The youngest members of the folded Miocene in the Andrychów region (Southern Poland)

Antoni Wójcik*, Małgorzata Jugowiec*

Deposits of the folded Miocene appear in the surrounding of Andrychów. In the profile of the sediments occurring here, clays with gravels and boulders, mainly flysch ones, clays with gravels of crystalline rocks, limestones and flysch deposits, dark clays with organic detritus and large flysch olistoliths as well as sandy clays and sands are distinguished. The youngest deposits, developed as gray clays, sandy clays with an irregular and thin sandy inter-lamination, have been identified in the Bulówka stream. Based on the presence of C. coalithus and C. cf. calyculus the age of the studied deposits has been determined as the nannoplankton zone NN9a/8 that corresponds to the Lower Pannonian in a stratigraphic division for Central Paratethys.

Key words: *Carpathian Foredeep, Andrychów Poland, Miocene, Panonnian, biozones, nannoplankton, new data*

Introduction

Up to this time, in the studies on the Miocene the youngest deposits have been identified in the eastern part of the Carpathian Foredeep. They are developed as clays and clay-shales with interlamination of sands or weakly cemented sandstones, known as Krakowiec Clays (Łomnicki, 1897; Ney, 1968; Czapowski, 1994) or as Przeworsk Beds being a member in the formation of Machów (Alexandrowicz et al., 1982; Jasionowski 1995). Inferring from the presence of *Anomanolinoides dividens* in the Przeworsk Beds, the youngest deposits in question are assigned to the Lower Sarmatian (Łuczkowska, 1964; Krach et al., 1970). Yet the overlaying Jarosław Beds have been attributed to the Volynian.

Studies on calcareous nannoplankton in the Carpathian Foredeep concentrated mainly on evaporites which form a characteristic correlation complex. Peryt (1991), Dudziak & Łaptaś (1991), Dudziak & Łuczkowska (1991) assign the evaporites to NN6 zone, although their part may belong to NN5 zone. Gaździcka (1994) allocates the series of the evaporites in NN7 zone. According to Peryt et al. (1998) presence of *Cyclicargolithus floridans* in the evaporites from Ryszkowa Wola indicates that these deposits are not younger than NN6 zone. Gaździcka's (1994) nannoplankton studies from the region of Tarnobrzeg suggest that sedimentation of clayey layers of the Miocene took place here in the Late Sarmatian (zones NN8 *Catinaster coalithus* and NN9 *Discoaster hamatus*). According to Gaździcka (1996), the presence of *Discoaster bellus* Bukry et Percival, *D. intercalaris* Bukry in Krakowiec Clays in the region of the Stalowa Wola allows for assigning the deposits to the uppermost part of NN9 zone to zone10. Unpublished records of Gaździecka (*vide* Laskowska-Wysoczańska, 1993), referring to the nannoplankton identification in the profiles of Hadykówka, Kupno, Zarzecza and Siedliska near Przemyśl, indicate that these deposits might be even younger (nannoplankton zones NN10 and NN11). Results of the investigations show that sedimentation in the Polish section of the Carpathian Foredeep lasted much longer than it has been assumed hitherto.

In the south-western part of the Carpathian Foredeep between Cracow and Cieszyn (zone of the Carpathian overthrust) occur the Lower Badenian deposits known as the Skawina Beds (Alexandrowicz, 1974; Buła & Jura, 1983). Lack of younger deposits is additionally explained by a lack of evaporites west of Cracow. Only Moryc (1989), based on unpublished micropaleontologic identification of Kirchner, claims that the para-autochthonous Miocene deposits, identified in borehole Kęty 8, are of the Late Badenian age (according to other authors these are deposits of the autochtonous Miocene — Moryc, 1989). Also Nowak (1959), based on micropaleontological data, assumes that the Miocene deposits in the area of Wieprz–Nidek are of the Middle Tortonian age (*recte* — Badenian, cf.). Younger deposits have been stated in the northern and western parts of the Carpathian Foredeep (Alexandrowicz et al., 1982).

In the territory of the Carpathians, the youngest deposits, dated as the Late Badenian–Sarmatian, occur in the Nowy Sącz Basin and in the region of Iwkowa (Oszczypko et al., 1991, 1992; Cieszkowski et al., 1989). In the surrounding of Andrychów Krach & Nowak (1956) singled out the older deposits (Helvetian), deposits of the Lower Badenian (Lower Tortonian and Lower Opolian) as well as the deposits corresponding to Chodenice and Grabowiec Beds being associated with the Middle and Upper Badenian. Krach (1956) believed that the Miocene in the Andrychów environs corresponded to sands from Rajsko and Bogucice which are determined to be of the Late Badenian age. Suggestions of Krach (1956) and Krach & Nowak (1956) that the deposits younger than the Opolian (*recte* — Lower Badenian) occur in the vicinity of Andrychów had been omitted in all successive papers in that field. The deposits in question used to be included to the Lower Badenian (Żytko et al., 1989). Younger deposits of the Lower Badenian identified in the Moravian section of the Carpathian Foredeep are dated as Late Badenian while those identified in the Moravian part of the Vienna Basin as Latest Sarmatian and Panonian (Čtyroký, 1994; Hámor, 1988).

