SYMPOSIUM I: EVOLUTION OF THE DEPOSITIONAL SYSTEMS

MINERALOGICAL CHARACTERIZATION OF FLYSCH SEQUENCES OF THE SE ALPS AND OUTER DINARIDES (NE ITALY, SLOVENIA, CROATIA)

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Key words: Flysch, X-ray powder diffraction, heavy mineral assemblage, source areas.

Introduction

An extensive Flysch complex of Late Cretaceous to Early Tertiary age outcrops in north-eastern Italy, western Slovenia and Istria (Croatia) (Fig. 1). The rock sequences belong to different depositional basins and have different ages. Sedimentation in the basins of the northern part of the complex (Slovenia and Friuli) occurred from the Maastrichtian to Middle Eocene (Engel 1974; Tunis & Venturini 1989), while in the southern part (Trieste, SW Slovenia and Istria) it took place from the Middle to Late Eocene (Marincic et al. 1996). Source areas can be postulated on the basis of heavy mineral occurrences.

Methods

The whole rocks were studied in thin section and the mineralogical composition was also determined by means of X-ray powder diffraction. Heavy minerals are scarce or rare. The following procedure was therefore used: the fraction ≥63 μm was separated from the clays, and the magnetic heavy minerals were concentrated by means of the Frantz apparatus; grains of hand-picked heavy minerals from the same fraction were then mounted in epoxy resin to be chemically analysed. X-ray single-crystal diffraction and chemical analyses were performed on Cr-spinel, while electron microprobe analyses on garnet, pyroxene, and amphibole are currently in progress.

Results

Under the microscope, the rocks are classified as lithic greywackes. Quartz and calcite are the most abundant minerals in thin section; plagioclases, microcline, micas (muscovite, chlorite, prehnite, biotite), opaque minerals also occur, in variable amounts, in most rocks. Cr-spinels, garnet, zircon, siderite and serpentine were also identified. In the QFL ternary diagram of Dickinson (1985) the rocks plot in the field of recycled orogens.

X-ray diffraction analysis established that quartz, calcite, feldspars, clay minerals and dolomite are the main phases. In the Flysch of Claut and Clauzetto (CL) the passage from Lower Eocene to Middle Eocene sedimentation shows a great increase of carbonates. In the Julian Basin (JB) the Maastrichtian to Lutetian sedimentation records a maximum carbonate content during the Paleocene wherever distal turbidites are present; henceforth there is a continuous increase of siliciclastic sedimentation with the progressive shallowing of the basin from deep-sea to delta facies. In the Vipava Flysch (VI) carbonates are predominant. In the Flysch of Brkini (BK) the mineral content is similar to that of the coeval sandstones in the JB. Dolomite appears only in the molasse samples. In the Istrian Basin (IB) no clear trend is noticed. In the western part the siliciclastic material content is higher than in the eastern part (Fig. 2).

As for heavy minerals, Cr-spinel, garnet (pyralspite and grandite series), zircon, tourmaline, rutile, pyrite, chloritoid, pyroxene (opx and cpx), staurolite and amphibole were identified, but their

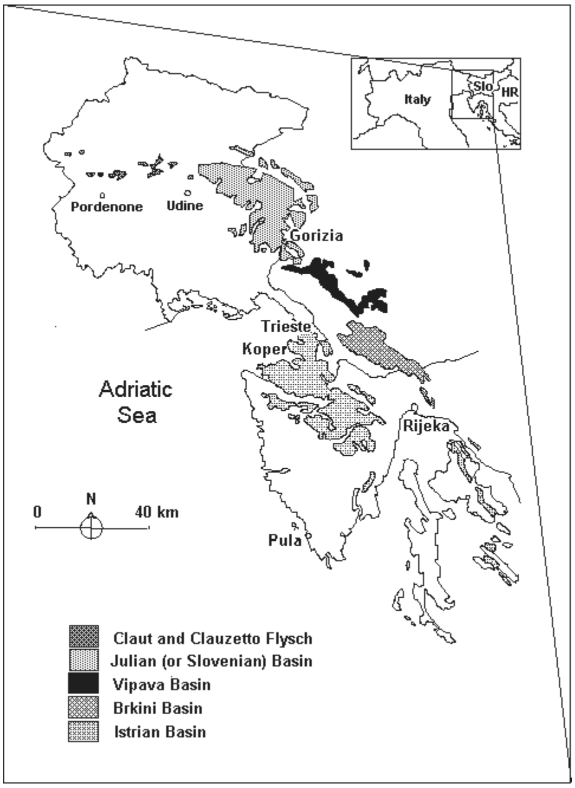

Fig. 1. Flysch deposits of the SE-Alps and Outer Dinarides.

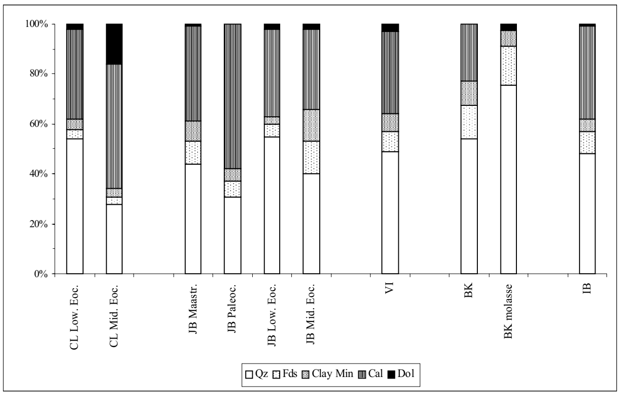

Fig. 2. Mean value of mineral content in the different basins. CL: Claut and Clauzetto Basin; JB: Julian Basin; VI: Vipava Basin; BK: Brkini Basin; IB: Istrian Basin; Qz: quartz; Fds: feldspars; Cal: calcite; Dol: dolomite.

occurrence is variable from basin to basin. Previous mineralogical studies were performed in the CL (Grandesso & Stefani 1996), in the northern part of the JB (Kuscer et al. 1974), in the BK (Orehek 1991) and in the IB (Magdalenic 1972); but no work has previously been done in the VI. This study shows for the first time the occurrence of amphibole in the IB and of pyroxene in the JB and the BK. Moreover, grandite and pyralspite garnets have been discriminated in JB for the first time.

Discussion

Cr-spinels provide evidence of a significant input of basic material in all basins of the SE Alps and Outer Dinarides. However, this study shows that the Cr-spinels from the northern basins (CL, JB and BK) are different from those of the southern basin (IB). Moreover, a supply of acidic material and of medium grade metamorphic rocks in CL is indicated by the occurrence of staurolite and pyrope-rich garnet, and it is suggested that their sources were north-western areas. Successively, the CL basin underwent infilling, with an increase of carbonates from the Friuli Mesozoic to Early Tertiary carbonatic platform. In the JB almandine-rich pyralspite garnets, different in composition from those of other basins, occur in most samples, while grandite series garnets are present only in one Maastrichtian sample. There is evidence of supply from northern and north-eastern areas, and this inference is supported by paleocurrent analysis and data obtained from the study of clasts of Cenozoic conglomerates (Venturini & Tunis 1992). The mineral assemblage in BK is the same as in the coeval JB sandstones. While supplies deduced from paleocurrent analysis are controversial, data obtained in this study indicate that inputs from the NW prevail. In the IB there are two groups of garnets: one is pyrope-rich and is held to indicate sources (e.g. amphibolitic rocks) from south-eastern areas, and the other is almandine-rich, similar to that of the JB. The following trend of heavy mineral assemblage is recognized: garnet and Cr-spinel are dominant minerals at the base of the sequences, and thereafter chloritoid and pyroxene appear in small, but significant amounts; finally, pyroxene occurs as the most abundant mineral at the top of the sequences. South-eastern areas are the most probable sources.

It can be concluded that a detailed mineralogical characterization provides a clue to the location of source areas and hence to the evolution of basins even in a flysch complex, such as the SE Alps and Outer Dinarides sequences, spanning a rather restricted age interval.

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BIOSTRATIGRAPHIC CORRELATIONS OF THE PALEOGENE DEPOSITS OF THE UKRAINIAN CARPATHIANS AND CRIMEA–BAKHCHISARAI AREA USING NANNOPLANKTON AND DINOCYSTS

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Key words: Paleogene, nannoplankton, dinocysts, biostratigraphy.

Fossil *Chrysophyceae* (nannoplankton) and *Dinophyceae* (dinocysts) algae were studied on the stratotype profiles of the northern slopes of the Ukrainian Carpathians and in the stratotype profiles and three parastratotype boreholes of the Crimea Bakhchisarai area. The Upper Oligocene sediments were studied in boreholes in the Northern part of the Black Sea depression. Dinoflagellata and nannoplankton enable us to correlate various facies of the Paleogene sediments, since nannoplankton occurs in the calcareous sediments exclusively and dinoflagellates occur in both types of sediments — calcareous and noncalcareous. On the basis of these groups of paleontological remains, it was possible to correlate various facial types of the Paleogene sediments of the Carpathians and Crimea. The nannoplankton scale used here (Fig. 1), based on the Martini (1971) and Okada-Bukry (1980), was approved by the Paleogene commitee (MSK) of the USSR.

The Lower Paleocene — Danian, Selandian

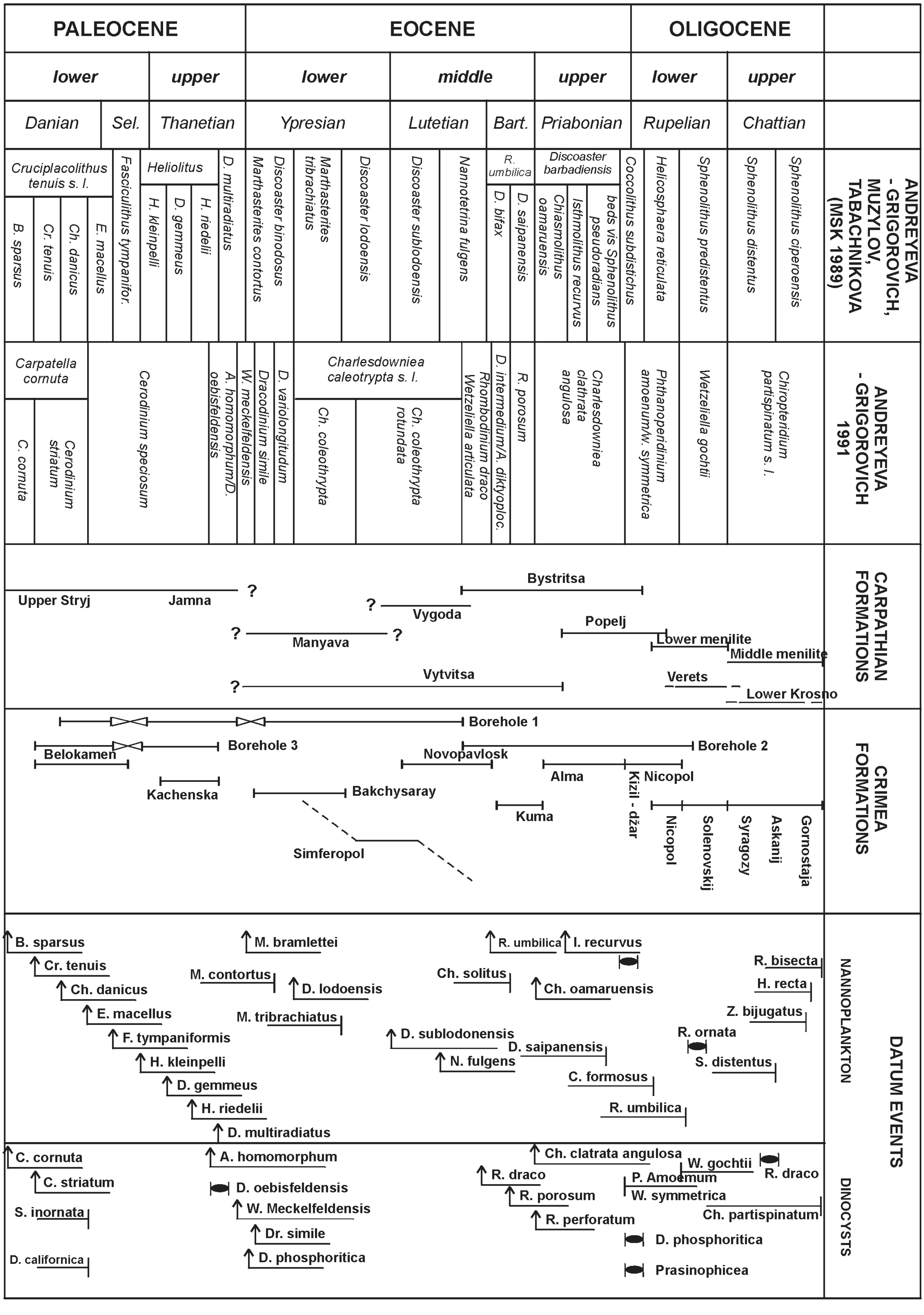
In the Carpathian Mts. the Lower Paleocene sediments are represented by the Stryj upper part subFm., where it is possible to determine all Lower Paleocene nannoplankton and dinocyst zones (Table 1). The Cretaceous/Paleogene boundary is distinct and it is determined on the basis of total extinction of the Cretaceous nannoplankton. The lower boundaries of the zones **Biantolithus sparsus** and **Carpatella cornuta** coincide. In the Crimea Lower Paleocene sediments are formed by the Belokamen Fm. (massive sandstones and limestones). There is a stratigraphic hiatus at the base, which corresponds to the **Biantolithus sparsus** Zone. The upper part of the Lower Paleocene is probably eroded. The **Fasciculithus tympaniformis** Zone is not present in the borehole. It was determined only in Suvlu-Kaya–Bakhchisarai profile (M. Muzyljov data).

The Upper Paleocene — Thanetian

The Jamna Fm. represents the Upper Paleocene sediments in the Carpathian Mts. In rare argilite intercallations, the **Heliolithus s.l.** Zone is determined. The **Discoaster multiradiatus** Zone is determined in the uppermost parts of this formation. On the basis of dinoflagellata, the **Apectodinium homomorphum** Zone with the acme of *Deflandrea oebisfeldensis* is in the upper part of the zone.

In the Crimea the Upper Paleocene is represented by the Kachenska Fm. (marls). It contains all the Upper Paleocene zones — nannoplankton, as well as dinoflagellata. The **Discoaster multiradiatus** Zone occurs only in borehole No. 1. The hiatus between the Kachenska Fm. (Upper Paleocene) and Bakhchisarai Fm. (Lower Eocene) corresponds to the upper part of **Discoaster multiradiatus** Zone and the whole **Tribrachathus contortus** Zone. In the Suvlu-Kaya profile, the above mentioned hiatus corresponds to the **Dis-**

Table 1: The nannoplankton zonation, correlations and events of the terrigenous and carbonate formations of the Carpathian Mts. and Crimea.



coaster multiradiatus Zone and lower part of the **Tribrachathus contortus** Zone.

Lower Eocene — Ypresian

In the Carpathians mountains the boundary of the Paleocene and Eocene is visible at the base of a strong facial alteration in the massive sandstones of the Jamna Fm. Ypresian sediments are also represented by the noncarbonate nannoplankton absent flysch of the Manyava and Vitvitsa Fms., except in the Opor river profile, where the **Tribrachathus orthostylus** Zone occurs in the carbonate intercallations. According to the data given above, a relative age cannot be determined on the basis of nannoplankton of the noncarbonate sediments of the Manyava and Vytvitsa Fms. There is a poor dinocysts association in the **Dracodinium simile** and **Charlesdowniea coleothrypta s.l.** zones in these deposits too.

In the Crimea, sediments of the Bakhchisarai Fm. (carbonate clays pass into the limestones in the upper part) and part of the Simferopol Fm. (nummulitic limestones) belong to the Lower Eocene. In Suvlu-Kaya profiles all Lower Eocene nannoplanktone zones — from the **Tribrachathus contortus** (upper part) to the **Discoaster lodoensis** Zone can be distinguished. In bore hole No. 1 the **Tribrachathus contortus** Zone is absent and the Lower Eocene sediments start with the **Discoaster binodosus** Zone. In these sediments the following dinoflagellate zones can be distinguished: **Wetzeliella meckelfeldensis, Dracodinium similie** and **Charlesdowniea coleothrypta.**

Middle Eocene — Lutetian and Barthonian

In the Carpathians Mts. we can include the Vygoda and Paseka Fms. (massive sandstones and limestones) and the upper part of the Vytvitsa Fm. (noncarbomnate flysch) among these sediments. Nannoplankton is absent in these formations, dinocysts occur only in the Vytvitsa Fm. (Table).

In the Crimea sediments the Simferopol, Novopavlovsk and Kuma Fms. (limestones, marls) belong into this interval. The nannoplankton data of the Simferopol Fm. (outcrops from the Sevastopol to Donskoe) show, that the nummulite limestones differ in time from the Late Ypresian to the Early Lutetian. The following nannoplankton zones occur — **Discoaster sublodoensis** and **Nannotetrina fulgens** in the Novopavlovsk Fm. The **Reticulofenestra umbilica** Zone in the Kuma Fm. is observed. On a basis of dinocyst research the following zones were determined in this interval: **Charledowniea coleothrypta s.l., Rhombodinium draco, Dracodinium intermedium** and **Rhombodinium porosum**.

Upper Eocene — Priabonian

In the Carpathians Mts. into the mentioned interval we range the Bystritsa Fm. and its age equivalent — the Popelj Fm. (weakly carbonate clayey flysch). On the basis of the Dinoflagellate and Nannoplankton associations contained in these sediments we can determine ages more precisely. In the sediments of the Bystritsa Fm., the upper part **Nannotetrina fulgens** Zone, **Reticulofenestra umbilica, Discoaster barbadiensis** and **Coccolithus subdistichus** zones occur in the Globigerina marls. In the Popelj Fm. the lower part of **Discoaster barbadiensis**, **Coccolithus subdistichus** and **Helicosphaera reticulata** zones can be distinguished. Thus Bystritsa Fm. in the upper Middle Eocene and Upper Eocene sediments and the upper part of Popelj Fm. sediments Upper Eocene and of the Lower Oligocene are developed. The Eocene/Oligocene boundary is situated at the base of the **Wetzeliella symmetrica** Zone, which practically agrees with the uppermost part of the Globigerina horizon. In the Crimea the Upper Eocene is represented by the Alma Fm. (marls), where the following zones have been distinguished: **Discoaster barbadiensis, Coccolithus subdistichus** (lower part) zones and on the dinocyst basis **Charlesdowniea clathrata angulosa** Zone. The Oligocene/Miocene boundary is situated at the base of the **Wetzeliella symmetrica** Zone (Table).

Lower Oligocene — Rupelian

In the Carpathians Mts. the Rupelian sediments are built up by Menilite and Krosno subFms. **Helicosphaera reticulata** and **Wetzeliella symmetrica** zones were distinguished in the undercherts sediments. The **Reticulofenestra ornata** association contains acme **Transversopontis pax** and **Wezeliella gochtii** zones (the level of the **Sphenolithus predistenthus** Zone) were discovered in the intercallations of the cherts in the Lower Menilite subFm. and Verets Fm. the Nikopol Fm. and Ostracoda beds belong to Lower Oligocene sediments in the Crimea and the northern part of the Black Sea depression. The upper part of the **Coccolithus subdistichus** Zone and **Helicosphaera reticulata** is observed at base of the Nikopol Fm. (Kizil-Dzjar beds). In the Ostracoda beds the associations of the **Reticulofenestra ornata acme**, **Transversopontis pax** association and **Wezteliella gochtii** zone were distinguished.

Upper Oligocene — Chattian

In the Carpathians Mts. sediments of the Middle Menilite and Krosno subFms. belong to this interval. The nannoplankton association of the **Sphenolithus distenthus** and **Sphenolithus ciperoensis** zones were observed here. On the basis of dinocysts these sediments belong to the **Chiropteridium partispinatum** Zone. The Oligocene/Miocene boundary is situated at the base of the nannoplankton sp. *Reticulofenestra bisecta, Helicosphaera recta, Zygrhablithus bijugatus* and dibnocyst sp. *Chiropteridium partispinatum* LAD. In the northern part of the Black Sea depression Syragoza, the Askanij and Gornostay Fms. (noncarbonate clays and sands) belong into this interval. Nannoplankton is absent in these sediments, only one planktonic group of fossil organism is common — dinocysts. The Oligocene/Miocene boundary is situated at the base of the uppermost part of the **Chiropteridium partispinatum** Zone — which is in accordance with the uppermost part of the Gornostay Fm.

Conclusions

The study of the dinocyst and nannoplankton associations of the Paleogene sediments of the Crimea and Carpathians area shows:

1. The Upper Eocene Bystritsa, Popelj and Alma formations seem to have different ages according to our data.
2. The Simferopolj Fm. is Upper Ypresian to Lower Lutetian in age.
3. The correlation of the Paleogene/Neogene boundary on the basis of dinocyst data in the Majkop Fm. and Krosno, Menilite Fms. is given.

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THE POSSIBLE MOLDANUBIC PROVENANCE OF THE PIENINY KLIPPEN BELT CRYSTALLINE BASEMENT DEDUCED FROM DETRITAL GARNETS

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Key words: Western Carpathians, Pieniny Klippen Belt, Bohemian Massif, Jurassic paleogeography, granulites, eclogites, garnets.

Introduction

The Pieniny Klippen Belt is the most tectonically complicated zone in the Western Carpathians. It involves mostly the Oravic Units, coming from an independent paleogeographical domain belonging to the Outer Western Carpathians (Czorsztyn, Pruské, Niedzica, Czertezik, Kysuca-Pieniny and some other units), as well as units of unknown origin, for example the Klape, Manín and Drietoma units which are frequently attributed to the Central Western Carpathians. However, the provenance of any unit of the recent Pieniny Klippen Belt has not been reliably proved. Because of the strong crustal shortening, all the units are incomplete. As a result reconstruction of the original position of the Pieniny Klippen Belt units is very difficult. Chemical analyses of detrital garnets from the Jurassic sediments of the Pieniny Klippen Belt yielded important information with possible application to paleogeography.

Results

Garnets of the Lower Jurassic sediments were analysed from the localities of Klape (Klape Unit?), Manín Narrows (Manín Unit), Sedliacka Dubová, Lúty Potok and Krásna Hôrka (all three localities are from the Nižná Unit). Along with these samples, Middle Jurassic samples from Hatné (Czorsztyn Unit), Vršatec (Czorsztyn Unit) and Horné Sŕnie-Samášky (Pruské Unit) were also analysed. According to chemical composition, the studied garnets can be divided into four groups (Fig. 1): ***A group*** — garnets with high pyrope content (more than 30 %), a relatively low content of grossular (less than 10 %) and a very low content of spessartine (less than 3 %); ***B group*** — garnets with high pyrope content (more than 25 %), a relatively high ratio of grossular (exceeding 15 %) and very low content of spessartine (less than 3 %); ***C group*** — garnets with contents of pyrope ranging between 20 and 30 %, grossular from 10 to 30 % and spessartine less than 5 %; ***D group*** — garnets with less than 20 % of pyrope component and variable amounts of the other components (spessartine, grossular, almandine).

Discussion

A characteristic feature of garnets in the fields A and B is the high content of pyrope in their composition. Such garnets are typical for high-grade metamorphosed rocks — granulites and eclogites. The difference between the groups A and B is in the content of the grossular component. The A group garnets, with a relatively lower grossular content, are typical for granulites, whereas the B group, with higher content of grossular, represents eclogitic source rock. Garnets of the C group occur either in the rocks metamorphosed in to high-grade amphibolite to granulite metamorphic facies (gneisses, amphibolites, granulites, eclogites) or in originally high-grade metamorphosed rocks (eclogites) later recrystallized into the amphibolite metamorphic facies (e.g. amphibolitized eclogites). The D group garnets are typical for rocks of the greenschist to amphibolite facies, for example phyllites, mica-schists, gneisses and amphibolites.

The chemical composition of the garnets from pre-Upper Carboniferous metamorphic rocks of the Western Carpathians is in Fig. 1 (field B). However, published chemical analyses of garnets from these metamorphic rocks possess pyrope components of less than 30 %. Along with some usual almandinic garnets, all the samples from the Pieniny Klippen Belt contained predominantly garnets with higher pyrope component (Mg) which reached 30 to 50 % (Fig. 1). The high content of the pyrope component in these garnets indicates that their source rocks were granulites and eclogites. The chemical compositions of garnets from the Moldanubic granulites and eclogites (Fig. 1, field A) correspond well to the composition of most of the studied detrital garnets from the Jurassic sediments (Fig. 1). The most important is that rocks such as granulites and eclogites were not reported from other zones of the Bohemian Massif, except for two small occurrences in the Western Sudetes (Poland) — Góry Sowie Block and the Snieznik area complex, or from the Western Carpathian crystalline complexes. The almandine-pyrope garnets, similar to those from our studied samples, are also common in the West Carpathian Flysch Belt (Otava et al. 1997, 1998). Their source was also identified as the Moldanubian Zone of the Bohemian Massif. Granulites are frequent among the exotic pebble material in the Silesian Unit (Wieser 1985), which suggests that the exotic Silesian Cordillera also represented a crustal segment similar to the Moldanubian Zone.

The common presence of the pyrope-almandine garnets also in the Manín Narrows and Klape localities is striking. Though the original paleogeographical position of the Manín and Klape units is uncertain, they are commonly attributed to the Central Western Carpathians. The Manín Unit was considered to be related to the Tatric domain by Andrusov (1938), then to the Pieniny Klippen Belt s.s. by Salaj & Samuel (1966) and later to the Fatric by Mahel' (1978). The Klape Unit was considered to represent an acretionary wedge in front of, or better along, the overriding Central Western Carpathian plate (e.g. Marschalko 1986; Birkenmajer 1988; Soták 1992). On the contrary, Plašienka (1995) stated that Klape Unit originated in the Fatric sedimentary area and it represents the highest part of the

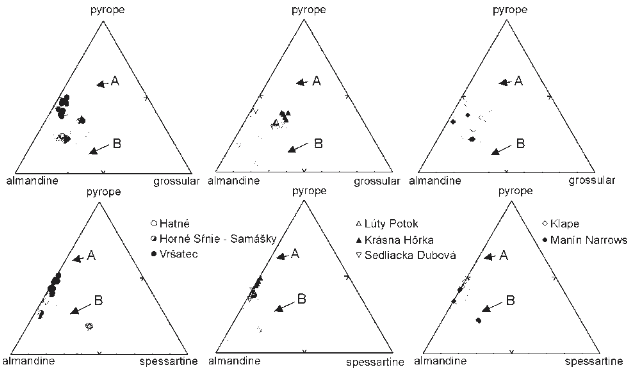

Fig. 1. Prp-Alm-Grs and Prp-Alm-Sps ternary diagrams of chemical compositions of the detrital garnets from the Jurassic sediments from the Western Carpathian localities. The field A represents the chemical composition of garnets granulites and eclogites from the Moldanubian Zone of the Bohemian Massif, the field B represents the chemical composition of garnets from the pre-Upper Carboniferous metamorphosed complexes of the Western Carpathians (Aubrecht & Méres, in press).

Krížna Nappe, detached and slid to its present position where it was subsequently tectonically involved into the Pieniny Klippen belt structure. There is also the problem of the position of Klape Hill itself. This single large Jurassic klippe occurs amidst the Cretaceous flysches which form the main portion of the Klape Unit. It is not clear whether it represents a block tectonically involved into this zone (Kysela 1984) or it is a huge olistolith which slid into the flysch basin from the Andrusov Exotic Ridge (Marschalko 1986). In any case, the data obtained from the Klape Hill are not automatically valid for the entire Klape Unit. There were some findings of eclogites among the exotic pebbles in the Klape Unit but with different compositions of their garnets (Šímová & Šamajová 1981). They contain only 28 % of pyrope component (interpreted only according to RTG analysis) which is depleted with respect to our results. Moreover, the results of chemical composition of the garnets presented in this paper are in favour of the theory about the appurtenance of the Manín and Klape units to the Oravic paleogeographical domain. The garnet-dominated heavy mineral spectra in the Pieniny Klippen Belt are consistent with those from the Gresten Zone of the Eastern Alps (Faupl 1975) and from the autochthonous Jurassic cover of the Bohemian Massif below the overthrust Carpathians (Štelcl et al. 1972, 1977). In our opinion, these domains all represent a single heavy mineral province, independent from the Central and Inner Western Carpathians.

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LACUSTRINE TO ALLUVIAL SEDIMENTARY CYCLICITY (PANNONIAN ZONE *E*, DANUBE BASIN)

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Key words: Pannonian, sedimentary cycles, sequence stratigraphy, Danube Basin.

The sandy-clayey sediments of the Pannonian zone *E* (sensu Papp 1951) occur at a well known paleontological and paleoecological locality in the Pezinok clay pit at the eastern margin of the Danube Basin (Holec et al. 1987; Fordinál 1997; Pipík 1998).

The new sedimentological and paleontological data reveal an interrelation of different sedimentary paleoenvironments and allow to distinguish seven facies associations (FA) within the 35 m thick outcropping sedimentary record: back-barrier transgressive FA, transgressive sand sheet FA, shallow offshore FA, beach-ridge FA, marsh FA, lagoonal FA and alluvial plain FA.

The vertical changes in facies associations mirror the relative changes of standing water level. In the lower part of the sedimentary record six lacustrine cycles were distinguished. The upper part of the profile is dominated by alluvial setting, and more data are needed to recognize cyclicity.

In the lowermost part of the section, medium-grained cross-bedded sands are interpreted to be upper wave-dominated, delta front, beach-ridge deposits. Their upper surface, acting later as a transgressive surface, is rippled and bioturbated by fossil plant roots.

The overlying composite back-barrier transgressive facies association marks the beginning of the first recognized sedimentary cycle. The facies consists of grey to green laminated silty clays and homogeneous clays with one organic-rich black horizon. Within these clays a sandy washover-related intercalation is also visible. The upper surface of the back-barrier transgressive sediments is truncated by a transgressive sand sheet. The truncation plane is interpreted as ravinement surface covered by a 3-10 cm thick, shell-rich, sandy layer, representing a transgressive winnowed lag and a disconformity due to shoreface retreat.

The molluscan shells consist of a poor gastropod assemblage represented by *Melanopsis sturii* Fuchs, *Valvata obtusaeformis* Lorenthey and minor bivalves of *Psilunio* genera. The ostracod assemblage is characterized by the genus *Cyprideis,* with the species *Cyprideis seminulum* (Reuss), *C. alberti* Kollmann, *C. heterostigma* (Reuss), *C. regularis* Jiříček, *Cypria abbreviata* (Reuss*), C. dorsoconcava* Krstić, *Amplocypris recta* (Reuss), *Hemicytheria* *brunnensis* (Reuss) and *H. reniformis* (Reuss). Presumably, the paleoecological environment was oligohaline to miohaline brackish.

The transgressive unit described below consists of silty sands to very fine sands with regular intercalations of clayey silts, deposited in the lower shoreface (or delta front) environment. This facies is gradationally overlain by coarser sands of the upper shoreface (or delta front) origin, representing the beach-ridge facies association with abundant carbonised roots. The presented cycle is capped by a lignite layer with as much as 1 m thick tree trunks, that originated in a forested marsh environment.

The second cycle starts by the erosive based, (transgressive surface) greenish-grey, laminated sandy clays, rich in roots, wood and plant fragments. This facies is interpreted to have originated in a back-barrier landward position, in fresh-water swamps and ponds during the initial transgression phase. The upper portion of these sediments is truncated (ravinement surface) by a fossil-rich lag layer with sandy matrix which is overlain abruptly by hummocky cross-bedded fine sands of lower shoreface origin, representing the transgressive facies association.

The faunal assemblage consists dominantly of gastropods, such as *Melanopsis impressa* Krauss (*M. i. impressa* Krauss, *M. i. carinatissima* Sacco, *M. i. pseudonarzolina* Papp, *M. i. posterior* Papp), *Melanopsis pygmaea pygmaea* Hoernes and *M. pygmaea mucronata* Handmann. The bivalves are represented by *Congeria doderleini* Brusina, *Dreissena bipartita* Brusina and *Lymnocardium conjugens* (Hoernes). The ostracod assemblage is predominated by the genus *Cyprideis.* The paleoecological environment can be interpreted as miohaline to mesohaline brackish.

The upper part of the cycle is missing, probably because of a subaerial erosion phase, documented by distal root remnants at the upper surface of the transgressive sand sheet.

The third cycle starts above the erosional flooding surface by a lag comprising thin sandy clay, rich in molluscan fauna.

The prevailing bivalve assemblage contains *Congeria ungulacaprae* Munster, *C. subglobosa subglobosa* Partsch, while the gastropods are represented by *Micromelania loczyi* Lorenthey, *Melanopsis affinis* Handmann and *Stenothyrella ovoidea* Pavlovic. The ostracod assemblage is predominated by *Candona (Caspiolla) praebalcanica.* The presented fossils suggest that the paleoecological conditions were miohaline to mesohaline brackish.

Above the molluscan-lag layer an abrupt onset of shallow offshore facies is visible. It consists of grey, laminated, silty clays, coarsening upwards into silts and sands of beach-ridge facies association. The cycle is capped by the lagoonal grey silty clays with mixed fresh-water and brackish molluscan fauna. The top of this unit is organic-rich and contains small rootlets.

The fourth cycle starts with a rapid flooding and with sedimentation of shallow offshore greenish-grey, laminated, silty clays that grade upwards into lower and upper shoreface sands representing the prograding beach-ridge facies association.

The cycle Nr. 5 starts with a very thin (3–15 cm), back-barrier, transgressive facies of sandy clays, rich in plant fragments. The transgression culminated with a thin layer of green clay, which we interpret as a maximum flooding surface. The overlying laminated offshore silty clays are slightly coarsening upwards. The sedimentary record continues by a yellow, well-sorted, fine sand with abundant shelly material. It represents a beach-ridge facies.

The faunal remnants consist of gastropods *Theodoxus soceni* Jekelius, *T. postkrenulatus* Papp, *Valvata obtusaeformis* Lorenthey and *Melanopsis pygmaea mucronata* Handmann, bivalves *Congeria neumayri* Andrusov and ostracods of *Cyprideis* genera. The salinity of the paleoenvironment is interpreted as oligohaline to miohaline brackish.

The overlying structureless fine sands to silty sands contain freshwater and continental molluscan fragments, as well as wood and plant debris. The sedimentary paleoenvironment is interpreted as the landward margin of beach ridges, at the margins of the lagunar/paludal areas.

The cycle is covered by a 10–40 cm thick, marsh-related lignite seam with roots, penetrating the basement more than 3 m deep.

The sixth cycle base displays a distinct flooding surface and an onset of greenish-grey laminated offshore clays. 18 cm above its base, there is a thin (4 cm) layer of grey pure clay with nodular central part. We propose that it settled under a sediment-starving conditions as a small-scale cycle maximum flooding surface. The overlying clays are coarsening upward into laminated silty and sandy clays and through flaser-laminated part they grade pass into sands, interpreted as a prograding beach-ridge facies association on the wave-dominated delta front. At the base, the sands are horizontally laminated, grading upwards into hummocky cross-stratified and rippled portions. The sandy facies is covered by lagoonal silty clays with fresh-water molluscan fragments, interpreted as a low energy delta plain.

The lacustrine cycles are overlain by a composite alluvial plain facies association, which includes an alternation of four different lithofacies:

1. floodplain clays and silty clays with abundant organic-rich layers and paleosol horizons;
2. rhytmically bedded sandy silts and clayey silts, interpreted as levee accummulations;
3. fining-upwards successions of well-sorted sands, forming chanell-fill and point-bar deposits, and
4. coarsening-upwards successions from silts to silt-sand alternations, interpreted as crevasse splay deposits.

The alluvial deposits display a homogeneous paleontological content, including continental and fresh-water molluscs and freshwater ostracods with characteristic species *Candona (Candona) candida* Muller, *Darwinulina stevensoni* (Brady & Robertson), *Il-*

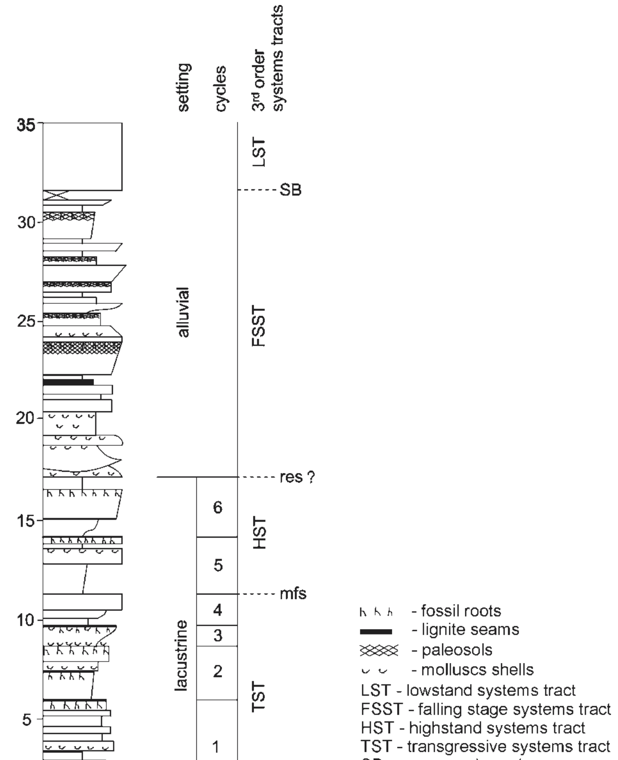

Fig. 1. Sedimentological profile.

iocypris gibba Ramdohr, *Leptocythere lacunosa* (Reuss) and *Paralimnocythere* sp.

In the studied sedimentary succession in Pezinok clay pit, the generalized stacking pattern of the recognized cycles (parasequences) display a relatively rising water level from the first cycle up to the cycle Nr. 5, and a relatively falling water level upwards in the profile. These results can outline, that most of the studied sedimentary record belongs to one 3rd-order sedimentary sequence, in which the upper alluvial-plain facies association may represent its falling stage systems tract. The presence of at least 3.5 m thick fluvial channel fill in the uppermost part of the section may indicate a 3rd-order sedimentary sequence boundary at its base. This guess could fit with such sequence boundary, recognized within the upper part of the Pannonian zone *E* in the seismic sections (Kováč et al. 1998).

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MODE AND FORMATION OF SUBTROPICAL EOCENE CARBONATES: CASE STUDIES FROM THE CENTRAL WESTERN CARPATHIANS AND TRANSDANUBIAN BASINS (POLAND AND HUNGARY)

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Key words: Subtropical carbonates, sequence stratigraphy, Central Western Carpathians, Transdanubian.

Introduction

Examples for the development of Eocene marine carbonate sequences are given from sedimentary basins of the Polish part of the Central Western Carpathians (Podhale Basin, Poland) and the Transdanubian Eocene, Intra-Carpathians (area of Tatabánya/Hungary). Geotectonically, both of them are related to the North-Pannonian unit. Opening and internal subsidence rates were controlled by subduction-induced collapse structures (Baráth et al. 1997; Soták & Bebej 1996; Wagreich & Marschalko 1995). Palinspastic reconstructions suggested for the late Eocene period a paleogeographical location some hundreds kilometers southwest of its present position (Csontos et al. 1992). The Eocene transgression was northeastward directed and used marine connections from the Buda-Paleogene towards the Central Western Carpathian Paleogene Basin. Sedimentation began in the Lower Lutetian and continued until the Oligocene.

The Podhale Basin is the northern part of the basin system surrounding the Tatra Mountains. Sections were studied from outcrops along the southern paleoshelf area. In the Paleogene depositional system, three sedimentary cycles in terms of composite sequences (cs) sensu Kerans & Tinker (1997) were distinguished (Bartholdy & Bellas 1998a,b,c; Bartholdy et al. under review). They are correlated with the Upper Lutetian/Lower Bartonian (cs 1), the Middle/Upper Bartonian (cs 2) and the Lower /Upper Priabonian (cs 3) stages respectively. The first two cs's were investigated in detail and determined by larger- and planktonic foraminifera and calcareous nannofossils integrated biostratigraphy, while, the third one was evaluated on the base of synthesizing previous literature (Olszewska & Wieczorek 1998). Glacioeustatic sea-level changes are regarded as controlling factors for the development of the stratigraphic architecture of the Podhale Basin during the Eocene period (comp. Abreu & Anderson 1998; Bartholdy et al. under review). Cs 1 and cs 2 are regarded as examples of carbonate sequences, developed under several environmental conditions: Generally, oligotrophic/mesotrophic conditions and a long-term stable environment (background-dominated) are determined for cs 1. In turn, cs 2 was dominated by oligotrophic/mesotrophic nutrient-level and short-term changes in the environmental conditions (event-dominated) (Bartholdy et al. under review; Hottinger 1997). In comparision to cs 1, relatively cooler conditions are recorded for cs 2 (Bartholdy & Bellas 1997).

The sedimentary succession in cs 1 is characterized by a transgressive character, a typical ”turn on” of the carbonate factory and a distinct larger foraminiferal association with a vertical deepening-upward trend in shape and morphostructure. Our data are easily compatible with the models, given by Loucks et al. (1998) for larger foraminifers bearing carbonate ramps in the tropical realm. As opposed to this model, the larger foraminiferal association in the Podhale Basin is characterized by a reduced species-diversity and scarce miliolids. The cs 1 succession is described as follows from the bottom to the top: 1st unit: Pebble-supported conglomerate with components up to 1 m in diameter(1–2 m), transgressively deposited above Mesozoic strata. 2nd unit: Back bank facies with bioclastic rudstones and intercalated fine-grained conglomerates in non-protected, relatively high-energy realm, while in protected areas *Nummulites*-rudstones with *N. brongniarti/N. puschi* and small, globular *Nummulites* with intercalated bioclastic packstones in the oligotrophic realm and scaphopods-*Nummulites*-rudstones, together with shells of molluscs in mesotrophic nutrient-level (12–14 m). 3rd unit bank-facies, consisting of buildups of *N. perforatus* (1–2 m). 4th unit fore-bank facies, with transitions from bioclastic packstones (allochthonous Orthophragminae-*Nummulites*-Packstones) at the bottom, followed by bedded autochthonous accumulations of flat formed larger foraminifers (*N.* cf. *dufrenoyi*, *D. sella*) in typical correlation of shape and paleodepth. At the top, during reduced accumulation-rates, the content of glauconite is increasing (maximum flooding surface, 0.3 m) (Kulka 1985; Bartholdy 1997; Drobne & Cosović 1998).

Cs 2 is completely preserved in the investigated sections. It includes sediments from the LST, TST, HST und SMST's. The following is a generalized description of the succession from the bottom to the top: 1st unit a Lowstand Systems Tract: Fine-grained conglomerates and calcareous-marly sandstones with intercalations of sandstones with higher land-plants and glauconite-bearing wackestones (max. 8 m). 2nd unit a Transgressive Systems Tract: The rising sea level caused a ”turn on” of the carbonate factory and produced red algae-packstones and -bindstones (ca. 5–6 m).

3rd unit a Highstand Systems Tract: Produced packstones, which are rich in planktonic foraminifers (max. 3 m). 4th, a Shelf Margin System Tract, produced under conditions of a slow fall in sea level and a mesotrophic milieu. Heterosteginids-, echinoderms-, red-algae- and bryozoan-packstones (max. 7 m) were accumulated.

The outcrop of Tatabánya/Hungary includes Eocene sediments of the Dorog-development from Hungary. In the investigated section, the marine sedimentation began in the Upper Lutetian. First, preliminary studies indicated the presence of two High Frequency Sequences (HFS 1 and HFS 2), distinguished by differences in the geometry of the sedimentary bodies and sedimentary/paleontology features:

1st, HFS 1 is characterized by prograding geometry, shallow marine sediments of the Csernyei Fm. (ca. 5 m). These accumulations of the lowstand-phase (LST) consist of limestones and sandy limestones with intercalated marls (wackestones to packstones), partly intensively bioturbated, rich in bioclasts and often with fine-disperse pyrite.

2nd, HFS 2 is generally transgressive with a retrograding symmetry (Transgressive Systems Tract). Lithologically, we could distinguish between two units: The lower unit (ca. 8 m) consists of alternations of bioclastic limestones and marls from the shallow to deeper marine sediments of the Csolnoki-Agyagmárga Marl Fm. (possibly with intercalations of brackish to shallow-marine accumulations of the Tokodi Marl Fm). The clearly visible increase in the thickness of the cycles points to an increase in the accomodation space and a relative rise in sea-level. The upper part (ca. 7 m) of the HFS 2 consists of neritic sediments of the Szöci-Mészkö Limestone Fm. (*N. perforatus* in the lower and *N.* cf. *millecaput* in the upper beds). A deepening upward is indicated by characteristic changes in the shape of the larger foraminifers.

In contrast to tropical carbonates, carbonate depositional systems from the non-tropical realm produce depositional sequences similar to the siliciclastic ones.

This is due to the dominance of hydrodynamic structures by the development of the accumulation-style. In the subtropical realm, the development of early-diagenetic cements plays a subordinate role. The main causes are the absence of widespread reefs, a slower carbonate-production-rate and the dominance of calcitic shells over the aragonitic material (comp. Betzler et al. 1997; Kerans & Tinker 1997). In contrast to siliciclastic depositional systems, the components for the sedimentation come not from an external source, but from the internal body of the carbonate-factory. These facts in relation to the switch on of the carbonate-factory effect during times of rising in sea level (TST), caused increased thickness within the TST in comparison to the siliciclastic systems. *Nummulites* and *Orthophragminae* occurred as strong K-strategists in the transgressive systems tract under oligotrophic conditions. Their shape and the shell-morphology are well correlated with the water-depth (comp. Hottinger 1997; Drobne & Cosović 1998; Kecskeméti 1989). Heterosteginids could tolerate meso- to eutrophic conditions (pers. comm. Hallock Muller 1999) and occur in the Lowstand Systems Tracts.

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RESULTS OF TAXONOMIC RESEARCH ON CRETACEOUS-PALEOGENE FLYSCH-TYPE AGGLUTINATED FORAMINIFERA

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Key words: Foraminifera, taxonomy, Cretaceous, Paleogene, Carpathian Flysch.

Introduction

Within the non-calcareous sediments deposited below the CCD, the agglutinated foraminifers represent the most common and often only preserved fossils. Their applicability for the biostratigraphy of flysch units and oceanic sediments world wide has already been proved by testing the Geroch & Nowak (1984) zonation. Among agglutinated foraminifers, especially some hormosinids *(Caudammina, Pseudonodosinella*), rzehakinids, lituolids (*Haplophragmoides, Plectorecurvoides*, *Recurvoides, Reticulophragmium*, and *Bulbobaculites*), and "verneuilinids" (*Uvigerinammina, Verneuilinoides, Pseudoreophax*) are of higher biostratigraphic potential. Despite the

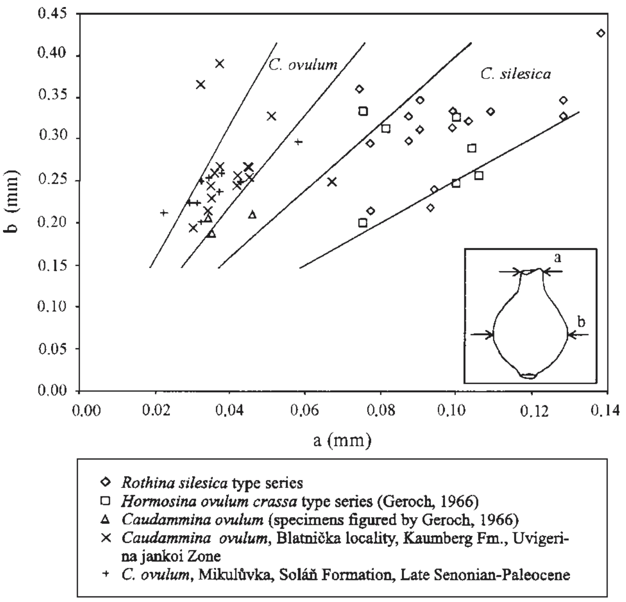

Fig. 1. Biometry of *Caudammina silesica* and *C. ovulum*. Limit lines of species after values given by Geroch (1959).

importance of these partial groups for applied micropaleontology their taxonomy is still unsufficient. As a result:

1. An unclear taxonomic concept of species is a source of permanent confusion.
2. The published data on distribution must be treated very critically.
3. Quite often unnamed new species are met (especially among lituolids and "verneuilinids").

The biostratigraphic potential of this group cannot be fully exploited unless the true taxonomic concept of species based on examination of the type specimens is recognized and variability based on biometry is delimited. The preliminary results of such research already realized in the framework of grant GAČR No. 205/97/0495: "Revision of Cretaceous to Paleogene Recurvoidinae" and in the framework of research tasks organized by the Czech Geological Survey are given below.

Methods

Taxonomic revision was based on the examination of type specimens when this was possible. For the delimitation of variability of rzehakinids and selected *Caudammina* species, the biometry was applied. Measures of types useful as standards were taken mostly from type figures. Besides the types sets of specimens from the Carpathian Flysch were measured to provide a statistically reliable group for study of variability. All measured specimens were drawn using "camera lucida". Biometric parameters were measured on drawings. For details on the measurements and ratios used see Figs. 1 and 2.

Revision of Recurvoidinae started with the examination and documentation (redrawing) of type specimens. The specimens were observed and drawn in transparency (in drop of water or glycerine) to learn the details of their coiling mode. The coiling of Recuvoidinae is often complex and variable. Therefore the six standard views derived from the position of an aperture were introduced and schemes of coiling mode ("rollograms") following Geroch (1962) were constructed.

Revision of selected hormosinids

The synonymy of the genus *Rothina* and *Caudammina* was already recognized earlier on the basis of revision of the *Rothina silesica* type series (Bubík 1997). Geroch (1959) was the first who applied biometry to hormosinids and within *Hormosina ovulum* group separate form with thicker necks later described as *Hormosina (=Caudammina) ovulum crassa*. Relatively thicker necks can be objectively expressed using the chamber/neck diameter ratio (b/a) introduced by Geroch (1959). The nearly identical b/a values of the *Rothina silesica* and *Hormosina ovulum crassa* ranging from 2.3 to 3.9 show that these two taxa are identical *(=Caudammina silesica)*, while *Caudammina ovulum* clearly differs (see Fig. 1). Transitional forms *C. ovulum-silesica* are relatively frequent in the Early Cretaceous.

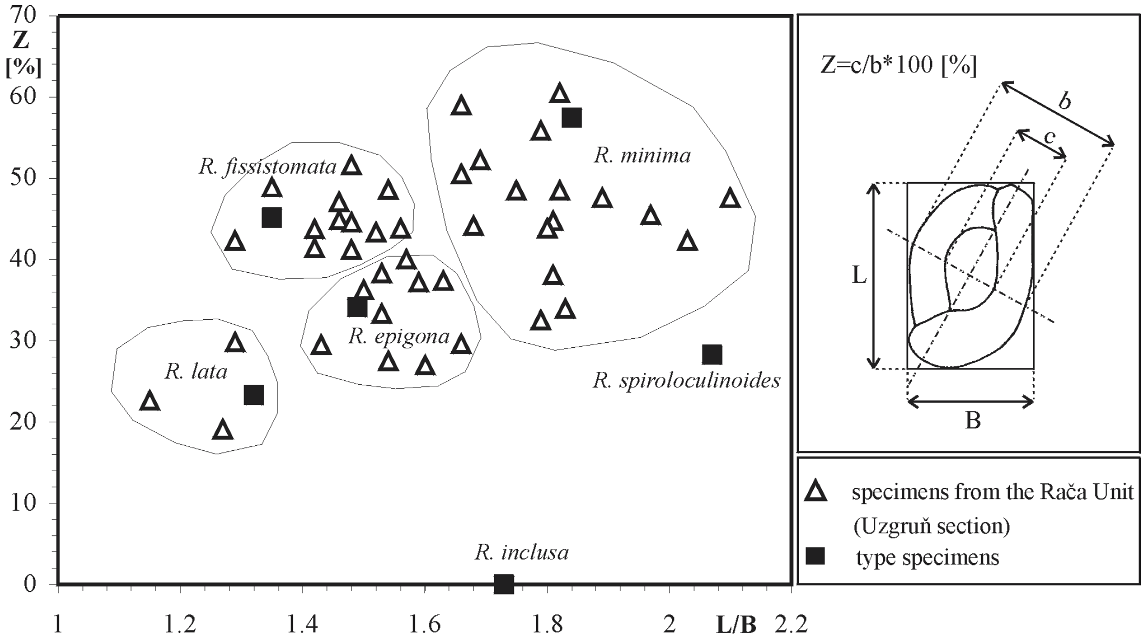

Fig. 2. Biometry of *Rzehakina* representatives with delimited fields of variability.

type reference	original designation	current name / status	material
Reuss (1863)	Haplophragmium nonioninoides	Labrospira nonioninoides	L
Grzybowski (1896)	Cyclammina retrosepta	Recurvoides retroseptus	S
	Cyclammina setosa	Recurvoides setosus	M
	Cyclammina globulosa	nomen dubium	none
Grzybowski (1898)	Haplophragmium subturbinatum	Thalmannammina subturbinata	L
	Haplophragmium immane	Recurvoides immane	L
	Haplophragmium walteri	Recurvoides walteri	L, P
	Trochammina nucleolus	Bulbobaculites(?) nucleolus	L
Friedberg (1901)	Trochammina bifaciata	nomen dubium	none
Noth (1912)	Trochammina deflexiformis	nomen dubium	none
	Endothyra barwinekensis	nomen dubium	none
Hanzlíková (1966)	Haplophragmoides imperfectus	Recurvoides imperfectus	H
Hanzlíková (1972)	Recurvoides gerochi	primary homonym	H
Hanzlíková (1973)	Recurvoides godulensis	Thalmannammina godulensis	H, P
	Recurvoides variabilis	Recurvoides variabilis	H, P
Mjatljuk (1970)	Recurvoides anormis	Recurvoides anormis	H
	Recurvoides dissonus	Cribrostomoides? dissonus	H
	Recurvoides nadvornensis	Recurvoides anormis Mjatl.	H
	Recurvoides primus	Recurvoides imperfectus (Hanzl.)	H
	Recurvoides pseudoregularis	Recurvoides pseudoregularis	H
	Recurvoides smugarensis	Recurvoides smugarensis	H, P
	Recurvoides varius	Recurvoides varius	H, P
	Cribrostomoides? pocutiensis	Recurvoides cf. retroseptus (Grz.)	H
Geroch (1962)	Plectorecurvoides irregularis	Plectorecurvoides irregularis	H
	Thalmannammina neocomiensis	Thalmannammina neocomiensis	H
Jednorowska (1968)	Recurvoides globosus	nomen dubium	none
Soliman (1972)	Recurvoides praedeflexiformis	Thalmannammina praedeflexiformis	H
	Recurvoides praeimperfectus	Recurvoides imperfectus (Hanzl.)	H
	Thalmannammina mariensis	Thalmannammina neocomiensis - Plectorecurvoides irregularis trans.	H
	Plectorecurvoides postalternans	Plectorecurvoides alternans Noth	H
Maslakova (1955)	Haplophragmoides enormis	nomen dubium	none
Noth (1952)	Plectorecurvoides alternans	Plectorecurvoides alternans	H
Fuchs (1971)	Recurvoides exiguus	Recurvoides exiguus	H

Fig. 3. Preliminary results of taxonomic revision of Recurvoidinae. Abbreviations: H — holotype, S — syntype, L — lectotype, P — paratype/paralectotype, M — metatype.

