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DINOFLAGELLATE CYST STRATIGRAPHY OF THE LOWER CRETACEOUS MONTE SORO FLYSCH IN SICILY (S ITALY)

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Riassunto. Vengono descritte e discusse le ricche associazioni a palinomorfi rinvenute in due sezioni stratigrafiche di superficie campionate nel Flysch di Monte Soro (Monti Nebrodi, Sicilia nord-orientale, Italia). Esse forniscono nuovi dati biostratigrafici utili per meglio definire l'età di questa successione torbiditica nella sua area-tipo e consentire correlazioni. La zonazione a cisti di dinoflagellata definita per il Cretaceo inferiore nel Mediterraneo occidentale, è applicata con successo alla parte bassa del Flysch di Monte Soro campionata nella sezione di Vallone Rosmarino, la cui età risulta estesa dal Valanginiano sommitale all'Hauteriviano superiore. La sezione di Pizzo Gilormo, invece, mostra una sequenza fining- e thinning-upward di età estesa dall'Aptiano inferiore all'Aptiano sommitale. Alla sommità della successione esposta a Monte dell'Abate, che si dimostra un'equivalente laterale della sezione di Pizzo Gilormo, le argille affioranti a Portella Buffali documentano nell'Albiano inferiore l'inizio della deposizione delle Argille Scagliose Superiori sopra il Flysch di Monte Soro. Sebbene il Barremiano non sia presente nei campioni analizzati in questo studio, esso è documentato sia in letteratura, sia nella successione riconducibile al Flysch di Monte Soro perforata dall'Agip presso Randazzo. Pertanto, l'età del Flysch di Monte Soro, determinata per mezzo dei palinomorfi, si estende dal Valanginiano sommitale all'Aptiano sommitale. Le cisti fossili di dinoflagellata, per la loro abbondanza, diversità, ottima conservazione e costante presenza attraverso la sezione composita del Flysch di Monte Soro, si dimostrano il migliore strumento di indagine biostratigrafica all'interno di questa formazione.

Viene condotta la rivisitazione della specie *Hystrichosphaeridium? atlasiense* Below appartenente alle dinoflagellate: la documentata presenza di un archeopyle precingolare a placca singola preclude la sua attribuzione al genere *Hystrichosphaeridium* Deflandre e ne suggerisce l'attribuzione al genere *Kleithriasphaeridium* Davey, di cui viene proposta l'emendazione. La comparsa evolutiva di *Kleithriasphaeridium atlasiense* (Below, 1982) Torricelli comb. nov. costituisce un importante evento biostratigrafico che approssima il limite Aptiano/Albiano nella Tetide.

Abstract. Rich and well preserved palynological assemblages recovered from two outcrop sections in the Monte Soro Flysch (Nebrodi Mountains, NE Sicily, Italy) are documented and discussed. They provide new and valuable information for age determination and correlation within this turbidite unit in the type-area. The dinoflagellate cyst zonation scheme established for the Lower Cretaceous in the western Mediterranean region, is successfully applied to the lower portion of the Monte Soro Flysch sampled at Vallone Rosmarino, ranging in age from the latest Valanginian to the Late Hauterivian. The Pizzo Gilormo section exhibits a fining and thinning-upward sequence and is dated as Early Aptian through latest Aptian. Turbidites of the Monte dell'Abate succession are proved to be a lateral equivalent of the Monte Soro Flysch at the Pizzo Gilormo section. Overlying these turbidites, the shales cropping out at Portella Buffali mark in the Early Albian the beginning of the deposition of the Argille Scagliose Superiori. Although the Barremian was not detected in the material of the present study, it is documented both in the literature and in the succession drilled by Agip close to Randazzo. Finally, an age extending from the latest Valanginian to the latest Aptian is established by means of palynomorphs for the Monte Soro Flysch. Owing to their abundance, diversity, excellent preservation and consistent record throughout the composite succession of the Monte Soro Flysch, dinoflagellate cysts represent an optimal tool for age and palaeoenvironmental assessment within this unit.

The reappraisal of the dinoflagellate species *Hystrichosphaeridium? atlasiense* Below is proposed: a single-plate precingular archeopyle is documented for the cyst, which precludes its assignment to the genus *Hystrichosphaeridium* Deflandre and suggests the attribution to the genus *Kleithriasphaeridium* Davey, herein emended. The first appearance of *Kleithriasphaeridium atlasiense* (Below, 1982) Torricelli comb. nov. is proposed as an important biostratigraphic event close to the Aptian/Albian boundary in the Tethyan Realm.

Introduction.

This study represents the first extensive use of palynology for biostratigraphic investigations on the sedimentary units grouped in the 'Sicilide Complex' (Ogniben, 1960), cropping out in the Northern Sicilian Chain (Fig. 1). Data presented in this paper acquire weight in the light of the fact that the biostratigraphic studies previously carried out on the Monte Soro Flysch (see Coccioni & Monechi, 1994 for a comprehensive summary), focused on the carbonate microfossils (foraminifers, tintinnids, calpionellids, calcareous nannoplankton), were heavily affected by the scarcity and/or discontinuous occurrence of the fossil content. In particular, the shales in the upper portion of the Monte Soro Flysch were found to be devoid of calcium carbonate, thus resulting completely barren in terms of

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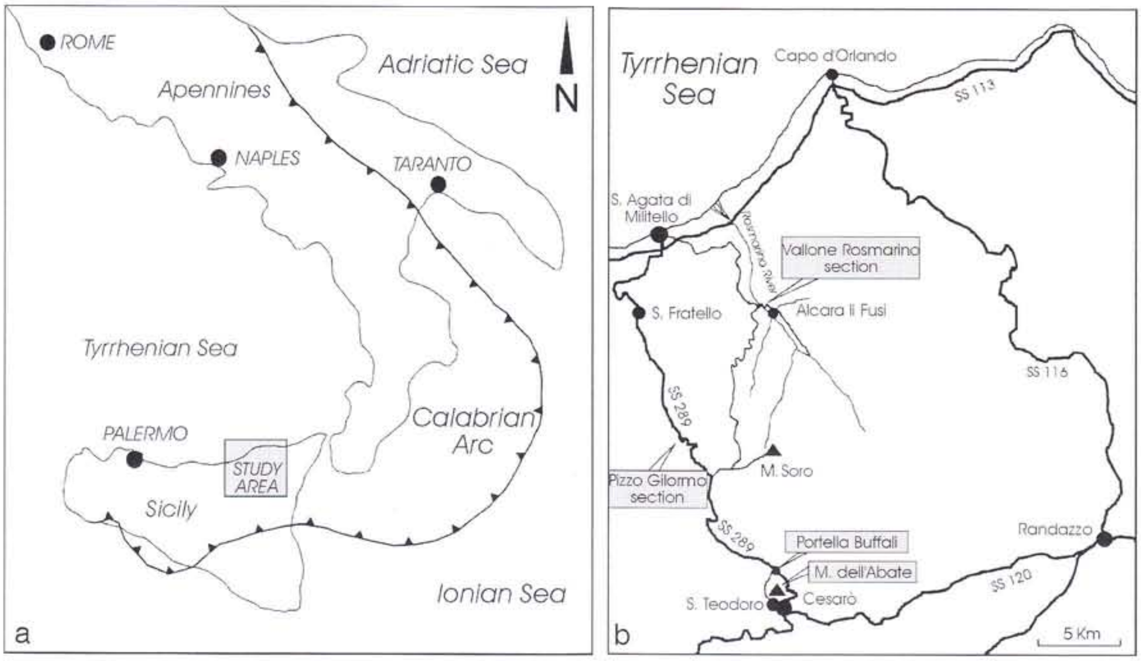


Fig. 1 - Location map and road map of the study area, showing location of sections and additional spot samples (b).

foraminifers and calcareous nannoflora (Coccioni & Monechi, 1994). This is confirmed by the analyses of smear slides obtained from the same samples investigated for palynomorphs in the present work: in the Vallone Rosmarino section nannofossil assemblages indicating a Hauterivian age are generally rich and well preserved; in contrast, higher in the succession, samples from Pizzo Gilormo (Aptian), Monte dell'Abate (Aptian) and Portella Buffali (Albian) are barren (F. Lottaroli, ENI S.p.A., pers. comm.).

The aim of this paper is to document the rich assemblages of organic-walled microplankton recorded throughout a composite outcrop section of the Monte Soro Flysch and to interpret their stratigraphic distribution in order to constrain better the age of this unit. Even though a preliminary paper describing two new dinoflagellate cyst species recorded from the lower portion of the Monte Soro Flysch has already been published (Torricelli, 1997), the results here presented prove for the first time the high age-resolution potential of palynomorphs in the Monte Soro Flysch and allow to improve considerably the previous bio-chronostratigraphic framework of this unit.

Geological and stratigraphic framework.

The Monte Soro Flysch crops out extensively in the Nebrodi Mountains (NE Sicily), a sector of the Maghrebian orogenic system which is made of a series of nappes and imbricated thrust-sheets emplaced with an African vergence during the Tertiary (Ogniben, 1960; Lentini & Vezzani 1978; Catalano & D'Argenio, 1982). The Monte Soro Flysch is the most internal of the sedimentary units grouped by Ogniben (1960) in the 'Sicilide Complex' and constitutes the highest structural element among the Africa-verging nappes of the Northern Sicilian Chain. The Monte Soro Flysch is tectonically overlain by the 'Calabride Complex': this contact appears evident in the Vallone Rosmarino section (Fig. 2), truncated at the top by massive carbonates related to the Peloritanian thrust front. The stratigraphic base of the Monte Soro Flysch is never exposed along the chain (Puglisi & Coccioni, 1987; Coccioni & Monechi 1994), since this unit is detached and thrusted south-westerly on more external units. However, Bouillin et al. (1995) recognized Upper Jurassic radiolarites (Contrada Lanzeri Formation) questionably interpreted as the base of the Monte Soro Flysch.

From a lithological point of view the Monte Soro Flysch was subdivided into a clayey-calcareous lower member and a clayey-arenaceous upper member (Lentini & Vezzani 1978; Lentini 1982; Lentini et al. 1987) with an overall estimated thickness of 700 m (Puglisi & Coccioni 1987). The first biostratigraphic studies of the Monte Soro Flysch, based on tintinnids, calpionellids and foraminifers, were mainly addressed to the marly and calcareous interbeds of the clayey-calcareous lower member, since the clayey-arenaceous upper member proved to be essentially barren of these fossil groups (Lentini 1973; Vezzani 1974; Carmisciano et al. 1983). Although these works pointed out its Early Cretaceous age, the Monte Soro Flysch remained one of the most puzzling sequences of the Maghrebian Chain, both in terms of chronostratigraphy and palaeogeography (Lentini et al. 1987). More recently Coccioni & Mo-

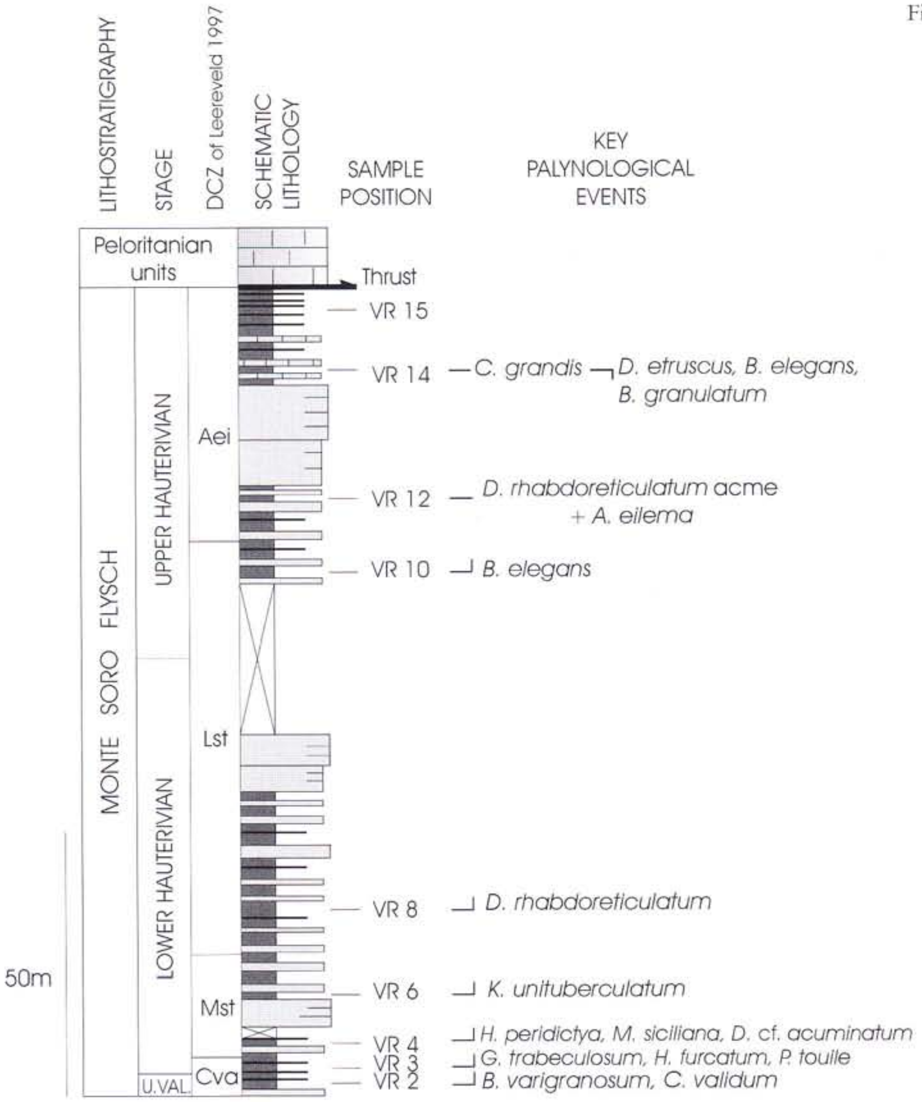


Fig. 2 - Schematic representation of the Vallone Rosmarino section with lithology (dark gray shales, siltstones and quartz sandstones with calcareous marl intercalations in the uppermost part), sample position, key palynological events, dinoflagellate cyst zonal attributions (DCZ) following Leereveld (1995, 1997a, b) and corresponding stratigraphy. Samples missing with respect to progressive numbering from VR 1 to VR 15 were collected from palynologically barren sandstones for petrographic investigations. Zonal boundaries are arbitrarily placed midway between samples.

nechi (1994) tried to constrain better the age of the Monte Soro Flysch with the integrated study of planktonic foraminifers and calcareous nannofossils: however, as only scattered outcrops of limited thickness (from few decimetres to about 10 m) were investigated and most of the samples proved to be barren, the previous bio-chronostratigraphic framework was only partially improved by assigning a Late Hauterivian-Early Aptian age to the samples which were thought to represent the clayey-calcareous lower member of the studied unit.

Material and methods.

A total of twenty-three samples of shale collected from two outcrop sections in NE Sicily were processed and analysed for palynomorphs. The sections are (Fig. 1):

a) Vallone Rosmarino (sample code VR), located near the village of Alcara li Fusi (Messina Province) on the eastern side of the Rosmarino River. The stratigraphic section available for the study is approximately 150 m thick and consists of regularly bedded turbidites mainly made up of fine grained quartzose sandstones interbedded with dark grey shales (Fig. 2). Thin bedded carbonate mudstones occur particularly in the upper part of this section, which represents in fact the clayey-calcareous lower member of the Monte Soro Flysch in the sense of Lentini & Vezzani (1978). As already stated by the previous workers (Puglisi & Coccioni 1987; Coccioni & Monechi 1994), the base of the Monte Soro Flysch is never exposed along the Sicilian Chain. The Vallone Rosmarino section is tectonically truncated at the top by a massive carbonate unit related to the Peloritanian thrust front.

b) Pizzo Gilormo (sample code GIL-C and GIL-D), located immediately south of Km 26.5, road SS 289 (Messina province). The section is approximately 150 m thick and consists of fine-grained quartzose sandstones interbedded with blackish and dark green shales. This turbidite succession exhibits an overall thinning- and fining-upward trend with thick-bedded sandstone lobe deposits at the base, thin-bedded lobe fringe de-posits in the middle and basinal shales at the top (Fig. 3).

