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DINOFLAGELLATE CYSTS AND CALCAREOUS NANNOFOSSILS FROM THE UPPER CRETACEOUS SARACENO FORMATION (CALABRIA, ITALY): IMPLICATIONS ABOUT THE HISTORY OF THE LIGURIDE COMPLEX

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Abstract. Organic-walled dinoflagellate cysts and calcareous nannofossils recovered from the turbidites of the Saraceno Formation outcropping in the type area (north-eastern Calabria, Italy) are presented. They provide new information about the age of the Saraceno Formation, hence a constraint to reconstruct the timing of deformations that affected the Liguride Complex.

The distribution of dinoflagellate cysts and calcareous nannofossils in the succession studied is compared with biostratigraphies available for the Upper Cretaceous. Accordingly, the age of the lowermost part of the Fiumara Saraceno section is latest Albian to Turonian, whereas the upper part of the section is dated as late Campanian-?earliest Maastrichtian. A hiatus spanning the Coniacian, the Santonian and most of the Campanian is inferred between these two successions, which are also distinguished by the presence and absence of flint respectively. Consistencies and discrepancies of the present data with biostratigraphical information previously published for the Saraceno Formation, are discussed.

Riassunto. Vengono illustrate le associazioni a cisti di dinoflagellati e a nannofossili calcarei rinvenute nelle torbiditi della Formazione del Saraceno campionata nell'area tipo (Calabria nord-orientale). Esse forniscono nuovi dati biostratigrafici utili per definire l'età della successione e per sviluppare considerazioni sulla storia deformativa subita dalle unità appartenenti al Complesso Liguride. Il confronto con le biostratigrafie a dinoflagellati e a nannofossili calcarei pubblicate per il Cretaceo superiore, consente di attribuire la parte più bassa della sezione di Fiumara Saraceno all'Albiano sommitale-Turoniano e la restante parte al Campaniano superiore-?Maastrichtiano basale. Tra queste due porzioni, distinguibili su base litologica anche per la presenza e per l'assenza di selce rispettivamente, s'ipotizza uno hiatus comprendente il Coniaciano, il Santoniano e larga parte del Campaniano. Su queste basi vengono discusse le incongruenze biostratigrafiche che si riscontrano nella letteratura riguardante la Formazione del Saraceno.

Introduction

The Saraceno Formation is a turbidite unit outcropping in the southern Apennines (Italy) at the Calabro-Lucano border (Figs.1, 2). Since the Saraceno Formation was named by Selli (1962), the age of this unit has been debated, due to the scarcity of age-diagnostic fossils. According to Selli (1962), the age of the Saraceno Formation is Turonian to early Eocene, whereas according to Pavan & Pirini (1963) it spans the late Early-Late Cretaceous. Vezzani (1968), in the most comprehensive study of the Saraceno Formation, dated this unit as late Albian to early Paleocene on the basis of foraminiferal assemblages recorded both in thin sections and in washed samples. Ogniben (1969) accepted the age proposed by Vezzani (1968) and grouped the Saraceno Formation together with the underlying Crete Nere Formation and the unconformably overlying Albidona Formation in the Liguride Complex (Fig. 3). By contrast, De Blasio et al. (1978) assigned a mid-late Eocene age to the Saraceno Formation outcropping at the Fiumara Saraceno section, on the basis of calcareous nannofossil and foraminiferal assemblages including Tertiary species.

The aim of this paper is to document, for the first time, the assemblages of marine organic-walled dinoflagellate cysts recovered from the Saraceno Formation in its type area. Their stratigraphical distribution is interpreted and discussed, together with new calcareous nannofossil data, in order to better constrain the age of this unit.

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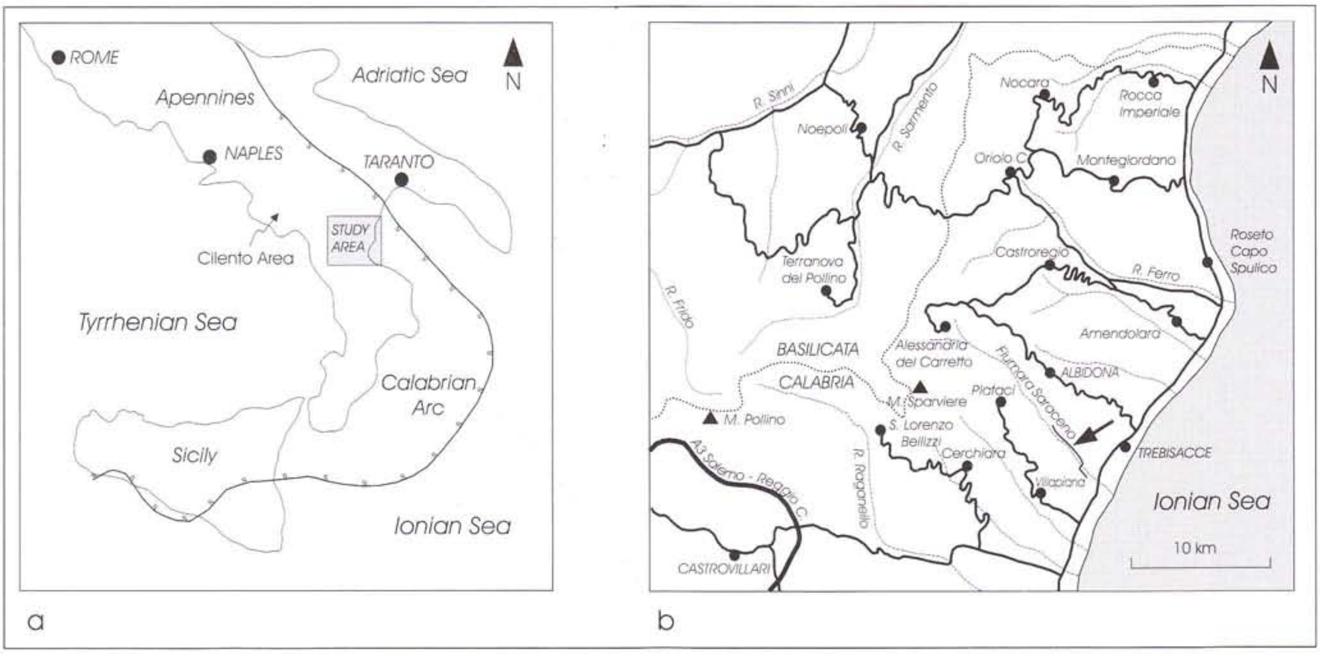


Fig. 1a, b - Location map and road map of the study area.

Geological setting

The geology of the area studied (Fig. 2) comprises three stacked thrust sheets, which represent stratigraphical successions originally deposited in different paleogeographical domains (Ogniben 1969). These three nappes are:
- the Monte Pollino unit, containing a Mesozoic to Paleogene carbonate platform and an Early Neogene terrigenous clastic cover;
- the "Sicilide Complex" or "Argille Scagliose" nappe, a texturally chaotic melange consisting of a matrix of Cretaceous chaotic shales ("Argille Scagliose Varicolori") containing large, strongly folded slabs of Paleogene calciclastic and volcaniclastic turbidites;

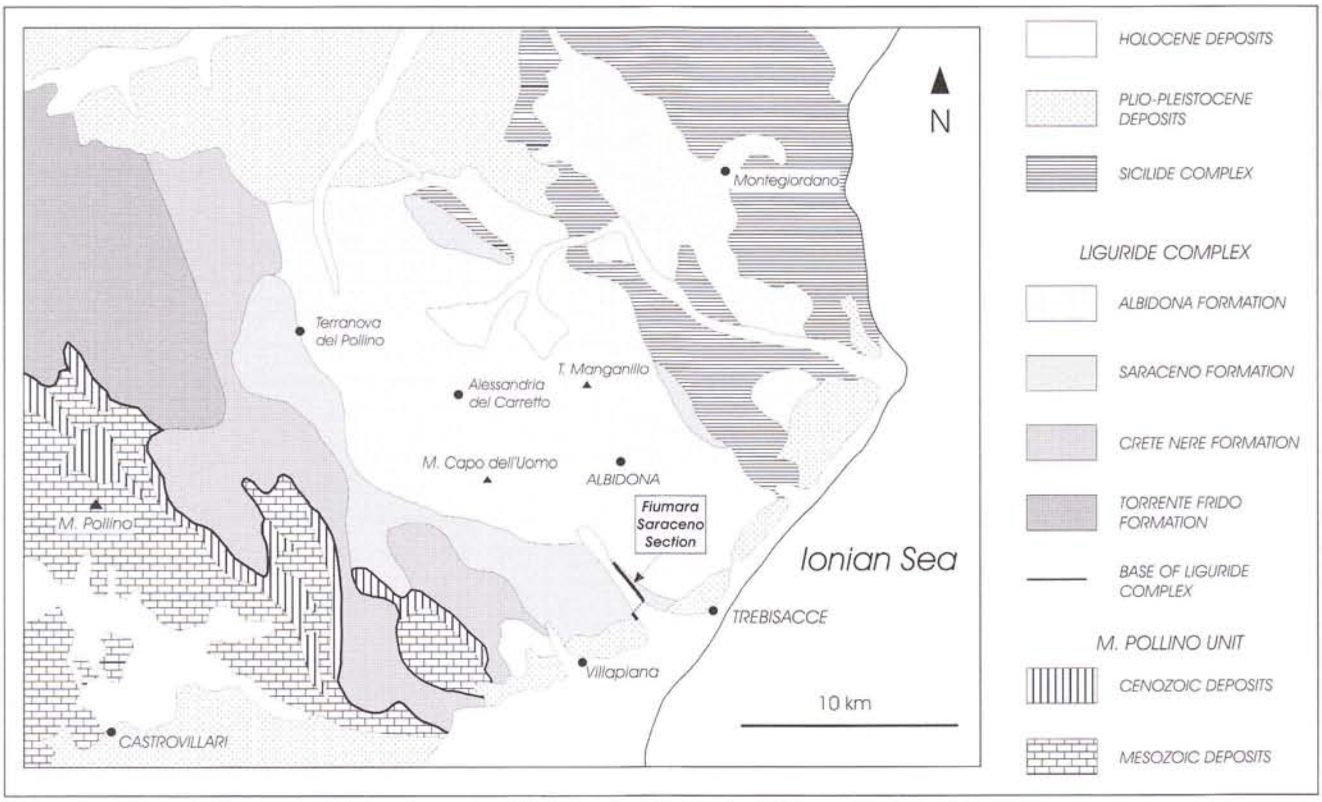


Fig. 2 - Geological sketch map of the study area modified after Baruffini et al. (2000).

- the "Liguride Complex" (Fig. 3), a Mesozoic to Paleogene deep-water succession interpreted as a detached sedimentary cover of oceanic crust (Knott 1987); from bottom to top, it includes slabs of Late Jurassic-Early Cretaceous pillow-lavas, radiolarian cherts, jaspers, cherty limestones, an Early Cretaceous anchimetamorphic turbidite suite (Torrente Frido–Crete Nere Formation) and Late Cretaceous to Paleogene mixed siliciclastic and calciclastic turbidite successions (Saraceno Formation and Albidona Formation).

