Acta Geologica Hungarica, Vol. 46/4, pp. 341–370 (2003)

Integrated palynology of the Upper Cretaceous in Crimea, Ukraine

Ágnes Siegl-Farkas
Geological Institute of Hungary, Budapest

The author provides new data for the paleontological and stratigraphic understanding of the Upper Cretaceous formations of the Crimean Peninsula. Within the classic Bakhchisaray region 24 samples from six sections (Cenomanian-Maastrichtian) were studied. About 130 palynomorphs have been identified, 11 associations (spore-pollen and dinoflagellate) were differentiated and correlated with nannozones, foram zones and macropaleontological zones. The study confirms that during the Senonian the Crimean Peninsula belonged to the northern nearshore–neritic region of the Tethys and on land to the boreal Normapolles Phytogeographic Province.

Key words: Crimean Peninsula, Bakhchisaray Region, Upper Cretaceous, integrated palynology, paleoenvironment, correlation

Introduction

During the Late Cretaceous the present-day Crimean Peninsula was covered by a relatively shallow marine basin belonging to the northern margin of the Tethys, with a wide connection to the boreal seas.

The Upper Cretaceous formations occur on the northern slope of the second range of the Crimean Mountains, in a strip between Sevastopol, Bakhchisaray, and Simferopol (SW–NE) and from Simferopol to Feodosiya (W–E). The classic study area is the neighborhood of Bakhchisaray (Fig. 1).

Based on earlier biostratigraphic analysis, the Upper Cretaceous sediments develop continuously from the Cenomanian up to the Maastrichtian. They are underlain by Albian glauconitic sandstone and covered by Danian limestone outcropping in the form of cuestas. They consist mainly of marl, less often of white limestone and sandstone. Their total thickness is about 350 m.

The Cretaceous formations have been studied since the mid-19th century. The most complete description of the sequences and their biostratigraphy was published by Maslakova (1971), Alekseev (1989), Alekseev et al. (1997), and Alekseev and Kopaevich (1997).

Palynological data have been published by Panova (1978), Rotman (1979) and Zaklinskaya and Naidin (1985).

Address: Á. Siegl-Farkas: H-1143 Budapest, Stefánia út 14, Hungary, E-mail: siegla@mafi.hu
Received: 21 April, 2004

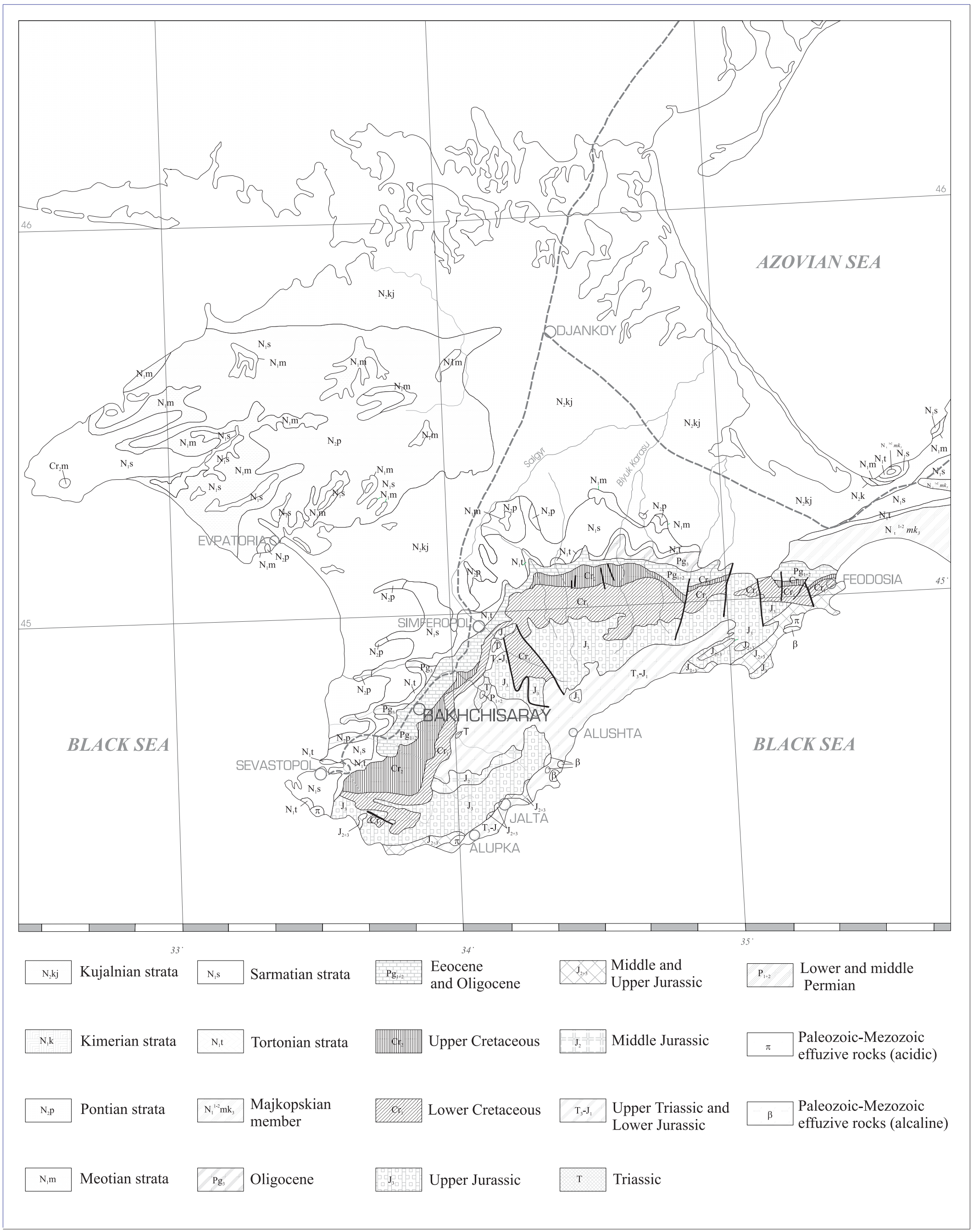

Fig. 1
Geological map of Crimean Peninsula (after Ershov ed. 1957, digital procession by A. Kókay)

Aims

The present integrated palynological investigations had the following aims:

– detailed study and documentation of the sporomorph associations (spores-pollen, dinoflagellates) of the Crimean Upper Cretaceous,

– their palynological characterization,

– their correlation with the micropaleontological biozones (nannoplankton, foraminifers), as well as with the macropaleontological ones (ammonites, belemnites).

Sampling, maceration and results

Some sections (e.g. Turonian, Santonian) of the Upper Cretaceous sequence were either inaccessible, or turned out to be unsuitable for palynological studies due to their high carbonate content.

Altogether 36 samples were taken from 6 sites; of these, 24 proved to be fossil-bearing.

The maceration was carried out in the Pollen Laboratory of the Geological Institute of Hungary. Samples were treated with HCL and HF acids. During processing sieved tap water was added to avoid too violent reactions. $ZnCl_2$ (s. g. 1.9–2.1) was used for gravity separation. The residues were mounted in glycerin jelly. Slides were examined using an Amplival Zeiss microscope and microphotographs were taken with HI-100/1.4 Apochromat objective.

The palynological characterization of the samples is given in geochronological order (from Cenomanian to Maastrichtian) of the sites: 1. Prokladnoe Village, 2. Selbukhra Mts, 3. Bodrak River (at Trudol'ubovka Village), 4. Beshkosh (Five Birds) Mts, 5. Bakla (Broad-bean) Mts and 6. Skalistoje Village (Devil's Cave) (Figs 2 and 3).

