Evolution of the bank to reef complex in the Devonian of the Holy Cross Mountains

GRZEGORZ RACKI

Racki, G. 1993. Evolution of the bank to reef complex in the Devonian of the Holy Cross Mountains. *Acta Palaeontologica Polonica* **37**, 2-4, 87-182.

Givetian and Frasnian stromatoporoid-coral limestone of the Kowala Formation in the southern Holy Cross Mts is subdivided stratigraphically, and correlated with strata elsewhere on the basis of identified sea-level cyclicity, with support from conodonts and other selected benthic fossils. After the Eifelian hypersaline sabkha phase, an extensive two-step regional colonization of the Kielce Region carbonate platform took place during the Eifelian/Givetian passage interval and the Middle Givetian. At least four deepening pulses resulted in intermittent drowning of the vast carbonate platform and sequential replacement of the undifferentiated *Stringocephalus* biostromal bank by the Sitkówka bank complex and, subsequently, by the Dyminy reef complex. The reef developed in the central Dyminy belt as result of the early Frasnian accelerated sea-level rise after some period of biotic stagnation near the Givetian-Frasnian boundary. Final demise of the reef resulted from combined eustatic and tectonic movements during the late Frasnian major crisis interval.

Key words: Reefs, lithostratigraphy, biostratigraphy, stromatoporoids, corals, cyclicity, benthic assemblages, eustasy, Devonian, Poland.

Grzegorz Racki, Katedra Paleontologii i Stratygrafii Uniwersytetu Śląskiego, ul. Będzińska 60, 41-200 Sosnowiec, Poland.

Introduction

An almost 800 m thick stromatoporoid-coral series of the Kowala Formation (Narkiewicz *et al.* 1990) forms the bulk of the epicontinental carbonate sequence in the Middle and Late Devonian of southern Poland (Fig. 1). The strata are known primarily from the Kielce Region in the southern Holy Cross Mountains, and being of economic importance have been the subject of geological studies for more than 120 years (see review in Czermiński 1960).

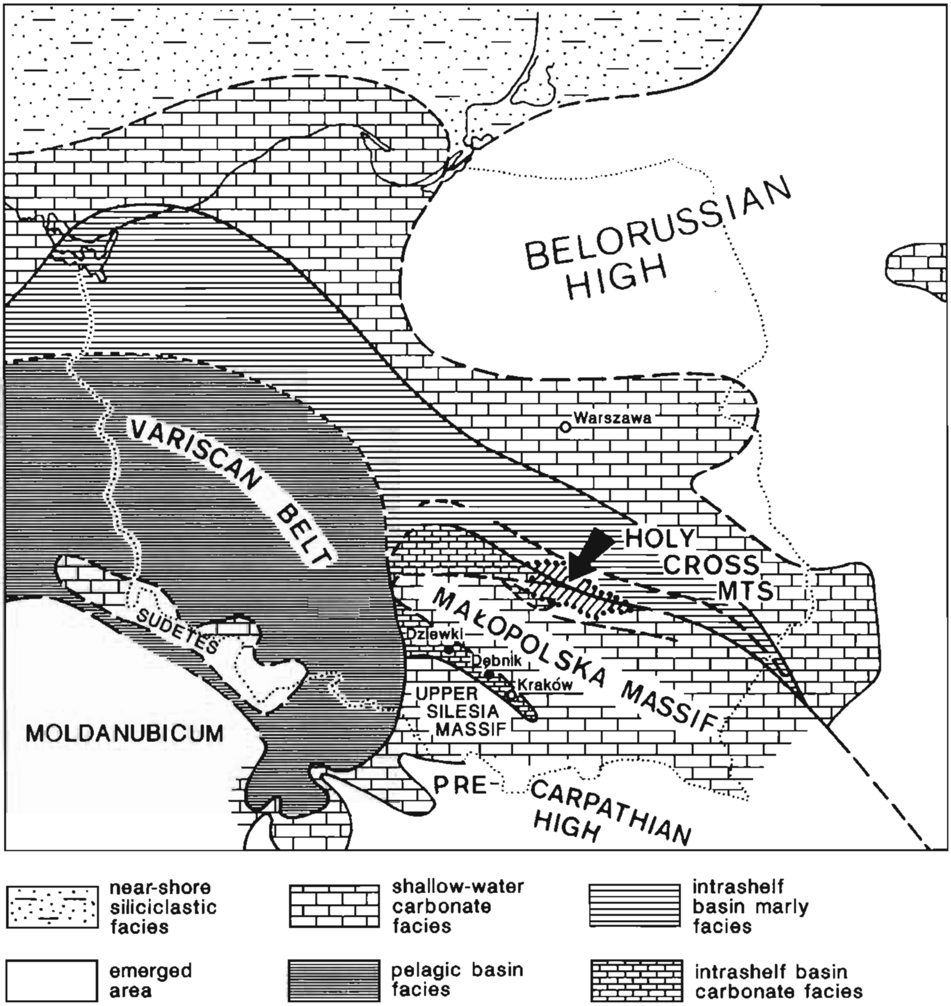


Fig. 1. Facies of Givetian to early Frasnian in Poland, based on Narkiewicz (1988: Fig. 1), Hladil (1988: Figs 1-2), Tsien (1988: Figs 10-11), and Stupnicka (1989: Figs 6.1, 6.13), to show location of the Holy Cross Mts, Siewierz (Dziewki), and Dębnik localities.

The stratigraphy of the stromatoporoid-coral limestone is still inadequately known, although its Givetian-Frasnian age has been accepted since Roemer (1866a, b) and Gürich (1896). The distinction between litho- and chronostratigraphic units has been rarely obeyed (Narkiewicz *et al.* 1990). Correlations remain ambiguous because of inadequate fossils like 'guide' *Amphipora ramosa* Phillips 1841, and even conodonts (Racki 1980). In the Lublin area late Frasnian brachiopods and rugosans occur in association with 'early Frasnian' stromatoporoids and 'Givetian' tabulates (Miłaczewski 1981). Variability of facies virtually precludes lithologic correlation even on local scale (Kaźmierczak 1971a, b). In addition, poor definitions of the lower and upper boundaries of the series investigated in the type area complicates the issue even further (Racki 1985b; Narkiewicz *et al.* 1990).

The overall unapplicability of the traditional biostratigraphic zonal procedure demands a more holistic approach, namely an application of event and ecosystem concepts paired with sequential analysis of the relatively weakly differentiated shallow-water limestone successions. This below is an attempt to consider the evolution of the Givetian to Frasnian carbonate complex in a framework of eustatic sea-level changes. The paper summarizes studies continued since 1975 on the Givetian and Frasnian strata. Descriptions of particular fossil groups, especially brachiopods, and sedimentary cyclicity have been already published (Racki & Baliński 1981; Racki 1985a, b, 1986a, b; Wrzołek 1988; Karczewski 1989), summarized by Racki (1988). Modifications of those interpretations appear necessary, especially in reference to the recently proposed international definition of the Middle/Late Devonian boundary (Klapper *et al.* 1987).

In the series of papers below we attempt to reconstruct both the geobiological history (ecology of colonization; Gekker 1980) of a fragment of the Devonian epeiric sea in Poland (Fig. 1) and to present particular fossil groups in a regional perspective.

Materials and methods

The main study area occupies the best exposed southwestern part of the Holy Cross Mountains (Fig. 2), including both the platform Kielce Region and broadly defined basinal Łysogóry Region (Racki & Bultynck in preparation). Additional sections are in the eastern part of the Holy Cross Mountains, and in the Silesia-Cracow area. The forty five exposures are presented in the locality register on p. 171. Complete borehole sequences (Romanek & Rup 1990; Narkiewicz 1991) are especially important in correlation and interpretation of particular exposures.

Primary macro-features of the biogenic limestones, observed in the measured bed-by-bed sections, enable their subdivision into lithologic sets, especially in regard to dominating rock-forming fossils. Because of usually parautochthonous nature of the biostromal fossil assemblages, Embry's & Klovan (1971) classification scheme has been applied only in most general facies interpretations (Figs 7, 13). Important lithostratigraphic contacts such as boundaries of the Jaźwica Member have been densely sampled. About 1000 thin-sections and 180 polished slabs were employed for facies interpretation. More than 200 samples (usually 1-2 kg in weight, occasionally up to 20 kg) were processed in order to extract conodonts, and the most extensive work has been done in the Góra Zamkowa, Jaźwica, Sowie Górki and Posłowice localities.

Conceptual framework

The idea for this study came from the ecostratigraphic approach to biostratigraphy, defined by Martinsson (1980) as a modification of the original Schindewolf's concept (*fide* Sokolov 1986) that refers solely to local correlation-hampering problems. The ecosystem approach to stratigraphical record (Boucot 1982; Brenner & McHargue 1988: pp. 257-258) is well exemplified by some regional syntheses, especially that of Gekker (1983) on the Main Devonian Field, and by the Estonian group working on the East Baltic Silurian (Kaljo & Klaaman 1986). The call for an integrated, cause-effect treatment of abiotic and biotic parameters of the sedimentary basin finds expression in other current trends in stratigraphy, in particular in various event, sequential and dynamic approaches (Ager 1973; Dott 1982; Walliser 1986; Van Steenwinkel 1990; Einsele *et al* 1991), developed finally into high resolution event stratigraphy by Kauffman (1986), and hierarchical genetic stratigraphy by Rollins *et al.* (1990).

Even if it is still not possible to apply these general ideas in practice, the way of thinking they propose seems to be intelectually stimulating. The ecosystem approach to regional stratigraphy refers to three basic research procedures: (1) paleobiological analysis (recognition of community pattern), (2) facies model (reconstruction of environmental setting), and (3) chronology (establishment of time-planes). In the case of the carbonate sequence studied the two latter aspects refer directly to cyclic facies development, recording chiefly eustatic fluctuations (Racki 1985b, 1986b, 1988). Because of the scarcity of guide fossils, the cyclicity remains almost the only base for regional correlation resulted from combined event and sequential analysis (cf. Van Steenwinkel 1990). Hopefully it will also enable verification of the time correlative potential of biostratigraphic units as many preserved biotic patterns appear attributable to forcing by different-scale sea level changes.

Commonly used substages of the Givetian and Frasnian remain undefined and of variable meaning. Recognition of the worldwide transgressive-regressive (T-R) cycles by Johnson *et al.* (1985; Hladil 1986, 1988) presents a convenient basis for 'natural' chronostratigraphy, as advocated by Walliser (1985). Consequently, the Taghanic onlap (T-R Cycle IIa) in the Middle *P. varcus* Zone is a good natural base of the Middle Givetian. The following deepening pulse near the beginning of the *K. falsiovalis* Zone (IIb) would then determine the bottom of the Late (post-*Stringocephalus*; cf. Racki 1986b) Givetian. The Middle Frasnian coincides with the T-R Cycle IIc, while the Late Frasnian is a gross equivalent of the complex T-R Cycle IId. In case of insufficient data, informal chronostratigraphic (basal, low, higher, etc) or chronologic (early, late) designations are applied.

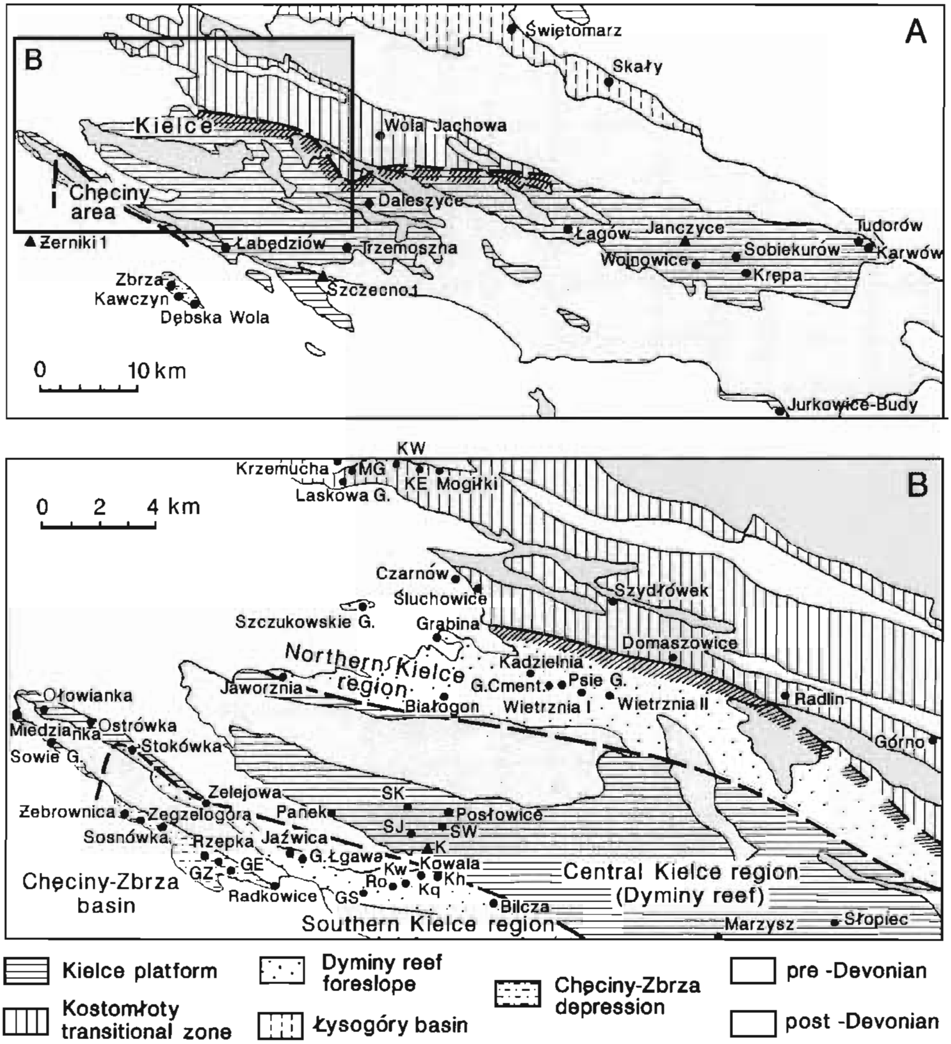


Fig. 2. ❑A. Location of studied localites (see 'Register of localities' for details) in the Holy Cross Mts, against late Givetian paleogeography. Points indicate exposures, triangles boreholes, edge of the Kielce carbonate platform hatchured. ❑B. Location of studied sites in the western part of the Holy Cross Mts, against early Frasnian facies distribution. KE – eastern Kostomłoty hill, KW – western Kostomłoty hill, MG – Małe Górki, SK – Sitkówka-Kostrzewa, SW – Sitkówka-Kowala, SJ – Sitkówka-Jaźwica, Kh – Kowala hill, Kq – Kowala quarry, Kw – Kowala railroad cut, Ro – Kowala road cut, GS – Sołtysia Góra, GZ – western Góra Zamkowa, GE – eastern Góra Zamkowa, K – Kowala 1 borehole.

Regional paleogeographic setting

The shallow-water biogenic deposition of the Holy Cross Mountains carbonate platform became gradually more and more areally restricted in a

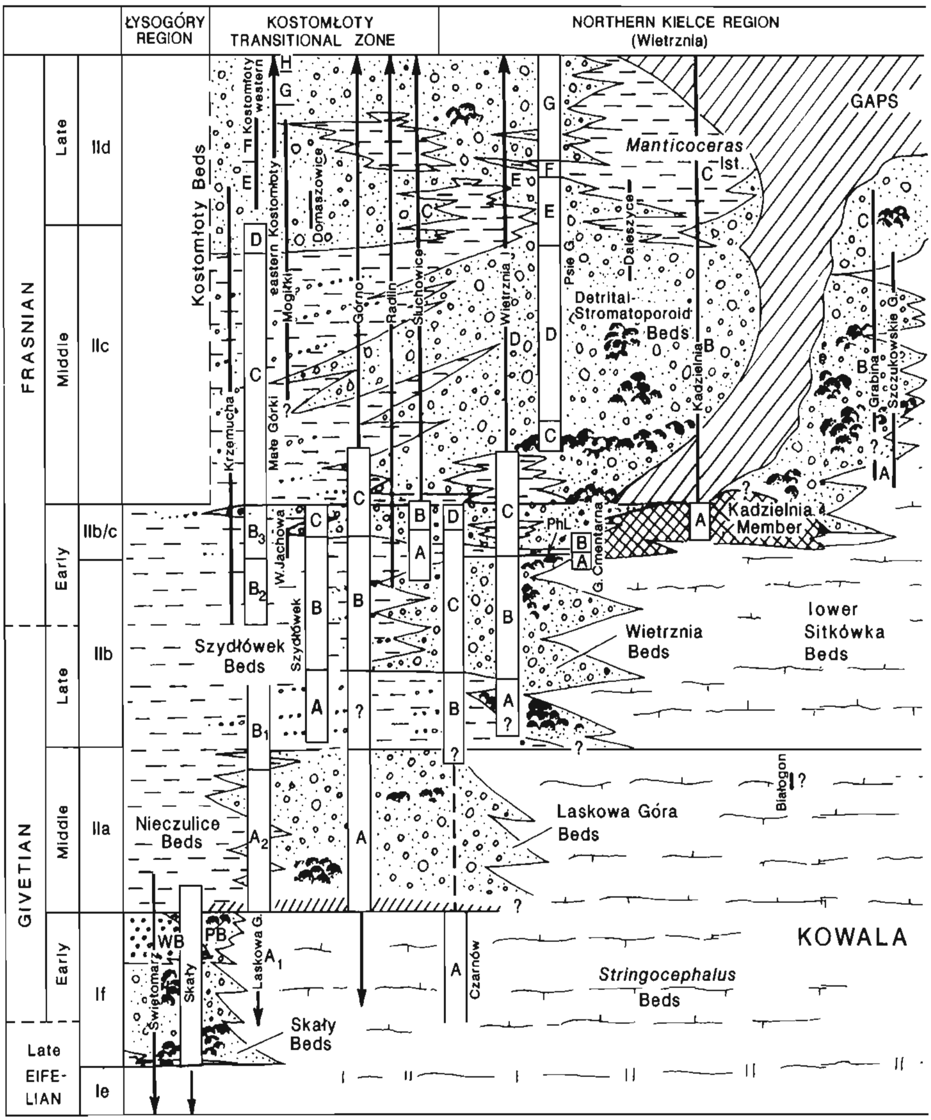
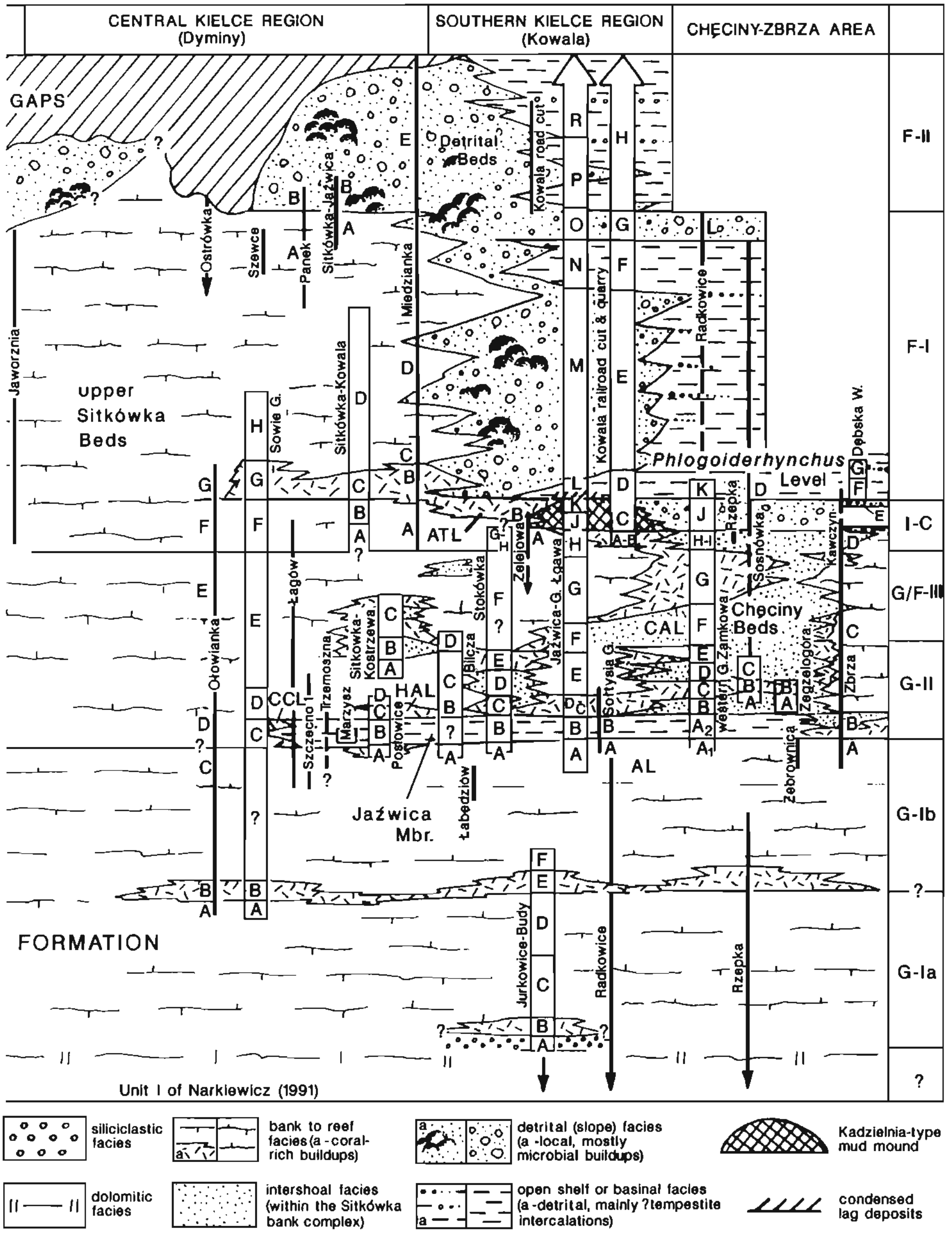


Fig. 3. Idealized stratigraphic-facies cross-section of the Givetian and Frasnian strata of the Holy Cross Mts, with extension and subdivision in sets of the sections, as in the 'Register of localities'; not to scale. Crucial profiles represented by empty columns, other by lines. If-IId – eustatic cycles from Johnson *et al.* (1985), modified in case of the Cycle IIc; regional depositional cycles (G-I–F-II) from Racki (1985b), supplemented. Secondary dolomitization and synsedimentary faults are omitted. Abbreviations: WB – Świętomarz Beds, PB – Pokrzywianka Beds, AL – Ambocoeliid Limestone Level, CCL – Crinoid-Coral Limestone Level, HAL – *Hexagonaria/Alveolitella* Limestone Level, ACL – Atrypid-Crinoid Limestone Level, ATL – *Alveolites-Thamnophyllum* Limestone Level, PhL – *Phlogoiderhynchus* Marly Level.

backstepping pattern during the Middle Devonian as a result of following deepening pulses (Fig. 3). The northern Łysogóry intrashelf basin ex-



panded southward, and in effect a strong facies polarization in two principal regions was established by the Givetian (Fig. 2A). A subordinate Chęciny-Zbrza paleolow delimits the southwestern portion of the Kielce Region, and the paleogeographical pattern is similar to that of the early Paleozoic (Szulczewski 1977). By the Frasnian the subsymmetrical plan was manifested in the central location of an ecologic reef structure (Narkiewicz 1988). The reef developed along the northern periphery of the stable fragment of carbonate shelf (Szulczewski 1979) corresponding to the Małopolska Massif, consolidated in the Vendian, and already separated from the East European Platform during the Early Paleozoic by a belt of deep-water Łysogóry-type (Modliński 1982) sedimentation. The reef was almost completely drowned in the latest Frasnian (Racki 1990).

