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AGE AND PALAEOENVIRONMENT OF THE KOŚCIELISKA MARL FORMATION (LOWER CRETACEOUS) IN THE TATRA MOUNTAINS, POLAND: PRELIMINARY RESULTS

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Abstract: The Kościeliska Marl Formation is a characteristic lithostratigraphic unit of the lower Sub-Tatric Unit in the Tatra Mountains. It consists mostly of marlstones and calcilutites and subordinately of calcarenites and sandstones, and contains the Valanginian through early Aptian nannofossils. Moreover, one sample contains calcareous nannoplankton from the Aptian/Albian boundary. The reverse position of beds is proved on the base of nannoplankton succession in the type locality of the formation in the Dolina Kościeliska Valley. Trace fossils and sedimentological observations indicate a well-oxygenated environment below the maximum wave base during sedimentation of these deposits. The nannoplankton assemblage is typical of the Tethyan realm. Some influence of the Boreal realm is suggested during Late Valanginian and Late Hauterivian.

Abstrakt: Formacja margli z Kościeliskiej (fm) jest charakterystyczną jednostką litostratygraficzną płaszczowiny reglowej dolnej w Tatrach. Zbudowana jest ona głównie z margli, kalcylutytów i podrzędnie z kalkarenitów i piaskowców. Zawiera ona nannoskamieniałości wskazujące na wiek od walanżynu po apt dolny. Ponadto jedna próba zawiera nannoplankton z przełomu aptu i albu. Wiekowe następstwo nannoskamieniałości wskazuje na odwrócenie warstw w części profilu typowego w Dolinie Kościeliskiej. Skamieniałości śladowe wskazują na dobrze utlenione środowisko depozycji osadów, położone poniżej maksymalnej podstawy falowania. Zespół nannoplanktonu jest charakterystyczny dla prowincji tetydzkiej. W późnym walanżynie i w późnym hoterywie nastąpilo prawdopodobnie połączenie ze zbiornikiem borealnym.

Key words: Cretaceous, Tatra Mountains, nannofossils, trace fossils, stratigraphy, palaeoecology, tectonic problems.

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INTRODUCTION

The "Neocomian marls", which are the youngest deposits of the lower Sub-Tatric (Kri_na) Unit in the Tatra Mountains, needs better stratigraphic documentation. They were distinguished as the Kościeliska Marl Formation, and the outcrops at the western, and partially at the eastern side of the Dolina Kościeliska Valley (Fig. 1) were selected as the typical section of this formation (Lefeld, 1985).

Age of the Kościeliska Marl Formation was previously determined on the basis of ammonites, with the Berriasian, Hauterivian, Valanginian, and Barremian stages being documented (Vigiliev, 1914; Lefeld, 1974). According to Lefeld (1985), the occurrence of ?Lower Aptian deposits is highly probable. The main problem with the age documentation of the Kościeliska Marl Formation is lack of detailed localization of the ammonites used for dating, as these were collected mostly from loose blocks. Moreover, the tectonic position of the type section is not clear.

The primary objective of this study is to document the age of the Kościeliska Marl Formation on the basis of *in situ* sampling nannofossils in the type section, and in an additional section in the Dolina Chochołowska Valley (Fig. 1). Moreover, new data on the palaeoenvironment based on trace fossils and nannofossils are presented. Nannofossil and trace fossil investigations of the Kościeliska Marl Formation were not hitherto carried out.

The problem of tectonics, however, is not resolved. It needs, further extensive investigations, especially a detailed mapping. For this reason the section of the Kościeliska Marl Formation cannot be completed, yet.

LOCATION, LITHOLOGY AND TECTONIC PROBLEM

The Kościeliska Marl Formation is a characteristic lithostratigraphic unit of the lower Sub-Tatric (Kri_na) tectonic unit in the western part of the Tatra Mountains. It is also a characteristic component of the "Neocomian facies", which are widely distributed in the Western Carpathians (Vašíček *et al.*, 1994). It occupies the highest position in the

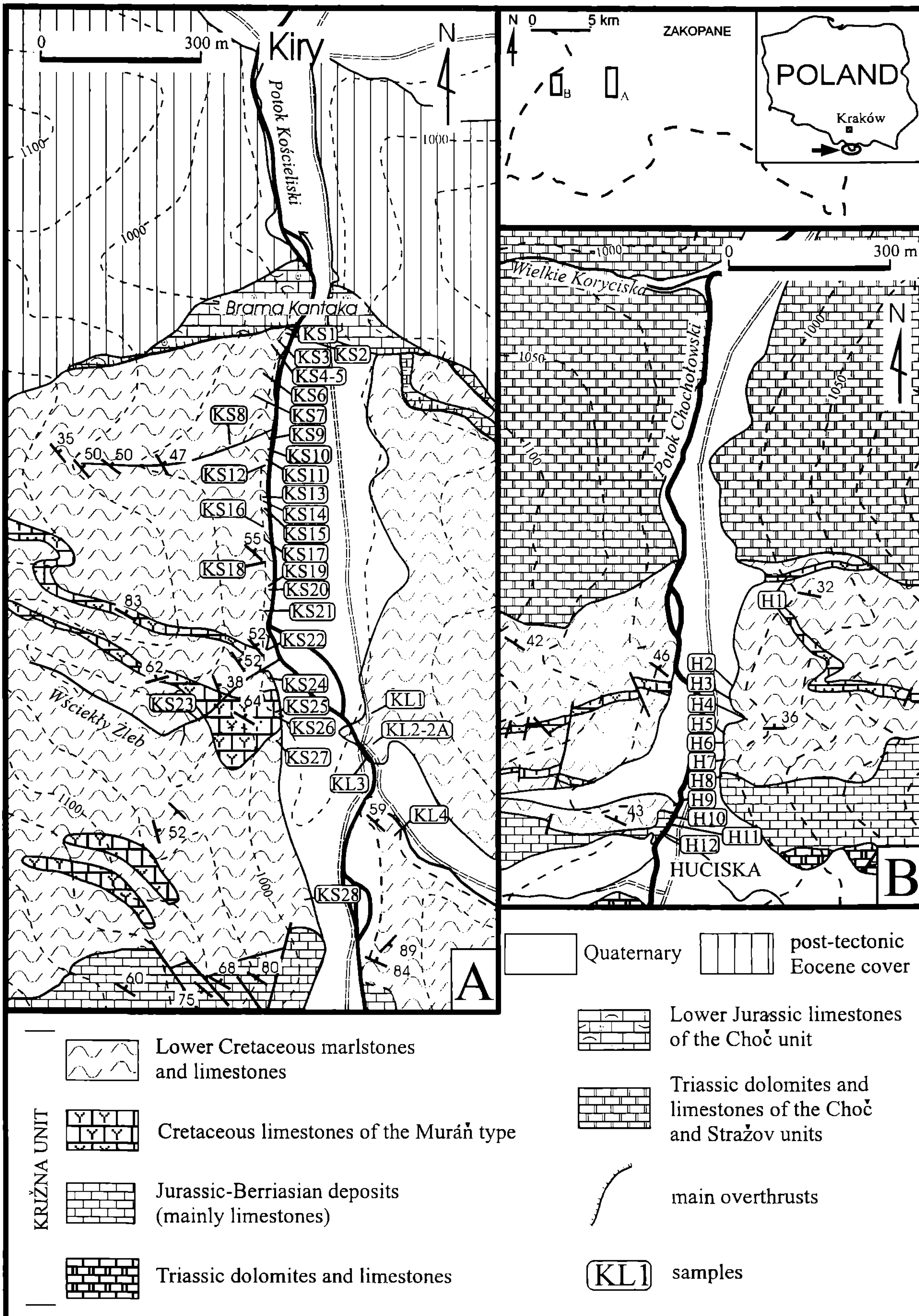

Fig. 1. Locality maps (based on Guzik & Guzik, 1958; Guzik *et al.*, 1958; Bac-Moszaszwili *et al.*, 1979), showing position of collected samples