Different interpretations have been proposed for the relationships between the Sicilide and Liguride Complexes. Ogniben (1969) suggested that the Liguride units are overlain by the Sicilide units along the outer edge of the fold belt. However, Van Dijk et al. (2001) pointed out that both the geometric relationships (i.e. Sicilide over Liguride and the opposite) are evident on the field, and interpreted this situation as associated to Plio-Pleistocene left-lateral strike-slip deformation along the northern edge of the Calabrian Ridge.

Within the Liguride Complex, the Saraceno Formation conformably overlies the Crete Nere Formation and is overlain by the Albidona Formation. Field observations confirm that the Albidona Formation, recently dated as Eocene on the basis of nannofossils and dinoflagellate cysts (Baruffini et al. 2000), rests unconformably on the folded and locally overturned Saraceno Formation, thus bearing the significance of a post-tectonic episutural suite relevant to a deformation phase that affected the older units of the Liguride Complex (i.e. Crete Nere and Saraceno Formations) before the Early Eocene.

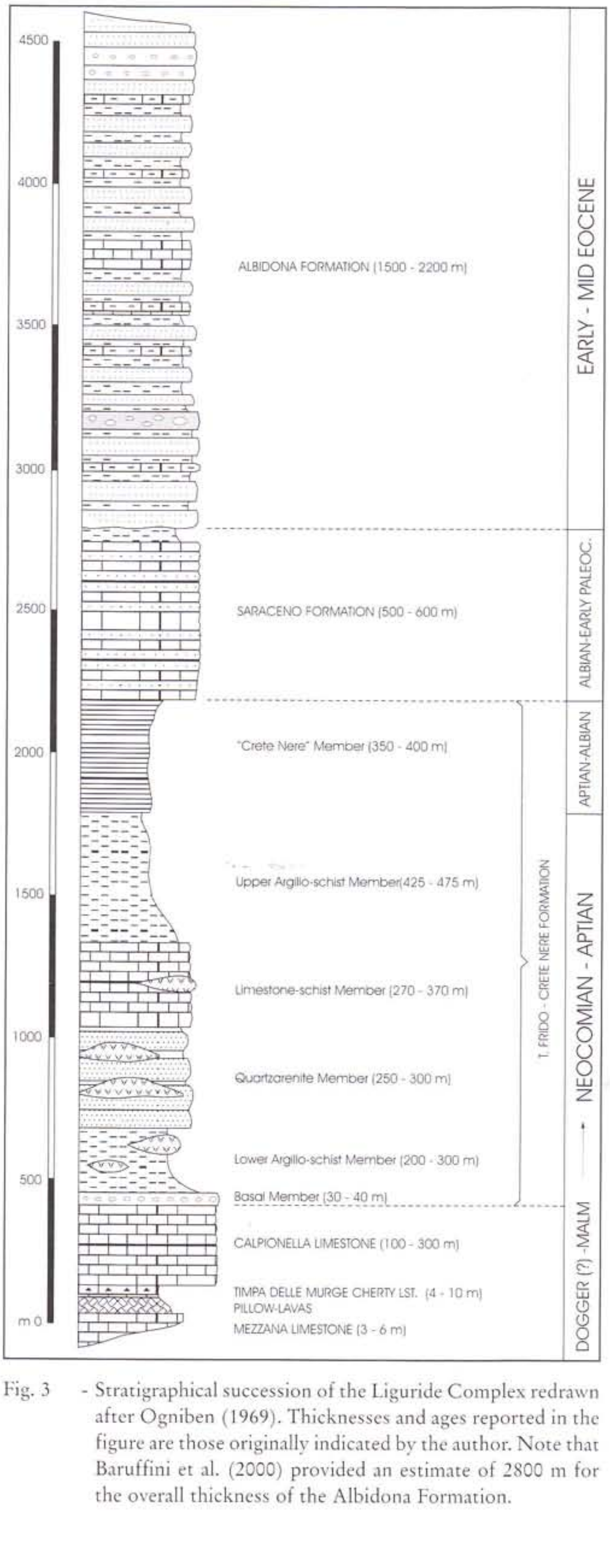
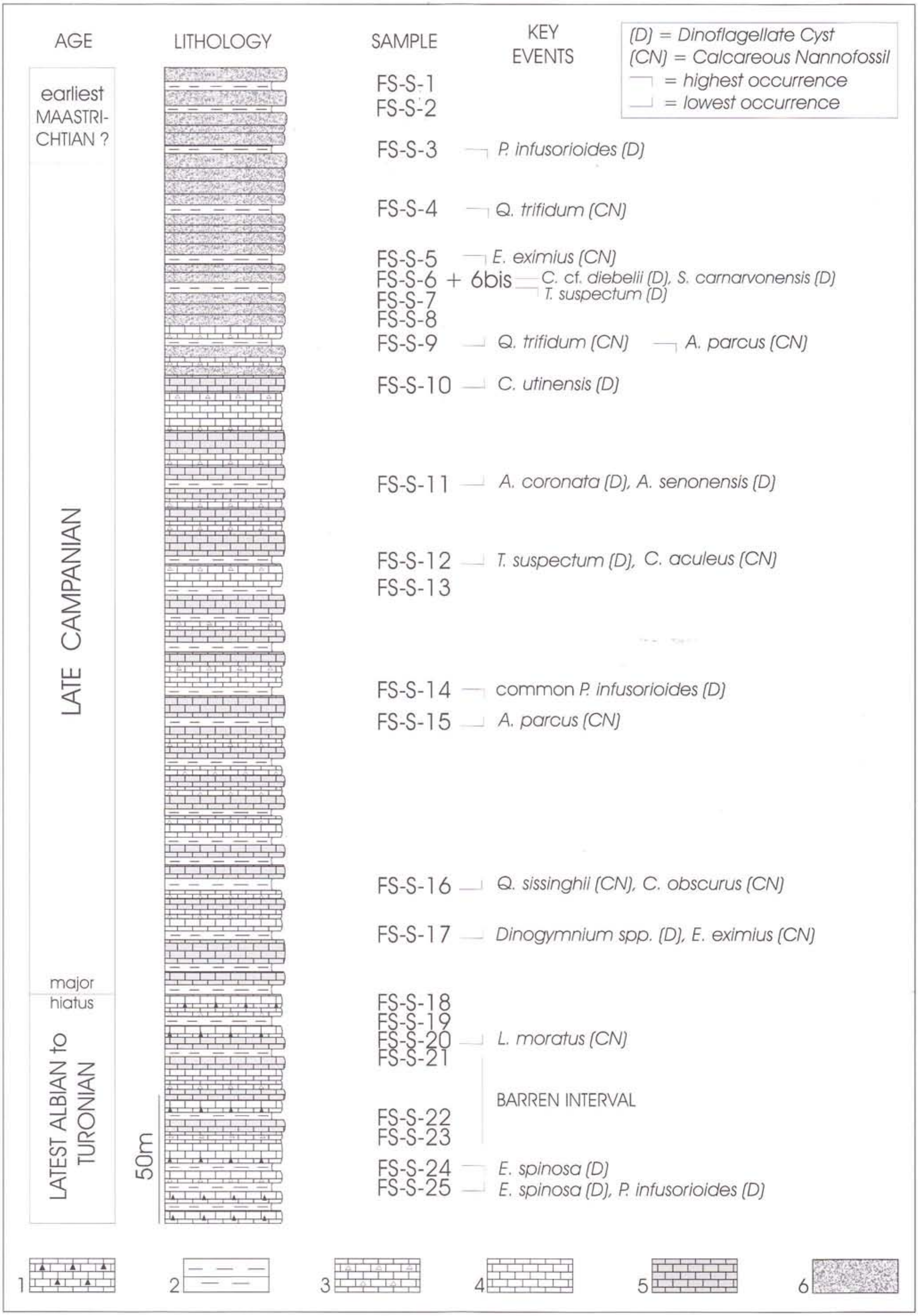


Fig. 3 - Stratigraphical succession of the Liguride Complex redrawn after Ogniben (1969). Thicknesses and ages reported in the figure are those originally indicated by the author. Note that Baruffini et al. (2000) provided an estimate of 2800 m for the overall thickness of the Albidona Formation.

Material

Twenty-six samples (FS-S-1 to 25), collected from a 450 m thick section exposed along the River Saraceno (Fiumara Saraceno) in north-eastern Calabria (Figs. 1, 2) were processed and analysed for palynomorphs and calcareous nannofossils. This stratigraphical section has been previously investigated for petrography and biostratigraphy by De Blasio et al. (1978), but palynology was not used by those authors. The succession consists of regularly bedded turbidites and can be lithologically divided into three main portions. The lowermost one consists of grey calcarenite and microbreccia, interbedded with calcareous sandstone and dark grey shale. It is characterized by the occurrence of dark brown and black flint nodules. The intermediate portion comprises grey calcarenite and calcareous sandstone, interbedded with grey and reddish marlstone and shales. The uppermost portion is composed of brown-yellowish medium to coarse-grained lithic sandstones, interbedded with grey, greenish and red shales. The strata are overturned and dip to the South-East. Since the lithostratigraphical column of De Blasio et al. (1978) was retained as sufficiently detailed for the present purposes, it was used during our field work for the stratigraphical location of samples (Fig. 4). All the samples analysed in this study were collected from grey, green and black shale beds.


AGE
LITHOLOGY
SAMPLE
KEY EVENTS
(D) = Dinoflagellate Cyst
(CN) = Calcareous Nannofossil
= highest occurrence
= lowest occurrence
earliest MAASTRICHTIAN ?
LATE CAMPANIAN
major hiatus
LATEST ALBIAN to TURONIAN
50m
FS-S-1
FS-S-2
FS-S-3 P. infusorioides (D)
FS-S-4 Q. trifidum (CN)
FS-S-5 E. eximius (CN)
FS-S-6 + 6bis C. cf. diebelii (D), S. carnarvonensis (D)
T. suspectum (D)
FS-S-7
FS-S-8
FS-S-9 Q. trifidum (CN) A. parcus (CN)
FS-S-10 C. utinensis (D)
FS-S-11 A. coronata (D), A. senonensis (D)
FS-S-12 T. suspectum (D), C. aculeus (CN)
FS-S-13
FS-S-14 common P. infusorioides (D)
FS-S-15 A. parcus (CN)
FS-S-16 Q. sissinghii (CN), C. obscurus (CN)
FS-S-17 Dinogymnium spp. (D), E. eximius (CN)
FS-S-18
FS-S-19
FS-S-20 L. moratus (CN)
FS-S-21
BARREN INTERVAL
FS-S-22
FS-S-23
FS-S-24 E. spinosa (D)
FS-S-25 E. spinosa (D), P. infusorioides (D)
1
2
3
4
5
6

Methods

Palynology. The palynological processing technique involved cold chemical treatment of 20 g of sediment with HCl (38%) to remove the calcareous fraction and with HF (40%) to remove silicates, sieving with 250 μm and 15 μm meshes, heavy liquid separation with $ZnCl_2$ and centrifuging to concentrate the residues. Two slides were prepared for each sample using residue greater than 15 μm and Norland adhesive as a mounting medium. No oxidation was required. One slide per sample was entirely counted in order to obtain the abundances of taxa, whereas the second slide was examined to check for the presence of species not detected during the count. The analytical results are fully tabulated in the occurrence chart (Fig. 5). The samples were treated non-quantitatively, i.e. cysts numbers per gram of sediment and percentages were not calculated as the numbers of cysts recovered were limited. Therefore, within the scope of the present study, palynological assemblages will be qualitatively discussed pertaining to their taxonomic composition and biostratigraphical significance.