Following the suggestions about occurrence of the Upper Badenian deposits in the Andrychów region, re-examination of this area has been undertaken. The main problem is a decisive determination of age of the Miocene deposits based on biostratigraphic data. That is particularly meaningful in solving numerous paleogeographic, tectonic and sedimentological issues which are subject to ongoing studies. Exposures in this region have been sampled for foraminifera and calcerous nannoplankton analysis.

Location of the study area

The region between Andrychów and Kęty is the area where Miocene deposits crop out (Fig. 1). These deposits are

*Polish Geological Institute, Carpathian Branch, ul. Skrzatów 1, 31-560 Kraków, Poland

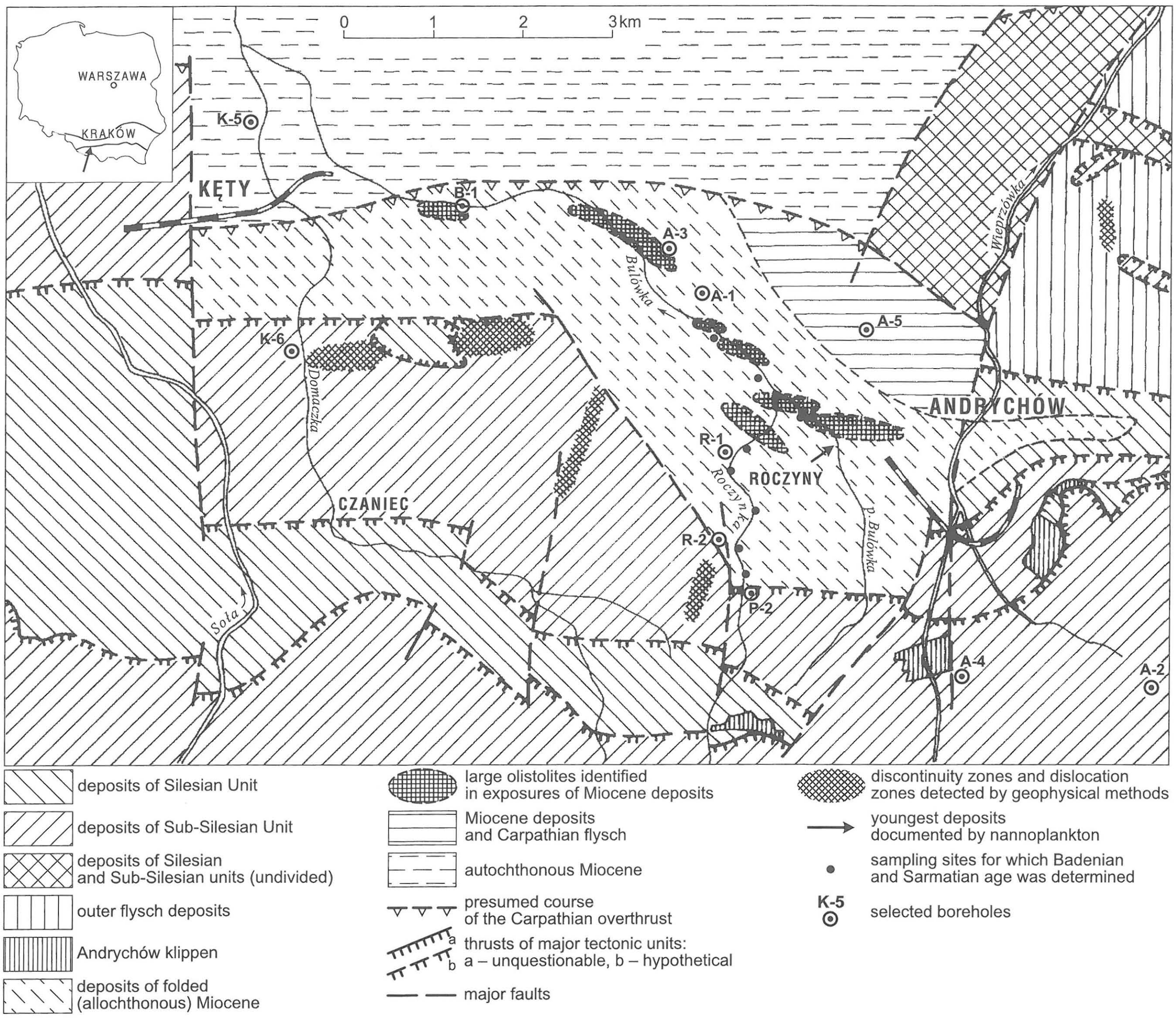


Fig. 1. Distribution of the Middle Miocene deposits in the Andrychów region on tectonic sketch after Nowak (1966), modified