In addition, a few spot samples were collected and analysed for palynology from the north-western sur-

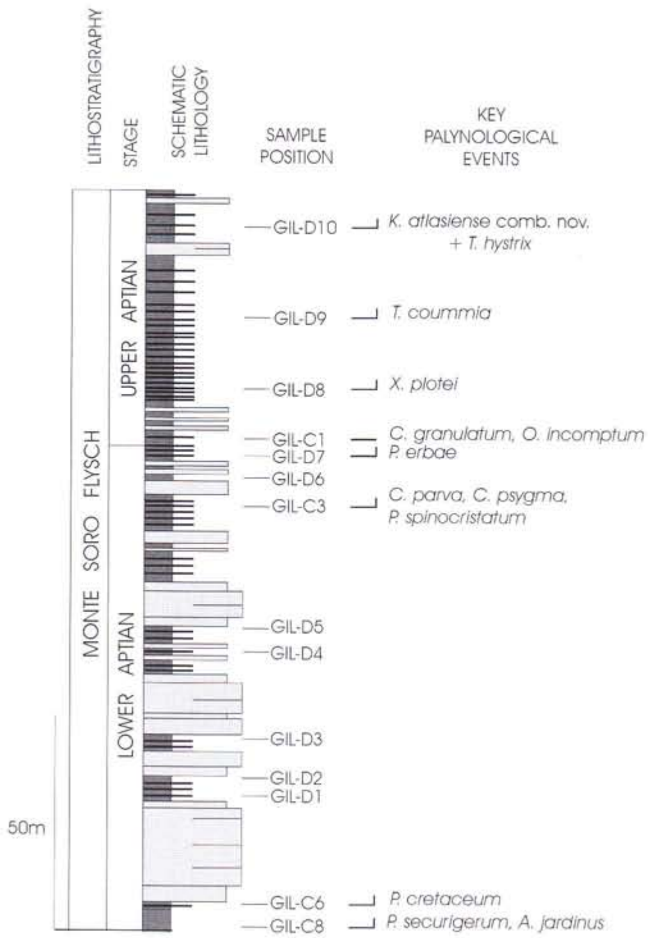


Fig. 3 - Schematic representation of the Pizzo Gilormo section with lithology (dark gray shales, siltstones and quartz sandstones), sample position, key palynological events and corresponding chronostratigraphy. Samples missing with respect to progressive numbering from GIL-C 1 to GIL-C 8 were collected from palynologically barren sandstones for petrographic investigations.

roundings of the city of Cesarò (Messina Province), in order to verify the litho- chronostratigraphic attribution of the sediments forming the Monte dell'Abate-Portella Buffali area.

The standard 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 ZnCl2 and centrifuging to concentrate the residues. Two slides were prepared for each sample using residue greater than 15 μm and Canada balsam as a mounting medium. No oxidation was required. One slide per sample was entirely counted in order to obtain the relative abundances of palynomorph taxa, whereas the second slide was examined to check for the presence of rare species. The analytical results are presented in the quantitative distribution charts with the corresponding bio-chronostratigraphic attributions (Figs. 4, 5). The analytical method applied in this study is not strictly quantitative (cf. Brinkhuis 1994), since all the samples prepared were used for palynostratigraphic evaluation independently on the overall fossil recovery. Accordingly, percentages were not used because in samples with low fossil recovery (less than 100 determinable specimens per slide) they may lead to anomalous values.

The palynological assemblages are composed of bisaccate pollen, inaperturate pollen and other pollen grains, trilete spores, dinoflagellate cysts, acritarchs and foraminiferal test linings in fluctuating relative abundances. In general the preservation ranges from moderate to excellent. Within the scope of the present study the palynological assemblages will be only qualitatively discussed pertaining to their biostratigraphic significance.

Light photomicrographs were taken using a Zeiss Axioplan microscope and interference-contrast illumination. For taxonomic citations reference is made to Williams et al. (1998). Taxa not included in Williams et al. (1998) are treated in the systematic section.

All the preparation slides examined in this study are housed in the palynological slide collection at the Stratigraphic Department (STIG) of ENI S.p.A., Agip Division, San Donato Milanese, Italy.

Palynomorph stratigraphy.

Vallone Rosmarino section.

A total of 9 samples were collected from the shale beds of the Vallone Rosmarino section and analysed for palynomorphs (Fig. 2). Even though the terrestrially derived fraction (pollen and spores) is always present and sometimes abundant, the extremely diverse marine assemblages obtained from these samples (82 taxa of dinoflagellate cysts and acritarchs have been identified; Fig. 4), provide the main tool in order to work out a precise biostratigraphy of the section. The dinoflagellate cyst zonation scheme established for the Lower Cretaceous of the western Mediterranean by Leereveld (1995, 1997a, 1997b, Fig. 6) has been successfully used as a framework for the interpretation of the dinoflagellate cyst distribution.

Based on the consistent occurrence of *Cymososphaeridium validum* (Pl. 7, Fig. 7) and *Batioladinium varigranosum* (Pl. 5, Fig. 13) in samples VR 2 and VR 3, the basal part of the section is assigned to the *Cva* dinoflagellate Zone of Leereveld (1997a), latest Valanginian-earliest Hauterivian in age. *Protoellipsodinium touile* has its lowest occurrence in sample VR 3: since the first occurrence of this taxon was proposed by Leereveld (1997a, b) as an additional event for recognition of the Hauterivian part of the *Cva* Zone, the Valanginian/Hauterivian boundary probably lies between samples VR 2 and VR 3. This assessment is sup-

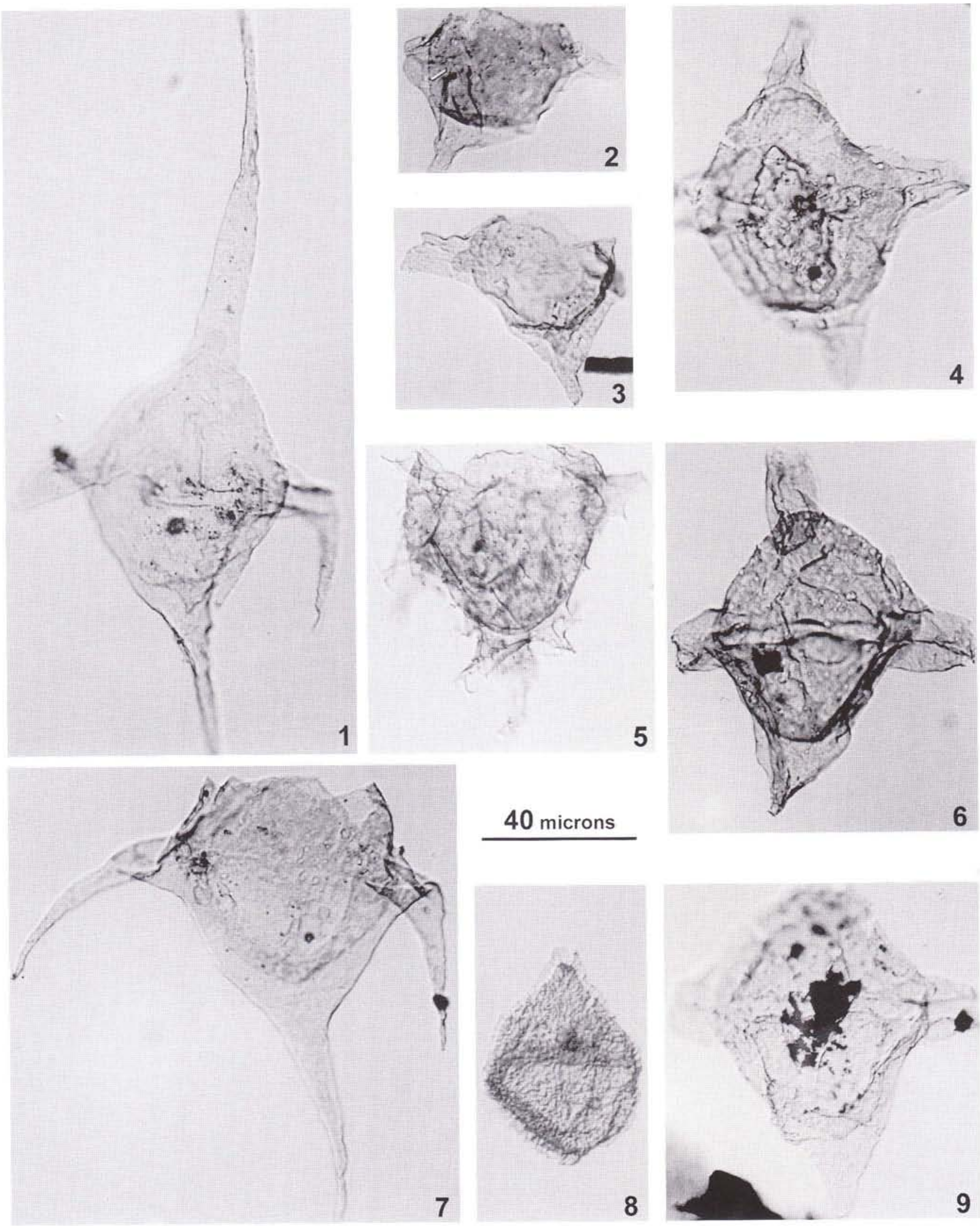


PLATE 1

Dinoflagellate cysts from the Monte Soro Flysch (VR = Vallone Rosmarino section).
For all magnifications reference is made to the scale bar = 40 µm.
(1, 7) *Muderongia staurota*, sample VR 10. (2) *Muderongia siciliana*, sample VR 4. (3) *Muderongia siciliana*, sample VR 6. (4) *Muderongia simplex*, sample VR 15. (5) *Phoberocysta neocomica*, sample VR 6. (6) *Muderongia pariata*, sample VR 12. (8) *Gardodinium trabeculosum*, sample VR 4. (9) *Muderongia simplex*, sample VR 2.

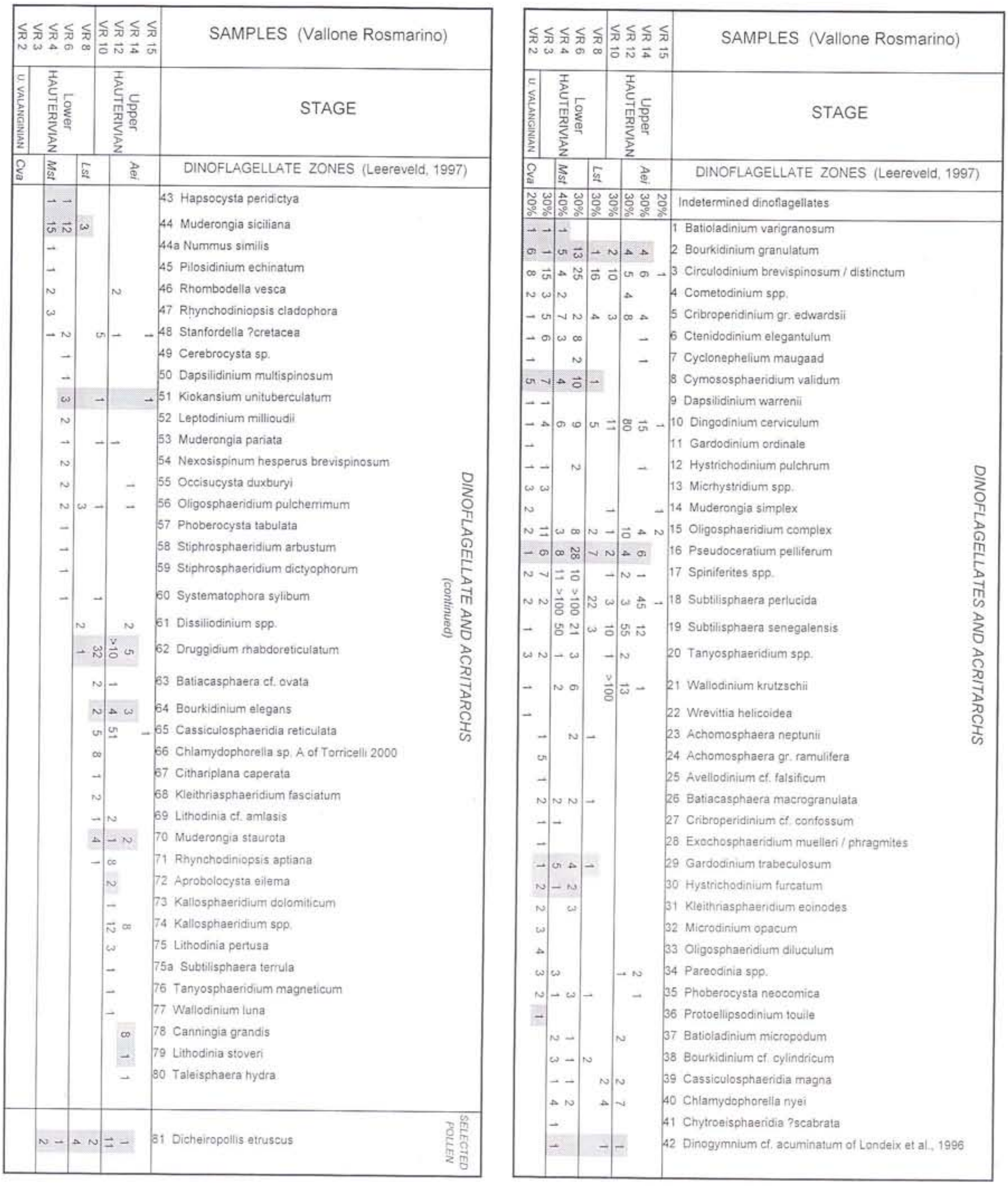
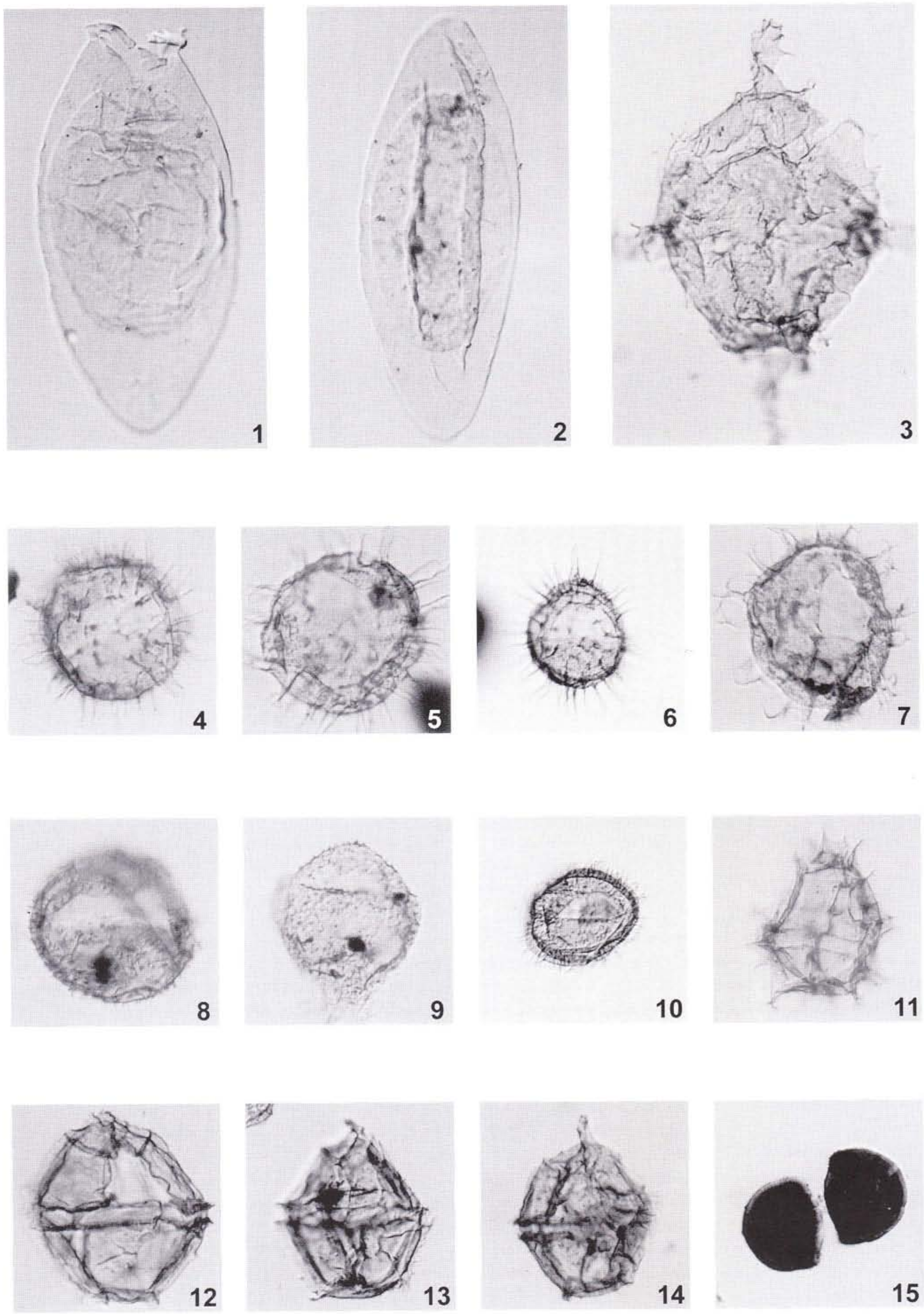


Fig. 4 - Quantitative distribution chart of dinoflagellate cyst, acritarch and selected pollen taxa in the Vallone Rosmarino section, ordered according to first occurrences. Samples missing with respect to progressive numbering from VR 1 to VR 15 were collected from palynologically barren sandstones for petrographic investigations. Numbers refer to counted specimens in a single slide preparation. The biostratigraphically important taxa are highlighted. Vertical scale not proportional to stratigraphic thicknesses.

