Givetian and Frasnian calcareous microbiotas of the Holy Cross Mountains

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Each developmental phase of the Givetian to Frasnian carbonate complex of the southern Holy Cross Mts is marked by distinctive calcareous microbiota. The *Stringocephalus* bank deposits contain a very rich, well-preserved microproblematica (of chiefly ?algal origin) dominated by calcispheroids, and many calcified cyanobacteria and green algae with filamentous *Bevocastria*, tubiform *Devonoscale*, and charophyte *Trochiliscus*. In the late Givetian biostromal complex more sparse microfossil associations occur, with the exception of locally abundant semitextulariid foraminifera (mainly *Nanicella*) and tubiform dasyclad(?) *Jansaella*. Also in the Frasnian back-reef facies, only limited and poorly preserved calcispheroids are identified. Contrarily, reef- and fore-reef microbiotas were present in great profusion. Microbial mats (including calcified cyanobacteria *Renalcis* and *Sphaerocodium*), associated with locally frequent solenoporids and multichambered foraminifera (*Nanicella*, also many nodosariids in the later Frasnian) played a significant depositional role and evidence progressive shoaling conditions within the Dyminy reef-complex.

Key words: algae, foraminifera, microproblematica, Devonian, Poland.

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Introduction

Middle and Upper Devonian limestones of southern Poland are known to contain abundant, frequently rock-building calcareous microfossils (e.g. Kaźmierczak 1971, 1976; Bilan & Golonka 1973; Tomaś 1974; Neumann *et al.* 1975). Nevertheless, published descriptions from the Holy Cross Mountains are scarce and limited mostly to their eastern portion (e.g. Duszyńska 1956; Ozonkowa 1961, 1962a, b).

The present paper deals in the first order with stratigraphic and ecologic aspects of calcareous microbiotas from the Givetian to Frasnian stromatoporoid-coral sequence (Kowala Formation; see Racki 1993) of the Kielce facies region. In addition, supplementary data from the paleogeographically related Siewierz area (Silesia Upland) and Kostomłoty region, as well as from the overlying Frasnian strata, are included. The study is based not only on thin-sections, but also on isolated specimens. Despite this, more comprehensive morphological analysis and taxonomic considerations are not attempted herein.

Localities and material

The microfossils studied were derived from selected localities (see Racki 1993 for set subdivision and other details), situated mostly in the SW part of Holy Cross Mountains. The most significant Givetian to early Frasnian sites are Góra Zamkowa at Chęciny, Góra Łgawa-Jaźwica near Bolechowice and the Posłowice-Sitkówka composite sequence, all representing the stromatoporoid-coral, mostly biostromal facies. For the lowermost unit (viz. Early-Middle Givetian *Stringocephalus* Beds) there is complementary informatione from Jurkowice-Budy (eastern part), Czarnów (Kostomłoty zone) and the Siewierz area (Silesia Upland).

Moreover, the varied Frasnian detrital limestones, mantling the Kowala Formation, were sampled in some localities (e.g. Bolechowice-Panek, Sitkówka-Jaźwica, Psie Górki) for comparative stratigraphic analysis. This includes Kostomłoty Beds at type sites that span the latest Frasnian.

More than seven hundred thin-sections have been taken for micropaleontological research in the course of microfacies analysis of the limestone series (Racki 1993). Furthermore, a bulk of the material consists of above two thousand completely isolated specimens. They were obtained by washing weathered parts of compact limestones in several localities (Jurkowice-Budy, Kadzielnia, Jaźwica, Szczukowskie Górki, and others). Some microfossils come from disintegrated argillaceous deposits (e.g. at Czarnów and Kowala); less suitable to study specimens were recovered from calcite residues left after chemical processing of rock samples in weakly buffered acetic acid. Preservation of the microfossils is diverse, but generally not very good as a result of both synsedimentary and diagenetic processes, and/or limitations of preparation techniques.

The collection of isolated microfossils is housed at the Silesian University in Sosnowiec (Cataloque Number GIUS 4).

Taxonomic framework

Several unresolved problems are connected with the in micropaleontological studies of the Devonian carbonate facies:

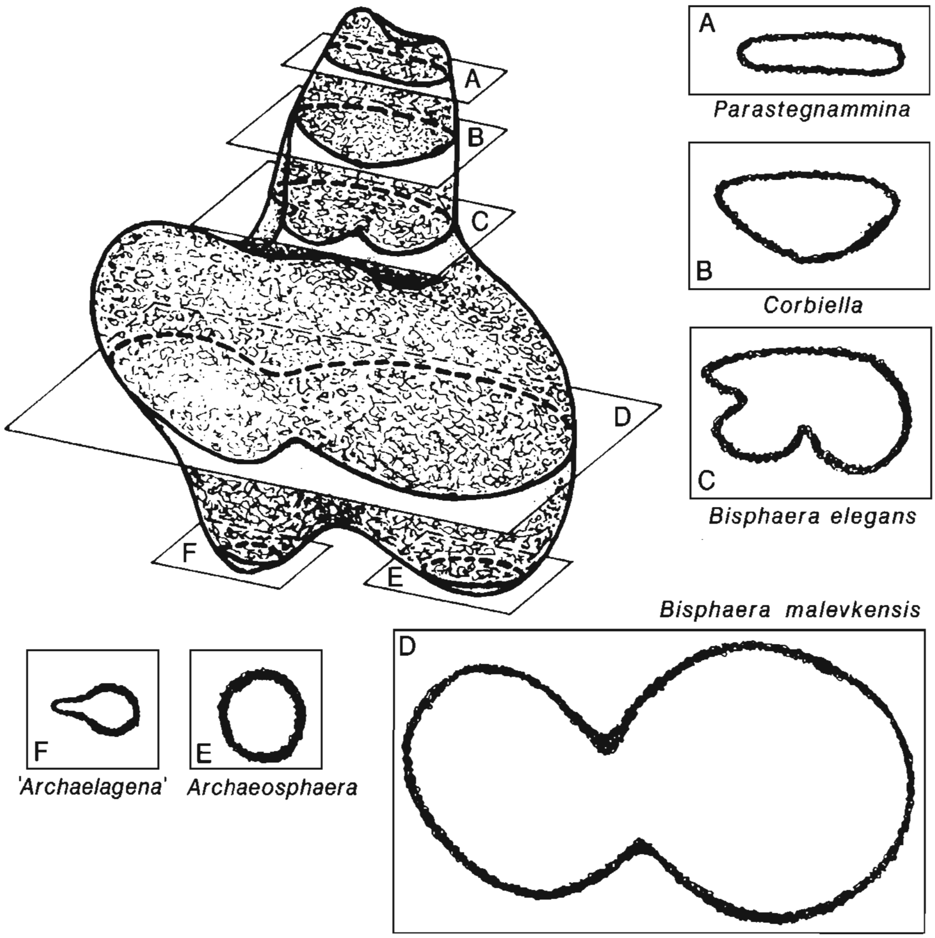

Fig. 1. Shapes obtained by sectioning an irregularly-shaped calcareous body in different planes (see Fig. 10J) which correspond to several 'section genera' of alleged foraminifera, based on Poyarkov (1979) illustriatons of types.

(1) Virtually all studies on microfossils are based on randomly cut thin-sections. This results in a quite confusing taxonomic approach (Toomey *et al.* 1970; Sabirov 1980). For example, irregularly-spherical calcareous bodies (see Fig. 9) may provide a wide variety of differently outlined sections, corresponding to many established 'genera' and 'species' ('secto-morphs', Fig. 1). Subdivision of the most parathuramminoid 'foraminifera' relies on variations of size and shape in thin-sections only (see also discussion and examples in Bykova 1955: p. 12; Toomey *et al.* 1970; Poyarkov 1979: p. 8; Zadorozhnyj 1987). Furthermore, many reconstructions based on thin-sections has appeared far from reality when confronted with isolated complete specimens; this is well exemplified by the case of alga *Calcifolium* (Skompski 1981; see also Chuvashov *in* Chuvashov *et al.* 1987: p. 11 for data on palaeoberesellids and umbellids).

(2) As shown by Kaźmierczak (1976), different preservational histories of an algal species may lead to the origin of various econdary structures (shadow fossils). Diagenetic phenomena (e.g. micritization and neomorphism) frequently cause misinterpretation of microfossils (diagenetic taxa; Toomey *et al.* 1970: p. 970; Pratt 1984). For example, some usloniid 'foraminifera' (especially tubular *Parastegnamina*, Fig. 8C; also Poyarkov 1979: Pl. 8: 9-13, 15, and Manukalova-Grebenjuk 1974) are difficult to distinguish from incipiently micritized molluscan shell fragments or agglutinated linings of 'worm' burrows (Andrews 1986; Vachard 1988: p. 89).

(3) Even for many well-studied extinct microorganisms it is hard to find modern counterparts. In consequence, their affinities remain equivocal and opinions differ from author to author (e.g. receptaculites; Riding 1977). It is notable that living algae are classified according to such unfossilized characters as pigments, chloroplasts, food reserves, etc. (Wray 1977: p. 28).

All these factors result in a speculative approach to the taxonomy of the Devonian microfossils. According to Toomey & Mamet (1979), at least half of the known Devonian foraminiferal genera are in a state of taxonomic confusion and should be transferred chiefly to algae.

In this ambiguous situation the following approach is applied herein:

(1) Algae (and calcified Cyanobacteria) are reviewed only in the framework of principal groups adopted from Chuvashov & Riding (1984; also Riding 1984, 1991a).

(2) Microproblematica, a large grouping of microfossils of doubtful, but possibly mostly algal affinities (?also some minute calcisponges, e.g. moravamminids *sensu* Vachard 1988), are subdivided into several informal groups, generally corresponding to 'foraminiferal families' of Poyarkov (1979; see also Zadorozhnyj 1987; Loeblich & Tappan 1988), and units of Langer (1979). The exclusion from protozoans is a result of the mentioned proposal by Toomey & Mamet (1979).

(3) Foraminifera are thus limited to *bona fide* forms classified according with Poyarkov (1979). Only part of them, based on isolated specimens, are treated here in more systematic manner.

Systematic review of calcified cyanobacteria and algae

Benthic microbial communities played an important depositional role in some, particularly lagoonal, environments within the carbonate platform. Several biosedimentary features (varied fenestral and spongiostromatid fabrics, algal ooze, intermittent algal laminations, structureless coatings), described by Machielse (1972) from the Canadian carbonate complexes (see also 'cryptic microbial carbonates' of Riding 1991b), are also quite common in the Holy Cross Mountains (Fig. 2). Apart from flat microbial mats, widespread in restricted shelf deposits, there are also found non-fenestral microbolites, associated with intershoal facies of the Late Givetian

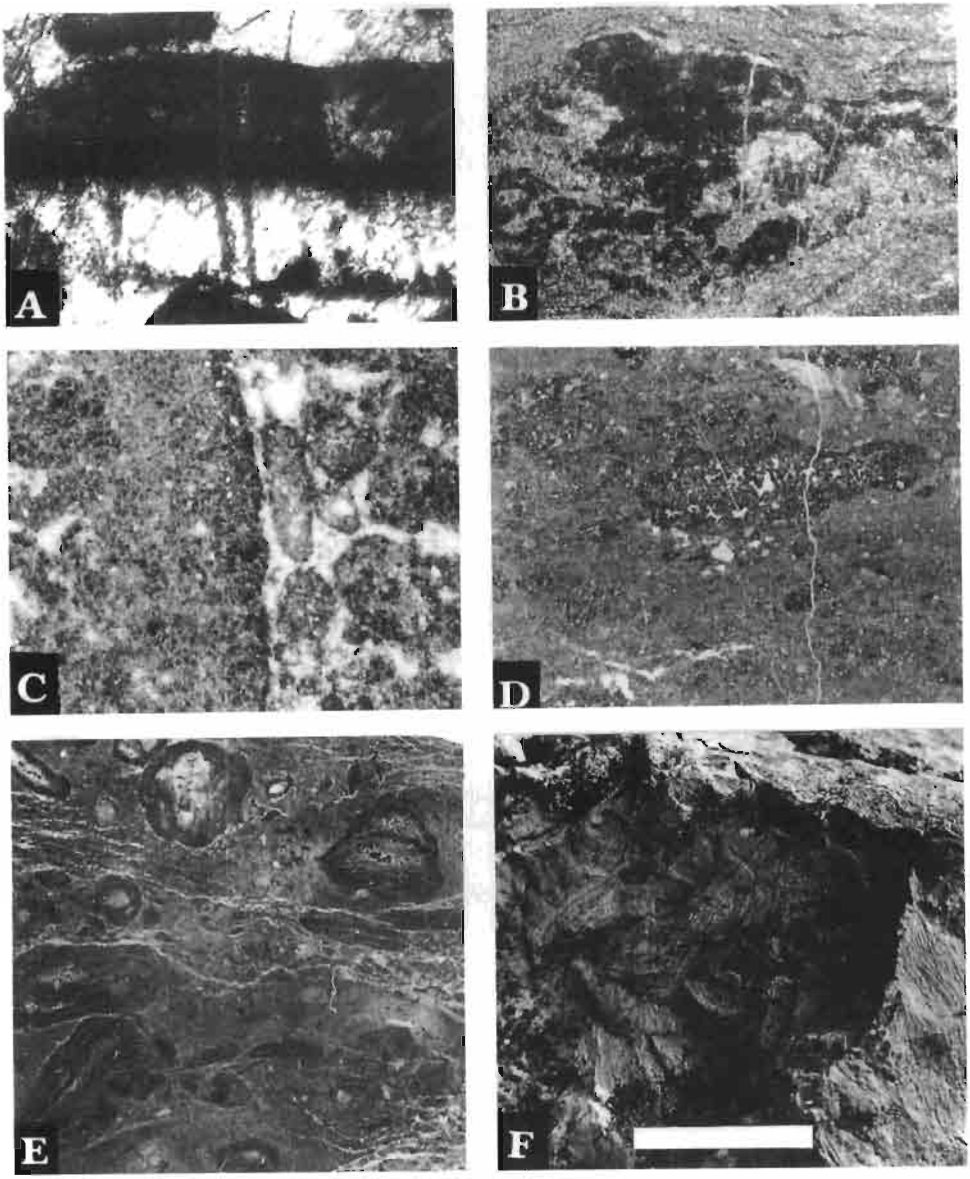

Fig. 2. Biosedimentary effects of microbial communities in the Holy Cross Mts Givetian (B-E) and Frasnian (A, F). ❑A. Coated and partly micritized molluscan(?) shell fragment; upper Sitkówka Beds, Jaźwica (set H); × 50. ❑B. Micrite clumps entrapped between microsparite layers in non-fenestral laminite; Chęciny Beds, Góra Zamkowa (set D); × 70. ❑C-E. *Bevocastria*-dominated nodule horizon (E; natural size), its spongiostromatid microfacies (D, × 5) and details of coated nodule periphery (C, × 40); *Stringocephalus* Beds(?), Wojnowice. ❑F. Stromatolite mound, with almost vertically inclined laminae; bar scale equals 5 cm; Detrital-Stromatoporoid Beds, Psie Górki (set C).

