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CORRELATION OF THE MIDDLE MIOCENE DEPOSITS IN SE POLAND AND WESTERN UKRAINE BASED ON FORAMINIFERA AND CALCAREOUS NANNOPLANKTON

Małgorzata GARECKA & Barbara OLSZEWSKA

Polish Geological Institute – National Research Institute, Carpathian Branch, Skrzatów 1, 31-560, Kraków, Poland, e-mails: malgorzata.garecka@pgi.gov.pl, barbara.olszewska@pgi.gov.pl

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Abstract: The aim of this study is to compare the assemblages of foraminifera and calcareous nannoplankton from the Middle Miocene sediments from SE Poland and western Ukraine. Detailed investigations revealed a high degree of similarity of foraminiferal assemblages of the *Pecten*/*Spirialis* beds of Poland and the Kosiv Formation of Ukraine. Assemblages from both areas are characterized by numerous arenaceous species of foraminifera (*Hyperammina granulosa*, *Ammodiscus miocenicus*, *Haplophragmoides indentatus*, *H. laminatus*), radiolarians, pteropods and index planktic species *Velapertina indigena*. High degrees of similarity also display assemblages from the Krakowiec beds (Poland) and the Dashava Formation (Ukraine). The lower parts of both subdivisions are characterized by the presence of *Anomalinoides dividens*. *Saccammina sarmatica*, *Bolivina sarmatica*, *Brizalina nisporenica*, and *Porosononion granosum* occur in the upper parts. Chloropycean *Halicoryne morelleti* is a characteristic element of the assemblages.

The calcareous nannoplankton assemblages contain almost identical species. The deposits lying above the evaporites (which belong to the NN6 zone) are included into the NN6, undivided NN6-NN7, and NN7 zones. The gradual impoverishment of the species of the upper part of NN6 and the lower part of NN7 zones is observed. The assemblages of the Krakowiec beds and the upper part of the Kosiv and Dashava formations are of low species diversity and are mainly restricted to a few species with high abundance. The assemblage is composed of placoliths (*Coccolithus* and *Reticulofenestra* species), high number of the reworked nannofossils and damaged elements.

Key words: foraminifera, calcareous nannoplankton, correlation, Middle Miocene, Carpathian Foredeep, Poland, Ukraine.

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INTRODUCTION

The studies of hydrocarbon resources of the Polish-Ukrainian borderland of the Carpathian Foredeep included stratigraphical calibration of potential reservoirs. Among microfossils suggested for stratigraphical research, only foraminifera and calcareous nannoplankton did provide satisfactory data. The Middle Miocene sediments that fill the foredeep basin are considerably diversified lithologically. A more detailed pattern of regional subdivision of the Polish part of the Carpathian Foredeep into eleven zones was proposed by Alexandrowicz (1971). In the eastern part of the foredeep, this author distinguished: the Marginal Zone of Roztocze (zone 8), the Eastern Central Zone, the Leżajsk–Lubaczów (zone 9) and the South-Eastern Zone, and the Przeworsk–Przemyśl (zone 10). In all mentioned zones the Middle Miocene sediments are represented by the Baranów beds, the chemical deposits, the *Spirialis*-bearing clays and sandy clays, passing laterally into the *Pecten* marls and the Krakowiec beds (Pawłowski *et al.*, 1985). Although further investigations led to the introduction of new subdivisions (Alexandrowicz *et al.*, 1982; Jasionowski, 1995, 1997), the essential lithological character of sediments remains the same. The present paper is an attempt of correlation of the Middle Miocene strata of the Polish-Ukrainian borderland based on foraminifera and calcareous nannoplankton.

GEOLOGICAL SETTING

The Miocene sediments of the Carpathian Foredeep have been extensively studied since the 19th century. The results of earlier investigations were summarized by Oszczypko *et al.* (2006). In SE Poland, the Middle Miocene sediments are represented by the following subdivisions: Baranów beds (early late Badenian), Krzyżanowice/Wie-

liczka formations (late Badenian), *Spirialis* and *Pecten* beds (latest Badenian–earliest Sarmatian), and Krakowiec beds (Sarmatian–early Pannonian) (Olszewska, 1999). The biostratigraphical research focused on the Baranów, *Pecten*/*Spirialis* and Krakowiec beds. The Baranów beds occur on the eastern and north-eastern part of the Polish Carpathian Foredeep. These beds are composed of sandy/clayey sediments with a layer of coralline algal limestones and tuffs, subdivided into three sequences: sandy (lower), limey with coralline algae (middle) and clayey/sandy (upper) ones (Ney, 1969). The presence of the coralline algal limestones (common in the northern part of the Carpathian Foredeep) led Alexandrowicz *et al.* (1982) to include the Baranów beds into the lower Badenian Pińczów Formation. According to Jasionowski (1997), the Baranów beds only partly (their middle and upper parts) correspond to the Pińczów Formation.

The Baranów beds are covered by the evaporitic horizon (Wieliczka/Krzyżanowice formations; Alexandrowicz *et al.*, 1982), the main correlative horizon of the Middle Miocene sedimentary succession of the Carpathian Foredeep (Peryt, 2006, with references therein). It is covered by the "*Pecten* beds" (Kowalewski, 1957). The deposits that constitute the main Upper Badenian part of the foredeep are grey-green carbonate siltstones and marls (Czapowski, 1994), with local sandy intercalations and tuffite layers. Microfossils are represented by foraminiferal assemblages of the Neobulimina longa and Hanzawaia crassiseptata zones of Łuczkowska (1964), radiolarians, and pteropods of the genus *Spirialis*. Alexandrowicz *et al.* (1982) included the *Pecten* beds into the Machów Formation. The *Pecten* beds pass towards the SE into open marine, clayey sediments of the *Spirialis* beds (Jurkiewicz & Karnkowski, 1961).

The Krakowiec beds, originally described by Łomnicki (1897), are composed of siltstones, claystones and coarse clastic sediments. The Krakowiec beds represent the youngest deposits of sedimentary sequence of the Polish part of the foredeep. In the lithostratigraphic scheme of Alexandrowicz *et al.* (1982), this subdivision forms the final segment of the Machów Formation.

The autochthonous Middle Miocene sediments of the Ukrainian part of the Carpathian Foredeep (the Bilche-Volytsia Zone) are composed of the following subdivisions: Zhuriv Formation (late early-early late Badenian), Tyras Formation/Ratyn limestones (late late Badenian), Kosiv Formation (latest Badenian), and Dashava Formation (early Sarmatian) (Andreyeva-Grigorovich *et al.*, 1997a). The transgressive Zhuriv Formation is composed of glauconitic sandstones, argillites and marls (Vyalov, 1965; Andreyeva-Grigorovich *et al.*, 1997a) and it is overlain by the Tyras Formation composed of gypsum, anhydrite and salts, intercalated by clays and limestones (Petryczenko *et al.*, 1994; Peryt *et al.*, 2010). In the NW part of the foredeep thick sediments of the Kosiv Formation occur. This formation is composed of four lithologically distinctive subdivisions: the Verbovets', Prut, Kolomyia and Kovalivka beds. The Verbovets' beds contain several layers of tuffs and tuffites and numerous radiolarians. Within the Prut beds sandstones predominate; characteristic is also a horizon with agglutinated foraminifera. The Kolomyia and Kovalivka beds occur in the SE part of the foredeep only. The latter beds are typified by the occurrence of brown coal seams (Vyalov *et al.*, 1981). The Sarmatian sediments occur mainly in the NW and central part of the Bilche-Volytsia Zone (Kultchytsky & Smirnov, 1995). The thick lower Sarmatian (Volhynian) clays, with sandstones in the upper part and numerous tuff layers, form the Dashava Formation. Lihological diversity of the formation (among others, the presence of tuff horizons) made it possible to distinguish several subdivisions (Andreyeva-Grigorovich *et al.*, 1997a; Kurovets *et al.*, 2004). (Fig. 1)

PREVIOUS BIOSTRATIGRAPHICAL RESEARCH

Foraminifera

Initial micropalaeontological investigations suggested that the Baranów beds comprise early Badenian foraminifera of the Candorbulina suturalis and Uvigerina costai zones of Łuczkowska (1963) as well as molluscs *Amussium denudatum* Reuss and *Ostrea cochlear* Poli (Odrzywolska-Bieńkowa, 1966, 1972). Later, it was demonstrated that the subdivision includes also sediments of the late Badenian age (Bielecka, 1974; Szczechura, 1982).

Micropalaeontological investigations of the *Pecten* beds were performed by Odrzywolska-Bieńkowa (1966) who identified foraminifera of the Neobulimina longa and Hanzawaia crassiseptata zones of Łuczkowska (1964) as well as radiolarians and pteropods. The coeval, open marine *Spirialis* beds are rich in pteropods of the genus *Spirialis*, radiolarians and fish remains. Foraminifera are more frequent in the upper part of the subdivision and contain, among others, *Hanzawaia crassiseptata* (Łuczkowska), *Velapertina indigena* (Łuczkowska), *Ammodiscus miocenicus* Karrer, *Cyclammina* sp., *Haplophragmoides* sp., and *Quinqueloculina* div. sp. (Jurkiewicz & Karnkowski, 1961).

Micropalaeontological studies of the Krakowiec beds were extensively carried out by Jurkiewicz (in: Ney, 1969) who identified two Sarmatian foraminiferal zones: 1 – with *Anomalinoides dividens*, and 2 – with numerous *Quinqueloculina* sp. Odrzywolska-Bieńkowa (1966) identified the Anomalinoides dividens and Elphidium hauerinum zones (Łuczkowska, 1964) within the Krakowiec beds; then Odrzywolska-Bieńkowa (1972) and Łuczkowska (1972) distinguished there foraminiferal zones representing the early and middle Sarmatian (Volhynian–Bessarabian). Subsequent foraminiferal studies (Czepiec, 1997; Olszewska, 1999) of the Krakowiec beds confirmed such an age assignment. In turn, the Pannonian (early Late Miocene) age was suggested by Paruch-Kulczycka (1999) based on foraminifera and the camoebians from the upper part of the Krakowiec beds in the well Jamnica S-119 (Fig. 2).

In western Ukraine, foraminifera occur in the upper part of the Zhuriv Formation only, and their assemblages are composed predominantly of planktic species. The characteristic species include: *Orbulina suturalis* Brönnimann, *Praeorbulina glomerosa* (Blow), *Globigerinoides trilobus* (Reuss), *Globoquadrina altispira* (Cushman et Jarvis), *Globoquadrina dehiscens* (Chapmann, Parr et Collins), and

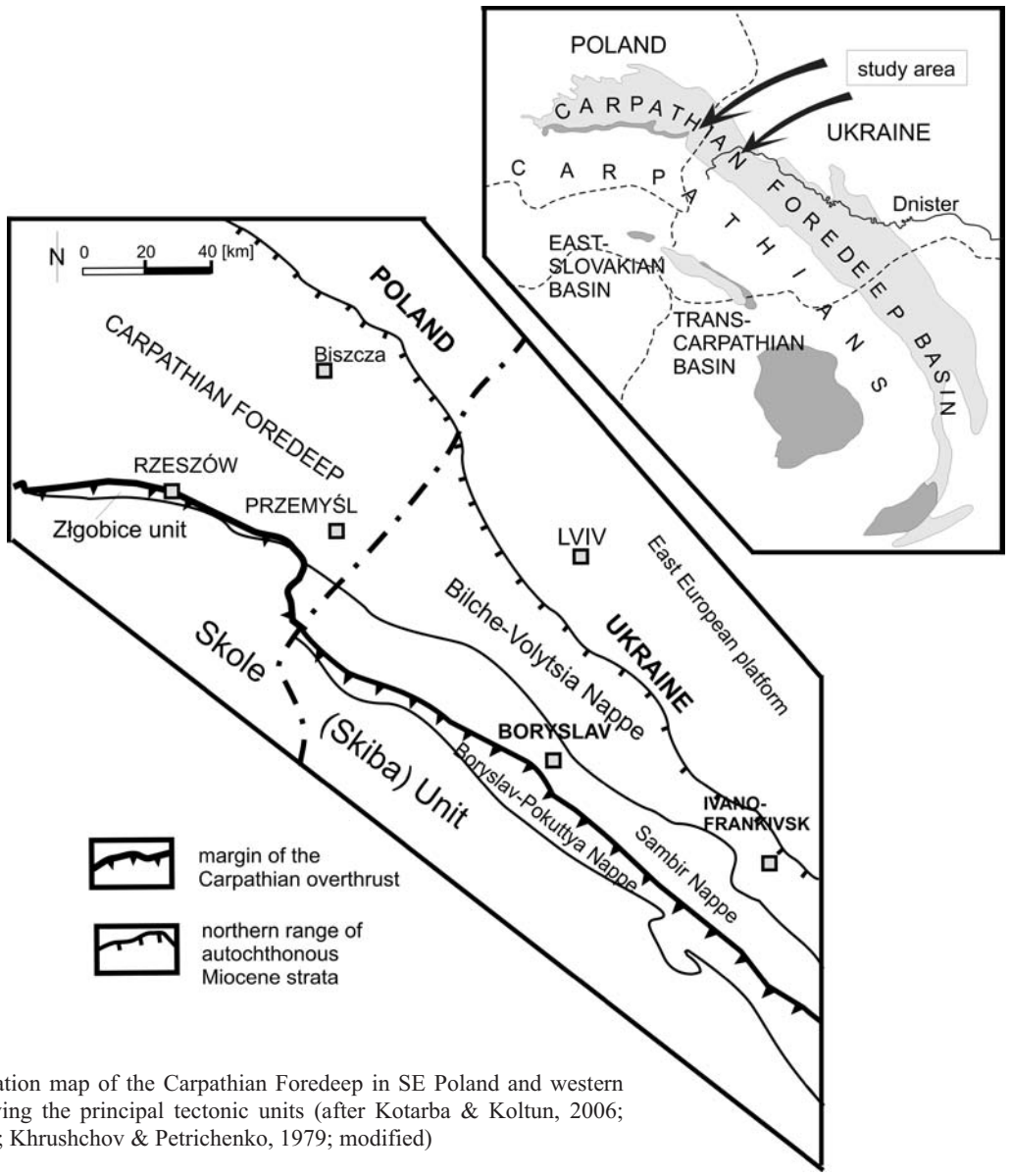

Fig. 1. Location map of the Carpathian Foredeep in SE Poland and western Ukraine, showing the principal tectonic units (after Kotarba & Koltun, 2006; Garlicki, 1979; Khrushchov & Petrichenko, 1979; modified)

Globorotalia scitula (Brady) (Pishvanova, 1969; Gruzman et Trofimovich, 1996; Andreyeva-Grigorovich *et al.*, 1997a). This assemblage corresponds to the Orbulina suturalis zone.