Bobrowiec Unit, which is the largest thrust-sheet of the western part of the Tatra Mountains. Between the Dolina Kościeliska and Dolina Chochołowska valleys, the Kościeliska Marl Formation is underlain by Tithonian–Berriasian pelagic Maiolica-type limestones (Pieniny Limestone Formation according to Lefeld, 1985), and its top is tectonically or erosively truncated. The formation is capped by the narrow, strongly tectonised belt of Jurassic rocks of the lower Sub-Tatric domain, carbonates of the Choč Unit (Brama Kantaka thrust sheet and Siwa Woda Unit), or Eocene conglomerates. In the eastern part of the Tatra Mountains, the Kościeliska Marl Formation is overlain by the platform-derived, mainly Hauterivian–Barremian Muráň Limestone Formation (Lefeld, 1985; Vašíček *et al.*, 1994).

The Kościeliska Marl Formation is composed mainly of light- to dark-gray marlstones, which are interbedded with calcilutites of similar colours. Locally, they are intercalated by beds consisting of up to a dozen-metres-thick packages of calcarenites, and beds of turbiditic calcareous sandstones. The marlstones and calciluties are characterised by "Flecken" structures, which are mainly a kind of ichnofabric. They contain benthic foraminifera, sponge spicules, and rarely ostracods, flattened ammonites, and belemnite guards. South of the Brama Kantaka thrust sheet, a 10-cm-thick layer of brown marlstone occurs within gray marlstones. The calcarenites are mainly pelsparites with crinoids or crinoidal biosparites. They are partially silicified and commonly contain discontinuous layers of spiculites. They are interpreted as calcareous turbidites and compare well to the Muráň limestones, which overlie the Kościeliska Marl Formation in the eastern part of the Tatra Mountains as the Muráň Limestone Formation (Lefeld, 1985). Vigiliev (1914) noted the occurrence of aptychi, bivalves, brachiopods, fish, and plant remains in the whole complex of the "Neocomian marls".

The tectonics of the area occupied by the Kościeliska Marl Formation between the Dolina Kościeliska and Dolina Chochołowska valleys is very complicated and remains obscure. According to the geological map 1 : 10 000 (Guzik *et al.*, 1958), the "Neocomian marls" form a synclinorium. According to Guzik (1960), the limestones of the Muráň-type in the Wściekły Żleb Gully form probably a false anticline. Pachciarek (1988) suggested occurrence of two synclines, with tectonically reduced northern flanks, in the "marlstone complex" between the Dolina Lejowa and Dolina Kościeliska valleys. However, the data confirming these interpretation are too scarce.

At this state of our knowledge about tectonics of the Kościeliska Marl Formation, it is impossible to present a reliable lithostratigraphic column of the type section. For the same reason, estimation of thickness of the formation can be only hypotethical. According to Lefeld (1985), the Kościeliska Marl Formation is 260 m thick in the Dolina Kościeliska Valley. Such a value is similar to the thickness of the "Neocomian marls" in the other parts of the Western Carpathians (Bujnovský & Polak, 1979).

For more detailed determination of the tectonic structure of the study area, additional detailed mapping is necessary.

METHODS

The outcrops of the Kościeliska Marl Formation along the western side of the Kościeliski Potok Stream and the outcrops near the mouth of the Dolina Miętusia Valley were sampled. Additionally, samples were taken from the Dolina Chochołowska Valley, north of Huciska Alp (Fig. 1). Samples H8-12 derive from the outcrop of transitional deposits to the Pieniny Limestone Formation (Tithonian–Berriasian) described by Lefeld (1986). Samples were prepared for examination in the light microscope using the simple cut and pipette smear-slide methods (see Crux, 1989). Observation of nannofossils were made at 1000 magnification.

RESULTS

Calcareous nannofossils

The calcareous nannofossils (Fig. 2) are not numerous, and in general badly preserved. Species diversity variability is low and only in a few samples do more than several taxa occur. These comprise mainly secondary calcite-overgrowth and dissolution-remnant species such as *Watznaueria barnesae*, and *Nannoconus steinmannii*. Calcareous nannofossils were absent in samples "KS1" to "KS5" and also in "KS26". Assemblages dominated by *Watznaueria barnesae* are considered as a sign of poor nannofossil preservation (e.g., Roth & Krumbach, 1986). The distribution of particular taxa in the investigated samples are indicated in Fig. 3.

Calcicalathina oblongata (Worsley, 1971), Thierstein, 1971, was found in samples KS7, KS10, KS13, KS17. This is a taxon characteristic of a shallow-marine and epicontinental-sea paleoenvironments of the Tethyan realm in the Early Cretaceous (e.g., Thierstein, 1976). *Calcicalathina oblongata* ranges from late Valanginian to early Barremian in the world scale (Thierstein, 1976), however its range differs regionally. In SE France it occurs from earliest Valanginian to early Barremian according to Bergen (1994). Its range was reported as earliest Valanginian to Late Barremian by Sissingh (1977) and Perch-Nielsen (1983).

Conusphaera mexicana Trejo, 1969 was found in samples KS8, KS11, KS14, H1, H7, H9, and H12. This species ranges from early Tithonian through early Aptian (Thierstein, 1976; Perch-Nielsen, 1985; Bergen, 1994). However, according to Bown and Cooper (1989), it ranges from the Tithonian to the Hauterivian, and its evolutionary successor *Conusphaera rothii* occurs from the Hauterivian to the Aptian. *Conusphaera mexicana* is typical of warm, shallow-marine and epicontinental-sea environments of the Tethyan realm (Thierstein, 1976).

Cruciellipsis cuvillieri (Manivit, 1966) Thierstein, 1971 (Fig. 2F) occurs in samples KS10, KS11, KS13, KS18, KL2, H6-H9 and H12. It ranges from the Tithonian/Berriasian boundary to late Hauterivian (Wind & Čepek, 1979; Bralower, 1991).