Sitkówka bank complex (Facies M-1 of Racki 1993). Stromatolitic buildups developed in upslope setting of the Middle Frasnian Dyminy reef (Psie

Górki, Fig. 2F; Grabina, Kadzielnia; Hoffman & Paszkowski 1992). Layered (or complex) oncoids were rarely discovered (Sowie Górki, set C; Miedzianka, set D), although the presence of an 'algal' nodule-bearing horizon (Fig. 2E) at the Wojnowice section (Racki 1986: Fig. 2D) is remarkable.

Interpretation of the common calcispheres and some parathuramminoid 'foraminifera' as permineralized remnants of green algae such as volvocaceans, is crucial for micropaleontology of the Devonian carbonate shelves (Kaźmierczak 1976). As both groups most probably contain a wide variety of organic remains, they are discussed under 'Microproblematica'.

Skeletal calcareous algae, reviewed below, are usually not very common. Their remnants are poorly preserved and only occassionally identifiable to the genus level. Of these, only the Dasycladaceae and Charophyta have, as a whole, firmly established taxonomic status.

Calcified cyanobacteria and related forms

***Hedstroemia-Ortonella* group**.– Nodular, free masses of *Ortonella*-like porostromates, up to 1 mm in size, are only rarely encountered (Fig. 3A-B). Their taxonomic differentiation is probable in regard of varying thickness of tubes and angle of divergence (cf. Mamet & Roux 1975a; Bourque *et al.* 1981) but lack of sufficient material precludes definitive determination.

Other variant of more irregularly-shaped and larger-sized (up to 6 mm) masses, attributable to genus *Bevocastria*, seems to be most common in the *Stringocephalus* Beds (Preat & Racki in press). Variable internal diameters of the characteristically constrained tubes in specimens from different sites (Fig. 3C, G) suggest also a specific differentiation (cf. Mamet & Roux 1975a; Bourque *et al.* 1981). Some bifurcated filament molds are contained frequently in cryptic microbial and trombolite deposits (cf. Browne & Demicco 1988; see also spongiostromid-*Bevocastria* bindstone, 'MF 11a' of Preat & Mamet 1989), point to possibly great significance of the alga as sediment-binders in the lagoonal settings. At one late Frasnian locality (Psie Górki, set E), fragmented tubes assignable to *Hedstroemia* are recognized in laminoid micrites.

***Girvanella* group.**– Simple flexuous tubes of uniform diameter occur mainly in widespread small irregular nodular masses (up to 1 mm in size). They are differently packed tangled filaments, but also isolated tubules (see Fig. 3D) grading toward micrite rods (see also Machielse 1972; Danielli 1981). The larger-sized porostromate variants, with internal tube diameters contained between 25 and 40 μm, are more frequent in the Frasnian strata (e.g. Kostomłoty, Sowie Górki, Góra Zamkowa, Kadzielnia), and they could be attributed to *G. kasakensis* Maslov 1949 according to the scheme of Mamet & Roux (1975a). Thin-tubed forms (14 to 30 μm), comparable to *G. problematica* Nicholson & Etheridge 1878, are known predominantly

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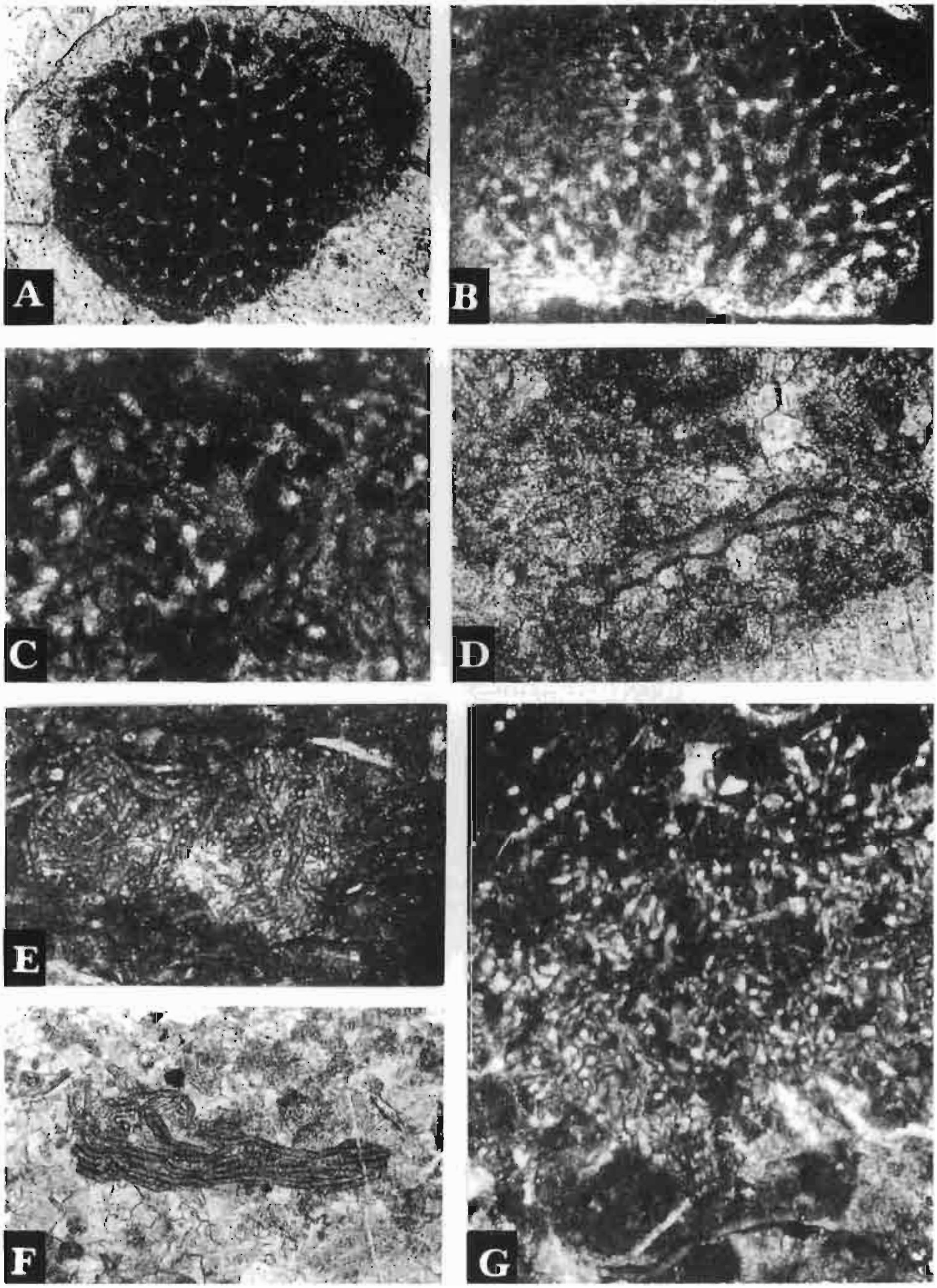
Fig. 3. *Hedstroemia-Ortonella* (A-C, G) and *Girvanella* (D-F) calcified cyanobacteria. Givetian (B-C, G) and Frasnian (A, D-F). ❑A-B. *Ortonella*(?) clusters; Kostomłoty Beds, Kostomłoty (A, × 100; set H) and *Stringocephalus* Beds, Czarnów (B, × 125; set A). ❑C, G. General (G) and



detailed view (C) of a *Bevocastria* clump, *Stringocephalus* Beds, Bilcza-II hill (C, × 85; set A) and Jurkowice-Budy (G, × 70; set E). ❑D. Isolated 'girvanellid' filament (?*Mitcheldaenia*); upper Sitkówka Beds, Sowie Górki (set G); × 150. ❑F. Clustered parallel girvanellid tubes (?*Botominella*); Detrital Beds, Psie Górki (set G); × 50.

from the Holy Cross Mountains Givetian, mostly from the Jaźwica Member (Posłowice, Jaźwica, Stokówka; Fig. 3E). However, Danielli (1981) as a result of biometric analysis suggests that most of the girvanellid taxa do not differ significantly in observable characteristics and should be classified as only one species.

Similarly-sized tubules sporadically display (e.g in the Kadzielnia Member, Detrital Beds and Kostomłoty Beds; Fig. 3F) a strictly parallel growth habit, and the aggregates can be attributed (cf. Shuysky 1973; Tsien 1979) to *Botominella*. Some loose filaments with regularly changing thickness (Fig. 3D) are suggestive of the problematic porostromate *Mitcheldeania*.

***Sphaerocodium* group.**– Discrete aggregates of fan-like branching filaments, which have a chain-like appearance in cross-section, are a minor component of the Givetian microbiota (Fig. 4A-B), known only from the Jaźwica Member and Szydłówek Beds. Instead, the crustose form of *Sphaerocodium*, representing chiefly complex symbiotic intergrowths with laminar metazoan reef-builders (mostly stromatoporoids) and microbial mats (Flugel & Wolf 1969; Tsien 1979), occurs in profusion in the Frasnian foreslope mounds and knolls (Psie Górki, Szczukowskie Górki).

Most of the identified porostromate colonies appear to be related to *S. devonicum* (Maslov 1956), a widespread Devonian species distinguished by internal filament diameters 30 and 40 μm (Chuvashov 1965; Wray 1967; Flügel & Wolf 1969). Only the Frasnian specimens from Psie Górki display larger thickness of tubes typical for *S. magnum* Wray 1967 (Mamet & Roux 1983).

***Renalcis* group.**– The cloud-like 'thalli' significantly add to, and locally dominate, the associated metazoan reef-builders in the Frasnian of the Holy Cross Mountains (Kaźmierczak 1971; Kaźmierczak & Goldring 1978), and in many other Paleozoic carbonate complexes (see review in Wray 1977; Pratt 1984). Renalcids were found as small, unattached clumps (Fig. 4C-D) or resedimented bioclasts, as well as larger free-standing masses displaying varied growth habits, and widespread in organic buildups at such sites as Grabina, Psie Górki, Daleszyce and Szczukowskie Górki; very similar foreslope bioherms were described by Mountjoy & Riding (1981) from Canada. Extensive incrustations of frame-building skeletons, mostly thick-branched *Stachyodes*, and different-sized cavities (Fig. 4G) were frequently observed. Most typical morphotypes comprise chambered and saccate forms, although their mergings into the clotted variant are encountered too.

These microfossils were originally assigned to many genera (Mamet & Roux 1983), but lotely they were reinterpretated by Pratt (1984) as representing merely an environmentally controlled intermittent calcification of variably growing coccoid cyanobacterial colonies, viz. diagenetic taxa (but see Riding 1991a). In fact, Mamet & Roux (1983; Roux 1985) considered all renalcids as belonging to one variable species *R. granosus* Volodgdin 1932.

