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JURASSIC SEDIMENTS AND MICROFOSSILS OF THE ANDRYCHÓW KLIPPES (OUTER WESTERN CARPATHIANS)

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Abstract: Shallow-water carbonate Jurassic sediments of the Andrychów Klippes (Inwałd, Pańska Góra, Targanice and Roczyny klippes) differ in origin and environment of deposition from the surrounding flysch complexes. In Jurassic paleogeography they represented a marginal part of the European Plate (Golonka et al. 2000), the morphology of which was characterized by the presence of elevated blocks, separated by basins. During Alpine north-directed movements, several blocks were detached from the continent and incorporated into flysch sediments, mainly in the front of the Silesian Nappe. Oxfordian cherty limestones of Andrychów Klippes show significant similarities to coeval sediments deposited on Eurasia's southern margin. The Tithonian shallow-water limestones with abundant nerineacean-diceratid-coral fauna, numerous algae (dasycladales, codiaceans, solenoporeaceans), foraminifers (lituolids, miliolids, involutinids) and calcareous dinocysts show similarities to the Štramberk limestones, and remnants of carbonate sediments of the European Plate which occur as blocks and exotics in flysch deposits of the Outer Carpathians.

Key words: Carpathians, stratigraphy, Jurassic sediments, carbonate facies, nerineaceans, calcareous dinocysts, algae, foraminifers.

Introduction

The Andrychów (External) Klippes (Roczyny, Targaniczanka N, Targaniczanka S, Pańska Góra N, Pańska Góra S, Inwałd W, Inwałd E) occur in the western part of the Polish Flysch Carpathians between the localities of Roczyny and Inwałd (Fig. 1) in a 6 km long zone directed NEE–SWW (Książkiewicz 1935a).

The history of geological investigations of the Andrychów Klippes covers the span of about 170 years. The first information was given by Ami Boue (1830) in his "Observations sur les Alpes et les Carpathes". Since that time the Andrychów Klippes were studied by many geologists and paleontologists (see Gasiński 1998) trying to resolve their origin and relations to the surrounding flysch and to the two great bio- and sedimentary provinces: oceanic (Tethyan) and epicontinental (peri-Tethyan shelf) in the area. The most complete study of the Andrychów Klippes was made by Książkiewicz (1935 a,b,c) and Nowak (1976, 1983, 1986). The Cretaceous sediments of Klippes were recently studied by Gasiński (1998). The present study concentrates on the Jurassic sediments of Klippes and coincides with the 150th anniversary of the Zeuschner's study (1849) of the gastropod faunas of the Inwałd klippe. In the search for the source area, the relationship of the Andrychów Klippes to the adjacent areas of carbonate sedimentation of the region is discussed.

Geological characteristic of the Andrychów Klippes

The Roczyny Klippe. The westernmost and the largest of the klippes (Książkiewicz 1935a) is composed of Upper Cretaceous (conglomerates, crinoidal limestones, marls) and Middle-Late Jurassic (crinoid and cherty limestones) sediments and the mylonitized vulcanites. The klippe contacts sediments of the Silesian and Sub-Silesian nappes (Nowak 1986). The mutual relationships of the klippe elements were the subject of contradictory interpretations (Książkiewicz 1935a, 1965; Nowak 1986).

The Targanice Klippes. The two klippes (N and S) occur in the Targanice stream valley between the villages of Targanice and Sułkowice, S from Andrychów. The klippes are separated by sediments of the Sub-Silesian Nappe (Nowak 1986). The Northern Targanice klippe is composed of the Upper Cretaceous marls, cherty limestones and Lower Paleogene detrital limestones with *Lithothamnium* and large foraminifers.

The tectonic interpretation of the Northern Targanice klippe is very difficult, an imbricated structure is assumed (Nowak 1986).

The much smaller Southern Targanice klippe consists of Upper Jurassic cherty limestones and subordinately, Upper Cretaceous conglomerates, marls and cherty limestones (Książkiewicz 1935b, 1968; Nowak 1986). The Southern Targanice klippe is an isolated block embedded in the sediments of the Sub-Silesian Nappe.

The Pańska Góra Klippes. The Pańska Góra klippes occur as separate blocks at the contact of the Silesian and Sub-Silesian nappes on the northern slope of the Pańska Góra hill (SE of Andrychów) (Książkiewicz 1935b; Nowak 1986). The Southern klippe (the biggest one) is formed by Upper Cretaceous marls, Paleogene dark shales and limestones and subordinately, by crystalline rocks and Upper Jurassic limestones. The Northern klippe, a block of granite-gneiss, is wedged up in the Krosno Beds of the Sub-Silesian Nappe. The Western

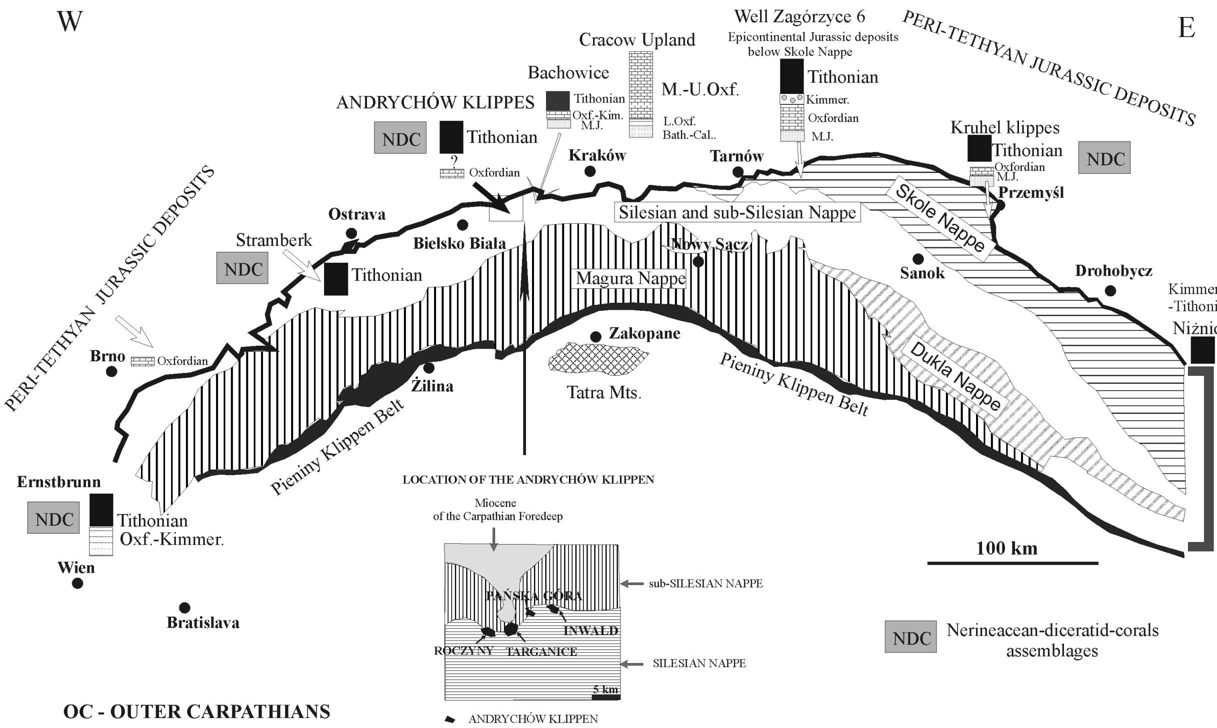

Fig. 1. Location of the Andrychów Klippes in relation to the other profiles of Jurassic sediments.

klippe (the smallest one) is composed of tectonized crystalline rocks and a small fragment of Paleogene limestones (Nowak 1986).

The Inwałd Klippes. Nowak (1986) described two Inwałd klippes, one of them being rather a set of blocks grouped around so called "main klippe" (the E Inwałd klippe), another, an isolated block (the W Inwałd klippe). The klippes outcrop in several abandoned quarries at the foot of the Wapienica hill S of Inwałd (Książkiewicz 1935a). They contact both the Silesian and the Sub-Silesian nappes (Książkiewicz 197l; Książkiewicz & Liszkowa 1972; Nowak 1986; Gasiński 1998). The Eastern klippe is composed of Upper Jurassic limestones (with the famous *Nerinea* fauna described by Zeuschner 1849), Upper Cretaceous marls and mudstones, Paleogene limestones and mylonitized granite gneisses (Nowak 1986; Gasiński 1998). The Western klippe is composed exclusively of mylonitized granitic rock.

