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EXOTICS-BEARING LAYER IN THE OLIGOCENE FLYSCH OF THE KROSNO BEDS IN THE FORE-DUKLA ZONE (SILESIAN NAPPE, OUTER CARPATHIANS), POLAND

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Abstract: A layer with exotic blocks has been found in the flysch of the Krosno Beds, in the Fore-Dukla Zone (the southernmost part of the Silesian Nappe in the Bieszczady Mts, Polish Outer Carpathians). It has been traced over a distance of 1 km near Wetlina (the Bieszczady Mts), in the southernmost exposed tectonic slice. The exotic blocks include crystalline schist (quartz-chlorite-muscovite-orthoclase schist with tourmaline and garnet) and three types of limestones: 1/ massive, sparitic, partly siliceous limestone, with numerous calcite veins; 2/ micritic limestone with rare planktic (*Globigerina*-like) foraminiferal tests; 3/ bioclastic limestone with numerous tests of small and large foraminifers, coralline algae (Rhodophyta), bivalves, bryozoans and rare echinoid spines. The exotics are embedded in light- and dark-grey argillaceous, partly sandy, calcareous matrix, together with a few small angular pebbles of grey mudstones and very fine-grained sandstones, which resemble lithological types of the Krosno Beds. The described rocks are similar to those found as exotic blocks in the Krosno Beds in neighbouring areas (Roztoki Dolne and Ustrzyki Górne) of the Central Carpathian Depression (Silesian Nappe). Calcareous nannoplankton from the exotic-bearing layer and neighbouring deposits show that they are not older than the NP24 Zone (late Kiscellian), below the isochronous marker horizon of the Jasło Limestone. It may correspond to the Tenuitella munda Zone of Olszewska (1997, 1998), proposed for the Polish part of the Central Paratethys. The source area of the layer with exotics (islands with narrow shelf margins), probably lay to the south and south-east, was built mainly of crystalline rocks, and partly covered by various types of carbonate Eocene-Oligocene rocks. The deeper parts of the island slopes were covered with Cretaceous-Paleogene sediments, related to deep-water sedimentation in the marginal zone between the Dukla and Silesian subbasins. These deep-water deposits have been partly eroded during the submarine mass movements descending to the Silesian Subbasin.

Key words: Outer Carpathians, Silesian Nappe, Fore-Dukla Zone, Oligocene, Krosno Beds, Foraminifera, calcareous nannoplankton, dinocysts, exotic rocks.

Introduction

The monotonous thick series of deep-water flysch deposits of the Outer Carpathians includes rocks (as pebbles and blocks), lithologically contrasting with their host sediments. In the Carpathians, they have been referred to as exotics (Świdziński 1948).

This paper presents the petrographic characteristics, stratigraphic position and interpretation of the source area of a layer with exotics which occurs in flysch deposits of the Krosno Beds in the Fore-Dukla Zone (Silesian Nappe, Outer Carpathians) in the Polish part of the Bieszczady Mts. The exotics in the Krosno Beds have not been described from this tectonic unit; however, they have been documented from the Central Carpathian Depression (Silesian Nappe), in the neighbouring area. Numerous descriptions of exotic rocks come from the localities of Riszkania and Bukowiec (Vacek 1881; Wójcik 1905; Rogala 1932; Rogala & Weigner 1935; Gans & Hiltermann 1951; Krajewski 1952, 1955; Ślączka 1959, 1961). Mochnacka & Tokarski (1972) found exotic blocks in the Krosno Beds near Ustrzyki Górne (the Zakopaniec stream). Recently, Haczewski and Bąk noted exotics at many localities in the Bieszczady Mts, from the Opołonek Mt through the Połonina Wetlińska Mt (Haczewski & Bąk 1999; Haczewski et al. submitted a–d).

The exotic rocks described here have been found in the Fore-Dukla Zone during detailed mapping by J. Rubinkiewicz and L. Mastella (Haczewski et al. submitted c).

Geological setting

The described exotic rocks occur in the Fore-Dukla Zone (Świdziński 1953), which lies in the southern part of the Silesian Nappe (Fig. 1). The Fore-Dukla Zone is a narrow tectonic belt (a few km wide), extending from Bukowsko in the northwest to the state boundary in the southeast. Its southern limit is a steep (45–70°) overthrust of the Dukla Nappe (Świdziński 1953; Ślączka 1969; Ślączka 1971; Tokarski 1975; Rubinkiewicz 1996). To the north, the Fore-Dukla Zone contacts with the Central Carpathian Depression across a large reverse fault, steeply (60–70°) dipping to NE (Opolski 1930; Koszarski et

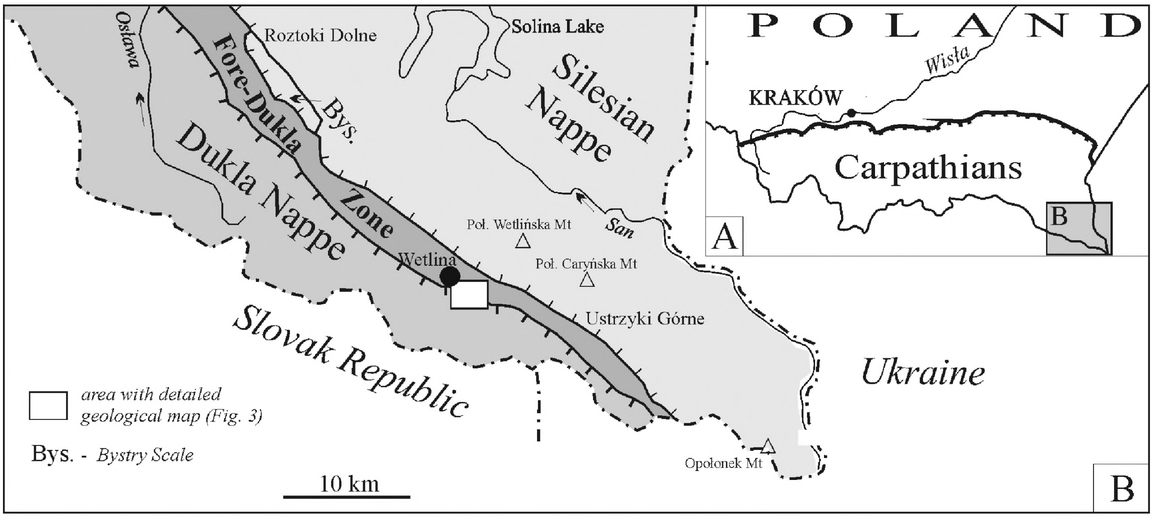

Fig. 1. Regional setting of the study area in the context of Poland (A) and the Outer Carpathians (B).

al. 1960; Ślączka 1963; Tokarski 1975; Kuśmierek 1979; Mastella 1995; Haczewski et al. submitted c).

The deposits of the Fore-Dukla Zone are tightly deformed due to their low competence relative to the overlying thick-bedded sandstone series. The thrust movements of the Dukla Nappe over the Silesian Nappe produced complex deformations in that area. The marginal part of the Dukla Nappe is formed by a series of rigid, thick-bedded sandstones (Cisna Beds; Ślączka 1971) up to 1250 m thick in the study area (Haczewski et al. submitted d). On the other side of the zone, the south-western part of the Silesian Nappe (the Central Carpathian Depression) consists of a series, up to 2000 m thick, with rigid, thick-bedded Otryt Sandstone (Haczewski et al. submitted d).

Intense tectonic deformations (numerous folds, slices, faults, thrusts) of the Fore-Dukla Zone make a stratigraphic reconstruction difficult. A general scheme for the stratigraphy of the whole unit in the Bieszczady region was presented by Kuśmierek (1979). The scheme presented below (Fig. 2) has resulted from the mapping of the eastern part of the Fore-Dukla Zone in the Bieszczady Mts by Mastella & Rubinkiewicz (Haczewski et al. submitted d). Within the studied area, the Fore-Dukla Zone consists of a 1.2 km thick sequence of Paleogene flysch deposits, including the Hieroglyphic Beds (up to 280 m), the Globigerina Marls (up to 20 m), the Menilite Beds (up to 230 m), the Passage Beds (up to 300 m) and the Krosno Beds (up to 320 m). The Krosno Beds in the Fore-Dukla Zone include the lower division (thin-bedded sandstones with marlstones) and the middle division (with thick-bedded Otryt Sandstone).

