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LOWER CRETACEOUS AMMONITE AND DINOCYST BIOSTRATIGRAPHY AND PALEOENVIRONMENT OF THE SILESIAN BASIN (OUTER WESTERN CARPATHIANS)

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Abstract: The basinal, or Godula sequence of the Silesian Unit of the Outer Western Carpathians incorporated in the present nappe structure is characterized by a considerable thickness of Lower Cretaceous dark-grey, prevailingly pelitic deposits. Barremian and Lower Aptian ammonites occur in several isolated fossiliferous beds. Non-calcareous dinoflagellate associations were analysed in the same beds to provide a correlation of both ammonite and dinoflagellate ranges. Where index ammonites are missing, associations of dinocysts become a key stratigraphic element in thick lithologically monotonous deposits. The composition of dinocysts also supports environmental and paleoclimatic reconstructions in the area studied.

Key words: Silesian Unit, Lower Cretaceous, Barremian–Aptian, dinoflagellate cysts, ammonites, paleoecology.

Introduction

The Barremian deposits and deposits of the lowermost Aptian of the Silesian Unit in the area of the Godula development in the Czech Republic's territory (Flysch Western Carpathians) have been famous (Hohenegger 1861; Uhlig 1883) for a relative abundance of ammonites (Vašíček 1972, and others). Deposits studied by us belong, according to the present-day lithostratigraphic division of the Silesian Unit in the Czech Republic (Menčík et al. 1983), to the Těšín-Hradiště Formation. However, rather soft, dark-grey, prevailingly fossiliferous clayey-marls with nodules of ironstones provide merely temporary and discontinuous sections for thorough studies from the standpoint of view of modern requirements. The most frequent ammonite associations of the Mediterranean type occur in rather small outcrops in separated beds situated several meters one from another. The ammonite-bearing beds have the thickness of only a few centimetres. This fact, as well as the badly uncovered, and also complicated tectonic structure of the Silesian Nappe make the observation of detailed ammonite succession more difficult. In spite of this, on the basis of a high number of known fossiliferous horizons that yielded a sufficiently rich ammonite spectrum, and according to the stratigraphic data in the current ammonite literature, the majority of standard Mediterranean ammonite zones (Hoedemaeker & Company et al. 1993) have been successfully assigned to the Silesian Unit (Table 1). Nevertheless, it is necessary to emphasize that index ammonite species of the defined Mediterranean zones do not usually occur in the Silesian Unit. Corresponding ammonite zones can usually be derived from the total composition of the ammonite association in the horizons studied. The most significant species enabling the recognition of the standard ammonite zones in the Silesian Unit and characterizing the zones are given below as far as they are known at present.

We have recently taken field samples for the analysis of cysts of non-calcareous dinoflagellata (see Fig. 1) from the localities, with stratigraphically well determined Lower Cretaceous strata of the Czech part of the Silesian Unit representing the ammonite zones. Their occurrences in Barremian to Aptian deposits were reported earlier (Skupien 1997, 1998, 1999). Table 1 contains results, and comments on them are presented below.

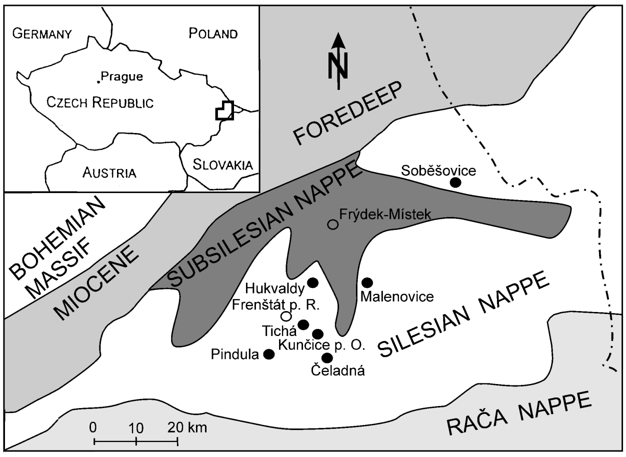
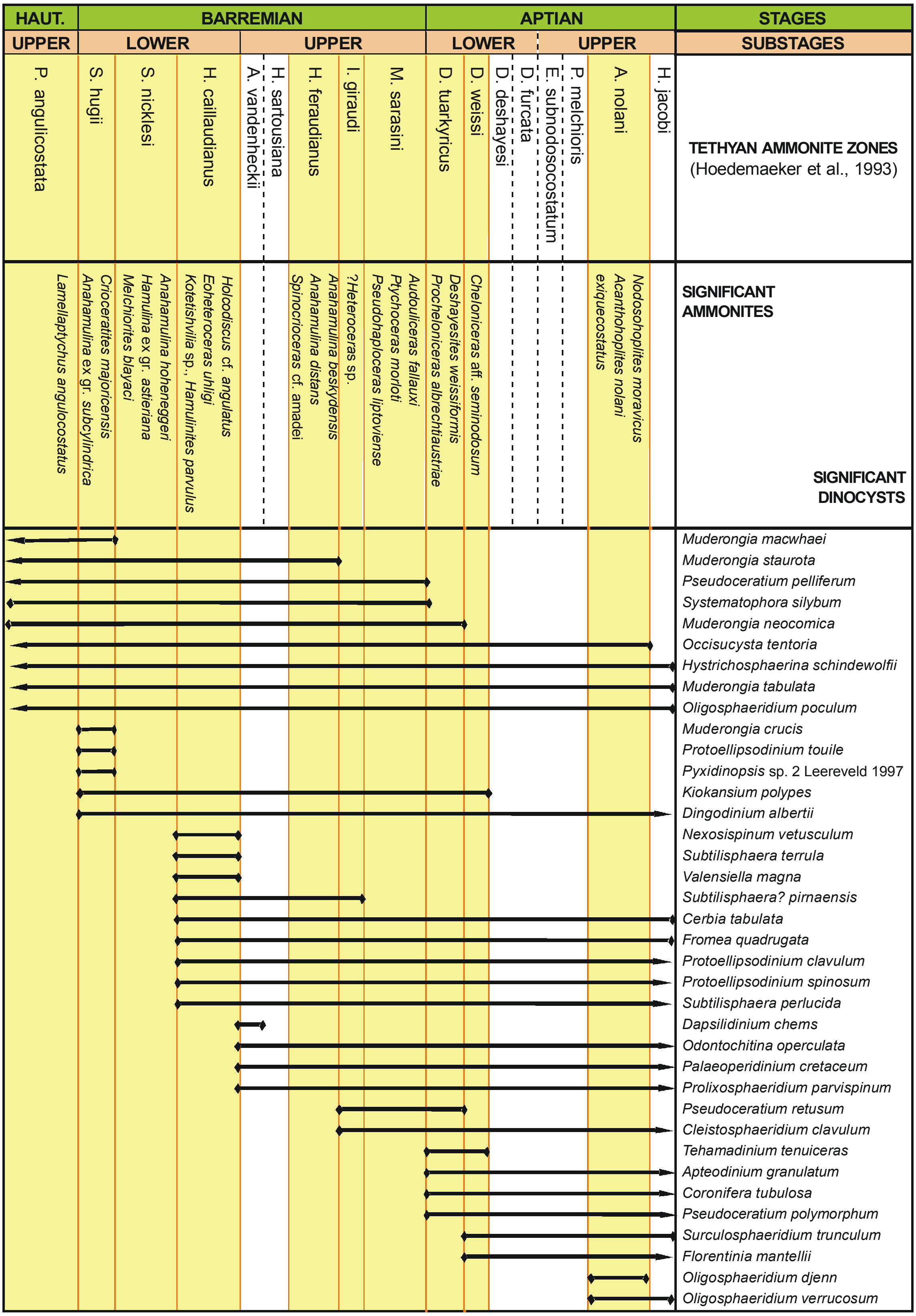