Distribution of fossils in sections studied

The Roczyny Klippe. Three types of Jurassic limestones are known from the Roczyny klippe: crinoidal limestones, cherty limestones and so called "Inwałd-type limestones" (Książkiewicz 1935a; Nowak 1986). Crinoidal limestones occurs in isolated blocks. Thin sections reveal their packstone texture with dense packed crinoid stems, bryozoans, ostracods and rare foraminifers. The lack of stratigraphically significant fossils makes proper age designation difficult. Most frequently they were attributed to the late Middle Jurassic (Książkiewicz 1935a, 1968).

Cherty limestones were found both in the surface outcrop (Książkiewicz 1935a; the author's studies) and in the Roczyny 6 borehole (Książkiewicz & Liszkowa 1972). The micritic limestones contain foraminifers: *Epistomina* sp., *Globuligerina* cf. *oxfordiana* Grigelis, *Paalzowella turbinella* Gümbel, *Opthalmidium* aff. *strumosum* (Gümbel), abundant sponge spicules, fragments of echinoderms and calcareous dinocysts: *Colomisphaera fibrata* (Nagy), *Crustocadosina semiradiata* (Wanner). They were attributed to the Lower-Middle Oxfordian which supports earlier age designations (Książkiewicz & Liszkowa 1972).

The "Inwałd limestones" (bioclastic grainstone) contain numerous organic remnants: thin sections investigated contained foraminifers — *Quinqueloculina* cf. *verbizhiensis* Dulub, *Mohlerina basiliensis* (Mohler), *Protopeneroplis* cf. *striata* Weynschenk, *Spirillina* sp., *Lenticulina* sp., *Globuligerina* sp.; zoospores (*Globochaete alpina* Lombard), microproblematics (*Tubiphytes* cf. *morronensis* Crescenti), isolated sections of calpionelids (presumably *Crassicollaria*), gastropods (*Ptygmatis pseudobruntrutana* mentioned by Zeuschner 1849), echinoderms, and also microoncoids and ooids. The assemblage suggests an Upper Tithonian age and a shallow, near reef environment of the sediments investigated.

The Targanice Klippes. The Jurassic cherty limestones (cherty grainstones) outcrops in the Southern klippe. Bioclasts are composed of foraminifers: *Globuligerina* cf. *oxfordiana* Grigelis, *Protomarssonella jurassica* (Mitjanina), *Glomospira variabilis* Kübler et Zwingli, *Protopeneroplis striata* Weynschenk, *Opthalmidium* aff. *marginata* Wiśniowski, *Paalzowella* sp., *Lenticulina* sp., *Spirillina* sp.; calcareous dinocysts: *Cadosina parvula* Nagy; microproblematics; *Koskinobullina*

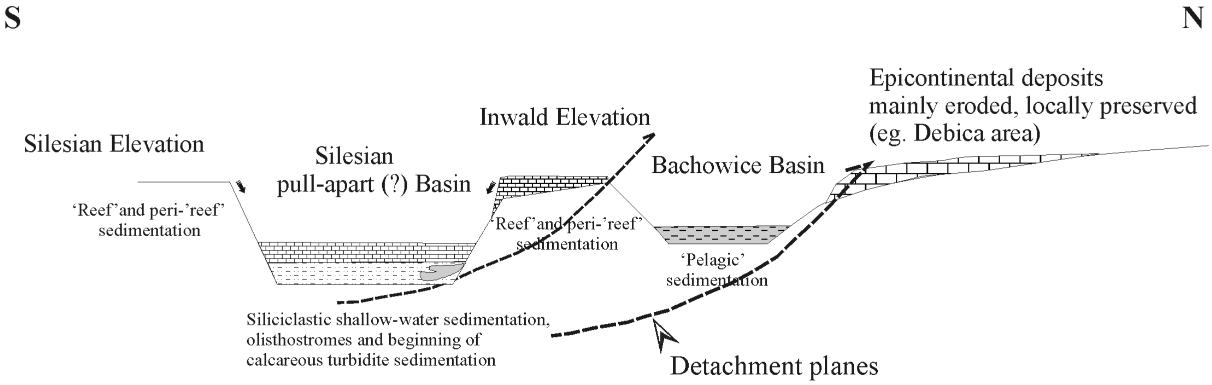

Fig. 2. Situation of the Tithonian Inwałd elevation on the Eurasian margin of Northern Tethys and possible location of the late Alpine (Middle Miocene) detachment planes.

socialis Cherchi et Schroeder; calcified radiolarians, sponge spicules, rare secundibranchia of *Saccocoma* sp.

The assemblage resembles typical Lower-Middle Oxfordian microfossil assemblages from the southern part of the Eurasian Plate underlying the Outer Carpathians (Golonka 1978; Matyszkiewicz 1997; Olszewska 1998), and probably represents the same age and open sea environment.

The Pańska Góra Klippes. The Jurassic cherty limestones (grainstones) occur in the Southern klippe. The microfossil content is similar to that already reported from this type of rock. Foraminifers are represented mainly by arenaceous species: *Textulariopsis jurassica* (Gümbel), *Reophax helveticus* Haeussler, *Glomospira variabilis* Kübler et Zwingli. Rare calcareous species belong to *Istriloculina fabaria* Matsieva et Temirbekova. Książkiewicz (1935b) reports numerous sponge spicules in investigated samples. This was also verified during recent studies.

The Inwałd Klippes. The Jurassic limestones occur mainly in the Eastern klippe. This is a yellowish or whitish massive, poorly bedded limestone with abundant nerineacean-diceratids-coral fauna. Zeuschner (1849) described from the limestones: *Cryptoplocus depressus* (Voltz), *Ptygmatis pseudobruntrutana* (Bronn), *Ptygmatis carpathica* (Zeuschner), ?*Diptyxis crispa* (Zeuschner), ?*Endoplocus staszycii* (Zeuschner), ?*Eunerinea hoheneggeri* (revised names!).

The "Inwałd limestones" are also rich in microfossils, especially foraminifers, calcareous algae and calcareous dinocysts. Foraminifers form an assemblage associated with a reefal environment. The most frequent species include: *Pseudocyclammina lituus* (Yoko) Yokoyama, *Valvulina alpina* Dragastan, *V. lugeoni* Septfontaine, *Protomarssonella* cf. *dumortieri* (Schwager), *Paleogaudryina* cf. *varsoviensis* (Bielecka et Pożaryski), *Mohlerina basiliensis* (Mohler), *Quinqueloculina mitchurini* Dain, *Quinqueloculina verbizhiensis* Dulub, *Quinqueloculina stellata* Matsieva et Temirbekova, *Istriloculina fabaria* Matsieva et Temirbekova, *Scythiloculina confusa* Neagu, *Trocholina alpina* (Leupold), *Andersenolina perconigi* Neagu, *A. elongata* (Leupold), *Spiroloculina* cf. *subpanda* Lloyd, *Nautiloculina* cf. *cretacea* Peybernes, *Protopeneroplis ultragranulata* (Gorbatchik), *P. striata* Weynschenk, *Charentia evoluta* (Gorbatchik) (Fig. 3).

The algal association consists of: *Salpingoporella annulata* Carozzi, *Salpingoporella* ex gr. *pygmaea* (Gümbel), *Actinoporella podolica* Alth, *Clypeina jurassica* Favre, *Eoteutloporella socialis* (Praturlon), *Thaumatporella parvovesiculifera* Rainieri, *Baccinella irregularis* (Radoicic), *Lithocodium aggregatum* Elliott, *Alpinella distincta* Dragastan, *Hedstroemia moldavica* Dragastan (Fig. 5).

The calcareous dinocysts are represented by: *Carpistomiosphaera tithonica* Nowak, *Colomisphaera carpathica* (Borza), *Colomisphaera ornata* Nowak, *Stomiosphaera moluccana* Wanner, *Cadosina fusca* Wanner, *Cadosina parvula* Nagy (Fig. 4).

From the thin bedded part of the massive limestones Książkiewicz (1971) reports numerous secundibranchia of *Saccocoma* Agassiz indicating proximity of the open sea.

The age of the "Inwałd limestones" based on foraminifers and the calcareous dinocysts as well as nerineaceans is Late Tithonian in the type locality.

In the Inwałd 5 borehole, the "Inwałd limestones" show traces of dolomitization (Książkiewicz & Liszkowa 1972).