Another case of biometry usefulness is determination of the *Caudammina gigantea* on the basis of its chamber length exceeding 0.6 mm. Geroch (1959) proved bimodal size distribution within the Late Senonian *Caudammina ovulum* group with smaller forms and the larger ones later described as *Hormosina ovulum gigantea* (=*Caudammina gigantea*).

Revision of the genus *Rzehakina*

It is sometimes difficult to distinguish *Rzehakina epigona, R. fissistomata*, and *R. minima* from Carpathian flysch because of transitional forms. For delimitation of the species variability the length/breath ratio (L/B) and involution index (Z sensu Hiltermann 1974) were plotted to a diagram (Fig. 2). 45 specimens from the Uzgruň section (Maastrichtian and Paleocene, Rača Unit) were measured. In contrast to the biometric data of Hiltermann (1974) the ”Z” values for *R. fissistomata* and *R. epigona* overlap with that of *R. minima*. The latter species differs by its relatively narrower test. Each species forms a relatively distinct area in the diagram (Fig. 2). Surprisingly *R. lata* considered recently by some authors synonymous with *R. epigona* forms a separate group in the diagram and is recognized as a distinct species. *R. lata* differs from all other species by its broader test. The set from Uzgruň does not contain specimens close to *R. inclusa* and *R. spiroloculinoides*. The latter species may represent juveniles of *R. epigona*. It will also be helpful to also plot in the diagram the topotype specimens of all the above mentioned species as the next step in the research.

Revision of the subfamily Recurvoidinae

Within Recurvoidinae the genera *Plectorecurvoides, Pokornyammina*, and *Cribrostomoides* are provisionally newly placed. In the Alpine-Carpathian flysch *Recurvoides* and *Thalmannammina* are the most frequent and important genera. Various authors reported about 50 species of the flysch-type Recurvoidinae from the Cretaceous to Paleogene of the Alpine-Carpathian region. Until now practically all the species described from Cretaceous-Paleogene flysch on Czech, Polish, Ukrainian and Austrian territory has been restudied. Unfortunately type material for 6 species is missing and they should be considered nomina dubia. A further 6 younger synonyms, one primary homonym and 19 valid species were recognized. Two synonyms were assigned to *Recurvoides imperfectus*: *Recurvoides primus* and *Recurvoides praeimperfectus*. *Thalmannammina meandertornata*, *T. godulensis*, and *T. praedeflexiformis* are further potential synonyms. Mutual relations and variability of these species could be recognized using biometry (number of chambers, their growth rate, and angularity of their outline). The lectotype of *Haplophragmium nonioninoides,* frequently reported by various authors from the middle Cretaceous of Carpathians as *Haplophragmoides nonioninoides*, was examined. The Carpathian material is not conspecific or congeneric.

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DEVELOPMENT AND STRATIGRAPHY OF THE PALEOCENE–EARLY EOCENE THICK-BEDDED TURBIDITES IN THE NORTH-WESTERN ZONE OF THE MAGURA NAPPE, OUTER CARPATHIANS, POLAND

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Key words: Magura Nappe, Paleocene–Early Eocene, thick-bedded turbidites, petrographic composition, biostratigraphy.

Introduction

The presented studies concern the development of the Mutne and “Ciężkowice” sandstones in the western segment of the Magura Nappe in Poland. These deposits were investigated in the four areas (I–IV, see Fig. 1) which belong to the outermost tectono-facies zone (northen Raca subunit). Their lithological features, heavy mineral contents, current directions and where possible foraminiferal assemblages were examined in details. The sedimentation of the studied deposits followed deposition of northern facies of the Inoceramian beds (Solan beds), Senonian–Paleocene in age. West of the Skawa River the Paleocene fan of the Mutne Sandstones was formed. During the Late Paleocene–Middle Eocene, hemipelagic sedimentation of variegated shales of the Labowa Shale Formation (Oszczypko 1992) took place. This slow sedimentation was interrupted once or twice by high-density sandy flows which formed fans of so-called “Ciężkowice” Sandstones, well developed east of the Soła River. The variegated shales are overlain by thin-bedded turbidites of the Hieroglyphic beds (Middle Eocene) locally developed in the northern Raca Subunit, and by thick- and medium-bedded turbidites of the Sub-Magura beds or/and glauconitic Magura Sandstone (Late Eocene–Oligocene).

Results

Within the Mutne and “Ciężkowice” Sandstones medium, coarse-grained or conglomeratic sandstones, and occasionally conglomerates, up to 2.5 m thick are observed. The sandstone grains consist of quartz, feldspars, clasts of sedimentary, magmatic and metamorphic rocks cemented with clayey and calcareous material. Though the lithological and sedimentological features of the Mutne and “Ciężkowice” sandstones are in many cases similar, their compositions show evident differences. Within the lithoclastic grains of the Mutne Sandstones metamorphic rocks are dominant. The “Ciężkowice” Sandstones are more often glauconitic than the Mutne Sandstones. Volcanic as well as different sedimentary rocks are also more frequent.

The heavy mineral compositions display important differences between studied sandstones. The “Ciężkowice” Sandstones contain 27–54 % of garnet and within the Mutne Sandstones this mineral is dominant (67–84 %). Other heavy minerals in the latter are represented by zircone (3–8 %), tourmaline (5–8 %), rutile (4–7 %, rarely up to 16 %) and sporadic apatite, epidote and chromite. The “Ciężkowice” Sandstones show an admixture of zircone (8–17 %), relatively more frequent tourmaline (16–33 %) as well as rutile (25–31 %), and rare staurolite and chromite. There are very distinct differences between the heavy mineral composition of the Ciężkowice Sandstones from the Silesian Nappe and their equivalents in the Magura Nappe. In those sandstones in the Silesian Nappe garnet content is low (2–12 %) and zircone is dominant (37–48 %). An important admixture consist of tourmaline (14–18 %) and rutile (29–34 %).

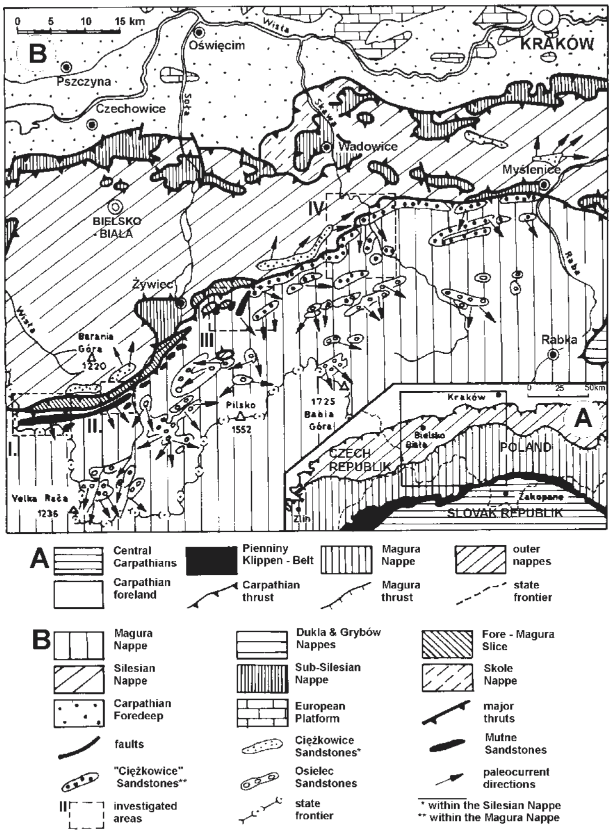

Fig. 1. Geological setting of the investigated areas of the Magura Nappe in the western sector of the Polish Carpathians (A, B) and location of the main exposures of ther examined Paleocene-Middle Eocene thick-bedded sandstones.

The detritic material of the Mutne and “Ciężkowice” Sandstones of the Magura Nappe came to the Magura Basin from the north. Its source area could have been located on a ridge that bordered the Magura Basin from the north during the Paleogene period (Cieszkowski 1992). The sedimentary area of the Ciężkowice Sandstones of the Silesian Nappe was connected with the Silesian Ridge situated north of the Dukla and Magura basins. This ridge supplied material towards the north and north-east to the Silesian Basin (cf. Książkiewicz 1962). The paleogeographical setting as well as the composition of detritic material show that the thick-bedded Lower Eocene sandstones in the northern Raca Subunit of the Magura Nappe formed quite different lithosome, completely separated from the lithosome of those Ciężkowice Sandstones which occur in the Silesian Nappe. Therefore, in our opinion the name “Ciężkowice Sandstones” should not be used for the deposits of the Magura Succession, even though there are some similarities in sedimentological and lithological features between them.

Shaly intercalations within the Mutne Sandstones are very poor in foraminifera. In the Mutne and Jaworzynka areas (Figs. 1 and 2), the underlying Inoceramian beds contain assemblages with dominating agglutinated taxa, with such characteristic species as *Hormosina excelsa* (Dylazanka), *Rzehakina inclusa* (Grzybowski) and *Remesella varians* (Glaessner). They are common elements of the Late Senonian assemblages in the Polish Carpathians (Olszewska 1997). In two cases single planktonic forms have been found *Rosita contusa* (Cushman) and *Abathomphalus* cf. *mayaroensis* (Bolli) which confirm Maastrichtian age of the examined Inoceramian beds. At Mutne locality, the Early Eocene agglutinated assemblages with abundant *Glomospira* have been found, in the red shales overlying the Mutne Sandstones. Thus the age of the Mutne Sand-

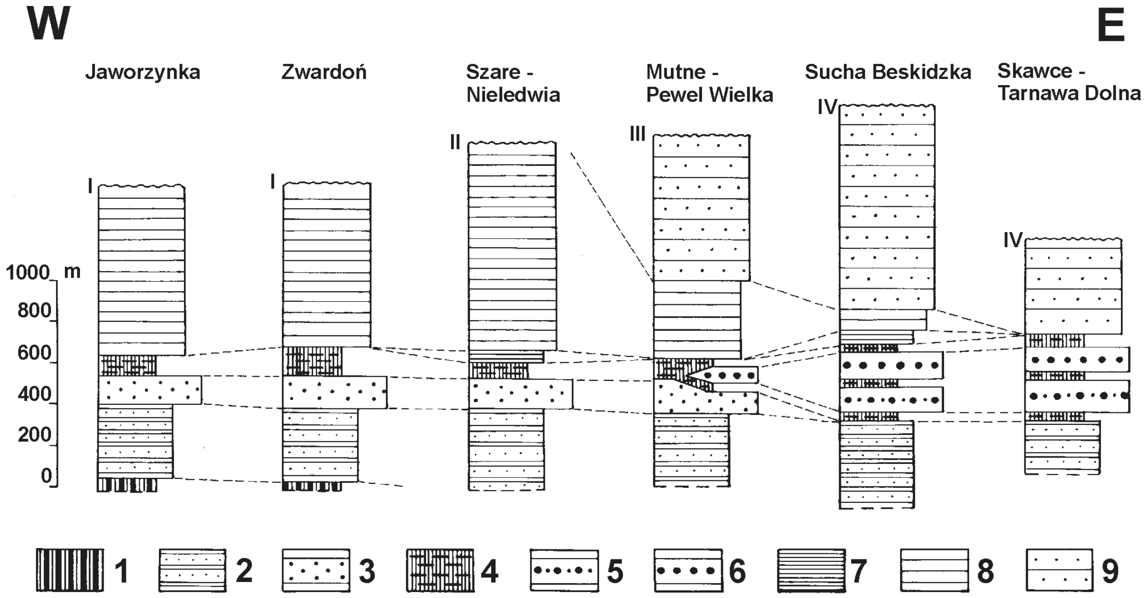

Fig. 2. Lithostratigraphic logs of the northern Raca sedimentary succession of the Magura Nappe in the investigated areas; Roman numbers correspond to particular areas in Fig. 1. 1 — variegated shales (Senonian), 2 — thin- and medium-bedded turbidites: Inoceramian beds (Senonian–Early Palaeocene), 3 — thick-bedded Mutne Sandstones (Paleocene), 4 — variegated shales of Labowa Shale Formation (Late Paleocene–Middle Eocene), 5 — thick-bedded "Ciężkowice" Sandstone — lower level (Late Paleocene - Early Eocene), 6 — thick-bedded "Ciężkowice" Sandstone — upper level (Early Eocene), 7 — thin-bedded turbidites — Hieroglyphic beds (Middle Eocene), 8 — medium- and thick-bedded turbidites — Sub-Magura beds (Late Eocene), 9 — thick-bedded glauconitic Magura Sandstones (Late Eocene–Oligocene).

stones can be inferred as Paleocene. The foraminiferal content of the Ciężkowice Sandstones has been examined in the area of Sucha Beskidzka (Fig. 2). The lower Ciężkowice Sandstone is Paleocene in age on the basis of the presence of agglutinated assemblages with *Glomospirella grzybowskii* (Jurkiewicz). The upper Ciężkowice Sandstone occurs between the middle variegated shales of the Labowa Sh. Fm. which contain Early Eocene assemblage of the *Glomospira* acme zone (Olszewska 1997) and upper variegated shales of Middle Eocene age with the agglutinated assemblage of the Reticulophragmium amplectens Zone.

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CRETACEOUS KARST ENVIRONMENT OF THE WESTERN CARPATHIANS

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Key words: paleogeographic zones, paleokarst sediments and forms.

Introduction

Paleokarsts or fossil karsts are features formed by agents active in the karst environment in the past under climatic conditions differing from the present. It is by no means always easy to distinguish between active, relic, buried and exhumed components of karst (Jennings 1985; Bosák et al. 1989).

Cretaceous karst phenomena are mainly developed in the carbonate complex of Middle and Upper Triassic age of the Fatric, Hronic and Silicic cover nappe systems. Carbonate complexes belonging mainly to the Fatric and Hronic predominate in the northern part of the Western Carpathians. In the southern part, the Tertiary sequences are underlain by extensive areas of carbonate complexes of the Silicic. Cretaceous paleokarst is notably developed on Wetterstein and Gutenstein limestones and dolomites, Hauptdolomites and Steinalm, Tisovec, and Furmanec limestones.

Cretaceous karst in main paleogeographic zones

Fatric

Albian karst. In the Vysoké Tatry Mts. on the top of the Urgonian limestones of the short living Urgonian carbonate platforms (northern Fatric–southern Tatric), traces of syngenetic karstification are known (Głazek 1989). Immediately after its deposition, during the Albian, the Urgonian carbonate platform was drowned and covered with pelagic sediments.

Hronic

Doline-like depressions. Depressions and different kinds of fissures developed in dolomites and limestones of the Hronic in the Brezovské Karpaty. They are sometimes filled with red ferrugineous clays. The clay fraction consists of chlorite, kaolinite, illite and illite/smectite (Činčura 1997a). The Upper Cretaceous Valchov conglomerates represent a more frequent fill of the shallow depressions. It can be stated that such shallow doline-like depres-

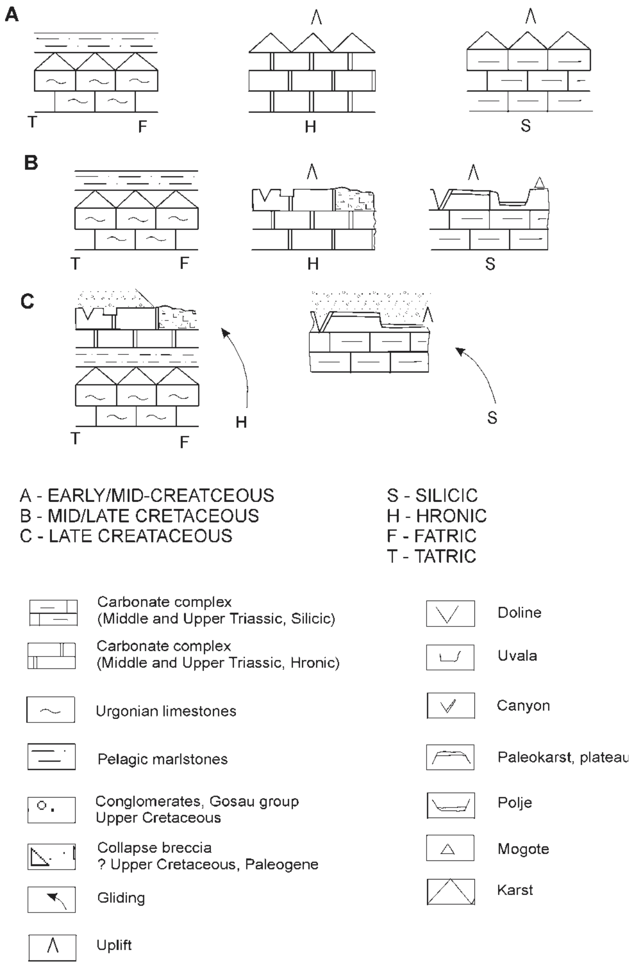

Fig. 1. Cretaceous karst evolution of the Western Carpathians.

sions are older than the Valchov conglomerates and they originated prior to the Late Cretaceous.

Canyon-like depressions. Deeper depressions occur mainly in the Hauptdolomite, less frequently in Dachstein limestones (Brezovské Karpaty Mts.). They are more or less linear, but not strictly straight. Their width on the surface does not exceed some tens of meters, exactly like their depth. The fill (red lens-shaped boehmite-kaolinite bauxite is rather rare, red ferrugineous silty clays and Valchov conglomerates are more frequent; Činčura 1997b) indicates their pre-Late Cretaceous age.

Uvalas. Occurrences of longitudinal bodies of freshwater limestones have been known in the Brezovské Karpaty Mts. (Pustá Ves Formation, Michalík et al. 1993; Mišík & Soták 1994; Činčura 1998). Relatively extensive outcrops N of Kočín represent the most important site consisting of brown to chocolate brown thickly bedded to massive limestones with abundant organic remnants (especially of algae). They overlay Wetterstein dolomite and can be dated, most probably to the Middle Cretaceous (Salaj et al. 1987). Pebbles of such freshwater limestones were found in the Upper Cretaceous Valchov conglomerates. We regard the limestones as paleokarst sediments deposited in lacustrine basins developed especially on the surface of karstified carbonate complexes. The bottoms were flooded during heavy precipitation. Intermittent lakes originated with the growth of freshwater algae which contributed to the deposition of limestones. We regard them as remains of sediments of pre-Upper Cretaceous uvala-like depressions.

Caves and collapse breccias. Carbonate breccias appear unconformably overlying Triassic limestones and dolomites in Malé Karpaty Mts. and fill various depressions. The thickness of the breccia complex often exceeds tens of metres and in some places is over 150 m. The breccia complex is composed of very local material which may be derived exclusively from the underlying rocks. The clasts of the carbonate breccias are characterized above all by the angularity and irregular arrangement of the material. In grain size there is a wide range of material, extending from fragments with a size of some centimetres up to megaclasts, which have a size of some hundreds of cubic metres. Lenticular beds of laminated marl with weakly rounded gravel in the breccia complex indicates fluvial transport. The areal and spacial extent of the breccia complex, indicates that an important cave system existed in the Malé Karpaty Mts. before the transgression of the Paleogene sea (Činčura 1992).

Silicic

Paleokarst plateaux. Plateau paleokarst is a typical feature of Middle and Upper Triassic carbonate sequences of the Slovak Karst, Slovenský Raj and Muránska Planina. While the predominant occurrence of plateau paleokarst in the Silicic is a result of paleotectonic development, the position of paleokarst plateaux at different heights above sea level is a result of neotectonic development. Karst depressions filled with — in situ or partly removed — freshwater chalk rocks, or of banded series of light coloured graded siltstones and black mudstones are known (Mello & Snopková 1973; Marschalko & Mello 1992; Činčura 1993; Cílek & Bednářová 1994) in different quarries (Gombasek, Hosťovce, Včeláre). According to plant pollen and spores the filling is of Upper Cretaceous (Santonian–Campanian) age.

Poljes and mogotes. An extensive karst depression has developed in a limestone-dolomite complex of Middle and Upper Triassic age (Slovenský Raj Mts.) near the Dobšiná Ice Cave. From the bottom of this depression rises the Steinalm limestone mogot/hum of Ostrá Skala hill, which is surrounded by remnants of the fill of the depression: conglomerates of continental origin and freshwater limestones of Upper Cretaceous age (Mišík & Sýkora 1980; Hovorka et al. 1990). The karst depression near the Dobšiná Ice Cave represents a subsided block of the paleokarst plateaux system — probably a Middle Cretaceous polje — which was later, during the Upper Cretaceous filled by conglomerates of continental origin. The polje-like depression and the mogot/hum of Ostrá skala hill represent exhumed forms. The exhumation of this paleokarst practically finished in the Lower Miocene and new karst forms of the Miocene karst period started to develop in changed climatic conditions.

Conclusions

Cretaceous karst forms and sediments are present-more or less preserved — in the main paleogeograhic zones of the Western Carpathians with important occurrences of Middle and Upper Triassic carbonate sequences and they are an integral part of the present-day relief.

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DIAGENETIC TRENDS IN THE CARPATHIAN FOREDEEP, MORAVIA

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Key words: Miocene, Carpathian Foredeep, diagenesis, compaction.

The Carpathian Foredeep in Moravia is situated on the SE margin of the Bohemian Massif which belongs to the North European Platform. The subsidence was driven by loading of the approaching Outer West Carpathian orogenic complex. As a result, the margin of the platform was bent down and a typical foreland basin was formed. The basement consists of crystalline rocks covered by Paleozoic and in the southern segment also Jurassic, Cretaceous, and Paleogene sediments.

The deposition started in the SW with coarser siliciclastic sediments in the Eggenburgian and Ottnangian. The depocenter moved towards the NE and marine shales and sandstones were deposited during the Karpatian. By the end of the Karpatian and during the Early Badenian, the allochthonous Flysch Belt was thrust over the Foredeep as much as 30 km in places. The Lower Miocene was partly incorporated in the outermost Flysch units. Badenian sandstones and shales were deposited after the main phase of overthrusting.

The present geometry of the Carpathian Foredeep gives an excellent opportunity to study the diagenesis of the Lower to Middle Miocene rocks which extend from a shallow depth to 4.7 km below the overthrust. Compaction is manifested as porosity reduction from 30 to 10 %.

Surface and borehole core samples from Miocene sediments of borehole Gottwaldov 1, 2, 3 were studied. Vitrinite reflectance was measured in non-polarized light (R_r). Clay minerals were analysed using X-ray diffraction and expandability of illite-smectite (% S) was evaluated.

Organic matter is especially sensitive to diagenesis and the early phases of catagenesis. Vitrinite reflectance increases with depth from 0.2 to 0.65 %. The T_{max} index of the Rock-Eval pyrolysis also shows a regular increase from 420 to 435 ^{o}C. The fingerprint of saturated hydrocarbons in the rock extracts bears typical features of inherited biogenic distribution.

Clay minerals comprise mixed-layer illite/smectite with rather high expandability. The illitization proceeds slowly with depth and can be observed only at greater depths than 3.5 km.

At a depth of 4 km the source rock maturation and hydrocarbon generation is only at an incipient phase. The diagenetic trends are fairly similar to those observed in the Vienna Basin and in the Carpathian Foredeep in Poland which have similar geothermal gradients. The absolute values of thermal maturity in the Miocene of the Foredeep is lower than the shales and siltstones of underlying Paleozoic or overlying Flysch Belt. This suggests that the latter experienced higher temperatures and burial depths than the present ones.

CLAY MINERALS AND CLINOPTILOLITE FROM THE VARIEGATED SHALES FORMATION IN THE SKOLE UNIT, POLISH FLYSCH CARPATHIANS

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Key words*:* Skole Unit, variegated shales, clay minerals, clinoptilolite.

Introduction

The Variegated Shales Formation is situated in the profile of the Scole Unit of the External Flysch Carpathians above the Ropianiecka Formation and below the Hieroglyphic Formation. It is dated to the Upper Paleocene–Lower Eocene, and its thickness varies between 130 and 190 metres.

The formation consists of argillaceous and clay-silty shales with some isolated sandy bodies; the Boguszówka sandstones at its bottom, lens-shaped lithosoms of the Kosztowa sandstones — in the middle part of the profile, and the Chmielnik striped sandstones in the upper part. The Paleocene part of the formation; the Żohatyn Variegated Shales Member contains lithosoms of the Babica clays, deposits of submarine cohesial flows, and a layer of the Bircza lithotamnium limestone (Rajchel & Myszkowska 1998) as well. The Lower Eocene part of the formation consists of the Trójca Red Shales Member, underlain and covered by variegated shales, not distinguished as a member (Rajchel 1990). The Trójca Red Shales are also called clinoptilolite-montmorillonite clays, because of their mineral composition (Wieser 1969, 1994).

Clay minerals from the aforementioned lithostratigraphical members of the Variegated Shales Formation, sampled in the central part of the Skole Unit, do not exhibit any important diversity in the profile. They are mostly represented by smectites, very often with over 80 % of swelling layers. Kaolinite and illite/glauconite are present in minor amounts, sometimes with accessory muscovite, biotite and chlorites.

Clinoptilolite — a zeolite mineral from the heulandite group — has been distinguished only in the Trójca Red Shales, and it most often occurs as a Ca-rich variety.

Methods

Minerals were identified and examined with transmitted light and scanning electron microscopy, X-ray diffraction and IR spectroscopy. The distinguished clay and zeolite fractions (< 0.2 μm and < 0.25 mm respectively) were analysed after removing carbonates and iron compounds.

X-ray analyses were carried out with the Philips X'pert diffractometer with a graphite monochromator and radiation $CuK\alpha_1$ (λ=1.540562 Å). Diffraction peaks were recorded in the 2Θ range 4–50^o with a scanning speed of 0.02^o(2Θ)/3s. FTIR spectrum was recorded with the BioRad FTS-165 spectrometer. Samples of clay minerals were prepared on Mylar foil.

SEM analyses were made with the JEOL 5200 microscope with Link analytical system and EDS Si-Li detector at 20 kV. The chemical composition of clinoptilolite was analysed with the SEMQuant JEOL 733 microprobe at 20kV in the Institute of non-Ferrous Metals, Gliwice, using the following spectral lines and standards: $SiK\alpha$ (SiO_2), $AlK\alpha$ (Al_2O_3), $KK\alpha$ ($K[AlSi_3O_8]$), $NaK\alpha$ ($Na[AlSi_3O_8]$), $CaK\alpha$ (Ca_2SiO_4), $FeK\alpha$, $SrK\alpha$ (SrF_2), $BaK\alpha$ (BaF_2), $MgK\alpha$ (MgO).

Results

Clay Minerals

The clay mineral assemblages in the examined samples from various members of the Variegated Shales of the Scole Unit are relatively uniform. Typical sequence consists of Ca-smectite, glauconite/illite, kaolinite/chlorite, muscovite and biotite. However, the quantitative relationships between these minerals vary.

In the whole profile of the Variegated Shales Formation predominating clays are dioctahedral smectite or randomly ordered (R0), illite/smectite, with over 80 % swelling layers (d in ranges 8.67–8.59 Å, and 5.58–5.61 Å) (Dudek & Środoń 1996). Values of the first peak (d_{001}) — ca. 15 Å for untreated samples and ca. 17 Å for ethylene glycol saturated ones — indicate that Ca^{2+} is the predominant cation in interlayer positions. Crystallochemical features of the analysed smectites were determined with the FTIR analysis. In the range 3000–4000 cm^{-1}, absorption bands related to interlayer water molecules (3400–3425 cm^{-1}) and a distinct peak (3621 cm^{-1}) related to vibrations Al-OH, typical for montmorillonite are observed (Kłapyta & Olkiewicz 1996). Asymmetry and broadening of this peak at lower wavenumbers is an effect of partial replacing of Al^{3+} by Fe^{3+} in octahedral layers, what indicates mixed, montmorillonite-nontronite composition of the analysed smectites. In the range 600–950 cm^{-1} vibrations of the groups AlAlOH, $AlFe^{3+}OH$, and AlMgOH (Russell 1987) occur at 914–916, 875–881, and 832–835 cm^{-1}, respectively. The relative intensity ratios of peaks reflecting vibrations of the groups AlAlOH, AlMgOH vary. The lowest Mg^{2+} content was detected in the clinoptilolite-montmorillonite clays, and the highest content in the underlying shales. The pattern of Fe^{3+} content in the analysed smectites is similar; the variegated shales being most distinctly of a mixed, montmorillonite-nontronite character.

Kaolinite and glauconite/illite are present in accessory amounts in the whole analysed profile. Kaolinite was identified by the X-ray (peaks 7.20–7.14 Å and 3.58–5.53 Å) and FTIR (distinct absorption band with a peak between 3968–3966 cm^{-1}) methods. The Trójca Red Shales are the richest in this mineral. Small aggregates (0.01–0.1 mm) of grassy-green glauconite were detected microscopically. Some elements of the analysed diffraction patterns (shape and width of the peak 001, intensity ratio of the peaks 001/002, as well as the position of the peak 060) indicate the presence of illite. The Trójca Red Shales contain the lowest amounts of illite/glauconite.

Another accessory mineral is detritical muscovite, of which tiny flakes very often emphasize parallel microtextures of the examined rocks. Rarer biotite and chlorite usually occur in the clinoptilolite-montmorillonite clays.

Clinoptilolite

Clinoptilolite is present in the analysed profile only in the Trójca Red Shales Member. This mineral fills CT-opal radiolaria shells or occurs in the form of platy microcrystals (up to 20 μm) dispersed in tiny aggregates of montmorillonite. The clinoptilolite content in the examined shales is up to 30 %.

Discussion

The investigations carried out indicate that the examined clays from the Variegated Shales Formation from the central part of the Skole Unit do not exhibit any important variability of mineral composition in the profile. The main mineral is Ca-smectite with over 80 % of swelling layers, occurring in its ferrous variety from the montmorillonite-nontronite series. It is also characterized by varying izomorphic substitution of Al-Mg and Al-Fe in octahedral layers.

Sedimentation of the Variegated Shales Formation, and the Trójca Red Shales in particular, took place during a period of intensive volcanic activity. Hydrolysis of tiny volcanic ashes and glassy dust led to the formation of montmorillonite and CT-opal. In a somewhat basic environment (pH around 8) they reacted to form clinoptilolite (Wieser 1969).

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BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE LATE CRETACEOUS SUBSILESIAN FACIES OF THE ŻEGOCINA WINDOW. PRELIMINARY RESULTS

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Key words: Polish Flysch Carpathians, Campanian-Maastrichtian, Foraminiferida, Subsilesian Unit.

Geological setting

The Żegocina window occurs in the inner part of the Silesian Nappe, in front of the Magura Nappe (Fig. 1). The Late Cretaceous Subsilesian marls and shales as well as the Early Cretaceous sediments crop out in this window. The latter are regarded as a part of the Silesian Unit. All these deposits are strongly folded and faulted, and most contacts between lithostratigraphic members are tectonic. However, in some places, interfingering of facies is observable. Nevertheless, the relationship between these members is still disputable.

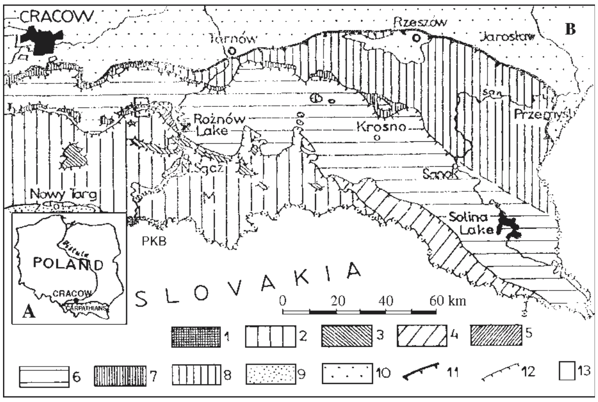

Fig. 1. A. Position of Polish Carpathians. **B.** General geological sketch of Northern Carpathians (Polish sector; after Cieszkowski 1992, simplified). 1 — Pieniny Klippen Belt (PKB); 2 — Magura Nappe; 3 — Grybów unit; 4 — Dukla unit; 5 — Michalczowa zone; 6 — Silesian Nappe; 7 — Subsilesian Nappe; 8 — Skole Nappe; 9 — Miocene deposits on the Carpathians; 10 — Carpathian Foredeep; 11 — the Carpathians overthrust; 12 — main thrust — zones; 13 — Żegocina window.

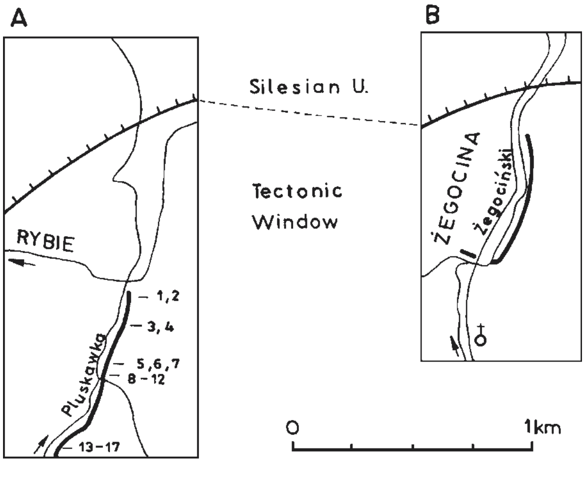

Fig. 2. Location and geological position of the Pluskawka stream (A; Numbers refer to locations of samples) and Żegocina (B) sections.

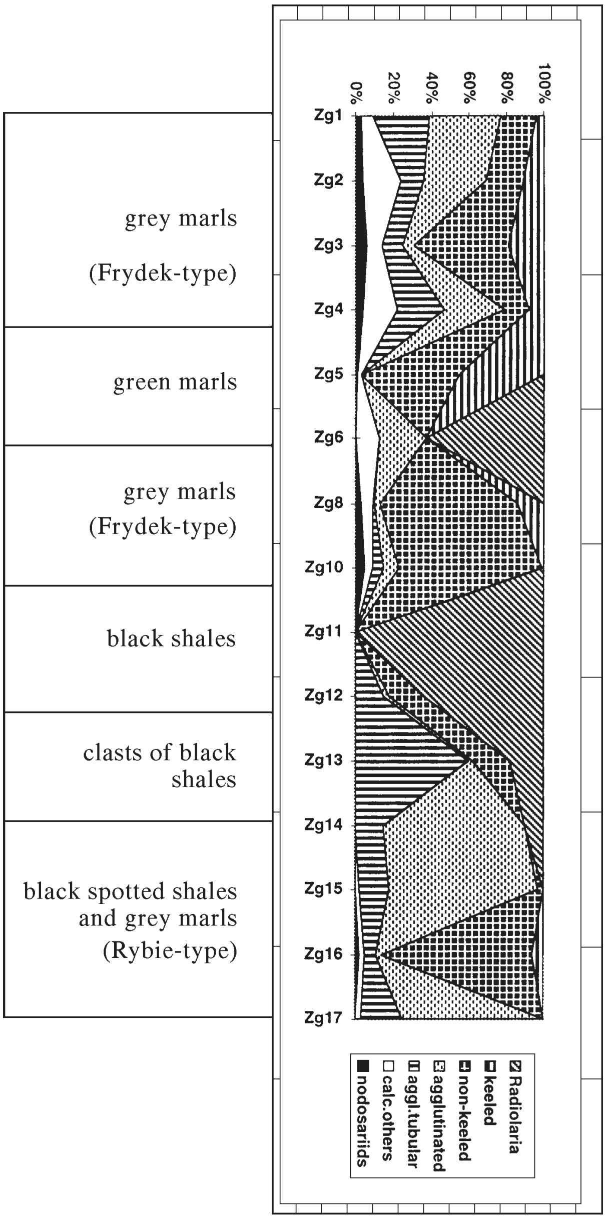

Fig. 3. Żegocina section: quantitative diagram of studied foraminiferids. Abbrev. keeled- non-keeled (planktonic taxa); calc. others — others calcareous benthic foraminiferids; aggl.tubular — agglutinated tubular foraminiferids (suspension feeders morphogroup).

The Late Cretaceous sediments are developed in several lithofacies:

1. variegated clayey shales (Turonian–?Early Senonian) with abundant agglutinated foraminiferids;
2. whitish-grey, thin- and medium-bedded, hard, often siliceous Żegocina Marls (Turonian–Coniacian) similar to the Biancone facies and to the Late Cretaceous siliceous marls of the Silesian and Skole units;
3. red and green Węglówka Marls (Santonian–Paleogene), generally abundant in calcareous foraminiferids;
4. black shales which form thin intercalations in grey marls. The black spotted marly shales occur as clasts in sedimentary breccias of the Rybie-type facies (Fig. 3).

5. soft, clayey-sandy, grey Frydek-type Marls (Coniacian-Palaeogene) with sporadic intercalations of thin- and medium bedded, micaceous sandstones and horizons with exotic blocks and boulders.

The Frydek Marls (in Polish sector traditionally named as Frydek-type) are mainly developed westward from the Żegocina in Moravia (Hanzlíková & Roth 1965). The Frydek-type Marls grade upward into a complex of greenish, glauconitic, graded Rybie Sandstones intercalated with grey and spotted black shales. Relationship of these three lithofacies of marls is still not clear. Koszarski (1985) proposed that the Żegocina and Frydek-type marls represent a western prolongation of the Skole Unit and do not belong to the Subsilesian Unit. However, interfingering of the variegated and grey marls that crop out in the Pluskawka stream section (Fig. 2) strongly suggests that these marls represent two different facies of the same sedimentary basin, the grey Frydek-type Marls a slope facies and the variegated Węglówka Marls a more distant facies. It is more probable that this sedimenatry basin that flanked the North European Platform from the South was a part of the Subsilesian Basin and its northern part, with the slope facies, was situated in the western prolongation of the Skole Basin. The occurrence of the white siliceous Żegocina Marls cannot be a conclusive factor because similar marls occur in the Silesian Unit.

Micropaleontological analysis

Samples of grey marls have been collected from both, Żegocina and Pluskawka stream sections (Fig. 2). Almost all samples contain relatively abundant, diversified and well-preserved foraminiferal assemblages. The Campanian–Late Maastrichtian foraminiferal biozones (sensu Robaszynski & Caron 1995) have been recognized. Quantitative analyses have shown the differences between the assemblages, which can be approximately correlated with the paleobathymetric and paleoecological changes (connected to the time-span and to lateral distribution). As an example, quantitative analysis of the foraminiferal assemblages of the Żegocina section is presented on Fig. 3. Similarly as in the previous studies of the Węglówka Marls (Gasiński et al. 1999), it is apparent that samples containing relatively abundant keeled planktonic forms (bathypelagic) comprise scarce non-keeled (epipelagic) plankton and subordinate agglutinated tubular forms ("suspension-feeders" morphogroup). Their presence can be interpreted as an indication of a deeper environment and/or sea level rise, correlated with lesser amount of organic flux (OF) on the sea bottom (cf. Gasiński et al. 1999). The samples collected from the black shales are enriched in Radiolaria and contain very scarce benthic foraminiferids. Due to the preliminary character of the presented results the affiliation of the recognized foraminiferal assemblages to the above mentioned lithofacies (i.e. Żegocina and Frydek-type) is not possible.

Conclusions

— Foraminiferal assemblages of the Żegocina and Pluskawka stream sections are Campanian–Late Maastrichtian in age;

— Based on foraminiferal assemblages, paleobathymetric fluctuations have been estimated similarly, as in the Węglówka Marls;

— Studied assemblages differ from those in the Węglówka Marls (type locality) by the absence of *Reussella* and other calcareous benthic genera which indicate a deeper part of the basin. Consequently, the Żegocina and Frydek-type marls (in this part of the Subsilesian Basin) were probably deposited in a shallower environment than the Węglówka Marls.

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CRETACEOUS EVOLUTION OF THE FORE-MARMAROSH FLYSCH BASINS (UKRAINIAN CARPATHIANS)

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Key words: Ukrainian Carpathians, flysch basins, turbidites, nappes, accretionary prism.

Introduction

Alpine compressional events within the Eastern Carpathians began during Early Cretaceous time (Săndulescu 1988) and led to the formation of the Marmarosh nappes. Influence of these Cretaceous tectonic movements on the development of the Carpathian flysch basins are not clarified yet in the Ukrainian Carpathians. The aim of the article is to reconstruct the Cretaceous sedimentary and uplift history of the flysch basins, which were situated outwards from the Marmarosh nappes. These paleobasins are called in the article "Fore-Marmarosh basins". Now they are represented by structural-facial units filled by mainly Cretaceous deposits and are located north of the Marmarosh metamorphic massif.

Geological setting

According to the existing schemes of the stratigraphic and tectonic subdivision of the geological complexes of the Ukrainian Carpathians north of the Marmarosh massif several structural-facial units consist of mainly Cretaceous flysch sediments without Paleogene rocks. From the SW to NE these are the Kamyany Potic scale, Rachiv and Suchiv-Burcut (Porkulets) nappes, Krasnoshora (Luzhanka) Unit and interior scales of Chornogora Nappe. They are overthrust onto each other towards the NE. The upper structural-facial units (Kamyany Potic, Rachiv, Suchiv-Burcut ones) are partly overthrust by Marmarosh nappes.

The *Kamyany Potic scale* extends a narrow slice at the front of the Marmarosh nappes and consists of Jurassic basic effusives up to 1000 m in thickness, Tithonian-Neocomian "Black Flysch" — mainly calcareous or siliceous hemipelagites, rarely thin-bedded turbidites, which pass upward into thick-bedded psammites. The *Rachiv Nappe* (to five km wide) prolongs the Ciuc digitation of the Ceahleu Nappe from Romania. It is formed exclusively of the Rachiv (Sinaya) flysch formation. The Formation is represented by Neocomian calcareous hemipelagites, thin-bedded turbidites and locally Barremian-Aptian thick-bedded turbidites. The coarse-grained deposits are rich in the detritus of crystalline schists, dolomites, limestones and basic volcanics.

The *Suchiv-Burkut (Porkulets) Nappe* in the south-eastern section of the Ukrainian Carpathians east of the Luzhanka river forms a belt (up to 20 km wide) of Cretaceous complexes. It is the prolongation of the Bodoc digitation of the Ceahleu Nappe. These complexes consist chiefly of Barremian-Albian clay-silt hemipelagites, contourites (Bila Tyssa Formation), thick-bedded sandy turbidites (Burcut Formation) and Albian conglomerates (Bronka-Bogdan Member). Lower Cretaceous deposits locally pass upward into the Vraconian-Turonian variegated marls (Suchiv Formation) and Senonian sandy sediments. The Upper Cretaceous marls and psammites contrary to the strongly folded rocks of Bila Tyssa Formation form the brachyaxial syncline in the basin of the Tereshova river (Byzova & Beyer 1974).

In the interior of the Suchiv-Burcut Nappe in the Chyvchyn Mountains, the Bila Tyssa Formation passes upward into an olistostrom with olistoliths of rocks derived from the Marmarosh and Kamyany Potic nappes. The olistostrom is overthrust by the Marmarosh (Dilovetsk) Nappe (Bazhenow & Burtman 1990). The mixtite complex also extended in the front of Suchiv-Burcut Nappe. It comprises rock fragments of Jurassic-Neocomian limestones and basalts.

East of the Luzhanka river Rachiv and Suchiv-Burkut nappes also contain remnants of Jurassic-Neocomian mafic rocks. These rocks and basalts of Kamyany Potic Unit are partly of oceanic origin according to the petrochemical data (Liashkevych et al. 1995). Probably Kamyany Potic, Rachiv and Suchiv-Burcut nappes, which Byzova & Beyer (1974) combined into the *Burcut-Rachiv group of zones* belong to the suture and originated from the oceanic realm.

East of the Rika river Suchiv-Burcut Nappe is thrust onto specific structural units represented by the series of narrow scales. Several scales are filled by Cretaceous flysh complex, which is coarse-grained in its upper part (Senonian Krasnoshora Formation).

Model of tectono-sedimentary evolution

During the Early Cretaceous period compressional events built up the Marmarosh Nappe orogenic belt, which marked the southern "active" convergent margin of the Carpathian Flysch basin. The Fore-Marmarosh flysch structural-facial units could be regarded as the accretionary prism, which appeared as a result of Cretaceous subduction in front of the Marmarosh belt. In my opinion, the Cretaceous Fore-Marmarosh accretionary prism formed a ridge (= cordillera), which was like an outer non-volcanic arc and separated the deep-see trench from the fore-arc basin. The trench was filled by coarse-clastic (including olistostromes, locally hemipelagites) deposits. These deposits are located in the upper part of the sedimetary sequences of the Fore-Marmarosh units (upper part of "Black Flysch" and Rachiv formations, Bronka-Bogdan Member, Burcut and Krasnoshora formations). The age of these formations becomes gradually younger towards the more external units. This phenomenon is related to the progradation of the accretionary wedge and to shifting of the trench to the NE. Sedimentary processes at the trench were synchronous to the growth of the accretionary prism. The clastic material of trench sediments was derived from both the Marmarosh nappes and the newly created Fore-Marmarosh flysch nappes.

The Early Cretaceous B-subduction of oceanic crust beneath the Marmarosh continental crust caused uplift and incorporation step by step into an accretionary prism Kamyany Potic, Rachiv and Suchiv-Burcut nappes. In the Late Cretaceous period the prism (and Marmarosh nappes) supplied clastic material to the Krasnoshora trench. During subsequent subduction the sediments of the Krasnoshora Unit were imbricated and uplifted to form narrow scales.

The Upper Cretaceous shallow-water variegated marls (Suchiv formations) and psammites, which form the consedimentary Tereshov brachyal syncline in the interior of the Suchiv-Burcut Nappe could be interpreted as the deposits of a trench-slope basin. Basins were probably formed between the thrusts bounding each accreted slice (Mithell & Reading 1986). The Vraconian-Cenomanian shallow-water clastic deposits (Sojmul Formation) overlie unconformably the rock complexes of the Marmarosh Nappe. They are located inside the Fore-Marmarosh flysch nappes (ancient accretionary prism). This fact suggests, that these clastic deposits can be regarded as sediments of the Cretaceous fore-arc basin.

Thus, the sedimentary and uplift development of the Fore-Marmarosh flysch basins was caused by Cretaceous subduction in front of the Marmarosh Nappe belt and growing accretionary prism.

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THE AGGLUTINATED FORAMINIFERA OF THE MIDDLE AND LATE EOCENE OF THE BIECZ AREA (POLISH FLYSCH CARPATHIANS)

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Key words: Middle–Late Eocene, agglutinated foraminifera, Biecz fold, Silesian Unit, Polish Flysch Carpathians.

Introduction

The study area is located in the SE part of Poland in the Polish Outer Carpathians (in the vicinity of Biecz town). As far as geology is concerned, a so called Biecz fold has been distinguished in this area. The Biecz-Ciezkowice fold is located in the southern part of the Silesian Nappe, directly in front of the Magura Nappe (Fig. 1). This fold extends over a relatively large distance of about 30 km, from the Harklowa tectonic peninsula in the east, through Biecz up to the anticlinal uplift in Ciezkowice in the west (Guzik & Pozaryski 1949). All material comes from the Hieroglyphic Beds underlying the upper Eocene–lower Oligocene Globigerina Marls. Good outcrops, rich and well preserved foraminiferal assemblages as well as the results of the stratigraphical research carried out by Guzik & Pozaryski (1949) in the studied area encouraged me to undertake the present studies. The main objective of this work was to determine occurring species according to the recent systematics of the agglutinated foraminifera as well as to distinguish foraminiferal zones.

Material and methods

For a microfaunal analysis 21 one-kilogram samples were collected in the vicinity of Biecz town from a tributary of the Ropa

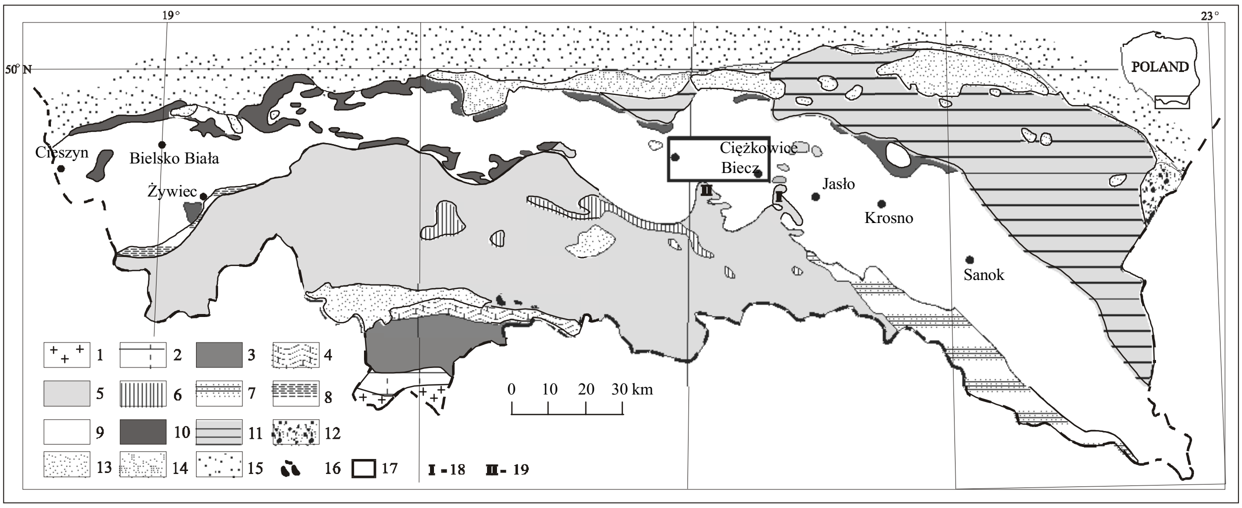

Fig. 1. Geological sketch-map of the Polish Outer Carpathians (after Malata et al. 1996, modified). 1 — crystaline core of the Tatra Mts., 2 — High Tatra and sub-Tatra units, 3 — Podhale flysch, 4 — Pieniny Klippen Belt, 5 — Magura Nappe, 6 — Grybów unit, 7 — Dukla unit, 8 — Fore-Magura unit, 9 — Silesian unit, 10 — Sub-Silesian unit, 11 — Skole unit, 12 — Stebnik unit-folded Miocene deposits, 13 — Miocene deposits upon the Carpathians, 14 — Zglobice unit, 15 — autochtonous Miocene deposit of the Carpathians Foredeep, 16 — Miocene andesits, 17 — study area, 18 — Harklowa tectonic peninsula, 19 — Luzna-Szalowa tectonic peninsula.

river flowing nearby Biecz. All samples were taken from the non-calcareous green shales of the Hieroglyphic Beds. The material was subjected to maceration process in the solution of Glauber's salt ($Na_2SO_4 \times 10\ H_2O$). However, most of the investigated samples came from the archival collections owned by the Institute of Geological Sciences of the Jagiellonian University.

Results

— The studies of foraminiferal assemblages have revealed the presence of a stratigraphic sequence of 3 zones from the middle and late Eocene (according to Geroch & Nowak 1984), based on index taxa. These zones are: Reticulophragmium amplectens PRZ (middle Eocene), Ammodiscus latus PRZ (middle Eocene) and Reticulophragmium rotundidorsatum TRZ (late Eocene).

— About fifty species of agglutinated foraminifera from the above horizons were determined.

— The species like *Ammodiscus peruvianus*, *Budashevaella multicamerata* and *Reticulophragmoides jarvisi* were for the first time found in the deposits of the Polish Outer Carpathians.

— There are no calcareous forms in the investigated material, so this fact indicates paleoenvironmental conditions below local CCD — the " lower slope paleobathymetric zone".

Faunal reference list of the Biecz fold agglutinated taxa

Ammolagena clavata (Jones & Parker 1860)
Ammodiscus latus Grzybowski 1898
Ammodiscus peruvianus Berry 1928
Ammodiscus tenuissimus Grzybowski 1898
Ammosphaeroidina pseudopauciloculata (Mjatliuk 1966)
Bathysiphon spp.
Budashevaella multicamerata (Voloshinova 1961)
Glomospira glomerata (Grzybowski 1898)
Glomospira gordialis (Jones & Parker 1860)
Glomospira charoides (Jones & Parker 1860)
Glomospira serpens (Grzybowski 1898)
Haplophragmoides spp.
Haplophragmoides horridus (Grzybowski 1901)
Haplophragmoides kirki Wickenden 1932
Haplophragmoides sp., aff. *Haplophragmoides suborbicularis* (Grzybowski 1896)
Haplophragmoides walteri (Grzybowski 1898)
Hyperammina spp.
Kalamopsis grzybowskii (Dylazanka 1923)
Karrerulina coniformis (Grzybowski 1898)
Lituotuba lituiformis (Brady 1879)
Paratrochamminoides spp.
Paratrochamminoides acervulatus (Grzybowski 1896)
Paratrochamminoides irregularis (White 1928)
Paratrochamminoides mitratus (Grzybowski 1901)
Paratrochamminoides olszewskii (Grzybowski 1898)
Recurvoides spp.
Recurvoides dissonus Mjatliuk 1970
Rhabdammina cylindrica Glaessner 1937
Rhizammina spp.
Reophax elongatus Grzybowski 1898
Reophax pilulifer Brady 1884
Pseudonodosinella nodulosa (Brady 1879)
Reticulophragmium amplectens (Grzybowski 1898)
Reticulophragmoides jarvisi (Thalmann 1932), emend. Gradstein & Kaminski 1989
Reticulophragmium rotundidorsatum (Hantken 1875)
Saccammina grzybowskii (Schubert 1902)
Spiroplectammina spectabilis (Grzybowski 1898)
Subreophax scalaris (Grzybowski 1896)
Subreophax splendidus (Grzybowski 1898)
Trochamminoides dubius (Grzybowski 1901)
Trochamminoides grzybowskii Kaminski & Geroch 1992
Trochamminoides proteus (Karrer 1866)
Trochamminoides septatus (Grzybowski 1898)
Trochamminoides subcoronatus (Grzybowski 1896)

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TRIASSIC CARBONATE SLOPES IN THE TRANSDANUBIAN RANGE (HUNGARY)

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Key words: slope, carbonates, Triassic, Transdanubian Range.