The samples yielded four distinct associations of spores and pollen, and dinoflagellates, respectively.

About 130 palynomorphs have been identified (see the flora list). The relative abundances of the stratigraphically most important taxa and the characteristic associations of spores-pollen and dinoflagellates, correlated with nannozones, are shown in Fig. 4 and on the annexed 9 photo plates.

Most of the sampled sections have been emplaced within ammonite and/or belemnite zones, or foraminifer zones (Maslakova 1971; Alekseev and Kopaevich 1997). These are referred to in the palynological characterization of each association.

Description by sampling localities

Prokladnoe (samples 1, 2) and Bodrak (samples 3–5)

Lower Cenomanian, *Thalmannina appeninica* Zone, corresponding to the *Mantelliceras mantelli* Zone. The investigated light to middle gray marl, at some places with limonite or marcasite concretions, overlies gray glauconitic sandstone of Albian age.

The two sites are of the same age. Their sporomorph associations are very similar to each other, but the samples collected from Bodrak Gully are more abundant and more varied.

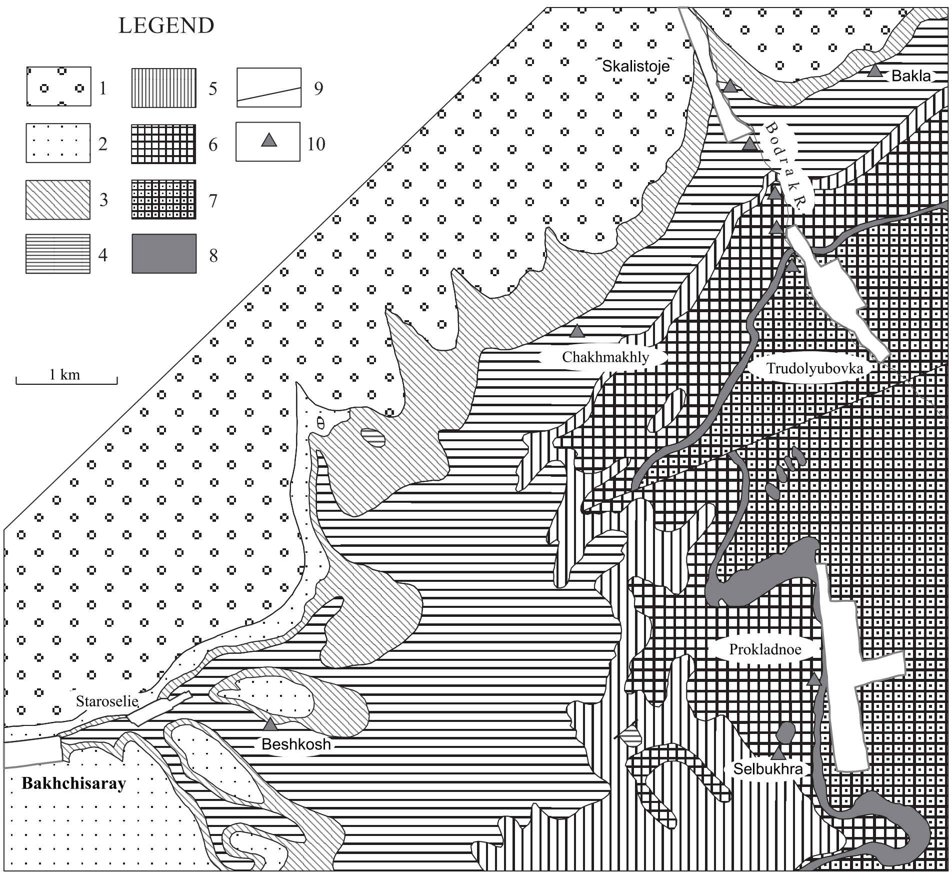

Fig. 2
Geological map of the studied area. (after: Alekseev and Kopaevich 1997). 1. Paleogene: Thanetian–Ypresian–Lutecian strata; 2. Paleogene: Montian strata; 3. Paleogene: Danian strata; 4. Upper Cretaceous: Santonian to Maastrichtian strata; 5. Upper Cretaceous: Upper Turonian strata; 6. Upper Cretaceous: Lower Turonian strata; 7. Lower Cretaceous: Upper Albian strata; 8. Lower–Middle Jurassic and Lower Cretaceous strata; 9. Faults; 10. Studied or referenced profiles (digital procession by A. Kókay)

The marine microphytoplankton is predominate. Abundant dinoflagellates (*Chlamidoporella nyei, Cribroperidinium pyrum, Florentinia daenei, Odontochitina* sp., *Odontochitina operculata, Oligosphaeridium pulcherrimum, Spinidinium angustispinum*) are accompanied by rare acritarchs (*Veryhachium reductum, Baltisphaeridium* sp.). In the deeper-sited samples organic foraminiferal tests and Scolecodonta (mud-eating annelids) are common. Terrestrial plants are represented in considerable number by fern spores well known from the Lower Cretaceous (*Appendicisporites auritus, Appendicisporites erdtmani, Bikolisporites toratus, Camarozonosporites concinnus, Cicatricosiporites* div. sp., *Converrucosisporites* sp., *Corniculatisporites bolchovitinae, Costatoperforosporites fistulosus, Costatoperforosporites triangulatus*) and gymnosperm pollen (*Alisporites* sp., *Classopollis* sp.,

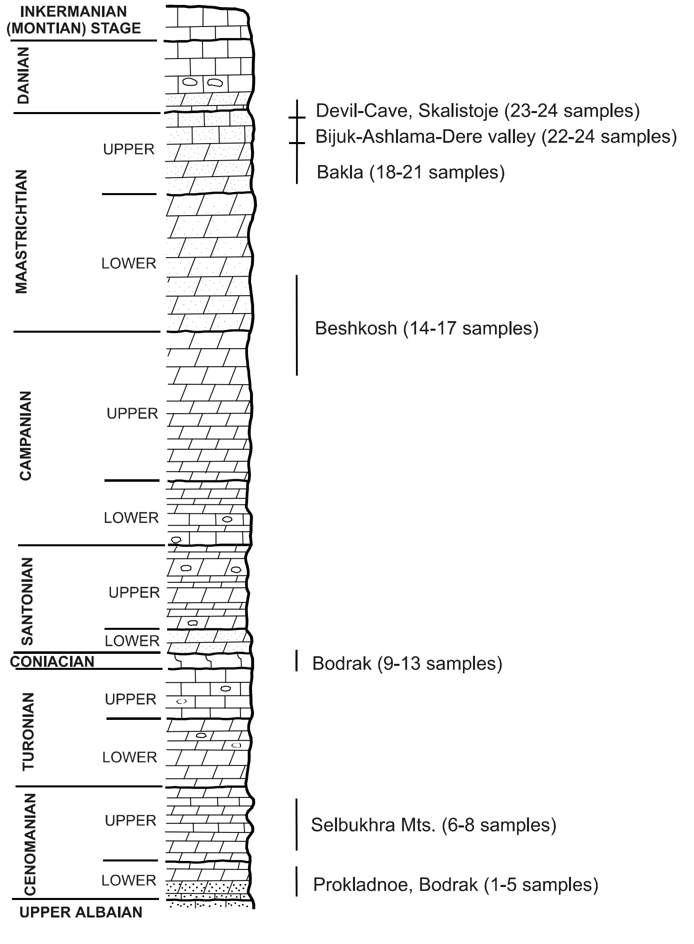

Fig. 3
Compiled section of the Upper Cretaceous deposits in the Crimea (after Maslakova 1971, digital procession by A. Kókay)