Light photomicrographs were taken using a Zeiss Axioplan microscope and interference-contrast illumination (Pls. 1-3). For taxonomic quotations see Williams et al. (1998).

Calcareous nannoplankton. Qualitative and semiquantitative calcareous nannofossil analyses were performed on all of the twenty-six samples. They were mechanically disaggregated and smeared onto slides without applying concentration techniques in order to retain the original nannofloral composition. Smear slides were permanently mounted using Norland optical adhesive. Analyses were carried out with a Zeiss Axioplan light polarising microscope at 1000x and 1250x magnification (Pl. 4). The analytical results are tabulated in the occurrence chart (Fig. 6). The total abundance of nannofossils was estimated as follows: A: >30 specimens/field; F:10-30 specimens/field; C:2-9 specimens /field; S:1 specimen/field; R:<1 specimen/field. For the absolute abundance of individual taxa, the following codes were adopted: a:>1 specimen/field; c:1 specimen/1-10 fields; s:1 specimen/>10 fields; r: some specimens/100 fields; rr: only one specimen during the analysis.

All the palynological and nannofossil slides examined in this study are housed in the collections of the Stratigraphical Department of ENI S.p.A., E. & P. Division, San Donato Milanese, Italy.

Dinoflagellate cyst stratigraphy of the Fiumara Saraceno section

Although some land-derived palynomorphs (i.e. pollen and spores) were recorded, this study concentrates on marine dinoflagellate cysts as they dominate the palynological assemblages and provide new data to assess the age of the Saraceno Formation. Fifty-five dinoflagellate cyst taxa have been identified and are listed alphabetically by genus in the Appendix. The quantitative composition of the assemblages is tabulated in the occurrence chart (Fig. 5). In general, the recovery ranges from poor to fair and dinoflagellate cyst assemblages exhibit low diversity. However, good recovery and relatively high species diversity (> 10 taxa) were observed in two samples (FS-S-11 and FS-S-14). Preservation of dinoflagellate cysts is poor to moderate.

To determine the age of the strata based on the distribution of fossils, species ranges must be compared with those of other studies. The main references used in this paper for the stratigraphical interpretation of the dinoflagellate cyst distribution in the Saraceno Formation are:

(a) the ammonite-calibrated dinoflagellate cyst events presented by Davey & Verdier (1973) for some Albian sections in France;
(b) the dinoflagellate cyst events reported by Schiøler & Wilson (2001) and Antonescu et al. (2001) from the Campanian/Maastrichtian GSSP at Tercis les Bains (south-western France);
(c) the dinoflagellate cyst zonation established by Kirsch (1991) for the Upper Cretaceous of the Sub-Boreal Helvetic and Ultrahelvetic Domains (southern Germany);
(d) the dinoflagellate zonation established by Roncaglia & Corradini (1997a, b) for the Campanian-Maastrichtian of the northern Apeninnes (Italy).

In addition, the oldest and youngest occurrences of Stover et al. (1996) and Williams, Brinkhuis et al. (submitted) are considered.

The lowermost part of the Fiumara Saraceno section is represented by two fossiliferous samples (FS-S-25 and FS-S-24) followed by a barren interval (Fig. 4). Samples FS-S-25 and FS-S-24 were collected from the south-western (right) bank of the river and yielded moderately diverse Cretaceous dinoflagellate cyst assemblages including common *Epelidosphaeridia spinosa* (Pl. 3, figs. 10-11) and *Palaeohystrichophora infusorioides* (Pl. 3, figs. 12-15). The lowest occurrences of both these species are known from the Upper Albian (Williams et al. submitted) and were calibrated in the uppermost Albian of the Tethyan Realm in ammonite-controlled sections from south-eastern France (Davey & Verdier 1973). At low to mid paleolatitudes of the Northern Hemisphere, *E. spinosa* disappeared in the earliest Turonian (Williams et al. submitted). Hence the age of these samples is between the latest Albian and earliest Turonian.

Samples FS-S-23, 22, 21 and 18 proved to be barren of palynomorphs and organic residues are mostly composed of black debris (i.e. fusinites and woody fragments) with a small amount of cuticles. Upwards, *P. infusorioides* exhibits a continuous record throughout the mid part of the Fiumara Saraceno section, with a maximum absolute abundance between samples FS-S-16 and FS-S-14 followed by a decrease from sample FS-S-13 upwards. The highest occurrence of *P. infusorioides* has been reported worldwide in the Lower Maastrichtian (Stover et al. 1996; Williams et al. submitted) but in the Tethyan and Sub-Boreal Provinces it is probably older, as it was

Fig. 4 - Schematic representation of the Fiumara Saraceno section with lithological column, sample position, key biostratigraphical events and corresponding ages. 1) calcarenite with flint nodules; 2) shale; 3) calcareous microbreccia; 4) calcarenite; 5) calcareous sandstone; 6) lithic sandstone. Lithological sketch modified from De Blasio et al. (1978).

PLATE 1

Dinoflagellate cysts from the Saraceno Formation at the Fiumara Saraceno section.

For all magnifications reference is made to the scale bar = 40 μm.

Fig. 1 - *Florentinia aculeata*, sample FS-S-11, slide A18499. Fig. 2 - *Florentinia radiculata*, sample FS-S-11, slide A18500. Fig. 3 - *Florentinia laciniata*, sample FS-S-14, slide A20319. Fig. 4 - *Coronifera oceanica*, sample FS-S-11, slide A18500. Figs. 5, 6 - *Hystrichosphaeridium salpingophorum*, sample FS-S-4, slide A20867, high focus and low focus. Figs. 7, 8 - *Hystrichosphaeridium salpingophorum*, sample FS-S-11, slide A18500, low focus and high focus. Fig. 9 - *Hystrichosphaeridium recurvatum*, sample FS-S-11, slide A18500. Fig. 10 - *Exochosphaeridium muelleri*, sample FS-S-10, slide A20876. Figs. 11, 12 - *Exochosphaeridium muelleri*, sample FS-S-4, slide A20868, low and high focus. Figs. 13, 14 - *Canningia senonica*, sample FS-S-11, slide A18500, same specimen in high focus and low focus. Fig. 15 - *Spiniferites ramosus granosus*, sample FS-S-3, slide A20866. Fig. 16 - *Spiniferites ramosus* group, sample FS-S-4, slide A20868. Fig. 17 - *Pterodinium cornutum*, sample FS-S-25, slide A22651. Fig. 18 - *Pterodinium cingulatum cingulatum*, sample FS-S-8, slide A20873. Fig. 19 - *Pterodinium* sp. B sensu Schiøler & Wilson 1993, sample FS-S-4, slide A20867. Fig. 20 - *Pterodinium* sp. B sensu Schiøler & Wilson 1993, sample FS-S-6bis, slide A21506. Figs. 21, 22 - *Cordosphaeridium varians*, both specimens from sample FS-S-6, slide A21505. Figs. 23, 24 - *Xenascus ceratioides* group, both specimens from sample FS-S-11, slide A18499.

PLATE 2

Dinoflagellate cysts from the Saraceno Formation at the Fiumara Saraceno section.

For all magnifications reference is made to the scale bar = 40 μm.

Fig. 1 - *Glaphyrocysta expansa*, sample FS-S-11, slide A18499. Fig. 2 - *Riculacysta? pala*, sample FS-S-11, slide A18499. Fig. 3 - *Dinogymnium* sp. (extralarge), sample FS-S-14, slide A20318. Fig. 4 - *Areoligera volata*, sample FS-S-11, slide A18499. Fig. 5 - *Cribroperidinium wilsonii*, sample FS-S-6, slide A21505. Fig. 6 - *Areoligera volata*, sample FS-S-11, slide A18499. Fig. 7 - *Areoligera volata*, sample FS-S-2, slide A20864. Fig. 8 - *Glaphyrocysta* cf. *wilsonii*, sample FS-S-11, slide A18499. Fig. 9 - *Areoligera* spp., sample FS-S-11, slide A18499. Figs.10,11 - *Areoligera* gr. *coronata*, sample FS-S-11, slide A18500. Fig. 12 - *Areoligera* gr. *senonensis*, sample FS-S-11, slide A18499. Fig. 13 - *Palynodinium biculleus*, sample FS-S-9, slide A18498. Fig. 14 - *Dinogymnium acuminatum*, sample FS-S-14, slide A20318. Fig. 15 - *Dinogymnium* cf. *albertii*, sample FS-S-14, slide A20318. Fig. 16 - *Dinogymnium albertii*, sample FS-S-17, slide A18505. Fig. 17 - *Dinogymnium acuminatum*, sample FS-S-13, slide A18501.

PLATE 3

Dinoflagellate cysts from the Saraceno Formation at the Fiumara Saraceno section.

For all magnifications reference is made to the scale bar = 40 μm.

Figs. 1, 3, 5 - *Samlandia carnarvonensis*, sample FS-S-6bis, slide A21507. Fig. 2 - *Samlandia carnarvonensis*, sample FS-S-6, slide A20869. Note the single-plate precingular archeopyle and opeculum still in place. Fig. 4 - *Samlandia carnarvonensis*, sample FS-S-6, slide A20870. Figs. 6, 7 - *Odontochitina streeli*, same specimen in high and low focus, sample FS-S-13, slide A18502. This species is distinguished by the striate ornamentation of the periphragm indicating a tabulation. Arrows indicate the original positions of broken horns. Fig. 8 - *Trithyrodinium suspectum*, sample FS-S-6bis, slide A21507. Fig. 9 - *Trithyrodinium suspectum*, sample FS-S-8, slide A20873. Figs. 10, 11 - *Epelidosphaeridia spinosa*, sample FS-S-25, slide A22651. Fig. 12 - *Palaeohystrichophora infusorioides*, sample FS-S-14, slide A20318. Fig. 13 - *Palaeohystrichophora infusorioides*, sample FS-S-12, slide A20316. Fig. 14 - *Palaeohystrichophora infusorioides*, sample FS-S-3, slide A20866. Fig. 15 - *Palaeohystrichophora infusorioides*, sample FS-S-16, slide A18503. Fig. 16 - *Palaeohystrichophora infusorioides*, sample FS-S-11, slide A18500. Fig. 17 - *Spinidinium echinoideum*, sample FS-S-17, slide A18505. Fig. 18 - *Spinidinium echinoideum*, sample FS-S-13, slide A18501. Fig. 19 - *Subtilisphaera cheit*, sample FS-S-11, slide A18499. Fig. 20 - *Subtilisphaera* cf. *cinctuta*, sample FS-S-11, slide A18500. Fig. 21 - *Isabelidinium* spp., sample FS-S-5, slide A18496. Fig. 22 - Fragment of *Cannosphaeropsis utinensis*, sample FS-S-4, slide A20868. Fig. 23 - Fragment of *Cannosphaeropsis utinensis*, sample FS-S-9, slide A18498. Figs. 24, 25 - *Cerodinium* cf. *diebelii*, sample FS-S-6, slide A20870. Fig. 26 - *Cerodinium* spp., sample FS-S-6bis, slide A21507. Fig. 27 - *Tarsisphaeridium geminiporatum*, sample FS-S-14, slide A20318.