Introduction

Study of carbonate slope deposits may provide an important information on the structure evolution, relation of the basins and platforms, their stratigraphic correlation and on the sea-level changes influencing the slope processes. Therefore, in the last years, we afforded a special interest to investigate in detail the Triassic slopes in the Transdanubian Range. In the present paper, an overview is given on the results of these studies and their fitting into the evolutionary history of the region.

Results

The first stage of the Triassic evolutionary history from the Induan to the Middle Anisian is characterised by a ramp setting. The ramps are very low angle slopes, on which real gravity mass flow processes may have hardly taken place. Hovever, mud-supported carbonate breccias, akin to the slope debrites, are known in the Olenekian Csopak Marl of open ramp facies and also in the Lower Anisian Iszkahegy Limestone of restricted ramp facies. These breccias may have fomed by porewater overpressure of confined aquifer layers beneath the seafloor (Spence & Tucker 1997).

As a consequence of the Neotethys rifting, segmentation of the ramps, initiated in the Middle Anisian, led to the formation of isolated platforms, intraplatform basins and tectonically controlled slopes between them. Structural and sedimentological aspects of these slopes were summarised by Budai & Vörös (1992), while the evaluation of the redeposited bioclasts (crinoids, brachiopods) was accomplished by Pálfy (1986).

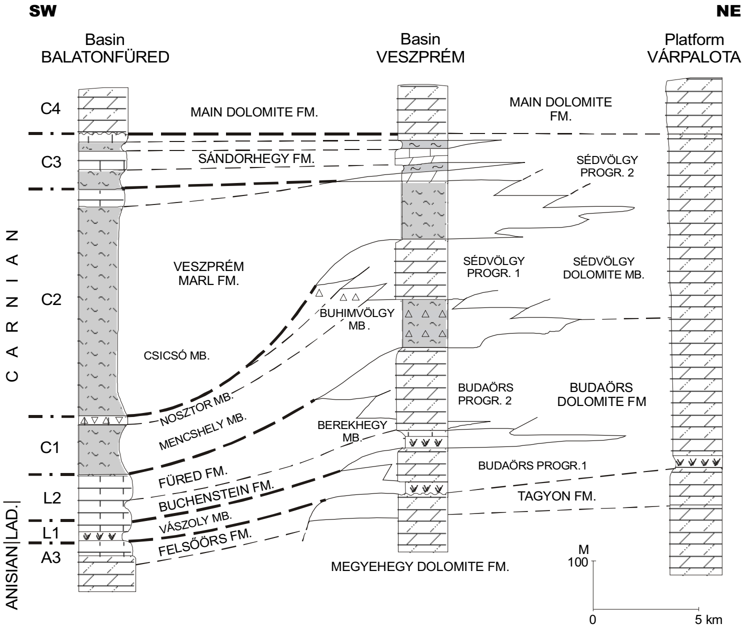

Fig. 1. Sequence stratigraphic interpretation of Middle to Upper Triassic coeval platform and basin facies in the strike of the Southern Bakony.

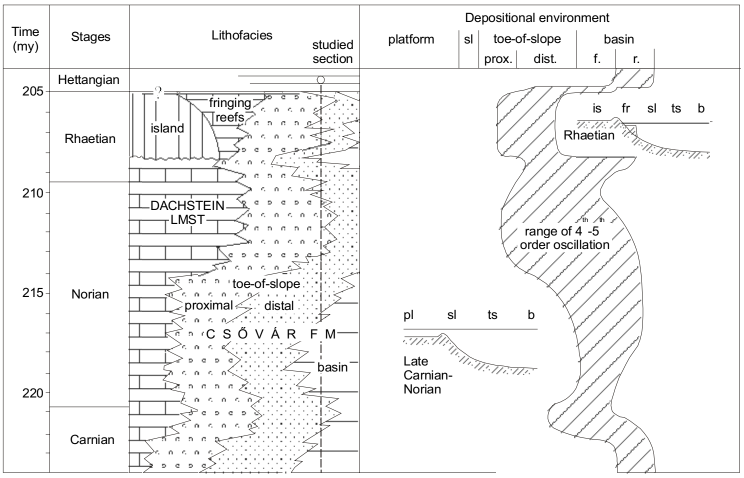

Fig. 2. Lithofacies pattern and interpretation of changes in the depositional environment in the Upper Triassic at Csővár.

During the Ladinian, a large carbonate platform came into being in the NE part of the Transdanubian Range. In a belt, between this platform ("Budaörs Platform") and the basin facies areas ("Füred Basin") in the environs of Veszprém, intertonguing platform and basin facies and slope deposits are exposed. The stratigraphic pattern reflects mainly the eustatically controlled platform progradations and retrogradations, thus, providing a tool for the sequence stratigraphic evaluation of the successions (Haas & Budai in print; Fig. l).

A dolomite intercalation in the basin succession marks the first progradation in the Late Fassanian (Budai et al. in prep.). It is ovelain by tuffaceous marls and grey nodular limestones (Buchenstein Fm.). The second progradation of the "Budaörs Platform" commenced in the latest Ladinian. In a quarry section, the toe-of-slope facies (graded allodapic limestones containing lithoclasts of platform origin) and the overlying platform dolomites are excellently exposed and comprehensively studied.

In the Early Julian, due to a climatic change, the predominance of the carbonate accumulation was replaced by the deposition of marls in the basins and a new transgression was initiated to result in the platform backstepping. This cycle was completed by a platform progradation in the later part of the Julian. Toe-of-slope breccias and brachiopod coquina interlayers in the marl successions mark the progradation in the marginal belt of the basin.

The appearence of the cherty, deep-water carbonates in the Buda Mts. and in the Csővár block east of the Danube indicates the establishment of deep intraplatform basins in the NE part of the Transdanubian Range in the Julian (Haas et al. 1997).

During late Tuvalian, a large basin in the central part of the Transdanubian Range had been completely filled up mainly by fine terrigenous material, thus, giving rise to the formation of a huge platform during the latest Carnian (Dachstein Platform). However, in the NE part of the Transdanubian Range, the intraplatform basins survived until Late Triassic and at least in the Csővár area until in early Jurassic. The analyses of core and outcrop sections in Csővár revealed a gradual shift of facies from a pelagic basin to distal and proximal slope facies in the course of the Carnian–Rhaetian (Fig. 2).

In the SW part of the Transdanubian Range, the Main Dolomite is overlain by the dolomites of the restricted basin facies. This change is attributed to the initiation of extensional tectonic movements in the external zone of the large Dachstein Platform at the beginning of the Sevatian (Budai & Kovács 1986), in response to the incipient rifting of the Ligurian-Penninic ocean branch. In the course of the Sevatian, the carbonate sedimentation was replaced by the deposition of shales (Kössen Fm.) reflecting probably a climatic change. As a consequence, gentle accretionary slopes were formed between the remnant part of the Dachstein Platform and the restricted, oxygen-depleted Kössen Basin (Haas 1993).

Conclusions

Triassic carbonate slopes in the Transdanubian Range were tectonically controlled. Their formation can be bound to extensional tectonic movements of the Neotethys rifting in the Middle and Late Triassic and to initiation of the opening of the Ligurian-Penninic ocean basin from the Late Triassic onward.

The sedimentation pattern of the slopes is governed mainly by the sea level changes (progradations and retrogradations), by the characteristic of the platform margin (biogenic buildup, biogenic incrustation, loose carbonate sediment, etc.) and by the sedimentation rate in the basin (state of upfilling) which influenced the slope angle.

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CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF LOWER CRETACEOUS PELAGIC CARBONATE SEQUENCES IN WESTERN CARPATHIANS

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Key words: Calcareous nannofossils, Upper Jurassic–Lower Cretaceous, biostratigraphy, nannofossil zonation, Western Carpathians.

The calcareous nannofossils are very good for the biostratigraphy because they are abundant, planktonic, rapidly evolving and largely cosmopolitan. A great number of data on the stratigraphic distribution of nannofossils is summarized in a number of biostratigraphic zonation schemes, which are based on the first and the last evolutionary occurrences of species or on the abundance based events. Such nannofossil zonation scheme was lacking in the Upper Tithonian–Barremian interval in the Western Carpathians.

Generally, the Upper Tithonian-Lower Cretaceous nannofossil assemblages in the Western Carpathians are poorly preserved and of low diversity, dominated by the most abundant and insoluble taxa such as, *Nannoconus steinmannii* Kamptner subspecies *steinmannii*, *Nannoconus globulus* Brönnimann, *Watznaueria barnease* (Black) Perch-Nielsen, *Rucinolithus terebrodentarius* Applegate*,* Bralower, Covington and Wise, *Micrantholithus hoschulzii* (Reinhardt) Thierstein. Other coccolith marker species were very rare or absent.

In spite of this, some important nannofossil taxa have been identified in the Upper Tithonian–Lower Cretaceous interval (Table 1):

Tithonian
Conusphaera mexicana Trejo subsp. *mexicana, Conusphaera mexicana* Trejo subsp. *minor* Bralower, FO *Polycostella beckmannii* Thierstein, FO *Microstaurus chiastus* (Worsley) Grün

Berriasian
FO *Nannoconus steinmannii* Kamptner subsp. *minor* Deres and Achéritéquy, FO *Nannoconus steinmannii* Kamptner subsp. *steinmannii,* FO *Percivalia fenestrata* (Worsley) Wise, FO *Cruciellipsis cuvillieri* (Manivit) Thierstein, FO *Cretarhabdus angustiforatus* (Black) Bukry

Valanginian
FO *Calcicalathina oblongata* (Worsley) Thierstein,
FO *Zeugrhabdotus diplogrammus* (Deflandre) Burnett

Hauterivian
FO *Nannoconus bucheri* Brönnimann, FO *Litraphidites bollii* (Thierstein) Thierstein, FO *Rucinolithus terebrodentarius* Applegate, Bralower, Covington and Wise, LO *Litraphidites bollii*, LO *Cruciellipsis cuvilieri* (Manivit) Thierstein

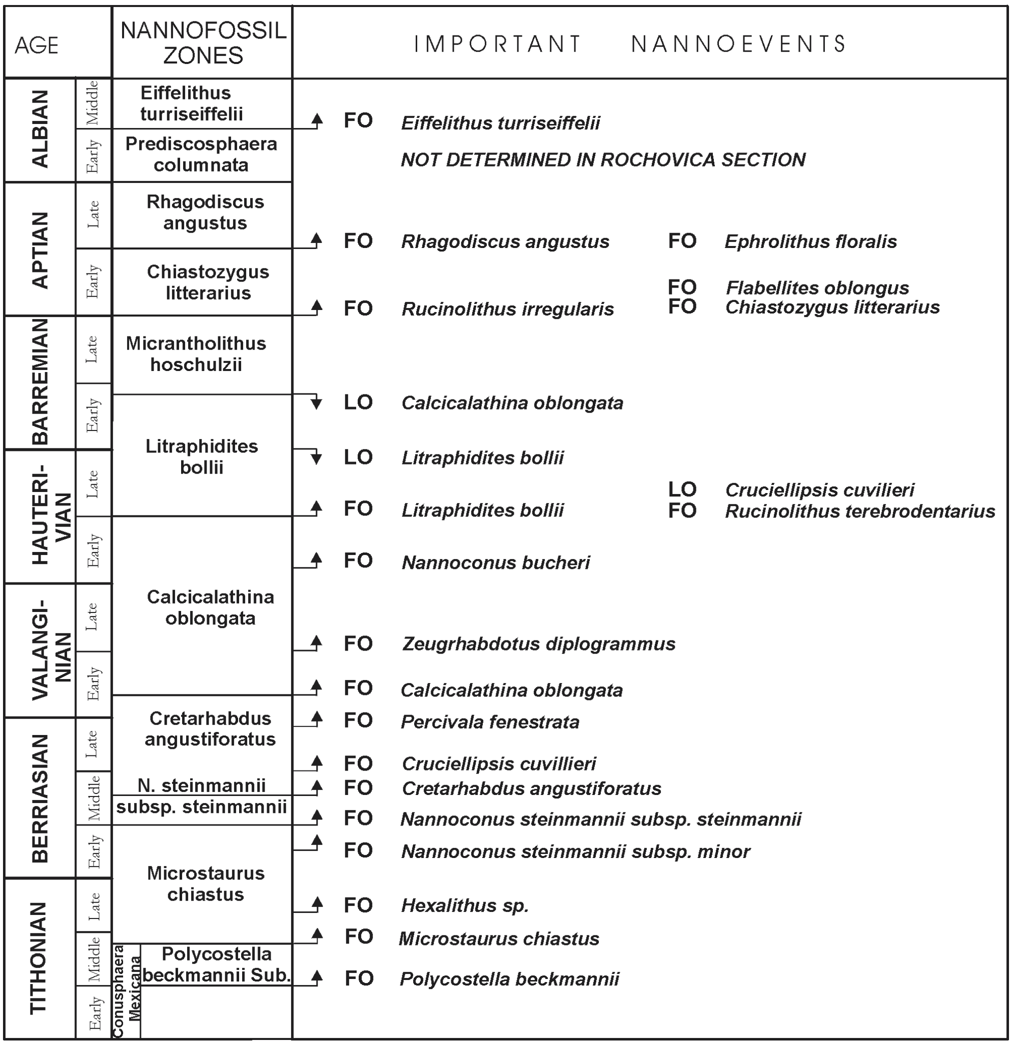
Barremian
LO *Calcicalathina oblongata* (Worsley) Thierstein

Aptian
FO *Chiastozygus litterarius* (Górka) Manivit, FO *Rucinolithus irregularis* Thierstein, FO *Flabellites oblongus* (Bukry) Crux, FO *Braarudosphaera hochwoldensis* Black, FO *Ephrolithes floralis* (Stradner) Stover, FO *Rhagodiscus angustus* (Stradner) Reinhardt

Albian
FO *Prediscosphaera columnata* (Stover) Reinhardt, FO *Eiffelithus turriseiffelii* (Deflandre) Reinhardt

The detailed investigations of the Upper Tithonian to Upper Albian sediments of the Brodno and Rochovica sections (Kysuca Unit, Klippen Belt., Michalík et al.1999) allowed us to see the succession of some nannofossil events in one profile and in established nannofossil zones (Table 1):
Zone Conusphaera mexicana (NJ20) Bralower et al. 1989
Zone Microstaurus chiastus (NJK) Bralower et al. 1989
Zone Nannoconus steinmannii subspecies steinmannii (NK-1) Bralower et al. 1989
Zone Cretarhabdus angustiforatus (NK-2) Bralower et al. 1989
Zone Calcicalathina oblongata Thierstein 1973
Zone Litraphidites bollii Thierstein 1973

Table 1



AGE		NANNOFOSSIL ZONES	IMPORTANT NANNOEVENTS
ALBIAN	Middle	Eiffelithus turriseiffelii	FO *Eiffelithus turriseiffelii*
	Early	Prediscosphaera columnata	*NOT DETERMINED IN ROCHOVICA SECTION*
APTIAN	Late	Rhagodiscus angustus	FO *Rhagodiscus angustus* FO *Ephrolithus floralis*
	Early	Chiastozygus litterarius	FO *Rucinolithus irregularis* FO *Flabellites oblongus* FO *Chiastozygus litterarius*
BARREMIAN	Late	Micrantholithus hoschulzii	
	Early		LO *Calcicalathina oblongata*
HAUTERI-VIAN	Late	Litraphidites bollii	LO *Litraphidites bollii* LO *Cruciellipsis cuvilieri* FO *Litraphidites bollii* FO *Rucinolithus terebrodentarius*
	Early	Calcicalathina oblongata	FO *Nannoconus bucheri*
VALANGI-NIAN	Late		FO *Zeugrhabdotus diplogrammus*
	Early		FO *Calcicalathina oblongata*
BERRIASIAN	Late	Cretarhabdus angustiforatus	FO *Percivala fenestrata* FO *Cruciellipsis cuvillieri*
	Middle	N. steinmannii subsp. steinmannii	FO *Cretarhabdus angustiforatus* FO *Nannoconus steinmannii subsp. steinmannii*
	Early	Microstaurus chiastus	FO *Nannoconus steinmannii subsp. minor*
TITHONIAN	Late		FO *Hexalithus sp.* FO *Microstaurus chiastus*
	Middle	Conusphaera Mexicana Polycostella beckmannii Sub.	FO *Polycostella beckmannii*
	Early		

Zone Micrantholithus hoschulzii Thierstein 1973
* Zone Chiastozygus litterarius Thierstein 1973
* Zone Rhagodiscus angustus Manivit 1971, modified Thierstein 1973
* Zone Prediscosphaera columnata Thierstein 1971, emended by Manivit et al.1977 was not identified in this section
* Zone Eiffellithus turriseiffelii Thierstein 1973
* Zones established in the Western Carpathians by Gašparíková (1984)

Recently the attention is paid to improve the biostratigraphic resolution, to add the quantitative results (total abundance, specific diversity) and to find out what opportunities offer the calcareous nannofossils for the sequence-stratigraphic interpretations.

The calcareous nannofossil distribution and its interaction with the changes of the paleoclimatic and paleoceanographic regime was studied at the Barremian/Aptian boundary of the Rochovica section (Kysuca Unit, Klippen Belt, Michalík et al. 1999) and as a result, the change of nannofossil assemblages composition was observed. The identification of the species *Micrantholithus speetonensis* Perch-Nielsen (considered to be an endemic boreal taxa) in the of Upper Hauterivian sediments at the locality Polomec Hill (Zliechov Unit, Krížna Nappe) gave an evidence of the Tethys-Boreal connection.

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COMPARISON OF SOME RELICS OF MIOCENE SEDIMENTS ON THE EASTERN MARGIN OF THE BOHEMIAN MASSIF

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Key words: Czech Republic, Bohemian Massif, relics of Miocene sediments, sedimentology, paleontology, isotopic analysis.

Introduction

On the eastern margin of the Bohemian Massif (BM), some isolated denudation relics of the Miocene marine sediments, genetically connected with the Carpathian Foredeep (CF), can be found. Four of them — the localities of Hostim, Nové Syrovice, České Libchavy and Kralice nad Oslavou — were studied.

Methods

The Miocene sediments were studied from exposures (Nové Syrovice, Hostim, Kralice nad Oslavou) and drill cores (České Libchavy, the borehole LA-1). Sedimentological methods included the studies of the structures and textures, the grain-size, the shape and roundness of psephitic and psammitic clasts, the heavy and light minerals assemblages including zircon varieties. Current paleontological methods were applied to the preparation and determination of fossils, namely of molluscs and palynomorphs. At Hostim and Kralice nad Oslavou, the isotopic analysis of C and O of fossil carbonate shells and of the sediments was made.

Results

At Hostim, fluvial clays to sands were found in the basal parts of the profile. Higher, marine sands with bioturbation traces, several laminae of calcareous clays and horizontal thin gravel laminae occur. The structural studies, grain-size and shape parameters indicate deposition very near to the shoreline, with intensive influences of the mainland. Repeated environmental oscillations (upper shoreface –foreshore–backshore) can be distinguished. The heavy minerals spectra from both types of sediments generally indicate a common source from the Moldanubian rocks. Teeth of teleosts and chondrichthyes were found in these sands (Schultz in Hladíková, Hladilová & Nehyba 1992). Sands with blocks and lentils of algal limestones occur in the uppermost part of the profile. They are very rich in fossils, first of all molluscs and cirripeds (Hladilová in Hladíková, Hladilová & Nehyba 1992). The molluscan fauna indicated depths of 12–20 m, a normal marine salinity and relatively high water dynamics. This part of the profile represents a transition to the offshore (a prograding clastic shoreline). The environment was partially protected, probably by a barrier. The δ^{13}C and δ^{18}O values of the analysed fossil shells confirmed that these organisms lived under normal marine conditions, at temperatures from 14 to 20 ^{o}C. The δ^{13}C and δ^{18}O values of calcareous clays from the middle part of the profile were much lower. It is supposed that these marine sediments were diagenetically changed by meteoric water in the vadose zone. The calculated low δ^{18}O values of ground water can be explained by a higher altitude of its recharge area (Hladíková in Hladíková, Hladilová & Nehyba 1992). With respect to the results and to the published data (Koutek 1971) we concluded that the sediments at Hostim are of Lower Badenian age. At Nové Syrovice, the Tertiary sediments are represented by sands with traces of bioturbation interbedded with a thin layer of sandy gravel. The ferruginous concretions and crusts occur in the upper parts of the sands. The grain-size studies together with structural features indicate foreshore sedimentation. The heavy minerals association can be derived from the surrounding crystalline rocks and it is closer to the associations expected for Lower Miocene sediments rather than for Lower Badenian ones. The fossils were found only in the ferruginous concretions (Tejkal & Laštovička 1970; Hladilová & Nehyba 1992). A predominant part of the fauna has conspicuous Lower Miocene features and it is most probably of Eggenburgian–?Ottnangian age. However, some younger elements were also found among molluscs and corals, therefore a possible redeposition of the older fauna into younger sediments cannot be eliminated. The fauna proves the water salinity of at least 30 ‰, good lighting and aeration of the water, the warm climate. The sediments accumulated at a depth of up to 30 m, but in an environment somewhat protected from direct surf effects. At České Libchavy, a considerable amount of Cretaceous redepositions, probably from the immediate surroundings of the locality, was found among fauna (foraminifers) and flora (fossil pollen and spores). The sedimentation took place in a shallow-marine environment with highly variable dynamics (claystones). A more precise stratigraphic classification within the Tertiary was impossible (Hladilová, Bubík, Doláková & Nehyba 1998).

At Kralice nad Oslavou, the sediments of Lower Badenian age were formed in a sea with normal salinity, at a greater distance from the shoreline and at depths of 60–90 m (Hamršmíd 1984; Hladíková & Hamršmíd 1986). In the uppermost parts of the profile at this locality, the Early Badenian marine regression was documented paleoecologically as well as isotopically (reduced depth 30–50 m, successive restriction of communication with the deeper parts of the sea).

Discussion

At Hostim, the beginning of the Lower Badenian marine transgression is documented. The shoreline was situated here for a relatively long time. A comparison with Nové Syrovice shows differences in heavy minerals assemblages, but some correspondence between zircon varieties. These results, together with the regional geological position of both localities and with the type of transport in the studied sediments, indicate certain stratigraphical differences with a high probability. At Nové Syrovice, the Badenian transgression probably affected older Miocene (Eggenburgian–?Ottnangian) sediments preserved there. The paleoenvironmental factors both at Hostim and at Nové Syrovice seem to be very similar. A mutual comparison between the localities of Hostim and Kralice nad Oslavou proves a stratigraphical equivalence (Lower Badenian age), but at Kralice the sedimentation depths as well as the distances from the shoreline were greater. In upper parts of the profile, the Lower Badenian marine regression was documented at this locality. The isotopic compositions of the molluscan shells at Kralice and at Hostim are very similar, the differences could be explained by various water depths. The paleobiotope at České Libchavy is generally comparable with the localities of Hostim and Nové Syrovice.

Conclusion

In the relics of Miocene sediments at Hostim a gradual transition from terrestrial to marine environments is documented. A shoreline of the transgreding Lower Badenian sea was situated at this locality (a prograding clastic shore). The marine environment was shallow, with depths up to 20 m, high dynamics and temperature (14–20 ^{o}C), good lighting and aeration, with a normal or only slightly lowered salinity. In comparison with Hostim, the locality of Nové Syrovice manifests certain differences in stratigraphy (sediments of Lower Miocene and ?Lower Badenian ages) and a very similar paleoecological situation (depths to 30 m). The locality of Kralice nad Oslavou is stratigraphically comparable with Hostim (Lower Badenian), but there are some differences of the paleobiotope (greater depths and lower water dynamics). The exact stratigraphic position of the locality of České Libchavy within the Tertiary is still unclear, but its biotope is generally comparable with the localities of Hostim and Nové Syrovice. The studied deposits represent the maximal extent of marine environment of the CF onto the BM. Their correlation is important for the paleogeography, basinal studies and also for the sequence stratigraphical concept of the CF (TST–HST).

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MAGNETOSTRATIGRAPHY AND MICROPALEONTOLOGY ACROSS THE J/K BOUNDARY STRATA IN THE TETHYAN REALM

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Key words: Jurassic/Cretaceous boundary, Tethyan realm, magnetostratigraphy, calpionellid zonation, correlation.

The main objective of this work is to briefly summarize principal results of detailed magnetostratigraphic studies across the Jurassic/Cretaceous (J/K) boundary initiated in 1992. The studies focused on boundary limestone strata from five selected localities: 1) Štramberk, northern Moravia, Czech Republic; 2) Brodno near Žilina, western Slovakia; 3) the Río Argos, Caravaca, Province of Murcia, SE Spain; 4) the Bosso Valley, Umbria, central Italy; 5) Puerto Escaño, Province of Córdoba, southern Spain. Although detailed investigations at the individual localities were preceded by the studies of essential paleomagnetic properties of rocks, problems with remagnetization of the studied limestones at the Río Argos locality were revealed only after completion of measurements on a larger set of samples. The geophysical investigations at all localities were preceded by long-term paleontological (calpionellids, ammonites) studies by many investigators. The laboratory examination of petromagnetic, magnetomineralogical and paleomagnetic data as well as the construction of magnetostratigraphic profiles were carried out in the Paleomagnetic Laboratory of the Institute of Geology, Academy of Sciences of the Czech Republic. For magnetostratigraphy, 1563 orientated limestone samples were collected and studied in total.

1) **Štramberk, northern Moravia**. Pilot samples from the quarries of "Kotouč" and "Horní skalka" provided very low values of moduli of natural remanent magnetization J_n, with mean values of $J_n = 98 \pm 75 \times 10^{-6}$ Am^{-1} and $J_n = 373 \pm 372 \times 10^{-6}$ Am^{-1}, respectively. After thermal demagnetization, many samples from the "Kotouč" locality showed $J_n \sim 5 \times 10^{-6}$Am^{-1}, close to the measuring noise of spinner magnetometers. However, three components of remanence could be defined in most of the samples. The results were inferred from 540 samples. The deposition of the Tithonian/Berriasian limestones took place in a peri-reef zone, in a dynamic sedimentary environment, which was not favourable for a precise record of the paleomagnetic field. The inferred magnetostratigraphic section is merely informative in its character.

2) **Brodno near Žilina, western Slovakia**. This section was selected for magnetostratigraphic study on the grounds of evaluation of data inferred from pilot samples collected at three localities: a) Brodno, b) Strážovce between the villages of Čičmany and Zliechov, c) Hlboč near the village of Smolenice. The values of moduli J_n from all the samples were found to be higher almost by one order than those from the Štramberk samples. The study of paleomagnetic properties also indicated that all the three localities were suitable for magnetostratigraphic study. The good accessibility of the outcrop for orientated sample acquisition, deposition in a quiet basin, results of previous paleontological investigations of the locality and the favourable physical properties of samples became the decisive factors for the selection of Brodno as a locality to be subjected to a detailed magnetostratigraphic study. The orientated samples (n = 368 in total) collected along a section within an interval of only 20 m of true thickness provided exceptionally reliable magnetostratigraphic results. The values of moduli of J_n were high enough; the progressive thermal demagnetization was, therefore, completed up to the unblocking temperature of magnetite in each sample. Mean values of moduli of J_n were calculated at $J_n = 678 \pm 343 \times 10^{-6}$ Am^{-1} for the Lower Berriasian limestones with normal polarity, $J_n = 452 \pm 386 \times 10^{-6}$ Am^{-1} for limestones with reverse polarity, $J_n = 1068 \pm 474 \times 10^{-6}$ Am^{-1} for Upper Tithonian limestones with normal polarity and $J_n = 1274 \pm 791 \times 10^{-6}$ Am^{-1} for those with reverse polarity. Remanent magnetization of all samples showed three components: A-, B- and C-component. The C-component of remanence, as the carrier of paleomagnetic directions, was separated after progressive thermal demagnetization in the temperature interval of 300 to 540 °C, or possibly 580 °C. The original synoptic magnetostratigraphic profile at Brodno, ranging between the magnetozones M21r and M17r (Houša et al. 1996), was further logged by additional data and has now the character of a high-resolution profile at around the J/K boundary. Two reverse subzones were detected within the magnetozones M20n and M19n and proposed to be named "Kysuca Subzone" and "Brodno Subzone". These two reverse subzones can be well correlated with analogous subzones in the M-sequence of marine magnetic anomalies. Two samples 2 cm thick collected from the boundary strata of the reverse "Kysuca Subzone" indicated two paleomagnetic components (normal N and reverse R) or intermediate polarity, respectively. The transition from N (R) to R (N) polarity of the Earth's paleomagnetic field occurred within a time interval of ca. ± 5 Ka at the calculated average sedimentation rate of the studied pelagic limestones of 2.25 mm/Ka. To make the results of high-resolution magnetostratigraphic studies available for other workers, the boundaries of both reverse subzones on the outcrop were identified by four aluminium cylinders marked "Kysuca" and "Brodno", 1 inch in diameter, cemented into the limestone strata.

3) **The Río Argos, SE Spain**. This locality was selected for magnetostratigraphic study as a result of the good previous knowledge of its geology and paleontology and the existence of adequate outcrops of the individual limestone beds ranging from the latest Tithonian to the Early Aptian in age. In total, 361 orientated

samples were collected and subjected to combined, generally thermal demagnetization, using the Schonstedt GSD-1 and MAVACS demagnetizers. The samples were progressively demagnetized up to the temperature of 590 °C and in many cases up to 690 °C. Three sets of samples were distinguished on the basis of their essential magnetic properties: i) very weakly magnetic (weathered) limestones, mean value of $J_n = 26 \pm 9 \times 10^{-6}$ Am^{-1}; ii) more strongly magnetic limestones, $J_n = 613 \pm 636 \times 10^{-6}$ Am^{-1}; iii) weakly magnetic limestones, generally prevailing in the Río Argos section, $J_n = 134 \pm 135 \times 10^{-6}$ Am^{-1}. As shown by the analysis of B- and C-components of remanence, the limestones sub ii) were totally remagnetized in the Neogene. The samples sub iii) provided three components of remanence: the A-component separable below 100 °C, the B-component separable in the interval of 100 to 400 °C and the C-component, which could be inferred in the interval of 400 to 580 °C. The B-component indicated a syn-tectonic origin of remanence, while the C-component could not be used for a reliable interpretation due to the low values of remanence and their broad dispersion. Therefore, the Río Argos section provided no data for the inference of the magnetostratigraphic profile.

4) **The Bosso Valley, central Italy**. The section at this locality was previously synoptically investigated already by Lowrie & Channell (1983). In total, 197 orientated hand samples were collected from the basal, 40 m thick portion of the Bosso Valley section in order to define magnetozones and subzones in much detail and correlate them with calpionellid zones. Most of the samples of the studied limestones provided reliable paleomagnetic directions with the values of J_n moduli being comparable with those of limestone samples from Brodno. Mean values were calculated at $J_n = 295 \pm 156 \times 10^{-6}$ Am^{-1} for the Lower Berriasian limestones with normal polarity, $J_n = 268 \pm 355 \times 10^{-6}$ Am^{-1} for limestones with reverse polarity, $J_n = 1146 \pm 1554 \times 10^{-6}$ Am^{-1} for Upper Tithonian limestones with normal polarity and $J_n = 197 \pm 71 \times 10^{-6}$ Am^{-1} for those with reverse polarity. The magnetozones M20n to M17r were precisely identified in the basal, 40 m thick portion of the section. Two reverse subzones were detected in the middle part of the magnetozone M20n ("Kysuca Subzone") and in the upper part of the magnetozone M19n ("Brodno Subzone"), respectively. These reverse subzones detected in both the Brodno and Bosso Valley sections were found at the same positions relative to the magnetozones above and below and can be well correlated with analogous subzones in the sequence of marine magnetic anomalies.

5) **Puerto Escaño, southern Spain**. As the Río Argos section provided no results in terms of magnetostratigraphy, another suitable section was searched for in the territory of Spain. The section at Puerto Escaño, recently thoroughly studied by F. Olóriz and J.M. Tavera was selected upon their recommendation. Being located some 2 km from the previously magnetostratigraphically studied synoptic section at Carcabuey, S Spain (Ogg et al. 1984), it allows the biostratigraphic correlation of ammonites, calpionellids and nannofossils (Tavera et al. 1994). In 1998, in total, 97 orientated hand samples were collected along a relatively short section across J/K limestones 5.5 m in true thickness. These samples were subjected to laboratory paleomagnetic study, especially the progressive thermal demagnetization using the MAVACS demagnetizer. Unblocking temperatures of ca. 560 °C were detected for all samples, pointing to magnetite as the main carrier of magnetization and paleomagnetization. Pilot samples were also subjected to the analysis of microcoercive forces, and unblocking temperatures were tested on isothermally magnetized samples (peak fields up to 900 mT). The samples from the Puerto Escaño locality are relatively strongly magnetic. Mean values of $J_n = 3911 \pm 1520 \times 10^{-6}$ Am^{-1} were obtained for the Lower Berriasian limestones with normal polarity, $J_n = 2977 \pm 598 \times 10^{-6}$ Am^{-1} for limestones with reverse polarity, $J_n = 8423 \pm 2462 \times 10^{-6}$ Am^{-1} for Upper Tithonian limestones with normal polarity and values of $J_n = 6366 \pm 1408 \times 10^{-6}$ Am^{-1} were obtained for limestones with reverse polarity. A high magnetization of all the studied samples is obvious with the highest values of moduli J_n, alike at the Brodno and Bosso Valley localities, being shown by samples of the Upper Tithonian limestones. Additional, denser sampling was carried out in 1999 with the aim to construct a high-resolution profile.

From the geophysical-methodological point of view, it can be concluded that three components of remanence were detected in the limestone samples from all the five above given localities: A-, B- and C-components. The C-components are carriers of paleomagnetic directions (with the exception of the totally remagnetized samples from the Río Argos), they were separated after progressive thermal demagnetization in the interval of 420 ± 20 °C to 560 ± 20 °C. The C-components of remanence represent only a small proportion of remanent magnetization of samples in their natural state. With respect to the measuring noise of the spinner magnetometers employed, it is critical that the primary values of moduli of natural remanent magnetization exceed 100×10^{-6} A m^{-1}.

The hitherto inferred magnetozones and subzones are schematically shown in Fig. 1 for the localities of Brodno and Bosso Valley in their final versions and for the Puerto Escaño locality in its present version. The magnetostratigraphic zonation of the Jurassic/Cretaceous boundary strata obtained for all the studied localities (except for the Río Argos where magnetostratigraphic zonation could not be established) was correlated with the calpionellid zonation, where positions of the individual zones and subzones were determined with the maximum precision possible (within several centimetres). With respect to the absence of ammonites at most localities, the Jurassic/Cretaceous boundary was placed at the base of the Calpionella Standard Zone. At all the studied localities, this boundary lies below the middle of the M19n magnetozone, at the level of approx. 35 to 40 % of its local thickness. Another significant level of the calpionellid zonation is the first appearance of species *Calpionella grandalpina*, which lies at the same position in all sections studied: immediately below the base of the magnetozone M19r. The thin "Kysuca Subzone" (in about the middle of the magnetozone M20n) lies always immediately

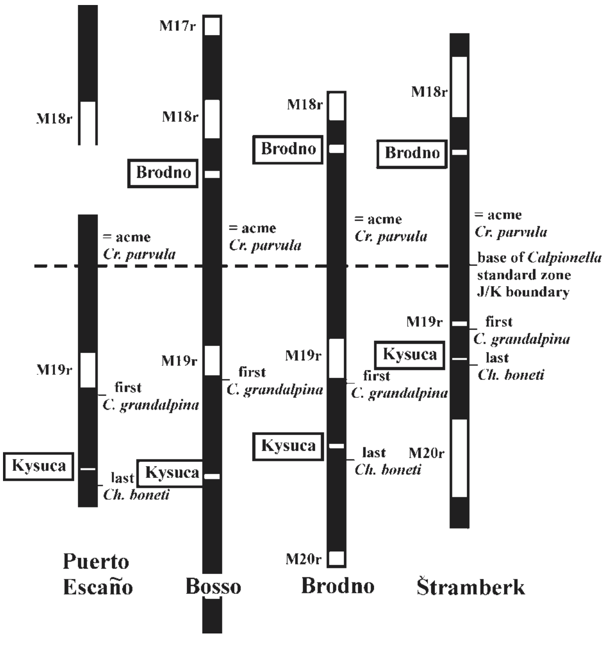

Fig. 1. Correlation of magnetozones and magnetosubzones with some calpionellid events.

above the base of the Crassicollaria Standard Zone (i.e., near the base of the Upper Tithonian). The “Brodno Subzone“ (lying in upper part of the magnetozone M19n) is Early Berriasian in age and always overlies the calpionellid horizon known as the acme of the species of *Crassicollaria parvula*.

None of the boundaries of the calpionellid zonation precisely coincides with any of the boundaries of paleomagnetic zonation. However, in all sections studied, these two scales always show the same mutually identical relationship. As it has been shown by Tavera et al. (1994) at the the Puerto Escaño locality, the base of the ammonite Jacobi Zone, defining the Jurassic/Cretaceous boundary in the ammonite zonation, is older than the base of the Calpionella Standard Zone (in this section, it lies 1 m below the base of the Calpionella Zone, i.e., also in the magnetozone M19n but immediately above its base, and within the calpionellid Intermedia Subzone, according to the preliminary results). The exact positions of other important horizons of ammonite zonation relative to magnetostratigraphic scale as well as to calpionellid zonation are the subject of the next study.

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BOHEMIAN CRETACEOUS BASIN — A PRESUMED SEA WAY BETWEEN THE NORTH EUROPEAN BASINS AND TETHYS, BASED ON STUDY OF FORAMINIFERS AND CALCAREOUS NANNOFOSSILS (TURONIAN–CONIACIAN)

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Key words: Upper Cretaceous, Tethys, North European basins, paleogeography, bioprovinces, foraminifers, calcareous nannofossils.

Introduction

The Bohemian Cretaceous Basin is filled by epicontinental marine sediments of the Cenomanian–Early Santonian age. From a paleogeographical point of view, it was a shallow-water strait which is considered to have been a probable sea way connecting the northern margin of Tethys with the North European basins. Kollmann et al. (1998) noted that the Bohemian/Saxonian Basin represents the northernmost distribution of Tethyan assemblages as indicated by nerineacean and other fauna and by paleobotanical evidence of subtropical/tropical climate. They proposed that Tethyan assemblages in the Bohemian Cretaceous Basin developed on paleo-highs (water column within 20 m) while the assemblages of deeper portions of the basin were under the Boreal influence. This theory is also supported by the study of foraminifers and calcareous nannofossils.

Material and methods

Data were collected from the Gosau Group of the Northern Calcareous Alps, from Waschberg-Ždánice Unit of the Western Carpathians and from the Turonian–Coniacian interval of the Bohemian Cretaceous Basin. In addition, the calcareous nannofossils were compared with the others of the same age from the Münster Basin, NW Germany (Švábenická 1986).

The foraminiferal plankton/benthos ratios were calculated and the quantitative and qualitative analyzes of these assemblages were made. A minimum of 300 countings per sample were made on each nannofossil. The appurtenance of Cretaceous nannofossil species to provinces was interpreted mainly on the basis of the results of Watkins et al. (1996) and Burnett (1998).

Results

The foraminiferal assemblages from the Bohemian Cretaceous Basin were formed by well-preserved tests of agglutinated and calcareous species which preferred rather cold environmental conditions. The benthic species prevailed (60–70 %) and the study from the Gosau Group show a similar character of the assemblages (Tollmann 1960; Hradecká et al. in print). The benthic species that are common in the Bohemian/Saxonian Cretaceous Basin (Wejda 1993; Hradecká in print) were also recorded in the Gosau Group and Waschberg-Ždánice Unit. The following species lived synchronously in the above mentioned paleogeographical areas: *Tritaxia tricarinata* Reuss, *Dorothia pupa* (Reuss), *Bolivinopsis praelonga* (Reuss), *Gaudryina laevigata* Franke, *G. carinata* Franke, *G. pyramidata* Cushman, *Gavelinella lorneiana* (d´Orbigny), *G. schloenbachi* (Reuss), *G. ukrainica* (Vasilenko), *Globorotalites michelinіana* (d´Orbigny), *Neoflabellina suturalis suturalis* (Cushman), *N. suturalis praecursor* (Wedekind), *Praebulimina intermedia* (Reuss), *P. hofkeri* (Brotzen), *Pyramidina kelleri* (Vasilenko), *Vaginulina trilobata* (d´Orbigny) and others. These species probably occupied relatively deep part of the shelf sea which can be interpreted as the middle to outer neritic environment with depths ranging between 100–200 m (Wagreich & Faupl 1996). The shallow-marine and warm-water preferring representatives of the Miliolidae family were recorded in only the Late Turonian-Early Coniacian sediments in the Gosau Basin.

The nannofossil associations of the Bohemian Cretaceous Basin resembled those in the Waschberg-Ždánice Unit and in the Münster Basin and shared the following features: 1. relative abundance of low-latitude species *Watznaueria barnesae* which reaches up to 35–40 %, 2. coincident first occurrence of *Lithastrinus septenarius* and *Marthasterites furcatus*. This contrast with the Münster Basin where *M. furcatus* was observed before the appearance of *L. septenarius*, 3. presence of a typical, high-latitude species *Thiersteinia ecclesiastica,* 4. in the Coniacian, the frequency of *Micula decussata* (5–10 %) and *M. furcatus* (3–5 %) is higher. In Gosau Group, the nannofossil associations have a different character (Hradecká et al. in print; Wagreich et al. in prep.): 1. assemblages are dominated by *W. barnesae* (44–61 %), 2. *L. septenarius* and *M. furcatus* occur in small numbers (reaching up to 1 % in maximum), 3. *M. decussata* is either absent or occurs sporadically.

Conclusion

The presence of common foraminiferal species in the Bohemian/Saxonian Basin and the Gosau Basin suggests that during the Turonian–Coniacian interval the Tethyan and Boreal provinces were in contact. The absence of the warm-water preferring family Miliolidae indicates an increasing influence of the Boreal province in the Bohemian Cretaceous Basin. The nannoflora contain here both Tethyan (high frequency of *W. barnesae*) and Boreal elements (presence of *T. ecclessiastica*, higher frequency of *M. furcatus* and *M. decussata* species).

The nannofossil assemblages show similar features in the Bohemian Cretaceous Basin, in Waschberg-Ždánice Unit and in Münster Basin, but differ in character from the Gosau Group.

The above mentioned phenomena indicate a sea way which enabled Boreal fauna to migrate to the northern part of the Tethys from the North European basins (Münster Basin) through the Bohemian Cretaceous Basin to the depositional areas of the Waschberg-Ždánice Unit and Gosau Group that were already parts of Tethys.

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EVOLUTION OF THE CENTRAL CARPATHIAN PALEOGENE BASIN IN THE SPIŠSKÁ MAGURA REGION, SLOVAKIA

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Key words: Central-Carpathian Paleogene Basin, deep-water deposits, turbidites, system tract, sea level.

Introduction

The post-Paleogene uplift of the Mesozoic and Paleozoic rocks of the High Tatras Mts. (ca. 15 Ma ago, Kráľ 1977) elevated the oldest, buried Paleogene deposits which now flank the slopes of the mountains and reveal a complete section through the Paleogene sedimentary succession in the region. The sedimentary succession resembles the successions known from the entire northern and eastern part of the basin (Podhale, Spiš, Levoča and Šariš regions), however, some sedimentary features show deposition in unique subenvironments within the basin which makes it important for understanding basin history.

Geological setting

The CCP Basin, developed in a forearc position, lies in the northern part of the Central Western Carpathians. To the south it is bounded by the pre-Paleogene, Mesozoic and Paleozoic formations of the Central Carpathians. In the north it is separated from the Outer-Carpathian Flysch zone by the Pieniny Klippen Belt. The northernmost part of the basin extends into Poland where it is called the Podhale Basin. The tectonics and sediments of the basin suggest a complex kinematic history with prevailing extensional regime and minor compression mostly occurring along the Pieniny Klippen Belt. The main volume of the CCP Basin fill deposits consists of deep-water turbidite systems prevailingly elongated in the SE–NW direction in the eastern part of the basin and in the NW–SE and W–E direction in the western part of the basin. A minor volume of the basin fill is composed of perpendicular, mostly gravity flow aprons.

Sedimentary succession

The CCP Basin fill in the region of the Spišská Magura consists of 1600 m thick sedimentary succession divided into 3 units reflecting different stages of the basin's evolution. Based on the analysis of the reflection seismics (profile 754/93) the maximum thickness of the sediments in the region is estimated at some 1600 m. Breccias, conglomerates, sandstones and sandy limestones comprise the base of the succession (unit 1). The age of the unit, determined by analysis of nummulite fauna, is late Middle Eocene and Late Eocene (Bartonian and Priabonian, P14–P15 zones of planktonic foraminifera). The breccias and conglomerates (subunit 1-1) consisting of angular dolomite and limestone clasts derived from the directly underlying Mesozoic basement were probably deposited in front of steep cliffs of a high relief shore as rock falls. The overlying conglomerate beds separated by sandstones (subunit 1-2) are better internally organized. The scoured and sharp bases of conglomerates, their massive character, poor sorting, occurrence of separating parallel and cross-laminated sandstones and fining-upward trend in 6–8 m thick cycles hint at deposition by fluctuating traction flow. We think that these sediments were deposited on a high gradient slope in a delta fan environment by hyperpycnal flow. Sandy limestones probably record deposition on marginal shoals.

The overlying Eocene–Early Oligocene (NP zones 17–21) deposits of unit 2 consist of three subunits: subunit 2-1 is composed of thick conglomerates filling an erosional scar cut into unit 1 and the Mesozoic basement; subunit 2-2 consists of dark shales containing up to 5 m thick bodies of conglomerates and thick sandstone beds; and subunit 2-3 is composed of dark shales with minor thin sandstone and conglomerate beds. The up to 200 m thick fining-upward succession of subunit 2-1 coarse-grained conglomerates and sandstones represents the fill of a canyon cut into the deposits of unit 1 or directly into the Mesozoic rocks. The conglomerates are prevailingly massive in the lower part and normally and inversely graded in the upper part. They are separated by pebbly sandstones and medium to coarse-grained sandstones. The sandstones are horizontally laminated and cross stratified, occasionally normally graded (facies F 4, 5 and F 6 of Mutti 1992). Water escape structures are common.

The black and blackish-brown shales with thick conglomerate and sandstone beds comprising subunit 2-2 are interpreted as basin slope and base-of-slope deposits. The massive and horizontally laminated shales were deposited from suspension clouds in a submarine slope (or steeply inclined ramp) environment. Poor sorting, weak internal organization and sharp bases of thick conglomerate beds are indicative for deposits of cohesive debris flows (e.g. Hampton 1975). The conglomerates probably originated by slope failures on shelf edge connected to relative sea level fall. The medium-grained massive sandstones (facies F 5 of Mutti 1992, S3 of Lowe 1982) of subunit 2-2 are interpreted as high-density turbidity current deposits generated by slope failures on the shelf edge.

Unit 2 gradually passes into unit 3 mostly showing Early Rupelian age on the basis nanoplankton. The alternating sandstone and shale deposits may be divided into two subunits based on sandstone:shale ratio and sandstone bed thickness. The spatial distribution of both subunits varies both vertically and laterally. The deposits are interpreted as proximal and distal overbank deposits of a turbidite system.

Discussion

The lowermost deposits of unit 1 were deposited during marine transgression and represent a transgressive systems tract. The coarse-grained deposits of subunit 2-1 and shales with conglomerates and sandstones of subunit 2-2 are thought to be deposited during relative sea level fall representing a lowstand systems tract. The shales of subunit 2-3 reflect deposition in a quiet, low-energy environment during rise of sea level (transgressive systems tract). The gradual transition to unit 3, interpreted as turbidite system deposits, suggest lowering of relative sea level. The nanoplankton from these deposits was mostly assigned to the nanoplankton zones NP 20–21 suggesting building of this turbidite system on the boundary between Eocene and Oligocene.

Comparison of the relative sea level curve constructed from sedimentary record in the studied area and the eustatic sea level curve (according to Abreau & Anderson 1998) shows little match, suggesting that the eustatic sea level variation was not the main trigger responsible for the sedimentation in the investigated part of the CCP Basin. Similarly the climate during the Late Eocene and Early Oligocene was stable (Brinkhuis 1994) and probably did not influenced the sedimentation. It seems that the most important factor influencing sedimentation was tectonic activity. It controlled basin size and shape, canyon floor gradient, shelf width and local relative sea level determining the type of sedimentation and resulting sedimentary succession.

Conclusion

Timing and environmental interpretation of the studied deposits provide some new knowledge on the CCP Basin's history. The most important determinant governing the sedimentation seems to be tectonics. We also suggest that the shales of subunit 2-2 commonly assigned to the Huty Formation do not necessarily represent a deep water deposition during one sedimentation cycle as assumed so far (e.g. Baráth et al. 1997; Buček et al. 1998). On the contrary, we think that it may represent deposition during a lowstand of relative sea level.

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PALEOGEOGRAPHY AND PALEOCEANOGRAPHY OF THE NORTH ATLANTIC DURING THE CRETACEOUS — AN OVERVIEW

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Key words: Western Tethys, Central North Atlantic, Cretaceous paleogeography, paleoceanography.

The Cretaceous epoch is one of the most variable and significant time periods from the whole Mesozoic. The four significant changes associated with the Cretaceous time period are:

1. major plate tectonic changes — such as a flip in the direction of rifting in the North Atlantic from southward directed to northward directed, continental plates separation; South America from African plate, Indian and Australian plates from Antarctica and eastern Africa;
2. paleoceanographic changes — change from latitudinal to longitudinal ocean circulation in the Atlantic;
3. climatic — the latest Cretaceous is considered by some to be period of extreme — hot climate, perhaps resulting in major changes in CO_2 in atmosphere and in ocean circulation; thus it could be a model for future global climate development as the industrial air contamination continues;
4. economic — middle Cretaceous has globally highest source rock potential for hydrocarbons generation from whole Phanerozoic, therefore it represents one of most important time period for hydrocarbon exploration.

During Cretaceous time period, the North Atlantic Ocean and marginal basins represented only a small part of the global oceanic system (1), (Fig. 1). The width of the central North Atlantic during the mid-Cretaceous was about 2000 km, thus comparable to the present width of the Norwegian Sea. In contrast, the Pacific Ocean occupied more than half of the globe. Consequently, smaller scale tectonic or climatic changes are reflected in the sedimentary deposits of the North Atlantic, but less likely they can be read in the sediments of the Pacific Ocean. The Cretaceous paleogeography of the North Atlantic oceanic basin and its margins was inherited primarily from the Triassic-early Jurassic rifting of Pangea. Seven different rifting processes, some of which could occur simulta-

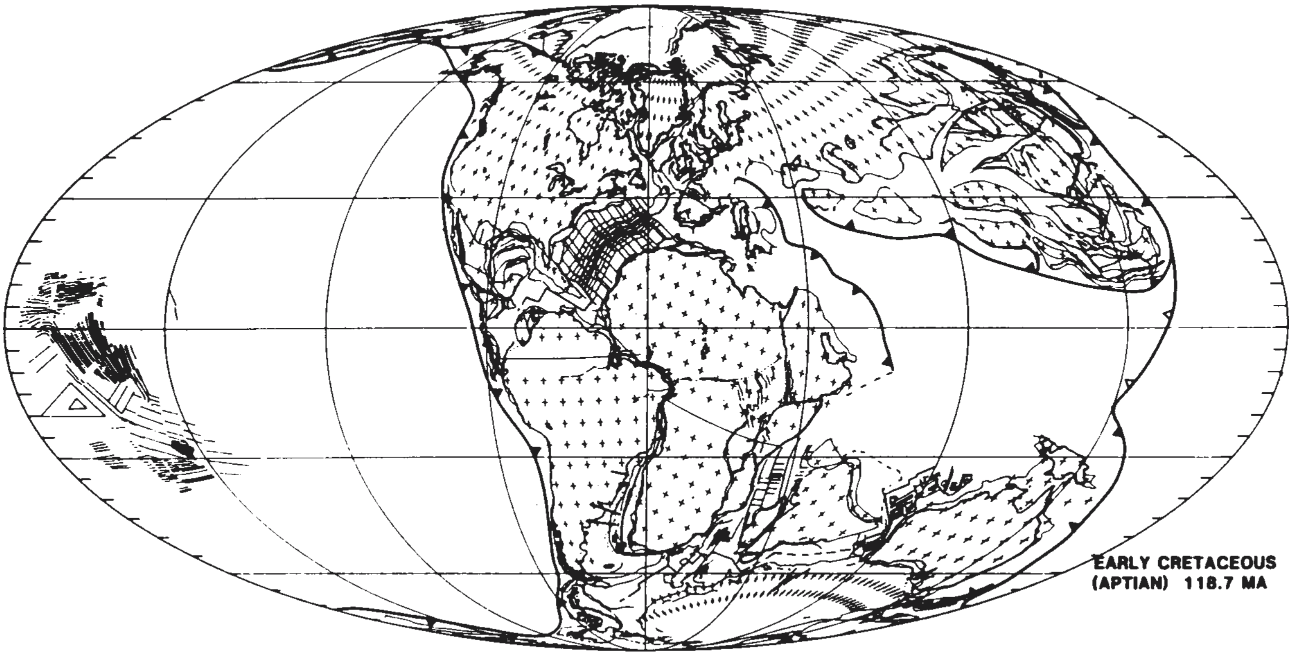

Fig. 1. Plate tectonic reconstruction of Early Cretaceous (Aptian), modified after Scotese 1991 (1).

neously but in different parts of the same basin, resulted in geomorphologic and paleogeographic interbasinal variability. These rift related processes include: 1) pure or simple shear; 2) separation by translation or rotation; 3) symmetry or asymmetry of rift basins; 4) synchronicity or diachronism of rifting; 5) single or multiple rifting; 6) subaerial or submarine rifting; 7) volcanic or avolcanic rifting. Awareness of such variability is important in studies of biota and eustatic sea level change.

