ciarapica & Passeri (1998), slightly modified (position of Capri), assuming that no substantial changes occurred between the Middle Eocene and the Upper Oligocene. Emerged parts of Appennine platform: **A**: Alburni Mts., **B**: Taburno-Picentini Mts., **C**: Aurunci-Ausoni-Lepini Mts., **D**: Simbruini-Ernici Mts., **E**: Matese-Maggiore Mts. Main outcrops; *SF*: *"Spirolina Facies"*; *LFF*: *"Larger foraminifera facies"*; *PFF*: *"Planktonic foraminifera facies"*; *TEA*: *"Temporary exposed areas"*: **1** - Matese Mts., *LFF* (Matese Mts.: Pescatore 1962; 1963; 1965; Signorini 1962; Signorini & Devoto 1962; Zanfrà 1963; Manfredini 1963; Ietto 1969; Sgrosso 1996; Monteroduni, Matese Mt.: Sgrosso & Torre 1968); **2** - Circeo, *PFF* (Mostardini & Merlini 1988); **3** - Porchio-Trocchio Mts., *EL* (Barattolo, personal data); **4** - Cusano/Pietraroia, *EL* (Selli 1957); **5** - Aurunci Mts., *SF* (Romano & Urgera 1995; Barattolo personal data); **6** - Pietravairano, Caserta, *SF* (Sgrosso 1963); **7** - Massico Mt., *EL* (Vallario 1963; Cestari, 1964; 1965); **8** - Maggiore Mt., *EL* (D'Argenio & Pescatore 1962); **9** - Caizzo, *EL* (Ogniben 1958); 10 - Taburno-Camposauro Mts., *EL* (D'Argenio 1961, 1967); **11** - Marzano Mt., *LFF* (Servizio Geologico d'Italia 1970); **12** - Capri, *LFF/PF* (Barattolo, personal data); **13** - Mai Mt., Picentini Mts., *LFF* (Sgrosso 1965); **14** - Accellica Mt., Picentini Mts., *LFF* (Servizio Geologico d'Italia 1970); **15** - Capaccio Vecchio, Soprano Mt., *SF* (Sgrosso 1968); **16** - Castelcivita, Alburni Mts., *SF* (Marini & Andri 1966; Cestari 1971; Barattolo & Vecchio 2000a); **17** - Ottati, Alburni Mts., *SF* (Cestari 1971; Marini & Andri 1966; Barattolo et al. 2000); **18** - Castel Ruggero, Lauria, *LFF* (Scandone 1971); **19** - Roccagloriosa, Cilento, *LFF* (Sgrosso & Torre 1967); **20** - Bulgheria Mt., Cilento, *LFF/PFF* (Cestari 1963; Torre 1969); **21** - Maddalena Mts., *BLFF* (Prever 1901; Scandone 1963; 1967; 1972; Vezzani 1966; Scandone & Bonardi 1968; Sgrosso 1966; Pappone 1990; Castellano & Sgrosso 1996); **22** - S. Domenica Talao, Verbicaro, *LFF* (Compagnoni & Damiani 1971); **23** - Serra Pastorella, Lauria, *SF* (Bonardi 1966; Vecchio 2003); 24 - Raparo Mt., *SF* (Barattolo personal data); **25** - Castelluccio Superiore, Lauria, *LFF* (Vezzani 1966); **26** - Pollino Mts., *SF* (Panno Bianco Mt.: Barattolo & Calcaterra 1993; Vecchio 2003; Sellaro Mt.: Carloni 1963; Colle San Martino: Foglia 1992); **27** - Timpa S. Lorenzo Bellizzi, Pollino Mts., *SF/LFF* (Santo & Sgrosso 1988; Barattolo, unpubl. data).

attempt is made to supply a tentative model for the southern Apennines (Fig. 6B). This takes into account both data from the literature and from the stratigraphic sequences here described.

During the Eocene three main carbonate facies can be identified in central and southern Italy: *Spirolina* Facies, Larger foraminifera facies, and Planktonic foraminifera facies.

Spirolina Facies (SF) corresponds to the Trentinara Formation and analogous facies discussed in the introduction, representing restricted marine environments. Moreover, this assemblage is the only one to be found in place, while the others are reworked.

Larger foraminifera facies (LFF) is represented by limestones yielding *Alveolina* sp., *Nummulites* sp. and *Discocyclina* sp., and is extensively recorded both in the geological maps and in the literature. However, the outcrops rarely represent *in situ* deposits. They are usually grain flows with a penecontemporaneous fauna transported out of their life-environments. The Eocene

PLATE 1

Figs. 1-2 - *Alveolina ellipsoidalis* Schwager, 1883, Trentinara Formation, Lower Ypresian. Fig. 1 - axial section, Capaccio Vecchio (Cilento), thin section BA 1905.4 x20; fig. 2 - tangential centered section, Castelcivita (Alburni Mts.), thin section BA 1905.8 x20.

Fig. 3 - *Glomalveolina lepidula* (Schwager, 1883), Capaccio Vecchio (Cilento), Trentinara Fm., Lower Ypresian, tangential centered section, thin section BA 1905.2 x40.

Figs. 4-5 - *Glomalveolina periloculinoides* (Silvestri, 1939), Capaccio Vecchio-Cilento, Trentinara Fm., Lower Ypresian. Fig. 4 - axial section, thin section BA 1905.7 x40; fig. 5 - subaxial section. Note the irregular coiling in the first whorl, thin section BA 1905.13 x20.

