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RADIOLARIANS FROM THE PALEOGENE DEPOSITS, SKOLE UNIT, POLISH CARPATHIANS

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Abstract. Preliminary results of the investigation of Radiolarian assemblages from the Paleogene of the Carpathians Outer Flysch (Polish part) are present. Radiolaria occur mainly in the variegated shales deposited in deep-sea conditions (bathyal depth). During the Early and Middle Eocene time there existed a radiolarian boom mainly in the northermost part of the Outer Carpathian basins. Based on about sixty radiolarian species three biostratigraphic zones was recognized and correlated to agglutinated foraminiferal zones.

Keywords: Flysch Carpathians, Skole Unit, Paleogene, variegated shales, clinoptilolite, radiolarians.

GEOLOGICAL SETTING

Paleogene Radiolarian assemblages have been found in the deposits of the Skole Unit area on the Polish Flysch Carpathian (Fig. 1). They occur in both the Variegated Shale Fm and the Hieroglyphic Fm (Rajchel, 1990) (Fig. 2). The Paleocene part of the Variegated Shale Fm consists of dark-red clayey and muddy shales, the Eocene part - of bright-red and green clayey shales in places with clinoptilolite. The Variegated Shale Fm is 130-190 m thick in the axial part of Skole Unit. It contains intercalations of Boguszówka Sandstone Mbr, Kosztowa Sandstone Mbr and Chmielnik Stripped Sandstone Mbr (Fig. 2). In the Paleocene part of this Formation there are Babica Clays. The latter are big lenses of black clayey and muddy cohesive flows with exotic material from the northern margin of Skole basin (Rajchel & Myszkowska, 1998a). In the Paleocene part of the Variegated Shale Fm, the Bircza Lithothamnium Limestone Bed also occur (Rajchel & Myszkowska, 1998b). It represent a regional correlation horizon of allodapic limestones. The Hieroglyphic Fm is 130-180 m thick. It consists of green clayey shales with sandstone