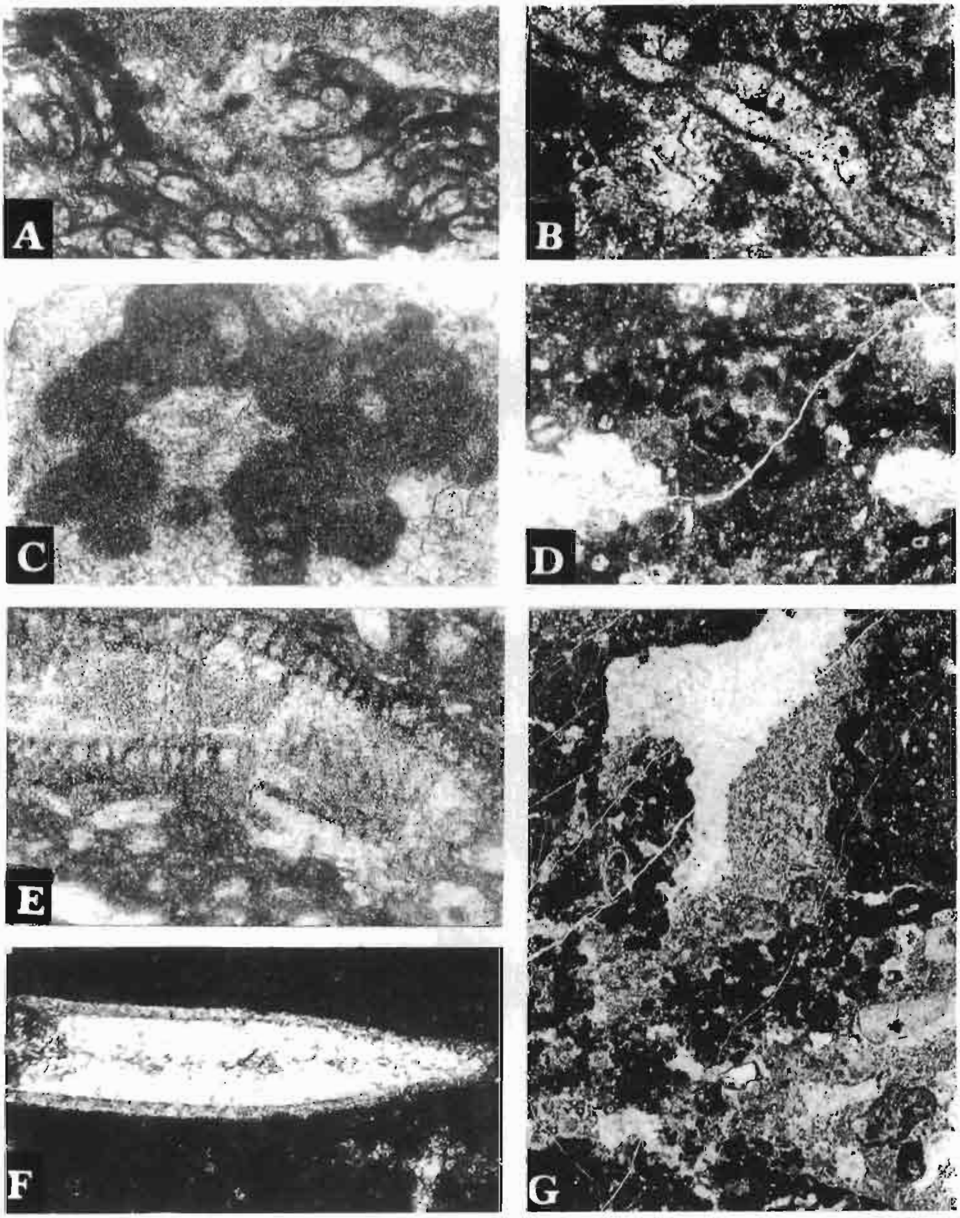


Fig. 4. *Sphaerocodium* (A-B) and *Renalcis* (C-D, G) calcified cyanobacteria, and dasyclad algae (E-F), Givetian (A-B, E-F) and Frasnian (C-D). ❑A-B. *Sphaerocodium* aggregates (A) and tubules (B) in cross section; Jaźwica Mbr., Posłowice (A, × 100; set B) and Szydłówek Beds, Szydłówek (B, × 180; set A). ❑C-D, G. *Renalcis* as clumps (C-D) and encrusting masses in void (G); upper Sitkówka Beds, Sowie Górki (C, × 100; set G), Kadzielnia Mbr., Góra Cmentarna (D, × 30; set B) and Kowala (northern hill; G, × 10). ❑E. Broken stem of *Vermiporella*(?); *Stingocephalus* Beds, Jurkowice-Budy (set E); × 90. ❑F. Cylindical palaeosiphonoclad thallus (?*Issinella*); *Stingocephalus* Beds, Góra Łgawa (set A); × 80.

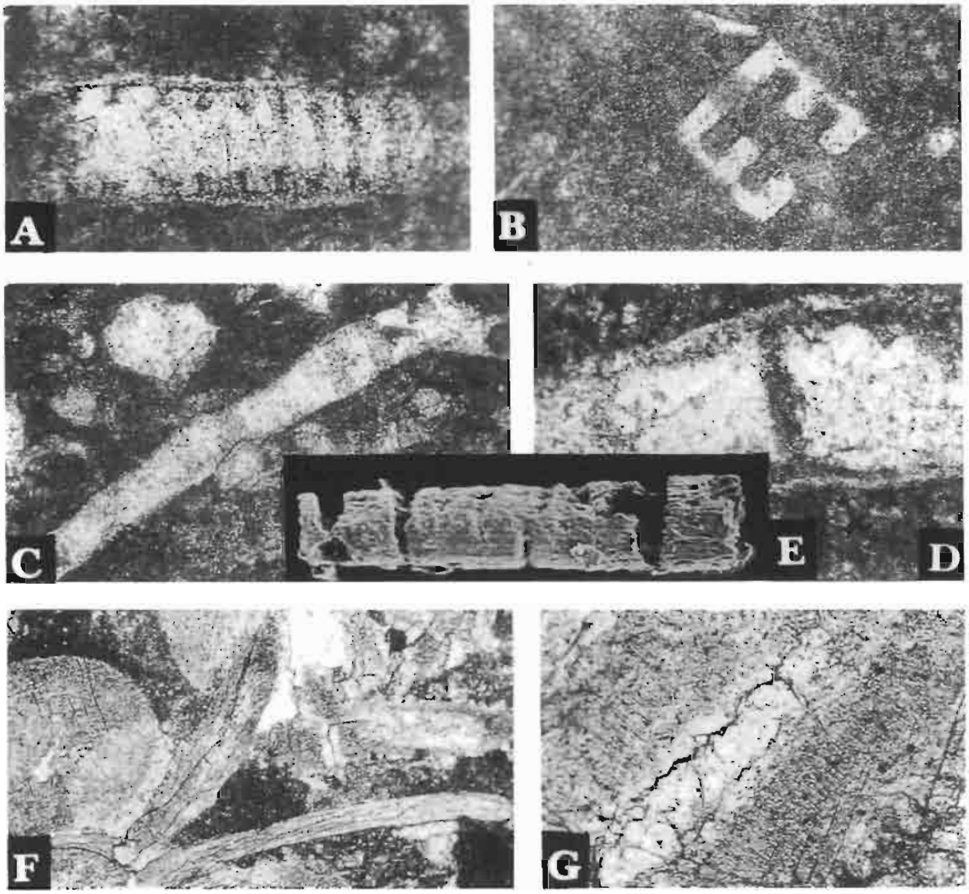


Fig. 5. *Devonoscale-Jansaella* (A-E) group and dasyclad (F-G) chlorophytes: Givetian (A-E) and Frasnian (F-G). ❑A-B. Septate tubes of *Devonoscale tatarstanicae* Antropov 1959 in thin section (A-B) and as isolated specimen (E): *Stingocephalus* Beds, Sowie Górki (A, × 180,set A; E, × 140, set C), Jurkowice-Budy (B, × 200; set D). ❑C-D. Longitudinal section of tubiform *Jansaella ridingi* Mamet & Roux 1975 (C, × 80), details of its septate thallus (D, × 200); Chęciny Beds, Zegzelogóra (set A; C), lower Sitkówka Beds, Jaźwica (set E; D). ❑F-G. Different sections and closeup of wall fabric of *Issinella devonica* Reitlinger 1954; Kostomłoty Beds, Kostomłoty (eastern hill; set F); × 30 (A) and × 120 (B).

Chlorophyta

Dasycladaceae.– Many poorly-preserved stem- and leaf-like fragments (Fig. 4F) are observed in thin-sections from varied bioclastic lihologies, but only two taxa are surely recognizable in the strata under discussion.

Single specimens may represent the widespread genus *Vermiporella* (Fig. 4E). On the other hand, frequent rock-building tubular thalli with fibrous-radial (finely porous) wall microstructure appear to represent the well-known Devonian and Carboniferous species *Issinella devonica* Reitlinger 1954 (Mamet & Roux 1981). The Holy Cross Mountains specimens

(Fig. 5F-G), most numerous in the Late Frasnian Kostomłoty Beds (in encrinite variety), exhibit low-angle branching tubes with diameter widely ranging from 80 to 460 μm, and wall thickness up to 120 μm.

***Devonoscale-Jansaella* group.**– The simple or rarely branched septate cylindrical algae with finely porous to almost homogenous walls are prominent skeletal constituents of some, mainly Givetian and restricted shelf micritic microfacies.

Tubiform thalli, 60 to 80 μm in diameter, display rectangular cells resulting from development of septa incomplete and typically much thicker (up to 30 μm) than wall (8-12μm; Fig. 5A-B); they are similar to *Devonoscale tatarstanicae* (Antropov 1959). This enigmatic Devonian microfossil reveals distinct longitudinal (and partially transversal) microporosity on straight, slightly conical tubes (Fig. 5E). As shown by Langer (1979, 1991a), there are conspicuous features differing *Devonoscale* from the typical Carboniferous dasyclad kamaenids (Skompski 1987). The specimens, most common in the *Stringocephalus* Beds, have their walls relatively thin, but comparable with those from other regions (Tomaś 1974; Langer 1979; Vachard 1988). Uniformly thick septa and walls, as well as frequently subtriangular cross-section of the thallus of the German specimens (Langer 1979), suggest, however, species differentiation within this genus. Sporadic triangularly-shaped tubes typical for the kamaenid *Triangularina* were found in the Late Frasnian rocks at Psie Górki (set G).

Very common in different facies, particularly in the late Givetian to early Frasnian (Sitkówka Beds, Chęciny Beds, Kadzielnia Member; *Phlogoiderhynchus* Level, e.g. Dębska Wola; Wietrznia Beds, Skwarek 1989; for late Frasnian occurrence see Kaźmierczak & Goldring 1978), is the controversial *Jansaella ridingi* Mamet & Roux 1975b, frequently compared with the Carboniferous beresellid *Uraloporella variabilis* Korde 1950 (Riding & Jansa 1974; see discussion in Roux 1991: p. 363). This alga is characterized by straight to gently curved thalli, up to 5 mm long, with entire septa and homogeneous, yellowish-colored wall, 5 to 20 μm in thicknes in most cases obscured by neomorphism (Fig. 5C-D; see also Fig. 10A-C, I). The external diameter of the tubes is mostly between 80 and 140 μm (the whole observed range 30-250 μm) and strongly varies from sample to sample.

Rhodophyta

Solenoporids.– Massive, nodular forms (up to 3.5 mm in size), with internal thickness of cellular filaments ranging from 12 to 30 μm (Fig 6A-B), are frequent only in the higher Frasnian detrital deposits (e.g. Sitkówka-Jaźwica, Panek, borehole Janczyce 1; Kaźmierczak 1971). Obliterated grid-like pattern of some vertical sections suggests the presence of *Parachaetetes*.

Charophyta

Excluding the equivocal group of umbellids, the charophytes were found only in two Givetian levels. One sample from the Jurkowice-Budy site (set E) yielded numerous, well-preserved non-coronulate gyrogonites (Fig. 6D, F-G) of *Trochiliscus ingricus* Karpinsky 1906, a characteristic species of the late Eifelian Narova Horizon of the Russian Platform (Samojlova & Prinada 1976). They were accompanied by a single oogonia of *Sycidium volborthi volborthi* Karpinsky 1906 (Fig. 6C), known also from the Givetian of the Cracow area (Malec *et al.* 1987).

The higher charophyte-bearing level is confined to the Jaźwica Member, where *Karpinskia oscoliensis* (Samojlova 1961) occurs not only at Posłowice (Racki & Racka 1981), but probably also in Marzysz (recovered as internal molds; Fig. 6E).

Systematic survey of microproblematica

A vast variety of problematic calcareous microfossils was discovered in thin sections (Figs 7-8), as well as among isolated specimens collected in large amounts in such sites as Jurkowice-Budy, Jaźwica, Kadzielnia and Jaworznia (Tab. 1). However, at this stage of research the latter material is extremely difficult to classify within taxonomic categories derived (with exception of taxa of Langer 1979) almost exclusively from thin-section observations. Consequently, the isolated material is only illustrated (Figs 9-11) and provisionally reviewed below.

Parathuramminoids and calcispheres.– This broadly-defined group includes remains of differently preserved phytoplankton (volvocacean green algae including, Kaźmierczak 1976; Toomey & Mamet 1979; Shuysky *in* Chuvashov *et al.* 1987), several *incertae sedis* microfossils (like post mortem calcified acritarchs, Kaźmierczak *et al.* 1985; ?dasycladacean reproductive cysts, Wray 1977), and perhaps very primitive unilocular, partly agglutinated foraminifera (?*Archaelagena*). These differently-shaped smooth calcareous bodies having irregular variants with elongated endings as well as strictly globular forms require great care in any taxonomic judgements.

The vast majority of these specimens display a uniformly homogenous micritic cover and their size does not exceed 1.2 mm (chiefly ranges from 0.2 to 0.5 mm). Spinose spheres (with diameter below 0.5 mm) have been found too (see also Coen 1985: Pl. 6: 13). With thin-sections, these bodies could be assigned (Fig. 1) to several parathuramminids (*Parathurammina, Irregularina*) and archaeosphaerids (*Archaeosphaera*), but mostly usloniid (*Bisphaera, Uslonia, Parastegnammina*) 'foraminifera' in the scheme of Poyarkov (1979), and/or both non-radiosphaerid and radiosphaerid calcispheres. The term calcispheroids is used to encompass this very heterogenous suite.