PLATE 2

Dinoflagellate cysts, acritarchs and pollen from the Monte Soro Flysch (VR = Vallone Rosmarino section; GIL = Pizzo Gilormo section). All magnifications x 750 unless otherwise stated.

(1-2) *Wallodinium krutschii*, sample VR 10. (3) *Phoberocysta neocomica*, sample VR 4. (4-5) *Kiokansium unituberculatum*, sample VR 6. (6) *Pervosphaeridium pseudhystrichodinium* x 550, sample GIL-D 9. (7) *Achomosphaera neptunii*, sample VR 8. (8-9) *Nexosispinum hesperus* subsp. *brevispinosum*, sample VR 6. (10) *Nexosispinum hesperus* subsp. *hesperus* x 550, sample GIL-D 4. (11) *Spiniferites* spp., sample VR 6. (12) *Leptodinium millioudii*, sample VR 6. (13) *Stanfordella ?cretacea*, sample VR 12. (14) *Wrevittia helicoidea*, sample VR 3. (15) *Dicheiropollis etruscus* x 550, sample VR 8.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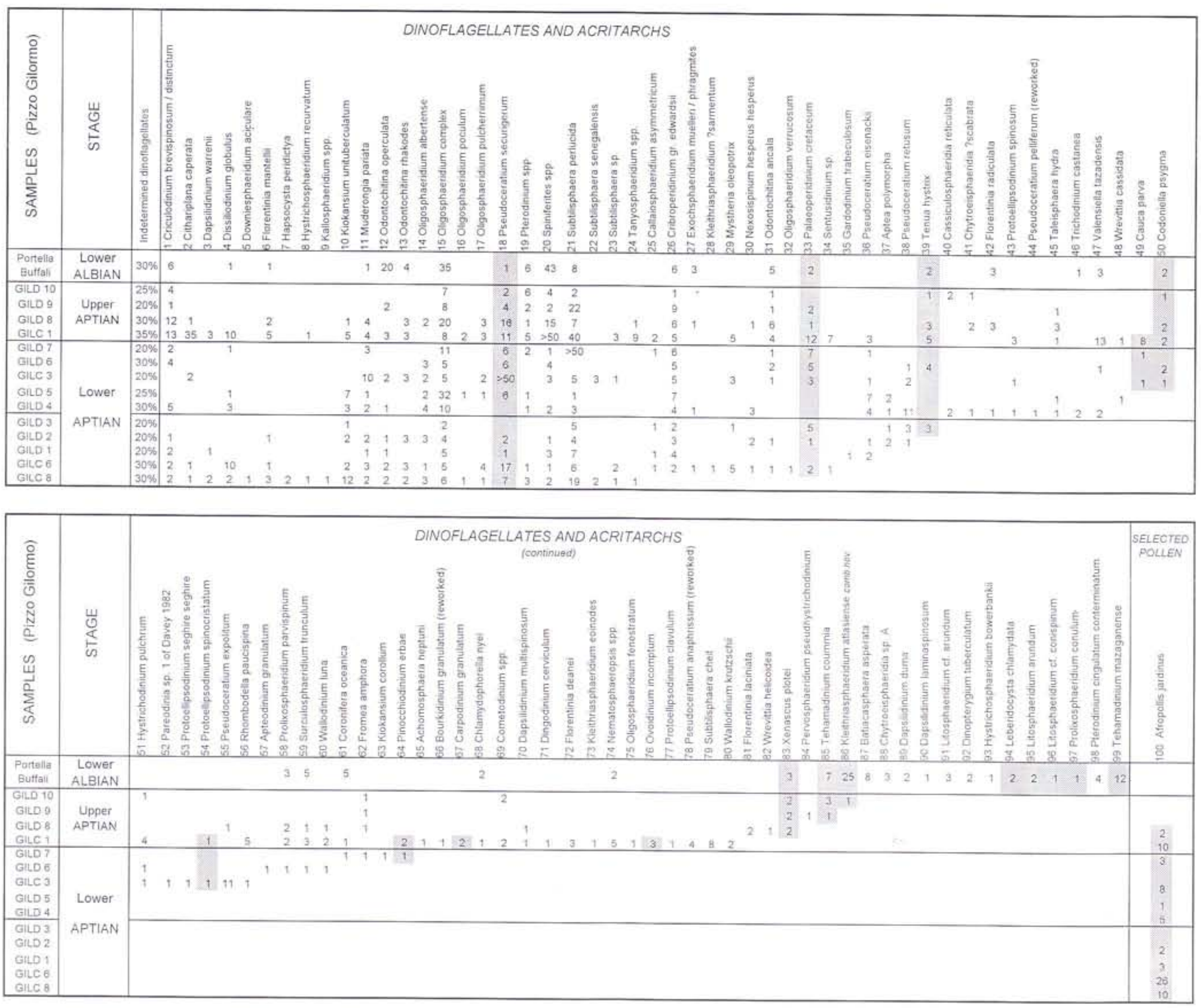


Fig. 5 - Composite quantitative distribution chart of dinoflagellate cyst, acritarch and selected pollen taxa in the Pizzo Gilormo section and the overlying Portella Buffali shales, ordered according to first occurrences. Samples missing with respect to progressive numbering from GIL-C 1 to GIL-C 8 were collected from palynologically barren sandstones for petrographic investigations. Numbers refer to counted specimens in the whole slide. The biostratigraphically important taxa are highlighted. Vertical scale not proportional to stratigraphic thicknesses.

ported also by the lowest occurrences in sample VR 3 of *Gardodinium trabeculosum* (Pl. 1, Fig. 8; Pl. 5, Figs. 5-7) and *Hystrichodinium furcatum* (Pl. 7, Fig. 1), whose total ranges, according to Stover et al. (1996), do not extend below the Valanginian/Hauterivian boundary.

Although in this section the zonal marker *Muderongia staurota* (Pl. 1, Figs. 1, 7) first occurs in sample VR 10, the interval from sample VR 4 to sample VR 6 can be assigned to the Lower Hauterivian *Mst* dinocyst Zone of Leereveld (1997b) on the basis of the lowest occurrences of *Hapsocysta peridictya* (Pl. 5, Fig. 16), *Kiokansium unituberculatum* (Pl. 2, Figs. 4-5) and *Dinogymnium* cf. *acuminatum* sensu Londeix et al. 1996 (Pl. 3, Figs. 12-13). All these dinostratigraphical events were in fact proposed as additional criteria for recognition of the *Mst* dinocyst Zone in SE Spain (Leereveld, 1997b). It is worth mentioning that this portion of the Monte Soro Flysch represents the type-stratum of *Muderongia siciliana* (Pl. 1, Figs. 2-3; Pl. 6, Fig. 9), a dinoflagellate cyst species formally described by Torricelli (1997) and recorded also from the Upper Hauterivian of the Southern Alps (Torricelli, 2000).

The section interval represented by samples VR 8 and VR 10 is referable to the *Lst* Zone spanning the Lower/Upper Hauterivian transition, since the lowest occurrence of *Druggidium rhabdoreticulatum* (Pl. 3, Fig. 10-11), herein recorded in sample VR 8, was proposed by Leereveld (1997b) as an horizon for defining the base of that dinocyst zone.

The lowest occurrence of the zonal marker *Aprobolocysta eilema* (Pl. 5, Figs. 14-15) in sample VR 12 and of several specimens referable to *Canningia grandis*

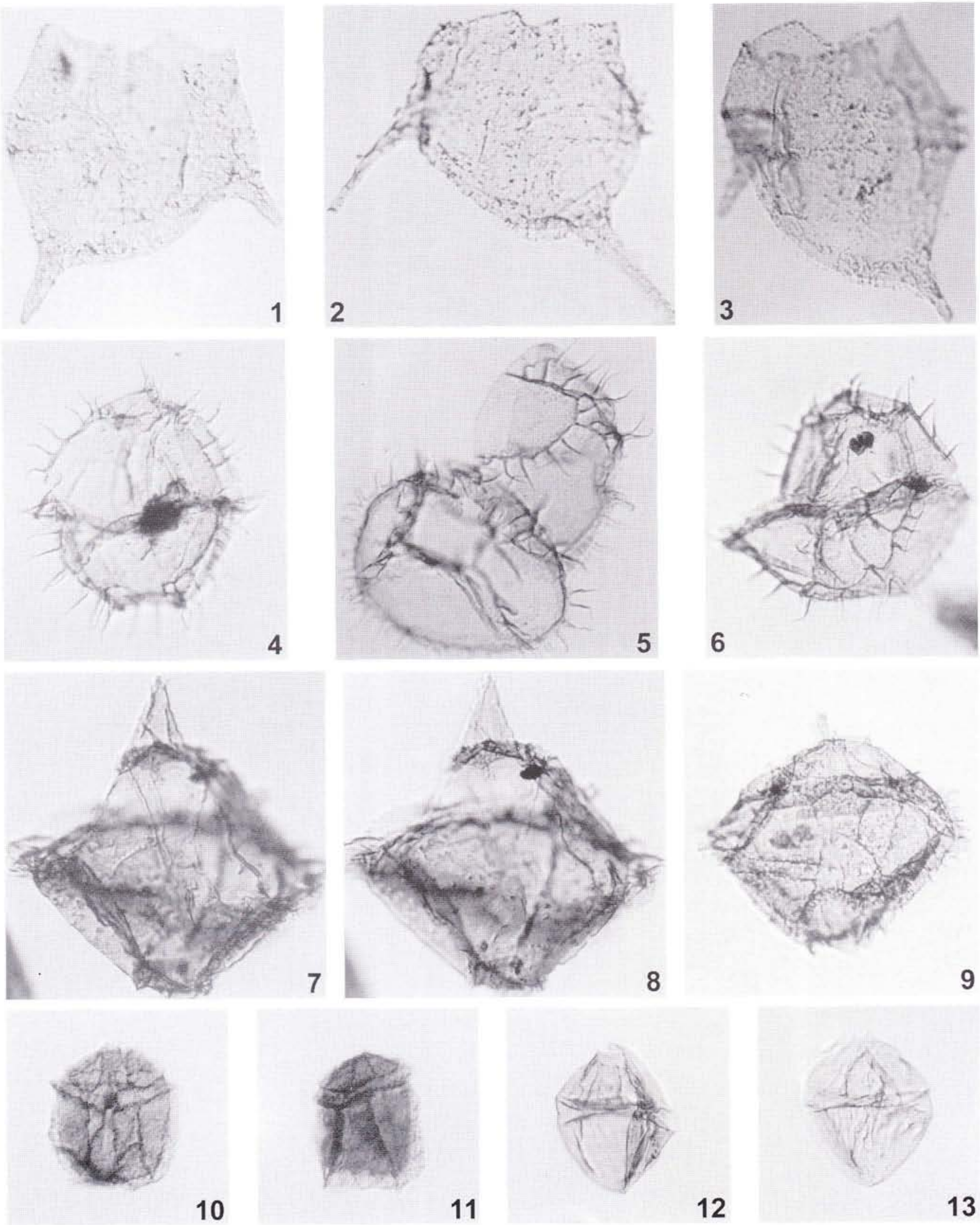


PLATE 3

Dinoflagellate cysts from the Monte Soro Flysch (VR = Vallone Rosmarino section). All magnifications x 750 unless otherwise stated.
(1) *Pseudoceratium pelliferum*, sample VR 8. (2-3) *Pseudoceratium pelliferum*, sample VR 6. (4) *Ctenidodinium elegantulum*, sample VR 4. (5-6) *Ctenidodinium elegantulum*, sample VR 6. (7-8) *Occisucysta duxburyi*, sample VR 6. (9) *Rhynchodiniopsis cladophora* x 550, sample VR 4. (10-11) *Druggidium rhabdoreticulatum*, sample VR 12. (12) *Dinogymnium* cf. *acuminatum* sensu Londeix et al. (1996), sample VR 12. (13) *Dinogymnium* cf. *acuminatum* sensu Londeix et al. (1996), sample VR 10.

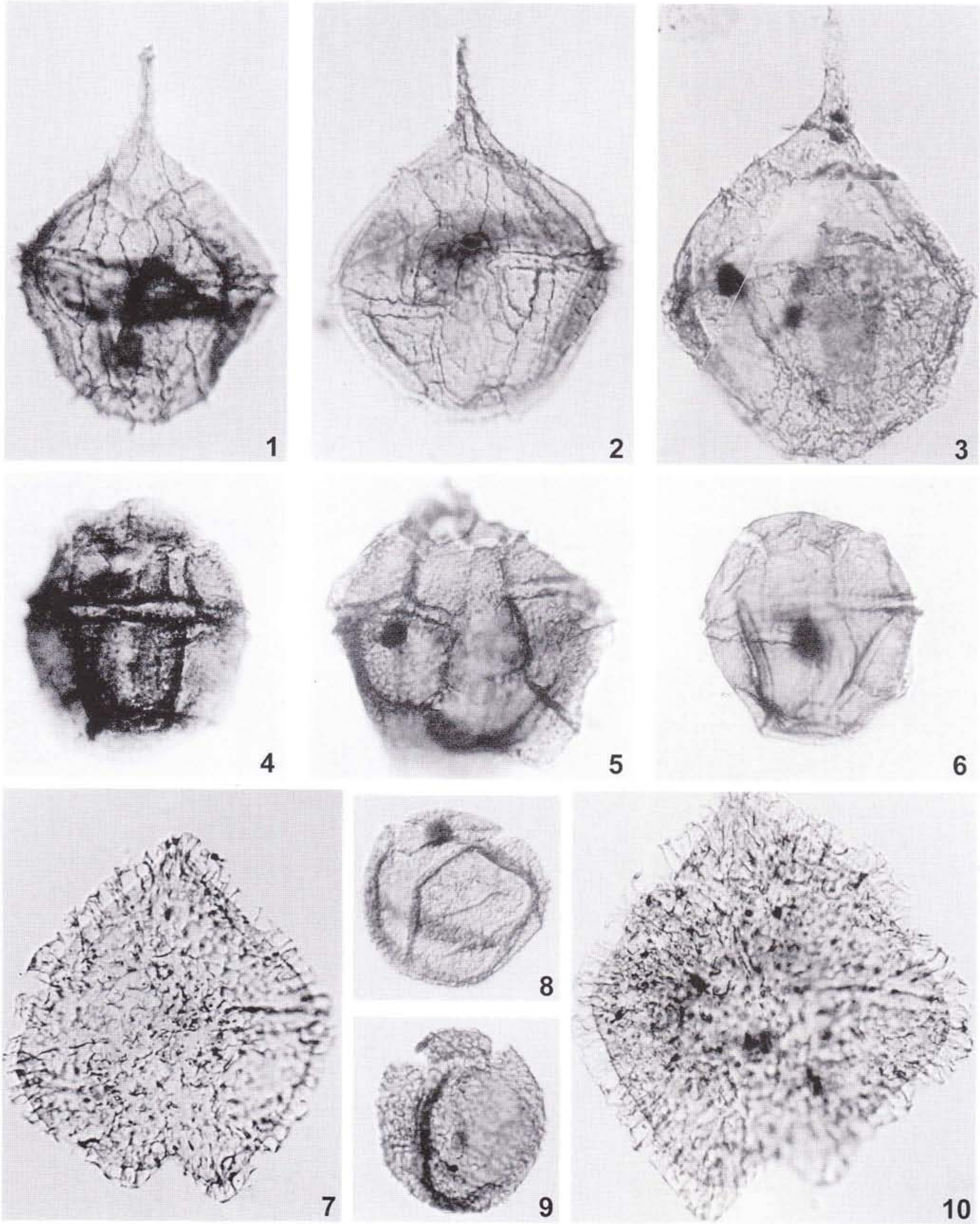


PLATE 4

Dinoflagellate cysts from the Monte Soro Flysch (VR = Vallone Rosmarino section). All magnifications x 750 unless otherwise stated. (1) *Cribroperidinium* gr. *edwardsii*, sample VR 12. (2) *Cribroperidinium* gr. *edwardsii*, sample VR 14. (3) *Cribroperidinium* cf. *confossum*, sample VR 3. (4) *Lithodinia pertusa*, sample VR 12. (5) *Lithodinia stoveri*, sample VR 14. (6) *Lithodinia* cf. *amlasis*, sample VR 10. (7, 10) *Canningia grandis* x 600, sample VR 14. (8) *Batiacasphaera macrogranulata*, sample VR 4. (9) *Cassiculosphaeridia reticulata*, sample VR 12.