The evaporatic sediments of the Tyras Formation are poor in foraminifera. Clayey intercalations contain, however, age-significant species, such as *Neobulimina longa* (Venglinskyi) and *Uvigerina semiornata* d'Orbigny indicating relationship of these assemblages with those of the Kosiv Formation (Pishvanova, 1969). Foraminifera of the Kosiv Formation were studied by Livental *et al.* (1953), Pishvanova (in: Subbotina *et al.*, 1960), Pishvanova (1969), and Gruzman and Trofimovich (1996). Peryt and Peryt (2009) and Gedl and Peryt (2011) studied foraminifera from the Tyras gypsum in the Kosiv Formation transition.

The Verbovets' beds are characterized by numerous *Globigerina bulloides* d'Orbigny, *G. regularis* d'Orbigny, *Subbotina cognata* (Pishvanova), and *Velapertina indigena*. In addition, radiolarians occur in the lower part of the subdivision while pteropods of the genus *Spiratella* and foraminifera occur in its upper part (Pishvanova, 1969). Foraminiferal assemblages were assigned to the local Globigerina decoraperta zone.

The Prut beds are characterized by co-occurrence of agglutinated and calcareous foraminifera of the Bogdanowiczia pokutica and Bulimina-Bolivina zones, with typical *Hyperammina granulosa* Venglinski, *Bogdaniowiczia pokutica* Pishvanova, *Cyclammina pleschakovi* Pishvanova, and numerous *Bulimina elongata* d'Orbigny (Pishvanova, 1969).

The Kolomyia beds represent the Cassidulina crista zone with numerous *Cassidulina crista* Pishvanova.

The Kovalivka beds contain mixed assemblages of euryhaline and stenohaline foraminiferal species assigned to the Ammonia galiciana zone. The index species *Ammonia galiciana* Putria is accompanied by *Porosononion granosum* (d'Orbigny), *Schackoinella imperatoria* (d'Orbigny) and representatives of genera *Quinqueloculina* and *Elphidium* (Pishvanova, 1969).

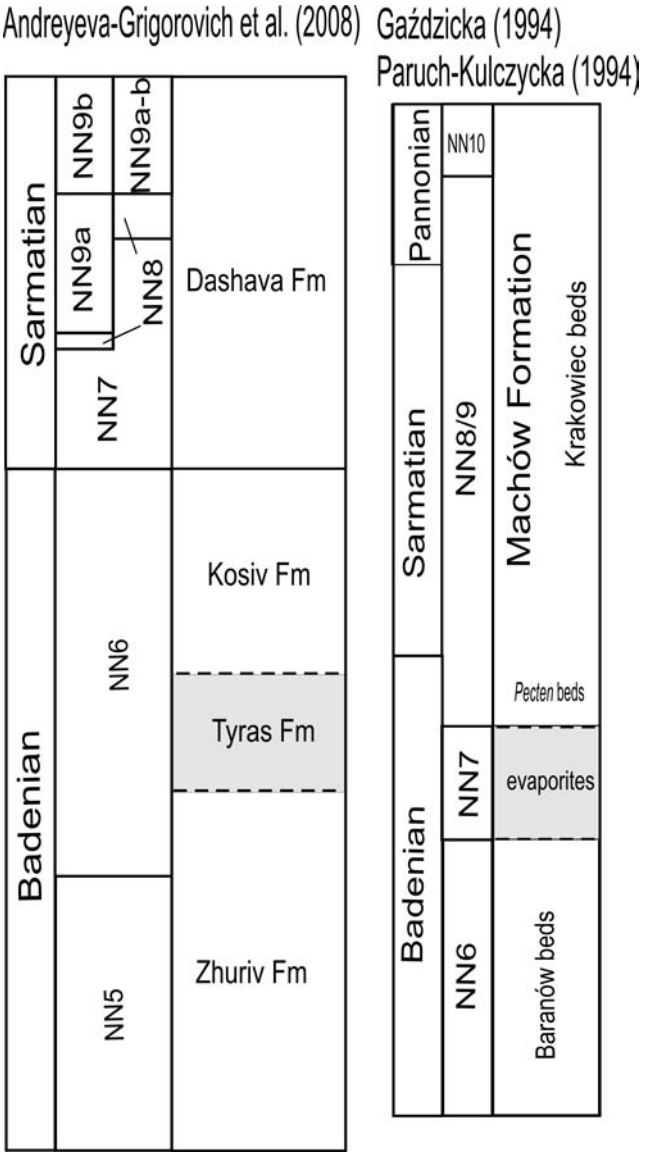

Fig. 2. Biostratigraphical position of the Miocene deposits of the Polish (after Gaździcka, 1994 and Paruch-Kulczycka, 1994) and Ukrainian – Bilche-Volytsia Zone (after Andryeva-Grigorovich *et al*., 2008) parts of the Carpathian Foredeep

Foraminiferal assemblages of the Dashava Formation are assigned to two zones. The lower Cibicides badenensis zone occurs at the base of the formation and is characterized by numerous specimens of the index species accompanied by *Sinoloculina nitens* (Reuss), *Articulina problema* Bogdanovich, and *Elphidium advenum* Cushman (Pishvanova, 1969). The upper Porosononion subgranosus – Quinqueloculina reussi zone contains numerous representatives of Miliolidae. To important species belong: *Varidentella reussi* (Bogdanovich), *V. sarmatica* (Karrer), *Articulina problema*, *Elphidium reginum* (d'Orbigny), and *E. obtusum* (d'Orbigny). Except for foraminifera, there also occur representatives of the calcareous algae *Halicoryne morelleti* and ostracods (Pishvanova, 1969; Gruzman & Trofimovich, 1996).

Calcareous nannoplankton

In SE Poland, calcareous nannoplankton from the Baranów beds is common but the species diversity is low (Peryt *et al.*, 1998). The most common species are: *Coccolithus pelagicus* (Wallich) Schiller; *Reticulofenestra* spp., and *Helicosphaera kamptneri* Hay et Mohler. The other species occur sporadically (*e.g.*, *Geminithella rotula* (Kamptner) Backman, *Helicosphaera* sp., *Sphenolithus* sp., *Thoracosphaera* sp., Cretaceous taxa). The long-ranging, resistant to dissolution species are predominant in the assemblage, but the guide species are lacking. The presence of *Cyclicargolithus floridanus* (Roth et Hay) Bukry in the assemblage of the anhydrite horizon (directly above the Baranów beds) indicates that the deposits are not younger than the NN6 Zone (Peryt *et al.*, 1998). Gaździcka (1994) included the Baranów beds to the NN6 Zone (Fig. 2) based on the occurrence of: *Calcidiscus leptoporus* (Murray et Blackman) Loeblich et Tappan, *Coccolithus pelagicus*, *Discoaster exilis* Martini et Bramlette, *Reticulofenestra minutula* (Gartner) Haq et Berggren, *Reticulofenestra pseudoumbilica* Gartner, and the absence of *Sphenolithus heteromorphus* Deflandre and *Discoaster kugleri* Martini et Bramlette. The *Pecten* beds (Gaździcka, 1994) were assigned to the undivided NN8/9 zones (Fig. 2). The characteristic feature of the assemblage is the occurrence of *Helicosphaera* genus. Helicoliths are accompanied by: placoliths, *Rhabdosphaera siccus* Stradner, *Sphenolithus abies* Deflandre, and Thoracosphaeraceae. According to Gaździcka (1994), the single occurrence of *Discoaster kugleri* (a zonal marker for the lower limit of NN7) in the *Pecten* beds suggests a redeposition and thus the deposits overlying evaporites (the *Pecten* beds) are younger than the NN7 Zone. The characteristic feature of the Syndesmya beds assemblage is the increase in number of *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre and *Thoracosphaera* genus. Gaździcka (1994) assigned these sediments to the NN8/9 zone. In the Krakowiec beds, *Helicosphaera sellii*, *H. walbersdorfensis* Muller, and *Sphenolithus abies* disappear and *H. kamptneri* becomes rare. The assemblage is restricted to some placoliths. Discoasteraceae are represented by *Discoaster calcaris* Gartner. Gaździcka (1994) suggested that these sediments belong to the NN8 and NN9 zones (Sarmatian according to Gaździcka, 1994; Pannonian according to Piller *et al.*, 2007) (Fig. 2). In the lower part of the Krakowiec beds, high abundance of *Coccolithus pelagicus* and layers with nearly monospecific assemblage (*Reticulofenestra pseudoumbilica* or *Umbilicosphaera jafarii*) without evidence of reworking are observed. In the upper part of the Machów Formation the number of reworking specimens increases. In the top part of the beds (the vicinity of Stalowa Wola) *Discoaster bellus* Bukry et Percival, *D. brouweri* Tan, *D. intercalaris* Bukry, *D. hamatus* Martini et Bramlette are found. It indicates, according to Gaździcka (1994), the NN9-NN10 zones. Preliminary studies by Jugowiec (in: Garecka & Jugowiec, 1999) of several samples of the Krakowiec beds indicated the NN5 zone. Garecka (in: Szydło *et al.*, 2009) assigned the Krakowiec beds, based on calcareous nannoplankton analysis, to the late late Badenian and to the lowermost part of the late Sarmatian. Placoliths (long-ranging)

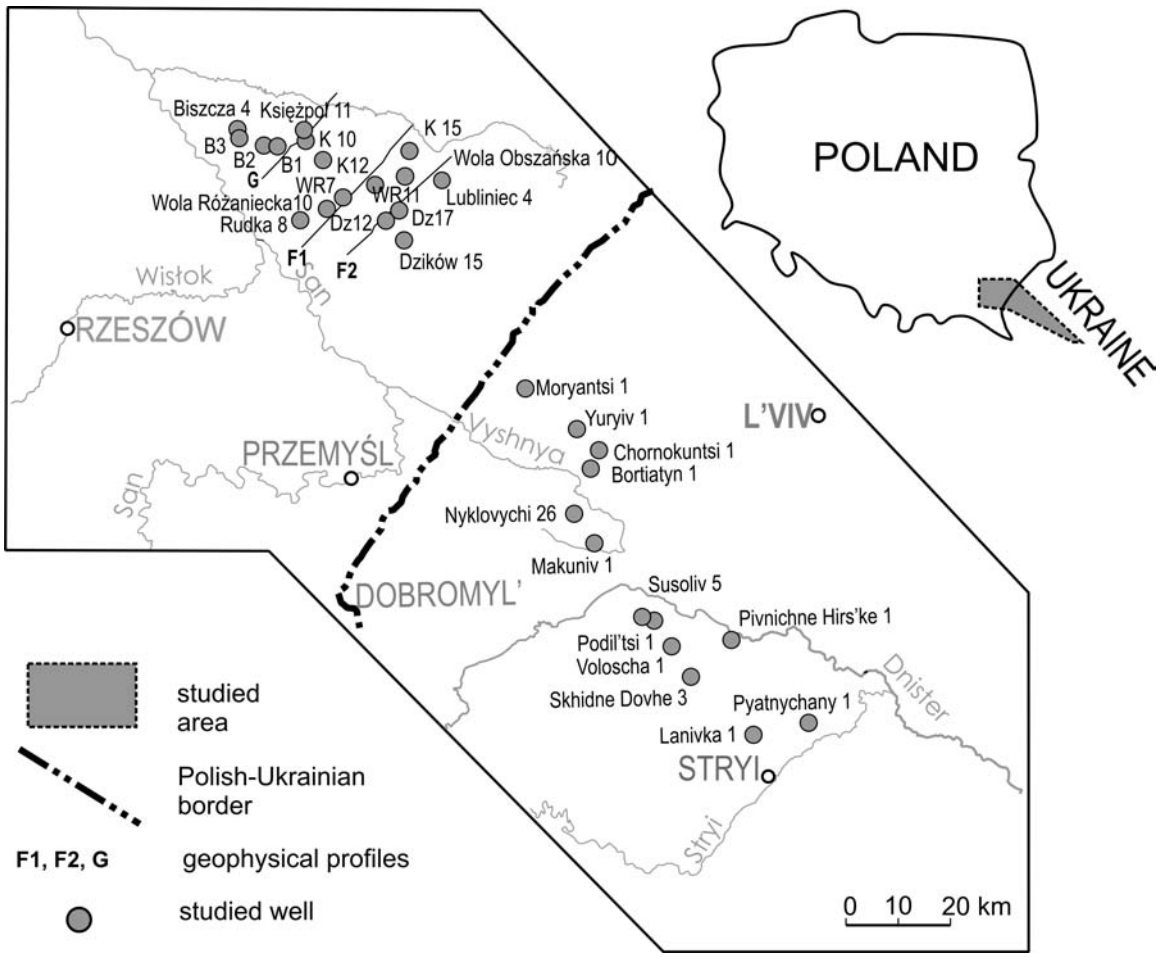

Fig. 3. Location of the studied wells in the Polish (SE part) and Ukrainian (NW part) Carpathian Foredeep

are the dominant forms in these deposits (*Coccolithus pelagicus*, *Reticulofenestra pseudoumbilica*, "small *reticulofenetrids*" and *Cyclicargolithus floridanus*). The majority of the assemblage consists of destroyed and small fragments of undistinguishable forms. The diagnostic species occurred as single specimens or were missing at all, and it was not possible to determine the age precisely. The occurrence of *Discoaster kugleri* (and/or the absence of *Cyclicargolithus floridanus*) in the samples indicated that they represent at least the uppermost part of the early Sarmatian or the lower part of the late Sarmatian. The sediments of the Machów Formation in the Rzeszów area belong to the upper part of the NN6 (the early Sarmatian) and to the NN7 (the lowermost part of the late Sarmatian) zones (Krzywiec *et al.*, 2008; Lelek *et al.*, 2010).

