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RECORD OF CHANGES IN THE OLIGOCENE–MIOCENE SEDIMENTS OF THE MENILITE–KROSNO SERIES OF THE SKOLE UNIT BASED ON CALCAREOUS NANNOPLANKTON STUDIES – BIOSTRATIGRAPHY AND PALAEOGEOGRAPHICAL IMPLICATIONS (POLISH OUTER CARPATHIANS)

ZAPIS ZMIAN W OLIGOCEŃSKO-MIOCEŃSKICH UTWORACH SERII MENILITOWO-KROŚNIEŃSKIEJ JEDNOSTKI SKOLSKIEJ NA PODSTAWIE NANOPLANKTONU WAPIENNEGO – BIOSTRATYGRAFIA I UWARUNKOWANIA PALEOGEOGRAFICZNE (POLSKIE KARPATY ZEWNĘTRZNE)

Małgorzata Garecka[1]

Abstract. The biostratigraphic investigation included the Menilite–Krosno Series of the Skole Unit overlying the Globigerina Marls. Seven calcareous nannoplankton zones (*sensu* Martini, 1971) were distinguished in these sediments: NP23, NP24, NP25, NN1, NN2, NN3? and NN4. Based on the species diversity of the assemblage, their abundances and preservation, as well as palaeoenvironmental and palaeoclimatic conditions that controlled the basin during deposition of the Menilite and Krosno Beds have been identified. The Skole region was located at the periphery of the Paratethys basin during Late Oligocene–Early Miocene times. Based on the calcareous nannoplankton assemblage, the phase of isolation of the Paratethys (NP23) from the Mediterranean was documented. The restoration of normal marine conditions (NP24–NP25), sea-level fluctuations (sea-level fall?) at the Oligocene–Miocene boundary (uppermost part of the NP25–NN1), a phase of relative sea-level rise (NN2, NN3?, NN4) and the end of flysch sedimentation in the Skole Unit in the NN4 Calcareous Nannoplankton Zone were also identified.

Key words: calcareous nannoplankton, biostratigraphy, palaeoenvironment, Skole Unit, Polish Outer Carpathians.

Abstrakt: Badaniami biostratygraficznymi objęto utwory serii menilitowo-krośnieńskiej jednostki skolskiej położone w profilu powyżej poziomu margli globigerynowych. W obrębie utworów tej serii wyróżniono siedem poziomów nanoplanktonowych *sensu* Martini (1971): NP23, NP24, NP25, NN1, NN2, NN3? i NN4. Na podstawie składu zespołu nanoplanktonu wapiennego, jego zróżnicowania gatunkowego, liczebności i stanu zachowania podjęto próbę określenia warunków paleośrodowiskowych i paleoklimatycznych w czasie osadzania warstw menilitowych i krośnieńskich jednostki skolskiej. Są one ściśle związane z warunkami, jakie panowały w późnym oligocenie–wczesnym miocenie w basenach Paratetydy i z położeniem rejonu skolskiego na peryferiach tego basenu. Udokumentowano etap odizolowania basenu Paratetydy (NP23) od innych jego rejonów, etap warunków normalno-morskich, a więc odzyskania połączeń z otwartym morzem (NP24–NP25), wahania poziomu morza na pograniczu późnego oligocenu i wczesnego miocenu (najwyższa część NP25–NN1), etap względnego podniesienia poziomu morza, transgresji (NN2, NN3?, NN4) i końca sedymentacji fliszowej w basenie skolskim w poziomie NN4.

Słowa kluczowe: nanoplankton wapienny, biostratygrafia, paleośrodowisko, jednostka skolska, polskie Karpaty zewnętrzne.

[1] Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Oddział Karpacki, ul. Skrzatów 1, 31-560 Kraków;
e-mail: malgorzata.garecka@pgi.gov.pl

INTRODUCTION

Calcareous nannoplankton is the most diversified and most widely distributed group of marine phytoplankton. Due to a simple preparation technique of smear slides for microscopic studies and the small amount of the material needed, the study of calcareous nannoflora is widely used in micropalaeontological analysis. Based on the species diversity, abundance and preservation of the forms, we can determine the nature of the assemblage and the conditions that prevailed in the basin at the time of deposition. The development and distribution of these microorganisms is controlled by many factors (Gaździcka, 1994; Melinte, 2004; Erba, 2006; Chira, Malacu, 2008). The most important are: availability and intensity of the light (photosynthesis), temperature of the surface water, salinity, supply of nutrients needed to build and grow the cells (nitrogen, phosphorus), oxidation of the surface water and fluctuation of the sea level. Sometimes, small changes in only one or several factors have a strong impact on the assemblage composition and species diversity, causing radiation or disappearance of certain species or families. It seems that modern coccolithophorales are characterized by a greater tolerance and greater adaptability than earlier species, although the group is not as common as in the Upper Cretaceous, Eocene or Miocene. Studies carried out in the Polish Carpathians have shown usefulness of the calcareous nannoplankton for both biostratigraphical and palaeoecological research. Due to their small size, coccolithophorales are easily susceptible to redeposition (redeposited species often are more common than autochthonous ones). The area of the Skole Unit was chosen because of the availability of sections ranging from the Globigerina Marls (Upper Eocene–Lower Oligocene), which was taken as the benchmark, to the youngest Menilite–Krosno Series.

MATERIAL AND METHODS

The studies included the Upper Oligocene–Lower Miocene sediments of the Menilite–Krosno Series of the Skole Unit that represents the outermost part of the Polish Outer Carpathians. The investigations were based on calcareous nannoplankton studies initiated in 2004. Samples were taken from nine sections: Podwaluczka, Krępak, Tyrawa Solna, Stańkowa, Monasterzec, Stańkowa Wschód, Ropienka, Ropienka Centrum and Wańkowa (Fig. 1). Smear slides were prepared according to the method described by Báldi-Beke (1984). For light microscope examination, a fine water suspension of the rock is spread out on a glass slide. A drop of the suspension is spread out on the microscope slide after stirring and short period of settling. After drying, the microscope slide is covered with Canada balsam and a cover glass. The slides were studied with a Nikon Eclipse E400Pol light microscope at 1000x magnification. The photos in this paper come from archival reports and publications and from the collection of the author.

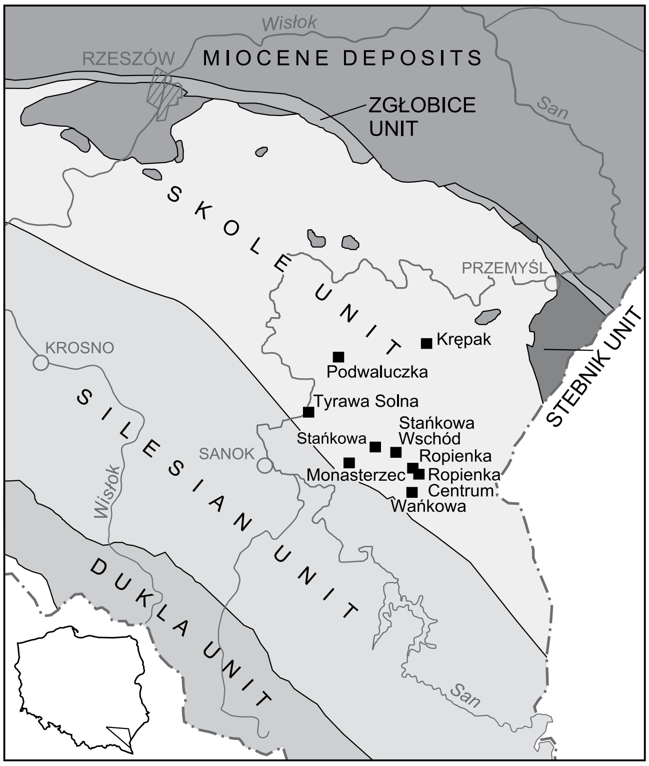

Fig. 1. Location of the investigated section of the Menilite–Krosno Series in the Skole Unit

Położenie badanych profili serii menilitowo-krośnieńskiej jednostki skolskiej

LITHOSTRATIGRAPHY OF THE MENILITE–KROSNO SERIES IN THE SKOLE UNIT

The Menilite Beds are subdivided into the lower and upper Menilite shales separated locally by a Krosno-type layer called the Łopianka Beds. The Menilite Beds are characterized by dark colour, leafy cleavage, brown scratch, high bitumen content and the presence of numerous disarticulated fish remains. In the outermost part of the Skole Unit the Menilite Beds very shallow facies occur, with the shallow-water Kliwa Sandstones (Jarmołowicz-Szulc, Jankowski, 2011) which are thick and laterally restricted. In the lower part of the Menilite Beds, chert horizon with the Dynów Marlstone and the Tylawa Limestone is distinguished (Jucha, 1969; Kotlarczyk, 1988; Haczewski, 1989). The Tylawa, Jasło and Zagórz coccolithic Limestones (Koszarski, Żytko, 1961; Haczewski, 1989; Garecka, 2008) are considered isochronous levels of regional coverage (from the foreland of the eastern Alps through the Carpathians and the Pannonian Basin to Azerbaijan – Ciurej, Haczewski, 2011). These horizons constitute a record of extremely intense events of carbon bound in the form of carbonate and organic matter. They were recognized based on fossils (fish, fecal pellets of zooplankton, coccospheres, coccoliths, foraminifers) and sedimentological features. In the Late Oligocene and/or Early Miocene, the Menilite facies overlapped with the Krosno facies. In the Skole Unit, the Krosno Beds are divided into the Lower Krosno Beds and Upper Krosno Beds (Żgiet, 1961). The boundary between them is the Niebylec Shale Member. The Lower Krosno Beds, which thin out to the north, are composed of thick-bedded muscovite sandstones. The overlying Niebylec Shale Member is represented by grey shales interbedded with brown shales, thin-bedded sandstones and tuffites. Above shales occurs a complex composed of medium- and thin-bedded sandstones interlayered with dark-grey marly shales, which dominated in the upper portion of the inner part of the Skole Unit.