Fig. 1. Schematical geological situation of study area showing location of sections and horizons.

Material and methods

The samples taken were processed by a standard palynological technique, that is by dissolving in HCl and HF with subsequent sieving on polyethylene sieves of the mesh size of 20 μm. Specimens with separated dinocysts are deposited at the Institute of Geological Engineering at the VŠB — Techni-

Table 1: Proved ammonite zones in the Silesian Unit and the range of stratigraphically significant dinocysts. Yellow fields represent those parts of the formation studied that are easily deducible from positions in the sequence of strata, or that are shown by ammonites; white fields represent parts without index ammonite occurrence. On the right, the significant, or interesting ammonite species are presented, the occurrences of which in the Silesian Unit are confined to the stated ammonite zones. Arrows indicate the continuation of the stratigraphic extent of dinocysts into the underlying beds, or overlying beds.



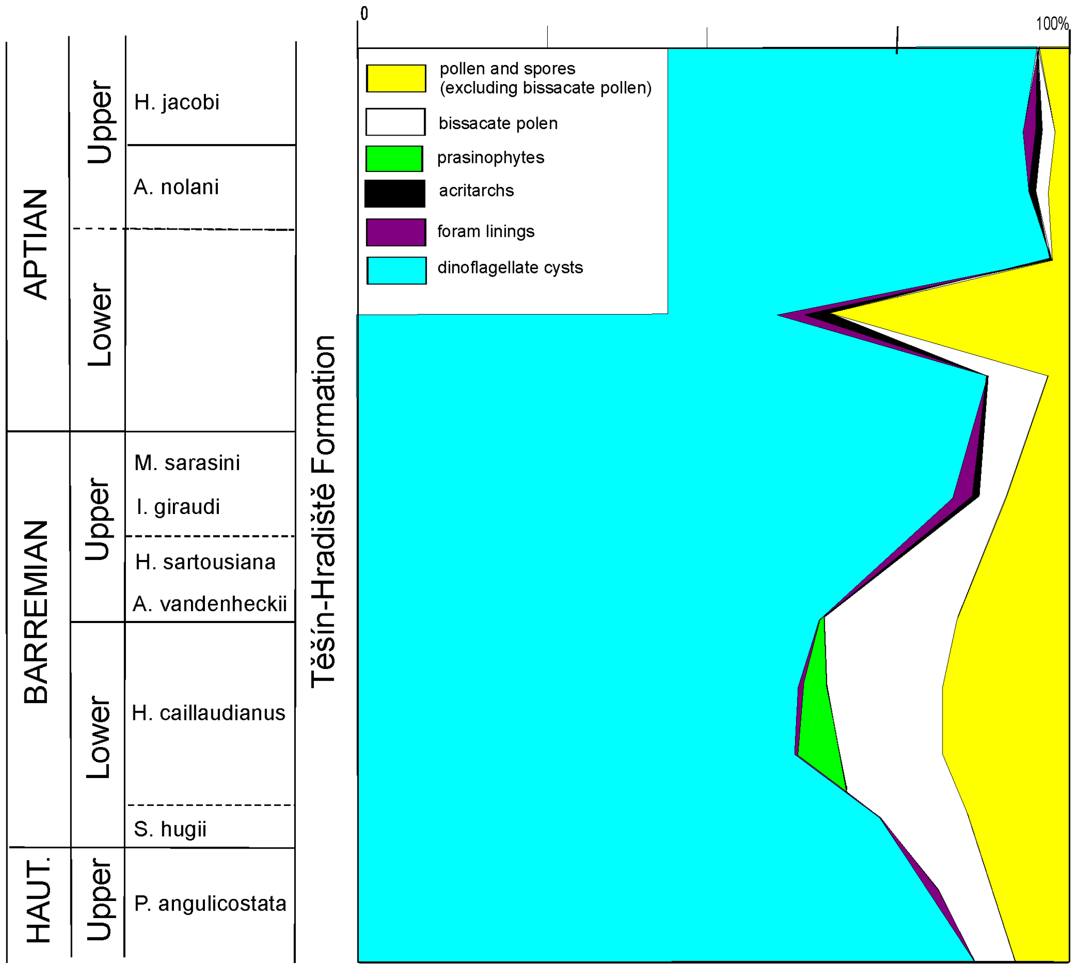


Fig. 2. Frequency pattern of main palynomorph groups in the Silesian Unit. Only those ammonite zones in the Silesian Unit are presented (as in Fig. 3) that are proved well by sufficiently rich associations of dinocysts.

cal University of Ostrava. In suitable samples, qualitative observation was supplemented by quantitative analysis.

The quantitative analysis included two steps:

1) counting of the whole palynological association up to 150 palynomorphs; this step included recognition of five broad palynomorph categories (Fig. 2): dinoflagellate cysts, acritarchs, foraminiferal linings (inner walls of foraminifers), bissacate pollen, other pollen and spores (sporomorphs excluding bisaccoids). Green algae of the group of prasinophytes are usually observed in addition to the five palynological groups presented above. Their abundant occurrence is related to a lagoonal to brackish environment. An increased amount of prasinophytes in deep-water facies indicates lower salinity of the sea surface and creation of stagnant waters.

