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Albian non-calcareous dinoflagellates of the Western Carpathians

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Abstract. This study describes the dinocysts extracted from Albian age sediments from western part of the Outer and Central Carpathians from the biostratigraphic viewpoint. Investigation of vertical distribution and abundance of the dinocyst taxa lead up to assign main bioevents of them, i. e. the first (FO) and last (LO) occurrences, high abundancy. The age determinations are almost exclusively based on dinoflagellate cyst ranges. Dinocyst events in the scheme described here approximates that of the ammonite zones. The study reveals that dinoflagellates prevailingly occur in the pelagic parts of the members of strata and that the assemblages of the dinoflagellates are, in principle, similar to each other. The summary is based above all on the author´s own collections in the field and his systematic study.

Key words: Western Carpathians, Albian, bioevents, biostratigraphy, dinoflagellate cyst, Czech Republic, Slovakia

Introduction

This study is a summarizing of the earlier investigation by Skupien (1997, 1999, 2002, 2003 etc.) which deal with the stratigraphic distribution of non-calcareous dinoflagellates in the Lower Cretaceous in the Czech and Slovak parts of the Western Carpathians. The Lower Cretaceous sediments contain organic-rich deposits with well preserved assemblages of palynomorphs, presenting opportunities for a more extensive palynological study of the stratigraphy of the these sediments. The dinoflagellate cyst assemblages described in this paper come from three different areas – one is situated in Czech Republic (Silesian Unit) and two are situated in Slovakia (Pieniny Klippen Belt and Manín Unit) – Fig.1.

The purpose of this paper is to document the rich assemblages of the dinocysts in the Albian and to interpret their stratigraphic significance for this region. It is nesesary to remark, that the sequence under study are without macrofaunal records. Therefore correlation of ammonite zones and dinoflagellates (which was done for Barremian – Aptian interval of the Silesian Unit, Skupien & Vašíček, 2002) are impossible.

Material

Mesozoic sedimentation in the Western Carpathians occured in two basic mega-units, which correspond to the Outer and Central Carpathians. The Outer Carpathians sedimentation basin were situated in the area of the Paleo-European Shelf in the foreland of the Bohemian Massif, the Central Carpathians on the Alpine-Carpathian microcontinent (Michalík, 1993, 1994, Vašíček et al., 1994). They were separated from each other by the oceanic crust of the Penninic, designated the Vahic Unit (Maheľ, 1981) in the Carpathians. The later phases of the Alpine folding in the Upper Cretaceous (in the Central Carpathians) and in the Tetriary (in the Outer Carpathians) led to the complex nappe structure of both these units, which became part of the extensive Alpine mountain belt. The Lower Cretaceous sediments in the Carpathian nappes are usually only incompletely preserved.

The studied sections are situated in the Silesian Unit of the Outer Carpathians (Czech Republic), the Kysuca and Klape Units of the Pieniny Klippen Belt and the Manín Unit of the Central Western Carpathians (Slovakia) – Fig. 1.

The Silesian Unit is formed by the hemipelagic and flysch deposits of the Upper Jurassic to Miocene age. The Albian of Godula development (basinal setting) of this unit is represented by the Lhoty Formation. The Lhoty Formation is composed of dark grey and green-grey calcareous and non-calcareous claystones spotted with chondrites, thin bedded sandstones alternated with claystones and spongiolite cherts (Menčík et al., 1983). The Lhoty Formation is underlain by dark grey to black non-calcareous claystones of the Veřovice Formation (Upper Aptian) formed during the maximum of the Lower Cretaceous anoxic event. The boundary of the Lhoty Formation with the owerlying Mazak Formation (Cenomanian) is gradational. This formation consists of an alternation of non-calcareous red-grey and green claystones with thin-bedded glauconitic sandstones (Roth, 1980, Skupien & Vašíček, 2003).

The Albian deposits of the Silesian Unit have been studied biostratigraphically using mainly foraminifera (Hanzlíková, 1963, 1966).

The dinoflagellate cyst assemblages described in this paper come from three sections (Fig. 1): Bystrá, located south-east of the town Frenštát pod Radhoštěm (Skupien,

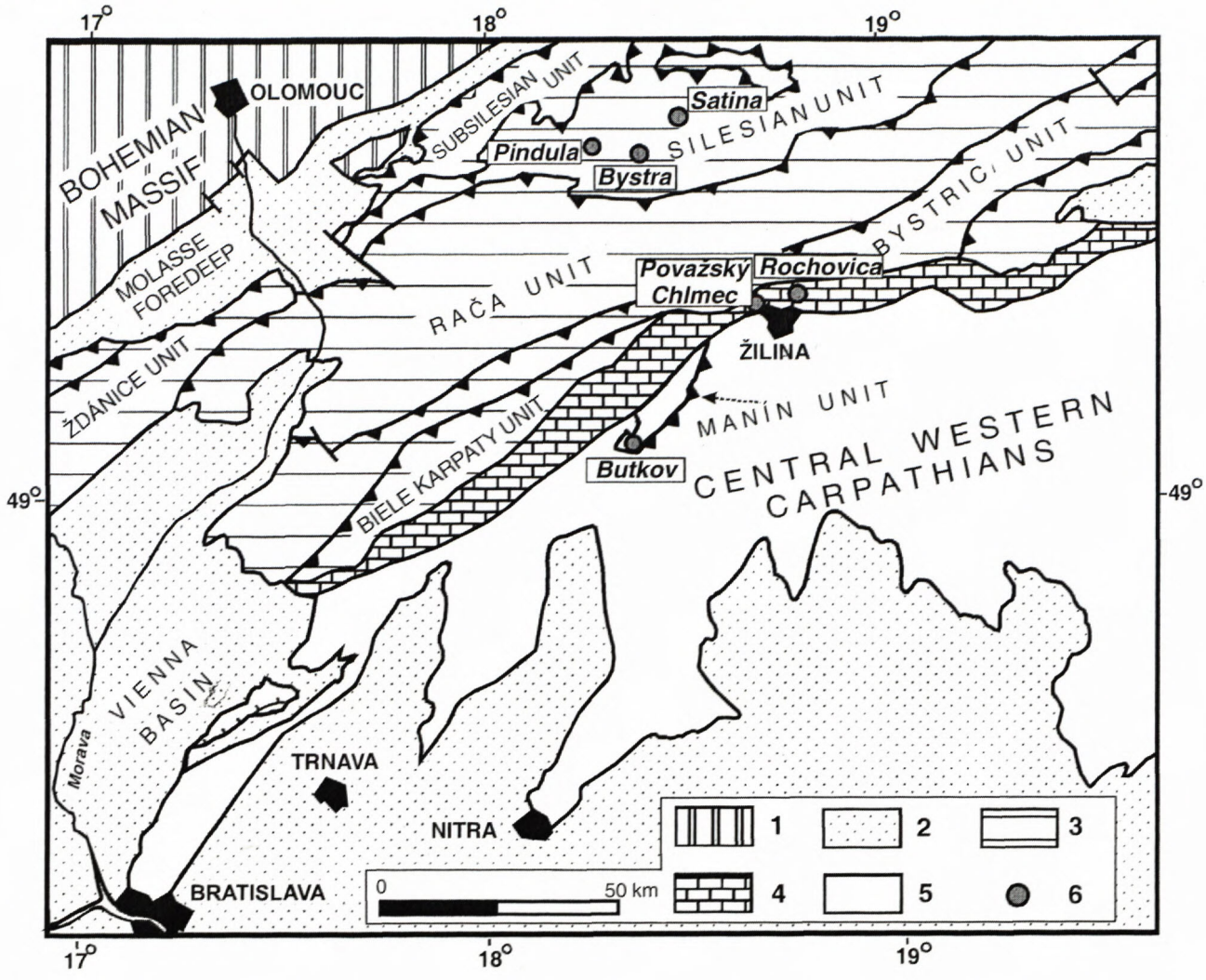

Fig. 1. Principal tectonic units of the Western Carpathians (after Vašíček et al., 1994) and localization of the sections studied. 1 – Bohemian Massif, 2 – Neogene cover, 3 – Outer Western Carpathians, 4 – Pieniny Klippen Belt, 5 – Central Western Carpathians, 6 – locality.