The significance of the microfossil assemblages for the interpretation of the Jurassic sequence of the Andrychów Klippes

Three main types of Jurassic limestones can be recognized in the Andrychów Klippes:

1 — the crinoidal limestones, 2 — the cherty limestones, 3 — the "Inwałd limestones".

They vary in age, microfossil content and the environment of deposition.

1. The crinoidal limestones (the Roczyny klippe). The crinoidal packstone. The lack of stratigraphically significant fossils precludes proper designation of age. However, Callovian age is very probable. The limestones are generally attributed to a quiet environment with a water depth of several tens of metres (Mišík 1974).

2. The cherty limestones (the Roczyny klippe, S Targanice klippe, S Pańska Góra klippe). The microfossil assemblage consists of foraminifers, calcareous dinocysts, sponge spicules, calcified radiolarians and rare secundibranchia of *Saccocoma* Agassiz. Foraminifers are represented by *Glomospira*

variabilis Kübler et Zwingli, *Textulariopsis jurassica* (Gümbel), *Protomarssonella jurassica* (Mityanina), *Paalzowella turbinella* Gümbel, *Vinelloidea crussolensis* Canu, *Protopeneroplis striata* Weynschenk, *Globuligerina oxfordiana* Grigelis, *Ophthalmidium* sp., *Spirillina* sp., *Epistomina* sp., *Lenticulina* sp. The assemblage resembles Oxfordian foraminiferal faunas known from the carbonate sediments of peripheral parts of the Eurasian Plate (Moryc & Morycowa 1976; Hanzliková & Bosák 1977; Golonka 1978; Eliáš & Eliášová 1984; Olszewska 1998). The calcareous dinocysts are rare but significant; *Colomisphaera fibrata* (Nagy), *Crustocadosina semiradiata* (Vogler), *Cadosina parvula* Nagy indicate the Early-early Late Oxfordian age (C. fibrata Zone) of cherty limestones of the Andrychów Klippes (Garlicka 1974; Garlicka & Tarkowski 1980; Řehánek & Heliasz 1993). Foraminifers, calcareous dinocysts, radiolarians and Saccocoma ossicles indicate the sublittoral environment, probably connected with the progressing Oxfordian transgression (Golonka 1978; Matyszkiewicz 1996).

3. The "Inwałd limestones" (Inwałd klippe, Roczyny klippe). The characteristic foraminiferal assemblage consists of: *Pseudocyclammina lituus* (Yokoyama), *Valvulina alpina* Dragastan, *V. lugeoni* Septfontaine, *Protomarssonella* cf. *dumortieri* (Schwager), *Palaeogaudryina varsoviensis* (Bielecka et Pożaryski), *Quinqueloculina mitchurini* Dain, *Q. stellata* Matsieva et Temirbekova *Istriloculina fabaria* Matsieva et Temirbekova, *Decussoloculina barbui* Neagu, *Scythiloculina confusa* Neagu, *Trocholina alpina (*Leupold), *T. burlini* Gorbatchik, *Andersenolina perconigi* Neagu, *A. elongata* (Leupold). Other common species include: *Mohlerina basiliensis* (Mohler), *Nautiloculina oolithica* Mohler, *N.* cf. *cretacea* Peybernes, *Protopeneroplis ultragranulata* (Gorbatchik)*, P. striata* Weynschenk, *Charentia evoluta* Gorbatchik, *Pfenderina* sp. They are characteristic for the peri-reefal and the intraplatform environments with prevalence of the latter. The stratigraphic distribution of the selected species (*N. cretacea*, *P. ultragranulata*) suggests at least a Late Tithonian age for the Inwałd limestones.

The algal association of the "Inwałd limestones" is composed of dasycladales: *Actinoporella podolica* (Alth), *Clypeina jurassica* Favre (rare), *Salpingoporella annulata* Carozzi, *S. pygmaea* (Gümbel), *Eoteutloporella socialis* (Praturlon); encrusting codiaceans: *Baccinella irregularis* Radoicic, *Lithocodium aggregatum* Elliot; encrusting solenoporaceans: *Thaumatoporella parvovesiculifera* Rainieri and rare cyanophyceans *Rivularia* sp.; microproblematics: *Koskinobullina socialis* Cherchi et Schroeder. Outer platform elements generally prevail with encrusting and high energy forms that probably fell down from the biostromes of the shelf margin (Flügel 1979; Dragastan 1980; Řehánek 1987; Soták & Mišík 1997). This supports Książkiewicz's (1971) view indicating a "sloping bottom" as the site of deposition of the Inwałd limestones. The calcareous dinocysts: *Colomisphaera carpathica* Borza, *C. cieszynica* Nowak, *Carpistomiosphaera tithonica* Nowak, *Cadosina parvula* Nagy, *Stomiosphaera moluccana* Wanner. represent the Middle-Late Tithonian C. carpathica-C. cieszynica Zone (Nowak 1968). Sections of unidentified calpionellids are also present.

The *Saccocoma* rich layer described by Książkiewicz (1971) from the bottom of the Inwałd limestones in the type locality can be correlated with the Kimmeridgian/Tithonian mass occurrences of these crinoids known from the Tethys (Borza 1969; Keupp & Matyszkiewicz 1997) only on the basis of their position in the profile.

Correlation with coeval microfossil assemblages of other carbonate sedimentation areas of the region

1. In the early 50-ties in the Bachowice wood (East of the Andrychów Klippes) Książkiewicz (1956) explored layers with exotics embedded in variegated Paleogene shales of the Sub-Silesian Nappe. Apart from exotic crystalline rocks an impressive number of sedimentary rocks was collected from artificial exposures. They covered the time span from Carboniferous (Tournaisian) to Cretaceous (Maastrichtian). Among these rocks those containing Tithonian fossils were common. Blocks of pale cryptocrystalline limestones contained frequent ammonite remains, small pebbles were made of whitish or yellowish *Calpionella* limestones with *Crassicollaria parvula* Remane, *Crassicollaria brevis* Remane, *Calpionella alpina* Lorenz. The *Calpionella* limestones also contained foraminifers, radiolarians, zoospores, and algae (Fig. 6). Recent investigations (Malata & Olszewska 1998) additionally revealed the presence of the calcareous dinocysts, among others: *Comittosphaera pulla* (Borza), *Colomisphaera lucida* Borza, *Colomisphaera lapidosa* (Vogler). The prevalence of the pelagic elements in the Tithonian sediments of the Bachowice succession indicates an open sea environment. Książkiewicz reports only one fragment of rock (oolitic-crinoidal limestones) that may represent neritic, peri-reefal facies similar to the "Inwałd limestones". Thus the Bachowice Tithonian sediments accumulated mainly in pelagic, open sea environment different from that where sediments of the Andrychów Klippes were deposited.

2. Interesting hints referring to the origin of the Andrychów Klippes come from the investigations of strata and fossils of the peri-Tethyan shelf submerged under the Outer Carpathians (well Zagórzyce 6) or incorporated into flysch deposits as olistholiths (Kruhel klippe).

Well Zagorzyce 6 situated at the marginal part of the Skole Nappe (Fig. 1) reached Tithonian-earliest Berriasian deposits (the Ropczyce Series) at the depth of 2810 m (Olszewska 1999). The Tithonian sediments show regressive character and are composed of hypersaline lagoon deposits with coprolithes (*Favreina* sp.) and Charophyta (*Clavatoraceae*). Alternating normal marine layers contain foraminifers (*Pseudocyclammina lituus* (Yokoyama), Miliolidae), algae, mainly dasyclads (*Salpingoporella pygmaea* (Gümbel)), or codiaceans (*Hedstroemia moldavica* Dragastan, *Pratumiella fastigiata* Dragastan, *Clypeina jurassica* Favre), calcareous dinocysts (*Cadosina fusca* Wanner, *Comittosphaera pulla* (Borza), *Crustocadosina semiradiata* (Wanner)) and single capionellids (*Calpionella alpina* Lorenz) (Fig. 7).