This paleogeographic pattern (Figs 2-3) can be refined as followings:

(1) Recent advances in the biostratigraphy of the Middle Devonian deposits (cf. Racki *et al.* 1985; Narkiewicz *et al.* 1990) clearly argue for a subdivision of the northern Holy Cross Mountains into two domains, which differ strongly in facies sequence. In the northeastern, Bodzentyn area the deeper-water deposition resumed in the latest Eifelian after the early Devonian regression, whereas the more southwestern, Kostomłoty part is marked by the platform development continuing up to the Middle Givetian. The limit between the intrashelf basin and the carbonate platform is traced along the southermost extent of the dominantly argillaceous Szydłówek Beds (Fig. 2) during the Givetian to Frasnian transition time. The assignment of the passage Kostomłoty area remains equivocal. The most important geotectonical lineament in the area is the deep Święty Krzyż Fracture that separates the belt north of the Łysogóry range from the rest of the Holy Cross Mountains (terranes boundary according to Pożaryski *et al* 1992). Devonian rocks were removed from the zone between the Bodzentyn syncline and the Kostomłoty belt after the Variscan epoch. Therefore, it is still difficult to compare the early Paleozoic record in the two areas. However, the Święty Krzyż Fracture was at least in the western part possibly coupled with additional dislocations (Święty Krzyż Fracture zone of Narkiewicz 1991; see also 'flower structure' model in Pożaryski *et al* 1992) controlling in step-like manner the Devonian facies progression quite differently from more stabilized southern areas; this is evident already in early Devonian successions in the light of new biostratigraphic data (Malec 1991). 'Kostomłoty transitional zone' is thus tentatively employed herein for the tectonically delineated area. Noteworthy, a persistance of the transversal Daleszyce depression is confirmed for the Givetian of the Górno-Daleszyce area (see Fig. 15D) as concluded already by Czarnocki (1950: p. 48; see also Kowalczewski 1963) for the Famennian.

(2) The Kielce paleohigh is subdivided into southern (Kowala), central (Dyminy), and northern (Wietrznia), subregions which correspond to the northern slope (transitional to the Kostomłoty basin), the central swell, and the southern flanking zone (transitional to the Chęciny-Zbrza paleolow), respectively (cf. Głazek *et al.* 1981). The term Dyminy subregion corresponds to the Frasnian Dyminy reef of Narkiewicz (1988), although Szulczewski (1977, 1978) used the name 'Kadzielnia reef' for the same structure. The last term is used herein solely for the organic buildups developed in the Wietrznia subregion. This facies differentiation was most apparent in the Frasnian of the western Kielce Region (Figs 2B, 3), but is probably traceable into the eastern part as well (cf. Samsonowicz 1917).

(3) Contrary to Sobolev (1909) and Szulczewski (1977), the Chęciny-Zbrza paleolow is classified as a subordinate unit within the major Kielce Region (*sensu* Czarnocki 1950). This was a distinctly localized intershoal area called Chęciny basin during the late Givetian (Kaźmierczak 1971a), and probably also ephemeral poorly-recognized Frasnian Chęciny-Zbrza intrashelf basin extending east no farther than the Skrzelczyce-Pierzchnica area (cf. Filonowicz 1973, 1976) and south to the Żerniki 1 borehole (cf. Kulicka & Nowiński 1983). In the Chęciny-Zbrza basin, the late Famennian organodetrital (foraminiferal-algal) limestone occurs (Kucia 1987) providing a record of bioclast source from a more southern shallow-water platform. Progressive filling of this basin in Frasnian is expressed by the presence of bioclastic deposits in Dębska Wola (see Fig. 23C), Skrzelczyce and Radkowice. Thus, the facies gradients in the depression discussed cannot be compared with the depositional contrasts which mark the northern edge of the Kielce Region.

Lithostratigraphic account

The stromatoporoid-coral series of the southern Holy Cross Mountains represents the Formation of Stromatoporoid-Coral Dolomites and Limestones from Kowala (Fig. 3), following the proposal by Narkiewicz *et al.* (1990). The unit, which ranges from 330 m to above 800 m in thickness, is comprised primarily of skeletal accumulations in situ. It is separated from detrital flanking slope deposits and reef-cap facies, called Detrital Beds (cf. Detrital Facies of Szulczewski 1971); the term Detrital-Stromatoporoid Beds is preferred for its talus variety. The bottom part of the Kowala Formation is composed of strongly dolomitized sabkha-type cyclic deposits with few biostromal layers (unit I of Narkiewicz 1991). These strata are not dealt with in this study.

The main object for study is the thin (up to 12.5 m) fossiliferous Micritic Limestone Member from Jaźwica, a micritic-marly suite with common wavy to nodular bedding and open shelf fossil assemblage dominated by shelly faunas and echinoderms; some other stratigraphically related units such as the underlying *Stringocephalus* Beds, mostly dolomitized and typified by thick biostromal/unfossiliferous calcilutite succession, as well as overlying coeval Sitkówka Beds (varied biostromal strata, with thick rhytmic amphiporid-laminite complexes), and Chęciny Beds (platy to subnodular fine-grained deposits typically devoid of any buildups), are investigated too.

The late Givetian to early Frasnian, fossil-rich detrital strata from the northern Kielce subregion are labelled as the lower part of the Wietrznia Beds (sets A-B). Gürich's (1896) name 'Uebergangsschichten an der Wietrznia' reflected originally their transitional nature between the Middle and Late Devonian, but Szulczewski (1971) underlined rather their intermediate position between fore-reef and basin facies. The applicability of this term to other detrital deposits, including those from the southern Kielce region, remains unanserved. In any case, the Wietrznia Limestone is quite different from the Kostomłoty Beds, typical of the 'western Łysogóry' Frasnian. The latter are marked by a paucity of fossils, variable contribution of marly-nodular lithologies, and black cherts in the type area (Szulczewski 1971; Racki *et al.* 1985).

Several other subordinate limestone levels, distinguished by their peculiar fossil content, are discussed below in reference to cyclic facies succession. Two more distinct informal units are defined below (Figs 3, 7):

(1) *Phlogoiderhynchus* Marly Level. The term was introduced as the 'level with *Leiorhynchus polonicus*' by Czarnocki (1927, 1948) for the early Frasnian marly set with numerous index rhynchonellids in the western Holy Cross Mountains (Biernat & Szulczewski 1975). His concept is narrowed herein to transgressive strata in the western Kielce Region capping the Kowala Formation as at Kowala-Jaźwica (Fig. 26), or occurring near its top as at Chęciny and Kawczyn-Dębska Wola. They correspond to the distinct set C intervening within the Wietrznia Beds.

(2) Laskowa Góra Beds. The term covers the Middle Givetian Fossiliferous Limestones and Marls of Racki *et al.* (1985), separating the dolomitized *Stringocephalus* Beds from the argillaceous Szydłówek Beds in the Kostomłoty area (set A of Laskowa). The level was established also at the Józefka hill near Górno (set A of Małkowski 1981), and may occur at Czarnów (Racki & Bultynck in preparation).

Principal analytical sections

Different sized surficial localities of the Kowala Formation, largely in abandoned quarries and ditches (Figs 4-6, 8-9, 38-42), were examined in a stratigraphic-facies context. Nevertheless, the Jaźwica and Góra Zamkowa sections, supplemented by nearby smaller sites, which represent different facies settings, appear crucial to the determination of the stratigraphic relationships in the western Kielce Region (Fig. 7). For documentation of the mainly dolomitized *Stringocephalus* Beds, the unique Jurkowice-Budy locality in the east is described too.

Góra Zamkowa

The western quarry on the Góra Zamkowa at Chęciny, close to the ruined castle (Figs 4B, 5, 39A), is among the most representative and best-known sections of the Kowala Formation (Racki & Baliński 1981). The following sets have been distinquished in the sequence (Fig. 7), characterized by well-layered, grey, fine-grained lithologies:

A. Amphiporid bafflestones, with shell-rich intercalations (subset A_1), succeeded by thicker stromatoporoid biostromes (bafflestones/floatstones) containing thin micrite-shaly, brachiopod- and crinoid-rich interbeds (subset A_2). This unique in the section stromatoporoid-bearing complex (Kaźmierczak 1971a; Szulczewski 1979), ca. 5 m thick, can apparently be

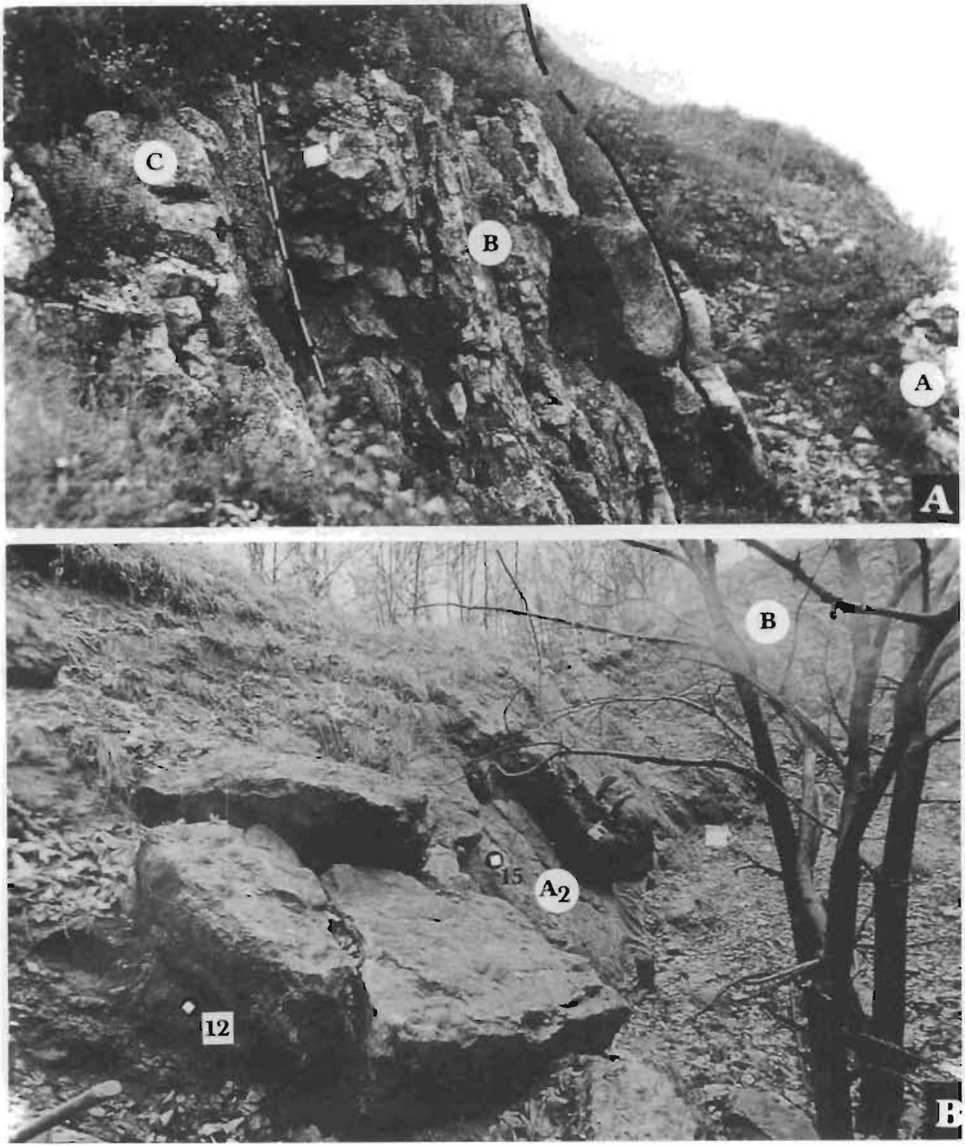


Fig. 4. ❑A. Western part of the Sosnówka hill, an outcrop of the lower Chęciny Beds (Fig. 35). ❑B. Northernmost part of the western Góra Zamkowa quarry. A_2-B – lithologic sets (Fig. 7). Number refers to selected conodont sample (Tab. 1).

subdivided into two quite different units representing topmost *Stringocephalus* Beds, and the Jaźwica Member, but the limits seem to be tectonically obliterated.

B. Thick-bedded wackestones/packstones with scattered brachiopods and crinoid debris, and sporadic *Disphyllum*-rich intercalations.

C. Chiefly dolomitized coral-stromatoporoid biostrome (bafflestones and bindstones) containing a wedging crinoid grainstone layer, up to 15 cm thick (Fig. 17E).

D. Medium-bedded, platy wackestones/packstones up to 10 m thick, comprising gastropod shells, and rare *Amphipora* and *Disphyllum*, and alternating with laminite and ribbon mudstone horizons.

E. Thick-bedded packstones/grainstones with up to 5 cm thick *Disphyllum* levels, and rare shells and crinoid ossicles.
F. Mainly thick-layered packstones/grainstones with numerous fossils (Racki & Baliński 1981) including common echinoderm debris, and atrypid and molluscan shells (*Desquamatia* coquinas).
G. Medium to thin-bedded up to 1.7 m thick *Disphyllum* bafflestone with single intercalations rich in ramose stromatoporoids and alveolitids, and finally capped with a laminated layer.
H. Thin- and platy-bedded wackestones, about 12 m thick, typified by delicate laminations, numerous chert bands and infrequent argillaceous partings (Fig. 11C), and an impoverished suite of fossils which include *Amphipora* and gastropods.
I. Thick-bedded, subnodular wackestones/packstones. Fossil content is generally poor, but crinoid-rich grainstone/rudstone partings, as well as brachiopod (mostly atrypid) and *Disphyllum* levels occur here and there. The set is only incompletely visible and tectonically disturbed in the western quarry, but occurs also along the southern, rocky slope of this hill, and in the other, more easterly exposures. The total thickness may be about 50 m.

The higher strata, poorly exposed in the most southeasterly part of the hill (Narkiewicz 1973), include bedded light-colored grainstones with rare coarse-grained layers (set J), followed by an argillaceous lime-shaly succession with *Phlogoiderhynchus polonicus* and *Styliolina* (set K). The exact relationships between the youngest sets are obscured by fault contacts. Still higher Frasnian coral- and brachiopod-bearing platy grained limestones, and styliolinid shaly partings are known from Radkowice.

The outcrops above the old Jewish cemetery record obvious changes within the *Desquamatia*-bearing set F (Fig. 27). On the other hand, the thick dolomite succession which includes thamnoporid biostromes (Narkiewicz 1973, 1991), and a small fragment of set I, comprising the atrypid- and *Disphyllum*-horizons, occurs in abandoned quarries on the Rzepka hill (see Fig. 39A).

Lower Chęciny Beds rich in corals, crinoid detritus and brachiopods, are visible in the west in many exposures near the Gościniec village, on Sosnówka (Fig. 4A) and Zegzelogóra. The strata are in tectonic contact with the Frasnian detrital-marly sequence of the Skiby Syncline (Narkiewicz 1973, 1991). In addition, slightly older well-bedded unfossiliferous and cherty strata were exposed in a trench in the western Zegzelogóra.

Jaźwica

Large Jaźwica Quarry, especially its temporarily abandoned, western part (Figs 6, 8A), provides the best exposure of the Kowala Formation (Racki 1981, 1985a). The almost 200 m thick sequence, mostly representing the Sitkówka Beds, developed above coarse-crystalline dolostones, is divisible into the following sets (Fig. 7):

A. The chiefly thick-bedded, grey wackestones/packstones with rare fine-grained and laminated-fenestral partings, sporadic coquinas, and several *Amphipora* and/or *Stachyodes* biostromal beds; the latter are most markedly developed in the topmost portion (unit A_2). The set represents the higher *Stringocephalus* Beds.
B. Thin-bedded, grey mudstones/wackestones with irregular argillaceous interbeds, rich in brachiopods, gastropods, and locally in crinoid detritus. Stratotype of the Jaźwica Member (Fig. 14).
C. *Hexagonaria*-biostrome, up to 1 m thick, comprising also numerous varied stromatoporoids and alveolitids (Fig. 18C), with thin marly intercalations.

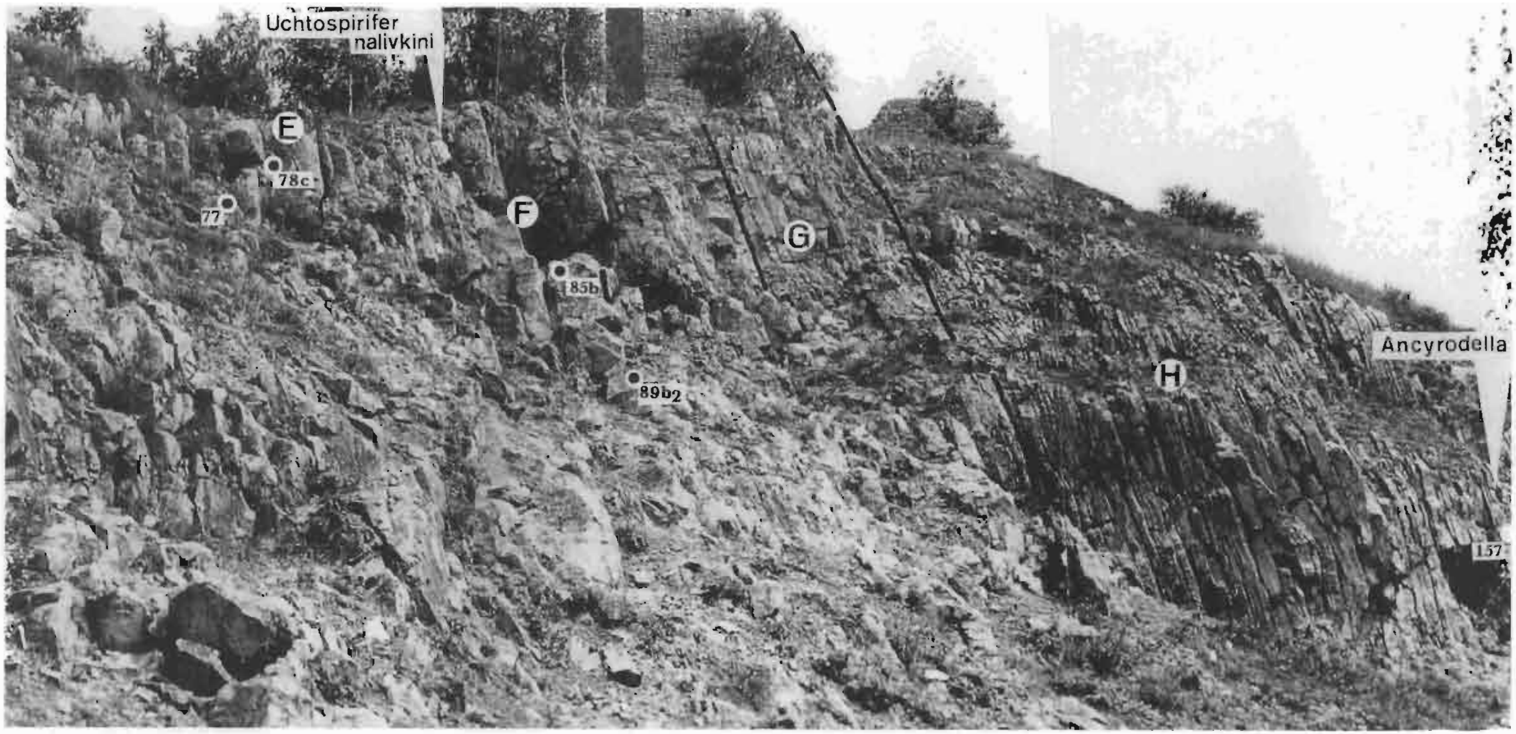


Fig. 5. Southern part of the western quarry on the Góra Zamkowa at Chęciny, with exposed middle fragment of the Chęciny Beds corresponding to the Givetian to Frasnian transition. E-H - lithologic sets (see Fig. 7). Numbers refer to selected conodont samples (see Tab. 1 for conodont frequency and distribution); most important biostratigraphic markers are pointed. The Middle-Late Devonian boundary is located somewhere within sets F-G.

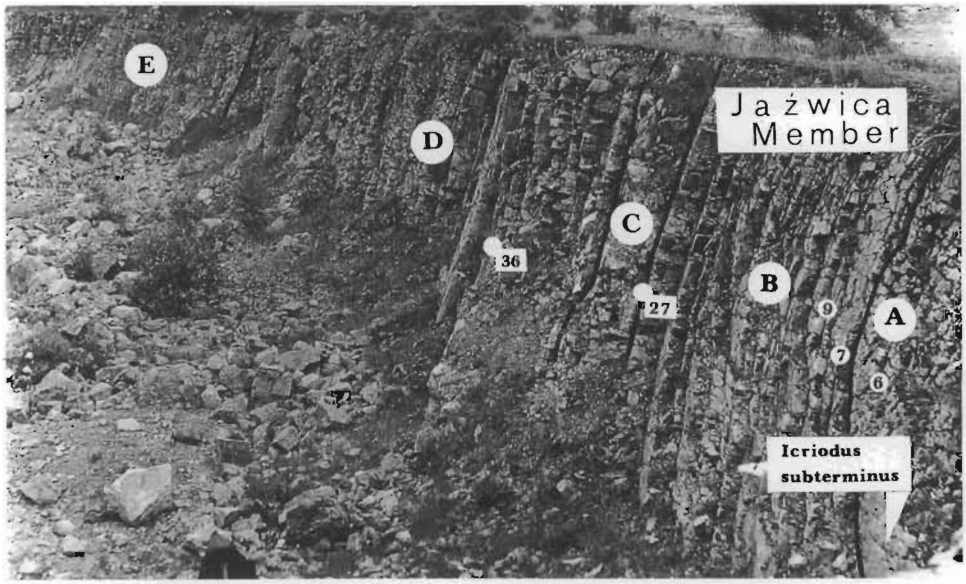


Fig. 6. Fragments of southern wall of the western Jaźwica Quarry near Bolechowice in 1979 showing lower part of the succession (sets A-E; Fig. 7). Numbers refer to selected conodont samples (Tab. 3).