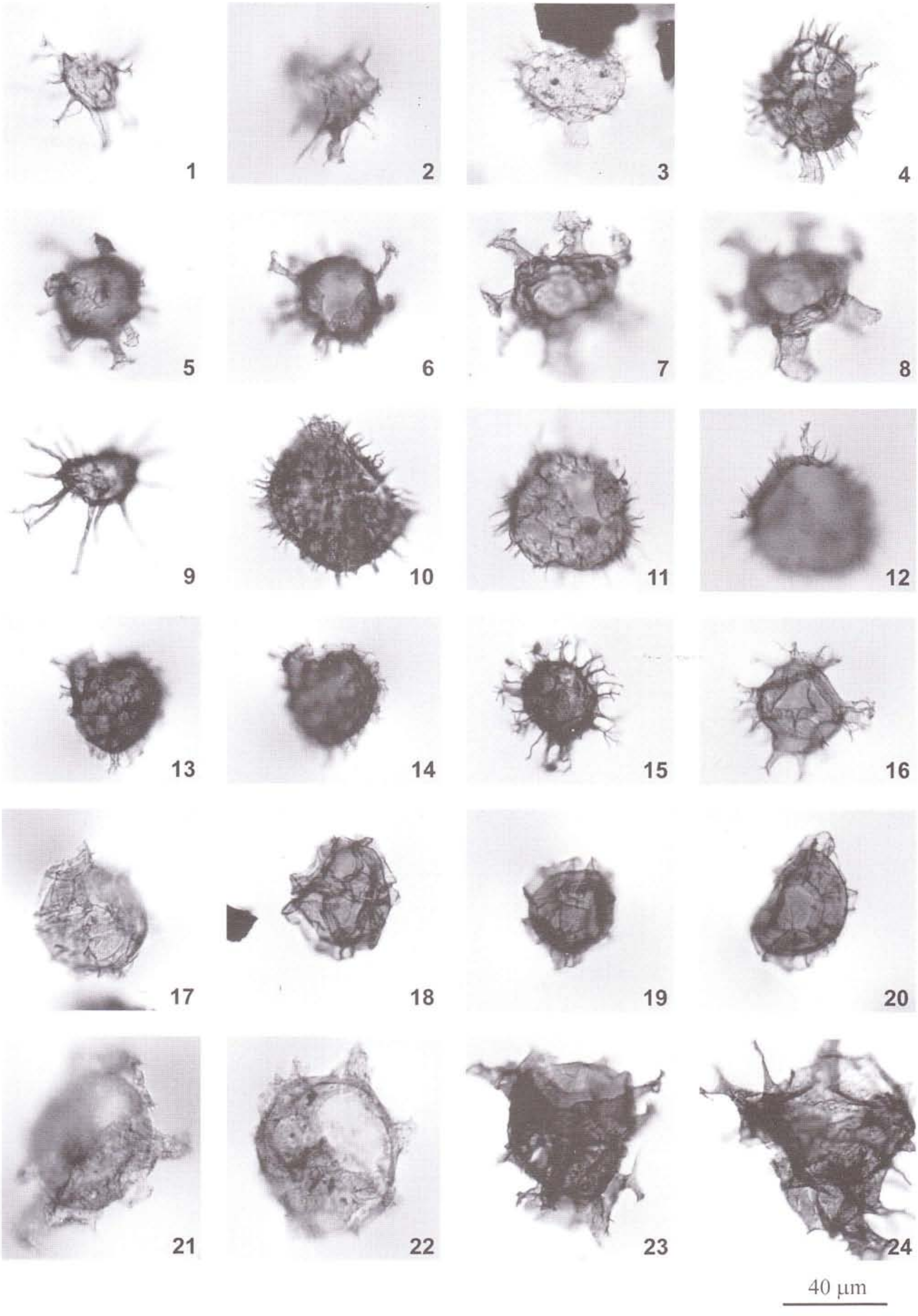


Plate 1

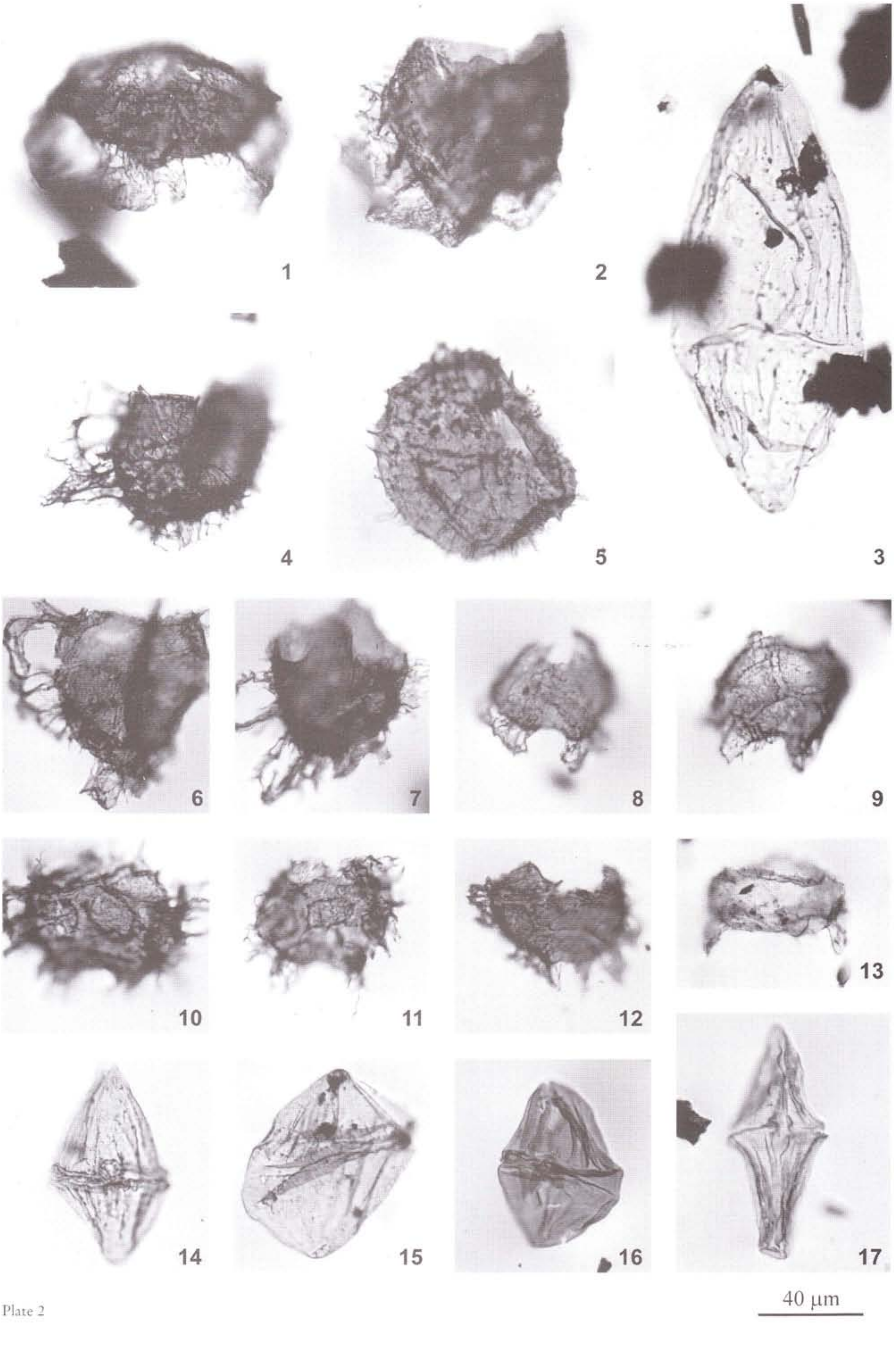


Plate 2

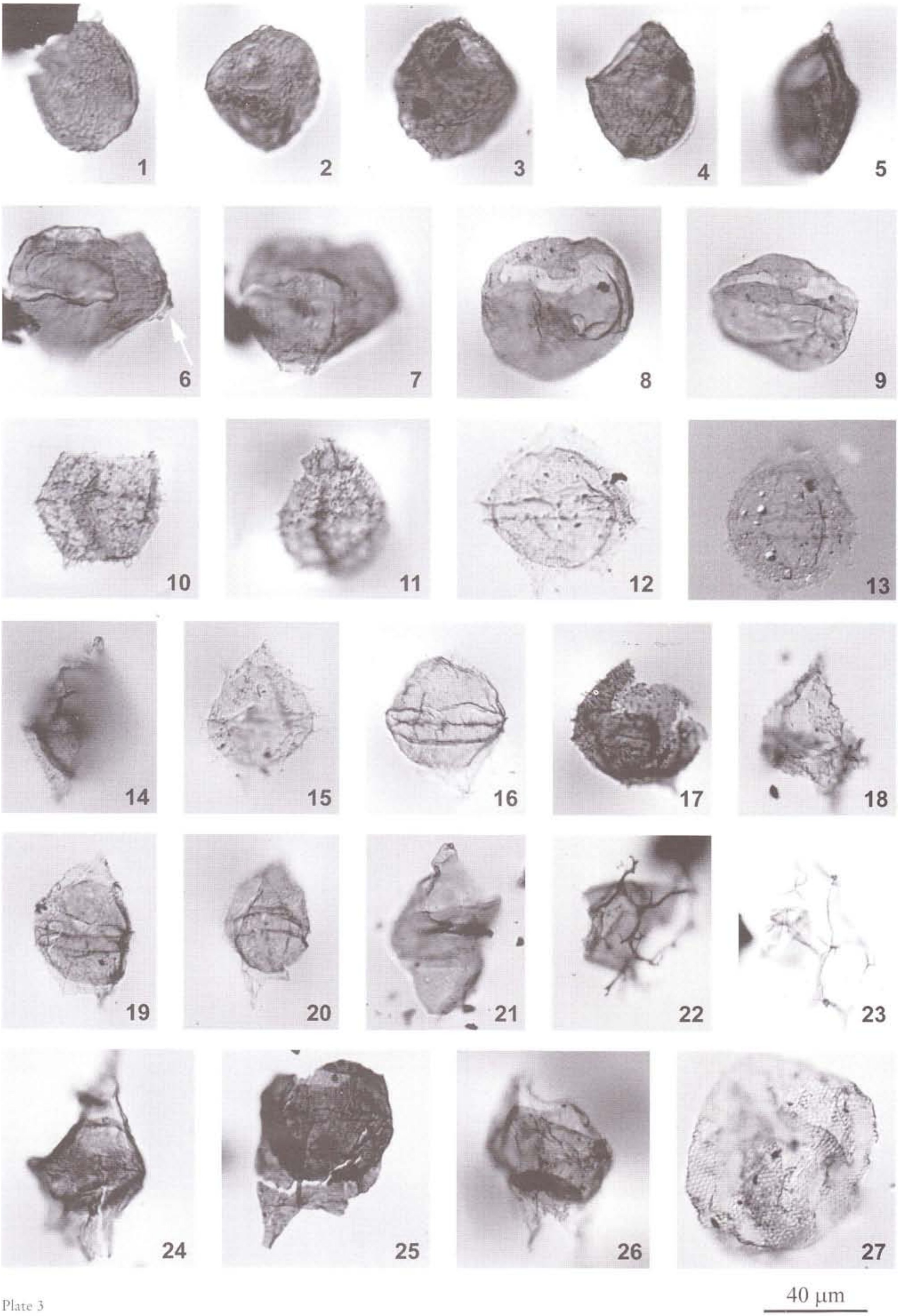


Plate 3

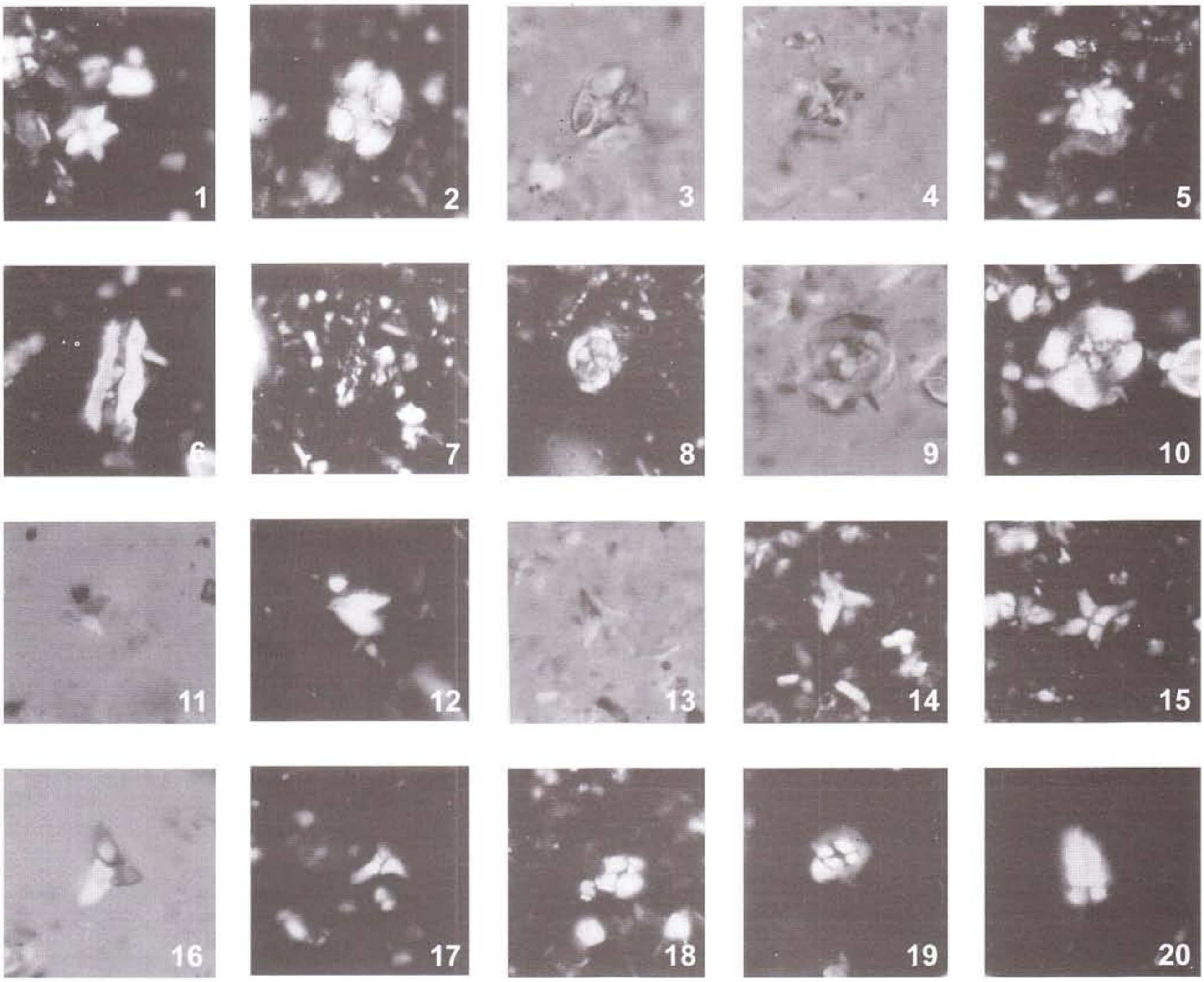


PLATE 4

Calcareous nannoplankton from the Saraceno Formation at the Fiumara Saraceno section. All magnifications x 1250.

Fig. 1 - *Lithastrinus moratus*, sample FS-S-16. Figs. 2, 3 - *Eiffellithus eximius*, sample FS-S-5. Figs. 4, 5 - *Micula concava*, sample FS-S-12. Fig. 6 - *Lucianorhabdus cayeuxii*, FS-S-12. Fig. 7 - *Microrhabdulus undosus*, sample FS-S-12. Fig. 8 - *Arkangelskiella cymbiformis*, sample FS-S-3. Figs. 9, 10 - *Aspidolithus parcus*, sample FS-S-14. Figs. 11, 12 - *Ceratolithoides aculeus* , sample FS-S-4. Figs. 13, 14 - *Ceratolithoides arcuatus*, sample FS-S-12. Fig. 15 - *Quadrum sissinghii*, sample FS-S-12. Figs. 16, 17 - *Quadrum trifidum*, sample FS-S-7. Fig. 18 - *Dictyococcites spp.*, sample FS-S-8. Fig. 19 - *Coccolithus pelagicus*, sample FS-S-8. Fig. 20 - *Sphenolithus radians*, sample FS-S-9.

reported from the Upper Campanian by Schiøler & Wilson (2001) and close to the Campanian/Maastrichtian boundary both by Kirsch (1991) and Roncaglia & Corradini (1997a). Therefore, considered together with other biostratigraphical evidence supporting a late Campanian age for these strata, the gradual disappearance of *P. infusorioides* in the upper part of the Fiumara Saraceno section is deemed to be a primary signal immediately preceding its extinction.

Owing to the acme of *P. infusorioides*, FS-S-14 is the most fossiliferous sample under investigation. It is furthermore characterised by:

1. the common occurrence of the distinctive dinoflagellate cyst genus *Dinogymnium* (Pl. 2, figs. 3, 14-17), which at mid latitudes first appeared in the Turonian immediately after the extinction of *E. spinosa* and disappeared at the K/T boundary (Williams et al. submitted);
2. the single occurrence of *Chatangiella madura*, whose youngest record is documented in the uppermost Campanian of Bavaria (Kirsch 1991) and Maastrichtian of the northern Apennines (Roncaglia & Corradini 1997a).

Sample FS-S-11 yielded the most diverse dinoflagellate cyst assemblage of this study including among others:

SAMPLES (Fiumara Saraceno section)	FS-S-25	FS-S-24	FS-S-23	FS-S-22	FS-S-21	FS-S-19	FS-S-18	FS-S-17	FS-S-16	FS-S-15	FS-S-14	FS-S-13	FS-S-12	FS-S-11	FS-S-10	FS-S-9	FS-S-8	FS-S-7	FS-S-6 bis	FS-S-6	FS-S-5	FS-S-4	FS-S-3	FS-S-2	FS-S-1
AGE	latest ALBIAN to TURONIAN						LATE CAMPANIAN																?EARLY MAAST.		
PRESERVATION	fair	fair				bad		bad	bad	bad	fair	fair	fair	fair	bad	poor	poor	bad	fair	fair	bad	fair	fair	bad	bad
Indetermined dinoflagellate cysts	30%	40%	barren	barren	barren	20%	barren	30%	30%	30%	30%	30%	20%	20%	30%	30%	20%	60%	20%	30%	20%	20%	20%	50%	50%
DINOFLAGELLATE CYSTS																									
1 *Circulodinium distinctum*	1	1																							
2 *Epelidosphaeridia spinosa*	18	8																							
3 *Palaeohystrichophora infusorioides*	5	2				8		3	16	7	60	4	5	5		1							2		
4 *Pterodinium cingulatum cingulatum*	1	1									3	1	2				3					1			
5 *Pterodinium cornutum*	2																								
6 *Spiniferites gr. ramosus*	10	12				3		1	3	2	15	3	3	25	3	11	12	1	3	5	1	34		1	2