Olistholiths of Jurassic rocks embedded in the Inoceramian Beds of the Skole Nappe at Kruhel (S from Przemyśl) yielded similar assemblage of microfossils (Fig. 8). More frequent calpionellids are represented by: *Crassicollaria brevis* Remane, *Crassicollaria intermedia* (Durand Delga), *Tintinopsella* cf. *carpathica* (Murgeanu et Filipescu), *Tintinopsella suba-*

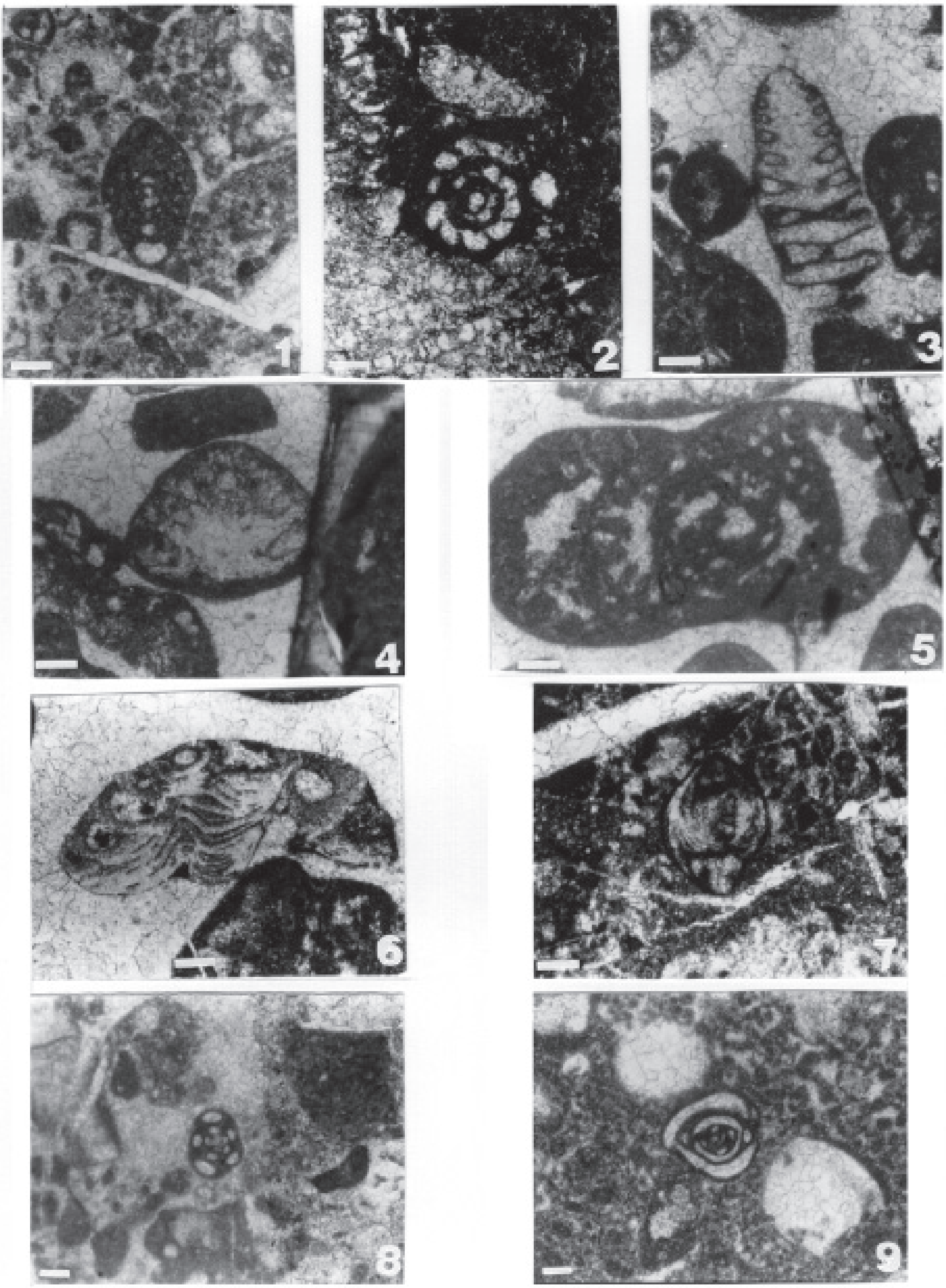

Fig. 3. Characteristic foraminifers of the Inwałd limestones. **1** — *Charentia evoluta* (Gorbatchik), axial section; scale bar = 0.09 mm. **2** — *Charentia evoluta* (Gorbatchik), equatorial section; scale bar = 0.09 mm. **3** — *Andersenolina perconigi* Neagu, subaxial section; scale bar = 0.03 mm. **4** — *Trocholina alpina* (Leupold), subaxial section; scale bar = 0.017 mm. **5** — *Pseudocyclammina lituus* (Yokoyama), transverse section; scale bar = 0.09 mm. **6** — *Mohlerina basiliensis* (Mohler), oblique section; scale bar = 0.09 mm. **7** — *Protopeneroplis striata* Weynschenk, subaxial section; scale bar = 0.08 mm. **8** — *Scythiloculina confusa* Neagu, transverse section; scale bar = 0.07 mm. **9** — *Scythiloculina confusa* Neagu, longitudinal section; scale bar = 0.07 mm.

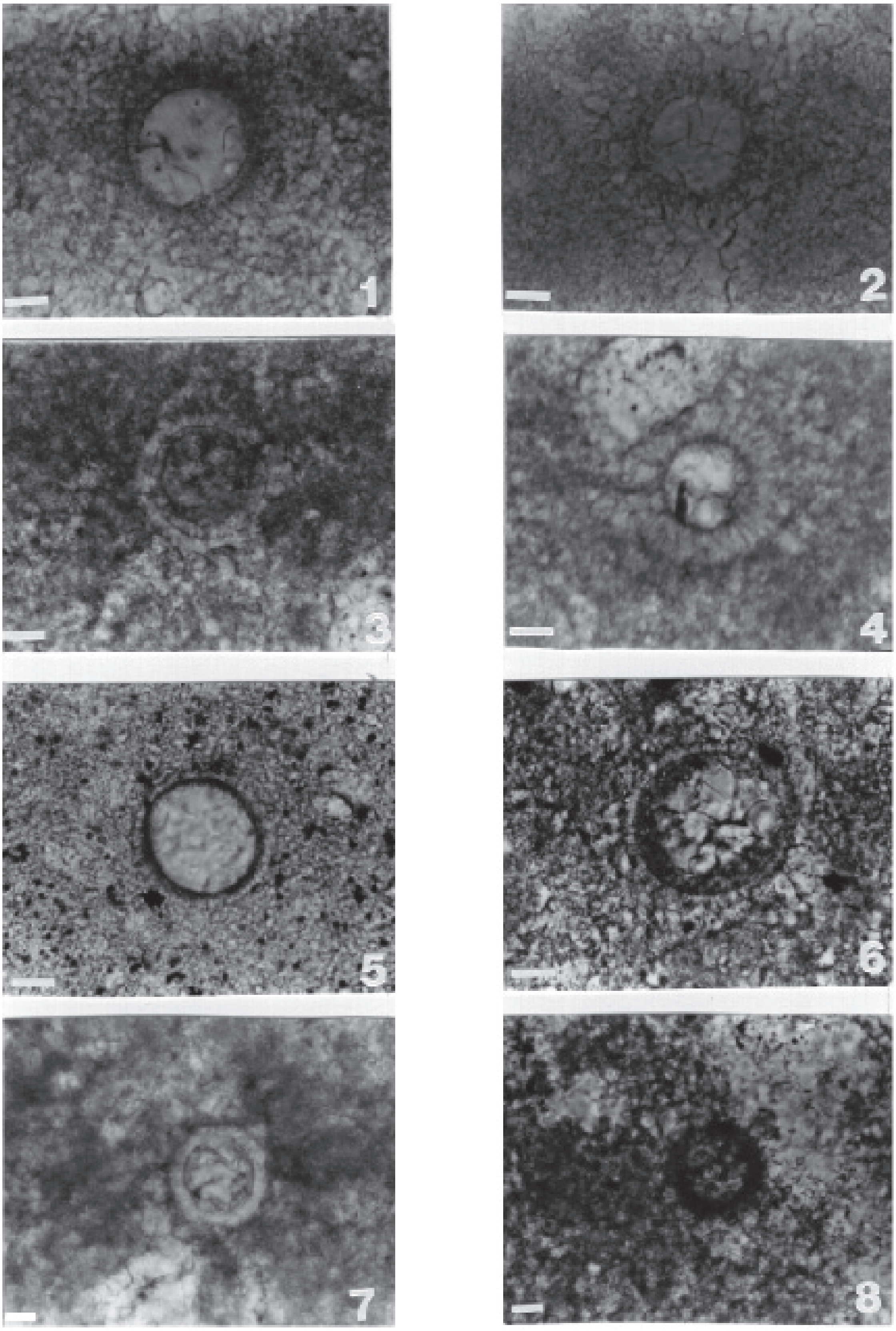

Fig. 4. Characteristic calcareous dinocysts of the Inwałd limestones. **1** — *Carpistomiosphaera tithonica* Nowak; scale bar = 0.01 mm. **2** — *Carpistomiosphaera tithonica* Nowak; scale bar = 0.008 mm. **3** — *Carpistomiosphaera borzai* (Nagy); scale bar = 0.008 mm. **4** — *Colomisphaera carpathica* (Borza); scale bar = 0.008 mm. **5** — *Comittosphaera sublapidosa* (Vogler); scale bar = 008 mm. **6** — *Crustocadosina semiradiata* (Wanner); scale bar = 0.008 mm. **7** — *Stomiosphaera moluccana* Wanner; scale bar = 0.007 mm. **8** — *Cadosina parvula* Nagy; scale bar = 0.007 mm.