The floor of the early Cretaceous central North Atlantic Basin was underlain by oceanic crust formed during the middle and late Jurassic (2). Important changes in the direction of continental rifting and oceanic spreading occurred near the Jurassic-Cretaceous boundary, as the region north of the Gibraltar-Newfoundland fracture zone underwent renewed submarine rifting. Final separation of the North American and European continental plates occurred during the Aptian and Albian, when the Grand Banks of Newfoundland, Galicia Bank and southern Europe drifted apart (3). At the same time, continental extension affected the equatorial region of the Atlantic with South American continental plate separating from Africa. This is confirmed by the major paleogeographic changes occurring at the post-rift unconformity separating different sedimentation regimes in the Aptian of the Potiquar and Reconcave basins of Brazil, and in the Gulf of Guinea. The effect of this plate separation on changes on ocean circulation is poorly understood. Until the opening of the equatorial Atlantic seaway, deep water flow from the Pacific Ocean extended through the Mediterranean Tethys and central North Atlantic into the proto Gulf of Mexico and across the central America seaway back into the Pacific. This circumglobal Tethys current had to change during the late Cretaceous with the opening of the equatorial Atlantic seaway. A brief period of oxidized bottom waters, indicated by the occurrence of reddish colored deposits in the Cape Verde Basin (4), may reflect this change. However, the development of a deep seaway, promoting meridional oceanic circulation in the Atlantic is poorly time-constrained and the influence of such a seaway on abyssal deposits remains untested.

The oceanic sedimentary deposits provide information not only on changes in ocean circulation, but also on water chemistry, bioproductivity and climate. Continuing pelagic carbonate deposition from upper Jurassic into early Cretaceous indicates that no substantial changes occurred in the depositional regime and paleoceanography of the western Tethys during this time. The first changes occurred in the Valanginian–Hauterivian, when organic-rich shale beds became intercalated within pelagic carbonates. In the Aptian, the black shale became the dominant lithology (3, 4) and their deposition continued into Cenomanian. Three brief periods characterized by an dysoxia/anoxia and ^{13}C isotopic shifts in the midst of a longer period of intermittent oxygen dexyciancy extending from late Barremian till early Turonian. Various hypotheses, such as a sudden rise in CCD, change in ocean circulation and water chemistry, bottom anoxia (5) were suggested to explain this change in sediment composition, but none of these theories is yet fully accepted. The timing of the onset of "black shale" deposition is broadly synchronous with thermal subsidence of the oceanic crust below CCD in western Tethys. Therefore, non-carbonate composition of middle Cretaceous sediments in the western Tethys reflects the thermal subsidence of ocean crust in this region. That pelagic carbonate deposition did not resume in the central North Atlantic would support the latter conclusion. However, the mid Cretaceous black shale facies is also extensive in the southern Atlantic, where the ocean crust is of early Cretaceous age. Therefore, the origin of mid-Cretaceous black shale facies is much more complex and their origin is continuing subject of disputes. If there is a uniqueness to the Aptian-Albian deep-sea deposits, than it is in the enrichment and preservation of terrestrial and marine organic matter (4, 6). It is significant that the increased input or organic carbon into marine deposits coincides with the evolution and expansion of angiosperms and with a climatic shift from subtropical to temperate-humid. This climatic change is reflected in high depositional rates of Aptian to lower Cenomanian deep-sea clastic sediments in the central North Atlantic, which were locally deposited at rates exceeding 100 m/m.y., and therefore were instrumental in organic carbon preservation. In comparison depositional rate for late Cretaceous sediments in the central North Atlantic was only several mm/m.y. (7).

The depositional conditions in the central North Atlantic changed dramatically after deposition of a prominent organic-rich

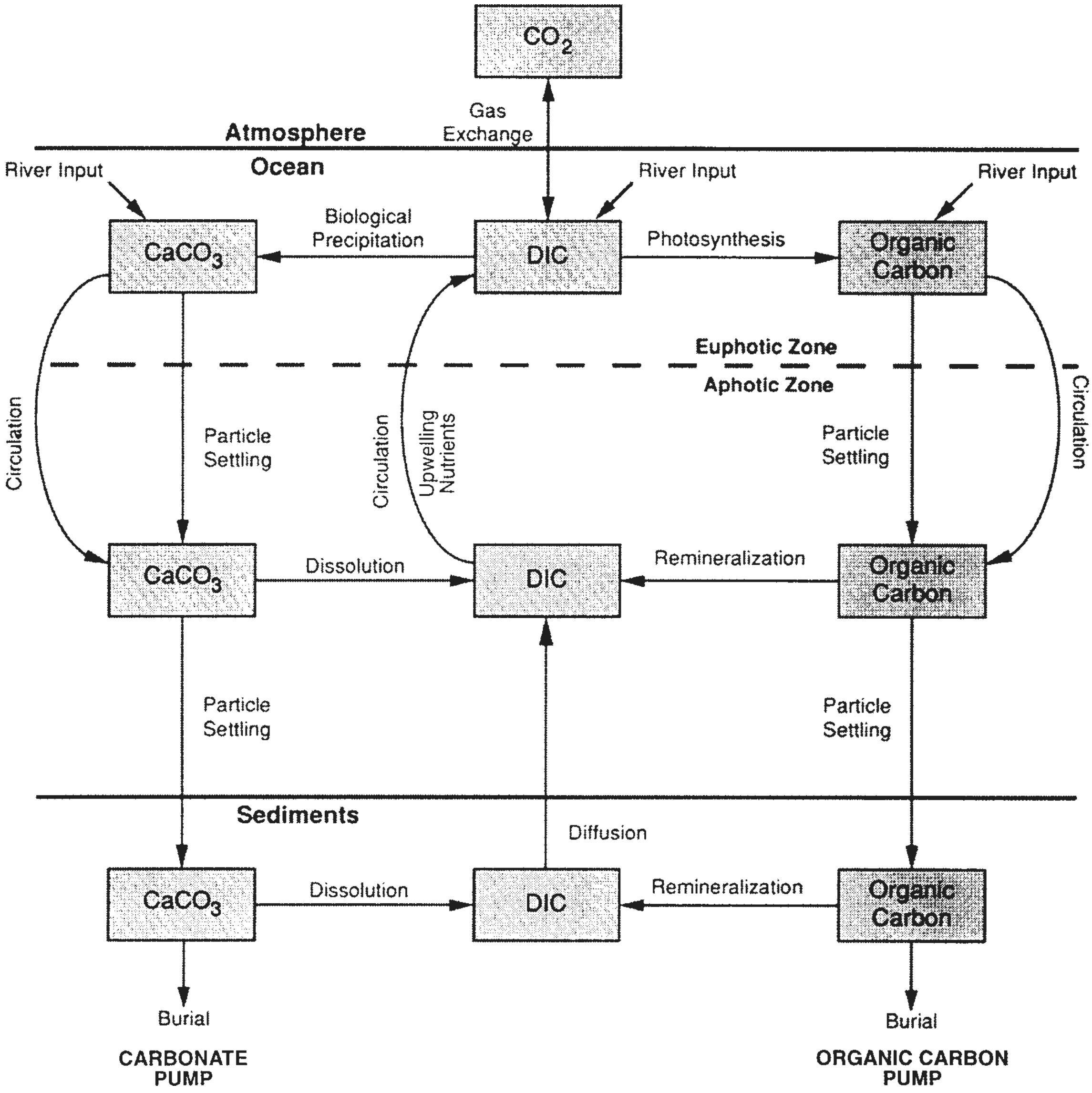

Fig. 2. A schematic diagram of the carbon cycle in the ocean, modified after Najjar 1992 (14).

shale horizon at the Cenomanian-Turonian boundary (3). This C/T horizon is correlative with the Bonarelli horizon outcropping in Italy. The predominantly marine organic matter locally exceeds 30 % in this clayey horizon. The isotopic analyses of marine carbonates and organic matter in this horizon (8) show a sharp increase in their $^{13}C/^{12}C$ isotope ratio. This isotopic shift indicates an increase in the rate of sedimentary burial of ^{13}C-depleted organic matter, which is corroborated by deep-sea deposits. The enhanced burial rate should have led to a significant drop in the atmospheric CO_2 concentration, which could explain the apparent climate cooling in early Turonian (9). Study of stable carbon isotopes from specific compounds from terrestrial leaves and marine phytoplankton (10) suggests that such event was rapid and lasted about 60,000 yr, and was accompanied by a change in plants from C3 to C4.

The C/T black shale horizon in the central North Atlantic is overlain by a multicolored, zeolitic clay, deposition of which in western Tethys continued throughout most of the late Cretaceous (7). The low sedimentation rate and clay mineral composition of this zeolitic clay reflects a major eustatic sea-level rise. Therefore, the C/T black shale horizon (correlative with the Bonarelli horizon of the western Tethys) developed during the initial stage of major eustatic sea-level rise. This rise would result in the development of a “hydrodynamic barrier”, so that terrigenous sediment from the continent could not be transported into the deep sea. With the continual transport of nutrients in solution from the continent, very favorable, brief conditions developed for rapid increase in bioproductivity, as recorded by the deep-sea deposits.

Not all of major paleogeographic and paleoceanographic changes seen in the basinal deposits of western Tethys are recorded in the marginal North Atlantic basins and vice versa. For example, one of the most significant, eustatic sea-level draw-down recorded by the expansion of sand-transporting, fluvial systems and deltas during early Cretaceous (11), is mostly unrecorded in the deep-sea deposits. In a contrast terrigenous sediment influx during the late Barremian–Aptian, associated with major sea-level rise, “drowned” the remnants of early Cretaceous carbonate platforms along the eastern North American margin (12) and is broadly synchronous with the onset of a major change in the pelagic sedimentation in the western Tethys (13).

The intrinsic relationship of the sedimentary regimes, paleogeography and paleoceanography provides a different focus on the marine carbon cycle, and allows to suggest an alternative hypothesis for the origin of extensive late Cretaceous chalk deposits in western Europe. The Jurassic-Cretaceous deep-sea deposits in the central North Atlantic document three distinct changes in the carbon reservoir. Carbon was buried as calcium carbonate during the late Jurassic–early Cretaceous and as organic carbon during the Aptian–early Cenomanian. As result of the organic matter remineralization, the acidity of seawater increased, which resulted in a shallower $CaCO_3$ saturation level. The third major change occurred after the Cenomanian, when no carbon accumulated in the North Atlantic deep-sea sedimentary reservoir. The particulate organic matter, which rained down, was incorporated into a deep, dissolved, inorganic carbon (DIC) pool (14) (Fig. 2). The close synchronicity between cessation of organic carbon burial in the deep central North Atlantic and the initiation of extensive chalk deposition over the western European shelf, suggest that both processes are intrinsically related. The extensive deposition of late Cretaceous chalks on western European shelf can be explained by "inclined carbonate pump", fueled by the upwelling of eastward flowing, deep, central Atlantic water, saturated with DIC and enriched in nutrients. As this upwelled water was mixed on the shelf, the biological activity in the euphotic zone converted DIC into calcium carbonate and organic matter (Fig. 2). The above hypothesis provides evidence for a different oceanic circulation system in the North Atlantic during late Cretaceous, which was dominated by a strong clockwise gyre in the central North Atlantic.

The last significant event, which occurred during the latest Cretaceous, is a meteorite impact in Yucatan, Mexico. The impact has been biostratigraphically placed at Cretaceous/Tertiary boundary (15). It resulted in 65 % of marine biota, dinosaurs extinctions (16), and in a collapse of a part of the Yucatan continental margin. The margin collapse produced debris flow that scoured deep ocean basin floor and can be traced for thousands of km from the impact site to Cuba (17). It should be noted that outside of the Carribean and Gulf of Mexico the impact of such large meteorite on the physical environment is unrecorded.

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RELATIONSHIPS BETWEEN EUSTATIC SEA LEVEL FLUCTUATIONS AND SEDIMENTARY SEQUENCES OF THE WESTERN CARPATHIAN NEOGENE BASINS

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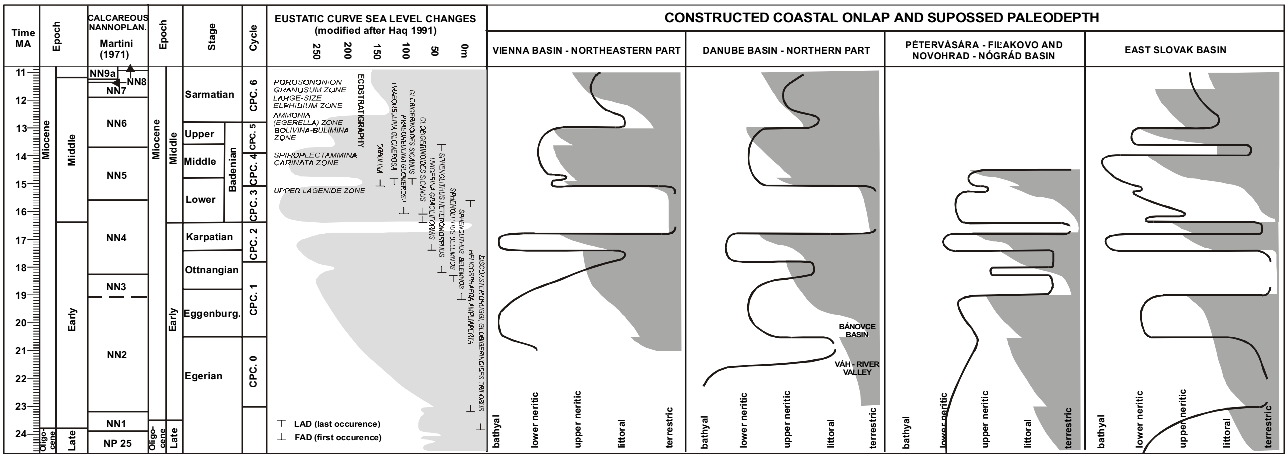
Key words: Western Carpathians, Neogene Basins, sequence stratigraphy.

Interaction of sea level changes and tectonics had an important influence on the paleogeography and paleoenvironment of the Central Western Carpathian basins (Table 1). The depth and the shape of the basins were predominantly controlled by the main tectonic events. Eustatic oscillations, reflected in coastal onlaps were followed mostly by the rise of water paleodepth in the offshore environment. The correlation of the constructed curves for the coastal onlap and predicted paleodepth with global reference curves (Haq 1991) shows some discrepancies, predominantly caused by tectonic events during the basin development.

In contradiction to the Burdigalian continuous relative sea level rise in the Mediterranean (TB 1.5 and TB 2.1 cycles), the paleoenvironment of the Vienna and East Slovak Basins changed from deep water high-energy to shallow water low-energy due to the compressive collision tectonics in the front of the orogen. The Late Egerian-Eggenburgian transgression (zone NN2) was followed by deepening of the sedimentary environment. The Ottnangian marine ingressions observed in the back arc area (Novohrad (Nógrad) Basin) can be related to highstand conditions. Latter on, during the Late Ottnangian (zone NN3) a brackish paleoenvironment developed in the Vienna Basin. In the East Slovak and Novohrad (Nógrád) Basins the uplift was associated with hiatus or deposition of terrestrial coal bearing formations.

Table 1: Table illustrating the relationship among chrono- and biostratigraphical division of the Western Carpathian Neogene, Carpathian-Pannonian 3rd-order cycles (CPC) of the sea level changes, first and last appearence of index microfossils (FAD and LAD), as well as correlation between Haqs (1991) eustatic curve, constructed coastal onlap and supposed paleodepth of the Vienna, Danube, Pétervására (Fiľakovo), Novohrad (Nógrád) and East Slovak Basins.



The Karpatian transgression (zone NN4) and highstand depositional system can be correlated with transgression and global sea level rise of the TB 2.2 cycle. The intra-Karpatian sea level oscillations have a regional character and were tectonically controlled during the stage of initial rifting in the Western Carpathian basins. In the East Slovak Basin the local sea level drop led to a salinity crisis. The following Langian sea level change of the global TB 2.3 cycle (zone NN4) is observable only in the East Slovak and (Nógrád) Novohrad Basins. In the Vienna and Danube Basins the erosion of uplifted areas or terrestrial deposition in depressions occurred between the Late Karpatian and beginning of the Early Badenian.

Pronounced Serravalian transgression followed by highstand is observed in the Vienna, Danube and East Slovak Basins during the extensional synrift stage of development in the late Early Badenian and Middle Badenian (zone NN5). This relative sea level change can be correlated with the global TB 2.4 cycle. The falling stage and lowstand at the end of this cycle is expressed only in the East Slovak Basin by the evaporite sedimentation. The next sea level change, which can be correlated with the global TB 2.5 cycle is proved by transgression followed by deepening of the sedimentary environment and stratification of water masses during the Late Badenian (zone NN6–NN7 lower part) in all the Western Carpathian basins.

The last well observed Serravalian global sea level change that can be correlated with the TB 2.6 cycle (sensu Haq 1991) was associated with the Sarmatian transgression (zone NN7), highstand and gradual shallowing. The local sea level rises or falls were controlled by synsedimentary tectonics during the basin development.

The Late Miocene global sea level changes cannot be satisfactorily interpreted and correlated in the Western Carpathian basins due to their isolation and lack of relevant chrono- and biostratigraphical data in the Pannonian and Pontian deposits.

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THE PROVENANCE AND STRUCTURE OF THE OUTER MARGINAL PART OF THE WESTERN SECTOR OF THE MAGURA FLYSCH ZONE

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Key words: Magura Flysch, detrital garnets, granitoid pebbles, geochemistry, tectogenesis, provenance.

The Magura Flysch Zone is on the contact of the Outer Flysch Group and Central Carpathians. Geochemical investigation of rocks is focused to the compounds which give the best evidence of the sedimentary environments and postdepositional alterations under conditions of increased temperature and pressure. Organic matter and clay minerals are the most sensitive indicators of these factors. The sedimentological research include a taxonomical detailed research of selected leading and index species and testing their stratigraphic range using planktonic foraminifers and nannofossils. Conglomerate layers of the Magura Flysch Zone contain locally abundant granitoid pebbles. Several hundreds of microprobe analyses of detrital garnets from flysch sandstones were evaluated. The paper summarises all available lithological, sedimentological, geochemical, and petrophysical data from the frontal part of the Magura Flysch Zone and should contribute, in this way, to the formulation of a comprehensive model of the Magura Basin evolution, tectogenesis and erosion. A special attention is given to the composition of shales and sandstones that constitute the major part of sediments and occur in all lithostratigraphic units. A synthesis of new data in a geodynamic model of evolution of the Magura Flysch Zone will formulate what mechanism of basin opening and filling, orogeny and forming of nappe structures is involved.

The general trends are characterised in changes of clastic garnet associations in the entire sampled stratigraphic interval, and the psammites of the Cretaceous units are compared with the Paleogene ones. The overall character of the garnet associations is almost identical both in quality and quantity. This suggests little changes in the material sources of the clastics and frequent redeposition during the basin evolution of the partial Rača Unit of the Magura Flysch Zone. Another common feature is the dominant occurrence of the clastic garnets typical of greywacks and conglomerates of the Eastern and partly also Western Part of the Moravosilesian Culm Basin. Pyrope-almandine and grossular-pyrope-almandine are the major garnet assemblages. The maximum diversification in the source units is manifested in the most variable clastic garnet assemblages in the Upper Cretaceous. In the Paleogene, simplification of the garnet assemblages occurred and clearly zoned garnets became more frequent. In the marginal Hostýn Zone of the Magura Flysch Zone the clastic garnets in the sandstones are very polymict both in the Hostýn and Rusava Members. In general, the variety of the clastic garnets in the Hostýn Zone is very similar to that encountered e.g. at the base of the Jeseníky Mts. part of the Easter Part of the Moravosilesian Culm (base of the Upper Viséan).

Earlier pebble analyses of the coarse-grained sediments include carbonates (Soták 1992), granitoids and metamorphites were investigated newly (Hanžl 1998). The crystallisation ages of monazite in the granite pebbles of the Soláň Formation and Rusava Member correspond to the magmatic activity at the Devonian/Carboniferous boundary. It is evident that the studied samples cannot be derived from the Cadomian Brunovistulian crystalline basement. Ages of about 350 Ma are very frequent in the I/S granites of the Tatric Unit of the Western Carpathians.

Results

According to traditional opinions, the Silesian cordillera separated the basins of the external Outer Flysch Zone and Magura Flysch Zone. The present petrographical and geochemical examination of the granite pebbles in the conglomerate layers in the Magura Flysch Zone suggests, in contrary to the earlier authors, that their origin is different from the Brunovistulian crystalline unit. The studied samples are of calc-alkaline character with dominant peraluminous affinity and geochemically they can be correlated with the Variscan granites of the Moldanubian unit and the Western Carpathians. The preliminary conclusion is that the possible source area of the marginal Magura Flysch Zone sediments is a basement equivalent to the Variscan consolidated margins of the North European Platform—Moldanubian of the Bohemian Massif. The palinspastic position of the Magura Basin probably occurred south of the present North European Platform margin in the area of the present Eastern Alps or even more to the south. The nappes of the Magura Flysch Zone were juxtaposed to the Outer Flysch Zone units during the Eocene and Oligocene orogeny. Our conclusions support the hypothesis of a lateral extrusion of the Magura Flysch Zone at the boundary zone of the Alpine and Carpathian paleogeographic domains (Ratschbacher et al. 1991).

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BERRIASIAN SUBMARINE MASS MOVEMENTS AS RESULTS OF TECTONIC ACTIVITY IN THE CARPATHIAN BASINS

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Key words: Tithonian–Berriasian, Neo-Cimmerian tectonic uplift, Pieniny Klippen Belt, Outer Carpathians, Cieszyn Beds.

The results of sedimentological and paleoecological studies (Birkenmajer 1958, 1975, 1986; Krobicki 1994, 1996; Słomka 1986) carried out in the Pieniny Klippen Belt and in the Outer Carpathians — Silesian Unit are discussed in this paper.

They were very important parts of the northernmost margin of the Western Tethys during the Jurassic/Cretaceous evolution of the whole Carpathian domain.

The effects of the Neo-Cimmerian tectonic movements (Osterwald Phase) in the Pieniny Klippen Belt are particularly well-visible in both the Tithonian and Berriasian sediments. Several tectonic horsts and grabens were formed partly on the older, Eo- and Meso-Cimmerian faults (Birkenmajer 1958, 1975, 1986). These movements, which affected mainly the shallowest zone (Czorsztyn Succession) of the submerged intraoceanic Czorsztyn pelagic swell (*sensu* Mišík 1994), are documented by facies diversification, hardgrounds and condensed beds with ferromanganese-rich crusts and/or nodules, by sedimentary/stratigraphic hiatuses, neptunian dykes and/or fauna redeposition, and also by sedimentary breccias (Birkenmajer *op. cit.*). The best example of synsedimentary breccia occurs within widely distributed, exclusively carbonate sedimentation of the Berriasian Łysa Limestone Formation which is tripartite and consists of Harbatowa Limestone Member, Walentowa Breccia Member and Kosarzyska Limestone Member (Birkenmajer 1977). The first and third members are represented by crinoid-brachiopod sparritic and micritic limestones. However, the most typical product of synsedimentary tectonic activity is the middle member (Calpionellopsis Zone (D) — Wierzbowski & Remane 1992) composed of light-coloured pelagic limestones containing angular fragments of micritic limestones of older, underlying beds (so-called *Callpionella* limestones — Sobótka Limestone Member of the Dursztyn Limestone Formation), interpreted as synsedimentary scarp breccia (Birkenmajer 1958, 1975, 1986). Sedimentation of this breccia coincides very well with the moment, when the shallowing effect was strongest, as indicated by synchronous, very rapid change of brachiopod assemblages from ”deep” to ”shallow” types (from predominating pygopids *s.l.* to rhynchonellids) (Krobicki 1994, 1996). The sedimentation depth after Neo-Cimmerian uplift can be estimated on the basis of paleoecological considerations which indicate that the deposition of the Lower Berriasian Rogoźnik coquina (partly facies equivalent of the Sobótka Limestone Member) took place at depths between 400–500 m (Cecca 1992). The sedimentological and the paleoecological data suggest that the Neo-Cimmerian uplift of the sea-bottom, reflected in the shallowing-upward record of sedimentation, reached about 100–200 m.

In the Outer Carpathian basins the most peculiar feature is the presence of the set of E–W trending troughs, separated by submarine and emergent ridges (cordilleras). The Silesian Basin is one of the oldest Carpathian basins. To the north it was bound by the Subsilesian Ridge containing the Baška and Inwałd cordilleras and to the south it was bound by the Silesian Ridge.

The Cieszyn Beds (Kimmeridgian–Hauterivian) are the oldest stratigraphic unit of the Silesian Nappe in the Outer Carpathians.

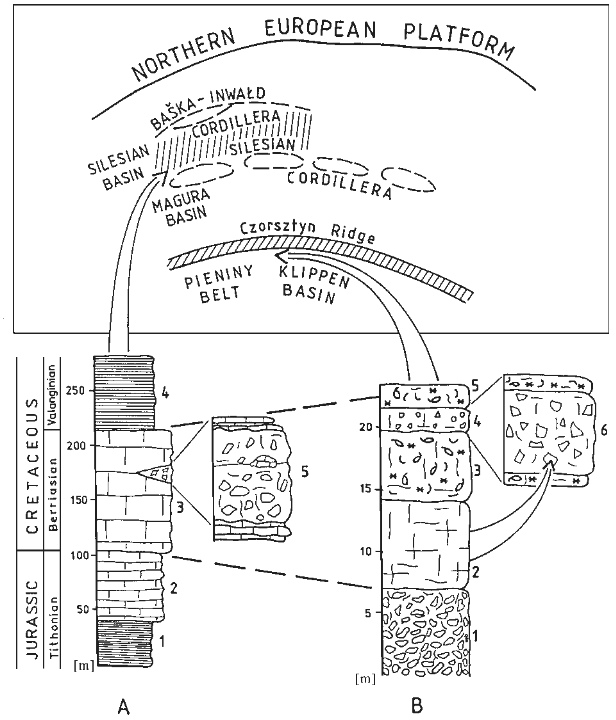

Fig. 1. Sketch of the Berriasian paleogeography of the Carpathian Basin and lithostratigraphic profiles of the Cieszyn Beds (A) (after Słomka 1986): 1 — Lower Cieszyn Shales; 2 — Lower Cieszyn Limestones; 3 — Upper Cieszyn Limestones; 4 — Upper Cieszyn Shales; 5 — debris flow deposits; and Tithonian/Berriasian units of the Pieniny Klippen Belt (B) (after Sobótka Klippe at Czorsztyn — lithostratigraphical units based on Birkenmajer 1977, stratigraphy after Wierzbowski & Remane 1992): 1 — Czorsztyn Limestone Formation (red nodular limestone — Ammonitico Rosso type); 2 — Sobótka Limestone Member of the Dursztyn Limestone Formation (micritic — *Calpionella* limestone); 3-5 — Łysa Limestone Formation: 3 — Harbatowa Limestone Member (crinoid-brachiopod limestone); 4 — Walentowa Breccia Member (limestone breccia); 5 — Kosarzyska Limestone Member (crinoid-brachiopod limestone); 6 — detailed view of the Walentowa Breccia Mbr. with redeposited clasts of the Sobótka Limestone Mbr. Detailed explanations — see text.

They consist mainly of detrital and pelitic limestones, calcareous sandstones, marls and marly shales. Their maximum thickness exceeds 800 m. However, the source area that supplied clastic material for the Cieszyn Beds is still a matter of discusion. Two concepts were proposed—the first postulated by Książkiewicz (1960), Peszat (1967) and Malik (1986), holds as the source area exclusively the Inwałd Ridge, while the second, advocated by Nowak (1973), Menčík (red.) (1983), Eliáš & Eliášová (1984), Słomka (1986) and Matyszkiewicz & Słomka (1994) suggests an additional supply from the islands located at the northern margins of the Silesian Ridge.

The Cieszyn Limestones and Upper Cieszyn Shales cropping out in the Żywiec region comprise several debris-flow deposits. Their thickness in the particular outcrops ranges from 2.5 to 30 meters. The share of the clastic framework does not exceed 30 %. These sediments can be correlated with the facies A1.3 of Pickering et al. (1986) and facies GyM of Ghibaudo (1992). They include numerous fragments and pebbles of detrital and pelitic limestones of the Cieszyn Beds, organodetrital limestones, marly shales, carboniferous and metamorphic rocks — granitic gneisses, gneisses and crystalline schists. Pebbles are randomly arranged in a mass of structureless, hard, marly silt. Generally both, the clays and embedded lumps of limestone have bends and folds closing towards the north suggesting that the sliding mass moved from the south.

Debris flow deposits indicate the building of the Silesian Ridge during the initial development of the active cordillera. The carbonate platform was developed at the submarine ridge. The basis of the carbonate platform consisted of Paleozoic sedimentary and metamorphic rocks. During the uplift of the Silesian Cordillera the part of the basin floor covered with the Cieszyn Beds facies rose. Tectonic activity of the Silesian Ridge caused that the part of the Silesian Basin floor rose. The Cieszyn Beds were eroded again and redeposited as debris flows. Much greater participation of the coarse-grained facies of the Upper Cieszyn Limestones and the appearance of mass-movement debris-flow deposits containing the fragments of the older Cieszyn Beds and exotics of the basement rocks suggest a higher rate of uplift during the Neo-Cimmerian activity (Osterwald Phase). As a result the following islands emerged in the east. Tectonic movements of the Silesian and Subsilesian ridges were probably connected with the development of initial rifting in the Silesian Basin, as documented by the presence of teschenitic magmatism.

Almost simultaneous tectonic events that took place in different types of sedimentary basins (Pieniny Klippen Belt and Outer Carpathians — Silesian) indicate how important was the role of the Neo-Cimmerian movements (mainly Osterwald Phase) in the geodynamic history of the northermost margin of the Tethyan Ocean (Fig. 1). The evolution of several, mainly longitudinal, Carpathian basins was probably connected with subduction processes (e.g. initial stages of subduction of the oceanic crust of the Pieniny Klippen Belt Basin under the southern, active margin (ridge) are related to these movements — Birkenmajer 1986), riftogenesis (Silesian Basin — Narębski 1990; Vašíček et al. 1994), volcanic activity (Rakús et al. 1988) and even paleoceanographical conditions (Birkenmajer 1986; Krobicki 1996). However, all alternatives were most probably connected with the Neo-Cimmerian tectonic event. Alternatively, the formation of such allodapic rock beds may also be interpreted as an effect of eustatic events (litohorizone Be-7) and very well corresponds with the Berriasian part of the Nozdrovice Breccia within the Inner Carpathians (Reháková & Michalík 1992; Michalík et al. 1995, 1996) that developed as a scarp breccias along the active submarine fault slopes (Michalík & Reháková 1995).

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COMPARATIVE PALEOMAGNETIC, PALEOTECTONIC AND PALEOGEOGRAPHICAL INVESTIGATIONS IN THE ALPINE AND VARISCAN TECTONIC BELTS: CASE HISTORIES FROM THE WESTERN CARPATHIANS AND THE BOHEMIAN MASSIF

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Key words: Western Carpathians, Bohemian Massif, paleomagnetism, paleogeography, comparison of paleotectonic deformations.

The objective of this study is to highlight some similarities and differences between the styles of paleotectonic deformation of rock complexes exemplified by the Western Carpathians (WCA) and the Bohemian Massif (BM), subjected to Alpine and Variscan tectonics, respectively. The global tectonic interpretations are based on the analysis of paleomagnetic data accumulated to the present day in considerable amounts for the Alpine as well as Variscan tectonic belts. The whole WCA are assigned to the Alpine tectonic belt, and pre-Early Permian formations in the BM are assigned to the Variscan tectonic belt. Both these territories became subject to intensive paleomagnetic studies in the last thirty years or more. However, the territories of the WCA and BM are relatively small to serve as bases for global tectonic interpretations. Experimentally inferred paleomagnetic results were therefore interpreted in the context of data derived from rocks coming from large regions of the European continent. For the WCA, paleomagnetic data were derived from Permian to Neogene rocks and the interpretation of results was preceded by processing of paleomagnetic data from the broader region of the Alpine-Carpathian-Pannonian zone extending from the Permian to the Neogene. In the territory of the BM, paleomagnetic data were inferred from Early Cambrian to Middle Devonian rocks of the Barrandian area (considered a peri-Gondwanide terrane), Middle to Late Devonian rocks of the Moravian Zone (eastern margin of the BM, a separate terrane?) and numerous data were inferred from Late Carboniferous to Early Permian rocks from different basins and grabens of the BM. In the BM, paleomagnetic results were obtained from rocks of Variscan and pre-Variscan age and even the waning of Variscan tectonic deformations was recorded on the basis of the decreasing dispersion of paleomagnetic pole positions. Results from the BM were interpreted again in the context of all-European data derived from the Devonian to Triassic rocks from large regions of Europe, from the territories north of the Alpine tectonic belt and west of the Ural Mts as far as to Great Britain. Paleomagnetic results from the BM, including inferred paleolatitudes for the respective formations and paleomeridian orientations, were interpreted in relation to the all-European Phanerozoic results. Paleomagnetic data mostly inferred by only one laboratory but supplemented by some data from Slovak, Hungarian and Polish geophysicists from the WCA and by some data of the paleomagnetic team in Munich from the BM allow: i) to demonstrate on the example of the Barrandian area some methodological problems related to paleomagnetic examination of terrane paleogeography, ii) to determine the extent of horizontal paleotectonic rotations as the dominant tectonic deformational effect in all the hitherto studied rock complexes in the WCA and in Variscan and pre-Variscan formations in the BM.

In the territory of the WCA, rocks from the Inner and Outer Carpathians and the Klippen Belt were studied by paleomagnetic methods and results for the Permian to Neogene interval were obtained. The interpretation of data inferred from a relatively small area of the WCA was, however, preceded by statistical and global tectonic processing of paleomagnetic data from the broader region comprising Permian to Neogene rocks of the Outer Western and Eastern Carpathians, Inner Western Carpathians including the Little Carpathians. A paleogeographical affinity to the African Plate was found for most of the studied nappes, nappe systems or particular microblocks. Orientations of paleomeridians for the individual areas of the Alpine-Carpathian-Pannonian zone indicated a predominating counter-clockwise paleotectonic rotation. Clockwise rotations were evidenced only for the NE Alps (documented for the Jurassic and Cretaceous only) and the Outer Eastern Carpathians (documented for the Jurassic and — with less probability — also for the Cretaceous). For the first time ever, horizontal paleotectonic rotations were proved for Permo-Triassic rocks of the WCA already in the initial phases of paleomagnetic studies (Kotásek & Krs 1965). It was only after the inference of larger sets

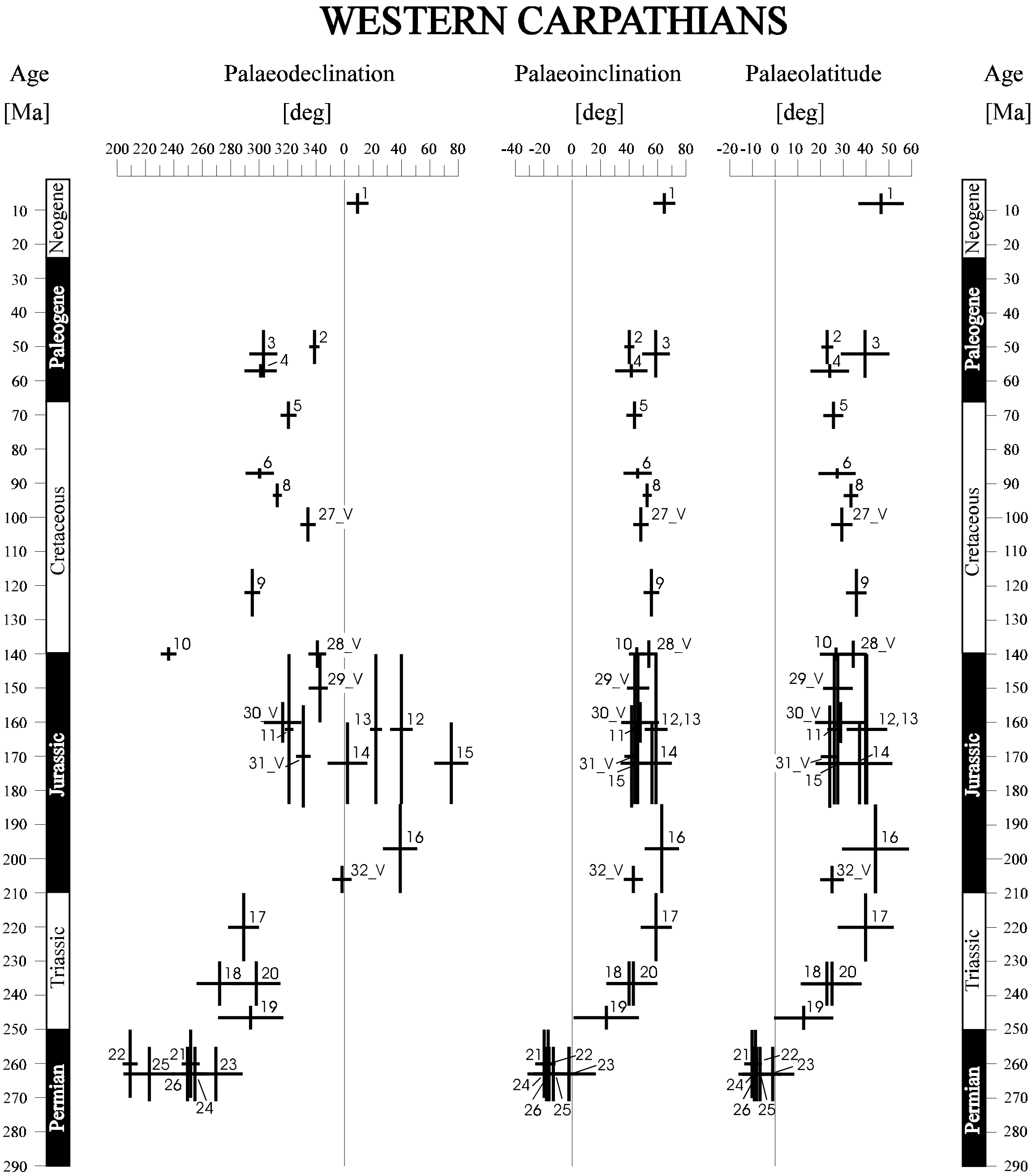

Fig. 1. Western Carpathians. Dependence of paleodeclination, paleoinclination and paleolatitude values on geological age for rocks of the Inner Western Carpathians, Klippen Belt and Outer Western Carpathians, see text.

of paleomagnetic data for the Alpine tectonic belt and a detailed paleomagnetic study in the WCA that sufficient amounts of data were obtained. These data permitted us to formulate a theoretical model simulating the distribution of paleomagnetic pole positions due to horizontal rotation of rock complexes (first published by Krs, Pruner & Potfaj 1992, and later extended by Krs, Krsová & Pruner 1996). Rocks from the Alpine tectonic belt thus provided evidence that, besides the effect of continental drift, local and regional deformations markedly affect the distribution of paleomagnetic pole positions, being mostly represented by horizontal rotations of whole rock complexes, nappes, etc. In the Tethyan realm, horizontal paleotectonic rotations were proved and exemplified in a number of case histories (cf. Morris & Tarling 1996 and others).

The values of paleodeclinations, paleoinclinations and paleolatitudes for rocks from the WCA in dependence on geological age are shown in Fig. 1. The “Geological Time Table” of Haq & Van Eysinga (1987) was used as the reference time scale. Numbers with the respective data correspond to reference numbers under which the studied rock formations are listed in the database of Krs, Krsová & Pruner (1996, Table 1, p. 178). Additional data recently inferred from virtual pole positions (derived from carbonate rocks) are marked by letter V. The dispersions of paleomagnetic directions are relatively wide; similar dispersions were also inferred for rocks from other regions of the Tethyan realm, the Iberian Meseta and adjacent mobile belts, Corsica and Sardinia, from the territory of Italy including the adjacent parts of the Alps, from Greece and S Bulgaria, from the Transdanubian region and the Adriatic promotory, and also from Turkey including the eastern Aegean region and Cyprus (cf. Van der Voo 1993). Paleoinclination values, thus also the paleolatitudes inferred from them, are

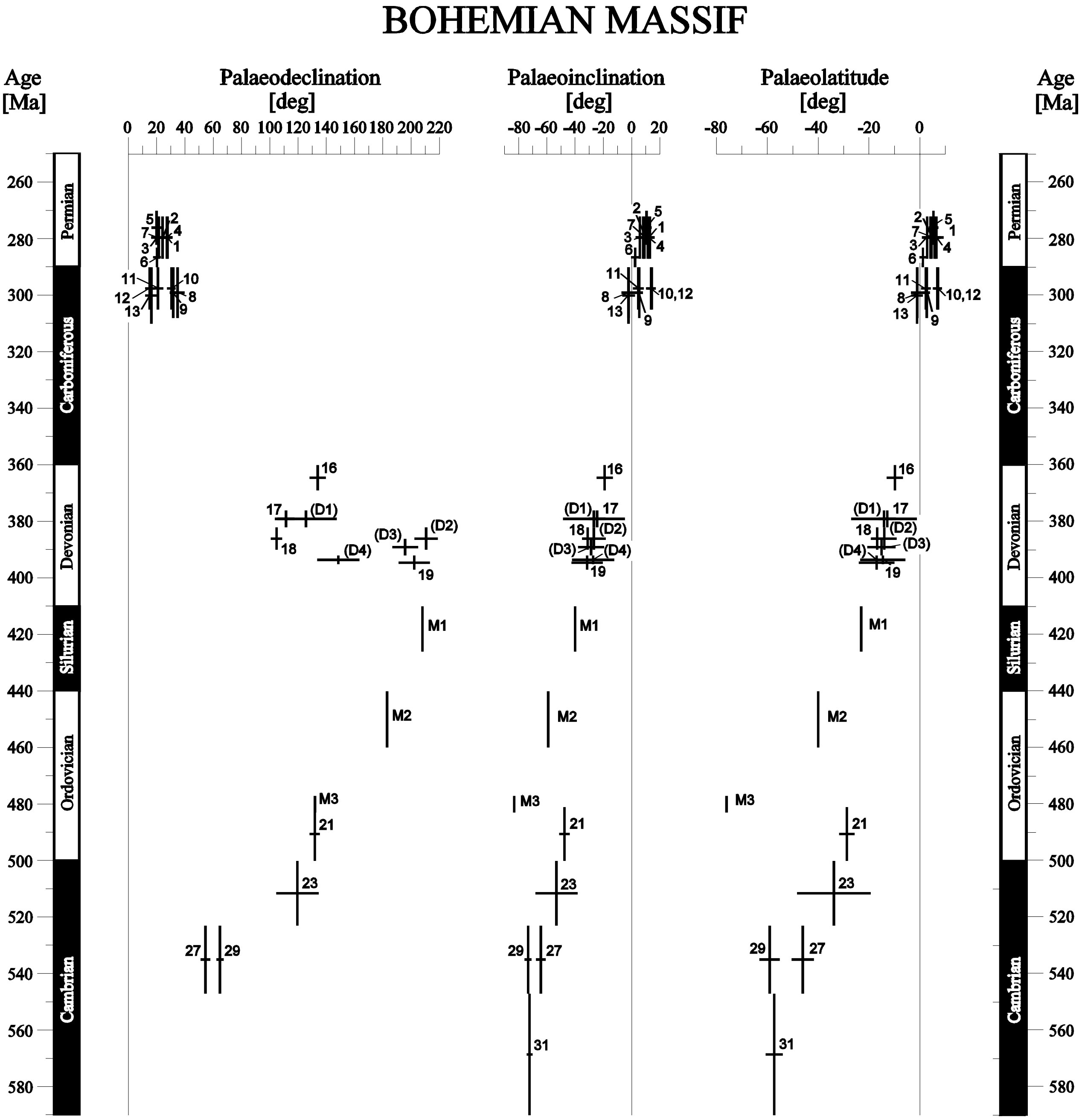

Fig. 2. Bohemian Massif. Dependence of paleodeclination, paleoinclination and paleolatitude values on geological age for rocks of the Barrandian, for Late Carboniferous and Early Permian rocks from different furrows and basins, see text.

charged with considerable errors partly also resulting from the inclined bedding planes of flysch sediments. The most prominent paleolatitudinal drift dates from the Permian and Triassic and similar drift was also documented for the Permo-Triassic rocks of the European lithospheric plate (cf. Dercourt, Ricou & Vrielynck 1993). Marked differences are, however, also present in paleomagnetic declinations, frequently even for rocks of close or identical ages but coming from different areas of the WCA. These differences in paleomagnetic declinations result from prominent horizontal paleotectonic rotations of whole rock complexes.

The results of the paleomagnetic measurements presented in Fig. 1 relate to the individual rock formations and to specific localities or areas. The inferred data were processed using yet another method: the values of paleodeclinations and paleolatitudes were recalculated from the paleomagnetic pole positions for a single reference point in the WCA with coordinates of $\varphi = 49^{o}$N and $\lambda = 17^{o}$E. Averaged values of paleomagnetic declination and inclination were extrapolated to the same reference point from pole positions for stable Europe published in the papers of Van der Voo (1993), Besse & Courtillot (1991), Krs & Pruner (1995) and from pole positions for Africa and western Gondwana given by Van der Voo (1993) and Besse & Courtillot (1991). Comparison of paleodeclinations and paleolatitudes recalculated for the same reference point confirmed the paleogeographical affinity of the studied rocks of the WCA to the African Plate.

Similar paleotectonic rotations of whole rock complexes, as originally experimentally inferred and tested on models in the Alpine tectonic belt, were later interpreted also in the Hercynian mobile belt including the territory of the BM. Tectonic stability of the BM was paleomagnetically documented for Early Permian rocks from different basins and grabens, Late Carboniferous rocks generally showed a higher dispersion of paleomagnetic data (Krs 1968). The former paleomagnetic results from Permian and Carboniferous rocks of the BM were later confirmed using more advanced interpretation and laboratory techniques, particularly the multi-component analysis of remanence (e.g. Kirschvink 1980) and employing the newly developed MAVACS demagnetizer securing a high magnetic vacuum in the process of progressive thermal demagnetization of rock samples (Příhoda et al. 1980; see database in Table 5, p. 19, in Krs & Pruner 1995). Statistical processing (Fisher 1953) has shown that the semi-vertical angle of the confidence cone at the 95 % probability level α_{95} = 2.9° for seven pole positions inferred from Early Permian rocks and α_{95} = 6.8° for seven pole positions inferred from Late Carboniferous rocks. The most remarkable difference in paleomeridian orientations was detected between the block of the Intrasudetic and Krkonoše Piedmont Basins on one side and the block of the Plzeň and Kladno-Rakovník Basins on the other side with the paleoazimuth difference being 17° ± 4°. Permian pole positions inferred for rocks from a large part of Europe west of the Ural Mts to Great Britain and north of the Alpine tectonic belt were also processed using the statistics of Fisher (1953). From the total of 71 Permian pole positions, α_{95} = 2.0° was calculated indicating consolidation of the European Plate in the Permian (as a component of the emerging Pangea supercontinent). Values of paleomagnetic declination determined for rocks older than Early Permian SW of the Trans-European Suture Zone (TESZ) vary considerably from area to area even for rocks with the same values of paleomagnetic inclination. Prominent paleoazimuth differences for pre-Early Permian rocks in the West European Hercynides (i.e., SW of the TESZ) were reported by Edel (1987); paleomeridian orientations indicate predominantly clockwise rotations. Middle Carboniferous rocks in the West European Hercynides show mean values of clockwise rotation of approx. 50° and the values for Early Carboniferous reach extreme values of clockwise rotation of 120°. Similar and even higher values of anomalous paleomagnetic declinations were also reported for rocks of the BM: for the Devonian rocks from the Barrandian area and Moravian Zone and generally for all hitherto studied pre-Variscan formations of the Barrandian area ranging from Early Cambrian to Devonian in age (Krs, Krsová & Pruner 1997).

The values of paleomagnetic declination, inclination and paleolatitude inferred from the hitherto studied rocks from the Barrandian area, Moravian Zone, Late Carboniferous and Early Permian rocks from different basins and grabens in the BM are shown in Fig. 2. The data calculated from paleomagnetic pole positions (see databases in Krs 1968; Krs & Pruner 1995; Krs, Krsová & Pruner 1997) are marked by numbers. Data calculated from hitherto unpublished virtual pole positions inferred from Early to Middle Devonian rocks of the Barrandian area are marked by symbols (D1), (D2), (D3) and (D4). The data calculated from paleomagnetic pole positions inferred for the Ordovician and Silurian rocks from the Barrandian area by paleomagnetists from Munich (Tait, Bachtadse & Soffel 1994a,b, 1995) are marked by symbols M1, M2 and M3. The values of paleomagnetic declination for Early Variscan and pre-Variscan rocks from the Barrandian area as well as the Moravian Zone are markedly anomalous, reflecting horizontal paleotectonic rotations due to the Variscan Orogeny.

The results of the paleomagnetic investigations presented in Figs. 1 and 2 provide a basic overview of aspects of global tectonic interpretations in Central Europe. The paleomagnetic data were inferred for rocks from two belts tectonically differing in space and time; however, comparison of the results allows a better interpretation of the principal paleotectonic deformations in both the Alpine and Hercynian mobile belts. For an easier correlation, the values of paleolatitudes and paleodeclinations calculated from paleomagnetic pole positions were extrapolated to a single reference point of φ = 50°N and λ = 14°E for the BM territory and φ = 49°N and λ = 17°E for the WCA territory.

The paleolatitudes inferred for the Cambrian and also Late Silurian to Early Permian rocks of the BM are in good agreement with the all-European data (cf. Van der Voo 1993). The Middle Devonian value of paleolatitudinal drift of 2 cm/year increased in the Carboniferous, Permian to ca. 4 cm/year in the Early Triassic. A similar acceleration of paleolatitudinal drift was also inferred for the Permian and Triassic rocks in the WCA (cf. Krs, Krsová & Pruner 1996). Crossing of the paleo-equator occurred during the Late Carboniferous in the BM territory but during the Middle to Late Permian in the WCA, undoubtedly as a result of the existence of Paleo-Tethys.

The comparison of data presented in Figs. 1 and 2 suggests a similarity in paleodeclination values due to Variscan Orogeny in the BM and Alpine Orogeny in the WCA. Paleotectonic predominantly counter-clockwise horizontal rotations were recorded in the territory of the WCA, whereas the BM is dominated by clockwise rotations. Prevailing counter-clockwise rotations were analogically recorded in numerous examples from the Alpine-Carpathian-Pannonian zone but clockwise rotational movements prevail in the European Hercynides. Experimentally inferred horizontal paleotectonic rotations of whole rock complexes, nappes, nappe systems, microblocks (?), often with markedly different paleodeclination values for rocks of the same or close age, were verified on theoretical models simulating the distribution of pole positions due to horizontal paleotectonic rotations. This, however, implies that horizontal paleotectonic rotations are the dominant element of tectonic deformation in the Alpine as well as Hercynian orogenic belts and probably represent a phenomenon typical for tectonic collisional zones.

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JOINT CHITINOZOAN AND ACRITARCH BIOSTRATIGRAPHY OF THE PRIDOLI AND LOCHKOVIAN FROM THE MOESIAN PLATFORM, BULGARIA

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Key words: Pridoli, Lochkovian, Moesian Platform, biostratigraphy, Chitinozoans, acritarchs.

Introduction

The marine argillaceous Silurian and Lower Devonian sedimentary rocks from the subsurface of the Moesian Platform consist of chiefly black shales and siltstones and minor sandstones and black clayey limestones. This succession is involved in the non-metamorphic pre-Variscan basement of the Moesian Platform. The backgrounds of the Silurian and Lower Devonian stratigraphy of the Moesian Platform in Bulgaria were made by Spasov & Janev (1966) and the age determinations were mainly based on single finds of graptolites, conodonts, bivalves and tentaculites in the core intervals.

The abundant and very diverse chitinozoans and acritarchs obtained from part of the Silurian-Lower Devonian black shales enabled a more precise age assignment and detailed biostratigraphic subdivision. Thus, the lowest parts of the borehole sections R-1 Dalgodeltsi and R-119 Kardam which were previously considered to be Sigenian have been determined as Pridoli and Lochkovian on the occurrence of characteristic chitinozoan species (Lakova 1993, 1995). A chitinozoan zonation of regional extent has been proposed for the Lochkovian in the Moesian Platform (Lakova 1993).

The purpose of this work is to present revised and new results on the chitinozoan zonation of the Pridoli and Lochkovian in the Moesian Platform along with newly obtained data on the parallel stratigraphical ranges of co-occurring chitinozoans and acritarchs.

Methods

The two subsurface sections studied are R-1 Dalgodeltsi and R-119 Kardam. R-1 Dalgodeltsi borehole is situated in Montana Region, NE Bulgaria. 31 palynological samples were obtained from six core intervals from depths of 4796.5–5001.0 m. In R-119 Kardam, which is located in Dobrich Region, NE Bulgaria, 15 samples were collected from six core intervals at depths of 3393.0–3704.0 m. All samples of 50 g of rock were treated following the standard HCl/HF palynological extraction technique. The palynological slides were studied with JENAVAL transmitted-light microscope. SEM photos of the chitinozoans were prepared on a JEOL-microprobe. The material is stored at the Department of Paleontology and Stratigraphy in the Geological Institute, Sofia.

Chitinozoan zonation

A total of 50 chitinozoan species have been recorded from the Pridoli and Lochkovian of the Moesian Platform in Bulgaria in the R-1 Dalgodeltsi and R-119 Kardam sections. The vertical ranges of chitinozoans allow the recognition of six chitinozoan zones of wide geographical occurrence. This also provides a good independent stratigraphical control to specify the vertical ranges of the co-occurring acritarchs and prasinophyte algae by direct correlation with the chitinozoan zones.

The studied part of the subsurface section R-1 Dalgodeltsi (4796.5–5001 m) consists of dark grey to black shales. The occurrence of chitinozoan species *Margachitina elegans*, *Fungochitina kosovensis*, *Bursachitina krizi* and *Conochitina gordonensis* at depths of 4995–5001 m and 4941–4947 m indicates F. kosovensis and M. elegans zones of Pridoli age (Fig. 1). These zones were defined by Verniers et al. (1996) and are of global application. Upwards in this section, the successive first occurrences of the chitinozoans *Eisenackitina bohemica*, *Fungochitina lata* and *Urochitina simplex*, documented at depths of 4910–4916 m, 4879–4885 m and 4842.5–4845.5 m, respectively, indicates the Lochkovian E. bohemica, F. lata and U. simplex zones as defined by Paris et al. (1999). The top of the section studied at a depth of 4796.5–4800 m was characterized as the interval between the last occurrences of *Urochitina simplex* and *Cingulochitina plusquelleci* and was assigned to the uppermost Lochkovian (Lakova 1993). This study reveals a slight inconsistency between the Lochkovian chitinozoan zonation of the Moesian Platform and the global chitinozoan zonation of the Devonian (Paris et al. 1999). In this country, U. simplex Zone is not the uppermost Lochkovian zone. *Cingulochitina plusquelleci* and *Fungochitina lata*, two distinct Lochkovian chitinozoans, persisted above the last occurrence of *U. simplex* (Fig. 1).