1999, Skupien & Vašíček, 2003), Pindula, located south of the town Frenštát pod Radhoštěm (Skupien, 1997, 1999) and Komorní Lhotka (Skupien, 1998, 1999).

The Pieniny Klippen Belt (PKB) is tectonically the most complicated part of the Western Carpathians. The Upper Aptian – the Lower Albian of the Kysuca Unit (Andrusov & Scheibner, 1960) is represented by spotted limestones with intercalations of dark and red marls (Brodno Formation). This formation is covered by red pelagic marls of the Upper Albian (Rudina Formation).

Attention was paid to Rochovica section situated near Žilina (Fig. 1, Michalík et al, 1999, Skupien, 2003 etc.).

The second section is exposed near Považský Chlmec (Andrusov & Kuthan, 1944, Marschalko, 1986, Vašíček & Rakús, 1993, Skupien et al., 2003). The section comprise Upper Albian flysch deposites of the Klape Unit. The Klape Unit = Periklippen belt (Salaj, 1995) was incorporated in the Pieniny Klippen Belt by the Sarian folding. The pelites contain ammonites of the *Mortoniceras inflatum* ammonite Zone, *Dipoloceras cristatum* Subzone in the quarry and *Hysteroceras orbignyi* Subzone in the river bank.

Manín Unit is regarded, from the paleogeografical point of view, to be either the most external extremity of the Tatric area and/or an independent paleogeographic zone between the Tatric area and the Klippen Belt (Rakús, 1977) or a consistuent of the Fatric nappe system (Maheľ, 1978, Michalík and Vašíček, 1987). Lower Albian is represented by the pale gray massive organodetritic limestones of „Urgonian" carbonate platform (Podhorie Formation). These are terminated by a hardground, which is overlain by monotonous complex of pelagic dark blue-grey spotted marlstones with thin fine-grained sandstone intercalations. This part repsented Butkov Formation. The marls contain a rich association of nannofossils and planktonic foraminifers indicating the upper part of the Middle Albian to the lower part of the Middle Cenomanian (Gašpariková & Salaj, 1984, Michalík et al., 1990, Boorová & Salaj, 1992).

This sequences are uncovered in the active quarry Butkov by the village Ladce. In the nineties of last century, the section was processed in detail in Vašíček and Michalík (1986), Borza et al. (1987), Boorová and Salaj, 1992, etc. The preliminary palynological result was presented by Skupien et al. (2003).

Methods

Palynological preparations were obtained using a standard procedure involving mineral acid treatment (38% HCl to remove the calcareous fraction, 40% HF to remove silicates). The residue was sieved in ultrasonic apparatus using a 15 μm sieve. Heavy liquid separation was used, when necessary, to remove remaining mineral components. No oxidation was required. Permanent mounts were made in glycerine jelly. Within the scope of the present study the palynological assemblages will be only qualitatively discussed pertaining to their biostratigraphic significance. The dinocyst taxonomy follows Lentin and Williams (1998). All materials are stored at the Institute of Geological Engineering, VŠB-Technical University of Ostrava (Czech Republic).

Stratigraphic evaluation

Silesian Unit

Pelitic sediments of Albian age studied in several localities of the Silesian Unit provided rich dinoflagellate assemblages (see Skupien, 1997, 1999, Skupien & Vašíček, 2003). In addition, in some parts representatives of acritarchs were determined successfully. Results achieved are summarised in Table 1. The stratigraphical division is based on the content of stratigraphically significant dinoflagellates.

At the Aptian/Albian boundary, representatives of *Hystrichosphaerina schindewolfii, Oligosphaeridium verrucosum* and *Surculosphaeridium trunculum* occur in the Silesian Unit for the last time. Simultaneously, *Achomosphaera triangulata, Ovoidinium scabrosum* and *Stephodinium coronatum* appear. Their presence is known already from the latest Aptian (e. g. Davey & Verdier, 1974, Verdier, 1974).

The beginning of the Albian is dated in virtue of the first occurrence of the species *Florentinia stellata* and *Hystrichostrongylon membraniphorum* (Skupien, 1997, 1999). *Florentinia stellata* is index species of the beginning of the Albian (Davey & Verdier, 1971). Together with the above-mentioned species merely the species *Subtilisphaera senegalensis* was found in the Lower Albian. The upper boundary of the Lower Albian may be correlated with the last occurrence of *Muderongia pariata* (e. g. Prössl, 1990). The whole interval from the uppermost Aptian to the Lower Albian is characterised by the dominance of the species *Oligosphaeridium complex*; the species *Oligosphaeridium perforatum* being the characteristic element. In the Lower Albian, *Cerbia tabulata* still occurs frequently. Consequently, one cannot say that its last occurrence is confined to the lowermost Albian as stated by Leereveld (1995).

In the Middle Albian determined according to dinoflagellates, primarily *Carpodinium granulatum, Litosphaeridium conispinum, Surculosphaeridium*? *longifurcatum* and *Xiphophoridium alatum* appear in the Silesian Unit. The index species for the determination of the beginning of the Middle Albian is *Surculosphaeridium*? *longifurcatum* that is only known from the Lower/Middle Albian boundary (Davey & Verdier, 1971, Verdier, 1974). What is characteristic is the abundant occurrence of representatives of the genus *Florentinia* (*F. cooksoniae, F. laciniata, F. mantellii, F. radiculata*) and the presence of the species *Atopodinium perforatum*. In its uppermost part, *Protoellipsodinium clavulum* appears for the last time.

In the Upper Albian, the lower part (Inflatum ammonite Zone) may be identified on the basis of the first occurrence of *Atopodinium mirabile, Litosphaeridium siphoniphorum* and *Pervosphaeridium truncatum* (Verdier, 1974, Leereveld, 1995). Simultaneously, the species *Pervosphaeridium pseudhystrichodinium* was observed in the assemblages of the Silesian Unit for the first time.

Table 1. Range chart of the Albian acritarchs and dinoflagellates in the Silesian Unit.

Stratigraphy	pre-Albian	Albian				post Albian
Taxa		Lower	Middle	Upper	Vrac.	
1. Cerbia tabulata						
2. Muderongia pariata						
3. Occisucysta duxburyi						
4. Systematophora complicata						
5. Florentinia radiculata						
6. Pseudoceratium polymorphum						
7. Systematophora cretacea						
8. Gonyaulacysta cretacea						
9. Hystrichosphaerina schindewolfii			?			
10. Batioladinium jaegeri						
11. Protoellipsodinium clavulum						
12. Dissiliodinium globolus						
13. Prolixosphaeridium parvispinum						
14. Achomosphaera neptunii						
15. Circulodinium distinctum						
16. Cribroperidinium edvardsii						
17. Cyclonephelium intonsum						
18. Oligosphaeridium perforatum colum						
19. Palaeoperidinium cretaceum						
20. Tanyosphaeridium boletus						
21. Fromea amphora						
22. Heterosphaeridium heteracanthum						
23. Hystrichodinium voigtii						
24. Kleithriasphaeridium corrugatum						
25. Muderongia neocomica						
26. Muderongia tabulata						
27. Oligosphaeridium poculum						
28. Protoellipsodinium spinosum						
29. Stephodinium spinulosum						
30. Achomosphaera ramulifera						
31. Achomosphaera triangulata						
32. Callaiosphaeridium asymmetricum						
33. Cometodinium? whitei						
34. Coronifera oceanica						
35. Cribroperidinium orthoceras						
36. Dapsilidinium multispinosum						
37. Dinopterygium tuberculatum						
38. Endoscrinium campanula						
39. Exochosphaeridium muelleri						
40. Florentinia cooksoniae						
41. Florentinia laciniata						
42. Florentinia mantellii						
43. Hystrichodinium pulchrum						
44. Kiokansium polypes						
45. Kleithriasphaeridium eoinodes						
46. Odontochitina operculata						
47. Oligosphaeridium asterigerum						
48. Oligosphaeridium complex						
49. Oligosphaeridium prolixispinosum						
50. Oligosphaeridium pulcherrimum					?	?
51. Ovoidinium scabrosum						
52. Pterodinium cingulatum cingulatum						
53. Spiniferites ramosus						
54. Spiniferites ramosus reticulatus						
55. Stephodinium coronatum						
56. Subtilisphaera perlucida						
57. Wallodinium krutzschii						
58. Wallodinium luna						
59. Subtilisphaera senegalensis						
60. Hystrichostrongylon membraniphorum						
61. Florentinia stellata						
62. Tubulospina oblongata						
63. Spiniferites alatus						