The exotics-bearing layer was found in the Krosno Beds (Fig. 2), which consist of marlstones with convolute and cross laminated, thin-bedded sandstones, in a series up to 220 m thick. They also include a smaller amount of black calcareous and non-calcareous shales, often with hard mudstone aggregates and rare thick-bedded (up to 1.5 m), medium- to coarse-grained, polymictic Otryt-type sandstones and thick-bedded (up to 0.5 m), medium grained, structureless sandstones. Single beds of medium- to thick-bedded ferruginous dolomites also occur in the section.

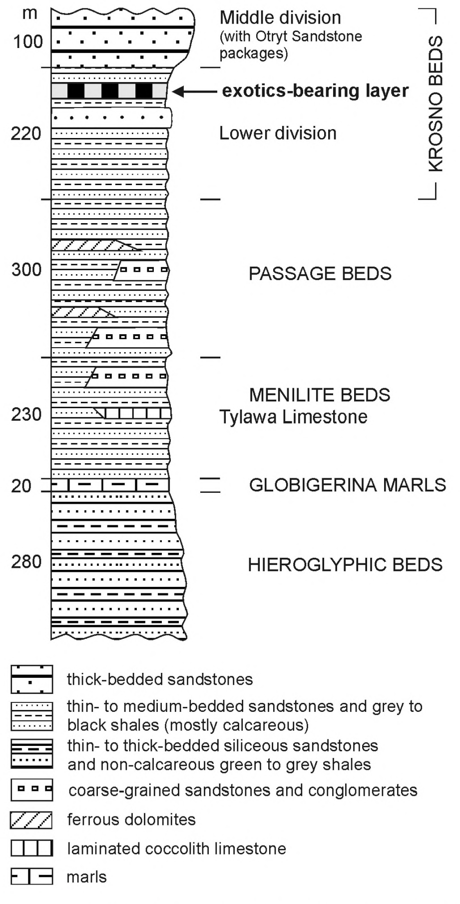

Fig. 2. Lithostratigraphical scheme of the Fore-Dukla Zone in the Polish part of the Bieszczady Mts (after Haczewski et al. submitted c).

Localities with exotic blocks

The exotics have been found in two streams which flow from the Dział Mt to the Wetlinka stream, near Wetlina village (Fig. 3). The names used for these streams herein — Owczarnia and Osada — have been given for the purposes of this work and are not used on published maps.

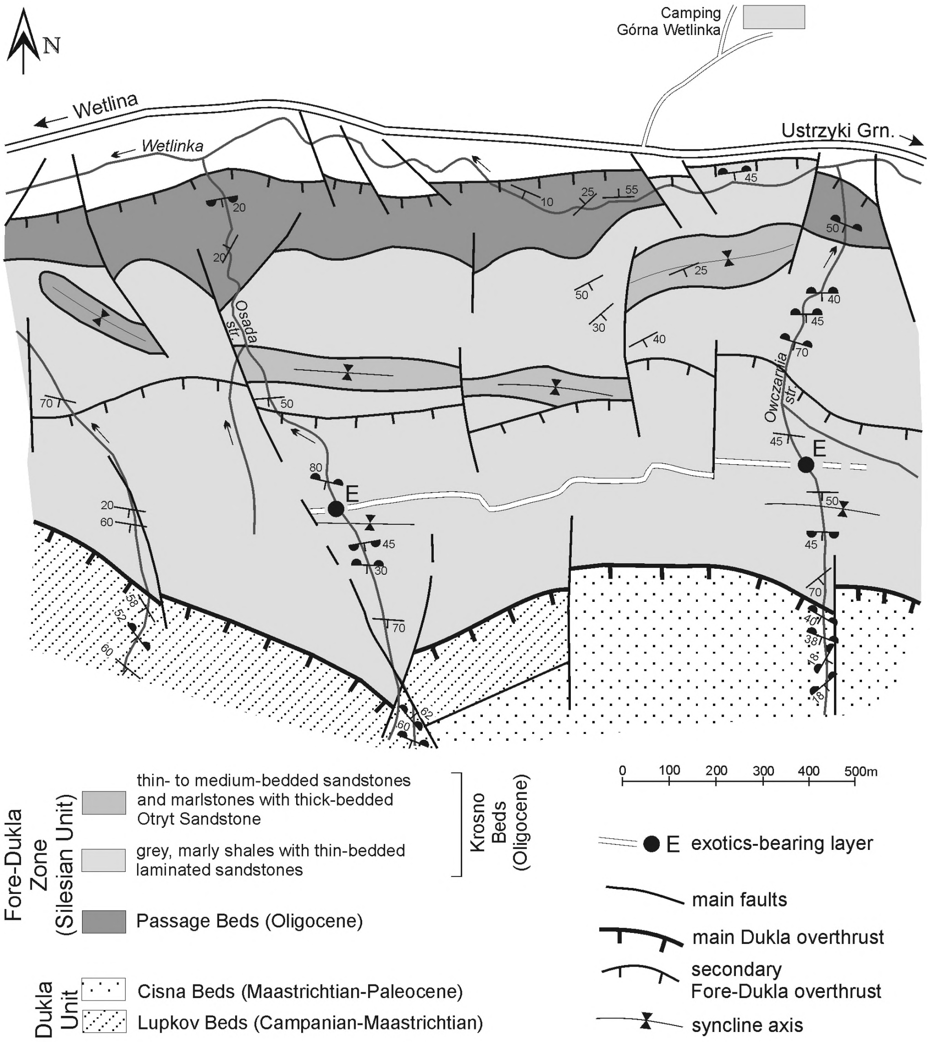

Fig. 3. Detailed geological map of the Fore-Dukla Zone and the Dukla Nappe in vicinity of Wetlina (Bieszczady Mts) with location of the exotics-bearing layer (after Haczewski et al. submitted c).

Owczarnia stream

Two exotic blocks have been found in the Owczarnia stream, whose confluence with the Wetlinka stream lies 400 m downstream along the Wetlinka from the entrance on the road to the Górna Wetlinka camping site (Fig. 3). The exotics occur about 170 m upstream from the mouth of a right affluent of the Owczarnia stream, in the right bank, 0.5 m above the stream bed. A thick bed (1.5 m) of the Otryt Sandstone occurs 40 m upstream of the exotics.

The exotic block is a cobble (25 × 20 × 18 cm) of bioclastic limestone with single bivalve shells, visible on weathered surface, and a boulder (40 × 32 × 20 cm) of strongly fractured sparitic limestone with thick calcite veins. These blocks seem to be loose; however, the orientation of the longest axis of the larger one corresponds with the strike (108°) of grey, calcareous shales, showing a dip of 65°N. The samples taken from these shales for micropaleontological analysis (left bank of the stream; Fig. 4) included a mixed, that is allochthonous (shallow-water), and autochthonous (deep-water) foraminiferal assemblage. The shales seem to be the matrix of the exotics in this place.

Osada stream

Several pebbles of the mudstone similar to those of the Krosno Beds and small exotic blocks occur in the left bank of Osada stream. This stream is the next one to the west of the Owczarnia stream, also flowing from the Dział Mt (Fig. 3). The mouth of this stream is located at Wetlina-Osada settlement, about 80 m above the mouth of the Kimakowski stream, which flows from the Połonina Wetlińska Mt. The exotic-bearing layer occurs in the left bank of the stream, about 140 m upstream of the confluence with its longest right tributary (Figs. 3, 4).