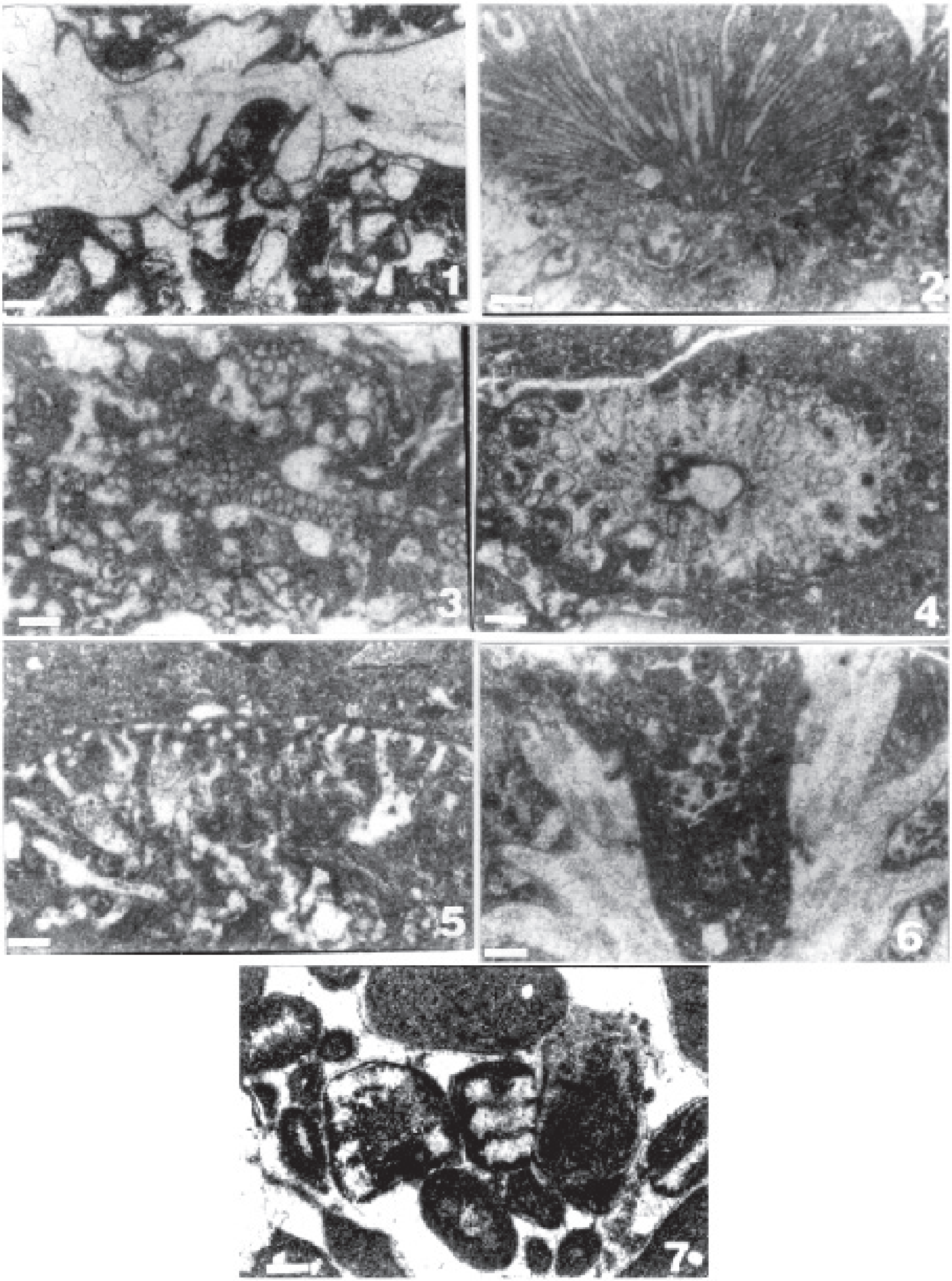

Fig. 5. Characteristic calcareous algae of Inwałd limestones. **1** — *Baccinella irregularis* Radoicic. **2** — *Alpinella distincta* Dragastan. **3** — *Thaumatoporella parvovesiculifera* (Raineri). **4** — *Salpingoporella* ex gr. *pygmaea* (Gümbel). **5** — *Lithocodium aggregatum* Elliott. **6** — *Eoteutloporella socialis* (Praturlon). **7** — *Salpingoporella annulata* Carozzi. Scale bar = 0.08 mm in 1–7.