Micrantholitus obtusus Stradner, 1963 (Fig. 2I) is quite common and occurs in almost every investigated sample (Fig. 3). This species is known from the Berriasian to the

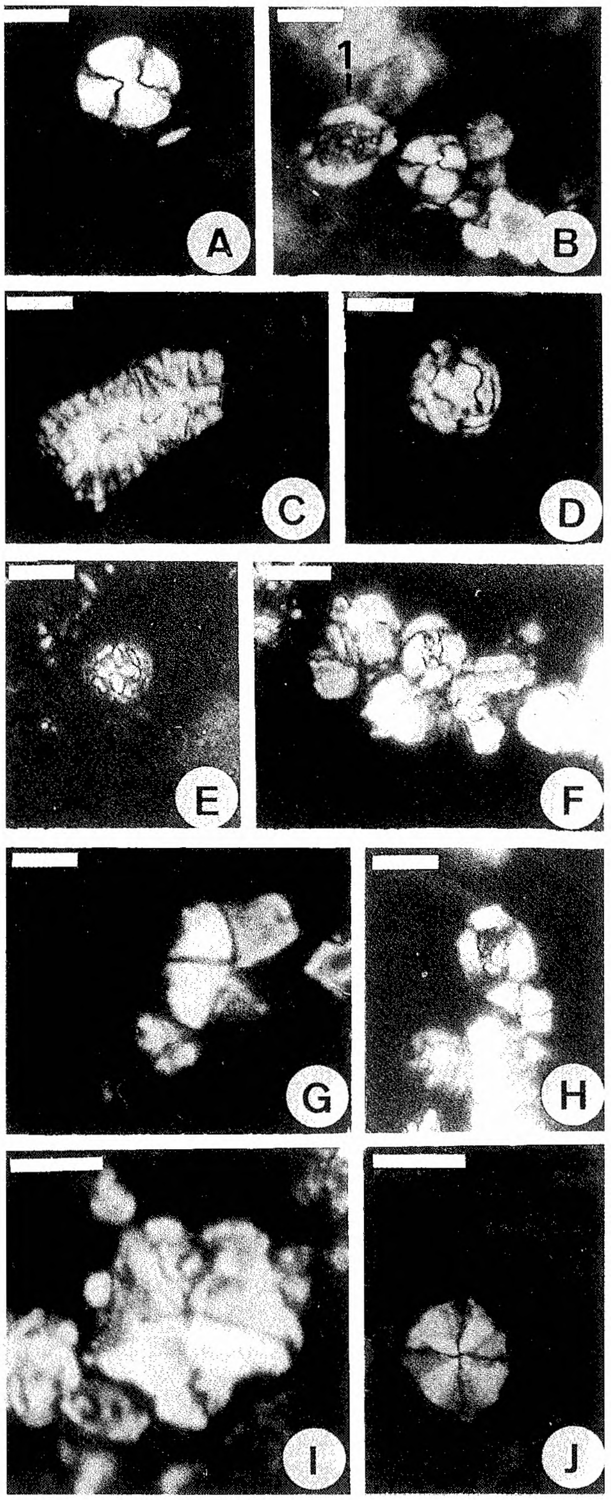

Fig. 2. Characteristic nannoplankton from the Kościeliska Marl Formation (scale bars = 5 μm). **A.** *Watznaueria barnesae* (Black in Black & Barnes) Perch-Nielsen, sample KS28; **B.** *Rhagodiscus* sp. (1) and *Watznaueria barnesae* (Black in Black & Barnes) Perch-Nielsen (2), sample KS28; **C.** *Nannoconus steinmannii* Kamptner, sample KS10; **D.** *Zeugrhabtodus embergeri* (Noel) Perch-Nielsen, sample KS12; **E.** *Prediscosphaera* cf. *columnata* (Stover) Perch-Nielsen, sample KS28; **F.** *Cruciellipsis cuvillieri* (Manivit) Thierstein, sample KS10; **G.** *Braarudosphaera regularis* Black, sample KS13; **H.** *Retecapsa angustiforata*, sample KS10; **I.** *Micrantholitus obtusus* Stradner, sample KS10; **J.** *Nannoconus* sp., sample KS10

Aptian (Sissingh, 1977; Jakubowski, 1987). *Micrantholithus hoschulzii*, which is considered as a synonym of *M. obtusus* according to some authors (e.g., Thomsen, 1987), has a similar stratigraphic range. It is characteristic of shallow-marine and epicontinetal-sea environments (e.g., Thierstein, 1976).

Micrantholithus speetonensis Perch-Nielsen, 1979, occurs in lower Valanginian (Jakubowski, 1987; Crux, 1989) and also in upper Valanginian (Taylor, 1982) of NW Europe. *Micrantholithus speetonensis* seems to be an endemic species restricted to NW Europe (Crux, 1989). The presence of this species in sample KS7 could be a record of influence of the Boreal province in the mid Valanginian. An upper Valanginian occurrence has been already recorded in the Southern Carpathians in Romania (Melinte, 1992).

Nannoconus steinmannii Kamptner, 1931 (Fig. 2C) was recorded in almost every sample. Its first occurrence is close to the Tithonian/Berriasian boundary, and defines the lower boundary of nannofossil Zone CC 1 (Perch-Nielsen, 1985). According to Bralower *et al.* (1989), the FO of this species is in the lowermost Berriasian. Similar findings were obtained by Bergen (1994) from southern Europe and from cores in the Bahamas region. The LO of *Nannoconus steinmannii* is in the lower Aptian (Sissingh, 1977; Perch-Nilesen, 1985). *Nannoconus colomii* displays similar a stratigraphic range. All nannoconids from the investigated samples are typical of the Tethyan realm. On the other hand, forms such as *Nannoconus abundans,* which are very abundant in the Boreal realm in the Barremian to lower Aptian deposits, are absent. It may be worth to mention that a lot of nannoconid specimens from differ taxa are included into *Nannoconus* sp. due to a problems with identification caused by secondary calcite-overgrowth.

The specimens tentatively identified as *Prediscosphaera columnata* (Stover, 1966), Perch-Nielsen, 1984 (Fig. 2E) was found in sample KS28. The first occurrence of this species coincides with the lower/middle Albian boundary (Verbeek, 1977; Jakubowski, 1987). However, Manivit *et al.* (1977) noticed *P. columnata* in the uppermost part of the Lower Albian, and Perch-Nielsen (1983) found it already at the Aptian/Albian boundary. During the Brussels'95 Symposium on the Cretaceous Stage Boundaries *P. columnata* was considered as an alternative fossil to identify the base of the Albian, but its FO is different in proposed candidates for stratotype sections. For example, in the Vocontian Trough (SE France) its FO is already in upper Aptian, but in North Germany FO is placed in Lower Albian (Hart *et al.*, 1996). This taxon is the earliest circular form of the genus *Prediscosphaera*. It is not excluded that at least some almost oval forms belong to *Prediscosphaera* cf. *stoveri*, which ranges from the Lower Aptian (e.g., Thomsen, 1987). If *Prediscosphaera columnata* appears at the same time span in the studied area as in the hitherto known sections, sample KS28 should be situated at least in Aptian/Albian boundary. Moreover, *N. steinmannii* is absent in KS28, however, *Nannoconus regularis* is present, which occurs from the Aptian/Albian boundary (e.g., Perch-Nielsen, 1985). Nevertheless, more detailed determination is not possible because of preservation.