present north of the Silesian nappe thrust over the Sub-Silesian nappe as well as north of the Andrychów Klippen Belt whose genesis is debatable. The klippes used to be considered as tectonically detached blocks occurring at the base of the Silesian Unit (Książkiewicz, 1972). However, these klippes are also believed to be of olistostrome origin (Koszarski, 1992). In the region of Andrychów and Roczyny Miocene deposits crop out mainly in the channels of the Roczynka and Bulówka streams. Unfortunately, the state of the exposures during the field work was not always satisfactory and, maybe because of that, not all the records registered during the preceding work have been confirmed, e.g. occurrence of tuffites. In the region between Andrychów, Roczyny and Kęty several research and exploratory boreholes (Roczyny 1, 2, Andrychów 1–5, Kęty 6, Bulowice 1; Fig. 1) have been drilled until now in the profiles where the allochtonic or para-autochtonic Miocene separated by flysch series connected with the Sub-Silesian Unit is stated.

Krach & Nowak (1956) presumed that the Miocene deposits in the Andrychów surrounding rest on the flysch and were simultaneously thrust and folded. Larger fragments of flysch, occurring north of the Silesian overthrust are included either to the Sub-Silesian or Silesian units which were subjected to a sea transgression during the Early and Middle Miocene.

Lithologic profile of the Miocene deposits (Badenian–Sarmatian?)

Krach & Nowak (1956) distinguished several rock series, differing with respect to their lithology, in the Miocene deposits of the discussed area. Based on the field studies of natural exposures and on the made drillings (X and Y — Roczyny 2 and Roczyny 1) these authors identified sandy clays with flysch blocks and pebbles — variegated conglomerates, dark conglomerates, clays with flysch fragments, clays with tuffites, dark clays with fauna detritus, sandy clays with inserts of sandstones, dark clays, clays with flora and fauna detritus and clays with sands.

The oldest deposits are clays and sandy clays with blocks and pebbles of flysch rocks and variegated conglomerates. They are exposed in the Roczynka stream (Fig. 1). Their outcrops are observed in a 450 m long section along the stream channel west of the school in Roczyny. The discussed deposits are dark grey and grey clays and clay-shales containing fragments (of various sizes) of red shales and marls, dark, light green and grey marls, dark red and green shales, blocks of conglomerates, rounded limestones, hornfelses, grey shales, grey shales with muscovite, sandstones, singular grey quartzes. In numerous spots larger content of red marls and shales causes some beds to be more reddish. Discontinuous sandy laminae were observed in the clays.

The material comprises with rocks originating mainly from the Carpathian flysch deposits: angular or weakly rounded blocks up to 40–150 cm in diameter as well as pebbles and cobbles or as pellitic material. Rock fragments with preserved layering are found in larger blocks. Bearing in mind that some exposures are weakly preserved determination of the clast content in the clays is not precise in many spots. In certain section of the profile a higher amount of large rocky blocks has been observed. Yet in some spots flysch becomes less abundant and clays with fine or very fine rock fragments occur.

North-west of the school in Roczyny, close to the outlet of the Roczynka tributary, „variegated conglomerates" crop out. These are 0.4–3 m thick layers consisting of sandy clays and coarse-grained sandstones with a quite large content of unevenly distributed angular red and green marls reaching up to 5–15 cm. Within these layers gradation of clastic material towards north is occasionally visible. Reverse situations were also observed. If the layers were dipping southward, the layers would be arranged in an opposite order. Besides the marls, angular sandy gravels, fragments of shales and other rocks crop out along 20–50 m section.

Based on lithology and composition of rock material present in the clays it is likely that the sediments of the discussed type were forming at Miocene sea coast built of flysch deposits with a high content of the series comprising marls that, according to Nowak (Krach & Nowak, 1956), belong to the Sub-Silesian Unit.

A similarly developed sediments were described from borehole Roczyny 2 (profile X, Krach & Nowak, 1956) where 45 m thick variegated conglomerates occur under the flysch. In this borehole, under the conglomerates described above, was pierced a 27 m thick series of dark conglomerates consisting of well rounded pebbles of dark quartz cemented with a dark sandy clay. Besides the dark quartz there occurred lemon-yellow, white and satin quartzes, the latter with a pyrite coating, rounded pebbles of various limestones, dark quartzites, and shales and sandstones originating most likely from the Carpathian flysch. They are believed to be lithologically closest to conglomerates known from the Dębowiec region and described by Tołwiński (1950) and Mitura & Kuciński (1952). Similar conglomerates were drilled at the depth of 392 m in borehole Roczyny 1 and were included to autochthone Miocene, yet in the light of the most recent studies and drillings it seems not very likely. On the ground surface such deposits have not been identified. Only to the north of the described variegated conglomerates, downstream of the left tributary of the Roczynka stream, a higher content of quartz pebbles was observed which maybe counterparts of dark conglomerates from borehole Roczyny 2 described by Krach & Nowak (1956).

Krach & Nowak (1956) assumed these sediments to be of the Helvetian–Early Badenian age. Results of foraminiferal studies performed for the referred section indicated the Carpathian–Early Badenian age (Olszewska — personal communication) while nannoplankton studies pointed to the Badenian age (Garecka — personal communication). One sample taken from a middle part of the exposure, upstream of the outlet of the first left tributary of the Roczynka stream, shows the Sarmatian age of the sediments (Garecka — personal communication).