D. *Stachyodes* and/or *Disphyllum* biostromes, locally replaced by stromatoporoid bindstones (Fig. 18D).
E. Dark *Amphipora* bafflestones/floatstones regularly interstratified with thin fenestral laminites and sporadic detrital partings.
F. Thick beds of stromatoporoid boundstones (bindstones/bafflestones) with interbeds of crinoid-rich packstones/grainstones (Fig. 27).
G. Amphiporid-fenestral rhythmic succession similar to the set E, but lighter, more grainy, and covered in the middle part.
H. Poorly-layered stromatoporoid limestones (intergrading floatstone/boundstone and rudstone) of a reefoid type (*sensu* Laevitt 1968; see also Racki 1985a). A stratified grainstone intercalation, up to 0.5 m thick, occurs there (Fig. 21C).
I. Stromatoporoid bindstones containing several rudstone and finer-grained partings, with a *Hexagonaria*-bearing bed at the bottom.
J. Stromatoporoid-coral bindstones with brachiopods, crinoids, bivalves, and trilobites. The set belongs to the Kadzielnia Member (Szulczewski & Racki 1981), and is widespread along the crest of the Góra Łgawa, east of the quarry.
K. Alveolitid-rich, coral-stromatoporoid biostromes. The mostly dark-colored strata are slightly wavy-bedded, and contain large micritic clasts and gastropod conchs in some of the topmost layers. The spatial relationships between sets I, J and K remain somewhat unclear, but their lateral passages are probable, as suggested by similarities to the Kowala sections (Szulczewski & Racki 1981).
L. Reddish-brown, marly-nodular deposits followed and/or laterally replaced by well-bedded brachiopod-bearing mudstones/wackestones with rare burrowed partings (Fig. 24). The Middle Frasnian set represents the *Phlogoiderhynchus* Level and is overlain by the thick Detrital Beds (see Fig. 8B).

Zelejowa hill, west of the Jaźwica locality, is built of the Sitkówka Beds. The lower, bedded portions of the unit are well exposed in their topmost part only (stromatoporoid-rich, cherty bedded floatstones). These, and higher poorly stratified stromatoporoid strata are visible in the western

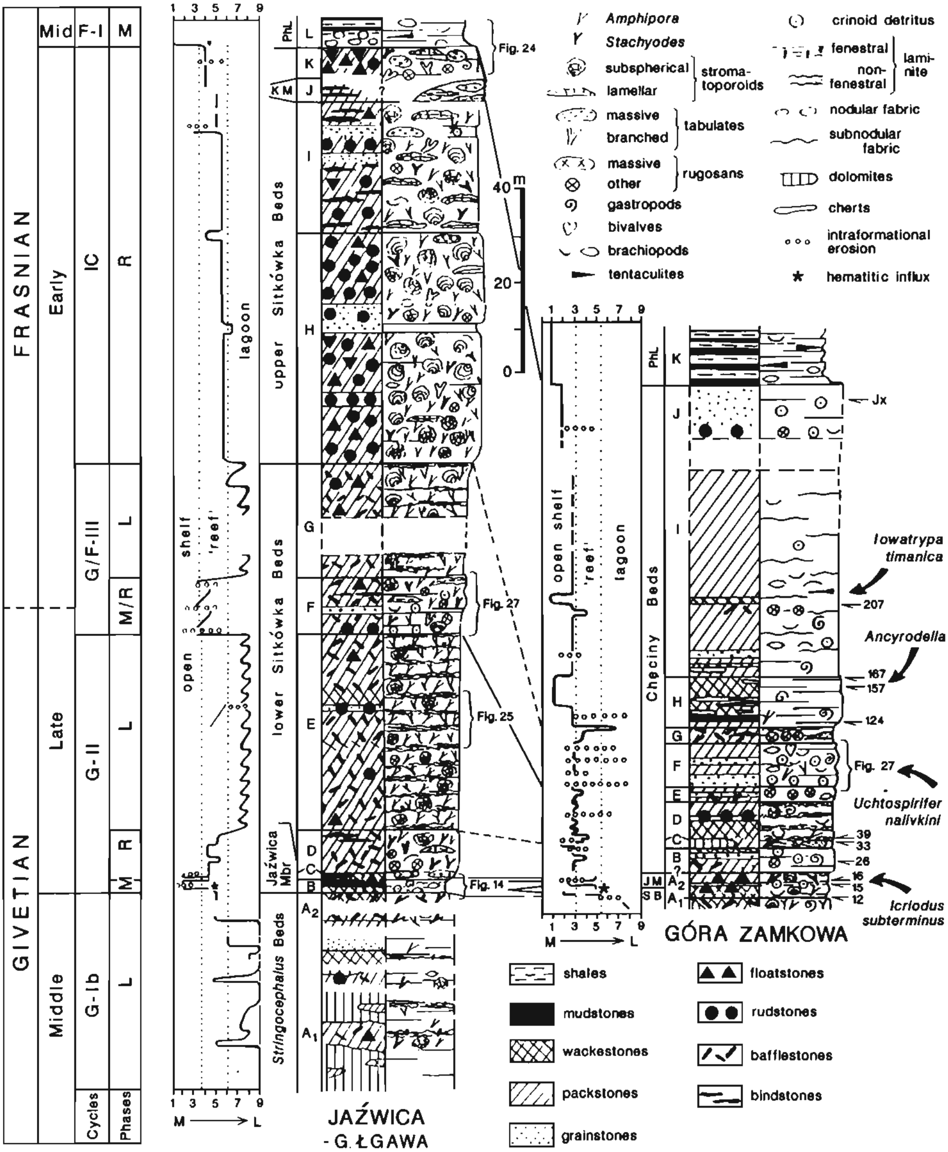


Fig. 7. Columnar composite sections of the Jaźwica-Góra Łgawa and Góra Zamkowa as key for different-scale depositional cyclicity and their correlative potentials around the Givetian-Frasnian boundary. Intra-cycle sedimentary phases (M – open marine, R – 'reef', L – lagoonal) and a nine-step relative transgression-regression scale ranging from the Facies M-5 to Facies L-4 adopted from Racki (1985b: Fig. 2). Numbers refer to conodont samples (Tabs 1, 3). SB – *Stringocephalus* Beds, JM – Jaźwica Mbr., PhL – *Phlogoiderhynchus* Level, KM – Kadzielnia Mbr. Matrix type is presented for 'reef' deposits.

quarry. They are replaced in the sequence by light, alveolitid-stromatoporoid deposits which in some parts resemble the Kadzielnia Member.

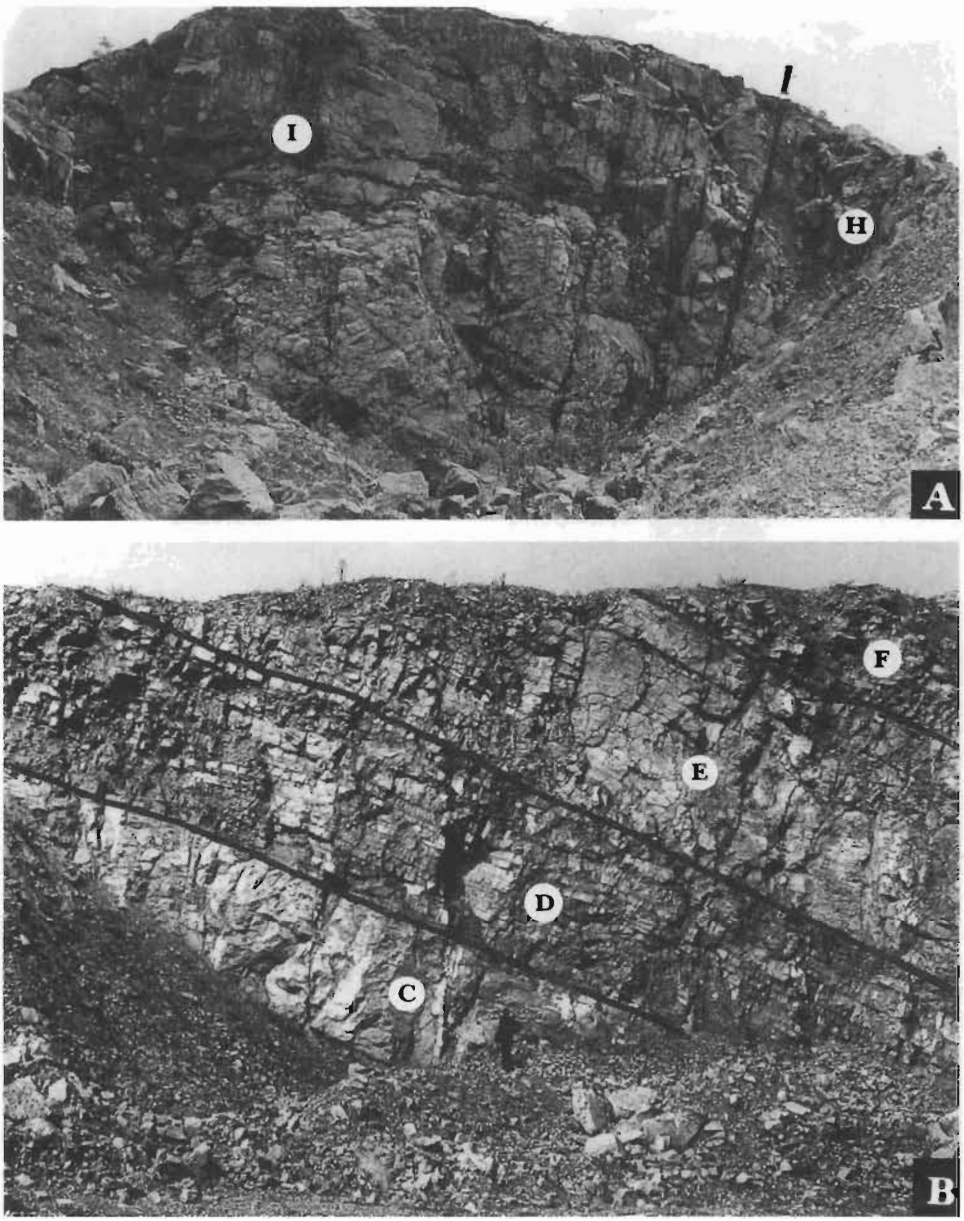


Fig. 8. ❑A. Northern part of the western Jaźwica Quarry in 1979 with visible upper part of the Kowala Formation (sets H-I; Fig. 7). ❑B. Part of the western wall of the Kowala Quarry in 1980, with exposed early Frasnian strata (sets C-E; Fig. 36) that include the transgressive *Phlogoiderhynchus* Marly Level (set D).

The lower part of the series exposed in Jaźwica continues in the east, and the equivalents of sets A-D occur on Sołtysia Góra (Czermiński 1960: Tab. 86; Kaźmierczak 1971b: Fig. 4). The Givetian saccharoidal dolomite,

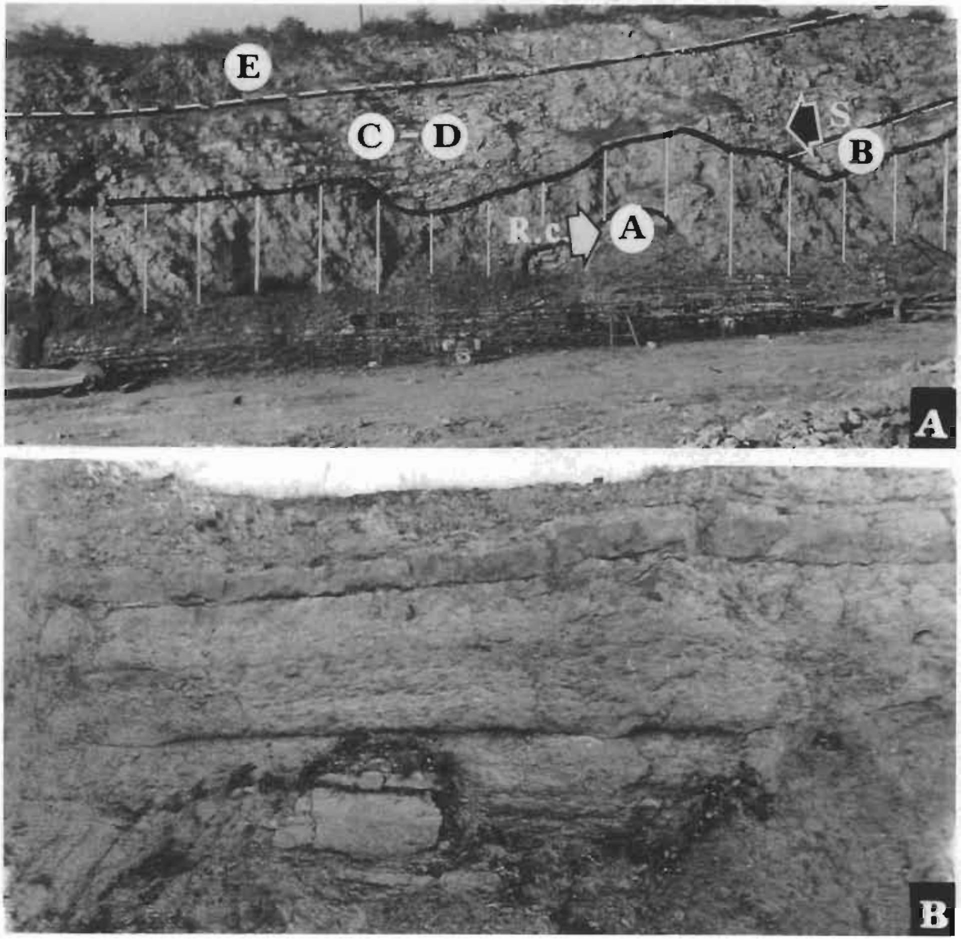


Fig. 9. Jurkowice-Budy Quarry, an outcrop of the lower *Stringocephalus* Beds (A-E - lithologic sets; Fig. 10). ❑A. Southern wall of the western exposure, showing basal part of the Kowala Formation (see also Narkiewicz 1991: Pl. 3); arrowed are levels of entry of *Rensselandia* (R.C.) and *Stringocephalus* (S), dolomitized parts are shown by vertical lines. ❑B. Fragment of the northern wall of the western outcrop; there is a strongly weathered reefoid set E, the main source of abundant fossil collection in the site.

containing several biostromal sets ('*Amphipora*'-dolomites) is quarried in the nearby Radkowice Quarry.

Jurkowice-Budy

The well-known active Jurkowice-Budy Quarry of the *Stringocephalus* Beds (Fig. 9) is the southeastern most extreme of the Devonian in the Holy Cross Mountains (Pajchlowa & Stasińska 1965; Kaźmierczak 1971b; Baliński 1973; Narkiewicz 1981, 1991; Preat & Racki in press).

The most accessible is the southern wall of the abandoned western part of this exposure, where above the fine- and crypto-crystalline dolomitic

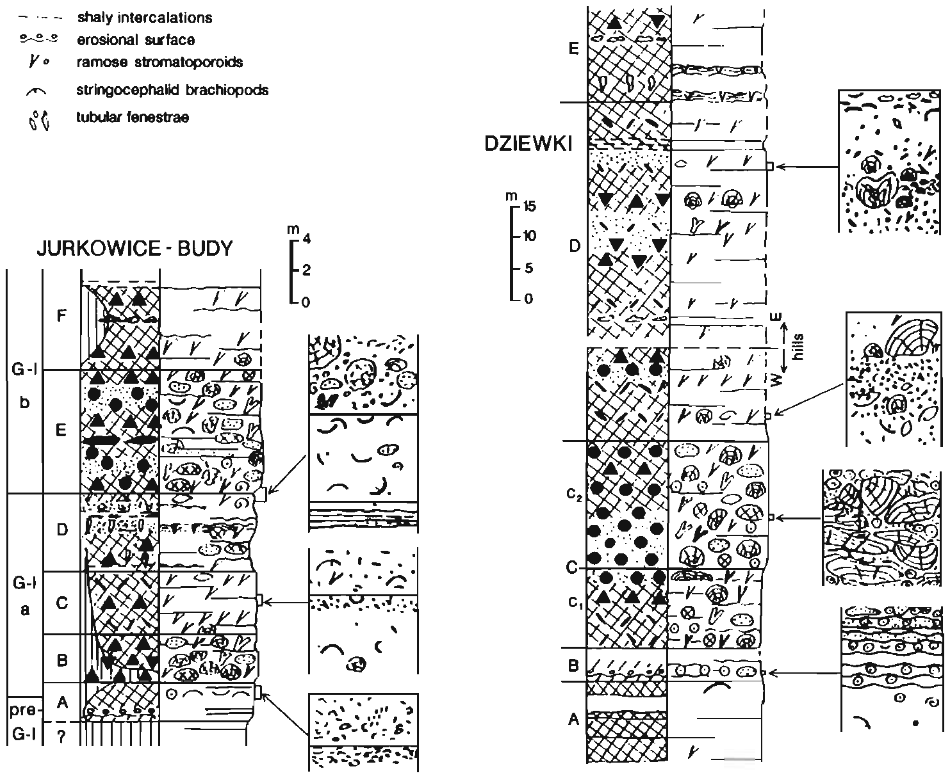


Fig. 10. Columnar sections of the Jurkowice-Budy Quarry to show sequences of the *Stringocephalus* Beds and two steps in the facies development referred to the subcycles G-Ia and G-Ib, and comparative sequence of the Dziewki Limestone from the hill near Siewierz. For others explanations see Fig. 7.

complex with marly interbeds, selectively and irregularly dolomitized grey layered limestones are visible. The following sets can be distinquished (Fig. 10):

A. Unfossiliferous wackestones/packstones with two coquinite brachiopod levels containing also numerous diminutive crinoid columnals and singular orthocone nautiloids. This set has been identified only in one non-dolomitized 'island'.

B. Thick- to poorly-stratified coral-stromatoporoid floatstones, with diverse assemblage of growth forms.

C. Thick-bedded amphiporid bafflestones interlayered with macrofossil-poor wackestones, *Stringocephalus*-bearing in places.

D. Dark-colored micritic complex with rare reef-builders, mainly massive corals, and stringocephalids. Several beds are marked by extensive burrows, varied fenestral fabric, scour-and-fill structures, and grainy-laminated and nodular-marly intercalations. Furthermore, a rapidly wedging coral-rich biostromal level was temporarily visible on the northern wall of this quarry.

E. Variably stratified floatstone/rudstone set containing abundant fossil assemblages, including diverse stromatoporoids and corals, brachiopods, gastropods, and rarer crinoid, sponge and trilobite remains. The strata occur also in the northern wall, and due to delicate weathering they are a rich source of perfectly preserved fossils (cf. Baliński 1973).

The overlying thick-bedded deposits (set F) are exposed in the mined eastern part and are characterized by biostromal, mostly amphiporid bafflestone beds alternating with fossil-poor micrite layers and sporadic cherrish, argillaceous horizons.

Facies-ecologic development and different-scale cyclicity

The carbonate sediments of the Kowala Formation are typical of the Devonian tropical realm (Heckel & Witzke 1988). The corresponding segment of the Devonian transgressive sequence was a period of shallow-water, intense biogenic deposition over the middle of a vast offshore carbonate shelf. The Givetian bank-type and Frasnian reef sedimentary systems were basically different as pointed out already by Szulczewski (1971: p. 112) and Narkiewicz & Racki (1987). This differentiation agrees with similar two-step succession in other Middle to Late Devonian carbonate platforms of the World (Klovan 1974; Krebs 1974; Wilson 1975; Hladil 1986, 1988; Tsien 1988; Playford *et al.* 1989), and corresponds to the aggraded and incipiently drowned shelf (cf. Read 1985), respectively. Therefore, the Kowala Formation can be subdivided into these two depositional phases, and further into shallowing-upward cycles.

The Kowala Formation includes three or four major asymmetric cycles (Racki 1985b) G-I to G/F-III for the Givetian bank phase, and F-I for the early Frasnian reef interval. In addition, a transitional inter-cycle unit, IC-Complex, has been distinguished (Racki 1986a) for bank-to-reef passage strata. The relatively well known (Narkiewicz 1988; Szulczewski 1989; Racki 1990) later reef growth stage, grossly labelled as the cycle F-II, is out of the scope of this paper.

The strictly rhythmic pattern of the cycle G-II is apparent in the lower part of the Jaźwica section (sets B-E; Fig. 7), which may serve as reference for following interpretations. The sequence there includes in ascending order: (1) micritic-marly set with abundant open-marine fauna, (2) biostromes built of massive corals followed by disphyllid or *Stachyodes* bafflestones, and finally by stromatoporoid floatstones, (3) rhythmic amphiporid-laminite complex. The section reveals an aggraded transitions from subtidal, open shelf environments to an extensive tidal-flat complex after a rapid sea-level rise drowning some portions of the shelf by submergence below the photic zone.