Table 1 – continued

Stratigraphy	pre-Albian	Albian				post Albian
Taxa		Lower	Middle	Upper	Vrac.	
64. Cleistosphaeridium clavulum						
65. Cyclonephelium brevispinatum						
66. Cyclonephelium maugaad						
67. Florentinia resex						
68. Muderongia tetracatha						
69. Subtilisphaera scabrata						
70. Subtilisphaera zawia						
71. Subtilisphaera sp.						
72. Valensiella reticulata						
73. Atopodinium perforatum						
74. Leberidocysta chlamydata						
75. Surculosphaeridium? longifurcatum						
76. Xiphophoridium alatum						
77. Hystrichosphaeridium arborispinum						
78. Carpodinium granulatum						
79. Gonyaulacysta cassidata						
80. Cyclonephelium compactum						
81. Hystrichosphaeridium recurvatum						
82. Rottnestia borussica						
83. Litosphaeridium conispinum						
84. Surculosphaeridium ? cassospinum						
85. Tanyosphaeridium variecalamus						
86. Apteodinium maculatum grande						
87. Vesperopsis digitata						
88. Atopodinium mirabile						
89. Spiniferites ancoriferus ghiran						
90. Cyclonephelium membraniphorum						
91. Hystrichosphaeridium bowerbankii						
92. Litosphaeridium siphoniphorum						
93. Pervosphaeridium pseudhystrichodinium						
94. Pervosphaeridium truncatum						
95. Micrhystridium inconspicuum						
96. Spiniferites scabrosus						
97. Surculosphaeridium ? basifurcatum						
98. Endoceratium dettmanniae						
99. Hapsocysta peridictya						
100. Protoellipsodinium spinocristatum						
101. Spiniferites ancoriferus						
102. Subtilisphaera cheit						
103. Achomosphaera verdieri						
104. Disphaeria munda						
105. Exochosphaeridium phragmites						
106. Ovoidinium verrucosum						
107. Palaeohystrichophora infusorioides						
108. Protoellipsodinium cf. seghire						
109. Pterodinium cingulatum reticulatum						
110. Surculosphaeridium cf. belowii						
111. Xenascus ceratioides						

The higher part of the Upper Albian (Vraconian – Dispar ammonite Zone) is characterised by the first occurrence of the species *Endoceratium dettmaniae* and *Palaeohystrichophora infusorioides* (Tocher & Jarvis, 1996). In the higher part, *Xenascus ceratoides* appears for the first time. The abundant representation of the genus *Ovoidinium* (*O. scabrosum, O. verrucosum*) and the species *Achomosphaera triangulata* is a characteristic feature.

The first joint occurrences of the species *Ovoidinium scabrosum* and *Ovoidinium verrucosum* are known from the uppermost Albian, namely from the Dispar ammonite zone (e. g. Foucher, 1981, Tocher & Jarvis, 1994, and others). At the same time, any occurrence of representatives of *Ovoidinium scabrosum* and *Protoellipsodinium spinocristatum* is not known from sediments younger than the uppermost Albian.

In the uppermost part of the Albian, a proportion of species *Litosphaeridium siphoniphorum* and *Palaeohystrichophora infusorioides* grows markedly. It is the occurrence of the species *Hapsocysta peridictya* appearing in the uppermost Albian of the Silesian Unit for the first time that is of interest. It is already known from the Upper Barremian in other parts of the Western Carpathians (Skupien, et al., 2003).

The Albian/Cenomanian boundary is indicated by the last occurrence of *Litosphaeridium conispinum* and the first occurrence of *Exochosphaeridium bifidum* in the locality of Bystrá (Skupien & Vašíček, 2003). In the Lower Cenomanian, *Odontochitina costata* appears for the first time; representatives of the species *Achomosphaera triangulata, Dinopterygium cladoides, D. tuberculatum* and *Pervosphaeridium pseudhystrichodinium* are abundant.

The Pieniny Klippen Belt

The Košer Albion is well determined by the planktonic foraminifers too (Salaj, 1995). Here are the well preserved dinoflagellate assemblages (Tab. 2). The beginning of the Lower Albian was concluded on the basis of the appearance of the *Xiphophoridium alatum* and *Pervosphaeridium pseudhystrichodinium* on the Rochovica section (Skupien, 2003). *Xiphophoridium alatum* is mostly regarded an Albian species; e. g. Monteil (in Stover et al., 1996) described it from the Upper Albian. Prössl (1990) reported it from the Middle Albian, but it also appeared in the uppermost Aptian in SE France (Vink, 1995). The Lower Albian dinoflagellate associations are characterized by the dominance of *Achomosphaera ramulifera, Pervosphaeridium pseudhystrichodinium* and *Spiniferites ramosus.*

Higher, the assemblages change significantly by enrichment in species *Adnatosphaeridium tutulosum, Hapsocysta dictiota, Litosphaeridium arundum, Litosphaeridium conispinum, Surculosphaeridium*? *longifurcatum* and other species representing a part of typical Albian dinoflagellate assemblages. *Litosphaeridium arundum*, the first occurrence of which has been generally reported from the Lower Albian, is the stratigraphically most significant. However, according to Verdier (1974), for example, *Surculosphaeridium*? *longifurcatum* appeared in the Middle Albian for the first time. This would correspond to the data of Prössl (1990) who described the occurrence of *L. arundum* in the uppermost part of the Lower Albian to the lowermost part of the Upper Albian. It is possible delimited the Middle Albian. *Achomosphaera ramulifera, Exochosphaeridium muelleri, Odontochitina operculata* and *Pterodinium cingulatum* are dominant.

Ammonite Inflatum Zone was determined in the Upper Albian (Skupien, 2003) on the basis of occurence of species *Litosphaeridium siphoniphorum* together with *Gardodinium trabeculosum, Hapsocysta peridictya, Litosphaeridium conispinum* and *Pervosphaeridium pseudohystrichodinium*. The first occurrence of *Litosphaeridium siphoniphorum* was confirmed to the Upper Albian ammonite Inflatum Zone. Simultaneously, the sample contains *Gardodinium trabeculosum*, the last occurrence of which has been reported from SE France from the Lower Albian (Van Erve et al., 1980, Leereveld, 1995), but Monteil (in Stover et al., 1996) described it from the lower part of the Upper Albian. No species characteristic of the higher part of the Upper Albian have been found in the Pieniny Klippen Belt. *Achomosphaera ramulifera, Hapsocysta peridictya, Litosphaeridium siphoniphorum* and *Pervosphaeridium pseudhystrichodinium* predominate.

Table 2. Range chart of the Albian acritarchs and dinoflagellates in the Pieniny Klippen Belt.