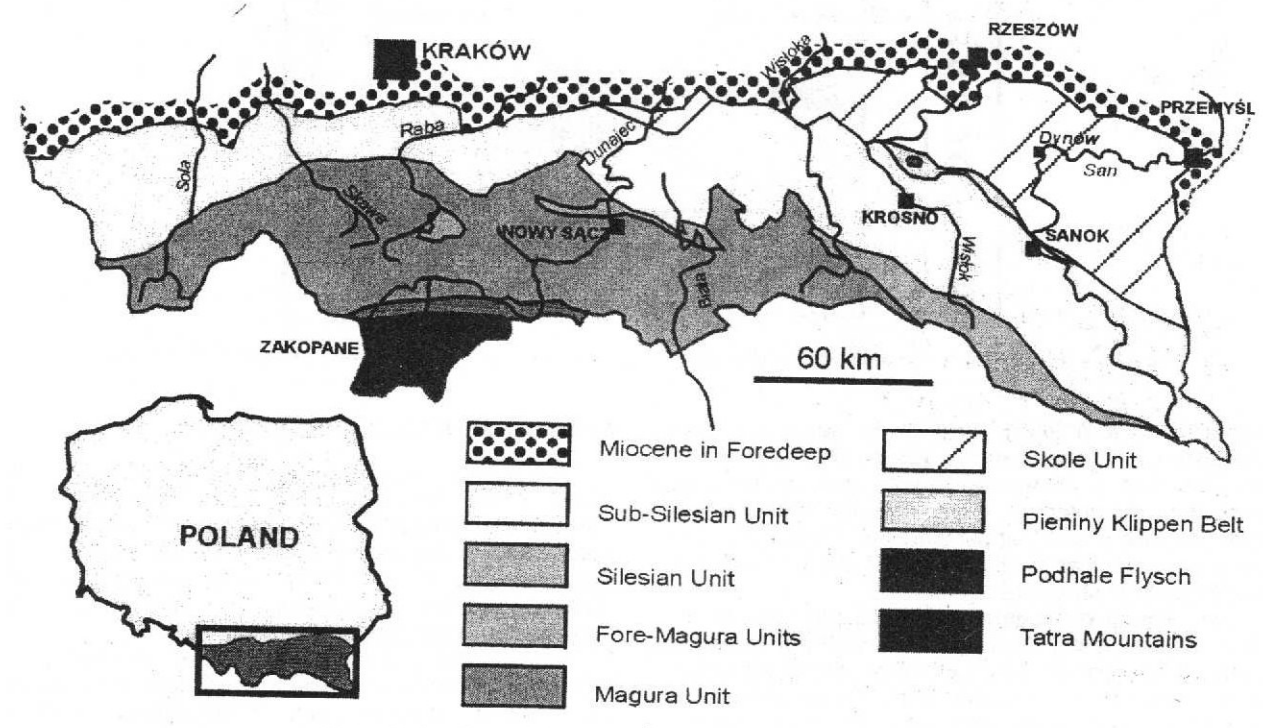

Figure 1 - Position of the area studied in the Polish Carpathians

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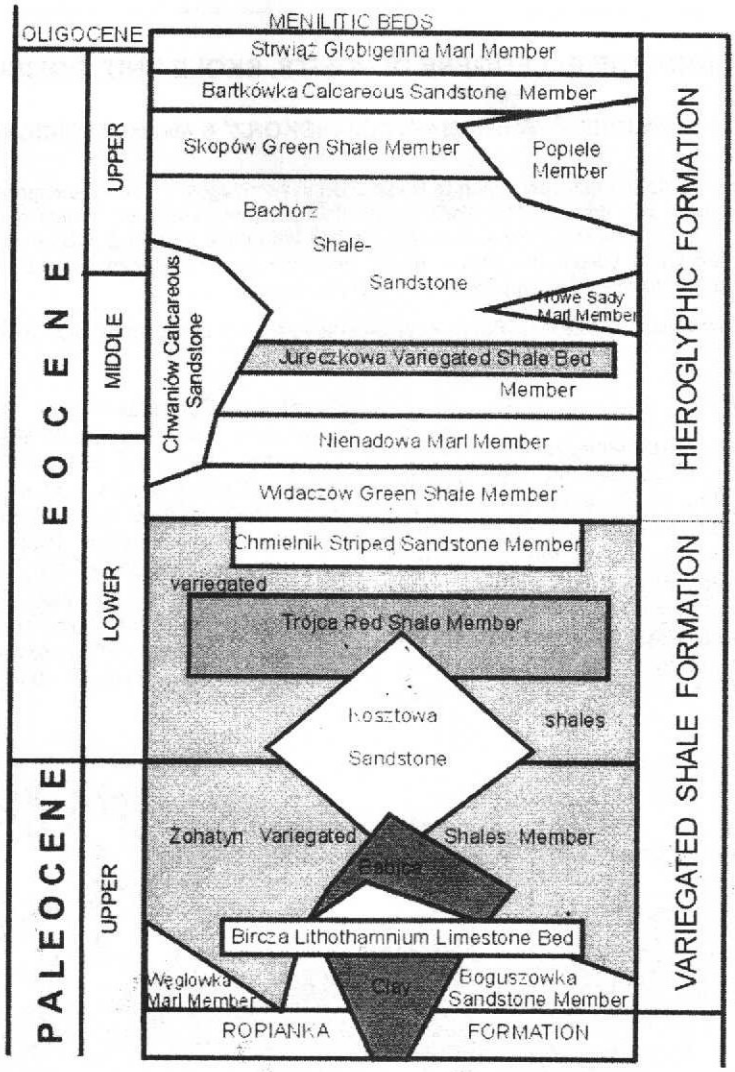

Figure 2 - Lithopstratigraphic profile of the Variegated Shale Formation and Hieroglyphic Formation in Skole Unit

intercalations and locally with chert, geize and marl intercalations. These marls known as Nienadowa Marl Mbr, are also a correlation horizon and contain very interesting ichnological assemblages (Rajchel & Uchman, 1998). In its upper part the Hieroglyphic Fm contains the Strwiąż Globigerina Marl Mbr which is also a regional correlation horizon.

Both Formations contain of Radiolaria (Bąk et al., 1997; Rajchel, 1990; Rajchel et al., 1998). Radiolarian fauna is the most abundant in the middle of the Lower Eocene part of the Variegated Shale Fm which is called the Trójca Red Shale Mbr (Fig. 2). This Member consists of vermilion and brick-red montmorillonite-clinoptilolite pelagic muds with pyroclastic material (Wieser, 1969, 1994; Rajchel, 1994). Sometimes the sediments in the Trójca Red Shale Mbr (up to 30 m thick) consist predominantly of radiolarian tests. These sediments represent deposits of lower batial and abyssal zones, that is the deepest stage of the Skole Unit basin development which was beneath CCD (Leszczyński & Uchman, 1991; Olszewska, 1984). They suggest a well-oxygenated environment similar to the recent radiolarian muds sedimentation conditions (Franus & Rajchel, 1999).