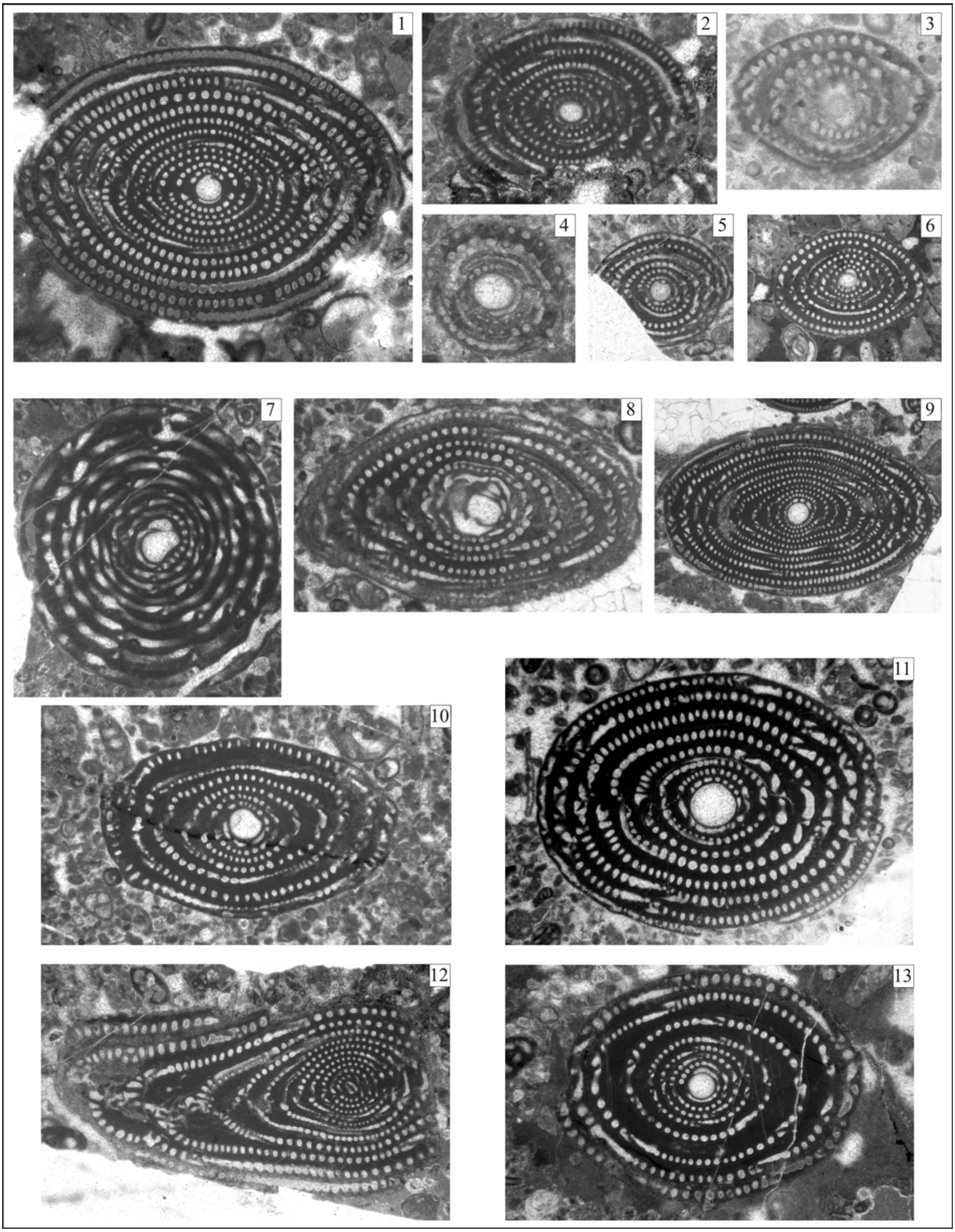
Fig. 6 - *Alveolina* aff. *ellipsoidalis* Schwager, 1883, Castelcivita-Alburni Mount, Trentinara Fm., Lower Ypresian, axial section, thin section BA 1563.21 x20.

Figs. 7-9 - *Alveolina* aff. *varians* Hottinger, 1960, Capaccio Vecchio-Cilento, Trentinara Fm., Lower Ypresian. Fig. 7 - oblique centered section close to equatorial, thin section BA 1905.6 x20; fig. 8 - closely centered oblique section near axial, thin section BA 1905.1 x20; fig. 9 - subaxial section, thin section BA 1905.12 x10.

Fig. 10 - *Alveolina* cf. *subpyrenaica* Leymerie, 1846, Capaccio Vecchio-Cilento, Trentinara Fm., Lower Ypresian, subaxial section, thin section BA 1905.15 x20.

Fig. 11 - *Alveolina* cf. *aragonensis* Hottinger, 1960, Capaccio Vecchio-Cilento, Trentinara Fm., Lower Ypresian, subaxial section, thin section BA 1905.9 x20.

Figs. 12-13 - *Alveolina decipiens* Schwager, 1883, Capaccio Vecchio-Cilento, Trentinara Fm., Lower Ypresian. Fig. 12 - subaxial section, thin section BA 1905.11 x20; fig. 13 - oblique centered section close to axial, thin section BA 1905.7 x20.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Larger foraminifera facies on the Apennine Platforms is also documented by a great amount of grain and debris flows in Miocene and younger synorogenic and post-orogenic deposits carrying fragments of carbonate rock showing this facies.

Planktonic foraminifera facies (PFF) is interpreted as representing sediments deposited on deep slopes or in pelagic environments. It is characterized by pelagic limestones where the fossil assemblage is exclusively composed of planktonic foraminifera, which may be mixed with allochthonous or reworked benthics from shallower environments.

Temporary exposed areas (TEA). In the literature the transgression of the Miocene over the Cretaceous limestone (Carannante et al. 1988) is well known. This is interpreted as an indication of subaerial exposure in post-Cretaceous times. Direct evidence of temporary Early Eocene emersion of the shallow-water carbonate domain is also recorded. For example, at Castelcivita (Alburni Mts.), in the Trentinara Fm., a paleokarstic cavity, partially filled by collapse deposits and alabaster concretions was recorded by Barattolo & Vecchio (2000a). At the Soprano-Sottano Mts., near the village of Trentinara, paleokarstification was reported at the top of the Trentinara Fm. (Boni et al. 1978). Moreover, in the same area residual red clays are recorded over Lower-Middle Eocene limestones of the Trentinara Fm., sometimes strongly altered by *Microcodium* (= *Paronipora*) (Boni 1974). Also, at Monte Coccovello, nodules of limestone embedded in red clays are recorded over Middle Eocene limestones of the Trentinara Fm. (Vecchio 2003).

Conclusions

The base of the Trentinara Fm. contains alveolinids (*Alveolina* Level 1), dated as SBZ 6 (*Alveolina ellipsoidalis* zone, Lower Ypresian). A second level (*Alveolina* Level 2) with abundant *Alveolina* occurs in the upper part of the formation, but not at the top. It provides an age of SBZ 13 (*Alveolina stipes* zone, Lower Lutetian).