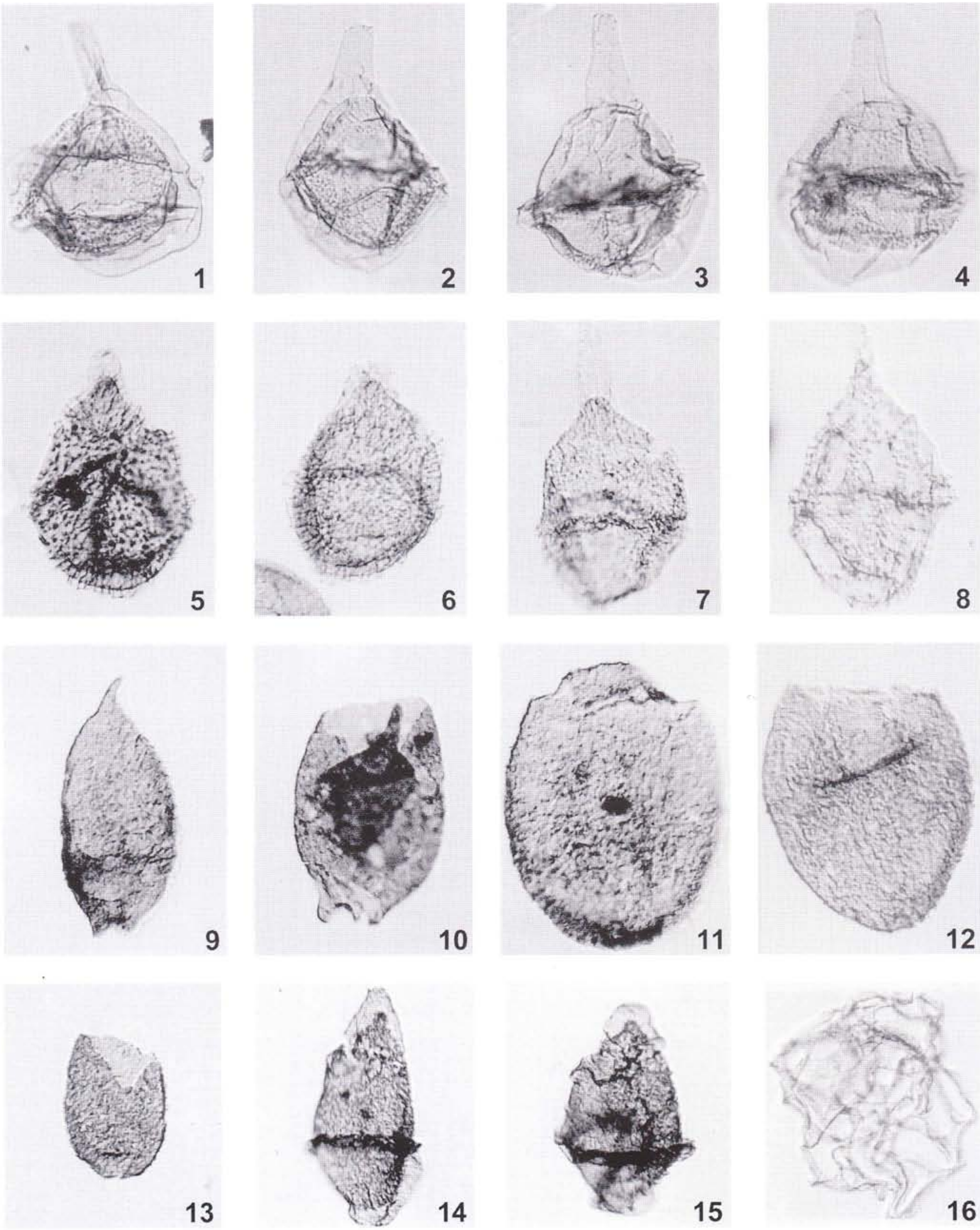


PLATE 5

Dinoflagellate cysts from the Monte Soro Flysch (VR = Vallone Rosmarino section). All magnifications x 750 unless otherwise stated.
(1-3) *Dingodinium cerviculum*, sample VR 12. (4) *Dingodinium cerviculum*, sample VR 6. (5-6) *Gardodinium trabeculosum*, sample VR 4. (7) *Gardodinium trabeculosum*, sample VR 8. (8) *Gardodinium ordinale*, sample VR 2. (9) *Batioladinium micropodum*, sample VR 12. (10) *Batioladinium micropodum*, sample VR 4. (11-12) *Batiacasphaera* cf. *ovata*, sample VR 10. (13) *Batioladinium varigranosum* x 550, sample VR 2. (14-15) *Aprobolocysta eilema* x 550, sample VR 12. (16) *Hapsocysta peridictya*, sample VR 4.

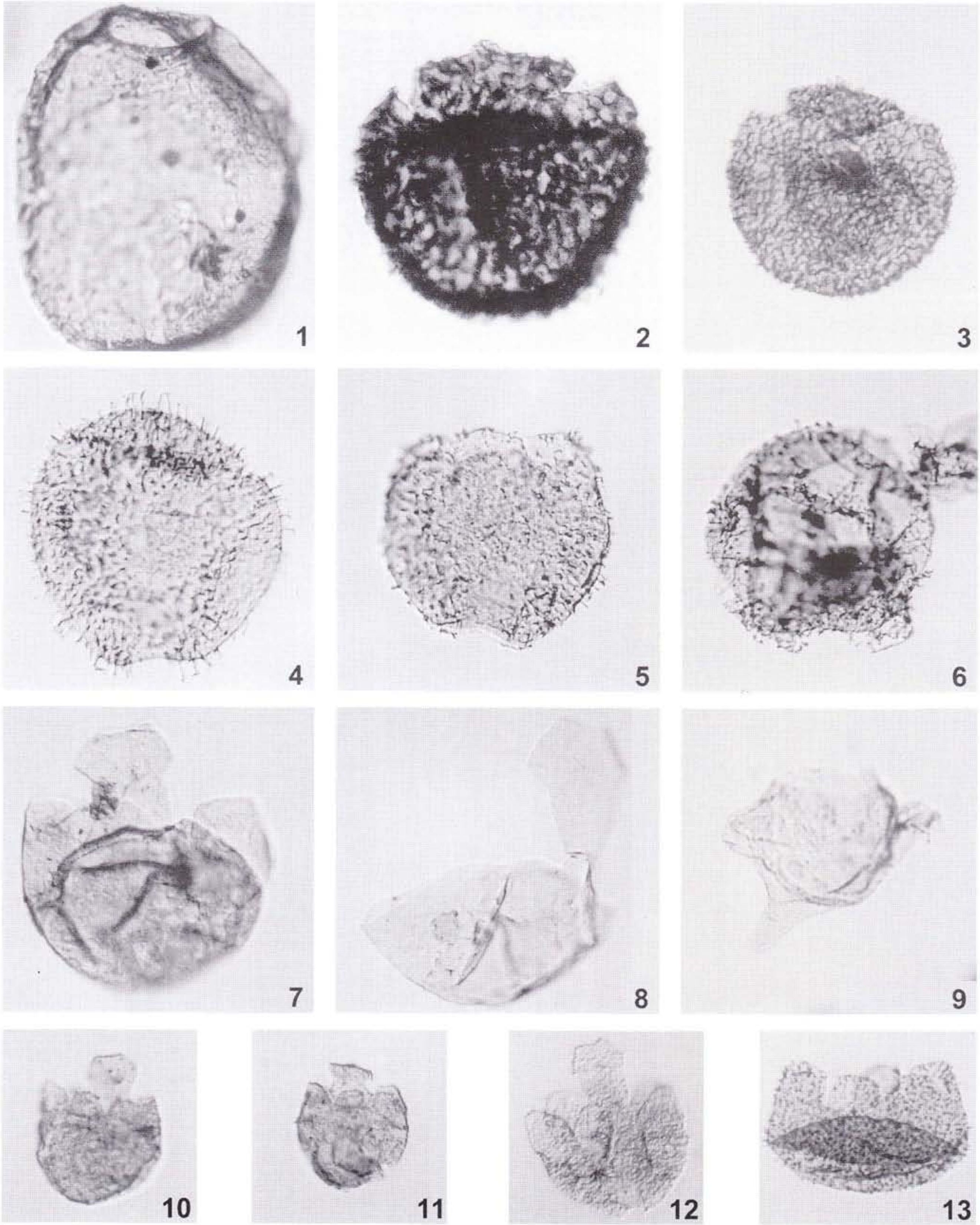


PLATE 6

Dinoflagellate cysts and acritarchs from the Monte Soro Flysch (VR = Vallone Rosmarino section). All magnifications x 750.
(1) *Nummus similis*, sample VR 4. (2) *Cassiculosphaeridia magna*, sample VR 12. (3) *Cassiculosphaeridia reticulata*, sample VR 4. (4) *Circulodinium distinctum*, sample VR 8. (5) *Circulodinium brevispinosum*, sample VR 12. (6) *Cyclonephelium maugaad*, sample VR 6. (7) *Kallosphaeridium* spp., sample VR 14. (8) *Dissiliodinium* spp., sample VR 8. (9) *Muderongia siciliana*, sample VR 4. (10-12) *Kallosphaeridium* spp., sample VR 12. (13) *Pilosidinium echinatum*, sample VR 4.

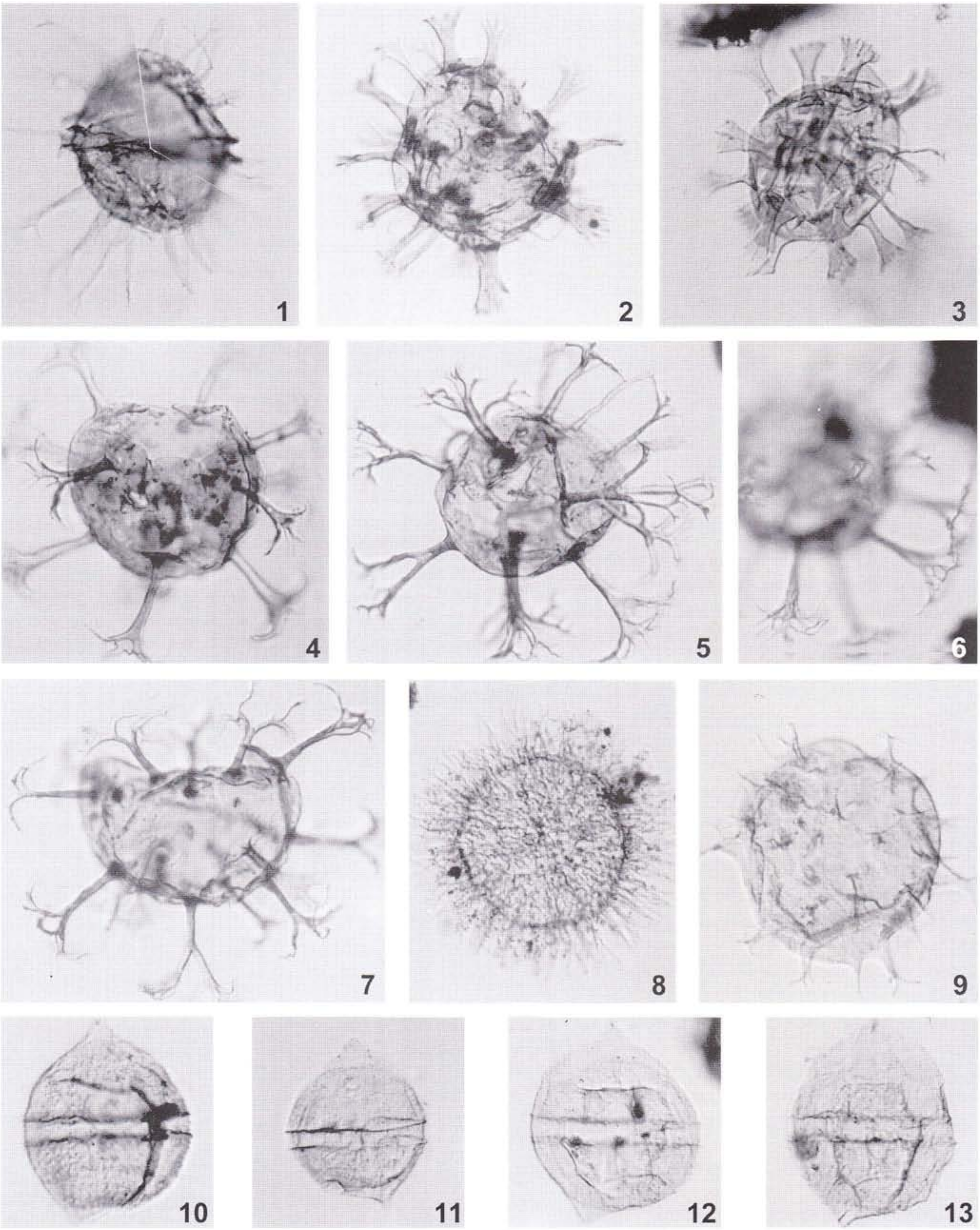


PLATE 7

Dinoflagellate cysts from the Monte Soro Flysch (VR = Vallone Rosmarino section). All magnifications x 750.
(1) *Hystrichodinium furcatum*, sample VR 4. (2-3) *Kleithriasphaeridium eoinodes*, sample VR 6. (4) *Oligosphaeridium complex*, sample VR 14. (5) *Oligosphaeridium diluculum*, sample VR 6. (6) *Oligosphaeridium pulcherrimum*, sample VR 8. (7) *Cymososphaeridium validum*, sample VR 6. (8) *Cometodinium* spp., sample VR 4. (9) *Achomosphaera* gr. *ramulifera*, sample VR 3. (10-11) *Subtilisphaera perlucida*, sample VR 4. (12-13) *Subtilisphaera senegalensis*, sample VR 12.