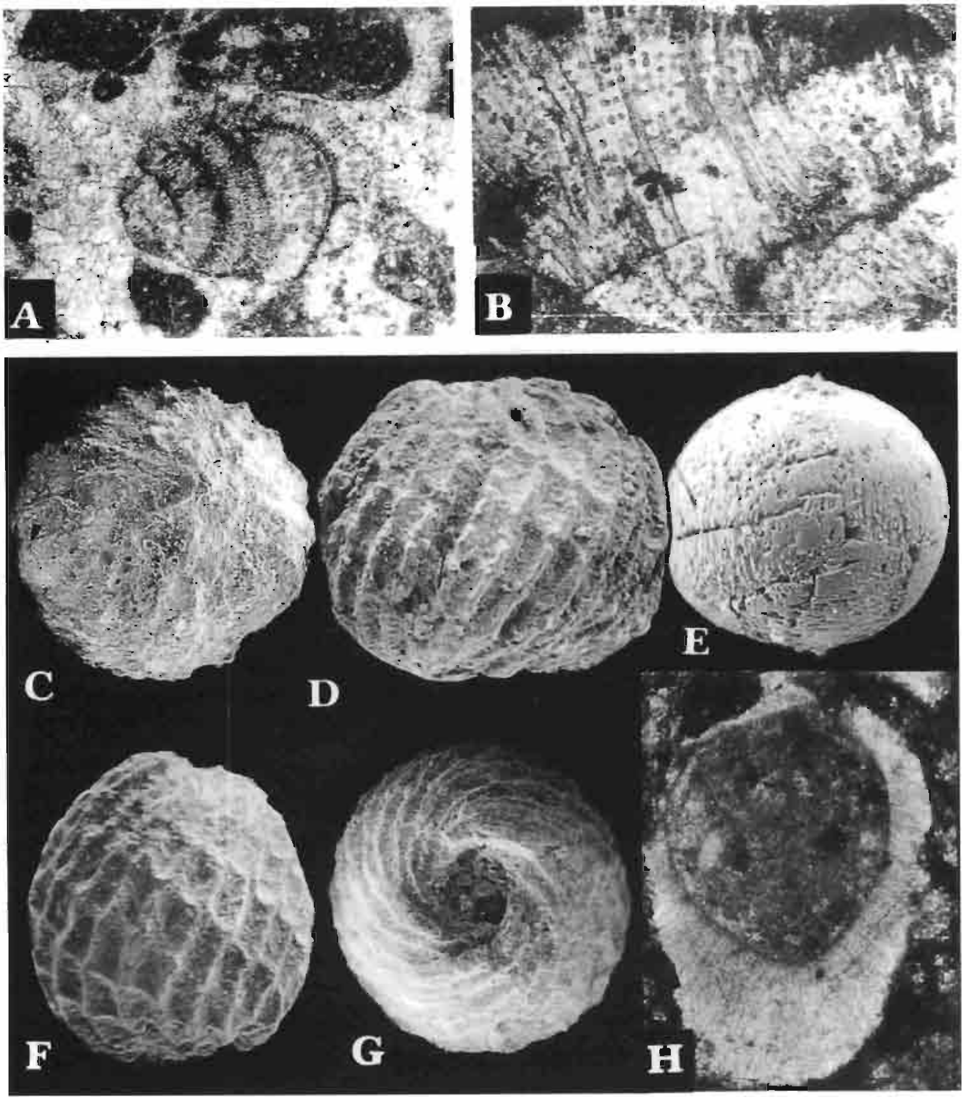


Fig. 6. Frasnian solenoporids (A-B), Givetian charophytes (C-G), and an umbellid (H). ❑A-B. Poorly-preserved solenoporoid nodule (A, × 30) and details of its celullar pattern (B, × 90): Detrital-Stromatoporoid Beds, Sitkówka-Jaźwica (A), Janczyce 1 borehole, depth 376.0 m (B). ❑C. *Sycidium volborthi volborthi* Karpinsky 1906 in apical view; *Stingocephalus* Beds, Jurkowice-Budy (set E); × 70. ❑D, F-G. Gyrogonites of *Trochiliscus ingricus* Karpinsky 1906 in lateral (D, F) and apical (G) views; Jurkowice-Budy (set E); × 60. ❑E. Internal cast of ?*Karpinskia oscoliensis* Samojlova 1961; Jaźwica Mbr., Marzysz; × 60. ❑H. *Umbellina* in longitudinal section; Jaźwica (set B); × 70.

Thin-section parathuramminoid 'taxa' show a progressive decrease in frequency, and particular diversity in the studied sequence (Fig. 7), and isolated specimens follow a similar trend. High diversity (21 'species') and remarkably good preservation characterize the Early to Middle Givetian *Stringocephalus* Beds. Contrarily, the Frasnian back-reef limestones con-

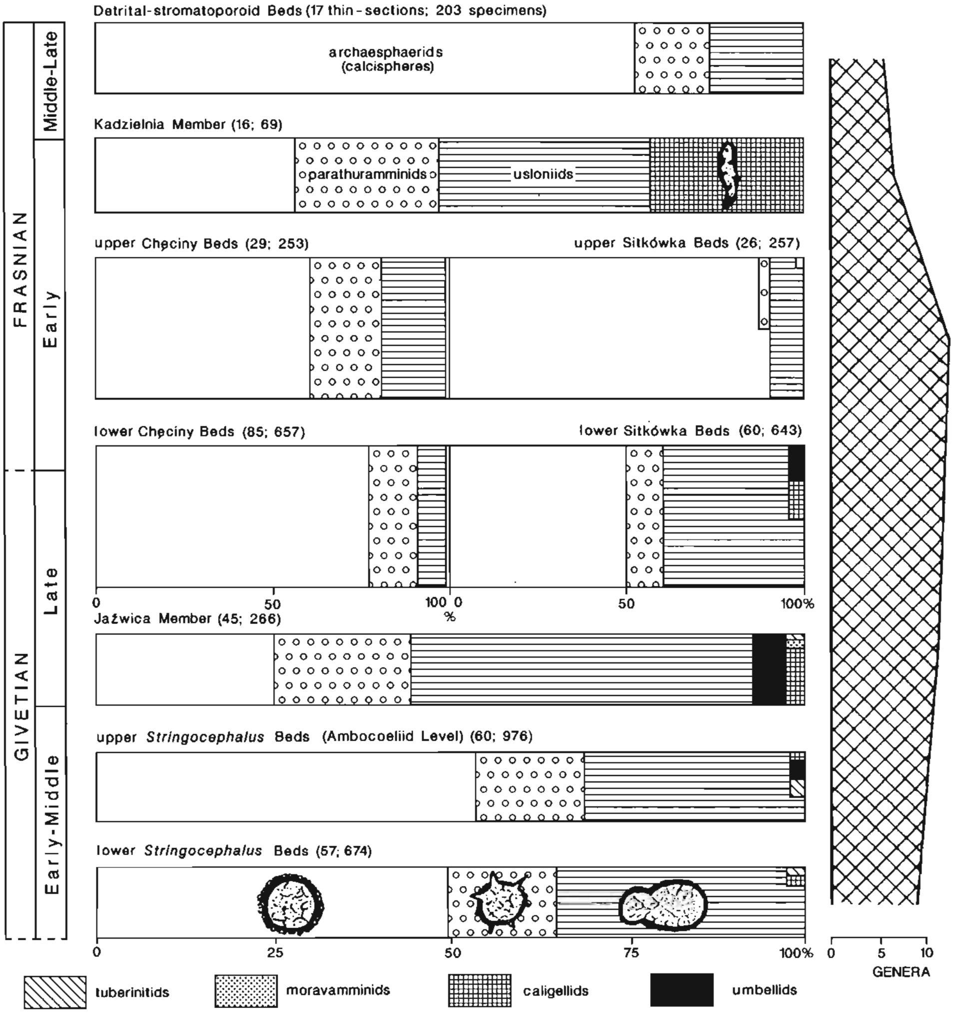


Fig. 7. Stratigraphic changes in composition and 'diversity' trend of microproblematic biotas within the Kowala Formation and overlying detrital strata, based on thin sections.

tain poorly preserved microproblematica limited to a few simple forms. To the most common 'genera' in almost all localities belong *Archaeosphaera*, *Bisphaera* and *Parathurammina*; locally (e.g. Posłowice, sets A-B$_1$) *Cribrosphaeroides* significantly contributes to the microbiota. Several other forms are randomly distributed in the studied sections, although, for instance, tuberitinids are found only in the Givetian units.

Caligellids.– These irregularly tubular to almost globular, pseudocamerate microfossils (?calcisponges; cf. Toomey & Mamet 1979) are rarely observed in thin-sections, and they occur more frequently solely in the Kadzielnia Member (above 20 per cent of all problematic foraminifera).

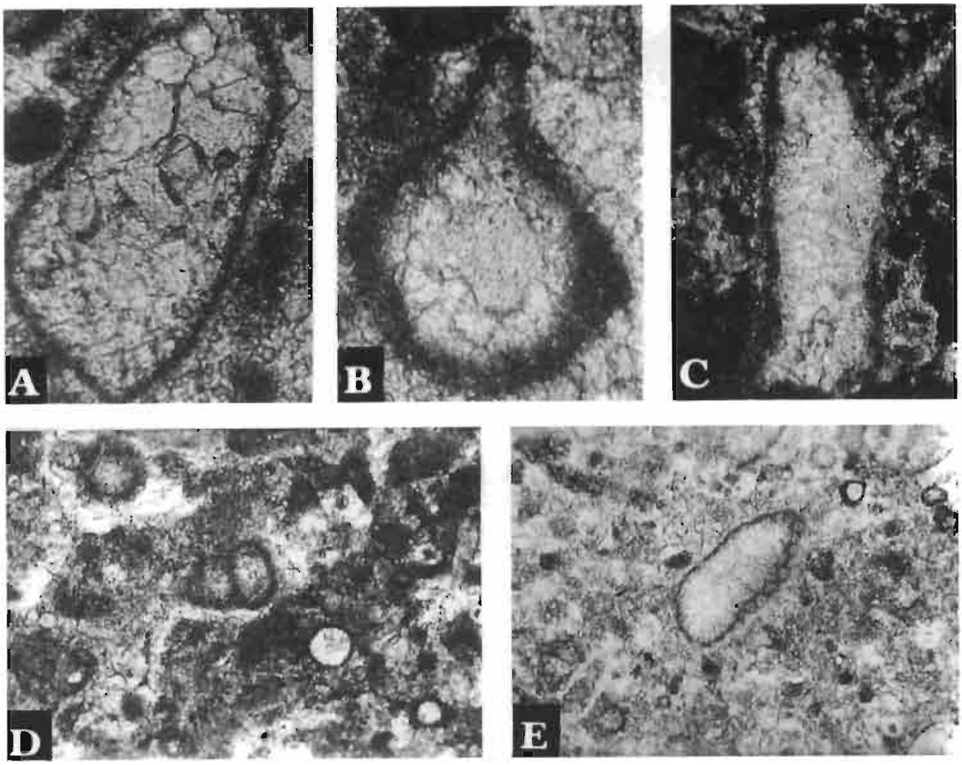


Fig. 8. Parathuramminoid 'foraminifera' in thin sections; Givetian (B-C) and Frasnian (A, D-E). ❑A. *Bisphaera malevkiensis* Birina 1948; upper Sitkówka Beds, Sitkówka-Kowala (set A); × 100. ❑B. *Archaelagena mirabilis* Poyarkov 1969; Dziewki Limestone, Siewierz (set D); × 150. ❑C. *Parastegnammina pseudocamerata* Poyarkov 1969; Dziewki Limestone, Siewierz (set C; × 100). ❑D. Neomorphozed calcispheroid-peloidal packstone with a single tikhinellid (in central part); Detrital-Stromatoporoid Beds, Miedzianka (set D); × 60. ❑E. *Cribrosphaeroides* in peloidal grainstone; upper Sitkówka Beds, Sitkówka-Kowala (set D); × 50.

Probably some elongated and ovally-shaped bodies (Form B) represent this group among loose specimens (Fig. 9M-N, S).

Umbellids.– These characteristic microfossils (?utricles of charophytes Sycidiales, e.g. Berchenko *in* Chuvashov *et al.* 1987; but see also Riding 1977; Roux 1991) were reported by Ozonkowa (1962b) and Bilan & Golonka (1973) as common, locally rock-forming in the Devonian limestones of southern Poland. They are however rarely found in the strata studied, with the Jaźwica Member and Łagów section among the most prolific (Fig. 6H).

Moravamminids.– This distinctive group of dubious sessile microfossils (Shuysky *in* Chuvashow *et al.* 1987: p. 79) composed of coiled and elongated erect, irregularly septate portions (Fig. 11), is a rare element in thin sections. However, isolated tubular specimens occur commonly in some samples (Żebrownica; Wietrznia, Skwarek 1990; Siewierz, Straszak 1987) and possibly belong to several taxa, the widespread *Moravammina*

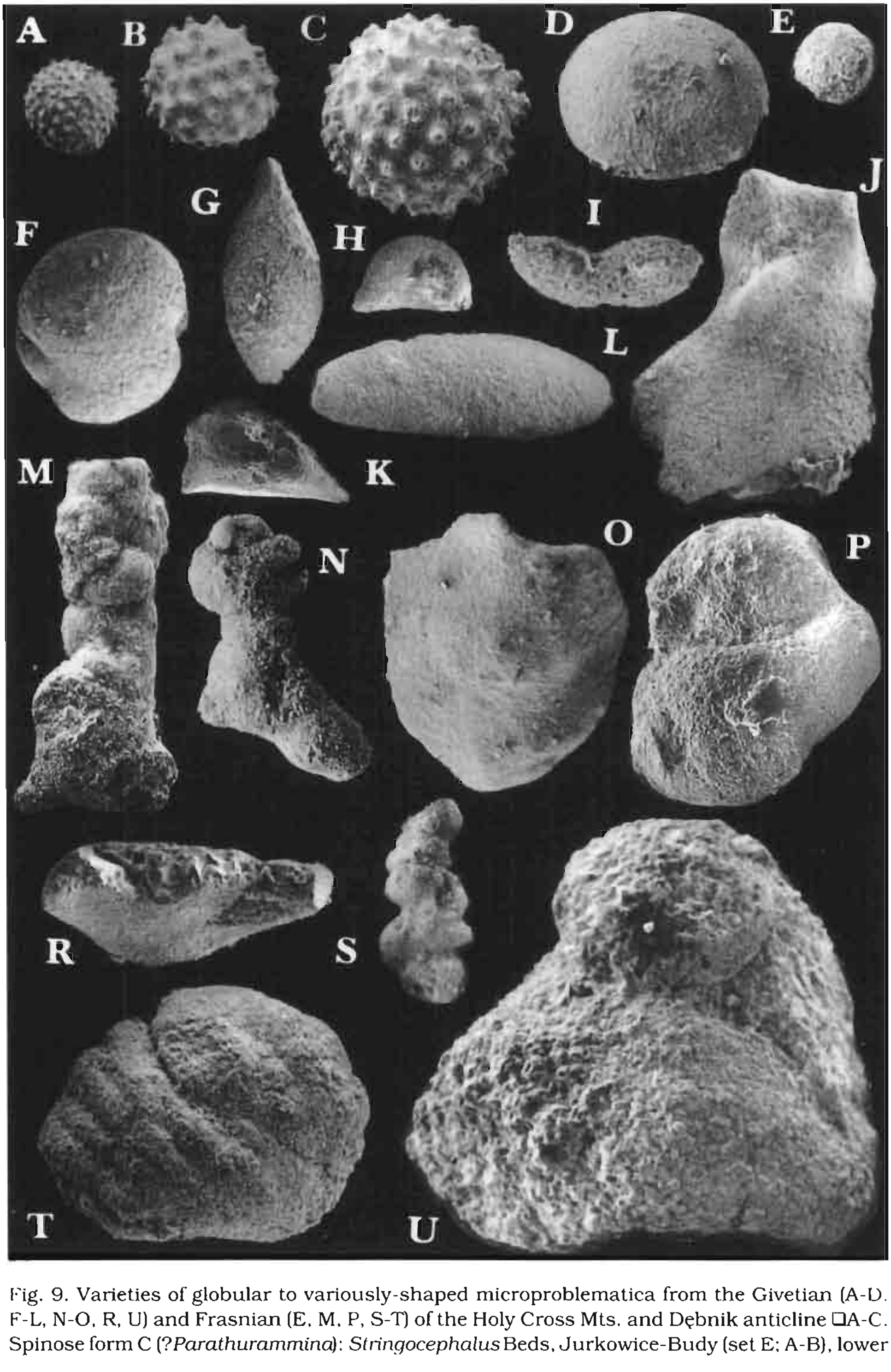


Fig. 9. Varieties of globular to variously-shaped microproblematica from the Givetian (A-D, F-L, N-O, R, U) and Frasnian (E, M, P, S-T) of the Holy Cross Mts. and Dębnik anticline ❑A-C. Spinose form C (?*Parathurammina*): *Stringocephalus* Beds, Jurkowice-Budy (set E; A-B), lower