BIOSTRATIGRAPHY OF THE MENILITE–KROSNO SERIES IN THE SKOLE UNIT

The Globigerina Marls contain the most abundant and diversified calcareous nannoplankton. According to Olszewska and Malata (2006), nearly 95% of the assemblage is composed of planktonic foraminifers. In the Wańkowa region, these deposits are assumed to Lower Oligocene (NP22 Calcareous Nannoplankton Zone). The assemblage consists of: *Cyclicargolithus floridanus* (Roth et Hay) Bukry, *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival (Pl. I, Figs. 1, 2), *H. bramlettei* Műller, *Transversopontis obliquipons* (Deflandre) Hay, Mohler et Wade (Pl. I., Fig. 3), *Lanternithus minutus* Stradner (Pl. I, Figs. 4, 5), *Helicosphaera compacta* Bramlette et Wilcoxon (Pl. I, Figs. 6, 7), sporadically: *Isthmolithus recurvus* Deflandre (Pl. I, Figs. 8, 9), *Ericsonia formosa* (Kamptner) Haq (Pl. I, Figs. 10, 11), *Reticulofenestra umbilica* (Levin) Martini et Ritzkowski (Pl. I, Figs. 12, 13), *Cribrocentrum reticulatum* (Gartner et Smith) Perch-Nielsen (Pl. I, Figs. 14, 15) and *Clausicoccus subdistichus* (Roth at Hay) Prins (Pl. I, Figs. 16, 17). *Discoaster barbadiensis* Tan and *D. saipanensis* Bramlette et Riedel are absent. The last evolutionary occurrence of these species took place at the Eocene/Oligocene boundary and/or in the earliest Oligocene. In the investigated samples, the first rare specimens of *Reticulofenestra lockeri* Műller and *R. ornata* Műller are observed, too. The samples from the Chert Beds (Lower Oligocene), contain only highly destroyed calcareous nannoplankton specimens (undistinguishable fragments). Nearly 90% of the specimens observed in the optical microscope were excluded from the identification procedure. The overlying lower part of the Lower Menilite Beds represents the NP23 Calcareous Nannoplankton Zone (middle Rupelian). The most common species in the samples are *Transversopontis fibula* Gheta (Pl. I, Figs. 18, 19) and *R. ornata* Műller (Pl. I, Fig. 20). In the samples collected near the Kliwa Sandstones and in the intercalation between them, common Pontosphaeracea, mainly *Pontosphaera latelliptica* (Báldi-Beke) Perch-Nielsen and *P. multipora* (Kamptner) Roth, were found. Below the Jasło laminite horizon, the assemblage consists mostly of: *D. bisectus* (Hay, Mohler et Wade) Bukry et Percival and *D. scrippsae* Bukry et Percival (the distinction between these two species is not always possible). The species of *Pontosphaera* occur sporadically. The interval corresponding to the more shaly Menilite Beds contains a more diversified assemblage with *Coccolithus pelagicus* (Wallich) Schiller, *Cy. floridanus* (Roth et Hay) Bukry (some forms are very small) and *D. bisectus* (Hay, Mohler et Wade) Bukry et Percival. An increase in the frequency of *Helicosphaera* species (*Helicosphaera euphratis* Haq (Pl. II. Figs. 1, 2), *H. intermedia* Martini (Pl. II, Figs. 3, 4), *Helicosphaera* sp.) and *P. latelliptica* (Báldi-Beke) Perch-Nielsen (Pl. II Figs. 5, 6) is observed. Directly above the Jasło laminite horizon, *Cy. floridanus* (Roth et Hay) Bukry (Pl. II, Figs. 7, 8) appears very common. The section of the Menilite Beds, the Jasło Limestone and the deposits between them are assigned to the NP24 Calcareous Nannoplankton Zone (late Rupelian–Chattian). The samples from the shaly intercalation between the limestones contain abundant *Cy. floridanus* (Roth et Hay) Bukry species. Less common species are: *Cyclicargolithus abisectus* (Műller) Wise (Pl. II, Figs. 9, 10) and *C. pelagicus* (Wallich) Schiller (Pl. II, Figs. 11, 12), *P. multipora* (Kamptner) Roth, *D. bisectus* (Hay, Mohler et Wade) Bukry et Percival and *Zygrhablithus bijugatus* Deflandre (Pl. II, Figs. 13, 14). The samples from the limestone contain a non-diagnostic assemblage. These represent recrystallized material in which only single specimens of *Cy. floridanus* (Roth et Hay) Bukry, *R. ornata* Műller, *Cyclicargolithus* sp. and *Cy. floridanus-abisectus* are identified. It is not always possible to distinguish *Cy. floridanus* and *Cy. abisectus*. The main reason is their state of preservation. According to Van Simaeys *et al*. (2004), *Cy. abisectus* is represented by very small forms (7–8 µm) in the lower part of its range. In poorly preserved material, it can be confused with *Cy. floridanus*. In well-preserved material, the optical pattern of these species is different. A very similar calcareous nannoplankton assemblage was found above the Jasło Limestone. The very good state of preservation of the *Cyclicargolithus* species and the increase in the number of redeposited forms (Eocene and Eocene–Oligocene) were observed. An equivalent assemblage occurs directly above the Zagórz Limestone horizon in the Mrzygłód region on the right bank of the San River. Above the Jasło and Zagórz limestones, an increase in the number of *Helicosphaera* species (*H. euphratis* Haq, *H. intermedia* Martini) is observed in light-coloured shaly layers. The calcareous nannoplankton assemblage of the Łopianka Beds is abundant but the species are poorly preserved. Placoliths (*Coccolithus* and *Reticulofenestra* species) are dominant. Among common (mainly) *H. intermedia* Martini and (sporadically) *H. euphratis* Haq, the

Early Miocene *Helicosphaera scissura* Miller and *H. kamptneri* Hay et Mohler occur (Koszarski *et al*., 1995; Melinte, 1995, 2005; Ślęzak *et al*., 1995a, b; Melinte *in*: Rusu *et al*., 1996; Garecka, 1997, 2005, 2008; Mărunteanu, 1999;Holcová, 2001). Based on the presence of these species, the sediments are assumed to belong to the NN1 Calcareous Nannoplankton Zone (upper Egerian = lowermost Aquitanian). *Pontosphaera multipora* (Kamptner) Roth, *P. latelliptica* (Báldi-Beke) Perch-Nielsen and their fragments also occur quite frequently. In the bottom part of the Upper Menilite Beds, the calcareous nannoplankton assemblage contains common species of *Helicosphaera* sp., *H. euphratis* Haq, *P. multipora* (Kamptner) Roth (Pl. II, Figs. 15, 16) and *C. pelagicus* (Wallich) Schiller. In the upper part of these beds, the following Early Miocene helicoliths appear in the assemblage: *H. scissura* Miller (Pl. II, Figs. 17, 18), *H. kamptneri* Hay et Mohler (Pl. II, Figs. 19, 20; Pl. III, Figs. 1, 2), *Helicosphaera truempyi* Biolzi et Perch-Nielsen and *Helicosphaera mediterranea* Műller (Pl. III, Figs. 3, 4) (Gheta, 1981; Műller, 1981; Finger *et al*., 1990; Melinte, 1995, 2005; Ślęzak, 1995a, b; Garecka, 1997, 2005, 2008; Melinte, *in*: Rusu *et al*., 1996; Mărunteanu, 1999; Holcová, 2001). Among cribriliths, *P. multipora* (Kamptner) Roth is always present. *C. pelagicus* (Wallich) Schiller is the dominant species whilst *Cy. floridanus* (Roth et Hay) Bukry is much rarer. *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival and *Z. bijugatus* Deflandre are absent. The last occurrence of these two species marks the boundary of the NP25/NN1 calcareous nannoplankton zones. The common occurrence of small reticulofenestrids is observed. The above described assemblage with Helicosphaeraceae suggests the NN1 Calcareous Nannoplankton Zone (upper Egerian = lowermost Aquitanian) (Garecka, 2008). In the Lower Krosno Beds, the most common species are: *Helicosphaera ampliaperta* Bramlette et Wilcoxon, *H. scissura* Miller (Pl. III, Figs. 5, 6), *H. kamptneri* Hay et Mohler (locally more numerous than the two previously mentioned forms), fragments of *P. multipora* (Kamptner) Roth and *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre. However, the assemblage is dominated by redeposited and long-ranging Coccolithaceae and Prinsiaceae (generally damaged). The deposits have been related to the NN2 Calcareous Nannoplankton Zone (upper Egerian–Eggenburgian = Aquitanian–lower Burdigalian). The most diversified and abundant assemblage (related also to the NN2 and NN3?) was found in the samples from the Niebylec Shale Member. Apart from the species which are characteristic for the NN1 and NN2, Middle Miocene *Helicosphaera walbersdorfensis* Műller (Pl. III, Figs. 7, 8) and *Helicosphaera* cf. *sellii* Bukry et Bramlette are observed (Ślęzak *et al*., 1995a, b; Garecka, Olszewska, 1997). Calcareous dinoflagellates (*Thoracosphaera fossata* Jafar) and abundant small reticulofenestrids occur too.

In the bottom part of the sandy-shaly series of the Upper Krosno Beds (above the Niebylec Shale Member), a very poor calcareous nannoplankton assemblage was found. *C. pelagicus* (Wallich) Schiller (Pl. III, Figs. 9, 10), *Cy. floridanus* (Roth et Hay) Bukry (Pl. III, Figs. 11, 12) and *B. bigelowii* (Gran et Braarud) Deflandre are dominant while the Early Miocene helicoliths occur sporadically. Only in the upper part of the series, an increase in the number of *Helicosphaera* species and almost mass occurrence of *C. pelagicus* (Wallich) Schiller were observed. The youngest Upper Krosno Beds (shaly series) in the innermost part of the Skole Unit (north-eastern wing of the Słonne Mountains syncline) have been included into the NN4 Calcareous Nannoplankton Zone (upper Burdigalian = Karpatian). The species diagnostic for the NN4 Zone, *Sphenolithus heteromorphus* Deflandre (PL. III, Figs. 13–18) is present (Steininger *et al*., 1976; Műller, 1978; Műller, 1986; Fornaciari, Rio, 1996; Andreyeva-Grigorovich, Halásova, 2000; Garecka, Malata, 2001; Švábenická *et al*., 2003; Martini, Piller *et al*., 2007; Spezzaferri *et al*., 2009). In addition to the diagnostic species, the assemblage also contains: *H. ampliaperta* Bramlette et Wilcoxon (Pl. III, Figs. 19, 20; Pl. IV, Figs. 1–4), *Helicosphaera californiana* Bukry, *H. kamptneri* Hay et Mohler, *Reticulofenestra pseudoumbilic*a Gartner (Pl. IV, Figs. 5–8), *C. pelagicus* (Wallich) Schiller and *Cy. floridanus* (Roth et Hay) Bukry.