2) counting up to 250 determinable dinoflagellate cysts when possible. Dinoflagellate cysts have been grouped into six paleoenvironmentally significant groups, see Fig. 3 (modified after Leereveld 1995; Wilpshaar & Leereveld 1994):

— salt marshy group (restricted shallow marine); this group comprises representatives of genera *Muderongia*, *Odontochitina* and *Subtilisphaera*;

— littoral group (*Canningia*, *Circulodinium*, *Pseudoceratium*);

— inner neritic group (*Cribroperidinium*, *Apteodinium*);

— neritic I group (*Spiniferites* and morphologically closely related taxa);

— neritic II group (*Florentinia*, *Kleithriasphaeridium*, *Oligosphaeridium*);

— oceanic group (*Hapsocysta*, *Pterodinium*). The oceanic group is the only autochthonous group (not transported from the shelf, but living in the oligotrophic pelagic waters) in studied type of sediments.

Stratigraphic evaluation

In the Silesian Unit, boundary deposits of the Hauterivian/Barremian and the basal Barremian (ammonite Hugii Zone) have been proved to be ammonite-bearing in only one locality — Hukvaldy (Vašíček 1977). In addition to the ammonite content, the last occurrence of aptychi of the *Lamellaptychus angulocostatus* (Peters) group contributes to definition of the Hauterivian/Barremian boundary here. The ammonite bed studied is rich in dinocysts (34 species were determined). Representatives of *Muderongia* (*M. crusis* Neale et Sarjeant, *M. macwhaei* Cookson et Eisenack, *M. neocomica* Gocht, *M.*