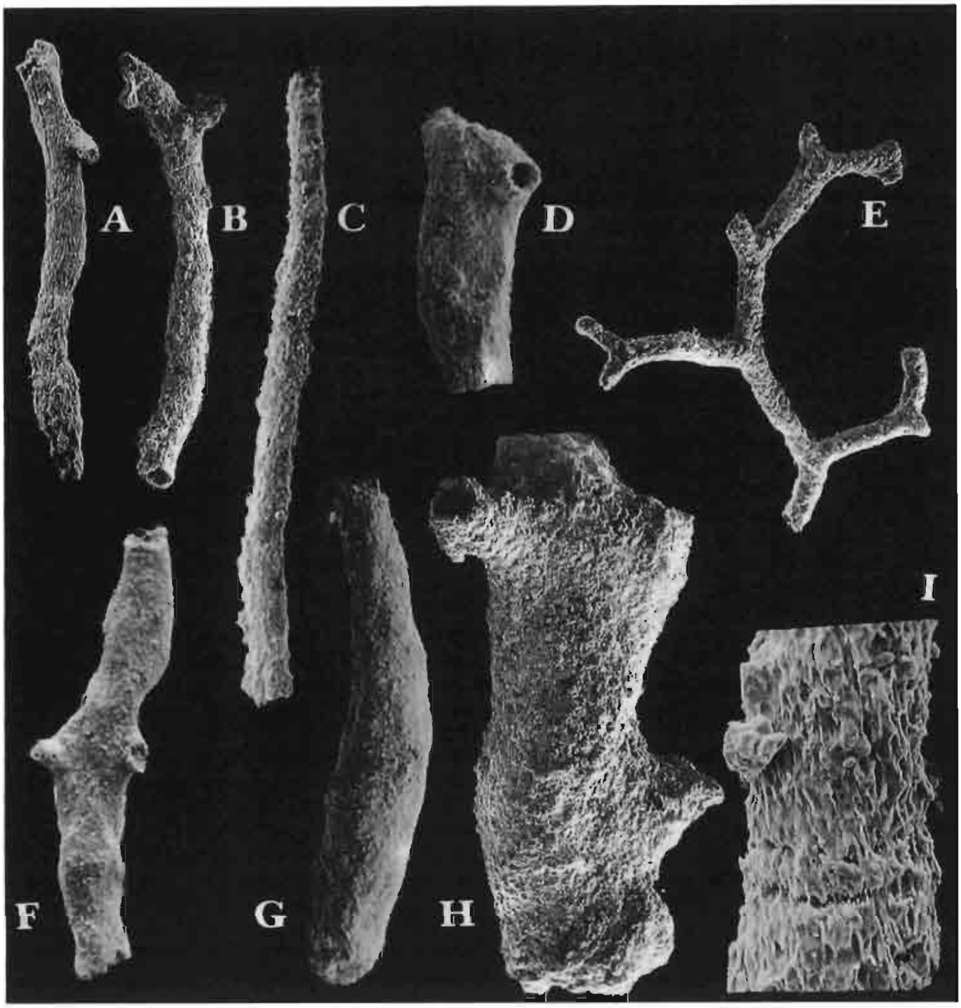


Fig. 10. Varieties of tubiform microfossils from the Givetian (A-B, D F-I) and Frasnian (C E) of the Holy Cross Mts. ❑A-C, G, I. Simple cylindrical Forms A (A-C, I – ?dasyclad *Jansaella ridingi*), Chęciny Bed, Zegzelogóra (set A: A, magnified in I); *Stringocephalus* Beds, Czarnów (set C: B), Panek (set B: C), *Stringocephalus* Beds, Jurkowice-Budy (set E: G). ❑D, F-H. Complex tubiform Form types B (D, F-G – ?moravamminids *Evlania*, ?*Proninella*); *Stringocephalus* Beds, Jurkowice-Budy (set E: D, F-G), *Stringocephalus* Beds, Góra Łgawa (set A: H). ❑E. Regularly bifurcating Form C; Kadzielnia Mbr., Kowala (set C). All × 40 except E (× 60) and I (× 150).

◄-

Sitkówka Beds, Jaźwica (set E: C). ❑D-T. Smooth spheroidal form (A) and transitions toward oval-elongated and/or irregular bodies (B), comprising mostly calcispheres, usloniids (Fig. 1), and ?caligellids (M, N, S). *Stringocephalus* Beds, Jurkowice-Budy (set E: D, F, L, O), upper Sitkówka Beds, Sitkówka-Kowala (set C: E), *Stringocephalus* Beds, Góra Łgawa (set A: G-I, N, R), Jaźwica (lower Sitkówka Beds, set E, U, set G, J; upper Sitkówka Beds, set H, M, P, S), Dębnik Limestone, Dębnik (K), upper Sitkówka Beds, Jaworznia (T). All × 40 except C that is × 80.

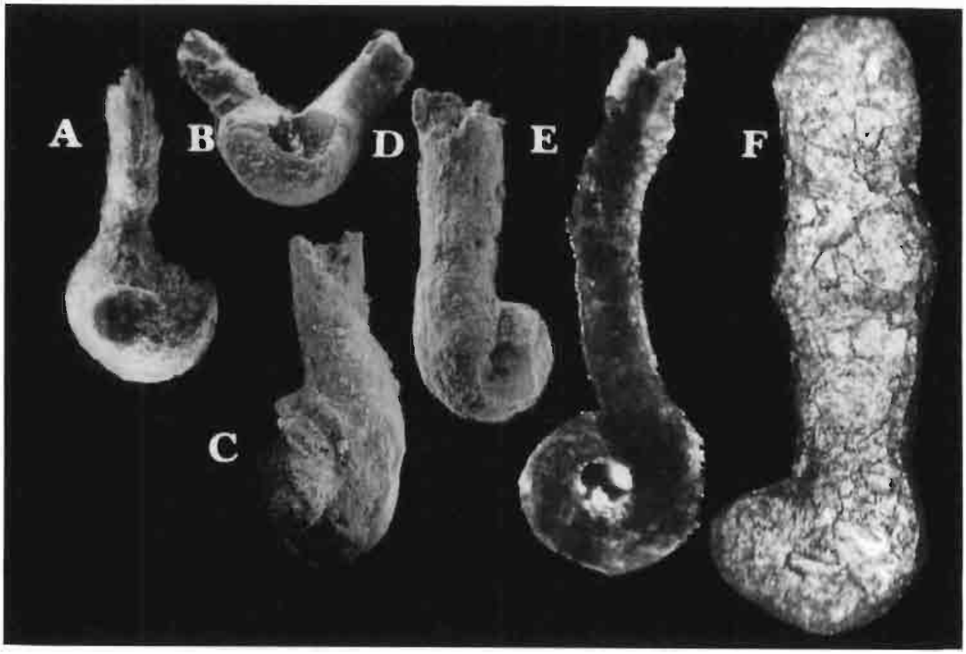


Fig. 11. Moravamminids from the Givetian (A, C-F) and Frasnian (B) of the Holy Cross Mts as isolated specimens (A-D), in transmitted light (E), and thin-section (F); Crinoid-Coral Level, Sowie Górki (set C; A), Kadzielnia Mbr., Kadzielnia (set A; B), *Stringocephalus* Beds, Jurkowice-Budy (set E, C-D), Dziewki Limestone, Siewierz (set B, E), and Jaźwica Mbr., Posłowice (set B, F). All × 40 except for F that is × 90.

segmentata Pokorný 1951, *Evlania* and bifurcated *Saccorhina* including (see Bykova 1955; Langer 1991b). However, repeatedly bifurcating, uniformly tubular Form C (Fig. 10E) might also represent a peculiar calcified cyanophyte (*Epiphyton*, cf. Chuvashov *et al.* 1985: Fig. 3) or unknown agglutinated foraminifera (e.g. rhabdamminid-like; Loeblich & Tappan 1988: Pls 15-16).

Labyrinthoconids.– Both genera of this 'family' (?calcisponges; ?green algae; Mamet *et al.* 1982; Vachard 1988) marked by anastomosing internal elements, described by Langer (1979, 1991a), were encountered in the strata studied (Fig. 12A-F).

Rare, and limited almost exclusively to the *Stringocephalus* Beds (Jurkowice-Budy), is the conical to weakly cylindrical form *Labyrinthoconus clausmulleri* (a variety of *Proninella*?). A more narrowly-shaped nominative 'subspecies' predominates over the *L. hyperconicus*-variant. Their lenght ranges from 0.45 to 1.5 mm, and width from 0.35 to 0.6 mm.

Fan-like *Eifeliflabellum opuntia* are quite common in the microbiotas from the Sitkówka Beds and different Frasnian limestone units. Large size and shape differences between associations from particular localities are remarkable. Minute (up to 0.8 mm in lenght) and slender (?juvenile) individuals came from the biohermal Kadzielnia Member, while the most robust (up to 1.4 mm long and 0.35 mm thick), and triangular to linqui-

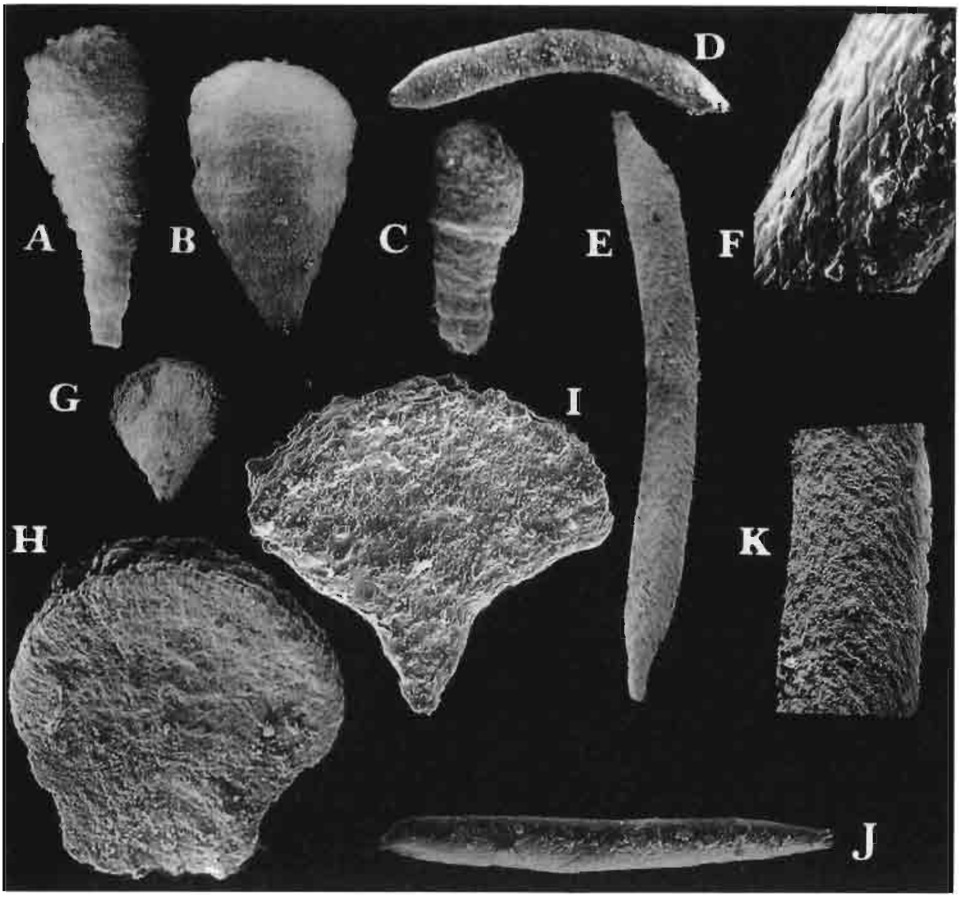


Fig. 12. Labyrinthoconids (A-C, G-I) and *Spirotubus* (D-F, J-K) from the Givetian (A-F, J-K) and Frasnian (G-I) of the Holy Cross Mts. □A-C. Varieties of *Labirynthoconus clausmilleri* Langer 1979; *Stringocephalus* Beds, Jurkowice-Budy (set E); × 40. □D-F, J-K. *Spirotubus* tubes (D-E, J, × 30) and their ornamentation pattern (F, × 100; K, × 75); *Stringocephalus* Beds, Góra Łgawa (set A; D), *Stringocephalus* Beds, Jurkowice-Budy (set E; E magnified in K), Crinoid-Coral Level, Sowie Górki (set C; J magnified in F). □G, I. *Eifeliflabellum opuntia* Langer 1979; Kadzielnia Mbr., Kadzielnia (G, × 40; set A), Góra Łgawa (I, × 60; set J). □H. ?*Eifeliflabellum* sp. n. *sensu* Langer 1979; upper Sitkówka Beds, Jaworznia; × 40.

form in outline morphotypes (Fig. 12H) were collected in Jaźwica (set E), Jaworznia, and Ostrówka.