MICROPALEONTOLOGICAL RESULTS

Micropaleontological samples have been taken from some dozen sections and some earthworks of Paleogene deposits. About 60 radiolarian species have been found in the studied material. Some of them are stratigraphicaly important but most are long-ranged (Table 1). Their preparation is rather easy but preservation is variable.

The quantity and quality changes of distribution of radiolarians, especially near the Paleocene/Eocene, Lower/Middle Eocene and Middle/Upper Eocene boundaries, are important in radiolarian biozonation. These changes are the base of reconstruction of paleoceanographical conditions, within northernmost part of the Carpathian basin, according to the global paleogeographical and paleoclimatical context (Thomas & Shackleton, 1996).

The frequency of Foraminifera and Radiolaria are given beneath: /A/ - abundant, /C/ - common, /F/ - few, /R/ - rare.

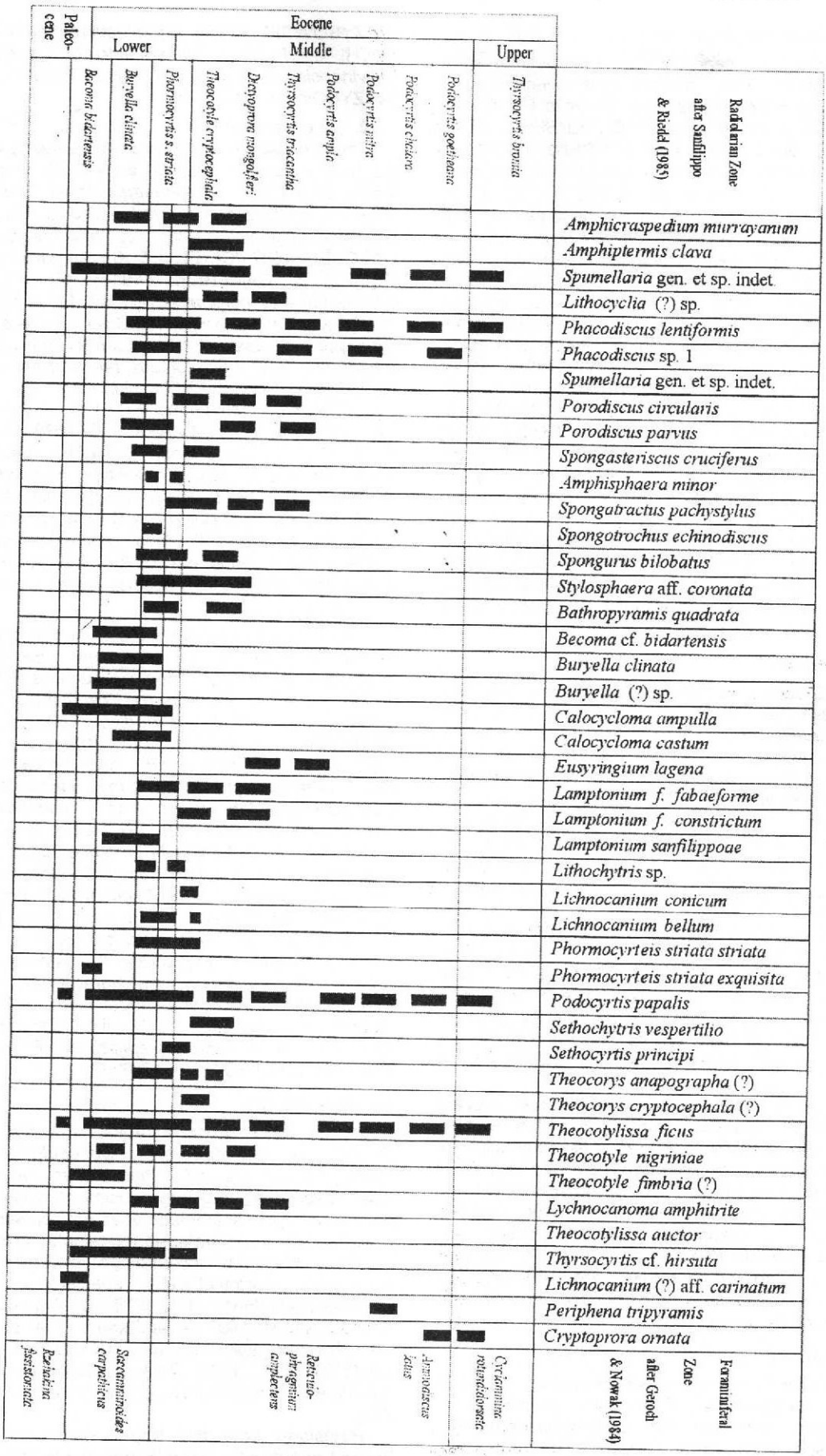

Figure 3 - Ranges of some chosen species of the Paleogene Radiolaria according to agglutinated Foraminifera zone