In western Ukraine, calcareous nannoplankton investigation conducted by Andreyeva-Grigorovich (in: Andreyeva-Grigorovich *et al.*, 1997a, b) allowed to relate the deposits of the Tyras Formation first to the lower part of the late Badenian (NN5 zone), with the calcareous association composed of *Helicosphaera kamptneri*, *Cyclicargolithus floridanus*, *Coccolithus pelagicus*, *Pontosphaera multipora*, *Calcidiscus leptoporus*, *Sphenolithus abies*, *S. heteromorphus*, *S. moriformis* (Brönnimann et Stradner) Bramlette et Wilcoxon, and then to the lower part of the NN6 zone and undivided NN6-7 zones (Andreyeva-Grigorovich *et al.*, 2003, 2008). According to Andreyeva-Grigorovich, calcareous nannoplankton of the NN5 zone was undoubtedly redeposited. The Ratyn Limestone, which directly overlies gypsum deposits, represents a part of the NN6/NN7 zones (Peryt & Peryt, 1994). Coccoliths were rare and poorly preserved due to intensive recrystallization. Andreyeva-Grigorovich (in: Andreyeva-Grigorovich *et al.*, 1997a, b) assigns the Kosiv Formation to the late Badenian. The lower part of the Kosiv Formation, *i.e*. the Verbovets' beds, contain, *i.a*.: *Sphenolithus heteromorphus*, *S. abies*, *Helicosphaera kamptneri*, *Discoaster variabilis* Martini et Bramlette, *Cyclicargolithus floridanus*, *Reticulofenestra pseudoumbilica*, *Calcidiscus leptoporus*, and *Thoracosphaera albatrosiana* Kamptner (Andreyeva-Grigorovich & Savitskaya, 1996; Andreyeva-Grigorovich *et al.*, 1997a, b). The upper part of the Verbovets' beds (SE part of the foredeep) contains nearly monospecific layers with *Sphenolithus abies* (Andreyeva-Grigorovich & Savitskaya, 1996, Andreyeva-Grigorovich *et al.*, 1997b). The upper part of the Kosiv Formation (Prut, Kolomyia and Kovalivka beds) belongs to the undivided zones NN6-NN7 (Discoaster exilis-Discoaster kugleri zones) based on co-occurrence of: *Triquetrorhabdulus rugosus* Bramlette et Wilcoxon, *Coronocyclus serratus* Hay, Mohler et Wade, *Calcidiscus leptoporus*, *Cyclicargolithus floridanus*, *Helicosphaera kamptneri*, *Pontosphaera multipora* (Kamptner) Roth, *Rhabdo-*

sphaera siccus, *Holodiscolithus macroporus* (Deflandre) Roth, *Reticulofenestra pseudoumbilica*, and the single appearance of *Discoaster variabilis*, *D. exilis* and *Sphenolithus abies*. A characteristic feature of nannoplankton association of the Kosiv Formation is its gradual impoverishment towards the upper part of the formation. Currently, Andreyeva-Grigorovich *et al.* (2008) include the Kosiv Formation into the undivided NN6-7 zones (the evaporites representing the lower part of the NN6 zone). Based on calcareous nannoplankton, the Dashava Formation represents the lower Sarmatian (see Andreyeva-Grigorovich *et al.*, 1997a, b, 2008) (Fig. 2). The nannoflora association of this formation is rather poor. At the base of the formation, some more species occur: *Coccolithus pelagicus*, *Helicosphaera kamptneri*, *Cyclicargolithus floridanus*, *Reticulofenestra pseudoumbilica*, and *Braarudosphaera bigelowii subsp. parvula* level (acme zone *parvula*) (Andreyeva-Grigorovich & Smirnov, 1996; Andreyeva-Grigorovich & Savitskaya, 1996; Andreyeva-Grigorovich *et al.*, 1997b). In the upper part of the lower Sarmatian, the beds with *Calcidiscus macintyrei* (Bukry et Bramlette) Loeblich et Tappan, *Cyclicargolithus floridanus* and *Reticulofenestra pseudoumbilic*a were established. The lower Sarmatian assemblage corresponds with the assemblage of the Upper Kosiv Formation. The discrimination between these two assemblages is impossible.

MATERIAL AND METHODS

The investigated material from the Polish part of the Carpathian Foredeep (about 100 samples) came from wells grouped along geophysical profiles G, F1 and F2, close to the Polish-Ukrainian border. Individual profiles included the following wells: G – Biszcza 1–4 and Księżpol 10, 11, 12, 15; F 1 – Wola Różaniecka 7, 10 and Rudka 8; and F 2 – Wola Obszańska 10, Lubliniec 4, and Dzików, 12, 15, 17. Samples from the Ukrainian part of the Carpathian Foredeep (about 70 samples) came from the Bilche-Volytsia Zone drilled by wells: Bortiatyn 1, Chornokuntsi 1, Lanivka 1, Makuniv 1, Mosty 1, Moryantsi 1, Nyklovychi 26, Pivnichne Hirs'ke 1, Podil'tsi 1, Pyatnychany 1, Skhidne Dovhe 3, Susoliv 5, and Voloscha 1 (Fig. 3).

Foraminiferal studies were performed on samples treated with water, washed and dried in oven. Photos of stratigraphically important species were taken under the SEM microscope.

The photo plates present exclusively foraminifera identified in the Ukrainian samples. The Polish specimens are to be found in plates published by Odrzywolska-Bieńkowa and Olszewska (1996) and Olszewska (1999).

The smear slides for nannoplankton studies 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 inspected with a Nikon Eclipse E400 Pol light microscope at 1000x magnification. Photos were taken under the light microscope.

BIOSTRATIGRAPHICAL RESULTS

Foraminifera

Sediments of the Baranów beds were recognised in wells Wola Różaniecka 10 (profile F1) and Dzików 12 (profile F2). Foraminiferal assemblages are composed of: *Amphistegina mamilla* (Fichtell et Moll), *Bulimina aculeata* d'Orbigny, *B. elongata*, *Heterolepa dutemplei* (d'Orbigny), *Pullenia bulloides* (Reuss), *Melonis barleeanus* (Williamson), *Sphaeroidina bulloides* d'Orbigny, *Uvigerina semiornata* (d'Orbigny), *Globigerina bulloides*, *Globigerinoides trilobus*, *Tenuitellinata tarchanensis* (Subbotina et Chiutzieva), and *Paragloborotalia mayeri* (Cushman et Ellisor). They represent the Uvigerina semiornata (=Uvigerina costai) zone. Foraminifera characteristic for the Baranów beds, representing Praeorbulina suturalis and Uvigerina semiornata zones (Łuczkowska, 1964), were also identified in wells Jedlinki 2 and Ryszkowa Wola 7.

Sediments of the *Pecten*/*Spirialis* beds were studied in wells Wola Różaniecka 7, 10, and 11 (profile F1). The foraminiferal assemblage contained: *Ammodiscus miocenicus*, *Hyperammina granulosa*, *Reticulophragmium crassum* (Reuss), *Pseudotriplasia elongata* Małecki, *Pavonitina adanula* Małecki, *Martinotiella communis* (d'Orbigny), *Haplophragmoides indentatus* Voloshinova, *H. laminatus* Voloshinova, *Spirorutilus carinatus* (d'Orbigny), *Bolivina tarchanensis* Subbotina et Chutzieva, *Neobulimina longa* Venglinski, *Sinoloculina nitens*, *Hanzawaia crassiseptata*, *Globigerina bulloides*, *Globoturborotalita druryi* (Akers), *Velapertina indigena*, and *Tenuitellinata tarchanensis*. Foraminifera were accompanied by pteropods: *Spiratella tarchanensis* (Kittl), *S. andrusovi* Kittl, bolboforms (*Protophyta*, incertae sedis): *Bolboforma badenensis* Szczechura, and radiolarians. The assemblage corresponds to the Neobulimina longa and Hanzawaia crassiseptata zones (Łuczkowska, 1964).

Sediments of the Krakowiec beds were investigated in wells: Rudka 8, Wola Różaniecka 7, 11, 10 (profile F1), Wola Obszańska 10, Lubliniec 4, Dzików 17 (profile F2), Biszcza 1, 3, 4, and Księżpol 10, 11, 12, 15 (profile G).

The Lower Sarmatian (Volhynian) is represented by two foraminiferal assemblages. The older (early Volhynian) assemblage is characterized by the occurrence of *Anomalinoides badenensis* (Łuczkowska), accompanied by *Brizalina dilatata* (Reuss), *Ammonia beccarii* (Linne), *Schackoinella imperatoria* (d'Orbigny), *Articulina problema*, *Elphidium puscharovski* Serova, *Globigerina bulloides*, *Tenuitella neobrevispira* Quianyu, *T. subcretacea* (Łomnicki), and *Turborotalita quinqueloba* (Natland). Characteristic are also representatives of the calcareous algae *Halicoryne morelleti*. The assemblage represents the Anomalinoides dividens and Cycloforina karreri ovata foraminiferal zones (Łuczkowska, 1964).

The younger (late Volhynian) assemblage contained: *Saccammina sarmatica* Venglinski, *Porosononion granosum*, *Brizalina nisporenica* Didkovskyi, *Bolivina sarmatica* Didkovski, *Varidentella sarmatica* Karrer, *Affinetrina cubanica* (Bogdanovich), *Elphidium hauerinum* d'Orbigny, *E. joukovi* Serova, *Caucasina subaculeata* Venglinski, *Nonion bogdanoviczi* Voloshinova, and *Rotaliella risilla*

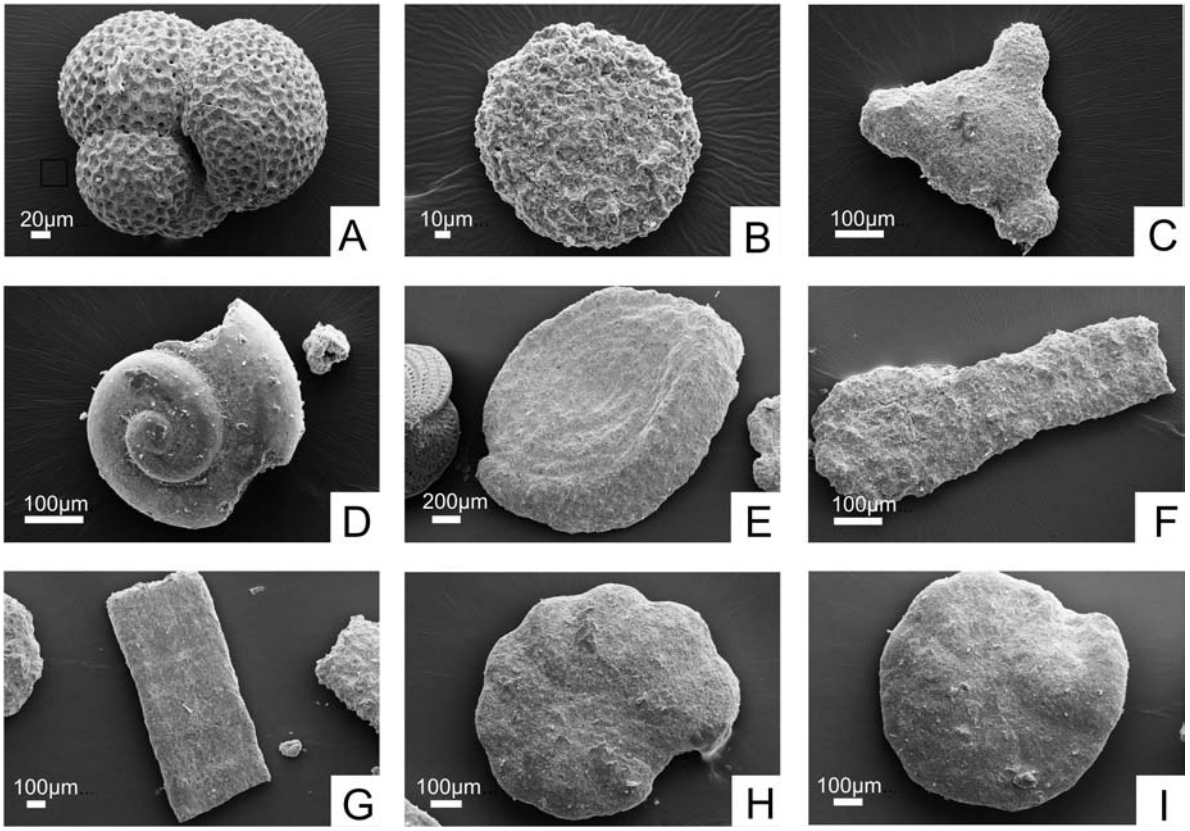

Fig. 4. Foraminifera of the Kosiv Formation (West Ukraine). **A** – *Globigerina bulloides* d'Orbigny, Kosiv Fm., Verbovets' beds, Mosty 1 well, depth 1,413.0–1,420.0 m; **B** – radiolaria, Kosiv Fm., Verbovets' beds, Mosty 1 well, depth 1,413.0–1,420.0 m; **C** – radiolaria, Kosiv Fm., Verbovets' beds, Mosty 1 well, depth 1,413.0–1,420.0 m; **D** – *Spirialis* sp., Kosiv Fm., Verbovets' beds, Mosty 1 well, depth 1,413.0–1,420.0 m; **E** – *Ammodiscus miocenicus* Karrer, Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **F** – *Hyperammina granulosa* Venglinskyi, Kosiv Fm., Prut beds, Bortiatyn 1 well, depth 1,802.0–1,810.0 m; **G** – *Hyperammina taurinensis* (Sacco), Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,150.0–1,160.0 m; **H** – *Cyclammina zemplinica* Cicha & Zapletalova, Kosiv Fm., Prut beds, Bortiatyn 1 well, depth 1,802.0–1,810.0 m; **I** – *Cyclammina vulchoviensis* Venglinskyi, Kosiv Fm., Prut beds, Bortiatyn 1 well, depth 1,802.0–1,810.0 m

(Bogdanovich). The assemblage corresponds to the Varidentella sarmatica and Elphidium hauerinum foraminiferal zones (Łuczkowska, 1964).