***Spirotubus* group.**– The straight to slightly bent, tapering tubules, mostly 'half-moon' in shape and bearing romb-like external patterns (Fig. 12G-K), are ubiquitous in most studied profiles. The best preserved specimens were found at Jurkowice-Budy, Marzysz and Sowie Górki (set C). Their total lenght ranges up to 3 mm, and maximal diameter up to 0.4 mm. The specific 'test' fabric is frequently obscured, especially in some shorter (below 1 mm in lenght), ovally-elongated bodies (e.g. from the Kadzielnia Member).

Systematic account of foraminifera

Only semitextulariid and nodosariid identified species are reviewed below. Other foraminiferal taxa comprise sporadic earlandiids, known from the Givetian localities only, viz. *Earlandia* sp. (Jaźwica, sets B, E; Stokówka, set C; Sitkówka-Kostrzewa, set B) and *Paratikhinella cannula* Bykova 1952 (Góra Sołtysia, set A). Poorly preserved tourneyellids have been found in the higher Kostomłoty Beds (Fig. 16B).

Abbreviations.– L – test lenght, W – test width (test diameter in globular forms), T – test thickness, Tw – wall thickness, Ts – septum thickness, α – umbonal angle, β – convexity angle (for upper part of semitextulariid test: cf. Poyarkov 1979: Fig. 6), Nc – number of chamber in last whorl, Nw – number of whorls, IL – lenght (or height) index (H/W ratio), IT – thickness index (T/W ratio), n – number of measurements.

Order Semitextulariida Poyarkov 1979

Family Semitextulariidae Pokorný 1951

Genus *Semitextularia* Miller & Carmer 1933

Remarks.– The genus is known only from the Late Givetian Jaźwica Member at Marzysz. Eight specimens of *Semitextularia oscoliensis* Bykova 1952 with strongly serrate margins (Fig. 13A) show strong affinities with the more narrowly outlined varieties illustrated by Bykova (1952: Pl. 8: 12, Pl. 9: 2) from the East European Platform (Givetian Staryi Oskol Horizon).

Semitextularia thomasi Miller & Carmer 1933 (Fig. 13B-C) is far more numerous (above 80 tests). Intra-sample variability is very extensive, in the first order in such characteristics as test shape and margin appearance (L – 0.23-0.8 mm, α – 35-70, β – 55-150). Therefore, the wide concept of the species proposed by Duszyńska (1956) is followed herein (contrary to Poyarkov 1979: p. 9). The species occurs in the Holy Cross Mountains from the latest Eifelian (Skały Beds; Duszyńska 1956) through Givetian (Jaźwica Member, Marzysz), and perhaps also in the Silesian Givetian (Dziewki Limestone; Siewierz, set B, Straszak 1987), as well as in the Russian Frasnian (Bykova 1952) and North American Givetian(?) to Frasnian (Mamet & Plafker 1982).

Family Nanicellidae Fursenko 1959

Genus *Nanicella* Henbest 1935

Remarks.– The bulk of the material studied comprises several hundred isolated tests (Fig. 14A-M), which display the intra- and inter-sample variability (Fig. 15). Species of *Nanicella* (see summary in Tab. 36 in Poyarkov 1979), based on small number of specimens and/or thin-sections, are difficult to identify.

Nanicella tchernyshevae Lipina 1950

Figs 14A-B, 15.

Remarks.– Distinctly biconvex axial profile with strongly sharped periphery, relatively small size (L – 0.35-0.63 mm), and straight to weakly bent septa are combinations of characteristics suggestive of assignment to the

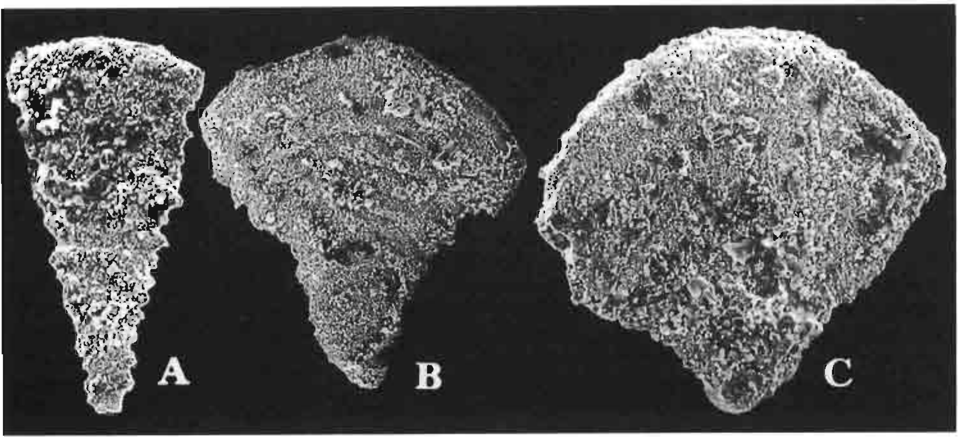


Fig. 13. Late Givetian foraminifers of *Semitextularia* from the Jaźwica Mbr., Marzysz. ❑A. *S. oscoliensis* Bykova 1955, ❑B-C. *S. thomasi* Miller & Carmer 1933; × 150.

species of Lipina (1950). The Holy Cross Mountains specimens (50 tests) are generally larger-sized and possess more numerous whorls and septa (Nc – 12-17, Nw – 2.5-3) in comparison with essentially stratigraphically younger Russian representatives. Furthermore, a few axial sections from the Frasnian of Miedzianka exhibit even larger sizes (L – 0.5-0.7 mm, IT – 0.33-0.39). Thus, the size differentiation might be a constant feature and is interpreted as population responses to primarily biogeographic factors.

Distribution.– Holy Cross Mountains, Early Frasnian (upper Sitkówka Beds; Kowala, set B) to ?later Frasnian (Detrital-Stromatoporoid Beds; Miedzianka, set D); East European Platform, Middle and Late Frasnian (Semiluki to Livny Horizons; Lipina 1950; Manukalova-Grebenjuk 1974), Ural Mountains, Late Givetian through Frasnian (Kyn to Askyn Horizons; Bykova 1955: Tab. 2; Chuvashov 1965); Central Asia, Frasnian (Sabirov 1980; Zadorozhnyj 1987), ?Siberian Platform, ?Frasnian (Bogush *et al.* 1975).

Nanicella sp. A

Figs 14C-H, M, and I.

Material.– Above 180 etched specimens.

Dimensions.– L=0.51 mm (0.3-0.75), n=170, W=0.43 mm (0.3-0.6), T=0.16 mm (0.09-0.25), IL=1.14 (1.0-1.47), IT=0.32 (0.22-0.61), Ts – 12-20 μm, Tw up to 18 μm, Nc – 12-16, Nw – 2.5-3.

Description.– Medium-sized, evolute, slightly elongated tests characterized by a narrowed, flattened to distincly biconcave axial profile with rounded periphery. Short and high chambers (mostly 15 in last whorl) are crowded toward aperture and weakly recurved. The tests consist of up to 3 whorls. About half of the mature specimens (i.e. above 0.5 mm in height) show a peculiar appearance of the last chamber in respect to its strong expansion. Test wall and septa are thin.

Remarks.– The Givetian specimens possibly represent a new species. Functional and taxonomic value of the last chamber modification (Fig. 14C, E) remains disputable; it was also found in some specimens of *Nanicella* sp. B.

Nanicella sp. A is most close to *N. evoluta* Reitlinger 1954 from the latest Frasnian of Russia because of the evolute, strongly depressed test. However, the nanicellids examined display an elongated, but not so significantly biconcave axial profile with a more rounded periphery, and larger number of whorls (2.5 to 3 in Polish form, and 1.5 to 2 in the Russian one; Poyarkov 1979: Tab. 36). The closest species seems to be *Nanicella* (or *Rhenothyra*) *reffrathensis* (Beckman 1950) from the Rhenish early Frasnian (W. Langer, letter communication 1991), that is distinguished by a narrowed and peripherally widely rounded test, and probably by the presence of an inner furrow in less bent septa.

Distribution.– Holy Cross Mountains, Late Givetian (Jaźwica Member, Posłowice, Marzysz; maybe lower Wietrznia Beds, Wietrznia-II, set A, Skwarek 1990).

Nanicella sp. B

Figs 14I-L, O, and 15.

Material.– Above 250 weathered specimens; 10 sectioned tests.

Dimensions.– L=0.64 mm (0.32-1.0, n=230), W=0.45 mm (0.29-0.65), T=0.20 mm (0.12-0.5), IL=1.20 (1.05-1.67), IT=0.45 (0.27-0.86), Ts – 15-30 µm, Tw – 15-35 µm, Nc – 12-20, Nw – 2-2,5.

Description.– Large (above 1 mm), typically strongly involute with elongated tests with notably high last whorl and a more or less rounded periphery; axial profile is frequently weakly biconvex, but with gradations into both strongly biconvex and flat to even incipiently biconcave variants. Bilateral asymmetry due to shift of the last whorl, as well as a distinct enlargement of the last chamber are observed in some specimens. Chambers are short and high, closely appressed, typically 18-19 in the last whorl. Septa are bent to strongly recurved, particularly the last ones in large specimens. The walls of the test and septa are thickened.

Remarks.– The Frasnian nanicellids, provisionally placed in this species, show considerable variability, especially in such characteristics as axial profile, test shape and size, and appearance of septa. This is best visible by comparison with several samples from Kadzielnia. At least two intergrading morphotypes are recognizable, and each of them shows affinities with different species (cf. Chuvashov 1965; Poyarkov 1979), known primarily from the East European Frasnian: (1) a thick, strongly involute

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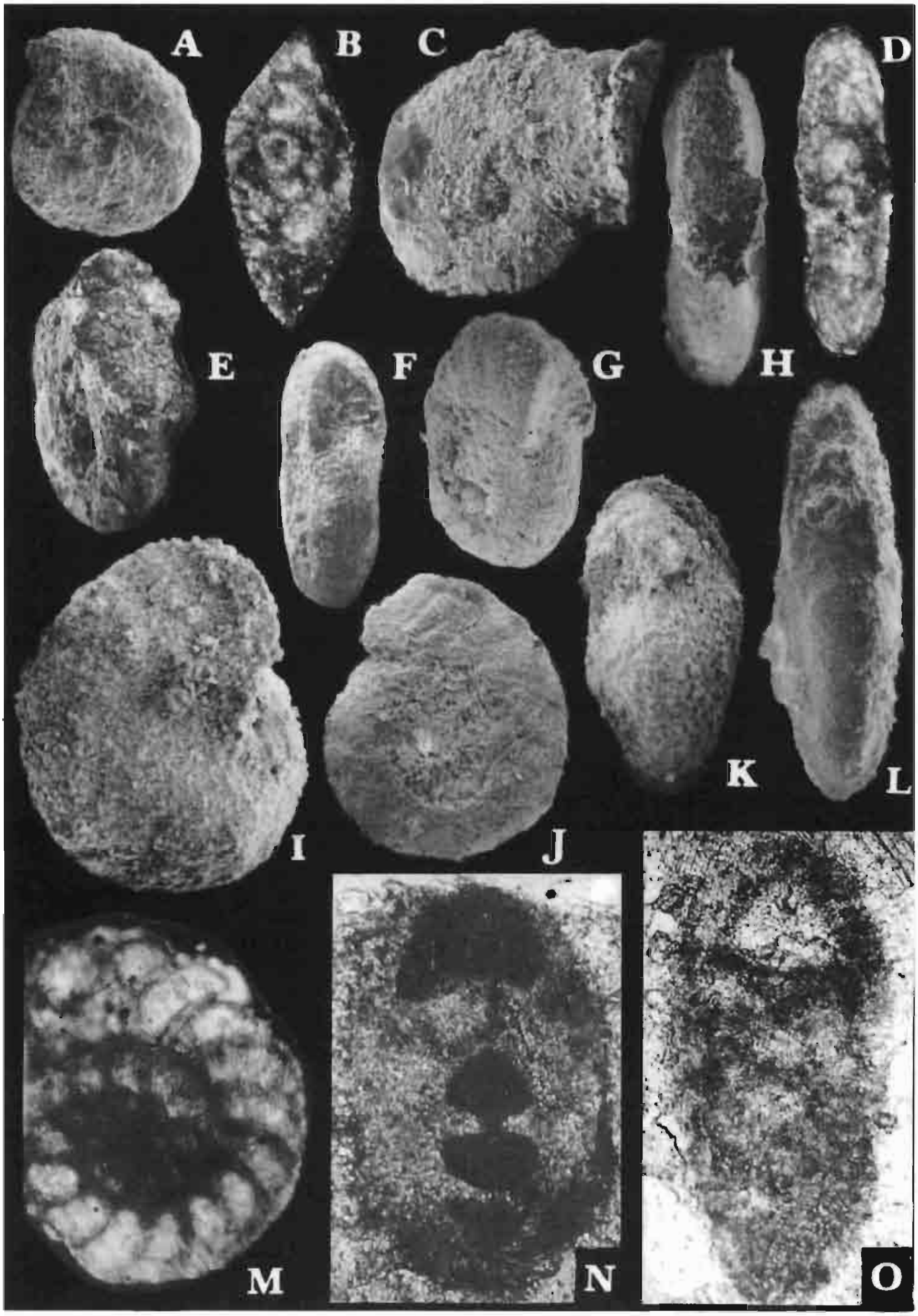
Fig. 14. Species of *Nanicella* from the Givetian (C-H, M) and Frasnian (H-L, N-O) of the Holy Cross Mts. ❑A-B. *Nanicella tchernyshevae* Lipina 1950; upper Sitkówka Beds, Kowala (set B); × 75 (A) and × 80 (B; axial cross section). ❑C. *Nanicella* sp. A in different views (C, E-H, × 75), cross-section (D, × 90) and transmitted light (M, × 100); note strongly expanded apertural portion (C, E); Jaźwica Mbr., Marzysz (C-D, F-H, M), Posłowice (set B; E). ❑I-L, O. *Nanicella* sp. B in different views (I-L, × 75) and thin-section (O; × 110); Kadzielnia Mbr., Kadzielnia (set



A: I. K-L). upper Sitkowka Beds. Sowie Górki (set G; J). Detrital-Stromatoporoid Beds. Miedzianka (set D; O). ❑N. *Nanicella* sp. C. axial cross-section: Detrital-Stromatoporoid Beds. Miedzianka (set D); × 150.

variety with ovally-outlined axial section, resembling *Nanicella bella* Bykova 1952 and *N. ovata* Reitlinger 1954, and (2) an involute, more highly variant with weakly biconvex to slightly biconcave median profile corresponding to *N. porrecta* Bykova 1952 (Menner & Reitlinger 1971; Jurkiewicz & Żakowa 1985; Zadorozhnyj 1987; Vanchard 1988; Kalvoda 1990a) and *N. uralica* Chuvashov 1965 (Vachard & Massa 1989).