Speetonia colligata Black, 1971 occurs in samples

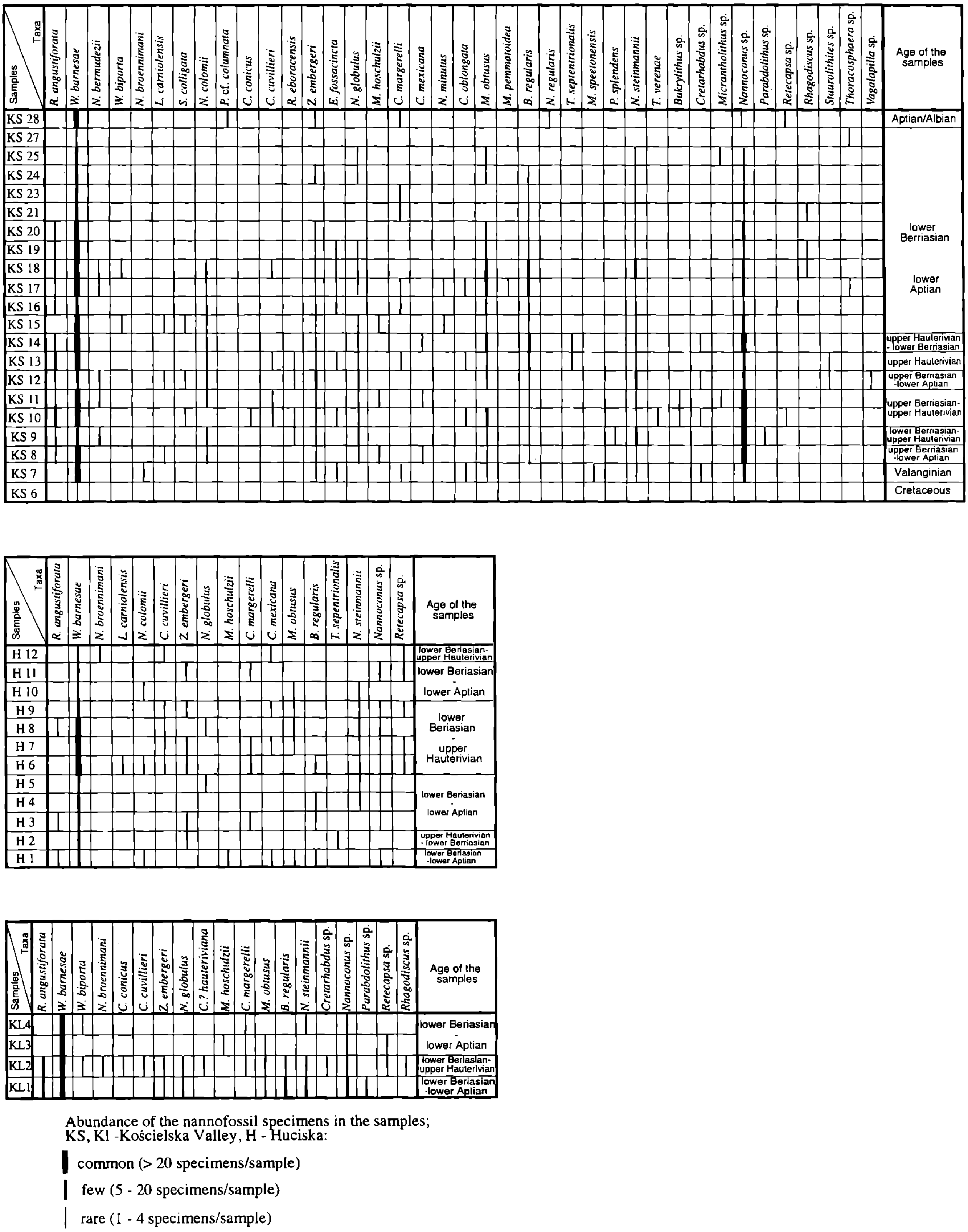

Fig. 3. Distribution of the calcareous nannofossils in the investigated samples

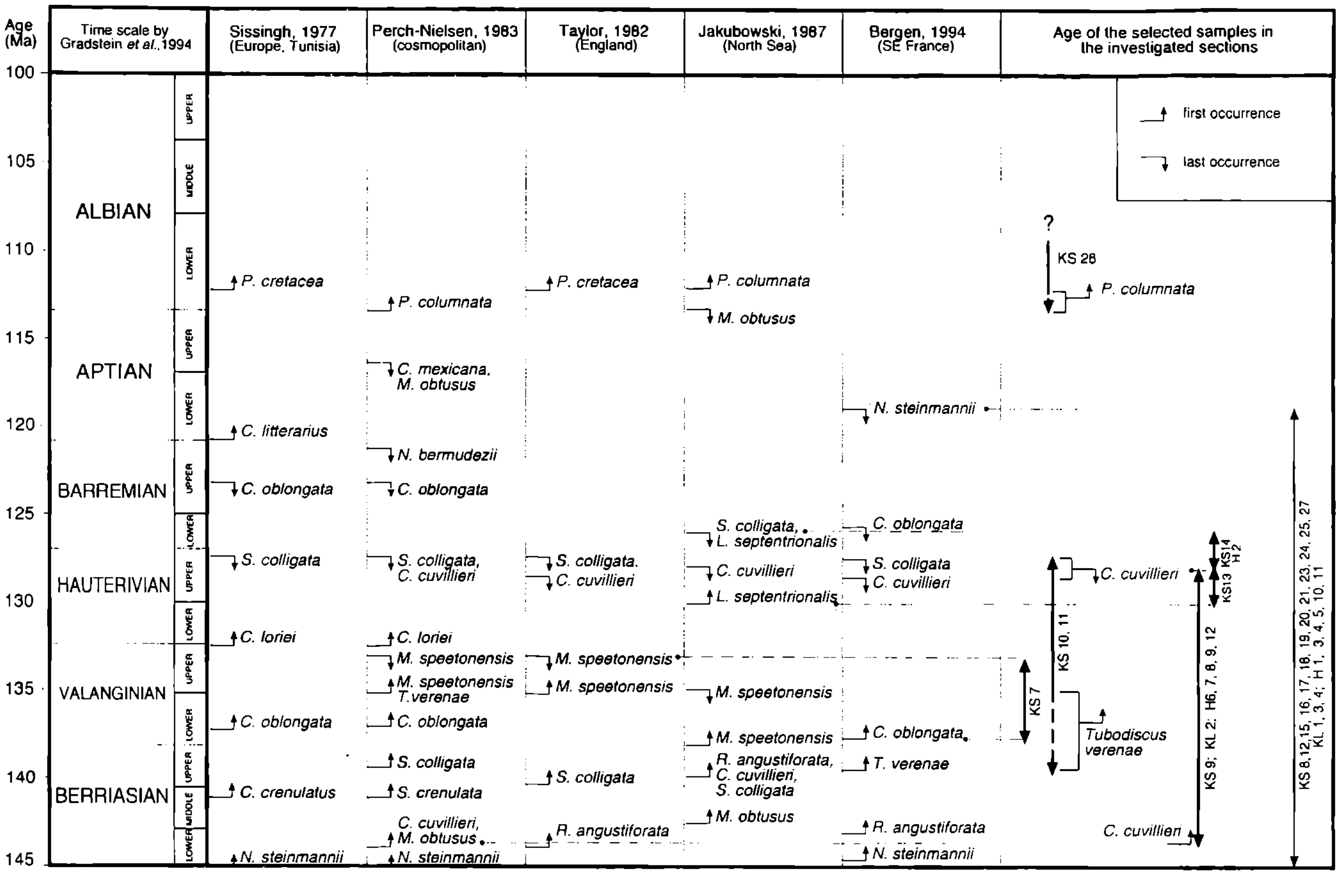

Fig. 4. Stratigraphic range of the nannofossils from the Kościeliska Marl Formation and position of the investigated samples