1. Upper Paleocene

In the Upper Paleocene the radiolarian assemblages are rather poor. They contain rare specimens of stratigraphicaly important species: *Buryella* (?) sp. /R/ (Pl. II, 18), *Calocycloma ampulla* (EHRENBERG, 1874) /R/ (Pl. I, 11), *Theocotylissa auctor* FOREMAN, 1973 /R/ (Pl. I, 17) and some longer-range species: *Cenosphaera* sp. /F/, *Theocotylissa ficus* (EHRENBERG, 1873) /R/ (Pl. I, 21). This assemblage is impossible to place in one of known radiolarian zone of Sanfilippo et al. (1985). A rich association of benthic agglutinated foraminifera consisting of: *Rzehakina epigona fissistomata* (GRZYBOWSKI, 1901) /F/, *R. epigona epigona* (RZEHAK, 1895) /R/, *Glomospira diffundens* CUSHMAN & RENZ, 1946 /C/, *Nodellum velascoense* (CUSHMAN, 1926) /R/, *Hormosina ovulum* (GRZYBOWSKI, 1901) /F/, *Hormosina ovuloides* (BRADY, 1879) /F/, *Haplophragmoides suborbicularis* (GRZYBOWSKI, 1897) /C/, *Recurvoides walteri* (GRZYBOWSKI, 1897) /F/, *Haplophragmoides miatliukae* MASLAKOVA, 1955 /C/, *Bolivinopsis spectabilis* (GRZYBOWSKI, 1897) /C/, *Dorothia crassa* (MARSSON,1880) /R/, *Kalamopsis grzybowskii* (DYLĄŻANKA, 1923) /F/ co-occur with radiolarians. Most of those species of foraminifera are characteristic for the Paleocene sediments of the Skole Unit. It is possible to distinguish *Rzehakina epigona fissistomata* Zone and *Bolivinopsis spectabilis* Zone (Geroch & Nowak, 1984).

2. Lower Eocene

Lower Eocene radiolarian assemblages are rich. They consist of many stratigraphically important species: *Buryella clinata* FOREMAN, 1973 /F/ (PL. I. 12), *Phormocyrthis striata striata* BRANDT, /C/ (Pl. I. 13) as well as *Lithocyclia* (?) sp. /C/ (Pl. I, 3), *Calocycloma ampulla* (EHRENBERG, 1873) /F/ (Pl. I, 11), *Phormocyrthis striata exquisita* (KOZLOVA, 1966) /R/, *Calocycloma castum* (HAECKEL, 1887) /F/ (Pl. I. 10), *Lamptonium fabaeforme fabaeforme* (KRASHENINNIKOV, 1960) /C/ (Pl. II, 21), *Lamptonium sanfilippoae* FOREMAN, 1973 /F/ (Pl. I. 16), *Thyrsocyrtis* cf. *hirsuta* (KRASHENINNIKOV, 1960) /F/. Besides these species occur: *Cenosphaera* sp. /A/, *Podocyrtis papalis* EHRENBERG, 1873 /C/ (Pl. I, 23), *Theocotylissa ficus* /F/ (Pl. I, 21). These radiolarian assemblages belong to three radioarian Zones: *Bekoma bidartensis* Zone, *Buriella clinata* Zone and the lower part of *Phormocyrtis strata striata* Zone of Sanfilippo et al. (1985).

The diagnostic agglutinated foraminiferal species *Saccaminoides carpathicus* GEROCH, 1955 is also present as well as many non-characteristic agglutinated foraminifera: *Reophax elongatus* GRZYBOWSKI, 1897 /F/, *Gerochammina tenuis* (GRZYBOWSKI, 1897) /F/, *Cystaminella pseudopauciloculata* MIJATLIUK, 1970 /F/, *Trochamminoides coronatus* (BRADY, 1884) /A/, *Recurvoides horridus* (GRZYBOWSKI, 1897) /C/, and *Glomospira* div. sp /A/. This foraminiferal assemblage belongs to the *Saccaminoides carpathicus* foraminiferal zone of Geroch & Nowak (1985).