STAGES	SUBSTAGES	TETHYAN AMMONITE ZONES	DINOFLAGELLATE CYST ZONES of Leereveld 1997	DINOFLAGELLATE CYST SUBZONES of Leereveld 1997	PLANKTONIC FORAMINIFER ZONES	CALCAREOUS NANNOFOSSIL ZONES
BARREMIAN	UPPER	M. sarasini				
		I. giraudi	Oop *p.p.*		G. blowi *p.p.*	
		H. feraudianus				
		H. sartousiana				M. hoschulzii
		A. vandenheckii				
	LOWER	H. caillaudianus	Ssc		H. similis - H. kuznetsovae	
		S. nicklesi				
		S. hugii				
HAUTERIVIAN	UPPER	P. angulicostata	Spe			M. obtusus
		B. balearis				
		P. ligatus	Aei	Capi		N. bucheri
		S. sayni	Lst	Flin	H. sigali - H. delrioensis	N. bollii
	LOWER	L. nodosoplicatum		Kiok Catr		
		C. loryi	Mst	Hiou Bour		
		A. radiatus				C. oblongata *p.p.*
VAL.	UPP.	N.(T.) pachydicranus	Cva			

Fig. 6 - Zonal correlation scheme for the Hauterivian-Barremian of the western Mediterranean including ammonites, planktonic foraminifers, calcareous nannoplankton and dinoflagellate cysts after Leereveld (1995, 1997b).

(Pl. 4, Figs. 7, 10) in sample VR 14, allow the identification of the Upper Hauterivian *Aei* Zone of Leereveld (1997b) in the uppermost part of the Vallone Rosmarino section. Moreover, since the extinctions of species belonging to the genus *Bourkidinium* were calibrated by Leereveld (1995, 1997b) and Torricelli (2000) close to the Hauterivian/Barremian boundary in the Tethyan Realm, the highest occurrences of *Bourkidinium elegans* (Pl. 8, Figs. 2-4) and *B. granulatum* (Pl. 8, Figs. 5-8) recorded in sample VR 14 are remarkably consistent with this chronostratigraphic attribution. It is noteworthy that *B. elegans*, reported as *Bourkidinium* sp. 2 by Leereveld (1995, 1997b), was formally described from this type-stratum by Torricelli (1997).

D. rhabdoreticulatum, retained by some workers as an indicator of warm oceanic waters (Habib & Drugg, 1987; Leereveld, 1995), quantitatively dominates the dinocyst assemblage of sample VR 12 (>100 specimens per slide), whereas *A. eilema*, regarded as a typical Boreal taxon (Duxbury, 1977; Leereveld, 1995), is rare in the same sample (only two specimens were detected). Hence, analytical data from the Tethyan section of Vallone Rosmarino seem to confirm the paleoecological preferences previously inferred for both these dinoflagellate species.

Pizzo Gilormo section.

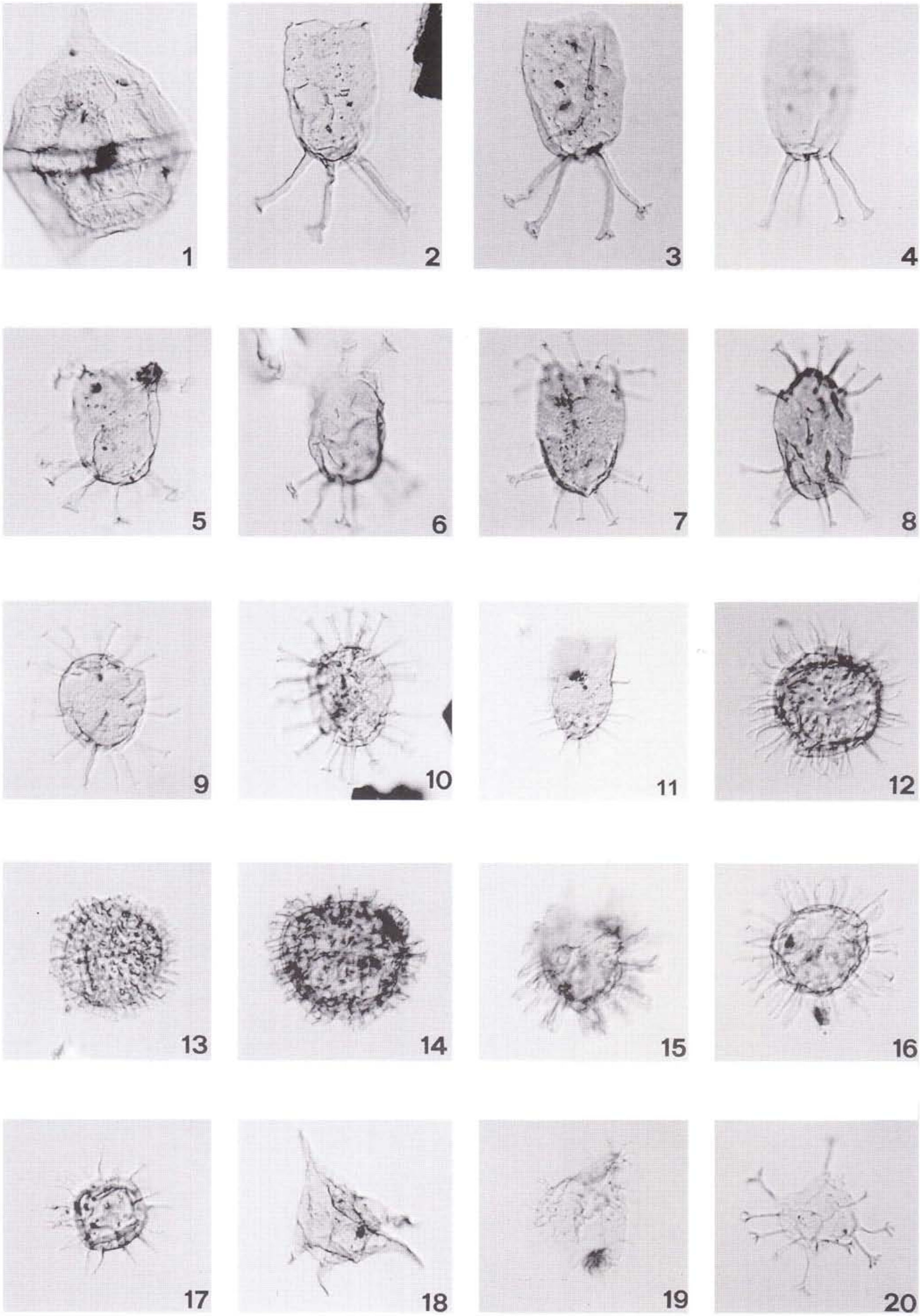
A total of 14 samples collected from the shale beds of the Pizzo Gilormo section in the course of two field trips (named GIL-C and GIL-D respectively) were investigated for palynomorphs (Fig. 3). Leereveld (1995, 1997a, 1997b) dinoflagellate zonation herein applied to the Vallone Rosmarino section does not extend above the Barremian and no other previously established dinoflagellate zones were identified in the Aptian portion of the Monte Soro Flysch sampled in the Pizzo Gilormo section. The chronostratigraphic significance of the rich palynological assemblages recovered from this section (86 taxa of dinoflagellate cysts and acritarchs have been identified; Fig. 5) is thus qualitatively evaluated for consistency with published information from a variety of ammonite-calibrated middle Cretaceous sections in the Northern Hemisphere.

Most of the representatives of the palynological assemblage obtained from the basal sample (GIL-C 8) of the Pizzo Gilormo section have their known range base in the Lower Barremian [*i.e. Odontochitina operculata* (Pl. 9, Fig. 5)] or below. However, the absence of three distinctive taxa that were recovered from the Vallone Rosmarino section, namely *Pseudoceratium pelliferum* (Pl. 3, Figs. 1-3), whose last appearance was proposed by Erba (1996) for the approximation of the Barremian/Aptian boundary, *Rhynchodiniopsis aptiana* and *Phoberocysta neocomica* (Pl. 1, Fig. 5; Pl. 2, Fig. 3), whose last appearances were calibrated in the basal Aptian of the Southern Alps (Erba et al. 1999; Torricelli 2000), consistently with data from the Aptian type-localities (Davey & Verdier, 1974), suggests an Aptian age for the base of the Pizzo Gilormo section. This inference is strongly supported by the remarkable occurrence throughout the section of: a) *Pseudoceratium securigerum* (Pl. 10, Figs. 3-4, 7), a dinocyst species whose range base was documented from the Lower Aptian (Davey & Verdier 1974; Duxbury 1983; Lister & Batten 1988); b) pollen belonging to the genus *Afropollis* (Pl. 12, Fig. 15), one of the first representatives of the angiosperms, whose inception in the Early Aptian of the Tethys is significantly younger than the Early Barremian extinction of *Dicheiropollis etruscus* (Hochuli 1981; Doyle et al. 1982), a gymnosperm pollen recorded at Vallone Rosmarino (Pl. 2, Fig. 15). Moreover, as suggested by the published

PLATE 8

Dinoflagellate cysts and acritarchs from the Monte Soro Flysch (VR = Vallone Rosmarino section). All magnifications x 750 unless otherwise stated.

(1) *Subtilisphaera terrula* x 600, sample VR 12. (2-3) *Bourkidinium elegans*, sample VR 14. (4) *Bourkidinium elegans*, sample VR 12. (5) *Bourkidinium granulatum*, sample VR 2. (6, 8) *Bourkidinium granulatum*, sample VR 6. (7) *Bourkidinium granulatum*, sample VR 14. (9-10) *Tanyosphaeridium* spp., sample VR 6. (11) *Tanyosphaeridium magneticum* x 550, sample VR 12. (12) *Cleistosphaeridium* spp., sample VR 6. (13) *Chlamydophorella nyei*, sample VR 10. (14) *Chlamydophorella nyei*, sample VR 4. (15) *Dapsilidinium warrenii*, sample VR 6. (16) *Dapsilidinium multispinosum*, sample VR 10. (17) *Micrhystridium* spp., sample VR 12. (18) *Veryachium* spp., sample VR 8. (19) *Rhombodella vesca*, sample VR 4. (20) *Rhombodella* spp., sample VR 6.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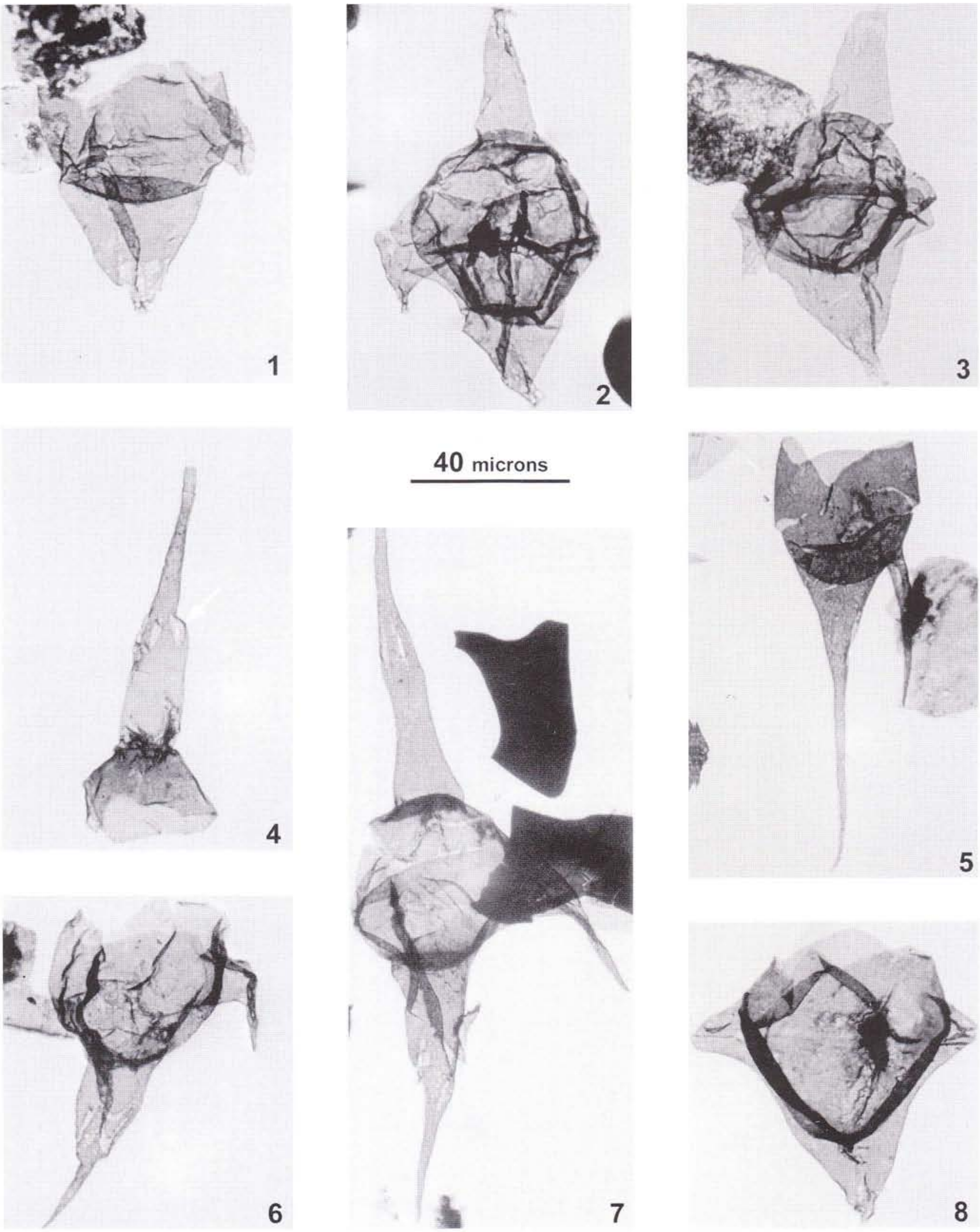


PLATE 9

Dinoflagellate cysts from the Monte Soro Flysch (GIL = Pizzo Gilormo section). For all magnifications reference is made to the scale bar = 40 µm.

(1-2) *Odontochitina rhakodes*, sample GIL-C 6. (3) cf. *Odontochitina rhakodes*, sample GIL-C 1. (4) Isolated operculum of *Odontochitina ancala*, sample GIL-C 6; the arrow indicates elliptical perforations about midway along the apical horn. (5) *Odontochitina operculata*, sample GIL-C 1. (6) *Odontochiina ancala*, sample GIL-C 1. (7) Complete specimen of *Odontochitina ancala*, sample GIL-C 1. (8) *Muderongia pariata*, sample GIL-C 1.