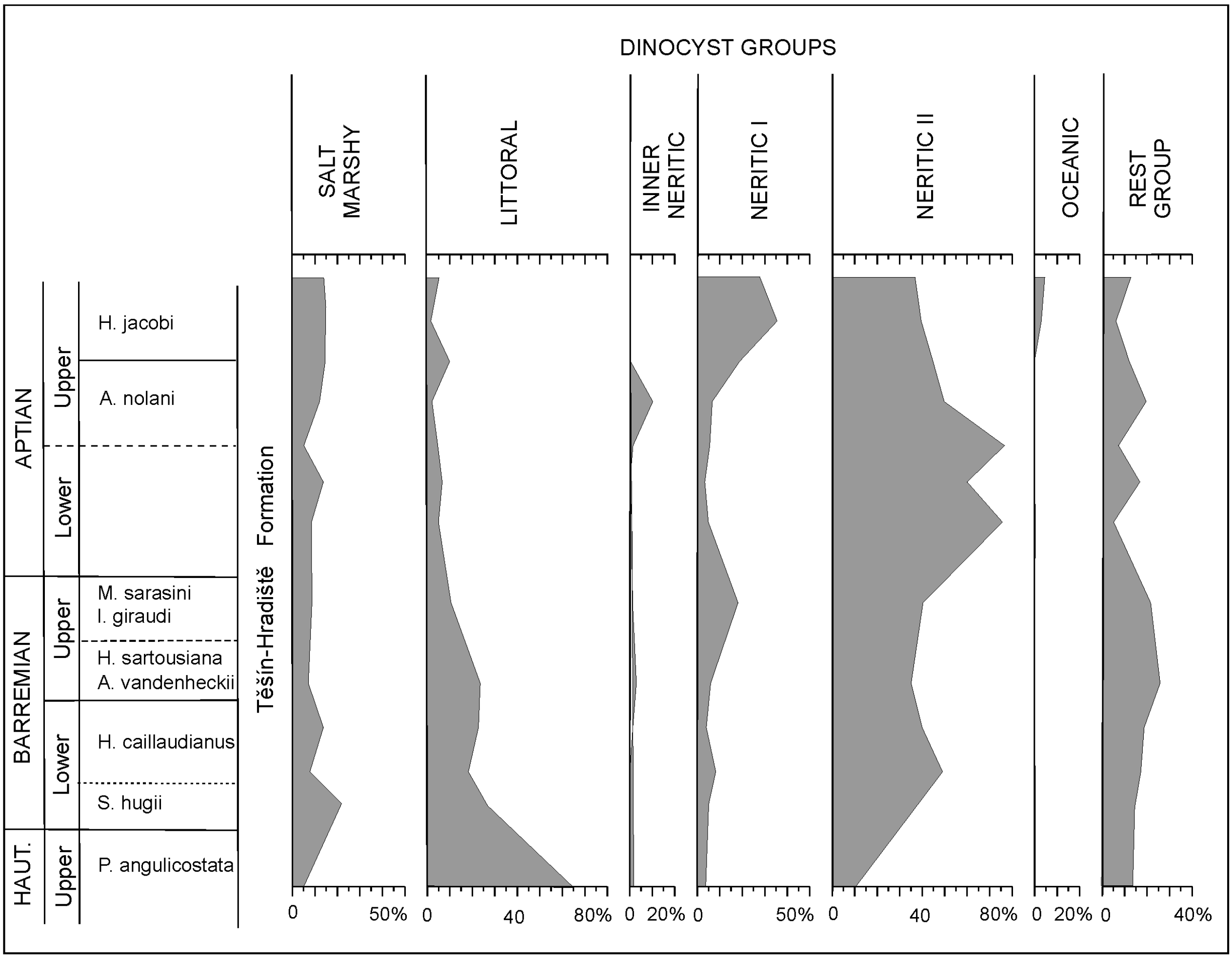


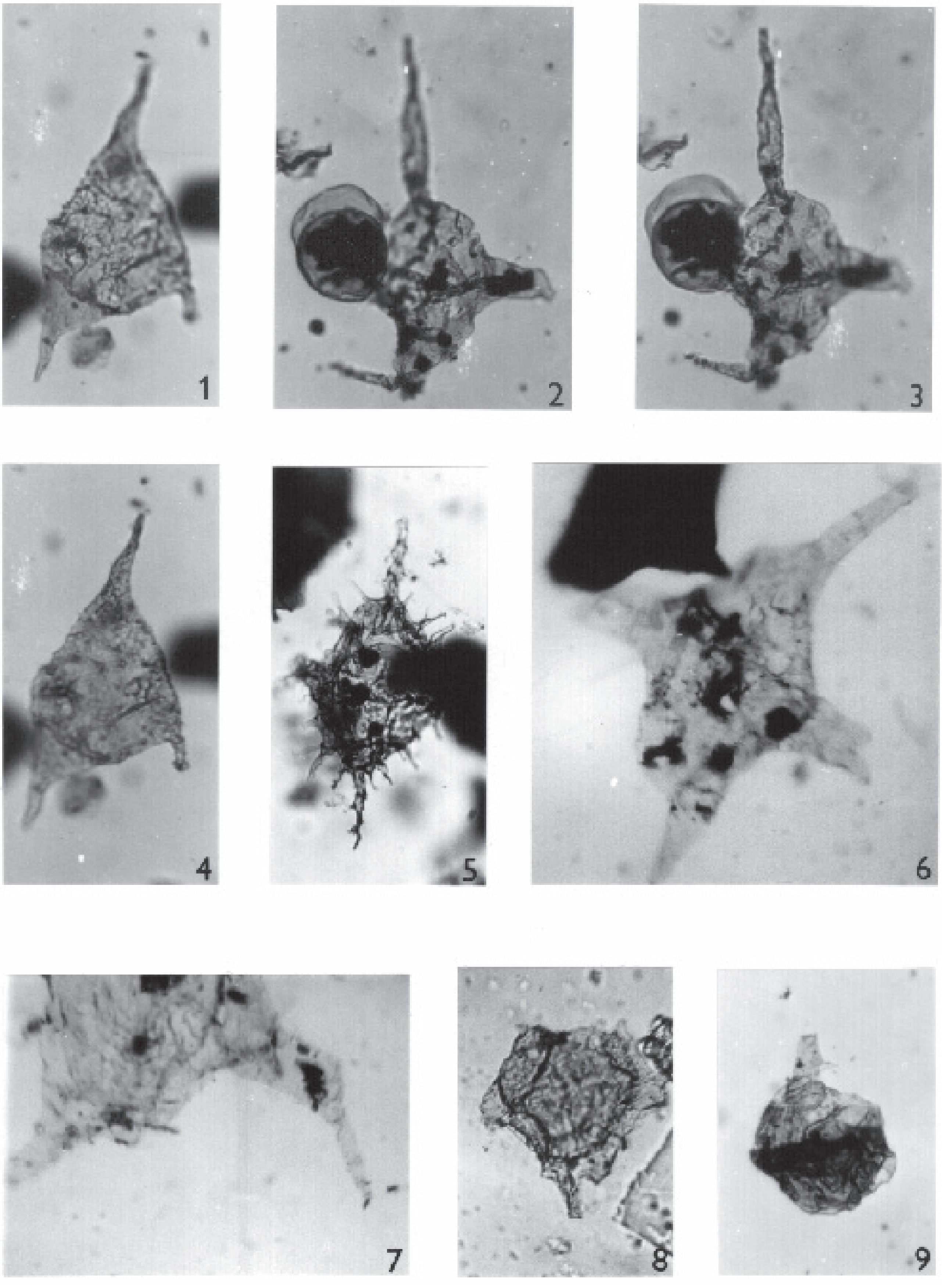
Fig. 3. Relative abundance of paleo-environmental groups of dinoflagellate cysts in the Silesian Unit.

staurota Sarjeant) and *Circulodinium distinctum* (Deflandre et Cookson) Jansonius, *Kiokansium polypes* (Cookson et Eisenack) Below and *Systematophora silybum* Davey, are of the greatest importance. The assemblage of dinocysts consists primarily of representatives of *Dissiliodinium globulus* Drugg, *Ctenidodinium elegantulum* Millioud, *Gonyaulacysta cretacea* (Neale et Sarjeant) Sarjeant, and *Oligosphaeridium poculum* Jain.

The higher Early Barremian (ammonite Nicklesi and Caillaudianus) zones identified especially in the localities situated by the village of Tichá (Vašíček 1971) are characterized by the abundance of phylloceratids and lytoceratids, further by representatives of *Anahamulina*, or *Hamulina* and also *Silesites vulpes* (Coquand). On the other hand, in contrast to similar deposits of the Mediterranean bioprovince, the ammonite association is extremely poor in representatives of Pulchelliidae. In the Caillaudianus Zone, accumulations are found in places that are formed by small heteromorph shells of Leptoceratoidinae usually accompanied by non-abundant representatives of *Holcodiscus* (Soběšovice — Klajmon et al. 1997; Vašíček & Klajmon 1998). The Caillaudianus Zone is characterized by a number of the first occurrences (FOs) of Barrremian stratigraphically significant species of dinocysts. In the assemblages, representatives of *Cerbia tabulata* (Davey et Verdier) Below, *Protoellipsodinium spinosum* Davey et Verdier, *Subtilisphaera pirnaensis* (Alberti) Jain et Millepied and *S. terrula* Davey (Skupien 1997, 1999) dominate.

Ammonites certainly do not prove the Early/Late Barremian boundary age of deposits in the Silesian Unit. The Vandenheckii and Sartousiana Zones are still a problem; they have not been verified by suitable ammonite species yet. With reference to the dinoflagellate occurrence, above all *Odontochitina*