The alveolinid assemblage is similar to the one observed on the Adriatic Platform (Ogorelec et al. 2001). However, the larger sedimentary cycles (Matteucci & Pignatti 1991) are much less expressed by faunal change since the ecological range of the faunas *in situ* is much more restricted. In particular, all the transitional assemblages between *Alveolina* and *Nummulites* dominated faunas (i.e., between "inner" and "outer shelf carbonate platform", Fig. 6A), was cut away by erosion.

The tentative reconstruction of the Apennine Platform during the Paleogene shows the *Spirolina* Facies to be located in the center of the platform in between and around emerging areas (Fig. 6B). Neither land-derived detritus nor Cretaceous clasts of the underlying Mesozoic platform has been observed. Consequently, the emerged parts of the platform must have had a low relief.

Materials and Methods

This study is based on thin sections (65 mm x 40 mm). In cases of oriented deposition, cuts parallel to the bedding plane were made. The 210 thin sections obtained, 112 from Lauria, 62 from Castelcivita and 36 from Capaccio Vecchio, are deposited at the Department of Earth Sciences, University of Naples Federico II (Barattolo Collection).

Anatomic and morphologic terms of the alveolinids are those used by Reichel (1931, 1936, 1937), Hottinger (1960) and Drobne (1977). The specimens are figured herein following the standard enlargements adopted by Hottinger (1960) and Drobne (1977), i.e. 10x, 20x and 40x.

Systematic Paleontology

Order **Foraminiferida** Eichwald, 1830
Suborder **Miliolina** Delage & Hérouard, 1896
Superfamily Alveolinacea Ehrenberg, 1839
Family Alveolinidae Ehrenberg, 1839
Genus *Glomalveolina* Hottinger, 1960

Glomalveolina lepidula (Schwager, 1883)

Pl. 1, fig. 3

1883 *Alveolina lepidula* v. typus *A. ellipsoidalis* Schwager, p. 98, pl. 25, figs. 3a-g.

1960 *A.* (*Glomalveolina*) *lepidula* - Hottinger, p. 57, text figs. 20-22, 80, pl. 1, figs. 25-29, pl. 2, figs. 9, 25 with synonymy.

1974 *A.* (*Glomalveolina*) *lepidula* - Hottinger, p. 35, pl. 32, fig. 6-13.

1977 *A.* (*Glomalveolina*) *lepidula* - Drobne, p. 13, figs. 2 e, 3 f-i.

1998 *A.* (*Glomalveolina*) *lepidula* - Sirel, p. 66, pl. 30, figs. 5, 6, 9-13.

1998 *Glomalveolina lepidula* - Accordi, Carbone & Pignatti, pl. 18, figs. 8-9.

Description. The only test available, cut parallel to the shell axis, tangential to the nepiont, is small, ovoidal, and slightly elongated in axial section. Basal layer thin. Chamberlets small and circular in axial section of shell. Four whorls: axial diameter 1 mm, equatorial diameter 0.65 mm, elongation index about 1.5.

Bio-chronozone. SBZ 5-SBZ 9: *Alveolina vredenburgi* zone to *A. trempina* zone (Lower Ypresian).

Occurrence in the Trentinara Formation. Capaccio Vecchio (sample BA 1905).

Glomalveolina delicatissima (Smout, 1954)
emended by Hottinger, 1999
Pl. 2, figs 9-11

1954 *Alveolina delicatissima* Smout, pl. 14, fig. 13.
1960 *A.* cf. *boscii* (Defrance in Bronn) - Hottinger, pag. 151, pl. 10, fig. 21.
1999 *Glomalveolina delicatissima* - Bassi & Broglio, figs. 6a-d.
1999 *Glomalveolina delicatissima* - Hottinger, pl. 1, figs. 1-16.

Description. Test elongate, fusiform, unflosculinised, distinctly tapering towards the poles. The shell wall is thick compared to the chamber lumen. Chamberlets very small in all growth stages, circular in axial shell sections and strictly confined to a single regular layer in each chamber. No supplementary passages in the polar region. Proloculus spherical, small, with a diameter of about 100 µm. The 2-3 early whorls are tightly coiled, in most cases streptospirally (Pl. 2, fig. 13), never elongated, forming a subspherical nepiont; the subsequent 5-7 whorls are elongated. In the elongated growth stages, the values of the elongation index increase distinctly, and accordingly the spire is tight in the equatorial area. Elongation index about 5 in megalospheric specimens. Axial length in megalospheric form 4 mm, equatorial diameter 0.8 mm. At a radius of 0.5 mm, there are 12 chamberlets per mm.

Remarks. The distinctive feature of this species is the small size of the test combined with the very small size of chamberlets. Consequently there are about twice as many chamberlets per millimeter, compared with any species of *Alveolina*. Specimens that do not show all the specific characters, due to the obliqueness of the sections or to their insufficient preservation, are here considered as *G.* cf. *delicatissima* (Pl. 2, figs. 12-14).

Bio-chronozone. SBZ 13-SBZ 14: Middle Eocene (Smout 1954); Lower Lutetian to lower part of Middle Lutetian (Middle Eocene), *Alveolina stipes* and *A. munieri* zones (Hottinger 1999).

Occurrence in the Trentinara Formation. Serra Pastorella (samples BA 1704, BA 1706).

Glomalveolina periloculinoides (Silvestri, 1939)
Pl. 1, figs 4, 5

1939 *Alveolina periloculinoides* Silvestri, p. 22, pl. 10, figs. 5, 6, 8.
1960 *A.* (*Glomalveolina*) aff. *periloculinoides* - Hottinger, p. 48, 63, text fig. 29(19).
1998 *A.* (*Glomalveolina*) aff. *periloculinoides* - Sirel, p. 65, pl. 30, figs. 1, 3, 4.

Description. Test small, subglobular with rounded poles. 4-6 whorls. Chamberlets closer in the early three whorls, rounded and separated by large septula in the following ones. Comparatively large chamber lumina: at a radius of 1 mm there are six chamberlets per mm. Basal layer thin, supplementary passages and intercalary chamberlets absent. Proloculus medium-sized, spherical, with a diameter of 200 µm. Axial length of shell 0.75-1.5 mm, equatorial diameter 0.65-1.2 mm, elongation index about 1.

Remarks. The few specimens recorded here possess a relatively large proloculus.

Stratigraphic range. Silvestri (1939) established the species from sediments of southern Somalia. Hottinger (1960) dubitatively referred the species to the Lower Ilerdian.

Occurrence in the Trentinara Formation: Capaccio Vecchio (sample BA 1905).