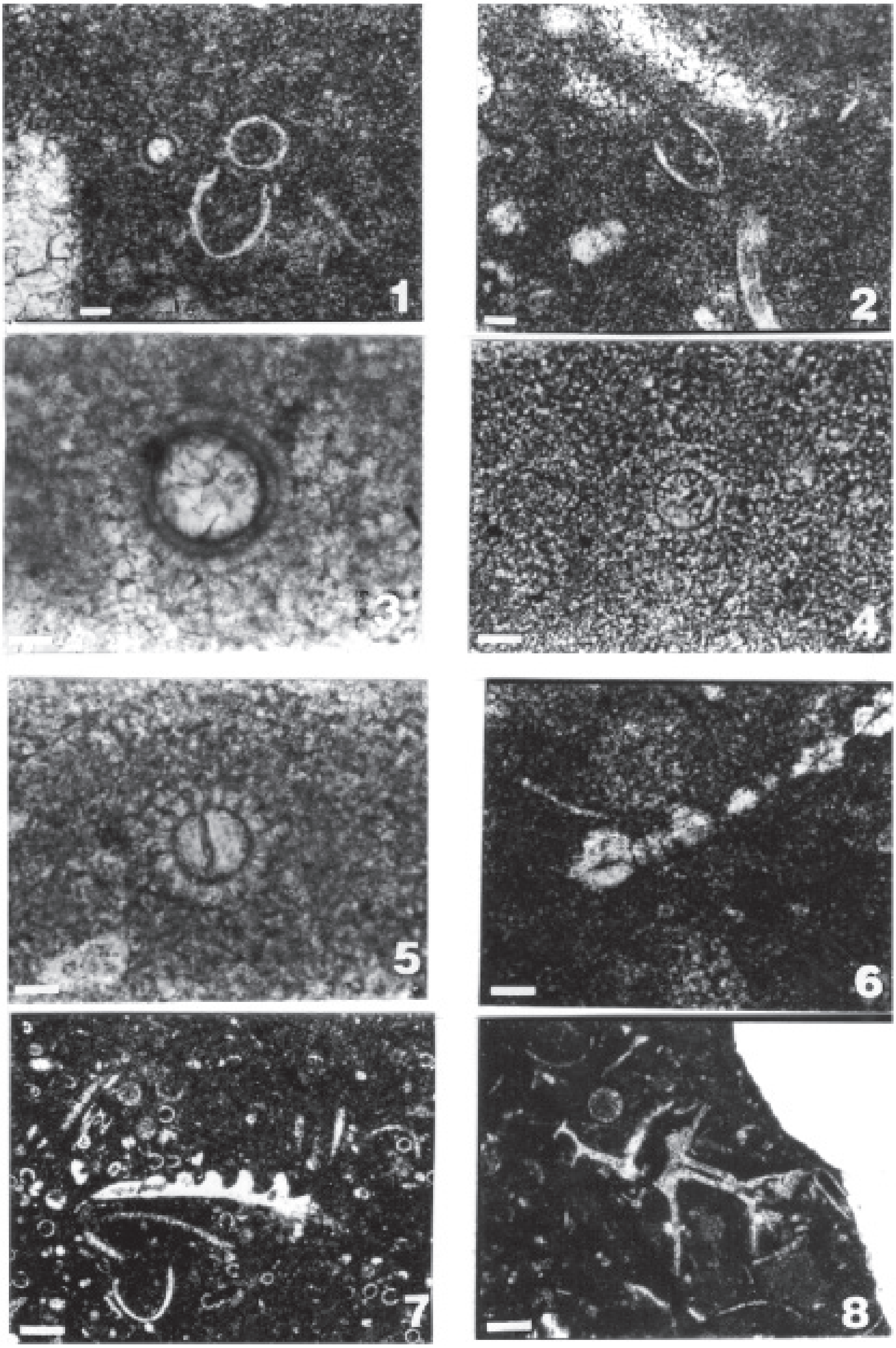

Fig. 6. Characteristic microfossils of the Tithonian sediments of Bachowice Succession. **1** — *Calpionella alpina* Lorenz and *Comittosphaera sublapidosa* (Vogler); scale bar = 0.015 mm. **2** — *Crassicollaria parvula* Remane; scale bar = 0.015 mm. **3** — *Comittosphaera pulla* (Borza); scale bar = 0.008 mm. **4** — *Colomisphaera lucida* Borza; scale bar = 0.004 mm. **5** — *Colomisphaera lapidosa* (Vogler); scale bar = 0.008 mm. **6** — *Globochaete alpina* (Lombard); scale bar = 0.03 mm. **7** — *Calpionella* limestones and *Aptychi*; scale bar = 0.09 mm. **8** — *Saccocoma* sp. Agassiz; scale bar = 0.035 mm.

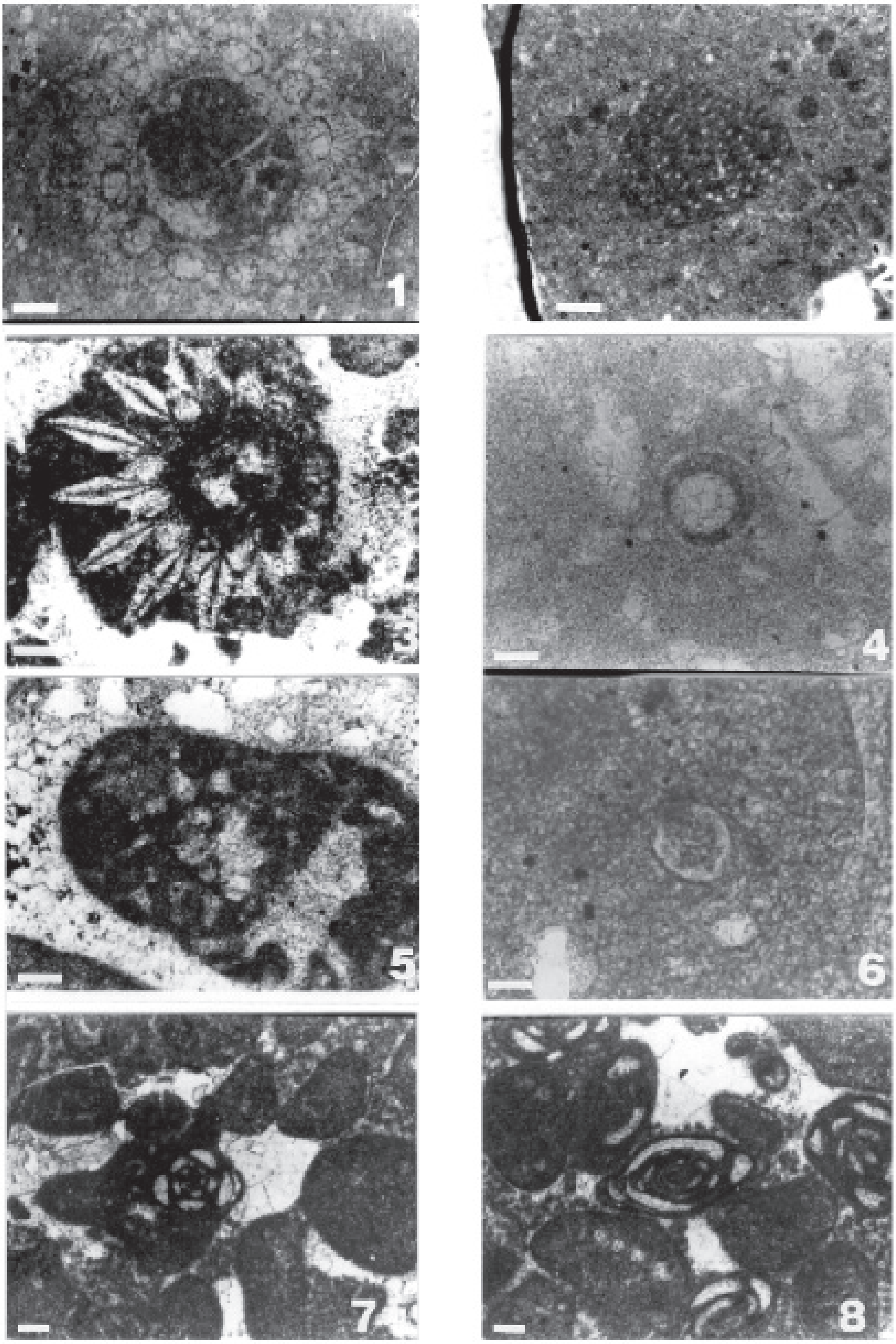

Fig. 7. Characteristic microfossils from the Tithonian-earliest Beriassian sediments of the marginal part of the Eurasian Plate in Zagórzyce 6 well. **1** — Charophyta (?*Clavator* sp.), transverse stem section; scale bar = 0.017 mm. **2** — Coprolites (*Favreina* sp.), transverse section; scale bar = 0.035 mm. **3** — *Clypeina jurassica* Favre; scale bar = 0.035 mm. **4** — *Crustocadosina semiradiata* (Wanner); scale bar = 0.008 mm. **5** — *Pseudocyclammina lituus* (Yokoyama), transverse section; scale bar = 0.09 mm. **6** — *Calpionella alpina* Lorenz; scale bar = 0.017 mm. **7** — *Quinqueloculina mitchurini* Dain, transverse section; scale bar = 0.075 mm. **8** — *Quinqueloculina mitchurini* Dain, longitudinal section; scale bar = 0.075 mm.