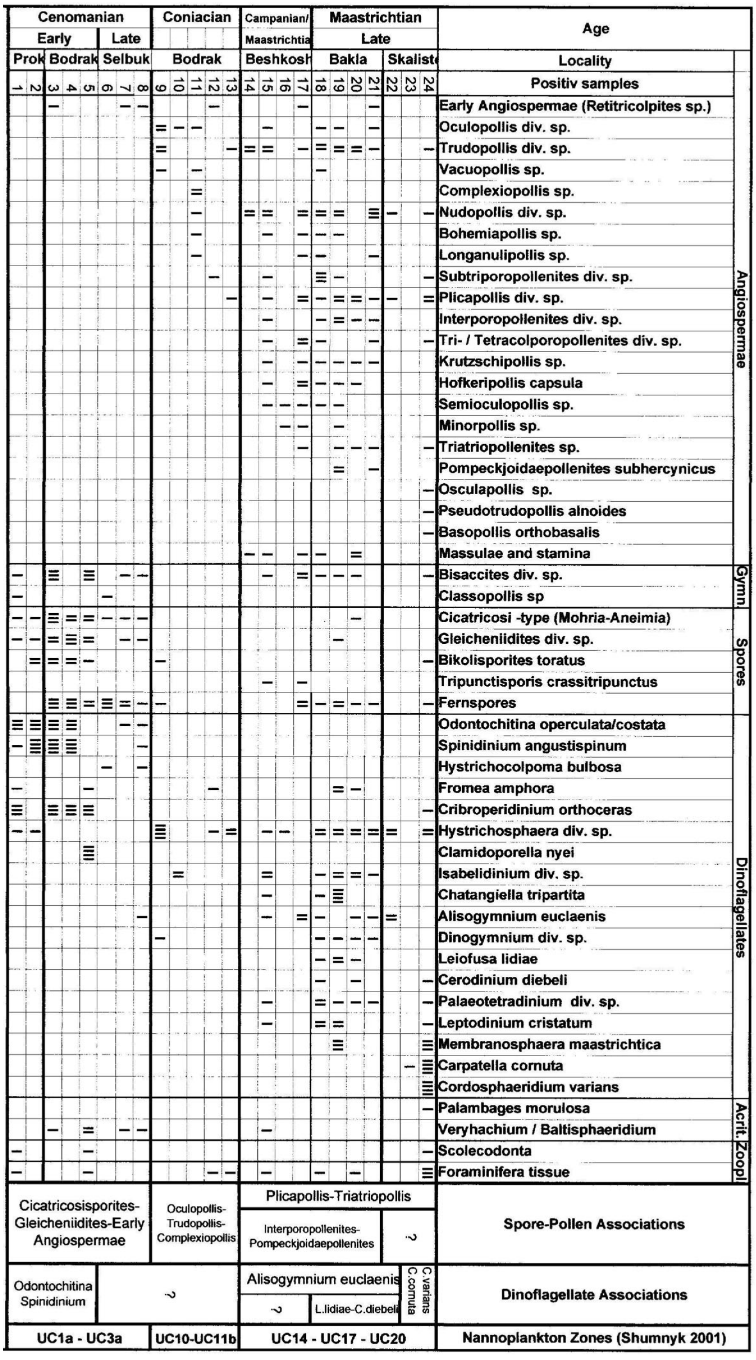

Fig. 4
Characteristic sporomorphs of the Upper Cretaceous in Crimea, | rare, || few, ||| common, |||| abundant

Podocarpidites sp.) An Early Angiospermae was identified only in sample no. 3 of the Bodrak site (*Retiricolpites* sp.).

The abundance of ferns indicates near-shore deposition; the composition of the predominant microphytoplankton suggests a restricted shallow marine environment. This is confirmed by the zoofossils (foraminifers, scolecodonts) as well.

Selbukhra

Southern slope of the plateau above Prokladnoe, samples 6–8. Upper Cenomanian, *Thalmanninella deeckei–Rotalipora cushmani* Zone, corresponding to the *Scaphites aequalis* Zone.

The 15 m-thick section is made of by alternating 10–15 m-thick dark and light-gray marl beds. Samples were taken from the dark gray beds of the lower, middle and upper parts of the section.

The section had been described as a Cenomanian-Turonian boundary formation (Alekseev et al. 1997; Maslakova 1971). The sites sampled for the present study represent the Upper Cenomanian.

The sporomorph associations are of varied composition, but much less numerous than the previous ones.

The fern vegetation is similar to that of the previous formations. Dinoflagellates are less common. In these associations the genus *Alisogymnium* and *Hystrichocolpoma bulbosa* appear. Early angiosperms (*Retitricolpites* sp., *Liliacidites* sp.) are regularly present.

According to the composition of the sporomorph association and its lesser abundance, an area of deposition farther offshore can be assumed.

Bodrak

Samples 9–13 taken from the partially dried-up bed of a temporary waterflow, to the north of Trudol'ubovka Village.

The light gray carbonatic clay and calcareous, slightly sandy marl seemed less suitable for a palynological study. In fact it has not been investigated paleontologically. The mapping geologist of the area who was our guide during the sampling trip, assumed these sediments to be of Coniacian age (Judin 2000).

The association is characterized by the scarce but regular occurrence of the Normapolles genera (*Bohemiapollis, Complexiopollis, Longanulipollis, Oculopollis, Pseudoplicapollis, Subtriporopollenites, Trudopollis, Vacuopollis*). This does not contradict a Coniacian age. Gymnosperm pollen and fern spores are absent.

The very scarce identified dinoflagellates (*Dinogymnium* sp., *Fromea amphora, Histrichosphaera* sp., *Isabelidinium microarmum*) and the few organic foraminifer tests indicate an inner neritic environment. This is also supported by the absence of ferns.

Beshkos

Upper Campanian – Lower Maastrichtian, *Belemnella langei, Acanthoscaphites tridens* Zone (Naidin et al. 1984 in Alekseev and Kopaevich 1997).

Of the 11 samples collected, 4 turned out to be positive (samples 14–17).

The nearly 160 m-thick exposure has been subdivided into 7 lithologic units (Alekseev 1989). It has been emplaced within the Upper Campanian–Maastrichtian into five foraminiferal zones (Alekseev and Kopaevich 1997).

Sample no. 14 (light gray carbonatic sandstone) comes from unit XXI (Uppermost Campanian, Beshkosh Formation, *Globotruncana morzovae* Zone). Samples no. 15–17 are from a light gray carbonatic sandstone (containing limonitized marcasite concretions) of Unit XXX a-c, Lower Maastrichtian, Staroselie Formation, *Globotruncanita stuarti* Zone; (Maslakova 1977).

Unfortunately, the sporomorph association yielded by sample no. 14 is very poor (*Nudopollis* sp., *Trudopollis* sp.). For this reason the youngest part of the Campanian of the area is virtually unknown.

Samples no. 15–17, representing the Lower Maastrichtian, are characterized by abundant and well-preserved associations (*Belemnella lanceolata–Acanthoscaphites tridens* Zone, *Globotruncanita stuarti* Zone).

In the association typical for the Lower Maastrichtian the genera of Normapolles- and Postnormapolles – Stemma occur regularly, predominantly and in increasing variety: *Bohemiapollis, Hofkeripollis, Interporopollenites, Krutzschipollis, Minorpollis, Nudopollis, Plicapollis, Subtriporopollenites, Triatriopollenites, Trudopollis*.

The occurrence of angiosperm pollen in form of massulae and staminae is characteristic; gymnosperm pollen and fern spores are scarce and very subordinate in number.