Stratigraphy	pre-Albian	Albian							
		Lower		Middle				Upper	
Taxa									
1. Apteodinium granulatum									
2. Callaiosphaeridium asymmetricum									
3. Callaiosphaeridium trycherium									
4. Hystrichosphaerina schindewolfii									
5. Muderongia cf. staurota									
6. Circulodinium brevispinosum									
7. Cribroperdinium sp.									
8. Florentinia cooksoniae									
9. Gonyaulacysta cretacea									
10. Wallodinium krutzschii									
11. Prolixosphaeridium parvispinum									
12. Achomosphaera verdieri									
13. Circulodinium vermiculatum									
14. Tehamadinium sp.									
15. Endoscrinium campanula									
16. Kiokansium polypes									
17. Spiniferites ramosus									
18. Oligosphaeridium poculum									
19. Achomosphaera ramulifera									
20. Achomosphaera triangulata									
21. Cometodinium? whitei									
22. Coronifera oceanica									
23. Dapsilidinium multispinosum									
24. Exochosphaeridium muelleri									
25. Florentinia mantellii									
26. Hapsocysta peridictya									
27. Kleithriasphaeridium eoinodes									
28. Odontochitina operculata									
29. Oligosphaeridium asterigerum									
30. Oligosphaeridium complex									
31. Palaeoperidinium cretaceum									
32. Protoellipsodinium spinosum									
33. Pterodinium cingulatum									
34. Spiniferites sp.									
35. Dapsilidinium duma									
36. Oligosphaeridium pulcherrimum									
37. Pervosphaeridium pseudhystrichodinium									
38. Xiphophoridium alatum									
39. Hapsocysta dictiota									
40. Litosphaeridium arundum									
41. Pseudoceratium polymorphum									
42. Surculosphaeridium? longifurcatum									
43. Stephodinium coronatum									
44. Adnatosphaeridium tutulosum									
45. Litosphaeridium conispinum									
46. Florentinia stellata									
47. Hystrichostrongylon membraniphorum									
48. Dingodinium albertii									
49. Protoellipsodinium seghire									
50. Tanyosphaeridium sp.									
51. Muderongia sp.									
52. Codoniella campanulata									
53. Gardodinium trabeculosum									
54. Leberidocysta sp.									
55. Hystrichosphaeridium bowerbankii									
56. Litosphaeridium siphoniphorum									
57. Cleistosphaeridium multispinosum									
58. Codoniella psygma									
59. Leberidocysta chlamydata									
60. Ovoidinium sp.									
61. Pervosphaeridium sp.									
62. Trabeculidinium quiquetrum									
63. Xenascus sp.									

Table 3. Range chart of the Albian acritarchs and dinoflagellates in the Manín Unit

Stratigraphy	pre-Albian	Upper Albian				
Ammonite Zones		Inflatum		Dispar		
Taxa						
1. Dapsilidinium multispinosum						
2. Hystrichodinium voigtii						
3. Protoellipsodinium spinosum						
4. Circulodinium distinctum						
5. Coronifera oceanica						
6. Exochosphaeridium muelleri						
7. Kiokansium polypes						
8. Spiniferites sp.						
9. Achomosphaera triangulata						
10. Cometodinium? whitei						
11. Cribroperidinium sp.						
12. Endoscrinium campanula						
13. Hystrichodinium pulchrum						
14. Kleithriasphaeridium eoinodes						
15. Oligosphaeridium complex						
16. Spiniferites ramosus						
17. Wallodinium krutzschii						
18. Pterodinium cingulatum						
19. Dinopterygium cladoides						
20. Florentinia cooksoniae						
21. Cauca parva						
22. Hystrichosphaeridium bowerbankii						
23. Cleistosphaeridium clavulum						
24. Litosphaeridium siphoniphorum						
25. Odontochitina operculata						
26. Pervosphaeridium truncatum						
27. Pervosphaeridium pseudhystrichodininum						
28. Pterodinium cingulatum reticulatum						
29. Xiphophoridium alatum						
30. Achomosphaera verdieri						
31. Achomosphaera ramulifera						
32. Cyclonephelium paucispinum						
33. Hystrichostrongylon membraniphorum						
34. Prolixosphaeridium conulum						
35. Spiniferites ramosus reticulatus						
36. Stephodinium coronatum						
37. Adnatosphaeridium tutulosum						
38. Gonyaulacysta extensa						
39. Ovoidinium scabrosum						
40. Leberidocysta chlamydata						
41. Ovoidinium sp.						
42. Endoceratium dettmanniae						
43. Veryhachium sp.						
44. Atopodinium perforatum						
45. Callaiosphaeridium assymmetricum						
46. Ovoidinium verrucosum						
47. Prolixosphaeridium sp.						
48. Tenua hystrix						
49. Kiokansium sp.						

Manín Unit

Albian dinoflagellate cysts were found in the lowermost part of the marlstones (Skupien et al., 2003) of the Upper Albian – Lower Cenomanian Butkov Formation (Boorová & Salaj, 1992). Dinoflagellate cysts dominate (Tab. 3), acritarchs (e. g. *Wallodinium* sp., *Veryhachium* sp.) occur sporadically.

The samples contain stratigraphically significant species of dinoflagellates, such as *Endoceratium dettmanniae, Litosphaeridium siphoniphorum, Ovoidinium verrucosum, Prolixosphaeridium conulum.* The first occurrence of *Litosphaeridium siphoniphorum* was confined to the Upper Albian Inflatum ammonite Zone and the first occurrence of *Prolixosphaeridium conulum* delimits the Dispar ammonite Zone, which is supported by the presence of species *Endoceratium dettmaniae* and *Ovoidinium verrucosum* (Davey & Verdier, 1973, Leereveld, 1995). *Litosphaeridium siphoniphorum, Pervosphaeridium pseudhystrichodinium, Pterodinium cingulatum* and *Xiphophorodium alatum* predominate in the Inflatum Zone. In the higher part (Dispar Zone) dominance of the *Exochosphaeridium muelleri* and *Spiniferites ramosus* increase.

Conclusion

All the studied formations of geological units of the Western Carpathians belonging to the Albian show the abundant representation of dinoflagellates associated