PALAEOENVIRONMENTAL REMARKS

Distinct palaeogeographical and palaeoclimatic changes took place in the Early Oligocene in Europe. Climatic cooling, formation of ice caps in Antarctica and related general sea-level drop (Haq *et al*., 1987, 1988), the birth of Paratethys on the northern periphery of the Tethys (Báldi, 1980; Rusu, 1988; Rőgl, 1998; Harzhauser and Piller, 2007; Piller *et al*., 2007), and the rising Alpine chain resulted in a greater provincialism among the marine species and created conditions for the development of endemic species (Melinte, 2005; Melinte-Dobrinescu and Brustur, 2008). Those changes can be detected also in the Polish Carpathians (the Carpathian basin was part of the Central Paratethys) – relative sea-level fall (to about 200 metres; Olszewska, 1984), tectonic uplift of the Carpathians and significant decrease of sedimentation rate (Żytko, 1977). As coccolithophorales are very sensitive to palaeoenvironmental changes due to the above listed changes, the species diversity was decreased. The Oligocene, especially Early Oligocene, was the time of the lowest speciation in the Paleogene: from 120 species in the Eocene to 40 in the Oligocene (Haq, 1973; Aubry, 1992). The changes are reflected by the cooler *Globigerina* assemblage of the Globigerina Marls (Olszewska, 1984). The cooling trend is observed in calcareous nannoplankton assemblages. *Discoaster* species (*D. barbadiensis* Tan, *D. saipanensis* Bramlette et Riedel), *Ericsonia formosa* (Kamptner) Haq, typically of warm water, became extinct. Cold-water *Lanternithus minutus* Stradner and *Isthmolithus recurvus* Deflandre occurred instead. At the NP22/NP23 boundary and in the lower part of the NP23 Calcareous Nannoplankton Zones, a stepwise disappearance of warm-, temperate- and cold-water species is observed; more species became extinct than appeared, as already noticed by Oszczypko-Clowes (2001) from the Magura Unit. It seems, therefore, that the climate changes which led to the change of the nature of the environment (from oligotrophic in the Eocene to eutrophic in the Early Oligocene) was the cause of elimination of many species non-adapted to new conditions in the basin (Aubry, 1992; Oszczypko-Clowes, 2001; Melinte, 2005). Fluctuations of the calcium carbonate compensation depth also caused the elimination of species (of simple construction) less resistant to dissolution processes: among others *Braarudosphaera*, *Transversopontis*, *Pontosphaera*-species and holococcoliths. At that time (even earlier in the NP21? – NP22 calcareous nannoplankton zones, Jurašova, 1974; Nagymarosy, Báldi-Beke, 1988; Smoleńska, Dudziak, 1989; Nagymarosy, Voronina, 1992; Garecka, 2008), the first rare occurrences of cold-water species typical of the NP23 were noted: *Reticulofenestra lockeri* Műller and *R. ornata* Műller (Jurašova, 1974; Nagymarosy, Báldi-Beke, 1984; Smoleńska, Dudziak, 1989; Nagymarosy, Voronina, 1992; Melinte, 1995; Garecka, 2005, 2008). Above the Globigerina Marls in the Skole Unit (and in the whole Carpathian arc – Báldi, 1998), dark bituminous shales of the Menilite Beds with abundant fish fauna (Jerzmańska, Kotlarczyk, 1988, 1991) appeared. Sedimentation of these deposits (which continued to the Early Miocene – Garecka, 2008) is associated with the period of isolation of the Paratethys from the Tethys (Báldi, 1980; Nagymarosy, 1991; Rusu *et al*., 1996; Rőgl, 1999) at the end of the NP22 and in NP23 calcareous nannoplankton zones. Foraminifers indicate the outer shelf – upper bathyal depths (Olszewska, 1984). The calcareous nannoplankton assemblage is composed of temperate- and temperate to cold-water species, which are successively replaced by the endemic species (Melinte-Dobrinescu, Brustur, 2008) such as: *Transversopontis fibula* Gheta and *R. ornata* Műller. The Dynów Marls (Hornstone Beds) contain *R. ornata* Műller (Pl. IV, Figs. 9, 10) and *Reticulofenestra tokodensis* Báldi-Beke (Pl. IV, Figs. 11, 12) in the assemblage. The occurrence of these species shows extreme environmental conditions (decrease in salinity and high nutrient content, Krhovsky *et al*., 1992). The blooms of *R. ornata* Műller is described in many papers from the Paratethys region and is considered as an important event useful for stratigraphic correlation of the Oligocene sediments in the Central and Eastern Paratethys (Krhovsky, 1985; Krhovsky *et al*., 1992; Melinte, 2005; Švábenická *et al*., 2007). At the same time, the bloom of the monospecific assemblage with *R. ornata* Műller of the Tylawa Limestone in the Skole Unit took place (Műller, 1970; Krhovsky, 1981; Haczewski, 1989; Melinte, 2005; Melinte-Dobrinescu, Brustur, 2008). The long-term and extreme blooms of calcareous nannoplankton arise as a result of low salinity in the surface water (related to the inflow of fresh water into the basin) and high nutrient supply (Nagymarosy, Voronina, 1992; Melinte, 2005; Melinte-Dobrinescu, Brustur, 2008). According to Haczewski (1989), the extremely intensive blooms indicate a low content of biogenic ingredients in the photic zone, while the extremely high density of blooms maintained for months requires constant ingredients. Especially in dark varieties of the Menilite Beds, *R. ornata* coexists with the other species with similar ecological preferences: *Transversopontis fibula* Gheta and *Reticulofenestra lockeri* Műller (Pl. IV, Figs. 13, 14), which confirms a suggestion of shallow water depths, decreased salinity and high nutrient supply. *R. lockeri* species adapted probably to the changed salinity, because its optimal living conditions are in a normal marine environment. The shallow, nearly near-shore environment is indicated by the presence of Pontosphaeraeae: *Pontosphaera latelliptica* and *P. multipora*, which occur almost in mass (abundant) in the Lower Menilite Beds (especially in the dark-type shales). They require stable environmental conditions and only slight fluctuations in salinity (increased rather than decreased) (Báldi-Beke, 1984; Melinte, 2005). Only under such conditions, the species can reproduce. An almost monospecific assemblages in the Lower Menilite Beds is formed by *Dictyococcites bisectus* and *Dictyococcites scrippsae*. According to Melinte (2005), the large number of these species is characteristic of near-shore facies and with the increase of nutrient form blooms. This association indicates a small depth (shallow-water environment) for the deposition of the Menilite Beds, normal salinity rather than decreased in the lower part, and a cooler to temperate climate. At the turn of NP23/NP24 and in the NP24 Calcareous Nannoplankton Zone, the palaeogeographical situation changed in Europe. The connection between the Paratethys and Mediterranean regions became renewed and normal marine conditions returned in the Paratethys (Melinte, 2005). Forms characteristic of normal salinity marine environments appeared: *Cy. floridanus* (Roth et Hay) Bukry, *C. pelagicus* (Wallich) Schiller, *P. multipora* (Kamptner) Roth, *D. bisectus* (Hay, Mohler et Wade) Bukry et Percival, *Z. bijugatus* Deflandre and *Sphenolithus moriformis* (Brönnimann et Stradner) Bramlette et Wilcoxon (Pl. IV, Figs. 15, 16) (Nagymarosy, Voronina, 1992). Species typical of pelagic environments, *Discoaster* and *Sphenolithus,* occur rarely. At that time, two horizons of the coccolith limestones originated: Jasło Limestone (PL. IV, Figs. 17, 18; Pl. V, Figs. 1–3) and Zagórz Limestone (Pl. V, Figs. 4, 5) (Koszarski, Żytko, 1961; Haczewski, 1989). The species composition of these two horizons shows that the conditions of their formation were similar. In contrast to the Tylawa horizon, which is composed of endemic species, the Jasło nad Zagórz coccolithic limestones record the bloom of cosmopolitan *Cyclicargolithus* species: *Cy. floridanus* (Pl. VI, Figs. 1–4), *Cy. abisectus* (Pl. VI, Figs. 5–12) (*Cy. floridanus* prevailed over *Cy. abisectus*) and *Cy. floridanus-abisectus*. The assemblage also contains *D. bisectus*, *Z. bijugatus*, *S. moriformis* and *Pontosphaera* sp. This record is observed in the whole Paratethys (Melinte, 1995, 2005; Rusu *et al*., 1996; Švábenická *et al*., 2007; Garecka, 2008; Melinte-Dobrinescu, Brustur, 2008). In Romania an increase in the number of *Discoaster* and *Sphenolithus* species was noted (bloom) between these two horizons. On the one hand, it indicates a warming, on the other – a relative sea-level rise (the global Late Oligocene Warming – Zachos *et al*., 2001). In the same interval in the Menilite–Krosno Series of the Skole Unit, asteroliths and sphenoliths are very rare. The genus *Discoaster* is represented only by rare specimens of *Discoaster deflandrei* Bramlette et Riedel (Pl. VI, Figs. 13, 14). Among sphenoliths, there is a long-ranging and rather cosmopolitan than warm-water species of *S. moriformis* (Pl. VI, Fig. 15). At that time, placoliths (*Coccolithus*, *Cyclicargolithus*, *Dictyococcites*), cribriliths (*Pontosphaera*) and helicoliths (*Helicosphaera*) occurred most commonly. In the Late Oligocene (NP25 Calcareous Nannoplankton Zone), an increase in the number of the *Helicosphaera* (*H. euphratis*, *H. intermedia*, *H. recta* – Pl. VI, Figs. 16–18) and *Pontosphaera* species (*P. multipora* – Pl. VI, Fig. 19 and *P. latelliptica* – Pl. VI, Fig. 20) is observed. It confirms a warm climate, shallower depths, stable marine conditions and slight salinity fluctuations. A similar calcareous nannoplankton association was described from the Romanian Carpathians (Melinte, 2005). Modern Helicosphaeraceae are associated with upwelling areas, avoid boreal regions and are considered eurythermal species. They are abundant in the warm water, but do not avoid cold water, too. In the warm water, the abundance of the species is greater (Chira, 2004). The latest Oligocene and Early Miocene is the period of subsequent changes in the Carpathian calcareous nannoplankton assemblages. Apart from a few exceptions from the Skole Unit, there is no biostratigraphical record of the Late Oligocene–Early Miocene interval. In the Upper Menilite Beds, Łopianka Beds and Lower Krosno Beds, this interval is defined based on the first occurrences of *H. scissura* Miller, *H. mediterranea* Műller, *H. kamptneri* Hay et Mohler (Melinte, 1985; Perch-Nielsen, 1985; Ślęzak *et al.,* 1995a, b; Melinte, *in*: Rusu *et al*., 1996; Garecka, 1997, 2008; Mărunteanu, 1999). *P. multipora* (Kamptner) Roth, *C. pelagicus* (Wallich) Schiller and small reticulofenestrids are common to abundant, whereas *Cy. floridanus* (Roth et Hay) Bukry is rare. It suggests a high content of nutrients in the environment (Chira, 2004). Common occurrence of small reticulofenestrids suggests, according to Ozdinová (2008), a relative sea-level rise. According to Melinte (2005), in the Romanian Carpathians, this interval is associated with high radiation of the species – seven new species appear.