In R-119 Kardam, the studied section consists of dark grey shales and siltstones and minor sandstones. The lowest two core intervals at the borehole bottom (at deths of 3698–3704 m and 3647–3653 m) are assigned to Fungochitina kosovensis and Margachitina elegans zones of Pridoli age due to the occurrence of *Fungochitina kosovensis*, *Margachitina elegans*, *Sphaerochitina sphaerocephala* and *Kalochitina lorensis* (Lakova 1995 and unpublished data). The successive first occurrences of *Eisenackitina bohemica*, *Fungochitina lata* and *Urochitina simplex* within the overlaying core intervals at depths of 3582–3587 m, 3519–3524 m and 3468–3474 m prove the Lochkovian E. bohemica, F. lata and U. simplex zones. At depths of 3393–3398 m, the co-occurrence of *Cingulochitina plusquelleci* and *Fungochitina lata* above the last occurrence of *Urochitina simplex* is evidence of the topmost Lochkovian U. simplex-C. plusquelleci Zone.

Acritarch biostratigraphy

In both sections studied, the Pridoli acritarch assemblages are extremely diverse, whereas the Lochkovian strata are much poorer in acritarchs. This is the first record of such a diverse marine microphytoplankton (90 species of acritarchs and prasinophyte algae) from the Upper Silurian and Lower Devonian of the Moesian Platform.

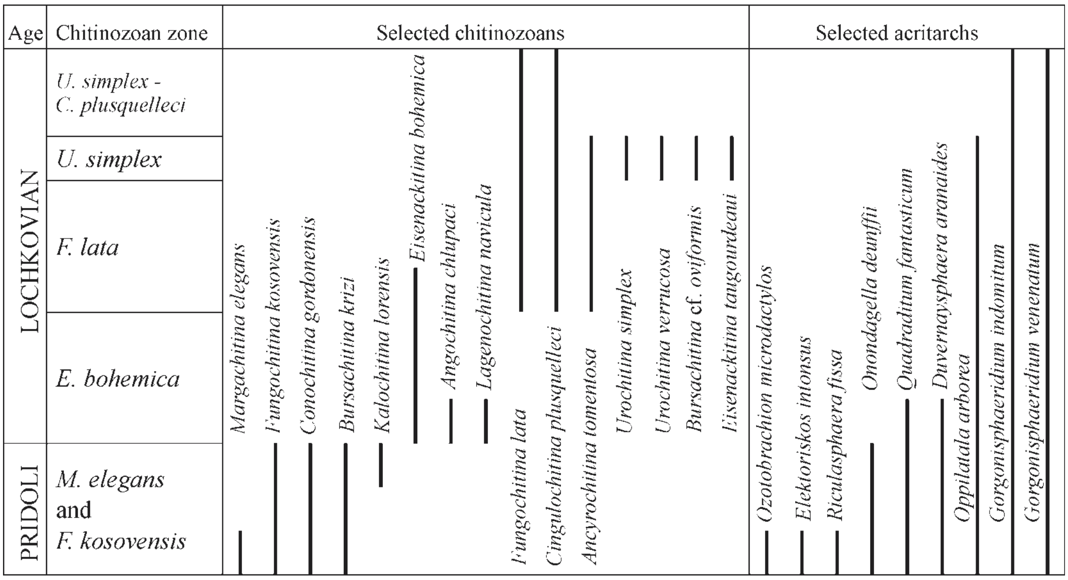

Fig. 1. Chitinozoan zonation and ranges of selected chitinozoan and acritarch species of the Pridoli and Lochkovian from the Moesian Platform. The chitinozoan zones are adapted to the Silurian and Devonian global zonations (Verniers et al. 1995; Paris et al. 1999).

In R-1 Dalgodeltsi and R-119 Kardam sections, an acritarch assemblage of *Duvernaysphaera aranaides*, *Onondagella deunffii* and *Quadraditum fantasticum* occurs which is also known from the Ludlow, Pridoli and the base of Lochkovian in many localities of the southern hemisphere during the mid-Paleozoic (Spain, Brittany, North Africa, Argentina, Florida). The almost simultaneous last occurrences of these three species over a wide geographic area is a reliable biostratigraphic event to distinguish the Pridoli and lowermost Lochkovian from the mid-upper Lochkovian. This marker approximates the base or lower portion of the Eisenackitina bohemica Zone of the Lochkovian chitinozoan zonation (Fig. 1) and is very close to the Silurian/Devonian boundary.

On the other hand, a large group of acritarch species previously considered as Lochkovian taxa in Brittany, France, and Oklahoma, USA (Deunff 1980; Loeblich & Wicander 1976) co-occur in the Pridoli of the Moesian Platform with the chitinozoan species *Margachitina elegans*, *Fungochitina kosovensis* and *Kalochitina lorensis* (Fig. 1). These acritarch are: *Ozotobrachion microdactylos*, *Gorgonisphaeridium indomitum*, *G. venenatum*, *Oppilatala arborea*, *Elektoriskos intonsus* and *Riculasphaera fissa*, the latter two species being even regarded as biostratigraphic markers restricted to the Lochkovian (Molyneux et al. 1996). In the Lochkovian of the Moesian Platform, there is a relatively scarse record of only longer-ranging acritarchs. Nevertheless, *Cymatiosphaera vespertilio*, *Gorgonisphaeridium indomitum*, *G. venenatum*, *Oppilatala arborea* and *Elektoriskos brevispinosum*, were reported as not exceeding the Lochkovian/Pragian boundary (Deunff 1980).

Discussion

This study of co-occurring chitinozoans and acritarchs across the Silurian/Devonian boundary in the Moesian Platform confirms the high biostratigraphical value of the chitinozoans and the much lower potential of the acritarchs (despite their great diversity) for fine subdivision. Six chitinozoan zones are here recognized, two for the Pridoli, and four for the Lochkovian. Most of these zones are of global application and allow wide and precise correlations. Only the topmost Lochkovian U. simplex-C. plusquelleci Zone is still of regional value. The vertical ranges of many acritarch species, specified in this study, allow us to place only tentatively the Silurian/Devonian boundary at the last occurrence of an assemblage of species. The previous palynostratigraphic practice to define combined palynozones based on chitinozoan, acritarch and spore asemblages for the Silurian and Devonian in North Africa and the Moesian Platform (Jardine et al. 1974; Beju 1972) did not provide exact and fine resolution. In terms of palynostratigraphy, the mid-Paleozoic marine black shale successions could be best divided using a complex procedure of four steps involving: 1/ chitinozoan record and zonation; 2/ direct correlation of the co-occurring acritarch and spore record with the chitinozoan zonation; 3/ separate definition of acritarch and spore zones; 4/ calibration of the zonations based on chitinozoans, acritarchs and spores. Only the first two steps are here executed due to the nature of the acritarch record in the Pridoli and Lochkovian of the Moesian Platform in Bulgaria.

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ORBITALLY INDUCED SEDIMENTATION CONTROL IN THE CARPATHIAN FLYSCH SEA AT THE EOCENE–OLIGOCENE TRANSITION

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Key words: Poland, Outer Flysch Carpathians, Eocene, orbital forcing.

Introduction

Distinctive enrichment in calcareous material is characteristic of the flysch sequence at the Eocene–Oligocene transition in the entire Outer Carpathians. The highest enrichment occurs in the widely dis-

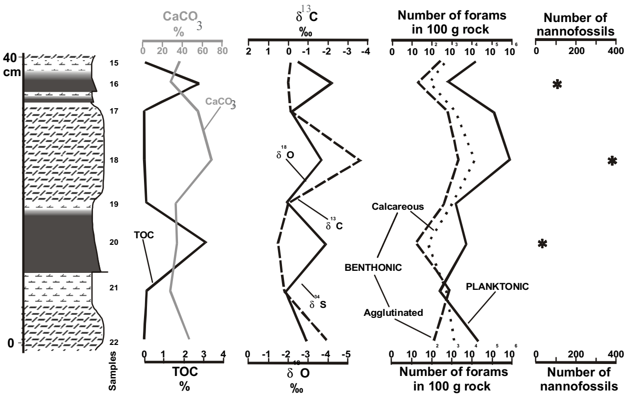

Fig. 1. Sequence styles and relationships between different rock types within the SMGMS. Example from the section at Znamirowice. Facies symbols explained in Fig. 2.

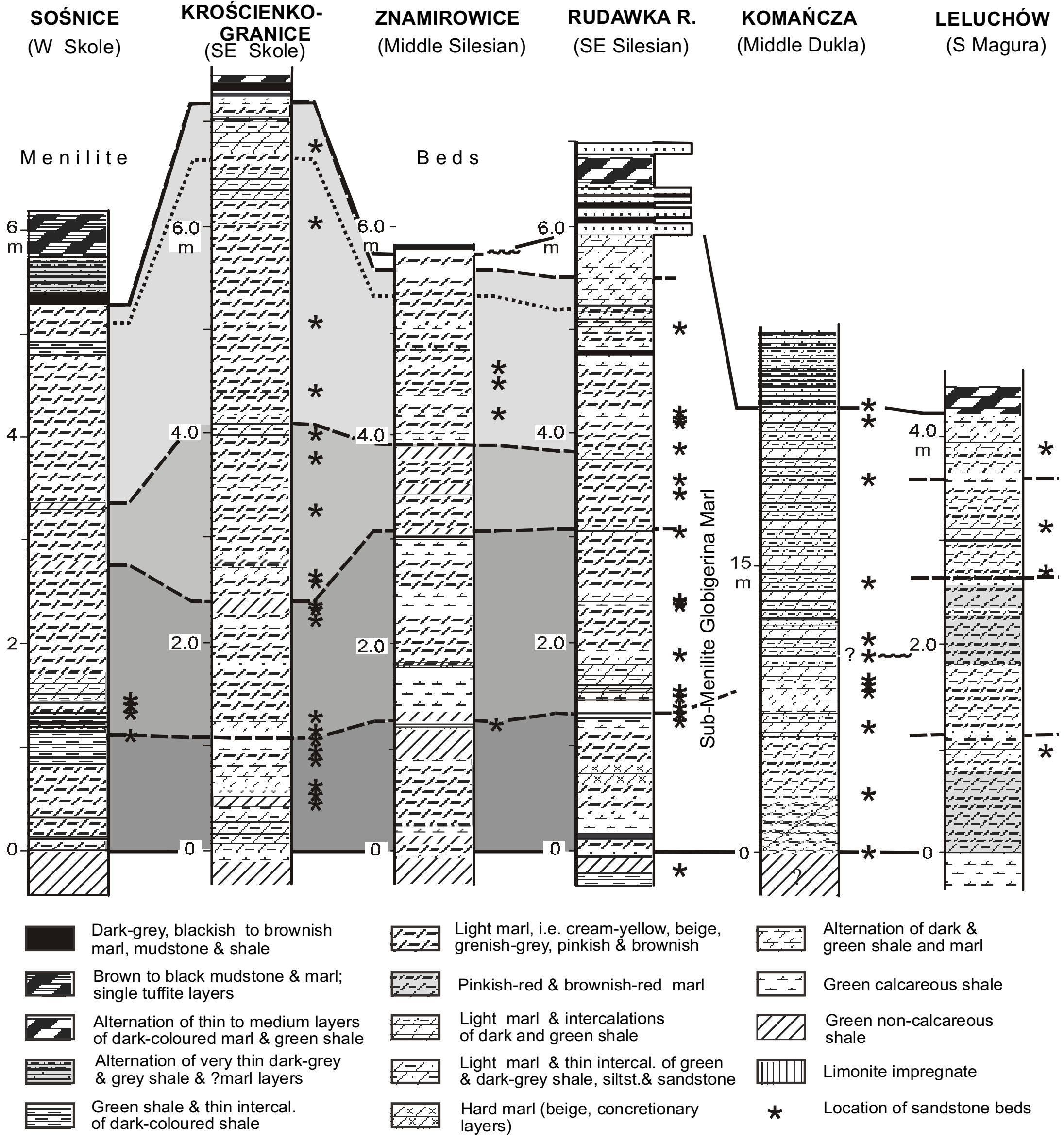

Fig. 2. Correlation of the Sub-Menilite Globigerina Marl Sequence deprived of sandstone beds from distant sections in different nappes of the Polish Outer Carpathians. Sandstone beds were omitted to accentuate the variability of fine-grained facies. The chief subunits separated by distinctive facies changes are indicated by the shadowed fields between logs.

tributed unit called the Sub-Menilite Globigerina Marl (SMGMS), Sheshory Marl, Sheshory horizon, or simply Globigerina Marl. Several years ago, Krhovský et al. (1993) interpreted the SMGMS exposed in several closely spaced sections in the Czech Carpathians as resulting from climatic and paleogeographical changes forced by Milankovitch orbital cyclicity. The interpretation by Krhovský et al. (1993) has recently been supported by investigations by the present author in many SMGMS sections in Poland (see Leszczyński 1997). Mesoscopic features, carbonate and total organic carbon content (TOC), $\delta^{18}O$ and $\delta^{13}C$ signals, and kerogen type were analysed to recognize the sedimentary origin of these deposits. The chief aspects of the results are repeated in this paper.

Features indicative of the SMGMS origin

The SMGMS consists of thin to thick beds of homogeneous cream-yellow, beige, greenish-grey and reddish marls, called further light marls, intercalated with green and dark-grey calcareous to noncalcareous muddy to clayey shales, dark-grey to brownish, usually calcareous mudstones, thin siltstone and usually thin sandstone beds. The amount of intercalations and their distribution vary in the sequence.

A very distinctive, recurrent, vertical facies stacking is recognizable in many sections (Fig. 1): the light marl passes down- and upwards into the green shale or is sharply bound from above either by the dark shale, marl, or by a sandstone, whereas the green shale passes downwards into the light marl or into the dark shale, mudstone or marl. Rarely, the light marl is sharply bound at the base by a sandstone. Sandstones and siltstones are concentrated within the less calcareous parts of the SMGMS. The vertical stacking of the fine-grained deposits is accentuated by distinctive differences in carbonate content, TOC, the content and composition of fossils, and in $\delta^{18}O$, $\delta^{13}C$ signals (Fig. 1).

The complete unit ranges between 5 and 10 metres in thickness. It shows gradual passages both down- and upwards into noncalcareous fine-grained deposits. The Green Shale unit usually occurs beneath the SMGMS, whereas the Menilite Beds, characterized by predominantly dark-coloured deposits in the fine-grained facies, occur above. The sequence displays distinctive lateral differentiation. Nevertheless, some common vertical trends appear to occur in the better preserved sections (Fig. 2).

Discussion

Mesoscopic features, mineral and textural composition indicate that the light marls and the green shales are mainly of hemipelagic origin. The dark-coloured mudstones and marls, like the siltstones and sandstones, are chiefly turbidites.

The recurrent gradual change of fine-grained facies in vertical sections is interpreted as resultant primarily from temporary changes in calcareous nannoplankton and planktonic foraminiferal production. Orbitally forced climate and water circulation changes appear to be mainly responsible for the variations of productivity and consequently the location of the calcite compensation depth (CCD). The thickness of the entire unit indicates sedimentation forcing within the long eccentricity cycle, i.e. 414 Ky. The major fluctuation of carbonate content within the SMGMS reflects the short eccentricity cycles (ca. 100 Ky), whereas the minor changes appear to reflect the obliquity (41 Ky) and precession (20 Ky) cycles. To some extent the minor fluctuation may result from an intermittent supply of terrigenous material. The supply was controlled primarily by tectonic activity in the area and subordinately by the orbitally forced climate changes.

Lateral changes in the patterns of the vertical fluctuation of carbonate content in the SMGMS are interpreted as due to highly contrasted morphology of the seafloor relative to the CCD. This factor, together with regionally varying supply of terrigenous material, were responsible for the general, lateral sequence changes. Enhanced resedimentation of organic and siliciclastic material and oceanographic changes that lowered carbonate production, were responsible for the retreat of the SMGM facies and the onset of sedimentation of the Menilite Beds.

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TECTONIC *VERSUS* EUSTATIC CONTROL OF FLYSCH SEDIMENTATION IN THE POLISH OUTER CARPATHIANS

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Key words: Poland, Outer flysch Carpathians, Cretaceous, Paleogene, sedimentation controls.

Introduction

Of the two primary sedimentation controls, that is tectonics and eustasy, the first mentioned is generally acknowledged as of basic significance in controlling flysch sedimentation. The effects of eustasy are hardly distinguishable in the flysch successions. In the flysch of the Polish Outer Carpathians (POC), the influence of eustasy has generally been omitted in previous interpretations. Several years ago, Leszczyński & Malik (1996) interpreted the distribution of calcareous material as in part reflecting sedimentation control by eustasy. Recently, the present author (Leszczyński 1998) has suggested that the relative influences of tectonics and eustasy on flysch sedimentation may be interpreted from stratigraphic distribution of the coarse clastic units alimented from the passive margins of the flysch basin. This interpretation is also explained in the present paper.

Basic features of the flysch of the POC

The flysch of the POC consists of Late Jurassic through Early Miocene deep-sea, mainly siliciclastic rocks, which form a north-verging fold-and-thrust belt. The facies distribution and paleotransport directions indicate sedimentation in several basins separated by subaqueous to subaeral ridges (Książkiewicz 1956). The main nappes are considered to represent the basic sedimentary realms of the flysch sea. The basins were fed with detritic material generally from their southern and northern peripheries. The proportions of the supply from opposite directions were different in particular basins (see Książkiewicz 1962). However, the locations of the source areas are not clear in many cases.

Features indicative of type of sedimentation control

1. *Differences in volumetrical and stratigraphic extension of the coarse clastic units alimented from opposite directions.* The units

Table 1: Features of sandstones alimented from opposite margins of the flysch basins.

Alimentation from S					Alimentation from N				
Lithostratigraphic unit	**Neritic biota**	**Rock fragm. %**	**Glauconite %**	**Matrix/ cement type**	**Lithostratigraphic unit**	**Neritic biota**	**Rock fragm. %**	**Glauconite %**	**Matrix/ cement type**
Cergowa Sdst.	F	0 - 3.	–	MC	Mszanka Sdst.	F	0 - 3.	>1.0	NC - MC
Gródek Sdst.	–	0 - 1.	2.5 - 12	NC	Magura Glauconitic Sdst.	R	2.4 - 9.3	1.2 - 2.8	MC
Poprad Mb	–	18. - 22.	–	MC					
Piwniczna Mb	–	12. - 16.	–	PC - MC	Pasierbiec Sdst.	A	1. - 15.0	>0.5	HC
Ciê¿kowice Sdst.	VR	1. - 7.	>1.0	NC	Ciê¿kowice Sdst.	F	0 - 11.5	0 - 5.0	PC - HC
Upper Istebna Bd	VR	0 - 11.	>1.0	NC(MC)	Mutne Sdst.	F	0 - 13.0	>1.0	MC(NC)
					Inoceramus Beds	R	0 - 15.5	0 - 5.0	HC(NC)
					Jaworzynka Sdst.	R	0 - 9.0	0 - 2.0	MC(NC)
Lower Istebna Bd	–	2. - 9.	>0.5	NC					

–	Absent to very rare
VR	Very rare
R	Rare
F	Frequent
A	Abundant

NC	Non-calcareous
PC	Poorly calcareous ($CaCO_3$ 1 - 7 %)
MC	Moderately calcareous ($CaCO_3$ 7 - 15 %)
HC	Poorly calcareous ($CaCO_3$ >15 %)

Symbols in brackets refer to rare cases

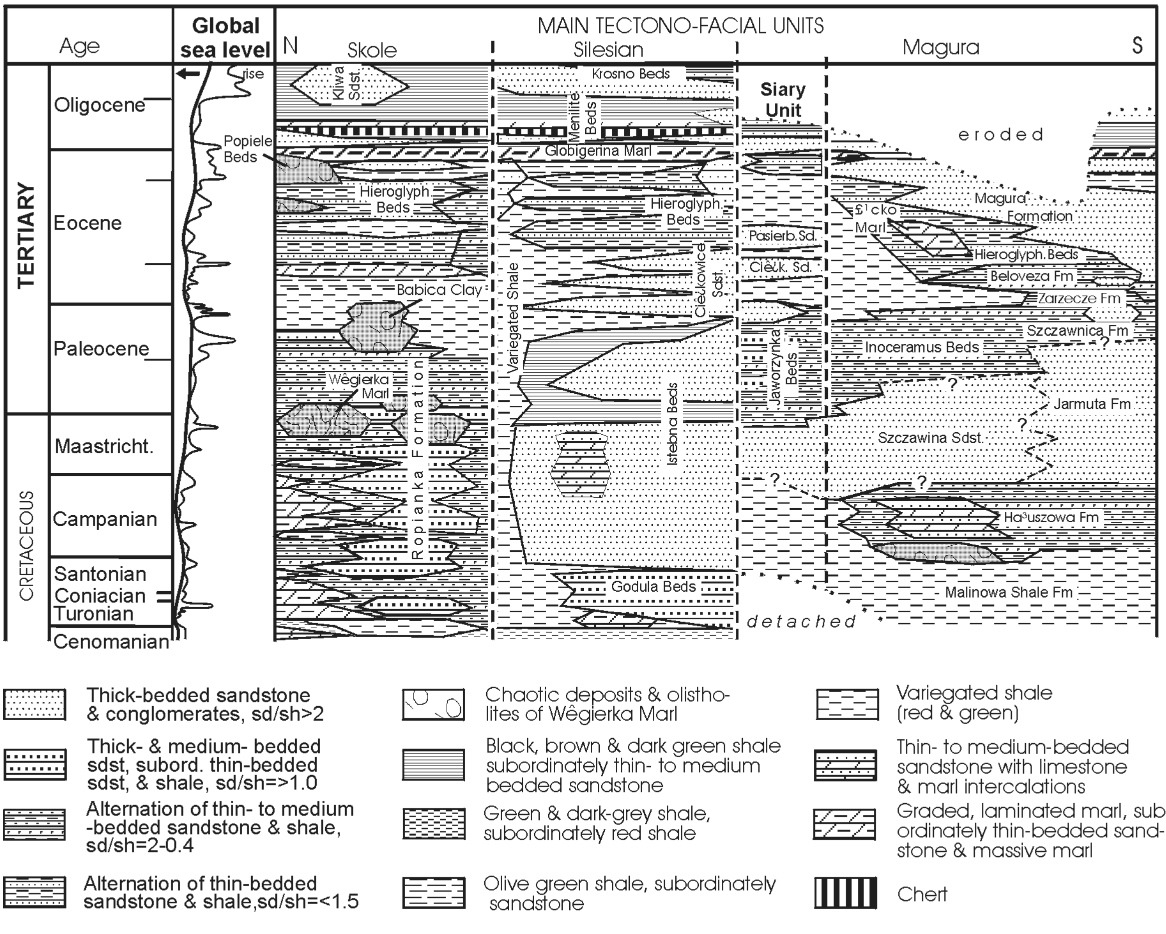

Fig. 1. Stratigraphy of the Upper Cretaceous — Paleogene part of the flysch succession of the main nappes of the Polish Outer Carpathians. Columns show distribution of facies along north–south sections of the nappes.

composed of the material of southerly origin highly prevail volumetrically and in stratigraphic extension over those of northerly alimentation (Fig. 1). The prevalence concerns the Upper Cretaceous–Tertiary part of the flysch succession. It is most evident in the Magura and Silesian nappe where the provenance of the coarse clastic material seems to be clearest.

2. *Difference in distribution of the coarse clastic units of opposite provenance in relation to the eustatic cycles by Haq et al. (1987).* The chief units dominated by the material of southerly origin, such as the Istebna Beds, and the Magura Formation (Fig. 1), do not display any clear correlation with the Haq et al. (1987) curves. They embrace time intervals longer than the long-term cycles shown by the Haq et al. (1987) curves. Nevertheless, location of the minor units, for example the Upper Istebna Sandstone or the Ciężkowice Sandstone, seems to coincide with periods of pronounced short-term sea-level falls of the Haq's et al. (1987) curve. In contrast, distribution of the redeposited units of northerly origin appears to follow the distinctive short-term sea-level falls of the eustatic curve by Haq et al. (1987).

3. *Difference in composition of the material supplied from opposite margins of the flysch basins.* The material supplied from northern sources is enriched in synsedimentary shallow-marine biota, glauconite, calcareous matrix and in more mature siliciclastic components when compared to that supplied from the southern sources (Table 1).

Discussion

The striking differences in the amount of material supplied from opposite directions as well as in its stratigraphic distribution clearly indicates different geotectonic character of the flysch basin margins during the Late Cretaceous–Tertiary history of the flysch sea. An active character of the southern margins seems to be obvious. At the same time, the sediment supply from these margins must have been chiefly tectonically controlled. In contrast, the moderate to negligible sediment supply from the northern peripheries of the basins suggest their rather passive character. Moreover, these features suggest a more gentle sloping of the northern margins, and occurrence of a more distinctive shelf in comparison with the southern margins. All these features support the assumption that the correlation of the coarse clastic units of northerly alimentation with the distinctive short-term sea-level falls is not fortuitous. Consequently, the northerly alimentation of the flysch basins appears to result significantly if not primarily from eustatic control.

Influences of eustasy on the southerly alimentation of the flysch basins were masked by the more serious effects of tectonics. However, chronostratigraphic location of some units, such as the Ciężkowice Sandstone, suggests that in some periods the southerly alimentation could also have been significantly controlled by eustasy.

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LATE VALANGINIAN AND EARLY APTIAN CARBON AND OXYGEN ISOTOPIC EVENTS (ROCHOVICA SECTION, WESTERN CARPATHIANS)

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Key words: C-isotopic stratigraphy, total organic carbon, oceanic anoxic event, primary productivity.

Introduction

The history of the sedimentary cycle and secular variations of biologic evolution, marine and atmospheric composition, oxidation/reduction, climate, erosion and oceanic circulation have been studied using long-term isotopic variation of isotopic O, C, Sr (S) ratios. The most frequent are carbon isotopic events that are equally divided between positive excursions (or simple rise) and negative excursions (or fall). Generally, the positive excursions were ascribed to "oceanic anoxic events" (OAE), or events characterized by gross storage of organic carbon and negative isotopic events were related to catastrophic reduction of primary productivity, although many records suggest a complex origin (Hosler et al. 1996). To interpret oxygen isotope events is not so simple as to do it with the carbon isotope events. The $\delta^{18}O$ excursion in the beds can not only respond to water composition changes, but also to water temperature variations during the sedimentary and (early) diagenetic stages of the limestone formation.

Methods

The isotopic compositions of carbon and oxygen were determined in carbonates using the CO_2 released from the rock samples by reaction with 100 % phosphoric acid. The results are reported in the usual per mil-δ notation relative to PDB international isotopic standard (Michalík et al. 1995, 1999).

Results

Two carbon isotopic events were identified in the Late Valanginian and in the Early Aptian beds in the Rochovica profile of the Pieniny, Vranie, Koňhora, Brodno and Rudina Limestone Formations (Michalík et al. 1995, 1999; Lintnerová et al. 1997). The first positive $\delta^{13}C$ excursion appeared in the nannofossils limestone beds (V4–V5). The background $\delta^{13}C$ level near +1.0 ‰ increased to +2.8 ‰ to indicate a global "greenhouse" event typical for the Upper Valanginian sequences (Weissert & Channell 1989; Lini et al. 1992; Weissert & Mohr 1996).

The Koňhora Formation of Aptian age (Fig. 1) consists of a several meters thick complex of black to dark brown clays and sporadic marly limestone. Silt-sized quartz, remnants of pyritized fauna (ammonites), carbonized fish scales and wood fragments occur sporadically in these "black shales". A characteristic feature of the Koňhora beds is the increase of TOC (Fig. 1) and terrestrial origin of organic matter (Michalík et al. 1999). The positive $\delta^{13}C$ excursion in the superjacent limestone beds probably corresponds to the gross storage of organic matter (or AOE) in the black shale. We suggested that the lower Aptian black shale beds of the Koňhora Formation (Ap1, Fig. 1) can be correlated with the "Selli event" (AOE 1a) (Erba 1994; Lintnerová et al. 1997). The observed decrease of the

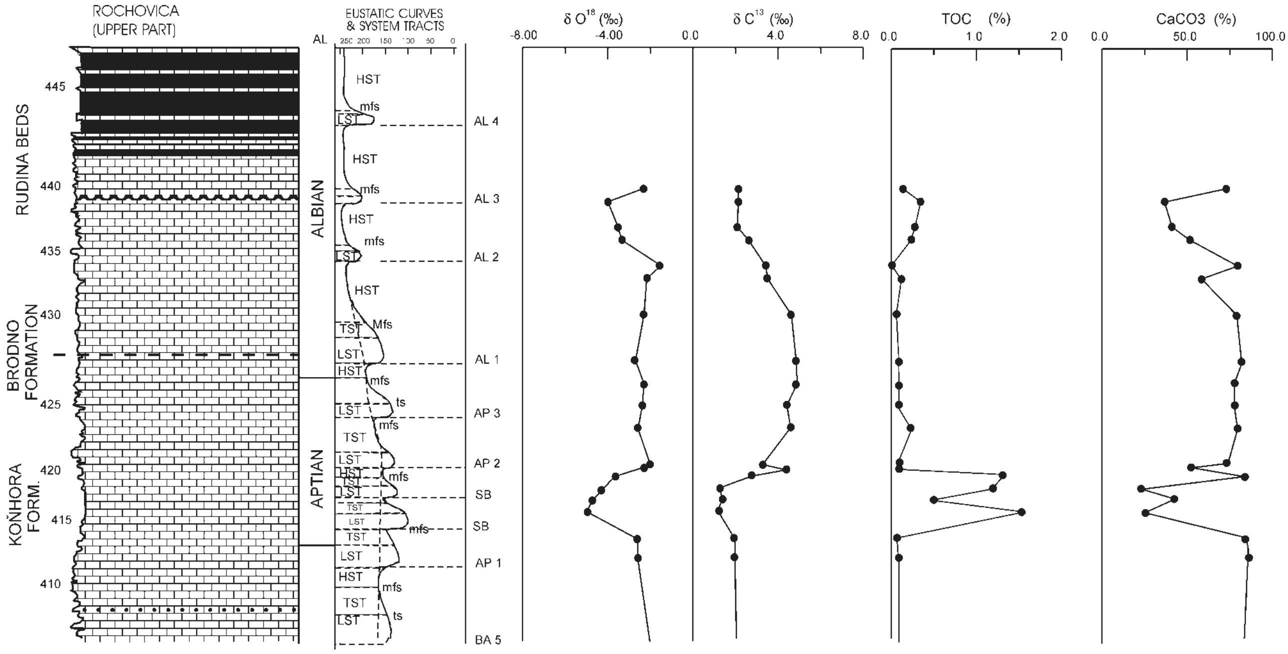

Fig. 1. C and O izotopic excursions in Aptian and Albian beds of the Rochovica section.

δ^{18}O values can be interpreted as the results of water temperature or/and composition (salinity) change in the water stratified middle Cretaceous ocean (Railsback 1990; Hosler et al. 1996). The increased TOC content should correspond to the increased organic matter productivity under greenhouse conditions.

The positive excursion in the carbonate beds of Albian age (AL1-AL2) should either indicate the second middle Cretaceous event, or the global AOE 1b (Fig.1). Because the sequences were tectonically shortened, both events are shown in the scheme as a continuous positive excursion (Fig. 1). The lithofacies changes in the lower Aptian and upper Albian beds correspond to the intensity of increased, or decreased sea level, combined with the input of siliciclastic (terrestrial and volcanic) material, which buried the carbonate sequencies.

Next negative δ^{18}O excursion appeared in the Albian marly limestone, while δ^{13}C values decreased to background values (Weissert & Channell 1989; Lini et al. 1992). A slight increase of TOC contents in the red to gray marls and in lime shale indicates an environment of enhanced organic carbon production. It is probable that no typical black shale formed in the uppermost part of Rochovica section (Fig. 1).

Discussion

C-isotopic stratigraphy is a valuable tool to identify geological events in the sedimentary sequences at regional, or global scales (Weissert & Mohr 1996). C-isotopic stratigraphy helps determine gross changes in the C-oceanic cycle, frequently interpreted as a response of AOE (Hosler et al. 1996). High primary production of surface ocean water is the main factor limiting organic matter storage in the bottom sediments and the formation of black shale facies (Pedersen & Calvert 1990). High productivity of sea water and accelerated terrestrial organic matter input resulted in an increased accumulation of organic carbon in the sediment. Simple presence of anoxia in the water column does not foster burial of organic-rich sediments (Pedersen & Calvert 1990). High accumulation rates of terrestrial organic carbon and formation of deep sea siliciclastic shales indicate that global carbon cycle coincides with the changes of the global water cycles (Lini et al. 1992). Increased volcanic activity and formation of greenhouse climatic condition (excessive CO_2 out-gassing) during the middle Cretaceous times were the sources and/or the reasons why the black shale formed and why was the organic matter stored in these beds. The spatial increase of primary production provides a better explanation for the origin of the carbon-rich Cretaceous shales (Parrish & Curtis 1982) without postulating stagnant (anoxic) oceans, or basins (Pedersen & Calvert 1990).

Observed strongly negative O-isotopic excursion in the Koňhora and Rudina beds correlates well with the TOC excursion and probably the corresponds to water composition and temperature during middle Cretaceous greenhouse conditions. Hot climate, high sea water salinity, stratification, vibrant ocean and greenhouse conditions were probably responsible for the decrease of δ^{18} O values to observed negative values (Railsback 1990).

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ELEMENTS OF MESOZOIC GLOBAL REGIMES AS RECORDED IN WEST CARPATHIAN BASINAL INFILLINGS

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Key words: Western Carpathians, paleogeographical evolution, sedimentary rates, paleoclimate, paleoceanography, eustatic global changes, paleotectonics, orbitally driven cycles.

According to Michalík (1994), the volume of Scythian clastics deposited in the Alpine-Carpathian area could have been derived from 250,000–400,000 km^3 of eroded granitoid rocks from a source area not smaller than 750,000 km^2, the erosional rate being 150 to 200 mm/ka. Thus, during 5 millions of years, more than 100,000 km^3 of terrigenous material was transported towards the sea by rivers. Accordingly, this indicates seasonal Scythian climate with monsoonal periods. Michalík (1993) estimated the subsidence of the whole Carpathian shelf at that time as 5 to 20 mm/ka, while the subsidence of its southern border was ten times higher.

During the Middle Triassic, the several hundred kilometer wide Tethyan shelves were exposed to an extremely hot climate expressed by uniform carbonate sedimentation with indicators of arid, hypersaline conditions. The character of sediments indicates a salinary regime in the adjacent ocean: the only currents were formed by hot saline brines sinking down to the oceanic bottom from marginal shelves. Periods of calm sedimentation contrasted with heavy storm events and with traces of seismic activity (tsunamites; cf. Michalík 1997). The sedimentation rate of Anisian carbonates was 20–39 mm/ka in northern zones of the West Carpathian section of the northern Tethyan shelf, but as much as 100 mm/ka along its southern margin, the subsidence being estimated as 40 mm/ka by Michalík (1993). According to the last author, the deep intrashelf Reifling basins originated during Ladinian left lateral shear movements.

The Lunz/Reingraben clastic wedge indicates an important short change in the global (?) climatic regime, which allowed a change in the salinary conditions and the origin of "glacial" conditions in the world ocean (circulation driven by thermal gradients between cold polar waters and warmer tropical surface waters). Monsoonal conditions in Laurasia have been argued by several authors, being documented by a striking change of sedimentary regime. The amount of fine clastics is astonishing: about 125 thousand km^3 of silt and clay were transported southwards during less than two millions of years !

During the Late Carnian, the salinary regime returned. Extensive basins with Keuper-type sedimentation were controlled mostly by an arid climate, less by tectonics (Dead Sea model). Expressive cyclicity of sedimentary record was ruled by combined orbital (eustatic), tectonic (subsidence) and sedimentological (autocyclic) factors. A renewed pull-apart mechanism resulted in the creation of intrashelf Kössen type basins.

The Hettangian was the time of a new change in the character of the global ocean regime. The carbonate platform system along the Mediterranean Tethys was destroyed by an abrupt climatic and change accompanying a major Early Cimmerian tectonic event (Michalík et al. 1991). The last input from the continent was fine clastics, which crossed the arising Pennine Rift valley. During the Lower Jurassic, carbonate depositional systems renewed on the Mediterranean shelves, being mostly controlled by eustatic global sea regime (Koša 1998, etc.). On the other hand, significant Toarcian extension, probably connected with the main rifting in the Penninic Zone, conditions of warm climate with tendency of stagnant regime and black shale formation has been documented in several basins (Michalík et al. 1994; Plašienka 1999). A significant thermal bottom collapse followed in many Middle Jurassic basins.

The beginning of the Late Jurassic was characterized by the maximum of the Callovian–Oxfordian transgression. Tensional decay of sialic crust affected both the Mediterranean shelf and the microcontinents in this area. This process resulted in condensation of the sedimentary record in basins (Ammonitico Rosso facies). On the other hand, the basinal sedimentation rate attained the highest Jurassic value.

An important change in oceanic current regime is indicated by the middle Tithonian onset of pelagic planktogene limestone (Neocomian type) sedimentation caused by an explosion of calpionellid/nannoconid plankton (Michalík & Reháková 1997). According to the "Neocomian" model of Reháková (1995), this situation should have been caused by the dominance of surface currents. However, Upper Berriasian-Hauterivian countourites have recently been detected in the pelagic limestone sequence (Michalík et al. 1999) indicating the presence of bottom currents at this time. Eustatic, hydrodynamic and geodynamic regime changes are detectable by both the presence of fluxoturbidite intercalations and by fluctuations of quantitative representation of detrital and planktonic skeletal particles in the sediment, as well. Northward transport of clastics into the Zliechov Basin indicates Late Cimmerian compression of the southern margin of the Alpine–Carpathian microplate during the Kimmeridgian and Early Tithonian. Moreover, Late Tithonian and earliest Berriasian tensional tectonics and pull-apart widening of this basin was indicated (Michalík & Reháková 1997).

Events accompanied with minima of biogenic components and anomalies of C isotope contents (Michalík et al. 1999) can be interpreted as deterioration of environmental conditions (probably greenhouse events). Early Aptian minimum was responsible for deposition of black shale Koňhora- and Párnica Formations. Rising sea level the (Phanerozoic maximum was attained during the Cenomanian), anomalous temperature and tectonic activity controlled sedimentation in arising flysch basins. The high Late Cretaceous sedimentary rate was interrupted during the Coniacian.

Comparative sedimentological study of neritic and pelagic deposits focused on paleocurrent indicators can explain several questions of the paleoceanological systems during the Mesozoic.

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MIDDLE JURASSIC-LOWER CRETACEOUS PELAGIC SEQUENCE ANALYSIS IN THE PODBRANČ SECTION, PIENINY KLIPPEN BELT, WESTERN CARPATHIANS

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Key words: Jurassic, Lower Cretaceous, lithofacies, bioevents, biostratigraphy, sequence stratigraphy, Pieniny Klippen Belt, Western Carpathians, Slovakia.

Introduction

Basinal sedimentary evolution in the westernmost part of the Pieniny Klippen Belt the Bajocian to the Aptian was documented on the basis of sedimentological, biostratigraphical and lithostratigraphical studies in the Podbranč Quarry. Nearly continuous sections on three quarry galleries expose a mostly pelagic limestone succession. Depositional sequences were delimited and after comparison with the global sea-level chart several additional sequences were identified. An integrated stratigraphic approach (combination of sequence stratigraphy and „classical„ ammonite and calpionellid biostratigraphy) enabled detailed chronostratigraphic calibration of the sequence.

The outcrops studied belong to the southernmost parts of the Pieniny Klippen Belt. Good exposure gives a possibility of detailed litho- bio-, sequence-, and isotope stratigraphic study. The lithology and structure of the Mesozoic complexes in the Podbranč section was described by Andrusov (1945), Andrusov & Scheibner (1966) and Scheibner (1968). A few years ago, detailed study of the sequence started in order to provide more precise data for its paleogeographical interpretation. The biostratigraphic framework is based mainly on calpionellid distribution (Reháková 1995) supplemented by calcareous nannofossil, calcareous dinoflagellate-, planktonic foraminifer-, radiolarian-, as well as ammonite- and aptychi zonations. Detailed studies of all fossil groups mentioned above are still in progress.

Litho and biofacies

The Jurassic sequence starts with an uppermost Bajocian-Bathonian complex of grey crinoidal grainstones and organodetrital wackestones with yellowish weathering surfaces alternating with marlstones and claystones. It resembles the **Samášky Formation** (sensu Aubrecht & Ožvoldová 1994) represented by crinoidal granitoides with yellowish weathering surfaces, less by wackestones with unperfectly washed-out lime mud. Crinoidal debris, bivalve fragments, ostracods, foraminifers, calcareous dinoflagellates, framboidal pyrite and silt quartz grains are also present. Grey to yellowish marly layers with a rich silty admixture contain abundant sponge spicules, less crinoids and foraminifers of the Nodosaridae, represented by *Lenticulina* div. sp.

The overlying grey nodular limestones are intercalated by two distinct marly layers (with ?volcanogenic admixture) with concentric lime concretions. They are followed by bedded grey cherty limestone passing to redish nodular limestone similar to the **Niedzica Limestone Formation** represented by biomicrite wackestone with abundant "fibres" (cross-sections of thin *Bositra* shells), gastropods, juvenile ammonites, ostracodes, globochaetes, lenticulinid and nodosariid foraminifers**.** Nodules reach 5–8 cm in diameter, frequently being formed by indeterminable ammonite molds, with strongly dissoluted surfaces. The stratigraphical range of this formation is Late Bathonian to Callovian.

The Oxfordian-lowermost Kimmeridgian pelagic sequence consists of regularly bedded brown to reddish-brown silicites and cherty limestones intercalated by thin marly layers. They contain microfossils of the Fibrata Subzone — *Colomisphaera fibrata* (Nagy), *Cadosina parvula* Nagy*,* calcified radiolarians, bivalves, ostracods, crinoids and foraminifers. A distinct, up to 1 meter thick fluxoturbidite layer divides this formation into two parts.

Its overlying middle Kimmeridgian sequence pass gradually to less siliceous limestone marly complex resembling the **Jasenina Formation** (Michalík et al. 1990). Greenish-grey nodular cherty limestones contain abundant *Saccocoma* Agassiz ramulae and secundibrachialia, zoospores of *Globochaete alpina* Lombard, as well as less frequent *Colomisphaera tenuis* (Nagy), *Schizosphaerella minutissima* (Vogler), *Parastomiosphaera malmica* Borza, *Carpistomiosphaera tithonica* Nowak typical for the early Tithonian Tithonica and Malmica zones (sensu Borza 1984). The middle Tithonian sequence is strongly reduced. Gray pseudonodular limestones contain microfossils of the upper Boneti Subzone*:* *Chitinoidella boneti* Doben and *Ch. tithonica* Borza.

Crassicollaria intermedia (Durand Delga), *Cr. massutiniana* (Colom), *Cr. brevis* Remane, *Cr. colomi* Doben, *Calpionella alpina* Lorenz, *C. grandalpina* Nagy, *Tintinnopsella carpathica* (Murg. et Filip.), less frequent saccocomas, globochaetes and calcareous dinoflagellates are present in overlying pale to grey biomicrites intercalated by thin marly layers. Macrofossils are represented by aptychi *Punctaptychus punctatus punctatus* (Voltz), *P. p. rectecostatus* Cuzzi, *Lamellaptychus b. beyrichi* (Oppel), *L. b. rectecostatus* (Peters). The microfossils identified belong to Late Tithonian Remanei-Brevis- and Parvula-Colomi subzones of the Crassicollaria Zone.

Thin-bedded white-gray subpelitomorph limestones of the "majolica" facies with dark cherts (the **Pieniny Limestone Formation**) form the lowermost part of the Lower Cretaceous sequence. The Early Berriasian age of bedded gray cherty biomicrites was proved by spherical *Calpionella alpina* dominating the microfaunal assemblage (Alpina Subzone). It is strongly reduced, followed by associations of Ferasini and Elliptica subzones of the standard Calpionella Zone. Overlying Late Berriasian biomicrite wackestones to packstones of the Calpionellopsis Zone contain *Calpionellopsis simplex* (Colom), *C. oblonga* and (Cadisch), *Lorenziella hungarica* Knauer. Abundant dinocyst form *Cadosina semiradiata fusca* (Wanner) appeared in the interval of increasing calpionellid diversity. The *C. semiradiata fusca* abundance event is visible in every section studied practically throughout the whole West Carpathian area. It coincides with an onset of more pelagic facies (Adatte et al. 1996; Reháková 1998).

The microfaunistic association of the Calpionellites Zone was found in the Lower Valanginian rhythmic sequence of thin bedded marly spotted limestones intercalated by organodetrite and fossiliferous limestone beds. Calpionellids are scarce and poorly preserved, but accompanied by abundant nannoconids and frequent radiolarians and sponge spicules which determine the prevailing type of microfacies. Small primitive lamellaptychi have been found in marly intercalations.

Biomicrite to biomicrosparite wackestones with infrequent biodetritus yield Late Valanginian ammonite association (Trinodosum Zone): *Olcostephanus* cf. *detonii* (Rodighiero). At the same time, an abrupt decrease in calpionellid and nannoconid abundance and diversity was recorded.

The overlying thin bedded dark-grey limestones contain belemnite rostra of *Pseudobelus brevis* (Paquier), ammonite molds of *Teschenites flucticulus* Thieuloy, *T.* cf. *castellenensiformis* Reb. Atr. et Autran, *Neolissoceras grasianum* (d´Orbigny), *Protetragonites quadrisulcatus* (d´Orbigny), *Lytoceras subfimbriatum* (d´Orbigny), *Eleniceras* sp., *Bochianites oosteri* Sarasin et Schoendelmayer, *Neolissoceras* cf. *desmoceratoides* Wiedmann, *Crioceratites nolani* (Kilian), *Crioceratites* sp., *Spitidiscus* cf. *rotula* (Sowerby), *Jeanthieulloyites* sp., *Oosterella* sp., *Olcostephanus* sp., *Abrytusites thieuloyi* Vašíček et Michalík and *Lamellaptychus didayi* (Coquand), *L. seranonis* (Coq.) belonging to Early Hauterivian Radiatus, Loryi, Nodosoplicatus zones.

The Upper Hauterivian part of the sequence contains a rich nannoplankton association dominated by nannoconids, rare ammonites: *Subsaynella sayni* (Paquier), *Crioceratites* ex gr. *duvali* Léveille, *C. majoricensis* (Nolan), *Phylloceras* sp., *Ptychoceras meyrati* Ooster, *Plesiospitidiscus* cf. *ligatus* (d´Orbigny), aptychi: (*Lamellaptychus angulocostatus* (Peters) of the Sayni and Ligatus zones). The youngest Hauterivian Angulicostata Zone is indicated by *Crioceratites binelli* Thomel, *Neolissoceras grasianum* (d´Orbigny) and *Lamellaptychus angulocostatus* (Peters). The marly limestones also contain the first forms of planktonic foraminifers.

Ammonites of *Barremites* sp. and planktonic foraminifers *Praehedbergella* aff. *sigali* (Moullade), *Pr.* aff. *sigali compacta* Banner, indicate Lower Barremian age (Sigali and Similis zones sensu Robaszynski & Caron 1995). Dark-grey marly spotted limestones are intercalated by less distinct calciturbiditic layers. Biomicrite wackestone to packstones are rich in radiolarians and sponge spicules. Ammonites of *Silesites seranonis* (d´Orbigny), *Hemihoplites soulieri* (Matheron), *Barremites* ex gr. *difficilis* (d´Orbigny) characterizing Late Barremian Ferraudianus Zone are accompanied by a planktonic foraminifera association (*Blefuscuiana* aff. *laculata* Banner, *Blefuscuiana* aff. *rudis* Banner, *Praehedbergella* aff. *sigali* (Moullade))of the Globigerinelloides blowi Zone. The upper most part of the Barremian sequence represented by dark marls contains relatively abundant representatives of *"Clavihedbergella" subcreatacea* Tappan.

The Pelagic and calciturbiditic Barremian limestone sequence is capped by almost eight meters of dark calcareous clay to marlstone with sporadic mica leaflets and pyritized microfossils. Its Aptian member contains less frequent limestone intercalations with nannoconids, radiolarians, sponge spicules and planktonic foraminifers: *Blefuscuiana* aff. *rudis* Banner, *Bl.* aff. *occulta* (Longoria), *Bl.* aff. *gorbachikae* (Longoria), *Bl. infracretacea* (Glaessner), *Blowiella* aff. *blowi* (Bolli) and *Bl.* aff. *gottisi* (Chevalier). This abrupt lithological change is similar to the Selli or Koňhora event (Erba l994; Michalík et al. 1999).

Sequence stratigraphic interpretation

Compared with the Samášky Formation, the crinoidal limestone complex is a distal product of basin fan sedimentation accumulated during the latest Bajocian–Bathonian Lower Zuni A-2 Supercycle (Haq et al. 1988). The following A-3 shelf margin- and transgressive stands, indicated by condensed nodular limestone sedimentation, were accompanied by distant volcanism (two disintegrated tuffaceous intercalations). The ZA-3.1 highstand is represented by Callovian cherty limestone. The LZA-3.2 shallowing is recorded by nodular limestone again, with maximum flooding surface nicely indicated by condensation. The uniform upper Callovian/Oxfordian radiolarite and radiolarian limestone sequence is interrupted by a thick fluxoturbidite layer (possible indicator of sea level change ?).

Kimmeridgian and Tithonian sequence (Jasenina Formation) consists of dark grey marlstones and marly limestones. Although sequence tracts are indicated by distinct changes in calcium carbonate content, their recognition is sometimes hampered due to intensive tectonization. The nodular limestones of the Czorsztyn Formation recorded general shallowing during the Late Tithonian.

The Berriasian majolica complex (Pieniny Limestone Formation) is terminated by Be-7 shallowing, widely recorded in the Western Carpathians as the Nozdrovica Breccia. Another tectoeustatic episode during the Late Valanginian, described as the Oravice Event, is recorded as an interval of black marlstone with few siliciclastic intercalations. The latest Valanginian–Barremian sequence of grey rhythmical bioturbated marlstones and marly limestones contains a rich ammonite fauna. The limestone/marlstone rhythms reflect orbital variations of climate. Eustatic changes are recorded by higher carbonate content derived from shallows during shallowing.

The Aptian black shale event (Koňhora Formation) reflects a sudden global (?) climatic change. The increase of terrigeneous influx has been attributed to transport from the continent during a time of anomalously high precipitation (Michalík et al. 1999).

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LOWER TRIASSIC QUARTZITES OF THE WESTERN CARPATHIANS: SOURCES OF CLASTICS, AND TRANSPORT DIRECTIONS

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Key words: Paleogeography, Tatricum, Považský Inovec Mts., Lower Triassic, quartzites.

The aim of our study is to determine the source area of the Lower Triassic quartzites and to propose two alternative paleogeographical schemes. The results from the Malé Karpaty Mts. (Mišík & Jablonský 1978, Figs. 1, 2) and from the Považský Inovec Mts. (submitted now, Fig. 1) show convincingly a transport from the NW; if we take into consideration the additional bending of the Carpathian arc, a transport from the north can generally be admitted. Consistent results from the High Tatra Mts. — the transport from the north, were published by Dźulyński & Gradziński (1960).

The first paleogeographical hypothesis of Michalík (1994) postulated a several hundreds of kilometers long left-lateral shift of the Tatricum with the whole Central-Carpathian Block against the Paleoeurope, including the Outer Carpathian units. In such case, the clastic material for the Lower Triassic quartzites of the Tatricum should have been derived from an Armorican Massif and its prolongation would now be hidden under the platform cover of the Paris Basin (Michalík, l.c. — Fig. 1).

According to the second alternative, which is more or less "autochtonous" and postulates a much smaller left-lateral shift, the eastern part of Bohemian Massif should have been the source of clastics.

Taking into consideration the mature stage of the clastics (e.g. total absence of carbonate rocks) the identification of the source area is very difficult. Only some specific index-rocks, such as a set of tourmalinized rocks (studied now by P. Uher) could shed some light upon the problem. The comparison of the identified clasts in the rocks of the proposed source areas is also handicapped by the erosion of a part of the Pre-Triassic substratum, by its considerable covering under the younger platform strata and by the subduction of the easternmost part of the Bohemian Massif under the Carpathian Belt.

In our previous paper (Mišík & Jablonský 1978) we discussed the Lower Triassic quartzites from the Malé Karpaty Mts. and now we present a similar investigation carried out in the Považský Inovec Mts. and try to compare them with other areas.

Clast analyses. The Lower Triassic quartzites (a part of the Lúžna Formation) contain rare conglomerate or breccia intercalations with dispersed clasts. They are mostly angular (l.c. Table XII, XIII) but at some localities rounded pebbles may also be found (e.g. Pred Kostolným vrchom). Most psephitic clasts are composed of the vein quartz (about 90 %); other most frequent components were graphitic metaquartzites (16×) with metamorphic lamination (10×) or without lamination (6×), tourmalinized rocks (9× — mostly tourmalinized greywackes and tuffites with initial tourmalinization by tiny acicular aggregates, rare tourmaline quartzite and quartz-tourmaline breccia with large spherulitic aggregates), actinolitic greywacke locally with pyroclastic admixture (4×), rosy postvolcanic silicites (2×), rosy rhyolite with β-quartz phenocrysts (1×), rosy spherulitic rhyolite (1×), porphyroid (1×). The Permian age for the mentioned volcanites is highly probable. One clast of the pophyroid with abundant sericite was probably derived from the Early Paleozoic strata. A sedimentary origin can be ascribed to only one clast (the biggest one — 7 cm across) of araucarite *Dadoxylon* sp. (silicified wood of Coniferous tree).

For comparison, some other rock types that are not found in the Považský Inovec, will be mentioned: Malé Karpaty — tourmalinized phyllite, hematite metaquartzite (with 25 % Fe_2O_3), silicite with ostracodes and tiny apatite (chert nodule) and radiolarian lydites (one clast was also found in the Nízke Tatry Mts. and another in the Zemplín Horst).

In the psammitic fraction from the Považský Inovec Mts. the lithoclasts of acid volcanic rocks (felsites, tuffites) prevail over the metaquartzites. The average granularity of the quartzite is about 0.5 mm. The scarce matrix (under 5 % — thin films around grains and some pore fillings) formed from recrystallized illite aggregates; a microquartz cement is exceptional. Syntaxial overgrowths are surprisingly rare and usually occur in samples that underwent an eolian transport (rounded grains and "Dreikanter" pebbles).