It is here that some dinoflagellate genera make their first appearance, e.g. *Alisogymnium euclaenis*, and several species of the genera *Chatangiella, Isabelidinium, Leptodinium, Paleotetradinium*.

The fact that pollen grains are present in form of massulae and staminae, the scarce occurrence of ferns, as well as the presence of phytoplankton suggest deposition in a quiet, neritic environment.

Bakla

Samples no. 18–21. Upper Maastrichtian, *Belemnella arkhangelsky–Pachydiscus neubergicus–Abathomphalus mayaroensis* Zone.

These sediments are of the same facies as those encountered at Beshkosh, 7 km distant. In contrast to those, the samples here contain rich associations.

Four of the eight collected samples were positive. The lower three consist of gray marl, and the uppermost one of gray, glauconitic sandstone. *Pachydiscus neubergicus* is common in these samples.

In the associations the sporomorphs of terrestrial angiosperm vegetation and the marine phytoplankton are equally important. In the glauconitic sample the spore-pollen assemblage is more abundant.

Ferns are rare; gymnosperms are also scarce, but regularly present.

The genera of *Normapolles-Postnormapolles stemma* which appear first in the Beshkosh samples (nos 14–17), are already common and numerous here: *Hofkeripollis, Interporopollenites, Nudopollis, Plicapollis, Subtriporopollenites, Triatriopollenites, Trudopollis*.

This is the first occurrence of *Pompeckjoidaepollenites* subhercynicus that has been described from the boreal Maastrichtian of Germany.

Just as in Beshkosh the occurrence of angiosperm pollen as massulae and stamina is also common here.

These samples have yielded a more varied and more numerous assemblage of dinoflagellates than the previously described ones. *Cerodinium diebeli, Leiofus lidiae, Membranosphaera maastrichtica* make their first appearance. *Fromea amphora, Leptodinium cristatum, Palaeotetradinium silicorum* as well as various species of the genera *Chatangiella, Dinogymnium, Hystrichosphaera* and *Isabelidinium* become common and are present in all samples.

The composition of the associations indicates a quiet, neritic environment of deposition. The glauconitic sample may have been deposited somewhat nearer to the seashore.

Skalistoje (Biyuk-Ashlama-dere Valley and Devil's Cave

Confines of Skalistoe Village, samples no. 22–24. Topmost Maastrichtian, *Belemnella arkhangelsky–Pachydiscus neubergicus* Zone, uppermost portion of the *Abathomphalus mayaroensis* Zone.

Sample no. 22 (At 10 m toward the village from Devil's Cave). Medium-gray glauconitic, biogenic limestone, with distinct bivalve shells on its weathered surface.

The sporomorph association is poor. Only a few Normapolles (*Nudopollis, Plicapollis*) and some dinoflagellates (*Alisogymnium euclaenis, Histrichosphaera* sp.) could be determined.

Sample no. 23 (Devil's Cave in the confines of Skalistoe Village, at 10 m from the previous one, taken from the floor of the cave situated at about 10 m above the road, at the boundary between the Danian and Maastrichtian beds, from the Uppermost Maastrichtian light gray limestone.)

Two specimens of *Carpatella cornuta* could be determined. This dinoflagellate species has been described from the Uppermost Maastrichtian of the Ukrainian Carpathians (Grigorovitch, 1969).

Sample no. 24 (taken from the gray sandy limestone just below the contact between the Danian and Maastrichtian beds, at the southeastern end of Skalistoe

Village). This terminal Maastrichtian is characterized by a very rich and well-preserved sporomorph association.

The genera of *Normapolles* and *Postnormapolles stemma* occur with relatively high number of species, but low number of specimens: *Basopollis orthobasalis, Nudopollis* cf. *terminalis, Nudopollis* sp., *Osculapollis* sp., *Plicapollis spatiosa, Pseudotrudopollis alnoides, Psilatricolpites glaber, Subtriporopollenites constans, Triatriopollenites aroboratus, Tricolporopollenites staresedloensis, Trudopollis pertrudens*.

The gymnosperms and the ferns are represented by one single specimen of *Alisporites* sp. and *Trilites* sp., respectively.

The association of dinoflagellates turned out to be the species-richest marine assemblage of the exposures studied. For the Late Maastrichtian the predominance and abundance of *Carpatella cornuta, Cordosphaeridium varians* and *Membranosphaera maastrichtica, Leptodinium cristatum* is characteristic.

The following species are represented by one or a few specimens only: *Areoligera senonensis, Ceratiopsis diebeli, Fibrocysta* sp., *Florentinia ferox, Hystrichospaeridium tubiferum, Palaeotetradinium silicorum, Palambages morulosa, Phanerodinium carinatum, Pterospermella danica, Spiniferites cornutus*, cf. *Trityrodinium evitti.*

Along with the phytoplankton a few mud-eating scolecodonts and organic foraminiferal tests were also found.

The association indicates deposition of sediments in a quiet, neritic environment.

Characteristic associations

Due to the non-continuous sampling situation no palynostratigraphic zonation could be established for the formations studied. For this reason they are characterized by means of spore-pollen and dinoflagellate associations which bear the names of the predominating or regularly occurring taxa (Fig. 4).

On the basis of the integrated studies, the palynomorphs of the Cenomanian, Coniacian, and Campanian-Maastrichtian sediments have been divided into eleven (11) associations. Eight of these have been given names, three are unnamed. Each of the formations could be characterized by one of them.

Spore-pollen

Cicatricosisporites–Gleicheniidites–Early Angiospermae Association

This comprises the associations of the Early and Late Cenomanian samples (samples nos 1–8; Prokladnoe, Bodrak, Selbukhra). It can be characterized by several early angiosperm and abundant gymnosperm pollen, as well as by numerous spores of ferns.

Oculopollis–Trudopollis–Complexiopollis Association

The Coniacian samples (samples nos 9–13; Bodrak) belong here. Rare Normapolles and scarce fern spores could be determined.

Plicapollis–Triatriopollis Association

This comprises the Campanian–Maastrichtian and Late Maastrichtian samples (samples 14–24; Beshkosh, Bakla, Skalistoje).

Within this association, for the Beshkosh and Bakla samples a characteristic *Interporopollenites–Pompeckjoidaepollenites* assemblage could be distinguished, with abundant and varied Normapolles species and medium number of gymnosperm pollen and fern spores. The occurrence of angiosperms as massulae and stamina is confined to this assemblage.

The younger portion contained very few angiosperm pollen (*Normapolles, Postnormapolles*), possibly only one, conifer pollen and fern spores. Being rather atypical, it has not been named.

Dinoflagellate

Odontochitina–Spinidinium Association

The Early Cenomanian samples (samples nos 1–5; Prokladnoe, Bodrak) could be established here. The association is not very diverse, but it is abundant.

Also the Late Cenomanian and Coniacian samples (samples 6–13; Selbukhra and Bodrak) received no name, because they comprise only a few species, and even those are not present in all samples.

Alisogymnium euclaenis Association

This is the association of the Campanian samples (samples nos 14–17; Beshkosh) and some of the Late Maastrichtian ones (samples nos 18–22; Bakla, Skalistoje). It is characterized by rich and varied dinoflagellate assemblages.

A distinct feature of the younger portion (Bakla) is the consequent presence of *Leiofusa lidiae–Cerodinium diebeli* Association.

Cordosphaeridium varians–Carpatella cornuta Association

The uppermost Maastrichtian samples (nos 23 and 24; Skalistoje, Bijuk-Ashlama-dere Valley) could be emplaced here. The youngest one has a not too varied, but numerous assemblage of dinoflagellates.