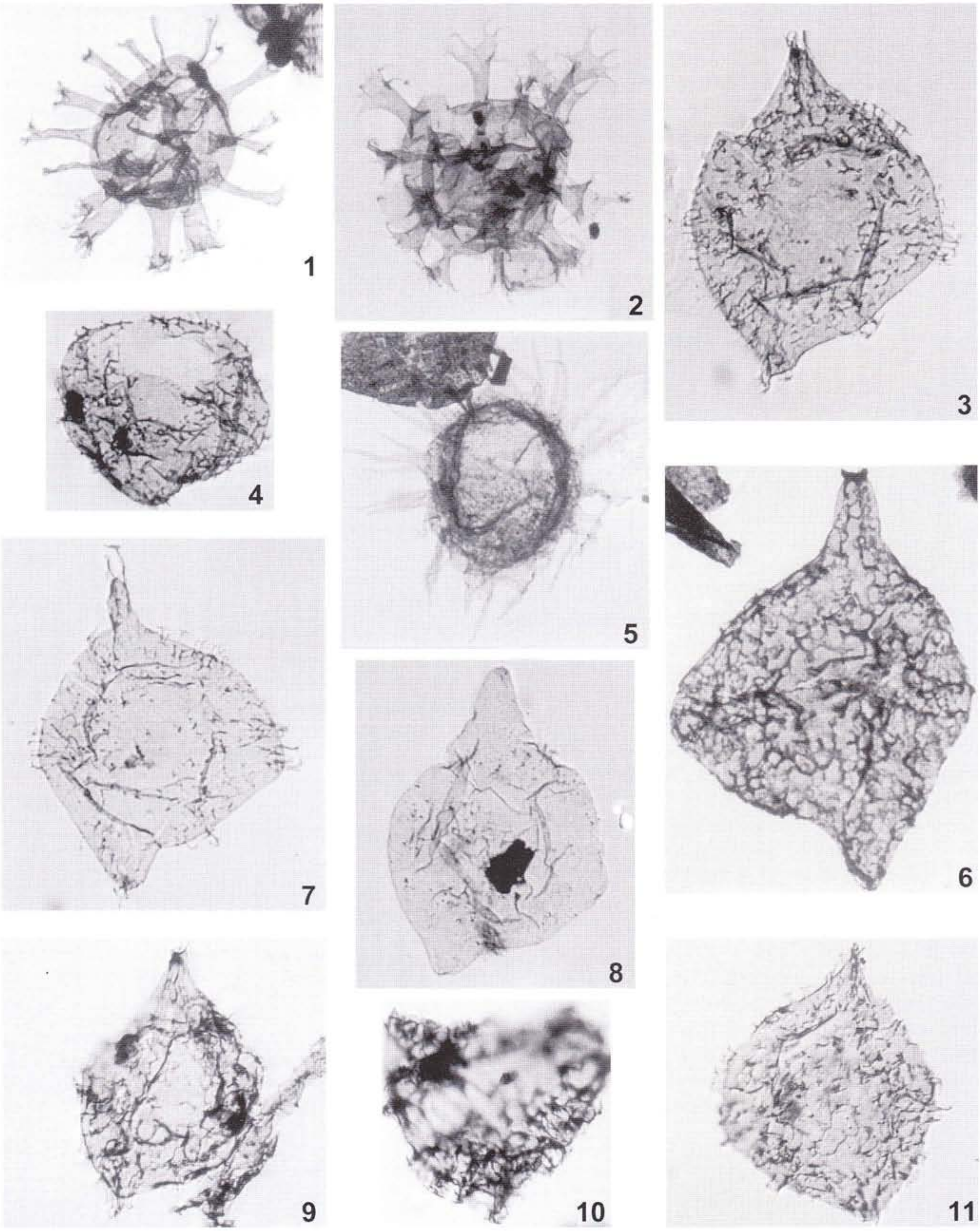


PLATE 10

Dinoflagellate cysts from the Monte Soro Flysch (GIL = Pizzo Gilormo section). All magnifications x 750 unless otherwise stated.
(1) *Florentinia mantellii*, sample GIL-C 8. (2) *Oligosphaeridium albertense*, sample GIL-C 3. (3-4, 7) *Pseudoceratium securigerum*, sample GIL-C 3. (5) *Hystrichodinium pulchrum*, sample GIL-C 1. (6) *Pseudoceratium* cf. *eisenackii*, sample GIL-C 1. (8) *Pseudoceratium expolitum*, sample GIL-C 3. (9) *Pseudoceratium eisenackii* x 550, sample GIL-C 3. (10) *Aptea polymorpha* x 550, sample GIL-D 5. (11) *Pseudoceratium retusum* x 550, sample GIL-D 4.

records of *Palaeoperidinium cretaceum* (Pl. 11, Fig. 14) in the Tethyan Realm (Davey & Verdier 1974; Below 1982; Torricelli 2000), the lowest occurrence of this species in sample GIL-C 6 may be used as additional evidence for supporting the Early Aptian age of this part of the section. *P. cretaceum* is in fact shown to be absent from the Barremian of the Tethyan Realm (De Renéville & Raynaud 1981; Srivastava 1984).

The lowest occurrences of *Protoellipsodinium spinocristatum* (Pl. 11, Fig. 1), *Cauca parva* (Pl. 11, Figs. 9-13) and *Codoniella psygma* (Pl. 11, Fig. 15) in sample GIL-C 3 are important events in order to assess a rejuvenation of the Pizzo Gilormo dinoflagellate cyst assemblages because: a) the range base of *P. spinocristatum* was recorded in the uppermost Bedoulian (Lower Aptian) of SE France (Davey & Verdier, 1974) and correlated to the top of the *Deshayesi* ammonite Zone (Lower Aptian) in the english sections from the Isle of Wight (Duxbury 1983) and West Sussex (Lister & Batten 1988); b) although its overall known distribution ranges down in the Barremian, the first consistent occurrence of *C. parva* in the Tethyan Realm was reported from the Upper Aptian (Davey & Verdier 1974; Stover et al. 1996); c) *C. psygma* was recorded in the Atlantic offshore of Morocco as part of dinoflagellate cyst assemblages indicating the Upper Aptian (Below 1984), whereas its occurrence in the Boreal Realm is higher in the Albian (Davey 1979; Prössl 1990).

Even though so far not retained as marker horizons at low paleolatitudes, the occurrences of *Ovoidinium incomptum* (Pl. 12, Fig. 7) and *Carpodinium granulatum* (Pl. 11, Fig. 11) in sample GIL-C 1 can be regarded as the first certain Upper Aptian evidence on the basis of data from northern Europe (Duxbury 1983; Prössl 1990; Heilmann-Clausen & Thomsen 1995). This chronostratigraphic attribution is confirmed by the consecutive lowermost occurrences of *Xenascus plotei* (Pl. 12, Fig. 5), *Tehamadinium coummia* and *Kleithriasphaeridium atlàsiense* comb. nov. in the uppermost part of the section from sample GIL-D 8 upward. In particular, the co-occurrences in sample GIL-D 10 of *K. atlasiense* comb. nov., that was described from the basal Albian of Morocco by Below (1982) and recovered from the uppermost Aptian *Jacobi* ammonite Zone in the Vocontian Basin of SE France (H. Leereveld, written comm.), and of *Tenua hystrix* (formerly reported by several workers as *Cerbia tabulata*), whose extinction in the Tethys was calibrated in the basal Albian (Leereveld 1995), point out the proximity of the Aptian/Albian boundary.

Finally, it may be worth noting the presence in the Pizzo Gilormo section of two quite distinctive organic-walled microfossils with uncertain biological affinities, that have not been reported before outside their respective type-areas: a) *Mystheria oleopotrix* (Pl. 12, Figs. 10, 17-18) was described from the Aptian of Brazil and supposed to be an insect egg (Regali and Sarjeant, 1986); b) *Pinocchiodinium erbae* (Pl. 11, Fig. 12; Pl. 12, Fig. 19) was described within the Group Acrtiarcha from the Cismon 'Apticore' section of the Southern Alps (Italy), and its total stratigraphic range proposed as a major event for the Aptian at low paleolatitudes (Torricelli 2000).

Spot samples from Monte dell'Abate and Portella Buffali.

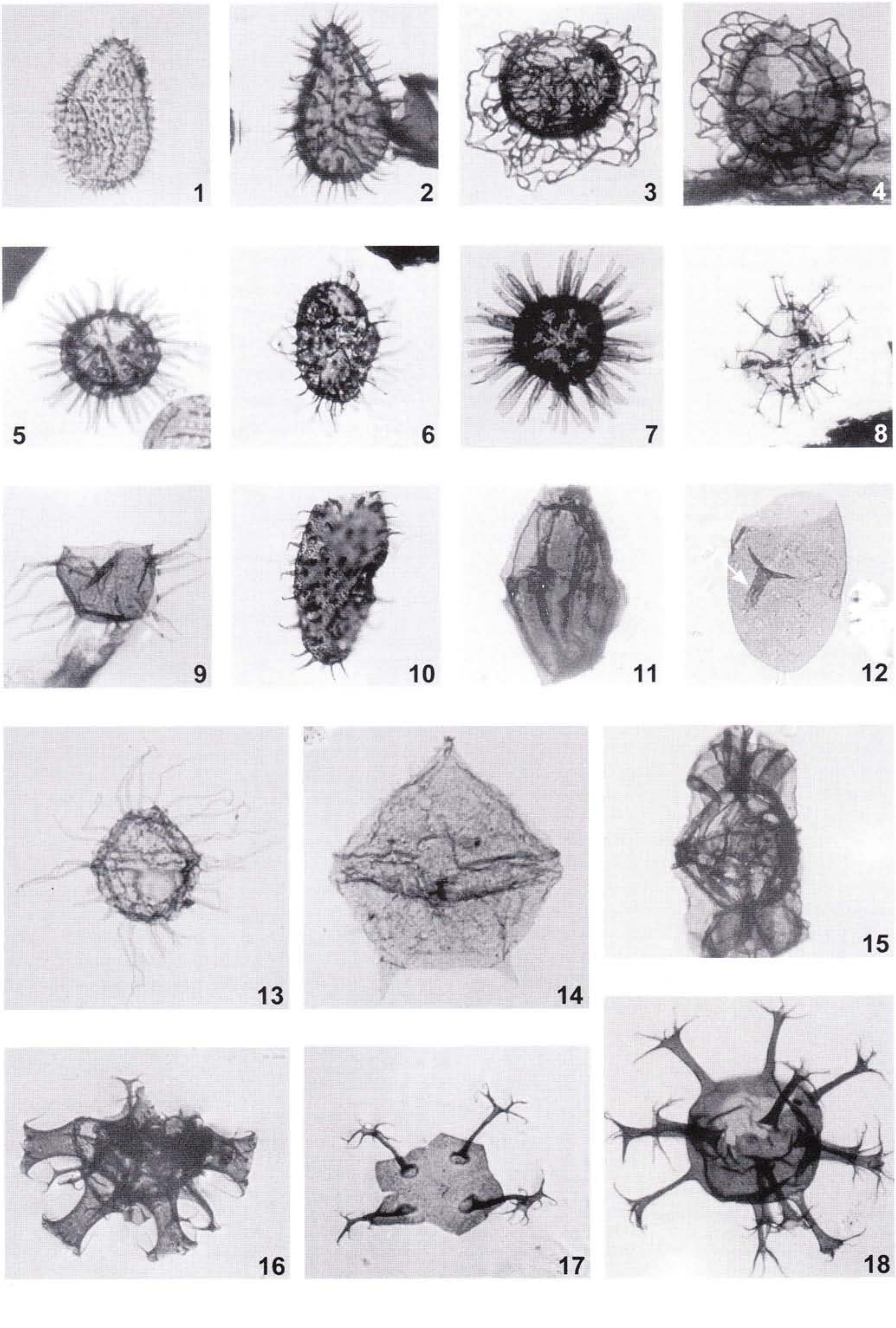
The Portella Buffali blackish shales crop out 2.5 Km north-west of the city of Cesarò, near the junction of the road which from S. Teodoro reaches the road SS 289 at Portella Buffali (Fig. 1). In this area, strongly affected by tectonics, the contacts between different tectonostratigraphic units resulting from the deformation of the Sicilide Basin were recognized. The Shales at Portella Buffali were reported in the Geological Map of the Messina Province (Lentini et al. 2000) as part of the Argille Scagliose Superiori sensu Lentini et al. (1995) and lie on the turbidite deposits exposed on the southern flank of Monte dell'Abate.

Three spot samples collected in the lower part of the Monte dell'Abate succession and analysed for palynomorphs in this study yielded assemblages including, among others, the dinoflagellate cyst species *Pseudoceratium retusum*, *P. securigerum* and *Tenua hystrix*, and the angiosperm pollen *Afropollis jardinus*. They unequivocally prove that the turbidites cropping out at Monte dell'Abate are a lateral equivalent of the Aptian clayey-arenaceous portion of the Monte Soro Flysch at the Pizzo Gilormo section.

The overlying Portella Buffali shales, instead, yielded diverse and excellently preserved dinoflagellate cyst assemblages characterized by the occurrences of

PLATE 11

Dinoflagellate cysts and acritarchs from the Monte Soro Flysch (GIL = Pizzo Gilormo section). All magnifications x 750 unless otherwise stated. (1) *Protoellipsodinium spinocristatum*, sample GIL-C 3. (2) *Protoellipsodinium spinosum*, sample GIL-C 1. (3-4) *Nematosphaeropsis* spp., sample GIL-C 1; note the well developed single-plate precingular archeopyle. (5) *Dapsilidinium multispinosum*, sample GIL-C 1. (6) *Protoellipsodinium clavulum* x 550, sample GIL-C 1. (7) *Dapsilidinium warrenii*, sample GIL-C 8. (8) *Kleithriasphaeridium ?sarmentum* x 550, sample GIL-C 6. (9) Hypocyst of *Cauca parva*, sample GIL-C 1. (10) *Prolixosphaeridium parvispinum* x 550, sample GIL-D 8. (11) *Carpodinium granulatum*, sample GIL-C 1. (12) *Pinocchiodinium erbae* x 550, sample GIL-C 1; the arrow indicates the very distinctive single lateral horn (the Pinocchio's nose). (13) *Cauca parva*, complete specimen, sample GIL-C 1. (14) *Palaeoperidinium cretaceum*, sample GIL-C 3. (15) *Codoniella psygma*, sample GIL-C 1. (16) *Callaiosphaeridium asymmetricum*, sample GIL-C 1. (17) Isolated operculum of *Oligosphaeridium complex*, sample GIL-C 1. (18) *Oligosphaeridium complex*, sample GIL-C 1.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Codoniella psygma, common *Kleithriasphaeridium atlasiense* comb. nov., *Leberidocysta chlamydata*, *Litosphaeridium arundum*, *Prolixosphaeridium conulum*, *Tehamadinium coummia*, *Tehamadinium mazaganense*, *Tenua hystrix* and *Xenascus plotei* (see Plate 13). A comparison with the published stratigraphic ranges of these forms (Stover et al., 1996) and the homogeneity in their state of preservation suggest that no reworked material is present in the assemblage. Since the extinction in the Tethyan Realm of *T. hystrix* (formerly reported as *Cerbia tabulata*) was calibrated by Leereveld (1995) in the *Tardefurcata* ammonite Zone (Lower Albian), the occurrence of this species together with the taxa mentioned above constrains the Portella Buffali shales to the Lower Albian. Although *Tehamadinium mazaganense* (Pl. 13, Fig. 15) has previously been reported only from the Upper Albian of Morocco (Below 1984) and Bahamas (Masure 1988), the chronostratigraphic attribution of these shales is further supported by the absence of firm Middle and Upper Albian dinoflagellate markers as *Xenascus ceratioides*, *Litosphaeridium siphoniphorum* and *Palaeohystrichophora infusorioides*, which were often recovered from the Argille Scagliose Superiori of central northern Sicily (present author, pers. obs.). The samples discussed in this section were also investigated for calcareous nannofossils but proved to be barren (F. Lottaroli, ENI S.p.A., pers. comm.).

The Early Albian age of the shales exposed at Portella Buffali shales, determined by means of palynostratigraphy, is thus slightly younger than the top of the Monte Soro Flysch succession exposed at Pizzo Gilormo and Monte dell'Abate (latest Aptian). In this framework, the Portella Buffali shales may be regarded as a transitional interval between of the thinning- and fining-upward cycle that characterizes the turbidite deposition of the upper clayey-arenaceous member of the Monte Soro Flysch and the overlying lithological unit represented by the Argille Scagliose Superiori. This chaotic formation, made up of varicoloured clays, marls and subordinate sandstones, was likely deposited from the Albian through the Late Cretaceous in stratigraphic continuity on top of the Monte Soro Flysch, and was tectonically sandwiched between the Peloritanian and the Monte Soro units during the emplacement of the nappe pile in the internal part of the Maghrebian Chain.

Systematic Palynology

Systematics follow Fensome et al. (1993). Taxa described prior to 1998 and mentioned below are referenced in Williams et al. (1998). All figured specimens are housed in the palynological slide collection at the Stratigraphic Department (LABO-STIG) of ENI S.p.A., Agip Division, San Donato Milanese, Italy.

Division DINOFLAGELLATA (Bütschli, 1885) Fensome et al., 1993
Subdivision Dinokaryota Fensome et al., 1993
Class Dinophyceae Pascher, 1914
Subclass Peridiniphycidae Fensome et al., 1993
Order Gonyaulacales Taylor, 1980
Suborder Gonyaulacynaceae Fensome et al., 1993
Family Gonyaulacaceae Lindemann, 1928
Subfamily Leptodinioideae Fensome et al., 1993

Genus *Kleithriasphaeridium* Davey, 1974; emend.