The share of feldspars oscillates between 3–20 %; some varieties are in fact arcosic quarzites, thus strongly contrasting with the total absence of granitoid pebbles, typical for Permian conglomerates (e.g. Devín Fm., Meďodoly Fm.) while the orthoclas predominates, the microcline is rare and plagioclas exceptional. The orthoclas grains frequently retain their tabular form indicating a mechanical disintegration (aride climate) and a fast transport. The muscovite is rare, and the biotite is absent except in entirely bleached specimens.

The source area — an elevated peneplain — should have been formed mostly by the Permian rocks of the post-tectonic molasse complexes from acid volcanic rocks and clastic sediments (a single direct evidence of Stephanian–Permian age yielded a *Dadoxlon* clast). Large part of the source area was also formed by the

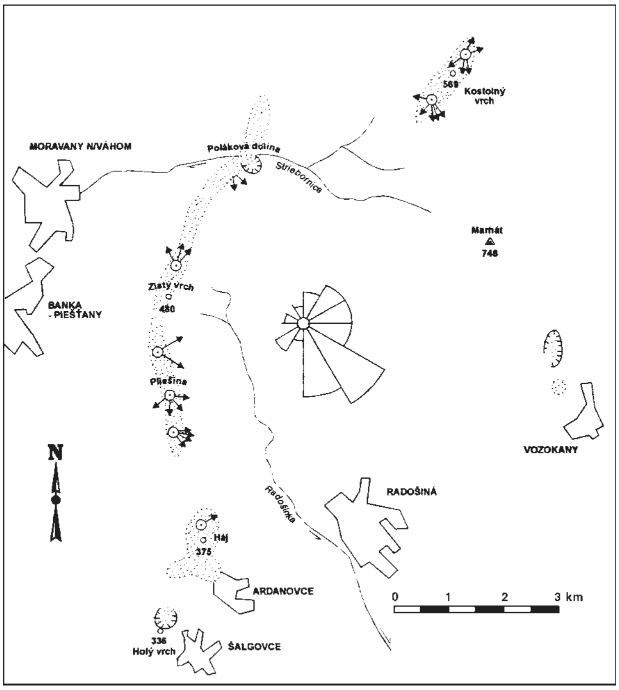

Fig. 1. Outcrops of the Lower Triassic quartzites of Tatricum in the southern part of Považský Inovec Mts. and paleotransport directions interpreted from the 27 cross bedding measurements (see the diagram in the centre).

granitoids disintegrated in the arid conditions. The tourmalinized rocks were probably connected with these granitoid massifs, or come from the intercalations in regionally metamorphosed Moldanubian rocks (Kebrt et al. 1984). Vein quartz, graphitic metaquartzites and other rocks might be redeposited from the Permian conglomerates already without carbonate clasts, or from some outcrops of Paleozoic complexes primarily poor in carbonate rocks. The absence of $CaCO_3$ is total, not even the calcite veinlets, occur in the quartzites. Large amount of vein-quartz clasts comes from the lateral secretion that affected epimetamorphosed complexes. Since the phyllite clasts lack in the Lower Triassic quartzites we assume that they weathered away already before Triassic and their clasts are redeposited from the Permian conglomerates.

The transport of the material to the piedmont areas took place in the ephemeral streams of braided rivers. Local eolian redeposition is less important. The sedimentary enviroment could be designated as bajada. The almost total removal of clayey fraction (outwashed or removed by eolian action) contrasts with the playa deposits.

Because the area covered by Lower Triassic quartzites, from Western Alps to Eastern Carpathians and Northern Apuseni Mts., is very extensive and partly connected to the Buntsandstein platform, it is an international challenge to determine several megafans within this large distributory province containing seemingly homogeneous material. Genetically, most promissing seem to be the clasts with tourmalinized rocks found between Wechsel in the Eastern Alps and Hainburg Mts., but also in the Malé Karpaty Mts., Považský Inovec Mts., Tribeč Mts. and Strážovské vrchy Mts. They are probably absent in the eastern part of Slovakia (Tatra Mts., Nízke Tatry Mts., Malá Fatra Mts. and Zemplín Horst).

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THE LATE EOCENE TO EARLY MIOCENE NANNOPLANKTON STRATIGRAPHY OF THE MAGURA NAPPE (WESTERN CARPATHIANS, POLAND)

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Key words: calcareous nannoplankton, Late Eocene, Late Oligocene, Early Miocene, Magura Basin.

Introduction

The Late Eocene time was a period of unification of sedimentary conditions in the northern part of the Outer Carpathian flysch basin. It was a period of hemipelagic and pelagic deep-water sedimentation. In the Late Eocene, the deposition of variegated shales was replaced by facies of pelagic green shales. These shales pass upwards into the Sub-Menilite Globigerina Marls (SGM) which is the most important Paleogene chronostratigraphic horizon of the Outer Carpathians (see Oszczypko-Clowes 1996). At the same time the Magura Basin revealed a huge differentiation of facies. This was manifested by the northward progradation of the fan-lobe system of the Magura Sandstone Fm (Oszczypko 1992). The variegated shales of the Łabowa Fm and thin-bedded Beloveža facies were laterally replaced by the Magura Sandstone lithosome. With respect to the differentiation of facies, the Magura Nappe is subdivided into four facies-tectonic subunits: Krynica, Bystrica, Rača and Siary (Fig. 1). In the Krynica, Bystrica and Rača subunits the youngest deposits belong mainly to the Malcov Formation and locally to the Zawada Fm, whereas in the Siary Subunit, they belong to the Glauconitic Sandstones (Wątkowa Sandstones) and Budzów Beds (Supra Magura Beds). The sedimentary record and calcareous nanoplankton of these deposits have been studied in Poland as well as in SE Slovakia (Raslavice Vyšné near Bardejov).

Lithostratigraphy

In the Leluchów (Krynica Su) and Raslavice V. (Bystrica Su) sections, SGM of the Malcov Fm occur at the top of the Magura Fm (Middle-Upper Eocene), which is represented by thick-bedded sandstones and variegated shales with *Reticulophragmium amplectens* (Mniszek Sh Mb, see Birkenmajer & Oszczypko 1989). The SGM (Leluchów Marl Mb) are represented by the green marly shales and soft, red and green marls up to 4 metres thick (Fig. 2, see also Oszczypko-Clowes 1996, 1998). In the Leluchów section the SGM are covered by a 19 m of dark Menilite-like shales (Smereczek Shale Mb). The lowermost portion of this member revealed the marly development with a few tuffites intercalations and thin (2–5

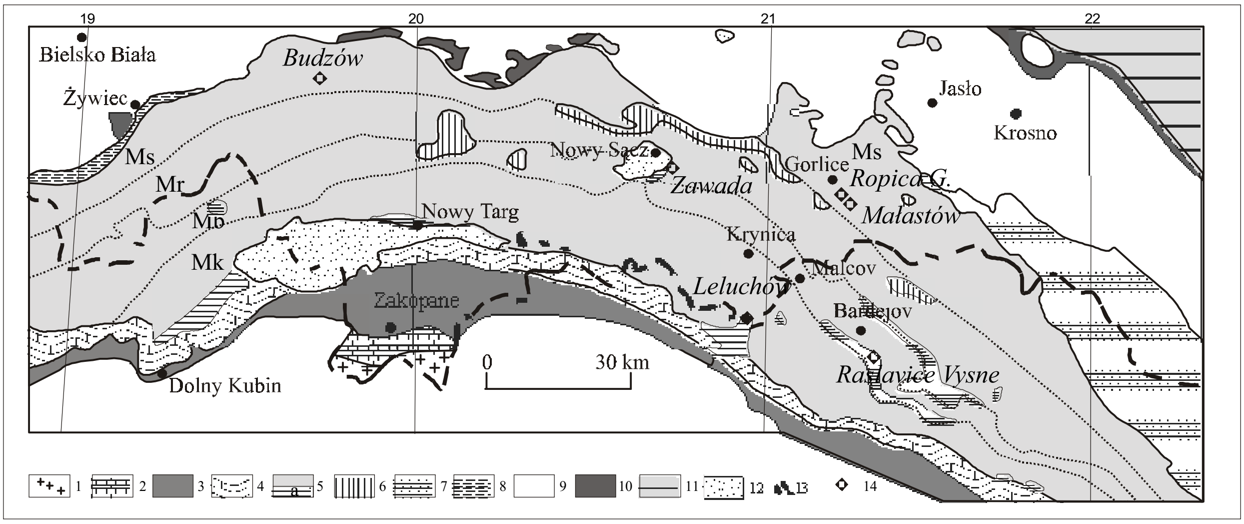

Fig. 1. Tectonic position of the Magura Nappe in Poland and Slovakia (after Żytko et al. 1989, supplemented). 1 — crystalline core of the Tatra Mts., 2 — High Tatra and sub-Tatra units, 3 —Podhale flysch, 4 — Pieniny Klippen Belt, 5 — Magura Nappe, 6 — Grybów Unit, 7 — Dukla Unit, 8 — Fore-Magura Unit, 9 — Silesian Unit, 10 — Sub-Silesian Unit, 11 — Skole Unit, 12 — Miocene deposits upon the Carpathians, 13 — andesite, 14 — investigated area; Su—Siary, Ru— Rača, Bu— Bystrica, and Ku— Krynica subunits.

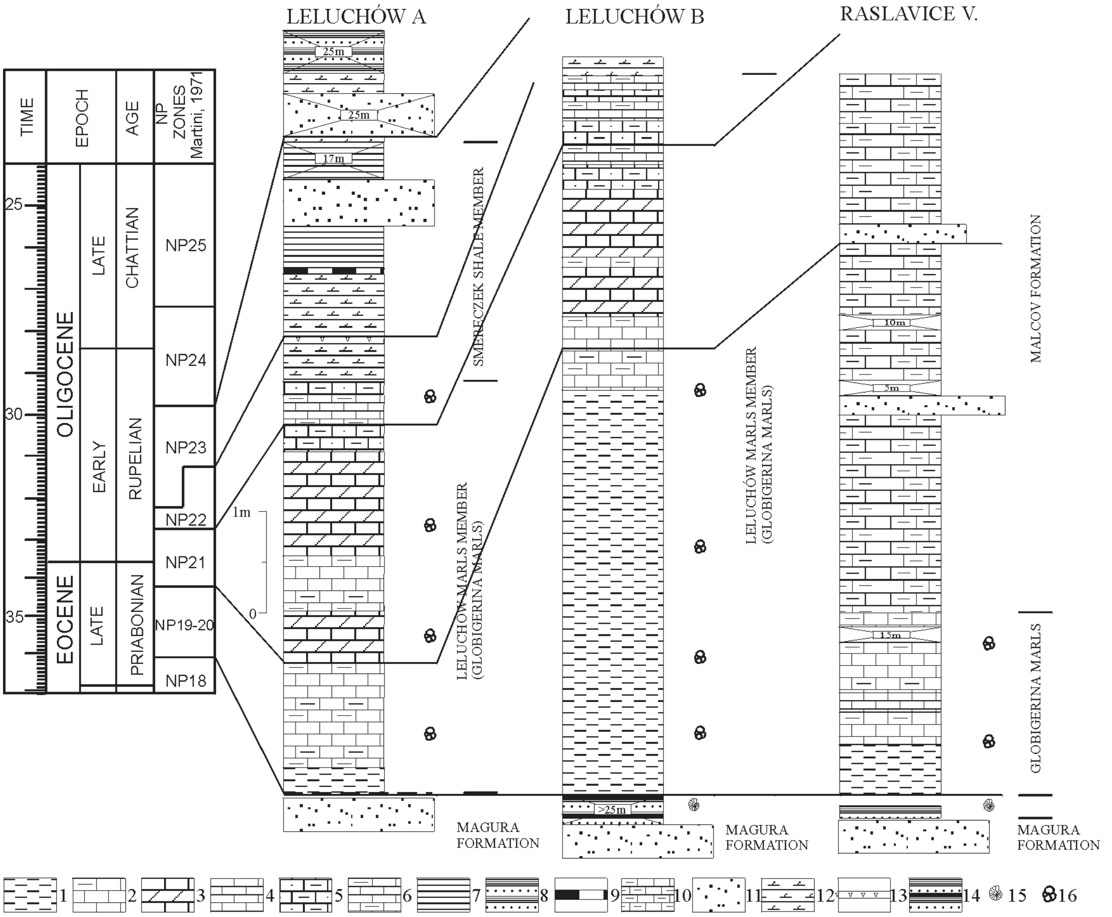

Fig. 2. Biostratigraphic correlation of Leluchów and Raslavice sections. 1 — green calcareous shales, 2 — red marls, 3 — greyish-green marls, 4 — green marls, 5 — olive marls, 6 — grey calcareous shales, 7 — Menilite shales, 8 — thin-bedded turbidites, 9 — hornstones,10 — bege marls, 11 — muscovite sandstone, 12 — greenish-grey marly mudstone, 13 — tuffites, 14 — thin-bedded turbidites with intercalation of red shales, 15 — *Reticulophragmium amplectens*, 16 — SGM type microfauna.

cm) intercalation of hornstones at the top (Fig. 2). The upper portion of the Menilite Shales belongs to black noncalcareous, bituminous shales with a few layers of coarse-grained, thick-bedded sandstone. The uppermost part of this section is represented by the 25 metres of massive thick-bedded sandstones, passing upwards into thin-bedded turbidites of the Malcov Formation (Birkenmajer & Oszczypko

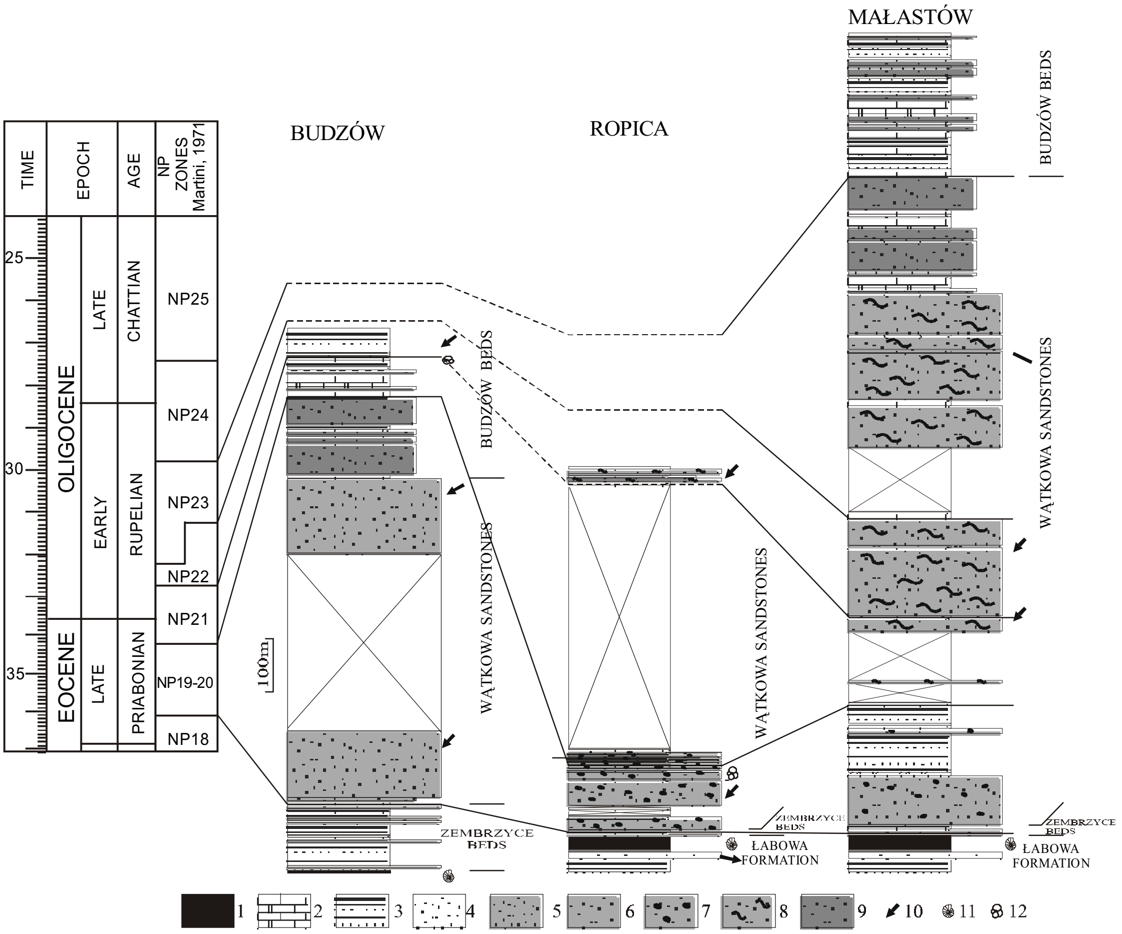

Fig. 3. Biostratigraphic correlation of the Budzów, Ropica G. and Małastów sections. 1 — variegated shales, 2 — turbiditic marls, 3 — thin-bedded turbidites, 4 — conglomerates; quartz-glaukonite sandstones: 5 — medium-grained, 6 — coarse and very coarse-grained, 7 — clasts, 8 — "slurried" sandstone, 9 — glauconite sandstone, 10 — paleotransport direcion, 11 — *Reticulophragmium amplectens*, 12 — SGM type microfauna.

1989). These flat-laying, south dipping strata consist of Krosno-like deposits which are dark-grey, marly shales with intercalations of thin bedded (10–12 cm), cross-laminated calcareous sandstones. In the Raslavice V. section the SGM are represented by green marly shales and red marls occurring at the top of variegated shales of the Magura Fm (Oszczypko-Clowes 1998). The SGM are covered by a 2 m thick complex of pale marls with a sandstone intercalation at the top (Fig. 2). In the uppermost part of the section, a complex of marls with minor sandstone intercalations is exposed. These turbiditic marls and sandstones belong to the Malcov Fm. In the northern marginal part of the Magura Nappe (Ropica, Małastów and Budzów sections, Figs. 1, 3) the Wątkowa Sandstones are underlain by variegated shales of the Łabowa Fm (Lower-Upper Eocene) and by thin-bedded turbidites and marls belonging to the Sub-Magura Beds. The thickness of these beds varies from a few metres in the Ropica and Małastów sections up to 150 m in the Budzów section (Fig. 3). The Wątkowa Sandstone is composed of thick-bedded glauconitic, medium to very coarse-grained sandstones with sporadic intercalations of dark turbiditic marls up to a few meters in thickness. The sandstones revealed the paleotransport direction from NE. The thickness of the Wątkowa Sandstone varies from 600 m in the Budzów section up to 1200 m in the Małastów section (Fig. 3). These deposits pass upwards into the Supra Magura Beds (Budzów Fm) which are turbiditic marls with intercalations of glauconitic sandstone. The thickness of these beds is at least 400 m. Deposits of the Zawada Fm described from the Rača Subunit in the area of Nowy Sącz (Oszczypko et al. in print) reveal the similar development. These folded deposits are represented by medium- to thick-bedded glauconitic sandstones with intercalations of thick-bedded marls and they probably overlap the Malcov Fm.

Biostratigraphy

In the Budzów section (Fig. 3) the Sub-Magura Beds belong to the NP 18 (Late Eocene) zones, whereas in the Ropica section, these beds has been placed into the combined interval zone NP 19–20 (Late Eocene). The samples obtained from the Wątkowa Sandstones contain a calcareous nannoplankton assemblage which has been assigned to zone NP 19–20 for the Budzów section and to zones NP 19–20, NP 21, NP 22, NP 23 (Late Eocene-Early Oligocene) for the Małastów section. In the Budzów section, the calcareous nannoplankton obtained from the Supra Magura Beds has been assigned to zones NP 19–20, NP 21 and NP 22 ?, whereas in the Małastów section, to NP 24 (Late Oligocene), only. In comparison with above described sections, the samples from the Leluchów and Raslavice sections (Fig. 2) contain abundant and well preserved calcareous nannoplankton assemblages (see Oszczypko-Clowes 1996, 1998). In the Leluchów sections SGM has been assigned to zones NP 19–20, NP 21, and NP 22, whereas the Menilite shales to NP 22 and NP 23. In the uppermost part of section, within the Malcov lithofacies, the zone NP 24 has been determined. In the Raslavice section, the zone NP 19–20 has been determined in the SGM as well as in the lowermost part of the Malcov Formation. The youngest deposits so far described from the Magura Nappe belong to the Zawada Fm whose age has been determined as NN 2–3 (Early Miocene) (Oszczypko et al. in print).

Conclusions

1. The nannoplankton research carried out for Leluchów (Krynica Su) sections proved that the Eocene/Oligocene boundary lies within the Globigerina Marls whereas in the Raslavice V. (Bystrica Su) this boundary is located within the Malcov lithofacies. In the marginal part of the Magura Nappe (Siary Su) this boundary has been documented within the Budzów Beds and Wątkowa Sandstone in the Budzów and Małastów section respectively.

2. At the Eocene/Oligocene boundary in the Magura Basin there was evolution of sedimentary conditions from the pelagic deposition in the south (Krynica Su) through the pelagic/turbidite (Bystrica Su) into the thick-bedded turbidite deposition in the north (Siary Su).

3. The flysch deposition in the Magura Basin persisted at least to the Late Oligocene and locally to the Early Miocene.

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ON THE AGE OF MIDDLE-UPPER JURASSIC RADIOLARITES IN THE EASTERN PART OF THE PIENINY KLIPPEN BELT

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Key words: Jurassic, Western Carpathians, Pieniny Klippen Belt, radiolarites, radiolarians.

Data on the age of Middle–Upper Jurassic radiolarites in the Pieniny Klippen Belt based on superposition become more precised by the study of radiolarian microfauna.

In the eastern part of the Pieniny Klippen Belt the initial investigation of radiolarian microfauna by Ondrejíčková (1985), was performed within the geological research of this area (Nemčok et al. 1982, 1986, 1990). The further study of radiolarians from a radiolarite horizon in the Pieniny part (locality Podsadek near Stará Ľubovňa) and the Šariš part (locality Šarišské Jastrabie, Kyjov, Lúčka and Milpoš) was done by Ožvoldová & Frantová (1997). According to Nemčok et al. (1990) the radiolarites in this area belong to the Pieniny Succession s.l.

The research of five sections from the locality Litmanová provides further knowledge on the age of these strata (Ožvoldová, Jablonský & Frantová in press). The radiolarite horizon is formed here by radiolarian limestones (radiolarian wackestone-packstone) of green-grey or pink-grey colour in the lower part and rusty-red one in the upper part of the sections, with radiolarian cherts and irregular layers of radiolarites. They overlie crinoidal limestones and underlie Czorsztyn nodular limestones.

Radiolarians occur in all samples, but the possibility of separation is complicated by frequent calcification of the tests, or occurrence of molds only. In all assemblages spumellarians highly prevail over nassellarians (70–80 %). The new species *Archaeospongoprunum mizutanii* Ožvoldová, n.sp. was described here.

The occurrence of the species *Emiluvia ordinaria* Ožvoldová, *Angulobracchia biordinalis* Ožvoldová, *Fultacapsa sphaerica* (Ožvoldová) with *Paronaella mulleri* Pessagno, *Tritrabs casmaliaensis* (Pessagno), *Paronaella broennimanni* Pessagno and *Paronaella pristidentata* Baumgartner with *Pseudocrucella adriani* Baumgartner in the assemblages results in the conclusion, that the studied sections represent, according to the biozonation of Baumgartner et al. (1995), the stratigraphical range — middle-late Oxfordian to late-early Kimmeridgian (U.A.Z.9–U.A.Z.10).

Up to now the results of our research show, that Middle-Upper Jurassic radiolarite horizon in the Pieniny and Šariš part of the Pieniny Klippen Belt is represented by:

1/ Dark-grey, green-grey, non-calcareous to weakly calcareous (max. 0.36 % of CaO) radiolarites with Mn coatings (max. 3.16 % of Mn) (Sokolica Radiolarite Formation according to Birkenmajer 1977), which are overlain in the lower part by green-grey to grey-green and in the upper part rusty-red radiolarites (Podmajerz Radiolarite Member and Buwald Radiolarite Member of the Czajakowa Radiolarite Formation according to Birkenmajer l.c.). These radiolarites underlie red Czorsztyn nodular limestones in the locality Šarišské Jastrabie. The underlying and overlying layers in the locality Lúčka are uncovered, but the radiolarites are similar to those in the locality Šarišské Jastrabie. The strata belong to the Kysuca Succession.

Using the biozonation of Baumgartner et al. (1995) the radiolarian fauna from the locality Šarišské Jastrabie represents the middle Callovian-early Oxfordian to late Oxfordian-early Kimmeridgian (U.A.Z.8–U.A.Z.10) and from the locality Lúčka — the upper part of this stratigraphical range — middle-late Oxfordian to the late Oxfordian-early Kimmeridgian (U.A.Z.9–U.A.Z.10).

2/ Green, in the upper part red radiolarian limestones with radiolarian cherts and the irregular layers of radiolarites of the same colours (Czajakowa Radiolarite Formation), which overlie crinoidal limestones and underlie red Czorsztyn nodular limestones (loc. Litmanová) or Kimmeridgian-Tithonian limestones (loc. Podsadek, Milpoš). Strata show the correspondence to the Czertezic Succession. Radiolarian assemblages show the stratigraphical range — the middle-late Oxfordian to the late Oxfordian-early Kimmeridgian (U.A.Z.9–U.A.Z.10).

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CORRELATION OF THE LOWER CRETACEOUS LITHO- AND BIOFACIES FROM THE UKRAINIAN SECTOR OF THE PIENINY KLIPPEN BELT

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Key words: Carpathians, Pieniny Klippen Belt, Svalyava and Tissalo Suites, Berriasian-Albian, Lower Cenomanian, lithostratigraphy, biostratigraphy.

Introduction

The Ukrainian sector of the Pieniny Klippen Belt (Pieniny tectonic unit) is a very complicated structure consisting of Mesozoic and Paleogene lithostratigraphic successions, which are connected by tectonically or stratigraphically comformable contact. The relationships between these deposits and the Klippen successions of the adjacent Slovak and Polish sectors of the Belt are still disputed.

Comparative analysis of the litho- and biofacies

The Pieniny tectonic unit occurs on the surface as narrow stripes, separating the Flysch Carpathians from the Transcarpathians depression. The Lower Cretaceous sequence in the studied area occupies the full time interval from the Berriasian to Albian and is represented by the Svalyava and Tissalo Suites.

The first of them is formed by light coloured pelitic limestones with cherts and seldom black and green shale interbeds. As a result of complicated tectonic development, these sediments can be observed on the surface only as separate fragments or sections. The Tithonian–Barremian age of the Svalyava limestones is based on the occurrences of Ammonites, Radiolaria, Calpionellids and Foraminifera (Kalenichenko & Kruglov 1966; Linetska 1968; Lozyniak 1969; Ponomaryova 1998). As a rule these fossils are seldom found, in most cases badly preserved and did not provide identification of the stage boundaries. On the whole the litho- and biofacies of the Svalyava Suite reflects sedimentary environments similar to the Pieniny Limestone Formation, widespread in practically all basinal successions of the Pieniny Klippen Belt from Vienna to Pojana Botizii (Romania). These deposits display a uniform facies and are presented by siliceous light coloured limestones with cherts. In the upper part of sections they become darker and thin black shale intercalations appear there. The Tithonian–Barremian age of the Pieniny limestone formation is based mainly on the calpionellids and aptychus biozonation (Birkenmajer 1977; Vašíček, Michalík & Reháková et al. 1992).

Tissalo Suite overlie the Svalyava limestones with a gradual transition and consist of black, grey and green marls with rare limestone and shale intercalations. These sediments are found in many sections in the basins of the Uzh, Latorytsa, Borzhava, Luzhanka, and Tereblya rivers. The typical locality is exposed at the left tributary of the Luzhanka–Kamenytskiy stream.

In the most of the sequences two parts can be distinguished in the Tissalo succession. The lower of them is formed by black and dark grey marls, limestones and shales. The foraminifers in these beds are seldom found and represented mainly by calcareous benthic species. Three foraminiferal biozones: Globigerinelloides ferreolensis, Discorbis wassoewiczi and Ticinella roberti, have been identified in the lower part of the Tissalo Suite. They indicate the Aptian–Lower Albian strata. These beds correspond to a lower part of the Kapuśnica Formation known as the Brodno Member (Aptian–Lower Albian) (Birkenmajer 1977) or Koňhora Beds (Salaj 1995).

In the upper part of the Tissalo Suite green and grey marls are dominant. Red and spotty marls appear towards the top. The planktonic foraminifers are very abundant there. Thalmanninella subticinensis, Thalmanninella ticinensis, Rotalipora appenninica and Thalmanninella brotzeni zones have been recognized. They indicate the Middle Albian–Lower Cenomanian strata (Salaj & Samuel 1984). This part of the sequences can be correlated with the Rudina Member (upper part of Kapuśnica Formation) and the lower part of the Jaworki Formation (Brynchkowa Marl Member) (Birkenmajer 1977; Bąk K., Bąk M. & Gasiński et al. 1995). According to Salaj (1995) the Albian–Lower Cenomanian strata of the Kysuca succession are designated the Tissalo Beds.

Conclusions

This study made it possible to correlate the Svalyava Suite with the Pieniny Limestone Formations and the Tissalo Suite with the Kapuśnica Formation and lowest part of the Jaworki Formation (Klippen successions of the Slovak and Polish sectors of the Pieniny Klippen Belt).

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RADIOLARIANS FROM THE VARIEGATED SHALE FORMATION (PALEOCENE–EOCENE) IN THE SKOLE UNIT, POLISH FLYSCH CARPATHIANS

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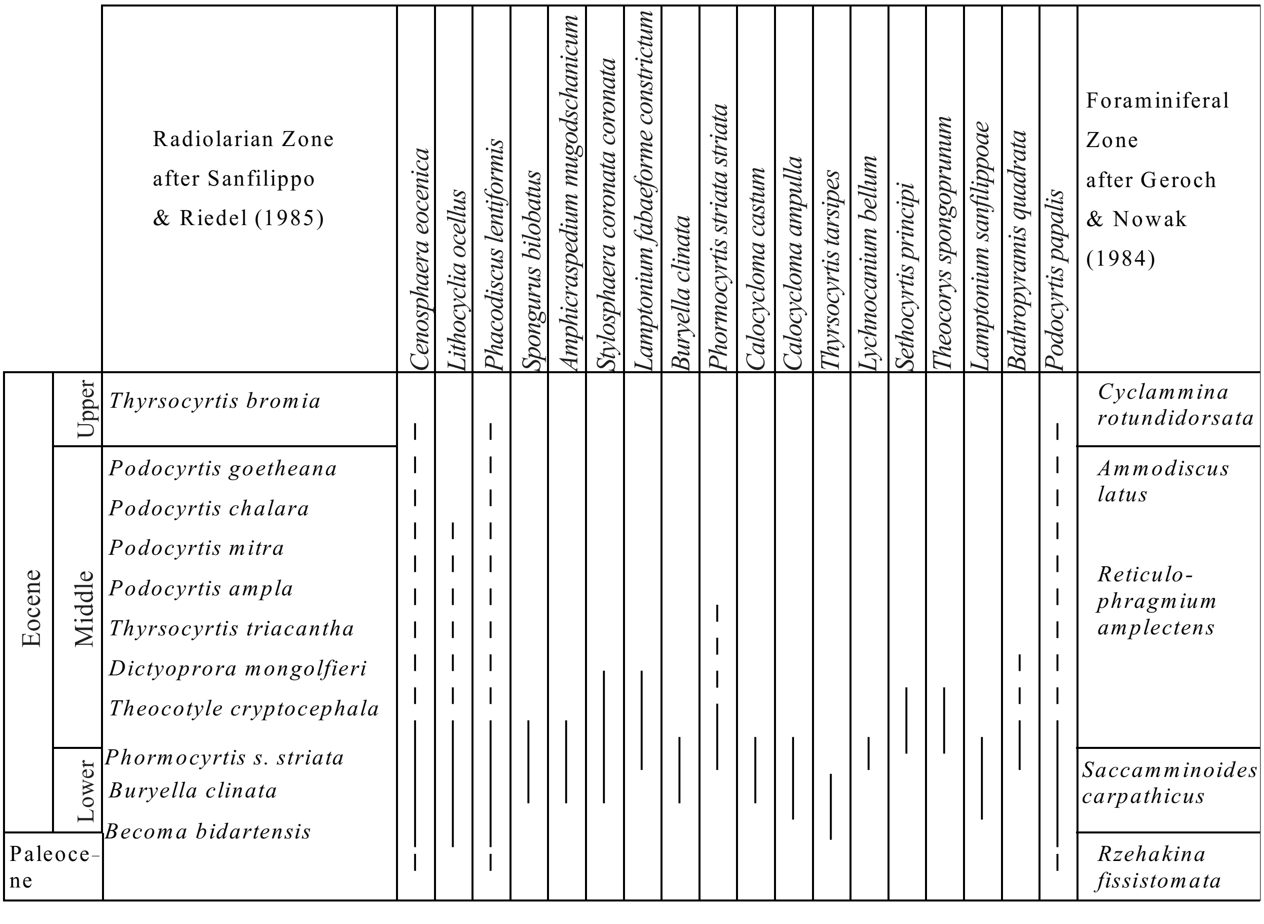
Key words: Paleogene, Poland, Outer Carpathians, Skole Unit, biostratigraphy radiolarians.

We studied the distribution and biostratigraphical significance of radiolarian fauna in the Paleogene deposits of the Skole Unit (Fig. 1). The Upper Paleocene up to the Upper Eocene deposits are dominated by pelagic variegated shales with variable amounts of siliciclastic intercalations. Several lithostratigraphical units, based on lithological characteristics have been distinguished (Rajchel 1990) and are included to two formations — Variegated Shale Fm. and Hieroglyphic Fm., and they occur between the Ropianka Fm. and Menilitic Beds (Fig. 2). The variegated shales of the both formations are represented mainly by red and green shales, and also by grey shales, claystones and mudstones. The investigation of Radiolaria concentrated especially on their biostratigraphical value and the comparison between diverse strata. The quantity and quality changes of distribution of radiolarians, especially near the Paleocene/Eocene, Lower/Middle Eocene and Middle/Upper Eocene boundaries, are the most important in radiolarian biozonation and in the reconstruction of paleoceanographical conditions throughout the time, within northernmost part of the Carpathian basins, according to wider (even global) paleogeographical and paleoclimatical contexts (Thomas & Shackleton 1996). The most abundant radiolarians occur in middle part of the Lower Eocene deposits of the Trójca Red Shale Mbr. This unit consists of vermilion and brick-red clinoptillolite-montmorillonite claystones of about 20–30 m in thickness with a lot of Fe-Mn concretions and pyroclastic material (Rajchel 1994).

Table 1: Biostatigraphy of the Variegated Shale Fm. based upon Radiolaria and deep-water agglutinated Foraminifera (DWAF).



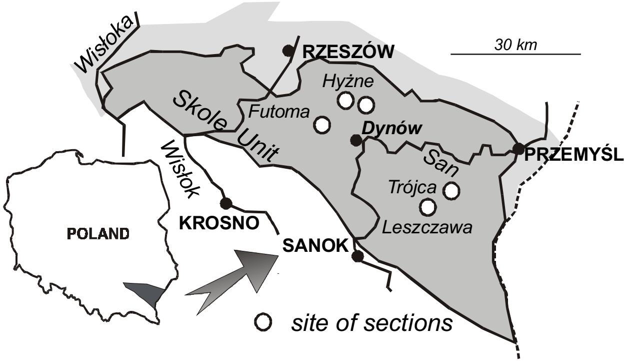


Fig. 1. Location of sections with radiolarian-bearing Paleocene-Eocene deposits.

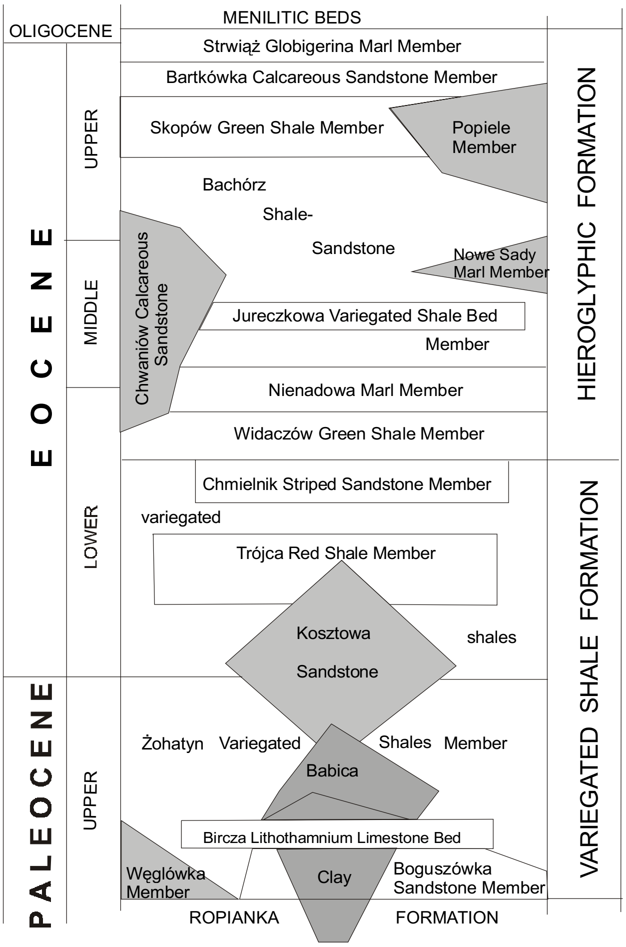


Fig. 2. Lithostratigraphy of the Variegated Shale Fm. and the Hieroglyphic Fm. in the Skole Unit.

The Radiolaria/Foraminifera ratio within a member suggests the deposition of this hemipelagic/eupelagic deposits below CCD and could be located at lower bathyal and abyssal depths (Olszewska 1984; Bąk et al. 1997) where the high oxydation took place, even near the bottom (Leszczyński & Uchman 1991). The younger variegated shales belonging to the Hieroglyphic Fm. (especially their upper part — Upper Eocene) are poorer in Radiolaria, presumably as an effect of a paleoenvironmetal change connected with the decrease of intensity of oceanic circulation.

The radiolarian fauna consists of more than 50 species. The Spumellaria are dominant in their specimens frequency but not the diversity. Most of the species are rather long-lived ones. Nassellaria in their specimens frequency are rare or common but more diverse. The radiolarian fauna in the discussed area was included in the biostratigraphical zonation scheme (Sanfilippo & Riedel 1985). Most of Nassellaria species are zone-diagnostic ones. *Buryella clinata* and *Phormocyrtis striata striata* are the index species in the radiolarian biozonation (Table 2). Paleocene fauna is missing or very poorly represented by Spumellaria which has no stratigraphical value. In the Upper Eocene Radiolaria are few and not diagnostic. Foraminifera (almost only agglutinated ones) have a different frequency. The foraminiferal assemblages were included to deep-water agglutinated foraminiferal zones (DWAF) (Geroch & Nowak 1984).

The reconstruction of paleoceanographical conditions within Carpathian basin were based both on the sedimentological and paleoecological investigations of the uppermost Cretaceous-Paleogene deposits of the Skole and Subsilesian Units. Probably an upwelling type of circulation took place during an this time. It suggests the occurrence of regional Maastrichtian horizons of huge phosphorite concretions (within Węglówka marls) which originated on a submerged pelagic swell (the Subsilesian Ridge). On the other hand, the mass occurrence of Radiolaria especially within the Lower Eocene variegated shales indicate a high primary organic production. Most likely it was due to an increased supply of nutrients carried by cold currents from deeper parts of the basin. Such phosphate structures and changes of foraminifera/radiolarian ratio during the Paleocene-Eocene presumably reflect fluctuations of intensity of upwelling currents which usually occur near the shelf/slope edge. Paleoclimate modelling (maps depict air pressure, wind directions, humid zones and areas favourable for upwelling conditions plotted on the paleogeographic background — PALEOCLIMATE program) suggests that prevailing Cretaceous-Paleogene wind directions in the northern Tethys were parallel to the axis of Outer Carpathian basins.

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EVOLUTION AND DISTRIBUTION OF THE LATE JURASSIC AND EARLY CRETACEOUS CALCAREOUS DINOFLAGELLATES RECORDED IN THE WESTERN CARPATHIAN PELAGIC CARBONATE FACIES

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Key words: Jurassic, Lower Cretaceous, calcareous dinoflagellates, biostratigraphy, paleoecology, Western Carpathians, Slovakia.

Introduction

The organisms considered today as calcareous dinoflagellate cysts were first described by Kaufmann (1865). Single-chambered, sphaerical to ovoid Mesozoic and Cenozoic organisms, described under the collective term "calcispheres" (Bonet 1956), are generally classified as calcdinocysts (Keupp 1980a,b) within the family Calciodinellaceae Deflandre 1947. According to the crystallographic orientation of the c-axes of the calcite crystals forming the outer wall of a cyst, Keupp (1987) and Kohring (1993) established the following four subfamilies: a) Pithonelloideae; b) Obliquipithonelloideae; c) Orthopithonelloideae and d) Fuettererelloideae. In contrast, the Calciodinelloideae were established as a subfamily within the family Peridiniacea in the classification system proposed by Fensome et al. (1993). Reháková & Michalík (1996) used a combination of optical and scanning electron microscope investigations and found a serious complication in the systematic concept proposed by Bolli (1974) and Keupp (1987). According to Hildebrand-Habel & Willems (1997) all the above mentioned investigations should have been accepted in the new system of calcareous dinoflagellates of Janofske, Keupp & Willems (in prep.).

Distribution patterns of calcareous dinoflagellates

Late Jurassic and Early Cretaceous assemblage of calcareous dinoflagellate cysts has been systematically studied in several selected sections through pelagic carbonate sequences of the Western Carpathians. The phyletic evolution of calcdinocysts studied includes a number of events favourable for a detailed interregional and intercontinental correlation in regions as are the Western Carpathians, where the cephalopod remains (ammonites, belemnite rostra, aptychi) are rare. The investigation of vertical distribution of the calcareous dinoflagellates in the Late Oxfordian to Upper Albian sedimentary sequences has shown a qualitative (first and last occurrence FO, LO; exctinction), quantitative (acme accumulation, high and low abundance of the cyst taxa) as well as their diversity changes (Fig. 1).

The distribution, diversity and abundance investigations of the dinocyst taxa and their associations lead to a revision of the previously established combined calpionellid-cyst zonation (Borza 1984). The distribution patterns of the cysts under study permit a rough selection of the diagnostic bioevents suitable for a definition of the determined cyst zones. A separate dinocyst zonation is proposed. In order to create a separate cyst biozonation, series of successive first occurrences and acme accumulations of calcareous dinoflagellates were recorded. Consequently, the following dinocyst zones are proposed: Ten cyst zones Moluccana Nowak 1976, Borzai Nowak 1976, Tithonica Lakova et al. 1999, Malmica Nowak 1968, Tenuis Řehánek 1992, Fortis Řehánek 1992, Proxima Řehánek 1992, Wanneri Lakova et al. 1999, Valanginiana Lakova et al. 1999, Echinata Lakova et al. 1999, by now existing are accepted, further four zones (Parvula, Semiradiata, Vogleri, Cieszynica–Olzae) and seven ecological event zones (acme Fibrata, acme Parvula, acme Pulla, acme Fusca, acme Minuta, acme Oraviensis, acme Innominata) were distinguished.

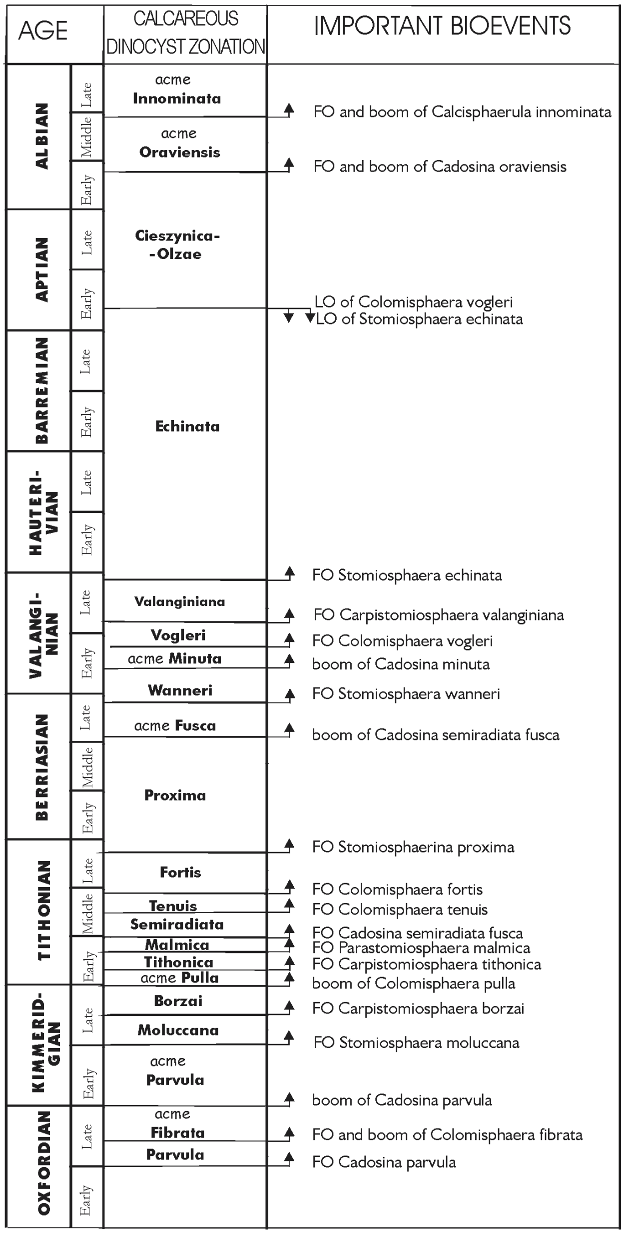

Fig. 1. Calcareous dinocyst zonation and important bioevents recorded in the Upper Jurassic and Lower Cretaceous carbonate pelagic sequences of the Western Carpathians.

Conclusions

Dinoflagellates formed a significant element of the marine phytoplankton during the Jurassic and Cretaceous, when they occurred throughout the world in the open shelf, slope and basinal environments. Due to very favourable conditions for the development of the planktonic associations, a rich and structured ecosystems could originate in the phothic zone of the Tethyan Realm during this time. Certain dinoflagellate taxa formed resistant calcareous/or sporopollenine cysts which were the only potentionally fossilisable stage of their life cycle. The focus of this study were the calcareous dinocyst associations. The investigation of their vertical distribution allowed us to:

a) propose an independant dinocyst zonation which can serve as one of the important tools of the integrated biostratigraphy of the Upper Jurassic and Lower Cretaceous carbonate deposits of the Western Carpathians;

b) correlate this zonation whith the dinocyst zonation established recently in the East Carpathian area in order to show its interregional availability;

c) distinguish several diversification events and diversity reduction events among the cyst associations studied in order to utilize them in a paleoenvironmental reconstruction. It seems that calcareous dinoflagellates also belonged to those planktonic elements that sensitively recorded a whole complex of environmental changes, such as climate perturbations, sea-level fluctuations and nutrient distribution.

This approach offers good arguments for establishing an integrated, high-resolution event, stratigraphic (HIRES) scale of the Western Carpathian Upper Jurassic and Lower Cretaceous pelagic sequences.

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UPPER TRIASSIC BRACHIOPOD FAUNA OF STEINPLATTE NEAR WAIDRING, AUSTRIA

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Key words: Upper Triassic, Brachiopods, Steinplatte, Northern Calcareous Alps.

Steinplatte is a world-wide known locality of the Upper Triassic “reef” complex at the Salzburg/Tyrol borderland near to Waidring, Tyrol. A very detailed study of the Steinplatte “reef” complex was published in 1989 by Stanton & Flügel bringing wealth of new data on Steinplatte including its microfacies etc.

Local Uppermost Triassic brachiopod fauna has been studied in the last few years, from both the shallow water carbonates — so-called Oberrhätkalk — and from basinal Kössen Formation. The latter occurrences are studied in the frame of the grant No. A3013801/1998 (Grant Agency of the Academy of Sciences of the Czech Republic).

The finds of the Triassic brachiopods of Steinplatte were mentioned already by several authors, starting with Hahn (1910) who found a series of brachiopod species coming mostly from the Kössen Beds. My recent studies of the brachiopod fauna of Steinplatte have been focused on 4 localities of the “Oberrhätkalk” and 6 localities of the Kössen Beds. Results of the study of brachiopods coming from the shallow water carbonates were already published (Siblík 1989), the study of brachiopods from the local Kössen Beds is almost finished. It is interesting that there was no mention of characteristic Rhaetian rhynchonellid *Austrirhynchia cornigera* (Schafh.) in the older literature on Steinplatte. My new samplings in the shallow water limestones (“Oberrhätkalk” = “Steinplattekalk”) yielded:

Thecospira haidingeri (Suess), *Fissirhynchia fissicostata* (Suess), *Austrirhynchia cornigera* (Schafh.), *“Rhynchonella”* ex gr. *subrimosa* (Schafh.), *Zugmayerella uncinata* (Schafh.), *Zugmayerella koessenensis* (Zugm.), *Laballa suessi* (Zugm.), *Oxycolpella oxycolpos* (Suess), *Rhaetina gregaria* (Suess), *Rhaetina pyriformis* (Suess), *Rhaetina* aff. *elliptica* Dagys, *Triadithyris gregariaeformis* (Zugm.), *Zeilleria austriaca* (Zugm.), and *Zeilleria norica* (Suess). The most variegated brachiopod fauna of the Kössen Beds was ascertained at the locality Köhrgatterl (Dreiländereck) which exposes upper parts of Kössen Formation — the Eiberg Member. Based on common *Oxycolpella oxycolpos*, this locality exhibits most probably the *Oxycolpella*-biofacies sensu Golebiowski (1991).

To draw the conclusion, it can be stated that the specific composition of brachiopod assemblages from both “Oberrhätkalk” and the Kössen Formation of Steinplatte are nearly the same. In contradiction to the “Oberrhätkalk” localities, the Kössen Beds yielded *Sinucosta emmrichi* (Suess) and *Zeilleria elliptica* (Zugm.) but were devoid of *Laballa suessi* (Zugm.), *Triadithyris gregariaeformis* (Zugm.) and *“Rhynchonella”* ex gr. *subrimosa* (Schafh.).

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PALYNOLOGY AND ENVIRONMENT OF THE WESTERN PART OF THE TETHYS

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Key words: Senonian, integrated palynostratigraphy, Normapolles, dinoflagellates, environment, Pelso- and Tisza Units, Hungary.

Introduction and method

The Upper Cretaceous formations in the territory of Hungary developed in two separated sub-basins in the northern part of the Mediterranean Domain of the Tethys realm. Because these areas (Pelso- and Tisza Unit) were situated in various distances from the land, their environments formed in different ways.

The palynological method can be used for the correlation of freshwater- and marine formations, integrating terrestrial origin pollen- and spore zones, with marine origin dinoflagellate zonation.

The Pelso Unit

In the Pelso Unit two types of Senonian sequences are developed: the Transdanubian type (Transdanubian Central Range) and the Gosau type (N Hungary, Uppony Mts.).

The Transdanubian type

Bauxite deposits can be found in the TCR only in the footwall of the Senonian formations of different ages. By the palynozones the most probable age of the covering process of the bauxite deposits can be obtained (Siegl-Farkas 1991). The bauxite deposits (Nagytárkány Bauxit-, Halimba Bauxit Formations and Kozmatag Formation) are covered either by the fluviatile-lacustrine Csehbánya-, the lacustrine-swampy Ajka Coal-, or by the marine Jákó Marl- and Ugod Limestone Formations. From this classical transgressive sequence only the most extended and the youngest marine Polány Marl Formation has a no connection to the Senonian bauxite horizon.

The full sequence was ranged into nine pollen dominance- or assemblage zones (within them 8 subzones) (Góczán 1973; Góczán & Siegl-Farkas1990; Siegl-Farkas 1993). The marine formations were ranged into 2 dinoflagellate assemblage zones (within them 6 subzones) (Siegl-Farkas 1997), and they were correlated with the Late Santonian–Late Campanian **CC16–CC22** Nannozone (Siegl-Farkas & Wagreich 1996).

The Gosau type

The Gosau type Nekézseny Conglomerate Formation is a redeposited, underslope marine sequence. On the basis of palynological evidence its deposition occurred during the Late Santonian–Early Campanian (Siegl Farkas 1984).

The Tisza Unit

In the Tisza Unit five types of Senonian sequences are distinguished. A most complete profile was developed in the Bácska area (S Great Hungarian Plain). The Senonian shelf deposits can be sub-divided vertically into (3) the: Szank Conglomerate-, Csikéria Marl- and Bácsalmás Formation. This sequence was ranged to two pollen assemblage zones (within them two subzones) and one dinoflagellate assemblage zone (within them three sub-zones) (Siegl-Farkas 1999) correlated with the Campanian **CC17–CC22** Nannozones. The Körös Formation (on basal breccia) and the Izsák Formation was correlated with the middle part of the Bácska type sequence. The older, terrigenous type Körös Formation, according to the palynological results belonging to a separate cycle, was ranged to the Late Coniacian–Santonian.

Flysh type sediments (E GHP) were not studied by the palynological method.

The environment

Palynological data show that during the same period (the Late Santonian–Late Campanian), in very close territories of TCR, bauxite-, swampy coal- and fluviatile formations were developed.

The first representatives of the Normapolles genera were found in the Late Santonian Oculopollis-Complexiopollis Dominance Zone. The fact that these plants were present in an earlier phase of the Senonian is proved by their mass occurrence in early reduction sediments. Around the marschy-boggy areas mainly tree-shaped Normapolles genera with rich brushwood vegetation was characteristic supplying the source material for the coal genesis. The dominant difference between the association of the fluvial and the swampy sediments appeared mainly in the fern vegetation.

During the Late Santonian the *Complexiopollis, Oculopollis, Brecolpites* and the *Hungaropollis* angiospermae (Normapolles) and the *Appendicisporites, Bikolisporites, Cicatricosisporites*, *Cyathidites, Trilobosporites* fern-spore genera were dominant. Gymnospermae can only scarcely be found. Almost endemic associations are known in the TCR area only.

An older assemblage (Coniacian–Early Santonian) was determined from the terrigenous type Körös Formation, which represents an earlier opening ingressional cycle. A similar assemblage was found in the Gosau basins (Gams and Weissenbachalm) in Austria (Siegl-Farkas & Wagreich 1996; Hradecká et al. 1999).