The exotics found include: a rounded cobble (20 × 15 × 10 cm) of massive micritic limestone, a rounded boulder (35 × 25 × 15 cm) of crystalline schist, and a few angular fragments of grey mudstone and very fine-grained sandstone (up to 5 cm in size), which resemble the lithological types from the Krosno Beds. These exotics are embedded in light-grey and dark-grey marly, partly arenaceous matrix. The visible part of the exotics-bearing layer is 70 cm thick. Four samples taken for micropaleontological studies (Fig. 4) include allochthonous, shallow-water fauna, mainly small and large foraminifers,

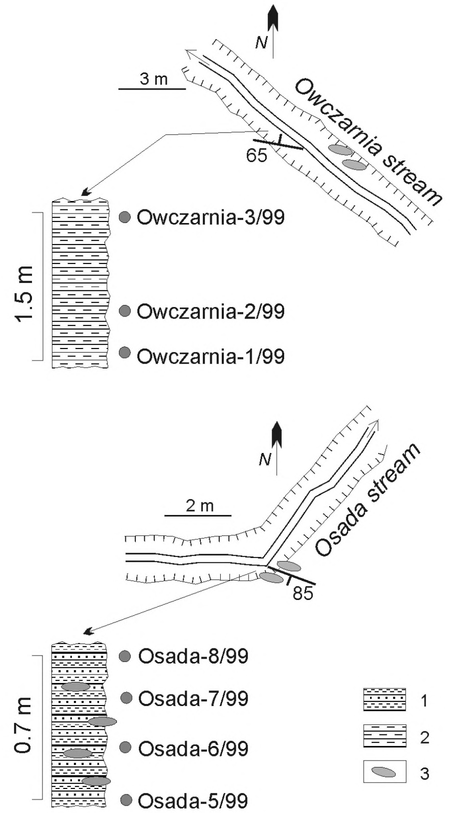

Fig. 4. Detailed location of samples for micropaleontological studies; Owczarnia and Osada streams in vicinity of Wetlina (Bieszczady Mts.): **1** — grey, calcareous shales, **2** — light-grey and dark-grey marly, partly arenaceous matrix of exotics-bearing layer, **3** — exotic blocks.

bryozoans, and juvenile gastropods and bivalves. The strike of this layer (120°), which dips at 85° to SW, corresponds to the strike of neighbouring strata.

The layer with exotics lies in the same stratigraphic position at both described localities, distant by 1 km from each other. It occurs in the southern limb of a syncline, near its hinge (Fig. 3). The syncline belongs to the southernmost horse of the Fore-Dukla duplex (Haczewski et al. submitted c).

Petrographic composition of exotics

The exotics found in two neighbouring streams include crystalline schist and three types of limestones.

Crystalline schist

Macroscopically the rock represents grey-green, fine-grained schist, with quartz-feldspar and mica laminae and lenses and veins of quartz, up 1 cm thick.

Microscopically the rock was determined as quartz-chlorite-muscovite-orthoclase schist with tourmaline and garnet (Fig. 5A–C). Orthoclase crystals are optically similar to quartz (Fig. 5A,C), but their indistinct fissility is diagnostic for orthoclase. The high content of orthoclase in this rock was confirmed by X-ray spectroscopy. Chlorite occurs as elongated grains, with light-grey pleochroism (Fig. 5C) and low interference colours. These crystals probably belong to orthochlorite from the pennine-clinochlore-scheridonite series. Chlorite is here a secondary mineral, due to chloritization of biotite, whose occurence in this rock is only accessory. Muscovite has been found as single crystals and intergrown with chlorite (Fig. 5A–C). Short columnar crystals of tourmaline (Fig. 5B), with distinct olive-grey pleochroism and well visible striped structure, are frequent. Carbonate minerals occur between the quartz-feldspar and chlorite-muscovite laminae (Fig. 5C).

The concurrence of chlorite with the orthoclase-biotite-garnet assemblage suggests that the rock represents a product of two types of metamorphism: progressive, medium-level and retrogressive, low-level.

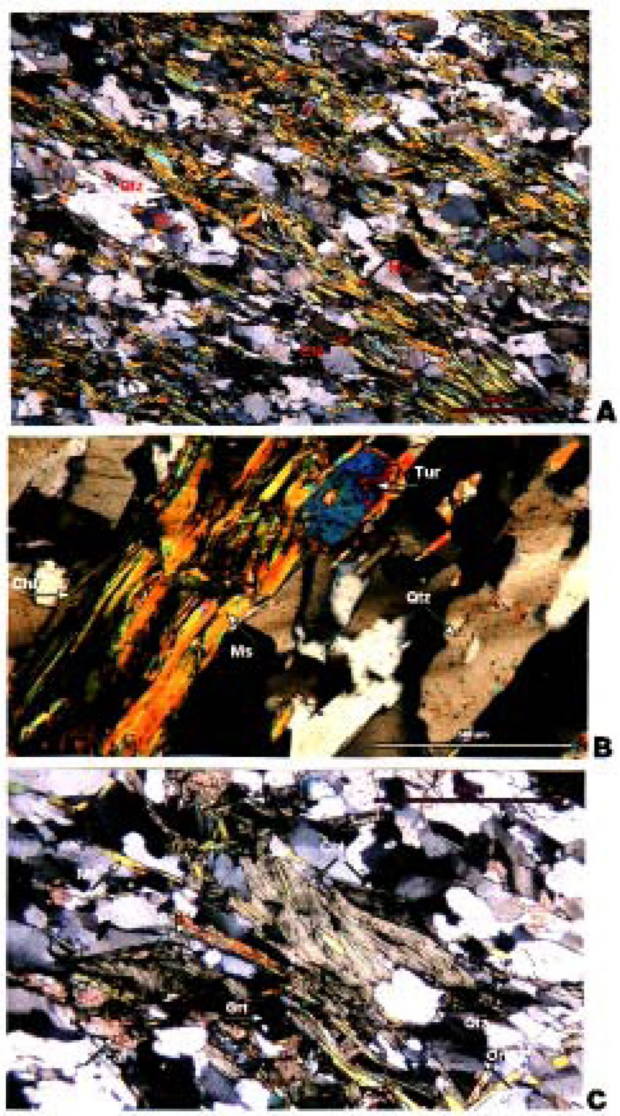

Fig. 5. Photomicrographs of crystalline schist; exotic block from the Krosno Beds of the Fore-Dukla Zone (Silesian Nappe), Outer Carpathians; Wetlina, Bieszczady Mts. **A** — fine-grained schist, with quartz-feldspar and muscovite-chlorite-biotite laminae. Enlarged view in **B** — documents occurrence of garnet and calcite; and in **C** — documents occurrence of tourmaline crystal.

Limestones

Three types of limestone were found:

a/ Massive, sparitic, partly siliceous limestone, with numerous calcite veins (Fig. 6A,B). Black, thin crusts of undetermined oxides? are visible on some cracks. A poorly preserved crinoide trochite has been found as the only biotic component in a thin section.

b/ Massive, micritic limestone with rare planktonic (*Globigerina*-like) foraminiferal tests (Fig. 6C,D). A thin lamina of sandy material occurs in the marginal part of the exotic block. Some of the foraminiferal tests (?*Globigerina praebulloides* Blow) are pyritized. The limestone represents a pelagic type of sediment.

c/ Massive bioclastic limestone with numerous tests of small and large foraminifers (Fig. 6D,F), fragments of coralline algae — Rhodophyta (*Lithophylum* spp.; Fig. 7H–J), bivalves (Fig. 7A), bryozoans (Fig. 7G) and echinoid spines (Fig. 7B,C). Among the small foraminifers, planktic genera such as *Globigerina* (Fig. 8A–D) and *Subbotina* (Fig. 8E,F), and calcareous benthonic genera such as *Cibicidoides* (Fig. 8G,H), *Saracenaria*? (Fig. 8I), *Lobatula* (Fig. 8J), *Valvulina* (Fig. 8K), *Quingueloculina* (Fig. 8L), *Paratrochamminoides* (Fig. 8M) and *Gyroidinoides* (Fig. 8N) have been determined in thin sections. Large foraminifers are represented by *Operculina* sp. (Fig. 7E), *Heterostegina* sp., *Nummulites* sp. and *Nummulites* cf. *fichteli* (Michelotti) (Fig. 7D,F). Identification of the last mentioned species in thin sections is very difficult. However, some characteristic features of this taxon, observed in our material such as: the curved shape of both sides of the test in axial section, the small size of the whole test and the proloculus seem to be sufficient for its identification. The first appearance of *Nummulites fichteli* has been described from the Oligocene (Schaub 1981). Thus the occurrence of this species in the exotic limestone block may indicate an Oligocene age of the limestone.