The Early late Sarmatian (early Bessarabian) foraminiferal assemblages are youngest in SE Poland. These assemblages are poor in foraminiferal species, which are represented by: *Ammonia beccarii*, *A. lepida* Cushman, *Porosononion granosum*, *Elphidium joukovi*, *Bolivina sarmatica*, and *Brizalina saggitula* (Didkovskyi). Foraminifera are accompanied by elements of statocysts of *Mysidacea* (shrimps) of the genus *Paramysis*, and fish otoliths. The assemblage represents the Porosononion granosum zone (Łuczkowska, 1964).

In western Ukraine, foraminifers tentatively related to those of the Zhuriv Formation were encountered in the Hrudivka 1 well. Poorly diversified assemblage contained *Brizalina dilatata*, *Cassidulina laevigata* d'Orbigny, *Ammonia beccarii*, *Cassigerinella chipolensis* (Cushman et Ponton), *Quinqueloculina* sp., *Tenuitellinata pseudoedita* (Subbotina), and sponge spicules.

Sediments of the Verbovets' beds were identified in wells: Chornokuntsi 1, Mosty 1, and Moryantsi 1. Foraminiferal assemblages are composed of numerous *Globigerina bulloides* (Fig. 4A), and *Subbotina cognata*, *Tenuitellinata pseudoedita*, *Angulogerina angulosa* (Willamson), *Cassidulina margareta* Karrer. Foramimifera are accompanied by numerous radiolarians (Figs 4B, 4C) and pteropods (Fig. 4D).

Sediments of the Prut beds were identified in wells: Bortiatyn 1, Pyatnychany 1, and Voloscha 1. Foraminiferal assemblages are characterized by numerous agglutinated species, among others: *Ammodiscus miocenicus* (Fig. 4E), *Bogdanoviczia pokutica*, *Hyperammina granulosa* (Fig. 4F), *Hyperammina taurinensis* (Sacco) (Fig. 4G) *Cyclammina zemplinica* Cicha et Zapletalova (Fig. 4H), *C. vulchovensis* Venglinski (Fig. 4I), *Haplophragmoides laminatus* (Fig. 5A), *H. indentatus*, and *Martinotiella communis* (Fig. 5B). Benthic calcareous foraminifera are represented by: *Fursenkoina acuta* (d'Orbigny) (Fig. 5C), *Bulimina insignis* Łuczkowska (Fig. 5D), *Pappina* cf. *graciliformis* (Papp et Turnovsky) (Fig. 5E), and *Sinuloculina consobrina* (d'Orbigny) (Fig. 5F). Among planktic species, the constant presence of the late Badenian index species *Velapertina indigena* (Fig. 5G) is noteworthy. The index species is accompanied by *Orbulina suturalis* (Fig. 5H), *Globoquadrina altispira* (Cushman et Jarvis) (Fig. 5I), and *Praeorbulina glomerosa* (Fig. 6A). The assemblage represents the Bogdanowiczia pokutica zone (Pishvanova, 1969).

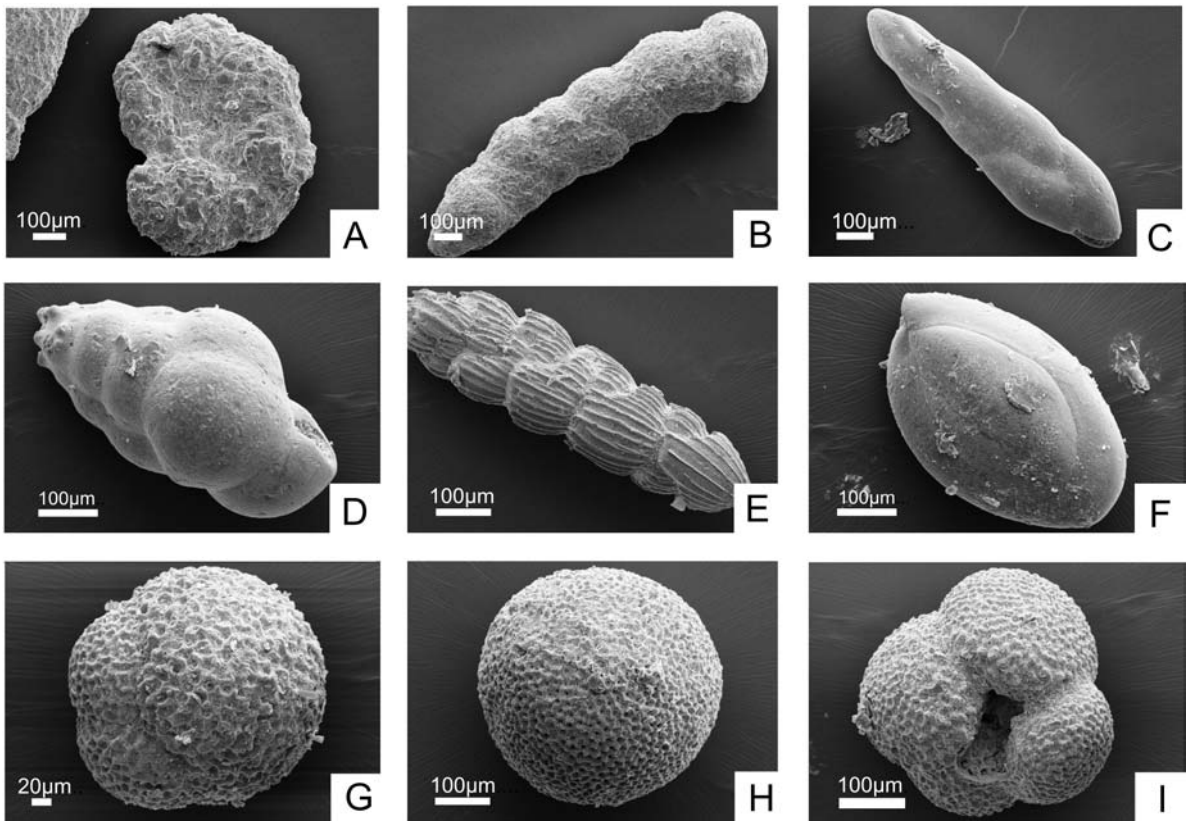

Fig. 5. Foraminifera of the Kosiv Formation (West Ukraine). **A** – *Haplophragmoides laminatus* Voloshinova, Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **B** – *Martinotiella communis* (d'Orbigny), Kosiv Fm., Prut beds, Moryantsi 1 well, depth 2,015.0–2,023.0 m; **C** – *Fursenkoina acuta* (d'Orbigny), Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **D** – *Bulimina insignis* Łuczkowska, Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,140.0–1,150.0 m; **E** – *Pappina* cf. *graciliformis* (Papp & Turnovsky), Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **F** – *Sinuloculina consobrina (d'Orbigny)*, Kosiv Fm., Prut beds, Bortiatyn 1 well, depth 1,802.0–1,810.0 m; **G** – *Velapertina indigena* (Łuczkowska), umbilical side, Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **H** – *Orbulina suturalis* Brönnimann, Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **I** – *Globoquadrina altispira* (Cushman & Jarvis), umbilical side, Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m

Foraminiferal assemblages that tentatively represent the Kolomyia beds were identified in wells: Podil'tsi 1, Lanivka 1, and Skhidne Dovhe 3. Foraminiferal assemblages contain the index species *Cassidulina crista* accompanied by *Hyperammina granulosa*, *Angulogerina angulosa*, *Nonion bogdanoviczi*, *Varidentella rotunda* (Gerke), *Brizalina dilatata*, *Ammonia beccarii* (Fig. 6B), *Globigerina bulloides*, *Globoturborotalita druryi*, and *Globorotalia scitula* (Brady).

Characteristic features of the Kovalivka beds are coalified plant remains and assemblages enriched in representatives of genera: *Ammonia*, *Porosononion* and *Elphidium* (Pishvanova, 1969). Intervals that may be referred to this subdivision occur in wells Podil'tsi 1, Makuniv 1 and Pivnichne Hirs'ke 3 where they directly underlie sediments of the Dashava Formation. Foraminiferal assemblages are very poor and contain species redeposited from the older strata.

Sediments of the lower part (Volhynian) of the Dashava Formation were identified in wells: Lanivka 1, Makuniv 1, Moryantsi 1, Nyklovychi 26, Pyatynychany 1, Pivnichne Hirs'ke 1, Podil'tsi 1, and Susoliv 5. A characteristic feature of foraminiferal assemblages is the persistent occurrence of *Anomalinoides dividens* (Łuczkowska) (Fig. 6C). Besides index species, there also occur: *Saccammina sarmatica* (Fig. 6D), *Porosononion granosum*, *Ammonia beccarii*, *Brizalina dilatata*, *Bolivina sarmatica* (Fig. 6E), *Brizalina nisporenica* Didkovski, *Globigerinita uvula* (Ehrenberg) (Fig.6F) *Rotaliella risilla* (Venglinski), *Pseudotriloculina fluviata* (Venglinski) (Fig. 6G), *Caucasina sarmatica* Venglinski, *Tenuitella neobrevispira*, *Tenuitellinata subcretacea* (Łomnicki) (Fig 6H), *Neogloboquadrina pseudopachyderma* Cita, Premoli-Silva et Rossi, and *Turborotalita quinqueloba* (Natland). Foraminifera are usually accompanied by cysts of algae *Halicoryne morelleti* (Pokorny) (Fig. 6I), characteristic for the lower Sarmatian clayey deposits (Paruch-Kulczycka, 1994).

Calcareous nannoplankton

The calcareous nannoplankton assemblage from the lower part of the Dzików 12 well (profile F2) consists of: *Reticulofenestra pseudoumbilica* (Fig. 7A, B), *Helicosphaera kamptneri* (Fig. 7C,D), *H. walbersdorfensis*, *Pontosphaera multipora*, *Discoaster* sp. (fragments), *D. exilis*, *Sphenolithus heteromorphus* (Fig. 7E–G), and *S. mori-*

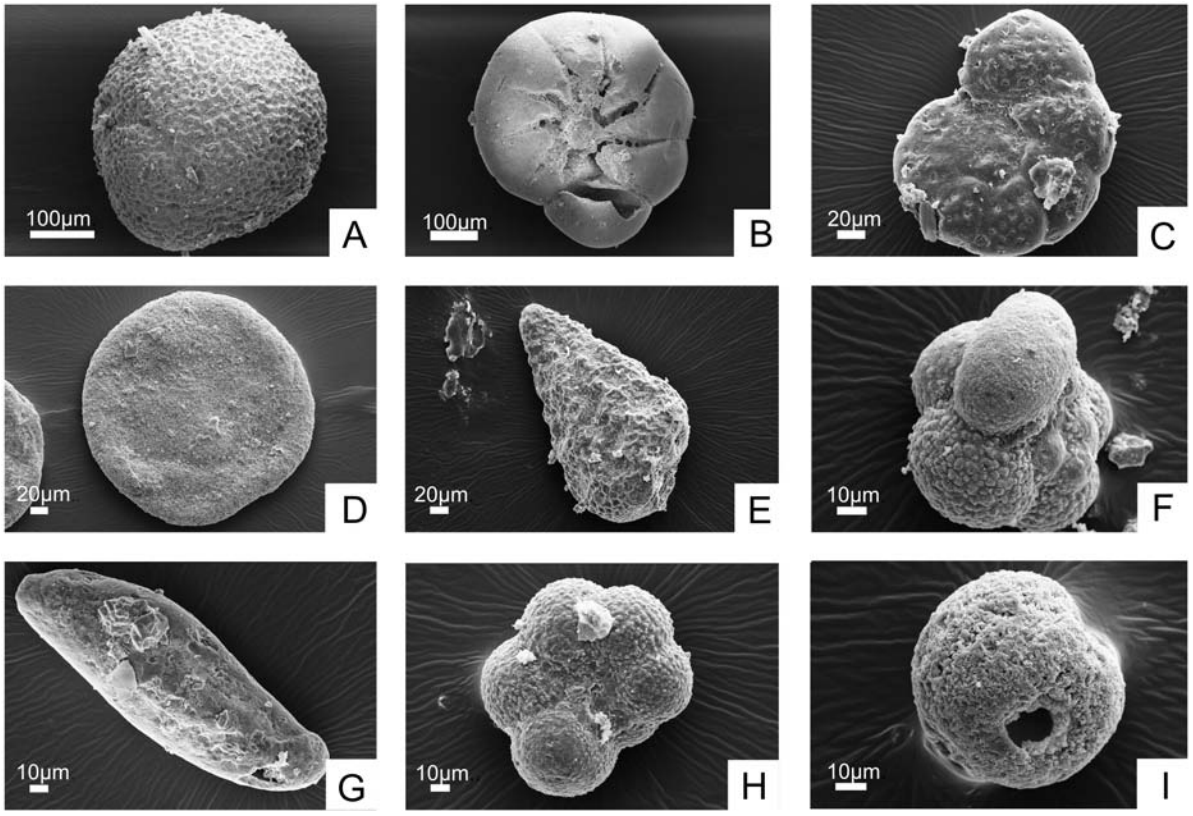

Fig. 6. Foraminifera of the Kosiv and Dashava formations (West Ukraine). **A** – *Praeorbulina glomerosa* (Blow), Kosiv Fm., Prut beds, Pyatnychany 1 well, depth 1,222.0–1,237.0 m; **B** – *Ammonia beccarii* (Linne), umbilical side, Kolomyia beds, Lanivka 1 well, depth 1,168.0–1,173.0 m; **C** – *Anomalinoides dividens* Łuczkowska, umbilical side, Dashava Fm., Podil'tsi 1 well, depth 1,200.0–1,211.0 m; **D** – *Saccammina sarmatica* Venglinskyi, Dashava Fm,. Pyatnychany 1 well, depth 962.0–973.0 m; **E** – *Bolivina sarmatica* Didkovskyi, Dashava Fm., Podilsti 1 well, depth 982.5–991.0 m; **F** – *Globigerinita uvula* (Ehrenberg), spiral side with " bulla", Dashava Fm., Podil'tsi 1 well, depth 976.6–982.5 m; **G** – *Pseudotriloculina fluviata* (Venglinskyi), Dashava Fm., Podil'tsi 1 well, depth. 982.5–991.0 m; **H** – *Tenuitellinata subcretacea* (Łomnicki), umbilical side, Dashava Fm., Podil'tsi 1 well, depth, 1,211.0–1,216.0 m; **I** – *Halicoryne morelleti* (Pokorny), Dashava Fm., Podil'tsi 1 well, depth 976.5–982.5 m