Since beginning of the Early Campanian in both areas the transgression has been the decisive factor. Those areas belonged to the same (Normapolles) flora province which is evidenced by the common flora elements. Palynologically a greater difference between the two areas appears in the length of the time of biozones. Apparently smaller pollen grains of the same genera in the TCR regions indicate a larger distance from the land at the end of the Campanian. The Late Campanian *Pseudopapillopollis* dominant association means large extensive forests along the northern mediterranean lands. These Normapolles genera were determined in the Late Senonian assemblages from Albania to Austria (Siegl-Farkas 1994; Siegl-Farkas et al. 1994).

Whereas on the continent the Normapolles vegetation was dominant, the sea was rich in phytoplankton. According to the dinoflagellate data the transgression in both sub-basins can be assigned to almost the same time, although in the TCR basin it happened gradually, but in area of GHP in a sudden way. The Early and Middle Campanian nearshore dinoflagellate associations show a strong similarity to each-other, with appereance of different species of *Odontochitina, Isabelidinium*, *Apteodinium*, *Tarsisphaeridium, Alisogymnium* and *Dinogymnium* genera.

A greater difference between the phytoplankton assemblages of the two areas appeared at the end of the Campanian. While in the area of GHP there was still a shallow marine environment, in the area of TCR already a deeper, open marine association with oceanic effect was formed (Siegl-Farkas 1997).

This is proved by the fact that from largely similar assemblages, the association of Pyxidinopsis bakonyensis Assemblage Zone with *Manumiella* and *Pterodinium* can be shown in the territory of the TCR only.

At the same time, a similar assemblage was determined from the Tercis profile, designated as a stratotype of the Campanian/Maastrichtian border (S France) (Siegl-Farkas in Odin et al. 1998). A connection to this direction has been confirmed by the appearance of the monotypic *Odontochitinopsis molesta* (Deflandre 1937) Eis. 1961 in the Pelso Unit, described from and found in the Paris Basin only, till this time. The occurrence of *Tarsisphaeridium geminiporatum* Riegel 1974 suppose a transition between the Mediterranean and Boreal areas.

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DEPOSITIONAL STACKING OF THE CENTRAL-CARPATHIAN PALEOGENE BASIN: SEQUENCES AND CYCLES

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Key words: Central Carpathians, Paleogene, deep-sea fans, sequence stratigraphy, eustasy, tectonics.

Introduction

The Central-Carpathian Paleogene Basin (CCPB) is filled up by sediments of the Subtatric Group (Gross et al. 1984) and Podhale Flysch (Golab 1959). From the base, the lithostratigraphic units are developed as follows: the **Borové Formation** (Eocen Tatranski), the **Huty Formation** (Zakopane Fm.), the **Zuberec Formation** (Chocholów Fm.) and the **Biely Potok Formation** (Ostrysz Fm.), all of which with clastic fans named as the **Pucov Member**. In fact, the lithostratigraphic units of the CCPB appear to be depositional sequences, which developed from continental alluvial-fan deposits, overlapped by shoreface sands and carbonate ramp deposits, through a syn-rift accumulation of shaly flysch deposits and scarp breccias (Šambron Beds), claystone subflysch deposits of mud-rich fans, progradational stacking of deep-sea fans with complex facial zones to the sandy-rich deposits of "suprafans" (e.g. Marschalko 1966, 1970, 1981, 1987; Soták et al. 1996a; Soták 1998; Janočko et al. 1998).

Sequence stratigraphy

The CCPB has experienced a two transgressive-regressive cycles of deposition (Subtatric and Menilite-Krosno supercycles). The transgression of the Subtatric supercycle (STS) was preceded by the deposition of alluvial-fan sediments, which consist of subaeric and subaquatic cycles of conglomerates and boulder breccias deposited from stream flows, fluidal surge flows, debris flows, traction currents and high-density turbidite currents (Marschalko 1970; Baráth & Kováč 1995). Continental footplain sediments of alluvial fans were flooded to the subaquatic zone and than overlapped by shoreface sands (Tomášovce Beds *sensu* Filo & Siráňová 1996) and carbonate platform deposits. The Upper Lutetian transgression of the STS (Andrusov & Köhler 1963) led to a shallow-marine deposition of nummulitic banks developed in two 3rd order cycles of deepening-upward successions (Bartholdy 1997). In the Priabonian, the transgression grades up to early highstand marked by the dominancy of hemipelagic deposition and high productivity of Globigerina Marls (P 16–P 17). At the same time, the basin subsidence became differentiated. Therefore, the Globigerina Marls and "Black Eocene shales" were deposited synchronously with the turbidite fans filling up intrabasinal depressions (Šambron Beds). Subsequently, the CCPB occurred in dominancy of turbidite fan deposition being forced both by tectonics and/or eustasy.

The Šambron fan (alike Tokáreň fan, etc.) were deposited in a falling stage of transgressive-regressive cycle (cf. Janočko & Jacko 1998), which coincided with a synrift stage of the tectonic subsidence. They overlap the prior TST/HST deposits erosionally (Type 1 sequence boundary). The high accumulation rate of shaly flysch deposits, shingled turbidites and scarp breccias of the Šambron Beds (ca. 800 m/Ma, duration 39–36 Ma) points to a fault-controlled lowstand accumulation of the slope fans and marginal delta-fed fans (alike Szaflary Fm. — Wieczorek 1989; Janočko & Jacko 1998). The lowstand setting of the Šambron Beds is also expressed by the presence of a large amount of shallow-marine detrital components (nummulites, coralline algae, etc.) in deep-water flysch lithologies (shelves exposed by sea-level fall). The sedimentation of the Šambron Beds occurred probably in the oxygen minimum zone (anoxic facies, scarcity of microfossils, dark sulphide-rich claystones, etc.) and below the upwelled calcite compensation depth (non- or weakly calcareous claystones).

The transgression of the Menilite-Krosno supercycle (MKS) was introduced by a mud-rich subflysch deposition. The sequence boundary at the base of the subflysch formation is locally developed as unconformity between the growth fault system tract (Šambron Beds) and the overlying sequence of mud-rich fans (the tectonically enchanced sequence boundary — Vail et al. 1991). This sequence kept on for about 5 Ma (36–31 Ma) reveals a slow accu-

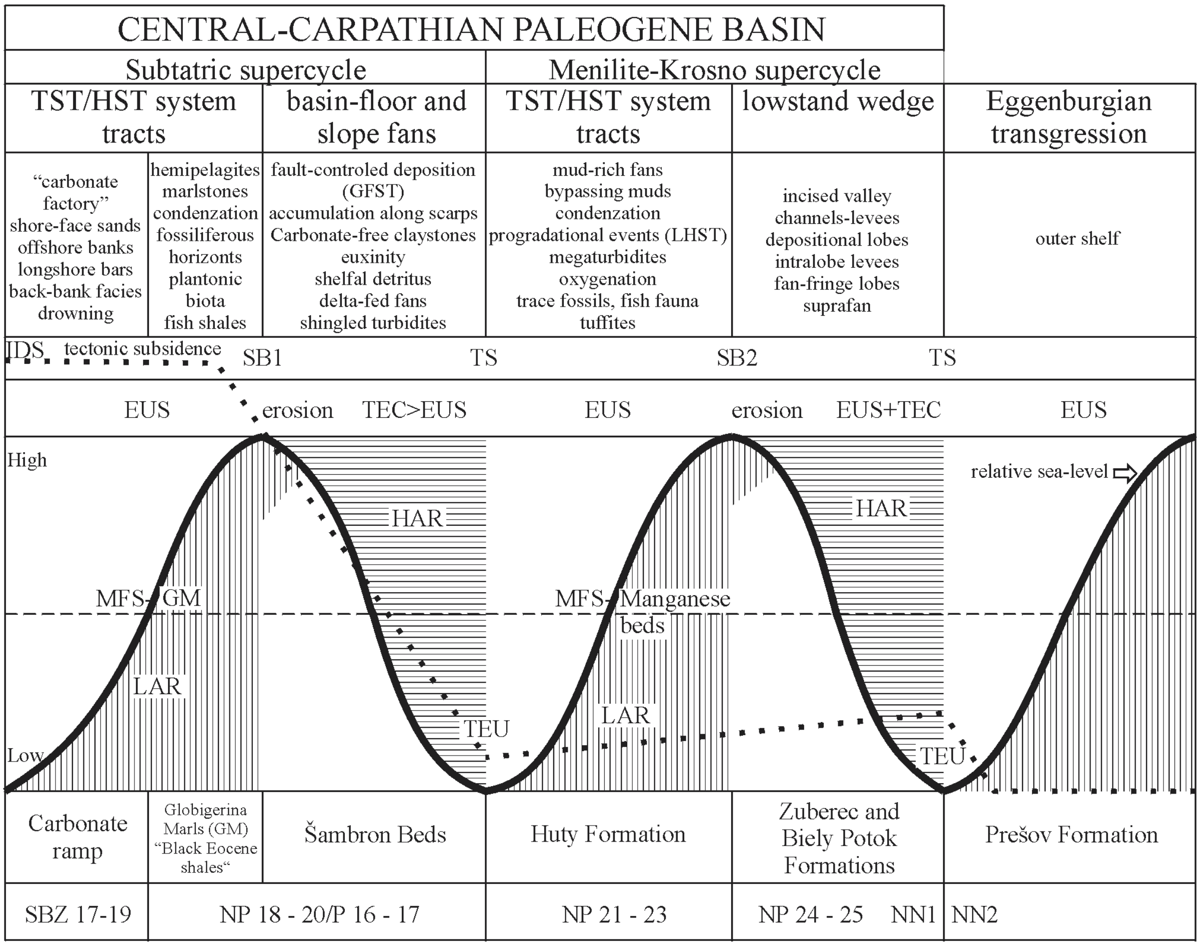

Fig. 1. The inferred interplay among eustasy, tectonics and depositional stacking of the Central-Carpathian Paleogene Basin. Abbreviations: TST — transgressive system tract, HST — highstand system tract, MSF — maximum flooding surface, LHST — late highstand system tract, GFST — growth fault system tract, IDS — initial depositional surface, SB — sequence boundary, TS — transgressive surface, TEU — tectonically enhanced unconformity, HAR — high accumulation rate, LAR — low accumulation rate, TEC — tectonics, EUS — eustasy.

mulation rate of mudstone deposits (ca. 80–160 m/Ma). Such a dominance of pelagic sedimentation in the basin responds to the transgressive and highstand systems tracts. The maximum flooding of this sequence falls into the horizons of manganese layers, that occur mainly in the Poprad Depression. The manganese layers represent a condensed section of marine transgression associated with a relative abundance of biota (e.g. nannofossils, fish fauna, etc.), glauconite-rich arenites (as contrast to the lowstand turbiditic sandstones of the Šambron Beds and Upper Oligocene sediments), pelocarbonates and sporadically also tuffaceous intercalations (e.g. loc. Bajerovce, Plavnica). The late highstand of this formation is evidenced by small-scale progradational events and megaturbidite beds (Orava region). The depositional environment of the claystone lithofacies became well-oxygenated, as can be seen from trace fossils and bioturbation (appearance of bathyal ichnofossils). The Early Oligocene highstand sedimentation of the CCPB correspods to the so-called Menilite event in the Outer Flysch Carpathians. The sediments of the Menilite Formation and associated nanno-chalk horizons in the Outer Flysch Carpathians (e.g. Jaslo Limestones, Dynów Marlstone, Štibořice Member) were deposited during a coeval sea-level highstand in the Rupelian (cf. Krhovský & Djurasinovič 1992).

The highstand starvation of the CCPB was changed by an abrupt sea-level fall near the time of 30 Ma which introduced the Upper Oligocene deep-sea fan deposition. The falling stage of the Late Oligocene regression in the CCPB is expressed by an offlap break of prior highstand sediments, which were eroded and reworked into conglomerate-slope accumulations of the deep-sea fans (e.g. blocks of Mn carbonatic ores — Marschalko 1966). The erosional truncation of the upper fan zones becomes less obvious towards to the basin, developing as a correlative conformity between mud-rich and sandy-rich fans. During the Late Oligocene, the CCPB basin was filled up by a progradational wedge of deep-sea fans, developed from a sandy-poor turbidite system (Zuberec Fm.) to a sandy-rich turbidite system (Biely Potok Fm.). The sandy-rich deposition of the CCPB lasted till to the Early Miocene, as has been already indicated by some nannoplankton and foraminiferal species (e.g. *Helicosphaera scissura*, *H. kamptneri*, *H.* cf. *carteri*, *H.* cf. *ampliaperta*, *Reticulofenestra* cf. *pseudoumbilica*, *Triquetrorhabdulus* cf. *carinatus?* — Nagymarosi, Hamršíd & Švábenická in Soták et al. 1996b; Molnár et al. 1992). However, the Early Miocene age is more apparent from sequence stratigraphy correlations. During the Late Oligocene–Early Miocene, a global eustasy occurred under distinctive regression, which led to gradual shallowing and brackishing of Paratethyan basins. In the CCPB, the Late Oligocene regression is recorded by the Biely Potok Fm., providing an input of sandy-rich deposits and shallow-water brackish species of dinoflagellates (Hudáčková 1998). The regressive trend of the Late Oligocene–Early Miocene sedimentation reached the maximum lowstand on the base of the NN2 zone, when the brackish fauna started to appear (Steininger et al. 1985). Such a brackish event, indicated by the fauna of small gastropods,

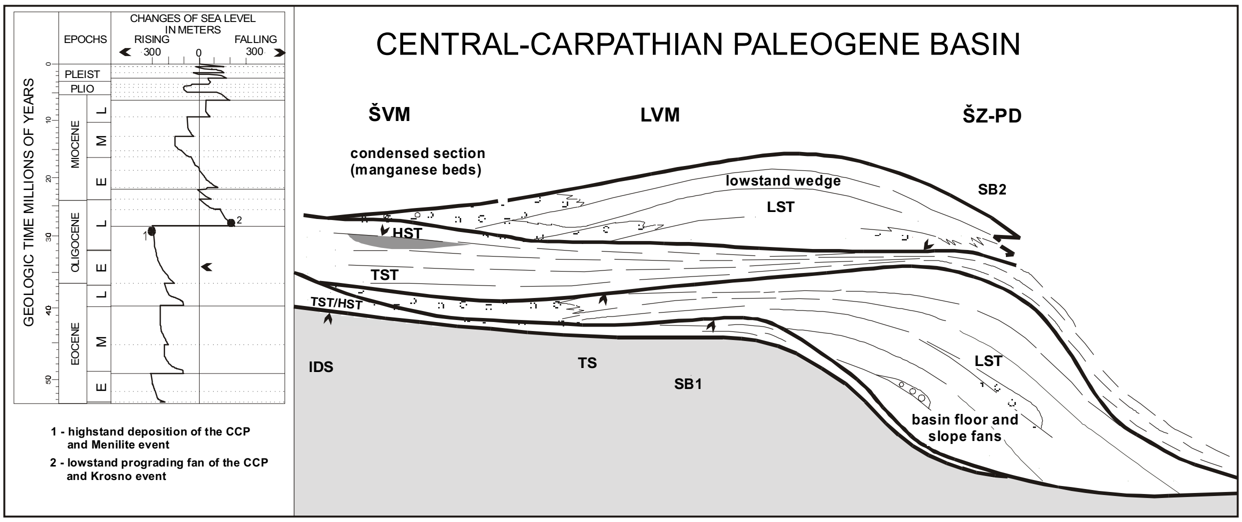

Fig. 2. The sequence stratigraphy pattern of the Central-Carpathian Paleogene Basin showing a transgressive-regressive cyles as follows: Subtatric supercycle — transgressive onlap and highstand deposition (carbonate ramp, Globigerina Marls and "Black Eocene shales"), — lowstand accumulation of basin-floor and slope fans (Šambron Beds); Menilite-Krosno supercycle — transgressive and highstand deposition of mud-rich fans with maximum condensation in manganese-rich horizons (Huty Formation), — lowstand accumulation of deep-sea fans and suprafans (Zuberec and Biely Potok Formations). The sequence bondary SB2 coincides with the abrupt sea-level fall near 30 Ma (see the Tertiary sea-level curve on the left). Abbreviations: ŠVM — Šarišská vrchovina Mts., LVM — Levočské vrchy Mts., ŠZ-PD — Šambron Zone and Poprad Depression.

was detected in the sandstone lithosome sediments of the Levočské vrchy Mts. By then, the deposition of the Biely Potok Fm. should have terminated till the Early Eggenburgian (the Late Egerian sensu Berggren et al. 1995), i.e. till the lowstand phase at the beginning of the NN2 zone, which preceded the next transgressive cycle TB 1.5 sensu Haq (1991), which occurred at the base of the Prešov Fm. (Kováč & Zlinská 1998). In fact, the gastropod-bearing sandstones and overlying sandstone lithosomes of the Biely Potok Fm. (ca. 300 m in the Levočské vrchy Mts.) could not have been assigned to "flysch", but rather to molasse sediments, deposited during a retrogressive stage of the basin evolution. Nevertheless, the vitrinite reflectance and illite-smectite diagenesis from the near-surface sediments of the Levočské vrchy Mts. point out, that, up to 2 km of this sequence is missing (Kotulová et al. 1998). So that, the last third-order cycle of deep-sea fan deposition in the CCPB kept on for about 7 Ma (29–22.5 Ma) giving a high accumulation rate of sandy-rich deposits (320–370 m/Ma). The time-equivalent sedimentation in the Outer Flysch Carpathians took also place in a lowstand setting, recorded by the Krosno Facies (incl. Ždánice-Hustopeče event — Krhovský & Djurasinovič 1992).

Conclusions

The CCPB shows a sequence stratigraphy pattern which has developed as follows: — alluvial-fan deposition; — the transgressive onlap by a shoreface zone and carbonate ramp deposits, mainly nummulitic banks (Upper Lutetian – Bartonian); — the drowning of carbonate platform and highstand aggradation marked by high productivity of Globigerina Marls (Priabonian); — the interference of lowstand and rapid tectonic subsidence in fault-controlled accumulation of marginal slope fans (Priabonian–Early Oligocene); — the transgressive and highstand deposition of mud-rich fans associated with condensation (manganese beds) and Menilite episodes (Lower Oligocene); — the lowstand, progradational wedging out of sandy-rich fans (Late Oligocene–Early Miocene). The correspondence of sequence-stratigraphic events (e.g. Globigerina-rich, Menilite as well as Krosno) indicates a connection between the basinal systems of the Central and Outer Carpathians accommodating the destructive plate margin, trench zone and accretionary terranes. This paper is a contrib. to VEGA grant no 4077.

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NEW MICROFOSSILS FROM THE EARLY PALEOZOIC FORMATIONS OF THE GEMERICUM (FORAMINIFERIDA)

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Key words: Inner Western Carpathians, Gemericum, Early Paleozoic, arenaceous foraminifers.

Introduction

The pre-Hercynian and Hercynian cycles of the Inner Western Carpathians were always difficult to reconstruct because of insufficient, or completely lacking biostratigraphical datings of the Early Paleozoic rock assemblages. Most surficial occurrences of Early Paleozoic formations of the Inner Western Carpathians are made up of volcanic-sedimentary formations of the Southern Gemericum that underwent a regional metamorphism under the temperature-pressure conditions of the lower part of the greenschist facies. To obtain a new biostratigraphical data, the material from lydite horizons of the Gelnica Group was systematically collected and diluted in hydrofluoric acid. At four localities (Henclová, Zlatý stôl, Jedlinka and Bystrý Potok), the lydites contain the microfossils described here for the first time.

Microfossils

The extracts from the Gemeric lydites contain a rich microfossil association. Most numerous are the spherical siliceous tests (Fig. 1). In some extracts they form even monoassociations (e.g. at the Jedlinka locality comprising 70 individual tests), so in thin sections they appear as rock-forming fossils (e.g. Henclová locality). Similar spherical forms were already described from the locality Betliar. Ondrejíčková & Snopko (1986) consider them as a radiolarians close to the genus *Pylentonema* Deflandre. Betliar's specimens, which exhibit a meshwork wall structure, "pylum" and tiny dimensions (80–100 μm) are not identical with the spherical fossils described herein (thus A. Ondrejíčková also refused their radiolarian nature). These organisms are more likely single-cell foraminifers of the **Psammosphaeridae** or **Saccamminidae** family, sometimes erroneously identified with the spores (e.g. *Calcisphaera* Williamson). An evidence of their appurtenance to forminifers is, however, the agglutinated character of siliceous tests, oversized dimensions (up to 1 mm) but mainly the presence of flat or neck-like shaped apertures. Similar forms of foraminifers were reported from the Early Cambrian (Koroljuk & Lagutenkova 1965; Koroljuk 1966) under the generic designation *Palaeospheroidina* Koroljuk. Alike the foraminifers of the genus *Palaeospheroidina* Koroljuk, the microfossils from lydites have a siliceous test, spherical shape, an aperture, dimensions ranging from 0.4 to 1 mm and mass occurrence (Koroljuk 1966 reported even 100 specimens from one washing). Foraminifers of the genus *Palaeospheroidina* Koroljuk may be considered as predecessors of simple agglutinated species, such as *Psammosphaera* Schultze, *Saccammina* Carpenter, *Sorosphaera* Brady, *Thurammina* Brady or *Hemisphaerammina* Leoblich & Tappan, which are frequently described from the Ordovician, but mainly from the Silurian and Devonian formations (Moreman 1930; Conkin & Conkin 1968; Conkin et al. 1968; Plummer 1945; Crepin 1961, etc.). Foraminifers with identical patterns were described, e.g. from the Ordovician rocks of the Baltic region (Eisenack 1967) and from Silurian rocks of the Grauwackenzone in Austria (Kristan-Tollmann 1971). Some species from Gemeric lydites may be assigned to them directly.

The foraminiferal association is predominated by two psammosphaerid species which substantially differ in size and structure of agglutination from each other. Larger forms, the thicker and coarsely agglutinated walls and spongy-like exterior belong to the species *Psammosphaera cava* Moreman (Fig. 1.3). Smaller forms of psammosphaerids whose tests are finely agglutinated to form subgranular, smoothly-walled and misty tranculent, belong to the species *Psammosphaera micrograna* Eisenack (unfigured specimens). The psammoshaerid tests have no definite aperture (their interstitial pores serve as an aperture — Fig. 1.3). The foraminifers with recognizable aperture belong to the genus *Saccammina* Carpenter, and to the following two taxa: *Saccammina glenisteri* Crespin (forms with simple rounded aperture — Fig. 1.1) and *Saccammina silurica* Eisenack (forms with raised apertural neck — Fig. 1.2). Some saccamminid forms have indications of spiny-like protuberances typical of the species *Amphitremoida tubulosa* Eisenack (Fig. 1.4). Beside single-cell forms there also occur small bilocular tests that recall some thuramminid species (e.g. *Tubeporina umbilicata* Poronina — cf. Poronina 1969).

Conclusions

The occurrence of arenaceous foraminifers in the Gelnica Group allows us to make some stratigraphic considerations. The foraminifers *Psammosphaeridae* are known since Cambrian period, but particularly rich association they formed during the Ordovician and Silurian. The Silurian associations of psammosphaerids and saccamminids, however, also comprise younger foraminiferal

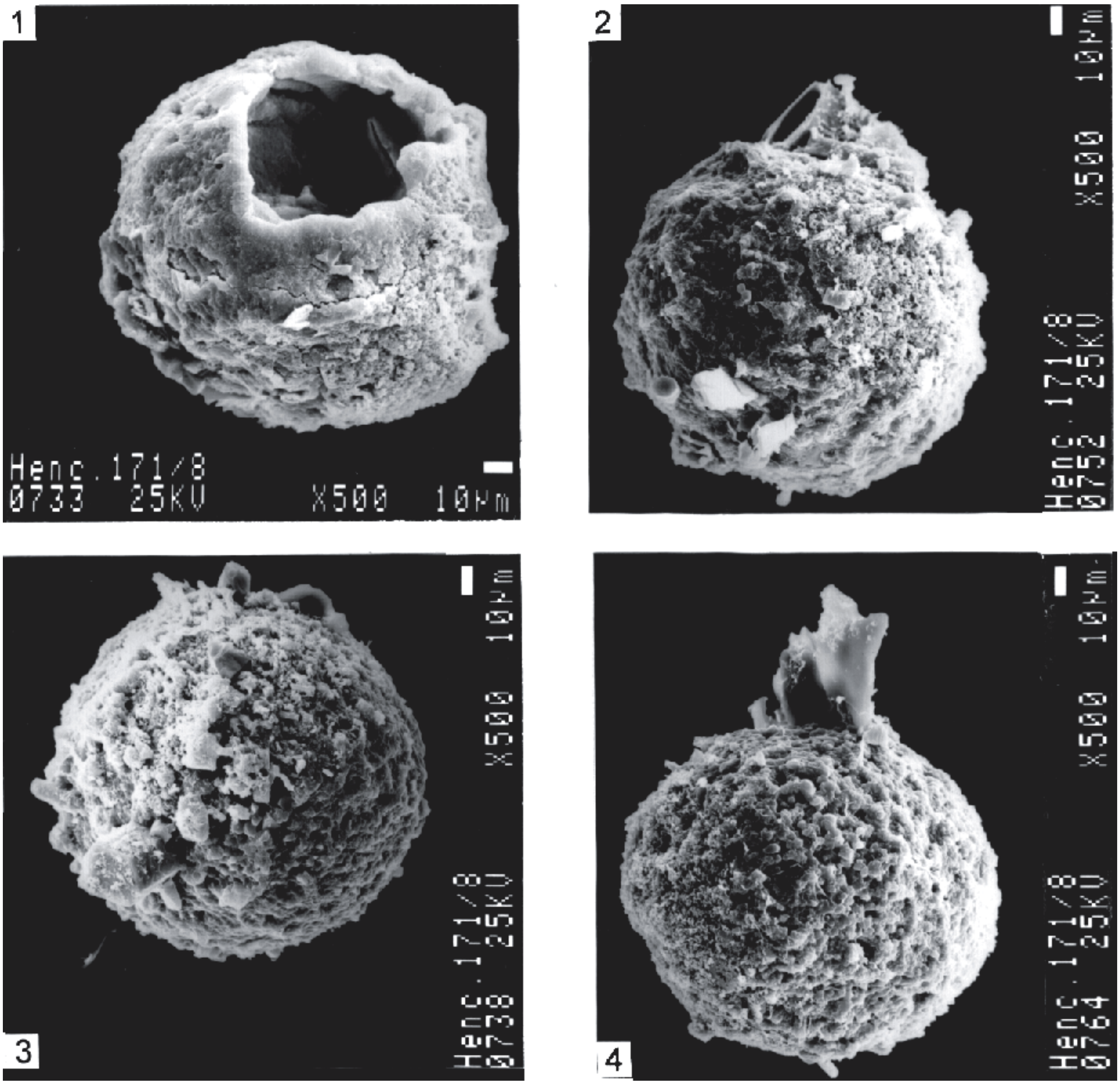

Fig. 1. Psammosphaerid and saccamminid foraminifers from the Gelnica Group lydites. 1. *Saccammina glenisteri* Crespin — single-cell agglutinated test with simple rounded aperture, Loc. Henclová. 2. *Sacammina silurica* Eisenack — spherical test with terminal neck-shaped aperture, Loc. Henclová. 3. *Psammosphaera cava* Moreman — single-cell tests, coarsely agglutinated, without aperture. Loc. Henclová. 4. *Amphitremoida tubulosa* Eisenack — globular, finely agglutinated tests with indication of spiny-like protuberances. Loc. Henclová.

taxa (*Ammodiscidae, Trochamminidae, Tolypamminidae*), which are missing in the Gemericum lydites. This age limit (Ordovician to Early Silurian) corresponds to the results of earlier biostratigraphical investigations in the Gelnica Group, based upon the study of palynomorphs and kerogen (Snopková 1964; Snopková & Snopko 1979; Čorná 1972; Čorná & Kamenický 1976, etc.)

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DEEP-SEA SILICICLASTIC SEDIMENTATION OF THE ISTEBNA BEDS (CAMPANIAN – PALEOCENE) IN THE SILESIAN BESKID, THE POLISH CARPATHIANS

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Key words: Sedimentation, Flysch Carpathians, Silesian Basin, Silesian Series, Silesian Beskid, Istebna Beds, Campanian–Paleocene.

Introduction

The author aims to reconstruct sedimentary conditions of deep-marine, siliciclastic Istebna Beds. In the study area the Istebna Beds form a huge, 1,500-meter-thick succession of conglomerate–sandstone–mudstone lithofacies. The age of the Istebna Beds was determined as Campanian–Palaeocene on the basis of the rare macrofossils and micropaleontological studies (Geroch 1960).

Methods

The basic method was sedimentological facial analysis. The field work included mostly the detailed lithological and sedimentological descriptions of selected sequences (Wisla Czarne, Czarna Wiselka Stream — Lower Istebna Beds and Istebna, Olecka Stream — Upper Istebna Beds). The changes in grain size, the presence and succession of sedimentary structures as well as the vertical and horizontal variability of bedding were analysed. Moreover, the paleotransport directions of clastic material were measured on the basis of the casts of flute marks and cross-stratification.

Results

The following lithofacies were distinguished: conglomerates, sandy conglomerates, conglomeratic sandstones, sandstones, sandstones with mudstones, conglomeratic mudstones, sandy mudstones, mudstones with sandstones, mudstones and claystones, bentonites and siderites.

Considering the thickness of beds and frequency of their occurrence, the Lower Istebna Beds are dominated by sandstones and conglomeratic sandstones (37.5 and 35.3 %, 57.1 and 19.5 %, respectively). The conglomeratic mudstones also make up a relatively high percentage of the thickness (9.6 % at 2.4 % frequency). However, this lithofacies has not been observed in the full thickness of the Upper Istebna Beds which are composed mostly of mudstones and claystones (over 55 % of thickness and almost 37 % of frequency). A significant role is played by mudstones with sandstones (18.6 % of thickness and 20.1 % of frequency). Siderite lithofacies contributes only 0.1 % of thickness in both the Lower and Upper Istebna Beds but its frequency is slightly higher (2.2 %) in the Upper Istebna Beds. Numerous, thin bentonite intercalations (illitic shales of tufogenic origin) were noticed only from the Upper Istebna Beds.

The coarse-clastic lithofacies form thick and very thick, rarely moderately thick beds. Commonly, the facies comprise multilayer successions, devoid of separating shales, with bed thicknesses quickly changing laterally. Amalgamation surfaces are frequent. The bottom surfaces are in most cases erosional (wash-outs), sometimes deformational (loadcasts). On the contrary, fine- and medium-grained lithofacies form thin or very thin, occasionally moderately thin layers in successions from several centimeters to a dozen meters thick. The bottom surfaces are usually flat and reveal numerous markings (mechanical and organic). The sole marks (usually flute casts) point to northeastern, eastern or southeastern palaeocurrent flow directions.

In the Istebna Beds the facial sequences of deep-sea fans were identified as well as the sequences formed by non-channelized deposition within the siliciclastic apron. Among others, the channel sediments were observed as typical successions of thinning-upward, grain-size-diminishing beds (so-called “positive cycles”) and interchannel deposits of the middle fan. The lobe sediments were poorly developed and usually formed sequences of thickening-upward layers with increasing grain size (so-called “negative” or “compensational”). The identified sediments of non-channelized deposition are characterized by irregular bedding, high facial variability, interfingering of strata produced by mechanisms of variable energy and amount of deposited clastics as well as the lack of regularities both in facies succession and thickness changes.

Discussion

The sedimentological features observed in many sequences of the Istebna Beds often do not correspond to any well-identified environment of deep-sea fans (Mutti & Ricci Lucchi 1972, 1975; Mutti 1977; Nilsen 1977; Pickering 1983; Shanmugam & Moiola 1988). Sequences of such sediments show distinct similarities to so-called siliciclastic apron (see Stow 1986; Reading & Richards 1994; Słomka 1995) deposited at the base of linear source and representing a chaotic, non-channelized environment.

Sedimentation of the Istebna Beds shows regularity, that is gradual change from non-channelized deposition to well-developed channels of the middle fan. The first signs of stabilization of sedimentary environment are ”positive” cycles composed of several layers. Then, the well-developed middle-fan feeding channels appear, as proved by typical channel successions. At the mouths of these channels depositional lobes were formed. In the studied area these lobes comprise sediments transitional between channel-mouth and proximal-lobe types.

The possible changes in architecture of cordilleras related to the variable uplift rate of source areas or to the eustatic changes in sea level again increased the vigorous, chaotic, apron deposition.

The changes described above occurred repeatedly during deposition of the Istebna Beds which points to the unstable sedimentation of this member.

Conclusions

Deposition of the Lower Istebna Beds took place in the environment of submarine fan interfingered with the non-channelized, apron-type deposition. Middle-fan, channel and interchannel sediments are dominating, but separated by products of vigorous, chaotic, non-channelized deposition.

The Upper Istebna Beds were sedimented in a more stable environment. The studied deposits were laid down in the marginal zone of basin plain and on the basin plain where two facies predominate: mudstones with claystones and mudstones with sandstones. These sediments interfinger with the submarine fan facies: sandy conglomerates, conglomeratic sandstones and sandstones.

The prevailing mechanism for the Istebna Beds was deposition from dense, sand-conglomerate gravity flows of variable energy, density and retardation type as well as deposition from dilute turbidity currents.

Both the vertical and lateral variability of the Istebna Beds along with the interfingering of different types of sediments may suggest rapid migration of various depositional environments.

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OLIGOCENE MOLLUSCAN FAUNA FROM THE SKIBAS AND BORYSLAV-POKUT UNITS (THE UKRAINIAN OUTER CARPATHIANS) — PRELIMINARY REPORT

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Key words: Oligocene, Ukraine, gastropods, bivalve molluscs.

The material available for the present study consists entirely of specimens collected by the present authors during the fieldwork season of 1989. The exposures sampled include the river sections the Pistynka at Kosmach and the Rybnica at Kosov in the Boryslav-Pokut Unit, as well as the river Chechva section in the Skibas Unit, at the locality of Spas. The state of preservation of the molluscan fauna is poor and any attribution to the species level is not possible at present.

In the Boryslav-Pokut Unit the molluscan fauna was derived from the dark micaceous argillite shales of the Subchert Member, immediately below the Lower Chert Level. On the basis of calcareous nannofossils an early Rupelian age is indicated for this basal member of the Menilite Formation (i.e. top of the NP22–bottom of the NP23 zones; Andreeva-Grigorovich 1987). Foraminiferal studies have shown that the Subchert Member represents the Globigerina vialovi Zone.

A paleoenvironmentally significant ichthyofauna derived from these shales indicated bathypelagic conditions. It represents IPM1 Zone of Jerzmańska and Kotlarczyk's ichthyofanal assemblage zonation.

The molluscan fauna at the Kosmach locality includes 30 bivalve species representing 15 families and 15 gastropod species belonging to 9 families. From the presence of large specimens of *Glycymeris* sp., *Nemocardium* (*Habecardium*) sp., venerids, typical inhabitants of shallow-water environments, as well as other lithological indicators it can be concluded that molluscan fauna occurs in the Subchert Member as an allochthonous assemblage.

Within the bivalve assemblage consisting largely of representatives of the following genera: *Nuculana*, *Glycymeris*, *Lucina*, *Thyasira*, *Astarte*, *Scalaricardita*, *Nemocardium*, *Callista*, *Pitar* and *Corbula* (*Varicorbula*), the elements of northern origin prevail, the boreal influences thus being clear. Of 12 bivalve species from Kosmach presented by Maximov (1987) only *Cardita laurae* Brongniart is a typical Mediterranean species. However, on the basis of the description and illustrations given by Maximov (1987, p. 72, Pl. 1, Figs. 4, 5) the specimens assigned to *C. laurae* show a close resemblance to *Cardites oswaldi* (Slodkevich) recorded from the Eastern Paratethys, namely from the lower Oligocene of Crimea and the upper Oligocene of the southern Ukraine (Popov et al. 1993).

On the basis of the present authors' collection the main difference between the molluscan assemblages from the Boryslav-Pokut Unit on the one hand and from Crimea and the Precaucasus on the other concerns the occurrence of representatives of the gastropod families Turritellidae, Volutidae, Conidae and Marginellidae, all warm-water species, in the Carpathians. This is contrary to the opinion of Maximov (1987) who has seen close similarities between the molluscan fauna from Kosmach and the Khadunian assemblages known from the Eastern Paratethys lower Oligocene strata of Crimea and Precaucasus.

The molluscan fauna at the Kosov locality includes 10 gastropod species representing 7 families (representatives of Pyramidallidae and Ficidae are missing from the isochronous Kosmach assemblage) and 12 bivalve species belonging to 7 families. Among these only *Pseudomiltha* sp. and *Venus* (*Venus*) sp. have not been recorded from the Kosmach locality.

In the Skibas Unit the molluscan fauna occurs in dark and dark-grey argillite shales of the basal part of the Middle Menilite Subformation, exposed in the Marginal Skiba, along the river Chechva at Spas. Calcareous nannoplankton shows the top of NP23–bottom of NP24 zones (Andreeva-Grigorovich in Gruzman 1990). On the basis of foraminifera the basal part of the Middle Menilite Subformation represents the Globigerina ampliapertura Zone (Gruzman 1990).

The fauna at the Spas locality includes 40 bivalve species belonging to 12 families (members of the Lucinidae dominating among them) and the representatives of 5 gastropod families: Turritellidae, Aporrhaidae, Naticidae, Fasciolariidae and Spiratellidae. This molluscan fauna unequivocally indicates a shallow-water environment and its taxonomic composition insignificantly resembles contemporaneous impoverished assemblages from the northern margins of the Eastern Paratethys, whereas the molluscan fauna from the southern margin is unknown, apart from single assemblages from Georgia (cf. Popov et al. 1993). In addition, the presence in the Carpathian assemblage of the species *Arctica usturtensis* Ilyina and *"Lucina" batalpaschinica* Korobkov (both Eastern Paratethyan endemics) reported by Maximov (1987) has not been confirmed by the present study.

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PALEOBIOGEOGRAPHICAL REMARKS OF TITHONIAN-BERRIASIAN FORAMINIFERS IN THE POLISH OUTER CARPATHIANS

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Key words: Tithonian–Berriasian, Polish Outer Carpathians, Silesian Unit, "Cieszyn Beds", foraminifers, paleogeography, paleobioprovince.

Introduction

Paleobiogeographical remarks on the Jurassic-Cretaceous passage in the Polish Outer Carpathians based on foraminifers are presented. These studies refer to the oldest sediments, the so-called "Cieszyn Beds" which were more completely developed in the Silesian Unit (Cieszyn Subunit) of the western part of the Polish Outer Carpathians. Typical region of their occurrence is the Cieszyn-Ustroń area (Fig. 1). The older part of these sediments belong to two informal litostratigraphical units (the "Lower Cieszyn Shales" and "Cieszyn Limestones") which contain Tithonian-Berriasian foraminiferal assemblages. The overlaying youngest unit — the "Upper Cieszyn Shales" — contains Valanginian-Early Hauterivian microfauna.

The Tithonian/Berriasian boundary was generally situated in the "Cieszyn Limestone", but we can assume it is also found in the transition sediments between the "Lower Cieszyn Shales" and "Cieszyn Limestone". Moreover it seems that the lithological boundary between them has been rather diachronous (Nowak 1965; Nescieruk & Szydło in press).

The preliminary analyses are part of projects of the Polish Geological Institute (6.20.1421.00.0, 6.20.1422.00.0), the results of which are partly published (Szydło 1996; Szydło & Jugowiec 1999).

Results

The results are based on samples collected from outcrops of the Tithonian-Berriasian "Cieszyn Beds" situated in the westernmost part of the Polish Carpathians (the vicinity of Goleszów, Puńców, Cisownica and partly the Olza River between the Castle Hill in Cieszyn and Puńcówka stream — Fig. 1).

The oldest sediments of the presented part of Carpathian basins, the so-called "Lower Cieszyn Shales" contain specific microfossil associations dominated by numerous calcareous foraminifers of the nodosariid and polymorphinid groups, rare and low-diversity agglutinated of ataxophragmiid foraminifers (*Paleogaudryina, Belorussiella, Protomarssonella*). The first foraminiferal group closely corresponds to epicontinental biota (Bielecka & Geroch 1977; Styk 1997). Naturally the similarity of forms from the Carpathian basin (Polish part) to those from epicontinental seas with boreal influences and Tethys (Mediterranean) seas with tropical influences depends on the differential depth of basins, distance to board line and rate of sedimentation.

The maximal regression at the Tithonian/Berriasian boundary was unfavourable to the development of diversified calcareous benthos of families: Nodosariidae and Polymorphinidae. Consequently the uppermost part of the "Lower Cieszyn Shales" yielded shallow water trocholinas, neotrocholinas and paalzowellids which are also characteristic for the detritic part of the "Cieszyn Limestones". In addition very shallow water lituolids (*Pseudocyclammina*) have been noted in the youngest part of the "Lower Cieszyn Shales" or the transitional member higher which "Cieszyn Limestones" also including the above mentioned microfauna (Geroch 1966). The presented association, mainly belonging to the Involutinidae are noted from northern margins of Tethys adjoining with platform areas (e.g. Arnaud-Vanneau et al. 1988; Kusnetzova & Gorbachik 1985; Hanzliková 1965). Moreover shallow water involutinids correlated with the regression at the Tithonian/Berriasian boundary are known from the border of the Pavlov platform as the so-called Trocholina Zone (Hanzliková 1965) and from Crimea as the assemblage with "trocholinas" (Kaptarenko-Tchernousova et al. 1979). Then again similar foraminifers (e.g. *A. alpina, A. elongata*) from the neighbouring Romanian Carpathians are not noted before the upper Berriasian (Neagu 1994).

The mentioned shallow water foraminifers preceded or co-existed with near-shore and low salinity Trochamminidae group also typical for "Cieszyn Limestones" (Geroch & Olszewska 1997). These mono- and numerous associations may reflect colonization of the near-shore part of the Carpathian basin connected with landed water.

The general deepening of the Carpathian basin at the end of the Berriasian was followed by changes in quality and quantity of foraminifers. The trochamminids coexisted with or later replaced by the poor agglutinated foraminiferal assemblages include rare ataxophragmids (assemblage with *Pseudoreophax cisovnicensis*), astrorhizids and badly preserved nodosarids. This process continued in the Valanginian "Upper Cieszyn Shales". The above mentioned foraminiferal association represented mainly cosmopolitan forms which are characteristic of the weakly diversified and oxygenated deeper part of flysch basin (Szydło 1997; Szydło & Jugowiec 1999).

Conclusion

Carpathian assemblages of Tithonian and at Early Berriasian foraminifers reflect more the nodosariid-epistominid faunas typical of the subboreal seas than cyclaminids-pavonitinids faunas typical for Tethys. It correlate with presence of epicontinental calcareous nannoplankton (Szydło & Jugowiec 1999). Howover numerous representatives of the Involutinidae and single foraminifers of Lituolidae correspond to the Mediterranean province. Consequently the presence of Boreal- and Tethyan-type microfossils in the Jurassic Cretaceous passage in the Polish Carpathians testified to the periodic influence of cool and tropical water into the northern marginal Tethyan.

This fact is correlated with the connection between the Boreal province through the Polish Lowlands with the Tethyan seas including also the Carpathian basin in the Late Tithonian–Early Berriasian (Pożaryski & Żytko 1979; Malinowska 1989). In this peri-

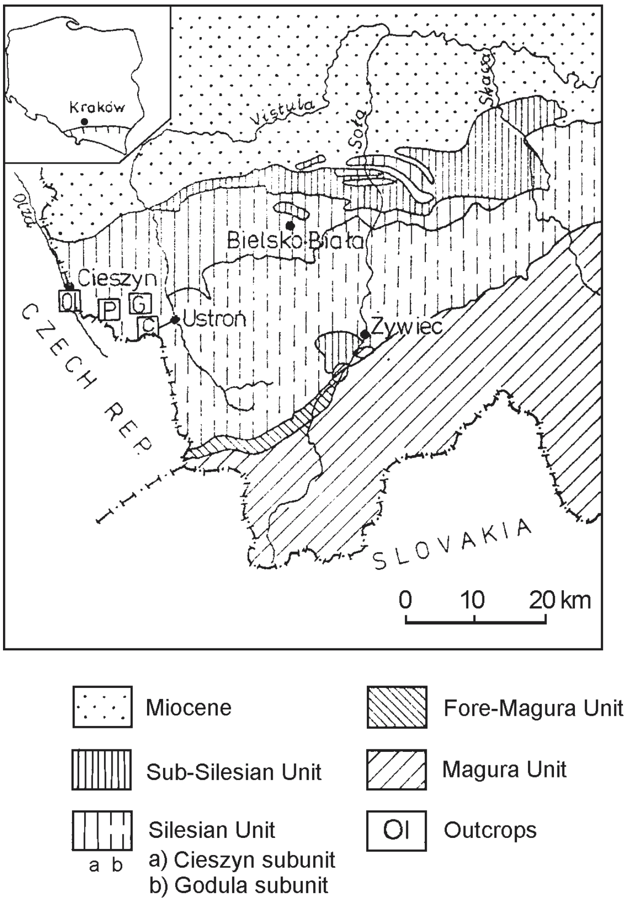

Fig. 1. Tectonic map of the Polish Western Carpathians (Malik 1986; modified) with localization of samples: OL — Olza River, P — Puńców, G — Goleszów, C — Cisownica.

od the initial Carpathian basin correspond to epicontinental areas not only with a view to microfossils (foraminifers and calcareous nannoplankton, Szydło & Jugowiec 1999) as well as environments and sedimentation types (Utrobin 1962; Eliáš & Eliášová 1986).

At the end of the Berriasian we can assume a decrease in more complicated and specialized foraminifers such as calcareous benthos which were more sensitive and connected with shallow habitat. This decrease was associated with deepening and unification of the basin in the Berriasian. The assemblages dominated by calcareous foraminifers were replaced by agglutinated ones which reflect the foraminiferal associations characteristic of flysch basin of Tethys including the most distans: Caribian and Australian provinces. Howeover the range of foraminifers was different because of geomorphological and chemical barriers (Kaminski et al. 1992).

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PENETRATION OF HIGH-LATITUDE NANNOFLORA TO THE DEPOSITIONAL AREA OF THE OUTER WESTERN CARPATHIANS IN THE TURONIAN–MAASTRICHTIAN

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Key words: Outer Western Carpathians, Upper Cretaceous, calcareous nannofossils, bioprovinces.

Introduction

Cold-water preferring (high-latitude) species are present in nannofossil associations in the Upper Cretaceous sediments of the Outer Western Carpathians in the Waschberg-Ždánice Unit and Magura Group of nappes in South Moravia (Czech Republic) and Lower Austria (Fig. 1). Sedimentary sequences of these geological units are supposed to the east of their present locations and, as a whole, they may be included into the warm-temperate realm within the framework of Tethys. The sedimentary sequences of the Waschberg-Ždánice Unit were situated on the southeastern passive margin of the European Platform, while the Pieniny-Magura depositional area is considered to be a periplatform terrane of the Tethyan mobile realm.

Methods

Samples were taken from lithic flysch (interval T_e sensu Bouma 1962) in the Magura Group of nappes and claystone sediments in the Waschberg-Ždánice Unit. Smear slides were prepared using a standard method of decantation, and inspected under light microscope Nikon at 1000× magnification. Biostratigraphic data were correlated with the UC zones introduced by Burnett (1998). The interpretation of the appurtenance of Cretaceous nannofossil species to provinces followed mainly Watkins et al. (1996) and Burnett (1998).

Results

The Waschberg-Ždánice Unit

Turonian and Coniacian nannofossil assemblages (UC8–UC10 zone interval) are very close to those in the Bohemian Cretaceous Basin and share the following features:

Watznaueria barnesae is relatively abundant and varies between 25–38 %. The first occurrence of *Lithastrinus septenarius* coincides with the first occurrence of *Marthasterites furcatus* which is typical of lower paleolatitudes. Both phenomena document the affinity to the warm-intermediate realm of Tethys. The presence of *Thiersteinia ecclesiastica,* which is suggested to be an exclusively high-latitude species, gives evidence for nannoflora penetration from the North European Sea.

Campanian and Campanian-Maastrichtian assemblages (UC13–UC16 zone interval) are characterized by high numbers of both low- and high-latitude species and document probably the transitional area between the Boreal and Tethyan bioprovinces. Low-latitude nannofossils are represented by genera *Uniplanarius* and *Ceratolithoides*, high-latitude species by *Reinhardtites levis, Monomarginatus quaternarius, M. pectinatus, Biscutum coronum,* and *Neocrepidolithus watkinsii*.

Late Maastrichtian deposits are known only from the Lower Austria where nannofossils of the UC20b-d^{BP} Zone show affinity rather to the Boreal realm. This is supported by a higher number of high-latitude species *Cribrosphaerella daniae* and *Nephrolithus frequens*.

The Magura Group of nappes (Rača and Bílé Karpaty units)

Campanian and basal Maastrichtian (UC15bTP–UC16 zone interval) nannofossil assemblages are rather of the Tethyan affinity with only minor penetration of high-latitude species observed. A usual component of the assemblages is represented by low-latitude nannofossils that include specimens of genus *Ceratolithoides,* and species *Quadrum sissinghii* and *Q. trifidum*. Though infrequent, high-latitude species, such as *Biscutum coronum, B. magnum* and *Prediscosphaera stoveri* also occur here.

Late Maastrichtian nannofossil associations (zone UC20) are generally characterized by more frequent penetration of high-latitude species, which is confirmed by higher quantities of species *Prediscosphaera stoveri, Biscutum coronum, Cribrosphaerella daniae* and *Nephrolithus frequens.* Low-latitude species are represented by rare *Micula murus* and *M. prinsii*.

Tectonic slices within the Magura Group of nappes (Púchov Marl) of the Late Campanian and basal Maastrichtian age (UC15d^{TP}–UC16 zone interval) yield nannofossil associations indicative of Tethyan bioprovince (high number of specimens of genera *Ceratolithoides, Uniplanarius* and *Petrarhabdus copulatus*). A very low number of high-latitude species documents a negligible Boreal influence and evidences a more low-latitude location of the depositional area of the Pieniny Klippen Belt.

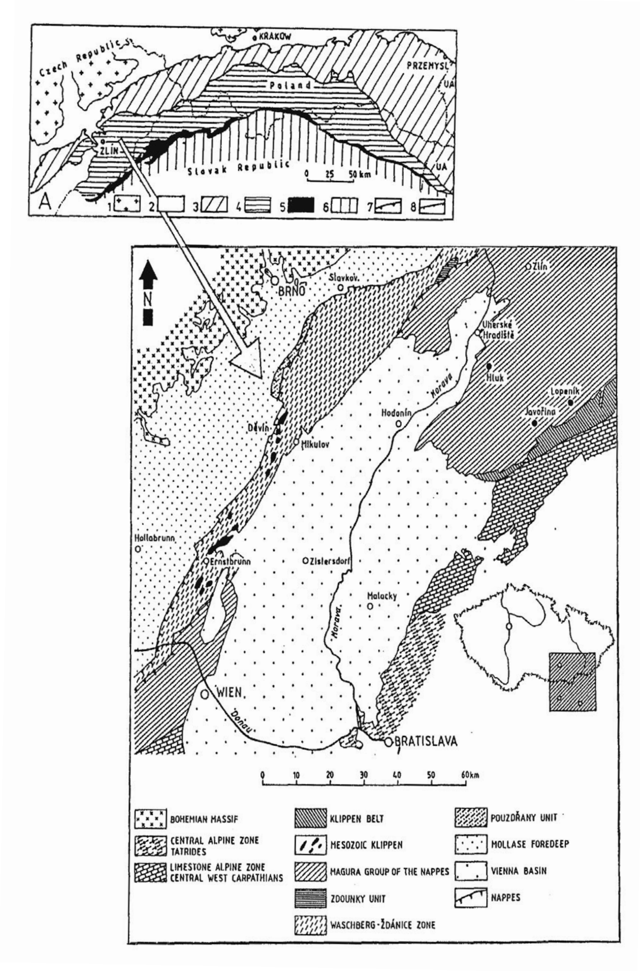

Fig. 1. Sketch-map of the Outer Western Carpathians including the studied area of the Waschberg-Ždánice Unit and Magura Group of nappes in South Moravia and Lower Austria.

Conclusions

The common occurrence of latitude-restricted nannofossils documents that the depositional area of the northern margin of Tethys was connected with North European basins in the Upper Cretaceous. The degree of influence by Tethyan and Boreal bioprovinces was a function of both the geographical positions of the basins (including the distance from shoreline, direction and temperature of sea currents, proximity to sea ways, depth, etc.) and geological time.

Two corridors could have caused the migration of high-latitude Boreal nannoflora species into the depositional area of the northern margin of Tethys:

1. The Bohemian/Saxonian Cretaceous Basin which was a narrow shallow-water strait connecting the Tethys with North European basins probably during the Upper Cenomanian–Coniacian. It represented the northernmost extension of the Tethyan realm in this period (sensu Kollmann et al. 1998). This corridor could have caused migration of high-latitude species into the depositional area of the Waschberg-Ždánice Unit.
2. The Polish Trough (Peri-Tethyan basins) which probably connected the northern Tethyan basins (depositional area of the Outer Western Carpathians including the Waschberg-Ždánice Unit and Magura Group of nappes) with North European basins since the Turonian-Coniacian until the Maastrichtian-Paleocene (Malata & Poprava 1997).

Note. By virtue of the common occurrence of high- and low-latitude nannofossil species, both Boreal and Tethyan zonations can be applied for biostratigraphical correlations of deposits in the Outer Western Carpathians within the Campanian–Maastrichtian interval.

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BIOSTRATIGRAPHICAL CORRELATION (FORAMINIFERS AND NANNOFOSSILS) OF THE KARPATIAN AND LOWER BADENIAN SEDIMENTS IN THE ALPINE-CARPATHIAN FOREDEEP (MORAVIA AND LOWER AUSTRIA)

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Key words: Badenian, Alpine-Carpathian Foredeep, biostratigraphy, foraminifers, calcareous nannofossils.

Biostratigraphical conclusions based on the study of foraminifers and calcareous nannofossils were carried out for the Lower/Middle Miocene boundary sediments of the Alpine-Carpathian Foredeep in South Moravia and Lower Austria. The study focused on the Karpatian-Badenian transitional strata, i.e. on deposits where foraminifers with *Globigerinoides bisphericus* and genera *Praeorbulina* and *Orbulina* appear for the first time (Table 1— see on page 80; Švábenická & Čtyroká 1998).