Genus *Alveolina* d'Orbigny, 1826

Alveolina ellipsoidalis Schwager, 1883
Pl. 1, figs 1-3

1883 *Alveolina ellipsoidalis* Schwager, pl. 25, figs. 1-2.
1960 *A. ellipsoidalis* - Hottinger, p. 64, text figs. 20c, 33a, b, pl. 2, figs. 1-8; with synonymy.
1964 *A. ellipsoidalis* - Devoto, pl. 2, fig. 2.
1974 *A.* (*Alveolina*) *ellipsoidalis* - Hottinger, p. 41, pl. 33, figs. 1-7.
1977 *A. ellipsoidalis* - Drobne, pl. 1, figs. 1-3.
1998 *A. ellipsoidalis* - Accordi, Carbone & Pignatti, pl. 18, fig. 1.

Description. Test oval, in axial outline with rounded poles, tightly coiled. Basal layer very thin, thickening only gradually in axial direction. Growth stages indistinct. Spherical megalosphere with a diameter of 250 µm. Elongation index of 1.5 in megalospheric specimens. 8-12 whorls. Axial length 3.6 mm, equatorial diameter 2.6 mm. Small-sized chamberlets, numerous, rounded in sections of the early 5 whorls, larger and oval in the subsequent whorls; chamberlet size increases with growth. In the last whorl, the chamberlets are more closely spaced than in the previous one. At a radius of 1 mm there are 7-8 chamberlets per mm. Intercalary chamberlets very few.

Remarks. One particularly small-sized specimen, described here as *Alveolina* aff. *ellipsoidalis*, (Pl.1, fig. 6) shows a spherical megalosphere with a diameter of only 190 µm but an axial length of 1.5 mm and equatorial diameter of 1 mm (taken at the seventh whorl).

Bio-chronozone. This species represents an index species of the bio-chronozone SBZ 6, *A. ellipsoidalis* zone (Ilerdian, Lower Ypresian, Lower Eocene).

Occurrence in the Trentinara Formation. Capaccio Vecchio (sample BA 1905); Castelcivita (sample BA 1563).

Alveolina aff. **varians** Hottinger, 1960
Pl. 1, figs 7-9

Description. Test oval in axial outline, moderately elongated, with rounded poles. Juvenile stage formed of 2-4 subspherical, tightly coiled whorls with a thin basal layer, followed by a moderately elongated adult stage with basal layer of irregular thickness. Chamberlets large and circular in axial section of early whorls, becoming distinctly oval in the adult growth stage. Adult growth stages irregular in all test characters. Spherical proloculus with a diameter of 300-400 μm. Axial length 3-5 mm, equatorial diameter 2-3 mm. Elongation index 1.7. At a radius of 1 mm there are 5-6 chamberlets per mm.

Remarks. *Alveolina* aff. *varians* differs from *A. varians* s. *str.* in having a larger proloculus (140-300 μm in *Alveolina varians* s. *str.*). In any case the irregularity of all characters in late growth stages is a distinctive feature.

Bio-chronozone: *Alveolina varians* is known from the bio-chronozone SBZ 5, *A. vredenburgi* zone (Ilerdian, Lower Ypresian, Lower Eocene) of the Pyrenees.

Occurrence in the Trentinara Formation. Capaccio Vecchio (sample BA 1905).

Alveolina cf. **aragonensis** Hottinger, 1960

Pl. 1, fig. 11

Description. Shell outline oval, with rounded poles, slightly truncated. About eight whorls. First three whorls tightly coiled, following whorls with thick basal layer, particularly in the polar region of the test. In the equatorial region the basal layer has the same thickness as the height of the chamberlets. Proloculus spherical, large, 450 μm in diameter. Chamberlets circular and small in axial sections of the first 4 whorls, larger and upright oval in the next four. At a radius of 1 mm there are 7 chamberlets per mm. No supplementary chamberlets in the basal layer, few intercalar chamberlets in outer whorls. Axial length 3.3 mm, equatorial diameter 2.5 mm. Elongation index 1.3.

Remarks. *Alveolina* cf. *aragonensis* differs from *A. aragonensis s. str.* in its larger proloculus size. Synonymy of *A. aragonensis* is given in Hottinger (1960). The species was later figured in Hottinger (1974) and Drobne (1977).

Bio-chronozone. *Alveolina aragonensis* is from SBZ 7; *A.* cf. *aragonensis* occurs in the Trentinara Formation in SBZ 6.

Occurrence in the Trentinara Formation. Capaccio Vecchio (sample BA 1905).

Alveolina decipiens Schwager, 1883

Pl. 1, figs 12, 13

1883 *Alveolina* (*Flosculina*) *decipiens* Schwager, p. 103, pl. 26, fig. 1.

1958 *A.* aff. *subpyrenaica* (Leymerie) - Hottinger, fig. 8d.

1960 *A. decipiens* - Hottinger, p. 123, text figs. 66a-e, 70g, pl. 8, figs. 1-3.

1967 *A. decipiens* - Gohrbandt & Hottinger, p. 700, text figs. 3a-g.

1974 *A.* (*Alveolina*) *decipiens* - Hottinger, p. 66, pl. 97, figs. 1-7.

1977 *A.* (*Alveolina*) *decipiens* - Drobne, p. 35, pl. 5, figs. 20-21, text fig. 17.

Description. *Megalospheric form*. Shell outline ovoidal with rounded poles. Early stage composed of four subspherical tight whorls with thin basal layer; adult stage moderately elongated and with very thick basal layer. Eight whorls. Chamberlets large and circular in the axial section of the early five whorls, then irregular in shape and larger. Few intercalary chamber-

PLATE 2

Fig. 1 - *Alveolina* sp., Castelcivita-Alburni Mt., Trentinara Fm., Ypresian, tangential section, thin section BA 1564.4 x10.

Figs. 2-4 - *Alveolina* spp., Castelcivita-Alburni Mts., Trentinara Fm., Lower Lutetian. Fig. 2 - centered oblique section, thin section BA 1565.4 x10; fig. 3 - centered oblique section, thin section BA 1565.13 x10; fig. 4 - equatorial section, thin section BA 1565.9 x20.

Figs. 5-6 - *Alveolina* cf. *boscii* (Defrance in Bronn, 1825), Trentinara Fm., Lower Lutetian. Fig. 5 - axial section, Castelcivita-Alburni Mts., thin section BA 2531.2 x40; fig. 6 - axial section, Serra Pastorella-Lauria, thin section BA 1704.15 x20.