formis (Table 1). A characteristic feature is the occurrence of *Sphenolithus heteromorphus* (a diagnostic species for the Middle Miocene) and the absence of *Helicosphaera amplia-perta* Bramlette et Wilcoxon. The assemblage identified above this interval and the assemblages in wells: Księżpol 10, 11, 12 (profile G) and Dzików 15, 17 (profile F2) contain mainly: *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre, *Calcidiscus macintyrei, Coccolithus pelagicus, Helicosphaera kamptneri*, *Pontosphaera multipora* (Fig. 7H,I), *Sphenolithus abies* (Fig. 7J, K), and *Reticulofenestra pseudoumbilica*. The stratigraphically important *Cyclicar-golithus floridanus* (Fig. 7L, M) occurred sporadically. Asteroliths appeared as single specimens. A noteworthy feature of the assemblage was the frequent occurrence of re-deposited taxa from the Palaeogene (Eocene) and Creta-ceous strata. The majority of the assemblage consists of de-stroyed and small fragments of undistinguishable forms/ele-ments. In the Księżpol 10 and 11 wells, *Braarudosphaera bigelowii* occurred in high quantity (Fig. 7N, O). In the top part of the Księżpol 11 well, *Calcidiscus macintyrei* ap-peared frequently. The samples in Dzików 12 well con-tained poorly preserved nannofossil assemblage in which redeposited species dominated. In the samples from the Dzi-ków 15 well, an increase in the number of *Braarudosphaera bigelowii* and *Calcidiscus macintyrei* (Fig. 7P–S) were marked (Table 1). The diversity of the assemblage was low. Coccolithaceae and Prinsiaceae dominated (*Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Reticulofenestra pseudoumbilica* as the most frequent species), whereas Dis-coasteraceae, Sphenolithaceae and Pontosphaeraceae oc-curred as single specimens. The calcareous nannoplankton from the Biszcza 1 well (G profile) was relatively abundant, but due to the commonly poor state of preservation identifi-cation of many species was impossible. The assemblage was dominated by placoliths, *i.e*., *Calcidiscus macintyrei*, *Coccolithus pelagicus* (Figs 7T, 8A), *Cyclicargolithus flori-danus* and *Reticulofenestra pseudoumbilica*. Helicospha-eraceae appeared frequently (many species, but not many specimens). Less frequently occurred Pontosphaeraceae (*Pontosphaera multipora*) and Sphenolithaceae (*Sphenoli-thus abies*, *S. moriformis*). Asteroliths occurred as single species (*Discoaster exilis*, *D. deflandrei*; Fig. 8B). All stud-ied samples contained pentaliths – *Braarudosphaera bige-lowii* and *Micrantolithus sp*. (Fig. 8C). The presence of cal-careous dinoflagellata (*Thoracosphaera fossata* Jafar) was recorded in the investigated samples (Table 2).

In western Ukraine, the calcareous nannoplankton as-semblage from the Chornokuntsi 1 well (Table 3) was

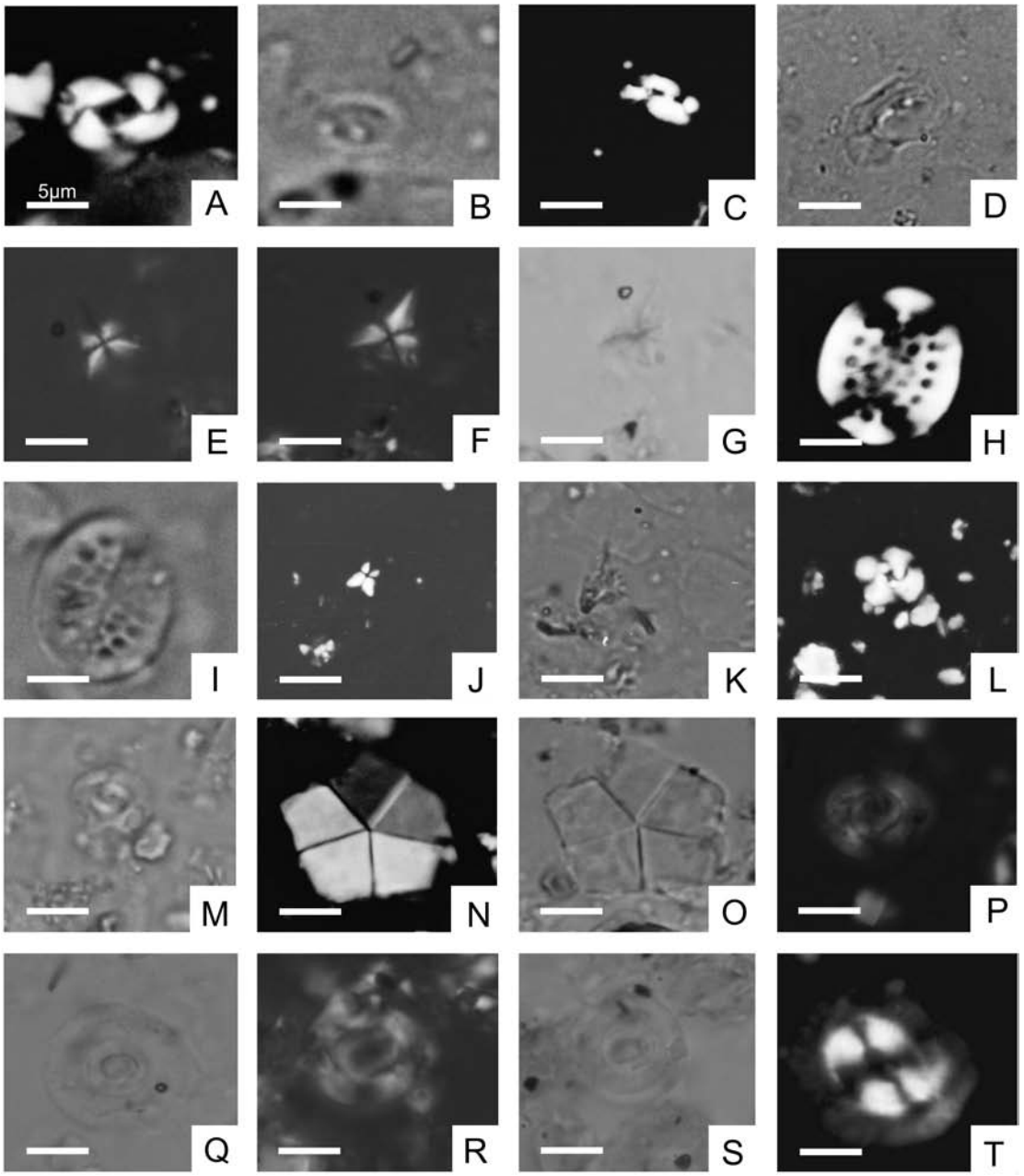

Fig. 7. Calcareous nannoplankton of the Baranów and Krakowiec beds (SE Poland). Scale bar is 5 µm. **A, B** – *Reticulofenestra pseudoumbilica* Gartner, Baranów beds, Dzików 12, depth 1,041.0–1,050.0 m; **C, D –** *Helicosphaera kamptneri* Hay et Mohler, Baranów beds. Dzików 12, depth 1,041.0–1,050.0 m; **E–G** – *Sphenolithus heteromorphus* Deflandre, Baranów beds, Dzików 12, depth 1041.0–1050.0 m; **H, I** – *Pontosphaera multipora* (Kamptner) Roth, Krakowiec beds, Księżpol 12, depth 740.0–749.0 m; **J, K** – *Sphenolithus abies* Deflandre, Krakowiec beds, Księżpol 10, depth 786.0–791.0 m; **L, M** – *Cyclicargolithus floridanus* (Roth et Hay) Bukry, Krakowiec beds, Księżpol 10, depth 786.0–791.0 m; **N, O** – *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre, Krakowiec beds, Księżpol 10, depth 677.0–682.0 m; **P–S** – *Calcidiscus macintyrei* (Bukry et Bramlette) Loeblich et Tappan, Krakowiec beds, Dzików 15, depth 1,087.0–1,096.0 m; **T** – *Coccolithus pelagicus* (Wallich) Schiller, Krakowiec beds, Biszcza 1, depth 510.0–514.0 m

scarce and damaged. The species diversity was low. The most abundant species was *Coccolithus pelagicus*. *Reticulofenestra pseudoumbilica* and *Cyclicargolithus floridanus* occurred less frequently or as single specimens. The redeposited specimens from older strata (mainly Eocene and Cretaceous) and damaged elements were also found. The sample from Yuryiv 1 (Table 3) well contained strongly destroyed coccoliths – almost ninety percent of the assemblage was found as fragments. The calcareous nannoplankton assemblage consisted mainly of long-ranging placoliths, helicoliths, cribriliths (*Pontosphaera multipora*) and pentaliths (*Braarudosphaera bigelowii*). The characteristic elements were radiolarian fragments. The samples from the Voloscha 1 well (Table 3) contained the following species: *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Pontosphaera multipora* (fragments), *Reticulofenestra pseudoumbilica* (Fig. 8D, E), "small *reticulofenestrids*" and *Umbilicosphaera rotula* (Kamptner) Varol (Fig. 8F–H). Helico-

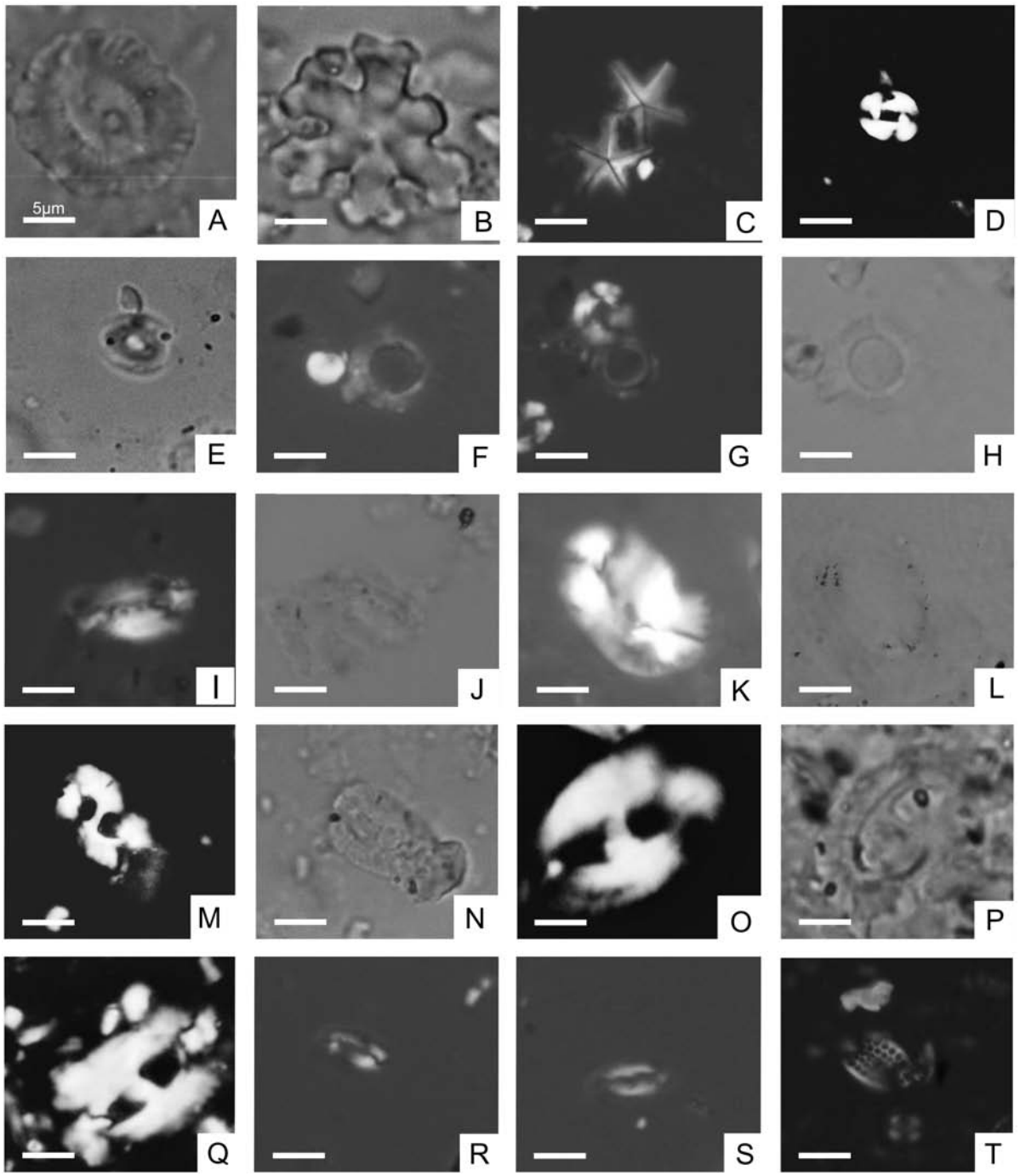

Fig. 8. Calcareous nannoplankton of the Krakowiec beds (SE Poland) and Kosiv Formation (West Ukraine). Scale bar is 5 µm. **A** – *Coccolithus pelagicus* (Wallich) Schiller, Krakowiec beds, Biszcza 1, depth 510.0–514.0 m; **B** – *Discoaster deflandrei* Bramlette et Riedel, Krakowiec beds, Biszcza 1, 630.0–634.0 m; **C** – *Micrantholithus* sp., Krakowiec beds, Biszcza 1, depth 540.0–544.0 m; **F–H** – *Umbilicosphaera rotula* (Kamptner) Varol, Kosiv Formation, Voloscha 1, depth 2,070.0–2,080.0 m; **I, J** – *Helicosphaera burkei* Black, Kosiv Formation, Voloshcha 1, depth 2,050.0–2,060.0 m; **K, L** – *Helicosphaera kamptneri* Hay et Mohler, Kosiv Formation, Voloscha 1, depth 2,050.0–2,060.0 m; **M, N** – *Helicosphaera mediterranea* Müller, Kosiv Formation, Voloscha 1, depth 2,050.0–2,060.0 m; **O–Q** – *Helicosphaera sellii* Bukry et Bramlette, Kosiv Formation, Voloscha 1, depth 2,050.0–2,060.0 m; **R, S** – *Helicosphaera walbersdorfensis* Müller, Kosiv Formation, Voloscha 1, depth 2,050.0–2,060.0 m; **T** – *Pontosphaera multipora* (Kamptner) Roth, Kosiv Formation, Makuniv 1, depth 1,681.0–1,688.6 m

sphaeraceae, including: *Helicosphaera burkei* Black (Fig. 8I,J), *H. kamptneri* (Fig. 8K,L), *H. mediterranea* Müller (Fig. 8M,N), *H. sellii* (Fig. 8O–Q), *H. walbersdorfensis* (Fig. 8R,S), occurred frequently. Sphenoliths and discoasters were missing. A similar assemblage of the calcareous nannoplankton was described from the Skhidne Dovhe 3 well (Table 3). Helicoliths dominated in only one sample from the Bortiatyn 1 well (Table 3). Many of them were preserved badly, as fragments. *Coccolithus pelagicus*, "small *reticulofenestrids*" and *Reticulofenestra pseudoumbilica*