The Holy Cross Mountains nanicellids are distinct in their large size and number of chambers, thick wall and septa. The most similar, large-sized (up to 0.77 mm) *N. porrecta* displays 14 to 17 chambers in the last whorl (*N.* sp. B – up to 20) and a test thickness of up to 24 μm (Polish form up to 30 μm). Their subdivision would require biometric analysis of the topotype materials of the species mentioned above.

Distribution.– Holy Cross Mountains, Early to Middle Frasnian (Kadzielnia Member: Kadzielnia, Kowala hill, ?Góra Łgawa; upper Sitkówka Beds: Sowie Górki, set G; Detrital-Stromatoporoid Beds: Szczukowskie Górki); possibly also in the latest Givetian (lower Szydłówek Beds: Czarnów, set B) and late Frasnian (Detrital-Stromatoporoid Beds: Grabina, Miedzianka).

Nanicella sp. C

Fig. 14N.

Material.– Nine isolated weathered tests, 4 specimens in thin sections.

Dimensions.– L – 0.31-0.45 mm, W – 0.29-0.33 mm, T – 0.25-0.30 mm, IL – 1.10-1.15, IT=0.54, Ts – 20-30 μm, Tw – 30-60 μm, Nc – 10-13, Nw – 1.5-2.

Description.– Small-sized, involute tests characterized by a widely-rounded axial profile, small number of whorls and chambers, and straight to weakly bent septa. Conspicuosly thickened test wall and strongly developed secondary deposits are the notable feature.

Remarks.– Scarce late Frasnian material comprises nanicellids resembling *N. suljonica* Chuvashov 1965 from the latest Frasnian of Urals.

Distribution.– Holy Cross Mountains, later Frasnian (Detrital-Stromatoporoid Beds: Miedzianka, Panek, and Kowala, set G).

Order Nodosariida Calkins 1926

Family Nodosariidae Ehrenberg 1838

Genus *Tikhinella* Bykova 1952

Remarks.– The genus is well represented in the Frasnian material studied (e.g. Ołowianka, Wietrznia, Janczyce 1 borehole; Fig. 16F). Single tests from Sitkówka-Jaźwica represent *Tikhinella fringa* Bykova 1952; this widespread late Frasnian nodosariid is known from the East European Platform (Voronezh and Mendym Horizons; Bykova 1952; Chuvashov 1965: p. 43), Urals (Chuvashov 1965), Siberian Platform (Upper Kalargon Horizon; Menner & Reitlinger 1971: p. 31), Central Asia (Tien Shan, Tajikistan; Poyarkov 1969), and Moravia (Friakova & Zukalova 1986; Kalvoda 1990a). Some late Frasnian specimens from Wietrznia and Psie

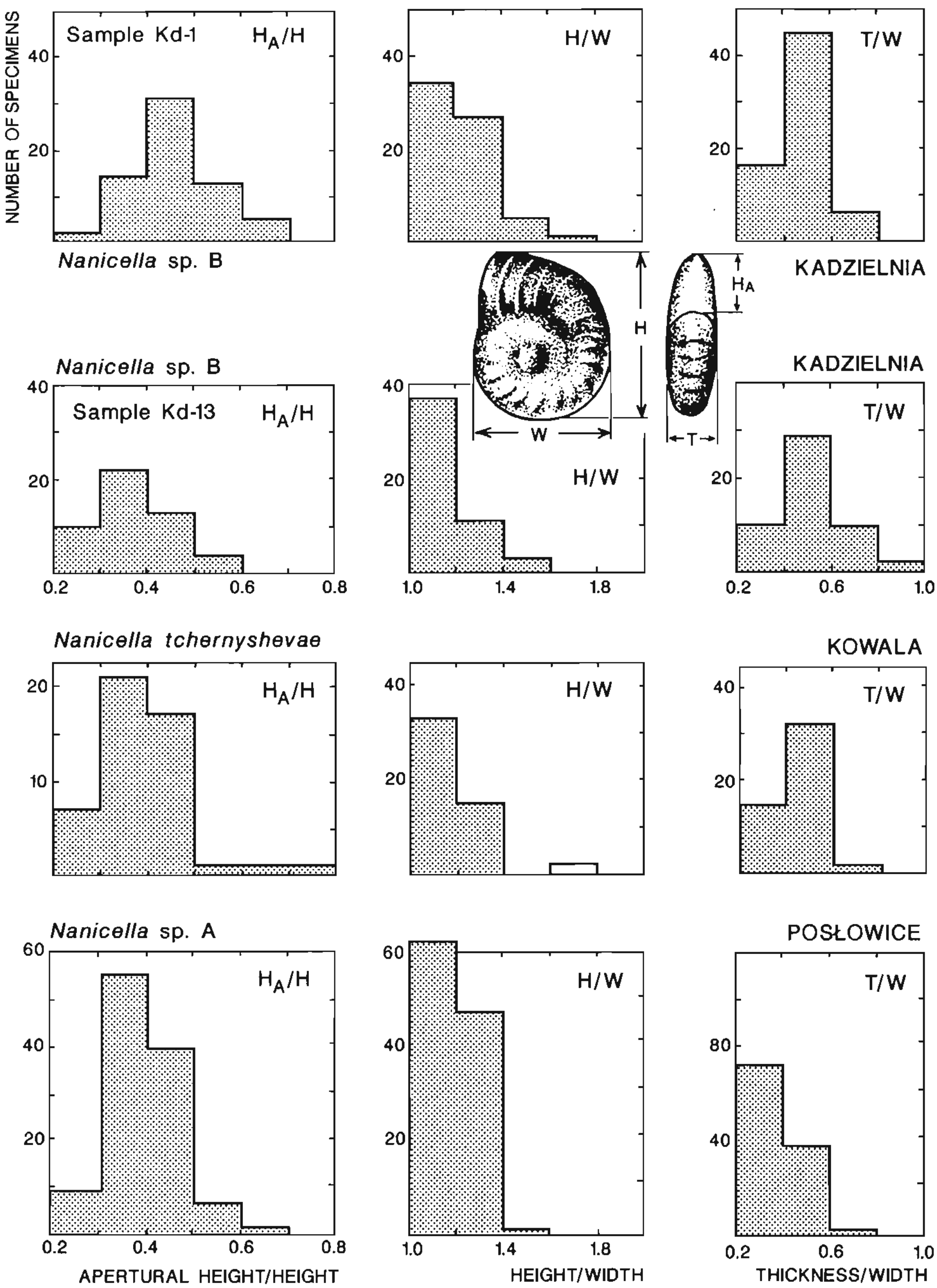


Fig. 15. Frequency distribution of principal test parameters for different species of *Nanicella* from the Holy Cross Mts. Sample numbers from Kadzielnia after Galińska (1984).

Górki, with distinctive septal sutures (Fig. 16C), agree with *T. aequalis* Konoplina 1959 or *T. multiformis* (Lipina 1950) *sensu* Zadorozhnyj (1987).

Genus *Eonodosaria* Lipina 1950

Remarks.– At least three species are identified in the late Frasnian of the Holy Cross Mountains, but are usually limited to infrequent specimens. *Eonodosaria evlanensis* Lipina 1950 occurs in the higher Kostomłoty Beds only, but the worldwide late Frasnian (zonal marker of Zadorozhnyj 1987 and Kalvoda 1990a) species is reported from East Europe (Evlan and Livny Horizons; Lipina 1950; Chuvashov 1965), the Siberian Platform (Menner & Reitlinger 1971: p. 31), Kuznetsk Basin (Zadorozhnyj 1987), Moravia (Friakova & Zukalova 1986), Bulgaria (Jovcheva 1980), and North America (Pfalker & Mamet 1982; Day 1990).

Two remaining Russian Frasnian species, *E. solida* Konoplina 1959 (Jovcheva 1980) and *E. stalinogorski* Lipina 1950, have been found in the Panek-Sitkówka and Psie Górki sites (Fig. 16D, I). Furthermore, poorly-preserved specimens resembling *E. kikinensis* Reitlinger 1954 occur in the detrital strata of Kadzielnia and Miedzianka.

Genus *Eogeinitzina* Lipina 1950

Remarks.– *Eogeinitzina rara* Lipina 1950 (Fig. 16G) is the most numerous nodosariid in the later Frasnian detrital strata of the western Holy Cross Mountains (Sitkówka-Jaźwica; Psie Górki, set G; Wietrznia), and has been identified also in the Silesian Upland (borehole Starczynów 1). This species was reported from Eastern Europe (Evlan and Livny Horizons; Lipina 1950; Reitlinger 1954; Bykova 1955: Tab. 2), Tien Shan (Poyarkov 1969), Moravia (Zukalova 1981; Friakova & Zukalova 1986; Kalvoda 1990a) and Bulgaria (Jovcheva 1980).

Eogeinitzina alta Lipina 1950 (Fig. 16H) has been identified at Sitkówka only. The nodosariid species is restricted to the Frasnian of East European Platform (Lipina 1950; Konoplina 1959), and perhaps Moravia (cf. Friakova & Zukalova 1986).

Stratigraphic distribution

The calcareous microfossils display a distinctive stratigraphic pattern in the Givetian to Frasnian limestones studied. This closely reflects cyclic facies development in the Kielce platform (Racki 1993), it probably also results from varying fossilization conditions being far more convenienient in the less oxygenated sediments of the vast Givetian shelf lagoon.

The most abundant, well-preserved microproblematica, comprising mainly calcispheres, parathuramminids and usloniids, characterize the oldest unit, the *Stringocephalus* Beds. The bank-type, micrite-rich facies contain also ubiquitous enigmatic *Labyrinthoconus* (?and *Proninella*), *Spi-*

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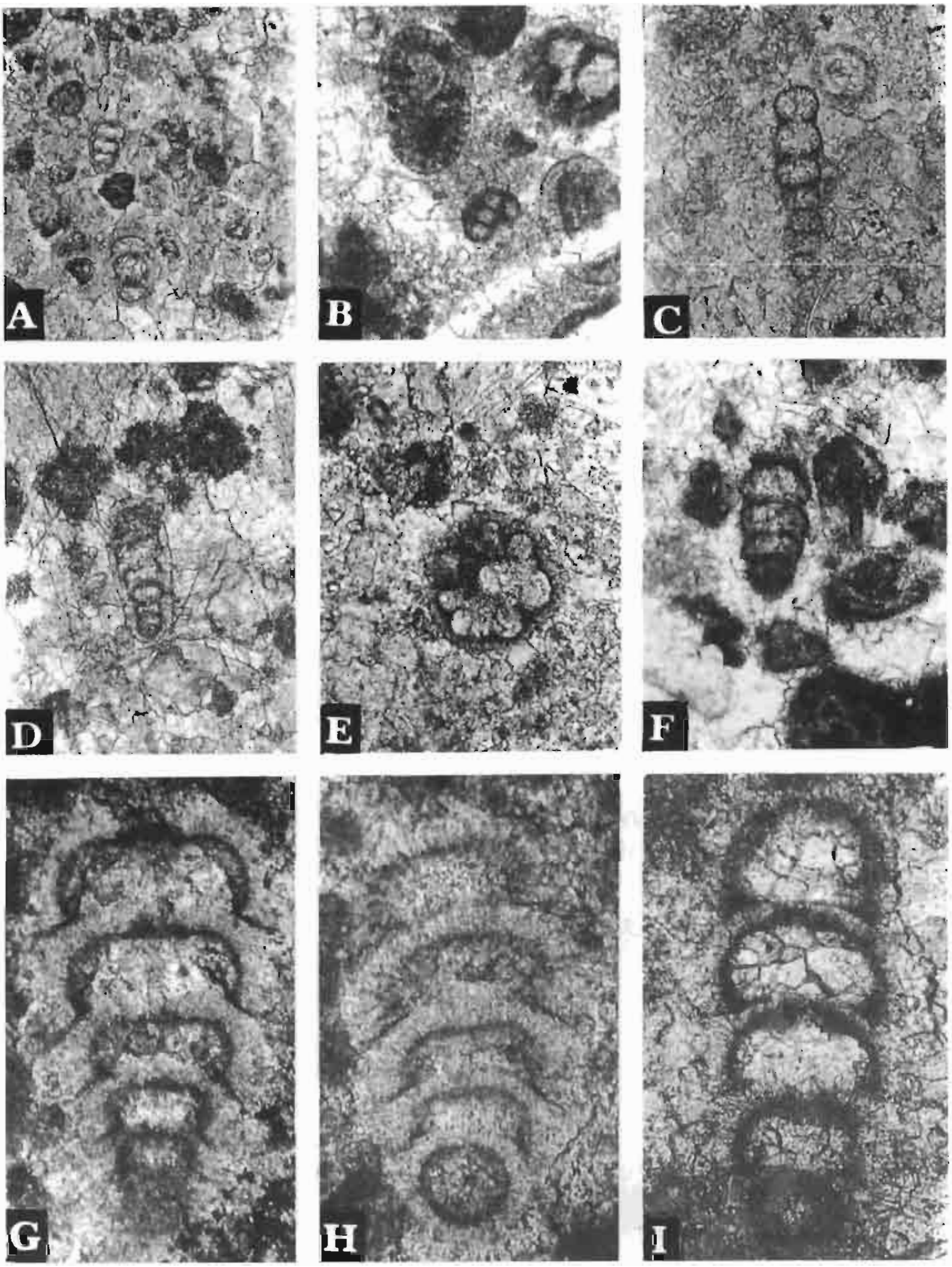
Fig. 16. Late Frasnian multichambered foraminifera from the Holy Cross Mts. ❑A. Nodosariid-rich sparry microfacies; Detrital Beds, Psie Górki (set G); × 60. ❑B. Oolite microfacies with a tourneyellid fragment; Kostomłoty Beds, Kostomłoty (set H); × 60. ❑C. *Tikhinella aequalis* Konoplina 1959; Detrital Beds, Psie Górki (set G); × 110. ❑D. *Eonodosaria solida* Ko-



noplina 1959; Detrital-Stromatoporoid Beds, Panek (set B); × 50. ❑E. *Multiseptida corallina* Bykova 1952; Detrital-Stromatoporoid Beds, Janczyce 1 borehole, depth 376.0 m; × 100. ❑F. *Tikhinella* sp.; Detrital Beds, Psie Górki (set E); × 50. ❑G. *Eogeinitzina rara* Lipina 1950; Detrital-Stromatoporoid Beds, Sitkówka-Jaźwica (set B); × 100. ❑H. *Eogeinitzina alta* Lipina 1950; Detrital-Stromatoporoid Beds, Sitkówka-Jaźwica (set B); × 100. ❑I. *Eonodosaria stalinogorski* Lipina 1950; Detrital Beds, Psie Górki (set G); × 135.

rotubus, and moravamminids such as *Evlania* (see Preat & Racki in press), as well as common algae dominated by tubiform *Devonoscale*, and, locally, profuse calcified cyanobacteria (*Bevocastria*, *Ortonella*), issinellids and charophytes. On the other hand, foraminiferal association is scarce (merely rare *Semitextularia*). In the upper part of the unit (Ambocoeliid Level), there are minor changes in the microbiota composition, and a few new elements (common tubular green algae *Jansaella*, also umbellids) appear.