Fig. 7 - *Alveolina* cf. *croatica* Drobne, 1977, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian, axial section, thin section BA 1704.17 x10.

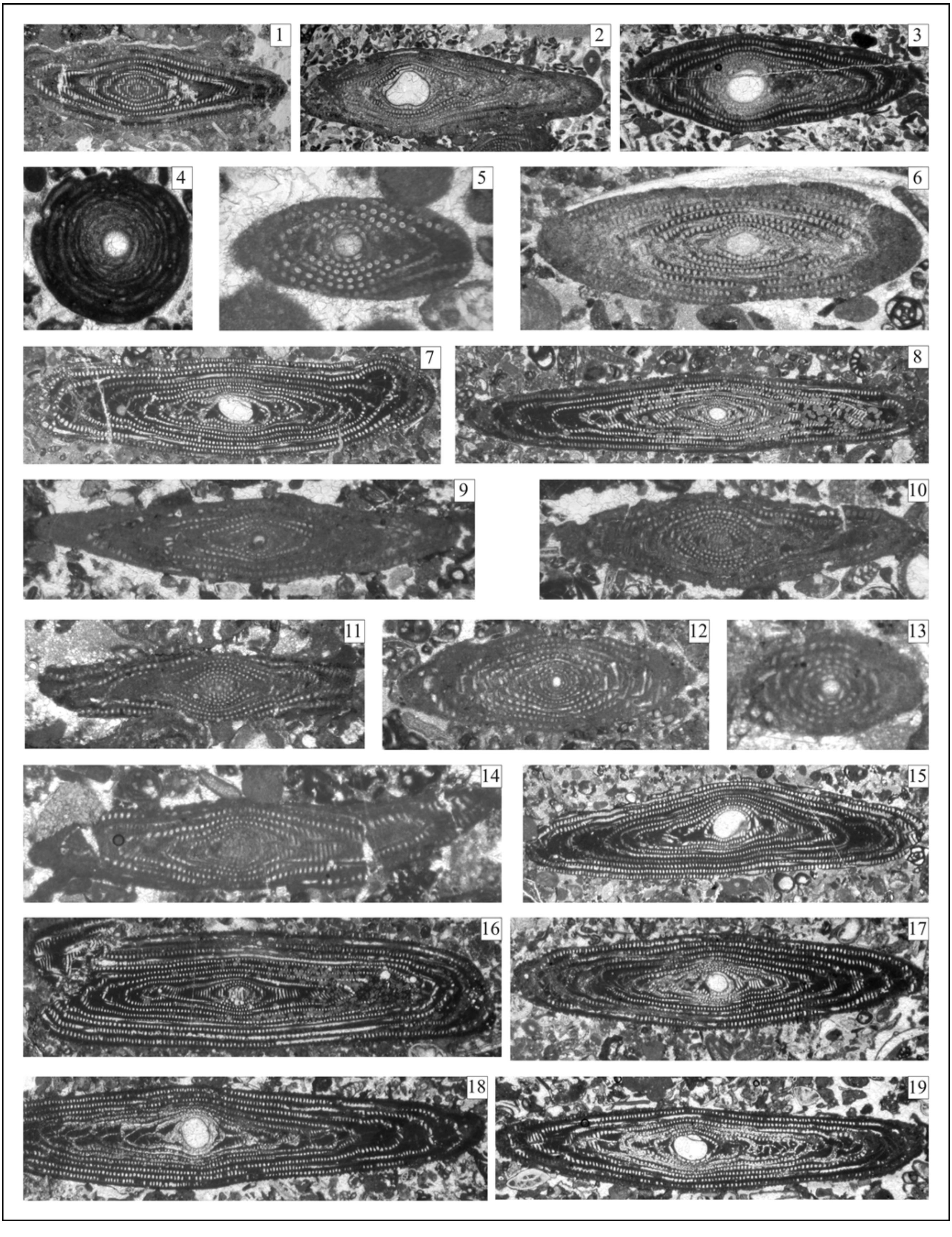
Fig. 8 - *Alveolina* cf. *tenuis* Hottinger, 1960, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian, tangential centered section, thin section BA 1705.20 x10.

Figs. 9-11 - *Glomalveolina delicatissima* (Smout, 1954), Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian. Fig. 9 - subaxial section, thin section BA 1706.19 x20; fig. 10 - oblique section, thin section BA 1706.15 x20; fig. 11 - axial section, thin section BA 1704.6 x20.

Figs. 12-14 - *Glomalveolina* cf. *delicatissima* (Smout, 1954), Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian. Fig. 12 - tangential section, thin section BA 1704.17 x20; fig. 13 - tangential centered section, thin section BA 1704.17 x40; fig. 14 - tangential section, thin section BA 1704.3 x20.

Figs. 15-17 - *Alveolina* cf. *levantina* Hottinger, 1960, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian. Fig. 15 - centered oblique section, thin section BA 1705.12 x10; fig. 16 - tangential section, thin section BA 1705.24 x10; fig. 17 - centered oblique section, thin section BA 1706.18 x10.

Figs. 18-19 - *Alveolina levantina* Hottinger, 1960, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian. Fig. 18 - axial section, thin section BA 1706.32 x10; fig. 19 - centered oblique section, thin section BA 1706.13 x10.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lets in outer whorls. Adult growth stages irregular in all test characters. No supplementary passages in the basal layer. Proloculus spherical with a diameter greater than 250 µm. Axial length 3 mm, equatorial diameter 2 mm. Elongation index close to 1.4.

Microspheric form. Twelve whorls. Subspherical nepiont of 5 tightly regular whorls followed by abruptly elongated thickened whorls in the adult stage. No supplementary passages in the basal layer. Chamberlets small and circular in axial section in the early 5 whorls, becoming larger and oval in the following ones, but only in the polar region. Few intercalary chamberlets in the polar region of the outer whorls. At a radius of 1 mm there are 8 chamberlets per mm. Axial length 5.6 mm, equatorial diameter 2.1 mm. Elongation index 2.75.

Bio-chronozone. SBZ 7 - SBZ 9: *A. moussoulensis* to the lower part of *A. trempina* zone. *A. decipiens* is a particularly variable species difficult to delimit from others; consequently its range is not very well established. The neotype from Egypt is from the SBZ 7 zone (Middle Ilerdian, Lower Ypresian).