In the calcareous nannoplankton assemblages of the Lower Krosno Beds, Menilite Beds and Łopianka Beds, the considerable proportion of redeposited (and long-ranging) taxa is observed. The autochthonous ones – very important for this time interval – occur sporadically.

The Niebylec Shale Member is a record of a relatively quiet phase of sedimentation in the Skole Unit and of the restoration of a warmer climate in the Early Miocene. The assemblage consists of common Helicosphaeraceae and, according to Ślęzak (Ślęzak *et al*., 1995a, b), Sphenolithaceae (*Sphenolithus belemnos* Bramlette et Wilcoxon, *S. calyculus* Bukry, *S. conicus* Bukry). Sphenolithus species suggest, according to Melinte (2005), warm, well-oxygenated surface water and rather open-marine environments. The calcareous nannoplankton assemblage, which contains, in addition to the warm-water species, also intermediate (temperate- and cold-water) species, indicates a transgressive phase. Collision between Africa and Europe in the late Early Miocene caused separation of the Tethys from the Paratethys. The Eastern Paratethys was closed into the inland lake, whereas the Western Paratethys was periodically isolated from the Mediterranean Sea (Steininger and Rőgl, 1985). Sedimentation of the Krosno Beds in the Skole Unit continued uninterruptedly until the NN4 Calcareous Nannoplankton Zone (Burdigalian = Ottnangian) (Ślęzak *et al*., 1995a, b; Garecka, Malata, 2001). In addition to *Helicosphaera ampliaperta* Bramlette et Wilcoxon, the assemblage also contains *Sphenolithus heteromorphus* Deflandre which is a diagnostic species for the NN4 Zone. At the end of the Ottnangian, the flysch basin was folded, uplifted and included into the Outer Carpathian accretionary prism (Oszczypko, 1998, 1999).

CONCLUSIONS

The changes that occurred in the Oligocene and Early Miocene in the Skole Unit are reflected in calcareous nannoplankton assemblages. Their distribution, growth, species diversity and abundance are closely related to the condition that prevailed in the basin, controlled by its location on the periphery of the Paratethys, depth, chemistry and temperature of the surface water. Already from the Early Oligocene, the character of the calcareous nannoplankton assemblage changed. The warm-water (tropical, subtropical) species that evolved in oligotrophic conditions were replaced by forms characteristic of cold and intermediate regions. The assemblage of the Menilite Beds is characterized by the presence of endemic species that are typical of shallow water, reduced salinity and high nutrient supply in the lower part of the Menilite Beds, and the normal salinity (presence of *Pontosphaera* and *Helicosphaera* species) with only small fluctuations in the upper part. The high content of nutrients in the environment led to the blooming of certain calcareous nannoplankton species. The coccolithic limestone horizons (Tylawa, Jasło and Zagórz) are the record of these blooms. Restoration of typical marine conditions in the late Rupelian (sea-level rise) resulted in mixing of forms and the return of species that are characteristic of pelagic environments. This phase continued, with a small fluctuation at the Oligocene–Miocene boundary, to the Karpatian (Burdigalian). The Krosno Beds are characterized by a different fossil inventory – redeposited species are dominant in the assemblage and often they are better preserved than autochthonous ones. It indicates unstable conditions during the sedimentation of these deposits.

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STRESZCZENIE

Nanoplankton wapienny stanowi najbardziej zróżnicowaną i rozprzestrzenioną grupę morskiego fitoplanktonu, która okazała się szczególnie przydatna w biostratygrafii i analizach paleośrodowskowych (w tym paleoklimatycznych). Analizując skład zespołu, jego zróżnicowanie, liczebność i stan zachowania, można określić zarówno jego charakter, jak i charakter warunków środowiskowych, jakie panowały w tym czasie w zbiorniku (basenie). Rozwój i rozprzestrzenienie tych organizmów jest uwarunkowane wieloma czynnikami, z których najważniejsze to: dostępność i natężenie światła (fotosynteza), temperatura wód powierzchniowych, zasolenie, dostępność składników odżywczych, natlenienie wód, zmiany poziomu morza. Czasami niewielkie zmiany jednego lub kilku czynników mają duży wpływ na skład zespołu, jego zróżnicowanie lub powodują wymieranie albo radiację form. Problemem, na jaki natrafia się w czasie badań, jest obecność form redeponowanych (niewielkie rozmiary Coccolithaceae sprawiają, że są łatwo przenoszone) i podatność na wtórne zmiany (mineralizacja, rozpuszczanie). Prowadzone badania obejmowały obszar jednostki skolskiej polskich Karpat zewnętrznych ze względu na dostępność profili, począwszy od poziomu podmenilitowych margli globigerynowych aż po najmłodsze osady serii menilitowo-krośnieńskiej. Wykonane analizy nie potwierdziły ustaleń Ślęzaka (Ślęzak i in., 1995b) o przynależności najmłodszych osadów jednostki skolskiej do poziomu nanoplanktonowego NN5 (baden). Badania obejmowały utwory późnego oligocenu–wczesnego miocenu serii menilitowo-krośnieńskiej jednostki skolskiej – najbardziej zewnętrznej części basenu Karpat zewnętrznych na terenie Polski. Próbki pochodziły z rejonów: Tyrawa Solna, Podwaluczka, Krępak, Stańkowa, Stańkowa Wschód, Ropienka Centrum, Wańkowa, Monasterzec. Zmiany, jakie zachodziły w oligocenie i wczesnym miocenie w basenie skolskim, znalazły odzwierciedlenie w zespołach nanoplanktonu wapiennego. Ich rozprzestrzenienie, rozwój, zróżnicowanie gatunkowe i liczebność są ściśle związane z warunkami panującymi w samym basenie, uwarunkowane jego położeniem, głębokością, chemizmem wód i temperaturą. Począwszy od wczesnego oligocenu zmienia się charakter całego zespołu, formy ciepłolubne, formy ewoluujące w warunkach oligotroficznych zostają wypierane przez gatunki charakterystyczne dla stref chłodnych i umiarkowanie chłodnych. Zespół warstw menilitowych cechuje przewaga gatunków endemicznych charakterystycznych dla stref płytkich o obniżonym zasoleniu i podwyższonej zawartości nutrientów w części niższej i normalnym zasoleniu, jedynie z niewielkimi wahnięciami (Pontosphaeraceae i Helicosphaeraceae), w części wyższej. Wysoka zawartość nutrientów w środowisku doprowadziła do zakwitu pewnych gatunków. Zapisem takich zakwitów są korelacyjne poziomy kokkolitowe. Powrót typowo morskich warunków w wyższym rupelu spowodował wymieszanie gatunków i powrót gatunków charakterystycznych dla stref otwartego morza, który to etap trwał z niewielkimi wahaniami na granicy oligocen/miocen (spłycenie) aż do ottnangu. Warstwy krośnieńskie cechuje odmienny inwentarz nanoskamieniałości – dominują gatunki redeponowane, niejednokrotnie zachowane lepiej niż nieliczne autochtoniczne, co wskazuje na niestabilne (dynamiczne) warunki w czasie sedymentacji tych utworów.

PLATE I

Scale bar is 5 µm. CN – crossed nicols; NL – normal light

Skala: 5 µm. CN – światło spolaryzowane; NL – światło przechodzące

Fig. 1. *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival – CN; Globigerina Marls
Dictyococcites bisectus (Hay, Mohler et Wade) Bukry et Percival – CN; margle globigerynowe

Fig. 2. *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival – CN; Globigerina Marls
Dictyococcites bisectus (Hay, Mohler et Wade) Bukry et Percival – CN; margle globigerynowe

Fig. 3. *Transversopontis obliquipons* (Deflandre) Hay, Mohler et Wade – CN; Globigerina Marls
Transversopontis obliquipons (Deflandre) Hay, Mohler et Wade – CN; margle globigerynowe

Fig. 4. *Lanternithus minutus* Stradner, – CN; Globigerina Marls
Lanternithus minutus Stradner – CN; margle globigerynowe

Fig. 5. *Lanternithus minutus* Stradner – NL; Globigerina Marls
Lanternithus minutus Stradner – NL; margle globigerynowe

Fig. 6. *Helicosphaera compacta* Bramlette et Wilcoxon – CN; Globigerina Marls
Helicosphaera compacta Bramlette et Wilcoxon – CN; margle globigerynowe

Fig. 7. *Helicosphaera compacta* Bramlette et Wilcoxon – NL; Globigerina Marls
Helicosphaera compacta Bramlette et Wilcoxon – NL; margle globigerynowe