Slovak Geol. Mag., 10, 3 (2004),203 – 214

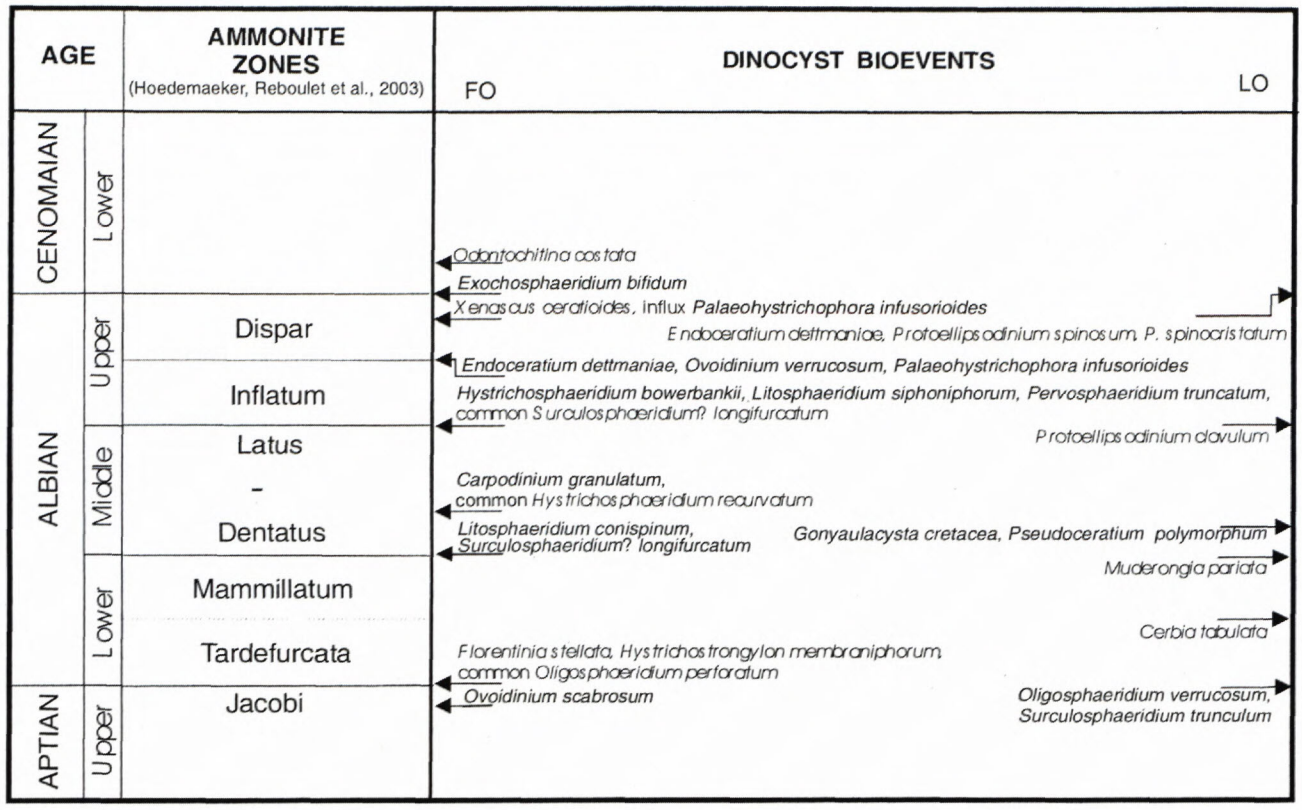

Fig. 2. Albian dinocyst events of the Western Carpathians.

especially with the pelagic members of the sequence of strata. Differences in the amount of the dinoflagellates are given above all by the lithological character of sediments. Occurrence of dinoflagellates is documented best in the Silesian Unit being characterised by the deepwater sedimentation of slightly calcareous pelites. On the other hand, Albian grey organodetritic limestones in the Manín Unit are totally unsuitable, and that is why merely a pelitic part of the Late Albian has been found.

At the same time, it is necessary to point out that the pelitic sediments of Albian age in the Western Carpathians do not enable any correlation of the dinoflagellates with ammonite zones, because there is a lack of the macrofauna (with the exception of the Upper Albian in the Považský Chlmec). The goal of this study is to show differences in the assemblages of particular parts of the Western Carpathians as well as possibilities of their biostratigraphical use in this region.

The investigation of vertical distribution of the dinoflagellates in Albian shown qualitative (first – FO and last – LO occurence) changes. The taxa used in the bioevents have been chosen because of their restricted stratigraphic distribution and, where possible, because of their known occurence in Tethyan deposits. The bioevents scheme can be seen in Fig. 2, and are compared with presumptive ammonite zones deduced on the dinocysts content. Significant dinocysts are illustrated in Plates 1 and 2.

The Aptian/Albian boundary can be observed best in the Silesian Unit. The first occurrences of *Hystrichostrongylon membraniphorum* and *Florentinia stellata* may be taken as identification characters. In the Klippen Belt, the first occurrence of *Xiphophoridium alatum* may be considered as well. The last occurrences of *Cerbia tabulata* and *Hystrichosphaerina schindewolfii* in the Lower Albian are interesting. They are generally connected with the Aptian/Albian boundary.

The Middle Albian is documented both in the Silesian Unit and the Klippen Belt. In both the units, its beginning is determined on the base of the first occurrence of *Surculosphaeridium? longifurcatum* together with the occurrences of *Litosphaeridium conispinum*. The last occurrence of *Gonyaulacysta cretacea* and *Pseudoceratium polymorphum* in the lower part of the Middle Albian is interesting.

The Upper Albian is documented in all the three units. The assemblages of dinoflagellates do not substantially differ from each other. The beginning of the Late Albian is determined according to the first occurrence of *Litosphaeridium siphoniphorum*. In all the units, *Hystrichosphaeridium bowerbankii* also appears for the first time.

In the higher part of the Upper Albian (from the Dispar ammonite zone), which was only found in the Silesian and the Manín Unit, *Endoceratium dettmaniae, Ovoidinium verrucosum* and *Palaeohystrichophora infusorioides* exist for the first time. The last occurrence of the species *Palaeoperidinium cretaceum* may be important. Moreover, the Silesian Unit is characterised by the last occurrence of *Achomosphaera neptunii* in the Upper Albian, although this is already generally known from the Late Aptian.

The Albian of all the units shows the abundance of *Achomosphaera ramulifera, A. triangulata, Coronifer*

oceanica, Kleithriasphaeridium eoinodes, Odontochitina operculata, Oligosphaeridium complex and *Xiphophoridium alatum.*

In the Silesian Unit the abundant representatives of the genera *Florentinia* and *Subtilisphaera* are typical. In the Pieniny Klippen Belt, in addition to this, the Albian is characterised by the abundant representatives of the genus *Hapsocysta.*

Many zonations exist concerning the distribution of Albian dinocysts. However, none of them covers the Tethyan area. Most of the published dinocyst zonations for the Lower Cretaceous are sumarized in Stover et al (1996). The concept of a „zonation" is felt to be too rigid for what should be a constantly evolving process of biostratigraphical refinement. Such zonation are only useful at the time of their erection, thereafter the scheme becomes more and more destabilised as new data is added. Instead of a formalised zonation, I have presented the data amassed in the form of an informal series of event, which is capable of being updated at any time in the future.

Acknowledgement

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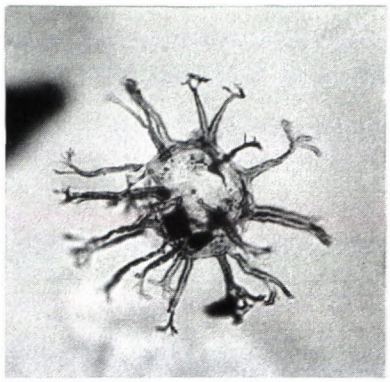
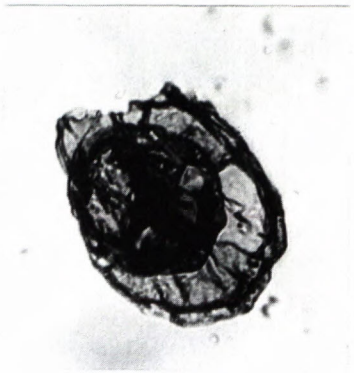
Appendix

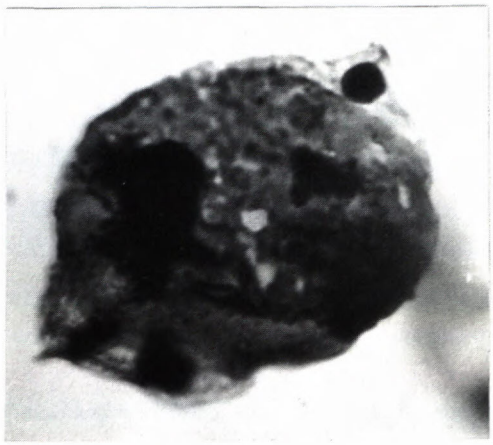
An alphabetic index of dinocyst taxa is provided below. Taxonomic citations can be found in Williams et al. (1998). Numbers in parentheses refer to the position of the species in the distribution chart of the Silesian Unit, PKB and Manín Unit (Figs 3, 4 and 5 respectively). A zero indicates that the species is absent from that particular locality. Significan dinocysts are illustrated in Plates 1 and 2.