Initiation of the Sitkówka biostromal complex in the late Givetian is marked by local flourishing of microbiota strongly dominated by usloniids (with many *Cribrosphaeroides*, *Auroria*, and *Uslonia*). This open-shelf episode, corresponding to the micritic-marly Jaźwica Member, was also the acme of the charophyte *Karpinskia oscoliensis*, and the time of intrusion of many new microfossils to the Kielce region, mostly foraminifers such as *Nanicella* sp. A, at least two species of *Semitextularia*, and perhaps *Earlandia*. For the latest Givetian (lower parts of Sitkówka and Chęciny Beds) the blossoming of tubiform dasyclads(?) *Jansaella ridingi* and the appearance of enigmatic *Eifeliflabellum opuntia* seem to provide stratigraphic guides.

The beginning of early Frasnian reef-type deposition was best evidenced by an abrupt increase in the abundance and diversity of calcified cyanobacteria and algae (up to 14 species; e.g. solenoporids, *Sphaerocodium*), and reef-building activity of the newly introduced renalcid community. The Kadzielnia-type buildups are marked by peculiar tube-like microproblematica, especially caligellids (*Baituganella*, *Petchorina*) in some places, and by the wide distribution of nanicellids (Galińska 1984). The later Frasnian back-reef association is (especially in the sparry-peloidal microfacies) poorly-preserved and unvariably dominated by calcispheres (archaeosphaerids) comparising up to 90 per cent of the total biota.

The late Frasnian change is, however, joined with the succesive invasion of advanced multilocular foraminifera comprising diversified and abundant nodosariids (with *Eogeinitzina rara* being most common), tikhinellids, and nanicellids (Fig. 16). Many species are cosmopolitan and this bio-event may be the key for a worldwide correlation of the late Frasnian carbonate sequences (*Multiseptida corallina-Eonodosaria evlanensis* Zone of Zadorozhnyj 1987 and Kalvoda 1990a; *Multiseptida-Eonodosaria-Eogeinitzina* complex of Kalvoda 1986). However, it should be emphasized that several species occur in Moravia (Kalvoda 1990a), the Ardennes (Vachard 1988: Fig. 2), and the Holy Cross Mountains in the Frasnian as early as the *'Palmatolepis' jamiae* Zone (see also Day 1990 for American occurrences), although they have been reported from Russia mostly from the latest Frasnian Evlano and Liven Horizons. Lin & Hao (1982) have quoted a somewhat similar association already from the Givetian of China.

Distribution of some characteristic foraminifera was controlled by strongly localized factors: *Multiseptida* is apparently limited to the eastern part of the Holy Cross Mountains (Ozonkowa 1961; and was recently identified also in the borehole Janczyce 1, Fig. 16E), and the Lublin area

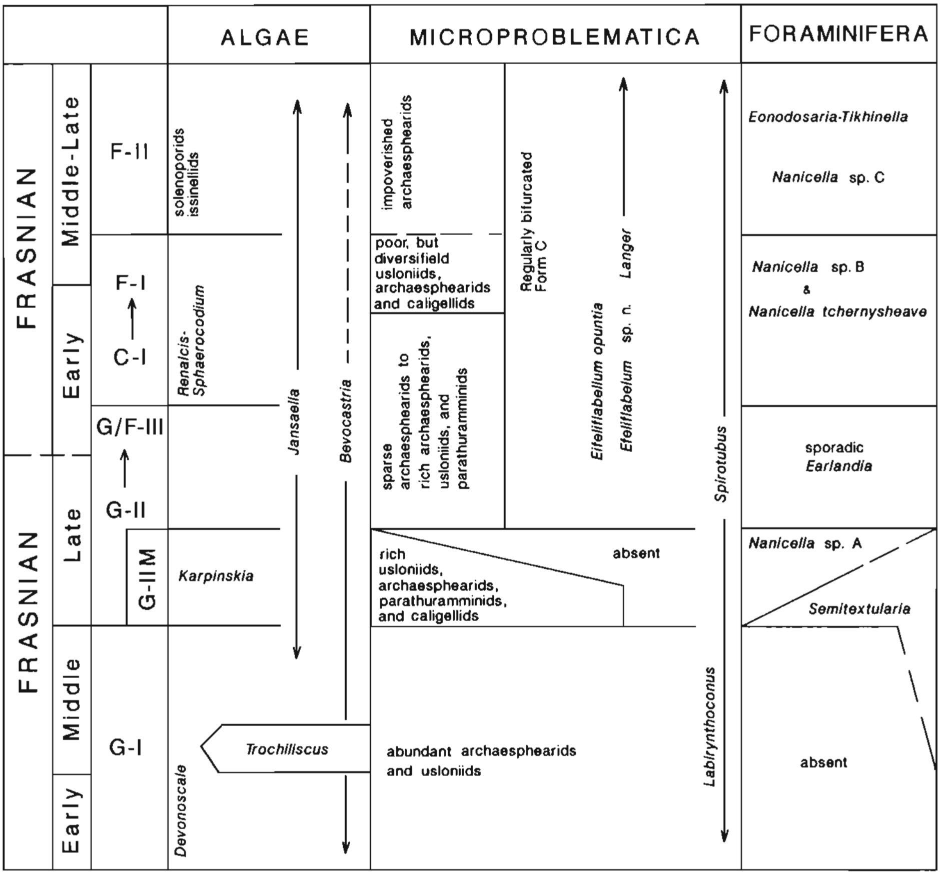


Fig. 17. Succession of calcareous microbiota in the Holy Cross Mts Givetian and Frasnian; depositional cycles after Racki (1993).

(Neumann *et al.* 1975). On the other side, uncommon arenaceous foraminifera, mostly *Tolypammina*, are found in the late Givetian of the northern sections (Wietrznia, Czarnów), but as high as the latest Frasnian (Kowala, set H) in the southern Kielce region.

The established microbiotic sequence is summarized in Fig. 17, and distinguished associations are broadly defined at varying levels of taxonomic coherence, according to still insufficient sampling of the thick limestone series. Although severely controlled by facies (e.g. Bykova 1955; Poyarkov 1979: p. 130), the microbenthic succession may allow correlation of carbonate sequences (cf. Zadorozhnyj 1987; Kalvoda 1990a), particularly in borehole sections. For example, the acme of *Labyrinthoconus clausmuelleri* occupies a surprisingly constant, earlier Givetian position in the Holy Cross Mountains and Rhenish-Ardenne Massif (Langer 1979; Vachard 1988). Future applications depend on refinement of both taxonomy and ranges of the Frasnian nodosariids, and nanicellids, which are known from the Early Devonian (Vachard & Massa 1989) through Frasnian, and perhaps Famennian (Jurkiewicz & Żakowa 1986). For the nanicellids Zadorozhnyj (1987: p. 111) proposed planktic mode of life.

Comments on paleoecology and bio-events

The Givetian and Frasnian microbiota from southern Poland reveal many features well-known in other Devonian carbonate complexes. The most typical is the predominance of the calcisphere-parathuramminoid suite in restricted-shelf and related facies (Fig. 8D-E), in both bank- and reef-phases (e.g. Flügel & Hotzl 1971; Kaźmierczak 1976). The habitats were not normal marine ones and oligohalinity, eutrophy, or calcium overload were invoked (Kaźmierczak *et al.* 1985; Racki 1986), but the ambiguity as to the biological status of the 'monolocular foraminifera' hampers reliable inferences. For example, the alleged volvocean nature of some microrganisms is sugestive of an extraordinary phytoplankton productivity. Till now, this habitat was proposed solely for thin-walled archaeosphaerids and *Bisphaera* (Bykova 1955: p. 106; see also Chuvashov 1963; Flügel & Hotzl 1971; Poyarkov 1979).

The extensive growth of microbial mats was widespread in the most shallow water areas, especially during shoaling interphases (Racki 1993), and some authors (e.g. Jamieson 1971; Machielse 1972; Mamet & Preat 1987) proposed a proliferation of algae as the primary factor governing lime-mud production in extensive restricted lagoonal settings.

Muddy, low-energy environments of the Givetian bank-interior areas presumably offered the most suitable conditions for the thriving of plankton, as well as for a variety of benthic microrganisms. For example, erect simple cylindrical green-algae (Palaeosiphonocladales; Roux 1991), possibly with an outer mucilagenous coating, developed in closely-packed thickets and baffles that stabilized unconsolidated bottom substrates. Progressive reduction of this type associations in Frasnian back-reef areas might result from unsuitable ecologic conditions (shallower and turbulent, better aereated waters, probably less restricted circulation), joined with a weak permineralization potential. Similar relationships have been recognized in the Devonian carbonate complexes of North America (Toomey *et al.* 1970; Kettenbrink & Toomey 1975).

Calcified cyanobacteria and algae seem to be of minor importance in the formation of quiet-water Givetian stromatoporoid-coral buildups in the southern Poland shelf. This is in contrast with data from the Ardennes where phylloids, giant dasyclads and porostromatids are important builders (Mamet & Preat 1987). The depositional role of cyanobacterial/microbial accretion (cf. Pratt 1982; Riding 1991a, b) was paramount in more open-marine, well-agitated Frasnian environments, resulting in renalcid/stromatolitic buildups (Hoffman & Paszkowski 1992) and metazoan-stromatactoid Kadzielnia-type mud-mounds.

As to unquestionable foraminifera, their thriving was clearly associated with open-shelf biotopes, and the oldest occurrence in the Kielce Region is within the late Givetian flooding. However, their acme corresponds to the late Frasnian. The benthic microbiota, including sediment stabilizing solenoporids and chlorophyte (*Issinella*) meadows, and grain-coating microbial mats, flourished on clear-water current-winnowed substrates, and even oolite shoals, as evidenced by the Kostomłoty Beds. This preference has been reported from many Devonian carbonate complexes (e.g. Chuvashov 1963; Toomey *et al.* 1970; Kalvoda 1986; Zadorozhnyj 1987).

Kalvoda (1986, 1990b) proposed climatic and eustatic oscillations as the main factor in the Late Devonian radiation and decline events of the Tethyan-type (tropic-subtropic) multilocular foraminifera (see also discussion in Poyarkov 1979: p. 125). Advanced (partitioned) forms with dependence on endosymbionts and/or a tendency towards K-strategy (Brasier 1988) were ecologically most sensitive. Riding (1984) stressed the importance of transgressive events for the diversification of benthic calcareous algae, especially chlorophytes and rhodophytes. The late Frasnian to early Famennian time interval was crucial in the evolution of calcareous microbiotas within disturbed shelf ecosystems of intermittently drowned carbonate shelves. For example in the area studied, reef-related labyrinthoconids suffered during the terminal Frasnian collapse. Remarkably, the rock-forming abilities of benthic microbial biota also continued to be important in the post-extinction early Famennian time (cf. Riding 1991b: p. 35), and the presence of such organic mounds can be inferred for some portions of the remnant ridges in the Kielce Region (Racki 1990).

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Streszczenie

Poszczególne fazy rozwojowe żywecko-frańskiego kompleksu węglanowego południowej części Gór Świętokrzyskich charakteryzują się specyficznym zespołem mikroskamieniałości wapiennych. Osady ławicy stringocefalowej zawierają szczególnie bogato reprezentowane i dobrze zachowane mikroproblematyki (?głównie pochodzenia glonowego) silnie zdominowane przez kalcysferoidy (kalcysfery i pokrewne „jednokomorowe otwornice"), szereg kalcyfikujących cjanobakterii i glonów zielenic, np. nitkowate *Bevocastria*, rurkowate *Devonoscale* oraz ramienice *Trochiliscus*. W poźnożyweckim kompleksie biostromalnym występuje bardziej uboga asocjacja mikroskamieniałości, poza miejscami licznymi semitekstularidami (głównie *Nanicella*), a zwłaszcza zielenicami (?Dasycladacae) *Jansaella*. Również z frańskich facji zarafowych znane są tylko mało zróżnicowane kalcysferoidy. Natomiast mikrobiocenozy rafowe i przedrafowe franu są bardzo bogate – przede wszystkim w cjanobakterie (np. kalcyfikujące formy *Renalcis* i *Sphaerocodium*), a miejscami też w solenoporidy i różnorodne wielokomorowe otwornice (*Nanicella*, w młodszym franie – nodozaridy). Odgrywały one znaczącą rolę biosedymentacyjną i dokumentują progresywne spłycanie biotopów kompleksu rafowego.