Table 1

Distribution of calcareous nannoplankton in Księżpol 10,11,12 and Dzików 12,15,17 wells

Species / Depth	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Discoaster* sp.	*Discoaster deflandrei*	*Discoaster exilis*	*Helicosphaera burkei*	*Helicosphaera californiana*	*Helicosphaera carteri*	*Helicosphaera elongata*	*Helicosphaera kamptneri*	*Helicosphaera mediterranea*	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Helicosphaera walbersdorfensis*	*Helicosphaera* sp.	*Pontosphaera* sp.	*Pontosphaera multipora*	*Reticulofenestra pseudoumbilica*	*Sphenolithus abies*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Thoracosphaera* sp.	Reworked species	Undistinguishable fragments	Preservation
Księżpol 10																													
1/300.0-305.0				R		R	T						T	T	T						T					T	C	C	P
2/502.0-504.0				R		T						aff.					T	T	T		T			T			C	C	P
3/677.0-682.0	C			R		T		cf.				T									cf.						R	C	P
4/824.0-829.0				R		T															T						R	C	P
5/786.0-791.0	C		T			T								T								T	T				C	C	P
6/862.0-867.0						T								cf.	T						T	T					C	C	P
Księżpol 11																													
1/330.0-339.0	T	T	T	R	T	T					T					T			T			T		T	T		C	R	P
2/535.0-544.0			T	R		T																					C	R	P
3/735.0-744.0				R		T				T									Cf								C	C	P
5/915.0-922.0						T								T													C	R	P
Księżpol 12																													
1/335.0-344.0						T																					C	C	P
2/540.0-549.0																											C	R	P
3/740.0-749.0/I/R5	T					T								aff.					Cf		T						C	C	P
4/740.0-749.0/VI/R3				T		T								cf.							T			T			R	R	P
5/740.0-749/IX/R3						T															T						C	C	P
Dzików 12																													
1/470.0-479.0			T			T															T						C	C	P
2/730.0-733.0						T								T					R		R		T	T			C	C	P
3/812.0-821.0				T	T	T								T		T		T			T						C	C	P
4/905.0-915.0																T											C	C	P
5/940.0-949.0						T																					C	C	P
6/1041.0-1050/0							T		T					T				T			T	T		R	T		C	C	P
Dzików 15																													
1/220.0-229.0						T						aff.							T	T		T	T				C	C	P
2/460.0-469.0	T		T			T			aff.		aff.										T	T	T				C	C	P
3/460.0-469.0/S2						T															T						C	C	P
4/830.0-839.0	T					T		T											T					aff.			R	C	P
5/830.0-839.0/VIII	T					T																T					C	C	P
6/920.0-929.0						T															T						C	C	P
7/1067.0-1078.0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B		B	B	B	B	B	B	B	C	B
8/1087.0-1096.0/I			C	T	C																				T		R	C	P
9/1087.0-1096.0/II	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B		B	B	B	B	B	B	B	B	P
10/1087.0-1096.0																											R	C	P
Dzików 17																													
1/494.0-503.0						T						cf.									T						C	C	P
2/743.0-750.0	T		T			T					T			aff.		cf.		T	T	T	T				T		R	C	P
947.0-956.0			T			T														T	T	T			T		C	C	P

A – more than 1 specimen per field of view; B – one specimen per 1–10 fields of view; R – one specimen per more than 10 fields of view; T– traces; f – fragments of the specimens; B – barren sample. State of preservation: M – moderate; P – poor

Table 2

Distribution of calcareous nannoplankton in Biszcza 1 well

Species / Depth	*Braarudosphaera bigelowii*	*Calcidiscus* sp.	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Calcidiscus tropicus*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Cyclicargolithus* sp.	*Discoaster* sp.	*Discoaster deflandrei*	*Discoaster exilis*	*Discoaster kugleri*	*Helicosphaera californiana*	*Helicosphaera carteri*	*Helicosphaera euphratis*	*Helicosphaera intermedia*	*Helicosphaera kamptneri*	*Helicosphaera mediterranea*	*Helicosphaera stalis*	*Helicosphaera walbersdorfensis*	*Helicosphaera* sp.	*Micrantholithus* sp.	*Pontosphaera sp. (fragments)*	*Pontosphaera multipora*	*Reticulofenestra pseudoumbilica*	small *reticulofenestrids*	*Sphenolithus abies*	*Sphenolithus moriformis*	*Scapolithus fossilis*	*Thoracosphaera* sp.	*Thoracosphaera fossata*	Reworked species	Undistinguishable fragments	Preservation
1/510.0-514.0						C		R	T									cf.						Cf		R		C	T				R	C	P
2/510.0-514.0	f	T				R		T	T																	T							R	R	P
3/510.0-514.0	R			T		R	T	T								T					T				T	T		R	T				R	R	P
4/540.0-544.0	T	T	T	R	aff.	R		T							T								T		f	R							R	C	M
5/540.0-544.0	R			R	T	R		T						T	T		T		T	T		T			T	T				T			R	R	P
6/540.0-544.0	f			T	T	R		R									T									R		T			f		T	R	P
7/580.0-584.0				T		T		T					T	aff.	T											T		T					T	R	P
8/580.0-584.0	f					R		T														T	f			T							R	C	P
9/580.0-584.0						R		T																	T	R		T	T				R	R	P
10/630.0-634.0						C		T		T							T	T							T	T							C	C	P
11/630.0-634.0						C	T	T							T		T						f		T	T							C	C	P
12/630.0-634.0						C	T	T			T					aff.		T				C			T	R							C	C	P
13/630.0-634.0						C	T	R			cf.							T								R	R		T				A	A	M
14/690.0-694.0	C			C		A	T	R														T			R	R		R				C	C	C	M
15/690.0-694.0				R		C		T														T										T	A	A	P
16/789.0-793.0	Cf					C		T																					T		f		C	C	M
17/789.0-793.0						C		R																	f							R	C	C	M
18/860.0-864.0						C																			T							aff.	A	A	P
19/860.0-864.0						A	T	T																	T	R						R	C	A	P
20/860.0-864.0						R		T																	T	T						C	C	A	P
21/860.0-864.0		T				C		T				T					cf.								f	R							C	A	P

were common, too. Sphenolithaceae and Pontosphaeraceae (fragments) occurred sporadically, whereas asteroliths were lacking. The calcareous nannoplankton assemblage from the Makuniv 1 well was marked by low species diversity and low abundance. In the samples from the lower part of the investigated interval, the following species were recorded: *Coccolithus pelagicus*, *Cyclicargolithus floridanus* (single specimens), *Reticulofenestra pseudoumbilica*, and *Pontosphaera multipora* (Figs 8T, 9A). Redeposited specimens, small fragments of destroyed and undistinguishable forms were noted as well. In the samples from shallower depths, the redeposited and destroyed forms prevailed (Table 3). The sediments lying above the anhydrite horizon in the Pyatnychany 1 well contained the following species: *Calcidiscus leptoporus* (Fig. 9B, C), *Coccolithus pelagicus* (abundant), *Reticulofenestra pseudoumbilica* (equally abundant as *C. pelagicus*), *Cyclicargolithus floridanus*, *Pontosphaera multipora* (fragments), *Helicosphaera burkei*, *H. kamptneri*, *H. sellii*, *H. vedderii*, *H. walbersdorfensis*, *Scapolithus fossilis* Deflandre, *Sphenolithus abies*, *Syracosphaera pulchra* Lohmann, *Umbilicosphaera rotula*, and the fragments of *Discoaster exilis*. The common occurrence of *Braarudosphaera bigelowii* and the coccosphers of this species were noted, too. The samples from a shallower interval included poorly preserved calcareous assemblage, in which *Coccolithus pelagicus*, *Reticulofenestra pseudoumbilica* and the redeposited specimens were dominating. The badly preserved, crumbled, undistinguishable elements of coccoliths and fragments of *Pontosphaera* and *Helicosphaera* genus were also found (Table 3). The nannofossil assemblage from the Podil'tsi 1 well (Table 4) corresponded with the assemblage from the Pyatnychany 1 well. Apart from the above mentioned species, the following forms occurred in the assemblage studied: *Calcidiscus macintyrei*, *C. premacintyrei* Theodoridis (Fig. 9D–F), *Coronocyclus nitescens* (Kamptner) Bramlette et Wilcoxon (Fig. 9G, H), *Cyclicargolithus floridanus* – small forms, *Helicosphaera intermedia* Martini (Fig. 9I, J), *H. mediterranea*, *H.* sp. (small forms), *H. stalis* Theodoridis (Fig. 9K, L), *Holodiscolithus macroporus*, *Micrantholithus* sp., "small

Table 3

Distribution of calcareous nannoplankton in Chornokuntsi 1, Yuriyiv 1, Voloscha 1, Skhidne Dovhe 3, Bortiatyn 1, Makuniv 1 and Pyatnychany 1 wells

Species / Depth	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Discoaster* sp.	*Discoaster deflandrei*	*Discoaster exilis*	*Helicosphaera burkei*	*Helicosphaera carteri*	*Helicosphaera euphratis*	*Helicosphaera intermedia*	*Helicosphaera kamptneri*	*Helicosphaera mediterranea*	*Helicosphaera sellii*	*Helicosphaera walbersdorfensis*	*Helicosphaera* sp.	*Helicosphaera* sp. (small forms)	*Holodiscolithus macroporus*	*Pontosphaera multipora*	*Reticulofenestra pseudoumbilica*	*small reticulofenestrids*	*Rhabdosphaera siccus*	*Sphenolithus abies*	*Sphenolithus moriformis*	*Sphenolithus* sp.	*Syracosphaera* sp.	*Thoracosphaera fossata*	*Thoracosphaera* sp.	*Umbilicosphaera rotula*	Reworked species	Undistinguishable fragments	Preservation
Chornokuntsi 1																																
1/1/1751.0-1756.0			A													T				T									T	C	P
1/2/1751.0-1756.0			A	T																T									T	C	P
Yuriyiv 1																																
1/1542.0-1551.0	T	T	R	R							T								Cf	T	C								C	C	P
Voloscha 1																																
2/2050.0-2060.0			A					C				C	C	aff.	C				f										C	C	P
3/2060.0-2070.0			A													T													C	C	P
6/2070.0-2080.0			R	R				T					T			R			f										C	C	P
Skhidno Dovhe 3																																
4/1624.0-1634.0			C	T								T																	R		P
6/1634.0-1641.0			C	T								T																	R	C	P
10/1700.0-1711.0			C																										R	C	P
28/1766.0-1775.0			C	T				T	T			f		T	cf	Cf			f					T				T		R	C	P
31/1793.0-1800.0			C													Rf												f		R	C	P
Bortyatyn 1																																
6/1800.0-1810.0			C	T				R		T		C		R		C	C		f			T	T		R					R	C	P
Makuniv 1																																
1/1343.0-1353.0			R												T								R				R		A	A	P
3/1681.0-1688.6			C	T					aff.										T	C							R		A	A	P
6/1857.2-1858.0			C	R							aff.					C											T	f		A	A	P
10/1880.7-1862.9			C													T				C										C	C	P
13/2212.0-2222.2			C																T	C	R									C	C	P
15/2512.0-2578.5								cf.												aff.										R	R	P
18/2992.5-3000.0			R																	T								f		R	R	P
21/3106.0-3110.6			R	R																										R	R	P
23/3261.0-3269.0			R																											R	R	P
25/3356.4-3438.0			R	aff.																										R	R	P
27/3538.0-3546.0			C																											R	R	P
28/3619.2-3626.8			R																											R	R	P
Pyatnychany 1																																
1/800.0-814.0			A	R		T			R																							
2/963.0-973.0			A	R					R																							
6/1140.0-1150.0			A	R		T						R					R															
8/1150.0-1160.0	T		A	R								C					R		f	C	R											
9/1197.0-1207.0	C	R	A	R				C				C					Cf		f	C	C			T	R	T						
11/1207.0-1227.0	f		A	T	f		cf.					C		R			Cf			C									T			
13/1222.0-1237.0			A	R				C	C			C					Cf	T	f	C	C		T			T			T			

Table 4

Distribution of calcareous nannoplankton in Podil'tsi 1, Moryantsi 1, Nyklovychi 26, Pivnichne Hirs'ke 1, Susoliv 5 and Lanivka 1 wells