The superficially uniform series exhibit a great internal microfacies variation, and the similar lithologic types, as well as some principal macrobenthic assemblages (Figs 12, 16, 22), occur in different time intervals. The discussion presented below focus on the rock varietes with abundant fossils of open-marine organisms; organic buildups and restricted shelf deposits are grouped in cosmopolitan types, according mainly to their pattern of bio-construction (see Figs 11-13, 16-18, 20-23; see review and code in the 'Facies types account' on p. 180). Detailed data

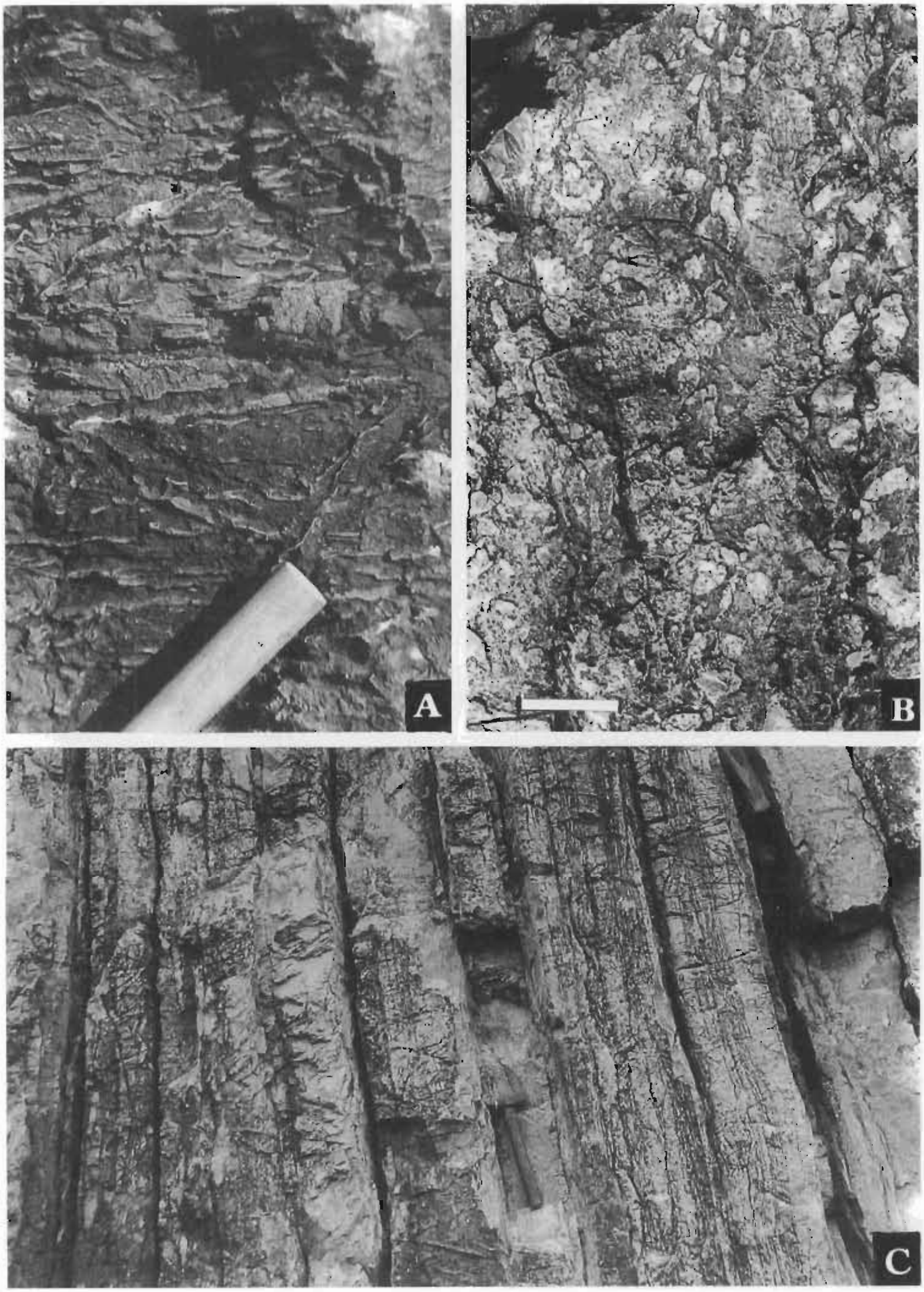


Fig. 11. Different bedding styles in the Kowala Formation. ❑A. Massive stromatoporoid bindstone, Facies R-3b; Kadzielnia, set A. ❑B. Nodular appearance of the Atrypid-Crinoid Level (unit F-IIa; Fig. 29); Góra Zamkowa, western quarry; bar scale 5 cm. ❑C. Platy, laminated spiculitic calcilutites with cherts and shaly interlayers, Facies M-4; Góra Zamkowa, set H.

on most paleoecologically significant groups of fossils is presented in following papers of the volume, and a supplementary comment is limited to the minor, poorly-known groups, including conodonts.

Sedimentation and biotic environment during the platform phase

In the Holy Cross Mountains part of the Laurasian carbonate shelf, there is a notable uniformity in the facies development of the oldest members of the Kowala Formation, despite of fragmentary outcrop data and obscuring effects of secondary dolomitization. Narkiewicz (1991) was able to trace the three units of the succession across the whole region. The stromatoporoid-coral platform stage is subdivided, after Burchette (1980), into poorly differentiated spatially *Stringocephalus* bank (or platform *sensu* Cook 1972) represented in the *Stringocephalus* Beds, and more laterally variable Sitkówka bank (or biostromal) complex of the lower Sitkówka and Chęciny Beds (Figs 12, 16). Kaźmierczak (1971a) invoked facies mosaic model for the whole succession, but it seems applicable only to lagoonal and back-reef portions of the *Stringocephalus* and Sitkówka Beds.

***Stringocephalus* Bank** (cycle G-I).– This segment of the sequence comprises deposits in between the sabkha-type cyclic strata and the Jaźwica Member (viz. unit II of Narkiewicz 1991). The middle part of the succession, with up to 35 m thick biostromal set (unit IIB), is particularly significant for correlation. In unaltered sections the sequence shows a predominance of the micritic Facies L-4 with scattered amphiporid (Facies L-3b) and stromatoporoid-coral patches (Facies R-3f) composed of parautochthonous diverse assemblages (Pajchlowa & Stasińska 1965; Kaźmierczak 1971b); argillaceous and/or subnodular intercalations are found in some sections (Ołowianka, set A; Jurkowice-Budy, sets D, F). Such rocks occur also in the Upper Silesian Upland (Racki *et al.* in press b), and possibly in the Dębnik Anticline near Cracow (Siedlec Limestone; Nowiński 1976: Fig. 4A; Narkiewicz & Racki 1984).

Scarce representation of open shelf deposits in the cycle G-I results in arbitrary definition of this variable but probably regressive unit. The basal part of the *Stringocephalus* Beds, well exposed at Jurkowice-Budy, exhibits two-step developmental pattern (Fig. 10). The first unit (G-Ia), comprising the lithologic sets A to D, reveals a consequently shallowing-upward passage from a thin, brachiopod-crinoid horizon through varied biostromes to lagoonal-peritidal cyclic mud sequence (Preat & Racki in press). The succeeding sets E-F document a reapperance of biostromal growth, and their gradual replacement by a restricted lagoon deposition with *Amphipora*-meadow and tidal flat mosaics. Weak open marine influences, indicated by diverse bioclasts (with crinoid debris), are recognizable in some detrital basal interlayers of the set E, as well as in the set B of Ołowianka.

In the western Holy Cross Mountains, the partly dolomitized Ambocoeliid Limestone Level, with common laminated-fenestral (see Fig. 20C) and brecciated deposits (unit IIE of Narkiewicz 1991), may represent a regressive portion of the upper subcycle G-Ib. It is included in the *Stringocephalus* Beds, although occurs above the poorly-known and possibly diachronous range of the nominal terebratulid *Stringocephalus*, corresponding thus to the 2nd Brachiopod Interval of Racki (1993). The micritic-biostromal strata are marked by the occurrence of shelly, brachiopod-gastropod intercalations, *Stachyodes*-dominated boundstones and wavy-bedding, related to increasing upward argillaceous admixture (e.g. Jaźwica-Góra Łgawa, Bilcza). A thick biostromal set with thamnoporids, atrypids, and crinoid-bearing intercalations (unit IIB of Narkiewicz 1991) is a proposed equivalent of the younger reefoid strata from Jurkowice-Budy. The Janczyce I borehole section (units IIC-D of Narkiewicz 1991) is thus a more differentiated and marly variant of the regressive segment of the succession.

The initially quite speculative cyclic framework for the the Holy Cross region finds now support in the clearly regressive facies succession in the Dziewki Limestone in the Silesia region (Racki *et al* in press b), even if general temporal relations between calcareous and dolomitic sedimentation remain still unclear in the more external shelf belt. Remarkably, there are two open marine episodes, interrupting the reefoid-lagoonal sequence: the older deepening (unit II of Racki *et al.* in press b) seems to correspond to the event initiating subcycle G-Ia. The most intense stromatoporoid-coral accretion (set C, Fig. 10) was preceded by subtidal mud deposition with thriving of sponge-crinoid biota (Straszak 1986) and it may record the transgressive input of the subcycle G-Ib.

It appears that the Givetian restricted shelf facies reveal some lateral continuity across southern Poland. The *Stringocephalus*-bearing strata can be compared with the coeval Schwelm facies of the Rhenish Slate Mountains (Krebs 1974; Burchette 1981) considered to represent extensive, sheet-like bodies comprising tiered biostromes and lagoonal-peritidal deposits. They were originated within vast shelf lagoon, with low-relief inner organic buildups coalescing in extensive irregular marginal bars (Fig. 21). Open marine influences developed more distinctly in the peripheral shelf band (Siewierz area).

In the vast platform biotopes peculiar communities flourished marked by abundant, both skeletal and non-skeletal microbiota, mostly calcispheres and other parathuramminid 'unilocular foraminifera' (calcispheroids *sensu* Racki & Soboń-Podgórska 1993), but also many enigmatic chlorophytes (*Jansaella, Devonoscale*) and other algae, ostracods, and soft-bodied benthos (Preat & Racki in press). The communities probably record specific high stress environments due to abnormal salinity (?oligohalinity; see summary in Racki 1986a), eutrophy, and high calcium content (Kaźmierczak *et al.* 1985).

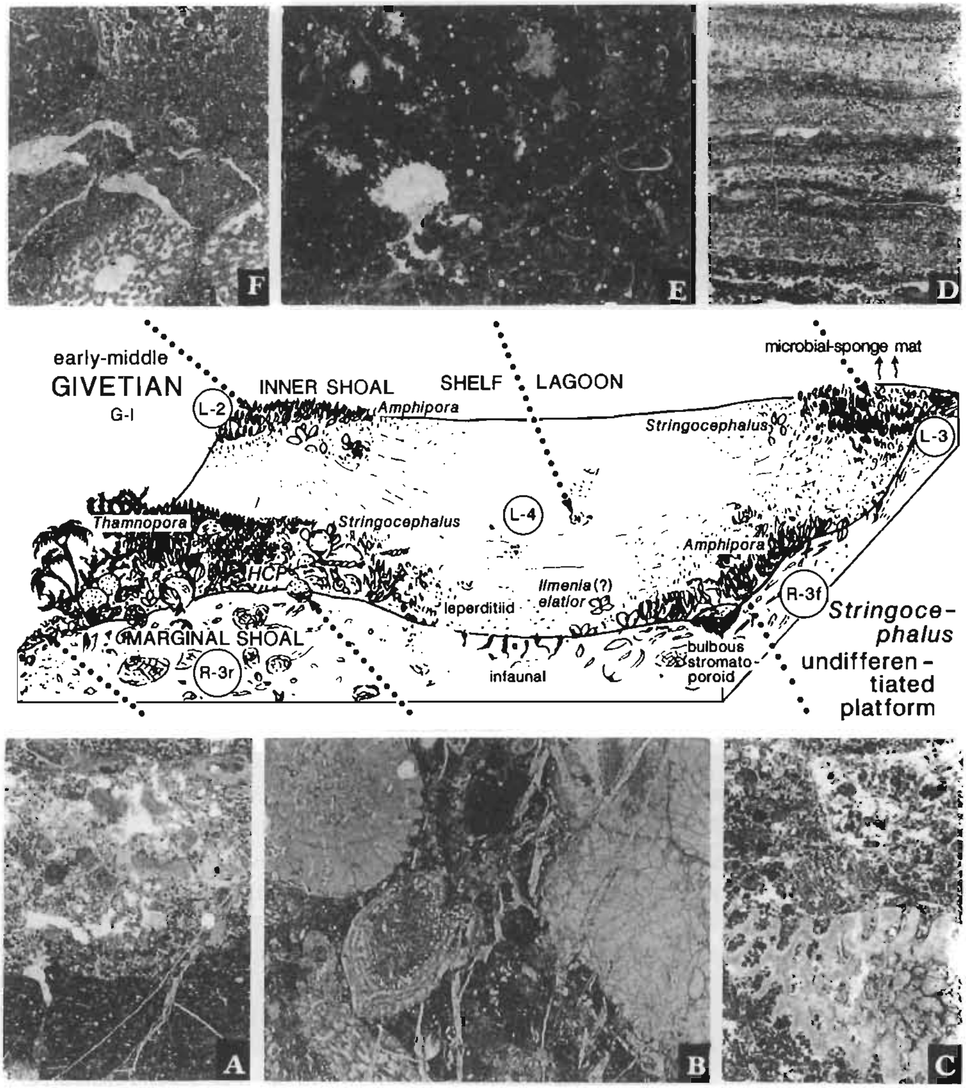


Fig. 12. Main macrobenthic assemblages (HCP – *Hermatostroma-Caliapora-?Pseudohexagonaria*), facies types (in circles) and characteristic microfacies (A-F) of the Givetian *Stringocephalus* biostromal bank (cf. Racki 1988: Fig. 4). ❑A. Unsorted crinoid grainstone with small intraclasts overlying spiculite wackestone, Facies M-2 and M-4; Siewierz, set B. ❑B. Stromatoporoid-coral rudstone; Sowie Górki, set B. ❑C. Coral-bearing packstone/grainstone with many calcispheroids, and varied micritic grains, Facies L-4/L-1; Bilcza-2, set A. ❑D. Fenestral 'cryptalgal' laminite exhibiting micrograding in some grainy laminae; Bilcza-3, set A. ❑E. Bioturbated ostracod-calcispheroid wackestone; Jurkowice-Budy, set F. ❑F. *Amphipora* bafflestone, note a pellet-filled burrow in the upper part; Olowianka, set D. All ca. × 5.

The most characteristic is the *Stringocephalus* Assemblage (typical locality Jurkowice-Budy, set C). These biota of giant terebratulid typified both calm, and subturbulent lagoonal to peri-biostromal habitats (Racki 1986a).

Infaunal Assemblage (typical locality Jurkowice-Budy, set D) comprises lagoonal mud biota composed of soft-bodied deposit-feeders, some ostracods and localized algal baffles and mats.

Leperditiid Assemblage (typical locality Sowie Górki, set A) resembles the preceding community, but differs in abundance of large eurytopic ostracodes which seems to indicate more restrictive, extremely shallowing conditions, possibly even periods od subaerial exposure (Krebs 1974).

Ilmenia(?) *elatior* Assemblage (typical locality Bilcza, set A) refers to brachiopod banks widespread within occassionally agitated lagoonal portions typical of the late regressive phase (Racki 1986a). Eurytopic euomphalid gastropods (Karczewski 1989) played the main role in the gastropod-dominated faunas of the time interval (*Straparollus* Assemblage; typical locality Góra Zamkowa, set A_1). These probably immobile suspension-feeders occur in several habitats, including microbial mats. Ambocoeliid brachiopods, ostracods and soft-bodied mud-ingesting infaunal organisms were most common associated organisms. Only singular bryozoans, like ramose trepostome *Atactotoechus* (identified by Dr M. Kiepura) at Sowie Górki represents an open marine element in the biota group.

Amphipora Assemblage (typical localities Jurkowice-Budy, set C, and Jaworznia; see also Gogolczyk 1956) is a worldwide Devonian community type of extensive, dense stromatoporoid meadows over the extremely shallow, frequently less than 1 m (Read 1973) lagoon floor. Apart of the twig-like amphiporid colonies, some gastropods, algal-sponge(?) associations and ostracods thrive here. The organisms probably acted as sediment baffles, enhancing deposition of fine particulate detritus in sheltered areas (Jamieson 1971; Krebs 1974; Wilson 1975). There are passages into the *Stachyodes* Assemblage (typical locality Jaźwica, set A), that includes biostromes composed almost entirely of stick-like colonies of *Stachyodes* (Gogolczyk 1959), with a minor contribution from other stromatoporoids, dendroid and solitary corals, and rare shelly inhabitants (gastropods, ambocoeliid brachiopods, ostracods). The irregularly dendroid, stubby stromatoporoid forms had rather wide bathymetric distribution, and probably dwelt in semiprotected habitats from middle slope to broad periphery belt of biogenic shoals being only locally subjects of severe hydrodynamic reworking (Laevitt 1968; Read 1973; Krebs 1974; Playford 1980).

Inner mounds and patch reefs were populated by the Bulbous Stromatoporoid Assemblage (typical locality Bilcza, set A), the concentrations of nodular stromatoporoid colonies that were presumedly unattached and frequently overturned during growth (Jamieson 1971: p. 1330). Particular skeletons are not in mutual contact and there is no constant tendency to form rigid frames in quiescent mud-rich habitats (Krebs 1974: p. 175; Tsien 1980). Episodic mild increases in energy level resulted in reorientation of stromatoporoid coenostea. The buildups record reef patches arrested in growth in inhospitable restricted marine environments (cf. Copper 1988). In addition to stromatoporoids, some shelly faunas (ambocoeliid brachiopods, gastropods) developed locally.

Hermatostroma-Caliapora-?Psudohexagonaria (HCP) Assemblage (typical locality Jurkowice-Budy, set E) corresponds to the buildup variety that was more or less affected by wave and current action in some exposed places (Kaźmierczak 1971b; Racki *et al.* in press b; Preat & Racki in press). Its bank-marginal nature is expressed in high diversity of the main builders. These were frequently intergrowing domal, bulbous and dendroid stromatoporoids (like *Stachyodes*), and various corals and microbial mats. Diverse dwellers include brachiopods, murchisoniid gastropods, crinoids, octactinellid sponges, trepostome bryozoans, many problematic algae, homoctenid tentaculites and dechenellid trilobites (Baliński 1973), as well as numerous ostracods (Olempska 1979).

Thamnopora Assemblage (typical locality Rzepka, unit IIB of Narkiewicz 1991) occurs in biostromal interbeds and packets within several reefoid sequences (Ołowianka, set B), but is also known as separate sets, up to 10 m thick. Finger-like colonies were tolerant of considerable biotope variations (Jamieson 1971: p. 1333), but dominated only in protected and/or slightly deeper portions of the bank to slope transition zone. The growth form is interpreted to prevent smothering by a mud suspended in water (Wilson 1975: p. 143). *Spinatrypina* is the most common dweller of the meadows. Open marine flank biota were not established in the Kielce Region, with possible exception of a fauna with rensselandiid brachiopods (Racki 1993).

Sitkówka Bank Complex (cycles G-II - G/F-III).– The inundation recorded in the Jaźwica Member initiated selective drowning of the flat topped biostromal bank and it was a turning point in the evolution of the Kielce platform. The beginning of the basal marker unit is evidenced by rather abrupt (within 0.4 to 1.5 m) replacement of biostromal strata by thin-bedded micritic/marly deposits with shelly faunas and crinoid debris. The most fossil-rich, largely basal part of the transgressive horizon, as well as underlying *Stachyodes* biostromes, in thin succession (Jaźwica, ?Stokówka) are red-cherrish stained due to high content of residual ferric material, and contain black-pigmented grains, as well as ferruginized clasts (Fig. 13E). This suggests locally reduced rates of deposition and reworking by an initial lag phase of transgression (Schlager 1989; Van Steenwinkel 1990).

The lithofacies of the Jaźwica Member are laterally subdivided into two variants (Figs 14, 15D):

(1) Bolechowice facies. Thin, but irregularly bedded (with layers up to 10 cm thick) successions marked by rock types ranging from homogenous micrite undulose layers with 1-2 cm thick shaly intercalations (see also Racki 1993: Fig. 31) up to differently isolated nodules surrounded during marly matrix. The latter is marked by clay seams, microstylolites and fossils crushed by compaction of the sediments (stylonodular fabric), and originally a dark grey to black coloration owing to bitumen as evidences by the Kowala-1 borehole section (Romanek & Rup 1990). Bafflestone intercalations, chiefly with *Stachyodes*, and dolomitized laminated beds

occur too. Largely non-micritized shelly and echinoderm material is arranged in swirly pattern within bioturbated skeletal concentrations (Fig. 13D-E). This kind of succession, up to 12.5 m thick, characterized central and southern parts of the area studied, extending from the Miedzianka area to Szczecno 1 drilling.

Tenticospirifer Limestone Level is treated as a broad equivalent of the Jaźwica Member in the eastern Holy Cross Mountains. This is a peculiar nodular-micritic set within the Givetian succession of Łagów (see Narkiewicz 1991) containing open-marine fossils like cyrtospiriferid brachiopods and crinoids (Racki 1993: Fig. 30; Głuchowski 1993).

(2) Posłowice facies. This facies variant from the more north-eastern area is distinguished by medium-layered, fossiliferous calcilutites and calcarenites, mainly echinoderm-spiculite wackestones and packstones (Figs 16C, 17C; Racki & Racka 1981), but containing calcispheroids and other microproblematica in some lowest beds. They include also shell- and crinoid-enriched partings, and sporadic thicker argillaceous beds, as well as interstratified biostromal horizons dominated by rugosan bafflestones. Such a succession is known solely from the Posłowice hill, while the Marzysz site reveals several differences like higher clay content in lower exposed part, and abundant rock-building corals. Some bioclastic grainstone partings in the Szczecno 1 section point its intermediate position between the both main facies domain.