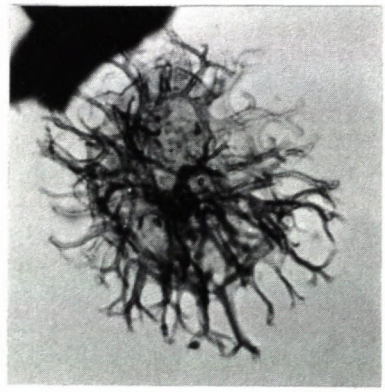
Dinoflagellates

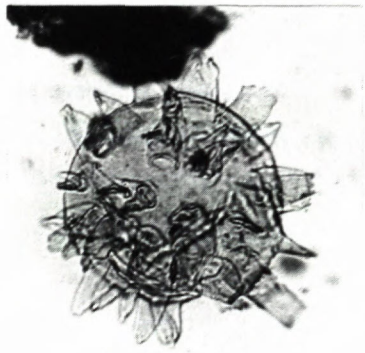
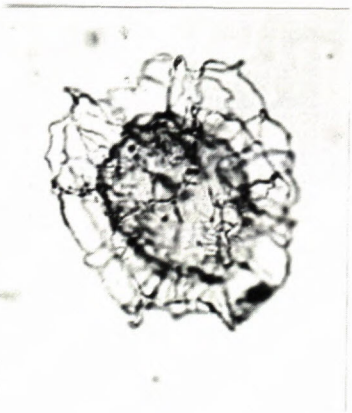
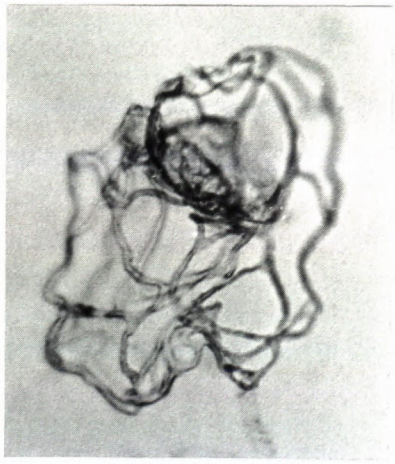
Achomosphaera neptunii (Eisenack, 1958) Davey & Williams, 1966 (14, 0, 0)
Achomosphaera ramulifera (Deflandre, 1937) Evitt, 1963 (30, 19, 31)
Achomosphaera triangulata (Gerlach, 1961) Davey & Williams, 1969 (31, 20, 9)
Achomosphaera verdieri Below, 1982 (103, 12, 30)
Adnatosphaeridium tutulosum (Cookson & Eisenack, 1960) Morgan, 1980 (0, 44, 37)
Apteodinium granulatum Eisenack, 1958 (0, 1, 0)
Apteodinium maculatum subsp. *grande* Eisenack & Cookson, 1960 (86, 0, 0)
Atopodinium mirabile (Below, 1984) Masure, 1991 (88, 0, 0)
Atopodinium perforatum (Clarke & Verdier, 1967) Masure, 1991 (73, 0, 44)
Batioladinium jaegeri (Alberti, 1961) Brideaux, 1975 (10, 0, 0)
Callaiosphaeridium asymmetricum (Deflandre & Courteville, 1939) Davey & Williams, 1966 (32, 2, 45)
Callaiosphaeridium trycherium Duxbury, 1980 (0, 3, 0)
Carpodinium granulatum Cookson & Eisenack, 1962 (78, 0, 0)
Cauca parva (Alberti, 1961) Davey & Verdier, 1971 (0, 0, 21)
Cerbia tabulata (Davey & Verdier, 1974), Below, 1981 (1, 0, 0)
Circulodinium brevispinosum (Apocock, 1960) Jansonius, 1986 (0, 6, 0)
Circulodinium distinctum (Deflandre & Cookson, 1955) Jansonius, 1986 (15, 0, 4)
Circulodinium vermiculatum Stover & Helby, 1987 (0, 13, 0)
Cleistosphaeridium clavulum (Davey, 1969) Below, 1982 (64, 0, 23)
Cleistosphaeridium? multispinosum (C. Singh, 1964) Brideaux, 1971 (0, 57, 0)
Codoniella campanulata Cookson & Eisenack, 1961 (0, 52, 0)
Codoniella psygma Davey, 1979 (0, 58, 0)
Cometodinium? whitei (Deflandre & Courteville, 1939) Stover & Evitt, 1978 (33, 21, 10)
Cometodinium sp. (0, 7, 0)
Coronifera oceanica Cookson & Eisenack, 1958 (34, 22, 5)
Cribroperidinium edwardsii (Cookson & Eisenack, 1958) Davey, 1969 (16, 0, 0)
Cribroperidinium orthoceras (Eisenack, 1958) Davey, 1969 (35, 0, 0)
Cribroperidinium sp. (0, 7, 11)
Cyclonephelium brevispinatum (Millioud, 1969) Below, 1981 (65, 0, 0)
Cyclonephelium compactum Deflandre & Cookson, 1955 (80, 0, 0)
Cyclonephelium intonsum Duxbury, 1983 (17, 0, 0)
Cyclonephelium maugaad Below, 1981 (66, 0, 0)
Cyclonephelium membraniphorum Cookson & Eisenack, 1962 (90, 0, 0)
Cyclonephelium paucispinum Davey, 1969 (0, 0, 32)
Dapsilidinium duma (Below, 1982) lentin & Williams, 1985 (0, 35, 0)
Dapsilidinium multispinosum (Davey, 1974) Bujak et al., 1980 (36, 23, 1)
Dingodinium albertii Sarjeant, 1966 (0, 48, 0)
Dinopterygium cladoides Deflandre, 1935 (0, 0, 19)
Dinopterygium tuberculatum (Eisenack & Cookson, 1960) Stover & Evitt, 1978 (37, 0, 0)
Disphaeria munda (Davey & Verdier, 1973) Norvick in Norvick & Burger, 1976 (104, 0, 0)
Dissiliodinium globulus Drugg, 1978 (12, 0, 0)
Endoceratium dettmanniae (Cookson & Hughes, 1964) Stover & Evitt, 1978 (98, 0, 42)
Endoscrinium campanula (Gocht, 1959) Vozzhennikova, 1967 (38, 15, 12)
Exochosphaeridium muelleri Yun, 1981 (39, 24, 6)
Exochosphaeridium phragmites Davey et al., 1966 (105, 0, 0)
Florentinia cooksoniae (C. Singh, 1971) Duxbury, 1980 (40, 8, 20)
Florentinia laciniata Davey & Verdier, 1973 (41, 0, 0)
Florentinia mantellii (Davey & Williams, 1966) Davey & Verdier, 1973 (42, 25, 0)
Florentinia radiculata (Davey & Williams, 1966) Davey & Verdier, 1973 (5, 0, 0)
Florentinia resex Davey & Verdier, 1976 (67, 0, 0)
Florentinia stellata (Maier, 1959) Below, 1982 (61, 46, 0)
Gardodinium trabeculosum (Gocht, 1959) Alberti, 1961 (0, 53, 0)
Gonyaulacysta cassidata (Eisenack & Cookson, 1960) Sarjeant, 1966 (79, 9, 0)
Gonyaulacysta cretacea (Neale & Sarjeant, 1962) Sarjeant, 1969 (8, 9, 0)
Gonyaulacysta extensa Clarke and Verdier, 1967 (0, 0, 38)
Hapsocysta dictyota Davey, 1979 (0, 39, 0)

Slovak Geol. Mag., 10, 3 (2004),203 – 214





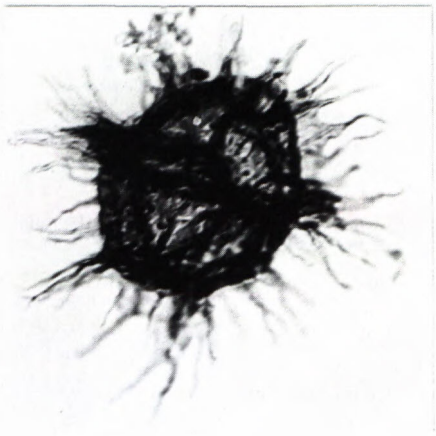
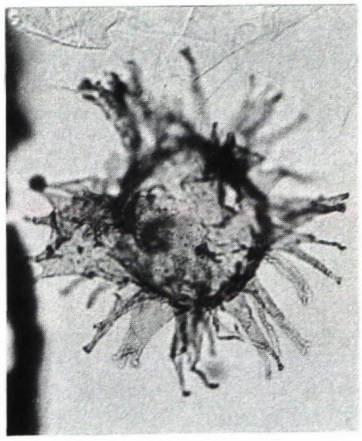