Type species: *Kleithriasphaeridium corrugatum* Davey 1974, pp. 56-57, pl. 5, figs. 1-5

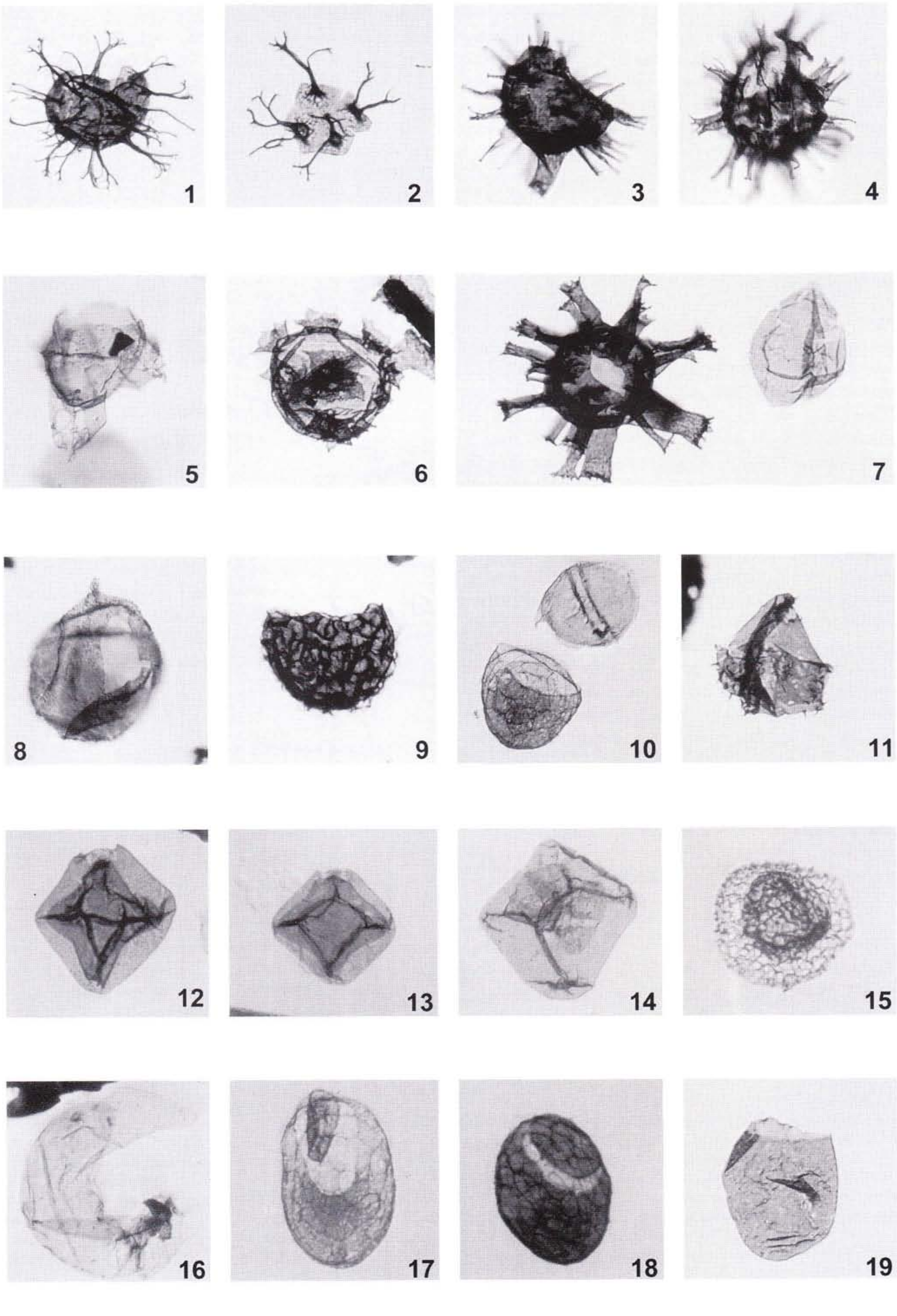
Emended Diagnosis. Cysts subspherical bearing one intratabular process per paraplate. The processes are hollow, nonfibrous, smooth to faintly striate, open distally; they vary in width with the smallest occupying the sulcal region (some of these may be solid). Rarely processes may be linked proximally by low septa. The cyst wall beneath the processes is unusually thickened and granular. A conical, distally closed protrusion, shorter than the processes, may be present at the apex. The reflected tabulation appears to be 3-4', 6'', 6c, 5-6''', 1p, 1'''' and 2 or more sulcal processes. The archeopyle is precingular, formed by the loss of plate 3'' only.

Discussion. The overall morphology of cysts hereby assigned to *Kleithriasphaeridium atlasiense* comb. nov. corresponds to the original description of the genus *Kleithriasphaeridium* of Davey (1974) except for the presence of a short apical protrusion and of six (instead of five) postcingular paraplates (see Below, 1982). Since the presence of the apical protrusion is not considered

PLATE 12

Dinoflagellate cysts, acritarchs and pollen from the Monte Soro Flysch (GIL = Pizzo Gilormo section). All magnifications x 550 unless otherwise stated.

(1) *Surculosphaeridium trunculum*, sample GIL-C 1. (2) Isolated operculum of *Surculosphaeridium trunculum*, sample GIL-C 1. (3) *Florentinia radiculata*, sample GIL-D 8. (4) *Florentina laciniata*, sample GIL-D 8. (5) *Xenascus plotei*, sample GIL-D 9. (6) *Oligosphaeridium poculum*, sample GIL-C 1. (7) *Florentinia deanei* and *Ovoidinium incomptum*, sample GIL-C 1. (8) *Apteodinium granulatum*, sample GIL-D 6. (9) *Valensiella tazadensis*, sample GIL-C 1. (10) *Mystheria oleopotrix* and *Subtilisphaera perlucida*, sample GIL-C 6. (11) *Rhombodella paucispina*, sample GIL-C 1. (12-14) *Cithariplana caperata* x 750, sample GIL-C 1. (15) *Afropollis jardinus* x 750, sample GIL-C 6. (16) *Wallodinium luna* x 750, sample GIL-C 1. (17-18) *Mystheria oleopotrix* x 750, sample GIL-C 1. (19) *Pinocchiodinium erbae*, sample GIL-D 7.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sufficient for the erection of a new genus and the presence of five or six postcingular paraplates is consistent with the description of the subfamily Leptodinioideae to which the genus *Kleithriasphaeridium* belongs (Fensome et al. 1993, p. 86), the present emendation of the generic description is proposed, in order to include also these forms in *Kleithriasphaeridium*.

Kleithriasphaeridium atlasiense (Below, 1982) Torricelli comb. nov.
Pl. 13, Figs. 9-12

Basionym. *Hystrichosphaeridium*? *atlasiense* Below 1982, p. 12, pl. 3, fig. 2 (Albian; Morocco).

Discussion. When first described, Below (1982) questionably placed this species within the genus *Hystrichosphaeridium* because the archeopyle was not observed in the original material composed by three specimens only. In addition, the processes were considered as distally closed, although this seems not the case judging from the illustrations of the holotype. Numerous well preserved specimens analysed in the present study exhibit a single-plate precingular archeopyle type P(3) with operculum free (Pl. 13, fig. 9-12) and the presence of tubiform processes distally open, thus suggesting that this species is attributable to the genus *Kleithriasphaeridium* Davey. *Kleithriasphaeridium atlasiense* comb. nov. shows considerable morphological variation concerning the width of processes, both within a single specimen and among different specimens. However, the constant presence of the conical protrusion in apical position and the faintly striate processes are highly distinctive features of this species.

Dimensions. Range of 10 measured specimens: cyst diameter (excluding processes) = 43(47)51 μm; processes length = 8(11)14 μm; length of the apical protrusion = 4(5.5)7 μm. These values are consistent with the type-material described by Below (1982).

Stratigraphic range. This species was previously recorded from the Albian of Morocco both onshore (Below 1982) and offshore (Below 1984), from the Middle-Upper Albian of NE Italy (Torricelli 2000), from the Albian of the Umbria-Marche Basin in central Italy (present author, pers. obs.) and from the uppermost Aptian *Jacobi* ammonite Zone through the Middle Albian *Dentatus* ammonite Zone in the Vocontian Basin of SE France (H. Leereveld, written comm., 2001). In the present study *Kleithriasphaeridium atlasiense* comb. nov. occurs in the highest sample of the Pizzo Gilormo section (GIL-D 10, a single specimen) and abundantly in the shales sampled at Portella Buffali. This confirmes its mostly Albian distribution. The lowest consistent occurrence of this taxon has to be considered as an important biostratigraphic event close to the Aptian/Albian boundary in the Tethyan Realm.

Subfamily uncertain
Genus *Chytroeisphaeridia* (Sarjeant, 1962) Downie & Sarjeant, 1965

Chytroeisphaeridia sp. A
Pl. 13, Fig. 1-3

Description. Large-sized proximate ellipsoidal cysts, with a single-layered wall exhibiting a coarsely granulate ornamentation. A short, conical, distally closed protrusion is present in apical position. The only evidence of tabulation is provided by the polygonal outline of the single-plate precingular archeopyle. The operculum is free.

Remarks. As just three specimens were encountered, the taxonomy is provisionally left open.

Stratigraphic range. Rare in the Portella Buffali shales, Lower Albian.

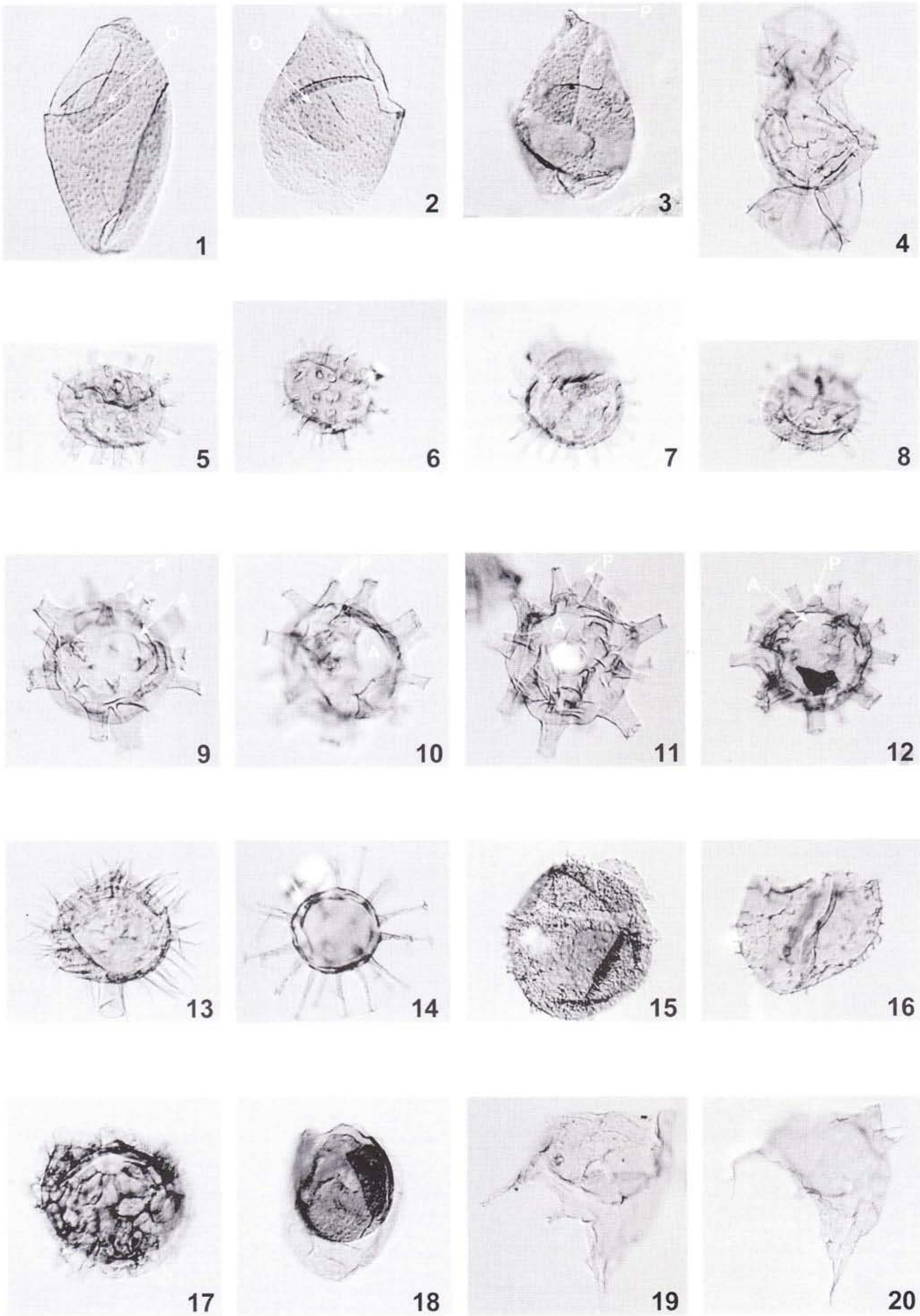
Summary and conclusions.

Outcrops of the Monte Soro Flysch in the type-area have yielded remarkably rich organic-walled microplankton assemblages. Comparisons between the distribution of key dinoflagellate cyst taxa from these assemblages and ammonite calibrated dinostratigraphical information (principally from the western Mediterranean), have shown for the Monte Soro Flysch an age extending from the latest Valanginian to the latest Aptian. Evidence from the Portella Buffali area suggests that in the Early Albian the deposition of turbidite sandstones had ceased and the Argille Scagliose Superiori

PLATE 13

Dinoflagellate cysts from the Portella Buffali shales. All magnifications x 550.

(1-3) *Chytroeisphaeridia* sp. A, slide A12464; O=isolated operculum within the cyst, P=apical protrusion. (4) *Codoniella psygma*, slide A14131. (5-6) *Litosphaeridium arundum*, slide A12448. (7) *Litosphaeridium cf. arundum*, slide A12448. (8) *Litosphaeridium* cf. *conispinum*, slide A12448. (9) *Kleithriasphaeridium atlasiense* comb. nov., slide A12463; P=conical protrusion in apical position, A=single-plate precingular archeopyle. (10) *Kleithriasphaeridium atlasiense* comb. nov., slide A14132; P=conical protrusion in apical position, A=single-plate precingular archeopyle. (11-12) *Kleithriasphaeridium atlasiense* comb. nov., slide A12448; P=conical protrusion in apical position, A=single-plate precingular archeopyle. (13) *Coronifera oceanica*, slide A14131. (14) *Hystrichosphaeridium bowerbankii*, slide A12448. (15) *Tehamadinium mazaganense*, slide A12447; note the double-plate precingular archeopyle. (16) *Tenua hystrix*, slide A12448. (17) *Valensiella tazadensis*, slide A14131. (18) *Leberidocysta chlamydata*, slide A14131. (19-20) *Xenascus plotei*, slide A12448.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were accumulating in stratigraphic continuity above the Monte Soro Flysch.

Close morphological examination of several well preserved specimens referable to *Hystrichosphaeridium? atlasiense* (see Below 1982) resulted in the identification of a single-plate precingular archeopyle for this form, which is thus transferred to the genus *Kleithriasphaeridium* Davey. The lowest consistent occurrence of *Kleithriasphaeridium atlasiense* comb. nov. is proposed as an important biostratigraphic event close to the Aptian/Albian boundary in the Tethyan Realm.

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Appendix

Alphabetical listing of dinoflagellate cyst, acritarch and selected pollen taxa recovered from the Monte Soro Flysch in the present study. Simple and asterisked numbers in parentheses refer respectively to the position in the Vallone Rosmarino and Pizzo Gilormo-Portella Buffali occurrence-charts (Figs. 4-5). Taxa illustrated are followed by plate and figure references in parentheses. The generic allocation and authorship of dinoflagellate cyst species follow Williams et al. (1998).