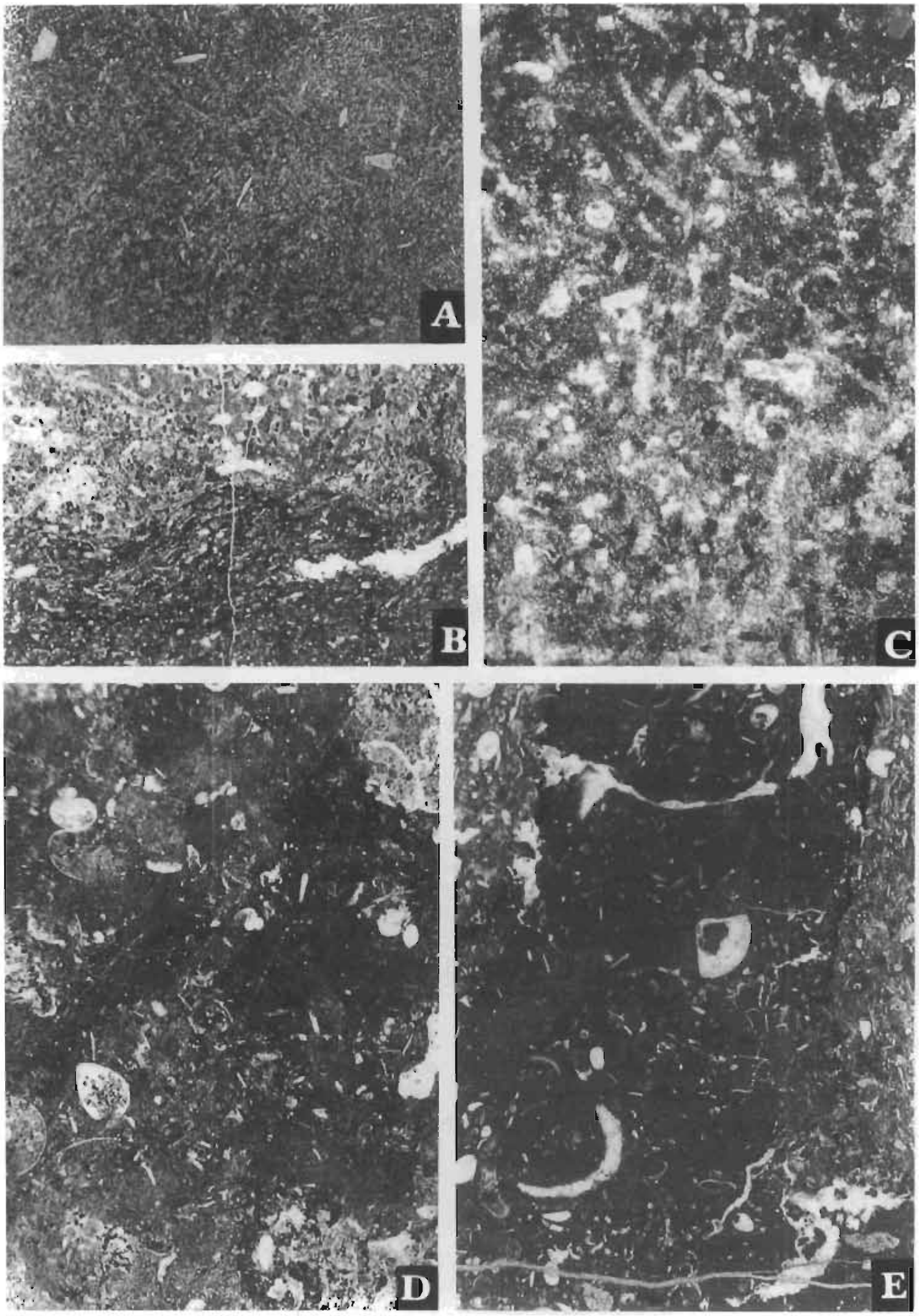
The Crinoid-Coral Limestone Level of Sowie Górki (set C) is developed in the thick-bedded coarse-grained strata that possibly exceeds 10 m in thickness. Only one micrite-shaly couplet of the Bolechowice facies, 0.3 m thick, was found here, and the fossiliferous succession consists of unsorted coral-stromatoporoid rudstones and floatstones (locally oncoidal; Fig. 17D), with crinoid-bearing intercalations varying from intraformational breccia to wackestone partings. Unfortunately, poor exposures do not allow precise estimation of the lithologies relationship.

Dark to reddish *Stachyodes* biostromes, enriched in corals and/or crinoid-shelly material, are regarded as possible biostromal-intershoal equivalent of the Jaźwica Member in the Zbrza area (set B) and maybe also in Kozi Grzbiet near Miedzianka.

The micrite-bioclastic Bolechowice facies (M-3) was formed in open shelf depression with prolific normal-salinity benthos thriving largely below the wave base. Mostly soft-bodied infaunal activity resulted in extensive skeletal fragment jumbling and homogenization. The Posłowice

---

Fig. 13. Varieties of open shelf and intershoal microfacies of the Kowala Formation. ❑A. Burrowed spicule-rich wackestone-packstone, Facies M-4; Kawczyn, set D, × 5. ❑B. Boundary between cemented nodule (neomorphozed peloidal-bioclastic packstone with *Amphipora*) and compacted (dark) internodular portion (stylonodular fabric), Facies M-6; Góra Zamkowa, set F, × 7. ❑C. Spiculitic packstone of the Facies M-4; Góra Zamkowa, set H, × 40. ❑D. Shelly wackestone with severe bioturbation, Facies M-3; Jaźwica, set B, × 7. ❑E. Intraclast of shelly wackestone, with pyritized rim, enclosed in crinoid packstone, Facies M-3; Góra Zamkowa, set A_2, × 5.


A
B
C
D
E

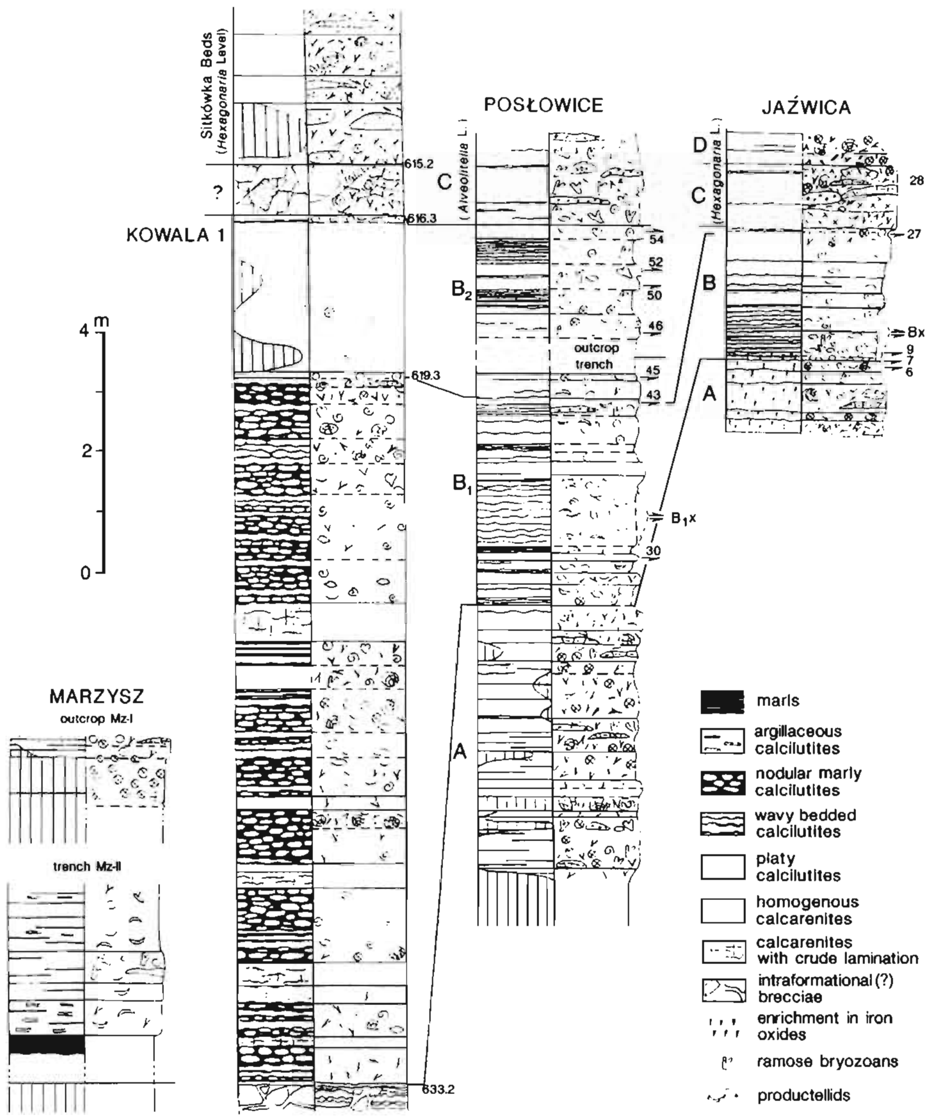


Fig. 14. Most important sections of the Jaźwica Member to show lateral variation in sedimentary record of the Late Givetian flooding (cycle G-II), and subdivision into the Posłowice and Bolechowice facies (Fig. 15D). For other explanations see Fig. 7. Only matrix type is presented for biostromal beds.

facies exhibits more variable hydrodynamic regimes and substrates probably partly related to gently inclined (ramp-style) concave-upward slope settings (cf. Kenter 1990). This is suggested also by increasing frequency of biostromal beds and lagoon-derived bioclasts in the north-eastern area. Some skeletal accumulations may represent burrowed distal tempestite varietes developed in mud blanketing events (cf. model of Miller *et al.* 1988:

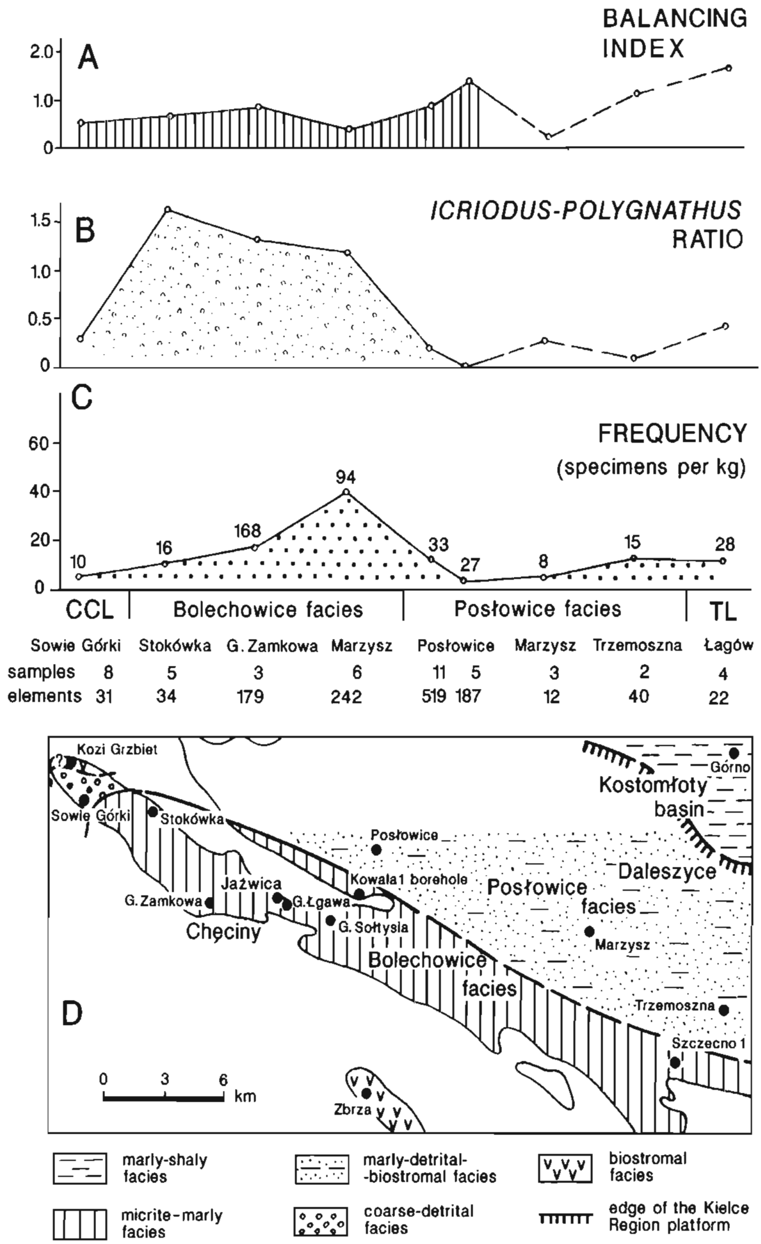


Fig. 15. Spatial gradients in paleoecologically significant indices characterizing conodont faunas of the Late Givetian Jaźwica Member (A-C; in C median values are plotted and maximum numbers given above) and paleogeography of the area during its sedimentation (D). Note that the assemblages show effects of synsedimentary selective transport as indicated by the overrepresentation of platform *versus* ramiform elements (balancing index; BI). For the common polygnathids the ratio is essentially below 1 while the original index value was about 7.5 (Nicoll 1985). Also acodinian cones were discovered sparingly as compared to icriodiontid elements. TL – Tenticospirifer Level, CCL – Crinoid-Coral Level.

Seilacher & Aigner 1991). Very fine grained disseminated pyrite suggests euxinic conditions near to the organic-rich mud-water interface, in generally exaerobic regime (cf. Brett *et al.* 1991). The bedding rhythms, manifested in variable nodular fabrics, record a combination of many post-depositional processes, mainly pressure solution and compaction (common in transgressive sets, Heckel 1983) related to episodic subseafloor cementation of the argillaceous-carbonate muds (Bathurst 1991).

Biotic differentiation between the main facies types is well documented (e.g. Malec & Racki 1993; Racki 1993). The diverse benthic biota of the Bolechowice facies, *Crurispina*-microcornid Assemblage, thrived on instable, muddy substrata which is expressed in a minute, thin-valved character of the shelly faunas, with abundant sessile suspension-feeders including index ambocoeliid brachiopods, microcornids ('spirorbids'; identified as *Semitubina* by Karczewski 1989), demosponges, crinoids and bryozoans. They associated with vagile epifauna (differentiated eleutherozoans including echinoids, holothurians, asterozoans and ophiocystoids, euomphalid gastropods, tentaculites, platycopid and palaeocopid ostracods), and infauna, mostly deposit-feeders and scavengers. Presence of filamentous cyanobacteria *Girvanella* and rhipidistian-bradyodont(?) fish association is remarkable, as well as the find of elsewhere sporadic cyclocystoids (Boczarowski in preparation). The assemblage is typified of the postmortem reworked icriodontid-polygnathid conodont biofacies (*Icriodus subterminus* fauna; Tab. 3; Figs 15A-C, 28). Some conodont faunas may represent a peculiar, icriodontid-dominated variety of the 'innermost' pandorinellinid biofacies (cf. Sandberg *et al.* 1989: p. 201). The low-relief bryozoan thickets constitute delicate tubular colonies, both trepostomes (?*Anomalotoechus*, ?*Leioclema*) and rhabdomesines (?*Petaloporella*, ?*Acanthoclema*). In the Jaźwica section both long-term allogenic faunal replacement (i.e. solitary coral-nuculoid bivalve assemblage precedes acme of brachiopods) and short-term successional changes (pioneer brachiopods followed by bryozoan-microcornid biota; Boucot 1975: p. 237; Copper 1988) are recorded. Episodic deposition and omissions (Kidwell 1991; see also Rollins *et al.* 1990 for temporal scales) resulted in chiefly autogenic taphonomic feedback interactions.

Echinoderm Assemblage corresponds to the peculiar extraordinarily diverse open marine biota of the Posłowice facies, distinguished by vide variety of echinoderms and varied shelly faunas, including productellid and ambocoeliid brachiopods and bivalve *Edmondia*. Fragmentary crinoid crowns of *Cupressocrinites* and octactinellid sponges have been found in the related abundant peri-biostromal association of the Crinoid-Coral Level at Sowie Górki. Abundant inventory of perfectly preserved eleutherozoan remains characterizes the Marzysz locality. At least three echinoid genera, with the most common *Kongielechinus*, were determined (Jesionek-Szymańska *in* Racki & Racka 1981). Associated are microcornids, sponges, podocopid and palaeocopid ostracods, semitextulariid foraminiferans, charophytes and other algae, and notably diversified vertebrates

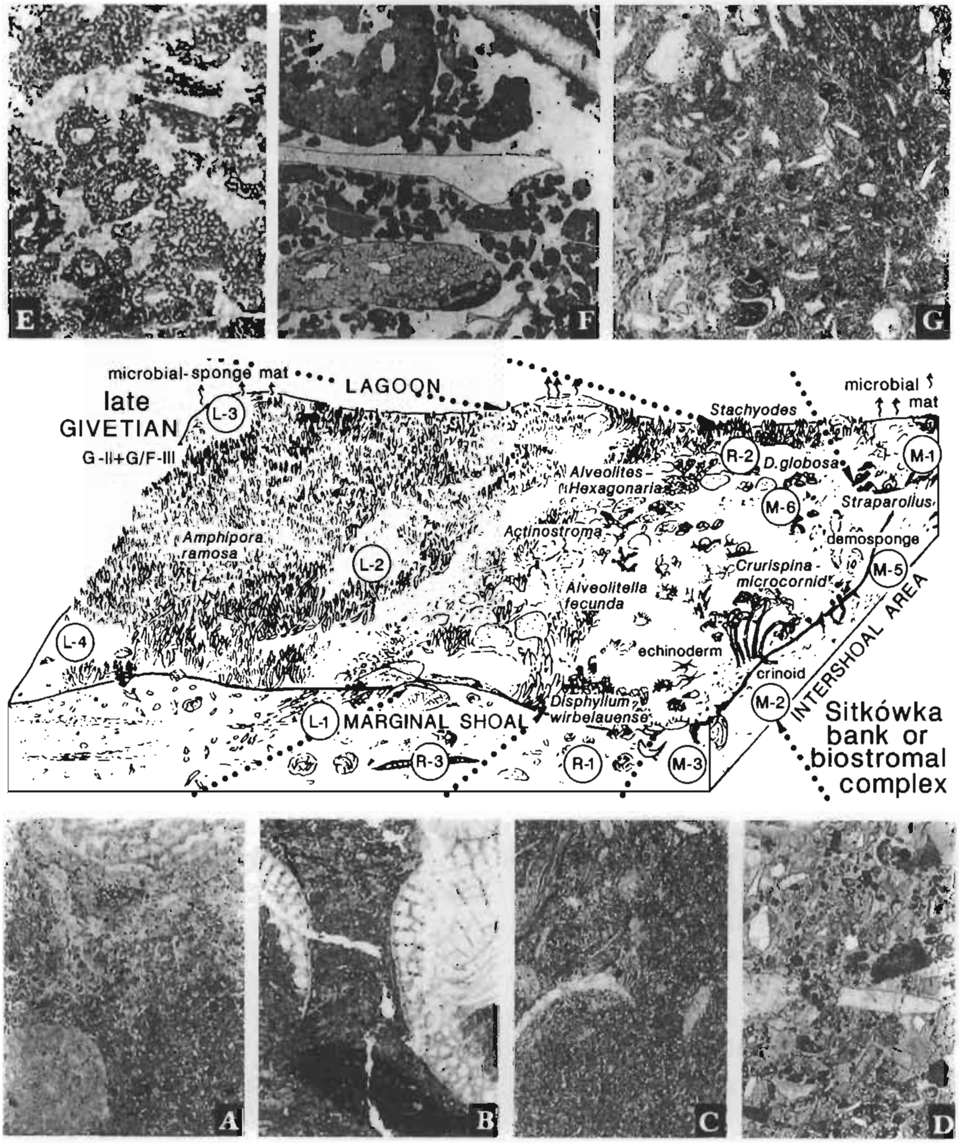


Fig. 16. Main macrobenthic assemblages, facies types (in circles) and characteristic micro-facies (A-G) of the Givetian Sitkówka bank complex. ❑A. Stromatoporoid floatstone; Jaźwica, set F. ❑B. *Disphyllum*-intraclastic rudstone; Jaźwica, set C. ❑C. Spicule-echinoderm packstone, with broken productellid and molluscan shells, Posłowice, set B_1. ❑D. Skeletal-intraclastic grainstone, composed mainly of crinoid detritus; Góra Zamkowa, set F. ❑E. Mud-free *Amphipora* rudstone, Bilcza, set C. ❑F. Poorly sorted intraclastic-*Stachyodes* grainstone/rudstone displaying coarse drusy spar cement, Facies R-2/L-1; Stokówka, set F. ❑G. Bioturbated gastropod packstone, Góra Zamkowa, set F. All ca. × 5.

(with placoderms and elasmobranchs), as well as single scutelluid trilobites and orthocone nautiloids. Bryozoans are less common (cyclostomes, fenestellids, halloporid trepostomes) but their successional role on the more firm substrates was probably taken by corals, especially solitary rugosans. The Posłowice section reveals a change from sparse polygnathid association to more rich and diverse polygnathid-ozarkodinid biofacies (*Ozarkordina brevis* fauna), while icriodontids are rare and limited to the higher beds (Tab. 2). The presence of conodont species *Polygnathus linguiformis linguiformis* Hinde 1879 is noticeable for Sowie Górki and Trzemoszna only as it is frequent species in the Laskowa Góra Beds. Very high diversity possibly reflects rich primary food resources at place and/or supply from nearby(?) charophyte meadows (Racki & Racka 1981) and changing bottom conditions. Trophic structure was complex with common deposit feeders (skeletonized and soft-bodied, like annelids evidenced by scolecodonts), scavengers, as well as diverse (also predatory) fish, and conodont associations.

Facies distribution (Fig. 15D) evidences that the Dyminy swell, especially its western part corresponding to the Miedzianka elevation (Kowalczewski 1963), was the refugium of shallow-water benthos during this deepening event, in the catch-up response *sensu* Neumann *et al.* (1985). The most agitated and clear-water biotopes are found in some intervals of the Crinoid-Coral Level deposition.

The Chęciny intershoal area was a local remnant of the Jaźwica Member depositional basin. Intershoal deposits originated in variety of regimes within irregular zones of the vast carbonate platform that were more (Facies M-6) or less (M-3, M-4) separated from the open marine basin by organic buildups (2- and 3-order intrashelf basins of Krebs 1979). The content of bioclasts derived from restricted-shelf lagoons (calcispheroids, also possible dasycladacean tubiform *Jansaella*), and depositional textures are highly variable but largely limited to micrite-dominated microfacies types. Despite some similarities, the environments differ from stratigraphically younger, Frasnian fore-reef settings (Szulczewski 1971; Każmierczak & Goldring 1978), as well as from coeval biotopes of the northern Kielce subregion (Wietrznia Beds; Racki *et al.* in press a) in representing limited, low-energy habitats.