The largest areas are occupied by clay and clay with fauna detritus as well as with gravels and olistoliths. The outcrops of these clays occur along the Roczynka and Bulówka streams and form a thick layer which is characterised by a large spatial differentiation. In the profile these deposits overlie the already mentioned clays with blocks and gravels, and the variegated conglomerates. The referred clays are facies equivalents of a rock series described above. In the southern part, along the exposures in the Bulówka stream, as well as north of the variegated conglomerates in the Roczynka stream, there are dark clays locally interbedded with sands. These clays are plastic, coarsely cleavable, dark-grey in colour. Below occurs the series consisting of dark clays with singular, rounded fragments of green, black and red shales, marls, sandstone blocks and large olistoliths occur locally. Clays are grey in colour and brownish, strongly calcareous, with shell-fracture on their weathered surfaces. These clays form a few cm thick layers, often containing fauna detritus on the layer planes. Sometimes these are soft, plastic clays, grey in colour with abundant fauna of thin-shell molluscs. This series crops out along the Roczynka stream, over about 800–900 m long section downstream of a playground and in the Bulówka stream, north of the outlet of the Roczynka stream. In the profile of borehole Roczyny 1 Krach & Nowak (1956) identified sandy clays with flora. These are dark brownish sandy clays with a large amount of plant detritus. In the bottom part of the profile these are mainly sands and weakly cemented sandstones with thin straps of plant detritus. At the surface, small admixtures of plant detritus in clays were observed in exposures in the lower reach of the Roczynka stream.

Olistoliths built of Miocene and flysch deposits occur along the exposures in the Bulówka stream, between Roczyny and Andrychów, and along the Roczynka stream. The Miocene olistoliths consist of blocks of Miocene clays with preserved lamination and containing detritus of calcareous shells, singular well rounded sandstone and limestone pebbles, as well as small fragments of marls and red, green and black shales.

Nannoplankton and foraminiferal specific composition of the sampled clays show that these are Badenian deposits containing significant admixtures of fossils from older periods (Garecka, Olszewska — personal communication). According to Krach & Nowak (1956) these deposits are attributed to Opolian (Lower Badenian) and maybe correspond to Heterostegina clays from Benczyn. The malacofauna assemblages, identified by Krach (Krach & Nowak, 1956), show that here occur the assemblages of a shallow shelf environment.

Large flysch olistoliths occur in this clay series. In the studies that have been carried out until now, they were treated as the deposits of the Sub-Silesian Series with the transgressively overlying Miocene deposits which were folded together (Nowak, 1959). Inferring from the performed observations these are large olistoliths transferred gravitationally. In the lower section of the Roczynka stream, there are exposures where contacts of these deposits with the Miocene clays are visible. Similar exposures are in the Bulówka stream both downstream and upstream of the Roczynka mouth (Fig. 1). A sedimentary character of deformations is evidenced by sedimentary breccias present at the bottom and top of the flysch deposits (of various sizes) as well as by flow structures, lack of open fissures and tectonic windows, and clays forced or interlocked with flysch. Besides, here the clays are interlayered with the flysch. However, flysch rocks do not form a uniform packet, they are worn out in places or interlaminated with grey clays containing Badenian microfauna. That is most simply explained by gravitational transfer of the whole, several meters thick packet.

On the profiles, based on the performed drilling, multiple sequences of the Miocene deposits interlaminated with flysch were interpreted as overthrusts. What is more, in the descriptions accompanying the drillings the deposits linked with the Sub-Silesian Unit used to be claimed „tectonic breccia of the Sub-Silesian Unit". It might be presumed that these are large olistoliths consisting of deposits, related to the Sub-Silesian Unit, which slipped to the Miocene basin. Similar deposits originating from the regions of Cieszyn and Dębowiec were described by Szymakowska (1986) who considered them as an olistostrome series within the autochthonous Miocene.

The youngest Miocene members in the Andrychów region

The youngest deposits are the grey clay series with sands. This series crops up in the Bulówka stream (Figs 1, 2) and consists of clays and irregular sandy laminae. The clays are grey and green in colour, yet at the surface their colour turns into brownish, are coarsely cleavable, form 5–10 cm thick layers and are separated with thin, irregular coarse-grained sandstones and sands, conglomerate-like in places. Sometimes, they form thin, weakly cemented beds with a calcareous-ferrous cement. Sandy beds vary in thickness in a wide range and in some sections they pinch out. In the sandy material, singular, very well rounded sandstone gravels emerge. Krach & Nowak (1956) supposed that they could correspond to the Grabowiec Beds.

South of the bridge over the Bulówka river, between Andrychów and Roczyny, dark grey sandy clays, whose beds reach to 10 cm, interlayered with weakly cemented, 2–8 cm thick, sandstones, occur. Sandy material forms a better cemented parts gradually changing into bed of loose sands. This series is lithologically similar to the deposits downstream the bridge. Unfortunately, paleontologic material sufficient for age determination has not been found yet. Beds of clays and weakly cemented sandstones are arranged almost vertically or dip 75–87°S.