Occurrence in the Trentinara Formation. Capaccio Vecchio (sample BA 1905).

Alveolina cf. **subpyrenaica** Leymerie, 1846

Pl. 1, fig. 10

Description. Shell outline oval, slightly elongated with truncated poles. Seven whorls. Early two whorls subspherical, tightly coiled, following three whorls elongated. Last two whorls loosely coiled, with a very thick basal layer both in axial and equatorial regions. Chamberlets circular in section in the early five whorls, distinctly oval with irregular outline and separated by large septula in the last two whorls. At a radius of 1 mm there are 6 chamberlets per mm. Proloculus spherical with a diameter of 300 µm. Axial length 2.7 mm, equatorial diameter 1.8 mm, elongation index 1.6.

Remarks. *Alveolina* cf. *subpyrenaica* differs from *A. subpyrenaica s. str.* in its larger proloculus (225 µm according to Hottinger, 1960).

Alveolina subpyrenaica s. str. is also figured in Hottinger (1974), Dizer (1965), Drobne (1977), Sameeni & Butt (1996; 2004).

Bio-chronozone. In accordance with the zonation scheme of Hottinger (1960), *Alveolina subpyrenaica* is known in the Pyrenees from SBZ 7 but its predecessors exist also in SBZ 6 and even in SBZ 5 (Hottinger, unpubl. observ.). In Slovenia and Istria their occurrence is dated as Lower-Middle Ilerdian (Drobne 1977).

Occurrence in the Trentinara Formation. Capaccio Vecchio (sample BA 1905).

Alveolina cf. **croatica** Drobne, 1977

Pl. 2, fig. 7

Description. Shell subcylindrical with rounded poles. Ten whorls. Proloculus large, ovoid, with a diameter of about 700 µm. Axial length 7.6 mm, equatorial diameter 1.9 mm. Elongation index about 4. Equatorial region shows a tight spire. Early whorls after the megalosphere elongated. Basal layer thin in equatorial region. In the axial region the basal layer becomes thin in the last two whorls. Chamberlets circular in axial section in the early five whorls, oval in the remaining ones. Subrectangular chamberlets only in the last two whorls of the polar region. At a radius of 1 mm there are 9 chamberlets per mm. Few supplementary passages in the basal layer.

Remarks. The attribution to *Alveolina croatica* remains questionable because our specimens lack the subrectangular chamberlets. *A. croatica* differs from *A. hottingeri* in its more rounded poles and less elongated shell and from *A. levantina* in having a less elongated adult stage. For the synonymy of *Alveolina croatica,* see Drobne (1977).

Bio-chronozone. SBZ 12 - SBZ 13, *A. violae* zone (Upper Cuisian) to *A. stipes* zone (Lower Lutetian).

Occurrence in the Trentinara Formation. Serra Pastorella (sample BA 1704).

Alveolina levantina Hottinger, 1960

Pl. 2, figs 18, 19

1960 *Alveolina levantina* Hottinger, p. 154, text fig. 92, pl. 10, fig. 11 (non 13), pl. 13, figs. 10, 11, pl. 14, figs. 5, 7, with synonymy.

1966 *A.* aff. *levantina* - Scotto di Carlo, p. 72, pl. 10, figs. 1-3, pl. 11, figs. 1-4, pl. 12, figs. 1-3.

1974 *A.* (*Alveolina*) *levantina* - Hottinger, p. 47, text figs. 18, 20A, pl. 49, fig. 1, pl. 50, figs. 1, 2, pl. 51, figs. 1-3.

1977 *A.* (*Alveolina*) *levantina* - Drobne, p. 57, text figs. 31 a, 32 a, 46 a-d, pl. 14, figs. 1-6, pl. 15, figs. 1, 2.

1977 *A. levantina* - Drobne et al., p. 74, pl. 4, fig. 5.

1981 *A. levantina* Hottinger - Jámbor-Kness, p. 76, pl. 6, figs. 71-80, pl. 15, figs. 189, 190, 193; pl. 17, fig. 206.

Description. *Megalospheric form*. Shell fusiform, elongated, with rounded poles. Early whorls elongated. Basal layer thin in tightly-coiled equatorial section. Megalosphere slightly ovoid in some specimens, spherical in others, with an axial diameter of 400-600 µm. Elongation index about 5.5 from the seventh to tenth whorl. Axial diameter 8.5-10.4 mm, equatorial diameter 1.5-2 mm. Chamberlets numerous, medium-sized, circular in axial section in the early 5-7 whorls, oval in the following ones. At a radius of 1 mm there are 8-9 chamberlets per mm. Rare intercalary chamberlets and secondary passages in the basal layer.

Some specimens here referred to *Alveolina* cf. *levantina* (Pl. 2, figs. 15-17) show close similarities with

A. levantina, but they exhibit lower elongation index values (about 4) in the first 10 whorls (5-7 in Hottinger, 1960), an axial diameter of 7.5 mm and an equatorial diameter of 1.8 mm.

Microspheric form. One probable microspheric specimen (Pl. 42, fig. 8), also referred to *Alveolina* cf. *levantina*, shows a large subcylindrical shell. At the eleventh whorl the elongation index is 3.7, axial diameter 8 mm and the equatorial diameter 2 mm. Basal layer thick with respect to the height of the chamberlets. Chamberlets very small, numerous and circular in axial section in the first 6 inner whorls, oval and larger in the last 5 whorls. At a radius of 1 mm there are 10 chamberlets per mm. Supplementary chamberlets frequent.

Remarks. Tightly-coiled variants of *Alveolina levantina* with fusiform-elongated shells and supplementary passages have been observed. Others are loosely coiled, with oval outline in the adult stages and a larger proloculus. The elongation index varies from 2.5-3.5 (in the early 7-10 whorls) in Early Eocene tightly-coiled forms, 5-7 in Middle Eocene tightly-coiled forms and 3-4 in Early-Middle Eocene loosely-coiled forms.

Bio-chronozone. The earliest occurrence of *A. levantina* s. l. is from *A. dainelli* zone SBZ 11, (Middle Cuisian), the latest from *A. munieri* zone SBZ 14 (Middle Lutetian). Its commonest occurrence is Upper Cuisian (*A. violae* zone, SBZ 12) to Lower Lutetian (*A. stipes* zone, SBZ 13) (Hottiger 1974).

Occurrence in the Trentinara Formation. Serra Pastorella (samples BA 1705, BA 1706).