Fig. 4. The species name is followed by the size of the specimens, preparation slide number, England Finder coordinates (for the localization of the specimen on the slide), sample location and stratigraphic position. **1, 4** — *Pseudoceratium pelliferum* Gocht, 1957. Body length 122 μm; Huk1/a, R33/4, Hukvaldy, Upper Hauterivian (ammonite Angulicostata Zone). **2, 3** — *Muderongia staurota* Sarjeant, 1966. Body length 120 μm; Huk1/a, T28, the same localization as in figure 1. **5** — *Muderongia neocomica* Gocht, 1957. Body length 118 μm; Huk1/a, V28/3, the same localization as in figure 1. **6, 7** — *Muderongia macwhaei* Cookson et Eisenack, 1958. 6 — Body length 120 μm, Huk1/b, Q32/1; 7 — A25, the same localization as in figure 1. **8** — *Muderongia tabulata* (Raynaud, 1978) Monteil, 1991. Body width 78 μm; Huk1/a, Q16/4, the same localization as in figure 1. **9** — *Dinogymnium albertii* Sarjeant, 1966. Body length 56 μm; Huk2/a, K/L39, Hukvaldy, Lower Barremian (ammonite Hugii Zone).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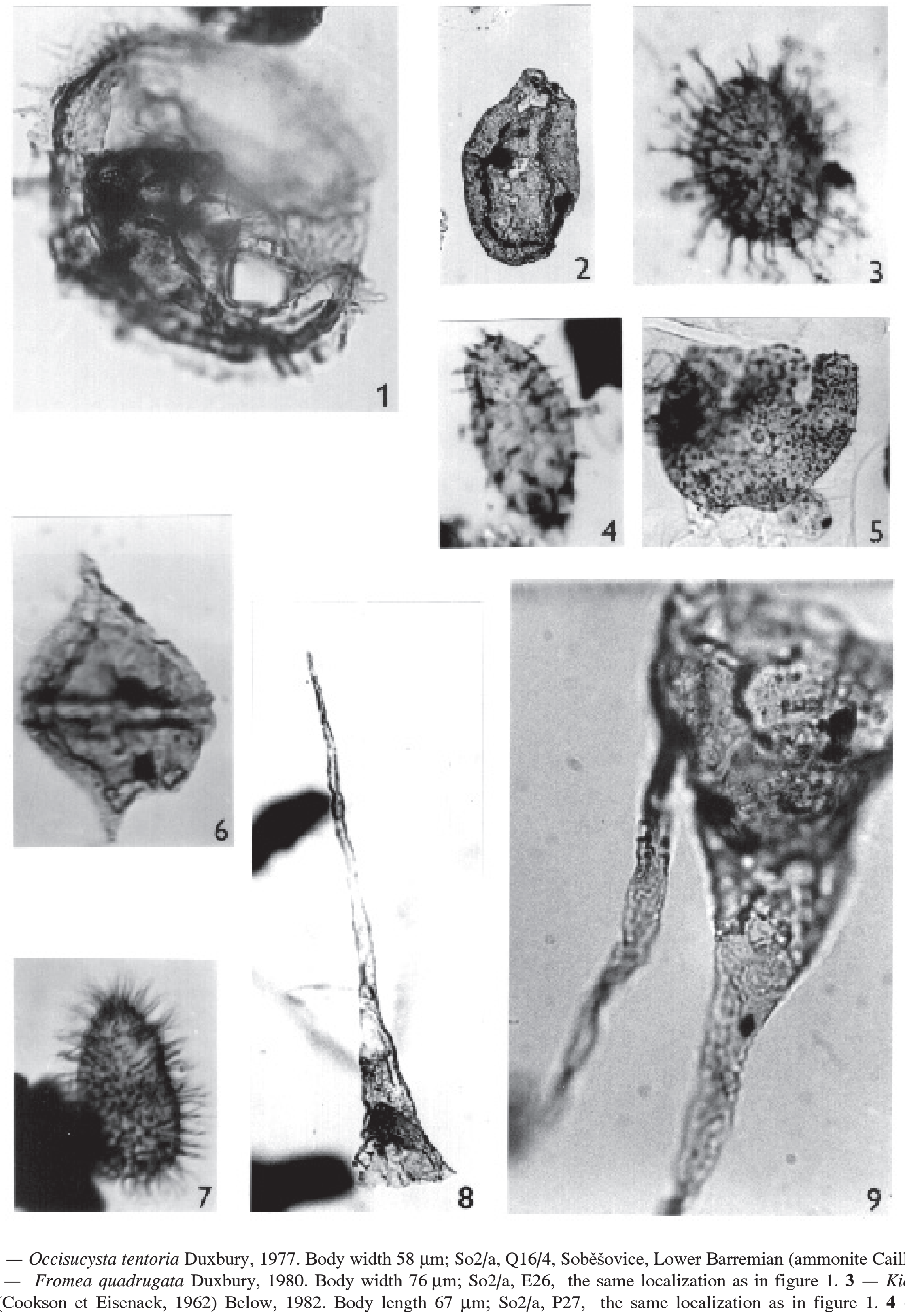


Fig. 5. **1** — *Occisucysta tentoria* Duxbury, 1977. Body width 58 μm; So2/a, Q16/4, Soběšovice, Lower Barremian (ammonite Caillaudianus Zone). **2** — *Fromea quadrugata* Duxbury, 1980. Body width 76 μm; So2/a, E26, the same localization as in figure 1. **3** — *Kiokansium polypes* (Cookson et Eisenack, 1962) Below, 1982. Body length 67 μm; So2/a, P27, the same localization as in figure 1. **4** — *Prolixosphaeridium parvispinum* (Deflandre, 1937b) Davey et al., 1969. Body length 85 μm; L13/a, O44/1, Pindula, Upper Barremian (ammonite Vandenheckii Zone). **5** — *Cerbia tabulata* (Davey et Verdier, 1974), Below, 1981. Body width 77 μm; So2/a, P48/49, the same localization as in figure 1. **6** — *Subtilisphaera* ? *pirnaensis* (Alberti, 1962) Jain et Millepied, 1973. Body width 48 μm; So2/a, E26, the same localization as in figure 1. **7** — *Protoellipsodinium clavulum* Davey et Verdier, 1974. Body length 76 μm; L13/a, T43, the same localization as in figure 4. **8, 9** — *Odontochitina operculata* (O. Wetzel, 1933) Deflandre et Cookson, 1955. 1. Length 102 μm; L13/a, S48; 2. free operculum, Body length 150 μm, L13/b, K32/33; the same localization as in figure 4.