Microfossils from the matrix

Six samples taken from shales in which the exotics occur (Fig. 4) and one sample taken from neighbouring calcareous marlstones of the Krosno Beds have been analysed for Foraminifera, calcareous nannoplankton and dinocysts.

Foraminifera

The foraminiferal assemblage includes autochthonous, pyritized Foraminifera, typical of the Krosno Beds in the Bieszczady Mts area (Bąk 1999) and allochthonous non-pyritized, well diversified forms with dominance of shallow-water calcareous benthos.

The autochthonous benthonic Foraminifera are represented by agglutinated forms such as *Rhabdammina* sp., *Bathysiphon* sp., *Spirorutilus carinatus* (d'Orbigny), *Haplophragmoides* ex gr. *suborbicularis* (Grzybowski), *Glomospira charoides* (Jones et Parker), *Gyroidina*? *constans* (Reiser), and calcareous forms belonging to *Uvigerina multistriata* Hantken, *Praeglobobulimina pupoides* (d'Orbigny), *Virgulinella chalkophila* (Hagn), *Virgulinella karagiensis* Mikhailova, *Guttulina problema* Cushman et Ozava, *Praebulimina* sp. and *Chilostomella oviformis* (Sherborn et Chapman). Planktic Foraminifera of the autochthonous assemblage, also pyritized, include *Globigerina praebulloides* Blow, *Tenuitella liverovskae* (Bykova), *Tenuitellinata angustiumbilicata* (Bolli), *Tenuitella*? *brevispira* (Subbotina), *Tenuitella munda* (Jenkins), *Globigerina postcretacea* Mjatljuk, *Globigerina ciperroensis* Bolli, *Globigerina ouachitaensis* Howe et Wallace, *Globigerina anguliofficinalis* Blow, *Beella rohiensis* (Popescu et Brotea), *Bolliella navazuelensis* (Molina) and *Paragloborotalia nana* (Bolli).

Calcareous non-pyritized benthic Foraminifera of the redeposited assemblage include *Spirorutilus carinatus* (d'Orbigny), *Reticulophragmium acutidorsatum* (Hantken), *Valvulina haeringensis* (Gümbel), *Elfidiella*? *dolfusi* (Cushman), *Asterigerinoides guerichi* (Franke), *Discorbis alteconicus* Pokorny, *Cibicidoides lopjanicus* (Mjatliuk), *Cibicidoides amphistylensis* (Andreae), *Cibicidoides eocenus* (Gümbel), *Lobatula carinata* Terquem, *Hanzawaia* sp., *Gyroidinoides mamillatus* Andreae, *Cribroporella pteromphalia* (Guembel), ?*Alabamina wolterstorfi* (Franke), *Nuttalides* sp., ?*Neoponides schreibersi* (d'Orbigny), *Planularia kubinyii* (Hantken), *Planularia costata* (Hantken), *Hemirobulina hantkeni* (Bandy), *Astacolus* sp., *Dentalina* cf. *communis* (Reuss), *Dentalina* sp., *Stilostomella* cf. *emaciata* (Reuss), *Stilostomella kressenbergensis* (Guembel), *Lenticulina inornata* (d'Orbigny), *Bulimina alsatica* Cushman et Parker, *Quiqueloculina hauerina* d'Orbigny, *Cribroparella pteromphalia* (Guembel), *Biapertorbis* cf. *alteconicus* Pokorny, *Heterolepa costata* Franzeman, and *Uvigerina* sp.

Single specimens of large Foraminifera have also been found. They include typical Eocene forms, such as *Nummulites fabianii* (Prever), *Operculina alpina* (Douvile) and *Heterostegina depressa* (d'Orbigny), and the Oligocene species *Nummulites vascus* Joly et Leymerie. Similar assemblages of large Foraminifera from the Krosno deposits were described by Cizancourt (1933) from exotic material at Bukowiec (Bieszczady Mts), and by Bieda (1938, 1963) from Seletyn (Bukowina; Romanian Carpathians) and Baligród (Bieszczady Mts; also from exotic rocks).

Redeposited, non-pyritized planktonic Foraminifera, also occur. Some are typical of Late Eocene *Turborotalia* ex gr. *cerroazulensis* (Cole), *Turborotalia centralis* (Cushman et Bermudez) and *Globigerina eocaena* (Guembel), as well as Late Eocene-Early Oligocene forms (cf. Popescu et al. 1998), such as *Subbotina linaperta* (Finlay), *Subbotina tapuriensis* Blow et Banner and *Subbotina praeturritilina* (Blow et Banner).

Calcareous nannoplankton

Two assemblages of calcareous nannoplankton have been found in the matrix of the layer with exotics. The first represents redeposited nannoplankton in which the youngest forms belong to *Cyclicargolithus floridanus* (Roth et Hay in Hay et al.) Bukry, *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival and *Reticulofenestra* cf. *umbilica* (Levin) Martini et Ritzkowski. This assemblage occurs in the matrix of the studied layer in the Osada stream (samples: Osada-6/99 & Osada-8/99), showing that it is not older than the NP16