3. Middle Eocene

In the Middle Eocene two assemblages of Radiolaria have been distinguished. The lower assemblage is richer than the upper one. The same deposits contain the diagnostic foraminiferal species - *Reticulophragmium amplectens* (GRZYBOWSKI, 1897) /C/, *Ammodiscus latus* GRZYBOWSKI, 1897 /C/ and species such as *Thalmanammina subturbinata* (GRZYBOWSKI, 1897) /F/, *Recurvoides deflexiformis* NOTH, 1967 /F/, *Trochamminoides coronatus* /C/, *Bolivinopsis spectabilis* /F/ and *Plectina conversa* (GRZYBOWSKI, 1897) /R/.

3. 1. Lower part

The radiolarian assemblage from the lower part of the Middle Eocene deposits consist of: *Phormocyrthis striata striata* /C/, *Amphiptermis clava* EHRENBERG, 1854 /F/, *Bathropyramis quadrata* HAECKEL, 1887 /R/ (Pl. I, 15), *Lithocyclia* (?) sp. /A/, *Phacodiscus lentiformis* HAECKEL, 1887 /C/ (Pl. II 5, 6), *Amphisphaera minor* (CLARK & CAMPBELL, 1942) /F/ (Pl. II, 14), *Stylosphaera* cf. *coronata* EHRENBERG, 1873 /F/ (Pl. I, 7), *Calocyclas* cf. *hispida* /R/, *Calocycloma ampulla* /F/, *Calocycloma castum* /F/, *Lamptonium fabaeforme fabaeforme* /C/, *Lamptonium fabaeforme constrictum* RIEDEL & SANFILIPPO, 1970 /R/ (Pl. I, 18), , *Lamptonium sanfilippoae* /F/, *Lithochytris* sp. /R/, *Lychnocanium bellum* CLARK & CAMPBELL, 1942 /F/ (Pl. I. 20), *Sethocyrthis principi* CLARK & CAMPBELL, 1942 /R/ (Pl. I, 22), *Theocotyle cryptocephala* (?) (EHRENBERG, 1873) /R/, *Theocorys auctor* FOREMAN, 1973 /R/, *Theocotyle nigriniae* RIEDEL & SANFILIPPO, 1970 /R/ (Pl. II, 22). This radiolarian assemblage belongs to the upper part of the *Phormocyrthis striata striata* Zone and to the *Theocorys cryptocephala* Zone.

3. 2. Upper part

The radiolarian assemblage from the upper part of Middle Eocene is a poor one. Besides some stratigraphical important species such as: *Phacodiscus lentiformis* /C/, *Porodiscus circularis* CLARK & CAMPBELL, 1942 /R/, *Porodiscus parvus* CLARK & CAMPBELL, 1942 /R/, *Amphisphaera minor* /F/, *Stylosphaera* cf. *coronata* /F/, *Bathropyramis quadrata* /R/, *Lamptonium fabaeforme fabaeforme* /C/, *Lamptonium fabaeforme* cf. *constrictum* /R/, *Phormocyrthis striata striata* /F/, *Sethochytris vespertilio* (HAECKEL) /R/, *Theocotyle cryptocephala* ? /R/, some long-ranged species also occur: *Cenosphaera* sp. /A/, *Podocyrtis papalis* /F/ and *Theocotylissa ficus* /F/. This assemblage is difficult to assign a radiolarian zone.

There are two diagnostic foraminiferal species - *Reticulophragmium amplectens* /C/, *Ammodiscus latus* /C/ and some non-characteristic species: *Thalmannammina subturbinata* /F/, *Recurvoides deflexiformis* NOTH, 1967 /F/, *Trochamminoides coronatus* /C/, *Bolivinopsis spectabilis* /F/ and *Plectina conversa* (GRZYBOWSKI, 1897) /R/.

4. Upper Eocene

In the Upper Eocene radiolarians are rare. Until present we recorded only: *Cenosphaera* sp. /R/, *Podocyrtis papalis* /R/, *Phacodiscus lentiformis* /F/, *Phacodiscus* sp., and one species of Nasselaria. This poor radiolarian assemblage does not contain diagnostic species and can not be assign to radiolarian zone.

The radiolarian assemblage co-occur with two diagnostic foraminiferal species: *Cyclammina rotundidorsata* (HANTKEN, 1975) /C/, *Ammodiscus latus* GRZYBOWSKI, 1897 /F/ and some other species such as: *Trochamminoides* sp., *Glomospira irregularis* GRZYBOWSKI, 1897. This assemblage belongs to agglutinated foraminifera *Cyclammina rotundidorsata* Zone.