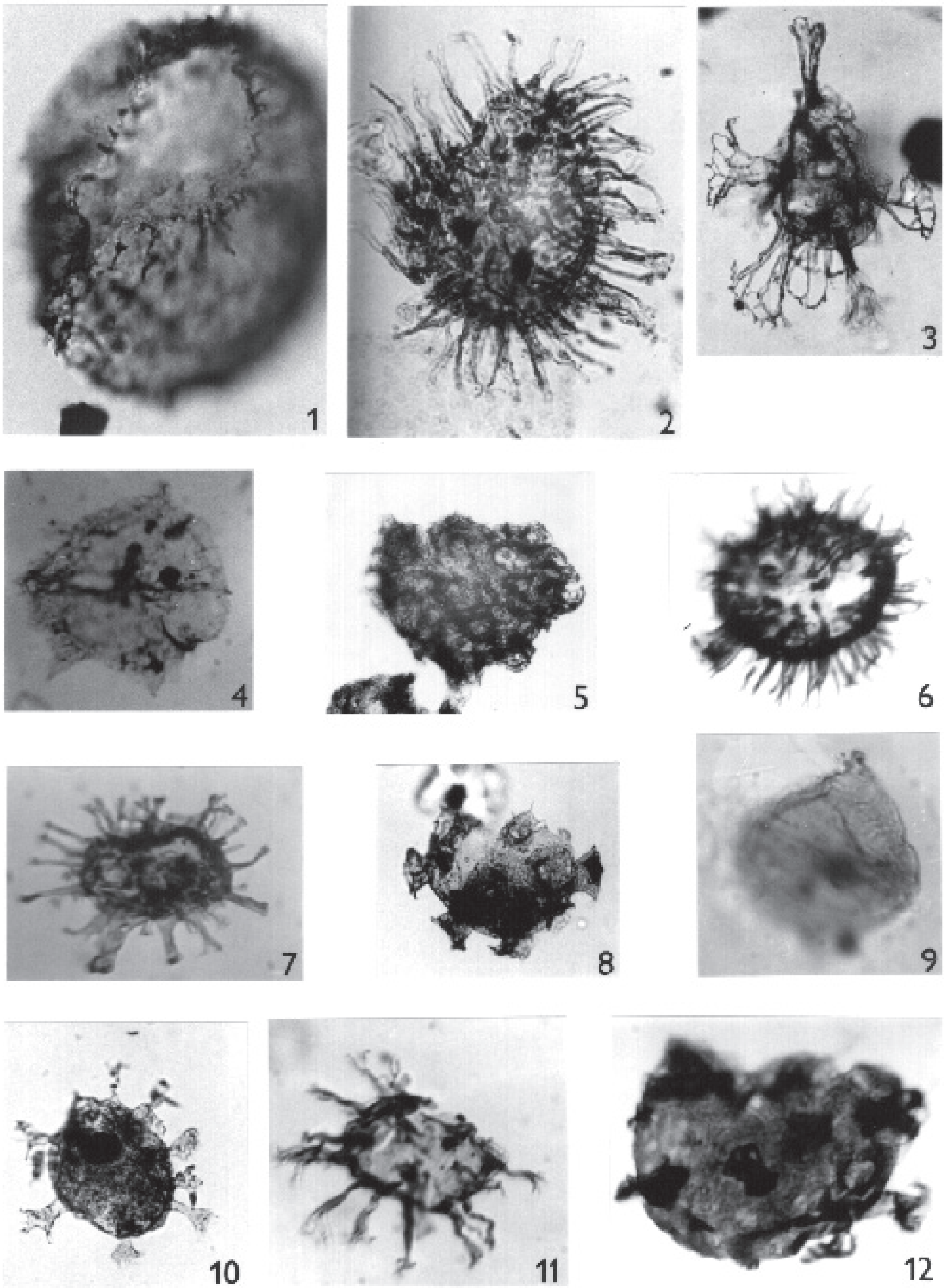
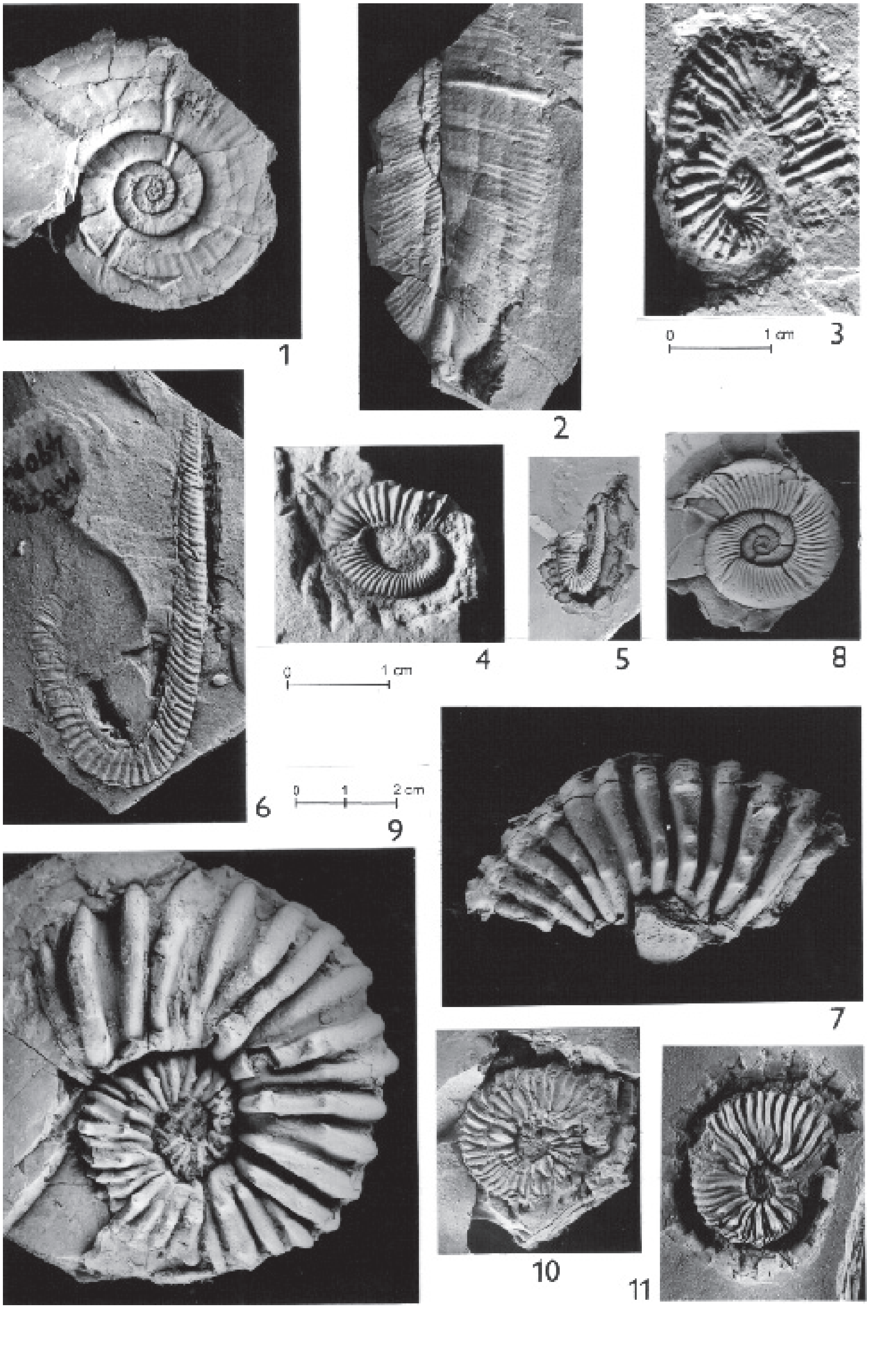