Achomosphaera neptunii (Eisenack, 1958) Davey and Williams, 1966 (23, *65; Pl. 2, Fig. 7)
Achomosphaera gr. *ramulifera* (Deflandre, 1937) Evitt, 1963 (24; Pl. 7, Fig. 9)
Afropollis jardinus Doyle, Jardiné and Doerenkamp, 1982 (*99; Pl. 12, Fig. 15)
Aprobolocysta eilema Duxbury, 1977 (72; Pl. 5, Figs. 14-15)
Aptea polymorpha Eisenack, 1958 (*37; Pl. 10, Fig. 10)
Apteodinium granulatum (Eisenack, 1958) Lucas-Clark, 1987 (*57; Pl. 12, Fig. 8)
Avellodinium cf. *falsificum* Duxbury, 1977 (25)
Batiacasphaera asperata Backhouse, 1987 (*87)
Batiacasphaera macrogranulata Morgan, 1975 (26; Pl. 4, Fig. 8)
Batiacasphaera cf. *ovata* Backhouse, 1987 (63; Pl. 5, Figs. 11-12)
Batioladinium micropodum (Eisenack and Cookson, 1960) Brideaux, 1975 (37; Pl. 5, Figs. 9-10)
Batioladinium varigranosum (Duxbury, 1977) Davey, 1982 (1; Pl. 5, Fig. 13)
Bourkidinium elegans Torricelli, 1997 (64, Pl. 8, Figs. 2-4)
Bourkidinium cf. *B. ?cylindricum* Dolding, 1992 (38)
Bourkidinium granulatum Morgan, 1975; emend. Torricelli, 2000 (2, *66; Pl. 8, Figs. 5-8)
Callaiosphaeridium asymmetricum (Deflandre and Couteville, 1939) Davey & Williams, 1966 (*25; Pl. 11, Fig. 16)
Canningia grandis Helby, 1987 (78; Pl. 4, Figs. 7, 10)
Carpodinium granulatum Cookson and Eisenack, 1962 (*67; Pl. 11, Fig. 11)
Cassiculosphaeridia magna Davey, 1974 (39; Pl. 6, Fig. 2)
Cassiculosphaeridia reticulata Davey, 1969 (65, *40; Pl. 6, Fig. 3; Pl. 4, Fig. 9)
Cauca parva (Alberti, 1961) Davey and Verdier, 1971 (*49; Pl. 11, Figs. 9, 13)
Cerebrocysta spp. (49)
Chlamydophorella nyei Cookson and Eisenack, 1958 (40, *68; Pl. 8, Figs. 13-14)
Chlamydophorella sp. *A* sensu Torricelli, 2000 (66)
Chytroeisphaeridia ?scabrata Pocock, 1972 (41, *41)
Chytroeisphaeridia sp. A (*88; Pl. 13, Figs. 1-3)
Circulodinium brevispinosum (Pocock, 1962) Jansonius, 1986 / *Circulodinium distinctum* (Deflandre and Cookson, 1955) Jansonius, 1986 (3, *1; Pl. 6, Figs. 4-5)

Remarks. Due to the intergrading nature of the characteristic features, no attempt has been made to distinguish between *C. brevispinosum* and *C. distinctum*.

Cithariplana caperata Srivastava, 1984 (67, *2; Pl. 12, Figs. 12-14)
Cleistosphaeridium spp. (Pl. 8, Fig. 12)
Codoniella psygma Davey, 1979 (*50; Pl. 11, Fig. 15; Pl. 13, Fig. 4)
Cometodinium spp. (4, *69; Pl. 7, Fig. 8)
Coronifera oceanica Cookson and Eisenack, 1958 (*61; Pl. 13, Fig. 13)
Cribroperidinium cf. *confossum* (Duxbury, 1977) Helenes, 1984 (27; Pl. 4, Fig. 3)
Cribroperidinium gr. *edwardsii* (Cookson and Eisenck, 1958) Davey, 1969 (5, *26; Pl. 4, Figs. 1-2)
Ctenidodinium elegantulum Millioud, 1969 (6; Pl. 3, Figs. 4-6)
Cyclonephelium maugaad Below, 1981 (7; Pl. 6, Fig. 6)
Cymososphaeridium validum Davey, 1982 (8; Pl. 7, Fig. 7)
Dapsilidinium duma (Below, 1982) Lentin and Williams, 1985 (*89)
Dapsilidinium laminaspinosum (Davey and Williams, 1966) Lentin and Wlliams, 1981 (*90)
Dapsilidinium multispinosum (Davey, 1974) Bujak et al., 1980 (50, *70; Pl. 8, Fig. 16; Pl. 11, Fig. 5)
Dapsilidinium warrenii (Habib, 1976) Lentin and Williams, 1981 (9, *3; Pl. 8, Fig. 15; Pl. 11, Fig. 7)
Dicheiropollis etruscus Trevisan, 1972 (81; Pl. 2, Fig. 15)
Dingodinium cerviculum Cookson and Eisenack, 1958 (10, *71; Pl. 5, Figs. 1-4)
Dinogymnium cf. *acuminatum* sensu Londeix et al., 1996 (42; Pl. 3, Figs. 12-13)
Dinopterygium tuberculatum (Eisenack and Cookson, 1960) Stover and Evitt, 1978 (*92)
Dissiliodinium globulus Drugg, 1978 (*4)
Dissiliodinium spp. (61; Pl. 6, Fig. 8)
Downiesphaeridium aciculare (Davey, 1969) Islam, 1993 (*5)
Druggidium rhabdoreticulatum Habib, 1973 (62; Pl. 3, Figs. 10-11)
Exochosphaeridium muelleri Yun, 1981 / *Exochosphaeridium phragmites* Davey et al., 1966 (28, *27)

Remarks. Due to the intergrading nature of the characteristic features, no attempt has been made to distinguish between *E. phragmites* and *E. muelleri*.

Florentinia deanei (Davey and Williams, 1966) Davey and Verdier, 1973 (*72; Pl. 12, Fig. 7)
Florentinia laciniata Davey and Verdier, 1973 (*81; Pl. 12, Fig. 4)
Florentinia mantellii (Davey and Williams, 1966) Davey and Verdier, 1973 (*6; Pl. 10, Fig. 1)
Florentinia radiculata (Davey and Williams, 1966) Davey and Verdier, 1973 (*42; Pl. 12, Fig. 3)
Fromea amphora Cookson and Eisenack, 1958 (*62)
Gardodinium ordinale Davey, 1974 (11; Pl. 5, Fig. 8)
Gardodinium trabeculosum (Gocht, 1959) Alberti, 1961 (29, *35; Pl. 1, Fig. 8; Pl. 5, Figs. 5-7)
Hapsocysta peridictya (Eisenack and Cookson, 1960) Davey, 1979 (43, *7; Pl. 5, Fig. 16)
Hystrichodinium furcatum Alberti, 1961 (30; Pl. 7, Fig. 1)
Hystrichodinium pulchrum Deflandre, 1935 (12, *51; Pl. 10, Fig. 5)

Hystrichosphaeridium bowerbankii Davey and Williams, 1966 (*93; Pl. 13, Fig. 14)
Hystrichosphaeridium recurvatum (White, 1842) Lejeune-Carpentier, 1940 (*8)
Kallosphaeridium dolomiticum Torricelli, 2000 (73)
Kallosphaeridium spp. (74, *9; Pl. 6, Figs. 7, 10-12)
Kiokansium corollum Hasenboehler in Below, 1984 (*63)
Kiokansium unituberculatum (Tasch, 1964) Stover and Evitt, 1978 (51, *10; Pl. 2, Figs. 4-5)
Kleithriasphaeridium atlasiense (Below, 1982) Torricelli, comb. nov. (*86; Pl. 13, Figs. 9-12)
Kleithriasphaeridium eoinodes (Eisenack, 1958) Davey, 1974 (31, *73; Pl. 7, Figs. 2-3)
Kleithriasphaeridium fasciatum (Davey and Williams, 1966) Davey, 1974 (68)
Kleithriasphaeridium ?sarmentum (Davey, 1979) Below, 1982 (*28; Pl. 11, Fig. 8)
Leberidocysta chlamydata (Cookson and Eisenack, 1962) Stover and Evitt, 1978 (*94; Pl. 13, Fig. 18)
Leptodinium millioudii (Sarjeant, 1963) Sarjeant, 1969 (52; Pl. 2, Fig. 12)
Lithodinia cf. *amlasis* (Below, 1981) Williams et al., 1993 (69; Pl. 4, Fig. 6)
Lithodinia pertusa Duxbury, 1977 (75; Pl. 4, Fig. 4)
Lithodinia stoveri (Millioud, 1969) Gocht, 1976 (79, Pl. 4, Fig. 5)
Litosphaeridium arundum (Eisenack and Cookson, 1960) Davey, 1979 (*95, Pl. 13, Figs. 5-6)
Litosphaeridium cf. *arundum* (Eisenack and Cookson, 1960) Davey, 1979 (*91; Pl. 13, Fig. 7)
Litosphaeridium cf. *conispinum* Davey and Verdier, 1973 (*96, Pl. 13, Fig. 8)
Micrhystridium spp. (13; Pl. 8, Fig. 17)
Microdinium opacum Brideaux, 1971 (32)
Muderongia pariata Duxbury, 1983 (53, *11; Pl. 1, Fig. 6; Pl. 9, Fig. 8)
Muderongia siciliana Torricelli, 1997 (44; Pl. 1, Figs. 2-3; Pl. 6, Fig. 9)
Muderongia simplex Alberti, 1961 (14; Pl. 1, Figs. 4, 9)
Muderongia staurota Sarjeant, 1966 (70; Pl. 1, Figs. 1, 7)
Mystheria oleopotrix Regali and Sarjeant, 1986 (*29; Pl. 12, Figs. 10, 17-18)
Nematosphaeropsis spp. (*74; Pl. 11, Figs. 3-4)
Nexosispinum hesperus subsp. *hesperus* Davey, 1979 (*30; Pl. 2, Fig. 10)
Nexosispinum hesperus subsp. *brevispinosum* Torricelli, 2000 (54; Pl. 2, Figs. 8-9)
Nummus similis (Cookson and Eisenack, 1960) Burger, 1980 (44a; Pl. 6, Fig. 1)
Occisucysta duxburyi Jan du Chêne et al., 1986 (55; Pl. 3, Figs. 7-8)
Odontochitina ancala Bint, 1986 (*31; Pl. 9, Figs. 4, 6-7)
Odontochitina operculata (Wetzel, 1933) Deflandre and Cookson, 1955 (*12; Pl. 9, Fig. 5)
Odontochitina rhakodes Bint, 1986 (*13; Pl. 9, Figs. 1-3)
Oligosphaeridium albertense (Pocock, 1962) Davey and Williams, 1969 (*14; Pl. 10, Fig. 2)
Oligosphaeridium complex (White, 1842) Davey and Williams, 1966 (15, *15; Pl. 7, Fig. 4; Pl. 11, Figs. 17-18)
Oligosphaeridium diluculum Davey, 1982 (33; Pl. 7, Fig. 5)
Oligosphaeridium fenestratum Duxbury, 1980 (*75)
Oligosphaeridium poculum Jain, 1977 (*16; Pl. 12, Fig. 6)
Oligosphaeridium pulcherrimum (Deflandre and Cookson, 1955) Davey and Williams, 1966 (56, *17; Pl. 7, Fig. 6)
Oligosphaeridium verrucosum Davey, 1979 (*32)
Ovoidinium incomptum Duxbury, 1983 (*76; Pl. 12, Fig. 7)
Palaeoperidinium cretaceum Pocock, 1962 (*33; Pl. 11, Fig. 14)
Pareodinia spp. (34)
Pareodinia sp I sensu Davey, 1982 (*52)
Pervosphaeridium pseudhystrichodinium (Deflandre, 1937) Yun, 1981 (*84; Pl. 2, Fig. 6)
Phoberocysta neocomica (Gocht, 1957) Millioud, 1969 (35; Pl. 1, Fig. 5; Pl. 2, Fig. 3)
Phoberocysta tabulata Raynaud, 1978 (57)
Pilosidinium echinatum (Gimez and Sarjeant, 1972) Courtinat, 1989 (45; Pl. 6, Fig. 13)
Pinocchiodinium erbae Torricelli, 2000 (*64; Pl. 11, Fig. 12; Pl. 12, Fig. 19)
Prolixosphaeridium conulum Davey, 1969 (*97)
Prolixosphaeridium parvispinum (Deflandre, 1937) Davey et al., 1966 (*58; Pl. 11, Fig. 10)
Protoellipsodinium clavulum Davey and Verdier, 1974 (*77; Pl. 11, Fig. 6)
Protoellipsodinium seghire subsp. *seghire* Below, 1981 (*53)
Protoellipsodinium spinocristatum Davey and Verdier, 1971 (*54, Pl. 11, Fig. 1)
Protoellipsodinium spinosum Davey and Verdier, 1971 (*43; Pl. 11, Fig. 2)
Protoellipsodinium touile Below, 1981 (36)
Pseudoceratium anaphrissum (Sarjeant, 1966) Bint, 1986 (*78)
Pseudoceratium eisenackii (Davey, 1969) Bint, 1986 (*36; Pl. 10, Figs. 6, 9)
Pseudoceratium expolitum Brideaux, 1971 (*55; Pl. 10, Fig. 8)
Pseudoceratium pelliferum Gocht, 1957 (16, *44; Pl. 3, Figs. 1-3)
Pseudoceratium retusum Brideaux, 1977 (*38; Pl. 10, Fig. 11)
Pseudoceratium securigerum (Davey and Williams, 1974) Bint, 1986 (*18; Pl. 10, Figs. 3-4, 7)
Pterodinium cingulatum conterminatum Marheinecke, 1992 (*98)
Pterodinium spp. (*19)
Rhombodella paucispina (Alberti, 1961) Duxbury, 1980 (*56; Pl. 12, Fig. 11)
Rhombodella vesca Duxbury, 1980 (46; Pl. 8, Fig. 19)
Rhombodella spp. (Pl. 8, Fig. 20)
Rhynchodiniopsis aptiana Deflandre, 1935 (71)
Rhynchodiniopsis cladophora (Deflandre, 1938) Below, 1981 (47; Pl. 3, Fig. 9)
Sentusidinium spp. (*34)
Spiniferites spp. (17, *20; Pl. 2, Fig. 11)
Stanfordella ?cretacea (Neale and Sarjeant, 1962) Helenes and Lucas-Clark, 1997 (48; Pl. 2, Fig. 13)
Stiphrosphaeridium arbustum Davey, 1982 (58)
Stiphrosphaeridium dictyophorum (Cookson and Eisenack, 1958) Lentin and Williams, 1985 (59)
Subtilisphaera cheit Below, 1981 (*79)
Subtilisphaera perlucida (Alberti, 1961) Jain and Millepied, 1973 (18, *21; Pl. 7, Figs. 10-11; Pl. 12, Fig. 10)
Subtilisphaera senegalensis Jain and Millepied, 1973 (19, *22; Pl. 7, Figs. 12-13)
Subtilisphaera terrula (Davey, 1974) Lentin and Williams, 1976 (75a; Pl. 8, Fig. 1)
Subtilisphaera sp. (*23)
Surculosphaeridium trunculum Davey, 1979 (*59; Pl. 12, Figs. 1-2)
Systematophora silybum Davey, 1979 (60)
Taleisphaera hydra Duxbury, 1979 (80, *45)
Tanyosphaeridium spp. (20, *24; Pl. 8, Figs. 9-10)
Tanyosphaeridium magneticum Davies, 1983 (76; Pl. 8, Fig. 11)
Tehamadinium coummia (Below, 1981) Jan du Chêne et al., 1986 (*85)
Tehamadinium mazaganense (Below, 1984) Jan du Chêne et al., 1986 (*99; Pl. 13, Fig. 15)
Tenua hystrix Eisenack, 1958 (*39; Pl. 13, Fig. 16)
Trichodinium castanea Deflandre, 1935 (*46)
Valensiella tazadensis (Below, 1981) Lentin and Williams, 1993 (*47; Pl. 12, Fig. 9; Pl. 13, Fig. 17)
Wallodinium luna (Cookson and Eisenack, 1960) Lentin and Williams, 1973 (77, *60; Pl. 12, Fig. 16)
Wallodinium krutzschii (Alberti, 1961) Habib, 1972 (21, *80; Pl. 2, Figs. 1-2)
Wrevittia cassidata (Eisenack and Cookson, 1960) Helenes and Lucas-Clark, 1997 (*48)
Wrevittia helicoidea (Eisenack and Cookson, 1960) Helenes and Lucas-Clark, 1997 (22, *82; Pl. 2, Fig. 14)
Xenascus plotei Below, 1981 (*83; Pl. 12, Fig. 5; Pl. 13, Figs. 19-20)

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