KS10, KS12 and KS15. According to Sissingh (1977), it ranges from the early Berriasian to the late Hauterivian. However, Jakubowski (1987) noted the occurrence of *Speetonia colligata* from the Upper Riazanian in the North Sea. In England, the LO of this taxon is noted in the Upper Hauterivian (Taylor, 1982; Crux, 1989). An identical range was found in cores from the region of the Canary Islands (Wind & Čepek, 1979) and from SE France (Bergen, 1994).

Tegulalithus septentrionalis (= *Eprolithus septentrionalis*) (Stradner, 1963), Crux, 1986 occurs in the samples KS13, KS14 and H2. This species occurs in the Upper Hauterivian to lowermost Barremian of the North Sea region, with maximum of abundance in the uppermost Hauterivian (Zone 16a to Zone 14), according to Jakubowski (1987) (note that numbers of zones distinguished by this author decrease towards to the younger deposits). The LO of *T. septentrionalis* is noted in the Barremian. However, according to the Bralower's data from North Sea cores (Bralower, 1991), it ranges from the upper part of the lower Hauterivian to the Hauterivian/Barremian boundary. This species is considered as characteristic of the Boreal realm (Crux, 1989). Its presence may be caused by the connection between the Tethyan and Boreal realm via the Mid-Polish Trough in the late Hauterivian. This connection is inferred by the increasing amount of the nannoconids in upper Hauterivian sediments of NW Europe (Crux, 1989).

Tubodiscus verenae Thierstein, 1973 was identified in sample KS10. This species ranges from the upper Valanginian to the Lower Hauterivian in the North Sea (Bralower, 1991). According to Bergen (1994) in the SE France, the FO of *Tubodiscus verenae* represents the upper Berriasian. Applegate *et al.* (1989) recorded it from the lower Valanginian to Upper Barremian sediments in cores off the coasts of Portugal and the U.S.A. Crux (1989) ranked this species among the Tethyan taxa.

All investigated samples, with the exception of sample KS28, contain early Berriasian to early Aptian nannofossils, as indicated on the presence of *N. steinmannii* and *M. obtusus*.

Age of sample KS28 reaches up at least Aptian/Albian boundary. Lack of the expected late Aptian taxa in the investigated samples may be caused by two reasons: the upper Aptian fragment of section was unsampled, or it is absent owing to tectonic expulsion. The stratigraphic position of samples H8-H12 taken from transitional deposits to the Pieniny Limestone Formation is difficult to determain. Samples H6-H9 and H12 are not older than early Berriasian age base on the presence of *Cruciellipsis cuvillieri*. H10, H11 do not contains nannofossils taxa to determain age precisely. Moreover, more accurate age can be determined for some samples, on the basis of the taxa such as *C. cuvillieri, S. colligata, T. verenae, C. oblongata, L. septentrionalis*, and *M. speetonesis* (Fig. 4).

Trace fossils

The marlstones and calcilutites of the Kościeliska Marl Formation are totally bioturbated. Trace fossils were ob-

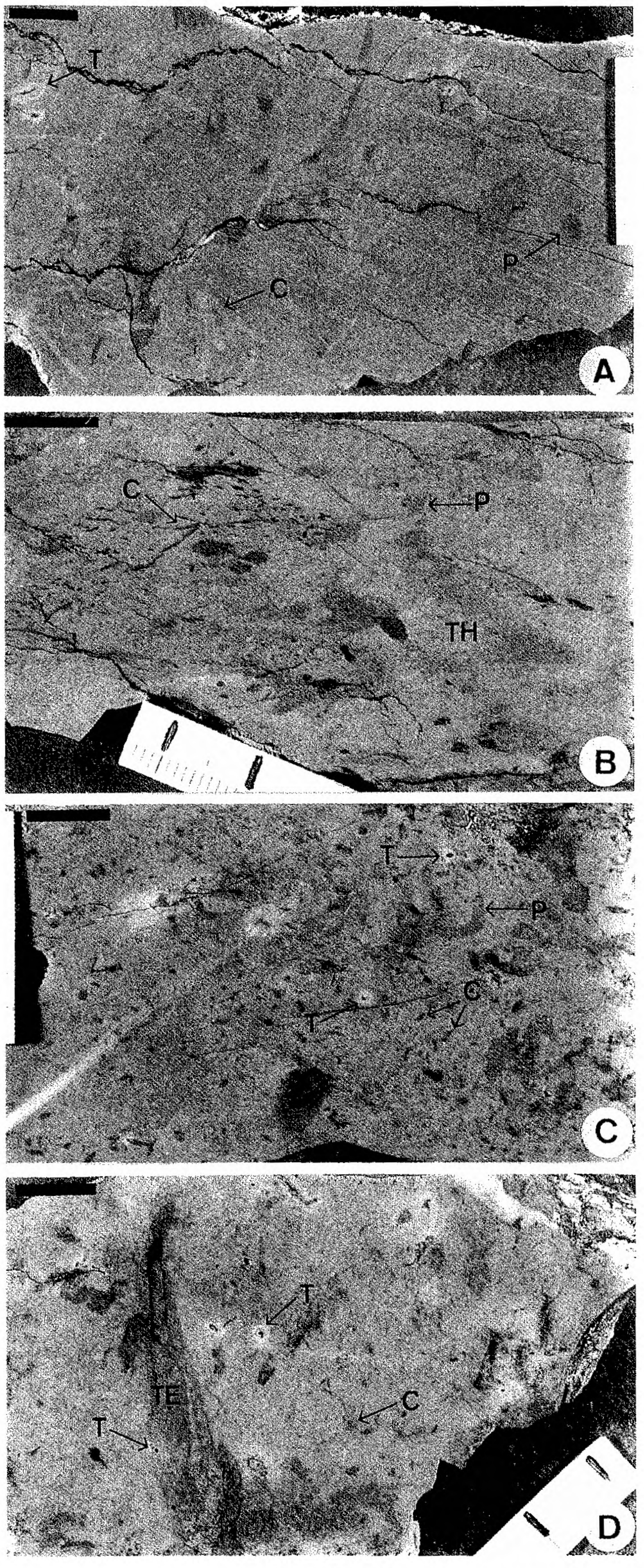

Fig. 5. Ichnofabrics from the Kościeliska Marl Formation on polished and oiled surfaces (black scale bars = 1 cm). C – *Chondrites*; P – *Planolites*, TH – ?*Thalassinoides*; T – *Trichichnus*, TE – ?*Teichichnus*. **A.** Oblique cross section, near sample KL2; **B.** Vertical cross-section, near sample KS8; **C.** Horizontal section, near sample H3; **D.** Horizontal section, near sample H5