The Chęciny Beds largely correspond to muddy to fine-grained bioclastic sediments (Facies M-6) containing diverse skeletal grains including shelly elements, amphiporids, ostracods, echinoderms, many problematic microfossil and algal fragments, and peloids, partly of a fecal origin. Shell-enriched layers (e.g. atrypid beds; Racki & Baliński 1981), tetracoral and amphiporid horizons, and tracks and trails on bedding planes are the main megafaunal occurrences. The bioturbated matrix is composed mainly of variably neomorphozed micrite with locally clotted fabrics, but transitions into both spicule-rich wackestones (Sitkówka-Kostrzewa, set B) and ill-sorted grainstones (Góra Zamkowa, sets F and I) are infrequent, similarly as typical shell hash, with micritized molluscan bioclasts. Small-scale scour-and-fill structures, intraclastic intercalations (e.g. related to disphyllid rudstones; Facies R-1r), grain-size gradings and crude lamina-

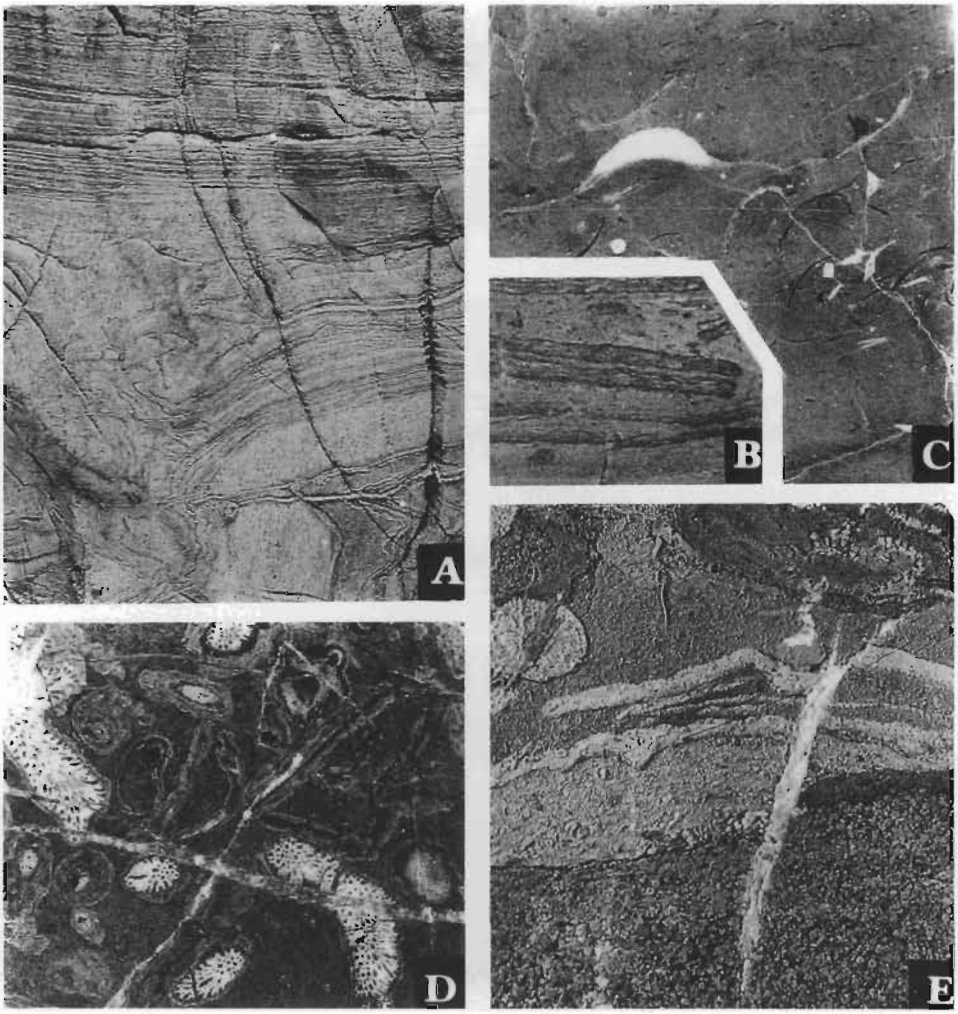


Fig. 17. Intershoal (A-C) and biostromal (C-D) facies. ❑A. Laminated calcilutite with slump folding, Facies M-1; Stokówka, set D. ❑B. The same facies as in A but with an intraclastic intercalaton, Góra Zamkowa, set D. ❑C. Productellid-crinoid calcilutite, Facies M-3; Posłowice, set B_1. ❑D. Oncoids in tabulate-shelly rudstone, Facies R-1r; Sowie Górki, set C. Partly dolomitized (darker areas) *Disphyllum* bafflestone/laminar stromatoporoid bindstone (Facies R-1b/R-3b) overlying an encrinite horizon of the Facies R-1; Góra Zamkowa, set C. All polished slabs taken in natural size.

tions occur in places (Góra Zamkowa, set B; Stokówka, sets D-E), while stylonodularity is a common feature (Fig. 15B). Passages from grain-supported to mud-supported fabric are observed within particular beds.

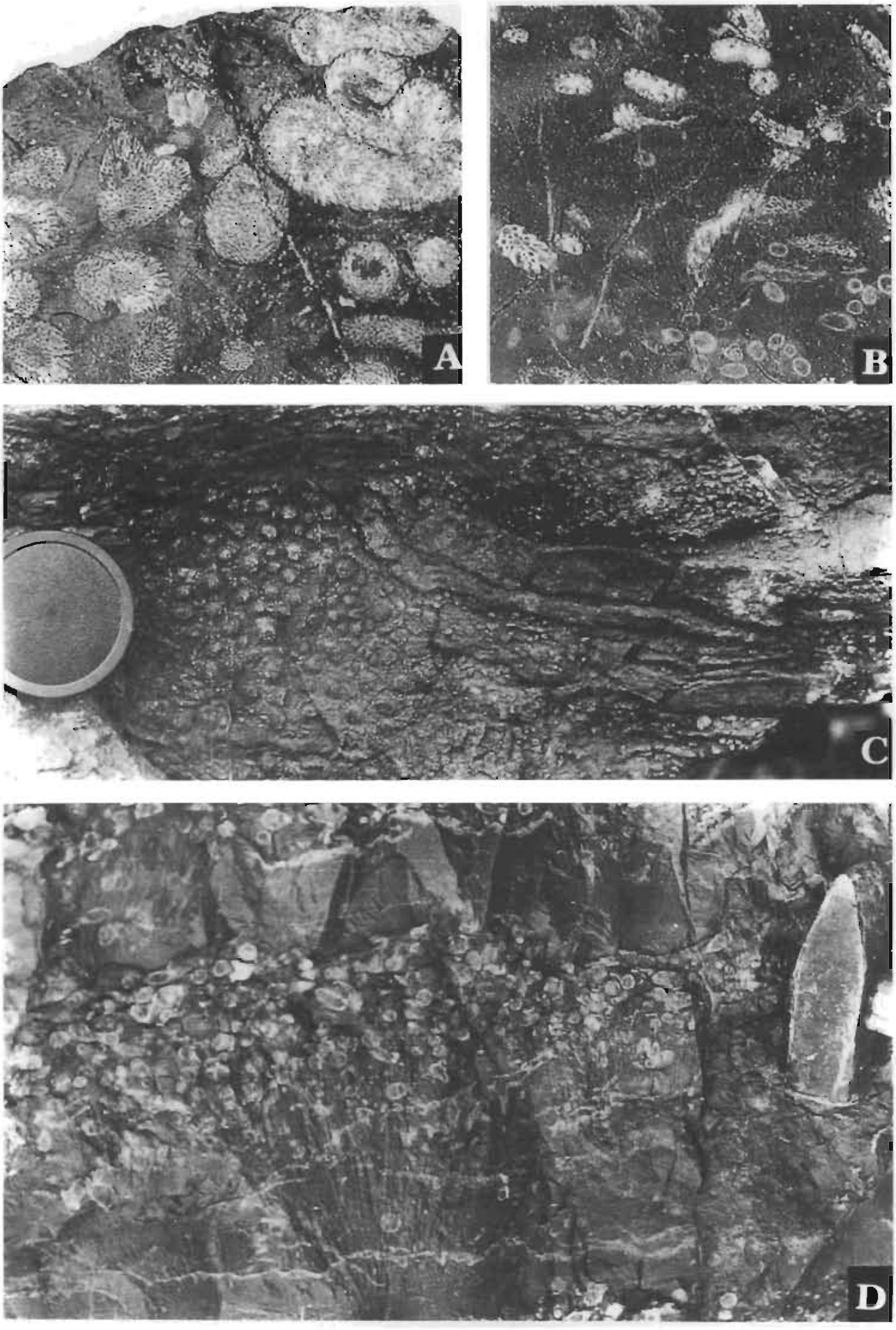
As suggested by ecologically 'mixed' character of skeletal particles (cf. Racki & Baliński 1981), the remains of native biotas were enriched by addition of floating amphiporid branches and fine debris swept off adjacent biostromal bank by storm pulses and tidal exchange, like recent peri-platform ooze (Tucker & Wright 1990: pp. 79-81, 264). The skeletal muds and muddy sands were macerated by infaunal organisms, what resulted in common occurrence of calcisiltites (cf. Lindholm 1969). The strong influence of restricted lagoons, coupled with essentially moderate circulation at a few to tens of meters depth, were presumably connected with some fluctuations in salinity and temperature. Strictly stenohaline forms were generally absent and developed only in periods of improved circulation, e.g. after violent storm events. It is well visible in frequencies of conodont faunas (Tab. 1; Figs 19A-C, 28), nearly all of which belong to the impoverished polygnathid biofacies.

The most widely distributed was a persistent low-diversity *Straparollus* Assemblage, in which the euomphalid gastropods were accompanied by few eurytopic echinoderms (mostly echinoids and holothurians) and ostracods. Peri-biostromal to intershoal atrypid shelly banks of the *Desquamatia globosa* Assemblage (typical locality Góra Zamkowa, set F), with variable associates, occur recurrently in the intershoal sequences (Baliński & Racki 1981).

The lower Sitkówka Beds do not display distinctive organic framebuilding and e.g. typically non-rigid stromatoporoid buildups, dominated by *Actinostroma* (Facies R-3f, rarely R-3b) and developed in result of a pioneer colonization of a muddy bottom or by stabilization of skeletal debris (coverstones of Tsien 1980), probably in shallow-water regimes (about 2 to 13 m depth; Read 1973). A biostromal fringe established around calm depression areas (Fig. 16) but only some *Stachyodes* and coral-dominated buildups were exposed to more severe hydrodynamic influences. The name *Hexagonaria/Alveolitella* Limestone Level, derived from the '*Hexagona* известняк' of Sobolev (1909), designates the varied coral and/or *Stachyodes* biostromal strata, up to 10-15 m thick, of the basal Sitkówka Beds (Jaźwica, Posłowice; Fig. 23). They are traceable into the Chęciny Beds, and even in the Kostomłoty area. This level caps directly the Jaźwica Member (unit G-IIR of Racki 1985b), with the exception of the Chęciny area (Wrzołek 1988).

As shown by many studies, the corals thrived in deeper waters than the stromatoporoids did, presumably in depths of order 20-30 m (Lecompte 1970; Klovan & Embry 1972; Playford 1980). In the Kowala Formation the coral associations show generally high autochthony and poorly winnowed sediment setting. Undulose tabular skeletons are usually preserved in the original, sediment-binding position (Fig. 21A), whilst hemispherical and domal coralla are essentially overturned or abraded. The coral thickets and mounds flourished even in a turbid environment. This is true for the *Alveolitella fecunda* Assemblage (typical locality Posłowice, set C), limited to more protected biotopes of the Sitkówka bank periphery. Rigid stubby

Fig. 18. Variants of the Givetian biostromal limestones. ❑A. *Alveolitella fecunda* bafflestone, Facies R-1b; Posłowice, set C, × 1. ❑B. Tabulate/*Stachyodes* bafflestone, Facies R-1b/R-2b; Zegzelogóra, set B, × 1. ❑C. *Hexagonaria*-stromatoporoid boundstone, with visible encrustation of coralla by tabular stromatoporoids. Facies R-1bf; Jaźwica, set C. ❑D. Alternating levels



of *Disphyllum* bafflestone, and local stromatoporoid bindstone within fossil-impoverished portions. Facies R-1b/R-3b. Jaźwica, set D.

alveolitid colonies were accompanied there by a rich benthic association, with other corals, stromatoporoids, brachiopods and echinoderms. This growth mode suggests quiet murky waters and a high rate of deposition. Usual mass occurrence of the index species indicates its opportunistic character. *Alveolites-Hexagonaria* Assemblage (typical locality Sosnówka, set B), probably of localized biohermal nature, represents coral-dominated portions of the marginal bank shoal, subjected to wave and current action. The major constituents were massive, hemispherical to tabular colonies of the alveolitids and/or in varying proportions *Hexagonaria*. Other corals, *Stachyodes*, crinoids and shelly fauna were common dwellers that include also eleutherozoan echinoderms and scutelluid trilobites.

The cycle G-II ends with a thick lagoonal suite corresponding to reapperance of the amphiporid/microbial communities (see Fig. 20), and the main departure is an appearance of sublagoonal muddy sediments (Facies L-4) in the Posłowice section. The dark micrite amphiporid bafflestones are locally associated with lighter detrital varietes (Facies L-2r), marked by presence of small micritic aggregates and intraclasts and common micritic coatings (e.g. Jaźwica, set E). The rudstones typify however especially some higher parts of the Sitkówka Beds, and originated in moderately agitated, variably shallow water conditions, with primary voids created largely by winnowing of fine-grained matrix, maybe paired with activity of burrowing organisms (Krebs 1974: p. 183). This is also true for *Stachyodes*-dominated beds (Facies R-2r), which may even represent lag accumulations on bars and beaches along shoal shores (cf. Klovan 1964; Havard & Oldershaw 1976).

Non-fenestral laminite-bearing sets (Facies M-1) cap the intershoal succession at the Chęciny and Stokówka sequences. Scour-and-fill structures, graded bedding, different scale foldings (Fig. 17A) and rather diverse skeletal grains, comprising shell fragments, echinoderm remains, sponge spicules, quite frequent conodonts, locally radiosphaerid calcispheres, are significant characters. The extremely shallow-water sediments record prolific microbial mat growth on 'algal' mounds and shoals, in places with steeply inclined flanks what resulted in common hydrodynamic reworking and synsedimentary displacements (cf. Machielse 1972).

The cycle G-II encompasses strata 25 to 60 m thick, and at least half of the succession is formed of the peritidal facies. Thus, following arguments of Read (1973) and Cutler (1983), the water depth increment may be estimated as at least 15 m for this deepening event (see also Schlager 1981; Neumann & Macintyre 1985). Knobby limestone suite, resembling the Bolechowice facies, has been shown as originated in the Frasnian sea at depth range 35 and 55 m (Stoakes 1980), typical of the intrashelf basins (Read 1985).

The cycle G/F-III occurs above the regressive suite of the cycle G-II, although there are some transitional strata (e.g. set E at Góra Zamkowa). The term Atrypid-Crinoid Limestone Level is proposed for the layered, fine-grained to micrite sets, up to 20 m thick, comprising at least three

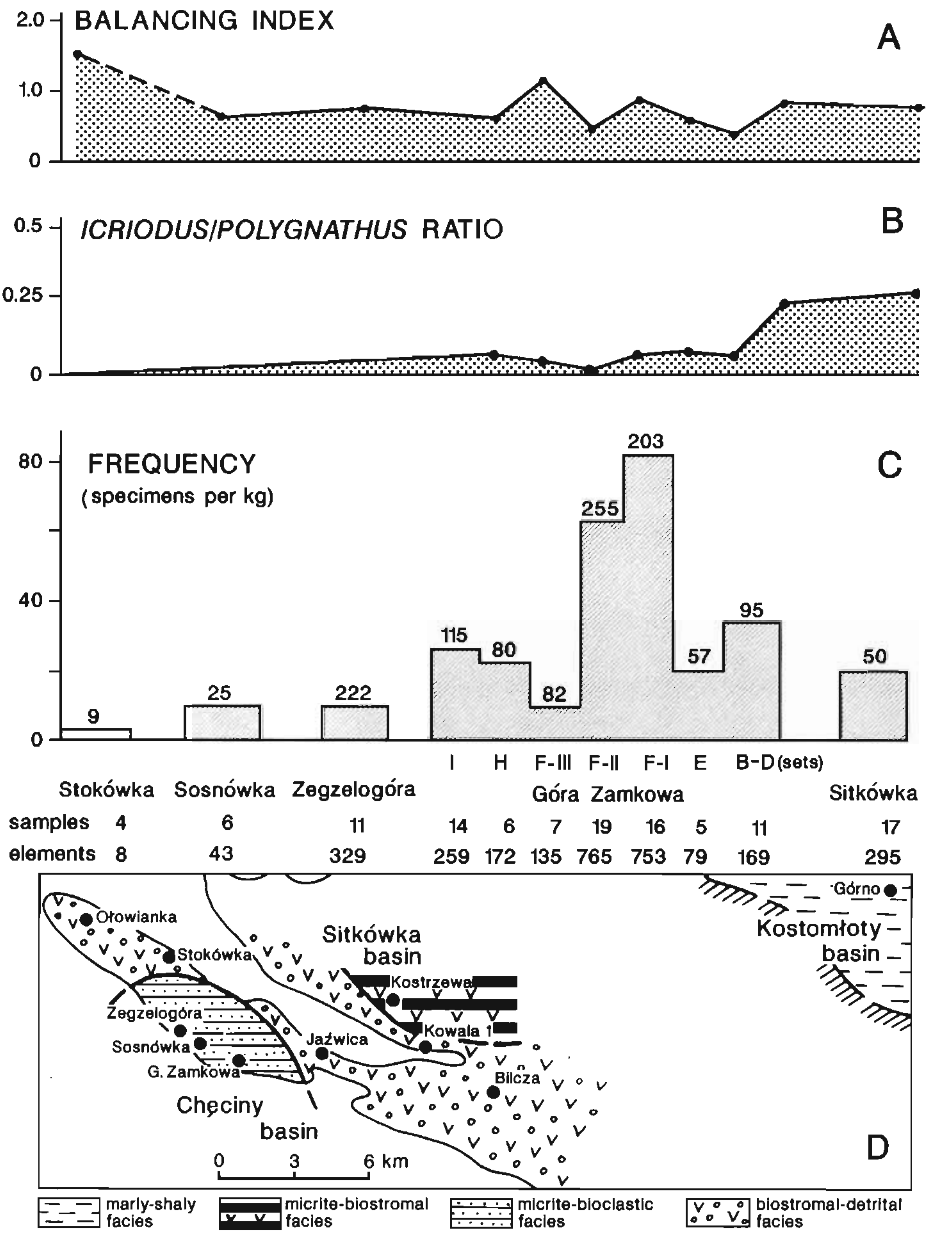


Fig. 19. Spatial gradients in paleoecologically significant indices characterizing conodont faunas of the latest Givetian to earliest Frasnian Chęciny Beds (A-C; see also Fig. 15A-C), and paleogeography of the area during sedimentation of the Atrypid-Crinoid Limestone Level (D) near the Givetian-Frasnian boundary. Samples from Góra Zamkowa are grouped according to lithologic sets or units (for set F; see Fig. 27).

Desquamatia shell beds (Góra Zamkowa, set F; Racki & Baliński 1981) and/or crinoid-enriched partings (Fig. 27). The complex rhythmic charac-

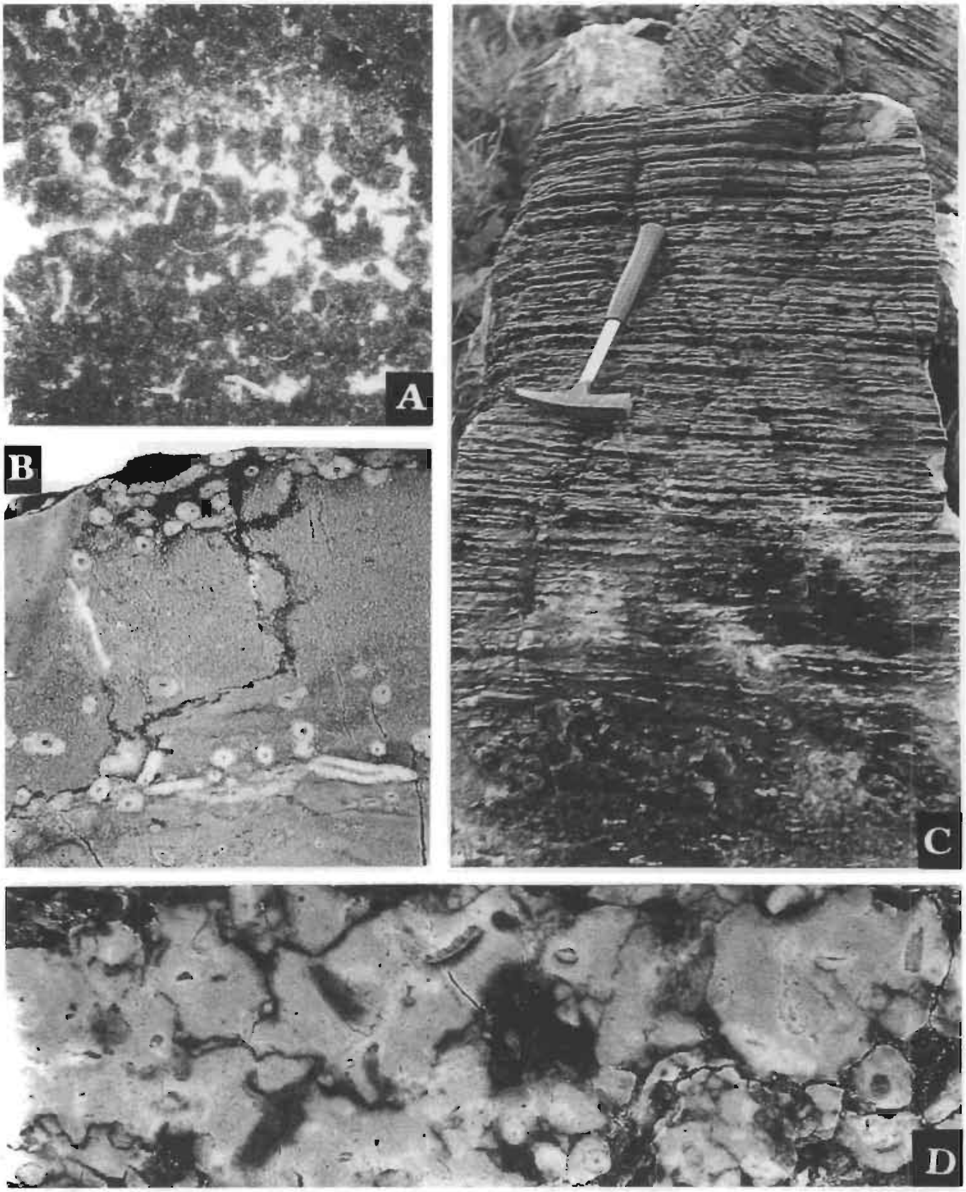


Fig. 20. Various aspects of extremely shallow-water lagoonal and peritidal facies. □A. Peloidal grainstone interlamination within fenestral 'cryptalgal' laminite, Facies L-3; Sowie Górki, set E, × 40. □B. Paleokarstic horizon developed on *Amphipora* bafflestone/floatstone, Facies L-2b; Jaźwica, set E, × 1. □C. Very thick laminite bed, Facies L-3; Góra Łgawa, set A. □D. Fenestral amphiporid floaststone, partly dissolved and filled with hematitic residual material, Facies L-2; Jaworznia, × 1.

ter of the early transgressive phase (unit G-IIIM of Racki 1985b) is expressed in repeated appearance of winnowed bioclastic sands apparent in both bank margin and the Chęciny intershoal area. The depositional pattern is more obscured in the newly established minor stagnant Sitkówka depression (perhaps only episodic development of atrypid banks; Racki 1993), being a short-lasting paleogeographic departure within the Dyminy subregion (Fig. 19). Conodont habitat differentiation is well detectable in faunas of the relatively open marine level and an increase in abundance of icriodontids is a feature of the more stagnant Sitkówka area.