The following foraminiferal and nannofossil associations were recognized:

1. The interval with *Globigerina* div. sp. (lower part of the Karpatian, which is an equivalent of the Laa Formation in Lower Austria). Foraminiferal assemblages contain planktonic species, such as *Globigerina ottnangiensis*, and benthonic species with *Pappina primiformis*, *P. breviformis* and *Uvigerina graciliformis*. Nannofossils are characterized by the presence of helicosphaerids (*Helicosphaera ampliaperta, H. scissura, H. carteri*, very rare *H. mediterranea* and others).
2. The interval with *Globorotalia* div. sp. and *Globigerinoides* div. sp. include *G. bisphericus* (upper part of the Karpatian, which is an equivalent of the lower part of the Grund Formation in Lower Austria). The base of the interval is marked by the first appearance of foraminifers *Globorotalia* div. sp. and *Vaginulinopsis pedum*. Its higher part is characterized by the first occurrence of *Globigerinoides* div. sp., including *Globigerinoides bisphericus*. As for the nannofossils, *Helicopshaera waltrans* and *H. walbersdorfensis* first appear in association with rare specimens of *H. ampliaperta*.
3. The interval with *Praeorbulina* ex gr. *glomerosa* (marginal facies and basal interval of the Lower Badenian, which can be partly paralleled with the upper part of the Grund Formation). The foraminiferal assemblages contain *Globigerinoides bisphericus, Globigerinoides* div. sp., *Orbulina suturalis* and a high number of *Globorotalia* div. sp. In contrast, specimens of genus *Pappina* and *Uvigerina graciliformis* occur for the last time in the lower part of the interval. Nannofossil assemblages are characterized by relatively common *Helicosphaera waltrans.*
4. The lower horizon with *Vaginulina legumen* (pelites of the Lower Badenian). *Uvigerina aculeata, Lenticulina echinata, Vaginulina legumen* and *Planularia* div. sp. appear in foraminiferal assemblages, and stratigraphically important species *Globigerinoides bisphericus* is already absent. Nannofossil associations are characterized by the absence of *Helicosphaera waltrans*, and by higher number of specimens of genera *Discoaster, Calcidiscus* and *Sphenolithus heteromorphus*.

Biostratigraphical remark

Nannofossil species *Helicosphaera waltrans* seems to be an important marker for the biostratigraphic evaluation of the Lower/Middle boundary deposits in the studied area. *H. waltrans* first appear in association with *H. ampliaperta*, within the upper part of the nannoplankton zone NN4 (Martini 1971 and Young 1998) and has short vertical distribution which probably corresponds with the stratigraphical range of foraminiferal species *Globigerinoides bisphericus.* This interval can be correlated with the upper part of M4 and the lower part of M5 (sub)tropical zones sensu Berggren et al. (1995). The M4/M5 zones boundary was postulated as the Lower/Middle Miocene boundary.

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TO THE NEW FINDINGS OF LOWER CRETACEOUS AMMONITES IN THE WESTERN PART OF THE PIENINY KLIPPEN BELT (WESTERN CARPATHIANS, SLOVAKIA)

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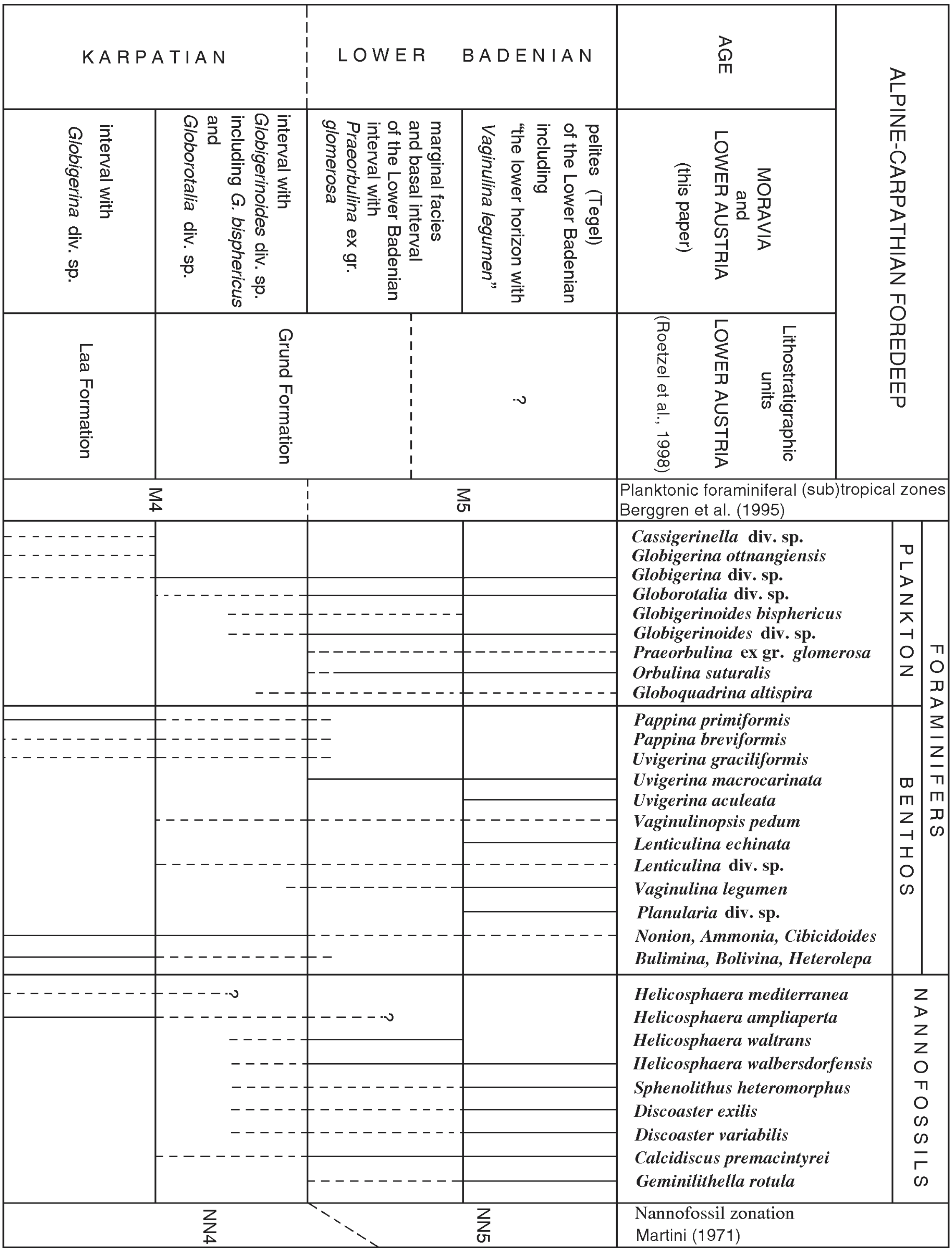
Key words: Pieniny Klippen Belt, Late Valanginian, Hauterivian, Barremian, ammonites.

Table 1 (to the abstract of Švábenická & Čtyroká — page 79).



In the course of the last several years, in the framework of co-operation with the Geological Institute of the Slovak Academy of Sciences (henceforth referred to as SAS), I have had a possibility to participate in field collections in the Jurrasic/Cretaceous and Lower Cretaceous deposits of the Klippen Belt (PKB). In some studied localities we succeeded, in a lesser or greater degree, in obtaining a new collection of fossil cephalopods (ammonites, aptychi, or belemnites). It was partly possible to employ the bed by bed method of collection. However, the Lower Cretaceous deposits are often poorly exposed so that we had to use only debris more frequently. As a result of a step inclination of rock strata, findings of fossils remain more or less in their places.

As far as visited localities are concerned, Podbiel and Revišné (Orava part of the PKB), Horné Sŕnie and Podbranč that belong generally to the Pieniny succession of the PKB localities are richest in ammonites. The collected cephalopod material has already been determined; however, the comprehensive evaluation of sections documented by the SAS research workers is still awaited.

The locality of Podbranč has been most fully studied (see the contribution of Michalík et al. this volume). In contrast with other documented localities a substantial part of the Lower Cretaceous sequence of strata has been, established with ammonite findings.

The results submitted should, however, be held as preliminary results indicating broader paleogeographical relations in the framework of Lower Cretaceous sedimentary spaces in the Alpine-Carpathian System. Therefore they do not analyze particular partial developments in the framework of the Klippen Belt itself.

The first rich occurrences of Lower Cretaceous ammonites come from light limestones intercalated with pelites of the Late Valanginian from the localities of Revišné and Horné Sŕnie (Dlhá quarry). In addition to rather abundant phylloceratids and lytoceratids that are, however, of small stratigraphical importance, neocomitids occur more frequently (*Neocomites teschenensis, N. praediscus),* haploceratids (*Neolissoceras grasianum*), sculptured bochianitids (*Bochianites neocomiensis*) and olcostephanitids. *Himantoceras trinodosum, Criohimantoceras gigas, Valanginites* cf. *nucleus* and *Oosterella* ex gr. *gaudryi* can be ranked among the most significant, although merely sporadically occurring species. Himantoceratids specify the stratigraphical position of fossiliferous deposits (ammonite Trinodosum Zone). A special complex of deposits mentioned is represented by condensed limestones in the Horné Sŕnie-Samášky area, cropping out in the section described by Aubrecht & Ožvoldová (1994). In the uppermost part of the condensed limestones we found a large shell belonging to *Varlheideites peregrinus.* This is the index species for the strata immediately underlying the Trinodosum Zone (Reboulet 1996). It dates the end of the local condensed sedimentation.

Grey marly limestones at the localities of Podbranč and Podbiel represent another, younger type of ammonite-bearing deposits. Besides less frequent phylloceratids and lytoceratids, both teschenitids (*Teschenites flucticulus, T.* cf. *castellanensiformis*) and smooth bochianitids (*Bochianites ooster*) prevail in the ammonite association. They indicate the Valanginian/Hauterivian boundary. Together with them, representatives of *Eleniceras, Jeanthieuloyites* and *Oosterella* occur sporadically. Later spitidiscids affiliate (*Spitidiscus* cf. *rotula*) and other representatives from the group of the genus *Jeanthieuloyites.* After that crioceratids appear (e.g. *Crioceratites nolani*) and *Abrytusites thieuloyi.* They indicate the younger Early Hauterivian age (ammonite Loryi- and Nodosoplicatum- Zones).

Younger fossiliferous deposits are known from the locality of Podbranč. They are represented by white-grey, usually spotted limestones. The ammonite abundance is lower than that of the underlying strata. Late Hauterivian zonal ammonites: *Subsaynella sayni* and *Plesiospitidiscus ligatus* are among the most significant findings. Together with them, phylloceratids and lytoceratids, further *Crioceratites majoricensis, Cr.* ex gr. *duvali* and *Ptychoceras meyrati* occur sporadically. A rich but almost monospecific assemblage of *Crioceratites binelli,* accompanied by rare shells of *Neolissoceras grasianum* occurs in the overlying strata. The last mentioned deposits can be regarded as an equivalent of the Pseudothurmannian Beds of the uppermost Hauterivian.

Marly limestones, darker than the underlying deposits, represent the youngest ammonite-bearing deposits from Podbranč. Incomplete shells of *Barremites* are dominating in them; *Silesites seranonis* occurs rather often too. Both *Emericiceras* cf. *barremense* and *Hemihoplites soulieri* can be ranked among rare accompanying findings. The latter species documents the higher Late Barremian (ammonite Feraudianus Zone).

From the standpoint of composition of the Late Valanginian to Early Hauterivian ammonite associations of the PKB, the closest relation within Western Carpathians can be found with the association of ammonites of the Manín Unit (Vašíček et al. 1994). In the time span from Late Valanginian to Late Hauterivian, the similarity to the Schrambach Formation in the Reichraming Nappe in the Northern Calcareous Alps (Bajuvarian Nappe Complex) — (Vašíček & Faupl in press) is striking.

In addition to pure Mediterranean ammonites, the occurrence of *Varlheideites peregrinus, Criohimantoceras gigas* and *Valanginites* cf. *nucleus* known also from the Lower Saxony Basin are specific of the PKB. They are assigned to the species indicating communication with Boreal Realm. We suppose a seaway connecting these regions through the Danish-Polish Depression.

Younger ammonite associations in the PKB are of the pure Mediterranean type. They miss Boreal elements because as the Danish-Polish Depression was already closed during the higher Early Hauterivian. The mass occurrence of *Crioceratites binelli* at Podbranč indicates presence of the Pseudothurmannia Beds in the PKB too, although no representative of the true pseudothurmannids has been found there. The first studing of *Hemihoplites soulieri* and *Emericiceras* cf. *barremse* in Upper Barremian deposits in the whole Western Carpathians system is interesting.

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PALEOECOLOGICAL INTERPRETATION OF SMALL FORAMINIFERAL ASSEMBLAGES FROM THE PALEOCENE-MIDDLE EOCENE DEPOSITS OF THE MAGURA NAPPE IN THE AREA OF SUCHA BESKIDZKA

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Key words: Polish Outer Carpathians, Magura Nappe, Siary Subunit, Paleocene–Middle Eocene, agglutinated foraminifera, morphogroups, paleoecology.

Introduction

The investigated area lies in the Skawa river basin between Sucha Beskidzka and Skawce (Fig. 1). Geologically this region belongs to the Siary Subunit of the Magura Nappe and its geology and stratigraphy was recorded in details by Książkiewicz (1974). One of the characteristic features of this northern subzone is development of the non-calcareous, variegated shales during the Late Paleocene–Middle Eocene. These shales are mostly hemipelagic in origin deposited from the suspension accompanying turbidity currents at bathyal and abyssal depths (Leszczyński & Uchman 1991). From time to time their sedimentation was interrupted by rapid deposition of thick-bedded turbidites.

The studied succession in the area of Sucha Beskidzka consists of the Inoceramian beds (Paloecene) which are developed as thick-bedded, hard, calcareous, grey sandstones intercalated by greenish clayey and marly shales. The Łabowa Shale Formation (Oszczypko 1992) is the next lithological unit (Late Paleocene-Middle Eocene). The variegated shales of this formation are divided by two complexes of the Ciężkowice Sandstones into three parts. The lower variegated shales (100 m thick) are mainly red in colour with very rare layers of sandstones. In the middle variegated shales (30 m) there are more intercalations of thin-bedded sandstones and greenish shales. The upper variegated shales (200 m) are mostly green with a considerable amount of thin-bedded turbidites. The Ciężkowice Sandstones are developed as thick-bedded sandstones with very thin intercalations of green, non-calcareous shales. Above the upper variegated shales there are thin-bedded turbidites (several m thick) similar to the Hieroglyphic beds (Middle Eocene). They are represented by grey-greenish silty or calcareous shales with subordinate thin layers of sandstones.

The main objective of the present study, besides biostratigraphy, was an attempt to use a morphogroup analysis for the envinronmental interpretation of the examined succession.

Methods

13 foraminiferal samples were collected from the variegated shales of the Łabowa Sh. Fm. and 11 from the shaly intervals of the Inoceramian beds, Ciężkowice Sandstones and Hieroglyphic beds (Fig. 1). The samples were divided into 500 g and 100 g parts and disintegrated by repeated boiling and drying using $Na_2SO_4 \times H_2O$ solution. Then, samples were washed over a 63 µm screen and dried. When possible at least 300 specimens were examined from the dry residue of 500 g samples for biostratigraphy purposes. All specimens were picked from the dry residue of 100 g samples, counted and then grouped into 5 morphotypes.

Biostratigraphic and paleoecological implications

The foraminiferal assemblages consist of entirely agglutinated benthic taxa except for one sample from the Inoceramian beds where a few Paleogene planktonic forms have been present. In the Inoceramian beds, lower variegated shales and the lower complex of the Ciężkowice Sandstone the Paleocene assemblages with *Glomospirella grzybowskii* (Jurkiewicz), *Remesella varians* (Glaessner), *Rzehakina epigona* (Rzehak) and *Spiroplectammina spectabilis* (Grzybowski) have been found. The planktonic species *Parasubbotina* cf. *pseudobulloides* (Plummer) confirms the Paleocene age of the Inoceramian beds. The Middle variegated shales of the Łabowa Sh. Fm. contain assemblages of the Glomospira acme zone commonly regarded as Early Eocene (Olszewska 1997). In one sample *Saccamminoides carpathicus* Geroch was also present. The foraminifera of the Middle Eocene Reticulophragmium amplectens Zone (Geroch & Nowak 1984; Olszewska 1997) occur in the upper variegated shales as well as in the Hieroglyphic beds.

Morphotype analysis rests on the assumption that there is a relationship between test shape and microhabitat preferences. Thus the morphogroup distribution can show the relation to environmental factors such as organic matter flux to the seafloor, oxygenation and substrate disturbance.

In the present study the benthic agglutinated genera have been combined into 5 morphogroups according to the models proposed by Jones & Charnock (1985), Nagy et. al. (1995) and Bąk et al. (1997): **A1** — tubular forms, erect epifauna, mostly suspension feeders (*Bathysiphon, Nothia, Rhabdammina, Rhizammina*); **A2** — planispiral or irregularly coiled forms, mobile epifauna, deposit feeders (*Ammodiscus, Glomospira, Paratrochamminoides, Rzehakina, Trochamminoides*); **A3** — more or less rounded forms, living with an aperture pointed into the sediment, epifauna, detrivores *(Ammosphaeroidina, Saccammina, Saccamminoides, Trochammina)*; **A4** — circular or ovate in shape, epifauna-shallow infauna and infauna, detrivores (*Haplophragmoides, Reticulophragmium, Recurvoides*); **A5** — elongated forms, infauna, detrivores (*Gerochammina, Karrerulina, Remesella, Reophax, Spiroplectammina*).

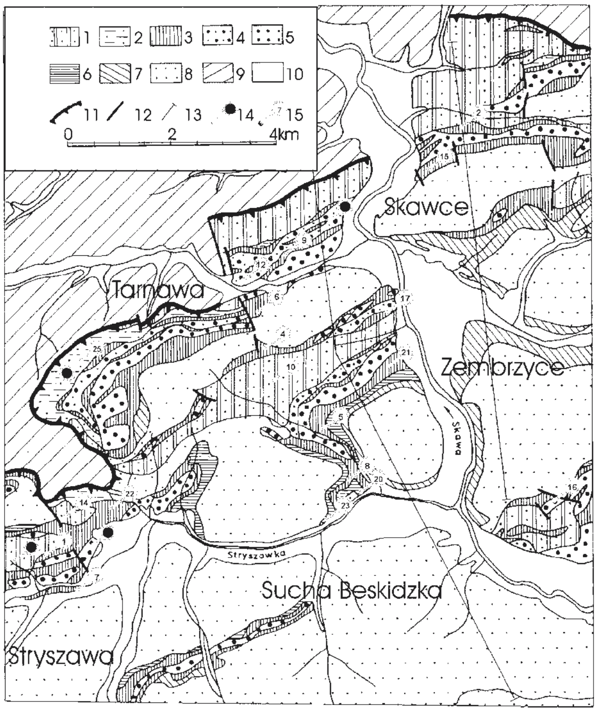

Fig. 1. Geological map of the Sucha Beskidzka area (after Książkiewicz 1974, supplemented). Magura Nappe, Siary Subunit: 1 — Inoceramian beds, 2 — Gołynia beds, 3 — variegated shales of the Łabowa Sh. Fm., 4 — lower Ciężkowice Sandstone, 5 — upper Ciężkowice Sandstone, 6 — Hieroglyphic beds, 7 — Submagura beds, 8 — glauconitic Magura Sandstone, 9 — Silesian Nappe, 10 — Quarternary deposits, 11 — thrust, 12 — faults, 13 — cross-section, 14 and 15 — location of foraminiferal samples.

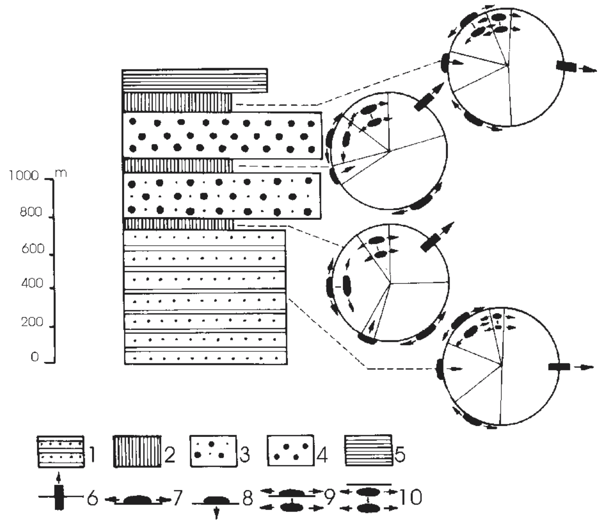

Fig. 2. Mean distribution of the foraminiferal morphogroups against litostratigraphic section of the Siary Subunit from Sucha Beskidzka: 1 — Inoceramian beds, 2 — variegated shales of the Łabowa Sh. Fm., 3 — lower Ciężkowice Sandstone, 4 — upper Ciężkowice Sandstone, 5 — Hieroglyphic beds; Morphogroups: 6 — A1, 7 — A2, 8 — A3, 9 — A4, 10 — A5.

The mean, generalized distribution of the particular morphogroups against the litostratigraphic column is presented in Fig. 2. The Paleocene Inoceramian beds are dominated by epifaunal forms (Fig. 2). A considerable amount of suspension feeders is usually connected with high energy environments such as those influenced by turbidity currents with relatively high organic flux. A small number of infaunal forms suggests insufficient oxygenation, which is in agreement with the greenish colour of the shales. In the lower variegated shales (Paleocene) the epifaunal suspension feeders are less frequent and the amount of infaunal forms increases. These facts imply more tranquil sedimentation and better oxygenation with lower organic flux. In the middle variegated shales the amount of mobile epifauna (A2) increases due to the abundance of *Glomospira*. The appearance of Glomospira acme zone follows the major changes in faunal composition at the Paleocene/Eocene boundary. This genus is inferred to be an opportunist occupying niches left vacant by other species, and the *Glomospira* biofacies are commonly regarded as an indicator of lowered productivity and well oxygenated deep-water conditions (Kaminski et al. 1996). In the upper variegated shales the proportion of suspension feeders rises again (Fig. 2) pointing to more frequent disturbance by turbidity currents supplying more organic matter which causes lowering in oxygenation. The lithological character of this complex (more frequent sandstone layers and green colour) reflects suggested changes.

The presence of some planktonic forms as well as *Remesella varians* known as the calcareous agglutinated species imply that the Inoceramian beds were deposited above the local CCD (though probably very close to it). The beginning of sedimentation of the variegated shales occurred close to the local CCD and later on it was connected with the paleodepths below the CCD which can be assumed from the entirely agglutinated, organic cemented foraminifera found higher up in the section.

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PALEOBIOGEOGRAPHIC ASPECTS OF LATE CRETACEOUS CALCAREOUS NANNOFOSSIL ASSEMBLAGES AT A TRANSECT FROM THE NORTHERN TETHYS TO THE EUROPEAN TEMPERATE REALM

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Key words: Calcareous nannoplankton, paleobiogeography, Late Cretaceous, Tethys.

Introduction

This paper describes differences in the compositon of Late Cretaceous nannofossil assemblages along a central European transect from the northern Tethyan margin within the Eastern Alps and the Western Carpathians to the European temperate to Boreal Realm. The paleogeographically southernmost sample group comes from the Austroalpine Units of the Eastern Alps (Gosau Group), the Inner Western Carpathians and from the Upper Cretaceous of the Transdanubian Central Range, comprising shallow water to slope environment. Nannofossil assemblages from the deep-water basins of the Flysch Zones towards north are generally redeposited and therefore represent a mixture from sourrounding shelves. Helvetic/Ultrahelvetic units together with the autochthonous Cretaceous deposits at the southern edge of the Bohemian Massif comprise the northernmost shelf and upper slope facies of the Tethys. The Waschberg-Ždánice Unit (Stráník et al. 1996) links the Tethys to the north-lying „temperate“ Bohemian Cretaceous Basin and the Münster Basin (e.g. Švábenická 1991).

Nannofossil assemblages from the following time slices were investigated under the light microscope (CC-zones of Perch-Nielsen 1985; UC zones of Burnett 1998): 1) Late Turonian to Early Coniacian; 2) Middle/Late Coniacian; 3) Late Campanian.

Late Turonian to Early Coniacian (CC13; UC8/UC9)

Nannofossil data from the Gosau Group (Švábenická in Hradecká et al. in press; Wagreich 1992) and the Brezova Group (Wagreich & Marschalko 1995) indicate rare (below 1%) but consistent occurrence of *M. furcatus* in the Upper Turonian. The assemblages are dominated by the genera *Watznaueria* (44–61 %) and *Glaukolithus*, *Eiffellithus*, *Stradneria/Cretarhabdus* and *Prediscosphaera*. Coeval nannofossil associations from both the Waschberg-Ždánice Unit of the Outer Western Carpathians (Švábenická et al. 1991; Stráník et al. 1996; Švábenická in Summesberger et al. in press) and the Bohemian Cretaceous Basin (e.g. Čech & Švábenická 1992) are also predominated by *Watznaueria barnesae*. *Marthasterites furcatus, Kamptnerius magnificus*, *Broinsonia* div.spec. and *Gartnerago obliquum* are present in higher amounts as well as the high-latitude species *Thiersteinia ecclesiastica*. Holococcoliths are less common than in the Gosau Group.

Late Coniacian (CC14; UC10)

Late Coniacian nannofossil assemblages of the Micula decussata Zone from the Gosau Group indicate decreasing amounts of

Watznaueria (5 to 28 %). Genera like *Glaukolithus*, *Stradneria*, *Cribrosphaerella*, *Prediscosphaera* and *Eiffellithus* predominate together with varying amounts of holococcoliths. A remarkable feature of the Gosau Group assemblages is the extremely low contents of *Micula*-species (below 1 %). Nannofossil assemblages from the Waschberg-Ždánice Unit are characterized by high abundances of the species *Watznaueria barnesae* (up to 20 %) and relative higher numbers (1–2 %) of species of the genera *Micula, Lithastrinus, Rucinolithus* and *Marthasterites*. Assemblages of the Bohemian Cretaceous Basin are characterized by higher numbers of *Glaukolithus*, *Marthasterites furcatus*, *Corollithion signum* and *Micula decussata*.

Late Campanian (CC22; UC15d–UC15e)

Nannofossil assemblages from the Gosau Group (Wagreich & Krenmayr 1993) comprise predominantly *Watznaueria barnesae* (16–30 %) and species of the *Prediscosphaera*-group (15 %) together with species of the genera *Biscutum*, *Cribrosphaerella*, *Stradneria*, *Eiffellithus*, *Micula* and *Glaukolithus*. *Uniplanarius* is present in percentages below 1 %. Mid-latitude to Boreal species like *Prediscosphaera* cf. *stoveri* or *Eiffellithus gorkae* are extremely rare. Nannofossil assemblages from the Rhenodanubian Flysch Zone and the Helvetic/Ultrahelvetic Units are also dominated by *Watznaueria barnesae* (Wagreich in press). In the Waschberg-Ždánice Unit (Švábenická 1995) nannofossil species normally confined to cold-temperate waters (*Monomarginatus quaternarius, Biscutum coronum, Petrarhabdus copulatus*, *Prediscosphaera stoveri*, *Neocrepidolithus watkinsii)* and warm water-preferring species are present (*Ceratolithoides*, *Uniplanarius*). The similarity of the assemblages gives evidence for only minor latitudinal differences between these separated paleogeographic realms at the nortern Tethyan-temperate boundary during the Late Campanian.

In comparison, Boreal assemblages from the Upper Campanian of northern Germany (Lägerdorf section) show predominance of *Prediscosphaera* and *Lucianorhabdus*. *Watznaueria* is common (8 %) as well as *Kamptnerius* and *Reinhardtites*, *Uniplanarius trifidum* and *Ceratolithoides aculeus* are missing.

Conclusions

1 — The general compositions of the nannofossil assemblages from the investigated transect display great similarities, e.g. the predominance of a few taxa (*Watznaueria*, *Prediscosphaera*, *Glaukolithus*, *Stradneria*).

2 — Only a few taxa show a clear latitudinal restriction, e.g. *Kamptnerius*, which increases from 0 % (Gosau Group) to 10 % (Münster Basin) from south to north.

3 — Typical northern temperate to boreal species comprise also *Petrarhabdus copulatus, Monomarginatus quaternarius, Biscutum coronum, Prediscosphaera stoveri*, and *Neocrepidolithus watkinsii*. They increase in abundances into the temperate realm.

4 — Low-latitude species like *Ceratolithoides aculeus*, *Uniplanarius trifidum* and *Cylindralithus* sp. are more or less confined to the northern margin of the Tethys and become very rare or absent farther to the north. Assemblages of the Waschberg-Ždánice Unit north of Vienna yield both low- and high-latitude species and are therefore interpreted as evidence for a connecting seaway for warm-water Tethyan currents and cold-water currents from the north.

5 — Paleoproductivity estimates based on the predominance of low-productivity nannofossil genera (NIP-index, Eshet & Almogi-Labin 1996) point to relatively low to intermediate marine productivity levels during the Late Campanian at the northern Tethyan margin during the Upper Campanian. Intermediate productivity values occur in the shallow-water shelf facies of the Late Turonian to Coniacian of the Gosau Group and the Bohemian Cretaceous Basin.

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MESOZOIC BASEMENT OF THE PODHALE BASIN (WESTERN CARPATHIANS, POLAND)

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Key words: subsurface geology, Mesozoic, Tatra Mts., Podhale region, Carpathians.

Introduction

The Podhale Basin situated between the Tatra Mts. and the Pieniny Klippen Belt is filled by up to 3000 m thick sequence of Paleogene deposits (see Olszewska & Wieczorek 1998). They cover the Mesozoic rocks which are exhumed in the Tatra Mts., in the Ružbachy "island". The knowledge of the Mesozoic basement of the Podhale Basin is indispensable for the reconstruction of geodynamic evolution of the Western Carpathians, as well as for the exploration and exploitation of thermal waters.

Drilling and seismic results

During the last forty years 19 wells have been completed in the Podhale Basin. 13 of them reached the Mesozoic basement. In the shallow hydrogeological wells situated on the foot of the Tatra Mts. the Mesozoic rocks belonging to Krížna or Choč nappe were recognised (Fig. 1). In the profile of Zakopane the IG-1 deep well some tectonic units of the Krížna nappe were interpreted (Sokołowski 1973). They are built mainly of Triassic and Lower Jurassic rocks, similarly as the Zakopane Regle at the Tatra Mts. (Bac-Moszaszwili 1998; Nemčok et al. 1995). Moreover, Upper Jurassic rocks of the High-Tatric (Tatricum) appearance were recognised at the depths 2916–2931 m. It is possible that they occur between the Križna scales, as we know from the Tatra Mts (Sywarowa Pass between Mała Łąka and Miętusia Valley — see Zawidzka 1967).

In the other deep wells, which are located in the central and northern part of the Podhale Basin, only the Krížna nappe is recognised without doubts. The presence of Choč nappe, as well as the Tatricum (High-Tatra units) is disputable. Moreover the profile of the Banská unit recognised in the Bańska IG-1 (Sokołowski 1992) and in the Poronin PAN-1 (Wieczorek in Jaromin et al. 1992a) is quite different from the tectonic units known from the Tatra Mts. but they show some features of the Manín unit (the presence of some hundred meters thick Middle/Upper Cretaceous succession).

In the Chochołów PIG-1 well, directly beneath the Paleogene rocks occurs a thin profile of Jurassic-Cretaceous deep water succession which cover the Carpathian Keuper and Middle Triassic dolomites belonging to the Krížna nappe. The presence of Choč nappe in this well postulated by Kotański (1997) is not justified.

In the Furmanowa PIG-1 well, below the Paleogene rocks Jurassic-Cretaceous marls were recognised . They cover the Lower Jurassic quarzites, which are known also from the Zakopane IG-1 well.

In the Poronin PAN-1 well, below the Paleogene occurs the sandwich of Triassic dolomites and Cretaceous marls. The underlying ~800 m thick succession comprising Uppermost Jurassic-Lowermost Cretaceous limestones with calpionellids and Lower-Upper Cretaceous (Cenomanian?) marls (locally spotted) with intercalations of siliciclastic turbidites was attributed to the Bańska unit. The drilled profiles end with the Carpathian Keuper level and Middle Triassic limestones and dolomites (Krížna nappe).

In the wells: Biały Dunajec PAN-1 and Biały Dunajec PGP-2 upper parts of the succession of Triassic dolomites and limestones, attributed to Biały Dunajec unit (Wieczorek in Jaromin et al. 1992b), were drilled beneath the Paleogene cover.

In the Bańska IG-1(Sokołowski 1992) — the deepest well on the Podhale basin, some tectonic units could be recognised in the Mesozoic succession. The thick succession of Triassic dolomites and limestones is regarded as the Biały Dunajec unit. The grey marls, which occur above (interval 2656–2714 m), attributed by Sokołowski (1992) to ? Upper Triassic (? Keuper) could represented a lower part of the Paleogene succession. Below occur: Upper Cretaceous conglomerates (?Gosau Beds), marls with siliciclastic turbidites (Middle-Upper Cretaceous) and deep water Middle Jurassic-Cretaceous rocks, which build the Bańska unit (Sokołowski 1992) of Manín unit affinities. The Jurassic-Cretaceous succession, which occurs at interval 4132–4484 m, could represent the similar unit, detached during overthrust movements, from the main body of the Bańska unit.

The lowest interval (4484–5261 m) belongs to ? the Keuper or most probably to the Lower Triassic of High-Tatra affinities (Kotański 1997).

The Bańska PGP-1 well reached the Mesozoic basement, the Triassic of the Biały Dunajec unit, at a depth of 2809 m and pierced them up to the depth of 3242 m. In the Bukowina Tatrzańska the PIG-1 well the Mesozoic rocks belonging to 2–3 tectonic units of the Krížna nappe occur at the of depth 2225–3780 m.

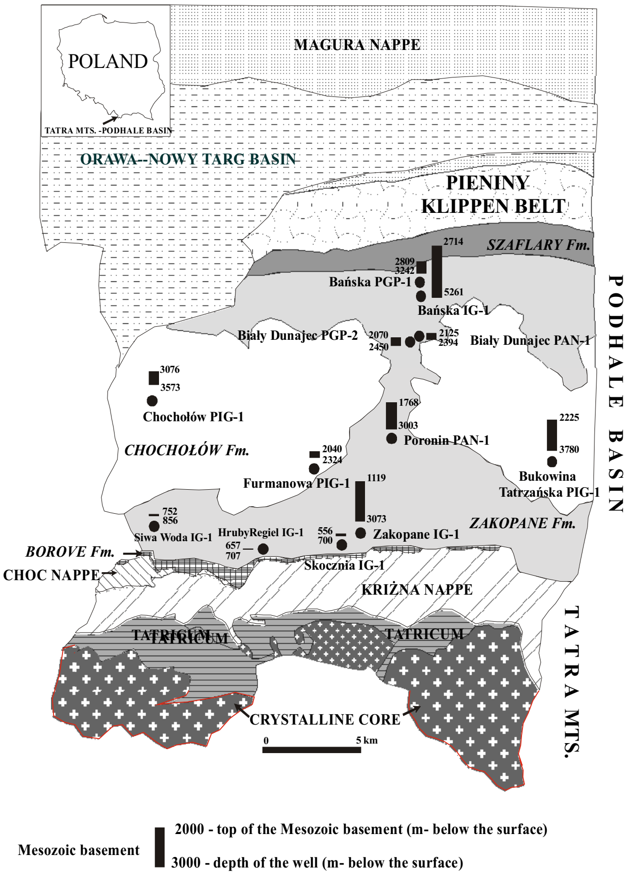

Fig. 1. Location of the wells that reached the Mesozoic basement on the geological map of the Tatra Mts.—Podhale region.

The Maruszyna IG-1 well situated at the southern border of the Pieniny Klippen Belt pierced only the Pieniny Klippen Belt structure (the Pieniny and Branisko nappe, Jarmuta Fm. and sandwiched Lower-Middle Jurassic rocks of unrecognised units) — see Chowaniec & Sokołowski 1985).

8 seismic lines of generally poor qualities were completed in the Podhale Basin. Their interpretation, in the link of the wells profiles, enabled to construct the geological profile between Tatra Mts. and the Pieniny Klippen Belt (Wieczorek & Barbacki 1997).

The geological cross-section between the Tatra Mts and the Pieniny Klippen Belt

The modified and completed profile through the Podhale (Fig. 2) shows, that the Podhale basin forms an asymmetric structure which is deeper in its northern limb. The Mesozoic basement is composed of numerous tectonic units, generally gently inclined, in contrast with the deeply inclined units at the northern border of the Tatra Mts.

Discussion

The units of the southern border of the Podhale basement could be related to the same tectonic units as are known from the Tatra Mts. border, but the further units, from central and northern Podhale show some differences. Generally they form a pile of units of Tethyan passive margins origin (Wieczorek 1995). They were transported to the north during long-time overthrust movements related to the early phases of Adria (Apulia)-European plate collision. The main overthrust movements took place during the

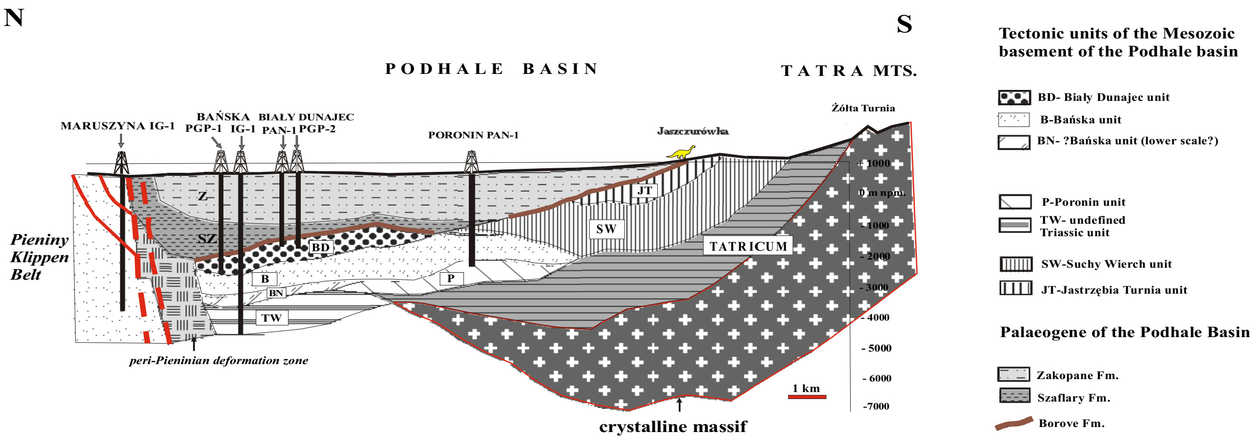

Fig. 2. Simplified geological cross-section from the Tatra Mts. to Pieniny Klippen Belt (after Wieczorek & Barbacki 1997, completed and modified).

Late Turonian time, but the younger Late Cretaceous/Early Paleogene movements are very likely (see also Plašienka et al. 1997).

The contact between the Podhale basement and the Pieniny Klippen Belt is probably too complicated to be recognised on the 2D seismic sections. There occurs a very narrow Maruszyna scale, which is composed of Upper Cretaceous-Early Paleogene deep-water sediments (Birkenmajer 1986; Kostka 1993). The minimum shortening, at the Podhale Mesozoic basement and the Pieniny Klippen Belt, in the post-Paleocene movements could be estimated as some tens of kilometres.

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STRATIGRAPHY, FAUNA, MICROFACIES, AND SEDIMENTATION OF THE UPPER BAJOCIAN TO CALLOVIAN LIMESTONES OF THE AMMONITICO ROSSO TYPE IN THE PIENINY KLIPPEN BELT IN POLAND

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Key words: Pieniny Klippen Belt, Ammonitico Rosso facies, Middle Jurassic, stratigraphy, ammonites, brachiopods, microfacies.

The nodular limestones of the Middle Jurassic age have been studied in selected sections of the Czorsztyn Succession, and the Niedzica Succession of the central and eastern parts of the Pieniny Klippen Belt in Poland. These deposits represent the lower part of the Czorsztyn Limestone Formation in the Czorsztyn Succession, and the Niedzica Limestone Formation in the Niedzica Succession, according to the formal lithostratigraphic scheme proposed by Birkenmajer (1977).

The fairly numerous ammonites collected bed by bed in the sections studied are used to revise and amplify earlier accounts dealing with the chronostratigraphy of the Czorsztyn and Niedzica Successions. It should be remembered that the oldest so far recognized deposits of the Czorsztyn Succession were attributed to the Bathonian and/or Callovian (see e.g. Birkenmajer & Myczynski 1984; Rakús 1990), while those of the Niedzica Succession were attributed to the Bathonian and/or Upper Bajocian (Birkenmajer & Znosko 1955).

The studied lower part of the Czorsztyn Limestone Formation in the Oblazowa Klippe, the Czorsztyn Castle Klippe and the Krupianka Creek sections has yielded the following ammonite faunas:

— fauna of *Dimorphinites dimorphus* (d'Orbigny), and *Vermisphinctes* sp. indicative of the Parkinsoni Zone of the uppermost Bajocian;

— fauna of *Nannolytoceras tripartitum* (Rasp.), *Oxycerites yeovillensis* Rollier, *Zigzagiceras pseudoprocerum* (Buckman), *Bullatimorphites ymir* (Oppel) indicative of the Lower Bathonian;

— fauna of *Procerites progracilis* Cox & Arkell, and *Choffatia uriniacensis* (Lissajous) indicative of the Middle and Upper Bathonian;

— fauna of *Macrocephalites* sp., and unidentifiable Peltoceratinae indicative of the Callovian.

The studied deposits of the Niedzica Limestone Formation in the Niedzica-Podmajerz and the Czajakowa Skala sections have yielded the following ammonite faunas:

— fauna of *Garantiana tetragona* Wetzel, and *Vermisphinctes* cf. *stomphus* (Buckman) indicative of the Garantiana Zone of the Upper Bajocian;

— fauna of *Dimorphinites* cf. *dimorphus* (d'Orbigny), *Parkinsonia* sp., and *Nannolytoceras tripartitum* (Rasp.) indicative of the Parkinsoni Zone of the Upper Bajocian;

— fauna of *Nannolytoceras tripartitum* (Rasp.), and *Bullatimorphites* sp. indicative of the Lower Bathonian;

— rare poorly preserved ammonites including unidentifiable Peltoceratinae found in the uppermost part of the sections, which represent the interval from the Middle Bathonian to the Callovian.

The nodular limestones of the Ammonitico Rosso type overlie in both successions the crinoid limestones attributed to the Smolegowa Limestone Fm., and the Krupianka Limestone Fm. The boundary is always a marked omission surface, and the corresponding stratigraphical gap is larger in the Czorsztyn Succession, than in the Niedzica Succession. This change in sedimentation from the shallow-water crinoid limestones to the deeper-water pelagic limestones was related to the Meso-Cimmerian faulting which affected the Czorsztyn Ridge splitting it into a series of blocks showing differential subsidence (cf. Birkenmajer 1986).

The studied deposits are very poor in benthic organisms, which become but slightly more common in the Bajocian interval of the sections: the red crinoid limestones of the uppermost part of the Krupianka Limestone Fm., and the nodular limestones of the lowermost part of the Czorsztyn Limestone Fm., and the Niedzica Limestone Fm. These have yielded fairly numerous crinoids, rare brachiopods, and sporadically found echinoids and gastropods.

All the recognized brachiopod species are characteristic of the Mediterranean brachiopod province. They are represented mainly by: *Apringia atla* (Oppel), *Septocrurella defluxa* (Oppel), *Liguithyris curviconcha* (Oppel), *Karadagithyris eduardi* Vörös, *Karadagella zorae* Tchorszhevsky & Radulović, and *Zittelina* ? *beneckeri* (Parona), and others found in single specimens, such as *Capillirhynchia bretoniaca* (Oppel), *Caucasella voultensis* (Oppel), *Septocrurella kaminskii* (Uhlig), *Striirhynchia subechinata* (Oppel), *Sphenorhynchia rubrisaxensis* (Rothplotz), "*Terebratula*" aff. *decipiens* Eud.-Deslongchamps. The distribution of Bajocian brachiopods was related to the character of the paleoenviroment: e.g. *Septocrurella defluxa* and *Karadagella zorae* occur only within shallow-water crinoid limestones, whereas *Apringia atla* and *Karadagithyris eduardi* — appear almost exclusively in Ammonitico Rosso type deeper water limestones. The bulk of the brachiopod species had narrow paleoenviromental tolerance, being restricted either to "crinoid meadows" or to "pelagic mud" (K-selected taxa) — but some were opportunistic (R-selected type species) occurring both in the crinoid and nodular limestones (e.g. *Liguithyris curviconcha*). Generally, most of the brachiopod species are known in the Western Carpathians (Slovakia), Transdanubian (Hungary) and Austroalpine units (Austria, Italy — Southern Alps and even Sicily). From the paleobiogeographical point of view this Bajocian brachiopod fauna of the Pieniny Klippen Belt is typical, together with those of the indicated regions, of the Periadriatic domain (=Mediterranean — sensu Vörös 1993).

The microfacies characteristics of the studied nodular limestones show a marked dominance of fragments (filaments) of thin-shelled pelecypods of the genus *Bositra*, revealing the presence of two microfacies types: the filament microfacies sensu stricto, and the filament–juvenile gastropod microfacies. The occurrence of deposits of the latter microfacies is diachronous. These deposits appear earlier in the Niedzica Succession (already during the Late Bajocian), than in the Czorsztyn Succession (during the Early Bathonian). It could be related to the continuous movement in time of a shallower-zone located on a slope of the submerged Czorsztyn Ridge where a more diversified benthic fauna (including gastropods) possibly existed.

The youngest nodular limestones include either limestones of the *Globuligerina* ("*Protoglobigerina*") microfacies (in the Czorsztyn Succession, and some sections of the Niedzica Succession), or limestones of the radiolarian microfacies (in the Niedzica Succession). The replacing of older deposits of the filament microfacies, by these containing abundant planktonic organisms indicates a general increase in plankton productivity which may have been related to a marked change in oceanic circulation in the northern part of the Tethys.

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WEATHERING OF THE CARPATHIAN FLYSCH SANDSTONES — A NATURAL OR ATMOSPHERIC-POLLUTION INFLUENCED PROCESS

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Key words: weathering, sandstones, atmospheric pollution, Carpathian flysch.

Introduction

The processes of weathering of rocks in the presence of anthropogenic pollution of the atmosphere differ from natural weathering. The rate of weathering in a polluted atmosphere increases significantly in comparison with natural process. The higher rate of weathering is related to the composition of the rocks, their texture and to the concentration of aggressive gaseous components of the air pollution and anthropogenic dusts particles (Wilczyńska-Michalik & Michalik 1996a; Michalik & Wilczyńska-Michalik 1998). Visual manifestations of natural weathering and that accelerated by air pollution are, however, sometimes similar.

There are several features which can be regarded as indicators of the influence of air pollution on the rocks (Wilczyńska-Michalik & Michalik 1996b):

A. The occurrence of a compact, continuous gypsum (or sometimes of other composition, e.g. other sulphates, halite) crust on the surface of the rock. The structure of the crust is related to the concentration of the pollution. Dispersed single gypsum crystals also occur in the areas of relatively low concentration of air pollution.

B. The occurrence of a layer of amorphous or poorly crystalline aluminosilicates with a relatively high concentration of sulphur, chlorine, and phosphorus.

C. The presence of numerous anthropogenic dusts on the surface of the rocks. Not all anthropogenic dust particles can be easily distinguished from natural, eolian ones. Single particles of anthropogenic dusts also occur in the areas of low concentration of air pollution.

D. A higher than natural concentration of some chemical elements of the surface of the rocks or in the superficial layer of the rock. Different processes contribute to the concentration of some elements. Very often it is difficult to properly distinguish those induced by atmospheric pollution from natural ones (e.g. concentration related to micro-organisms inhabiting the rock surface).

Weathering of sandstones in the flysch Carpathians

The Carpathian Flysch sandstones differ significantly in composition and texture. The exposure to weathering factors is also different due to the place and form of occurrence (outcrops in deep valleys, on mountain ridges, old quarries, isolated tors, abundance of vegetation, and microenvironment conditions). Manifestations of the weathering processes of the Carpathian Flysch sandstones are numerous — granular disintegration, exfoliation, formation of Fe-oxides-rich (or Fe- and Mn-oxides-rich) layers on the rock surface. The intensity of natural weathering is co-related to the lithological type of the sandstone, local climatic conditions, development of vegetation cover, and numerous other factors. Some weathering features (e.g. weathering pits, honeycomb structure) were the subject of consideration of several authors (Alexandrowicz 1978; Alexandrowicz 1989; Alexandrowicz & Brzeźniak 1989; Alexandrowicz & Pawlikowski 1982).

Michalik & Wilczyńska-Michalik (1998) presented preliminary studies of the influence of atmospheric pollution on weathering of sandstones in the Carpathians. A comparison of weathering of sandstones subjected to the action of the highly polluted urban atmosphere in Kraków and from natural outcrops in the Carpathians (Wilczyńska-Michalik & Michalik 1996a) was also made. The results indicate that in heavily polluted areas salt weathering (Goudie & Viles 1997) is very active.

A crust of secondary minerals (mainly gypsum) crystallizes on the rock surface and inside the superficial layer of the rock. During blistering and exfoliation of this crust the outer part of the rock is peeled of. Crystallization of salts inside the rock and replacement of natural cements by gypsum cause granular disintegration of rocks.

Sampling sites

Different parts of the Beskidy Mountains (the northern part of the Beskid Makowski Mts., Beskid Niski Mts., Bieszczady Mts., Carpathian Foothills — Dynów Foothill) were chosen for sampling due to differences in composition and concentration of dust and gases (SO_2, NO_x, CO, CO_2) in the atmosphere. Samples were collected from surface layers of sandstones in natural outcrops and buildings in which sandstones of local origin had been used as building material.

Methods of laboratory studies

After the preliminary selection based on field observation samples were subjected to microscopic investigations. Both optical and electron microscopy were used. An electron microscope fitted with an energy dispersive spectrometer (SEM-EDS) was used for the determination of the chemical composition of the secondary minerals of rocks. Natural surfaces of weathered rocks and polished sections were examined. A coal film coating was applied before SEM-EDS analyses.

Results

In Kalwaria Zebrzydowska, a relatively highly polluted area in the Carpathians, a compact, dark coloured gypsum crust was noticed on stone surfaces sheltered against direct washout by rainwater. The crust is composed of numerous platy gypsum crystals, which are more or less euhedral. Very often anthropogenic dust particles are present between the gypsum crystals. Blistering and exfoliation of the gypsum crust is relatively common. Together with the detached gypsum crust some components of sandstone are removed from the rock surface.

In Kalwaria Zebrzydowska, on surfaces exposed to washout by rain, dispersed, small (visible in SEM) gypsum crystals are present. On some samples the amount of gypsum is significant. The surfaces on which the described gypsum crystals are present exhibit more or less intensive granular disintegration.

In the Carpathian Foothills (Ciężkowice and Krosno area) and in the Beskid Niski where the concentration of air pollution is lower, a continuous, compact gypsum crust on rock surfaces is not developed. Dispersed efflorescences and single gypsum crystals are present. The variation of the amount of gypsum on rock surfaces of different samples is probably related not only to differences in the concentration of air pollution between the localities but also to local conditions (exposure of rock surface, lithological characteristics, etc.). Besides gypsum, potassium alum was noted on the surface of a sample from the Ciężkowice area. In each of the above mentioned sites, numerous anthropogenic dust particles were observed on rock surfaces.

During detailed SEM-EDS examinations of polished sections of samples from Odrzykoń near Krosno (the Carpathian Foothils) corrosion of quartz grain surfaces was noted. In embayments and in pits in quartz grains, besides numerous aluminosilicate grains, barite and dolomite have been recognized. Irregular grains of barite are very small (> 1–2 μm). It is necessary to add that barite cement is not present in the Ciężkowice sandstones outcropping here.

In the Bieszczady Mts., where the concentration of air pollution is lowest in comparison with other localities, crystallization of salts on rock surfaces was not noticed. The presence of antropogenic dust particles on rock surfaces is the only manifestation of the presence of atmospheric pollution.

Dicussion of results

The occurrence of a gypsum crust, dispersed efflorescences of gypsum, single gypsum crystals and the presence of anthropogenic dust particles on the surfaces of rocks are related to atmospheric pollution. It is possible to exclude the influence of weathering sulphides in sandstones on the development of sulphates in the studied samples. Gypsum, in most cases, is the product of crystallization from rainwater, but formation in the reaction between SO_4^{2-} ion from atmospheric precipitation and Ca^{2+} ion delivered from decomposed rock components is also possible.

The thickness of the gypsum crust is related partly to the concentration of atmospheric pollution. Porosity of sandstone is also very important as a factor controlling the depth of penetration of atmospheric precipitation solutions into the rock. Composition of the rock (presence of carbonates) is also meaningful.

Barite is formed, most probably, in the reaction between atmospheric SO_4^{2-} and Ba^{2+} ions originating from decomposed K-feldspars. Barite in the superficial layer of the rock is an insoluble mineral and may be considered as evidence of the presence of sulphur compounds in rainwater. Other, more soluble salts (e.g. gypsum) are, perhaps, periodically dissolved by rainwater of relatively low pH and low concentration of pollutants.

The formation of a gypsum crust on the rock surface significantly increases the rate of decay of the rock. In each cycle of detachment the removal of sandstone framework grains took place. The rate of decay is strongly related to the porosity of the sandstone. Development of a gypsum crust partly inside the rock facilitates the detachment (loosening of the rock structure by growing crystals) and increases the volume of peeled rock material.

Crystallization of gypsum (and/or other salts) in the superficial layer of the rock is the reason for accelerated granular disintegration. The role of salt weathering is related to the concentration of salts in solutions penetrating the rock and composition of the salts.

The evaluation of the influence of atmospheric pollution on the rate of weathering of sandstones in the Carpathians is difficult. Salt weathering induced by atmospheric pollution is significant, only in some areas, where gypsum crust is formed and crystallization of salts is voluminously significant.

In areas where only dispersed efflorescences and single gypsum crystals on rock surface are noted, the role of this type of weathering is not significant. On the other hand it is also possible to suggest that the presence of barite in a superficial layer of sandstone indicates activity of a sulphate ion. The absence or scarcity of gypsum on the surfaces of rock from the same locality can be explained by the removal (dissolution) of gypsum from the surface by rains of relatively low pH.

Conclusions

The presence of atmospheric pollution is marked on the surfaces of the rocks (occurrences of gypsum crust, gypsum efflorescences, anthropogenic dusts). However the intensity and mechanisms of natural weathering processes are not significantly changed. Salt weathering related to a high concentration of atmospheric pollution significantly accelerates the decay of rocks only locally.

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