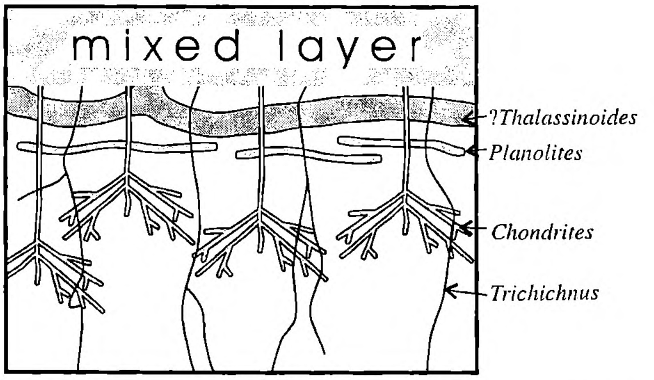

Fig. 6. Tiering pattern of trace fossils from the Kościeliska Marl Formation. The rare trace fossils are not considered in the scheme

served in cross-section. They are visible as variable "spots" (Fig. 5), typical of the variable "Flecken" facies of the Tethys realm. For this reason Stache (1868) determined part of the Neocomian deposits in the Tatra Mountains as "Fleckenmergel". The trace fossil assemblage is of low diversity, and is dominated by *Chondrites*, *Planolites* and *Trichichnus*. ?*Thalassinoides* burrows are common. Meniscate trace fossils (?*Zoophycos*, ?*Teichichnus*) are very rare. The presence of *Phycosiphon* is problematic. *Trichichnus* is a long thread-like, rarely branched, presumably vertical form, filled with pyrite. Owing to oxidization of the pyrite, a yellowish halo occurs around the burrows. *Chondrites* cross-cuts *Planolites* and ?*Thalassinoides*. All of them are cross-cut by *Trichichnus*. The cross-cutting relationships allow us to reconstruct of order of burrowing and tiering pattern (cf. Bromley & Ekdale, 1986), in a manner analogous to investigations in the chalk (Ekdale & Bromley, 1991).

The deepest tier is occupied by *Trichichnus*, the shallower by *Chondrites*, and the shallowest by *Planolites* and ?*Thalassinoides* (Fig. 6). In all probability only the deepest tiers formed in the transitional layer (Bromley, 1996) are preserved. The shallower near-floor layer (the so-called mixed layer) is preserved as the background of the deeper tiers. The mixed layer is most intensively burrowed and trace fossils are not formed in this layer owing to intensive mixing and soupy consistence of sediment.

DISCUSSION

Chronostratigraphy of the Kościeliska Marl Formation

Vigiliev (1914) originally regarded the Kościeliska Marl Formation as "not younger than Hauterivian". However, Lefeld (1974) reassigned the upper limit of the Kościeliska Marl Formation age to the Barremian on the basis of the ammonite *Crioceratites emerici* Lev. collected by Vigiliev. Kantorová and Andrusov (1958) indicated the occurrence of Cenomanian Foraminifera in the Cretaceous marls of the lower Sub-Tatric Unit in the Choč Mountains, west of the Tatra Mountains, but no Foraminifera data from the western part of the Tatra Mountains have been published to date. In the eastern part of the Tatra Mountains, upper

Aptian and probably lower Albian foraminifera were found in marly deposits of the Muráňská Luka Formation, which overlies the Muráň Limestone Formation (Vašíček *et al.*, 1994). If the calcarenites from the Kościeliska Marl Formation are virtually equivalent to the Muráň Limestone Formation, a younger age of the upper part of the Kościeliska Marl Formation from the western part of the Tatra Mountains is expected.

Our new age determinations of the investigated samples shed new light on stratigraphy of the Kościeliska Marl Formation. In the Dolina Kościeliska Valley (Fig. 1), the succession of ages from sample KS7 (Valanginian) to sample KS14 (Hauterivian/Barremian boundary) indicates that at least a part of the complex of the Kościeliska Marl Formation between the Wściekły Żleb Gully and the Brama Kantaka Gate is in overturned position. The Albian age of sample KS28 is very interesting. First of all, the sample is located very close to the belt of Jurassic deposits on the slopes of the Zadnia Kopka mount.

All maps (Guzik *et al.*, 1958; Bac-Moszaszwili *et al.*, 1979) suggest the oldest part of the Kościeliska Marl Formation above the Jurassic deposits in this region. In contrast, sample KS28 represents the youngest deposits of this formation. Such a position of sample KS28 suggests a reverse succession between the Wściekły Żleb Gully and the Jurassic deposits. This situation suggests a thrust at the top or immediately above the top of the belt of Jurassic deposits on the slopes of the Zadnia Kopka Mount.

In the Dolina Chochołowska Valley, the age of succession from sample H2 (Hauterivian/Barremian boundary) to samples H6-H9, H12 (no younger than Late Hauterivian) suggests a normal position of beds in the southern part of the Kościeliska Marl Formation in the Dolina Chochołowska Valley.

An early Albian age in the Kościeliska Marl Formation was not hitherto determined in the western part of the Tatra Mountains. Nevertheless, it agrees with foraminiferal data from the Muráňská Luka Formation, which overlies the Muráň Limestone Formation in the eastern part of the Tatra Mountains (Vašíček *et al.*, 1994). This confirms that the calcarenites from the Kościeliska Marl Formation are equivalent to the Muráň Limestone Formation.

Palaeoenvironment of the Kościeliska Marl Formation

According to Passendorfer (1961), the Kościeliska Marl Formation have been accumulated in the deep-sea basin. Lefeld (1974) noted that the environment was far away from the source area of the turbidites. Kuźniar (1913) regarded the deposits as fossil muds, which are transitional between the recent blue muds and foraminiferal oozes. Michalík and Vašíček (1989), and Vašíček *et al.* (1994) interpreted the environment of the "Neocomian facies" as deposits of a small basin (Zliechov Basin) in tensional regime, surrounded by carbonate ramps, and located on continental crust of the "Kreios" microplate. The development of the Zliechov Basin includes an episode of growing of the "Urgonian carbonate platforms" on the surrounding shallower areas.

The sediments of the Kościeliska Marl Formation are totally bioturbated with the ichnofabric composed of totally bioturbated background and deep-tier trace fossils. This is typical of well oxygenated sediments (Savrda, 1992). Thus, the deposits of the Kościeliska Marl Formation accumulated in a relatively well aerated environment.