Species / Depth	*Braarudosphaera bigelowii*	*Calcidiscus macintyrei*	*Calcidiscus premacintyrei*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Discoaster* sp.	*Discoaster deflandrei*	*Helicosphaera burkei*	*Helicosphaera carteri*	*Helicosphaera intermedia*	*Helicosphaera kamptneri*	*Helicosphaera mediterranea*	*Helicosphaera sellii*	*Helicosphaera stalis*	*Helicosphaera walbersdorfensis*	*Helicosphaera* sp.	*Helicosphaera* sp. (small forms)	*Holodiscolithus macroporus*	*Pontosphaera multipora*	*Reticulofenestra pseudoumbilica*	*small reticulofenestrids*	*Sphenolithus* sp.	*Sphenolithus abies*	*Sphenolithus moriformis*	*Syracosphaera pulchra*	*Thoracosphaera* sp.	*Thoracosphaera fossata.*	*Umbilicosphaera jafarii*	Reworked species	Undistinguishable fragments	Preservation
Podil'tsi 1																																
3/683.0-700.0				C																	C			T				T		R	C	P
6/959.0-965.2				C		R	f		T			aff.	T			T			T	T	C	C	T		T			T	T	C	C	M
14/976.5-982.5	C			A		C				T		T	T							R	C							T		A	C	M
15/982.5-991.0	T			A		T		f			T									T	C							T		C	C	P
17/1200.0-1211.0	T		T	A	T	T						C		T				C		T	C			T	T					C	C	P
23/1231.7-1243.2				A		T																						f		C	C	P
26/1500.0-1510.0				A		R			T							T		R	T	f	A	C							T	A	C	M
27/1700.0-1714.7				A																T	C									C	C	P
31/1756.8-1774.3				T		T				T											T	T								R		P
33/1860.8-1875.9		T		A		R				T								C		T	C	R	T							R	R	P
34/1875.9-1889.1	f			A		T	T								T	T		R			C	R			T	T				R	C	P
Moryantsi 1																																
1/1701.4-1706.8				T		T						cf.				T					T	C					T			A	A	P
4/1762.4-1768.9	f			T		T					cf.							T		f	aff.	C								A	A	P
6/1829.7-1834.7				C		T																					T			A	A	P
11/1875.0-1881.0				C		T																								R	A	P
14/2015.0-2023.0				A		T			aff.	T		A					A	C		T										A	A	P
16/2048.8-2054.7				A													A	C				R					T			R	A	P
Nyklovychi 26																																
19/1752.0-1762.0				C		R															C	T								A	A	M
26/1880.0-1890.0				C		R															C									A	A	P
29/1926.0-1936.0				C		R															C									A	A	P
34/2101.0-2111.0				A		R				T			T	T						T	C	T					T			A	A	P
37/2111.0-2111.0	f			C		R											R				C	T								A	A	P
Pivnichne Hirs'ke 1																																
2/887.8-900.8				A		R	T					C	C				T			f	C									A	A	P
4/980.4-986.0				A		C				T			C					R			C						f			R	A	P
5/1028.0-1036.0				A								aff.					T				C									A	A	P
6/1200.0-1210.0				A					T			C	C			T	f	C		T	C		R	T	T					A	R	P
Susoliv 5																																
1/2002.0-2101.0	C			A		C				R	T									R	C									C	A	P
8/2418.0-2428.0	f			A																							f			C	A	P
10/2441.0-2451.0				A																							f			f	A	P
14/2461.0-2471.0				A		T				R										aff.	C						R			C	R	P
18/2486.2-2498.3				A		R															C									R	R	P
24/2550.0-2570.0				A		T	T					C									R									C	A	P
29/2586.0-2608.0						R			T												R							T		C	R	P
35/2622.0-2634.0	C			A		T														cf.	R						T			C	A	P
40/2699.5-2708.8				A																	R									C	A	P

Table 4 continued

Species / Depth	*Braarudosphaera bigelowii*	*Calcidiscus macintyrei*	*Calcidiscus premacintyrei*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Discoaster* sp.	*Discoaster deflandrei*	*Helicosphaera burkei*	*Helicosphaera carteri*	*Helicosphaera intermedia*	*Helicosphaera kamptneri*	*Helicosphaera mediterranea*	*Helicosphaera sellii*	*Helicosphaera stalis*	*Helicosphaera walbersdorfensis*	*Helicosphaera* sp.	*Helicosphaera* sp. (small forms)	*Holodiscolithus macroporus*	*Pontosphaera multipora*	*Reticulofenestra pseudoumbilica*	*small reticulofenestrids*	*Sphenolithus* sp.	*Sphenolithus abies*	*Sphenolithus moriformis*	*Syracosphaera pulchra*	*Thoracosphaera* sp.	*Thoracosphaera fossata.*	*Umbilicosphaera jafarii*	Reworked species	Undistinguishable fragments	Preservation
Susoliv 5																																
43/2808.0-2822.0				A		T																								C	R	P
49/2947.0-2957.0	f			A		T						f			T		T			T	C								C	A	P
Lanivka 1																																
1/1125.0-1130.0				A		T											f					T								R	R	P
5/1168.0-1173.0				T																	T		T							C	A	P
9/1510.0-1515.0				T		T											T													C	R	P

reticulofenestrids", *Sphenolithus moriformis*, and *Umbilicosphaera jafarii* (Fig. 9M, N). The fragments or small forms of *Braarudosphaera bigelowii* were noted. In the samples from the shallowest intervals, *Coccolithus pelagicus*, *Reticulofenestra pseudoumbilica* and *Thoracosphaera* sp. (Fig. 9O, P) occurred as the only specimens. In the deepest sample in the Moryantsi 1 well (Table 4) *Helicosphaeraceae* were abundant, but the state of their preservation was generally bad (many of them were described as *Helicosphaera* sp.). The most abundant species in all investigated samples was *Coccolithus pelagicus*, represented mainly by small forms. In the shallower samples the assemblage was very poor. *Coccolithus pelagicus*, *Cyclicargolithus floridanus* (rare, small forms), the fragments of *Braarudosphaera bigelowii* and undistinguishable forms were identified. The calcareous nannoplankton from the Nyklovychi 26 well (Table 4) was dominated by long-ranging species. *Coccolithus pelagicus* and *Reticulofenestra pseudoumbilica* (various in size) were the most common species in all examined samples, whereas *Cyclicargolithus floridanus* and "small *reticulofenestrids*" occurred sporadically. Due to the commonly poor state of preservation (undistinguishable fragments) many species were excluded from the identification procedure. The samples from the Pivnichne Hirs'ke 1 well contained the same species as those mentioned in the Nyklovychi 26 well. Among helicoliths, *Helicosphaera kamptneri* and *H. mediterranea* were commonly present (Table 4). In the deepest sample small helicoliths were identified. Placoliths, helicoliths, cribriliths and pentaliths (mainly *Braarudosphaera bigelowii*) occurred commonly in the samples from the Susoliv 1 well (Table 4). However, the redeposited and damaged specimens predominated in all investigated samples. The calcareous nannofossils in the examined samples from the Lanivka 1 well were rare and poorly preserved. Only *Coccolithus pelagicus*, *Reticulofenestra pseudoumbilica*, *Cyclicargolithus floridanus* (single specimens) and the fragments of undistinguishable forms were found (Table 4). Calcareous dinoflagellata – Thoracosphaeraceae occurred also in samples from the Nyklovychi 26, Pivn. Hirs'ke 1 and Susoliv 1 wells.

DISCUSSION

A comparison of above mentioned microfossils points to similarity of the specific composition of foraminiferal assemblages from the *Pecten*/*Spirialis* beds and subdivisions of the Kosiv Formation of Ukraine (the Verbovets', Prut and Kolomyia beds). A characteristic feature is the occurrence of arenaceous taxa (*Hyperammina granulosa*, *Ammodiscus miocenicus*, *Haplophragmoides indentatus*, *H. laminatus*), planktic species *Velapertina indigena*, as well as numerous radiolarians and pteropods (Table 5).

Foraminiferal assemblages of the Krakowiec beds (SE Poland) and the Dashava Formation (western Ukraine) display a high degree of similarity (Table 6). Characteristic is the occurrence of *Anomalinoides dividens* in lower parts of both subdivisions. In the upper parts, *Bolivina sarmatica*, *Brizalina nisporenica*, *Saccammina sarmatica*, and *Rotaliella risilla* occur. Assemblages of miliolids and elphiids have many species in common; frequent is *Porosononion granosum*. Another common element of the discussed assemblages is a chlorophycean *Halicoryne morelleti*. The similarity of microfossil assemblages enables one to conclude about equivalence of the discussed subdivisions. In SE Poland, the calcareous nannoplankton assemblage from the Baranów beds – the lowest part of the Dzików 12 well – represents the NN5 (higher part of this zone) zone (late Badenian; Rögl, in: Cicha *et al.*, 1998; Piller *et al.*, 2007; Rögl *et al.*, 2008). The Krakowiec beds (Księżpol 10, 11, 12 and Dzików 12 (upper part), 15 and 17 wells) were early

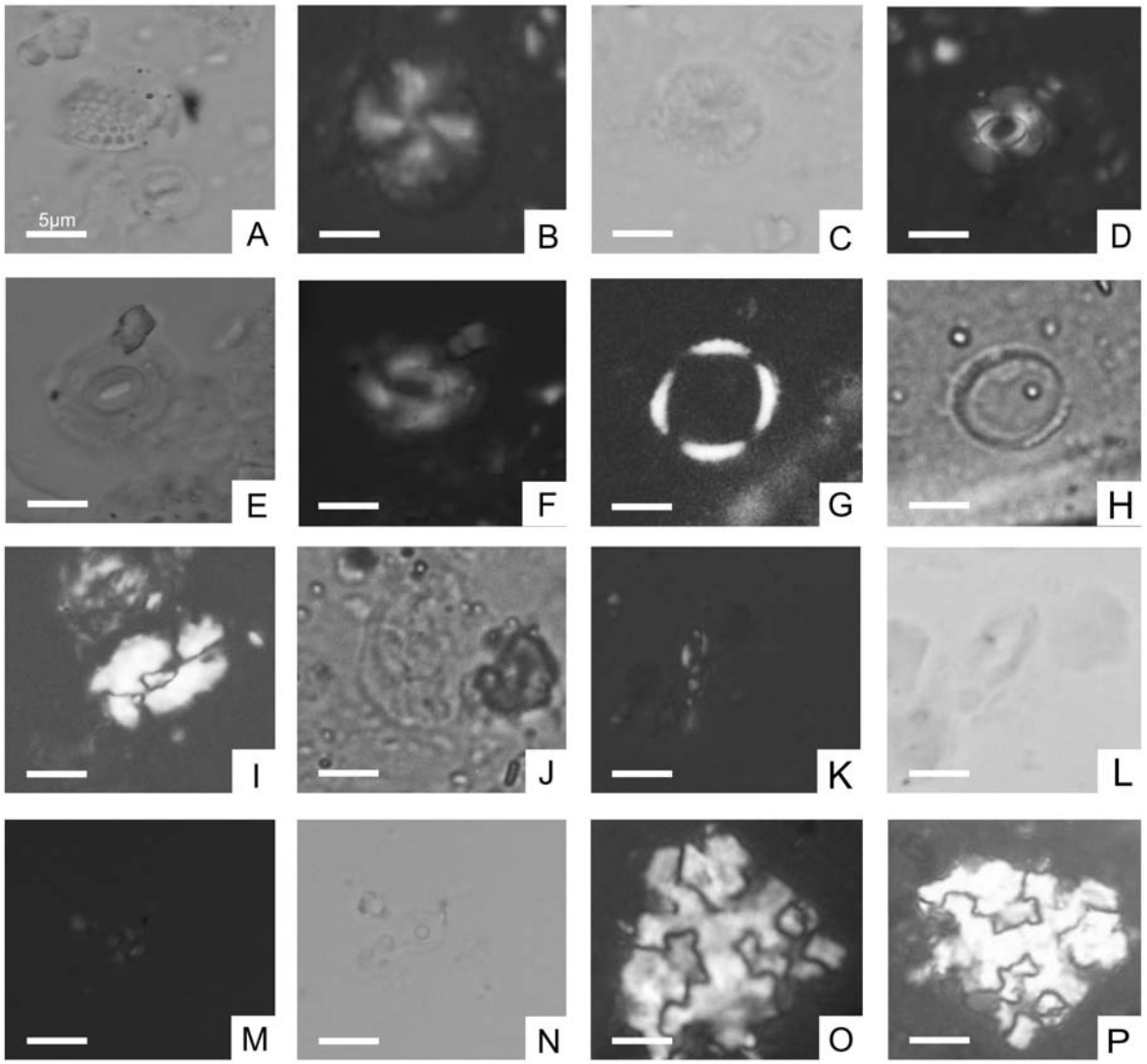

Fig. 9. Calcareous nannoplankton of the Kosiv and Dashava formations (West Ukraine). Scale bar is 5 μm. **A** – *Pontosphaera multipora* (Kamptner) Roth, Kosiv Formations, Makuniv 1, depth 1,681.0–1,688.6 m; **B, C** – *Calcidiscus leptoporus* (Murray et Blackman) Loeblich et Tappan, Kosiv and Dashava Formations, Pyatnychany 1, depth 1,197.0–1,207.0 m; **D–F** – *Calcidiscus premacintyrei* Theodoridis, Kosiv and Dashava formations, Podil'tsi 1, depth 1,200.0–1,211.0 m; **G, H** – *Coronocyclus nitescens* (Kamptner) Bramlette et Wilcoxon, Kosiv and Dashava formations, Podiltsi 1, depth 1,200.0–1,211.0 m; **I, J** – *Helicosphaera intermedia* Martini, Kosiv and Dashava formations, Podil'tsi 1, depth 982.5–991.0 m; **K, L** – *Helicosphaera stalis* Theodoridis, Kosiv and Dashava formations, Podil'tsi 1, depth 1,875.9–1,889.1 m; **M, N** – *Umbilicosphaera jafarii* Müller, Kosiv and Dashava formations, Podil'tsi 1, depth 1,500.0–1,510.0 m; **O, P** – *Thoracosphaera* sp., Kosiv and Dashava formations, Podil'tsi 1, 683.0–700.0 m

and late Sarmatian in age – the NN6, undivided NN6-NN7 and NN7 zones. The lower boundary of the NN6 zone in Martini's scheme (1971) was defined based on the last occurrence (LO) of *Sphenolithus heteromorphus* species. The upper boundary of the zone was identified based on the first occurrence (FO) of *Discoaster kugleri* and/or the last occurrence of *Cyclicargolithus floridanus*. A very low number or the absence of this species made age determination difficult. In badly preserved material it was difficult to distinguish *Discoaster kugleri* from other similar, overgrown discoasters. The LO of the long-ranging *Cyclicargolithus floridanus* varies with latitude and should be used carefully for long-distance correlation. In mid- and high latitudes, this species continued to the Late Miocene. Therefore, it was difficult or even impossible to distinguish between autochthonous and redeposited specimens. According to Martini (1971), the top part of the NN6 zone was characterized by low frequency of this species, whereas the *Reticulofenestra pseudoumbilica* increased in numbers. On the basis of the lack of *Discoaster kugleri*, some stratigraphers supposed that in the Central Paratethys the NN7 zone belongs to the brackish-water Sarmatian. Because of the absence of this species, Lehotayova (1978) stated that the Upper Badenian Kosovian substage belongs to the NN6 zone. According to Cicha *et al.* (1998), the extent of the NN6 zone (Upper Badenian–Lower Sarmatian) does not allow to mark the Badenian/Sarmatian boundary based solely on the calcareous nannoplankton group. Due to these difficulties, the two zones (NN6 and NN7) were connected into one undivided zone NN6-NN7 (Andreyeva-Grigorovich & Savits-