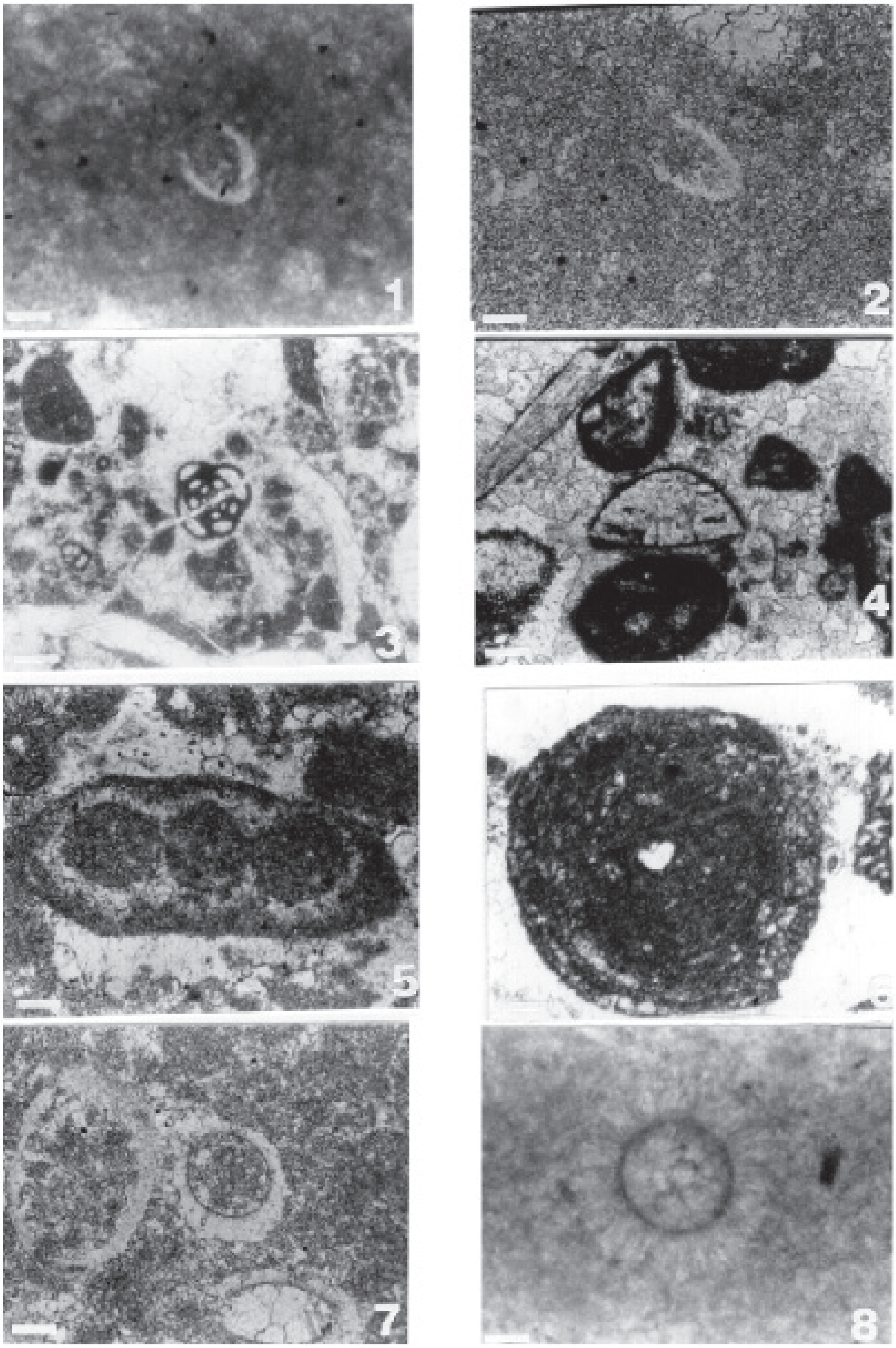

Fig. 8. Characteristic microfossils of the Tithonian sediments of the Kruhel klippe. **1** — *Crassicollaria brevis* Remane; scale bar = 0.017 mm. **2** — *Crassicollaria intermedia* (Durand Delga); scale bar = 0.017 mm. **3** — *Decussoloculina barbui* Neagu, transverse section; scale bar = 0.08 mm. **4** — *Trocholina molesta* Gorbatchik, subaxial section; scale bar = 0.034 mm. **5** — *Actinoporella podolica* Alth; scale bar = 0.034 mm. **6** — *Tubiphytes* sp.; scale bar = 0.09 mm. **7** — *Charophyta*; scale bar = 0.08 mm. **8** — *Colomisphaera carpathica* (Borza); scale bar = 0.009 mm.

cuta (Colom), *Calpionella alpina* Lorenz, (Geroch et Morycowa 1966; authors investigations). Among foraminifers the following are frequent: *Protomarssonella hechti* (Dieni et Massari), *Trocholina burlini* Gorbatchik, *Protopeneroplis ultraganulata* (Gorbatchik), *Andersenolina delphinensis* (Arnaud Vanneau, Boisseau, Darsac), *Troglotella incrustans* Wernli et Fookes, Miliolidae. Algae are represented by dasycladales: *Actinoporella podolica* Alth, *Salpingoporella annulata* Carozzi, *Lithocodium aggregatum* Elliott, and Charophyta. *Colomisphaera carpathica* (Borza) (Fig. 8) is frequent in the calcareous dinocyst assemblage.

Compared to microfossils of the Andrychów Klippes peri-Tethyan shelf assemblages are more environmentally diversified, probably due to different localization of investigated sites on the margin of European Plate. Local abundance of calpionellids (Kruhel klippe) indicates that some sites were situated closer to ducts that distributed pelagic elements on the platform (Danian-Polish seaway).

Andrychów Klippes — elevated blocks of the rifted Jurassic sediments of the Eurasian margin

Both rock types and the fossil content of the Late Jurassic sequences of Andrychów Klippes show strong silimarities to coeval sediments and faunas of the southern margin of the Eurasian Plate. Oxfordian cherty limestones show significant correlation to coeval sediments known from the Brno area, Cracow Upland, Carpathian basement, Southern Ukraine. Microfossil assemblages contain the same species of foraminifers, calcareous dinocysts and calcareous algae.

Tithonian shallow water limestones (the "Inwałd limestones") with abundant nerineacean-diceratid-coral fauna, numerous algae (dasycladales, codiaceans, solenoporaceans) and foraminifers (lituolids, miliolids, involutinids) are similar to Štramberk-type reefal limestones frequently found in flysch sediments of the Outer Carpathians and Waschberg Zone of Austrian Alps (Blaschke 1911; Bachmayer 1961; Eliáš & Eliášová 1984; Řehánek 1987; Wieczorek 1988, 1998; Wójcik 1914; Zittel 1873).

The "Inwałd limestones" also resemble Tithonian deposits of the European Plate found in Zagorzyce 6 well (Olszewska 1998) under the Skole Nappe of the Outer Carpathians. At the surface similar shallow water Tithonian limestones, with nerineaceans, algae and peri-reefal foraminifers, is known from the Niżniow Formation in Ukraine (Alth 1882; Dulub et al. 1986).

In the present state of our knowledge of Tithonian paleogeography, it is justified to interpret the Andrychów Klippes (Fig. 2) as elevated blocks, which separated the Bachowice basin in the outer position and the Silesian pull-apart (?) basin in the inner position (Książkiewicz 1956; Nowak 1976; Matyszkiewicz & Slomka 1994). This topography resulted from initial disintegration of the Southern margin of the Eurasian Plate related to, probably oblique, rifting processes.

During Alpine north-directed movements block fragments were detached from the Eurasian Plate and incorporated into flysch deposits, mainly in front of the Silesian Nappe.

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References

Alth A. 1882: Die Versteinerungen des Nizniower Kalksteines. *Beitr. Paläont. Österr.-Ung. Orients* 1**,** 183–332.

Bachmayer F. 1961: Das Mesozoikum der Niederöstereichischen Klippen (Waschbergzone). *Ann. Inst. Geol. Publ. Hung.* 49, 1, 299–334.

Blaschke F. 1911: Zur Titonfauna von Stramberg in Maehren. *Ann.K.K. Nat. Hofmus*. 25, 143–222.

Boué A. 1830: Observations sur les Alpes et les Carpathes. *J. Géol.* 1, 125, 50–151.

Borza K. 1969: Die Mikrofazies und Mikrofossilien des Oberjuras und der Unterkreide der Klippenzone des Westkarpaten. *Slovak Akad. Vied*, 1–301.

Decrouez D. & Morycowa E. 1996: Pesence de *Protopeneroplis ultragranulata* (Foraminifere) dans des Calcaires de Cieszyn (nappe silésienne, Carpathes polonaises externes). *Archs Sci. Genève* 49, 3, 267–271.

Dragastan O. 1980: Calcareous algae of the Mesozoic and Tertiary of Romania. *Acad. Rep. Soc. România,* 1–158 (in Rumanian).

Dulub V.G., Burova M.I., Burov V.S. & Vishnyakov I.B. 1986: Explanations of the regional stratigraphical scheme of the Jurassic deposits of the Forecarpathian Depression and the Volhyno-Podolian part of the Eastern European Platform. *Ukr. NIGRI,* 1–51 (in Russian).

Eliáš M. & Eliášová H. 1984: Facies and paleogeography of the Jurassic in the western part of the Outer Flysch Carpathians in Czechoslovakia. *Sbor. Geol. Ved*, *Geol.* 39, 105–170.

Eliáš M. & Eliášová H. 1986: Elevation facies of the Malm in Moravia. *Geol. Zbor. Geol. Carpath.* 37, 4, 533–550.

Flügel E. 1979: Paleoecology and microfacies of Permian, Triassic and Jurassic algal communities of platform and reef carbonates from the Alps. *Bull. Cent. Rech. Explor. Prod. Elf-Aquitaine* 3, 2, 569–587.

Gasiński M.A. 1998: Campanian-Maastrichtian paleoecology and paleobiogeography of the Andrychów Klippes, Outer Carpathians, Poland. *Wyd. U.J. Rozpr. Habilitacyjne* 333, 1–4.

Garlicka I. 1974: Horizon with stomiosphaerids in the Upper Jurassic of the Carpathian Foreland (Southern Poland). *Ann. Soc. Geol. Pol.* 44, 1, 37–50.

Garlicka I. & Tarkowski R. 1980: Biostratigraphy and microfacies development of the Lower and Middle Oxfordian at Zalas near Cracow. *Bull. Acad. Pol. Sci*. 28, 1, 59–67.