The crinoid-rich Facies M-2 belongs to a widespread type of Paleozoic deposits. The sparry and intraclast-rich lithologic variants with partly micritized grains comprise shallow-water sediments formed in an environment of constant wave and current action, including proximal storm effects (cf. Miller *et al.* 1988; Seilacher & Aigner 1991). However, sedimentary structures, like crude stratifications, are rarely observed in result of severe bioturbation. Migrating skeletal sands characterize intershoal areas (Racki & Baliński 1981). They are also known as heavy storm accumulations in channels of biostromal shoal that may reach as prograding washover fans even to lagoonal bays (Krebs 1974; Galli 1985). Crinoid Assemblage (typical locality Góra Zamkowa, set F) refers to different-size crinoid thickets, meadows and patches that were evidently a common feature in the open shelf regimes in the bank- and reef-complex, e.g. in the Wietrznia subregion (Głuchowski 1993). They commonly bordered different kinds of buildups or preceded their growth (cf. Wilson 1975) and contributed most to the debris in these flank and intershoal environments (Szulczewski 1971; Baliński & Racki 1981). These normal-marine biotas include some shelly and infaunal organisms, and corals. Their low taxonomic diversity and diminutive columnal sizes point to hard life conditions in the Chęciny-type intershoal biotopes.

The regressive phase of the cycle is connected with a renewed amphiporid-microbial biota (Jaźwica) or prograding biostromal, mostly disphyllid thicket growth in the intershoal domain (Góra Zamkowa, Sitkówka-Kostrzewa). The *Disphyllum wirbelauense* Assemblage (cf. Różkowska & Fedorowski 1972) recurred, at least five times in the Góra Zamkowa succession, as episodes of successful muddy bottom colonization. The wide distribution of the dendroid-fasciculate rugosan species indicates its relatively high competitive capabilities. Its dense growth was usually joined with almost complete exclusion of the other skeletonized benthos with exception of echinoids and ostracods.

In some sections (Stokówka, Ołowianka, Kowala-1 borehole), however, the facies changes are manifested solely in the disappearance of the peritidal facies and/or entry of intraclast-rich grainstones (Facies L-1), frequently with sorted, well-rounded and micritized or coated particles, partly of algal origin. The winnowed sandy sediments mark rough water zones comprising shifting tidal bars and lagoon channels, not more than 10 m deep (Wilson 1975: p. 358), with few indigenous, mostly infaunal organisms (cf. Purdy 1964).

Generally, the cycle G/F-III, usually less than 30 m thick, is far less distinct in sedimentary record than the preceding unit, in some cases difficult to recognition. Thus, an epeirogenic origin is supposed for this cycle and its more limited significance is shown also by weak biotic changes (Racki 1988).

Sedimentation and biotic environment during the reef phase

Bank to reef transition belongs to the most disputable problems in the depositional history of the Kowala Formation (cf. Szulczewski 1971: p. 113), and the beginning of the reef growth is ultimately linked with the upper Sitkówka Beds (Narkiewicz *et al.* 1990). This facies change is an expression of the progressive platform drowning that continued in the Frasnian time. Intensive organic upbuilding on flanks of the growing Dyminy reef was possible owing to increasing role of microbial mats and early cementation, with growing evidences of reef-flat to talus deposits (cf. Narkiewicz 1988).

Reef foundation stage (IC-Complex).– The inter-cycle unit contains the 50-80 m thick basal part of the upper Sitkówka Beds sandwiched in between the two cyclic units G/F-III and F-I. It was a period of relatively stable sedimentary conditions probably in effect of short-lasting relative sea-level stillstand. These are poorly-stratified reefoid deposits (Fig. 40B), with Kadzielnia-type bioherms in upper parts and weak talus on the southern flank (Góra Zamkowa, set J).

In contrary to previous distinctly rhythmic suites, deepening is not so apparent in the stromatoporoid series. The abrupt appearance of platy spiculite micrites (Facies M-4) above the biostromal beds in the Chęciny profile (sets G-H) is the best evidence of the sea level rise within the southward spreading intershoal basin (e.g. Chęciny Limestone-type set D in the Kawczyn profile near Zbrza; see Fig. 35). The cherty deposits show fine laminations, and sparse macrofaunal remains, limited to few shell-rich or amphiporid intercalations. They are markedly abundant in delicate calcitized monaxone sponge spicules, exhibiting crude directional orientations in places. Silicified dendroid corals and stromatoporoids are numerous in some sites (Kawczyn, Sitkówka-Kostrzewa), and some spicule-bearing stromatoporoid floatstones (Zelejowa, set A) reveal transitions to reefoid facies.

The Facies M-4 somewhat resembles deep-water microfacies SMF-1, but is less marly with acid-resistant residuum rarely above 5 per cent and seems to contain only benthic organisms, which argue for shallower setting. Sedimentation took place in submerged portions, more than 30 m depth (cf. Wilson 1975: p. 414) of the expanding Chęciny-Zbrza intershoal basin, with negligible bioclast supply from the nearby buildups and restricted lagoons. The siliceous monaxonic sponges (Demosponge Assemblage) and concentrations of their spicules formed extensive mats (cf. Lane 1981) veneered muddy bottom in stagnant portions of intershoal areas. Very few accompanying benthic organisms (gastropods, nuculoid bivalves, lingulids, ostracods, conodonts) were adapted to the peculiar biotope.

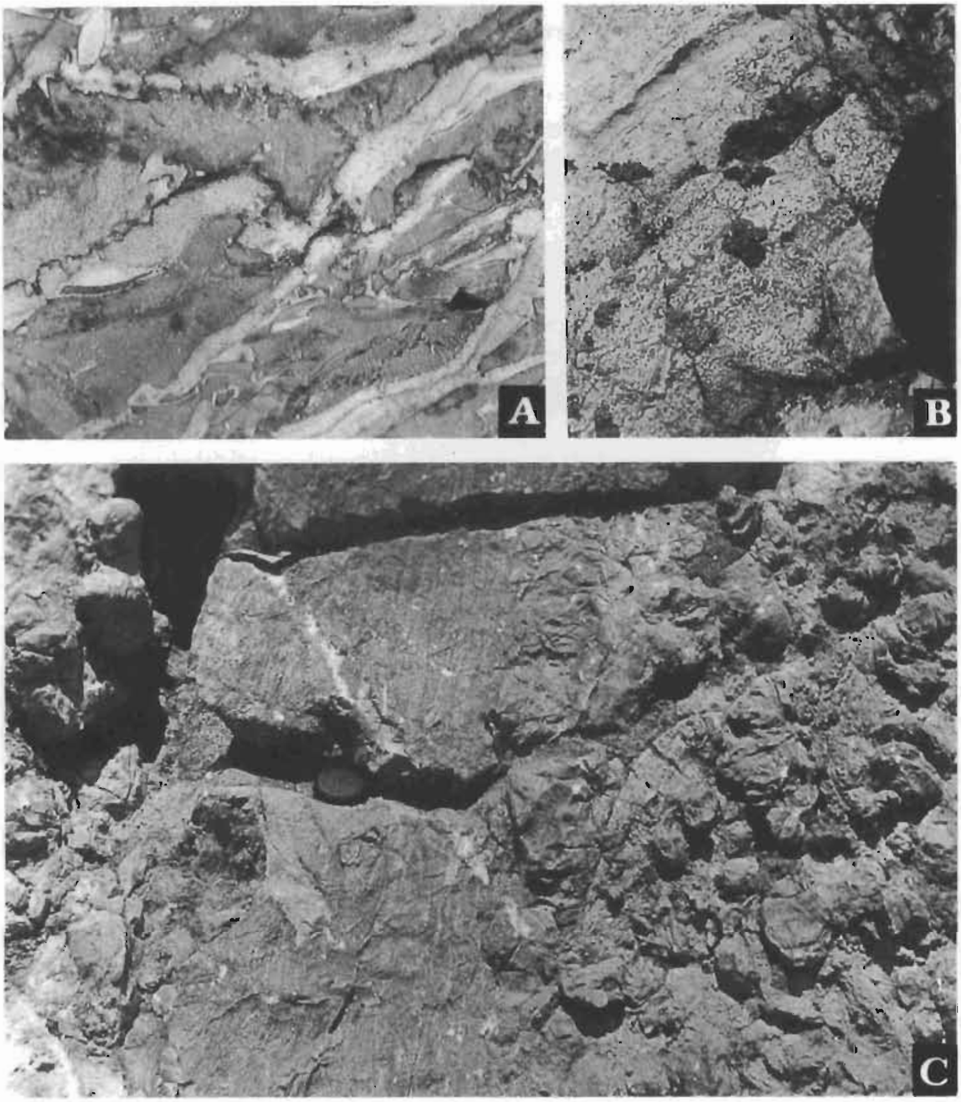


Fig. 21. Varietes of the Frasnian reef limestones and related facies. □A. *Alveolites* bindstone with many umbrella structures, Facies R-1; Kowala, set C; × 1. □B. Fenestral calcilutite of the Facies L-3 capping the coral-stromatoporoid complex; Miedzianka, set C. □C. Horizontally stratified calcaarenite layer of the Facies L-1 within the stromatoporoid rudstone, Facies R-3r; Jaźwica, set H.

Toward the top of the unit, an obscured shoaling trend is recognizable in upward-coarsening character of the successions, and the grained deposits cap the subnodular, chiefly micritic uppermost Chęciny Beds (sets I-J) marked by a tentaculite-bearing horizon with *Dicricoconus*. *Iowatrypa timanica* Assemblage (typical locality Góra Zamkowa, set I) is a successor of the *Desquamatia globosa* Assemblage in protected portions of the weakly inclined reef flank.

The IC-Complex shows a pronounced bipartity in the Kowala subregion. The lower half is made of massive stromatoporoid reefoid strata whilst the higher portion is more distinctly bedded and coral-rich, characterized by a distinctive rock-building fossil assemblage (Wrzołek 1988, 1993; Nowiński 1993). These strata, *Alveolites-Thamnophyllum* Limestone Level, up to 50 m thick, partly represent non-biohermal equivalents of the Kadzielnia Member, e.g. at Kowala (Szulczewski & Racki 1981). Argillaceous interbeds and Kadzielnia-type bioherms are the first symptoms of the accelerated sea-level rise near ending of this interval.

The stromatoporoid strata are the key facies of the Devonian reefs (Fagerstrom 1987). The lighter-colored (in comparision to the Givetian equivalents; Kaźmierczak 1971b) deposits exhibit continuous passages into other undoubtedly detrital varietes in some sites (Psie Górki, Miedzianka) and include several intraclastic fine-grained lenses and interlayers (Fig. 21C). The massive stromatoporoid-detrital subfacies (R-3r) comprises assemblages of variably redeposited and abraded stromatoporoids in different marginal parts of the shoal domain with fairly agitated waters at most 10 m to the sea level (turbulent zone of Lecompte 1970). Real stromatoporoid framestones being fragments of wave-resistant organic reef are preserved exceptionally in the region (cf. Szulczewski 1971: p. 112) what is a rule in ancient reef complexes (Longman 1981; but see Stanton & Flügel 1989). A few parts of the Stromatoporoid-Detrital Beds and related strata (Zelejowa; Sowie Górki, set F; Karwów; Wietrznia) can be regarded as a boundstone owing to the presence of very large, up to several meters in diameter (cf. Szulczewski 1971: p. 95) massive coenostea. The most spectacular example has been found at the Śluchowice quarry (set B) where a giant probably tubular colony occurs, being not less than 8 m in length and 0.8 m in height. Nevertheless, probably only a minor reworking was involved in most other instances (Racki 1985a). Encrusting microbial communities can secondarily bind large amounts of rubbles (bindstones *sensu* Tsien 1980; also Kaźmierczak 1971b; Preat & Mamet 1989) after periods of destruction. Thus, the distinction between reef and detrital (talus) lithologies may appear disputable, e.g. in the Kowala 1 borehole (compare Narkiewicz *et al.* 1990 and Romanek & Rup 1990).

Actinostroma Assemblage (typical locality Sitkówka-Kowala, set A), the massive stromatoporoid community is typical for all the Sitkówka Beds (Kaźmierczak 1971b) being far more common in their upper reefal segment. The Frasnian variety is thought to represent the wave-resistant accretion rim of the Dyminy reef (Fig. 22) situated in the zone of continuous turbulence, and more or less intense destruction (Krebs 1974; Wilson 1975). Variable massive colonies, typically up to 50 cm in diameter, predominated among constructors, while ramose stromatoporoids, corals, and calcisponges grew under protection of the framework. Specialized brachiopods (atrypids), gastropods and ostracods were common inhabitants of the stressed marginal flats (Racki 1985a). In all likelihood, non-skeletal microbiota (including corroding and boring associations)

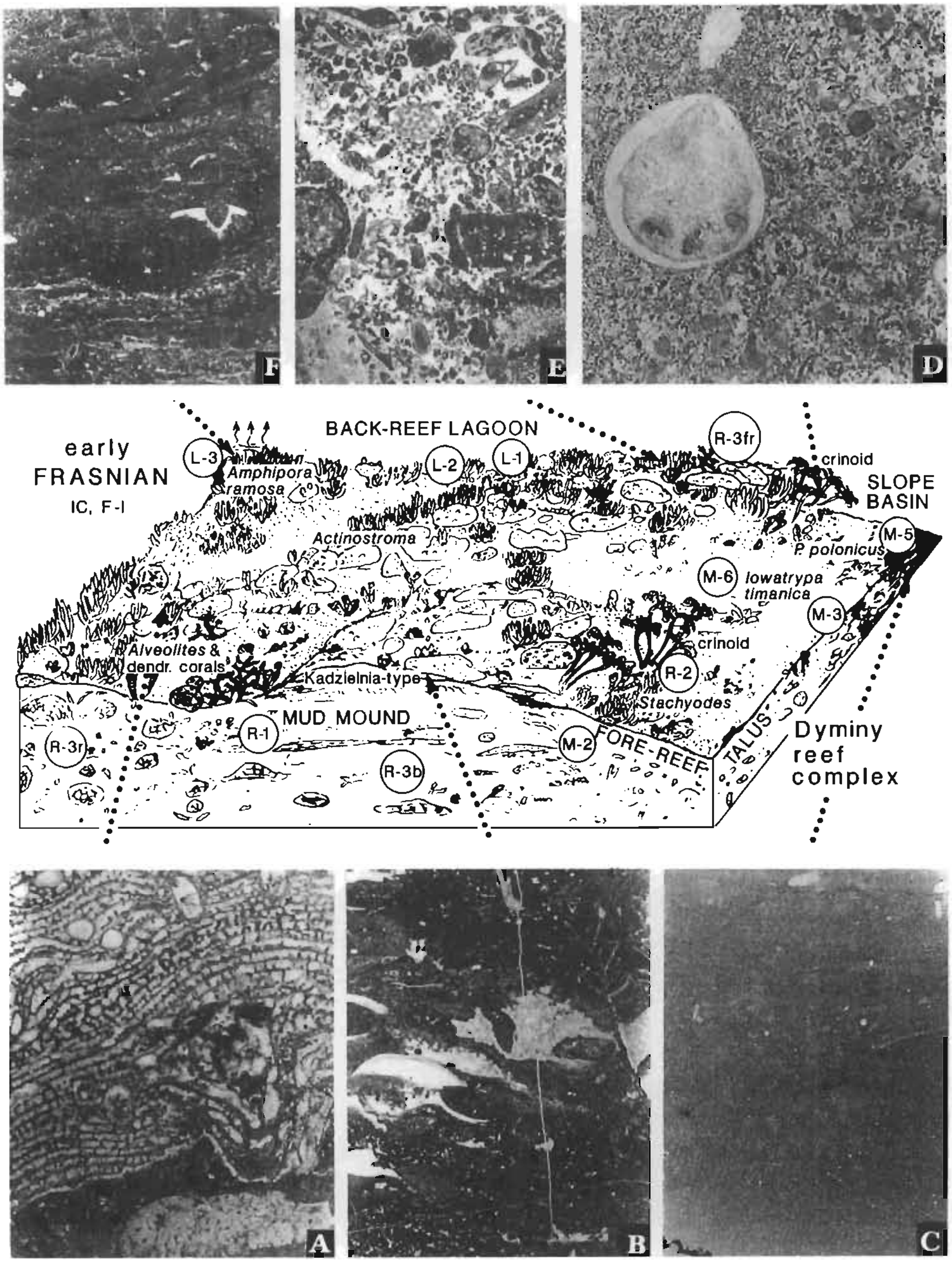


Fig. 22. Main macrobenthic assemblages, facies types (in circles) and typical microfacies (A-F) of the Frasnian Dyminy reef complex. ❑A. Stromatoporoid floatstone; Sitkówka-Kowala, set C. ❑B. Wackestone matrix of the stromatoporoid bindstone, note fenestrae in the lower left. Jaźwica, set J. ❑C. Marly mudstone with single tentaculites (upper part); Zamkowa Góra, set K. ❑D. Unsorted intraclastic-crinoid-brachiopod grainstone; Kawczyn, set E. ❑E. Stromatoporoid grainstone/rudstone, note a weak micritization of grains; Jaźwica, set H. ❑F. Fenestral laminite, with a single gypidulid brachiopod fragment; Ostrówka. All ca. × 5.

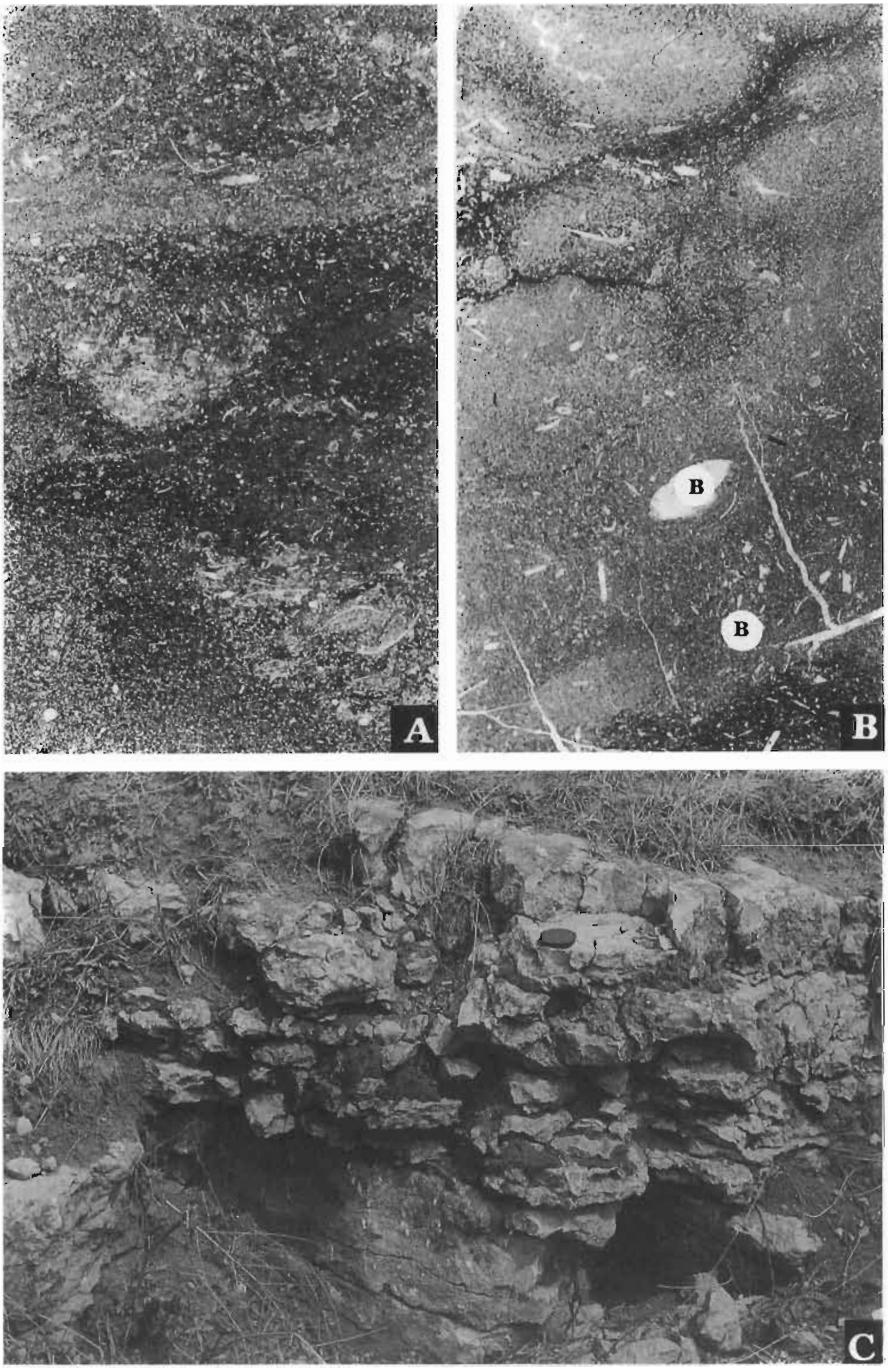
proliferated in this zone, e.g. in sheltered pools. *Renalcis* belongs to common reef-builders but is more significant in younger Frasnian biota.

Kadzielnia-type Assemblage corresponds to the midslope, quickly lithified buildups that developed in a subturbulent zone (Lecompte 1970), in depths estimated to range from 10 to 20 m (Embry & Klovan 1972). The presence of clotted and spongy, fenestral fabrics (Fig. 22B) in stromatactoid micrite matrix is notable, and the microbial accretion probably resulted in localized framework development (cf. Pratt 1982). The stromatoporid-alveolitid-microbial sediment-binding community is inferred to build low-energy mud mounds (Hoffmann & Paszkowski 1992). This is the unique site of the most abundant benthic organisms proliferation in the reef-complex (Szulczewski & Racki 1981). Kadzielnia-reef biota comprise rare pseudorthoceratid nautiloids, as well as zoaria of minute ramose cryptostomes *Penniretepora* and stenoporid trepostomes, known from the Kadzielnia section, and large fenestrate colonies ('*Fenestella rectangularis* Sandberger 1855'; Gürich 1896) occurring at Góra Cmentarna. Diverse, and locally large-sized skeletal eleutherozoan elements are numerous in the Kadzielnia Member and related strata (Kadzielnia, Szczukowskie Górki), where remnants of echinoids *Lepidocentrotus* and *Aptilechinus* have been determined (Jesionek-Szymańska *in* Galińska 1984).