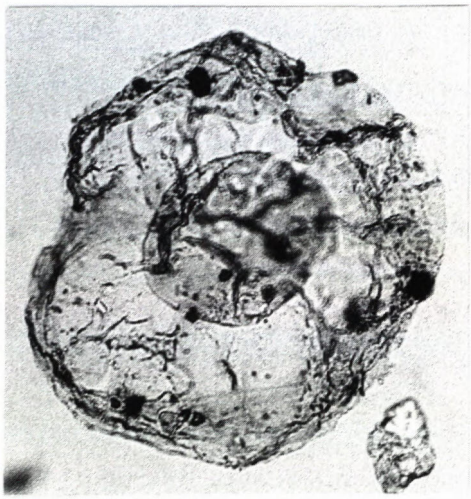
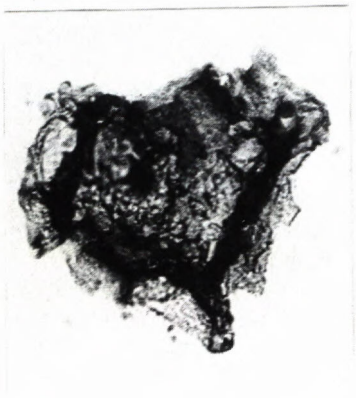
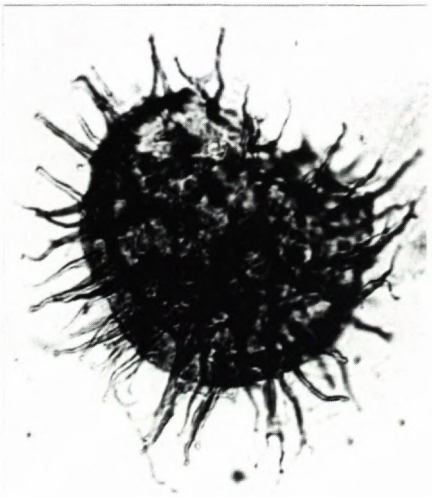
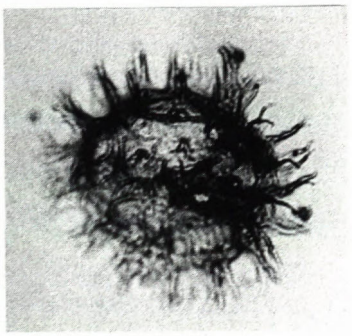

Hapsocysta peridictya (Eisenack and Cookson, 1960) Davey, 1979 (99, 26, 0)
Heterosphaeridium? *heteracanthum* (Deflandre & Cookson, 1955) Eisenack & Kjellström, 1971 (22, 0, 0)
Hystrichodinium pulchrum Deflandre, 1935 (43, 0, 13)
Hystrichodinium voigtii Alberti, 1961 (23, 0, 2)
Hystrichosphaeridium arborispinum Davey & Williams, 1966 (77, 0, 0)
Hystrichosphaeridium bowerbankii Davey & Williams, 1966 (91, 55, 22)
Hystrichosphaeridium recurvatum (White, 1842) Lejeune-Carpentier, 1940 (81, 0, 0)
Hystrichosphaerina schindewolfii Alberti, 1961 (9, 4, 0)
Hystrichostrongylon membraniphorum Agelopoulos, 1964 (60, 47, 33)
Kiokansium polypes (Tasch, 1964) Stover & Evitt, 1978 (44, 16, 7)
Kiokansium sp. (0, 0, 49)
Kleithriasphaeridium corrugatum Davey, 1974 (24, 0, 0)
Kleithriasphaeridium eoinodes (Eisenack, 1958) Davey, 1974 (45, 27, 14)
Leberidocysta chlamydata Cookson & Eisenack, 1962 (74, 59, 40)
Leberidocysta sp. (0, 54, 0)
Litosphaeridium arundum (Eisenack & Cookson, 1960) Davey, 1979 (0, 40, 0)
Litosphaeridium conispinum Davey & Verdier, 1973 (83, 45, 0)
Litosphaeridium siphoniphorum (Cookson & Eisenack, 1958) Davey & Williams, 1966 (92, 56, 24)
Muderongia neocomica Gocht, 1957 (25, 0, 0)
Muderongia pariata Duxbury, 1983 (2, 0, 0)
Muderongia cf. *staurota* Sarjeant, 1966 (0, 5, 0)
Muderongia tabulata (Raynaud, 1978) Monteil, 1991 (26, 0, 0)
Muderongia tetracatha (Gocht, 1957) Alberti, 1961 (68, 0, 0)
Muderongia sp. (0, 51, 0)
Occisucysta duxburyi Jan du Chęne et al., 1986 (3, 0, 0)
Odontochitina operculata (O. Wetzel, 1933) Deflandre & Cookson, 1955 (46, 28, 25)
Oligosphaeridium? *asterigerum* (Gocht, 1959) Davey & Williams, 1969 (47, 29, 0)
Oligosphaeridium complex (White, 1842) Davey & Williams, 1969 (48, 30, 15)
Oligosphaeridium perforatum subsp. *colum* Duxbury, 1983 (18, 0, 0)
Oligosphaeridium poculum Jain, 1977 (27, 18, 0)
Oligosphaeridium prolixispinosum Davey & Williams, 1966 (49, 0, 0)
Oligosphaeridium pulcherrimum (Deflandre & Cookson, 1955) Davey & Williams, 1966 (50, 36, 0)
Oligosphaeridium sp. (0, 60, 0)
Ovoidinium sp. (0, 0, 3)
Ovoidinium scabrosum (Cookson & Hughes, 1964) Davey, 1970 (51, 0, 39)
Ovoidinium verrucosum (Cookson & Hughes, 1964) Davey, 1970 (106, 0, 46)
Palaeohystrichophora infusorioides Deflandre, 1935 (107, 0, 0)
Palaeoperidinium cretaceum Pocock, 1962 (19, 31, 0)
Pervosphaeridium pseudhystrichodinium (Deflandre, 1937b) Yun, 1981 (93, 37, 27)
Pervosphaeridium truncatum (Davey, 1969) Below, 1982 (94, 0, 26)
Polysphaeridium sp. (0, 61, 0)
Prolixosphaeridium conulum Davey et al. (0, 0, 34)
Prolixosphaeridium parvispinum (Deflandre, 1937) Davey et al. 1969 (13, 11, 0)
Prolixosphaeridium sp. A podle Monteila (1993) (0, 0, 47)
Protoellipsodinium clavulum Davey & Verdier, 1974 (11, 0, 0)
Protoellipsodinium seghire Below, 1981 (0, 49, 0)
Protoellipsodinium cf. *seghire* Below, 1981 (108, 0, 0)
Protoellipsodinium spinosum Davey & Verdier, 1971 (28, 32, 3)
Protoellipsodinium spinocristatum Davey & Verdier, 1971 (100, 0, 0)
Pseudoceratium polymorphum (Eisenack, 1958) Bint, 1986 (6, 41, 0)
Pterodinium cingulatum (O. Wetzel, 1933) Below, 1981 (0, 33, 18)
Pterodinium cingulatum (O. Wetzel, 1933) Below, 1981 subsp. *cingulatum* (52, 0, 0)
Pterodinium cingulatum (O. Wetzel, 1933) Below, 1981 subsp. *reticulatum* Davey & Williams, 1966 (109, 0, 28)
Rottnestia borussica (Eisenack, 1954) Cookson & Eisenack, 1961 (82, 0, 0)
Spiniferites alatus Duxbury, 1977 (63, 0, 0)
Spiniferites ancoriferus Cookson & Eisenack, 1974 (101, 0, 0)
Spiniferites ancoriferus Cookson & Eisenack, 1974 subsp. *ghiran* Below, 1982 (89, 0, 0)
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854 (53, 17, 16)
Spiniferites ramosus subsp. *reticulatus* (Davey & Williams, 1966) Lentin & Williams, 1973 (54, 0, 35)
Spiniferites scabrosus (Wall, 1967) Sarjeant, 1970 (96, 0, 0)
Spiniferites sp. (0, 34, 8)
Stephodinium coronatum Deflandre, 1936 (55, 43, 36)
Stephodinium spinulosum Duxbury, 1983 (29, 0, 0)
Subtilisphaera cheit Below, 1981 (102, 0, 0)
Subtilisphaera perlucida (Alberti, 1959) Jain & Millepied, 1973 (56, 0, 0)
Subtilisphaera scabrata Jain & Millepied, 1973 (69, 0, 0)