Radiolaria from the Upper Paleocene to Upper Eocene deposits have a differentiated lateral distribution (Morgiel & Szymakowska, 1978). The most abundant Radiolaria occur in the axial part of Skole basin, but a

large elongated area without Radiolaria existed also there. Unlike radiolarians, the distribution of agglutinated Foraminifera was rather uniform.

DISCUSSION

Paleocene/Eocene variegated shales of the Skole Unit are part of the same deposits which occur within the whole Outer Carpathian Flysch and represent a short, final episode of the Cretaceous-Paleogene (Cenomanian - Late Eocene) sedimentation of these multicoloured deposits (Leszczyński & Malik, 1996 and references cited therein). Some of them, especially red shales (e.g., Trójca Red Shale), represent hemipelagic deposits, sedimentated in deep-sea basins (bathyal depths), below CCD level (Leszczyński & Uchman, 1991; Bąk et al., 1997). Paleocene radiolarian fauna is absent or very rare within the Skole Unit deposits, contrary to the Eocene, when radiolarians were very rich (especially in the lower and middle part of the Middle Eocene), probably as effect of some paleoceanographic change. The restricted paleoenvironmental conditions during the end of the Paleocene/Early Eocene, reflected by unfavourable oceanic water (e.g. warm water masses and their slow conversion - „greenhouse" effect) (Kenett & Stott, 1991; Kaiho, 1991), rapidly changed during the Early/Middle Eocene time, when a radiolarian-boom took place. This boom was presumably associated with more open ocean circulation reflecting higher primary productivity of biogenic matter. The next strong change is recorded in the Oligocene deposits, when the variegated shale facies disappeared, probably because of lack of good connections with the open ocean and climate change to so-called „icehouse" type conditions (Leszczyński, 1996).

In our opinion, it is possible that upwelling-type of oceanic circulation might have taken place during the uppermost Cretaceous and Paleogene in the northernmost parts of the Outer Carpathian basins. It is suggested by the occurrence of regional Maastrichtian horizons of phosphorite concretions which originated on the submerged swell (Subsilesian Ridge). On the other hand, the mass occurrence of radiolarian faunas in the Eocene variegated shales indicates high primary organic production. Most likely it was due to increased supply of nutrients carried by cold currents from deeper parts of the basin. Changes of foraminifera/radiolarian ratio during the Paleogene presumably reflect fluctuations of intensity of upwelling currents (Krobicki et al., 1998).