From the outcrops in the Bulówka stream, upstream of the bridge from Roczyny to Andrychów, there were taken five samples which did not contain calcareous nannoplankton or which contained only single forms of *Coccolithus pelagicus* (Wallich) Schiller and unidentified as to the species but belonging to Prinsiaceae family. The samples taken upstream the mouth of Roczynka stream did not contain calcareous nannoplankton as well. Only in two samples nannoflora were identified which helped to determine the age of the deposits as the Late Cretaceous without detail studies (the deposits are most likely re-deposited from the flysch or originate from clasts stuck in the Miocene material).

The best exposure of grey Miocene clays with irregular sandy intercalation occurs along the right bank of the Bulówka stream downstream the bridge in Roczyny of the road Roczyny–Andrychów (Figs 1, 2). Three samples taken here are characterized by a rich, both as to its abundance and

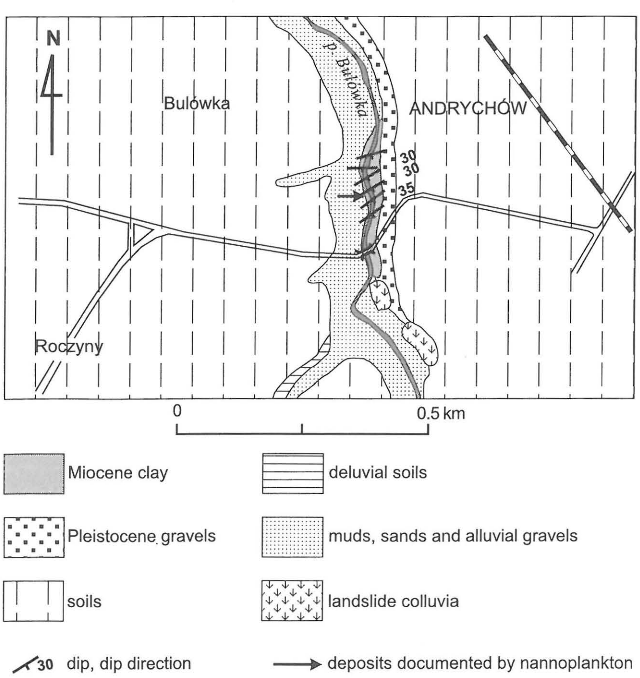
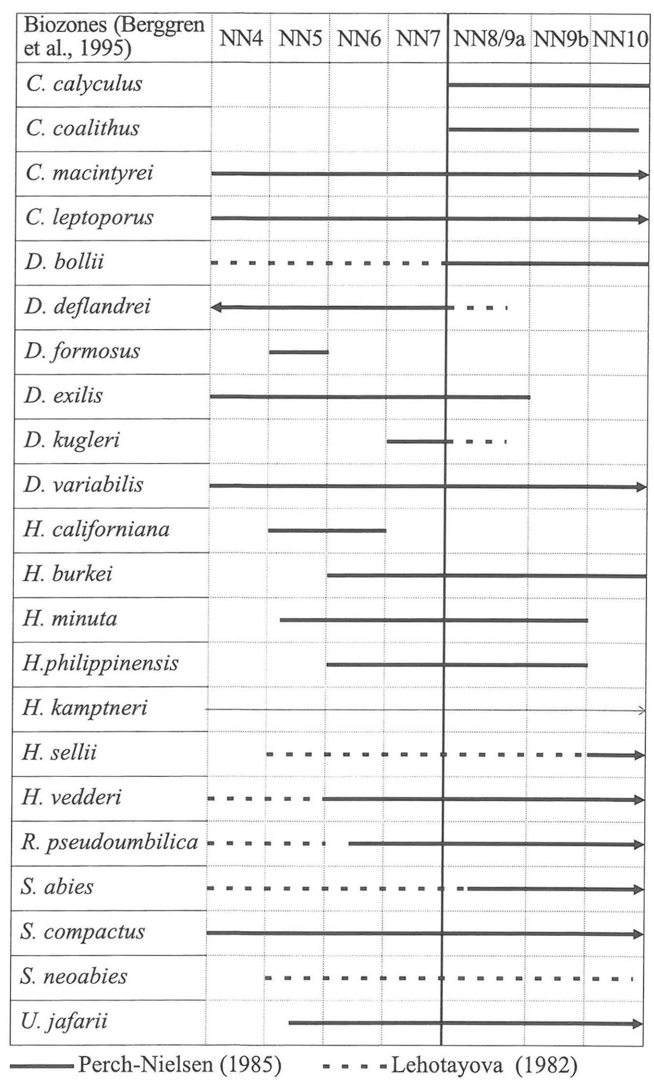


Fig. 2. Location of the Micene clay outcrops in Andrychów



Tab. 1. Stratigraphic range of major species after Perch-Nielsen (1985) and Lehotayova (1982)