7 *Trichodinium castanea*	2	2																							
8 *Isabelidinium sp.*						1					1						1				1				
9 *Cyclonephelium chabaca*								2																	
10 *Dinogymnium albertii*								1			3		1												
11 *Muderongia simplex* (reworked)								1																	
12 *Spinidinium echinoideum*								3				3	2												
13 *Subtilisphaera cheit*								5	6	1			1	20								1			
14 *Chatangiella sp.*									1		2														
15 *Cyclonephelium paucimarginatum*									1		1	1													
16 *Spiniferites ramosus granosus*									1													2	1	2	
17 *Chatangiella madura*											1														
18 *Dinogymnium acuminatum*											15	3		1											
19 *Dinogymnium sp.* (extralarge)											1														
20 *Florentinia laciniata*											1														
21 *Circulodinium brevispinosum*												1	1												
22 *Odontochitina streeli*												1													
23 *Palynodinium bicullleus*												1	1			2									
24 *Xenascus ceratioides*												1		7						3					
25 *Exochosphaeridium muelleri*													1	10	1							3			
26 *Trithyrodinium suspectum*													1	5		8	1	4	12	8					
27 *Areoligera gr. coronata*														5									2		
28 *Areoligera gr. senonensis*														8				1				2	2		
29 *Areoligera volata*														3								2		1	
30 *Canningia reticulata*														1											
31 *Canningia senonica*														2											
32 *Coronifera oceanica*														1											
33 *Florentinia aculeata*														1											
34 *Florentinia radiculata*														3											
35 *Glaphyrocysta expansa*														1											
36 *Glaphyrocysta cf. wilsonii*														1		1									
37 *Hystrichodinium pulchrum*														1											
38 *Hystrichosphaeridium recurvatum*														2								1			
39 *Hystrichosphaeridium salpingophorum*														1								2			
40 *Odontochitina operculata*														1											
41 *Riculacysta? pala*														3											
42 *Spinidinium cf. echinoideum* sensu Kirsch 1991														1							5				
43 *Subtilisphaera cf. cinctuta*														4											
44 *Surculosphaeridium longifurcatum*														2											1
45 *Cannosphaeropsis utinensis*															1	1				1		1			
46 *Oligosphaeridium complex*															1										
47 *Spiniferites compactus*															1										
48 *Florentinia resex*																1									
49 *Samlandia carnarvonensis*																			6	5					
50 *Cerodinium cf. diebelii*																			1	2					
51 *Cribroperidinium wilsonii*																			1	1					
52 *Cribroperidinium spp.*																			1	2					
53 *Pterodinium* sp. B sensu Schioler & Wilson 1993																			1			3			
54 *Cordosphaeridium varians*																				2		1		1	
55 *Alterbidinium sp.*																						1			
PRASINOPHYCEAN ALGAE																									
56 *Tarsisphaeridium geminiporatum*								1		2	8														
POLLEN & SPORES																									
57 *Bisaccates*								4	5			5	5			1			6	7	2				
58 *Araucariacites sp.*								1	1		25	15	3					1	5	12					
59 *Indetermined trilete spores*								1	4	2		7	3			1			9	5					
60 *Triadispora sp.* (reworked)								1																	