The ichnoassemblage of the Kościeliska Marl Formation resembles the *Zoophycos* ichnofacies, which is characteristic of quiet environments below lower offshore (maximum wave base) (MacEachern & Pemberton, 1992). However, the occurrence of *Zoophycos* in the Kościeliska Marl Formation is problematic. It is also similar to some variants of the *Chondrites-Zoophycos* ichnoguild, produced by deposit feeders and chemosymbionts, which is typical of the deepest tier in chalk facies (Bromley, 1996). However, *Zoophycos* is uncommon in the Kościeliska Marl Formation, and *Trichichnus* is commonly not present in this ichnoguild. *Planolites* forms the monotypic *Planolites* ichnoguild connected with shallower tiers. Savrda (1992) postulated that *Trichichnus* is common in this ichnoguild in poorly oxygenated sediments. However, the Kościeliska Marl Formation is well oxygenated. Of course, it is possible that the deepest tiers with *Trichichnus* in the transitional layer can be less oxygenated. The ichnoassemblage displays similarities to deep-sea marly muds of the Miocene Marnoso-arenacea Formation and associated marlstone facies from the Northern Apennines (McBride & Pickard, 1991; Uchman, 1995), where *Trichichnus* is very common and *Zoophycos* is relatively rare. Those deposits are regarded as deposited in well oxygenated, slightly oligotrophic environments (Uchman, 1995).

Probably, trace fossils from the "Neocomian marls" differ in other localities, but data on trace fossils from other areas of Western Carpathians are very scarce. Michalík and Vašíček (1989) noted the occurrence of *Zoophycos*, *Planolites*, *Chondrites*, and *Helminthopsis* in the coeval Valanginian–Hauterivian micritic limestones of the Mráznica Formation in Slovakia. Albian–Cenomanian marlstones and marly mudstones of the Zabijak Marlstone Formation in the High-Tatric Unit (Krajewski, 1985) display a similar trace fossil assemblage as in the Kościeliska Marl Formation. The trace fossil community of the underlying Pieniny Limestone Formation is dominated by *Chondrites*, *Zoophycos* and *Teichichnus* (Wieczorek, 1988). The absence of *Trichichnus* in this formation is the most important and striking difference.

The nannoplankton taxa *Micrantholithus obtusus*, *Braarudosphaera regularis*, *Calcicalathina oblongata*, *Conusphaera mexicana*, as well as *Nannoconus* spp. have been considered as indicators of epicontinental seas and large shelf areas in the Tethyan realm (Thierstein, 1976; Perch-Nielsen, 1985). The environment of the Kościeliska Marl Formation more probably corresponds to the former. All sediments, including the redeposited calcarenites accumulated below the maximum wave base.

The occurrence of *Micrantholithus speetonensis*, *Tegulalithus septentrionalis* together with the typical Tethyan taxa testify periodic connections between the Tethyan and Boreal realms during the late Valanginian and late Hauterivian (Crux, 1989; Melinte, 1992). Nevertheless, Tethyan nannofossils distinctly dominate. The fauna of the "Neocomian facies" in the Central Western Carpathians is exlusively of the Mediterranean character (Vašíček *et al.*, 1994).

CONCLUSIONS

1. The Kościeliska Marl Formation contains the Valanginian through early Aptian nannofossils. Moreover, one sample (KS28) contains calcareous nannoplankton from the Aptian/Albian boundary.

2. The reverse position of beds is proven on the basis of the nannoplankton succession in the Kościeliska Marl Formation in the type section of the formation in the Dolina Kościeliska Valley.

3. Trace fossils and sedimentological observations indicate well oxygenated palaeoenvironment below the maximum wave base.

4. The nannoplankton is typical of the Tethyan realm. Some influences of the Boreal realm are suggested during Late Valanginian and Late Hauterivian.

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Streszczenie

WIEK I PALEOŚRODOWISKO FORMACJI MARGLI Z KOŚCIELISKIEJ (FM) (KREDA DOLNA) W TATRACH POLSKICH – WSTĘPNE WYNIKI BADAŃ

Mariusz Kędzierski & Alfred Uchman

Skomplikowana sytuacja tektoniczna formacji margli z Kościeliskiej (fm) w jednostce kriżniańskiej w Tatrach sprawia, iż jej stratygrafia jest ciągle przedmiotem dociekań. W niniejszej pracy podjęto po raz pierwszy próbę określenia wieku formacji margli z Kościeliskiej (fm) na podstawie nannoplanktonu wapiennego oraz dokonano interpretacji paleośrodowiska przy pomocy skamieniałości śladowych i nannoskamieniałości. Formacja margli z Kościeliskiej została wyróżniona przez Lefelda (1985) jako formalna jednostka litostratygraficzna, której profil stratotypowy znajduje się po zachodniej i częściowo wschodniej stronie Doliny Kościeliskiej, powyżej Bramy Kantaka (Fig. 1). Margle te są najmłodszymi osadami jednostki kriżniańskiej w zachodniej części Tatr. Są one również jedną z charakterystycznych „facji neokomu", szeroko rozprzestrzenionych w Karpatach zachodnich (Vašíček *et al.*, 1994). Formacja margli z Kościelskiej (fm) jest najmłodszym ogniwem litostratygraficznym w jednostce Bobrowca. Pomiędzy Doliną Kościeliską i Doliną Chochołowską margle te leżą na tytońsko-beriaskich wapieniach typu maiolica, a ich strop, tektonicznie lub erozyjnie ścięty jest przykryty przez jurajsko-kredowe skały jednostki kriżniańskiej, wapienie jednostki choczańskiej lub eoceńskie zlepieńce. We wschodniej części Tatr, nad utworami tej formacji zalegają hoterywsko-barremskie wapienie murańskie pochodzenia platformowego (Lefeld, 1985; Vašíček *et al.*, 1994). Formacja margli z Kościeliskiej (fm) zbudowana jest głównie z jasnych i ciemnoszarych margli, które są przekładane kalcilutytami podobnego koloru, lub lokalnie warstwami kalkarenitów, dochodzącymi do kilkunastu metrów miąższości, oraz ławicami wapnistych piaskowców turbidytowych. Kalkarenity traktowane są jako turbidyty wapienne, będące odpowiednikiem wapieni murańskich ze wschodniej części Tatr. W marglach i kalcilutytach występują charakterystyczne struktury bioturbacyjne. Margle zawierają otwornice bentoniczne, spikule gąbek, rzadziej małżoraczki, fragmenty amonitów i belemnitów. Tektonika formacji margli z Kościelskiej (fm) pomiędzy Doliną Kościeliską i Doliną Chochołowską nie jest wyjaśniona. Według mapy geologicznej w skali 1:10 000 (Guzik *et al.*, 1958) jest to synklinorium. Guzik (1960) uważał, iż wapienie typu murańskiego w rejonie Wściekłego Żlebu tworzą fałszywą antyklinę. Natomiast Pachciarek (1988) sugerował występowanie dwóch synklin, z tektonicznie zredukowanymi północnymi skrzydłami w rejonie Doliny Lejowej i Doliny Kościeliskiej. Z powodu niejasnej tektoniki nie można przedstawić wiarygodnego profilu i ocenić prawidłowo miąższość formacji. Według Lefelda (1985) miąższość formacji wynosi 260 metrów, co daje wartość podobną do miąższości „margli neokomu" w innych częściach Karpat zachodnich (por. Bujnowský & Polak, 1979).