Paleogeographic and paleoecological conclusions

Both the terrestrial and the marine palynoflora have provided us with considerable information about the paleogeographic connections of the present-day Crimean Peninsula.

Sampling was of necessity incomplete: some outcrops were inaccessible, while some sediments were unsuitable for palynological studies. Consequently no complete paleogeographic and paleoecological history of the region can be presented.

At the same time, it was lucky that both the early and the late portion of the Upper Cretaceous could be investigated. This enabled the author to trace the most significant palynological changes through time.

In each studied palynological group (spores, pollen and dinoflagellates) characteristic changes can be recognized, which affect the entire region.

In the Cenomanian sediments only a few grains of Early Angiospermae pollen occur. This testifies to the scarcity of angiosperms at that time, and their subordinate role in the associations.

In the Coniacian the more developed Normapolles group is represented by several genera. In the Campanian-Maastrichtian association it becomes predominating, with a great number of genera and species. At that time also members of the Postnormapolles group are common, which become predominant in Paleogene time.

The gymnosperms are represented in the Cenomanian by the ancient types, and in the younger associations become more and more subordinate. This trend is also typical for the conifers and the angiosperms, in both the Mediterranean and the Boreal regions.

Fern spores indicative of the underbrush are numerous in the Cenomanian. Above all the genera surviving from the Early Cretaceous are characteristic. In the younger formations their presence is not significant in comparison to the other palynomorphs.

The dinoflagellate associations of the early and the late Upper Cretaceous are rather distinct. In the Cenomanian the dinoflagellates play a predominant role. In the Coniacian and Campanian their numbers drop considerably. In the Campanian they can be characterized by rich associations, twice renewed.

Their relative abundance as compared to the ferns and angiosperms representing terrestrial vegetation, as well as the changes in the abundance of foraminifers suggest that the younger sediments were deposited in a near-shore and neritic environment (in the inner zone of the outer neriticum).

The deposition of the older sediments near the seashore, in quiet water, is also supported by the abundant occurrence of fern spores, as well as the appearance of the angiosperms in form of massulae and staminae.

The farthest offshore, open-water sediments are those of the Uppermost Maastrichtian, near the Cretaceous/Tertiary boundary.

On the basis of the angiosperm associations, in Senonian time the Crimean Peninsula belonged to the northern (boreal) region of the Normapolles Phytogeographic Province.

This is confirmed by previously published palynological data about the area of The Netherlands, Bohemia, Poland and the Ukraine, the comparative bibliographic studies (Góczán et al. 1967; Herngreen et al. 1986; Kedves and Herngreen 1980; Mikhelis 1981; Portnyagina 1981; Panova 1978; Rotman 1979; Schach 1968; Zaklinskaya and Naidin 1985) and the paleogeographic maps as well (Dercourt et al. 1993).

Along with the cosmopolitan elements (*Nudopollis, Oculopollis*, etc.) the species of the genera *Basopollis, Hofkeripollis, Osculapollis, Pseudotrudopollis, Pompeckjoidaepollenites* that have been described from the areas enumerated above are often present.

Based upon the presence of species of the genus *Interporopollenites* the peninsula must have been part of the boreal, *Interporopollenites* Subprovince of the Normapolles Province (Siegl-Farkas 1997, 1999, 2000). On the basis of the occurrence of this genus, a paleobotanical connection can be proved, for the Campanian–early Maastrichtian times, with the Pelso and Tisza units of Hungary belonging to the Tethyan Archipelago, with an intermediate position and climate.

In the course of the present study of dinoflagellates, beside cosmopolitan elements (*Alisogymnium, Chatangiella, Dinogymnium, Isabelidinium* etc.) also such genera and species known only from boreal areas and have been described from there, were determined. Among these are e.g. *Leiofusa lidiae, Cerodinium diebeli, Palaeotetradinium silicorum, Membranosphaera maastrichtica, Palambages morulosa*, etc. (Gorka 1963; Herngreen et al. 1998; Kirsch 1991; Marheinecke 1986). From the Uppermost Maastrichtian (near the Cretaceous/Tertiary boundary) *Carpatella cornuta* (from the flysch of the Ukrainian Carpathians; Grigorovich 1969) and *Danea mutabilis* (NW Germany; Morgenroth 1968) have been described.

Nannoplankton

During the field trip along with the palynological sampling, samples were also taken for nannoplankton study.

Systematic data on the nannoplankton stratigraphy of the Crimean Upper Cretaceous have already been published (Plotnikova and Luleyeva 1977; Shymkus and Shumenko 1977; Shumenko and Stechenko 1978; Shumenko 1987).

As a result of the present study, of the UC0-UC20 Upper Cretaceous nannozones established by Burnett (1998) the zones UC1a-UC3a, UC10-UC11b, UC14-UC17, UC17-UC20 were identified (Shumnyk 2001a-b; Voronova et al. 2002). The correlation of the nannozones with the palyno-associations is shown in Fig. 4 (Siegl-Farkas et al. 2002).

The nannoplankton studies indicate a shallow marine environment for the Cenomanian and the Campanian-Maastrichtian and a neritic one for the Turonian–Santonian.

Announcement

The palynological investigation described above was carried out during the last year (2002) of the existence of the Paleontology and Paleoenvironment Project of the Geological Institute of Hungary.

Acknowledgement

This work was carried out in the framework of Hungarian-Ukrainian cooperation supported by the Science and Technology Foundation, No-UK/22-00, (2000–2002).

The author is indebted to the readers Ferenc Góczán and †Miklós Kedves for the valuable advices and is grateful to Ildikó Bátori for the pollen as well as Ildikó Laky for the photo laboratory work.

References

Alekseev, A.S. 1989: Cretaceous System. – In: Mazarovich, O.A., V.S. Mileev (Eds): Geologic structure of the Kacha uplift of Mountain Crimea. – Mesozoic Stratigraphy. pp. 123–157. Moscow University, Moscow. (In Russian.)

Alekseev, A.S., F.F. Kopaevich 1997: Foraminiferal biostratigraphy of the uppermost Campanian–Maastrichtian in SW Crimea (Bakhchisaray and Chakhmakhly sections). – Bulletin van het Koninklijk Belgisch Instituut Voor Naturwetenschappen. Sci. De la Terre Aarswetenschappen, 67, pp. 103–118. Brussel.

Alekseev, A.S., V.C. Vengercev, F.F. Kopaevich, T.A. Kuzmicheva 1997: Lithology and micropaleontology of the Turonian–Cenomanian boundary in the SW Crimea. – Ocherki Geologii Krima. Geol., pp. 54–73, Fac. of Lomonosov Univ. Moskow.

Burnett, J.A. 1998: Upper Cretaceous. – In: Bown, P.R. (Ed.): Calcareous nannofossil biostratigraphy – Chapman and Hall, London, pp. 132–191.

Dercourt, J., L.E. Ricou, B. Vrielynck (Eds) 1993: Atlas Tethys Paleoenvironmental maps. (Late Maastrichtian Paleoenvironments, 69.5–65 Ma). Paris, France.

Ershov, V.A. 1958: Geologicheskaja Karta Ukrainskojj i Moldavskojj SSR. – Geologija SSSR V., VSEGEI, Lvov.

Góczán, F., J.J. Groot, W. Krutzsch, B. Pacltová 1967: Die Gattungen des "Stemma Normapolles Pflug 1953 b" (Angiospermae). – Palaontologie, Abh. B, 2, pp. 427–540.

Górka, H. 1963: Coccolithophoridés, Dinoflagellés, Hystrichosphearidés et Microfossiles incertae sedis du Crétacé Supérieur de Pologne. – Acta Paleontologica Polonica, 8/1, 101 p., Warsawa.