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PLATES

Plate I

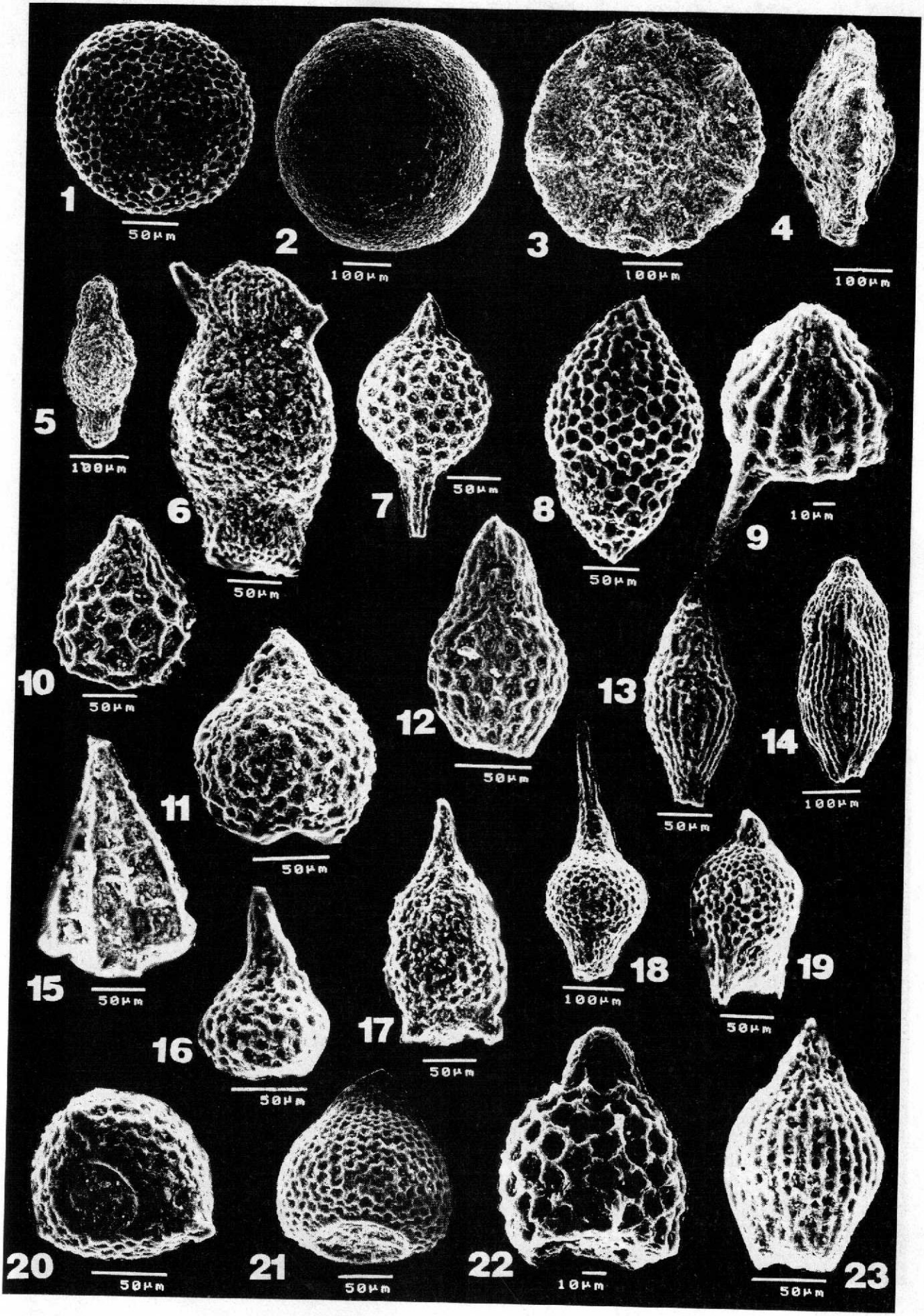
Radiolaria in the Variegated Shale Formation (uppermost Paleocene - Middle Eocene)

1. Spumellaria gen. et sp. indet. **2.** Spumellaria gen. et sp. indet. **3.** *Lithocyclia* (?) sp. - frontal view. **4.** *Lithocyclia* (?) sp. - side view. **5.** *Spongurus bilobatus* (CLARK & CAMPBELL). **6.** *Amphicraspedium murrayanum* HAECKEL. **7.** *Stylosphaera* aff. *coronata* EHRENBERG. **8.** *Theocorys* sp. aff. (?) *spongocorum* (KLING). **9.** *Lichnocanium* aff. *carinatum* EHRENBERG. **10.** *Calocycloma castum* (HAECKEL). **11.** *Calocycloma ampulla* (EHRENBERG). **12.** *Buryella clinata* FOREMAN. **13.** *Phormocyrtis striata striata* BRANDT. **14.** *Lithocampe* sp. **15.** *Bathropyramis quadrata* HAECKEL. **16.** *Lamptonium sanfilippoae* FOREMAN. **17.** *Theocotylissa auctor* (FOREMAN). **18.** *Lamptonium fabaeforme* cf. *constrictum* RIEDEL & SANFILIPPO. **19.** *Lychnocanoma amphitrite* FOREMAN. **20.** *Lychnocanium bellum* (CLARK & CAMPBELL). **21.** *Theocotylissa ficus* (EHRENBERG). **22.** *Sethocyrtis principii* CLARK & CAMPBELL. **23.** *Podocyrtis papalis* EHRENBERG.

Plate II

Radiolaria in the Variegated Shale Formation (uppermost Paleocene - Middle Eocene)