Dotychczasowe datowania formacji margli z Kościeliskiej (fm) opierały się głównie na amonitach, wskazujących na występownie osadów beriasu, hoterywu, walanżynu, barremu (Vigiliev, 1914; Lefeld, 1974) i możliwości występowania dolnego aptu (Lefeld, 1985). Jednakże większość fauny zbierana była z luźnych bloków, co stwarza dodatkowy problem lokalizacji oznaczonych skamieniałości. Vigiliev (1914) uważał, że wiek omawianych osadów jest nie młodszy niż hoteryw, jednakże Lefeld (1974) na podstawie amonita *Crioceratites emerici* ocenił wiek najmłodszych osadów na barrem. Kantorová i Andrusov (1958) wskazali występowanie cenomańskich otwornic w kredowych marglach jednostki kriżniańskiej w Górach Choczańskich, na zachód od Tatr. We wschodniej części Tatr znaleziono otwornice aptu górnego, a być może i albu dolnego w marglistych osadach formacji z Hali Murańskiej (fm), leżących ponad formacją wapienia murańskiego (fm) (Vašíček *et al.*, 1994). Jeżeli przyjmiemy, że kalkarenity z formacji margli z Kościeliskiej (fm) są odpowiednikiem formacji wapienia murańskiego, to należy oczekiwać młodszego wieku najwyższej części margli z Kościeliskiej w zachodniej części Tatr, co zostało potwierdzone w niniejszej publikacji.

W pracy tej do analizy nannoskamieniałości i skamieniałości śladowych wykorzystano próby zebrane bezpośrednio w odsłonięciach wzdłuż zachodniego brzegu Potoku Kościeliskiego oraz w pobliżu wylotu Doliny Miętusiej. Dodatkowe próby pobrano w Dolinie Chochołowskiej, a także w północnej części Hali Huciska (Fig. 1). Próby od H8 do H12 pochodzą z odsłonięcia formacji wapienia pienińskiego (fm) opisanego przez Lefelda (1986). Preparaty do oznaczania nannoplanktonu wykonano metodą zeskrobywania osadu na szkiełko podstawkowe, a także wybierania pipetą frakcji odpowiadającej nannoskamieniałościom z kolumny wody (por. Crux, 1989). Nannoplankton oznaczano pod mikroskopem świetlnym w powiększeniu x1000. Nannoflora jest słabo zachowana i nieliczna, zdominowana przez *Watznaueria barnesae* i *Nannoconus steinmannii*, a preparaty od KS1 do KS5 oraz KS26 były negatywne (Figs. 2, 3). Ze stratygraficznie istotnych taksonów stwierdzono *Calcicalathina oblongata*, *Conusphaera mexicana*, *Cruciellipsis cuvillieri*, *Micrantholithus obtusus*, *Micrantholithus speetonensis*, *Nannoconus steinmannii*, *Prediscosphaera* cf. *columnata*, *Speetonia colligata*, *Tegulalithus septentrionalis*, *Tubodiscus verenae* (Fig. 2).

Skamieniałości śladowe obserwowano w zgładach. Tworzą one różnorodne plamy (Fig. 5), typowe dla alpejskiej facji „Fleckenmergel". Zespół skamieniałości śladowych jest ubogi. Dominują *Chondrites*, *Planolites* i *Trichichnus*. Często spotykaną formą jest ?*Thalassinoides*. Formy typu *Zoophycos* i ?*Teichichnus* są bardzo rzadkie. Obecność *Phycosiphon* jest problematyczna. *Chondrites* przecina *Planolites* oraz ?*Thalassinoides* (Figs. 5, 6). Wszystkie ślady są przecinane przez *Trichichnus*. Tło wszystkich skamieniałości śladowych jest całkowicie zbioturbowane. Wzajemne relacje między skamieniałościami śladowymi posłużyły do rekonstrukcji pierwotnej piętrowości w osadzie (Fig. 6) (por. Bromley & Ekdale, 1986). Prawdopodobnie, omawiany zespół skamieniałości śladowych reprezentuje jedynie najgłębsze piętra zajęte przez oportunistyczne ichnotaksony. Jest to sytuacja typowa dla dobrze natlenionych osadów (Savrda, 1992). Całkowicie zbioturbowane tło jest przypuszczalnie efektem intensywnej bioturbacji i rozwodnienia w przydennej warstwie osadu. Zespół skamieniałości śladowych przypomina ichnofację *Zoophycos*, charakterystyczną dla pełnomorskich środowisk poniżej maksymalnej podstawy falowania.

Wszystkie badane preparaty, zawierające nannoskamieniałości, za wyjątkiem KS28 są wieku od beriasu wczesnego do aptu wczesnego na podstawie obecności *Nannoconus steinmannii* i *Micrantholithus obtusus*. W niektórych przypadkach możliwe było dokładniejsze określenie wieku (Figs. 3, 4). W szczególności dotyczy to prób KS13 (hoteryw późny) i KS14 (przełom hoterywu późnego i barremu wczesnego). W preparacie KS28 znaleziono takson znany dopiero od pogranicza aptu i albu – *Prediscosphaera*. cf. *columnata*. Jeśli gatunek ten w badanym obszarze ma podobny do cytowanego zasięg stratygraficzny, to próba KS28 reprezentuje utwory nie starsze niż granica aptu i albu. Tak młody wiek utworów w formacji margli z Kościelskiej (fm) został stwierdzony po raz pierwszy. Niemniej jednak koresponduje on z wiekiem formacji z Hali Murańskiej (fm), określonym na podstawie otwornic (Vašíček *et al.*, 1994). Potwierdza to także pogląd, że kalkarenity z formacji margli z Kościeliskiej (fm) są odpowiednikiem formacji wapieni murańskich (fm). Następstwo wiekowe prób wskazuje na odwróconą pozycję części utworów formacji margli z Kościeliskiej (fm) między próbami KS7 (walanżyn) i KS14 (granica hoterywu/barremu) (Fig. 1). Interesujący jest też wczesnoalbski wiek próby KS28, gdyż usytuowana jest ona blisko jurajskich osadów na zboczu Zadniej Kopki, gdzie należałoby się spodziewać najstarszych utworów badanej formacji. Taka pozycja stratygraficzna próby KS28 w porównaniu z próbami KS24-25 sugeruje odwróconą pozycję warstw pomiędzy Wściekłym Żlebem a utworami jurajskimi z Zadniej Kopki. W Dolinie Chochołowskiej pozycja wiekowa badanych prób wskazuje na normalne ułożenie warstw, a wiek ich jest nie młodszy niż hoteryw późny. Paleośrodowisko nannoflory określono jako typowe dla strefy tetydzkiej. Na podstawie nannoflory charakterystycznej dla NW Europy (*Micrantholithus speetonensis*), znalezionej w niektórych preparatach, autorzy sugerują, że podczas późnego walanżynu i późnego hoterywu w strefie tej nastąpiło połączenie ze zbiornikiem borealnym.