Fig. 5 - Occurrence-chart of palynomorphs recovered from the Fiumara Saraceno section, ordered according to first occurrences. Numbers refer to counted specimens in a single palynological slide. Vertical scale not proportional to stratigraphical thicknesses.

1. *Areoligera* gr. *coronata* (Pl. 2, figs. 10-11) and *Areoligera* gr. *senonensis* (Pl. 2, fig. 12), whose lowest occurrences are calibrated in the Upper Campanian of the type-Maastrichtian area (Robaszynski et al. 1985), of southern Germany (Kirsch 1991), of the northern Apennines (Roncaglia & Corradini 1997a), and close to the Campanian/Maastrichtian boundary of the Caribbean (Yepes 2001);
2. *Areoligera volata* (Pl. 2, figs. 4, 6-7), a dinoflagellate cyst species previously reported from the Maastrichtian of the Helvetic and Ultrahelvetic Domains (Kirsch 1991);
3. *Xenascus ceratioides* (Pl. 1, figs. 23-24), *Hystrichodinium pulchrum* and *Odontochitina operculata*, whose highest occurrences are calibrated against the Lower Maastrichtian both in the northern Apennines (Roncaglia & Corradini 1997b) and in the type-Maastrichtian area (Robaszynski et al. 1985);
4. *Glaphyrocysta expansa* (Pl. 2, fig. 1), whose lowest occurrence was found in the Lower Maastrichtian of the northern Apennines (Roncaglia & Corradini 1997a);
5. *Riculacysta? pala* (Pl. 2, fig. 2), a dinoflagellate cyst species described from the Maastrichtian of the Helvetic and Ultrahelvetic Domains (Kirsch 1991).

Consistently with trends in the composition of the assemblages throughout the section, this sample is indicative of an age close to the Campanian/Maastrichtian boundary.

From sample FS-S-12 to sample FS-S-6 several specimens of *Trithyrodinium suspectum* (Pl. 3, figs. 8-9) have been encountered. As well as most of representatives of the dinoflagellate genus *Trithyrodinium*, this is a Late Cretaceous species with a relatively thick endophragm exhibiting a distinctive 3a intercalary archeopyle and a very thin periphragm that is seldom preserved (Aurisano 1989): in the studied material the periphragm is missing indeed. In southern Germany the highest occurrence of *T. suspectum* is close to the Campanian/Maastrichtian boundary (Kirsch 1991) and in the Northern Hemisphere its total stratigraphical distribution ranges slightly higher into basal Maastrichtian (Stover et al. 1996). Assemblages from this part of the section are furthermore characterised by fragments unequivocally referable to *Cannosphaeropsis utinensis* (Pl. 3, figs. 22-23) whose worldwide distribution straddles the Santonian to mid Maastrichtian interval (Stover et al. 1996; Williams et al. submitted).

The late Campanian-?earliest Maastrichtian age of the upper part of the Fiumara Saraceno section is confirmed by the presence of *Cerodinium* cf. *diebelii* (Pl. 3, figs. 24-25) in samples FS-S-6 and FS-S-6bis. The specific assignment is left questionable as only three broken specimens were found. Nevertheless, shape of the overall cyst, type of archeopyle and type of cavation leave *C. diebelii* as the closest fit. The lowest occurrence of *Cerodinium diebelii* and its related forms (Yepes 2001) is close to the Campanian/Maastrichtian boundary (Kirsch 1991; Roncaglia & Corradini 1997a; Schiøler & Wilson 2001; Antonescu et al. 2001), whereas its worldwide total distribution ranges earlier in the Campanian (Williams et al. submitted). This is also the stratum which yielded several specimens of *Samlandia carnarvonensis* (Pl. 3, figs. 1-5), a dinoflagellate cyst formally described from late Campanian-early Maastrichtian sediments offshore western Australia (McMinn 1988). Although identical in overall shape, wall structures and ornamentation, the Fiumara Saraceno specimens are slightly smaller than the type material and exhibit a close fit with cysts reported as *Apteodinium* sp. A by Mohr & Mao (1997) from the early Maastrichtian *N. watkinsii* nannofossil zone of Maud Rise, Antarctica. However, judging from the illustration and the short description provided by these authors (Mohr & Mao 1997; pl. 2, fig. 5), *Apteodinium* sp. A must be seen as conspecific with *S. carnarvonensis*. The only previous record of *S. carnarvonensis* documented from the Northern Hemisphere is again in the Campanian-basal Maastrichtian interval at Tercis les Bains (south-western France), where its highest occurrence in the earliest Maastrichtian *Belemnella lanceolata* zone is proposed as a convenient tool for correlating the Campanian/Maastrichtian boundary interval (Schiøler & Wilson 2001).

Samples FS-S-17, 15 and 14 include *Tarsisphaeridium geminiporatum* (Pl. 3, fig. 27), a palynomorph belonging to Prasinophycean algae described by Riegel (1974) from the Upper Cretaceous of southern Spain and reported by Kirsch (1991) from the Santonian-Campanian of Bavaria (southern Germany).

In conclusion, except for a reworked specimen of *Muderongia simplex*, all the dinoflagellate cysts and Prasinophycean algae taxonomically identified in this study have known stratigraphical ranges within the Upper Cretaceous. Based on comparisons between their distribution in the Fiumara Saraceno section and stratigraphical data published particularly from Tethyan and Sub-Boreal sections (Davey & Verdier 1973; Roncaglia & Corradini 1997a, b; Kirsch 1991; Schiøler & Wilson 2001; Antonescu et al. 2001), the age of the lowermost part of the section is bracketed between the latest Albian and earliest Turonian, whereas the remaining section is dated as late Campanian-?early Maastrichtian. Hence, a major hiatus spanning the Coniacian, the Santonian and most of the Campanian can be inferred between samples FS-S-18 and FS-S-17. This hiatus corresponds to important changes in the lithological characters of the Fiumara Saraceno succession, since flint nodules occur only in the section beneath.

Calcareous nannofossil stratigraphy of the Fiumara Saraceno section

As mentioned above, the Fiumara Saraceno section was studied for nannofossils by De Blasio et al. (1978), who assigned the succession a mid-late Eocene age. According to these authors, Cretaceous forms recovered abundantly throughout the section are reworked, whereas the occurrences of Eocene taxa were interpreted as indigenous.

In the present study, twenty-six samples were prepared and analysed for calcareous nannoplankton. Seven samples proved to be barren, whereas the others yielded rare to abundant nannofossil assemblages. Fifty-two taxa were recognized: they are tabulated in the occurrence-chart (Fig. 6) and listed alphabetically by genus in the Appendix. Preservation varies from poor to moderate. Placoliths usually show overgrowth and/or etching, making the taxonomic attribution sometimes difficult.

The stratigraphical framework published by Erba et al. (1995; see Fig. 7) has been adopted in this study for the interpretation of the calcareous nannoplankton distribution in the Fiumara Saraceno section. In that scheme, nannofossil first and last occurrences are correlated to standard foraminifera and nannoplankton zonations, and to magnetostratigraphy according to the Gradstein et al. (1994) time scale. Although that paper is focused on the Western Pacific area, it was already adopted in Tethyan sections (Tremolada 2002). It has been possible to recognize the same suite of events presented by Erba et al. (1995) even in the upper part of the Fiumara Saraceno section.

The Fiumara Saraceno section starts with samples FS-S-25 and FS-S-24, which are characterized by poor, non age-diagnostic associations. Upwards, a mainly bar-