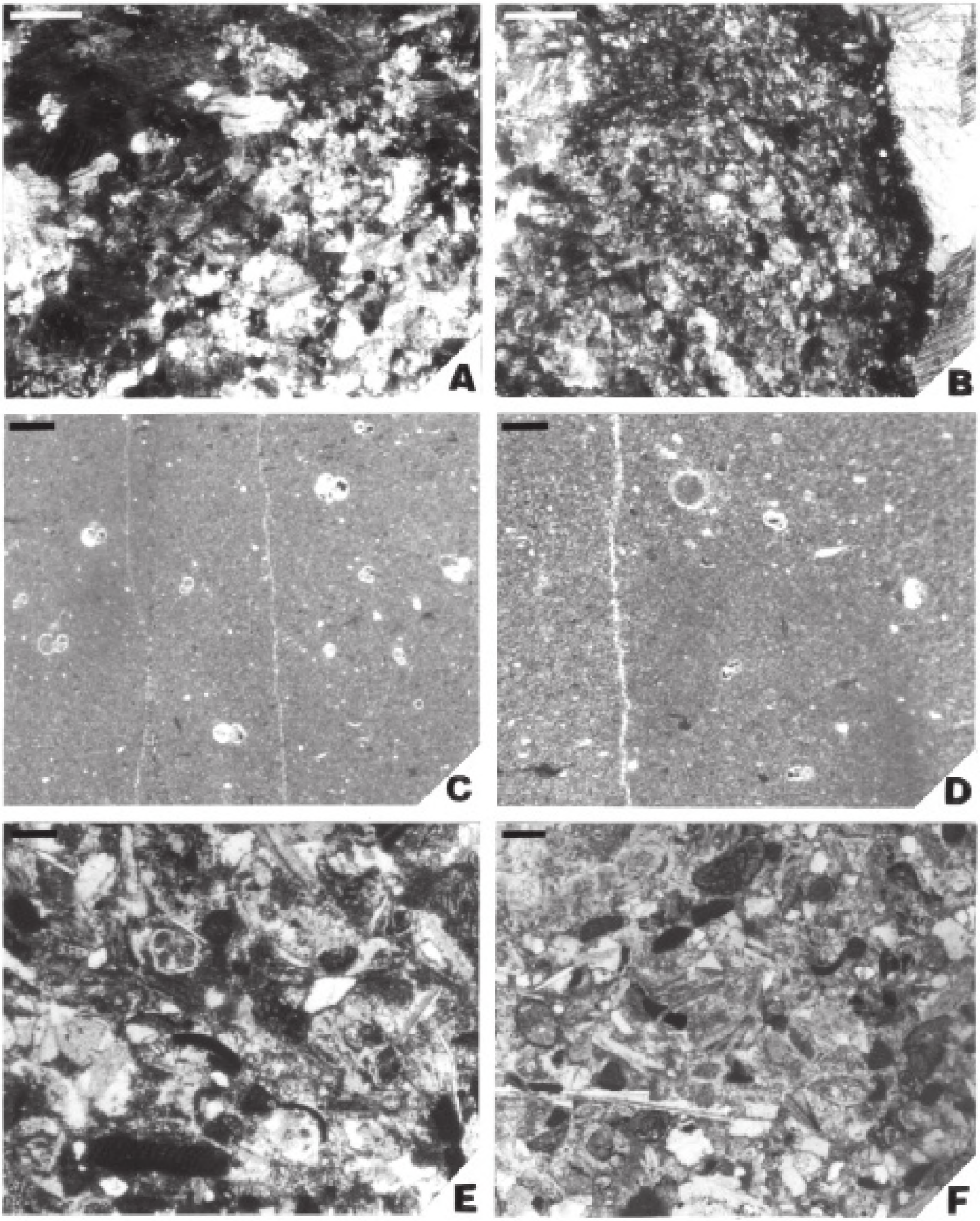

Fig. 6. Photomicrographs of limestones from exotic blocks; exotic blocks from the Krosno Beds of the Fore-Dukla Zone (Silesian Nappe), Outer Carpathians; Wetlina, Bieszczady Mts. **A, B** — Massive, sparitic, partly siliceous limestone, with calcite vein; Owczarnia stream-2/99. **C, D** — Massive, micritic limestone with rare planktic (*Globigerina*-like) foraminiferal tests; Osada stream-9b/99; **E, F** — Massive, bioclastic limestone with numerous tests of small and large Foraminifera, fragments of coralline algae (Rhodophyta) and rare bivalves and bryozoans; Owczarnia stream-1/99. Scale bar — 0.1 mm (for A, B) and 0.5 mm (for C–F).

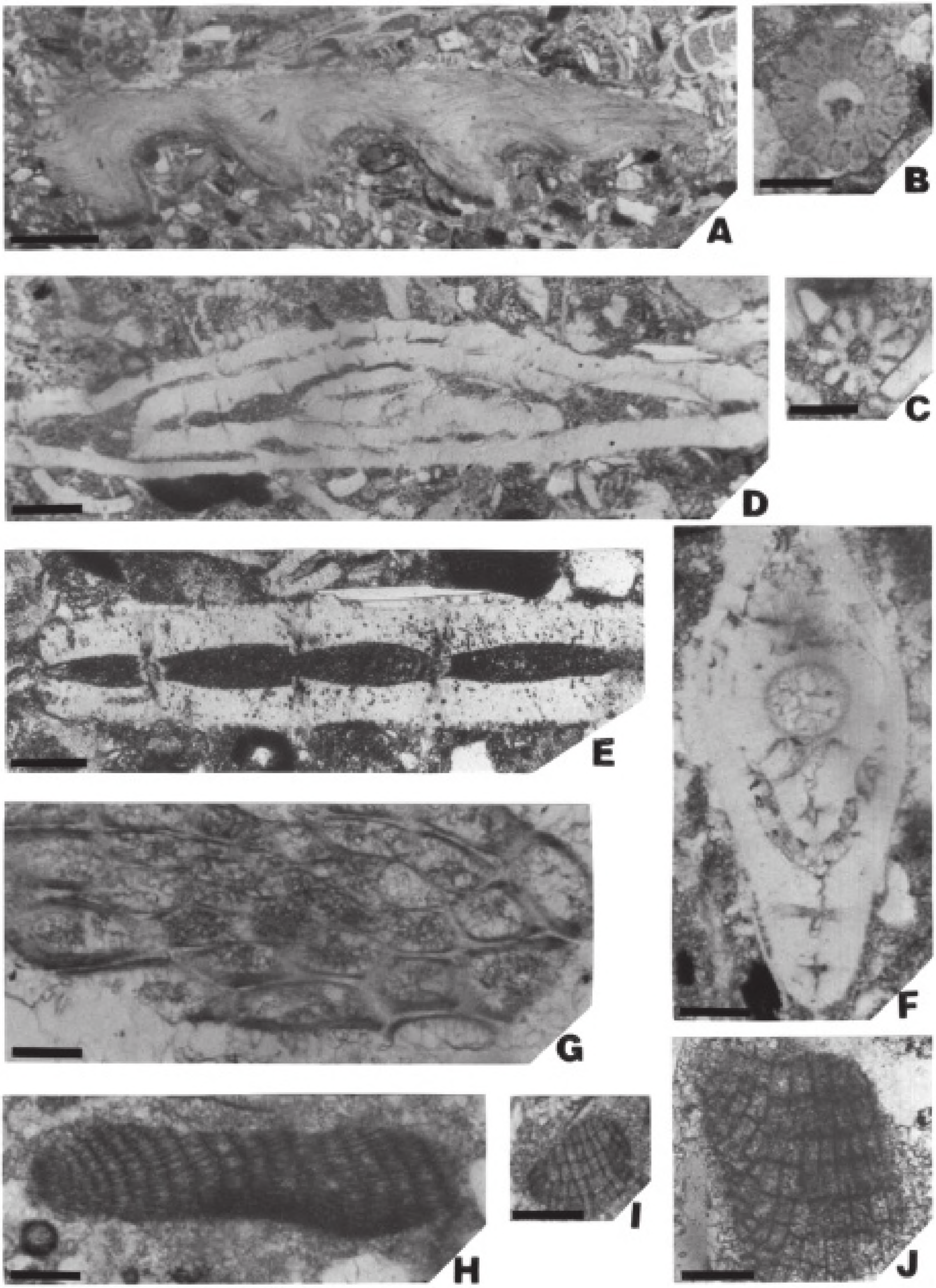

Fig. 7. Microfossils from bioclastic limestone; exotic block from the Krosno Beds of the Fore-Dukla Zone (Silesian Nappe), Outer Carpathians; Wetlina, Bieszczady Mts; sample Owczarnia stream-2/99: **A** — fragment of juvenile bivalve test; **B, C** — echinoid spine; **D, F** — *Nummulites* cf. *fichteli* Michelotti; **E** — *Operculina* sp.; **G** — fragment of bryozoan colony (*Hornera*? sp.); **H–J** — fragment of coralline algae (Rhodophyta: *Litophyllum* sp.). Scale bar — 0.5 mm (for A) and 0.1 mm (for B–J).