Fig. 8. *Isthmolithus recurvus* Deflandre – CN; Globigerina Marls
Isthmolithus recurvus Deflandre – CN; margle globigerynowe

Fig. 9. *Isthmolithus recurvus* Deflandre – NL; Globigerina Marls
Isthmolithus recurvus Deflandre – NL; margle globigerynowe

Fig. 10. *Ericsonia formosa* (Kamptner) Haq – CN; Globigerina Marls
Ericsonia formosa (Kamptner) Haq – CN; margle globigerynowe

Fig. 11. *Ericsonia formosa* (Kamptner) Haq – NL; Globigerina Marls
Ericsonia formosa (Kamptner) Haq – NL; margle globigerynowe

Fig. 12. *Reticulofenestra umbilica* (Levin) Martini et Ritzkowski – CN; Globigerina Marls
Reticulofenestra umbilica (Levin) Martini et Ritzkowski – CN; margle globigerynowe

Fig. 13. *Reticulofenestra umbilica* (Levin) Martini et Ritzkowski – NL; Globigerina Marls
Reticulofenestra umbilica (Levin) Martini et Ritzkowski – NL; margle globigerynowe

Fig. 14. *Cribrocentrum reticulatum* (Gartner et Smith) Perch-Nielsen – CN; Globigerina Marls
Cribrocentrum reticulatum (Gartner et Smith) Perch-Nielsen – CN; margle globigerynowe

Fig. 15. *Cribrocentrum reticulatum* (Gartner et Smith) Perch-Nielsen – NL; Globigerina Marls
Cribrocentrum reticulatum (Gartner et Smith) Perch-Nielsen – NL; margle globigerynowe

Fig. 16. *Clausicoccus subdistichu*s (Roth et Hay) Prins – CN; Globigerina Marls
*Clausicoccus subdistichu*s (Roth et Hay) Prins – CN; margle globigerynowe

Fig. 17. *Clausicoccus subdistichu*s (Roth et Hay) Prins – CN; Globigerina Marls
*Clausicoccus subdistichu*s (Roth et Hay) Prins – CN; margle globigerynowe

Fig. 18. *Transversopontis fibula* Gheta – CN; Lower Menilite Beds
Transversopontis fibula Gheta – CN; warstwy menilitowe dolne

Fig. 19. *Transversopontis fibula* Gheta – NL; Lower Menilite Beds
Transversopontis fibula Gheta – NL; warstwy menilitowe dolne

Fig. 20. *Reticulofenestra ornata* Műller – CN; Lower Menilite Beds
Reticulofenestra ornata Műller – CN; warstwy menilitowe dolne

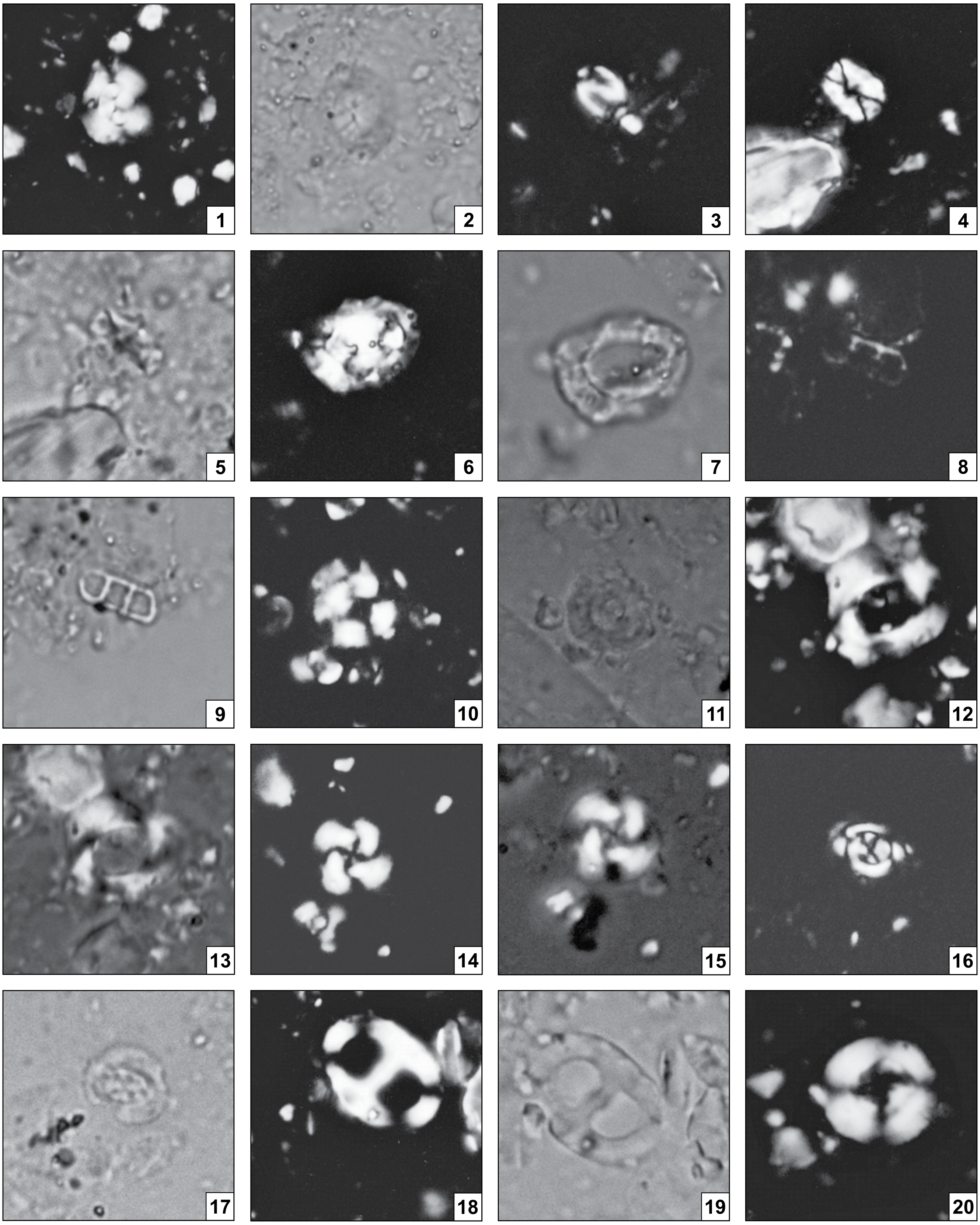
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PLATE II

Fig. 1. *Helicosphaera euphratis* Haq – CN; Lower Menilite Beds
Helicosphaera euphratis Haq – CN; warstwy menilitowe dolne

Fig. 2. *Helicosphaera euphratis* Haq – NL; Lower Menilite Beds
Helicosphaera euphratis Haq – NL; warstwy menilitowe dolne

Fig. 3. *Helicosphaera intermedia* Martini – CN; Lower Menilite Beds
Helicosphaera intermedia Martini – CN; warstwy menilitowe dolne

Fig. 4. *Helicosphaera intermedia* Martini – NL; Lower Menilite Beds
Helicosphaera intermedia Martini – NL; warstwy menilitowe dolne

Fig. 5. *Pontosphaera latelliptica* (Báldi-Beke) Perch-Nielsen – CN; Lower Menilite Beds
Pontosphaera latelliptica (Báldi-Beke) Perch-Nielsen – CN; warstwy menilitowe dolne

Fig. 6. *Pontosphaera latelliptica* (Báldi-Beke) Perch-Nielsen – NL; Lower Menilite Beds
Pontosphaera latelliptica (Báldi-Beke) Perch-Nielsen – NL; warstwy menilitowe dolne

Fig. 7. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – CN; Lower Menilite Beds
Cyclicargolithus floridanus (Roth et Hay) Bukry – CN; warstwy menilitowe dolne

Fig. 8. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – NL; Lower Menilite Beds
Cyclicargolithus floridanus (Roth et Hay) Bukry – NL; warstwy menilitowe dolne

Fig. 9. *Cyclicargolithus abisectus* (Műller) Wise – CN; Lower Menilite Beds
Cyclicargolithus abisectus (Műller) Wise – CN; warstwy menilitowe dolne

Fig. 10. *Cyclicargolithus abisectus* (Műller) Wise – NL; Lowe Menilite Beds
Cyclicargolithus abisectus (Műller) Wise – NL; warstwy menilitowe dolne

Fig. 11. *Coccolithus pelagicus* (Wallich) Schiller – CN; Lower Menilite Beds
Coccolithus pelagicus (Wallich) Schiller – CN; warstwy menilitowe dolne

Fig. 12. *Coccolithus pelagicus* (Wallich) Schiller – NL; Lower Menilite Beds
Coccolithus pelagicus (Wallich) Schiller – NL; warstwy menilitowe dolne

Fig. 13. *Zygrhablithus bijugatus* Deflandre – CN; Lower Menilite Beds
Zygrhablithus bijugatus Deflandre – CN; warstwy menilitowe dolne

Fig. 14. *Zygrhablithus bijugatus* Deflandre – NL; Lower Menilite Beds
Zygrhablithus bijugatus Deflandre – NL; warstwy menilitowe dolne

Fig. 15. *Pontosphaera multipora* (Kamptner) Haq – CN; Upper Menilite Beds
Pontosphaera multipora (Kamptner) Haq – CN; warstwy menilitowe górne