Table 5

Distribution of characteristic microfossils in the *Pecten/Spirialis* beds (Poland) and equivalent Ukrainian subdivisions (Verbovets' beds, Prut beds, Kolomyia beds)

Species	*Pecten/ Sprialis* beds	Verbovets beds	Prut beds	Kolomyia beds
Ammodiscus miocenicus	X		X	
Hyperammina granulosa	X		X	X
Hyperammina taurinensis			X	
Reticulophragmium crassum	X			
Pseudotriplasia elongata	X			
Pavonitina adanula	X			
Martinotiella communis	X		X	
Haplophragmoides indentatus	X		X	
Haplophragmoides laminatus	X		X	
Spirorutilus carinatus	X			
Bolivina tarchanensis	X			
Neobulimina longa	X			
Sinoloculina nitens	X			
Hanzawaia crassiseptata	X			
Globigerina bulloides	X	X		X
Globorotalita druryi	X			X
Orbulina suturalis	X		X	
Praeorbulina glomerosa			X	
Globoquadrina altispira			X	
Velapertina indigena	X	X	X	
Globorotalia scitula				X
Tenuitellinata tarchanensis	X			
Subbotina cognata		X		
Tenuitellinata pseudoedita		X		
Angulogerina angulosa		X		X
Ammonia beccarii				X
Sinuloculina consobrina			X	
Fursenkoina acuta			X	
Bulimina insignis			X	
Pappina graciliformis			X	
Bogdanoviczia pokutica			X	
Cyclammina zemplenica			X	
Cyclammina vulchoviensis			X	
Cassidulina crista				X
Nonion bogdanoviczi				X
Varidentella rotunda				X
Pterpods	X	X		
Radiolarians	X	X		

Table 6

Distribution of characteristic microfossils in the Krakowiec beds (Poland) and Dashava Formation (Ukraine)

Species	Krakowiec beds (Poland)	Dashava Formation (Ukraine)
Anomalinoides dividens	X	X
Brizalina dilatata	X	X
Schackoinella imperatoria	X	
Articulina problema	X	X
Elphidium puscharowski	X	
Elphidium joukovi	X	
Globigerina bulloides	X	
Globigerinita uvula	X	X
Tenuitella neobrevispira	X	X
Turborotalita quinqueloba	X	X
Tenuitellinata subcretacea	X	X
Neogloboquadrina pseudopachyderma		X
Saccammina sarmatica	X	X
Porosononion granosum	X	X
Brizalina nisporenica	X	X
Bolivina sarmatica	X	X
Brizalina saggitula	X	
Varidentella sarmatica	X	
Varidentella reusi		X
Affinetrina cubanica	X	
Caucasina subaculeata	X	
Nonion bogdanoviczi	X	
Rotaliella risilla	X	X
Ammonia beccarii	X	X
Ammonia lepida	X	
Pseudotriloculina fluviata		X
Caucasina sarmatica		X
Elphidium reginum		X
Elphidium obtusum		X
Mysidacea (shrimps)	X	
Halicoryne morelleti	X	X

kaya, 1996a, Andreyeva-Grigorovich *et al.*, 1997a,b, 2003, 2008).

The observed calcareous nannoplankton assemblage was typified by low species diversity and high number of specimens (exept of *Helicosphaera* genus). The mechanical deformation (fragmentation) of the nannoplankton was the main type of destruction. The majority of the assemblage consisted of destroyed small fragments of undistinguishable coccoliths and redeposited forms from the Upper Cretaceous and Eocene (mainly). The dissolution seems to be less important because nannoplankton did not show traces of dissolution. The calcareous nannoplankton assemblages were dominated by long-ranging placoliths without stratigraphical value (in particular *Coccolithus pelagicus*, *Reticulofenestra pseudoumbilica*) while *Cyclicargolithus* and *Calcidiscus* were subordinate. Helicosphaeraceae occurred less frequently. Due to a commonly poor state of preservation, many of them were excluded from identification procedure (especially small forms). *Pontosphaera* and *Braarudosphaera* species occurred with unstable frequency. *Pontosphaera multipora* was found in all investigated samples mainly as fragments. The index asteroliths were miss-

ing or occurred very rare as fragments (fragments of the arms) (*Discoaster* aff. *kugleri* was found only in the one sample from the Moryantsi 1 well, Ukrainian part of the foredeep). Sphenoliths were represented by small specimens of *Sphenolithus abies* only. The index *Sphenolithus heteromorphus* was missing in all the investigated samples, except of single occurrences (redeposited?) in the some samples. Characteristic features of the calcareous assemblage of the Krakowiec beds (except of Dzików 17 well) included: frequent presence of redeposited taxa, destroyed fragments of coccoliths, and low species diversity. An increase in the number of *Braarudosphaera bigelowii* and *Calcidiscus macintyrei* were observed in samples from the Księżpol 10, 11, 12, Dzików 15, and Biszcza 1 wells. Samples from the Dzików 17 well were included into the upper part of the Sarmatian. The assemblage was more diversified in comparison to those described in the other wells.

The sediments of the Kosiv Formation (Verbovets', Prut, Kolomyia nad Kovalivka beds) in western Ukraine were assigned to the NN6, undivided NN6-NN7 and NN7 zones. A gradual impoverishment of the specimens towards the upper part of the sampled formation was observed. In the upper part of the investigated wells, only Coccolithaceae and Prinsiaceae were found. In shallower intervals the numbers of redeposited form were growing. Many of the observed forms were found as fragments (*i.e.*, *Braarudosphaera* sp., *Helicosphaera* sp., *Pontosphaera* sp.). A typical assemblage was composed of: *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, (single specimens), *Pontosphaera multipora* (fragments), *Reticulofenestra pseudoumbilica*, *Umbilicosphaera rotula*, *Helicosphaera kamptneri*, *Sphenolithus abies*, and *Scapolithus fossilis*. The occurrences of small-sized helicoliths (*i.e.*, *Helicosphaera stalis*, *H. walbersdorfensis*) in the Podil'tsi 1 well suggest rather the NN6 zone. In samples collected from the Dashava Formation, the redeposited and damaged species predominated. In the extremely poor nannoplankton assemblage, mainly *C. pelagicus* and *R. pseudoumbilica* were identified. The composition of the calcareous assemblage was similar to that described from the upper part of the Kosiv Formation (Kolomyia nad Kovalivka beds). It was impossible to separate the calcareous nannoplankton assemblages from the investigated Kosiv and Dashava formations. It appeared that investigated samples from Dashava Formation were more impoverished than those from the older deposits and represented most likely the lower part of the NN7 zone (Fig. 10).

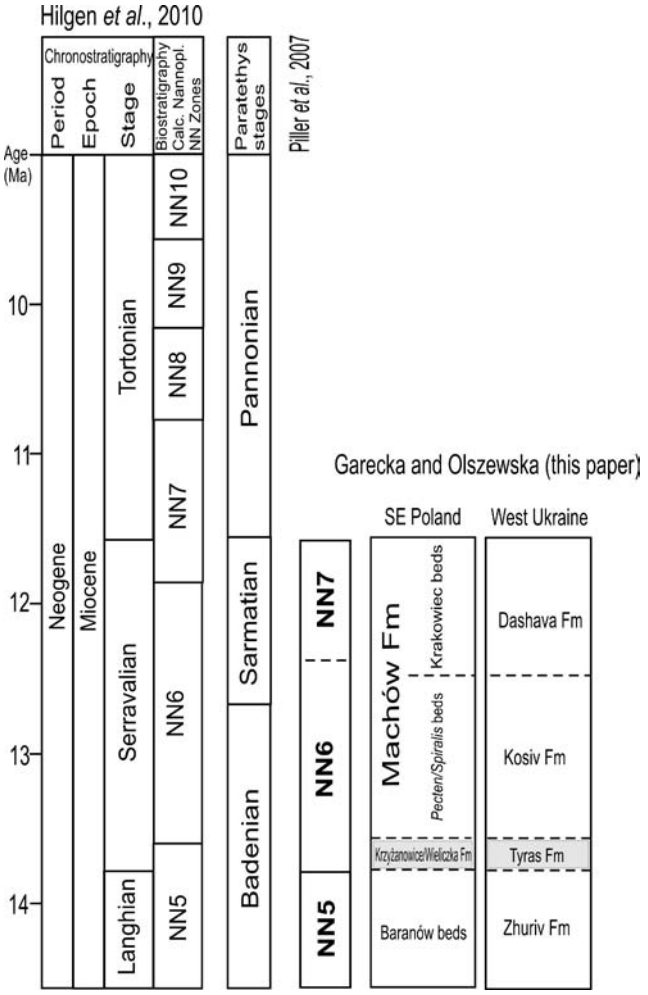

Fig. 10. Biostratigraphical scheme of the investigated Miocene deposits of the SE part of the Polish and NW part of the Ukrainian Carpathian Foredeep (Bilche – Volytsia Zone)

REMARKS ON THE PALAEOENVIRONMENT

The origin and development of the epicontinental sea – the Central Paratethys – during the Middle Miocene were subject of numerous studies (*vide* Kováč *et al.*, 2007). Changes of sedimentary conditions, to a certain degree, reflected global events depending on functioning of the gateways that transmitted oceanographic and climatic modifications (Mühlstrasser, 2001). Palaeoecological changes of sedimentary environment in the Polish part of the Central Paratethys were studied, among others, by Szczechura (1982), Czepiec (1991, 1996), Gonera (1994, 2001), Czepiec and Kotarba (1998), Gonera *et al.* (2000), and Peryt and Gedl (2010). Generally, two transgressive episodes took place in the Early Badenian. The first episode is marked by the presence of planktonic foraminifer *Praeorbulina glomerosa* (NN4 calcareous nannoplankton Zone), the second one by *Orbulina suturalis* (NN5 calcareous nannoplankton Zone) (Kováč *et al.*, 2007). The overlying evaporite sediments indicate temporal isolation of the eastern part of the Central Paratethys (Carpathian Foredeep, Transcarpathian and Transylvanian basins) (Peryt, 2006, with references herein). The late Badenian is marked by the last large transgression over the entire Central Paratethys basin (Kováč *et al.*, 2007). The foraminiferal assemblages are characterized by the presence of species *Velapertina indigena* and calcareous nannoplankton of the NN6 Zone.

The end of the Badenian brought about a significant sea-level fall accompanied by changes in water geochemistry (Gąsiewicz *et al.*, 2004). Both were reflected in assemblages of shallow-water (lagoonal), dwarfed, euryhaline foraminifera (Czepiec & Kotarba, 1998). Calcareous

nannoplankton assemblages were dominated by nearshore (*Coccolithus*, *Cyclicargolitus* and *Reticulofenestra*), shallow-water (*Braarudosphaera*, *Pontosphaera*) species. The open oceanic, typically warm-water forms (Discoasters, Sphenoliths) occurred sporadically or were mostly absent. Deltaic character of sedimentary conditions continued to the end of the Sarmatian. However, some restricted connections with the open seas were possible, as documented by the Mediterranean type of calcareous nannoplankton (Crihan & Marunteanu, 2006; Piller *et al.*, 2007). The problem of existing connections between the Central and Eastern Paratethys and the oceanic domain during the Middle Miocene, however, still remains controversial (Piller *et al.*, 2007).

CONCLUSIONS

The analysis of foraminiferal assemblages presented in this study confirmed two important facts connected with the Middle Miocene Central Paratethys faunas of the investigated region: reliability of foraminiferal zones described by Łuczkowska (1964), and the high degree of correlation between the Polish and Ukrainian assemblages (already indicated by Łuczkowska, 1964). Our results show that the calcareous nannoplankton assemblages, both of the Polish and Ukrainian part of the Carpathian Foredeep, are similar. The correlation of these deposits on the basis of this group of microfossils is, therefore, possible. The obtained results concur with the earlier observations (*i.e.*, Andreyeva-Grigorovich *et al.*, 2003; Peryt *et al.*, 1998; Peryt, 1999). In the majority of the analysed wells of the Ukrainian part of the Carpathian Foredeep it is not possible to discriminate the calcareous nannoplankton assemblages of the highest part of the Kosiv Formation (Kolomyia and Kovalivka beds) from those of the lower Dashava Formation. The gradual impoverishment of species in the assemblages of the upper part of NN6 and the lower part of NN7 Zones are observed. The assemblages are of low diversity and mainly restricted to a few species with high abundance (*i.e.*, the Krakowiec beds and upper parts of the Kosiv and Dashava formations). The assemblage is composed mainly of placoliths (nearshore) and shallow-water pentaliths, which only confirm the isolation of the basin. The high number of reworked nannofossils and damaged elements of the coccoliths suggest a high supply of terrigenous material, unstable condition in the basin and suggest shallow-water conditions.

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