Grigorovitch, A.S. 1969: A new genus Carpatella cornuta (Dinoflagellata) from Danian-Paleocene deposits of Carpathians. – Paleontologiceskij Sbornik, 6/2, pp. 74–75. (In Russian.)

Herngreen, G.F.W., W.M. Felder, M. Kedves, J.P.M.T. Meessen 1986: Micropaleontology of the Maestrichtian in borehole Bunde, The Netherlands. – Review of Palaeobotany and Palynology, 48, pp. 1–70.

Herngreen, G.F.W, H.A.H.M. Schuurman, J.W. Verbeek, H. Brinkhuis, J. A. Burnett, W.M. Felder, M. Kedves 1998: Biostratigraphy of Cretaceous/Tertiary boundary strata in the Curfs quarry, the Netherlands. – Medeedelingen Netherlands Instituut voor Toegepaste Geowetenschappen TNO, 61. (Ed.: Herngreen, G. F. W.)

Judin, V.V. 2000: Geologie of Crimea based on geodinamika. – Acad. Inst. of Russia, pp. 3–42. (In Russian.)

Kedves, M., G.W.F. Herngreen 1980: Palynology of the Stratotype of the Maestrichtian and Gulpen Formation, ENCI section, Maastricht, The Netherlands. – Pollen et Spores, 12/3–4, pp. 483–544.

Kirsch, K.-H. 1991: Dinoflagellatenzysten aus der Oberkreide des Helvetikums und Nordultrahelvetikums von Oberbayern. – Münchner Geowissenschaftliche Abhandlungen., A. Geologie und Paleontologie, 22, 306 p.

Marheinecke, U. 1986: Dinoflagellaten des Maastrichtium der Grube Hemmoor (Niedersachsen). – Geologisches Jahrbuch, A. 93, 93 p., Hannover.

Maslakova, N.I. 1971: Short characteristics of the Cretaceous and the Paleogene of Mountain Crimea. Upper Cretaceous. XII. European Micropaleontological Colloquium USSR 1971. Field Trip Guide. Part I – Crimea. pp. 28–40.
Maslakova, N.I. 1977: Zonal scale of the Upper Cretaceous of southern USSR, based on globotruncanids and methods of its development. – Voprosy Mikropaleontologii, 19, pp. 77–98. (In Russian.)
Mikhelis, A.A. 1981: Normapolles pollen in Cretaceous/Paleogene boundary deposits of the Priazov'ye (Azov Sea area). – Review of Palaeobotany and Palynology, 35, pp. 209–229.
Morgenroth, P. 1968: Zur Kenntnis der Dinoflagellaten und Hystrichosphaeridien des Danien. – Geol. Jb., 86, pp. 533–578.
Panova, L.A., 1978: Paleogene pollen and spores from the stratotype section of Bakhchisaray (Crimea). – Cenozoic Stratigraphy of N Black-Sea area and Crimea. pp. 69–80, Dnyepropetrovsk. (In Russian.)
Plotnikova L.F., S.A. Luleyeva 1977: New data on the stratigraphical subdivision of the Upper Cretaceous of the Black sea self. – Reports of Academy of Sciences of UkrSSR. Ser. B, 1., pp. 21–24. (In Russian.)
Portnyagina L.A. 1981: Normapolles pollen in Upper Cretaceous and Paleogene deposits of the Skale Zone of the Carpathians. – Review of Palaeobotany and Palynology, 35, pp. 231–235.
Rotman, R.N. 1979: Pollen and spores in the Upper Maastrichtian sediments at Crimea. – Geol. Journal, 39/1, pp. 65–72. (In Russian.)
Schach, L.N. 1968: Some results of Palynological research of Upper Senonian deposits of Lvov Depression. – Paleontologiceskij Sbornik, 5/2, pp. 71–76. (In Russian.)
Shumenko, S.I. 1987: Calcareous nannoplankton (Practigal guide). – Nedra, (Leningrad). (In Russian.)
Shumenko, S.I., V.P. Stechenko 1978: Zonal subdivision of the calcareous nannofossils on the Upper Cretaceous sediments of Mountain Crimea. – Reports of the Academy of Sciences of the USSR, 241/5, pp. 1160–1162. (In Russian.)
Shumnyk, A.V. 2001a: Upper Cretaceous Nannofossil biostratigraphy of the Black Sea north-west shelf and Crimea continental slope. – Geol. Journal, 3, pp. 96–104, Kiev.
Shumnyk, A.V. 2001b: Nannofossils as good paleoenvironmental tool for reconstruction of sedimentation during Late Cretaceous of Black Sea Self. – Abstracts of the 7th International Conf. on Paleoceanography, p. 188, Sapporo (Japan).
Shymkus, K.M., S.I. Shumenko 1977: The first discovery of the Cretaceous sediments of the Black Sea slope. – Oceanology, 17/5, pp. 862–866. (In Russian.)
Siegl-Farkas, Á. 1997: Dinoflagellate stratigraphy of the Senonian formations of the Transdanubian Range. – Acta Geol. Hung., 40/1, pp. 73–100.
Siegl-Farkas, Á. 1999: Integrated palynostratigraphy of the Senonian formations in the Tisza Unit (South Great Hungarian Plain, Hungary). – Acta Geol. Hung., 42/2, pp. 161–191.
Siegl-Farkas, Á. 2000: Late Cretaceous palynology and environment on the European side of the Tethys. – 6th Intern. Cretaceous Symp. Vienna, Abst., p. 127.
Siegl-Farkas, Á., A. Shumnyk, M. Voronova 2002: Integrated palynology and nannoplankton zonation of the Upper Cretaceous formations in the Crimean Peninsula. – 6th European Paleobotany-Palynology Conference, Athens, Program Book and Abstracts. pp. 239–240.
Voronova, M., A. Shumnyk, Á. Siegl-Farkas 2002: Calcareous nannoplankton zonation and palynology of the Upper Cretaceous Mountain Crimean Formations. – Journal of Nannoplankton Research, 24/2, p. 176. 9th Intern. Nannoplankton Conf. Parma, Abstracts and Programme.
Zaklinskaya, E.D., D.P. Naidin 1985: On the palynological characteristics of the Upper Maastrichtian of Crimea. – Bulletin of the Moscow Society of Naturalists, Geoogical Series, 23/3, pp. 3–10. (In Russian.)