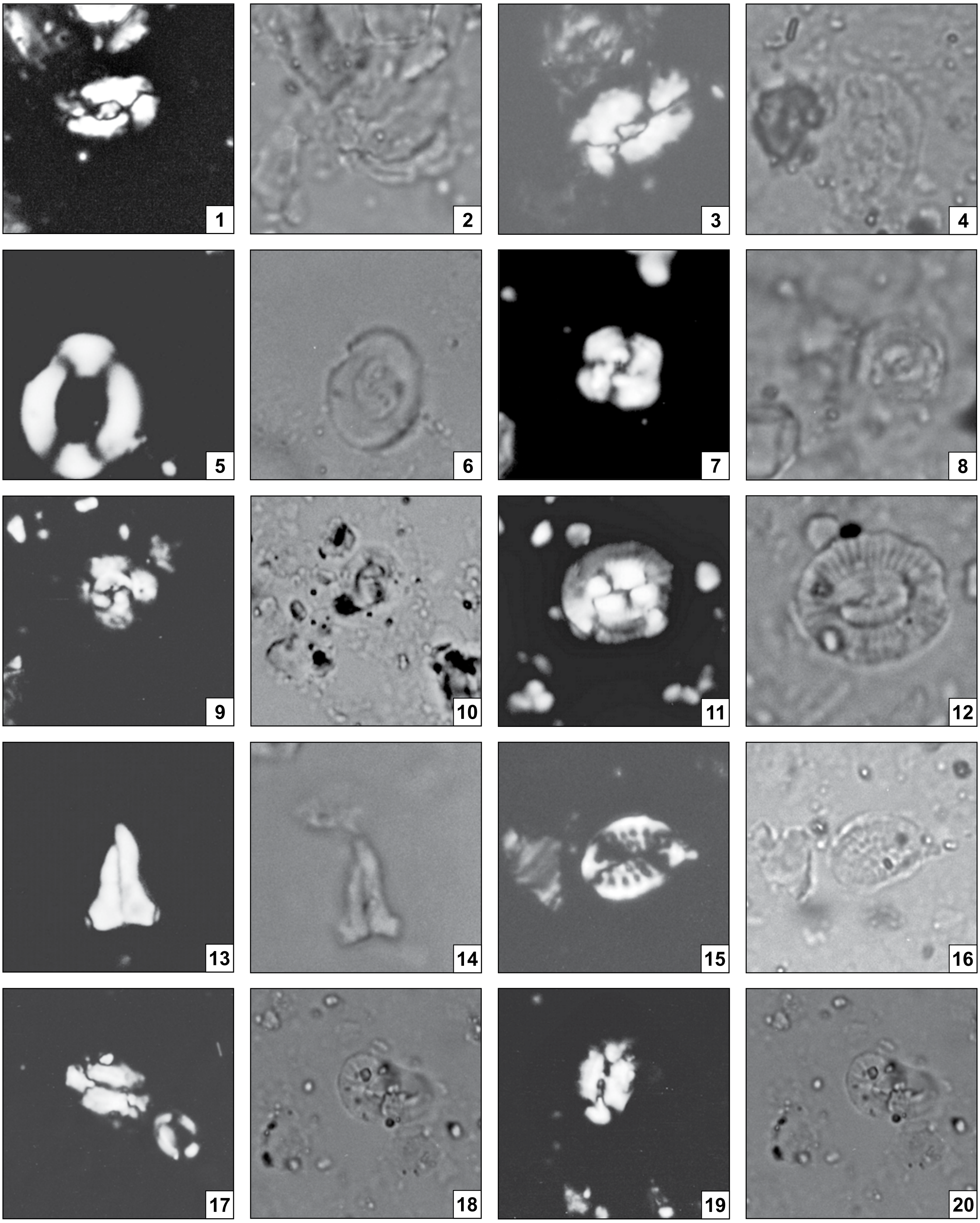
Fig. 16. *Pontosphaera multipora* (Kamptner) Haq – NL; Upper Menilite Beds
Pontosphaera multipora (Kamptner) Haq – NL; warstwy menilitowe górne

Fig. 17. *Helicosphaera scissura* Miller – CN; Upper Menilite Beds
Helicosphaera scissura Miller – CN; warstwy menilitowe górne

Fig. 18. *Helicosphaera scissura* Miller – NL; Upper Menilite Beds
Helicosphaera scissura Miller – NL; warstwy menilitowe górne

Fig. 19. *Helicosphaera kamptneri* Hay et Mohler – CN; Upper Menilite Beds
Helicosphaera kamptneri Hay et Mohler – CN; warstwy menilitowe górne

Fig. 20. *Helicosphaera kamptneri* Hay et Mohler – NL; Upper Menilite Beds
Helicosphaera kamptneri Hay et Mohler – NL; warstwy menilitowe górne



Małgorzata Garecka — Record of changes in the Oligocene–Miocene sediments of the Menilite–Krosno Series of the Skole Unit based on calcareous nannoplankton studies – biostratigraphy and palaeogeographical implications (Polish Outer Carpathians)

PLATE III

Fig. 1. *Helicosphaera kamptneri* Hay et Mohler – CN; Upper Menilite Beds
Helicosphaera kamptneri Hay et Mohler – CN; warstwy menilitowe górne

Fig. 2. *Helicosphaera kamptneri* Hay et Mohler – NL; Upper Menilite Beds
Helicosphaera kamptneri Hay et Mohler – NL; warstwy menilitowe górne

Fig. 3. *Helicosphaera mediterranea* Műller – CN; Upper Menilite Beds
Helicosphaera mediterranea Műller – CN; warstwy menilitowe górne

Fig. 4. *Helicosphaera mediterranea* Műller – NL; Upper Menilite Beds
Helicosphaera mediterranea Műller – NL; warstwy menilitowe górne

Fig. 5. *Helicosphaera scissura* Miller – CN; Lower Krosno Beds
Helicosphaera scissura Miller – CN; warstwy krośnieńskie dolne

Fig. 6. *Helicosphaera scissura* Miller – NL; Lower Krosno Beds
Helicosphaera scissura Miller – NL; warstwy krośnieńskie dolne

Fig. 7, 8. *Helicosphaera walbersdorfensis* Műller – CN; Niebylec Shale Member
Helicosphaera walbersdorfensis Műller – CN; poziom łupków z Niebylca

Fig. 9. *Coccolithus pelagicus* (Wallich) Schiller – CN; Upper Krosno Beds
Coccolithus pelagicus (Wallich) Schiller – CN; warstwy krośnieńskie górne

Fig. 10. *Coccolithus pelagicus* (Wallich) Schiller – NL; Upper Krosno Beds
Coccolithus pelagicus (Wallich) Schiller – NL; warstwy krośnieńskie górne

Fig. 11. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – CN; Upper Krosno Beds
Cyclicargolithus floridanus (Roth et Hay) Bukry – CN; warstwy krośnieńskie górne

Fig. 12. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – NL; Upper Krosno Beds
Cyclicargolithus floridanus (Roth et Hay) Bukry – NL; warstwy krośnieńskie górne

Fig. 13. *Sphenolithus heteromorphus* Deflandre – CN0°; Upper Krosno Beds
Sphenolithus heteromorphus Deflandre – CN0°; warstwy krośnieńskie górne

Fig. 14. *Sphenolithus heteromorphus* Deflandre – CN45°; Upper Krosno Beds
Sphenolithus heteromorphus Deflandre – CN45°; warstwy krośnieńskie górne

Fig. 15. *Sphenolithus heteromorphus* Deflandre – NL45°; Upper Krosno Beds
Sphenolithus heteromorphus Deflandre – NL45°; warstwy krośnieńskie górne

Fig. 16. *Sphenolithus heteromorphus* Deflandre – CN0°; Upper Krosno Beds
Sphenolithus heteromorphus Deflandre – CN0°; warstwy krośnieńskie górne

Fig. 17. *Sphenolithus heteromorphus* Deflandre – CN45°; Upper Krosno Beds
Sphenolithus heteromorphus Deflandre – CN45°; warstwy krośnieńskie górne

Fig. 18. *Sphenolithus heteromorphus* Deflandre – NL45°; Upper Krosno Beds
Sphenolithus heteromorphus Deflandre – NL45°; warstwy krośnieńskie górne

Fig. 19. *Helicosphaera ampliaperta* Bramlette et Wilcoxon – CN; Upper Krosno Beds
Helicosphaera ampliaperta Bramlette et Wilcoxon – CN; warstwy krośnieńskie górne

Fig. 20. *Helicosphaera ampliaperta* Bramlette et Wilcoxon – NL; Upper Krosno Beds
Helicosphaera ampliaperta Bramlette et Wilcoxon – NL; warstwy krośnieńskie górne