Geroch S. & Morycowa E. 1966: Contribution à la connaissance des faciès et fossiles des calcaires tithoniques à Kruhel Wielki près de Przemysl (Carpathes de Flysch, Pologne). *Ann. Soc. Geol. Pol.* 36, 3, 295–298 (in Polish).

Golonka J. 1978: Upper Jurassic Microfacies in the Carpathian Foreland. *Inst. Geol. Bull.* 310, 5–30.

Golonka J., Oszczypko N. & Ślączka A. 2000: Late Carboniferous-Neogene geodynamic evolution and paleogeography of the Circum-Carpathian region and adjacent areas. *Ann. Soc. Geol. Pol.* 70, 107–136.

Hanzliková E. & Bosák P. 1977: Microfossils and microfacies of the Jurassic relict near Olomuncany (Blansko district). *Věst. Ústř. Úst. Geol.* 52, 73–78.

Keupp H. & Matyszkiewicz J. 1997: Zur Faziesrelevanz von *Saccocoma*-Resten (Schwebcrinoiden) in Oberjura-Kalken des nördlichen Tethys-Schelfs. *Geol. Bl. NO-Bayern* 47, 1–4, 53–70.

Książkiewicz M. 1935a: Die äussere karpatische Klippenzone bei Andrychów. I. Die Klippen von Inwałd und Roczyny. *Bull. Acad. Pol. Sci. Lett. Classe Sci. Math. Nat. Ser. A* 92–108.

Książkiewicz M. 1935b: Die äussere karpatische Klippenzone bei Andrychów. II. Die Klippen von Pańska Góra und Targanice. *Bull. Acad. Pol. Sci. Lett. Classe Sci. Math. Nat. Ser. A* 210–220.

Książkiewicz M. 1935c: Die äussere karpatische Klippenzone bei Andrychów. III. Die stratigraphie der Klippenserie und ihre Stellung im Bau der West-Karpaten. *Bull. Acad. Pol. Sci. Lett. Classe Sci. Math. Nat. Ser. A* 221–233.

Książkiewicz M. 1956: The Jurassic and Cretaceous of Bachowice. *Ann. Soc. Geol. Pol.* 26, 121–285 (in Polish).

Książkiewicz M. 1965: Les cordilléres dans les mers crétacées et paléogénes des Carpathes du Nord. *Bull. Soc. Géol. France* 7, 443–455.

Książkiewicz M. 1968: Andrychów Klippen Zone. *Intern. Geol. Congr., 23 Session, Prague 1968. Guide to Excursions No C 44, Pol. Geol. Pol. Flysch Carpathian* 3–17.

Książkiewicz M. 1971: On the origin of the Inwałd Limestones (Outer Carpathian Klippes). *Bull. Acad. Pol. Sci., Sér. Sci. Terre* 19, 2, 91–98.

Książkiewicz M. & Liszkowa J. 1972: On the beds underlying the Andrychów Klippen (Western Carpathians), *Ann. Soc. Geol. Pol.* 42, 2–3, 239–267 (in Polish).

Malata T. & Olszewska B. 1998: The Jurassic and Cretaceous of Bachowice — 40 years later. *Posiedz. Nauk. Państw. Inst. Geol.* 54, 6, 75–76 (in Polish).

Matyszkiewicz J. 1996: The significance of Saccocoma-calciturbidites for the analysis of the Polish epicontinental Late Jurassic Basins: An example from the Southern Cracow-Wieluń Upland (Poland). *Facies* 34, 23–40.

Matyszkiewicz J. 1997: Microfacies, sedimentation and some aspects of diagenesis of Upper Jurassic sediments from the elevated part of the Northern peri-Tethyan Shelf: a comparative study on the Lochen area (Schwäbische Alb) and the Cracow area (Cracow-Wieluń Upland, Polen). *Berliner Geowiss. Abh. R. E, Bd.* 2, 1–66.

Matyszkiewicz J. & Slomka 1994: Organodetrital conglomerates with ooids in the Cieszyn Limestones (Tithonian–Berriasian) of the Polish Flysch Carpathians and their paleogeographic significance. *Ann. Soc. Geol. Pol.* 63, 211–248.

Mišík M. 1974: Paleogeographic outline of the Tithonian in the Czechoslovakian Carpathians. *Acta Geol. Pol.* 24, 3, 485–503.

Moryc W. & Morycowa E. 1976: The Upper Jurassic sediments in the Foreland of the Polish Carpathians (Sandomierz Basin). *Ann. Soc. Geol. Pol.* 46, 1–2, 231–265 (in Polish).

Nowak W. 1968: Stomiosphaerids of the Cieszyn Beds (Kimmeridgian-Hauterivian) in the Polish Cieszyn Silesia and their stratigraphical value. *Rocz. Pol. Tow. Geol.* 38, 2–3, 275–312 (in Polish).

Nowak W. 1976: The Outer (Flysch) Carpathians. In: S. Sokolowski (Ed.): Geology of Poland, Mesozoic. *Geol. Inst.,* Warsaw. 1, 2, 401–42.

Nowak W. 1983: Actual geological problems of the external klippes. *Kwart. Geol.* 27, 2, 438–439 (in Polish).

Nowak W. 1986: A monograph of the Cieszyn unit of the western part of Carpathians. *Central Geological Archives, PIG Oddział Karpacki* 1–110 (in Polish).

Olszewska B. 1998: New trends in the stratigraphical investigations in Carpathians and their significance for hydrocarbons prospecting. In: *Konferencja Naukowo-techniczna: "Dzien dzisiejszy przemyslu naftowego" 50-lecie Oddzialu Gorlice SITPNiG Wysowa 27–30. 05.199,* 62–64 (in Polish).

Olszewska B. 1999: Thin section microbiostratigraphy of the well Zagorzyce 6. *Biul. Państw. Inst. Geol.* 387, 149–153.

Řehánek J. 1987: Facies development and biostratigraphy of the Ernstbrunn Limestones (Middle to Upper Tithonian, southern Moravia). *Geol. Práce Spr.* 87, 27–60 (in Czech with English summary).

Řehánek J. & Heliasz Z. 1993: Microfacies and microbiostratigraphy of the Oxfordian–Lower Kimmeridgian, on the basis of Cadosinids and Stomiosphaerids in the Czestochowa region of Poland. *Geol. Carpathica* 44, 2, 81–93.

Soták J. 1987: Protopeneroplide foraminifers from Lowermost Cretaceous of Štramberk carbonate platform (Outer West Carpathians). *Geol. Zbor. Geol. Carpath.* 38, 6, 651–667.

Soták J. 1988: On distribution of Dasycladaceans algae in the Jurassic and Lower Cretaceous shallow-water limestones from products of the Silesian codillera (Outer West Carpathians). *Misc. micropaleont.* II, 1, 215–249.

Soták J. 1989: Findings of Lower Cretaceous representatives of the family Pfenderinidae Smout et Sugden (Foraminifera) in flysch conglomerate pebbles in the Outer West Carpathians. In: Michalík J. & Samuel O. (Eds.): Zborník z paleont. konferencie. *Geologický Ústav Dionýza Štúra,* Bratislava, 37–45 (in Slovak).

Soták J. & Mišík M. 1997: Late Jurassic and Early Cretaceous algal and foraminiferal benthic communities and biofacies from the Western Carpathians. *Miner. Slovaca* 29, 345–346.

Wieczorek J. 1988: Biogeography of Tithonian Nerineacean Gastropods. *Mem. Soc. Geol. France*, *Nov. Ser.* 154, 35–40.

Wieczorek J. 1998: Nerineaceans from the Ernstbrunn Limestones (Tithonian, Austria). *Ann. Naturhist. Mus.* Wien 99A, 311–329.

Wieczorek J. 1998: New data on the North-Tethyan Tithonian Nerineaceans (the Ernsbrunn Limestones fauna, Austria). *Carpathian-Balkan Association XVI Congress, Vienna, Austria. Abstracts,* 634.

Wójcik K. 1914: The Jurassic at Kruhel Wielki near Przemysl. *Rozpr. Wydz. Mat. Przyr. Akad. Umiej. Ser. B.* 53/54, 1–260.

Zeuschner L. 1849: Geognistische Beschreibung des Nerineen-Kalkes von Inwald und Roczyny. *Natuwiss. Abh.* 3, 1, 133–146.

Zittel K.A. 1873: Die Gastropoden der Stramberger Schichten. *Paläont. Mitt. Mus. Königl. Bayer. Staates* 2, 311–491.