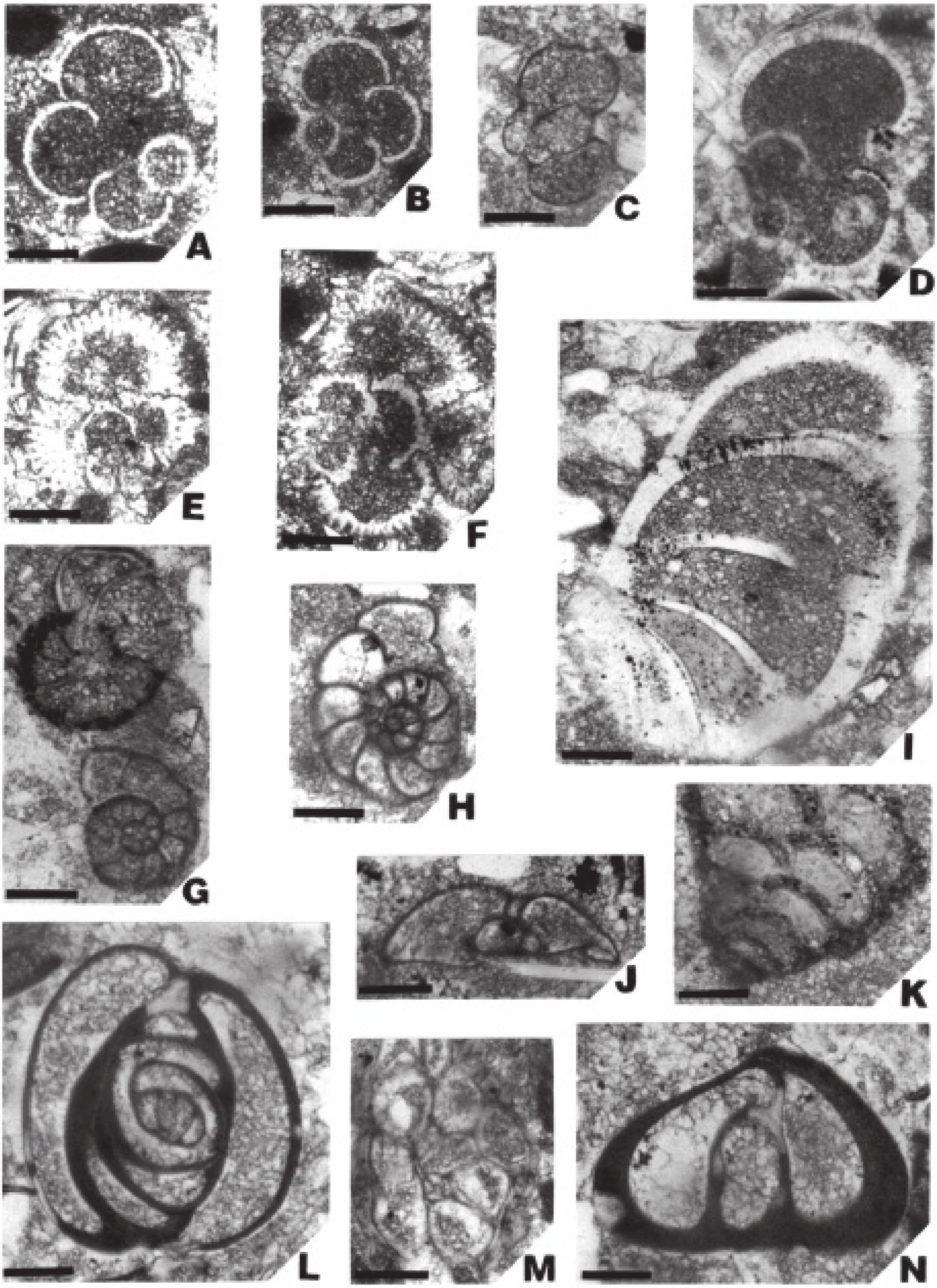

Fig. 8. Small Foraminifera from bioclastic limestone; exotic block from Krosno Beds of the Fore-Dukla Zone (Silesian Nappe), Outer Carpathians; Wetlina, Bieszczady Mts; Owczarnia stream-2/99: **A–C** — *Globigerina* sp.; **D** — *Globigerina* sp. cf. *G. eocaena* Guembel; **E** — *Subbotina* sp.; **F** — *Subbotina* sp. cf. *S. pseudovenezuelana* (Blow et Banner); **G, H** — *Cibicidoides*? sp.; **I** — *Saracenaria*? sp.; **J** — *Lobatula* sp. cf. *Lobatula lobatula* (Terquem); **K** — *Valvulina* sp.; **L** — *Quinqueloculina* sp.; **M** — *Paratrochamminoides* sp.; **N** — *Gyroidinoides* sp. Scale bar — 0.1 mm.

Zone (middle Eocene; Perch-Nielsen 1985). The following have also been determined: *Braarudosphaera* cf. *bigelowii* (Gran et Braarud) Deflandre, *Coccolithus pelagicus* (Wallich) Schiller, *Discoaster barbadiensis* Tan, *Ericsonia formosa* (Kamptner) Haq, *Pontosphaera* cf. *multipora* (Kamptner) Roth, *Sphenolithus moriformis* (Bronnimann et Stradner) Bramlette et Wilcoxon, *Tribrachiatus orthostylus* Shamraî, *Zygrhablithus bijugatus* (Deflandre in Deflandre et Fert) Deflandre.

The second assemblage includes younger calcareous nannoplankton. The youngest species with FAD in the NP24 Zone (late early Oligocene through early late Oligocene; Perch-Nielsen 1985; Berggren et al. 1995) is *Helicosphaera recta* Haq. This assemblage occurs in the marly shales, which seem to be the matrix of the exotic blocks (samples: Owczarnia-1/99 & Owczarnia-3/99). Other calcareous nannoplankton of this assemblage is represented by *Coccolithus pelagicus* (Wallich) Schiller, *Cyclicargolithus floridanus* (Roth et Hay in Hay et al.) Bukry, *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival, *Ericsonia subdisticha* (Roth et Hay in Hay et al.) Roth in Baumann et Roth, *Helicosphaera perch-nielseniae* Haq, *Pontosphaera* cf. *latelliptica* and *Reticulofenestra* cf. *umbilica* (Levin) Martini et Ritzkowski.

Dinocysts

Two assemblages characterize the dinocysts from the layer with exotics (Gedl 2000). The first of them occurs in the sample Osada-7/99 including only redeposited, Late Paleocene-Early Eocene dinocysts: *Cordosphaeridium* sp., *Glaphyrocysta intricata* (Eaton) Stover et Evitt, *Homotryblium* sp., *Hystrichokolpoma cincatum* Klumpp, *Impagidinum* sp., *Lanternosphaeridium*? sp., *Oligosphaeridium* spp., *Spiniferites ramosus* (Ehrenberg) Mantell, *Thalassiphora pelagica* (Eisenack) Eisenack et Gocht, and *Wetzeliella unicaudalis* Caro.

The second assemblage includes younger forms with *Caligodinium amiculum* Drugg, *Cleistosphaeridium* sp., *Cordosphaeridium cantharellum* (Brosius) Gocht, *Cribroperidinium* sp., *Chiropteridium* sp., *Deflandrea* spp., *Glaphyrocysta pastielsii* (Deflandre et Cookson) Stover et Evitt, *Glaphyrocysta?* sp., *Homotryblium pallidum* Davey et Williams, *Homotryblium vallum*, *Homotryblium* sp., *Pentadinium lophophorum* (Benedek) Benedek et al., *Reticulatosphaera actinocoronata*, *Spiniferites pseudofurcatus* (Klumpp) Sarjeant, *Spiniferites ramosus* (Ehrenberg) Mantell, *Systematophora placacantha* (Deflandre et Cookson) Davey and *Thalassiphora pelagica* (Eisenack) Eisenack et Gocht.

The occurrence of *Chiropteridium* sp. and *Caligodinium amiculum* Drugg as well as the type of palinofacies suggest an age for the matrix not older than Kiscellian (see Andreyeva-Grigorovich & Gruzman 1994).

Age of the exotics-bearing layer

The youngest assemblage of calcareous nannoplankton suggests that the exotics-bearing layer is not older than the NP24 Zone (late Kiscellian in the Central Paratethys; Rögl 1998). It is probably older than the coccolith Jasło Limestone chronohorizon (see Koszarski & Żytko 1959, 1961; Jucha & Kotlarczyk 1961; Haczewski 1989), as suggests the lack of *Cyclicargolithus abisectus* (Müller). The first occurrence of *C. abisectus* was noted just below the Jasło Limestone in the area with a similar type of sequence in the Krosno Beds (Baligród Syncline — M. Garecka, *unpublished data*).

Planktic Foraminifera confirm the late Kiscellian age of the Krosno Beds in which the exotics-bearing layer has been found. The youngest taxa in this assemblage are *Tenuitella munda* and *Globigerina ciperroensis*, for which the first occurrences were noted near the Early/Late Kiscellian boundary (Popescu et al. 1998). The autochthonous planktic assemblage may correspond to the Tenuitella munda Zone, proposed for the Polish part of the Central Paratethys by Olszewska (1997, 1998).

An additional confirmation of the Oligocene age is the assemblage of dinocysts. The occurrence of *Hiropteridium* sp. and *Caligodinium amiculum* Drugg suggests the age of the exotics-bearing layer not older than Kiscellian.

Comparison with other exotic occurrences in the Krosno Beds (Bieszczady Mts)

Exotics have been described from a few localities in the southern part of the Silesian Nappe (Central Carpathian Depression), within its Polish part.