Fig. 6. **1** — *Protoellipsodinium touile* Below, 1981. Body length 70 μm; Huk 2/a, N46, Hukvaldy, Lower Barremian (ammonite Hugii Zone). **2** — *Protoellipsodinium spinosum* Davey et Verdier, 1971. Body length 71 μm; L13/a, T34, Pindula, Upper Barremian (ammonite Vandenheckii Zone). **3** — *Hystrichosphaerina schindewolfii* Alberti, 1961. Body width 66 μm; L13/c, N46, the same localization as in figure 2. **4** — *Palaeoperidinium cretaceum* Pocock, 1962. Body length 53 μm; L13/a, A12, the same localization as in figure 2. **5** — *Pseudoceratium polymorphum* (Eisenack, 1958) Bint, 1986. Body width 86.6 μm; S31/c, N29/3, Satina, Lower Aptian (ammonite Tuarkyricus Zone). **6** — *Coronifera tubulosa* Cookson et Eisenack 1974. Body length 46 μm; S31/b, B25, the same localization as in figure 5. **7** — *Florentinia mantellii* (Davey et Williams, 1966) Davey et Verdier, 1973. Body width 61 μm; S31/a, G41/3, the same localization as in figure 5. **8** — *Oligosphaeridium poculum* Jain, 1977. Body width 60 μm; BP1/a, Z23/1, Bílý Potok, Lower Aptian (ammonite Weissi Zone). **9** — *Subtilisphaera perlucida* (Alberti, 1959) Jain et Millepied, 1973. Body width 50 μm. BP1/a, P33, Bílý Potok, Lower Aptian (ammonite Weissi Zone). **10** — *Oligosphaeridium verrucosum* Davey, 1979. Body width 60 μm; L20/a, Y53, Pindula, Upper Aptian (ammonite Nolani Zone). **11** — *Surculosphaeridium trunculum* Davey, 1979. Body width 56 μm; L20/b, F43, the same localization as in figure 10. **12** — *Oligosphaeridium djenn* Below, 1982. Body diameter 48 μm; L20/b, O/P37, the same localization as in figure 10.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operculata (O. Wetzel) Deflandre et Cookson, *Palaeoperidinium cretaceum* Pocock and *Prolixosphaeridium parvispinum* (Deflandre) Davey et al., the beginning of the Late Barremian is considered. Their first occurrences characterizing the Early/Late Barremian boundary (Costa & Davey 1992; Leereveld 1995) were found in several localities (primarily Kunčice p. O., Pindula, Malenovice-Satina; Skupien 1997, 1999).

Late Barremian ammonite zones (Feraudianus, Giraudi, Sarasini) found especially in the surroundings of Kunčice p. O. (Vašíček 1971, 1973) were characterized, besides stratigraphically less important phylloceratids and lytoceratids, mainly by occurrences of *Macroscaphites yvani* (Puzos), *Costidiscus recticostatus* (d'Orbigny) and *Silesites seranonis* (d'Orbigny). Moreover, in the Feraudianus Zone, representatives of *Anahamulina* are abundant; representatives of *Spinocrioceras* (locality of Malenovice 5 — Vašíček 1971, 1972) being a new element. In the assemblage of dinocysts from samples taken from localities in the vicinity of Kunčice p. O., species stratigraphically insignificant for this part of the Barremian prevail, for example, *Cerbia tabulata* (Davey et Verdier) Below, *Odontochitina operculata* (O. Wetzel) Deflandre et Cookson, *Oligosphaeridium complex* (White) Davey et Williams. However, what can be regarded as stratigraphically important, is the last occurrence (LO) of *Muderongia staurota* Sarjeant and *Pseudoceratium pelliferum* Gocht which indicates, according to Leereveld (1995), the end of the Barremian/Aptian boundary (Pindula, Malenovice-Satina; Skupien 1997).

In that part of the sequence of strata which we regard as the ammonite Giraudi Zone anahamulinids do not occur any more. On the other hand, no pseudohaploceratids occur here yet. Sporadic occurrences of ammonites of Heteroceratidae, to which beside *Heteroceras,* colchidits also belong, are interesting. The overlying Sarasini Zone is characterized by the first appearance of *Pseudohaploceras liptoviense* (Zeuschner). The first occurrences of this genus, or species from the beginning of the presented zone is stated by Delanoy (1998) as well. Representatives of *Ptychoceras* are relatively abundant in places. Findings of *Audouliceras fallauxi* (Uhlig) and the occurrence of *Toxoceratoides* are of interest too.

The ammonite spectrum of the basal Aptian (ammonite Tuarkyricus Zone) remains, in principle, equal to that of the previous zone. We connect the base of the Aptian with the first occurrences of representatives of *Procheloniceras* (Vašíček 1973), especially with the occurrence of *P. albrechtiaustriae* (Uhlig). Only exceptionally, representatives of *Deshayesites* (Veřovice — Vašíček 1971) can be found here as well.

In the overlying beds of the basal Aptian, ammonites rather suddenly disappear from deposits with the ever-decreasing calcareous content. The unique occurrence of *Cheloniceras* aff. *seminodosum* (Sinzow) and the position of its occurrence in the beds overlying those with *Procheloniceras* could identify the ammonite Weissi Zone (Bílý potok at Čeladná — Vašíček 1981a).

However, the Early Aptian dinocyst spectrum is characterized well by the first occurrences of stratigraphically significant forms, above all *Apteodinium granulatum* Eisenack, *Coronifera tubulosa* Cookson et Eisenack, *Pseudoceratium polymorphum* Gocht and *Tehamadinium tenuiceras* (Eisenack) Jan du Chêne et al. (localities of Bílý potok at Čeladná and Kunčice p. O.). In the locality of Bílý potok, in the supposed Weissi Zone, the first occurrence of *Florentinia mantelii* (Davey et Williams) Davey et Verdier and *Surculosphaeridium trunculum* Davey can be taken as significant for the dinocysts. In the assemblages of Early Aptian dinocysts of the Silesian Unit, representatives of the genus *Achomosphaera (A. triangulata* (Gerlach) Davey et Williams, *A. verdieri* Below) prevail.

After a rather long period without any ammonite occurrence in the Silesian Unit, the last ammonite horizon of Lower Cretaceous (Late Aptian) age appears (Pindula — Vašíček 1981b; Skupien 1997). In addition to endemic ammonites, the unique occurrence of *Acanthohoplites nolani exiquecostatus* Egoian is important here. It proves the Late Aptian ammonite Nolani Zone. Dinocysts have not furnished any suitable stratigraphic data for the presented part of the Aptian (except the Nolani Zone mentioned above). In this zone, representatives of *Oligosphaeridium djenn* Below and *O. verrucosum* Davey appear for the first time. The uppermost Aptian (Jacobi Zone) can be considered in virtue of the last occurrences of some dinocyst species (Davey 1979; Below 1984), namely *Cerbia tabulata* (Davey et Verdier) Below, *Hystrichosphaerina schindewolfii* Alberti, *Oligosphaeridium verrucosum* Davey and *Surculosphaeridium trunculum* Davey. Their occurrences were found in several rather continuous sections with exposed Aptian/Albian boundary deposits (localities of Komorní Lhotka — Skupien 1998; Pindula — Skupien 1997, 1999). However, the uppermost Aptian zone mentioned has not been proved by any macrofaunistic findings.