FS-S-25	FS-S-24	FS-S-23	FS-S-22	FS-S-21	FS-S-20	FS-S-19	FS-S-18	FS-S-17	FS-S-16	FS-S-15	FS-S-14	FS-S-13	FS-S-12	FS-S-11	FS-S-10	FS-S-9	FS-S-8	FS-S-7	FS-S-6 bis	FS-S-6	FS-S-5	FS-S-4	FS-S-3	FS-S-2	FS-S-1	SAMPLES (Fiumara Saraceno section)
latest ALBIAN to TURONIAN								LATE CAMPANIAN															?EARLY MAAST			AGE
P	P				P			M	M	M	P	P	M	M	M	M	M	M	M	M	M	M	P			PRESERVATION
R	R	barren	barren	barren	R	barren	barren	S	C	C	A	R	A	R	R	S	R	R	R	R	R	F	C	barren	barren	TOTAL ABUNDANCE
c													c													1 *Watznaueria* spp.
c								r	c	c	c		c	rr		r	r	r	rr	rr	rr	c	r			2 *Watznaueria communis*
c	r							r	c	c	c	r	c			r	r	r	rr	rr	rr	c	r			3 *Watznaueria barnesae*
rr																										4 *Zeugrabdothus acanthus*
r	rr								r	s	r															5 *Cretarhabdus surirellus*
r																										6 *Watznaueria britannica*
					rr																					7 *Eprolithus floralis*
					rr				r																	8 *Lithastrinus moratus*
								r	c	c	s	r	c			rr		rr			rr	c	r			9 *Micula decussata*
								rr																		10 *Micula* spp.
								rr		rr	rr		rr							rr	rr					11 *Eiffellithus eximius*
								r	r	s	c	rr	s			rr		rr		rr	rr		r			12 *Stradneria crenulata*
								rr					rr			rr				rr						13 *Quadrum gothicum*
								rr	c		r	r	c			rr	rr				rr	c	r			14 *Micula concava*
									rr								rr									15 *Aspidolithus* spp.
									r		rr		rr			rr					rr					16 *Tranolithus phacelosus*
									r	rr	r		r			rr										17 *Calculites obscurus*
									rr				rr								rr					18 *Lucianorhabdus maleformis*
									rr							rr										19 *Nannoconus* spp. (reworked)
									r	r	s		c						rr	rr	rr		rr			20 *Prediscosphaera cretacea*
									r	rr																21 *Calculites ovalis*
									rr		rr		rr													22 *Reinhardtites antophorus*
									o	rr	o		o													23 *Reinhardtites levis*
									r	rr	r		r			rr		r	rr				r			24 *Cribrosphaerella ehrenbergii*
									rr				r			rr										25 *Quadrum sissinghii*
									rr																	26 *Thoracosphera* spp.
									rr		rr															27 *Chiastozygus* cf. *litterarius*
									rr																	28 *Micrantholithus hoschulzi* (reworked)
									rr	rr	rr		rr				rr	rr			rr		rr			29 *Eiffellithus turriseiffelii*
										rr			rr													30 *Lucianorhabdus cayeuxii*
										rr																31 *Rucinolithus* cf. *hayi*
										rr	rr		rr			rr										32 *Aspidolithus parcus*
											rr	rr														33 *Rucinolithus* spp.
											rr	rr	rr													34 *Glaukolithus diplogrammus*
											rr															35 *Quadrum gartneri*
											rr		rr					rr		rr	rr		rr			36 *Microrhabdulus attenuatus*
												rr	rr			rr							rr			37 *Microrhabdulus decoratus*
													rr					rr				r				38 *Ceratolithoides arcuatus*
													rr				rr									39 *Lithraphidites bollii* (reworked)
													rr													40 *Microrhabdulus undosus*
													rr													41 *Zeugrhabdotus embergeri*
													rr			rr		rr		rr		c	rr			42 *Ceratolithoides aculeus*
													r										rr			43 *Praediscosphaera columnata*
													rr													44 *Chiastozygus bifarius*
															rr		rr									45 *Dictyococcites* spp.
																rr										46 *Lithastrinus grillii*
																rr	rr	rr			o	rr				47 *Quadrum trifidum*
																rr										48 *Sphenolithus radians*
																	r									49 *Coccolithus pelagicus*
																	rr									50 *Sphenolithus moriformis*
																	r									51 *Ericsonia* spp.
																			rr				rr			52 *Arkhangelskiella cymbiformis*

Fig. 6 - Occurrence-chart of calcareous nannofossils recovered from the Fiumara Saraceno section, ordered according to first occurrences. Total abundance of nannofossils as follows: A:>30 specimens/field; F:10-30 specimens/field; C:2-9 specimens /field; S:1 specimen/field; R:<1 specimen/field. For the absolute abundance of individual taxa, the following codes were adopted: c:1 specimen/1-10 fields; s:1 specimen/>10 fields; r: some specimens/100 fields; rr:1 specimen only during the analysis. Vertical scale not proportional to stratigraphical thicknesses.

ren interval spans from sample FS-S-23 to FS-S-18, with the exception of sample FS-S-20 which yielded two significant species: *Eprolithus floralis* and *Lithastrinus moratus*. In particular, according to Bralower (1988), *L. moratus* first occurs within the *E. floralis* zone, in the Turonian.

In general, from sample FS-S-17 to FS-S-3 calcareous nannofossil assemblages show greater diversity and better preservation, with abundance of Late Cretaceous species. Samples FS-S-16 and FS-S-15 record the lowest occurrences of important stratigraphical markers, namely *Aspidolithus parcus, Calculites obscurus, Lucianorhabdus cayeuxii, Quadrum sissinghii, Reinhardtites anthophorus, Reinhardtites levis* (Fig. 4). Following the calibrations proposed by Erba et al. (1995), the occurrence of *Q. sissinghii* in sample FS-S-16 suggests an age not older than late Campanian (zone CC21 of Sissingh 1977).

In samples FS-S-8 and FS-S-9 rare specimens of *Coccolithus pelagicus*, *Ericsonia* spp., *Sphenolithus moriformis* and *Sphenolithus radians* occur in association with Late Cretaceous taxa. In order to assess the reliability of these records, new slides were prepared from the same samples and no more Tertiary forms were found in the course of the subsequent analyses. Therefore, taking in consideration the overall biostratigraphies discussed in this paper, the specimens of *C. pelagicus*, *Ericsonia* spp., *S. moriformis* and *S. radians* observed in the first slides prepared from samples FS-S-8 and FS-S-9, are herein interpreted as the occasional result of post-depositional contamination. The superficial contamination was probably operated by water circulation and runoff of material derived from the overlying Albidona Formation where these taxa were reported as frequent components of the in-situ nannoflora (Baruffini et al. 2000). A more extended discussion on this issue is presented in the following paragraph.

From sample FS-S-9 to FS-S-4 nannofossil assemblages are characterised by the occurrence of *Quadrum trifidum* (Pl. 4, figs. 16-17), which is the youngest species recognized in this study. According to Perch-Nielsen (1985a), *Q. trifidum* ranges from Zone CC22 to the top of zone CC23 and according to Erba & Covington (1992) its last appearance approximates the Campanian/Maastrichtian boundary. Since sample FS-S-3 yielded just a few species and samples FS-S-2 and FS-S-1 are barren, no additional information is available for the uppermost section.

In conclusion, nannofossils indicate for the most fossiliferous part of the Fiumara Saraceno section (from sample FS-S-17 to FS-S-4) a late Campanian age.

Summary and discussion of biostratigraphical results

Comparisons between the distribution of dinoflagellate cysts from the Fiumara Saraceno section and palynostratigraphical data published for the Tethyan and Sub-Boreal Provinces (Davey & Verdier 1973; Roncaglia & Corradini 1997a, b; Schiøler & Wilson 2001; Antonescu et al. 2001; Kirsch 1991) and worldwide (Stover et al. 1996; Williams et al. submitted), suggest for the lowermost part of the section a latest Albian to Turonian age, and for the remaining section a late Campanian age, possibly extending into earliest Maastrichtian. Hence, a hiatus spanning the Coniacian, the Santonian and most of the Campanian is inferred between these two portions, which are distinguished also for the presence and absence of flint respectively.

Calcareous nannofossil analyses, carried out on the same samples investigated for palynomorphs, provide congruent stratigraphical information, since the suite of events documented in the mid-upper part of the section further confirms a late Campanian age.

These results are consistent with the age assessments originally proposed for the Saraceno Formation by Selli (1962) and subsequently confirmed by Pavan & Pirini (1963) and Vezzani (1968). Moreover, they are in close agreement with the framework outlined by Baruffini et al. (2000) who dated as earliest Eocene the base of the Albidona Formation that unconformably overlays the Saraceno Formation. In such a framework, the Albidona Formation represents an episutural deposit relevant to a deformation that affected during the Paleocene the older units of the Liguride Complex (i.e. Crete Nere and Saraceno Formations).

In contrast, the mid- to late Eocene age established for the Saraceno Formation by De Blasio et al. (1978) on the basis of the occurrences of Tertiary nannofossils and foraminifera within mainly Cretaceous assemblages, is inconsistent with our data. We suggest that Eocene forms encountered by De Blasio et al. (1978) are due to superficial contamination operated by circulation of meteoric and fluvial waters transporting material derived from the Albidona Formation. Indeed, the Eocene Albidona Formation (Baruffini et al. 2000) outcrops on the steep flanks of the Fiumara Saraceno valley immediately above the Saraceno Formation, and the Saraceno River is the only route of dispersion toward the Ionian Sea of all the rocks dismantled by erosion in its hydrographical basin. It is worthwhile noting that De Blasio et al. (1978) found Eocene micro- and nannofossils only in samples collected from pelitic strata of the Saraceno Formation, whereas harder lithologies examined in thin section "confirmed the Albian-Danian age assessed by Vezzani (1968)" (De Blasio et al. 1978, p.966, translated from Italian). Hard lithologies are not as vulnerable to water penetration and subsequent contamination as pelitic layers. We also have found traces of Eocene nannofossils in two of our samples (FS-S-8 and 9), but they were occasionally present in one of the two slides prepared from each of those samples. Moreover, these are the same taxa reported from the Eocene assemblages of the Albidona Formation by Baruffini et al. (2000).

Finally, since Cretaceous palynological and nannofossil assemblages documented herein show a progressive rejuvenation from the base of the Fiumara Saraceno

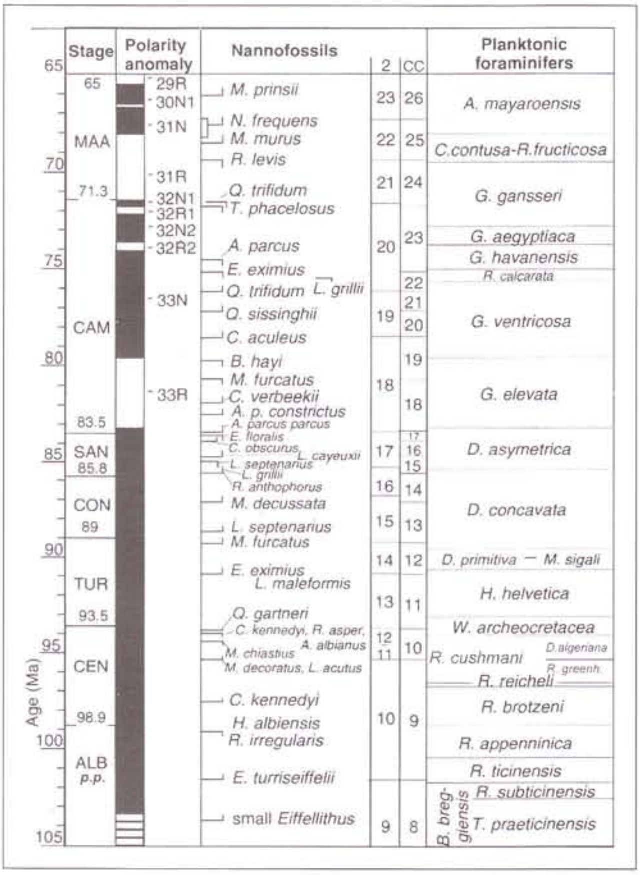


Fig. 7 - Integrated stratigraphical scheme for the Upper Cretaceous modified from Erba et al. (1995). Codes for nannofossil zonations: 2=Roth (1978); CC=Sissingh (1977). Planktonic foraminiferal zones from Premoli Silva & Sliter (1999).

section to the top, it would be problematical to interpret them as reworked. This argument is valid also for the stratigraphically ordered evolution of the foraminiferal assemblages documented by Vezzani (1968) from six outcrop sections of the Saraceno Formation, always indicating ages becoming progressively younger from bottom (latest Albian) to top (Maastrichtian-earliest Paleocene). Unlike the Fiumara Saraceno section, the six sections investigated by Vezzani (1968) are located far from the Saraceno River bed, and their positions have probably prevented them from heavy contamination related to water circulation. Owing to the large amount of data presented, the work of Vezzani (1968) has still to be retained as the main reference for the stratigraphy of the Saraceno Formation even though hiatuses were probably overlooked.