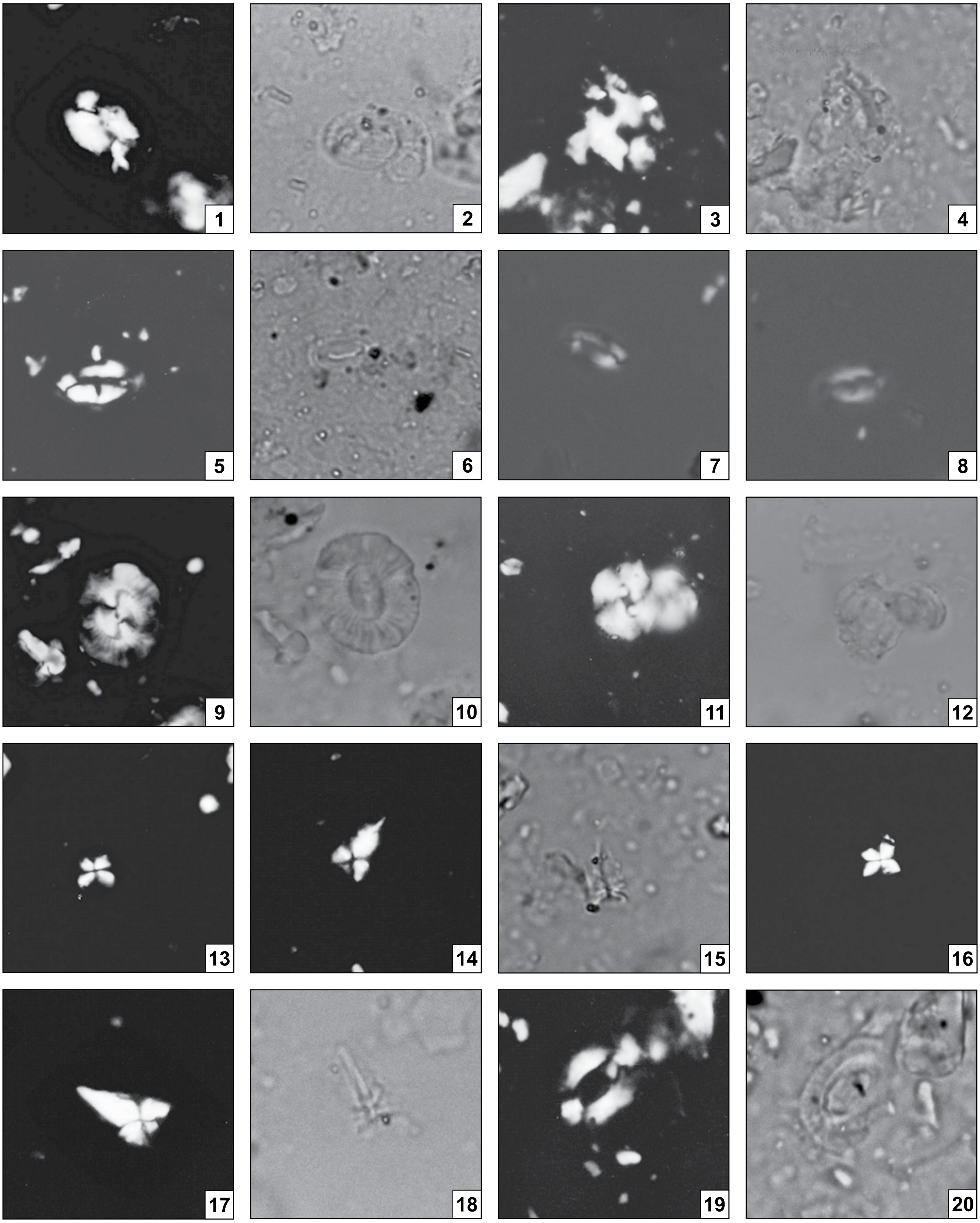

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PLATE IV

Fig. 1. *Helicosphaera ampliaperta* Bramlette et Wilcoxon – CN; Upper Krosno Beds
Helicosphaera ampliaperta Bramlette et Wilcoxon – CN; warstwy krośnieńskie górne

Fig. 2. *Helicosphaera ampliaperta* Bramlette et Wilcoxon – NL; Upper Krosno Beds
Helicosphaera ampliaperta Bramlette et Wilcoxon – NL; warstwy krośnieńskie górne

Fig. 3. *Helicosphaera ampliaperta* Bramlette et Wilcoxon – CN; Upper Krosno Beds
Helicosphaera ampliaperta Bramlette et Wilcoxon – CN; warstwy krośnieńskie górne

Fig. 4. *Helicosphaera ampliaperta* Bramlette et Wilcoxon – NL; Upper Krosno Beds
Helicosphaera ampliaperta Bramlette et Wilcoxon – NL; warstwy krośnieńskie górne

Fig. 5. *Reticulofenestra pseudoumbilica* Gartner – CN; Upper Krosno Beds
Reticulofenestra pseudoumbilica Gartner – CN; warstwy krośnieńskie górne

Fig. 6. *Reticulofenestra pseudoumbilica* Gartner – NL; Upper Krosno Beds
Reticulofenestra pseudoumbilica Gartner – NL; warstwy krośnieńskie górne

Fig. 7. *Reticulofenestra pseudoumbilica* Gartner – CN; Upper Krosno Beds
Reticulofenestra pseudoumbilica Gartner – CN; warstwy krośnieńskie górne

Fig. 8. *Reticulofenestra pseudoumbilica* Gartner – NL; Upper Krosno Beds
Reticulofenestra pseudoumbilica Gartner – NL; warstwy krośnieńskie górne

Fig. 9. *Reticulofenestra ornata* Műller – CN; Dynów Marls
Reticulofenestra ornata Műller – CN; margle dynowskie

Fig. 10. *Reticulofenestra ornata* Műller – NL; Dynów Marls
Reticulofenestra ornata Műller – NL; margle dynowskie

Fig. 11. *Reticulofenestra tokodensis* Báldi-Beke – CN; Dynów Marls
Reticulofenestra tokodensis Báldi-Beke – CN; margle dynowskie

Fig. 12. *Reticulofenestra tokodensis* Báldi-Beke – NL; Dynów Marls
Reticulofenestra tokodensis Báldi-Beke – NL; margle dynowskie

Fig. 13. *Reticulofenestra lockeri* Műller – CN; Lower Menilite Beds
Reticulofenestra lockeri Műller – CN; warstwy menilitowe dolne

Fig. 14. *Reticulofenestra lockeri* Műller – NL; Lower Menilite Beds
Reticulofenestra lockeri Műller – NL; warstwy menilitowe dolne

Fig. 15. *Sphenolithus moriformis* (Brőnnimann et Stradner) Bramlette et Wilcoxon – CN0°; Lower Menilite Beds
Sphenolithus moriformis (Brőnnimann et Stradner) Bramlette et Wilcoxon – CN0°; warstwy menilitowe dolne

Fig. 16. *Sphenolithus moriformis* (Brőnnimann et Stradner) Bramlette et Wilcoxon – NL0°; Lower Menilite Beds
Sphenolithus moriformis (Brőnnimann et Stradner) Bramlette et Wilcoxon – NL0°; warstwy menilitowe dolne

Fig. 17. Jasło Limestone – CN
Wapień jasielski – CN

Fig. 18. Jasło Limestone – NL
Wapień jasielski – NL

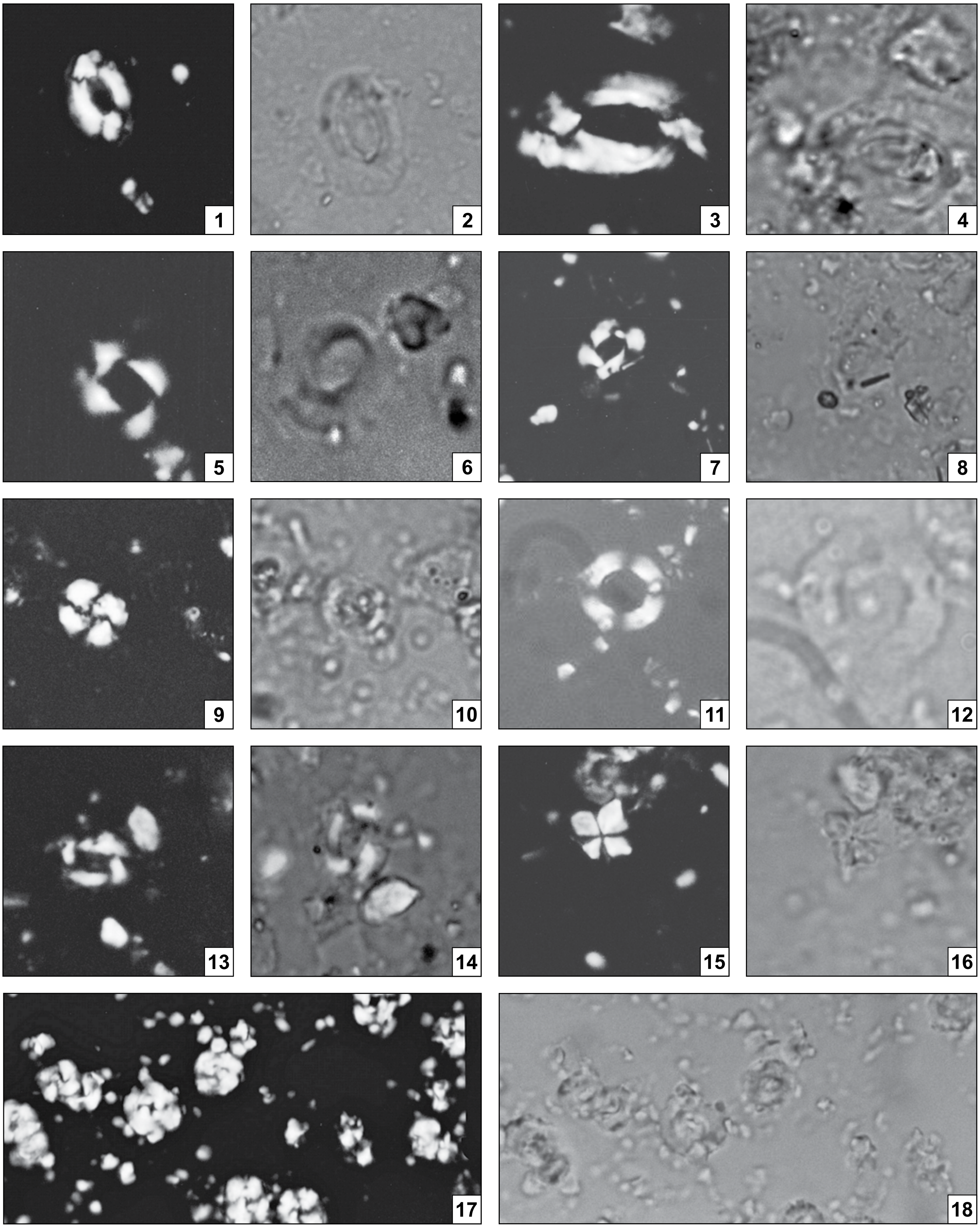
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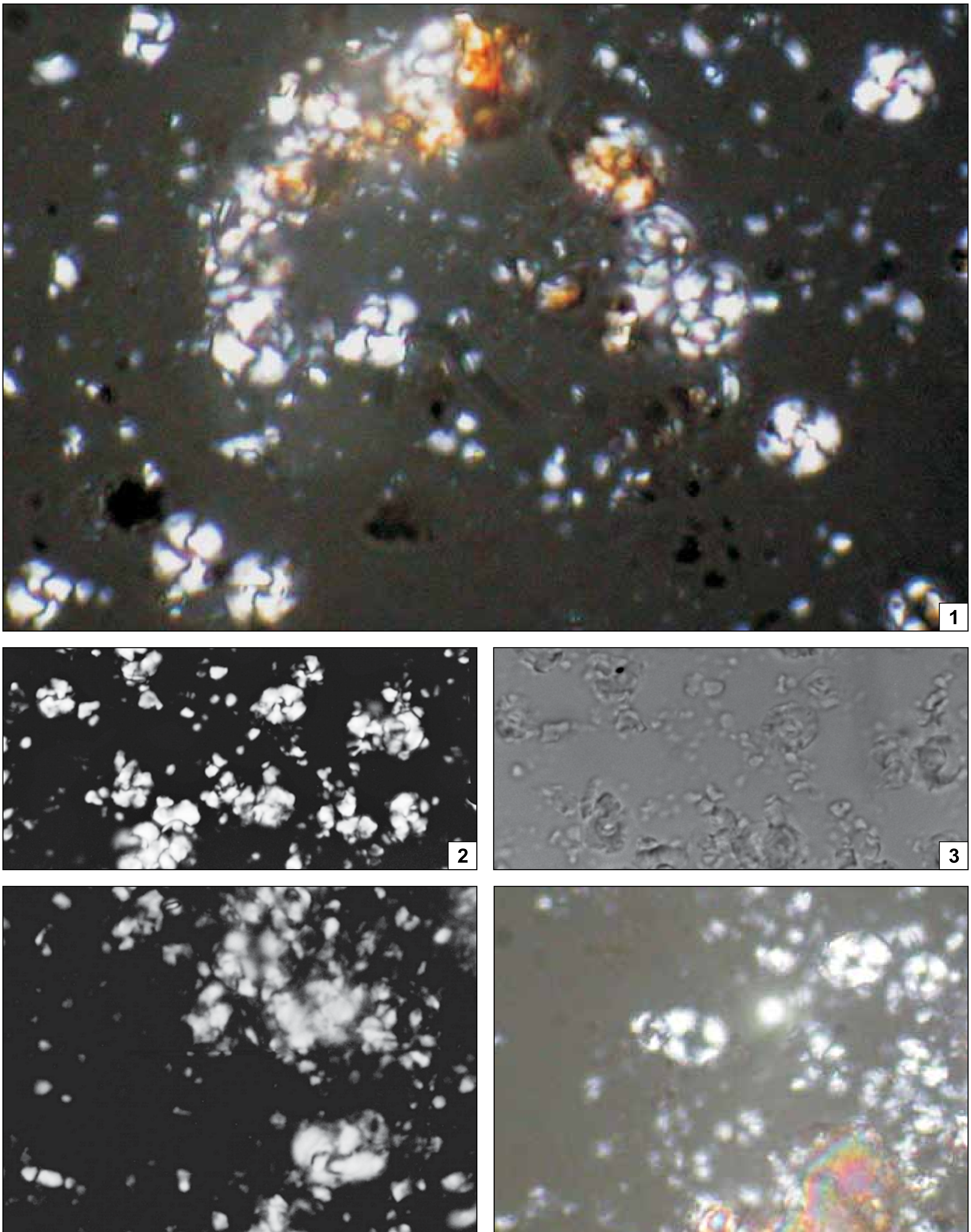
PLATE V