Alveolina stipes Hottinger, 1960

Pl. 3, figs 1-10

1909 *Alveolina bulloides* (d'Orbigny) var. *oblonga* n. f. Osimo, pl. 7 (4), figs. 12, 13.

1960 *Alveolina stipes* Hottinger, p. 163, text figs. 8 a-d, 19 e, 21 k, pl. 16, figs. 8, 9, pl. 17, figs. 5-10, pl. 18, fig. 16, with synonymy.

1964 *A. stipes* - Hottinger, Lehmann & Schaub, p. 638, pl. 3.

1974 *A.* (*Alveolina*) *stipes* - Hottinger, p. 44, text figs. 15, 18, pl. 43, figs. 1-6.

1977 *A.* (*Alveolina*) *stipes* - Drobne, p. 69, pl. 21, figs. 2-4.

1977 *A. stipes* - Drobne et al., p. 77, pl. 6, figs. 1, 2.

1981 *A. stipes* - Jámbor-Kness, p. 82, pl. 8, figs. 103-107, pl. 17, fig. 204, pl. 19, figs. 210, 211, pl. 20, fig. 212.

Description. Shell elongated, subcylindrical, large-sized, with rounded poles. Spire in equatorial section tightly coiled and basal layer very thin. Seven to eleven elongated whorls; the second whorl after the megalosphere is already elongated. The elongation index reaches ca. 5.7 after ten elongated whorls. Axial length 10-15 mm, equatorial diameter 1.8-2.6 mm. Megalosphere with a circular outline in axial section, 450-600 µm in diameter. Chamberlets circular in axial sections. At a radius of 1 mm there are 7-9 chamberlets per mm. Numerous secondary passages in the basal layer.

Remarks. *Alveolina stipes* differs from *A. levantina* in its numerous secondary passages in the basal layer and from *A. tenuis* in its larger test. *Alveolina stipes* and *A. tenuis* are characterized by a subcylindrical megalospheric shell, while *A. levantina* shows a fusiform megalospheric shell. However, the difference between cylindrical and fusiform shell is often difficult to recognize in oblique axial sections.

The specimens assigned here to *Alveolina* cf. *stipes* (Pl. 3, fig. 11) show a proloculus with a diameter of 700 µm, larger than the range (320-500 µm) given in Hottinger (1960).

Bio-chronozone. SBZ 13 *A. stipes* zone (Lower Lutetian).

Occurrence in the Trentinara Formation. Serra Pastorella (samples BA 1704-BA 1706).

Alveolina cf. **boscii** (Defrance in Bronn, 1825)

Pl. 2, figs 5, 6

Description. Shell fusiform, with slightly pointed poles and minute structure. Megalosphere spherical to slightly ovoid with an axial diameter of 125-350 µm. Elongation index 2.6-3.5. Spire extremely tight in equatorial section. Chamberlets numerous, medium-sized, circular in axial section. At a radius of 1 mm there are 9-12 chamberlets per mm. No intercalary chamberlets and supplementary passages in the basal layer.

Remarks. The present taxon differs from the typical form in its larger proloculus and greater elongation index. It differs from *G. delicatissima* in the larger size of the chamberlets and a less elongated test. No supplementary passages are present in the basal layer.

The synonymy of *A. boscii* is given in Hottinger (1960). The species was later figured by Adams (1962), Hottinger et al. (1964), Hottinger (1974), Drobne (1977), Drobne et al. (1977) and Jámbor-Kness (1981).

Remarks. *Alveolina boscii*, type species of the genus *Alveolina* d'Orbigny, was originally described from the Lower Lutetian of the Paris Basin, where it occurs as "San partner" of *Alveolina stipes* in an odd association (Hottinger 1999). The Paris Basin must be considered as marginal with respect to the Mediterranean Neotethys and also to the Aquitaine Basin in southern France. Its faunas of low diversity tend to produce few but exceptionally variable species. A similar situation may be observed today in the Red Sea, marginal to the eastern Indian Ocean, where *Borelis schlumbergeri* is alone in representing the alveolinids and has a particularly broad intraspecific variation. Thus, *A. boscii*, of similar size and shape relationships, needs revision as soon as enough material for study has accumulated. However, *A. boscii* represents in fact a whole phyletic lineage ranging at least from the Cuisian (Ypresian) to the Upper Lutetian.

Occurrence in the Trentinara Formation. Castelcivita (sample BA 2531), Serra Pastorella (sample BA 1704).

Alveolina cf. **tenuis** Hottinger, 1960
Pl. 2, fig. 8

Description. Elongated, subcylindrical shell of large size with rounded poles. 8 whorls. The second whorl after the megalosphere is already elongated. Elongation index 6, axial length 4.6 mm, equatorial diameter 0.7 mm (these biometrical values may be underestimated because of slightly oblique axial sections). Very small and numerous circular chamberlets in axial section, thin basal layer and tightly coiled spiral in equatorial section. At a radius of 1 mm there are 10 chamberlets per mm axial length.

Remarks. This taxon differs from *A. stipes* in its tighter equatorial spire and its smaller and more numerous chamberlets. The synonymy of *A. tenuis* is given in Hottinger (1960). *A. tenuis* was later figured by Dizer (1965), Hottinger (1974) and Drobne (1977).

Bio-chronozone. SBZ 13-SBZ 14 *A. stipes* zone (Lower Lutetian) to *A. munieri* zone (Lower-Middle Lutetian) according to Serra-Kiel et al. (1998).

Occurrence in the Trentinara Formation. Serra Pastorella (sample BA 1705).

Alveolina hottingeri Drobne, 1977
Pl. 3, figs 12, 13

1950 *A.* cfr. *frumentiformis* (Schwager) - Azzaroli, p. 113, pl. 2, fig. 5.

1977 *Alveolina hottingeri* Drobne, p. 57, pl. 14, figs. 7, 8, pl. 15, fig. 3, pl. 19, fig. 7; text figs. 31a, 32b, c, 46e, f.

Description. Test fusiform, elongated, of large size with rounded to pointed poles. Elongation starts in the first whorl following the megalosphere. Basal layer thin in the equatorial plane, thickening in the columellar region of the shell. Chamberlets rounded in axial section of the shell and very numerous, only in the last 2-3 whorls do they show an oval-subrectangular section. Their size increases during growth. At a radius of 1 mm there are 7 chamberlets per mm. Intercalary chamberlets absent. Proloculus ovoid, large, with a diameter of 650-750 μm. Elongation index 5-5.8 after ten elongated whorls. At an axial length of about 10 mm the equatorial diameter is 2 mm. Few supplementary passages in the polar region.