Floralist

Dinoflagellates

Alisogymnium euclaense (Cookson and Eisenack) Lentin and Vozzhennikova
Apteodinium cf. *deflandrei* (Clarke and Verdier) Lucas-Clark
cf. *Areoligera senonensis* Lejune-Carpenter
Carpatella cornuta Grigorovich
Ceratiopsis diebeli (Alberti) Vozzhennikova
Chatangiella granulifera (Manum) Lentin and Williams
Chlamidoporella nyei Cookson and Eisenack
Cimathiosphaera sp.
Coronifera sp.
Cordosphaeridium varians May
Cribroperidinium cf. *pyrum* (Drugg) Stover and Evitt
Cribropridinum sp.
cf. *Danea mutabilis* Morgenroth
Dinogymnium westralium (Cookson and Eisenack) Evitt et al.
Dinogymnium div. sp.
Fibrocysta sp.
Florentinia daenei (Davey and Williams) Davey and Verdier
Florentinia ferox (Deflandre) Duxbury
Fromea amphora Cookson and Eisenack
Hystrichodinium pulchrum Deflandre
Hystrichokolpoma bulbosa (Ehrenberg) Morgenroth
Hystrichocolpoma cinctum Klumpp
Hystrichosphaeridium tubiferum (Ehrrenberg) Davey and Williams
Hystrichosphaera div. sp.
Isabelidinium korojonense (Cookson and Eisenack) Lentin and Williams
Isabelidinium microarmum (McIntyre) Lentin and Williams
Isabelidinium div. sp.
Leberidocysta chlamidata (Cookson and Eisenack) Stover and Evitt
Leiofusa lidiae Gorka
Leptodinium cristatum May
cf. *Manumiella ?cretacea* (Cookson) Bujak and Davis
Membranosphaera maastrichtica Samoilovich
Odontochitina sp.
Odontochitina operculata (O. Wetzel) Deflandre and Cookson
Oligosphaeridium pulcherrimum (Deflandre and Cookson) Davey and Will.
Oligosphaeridium sp.
Palambages morulosa O. Wetzel
Paleotetradinium silicorum Deflandre
Paleotetradinium cf. *maastrichtiense* Herngreen et al.
Phanerodinium carinatum Below
Phanerodinium cf. *squamosum* Below
Pterospermopsis barbarae Gorka
cf. *Pterodinium cingulatum* ssp. *conterminatus* Marheinecke
Rhyptocorys veligera (Deflandre) Lejune-Carpenter and Sarjeant
Spinidinium angustispinum Wilson
Spinidinium sp.
Spiniferites cornutus (Gerlach) Sarjeant
Spiniferites hyperacanthus Deflandre and Cookson
Spiniferites ramosus var. *brevifurcatus* Cookson and Eisenack

Spiniferites ramosus granosus Kjellström
Tenua hystrix Eisenack
cf. *Trithyrodinium evitti* Drugg

Acritarcha div. sp.

Baltisphaeridium sp.
Micrhystridium sp.
Veryhachium cf. *reductum* Deunff
Tytthodiscus sp.
Botryococcus sp.

Marine zoofossiles

Foraminifera tissue
Scolecodonta (Annelidae)

Fern spores

Appendicisporites auritus Agasie
Appendicisporites cristatus Markova
Appendicisporites erdtmani Pocock
Baculatisporites kolpascheviensis Klimko
Bikolisporites toratus (Weyland and Greifeld) Srivastava
Camarozonosporites concinnus Srivastava
Cardioangulina sp.
Cicatricosisporites sp.
Corniculatisporites bolchovitinae Kuvaeva
Costatoperforosporites fistulosus Deák
Costatoperforosporites triangulatus Deák
Cyathidites sp.
Dictyophyllidites sp.
Echinatisporites sp.
Foveolatosporites sp.
Gleicheniidites senonicus Ross
Gleicheniidites sp.
Hamulatisporites insignis (Norris) Herngreen et al.
Leiotriletes sp.
Phaeocerisporites purus Deák
Plicatella sp.
Stereisporites sp.
Trilites sp.
Tripunctisporites crassitripunctus (Krutzsch) Herngreen et al.
Vadaszisporites microreticulatus Deák

Gymnospermae

Alisporites sp.
Pinuspollenites sp.
Podocarpidites sp.

Angiospermae

cf. *Accuratipollis rodaensis* Krutzsch and Lenk
Basopollis atumescens (Pflug) Pflug
Basopollis orthobasalis (Pflug) Pflug
Bohemiapollis compactus Krutzsch
Bohemiapollis cf. *paleocenicus* Krutzsch
Bohemiapollis sp.
Complexiopollis sp.
Crassipollis minor Góczán and Juhász
Extratriporopollenites sp.
Hofkeripollis capsula (Pfug) Kedves and Herngreen
Hofkeripollis sp.
Interporopollenites germanicus Krutzsch
Interporopollenites initium Greifeld
Interporopollenites magnoides Krutzsch
Interporopollenites sp.
Krutzschipollis sp.
Labraferoidaepollenites rurensis (Pflug) Kedves
Labrapollenites labraferus (Pflug) Krutzsch
Longanulipollis sp.
Minorpollis sp.
Nudopollis endangulatus (Pflug) Pflug
Nudopollis minutus Zaklinskaia
Nudopollis cf. *terminalis* Pflug and Thomson
Nudopollis thiergartii (Potonie) Pflug
Nudopollis sp.
Oculopollis sp.
Osculapollis sp.
Plicapollis serta Pflug
Plicapollis spatiosa Frederiksen
Plicapollis sp.
Pompeckjoidaepollenites subhercynicus (Krutzsch) Krutzsch
Pompeckjoidaepollenites peneperfectus (Pflug) Krutzsch
Pseudotrudopollis crassiexinus Krutzsch
Pseudotrudopollis alnoides Krutzsch
Psilatricolpites glaber (Deák) Kedves
Retitricolpites sp.
Rossipollis foveolatus Krutzsch
Semioculopollis sp.
Subtriporopollenites anulatus Pflug
Subtriporopollenites constans Pflug
Suemegipollis triangularis Góczán
Tetracolporopollenites sp.
Triatriopollenites aroboratus Greifeld
Triatriopollenites roboratus Pflug
Triatriopollenites sp.
Tricolporopollenites staresedloensis Krutzsch and Pacltova
Triporopollenites robustus Pflug
Trudopollis oculoides Krutzsch
Trudopollis parvotrudens (Greifeld) Pflug
Trudopollis pertrudens (Pflug) Pflug
Trudopollis sp.
Vacuopollis concavus (Pflug) Krutzsch

Plate I

1. *Gleicheniidites* sp. (Beshkosh 5)
2. *Tripunctisporis crassitripunctum* (Krutzsch) Herngreen et al. (Beshkosh 7)
3. *Camerosporites* sp. (Selj-Buhra 34)
4. *Dictyophyllidites* sp. (Bakla 17)
5. *Hamulatisporites insignis* (Norris) Herngreen et al. (Bakla 20)
6. *Camarozonosporites concinnus* Srivastava (Prokladnoje 32)
7. *Gleicheniidites senonicus* Ross (Bodrak 28)
8. *Bikolisporites toratus* (Weyland and Greifeld) Srivastava (Bodrak 29)
9. *Corniculatisporites bolchovitinae* Kuvaeva (Bodrak 29)
10. cf. *Appendicisporites cristatus* Markova (Selj-Buhra 34)
11. *Cicatricosisporites* sp. (Bakla 18)
12. *Trilites* sp. (Skalistoe 12)
13. *Appendicisporites erdtmani* Pocock (Bodrak 30)
14. *Corniculatisporites* sp. (Bodrak 30)
15. *Appendicisporites auritus* Agasie (Bodrak 30)
16. *Costatoperforosporites fistulosus* Deák (Bodrak 30)
17. *Costatoperforosporites triangulatus* Deák (Bodrak 29)
18. *Echinatisporites* sp. (Beshkosh 5)