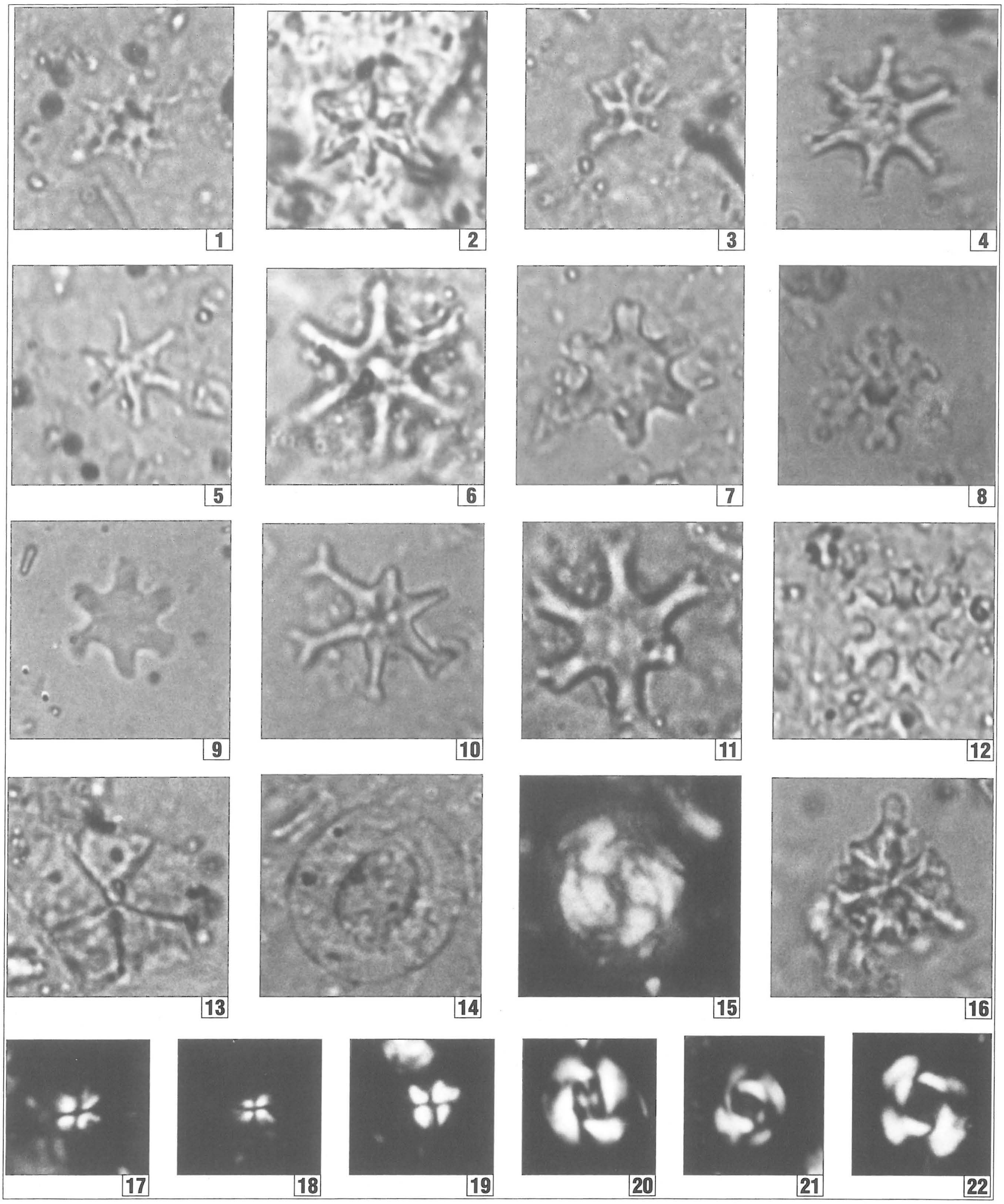


Fig. 3. Miocene calcereous nannoplankton from the Adrychów: 1, 2 — *Catinaster coalithus* Martini & Bramlette; 3 — *Catinaster* cf. *calyculus* Martini & Bramlette; 4, 5 — *Discoaster exilis* Martini & Bramlette; 6 — *Discoaster formosus* Martini & Worsley: 7, 8 — *Discoaster bollii* Martini & Bramlette; 9 — *Discoaster kugleri* Martini & Bramlette; 10, 11 — *Discoaster variabilis* Martini & Bramlette; 12 — *Discoaster deflandrei* Bramlette & Riedel; 13 — *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre; 14, 15 — *Coccolithus miopelagicus* Bukry; 16 — *Lithostromation perdurum* Deflandre; 17, 18 — *Sphenolithus abies* Deflandre; 19 — *Sphenolithus neoabies* Bukry & Bramlette; 20 — *Reticulofenestra lockeri* Müller; 21, 22 — *Reticulofenestra pseudoumbilica* Gartner (all specimens at magnification x 2,400)

preservation, nannoflora. The state of nannoplankton preservation has been recognized as good. Majority of species bear traces of secondary calcification and re-crystallization while the discoasters are mechanically damaged (broken arms) yet they are still suitable for age determination. In the studied samples there is a large percent of re-deposited Paleogene