1. Spumellaria gen. et sp. indet. **2.** Spumellaria gen. et sp. indet. **3.** *Pseudostaurosphaera perelegans* KRASHENINNIKOV - frontal view. **4.** *Pseudostaurosphaera perelegans* KRASHENINNIKOV - back view. **5.** *Phacodiscus lentiformis* HAECKEL - frontal view. **6.** *Phacodiscus lentiformis* HAECKEL - side view. **7.** *Phacodiscus* (?) sp. - frontal view. **8.** *Phacodiscus* (?) sp. - side view. **9.** *Spongatractus pachystylus* (EHRENBERG). **10.** *Phacodiscus* sp. - frontal view. **11.** *Phacodiscus* sp. - side view. **12.** *Porodiscus* sp. **13.** Spumellaria gen. et sp. indet. **14.** *Amphisphaera minor* (CLARK & CAMPBELL). **15.** *Spongurus* sp. **16.** *Periphaena* cf. *perplexus* CLARK & CAMPBELL. **17.** *Histiastrum* cf. *quaternalis* EHRENBERG. **18.** *Buryella* (?) sp. **19.** *Sethochytris vespertilio* (EHRENBERG). **20.** *Theocotylissa auctor* FOREMAN. **21.** *Lamptonium fabaeforme fabaeforme* (KRASHENNIKOV). **22.** *Theocotyle nigriniae* RIEDEL & SANFILIPPO.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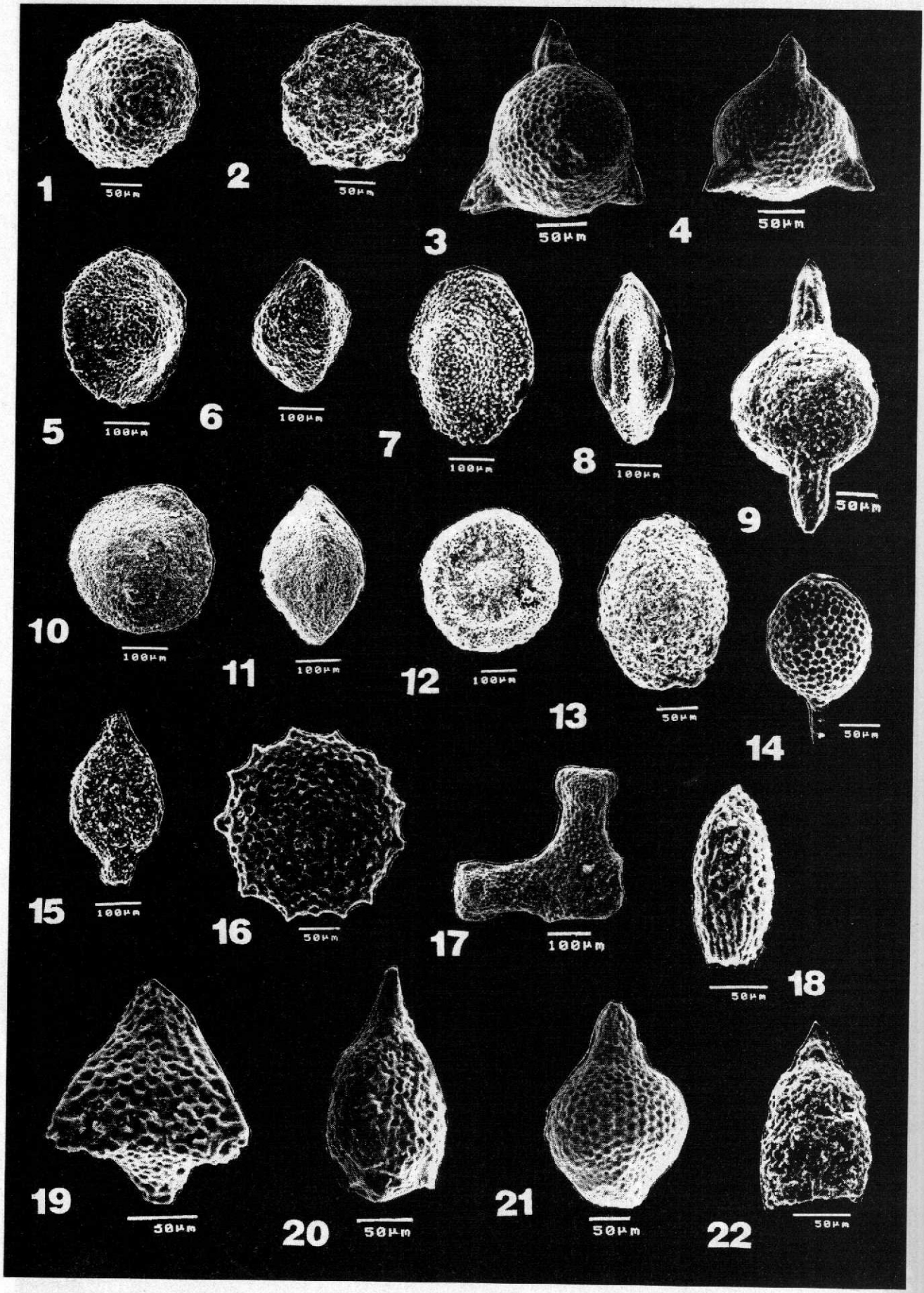
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