Plate II

1–2. *Crassipollis minor* Góczán and Juhász (Bakla 17)
3. *Rossipollis foveolatus* Krutzsch (Beshkosh 7)
4. *Retiricolpites* sp. (Skalistoe 12)
5–6. *Retitricolpites* sp. (Selj-Buhra 36)
7. *Basopollis atumescens* (Pflug) Pflug (Bodrak 25)
8. *Bohemiapollis* cf. *paleocenicus* Krutzsch (Bodrak 25)
9. Bohemiapollis n. sp.
10. *Triatriopollenites aroboratus* Greifeld (Skalistoe 12)
11. *Nudopollis thiergartii* (Potonie) Pflug (Bakla 18)
12. *Nudopollis thiergartii* (Potonie) Pflug (Bakla 20)
13. *Nudopollis* sp. (Bodrak 25)
14. *Trudopollis* cf. *pertrudens* Krutzsch (Bakla 17)
15. *Trudopollis pertudens* Krutzsch (Skalistoe 12)
16. *Trudopollis pertudens* Krutzsch (Bodrak 27)
17. *Pseudotrudopollis crassieximius* Krutzsch (Beshkosh 7)
18. *Trudopollis oculoides* Krutzsch (Bodrak 27)
19. *Trudopollis* sp. (Bakla 17)
20. *Triatriopollenites* sp. (Beshkosh 5)
21. *Triatriopollenites* sp. (Beshkosh 5)
22. cf. *Osculapollis* sp. (Skalistoe 12)
23. *Osculapollis* sp. (Skalistoe 12)
24. *Trudopollis pertrudens* Krutzsch (Skalistoe 12)
25. *Interporopollenites magnoides* Krutzsch (Bakla 17)
26. *Interporopollenites magnoides* Krutzsch (Bakla 18)
27. *Interporopollenites germanicus* Krutzsch (Bakla 19)
28–29. *Interporopollenites germanicus* Krutzsch (Beshkosh 7)
30–31. *Interporopollenites magnoides* Krutzsch (Bakla 17)
32. *Interporopollenites* sp. (Bakla 19)
33. *Interporopollenites magnoides* Krutzsch (Bakla 19)
34. *Plicapollis spatiosa* Frederiksen (Bakla 17)

35. *Plicapollis spatiosa* Frederiksen (Skalistoe 12)
36. *Plicapollis spatiosa* Frederiksen (Skalistoe 12)
37. *Basopollis orthobasalis* (Pflug) Pflug (Skalistoe 12)

Plate III

1–2. *Hofkeripollenites capsula* Kedves and Herngreen (Beshkosh 7)
3–4. *Hofkeripollenites* sp. (Beshkosh 5)
5–6. *Hofkeripollenites capsula* Kedves and Herngreen (Beshkosh 5)
7–8. *Pompeckjoidaepollenites subhercynicus* (Krutzsch) Krutzsch (Bakla 17)
9–10. *Pompeckjoidaepollenites subhercynicus* (Krutzsch) Krutzsch (Bakla 17)
11–12. *Pompeckjoidaepollenites* sp. (Bakla 19)
13–14. cf. *Accuratipollis rodaensis* Krutzsch and Lenk (Bakla 17)
15. *Plicapollis serta* Pflug (Beshkosh 7)
16. *Plicapollis* sp. (Bakla 20)
17. *Plicapollis serta* Pflug (Beshkosh 7)
18. *Vacuopollis concavus* (Pflug) Krutzsch (Bodrak 25)
19. *Labrapollis labraferus* (Potonie) Krutzsch (Beshkosh 5)
20. *Bohemiapollis compactus* Krutzsch (Bakla 19)
21. *Bohemiapollis compactus* Krutzsch (Bakla 20)
22. *Subtriporopollenites* sp. (tetrade) (Bakla 20)
23. S*ubtriporopollenites constans* Pfug (Skalistoe 12)
24. *Oculopollis* sp. (Bakla 20)
25. *Triporopollenites* sp. (massula) (Beshkosh 5)
26. cf. *Platycaryapollenites* sp. (Bodrak 28)
27. *Triporopollenites robustus* Pflug. (Bakla 20)
28–29. *Tetracolporopollenites* sp. (Beshkosh 5
30–31. *Tetracolporopollenites* sp. (Beshkosh 5)
32–33. *Tetracoporopollenites* sp. (Bakla 17)
34–35. *Psilatricolporites glaber* (Deák) Kedves (Skalistoe 12)
36–37. *Tetracolporopollenites* sp. (Beshkosh 7)

Plate IV

1–2. *Alysogymnium euclaense* (Cookson and Eisenack) Lentin and Vozzhennikova (Beshkosh 5)
3. *Alysogymnium* cf. *euclaense* (Cookson and Eisenack) Lentin and Vozzhennikova (Seljbuhra 36)
4–5. *Alysogymnium euclaense* (Cookson and Eisenack) Lentin and Vozzhennikova (Bakla 17)
6–8. *Dinogymnium westralium* (Cookson and Eisenack) Evitt et al. (Bakla 19)
9. *Dinogymnium* sp. (Bakla 17)
10–11. *Dinogymnium* sp. (Bakla 18) × 400
12. *Dinogymnium* sp. (Beshkosh 5)
13. *Paleotetradinium silicorum* Deflandre (Skalistoe 12)
14–15. *Isabelidinium microarmum* (McIntyre) Lentin and Williams (Bodrak 26)
16. *Leiofusa lidiae* Gorka (Bakla 19) 400 ×

Plate V

1–2. *Chatangiella granulifera* (Manum) Lentin and Williams (Bakla 19)
3. *Isabelidinium* cf. *korojonense* (Cooks. and Eis.) Lentin and Williams (Beshkosh 7)
4–5. *Chatangiella granulifera* (Manum) Lentin and Williams (Bakla 20)
6. *Cribroperidinium* cf. ?*pyrum* (Drugg) Stover and Evitt (Bodrak 28)
7–8. *Hystrichocolpoma bulbosa* (Ehrenberg) Morgenroth (Seljbuhra 34)
9. *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson (Bodrak 29) 400 ×

Plate VI

1. *Oligosphaeridium* sp. (Bodrak 30) 400 ×
2. *Oligosphaeridium pulcherrimum* (Deflandre and Cookson) Davey and Williams (Prokladnoje 33) 400 ×

3–5. *Membranosphaera maastrichtica* Samoilovich (Skalistoe 12)
6. cf. *Thalassiphora* sp. (Bodrak 29) 400 ×
7–8. *Phanerodinium carinatum* Below (Skalistoe 12)
9. *Leberidocysta chlamidata* (Cookson and Eisenack) Stover and Evitt (Skalistoe 12)
10–11. *Membranosphaera maastrichtica* Samoilovich (Skalistoe 12)
12–13. *Leptodinium cristatum* May (Skalistoe 12)
14–15. *Chlamidoporella nyei* Cookson and Eisenack (Bodrak 28)
16. *Palambages morulosa* O. Wetzel (Skalistoe 12) 400 ×

Plate VII

1–2. *Ceratiopsis diebeli* (Alberti) Vozzhennokova (Skalistoe 12) 400 ×
3. *Spinidinium angustispinum* Wilson (Bodrak 29)
4–5. *Leptodinium cristatum* May (Skalistoe 12)
6–8. *Spiniferites cornutus* (Gerlach) Sarjeant (Skalistoe 12) 400 ×
9–10. *Spiniferites ramosus granosus* Kjellström (Bodrak 28)

Plate VIII

1–3. *Cordosphaeridium varians* May (Skalistoe 12) 400 ×
4–5. *Cordosphaeridium varians* May (Skalistoe 12) 400 ×
6. *Cordosphaeridium varians* May (Skalistoe 12) 400 ×
7–8. *Carpatella cornuta* Grigorovich (Skalistoe 12) 400 ×
9–10. *Fibrocysta* sp. (Skalistoe 12) 400 ×

Plate IX

1. *Carpatella cornuta* Grigorovich (Skalistoe 12)
2–3. *Carpatella cornuta* Grigorovich (Skalistoe 12) 400 ×
4–5. *Carpatella cornuta* Grigorovich (Skalistoe 12) 400 ×
6. Scolecodonta (Annelidae) (Skalistoe 12)
7. *Botryococcus* sp. (Bakla 20)
8. *Scolecodonta* sp. (Annelidae) (Skalistoe 12)
9. *Tytthodiscus* sp. (Seljbukra 34)

Magnification is × 1000 except is signed.