Remarks. The large proloculus and all other characters mentioned allow us to refer our specimens to *A. hottingeri*. However, the proloculus is larger than in Drobne's (1977) original description (400-650 μm). *A. hottingeri* differs from *A. levantina* in its larger size and more numerous supplementary passages in the basal layer forming the polar columella.

Bio-chronozone. SBZ 13 *A. stipes* zone (Lower Lutetian).

Occurrence in the Trentinara Formation. Serra Pastorella (sample BA 1704).

Alveolina spp.
Pl. 2, figs 1-4

Description. Test fusiform, elongated with rounded poles, basal layer thin and chamberlets rounded in axial section.

Remarks. The specimens do not permit a specific attribution, but the large size of the proloculus (500-780 μm), the elongate fusiform test and the great number of chamberlets (15 per 0.5 mm) are typical for Upper Cuisian to Lutetian alveolinids.

Occurrence in the Trentinara Formation. Castelcivita (samples BA1564; BA 1565).

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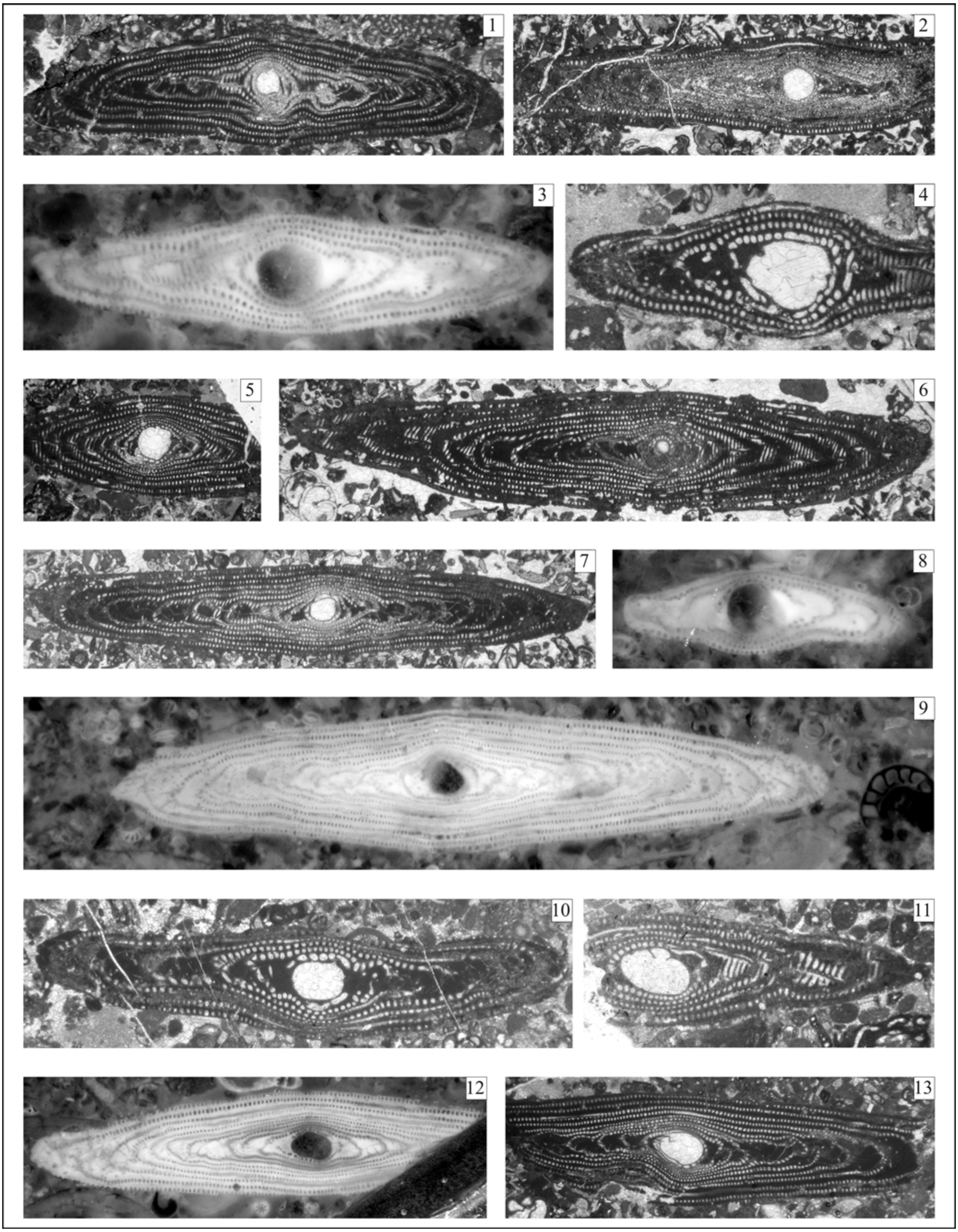
PLATE 3

Figs. 1-10 - *Alveolina stipes* Hottinger, 1960, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian. Fig. 1 - not quite centered transverse section parallel to shell axis, thin section BA 1704.27 x10; fig. 2 - subaxial section, thin section BA 1706.16 x10; fig. 3 - centered oblique section of inner whorls, thin section BA 1704.19 x20; fig. 4 - centered oblique section, thin section BA 1705.17 x20; fig. 5 - centered oblique section, thin section BA 1704.21 x10; fig. 6 - oblique section, thin section BA 1706.20 x10; fig. 7 - axial section, thin section BA 1706.1 x10; fig. 8 - centered oblique section close to axial, inner whorls only, thin section BA 1704.19 x20; fig. 9 - centered oblique section, thin section BA 1704.19 x10; fig. 10 - subaxial section of inner whorls, thin section BA 1705.8 x20.

Fig. 11 - *Alveolina* cf. *stipes* Hottinger, 1960, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian, centered oblique section of inner whorls, thin section BA 1705.9 x20.

Figs. 12-13 - *Alveolina hottingeri* Drobne, 1977, Serra Pastorella-Lauria, Trentinara Fm., Lower Lutetian. Fig. 12 - axial section, thin section BA 1704.28 x10; fig. 13 - axial section, thin section BA 1704.23 x10.

Figs. 3, 8, 9, 12- incident light; all others: transmitted light.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