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Appendix

DINOFLAGELLATE CYSTS AND PRASINOPHYCEAN ALGAE

Alphabetical listing of dinoflagellate cysts and prasinophycean algae recovered from the Saraceno Formation in the present study. Numbers in brackets refer to the position in the occurrence-chart (Fig. 5). Taxa illustrated are followed by plate and figure references in brackets. The generic allocation and authorship of dinoflagellate cyst species follow Williams et al. (1998).

Alterbidinium sp. (55)
Areoligera gr. *coronata* (Wetzel, 1933) Lejeune-Carpentier, 1938 (27, Pl. 2, figs. 10-11)
Areoligera gr. *senonensis* Lejeune-Carpentier, 1938 (28, Pl. 2, fig. 12)
Areoligera volata Drugg, 1967 (29, Pl. 2, figs. 4, 6-7)
Canningia reticulata Cookson & Eisenack, 1960 (30)
Canningia senonica Clarke & Verdier, 1967 (31, Pl. 1, figs. 13-14)
Cannosphaeropsis utinensis Wetzel, 1933 (45, Pl. 3, figs. 22-23)
Cerodinium cf. *diebelii* (Alberti, 1959) Lentin & Williams, 1987 (50, Pl. 3, figs. 24-25)
Chatangiella madura Lentin & Williams, 1976 (17)
Chatangiella sp. (14)
Circulodinium brevispinosum (Pocock, 1962) Jansonius 1986 (21)
Circulodinium distinctum (Deflandre & Cookson, 1955) Jansonius 1986 (1)
Cordosphaeridium varians May, 1980 (54, Pl. 1, figs. 21-22)
Coronifera oceanica Cookson & Eisenack, 1958 (32, Pl. 1, fig. 4)
Cribroperidinium wilsonii (Yun 1981) Poulsen, 1996 (51, Pl. 2, fig. 5)
Cribroperidinium spp. (52)
Cyclonephelium chabaca Below, 1981 (9)
Cyclonephelium paucimarginatum Cookson & Eisenack, 1962 (15)
Dinogymnium albertii Clarke & Verdier, 1967 (10, Pl. 2, fig. 16)
Dinogymnium acuminatum Evitt et al., 1967 (18, Pl. 2, figs. 14, 17)
Dinogymnium sp. (extralarge) (19, Pl. 2, fig. 3)
Epelidosphaeridia spinosa Cookson & Huges, 1964 (2, Pl. 3, figs. 10-11)
Exochosphaeridium muelleri Yun, 1981 (25, Pl. 1, figs. 10-12)
Florentinia aculeata Kirsch, 1991 (33, Pl. 1, fig. 1)
Florentinia laciniata Davey & Verdier, 1973 (20, Pl. 1, fig. 3)
Florentinia radiculata (Davey & Williams, 1966) Davey & Verdier, 1973 (34, Pl. 1, fig. 2)
Florentinia resex Davey & Verdier, 1976 (48)
Glaphyrocysta expansa (Corradini, 1973) Roncaglia & Corradini 1997 (35, Pl. 2, fig. 1)
Glaphyrocysta cf. *wilsonii* Kirsch, 1991 (36, Pl. 2, fig. 8)
Hystrichodinium pulchrum Deflandre, 1935 (37)
Hystrichosphaeridium recurvatum (White, 1842) Lejeune-Carpentier 1940 (38, Pl. 1, fig. 9)
Hystrichosphaeridium salpingophorum Deflandre, 1935 (39, Pl. 1, figs. 5-8)
Isabelidinium spp. (8, Pl. 3, fig. 21)
Muderongia simplex Alberti, 1961 (11)
Odontochitina operculata (Wetzel, 1933) Deflandre & Cookson 1955 (40)
Odontochitina streeli Slimani, 2001 (22, Pl. 3, figs. 6-7)
Oligosphaeridium complex (White, 1842) Davey & Williams, 1966 (46)
Palaeohystrichophora infusorioides Deflandre, 1935 (3, Pl. 3, figs. 12-16)
Palynodinium biculleus Kirsch, 1991 (23, Pl. 2, fig. 13)
Pterodinium cingulatum cingulatum (Wetzel, 1933) Below, 1981 (4, Pl. 1, fig. 18)
Pterodinium cornutum Cookson & Eisenack, 1962 (5, Pl. 1, fig. 17)
Pterodinium sp. B sensu Schiøler & Wilson, 1993 (53, Pl. 1, figs. 19-20)
Riculacysta? pala Kirsch, 1991 (41, Pl. 2, fig. 2)
Samlandia carnarvonensis (49, Pl. 3, figs. 1-5)
Spinidinium echinoideum (Cookson & Eisenack, 1960) Lentin & Williams, 1976 (12, Pl. 3, figs. 17-18)
Spinidinium cf. *echinoideum* sensu Kirsch, 1991 (42)
Spiniferites compactus Cookson & Eisenack, 1974 (47)
Spiniferites gr. *ramosus* (Ehrenberg, 1938) Manell, 1954 (6, Pl. 1, fig. 16)
Spiniferites ramosus granosus (Davey & Williams, 1966) Corradini, 1973 (16, Pl. 1, fig. 5)
Subtilisphaera cheit Below, 1981 (13, Pl. 3, fig. 19)
Subtilisphaera cf. *cinctuta* Roncaglia & Corradini, 1997 (43, Pl. 3, fig. 20)
Surculosphaeridium longifurcatum (Firtion, 1952) Davey et al. 1966 (44)
Tarsisphaeridium geminiporatum Riegel, 1974 (56, Pl. 3, fig. 27)
Trichodinium castanea Deflandre, 1935 (7)
Trithyrodinium suspectum (Manum & Cookson, 1964) Davey, 1969 (26, Pl. 3, figs. 8-9)
Xenascus ceratioides (Deflandre, 1937) Lentin & Williams, 1973 (24, Pl. 1, figs. 23-24)

CALCAREOUS NANNOFOSSILS

Alphabetical listing of taxa cited in text and figures. Numbers in brackets refer to the position in the occurrence-chart (Fig. 6); taxa illustrated are followed by plate and figure references. Further taxonomic information can be found in Perch-Nielsen (1985a, b) and Erba & Covington (1992).

Arkhangelskiella cymbiformis Vekshina, 1959 (52, Pl. 4, fig. 8)
Aspidolithus spp. (15)
Aspidolithus parcus (Stradner, 1963) Noël, 1969 (32, Pl. 4, figs. 9-10)
Calculites obscurus (Deflandre, 1959) Prins & Sissingh *in* Sissingh 1977 (17)
Calculites ovalis (Stradner, 1963) Prins & Sissingh *in* Sissingh 1977 (21)
Ceratolithoides aculeus (Stradner 1961) Prins & Sissingh *in* Sissingh 1977 (42, Pl. 4, figs. 11-12)
Ceratolithoides arcuatus Prins & Sissingh *in* Sissingh 1977 (38, Pl. 4, figs. 13-14)
Chiastozygus bifarius Bukry, 1969 (44)
Chiastozygus cf. *litterarius* (Gorka, 1957) Manivit 1971 (27)
Coccolithus pelagicus (Wallich, 1877) Schiller 1930 (49, Pl. 4, fig. 19)
Cribrosphaerella ehrenbergii (Arkhangelsky, 1912) Deflandre *in* Piveteau 1952 (24)
Cretarhabdus surirellus (Deflandre *in* Deflandre & Fert 1954) Reinhardt, 1970 (5)
Dictyococcites spp. (45, Pl. 4, fig. 18)
Eiffellithus eximius (Stover 1966) Perch-Nielsen 1968 (11, Pl. 4, figs. 2-3)
Eiffellithus turriseiffelii (Deflandre *in* Deflandre & Fert 1954) Reinhardt, 1965 (29)
Eprolithus floralis (Stradner, 1962) Stover, 1966 (7)
Ericsonia spp. (51)
Glaukolithus diplogrammus (Deflandre *in* Deflandre & Fert 1954) Reinhardt, 1964 (34)
Lithastrinus grillii Stradner, 1962 (46)
Lithastrinus moratus Stover, 1966 (8, Pl. 4, fig. 1)
Lithraphidites bollii (Thierstein, 1971) Thierstein, 1973 (39)
Lucianorhabdus cayeuxii Deflandre, 1959 (30, Pl. 4, fig. 6)
Lucianorhabdus maleformis Reinhardt, 1966 (18)
Micrantholithus hoschulzii (Reinhardt, 1966) Thierstein, 1971 (28)
Microrhabdulus attenuatus (Deflandre, 1959) Deflandre, 1963 (36)
Microrhabdulus decoratus Deflandre, 1959 (37)
Microrhabdulus undosus Perch-Nielsen, 1973 (40, Pl. 4, fig. 7)
Micula spp. (10)
Micula concava (Stradner *in* Martini & Stradner 1960) Verbeek, 1976 (14, Pl. 4, figs. 4-5)
Micula decussata Vekshina, 1959 (9)
Nannoconus spp. (19)
Praediscosphaera columnata (Stover, 1966) Perch-Nielsen, 1984 (43)
Praediscosphaera cretacea (Arkhangelsky, 1912) Gartner, 1968 (20)
Quadrum gartneri Prins & Perch-Nielsen *in* Manivit et al. 1977 (35)
Quadrum gothicum (Deflandre 1959) Prins & Perch-Nielsen *in* Manivit et al. 1977 (13)
Quadrum sissinghii Perch-Nielsen, 1984 (25, Pl. 4, fig. 15)
Quadrum trifidum (Stradner *in* Stradner & Papp 1961) Prins & Perch-Nielsen *in* Manivit et al. 1977 (47, Pl. 4, figs. 16-17)
Reinhardtites anthophorus (Deflandre, 1959) Perch-Nielsen 1968 (22)

Reinhardtites levis Prins & Sissingh *in* Sissingh 1977 (23)
Rucinolithus spp. (33)
Rucinolithus cf. *hayi* Stover, 1966 (31)
Sphenolithus moriformis (Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967 (50)
Sphenolithus radians Deflandre *in* Grassé 1952 (48, Pl. 4, fig. 20)
Stradneria crenulata (Bramlette & Martini, 1964) Noël, 1970 (12)
Thoracosphaera spp. (26)
Tranolithus phacelosus Stover, 1966 (16)
Watznaueria spp. (1)
Watznaueria barnesae (Black *in* Black & Barnes 1959) Perch-Nielsen, 1984 (3)
Watznaueria britannica (Stradner, 1963) Reinhardt, 1964 (6)
Watznaueria communis Reinhardt, 1964 (2)
Zeugrhabdotus acanthus Reinhardt, 1965 (4)
Zeugrhabdotus embergeri (Noël, 1959) Perch-Nielsen, 1984 (41)