Figs. 1, 2. Jasło Limestone – CN
Wapień jasielski – CN

Fig. 3. Jasło Limestone – NL
Wapień jasielski – NL

Fig. 4. Zagórz Limestone – CN
Wapień z Zagórza – CN

Fig. 5. Zagórz Limestone – NL
Wapień z Zagórza – NL



Małgorzata Garecka — Record of changes in the Oligocene–Miocene sediments of the Menilite–Krosno Series of the Skole Unit based on calcareous nannoplankton studies – biostratigraphy and palaeogeographical implications (Polish Outer Carpathians)

PLATE VI

Fig. 1. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – CN; Jasło Limestone
Cyclicargolithus floridanus (Roth et Hay) Bukry – CN; wapień jasielski

Fig. 2. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – NL; Jasło Limestone
Cyclicargolithus floridanus (Roth et Hay) Bukry – NL; wapień jasielski

Fig. 3. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – CN; Zagórz Limestone
Cyclicargolithus floridanus (Roth et Hay) Bukry – CN; wapień z Zagórza

Fig. 4. *Cyclicargolithus floridanus* (Roth et Hay) Bukry – NL; Zagórz Limestone
Cyclicargolithus floridanus (Roth et Hay) Bukry – NL; wapień z Zagórza

Fig. 5. *Cyclicargolithus abisectus* (Műller) Wise – CN; Jasło Limestone
Cyclicargolithus abisectus (Műller) Wise – CN; wapień jasielski

Fig. 6. *Cyclicargolithus abisectus* (Műller) Wise – NL; Jasło Limestone
Cyclicargolithus abisectus (Műller) Wise – NL; wapień jasielski

Fig. 7. *Cyclicargolithus abisectus* (Műller) Wise – CN; Jasło Limestone
Cyclicargolithus abisectus (Műller) Wise – CN; wapień jasielski

Fig. 8. *Cyclicargolithus abisectus* (Műller) Wise – NL; Jasło Limestone
Cyclicargolithus abisectus (Műller) Wise – NL; wapień jasielski

Fig. 9. *Cyclicargolithus abisectus* (Műller) Wise – CN; Jasło Limestone
Cyclicargolithus abisectus (Műller) Wise – CN; wapień jasielski

Fig. 10. *Cyclicargolithus abisectus* (Műller) Wise – NL; Jasło Limestone
Cyclicargolithus abisectus (Műller) Wise – NL; wapień jasielski

Fig. 11. *Cyclicargolithus abisectus* (Műller) Wise – CN; Zagórz Limestone
Cyclicargolithus abisectus (Műller) Wise – CN; wapień z Zagórza

Fig. 12. *Cyclicargolithus abisectus* (Műller) Wise – NL; Zagórz Limestone
Cyclicargolithus abisectus (Műller) Wise – NL; wapień z Zagórza

Figs. 13, 14. *Discoaster deflandrei* Bramlette et Riedel – NL; Upper Menilite Beds
Discoaster deflandrei Bramlette et Riedel – NL; warstwy menilitowe górne

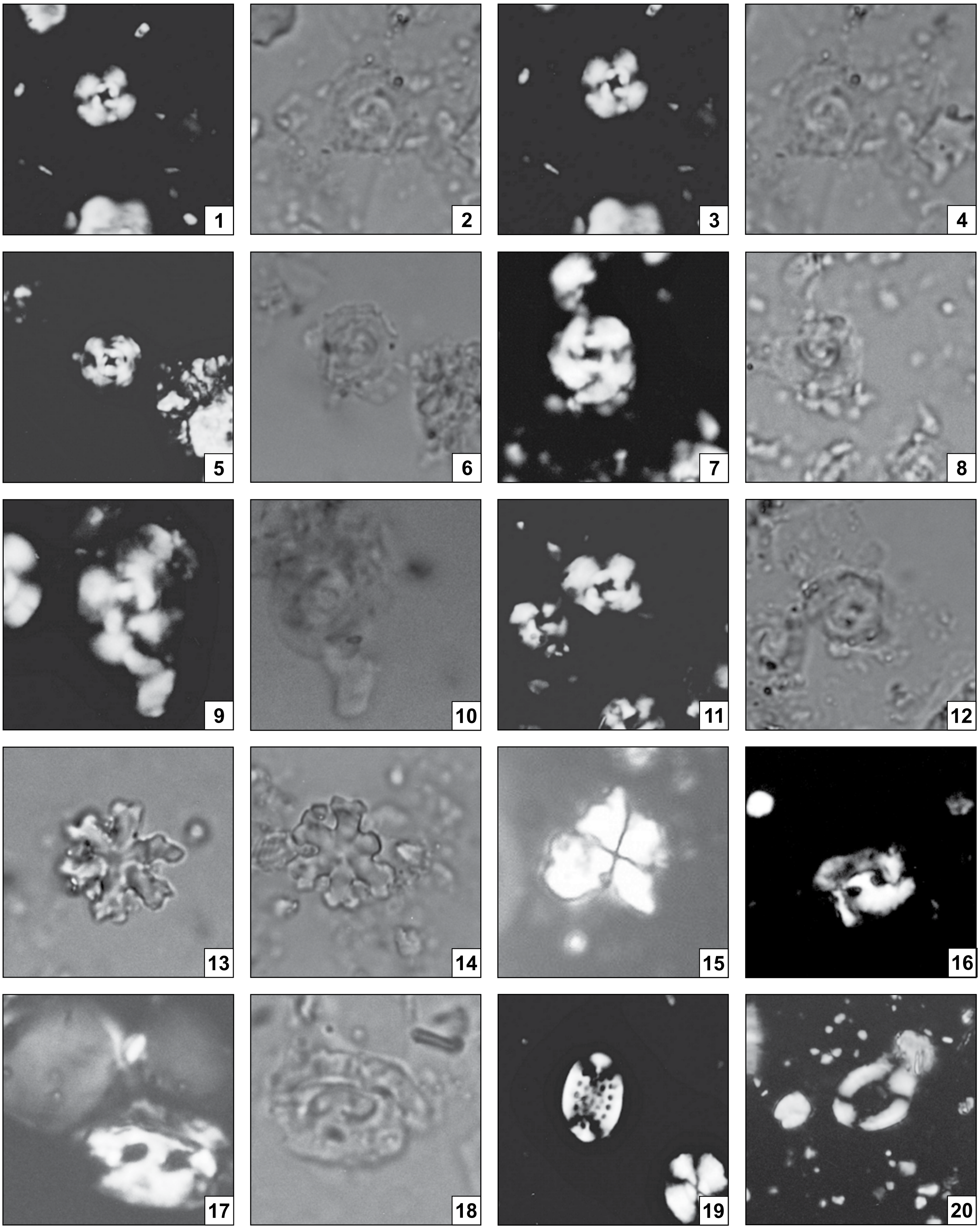
Fig. 15. *Sphenolithus moriformis* (Brőnnimann et Stradner) Bramlette et Wilcoxon – CN0°; Upper Menilite Beds
Sphenolithus moriformis (Brőnnimann et Stradner) Bramlette et Wilcoxon – CN0°; warstwy menilitowe górne

Figs. 16, 17. *Helicosphaera recta* Haq – CN; Upper Menilite Beds
Helicosphaera recta Haq – CN; warstwy menilitowe górne

Fig. 18. *Helicosphaera recta* Haq – NL; Upper Menilite Beds
Helicosphaera recta Haq – NL; warstwy menilitowe górne

Fig. 19. *Pontosphaera multipora* (Kamptner) Haq – CN; Upper Menilite Beds
Pontosphaera multipora (Kamptner) Haq – CN; warstwy menilitowe górne

Fig. 20. *Pontosphaera latelliptica* (Báldi-Beke) Perch-Nielsen – CN; Upper Menilite Beds
Pontosphaera latelliptica (Báldi-Beke) Perch-Nielsen – CN; warstwy menilitowe górne



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