Scattered exotic blocks were found in the Krosno Beds near **Ustrzyki Górne**, in the Zakopaniec stream (about 15 km SE from Wetlina) by A.K. Tokarski (Mochnacka & Tokarski 1972) (Fig. 9). There occur steel-grey coloured, chlorite-muscovite schist with garnet crystals, locally "saturated" with silica, and crossed by veins of white quartz, a few cm thick. According to Tokarski (1975), the exotics occur within the upper division of the Krosno Beds, about 250 m above the top of the youngest package of the Otryt Sandstone belonging to the middle division of the Krosno Beds. This position was recently reinterpreted by G. Haczewski (Haczewski et al. submitted c,d) as near the top of the middle division of the Krosno Beds. The basis for this reinterpretation was the different criterion to define the upper boundary of the middle division of the Krosno Beds (top of the last thick-bedded Otryt-type sandstones). The exotic blocks are loose, and the matrix of the exotic layer has not been found at this locality. Thus the precise stratigraphic correlation is impossible, though the exotic crystalline schist from this place is similar to that at Wetlina.

Another occurrence of exotics in the Krosno Beds has been described from **Roztoki Dolne** south of Baligród (about 26 km to NW from Wetlina) (Ślączka 1959) (Fig. 1). These exotics occur in a few layers 1-70 m thick, visible over a distance of 8 km (Ślączka 1959, 1963; Malata et al. in print). The most abundant are crystalline rocks (0.5-2 m of diameter), classified as: phyllites, albite and albite-calcite gneiss-phyllites, garnet phyllites, phyllitic epidote-albite amphibolites and quartzites (Ślączka & Wieser 1962). Moreover, rounded blocks of Eocene bioclastic limestone (up to 0.5 m in diameter), conglomerate boulders (up to 2 m in diameter) and platy fragments of dark shales, green marls and shales (up to 1.5 m long) have been found there. Unstratified grey, calcareous, siltstones form the matrix of the exotics. Lenses of thick-bedded, coarse-grained sandstones are another component of the matrix. The shales, mudstones and sandstones include bivalves, echinoids,

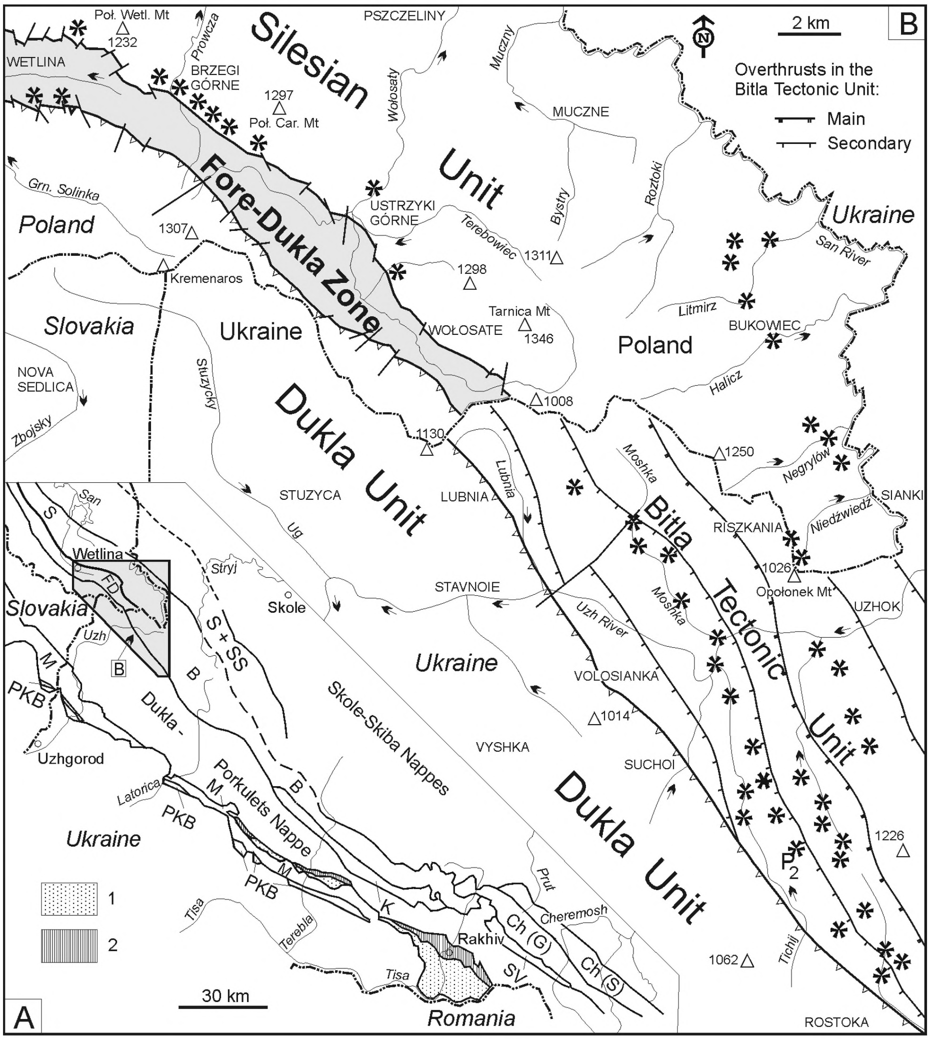

Fig. 9. A: Fore-Dukla Zone against a background of the main tectonic elements of the Eastern Carpathians (after Żytko 1999; simplified); emphasized the location of recent position of the Maramuresh Massif and Rakhiv-Ceahlau Nappe — the area with rocks similar to the studied exotics: **1** — Maramureh Massif and their post-Austrian covers, **2** — Rakhiv-Ceahlau Nappe; **B** — Bitla tectonic unit, **Ch (G)** — Chornogora Nappe (Goverla), **Ch (S)** — Chornogora Nappe (Skupovna), **FD** — Fore-Dukla Zone, **K** — Krasnoshora Subunit, **M** — Magura Nappe, **PKB** — Pieniny Klippen Belt, **S** — Silesian Nappe, **S + SS** — Silesian Nappe (northern part) and Sub-Silesian Nappe, **SV** — Svidovets tectonic subunit. **B:** Exotic occurrences (stars) in the most southern part of the Silesian Nappe and the Bitla tectonic unit, the Bieszczady Mts (boundaries of the Fore-Dukla Zone after Haczewski et al. (submitted a,c); overthrusts in the Bitla tectonic unit after Glushko et al. (1999); exotic localities — see in the text).

bryozoans and large Foraminifera, including *Nummulites vascus* Joly et Leymerie. The age of the matrix has been determined as Oligocene (Bieda 1963). The exotics-bearing layer at Roztoki Dolne occurs in the upper division of the Krosno Beds, about 180–200 m above a thick package of the Otryt Sandstone (Ślączka 1959; Malata et al. in print). However, it should be stressed that the thick-bedded sandstones (Otryt Sandstone?) also occur within the series with exotics and immediately above them (Ślączka 1963).

The lithological types of described exotics in the Fore-Dukla Zone are similar to some rocks from Roztoki Dolne. The crystalline schist from the Owczarnia stream may correspond to the "garnet phyllite", determined by T. Wieser (Ślączka & Wieser 1962). Moreover, the assemblage of large Foraminifera in the massive bioclastic limestone (Osada stream) is similar to that from the bioclastic limestone, described by Bieda (1963).

Other occurrences of exotic blocks in the Krosno Beds in the front of the Dukla Nappe are known, in Poland, from the ranges between the Opołonek Mt through the Połonina Wetlińska Mt. Some of the localities with exotics, such as Bukowiec, the Litmirz and Negrylów streams, and Riszkania (all of them located 22–27 km SE from Wetlina) (Fig. 9) have been studied mainly in relation to abundant macrofauna, which occur in the redeposited bioclastic limestone blocks and in the matrix of exotic layer (Wójcik 1905; Rogala 1932; Cinzancourt 1933; Rogala & Weigner 1935; Krach & Liszka 1961; Danysh 1966). According to Ślączka (1961), the exotics-bearing layer from these localities (representing a single horizon) occurs in a similar stratigraphic position as at Roztoki Dolne, that is within the upper division of the Krosno Beds. This view was revised during the detailed mapping of this area (Haczewski & Bąk 1999; Haczewski et al. submitted a,b). The exotics-bearing layer occurs significantly lower in this area —

about 200 m above the base of the middle division of the Krosno Beds. Thus it could not be correlated with the exotic-bearing strata at Roztoki Dolne and Ustrzyki Górne.