Our knowledge is graphically summarized and expressed in Table 1. Significant dinocysts are illustrated in Figs. 4–6, some important ammonites are shown in Fig. 7. A special study (Vašíček & Skupien, in prep.) deals with the systematic processing of the specific ammonite group of ancyloceratids occurring in the given time period.

Fig. 7. **1** — *Silesites vulpes* (Coquand). Early Barremian (ammonite Nicklesi Zone), Tichá. **2** — *Anahamulina hoheneggeri* (Uhlig). Early Barremian (Nicklesi Zone), coal shaft Frenštát 4, depth 250 m. **3** — *Eoheteroceras uhligi* (Vašíček). Early Barremian (ammonite Caillaudianus Zone), Soběšovice. **4** — *Karsteniceras beyrichoide* Vašíček et Wiedmann. Early Barremian (Caillaudianus Zone), Soběšovice. **5** — *Hamulinites parvulus* (Uhlig). Early Barremian (Caillaudianus Zone), Pindula. **6** — *Anahamulina distans* Vašíček. Late Barremian (ammonite Feraudianus Zone), Malenovice. **7** — *Spinocrioceras* cf. *amadei* (Uhlig). Late Barremian (Feraudianus Zone), Malenovice. **8** — *Silesites seranonis* (d'Orbigny). Late Barremian (ammonite Sarasini Zone), Kozlovice. **9** — *Procheloniceras albrechtiaustriae* (Uhlig). Lowermost Aptian (ammonite Tuarkyricus Zone), Kunčice p. O. **10** — *Acanthohoplites nolani exiquecostatus* Egoian. Late Aptian (ammonite Nolani Zone), Pindula. **11** — *Nodosohoplites moravicus* Vašíček. Late Aptian (Nolani Zone), Pindula. Where no graphical scale is given, the magnification is equal to that in figure 9.

Remarks about paleoecology and paleoclimatology

With regard to the quality of preservation and especially the amount of palynomorphs, only some samples were suitable for the quantitative palynological evaluation of the part under study. The analysis given below is based on the data presented in Figs. 2 and 3. In the stratigraphic scale of both the figures, merely those ammonite zones are stated that are examined well according to sufficiently rich contents of dinocysts.

The Hauterivian/Barremian boundary deposits studied in the locality of Hukvaldy are characterized by an abundance of dinocysts with the prevailing part formed by the littoral group (primarily *Systematophora*). Simultaneously, dinocysts typical of the open neritic sea are present in small numbers. Thus, it is possible to suppose a redeposition of littoral material into deeper parts of the basin (into the area of the open sea).

The composition of palynomorphs of the Early Barremian (Caillaudianus Ammonite Zone) of the Soběšovice locality is characterized by a rather high content of sporomorphs and by the presence of prasinophytes (these indicate a lower salinity of the surface waters). In the composition of dinocysts of this part of the Early Barremian, neritic species prevail (e.g. *Kleithriasphaeridium eoinodes* (Eisenack) Davey, *Oligosphaeridium asterigerum* (Gocht) Davey et Williams, *O. complex* (White) Davey et Williams) with a significant share of littoral types (e.g. *Subtilisphaera*). It is possible to state that the original environment of the redeposited assemblage of dinocysts was in the area of the deeper shelf. The increased number of peridinioid cysts, present most frequent in the environment of the higher supply of nutrients, indicates a possibility of a high drift from the continent (which is shown by the considerably high content of sporomorphs as well) and also the reduction of salinity of the sea surface (the presence of prasinophytes). Fresh water and nutrient influx implies increased runoff, possibly as a result of increased precipitation. High productivity and limited water circulation at the bottom cause anoxic conditions of sedimentation.

During the Late Barremian (Vandenheckii and Sartousiana Ammonite Zones of the Pindula section; Giraudi and Sarasini Ammonite Zones of the Malenovice-Satina section) and the Aptian (Early Aptian of the Malenovice-Satina section and Late Aptian of the Pindula section), a share of terrestrial material (sporomorphs) decreased. During the Late Aptian, dinocysts begun to prevail totally. Simultaneously, a change in the composition of the assemblage of dinocysts occurs, when the share of the littoral group declines markedly and, on the contrary, an increase in the proportion of dinocysts characteristic of the open neritic sea (*Spiniferites*) can be observed here. Since the uppermost Aptian, an autochthonous element appeared here for the first time, namely the oceanic group of dinocysts.

On the basis of the quantitative content of palynomorphs and dinocysts of the Těšín-Hradiště Formation of the uppermost Barremian and the Early Aptian, the environment of deeper shelf to basin can be considered still with a marked supply of terrestrial material. During the Late Aptian, the terrestrial influence weakened, and dinocysts typical of the open sea became dominant.

The dinocysts present in the Silesian Unit material are almost entirely warm-water taxa indicating a relatively high sea surface temperature during deposition. Only several Aptian samples contain few cold-water species. These could imply a temporary drop in the sea surface temperature.

Conclusions

The contribution submitted develops and makes more accurate a part of the previous results briefly presented at the 6th International Cretaceous Symposium in Vienna (Skupien & Vašíček 2000). A rich content of non-calcareous dinocysts especially in the period of the uppermost Hauterivian to the Early Aptian, the species composition of their assemblage, the first and last occurrences of some significant species, and others enable their stratigraphic utilization for the detailed determination of the age of outcrops in monotonous, grey pelitic deposits of the Silesian Unit, in some cases up to the level of ammonite zones. Dinocysts can be used suitably for defining the lower and upper boundaries of the Barremian Stage, or for distinguishing the Early/Late Barremian boundary especially in such places where ammonites are missing in the deposits of the Silesian Unit.

The quantitative compositions of palynomorphs and assemblages of dinocysts in the Silesian Unit reflect the environment of the open sea with a gradually decreasing supply of terrestrial and shallow-sea materials. An increased portion of terrestrial material in the Lower Barremian (here also the presence of prasinophytes) and in the Lower Aptian strata indicates higher precipitation (humid climate). A deepening of the sedimentation environment can be observed as well (during the Late Aptian, the first representatives of oceanic dinocysts already appeared) which can be connected with tectonic subsidence and sea level rise in the uppermost Aptian to Albian (according to the second order eustatic curve of the level, Haq et al. 1988). During Aptian, dinocysts appear that are considered to be Boreal elements and which indicate a cooling of the sea level.

The prevailing majority of significant ammonite species presented in the correlation Table 1 and in the text (if not depicted in Fig. 7) have been illustrated in previous publications by Vašíček (1972, 1977, 1981a,b), or they will be mentioned in an ammonite study under preparation (Vašíček & Skupien, in prep.). The detailed processing of the associations of dinocysts of most of the localities has been published by Skupien (1997, 1998, 1999).

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