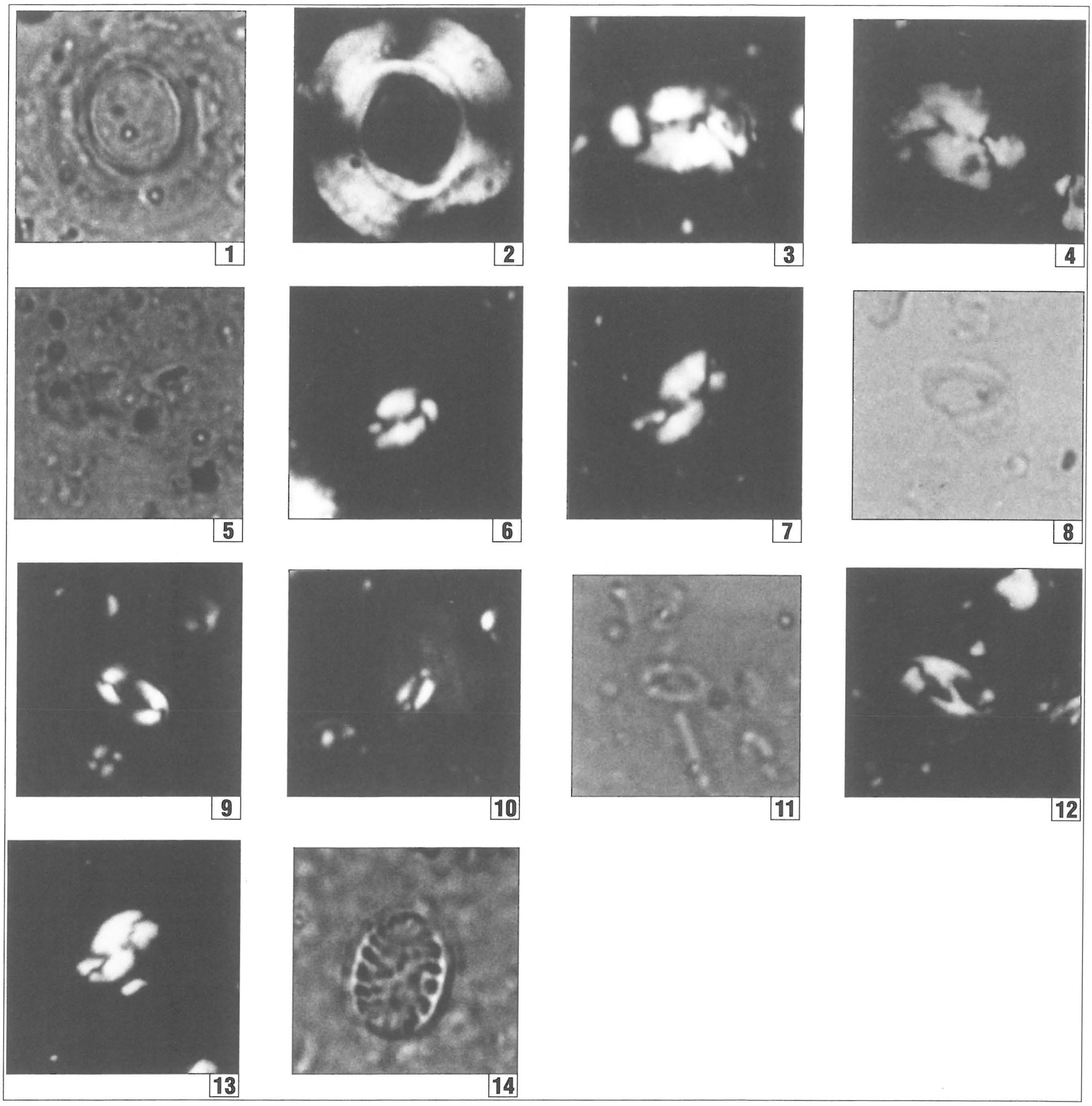


Fig. 4. Miocene calcereous nannoplankton from the Adrychów: 1, 2 — *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski; 3, 4, 5 — *Helicosphaera kamptneri* Hay & Mohler; 6 — *Helicosphaera philippinensis* Müller; 7 — *Helicosphaera carteri* (Wallich)Kamptner; 8, 9 — *Helicosphaera walsberdorfensis* Müller; 10, 11 — *Helicosphaera minuta* Müller; 12 — *Helicosphaera vedderi* Bukry; 13 — *Helicosphaera sellii* Bukry & Bramlette; 14 — *Pontosphaera rothii* Haq (all specimens at magnification x 2,400)

forms, mainly Eocene ones, as well as not numerous Upper Cretaceous species which are very well preserved.