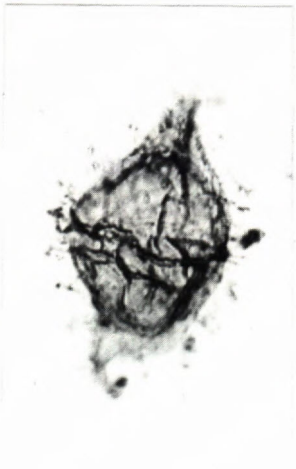
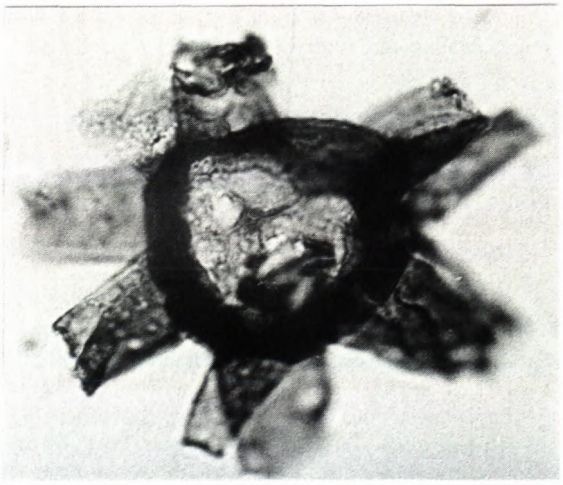
Plate 1

1. *Surculosphaeridium*? *longifurcatum* (Firtion, 1952) Davey et al., 1966; diameter 84 μm, Lower Albian, Rochovica section.
2. *Stephodinium coronatum* Deflandre, 1936; length 65 μm, Lower Albian, Pindula section.
3. *Protoellipsodinium spinosum* Davey & Verdier, 1971; length 63 μm, Lower Albian, Pindula section.
4. *Ovoidinium scabrosum* (Cookson & Hughes, 1964) Davey, 1970; length 60 μm, Lower Albian, Pindula section.
5. *Achomosphaera ramulifera* (Deflandre, 1937) Evitt, 1963; length 59 μm, Lower Albian, Pindula section.
6. *Hystrichosphaeridium recurvatum* (White, 1842) Lejeune-Carpentier, 1940; diameter 67 μm, Lower Albian, Pindula section.
7. *Litosphaeridium conispinum* Davey & Verdier, 1973; diameter 52 μm, Lower Albian, Rochovica section.
8. *Achomosphaera triangulata* (Gerlach, 1961) Davey & Williams, 1969; length 81 μm, Lower Albian, Rochovica section.
9. *Adnatosphaeridium tutulosum* (Cookson & Eisenack, 1960) Morgan, 1980; diameter 65 μm, Lower Albian, Rochovica section.
10. *Hapsocysta peridictya* (Eisenack & Cookson, 1960) Davey, 1979; diameter 68 μm, Lower Albian, Rochovica section
11. *Oligosphaeridium perforatum* subsp. *colum* Duxbury, 1983; diameter 90 μm, Middle Albian, Komorní Lhotka.

Slovak Geol. Mag., 10, 3 (2004),203 – 214

Subtilisphaera senegalensis Jain & Millepied, 1973 (59, 0, 0)
Subtilisphaera zawia Below, 1981 (70, 0, 0)
Subtilisphaera sp. (71, 0, 0)
Surculosphaeridium? basifurcatum Yun, 1981 (97, 0, 0)
Surculosphaeridium cf. *belowii* Yun, 1981 (110, 0, 0)
Surculosphaeridium? cassospinum Yun, 1981 (84, 0, 0)
Surculosphaeridium? longifurcatum (Firtion, 1952) Davey et al., 1966 (75, 42, 0)
Systematophora complicata (Cookson & Eisenack, 1965) Eisenack, 1969 (4, 0, 0)
Systematophora cretacea Davey, 1979 (7, 0, 0)
Tanyosphaeridium boletus Davey, 1974 (20, 0, 0)
Tanyosphaeridium variecalamus Davey & Williams, 1966 (85, 0, 0)
Tanyosphaeridium sp. (0, 50, 0)
Tehamadinium sp. (0, 14, 0)
Tenua hystrix Eisenack, 1958 (0, 0, 48)
Trabeculidium quinquetrum Duxbury, 1980 (0, 62, 0)
Valensiella reticulata (Davey, 1969) Courtinat, 1989 (72, 0, 0)
?Vesperopsis digitata (Duxbury, 1983) Bint, 1986 (87, 0, 0)
Xenascus sp. (0, 63, 0)
Xenascus ceratioides (Deflandre, 1937) Lentin & Williams, 1973 (111, 0, 0)
Xiphophoridium alatum (Cookson & Eisenack, 1962) Sarjeant, 1966 (76, 38, 29)

Acritarchs

Fromea amphora Cookson & Eisenack, 1958 (21, 0, 0)
Micrhystridinium inconspicuum (Deflandre, 1935) Deflandre, 1937 (95, 0, 0)
Tubulospina oblongata Davey,1970 (62, 0, 0)
Veryhachium sp. (0, 0, 43)
Wallodinium krutzschii (Alberti, 1961) Habib, 1972 (57, 10, 17)
Wallodinium luna (Cookson & Eisenack, 1960) Lentin & Williams, 1973 (58, 0, 0)

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Plate 2

1. *Xiphophoridium alatum* (Cookson & Eisenack, 1962) Sarjeant, 1966; length 74 μm, Upper Albian, Butkov quarry.
2. *Florentinia laciniata* Davey & Verdier, 1973; length 70 μm, Upper Albian, Komorní Lhotka.
3. *Hystrichostrogylon membraniphorum* Agelopoulos, 1964; length 65 μm, Middle Albian, Rochovica section.
4. *Disphaeria munda* (Davey & Verdier, 1973) Norvick in Norvick & Burger, 1976; diameter 72 μm, Upper Albian, Komorní Lhotka.
5. *Endoceratium dettmanniae* (Cookson & Hughes, 1964) Stover & Evitt, 1978; width 60 μm, Upper Albian, Komorní Lhotka.
6. *Pervosphaeridium truncatum* (Davey, 1969) Below, 1982; length 59 μm, Upper Albian, Komorní Lhotka.
7. *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937) Yun, 1981; length 81 μm, Upper Albian, Butkov quarry.
8. *Ovoidinium verrucosum* (Cookson & Hughes, 1964) Davey, 1970; length 66 μm, Upper Albian, Komorní Lhotka.
9. *Palaeohystrichophora infusorioides* Deflandre, 1935; length 60 μm, Upper Albian, Bystrá section.
10. *Litosphaeridium siphoniphorum* (Cookson & Eisenack, 1958) Davey & Williams, 1966; diameter 52 μm, Upper Albian, Rochovica section.

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