Recently, G. Haczewski (Haczewski et al. submitted c,d) found exotics on the south-western slopes of the Połonina Wetlińska Mt and the Połonina Caryńska Mt (2–7 km from our localities) and traced them to the localities near Ustrzyki Górne. The lithological spectrum of the exotic rocks seems to be similar to those from Roztoki Dolne, Ustrzyki Górne and Wetlina.

The exotic rocks (within olistostromes and as isolated olistoliths) occur also in the Ukrainian Carpathians, immediately in front of the Dukla overthrust (Fig. 9; Shakin et al. 1976). The Oligocene Krosno Beds include, among others, blocks of dark-grey "glassy" sandstones, related to the Lower Cretaceous Shipot Beds, and grey-green and variegated shales (Danysh 1973; Smirnov 1975). The latter lithological type may correspond to the Eocene Hieroglyphic Beds. The Krosno Beds are represented there by medium-bedded flysch. The stratigraphic position of the exotics within the Krosno Beds is unknown here.

Source area of the exotics

The exposures of the exotics-bearing layer in the Fore-Dukla Zone do not provide unequivocal clues on the location of the source area for this material. We speculate that these deposits were transported from south and south-east, like the material of the Otryt Sandstone. All known exotic findings in the Bieszczady Mts are related to the occurrence of thick-bedded, middle- to coarse-grained, polymictic sandstones (the Otryt Sandstone). Single layers of such sandstone (1.5 thick) also occur just above the described layer with exotics. The petrographic composition of the grains in the Otryt-type sandstones resembles the composition of the exotic blocks. The grains in the Otryt Sandstone include fragments of crystalline schists, other crystalline rocks (with quartz, alkaline feldspar, plagioclase, muscovite, biotite), quartzite and limestone (Haczewski et al. submitted b).

On the basis of the composition of the Otryt-type sandstones and the exotics, we suggest that the source area of the exotics-bearing layer was composed of crystalline rocks and partly of Eocene-Oligocene limestones. The latter lithological types originate from two types of environment (based on the exotic rocks): inner shelf (bioclastic limestone with numerous and diversified macro- and microfossils) and outer shelf-upper bathyal zone (micritic limestone with planktic Foraminifera). The Foraminifera from the exotic matrix also represent various environments. Some of them are shallow-water taxa from inner shelf (e.g. *Nummulites vascus* Joly et Leymerie, *Quiqueloculina hauerina* d'Orbigny), others belong to outer shelf and bathyal assemblages (e.g. *Spirorutilus carinatus* (d'Orbigny), *Haplophragmoides* ex gr. *suborbicularis* (Grzybowski), *Glomospira charoides* (Jones et Parker), *Uvigerina multistriata* Hantken, *Praeglobobulimina pupoides* (d'Orbigny), *Virgulinella chalkophila* (Hagn), *V. karagiensis* Mikhailova, *Guttulina problema* Cushman et Ozava, *Praebulimina* sp. and *Chilostomella oviformis* (Sherborn et Chapman)).

A similar source area for the exotic rocks from Roztoki Dolne was proposed by Ślączka & Wieser (1962) and Ślączka (1963). According to these authors, the submarine slumps with exotic rocks descended from the north-western extension of the Marmaros or Rachów massifs, which formed small islands between the Dukla and Silesian subbasins.

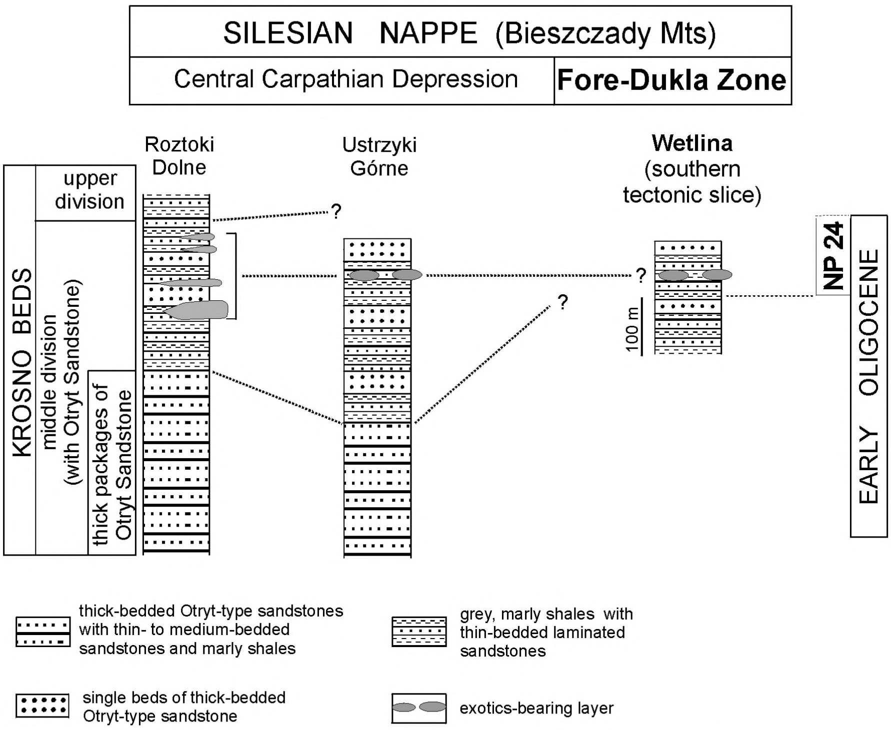

Fig. 10. Trial of correlation of the exotics-bearing layers in the south-western part of the Silesian Nappe and the Fore-Dukla Zone, the Bieszczady Mts.

The composition of the exotic material from the Ukrainian part of the Fore-Dukla Zone (the Tikhyy stream — a left tributary of the Uzh river; Smirnov 1975), may additionally suggest submarine erosion of older lithostratigraphic units (Shipot Beds, Hieroglyphic Beds) during the dense gravitational flows from the shelf area.

Conclusions

The reduction in the thickness of the Krosno Beds (Tokarski 1975) in the Fore-Dukla Zone, scarcity of paleontological data from this area and from the south-western margin of the Central Carpathians Depression (Silesian Nappe), and the likely diachronism of facies, make a precise correlation of the Krosno Beds difficult and, in consequence, also the correlation of the described exotic layer with other exotic localities. It seems that the exotics at Roztoki Dolne and Ustrzyki Górne may be in a similar stratigraphic position, that is near the boundary between the middle and upper divisions of the Krosno Beds (Fig. 10). The lack of thick packages of the Otryt Sandstone in the southernmost tectonic slice of the Fore-Dukla Zone, precludes the determination of the position of the exotic-bearing layer with respect to the boundary between the middle and upper divisions of the Krosno Beds.

The fossils in the exotic layer and the host strata in the Fore Dukla Zone, indicate their position not older than the NP24 Zone (late Kiscellian), below the Jasło Limestone, corresponding to the Tenuitella munda Zone *sensu* Olszewska (1997, 1998). The lack of similar data from other exotic localities precludes a precise biostratigraphic correlation between these localities. It seems likely that these localities represent several independent gravity flows and submarine slumps of similar age.

Paleotransport direction of the exotic material are suggested here on the basis of the paleocurrent directions in the Otryt Sandstone, whose grains are similar in petrographic composition to the exotics. The paleotransport is from the south and south-east. The source area (islands with narrow shelf margins) was composed of crystalline schists, covered partly with various types of carbonate Eocene-Oligocene rocks. Deeper parts of the island slopes could be covered with Cretaceous-Paleogene sediments, related to deep-water sedimentation on a submarine elevation between the Dukla and Silesian subbasins. These deep-water deposits have been included in the submarine mass movements descending to the Silesian Subbasin.

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