The following Miocene species have been determined (Tab. 1): *Catinaster* cf. *calyculus* Martini & Bramlette, *C. coalithus* Martini & Bramlette, *Calcidiscus leptoporus* (Murray & Blackman) Loeblich & Tappan, *C. macintyrei* (Bukry & Bramlette) Loeblich & Tappan, *Coccolithus miopelagicus* Bukry, *C.pelagicus* (Wallich) Schiller, *Discoaster bollii* Martini & Bramlette, *D. exilis* Martini & Bramlette, *D. kugleri* Martini & Bramlette, *D. musicus* Stradner, *D. variabilis* Martini & Bramlette, *Helicosphaera burkei* Black, *H. carteri* (Wallich) Kamptner, *H. minuta* Müller, *H. philippinensis* Müller, *H. sellii* Bukry & Bramlette, *H. vedderi* Bukry, *Reticulofenestra pseudoumbilica* Gartner, *Sphenolithus abies* Deflandre, *S. compactus* Backman, *S. moriformis* (Bronnimann & Stradner) Bramlatte & Wilcoxon, *S. neoabies* Bukry & Bramlatte, *Umbilicosphaera jafarii* Müller (Figs 3, 4).

The presence of *C. coalithus* and *C.* cf. *calyculus* (Fig. 3, 1–3) together with the described above Miocene assemblage allows for assigning the studied sediments to the nannoplankton zone NN8 — *Catinaster coalithus. C. coalithus* and *C.* cf. *calyculus* occurs in this zone for the first time. According to Perch-Nielsen (1985) *C. miopelagicus* and *D. exilis*, a few species of which are present in slides prepared from the taken samples, disappear before the upper boundary of the NN8 zone. Sporadically occurring *D. kugleri* which is limited to the NN7 zone and lack of *D. hamatus* which indicates the upper boundary of zone NN8 allow for including the investigated samples to the lowermost part of zone NN8. At present, in Central Paratethys NN8 and NN9 zones are joined in one zone NN9a/8 comprising the lower part of the Pannonian (Rögl, 1995).

Gaździcka's studies (1994) from the Pecten Beds and Krakowiec Clays in vicinity of Tarnobrzeg suggest that the age of these Miocene deposits is of NN 8 and NN 9 zones because of lack of *D. kugleri* and *D. exilis* and presence of *D. calcaris*. The age of the Miocene deposits from the Roczyny region is assigned to the same zones, nevertheless *D. kugleri* and *D. exilis* still occur here (although sporadically) but *D. calcaris* is lacking while index taxa of zone NN8, i.e. *C. coalithus* and *C.* cf. *calyculus* appear (Tab. 1).

As in the case of the Tarnobrzeg region there is a large content of the Upper Cretaceous and Eocene species in the nannoplankton assemblage which indicates a high supply of terrigenic material to the basin (Gaździcka, 1994). Numerous forms of *Helicosphaera* and singular forms *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre suggest that the deposits were deposited in a hemipelagic environment.

Final remarks

The results presented above provide evidence of the upper part of Middle Miocene and Upper Miocene deposits occurring in the Andrychów region. The deposits are younger than the series of evaporites and show that the area of the Middle–Late Miocene marine sedimentation should be extended further to the west when compared with the presently accepted range. Depending on the accepted stratigraphic division these deposits might be included to the Latest Sarmatian or to the Early Pannonian. The identification of nannoplankton performed hitherto referred in majority to the series of evaporites (Peryt, 1991; Dudziak & Łuczkowska, 1991; Dudziak & Łaptaś, 1991; Peryt et al. 1998) whose deposition took place in the lower NN6 zone.

Comparing the nannoflora assemblages from the Andrychów region with the assemblages from the eastern part of the Polish Carpathian Foredeep in the Tarnobrzeg region (Gaździcka, 1994) one concludes that they are alike thus, much younger than the evaporites. However, these issues require further micropaleontological and geological studies.

Determination of so young age of the deposits occurring here has certain paleogeographic and tectonic implications. Sedimentation of these deposits took place south of the area where these deposits occur at present. Yet there is still a puzzle to which part of the Carpathian Foredeep these deposits should be related. In the paleogeographic studies carried out hitherto, the area extending west of Cracow to the Opava–Rybnik Basin was land in the Sarmatian or maybe even in the Middle Badenian, because the marine sediments of these stages were not known (Alexandrowicz, 1963; Hámor, 1988; Ney, 1968).

Results of these studies show that the thrusting process in the western section is much younger than it has been assumed (Alexandrowicz, 1965; Książkiewicz, 1972). Książkiewicz (1972) presumed that the rim of the Carpathian thrust over its foreland earlier in the west and later in the east. So young age determined for the folded Miocene deposits in the Andrychów region indicates that also in the younger Miocene thrusting took place in the western part of the Carpathians as well as in the eastern part. Moreover, these deposits are folded. Thus, there are many problems to be explained in future research. The most important are those related to: sedimentation and supply area of Miocene deposits; occurrence of crystalline rocks and limestones in conglomerates; locality of paleogeographic basin in which young-Miocene sediments were deposited; and to post-sedimentary tectonic movements. The presented reasoning suggests that thrusting movements in the western part of the Carpathians are post-Sarmatian in age.

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