The Kadzielnia-type mounds were bordered by coral-rich biostromes, e.g. in the Kowala and Kadzielnia-Wietrznia environs, and by shallower agitated belts of stromatoporoid and growth destruction (Jaźwica-Góra Łgawa-Zelejowa, Góra Cmentarna). The wavy-bedded coral biostromes interstratified with shaly partings (e.g. Kowala, sets A-B; Szulczewski 1971). Therefore, *Alveolites*-dendroid corals Assemblage flourished on gentle Dyminy reef flanks, spreading somewhat downslope. Their main builders comprised nodular to tabular alveolitids, branched corals (*Thamnopora, Thamnophyllum*), massive rugosans which include *Hexagonaria* in one horizon, and various stromatoporoids, locally also renalcids. Accessory inhabitants, such as crinoids, gastropods, octactinellid sponges, nanicellid foraminifers, and receptaculites, were more abundant and diverse there than in the stromatoporoid shoals and knolls. The common upslope variety of the *Stachyodes* thickets, with robust coenostea up to 1.5 m in size, is marked by asscociation with renalcids and other microbial biota (Szczukowskie Górki, Grabina, Wietrznia-Psie Górki).

Early phase of the Dyminy reef (cycle F-I).– Basal part of the cycle F-I corresponds to the period of the maximum depth in the once more expanding Chęciny-Zbrza intrashelf basin as manifested by widespread dark, more argillaceous deposits (Facies M-5) of the *Phlogoiderhynchus* Marly Level overlapping the Kowala Formation. A rapid transition from

Fig. 23. Peculiar lithologies of the *Phlogoiderhynchus* Marly Level. ❑A. Bioturbated algal wackestone-packstone with tubiform green alga *Jansaella*, Facies M-6; Dębska Wola, set F; × 5. ❑B. Burrowed nodular wackestone with dispersed brachiopod bioclasts, B – large burrows, Facies M-3/M-5; Jaźwica, set L; × 5. ❑C. Nodular to wavy bedded calcilutites with crinoid-brachiopod detritus intercalations, Facies M-3; Dębska Wola, set G.


A
B
B
B
C

shaly and/or knobby basal horizon to thicker, regularly layered micritic suite with some brachiopod shelly partings and styliolinids is typical for the transgressive horizon of the Gałęzice Syncline (Fig. 24). Lowest lime beds in the Jaźwica-Góra Łgawa sections display red staining, burrowed to bored intercalations (Fig. 23B) and glauconitized(?) echinoderm remains, all suggestive of reduced deposition in the upper foreslope of the rapidly upbuilding reef, during a lag phase of the inundation. Otherwise, some layers at Kowala and Dębska Wola contain still many lagoon-derived bioclasts (Fig. 23A) what points to nearby persistence of the restricted areas (Fig. 22).

The rhynchonellid level-bottom fauna, *Phlogoiderhynchus polonicus* Assemblage (type site Kowala, set D), thrived in deeper slope to basin, partly dysaerobic to exaerobic environments (Biernat & Szulczewski 1975; Racki *et al.* in press a). Ecologically mixed, mesotaxid- to ancyrodellid-polygnathid conodont associations (see Fig. 34), commonly with 'euphotic' icriodontid species *Icriodus symmetricus* Branson & Mehl 1934, were commonly represented in the fauna (Szulczewski 1971). This deepening was responsible for a broad conodont biofacies unification in the hemipelagic setting around the flanks of the Dyminy reef.

The central Kielce subregion was the area of a prolongated reef accretion and the record of the sea-level rise is unclear. However, this provides an opportunity to employ the event correlation concept derived from sequential analysis (Racki 1985b). According to it, the age equivalent of the *Phlogoiderhynchus* Level are coral-enriched biostromal beds with brachiopods and crinoids, representing the most open-shelf facies within reefoid-lagoonal sequences, and locally containing many marly interbeds (Sitkówka-Kowala, set C; Sowie Górki, set G; Miedzianka, set B). The above sets are treated as an example of diachronous coral facies of the *Alveolites-Thamnophyllum* Level (cf. Racki 1991: Fig. 2), and form a basal part of the more or less clearly developed upward-shallowing succession, especially well expressed in the Sitkówka area (thick amphiporid-laminite complex D) and at Jaworznia (Słupik in press). Wide distribution of the micritic to fine-grained macrofossil-poor sediments (Facies L-1/L-4), with fenestral horizons in some parts (Fig. 21B), is a notable feature of the Miedzianka area. They may correspond to small flats atop and on the lee side of the emergent sand shoals of the reef barrier (Tucker & Wright 1991: p. 114). Generally, the back-reef biotopes display far higher turbulency and oxygenation levels than their platform, shelf lagoon equivalents.

In some sections the flooding event remains unrecognized (Ołowianka, Stokówka), perhaps in the most quickly growing reef parts (keep-up reefs; Neumann *et al.* 1985). The more differentiated subsidence around the stable Caledonian paleohigh, maybe locally linked with synsedimentary block faulting (cf. Szulczewski 1989), is manifested in contrasting thicknesses of such interpretated cycle F-I ranging from 35 m (deep foreslope; Kowala) to more than 230 m (reef-interior; Sitkówka).

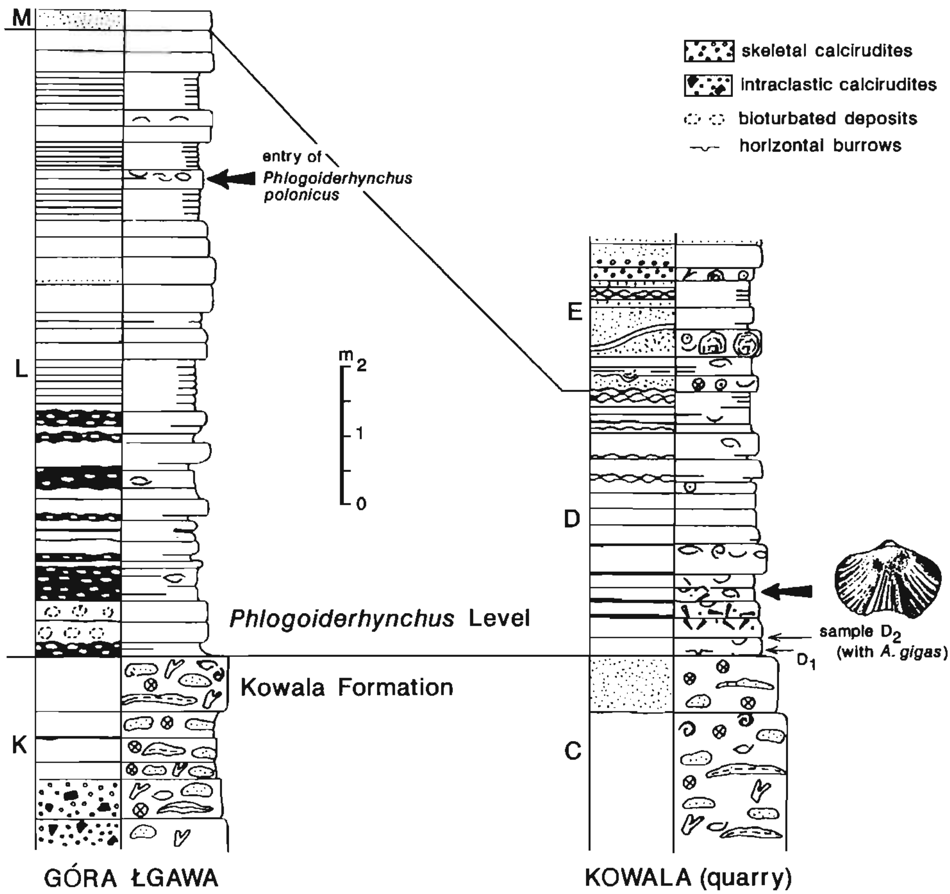


Fig. 24. *Phlogoiderhynchus* Marly Level at Góra Łgawa (measured in 1975) and Kowala quarries exemplifying variation in the drowning uncornformity (*sensu* Schlager 1989) of the Middle Frasnian onlap (cycle F-I). For other explanations see Fig. 14.

As evidenced mainly by the Kowala-Góra Łgawa sections, fluctuating progradation of the fore-reef debris on flanks of the finally established Dyminy reef took place during next poorly-known, probably filling developmental stage of the Chęciny-Zbrza basin.

Small-scale depositional cyclicity

Repetitive rhythms, each of a few meters thick, are common feature in the shallow-water carbonate sequences (Strasser 1991; Tucker & Wright 1991). They correspond to punctuated aggraded cycles (PACs; Goodwin & Anderson 1985) and 6th order cyclicity of Rollins *et al.* (1990; see Vail *et al.* 1991 for another scheme); thus, the major cycles described above are at least partly of internally complex nature (cf. cyclothemic PAC-sequence; Rollins *et al.* 1990).

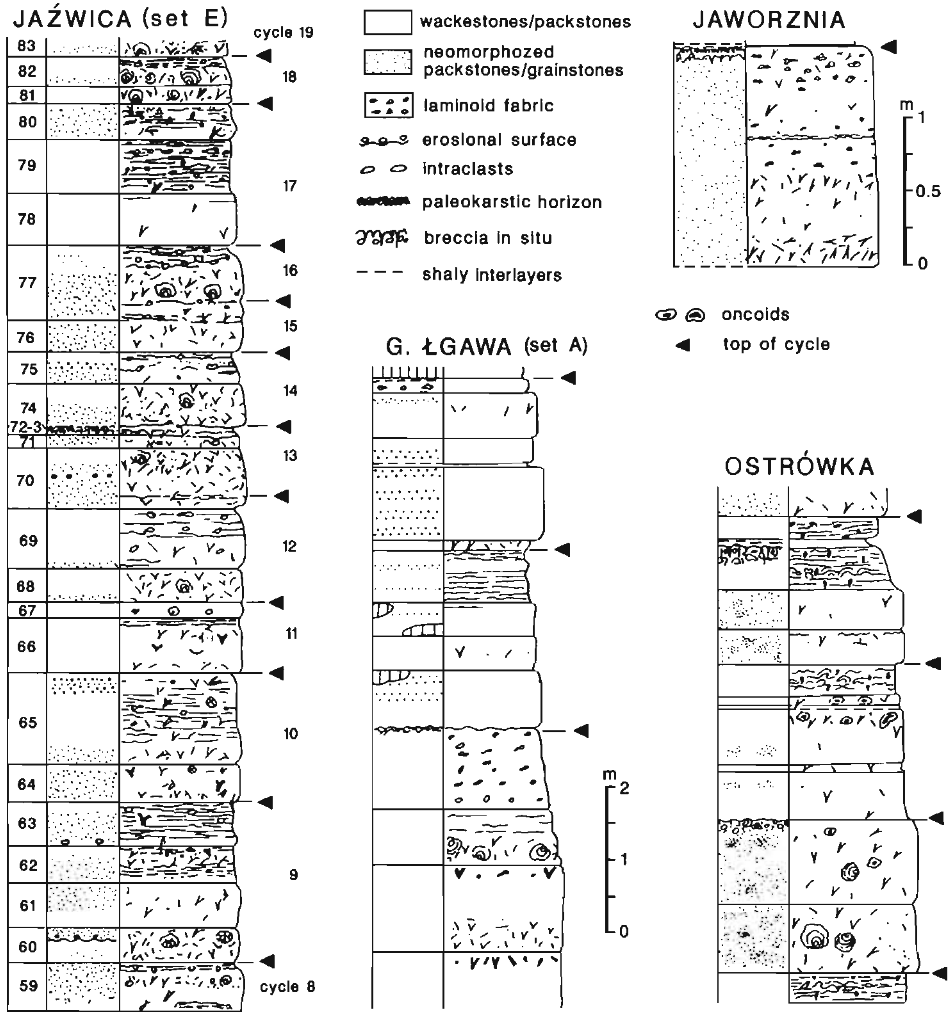


Fig. 25. Typical restricted lagoon successions showing small-scale shallowing upward rhythmic depositional pattern. Numbering of beds and cycles is shown in case of the Jaźwica section. For other explanations see Fig. 7.

Lagoonal cycles.– Minor cycles represent sequences of three principal facies. Listed in ascending order (Figs 25-26) these are: (1) subspherical stromatoporoid floatstone (Facies R-2f), locally replaced by tabular stromatoporoid bindstone (Facies R-2b), (2) *Amphipora* bafflestone (or floatstone-rudstone; Facies L-2), sporadically interlayered and/or replaced with *Stachyodes*-rich parts, and (3) 'cryptalgal' fenestral/laminited unit, occassionally in association with non-skeletal calcarenites, and calcilutites (Facies L-1 or L-4). *In situ* brecciae paired with green to cherrish powdery-shaly horizons (Fig. 20B, D), dessication structures, flat pebbles, irregular to curved plane fructures, vadose silts and cements, and micro-

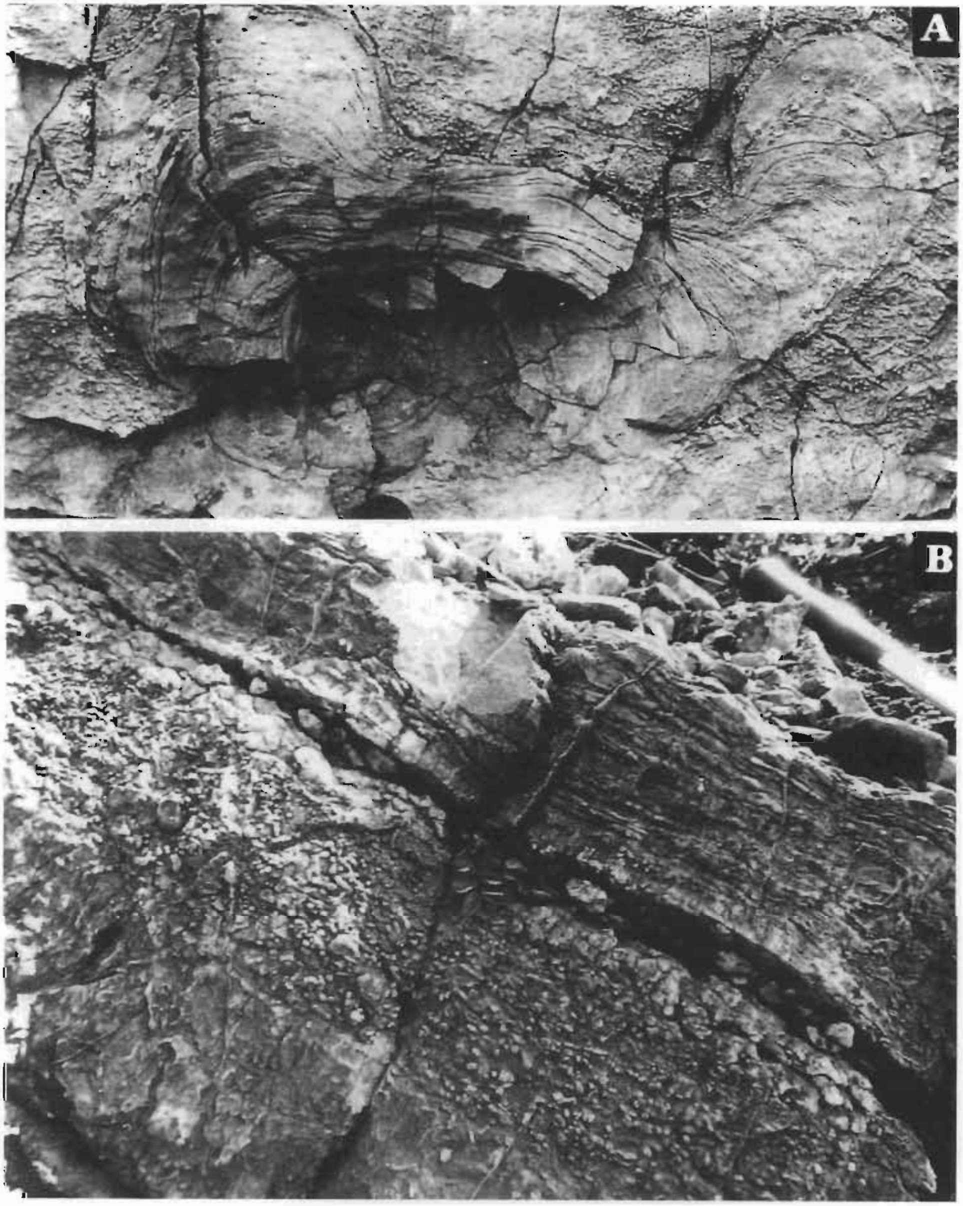


Fig. 26. Lagoonal facies associated with upward-shoaling units in the Sitkówka Beds. ❑A. Large spherical-columnar stromatoporoid coenosteum (0.8 m in width) in growth position within *Amphipora* bafflestone, typical of the basal part of the cycle; Łagów. ❑B. Amphiporid bafflestone/rudstone, with oncoids and micrite-coated skeletal fragments, capped by laminite level ending the cycle; Panek, set A.

sparitization and dissolution features indicate termination of the subtidal to supratidal sequence. Strict resemblance to cycles of Type A of Read (1973) from the Pillara Formation of the Western Australia is notable.

Typically, the bulk of the cycle thickness is occupied by an *Amphipora*-rich unit. Emergence characters are rarely well developed with the exception of the Jaworznia section. Rapid tapering of a thick (ca. 0.5 m) paleokarstic level is observed at Ostrówka (Fig. 38A) what suggest a common removal of the residual sediments, and maybe significant stratigraphic thinning during karstification and pedogenesis (cf. Goldhammer & Elmore 1984). As visible in the measured Jaźwica succession, the average thickness of the 23 recognized elementary regressive rhytms equals 1.8 m varying from 0.6 m to possibly 4 m, i.e. similar as in the sequences of Canada (Wong & Oldershaw 1980) and Ardennes (Preat & Mamet 1989), and in the eastern Holy Cross Mountains (Preat & Racki in press).

Preat & Racki (in press) described the depositional rhythmicity from more uniform, largely muddy facies succession of Jurkowice-Budy, with prominent diagenetic overprint, and this sedimentary pattern occurs also in the *Stringocephalus* Beds of the western region (e.g. at Góra Łgawa, Fig. 25).

In the Atrypid-Crinoid Level, developed in the biostromal facies, there are cycles comparable with the Type B of Read (1973). Rhythmic couplets include in ascending order (Fig. 27): (1) thin (up to 40 cm) grainstone, typically well-sorted and enriched in crinoid ossicles, with internal erosional surfaces (Facies M-2/L-1), (2) thick (1.7-?4.7 m) variable biostromal succession, chiefly from coral (disphyllid)-*Stachyodes* bafflestone to tabular stromatoporoid bindstone to globular stromatoporoid floatstone and/or amphiporid bafflestone, locally with small oncoids. At least four such units occur at Jaźwica (set F). The highest one is covered with the cycle Type A sediments, including stromatoporoid biostromes passing into a laminite, but contains thin calcarenite level at the bottom. In the other sections (Stokówka, Ołowianka) single cycles with thick grained set (Facies L-1) were found in stratigraphically corresponding interval (see Figs 35-36); they might appear to be amalgamated packages. Relatively open shelf and deeper-water regime (5 to 13 m; cf. Read 1973), and intensive reworking of bottom sediments characterized the flooding events of the cycle G/F-III within the biostromal shoal of the described type (see also Read 1985: p. 16; Van Steenwinkel 1990).

Both kinds of the elementary fining-upward cycles were marked by increasing biotic restriction from the base to top. In general, the phenomenon of periodic disappearance and reappearance of the stromatoporoid biotas might indicate rapid, fluctuating bathymetric changes and the consistently repeated shallowing of the basin (Kaźmierczak 1971a, b). Shoaling possibly resulted in increasing temperature and salinity changes, as well as periodic exposures in a catch-up phase of rapid vertical accretion and progradation (Cutler 1983). The nature of the cycles remains, however, disputable (Preat & Racki in press). A general lack of lateral continuity of the rhythms in the regressive phase of cycle G-II (i.e. between Jaźwica, Kowala 1, Góra Zamkowa and Stokówka sections) suggests that processes were mainly autocyclic, controlled by depth-depend-

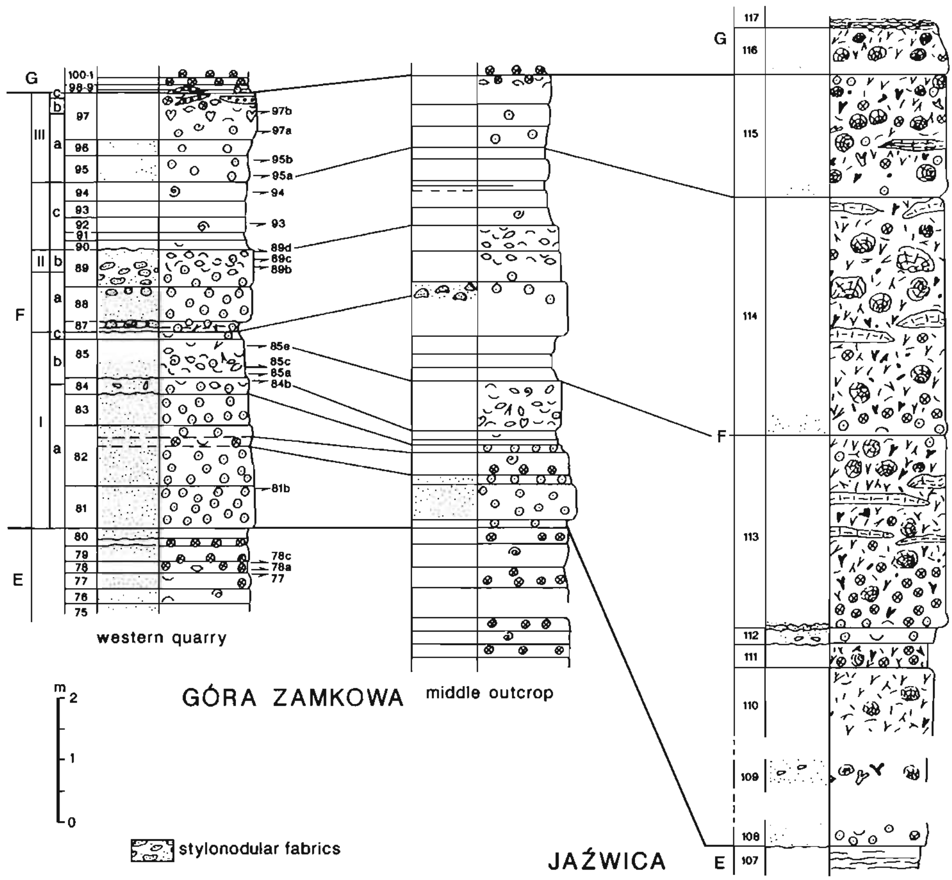


Fig. 27. Lithological correlation of the typical sequences of the Atrypid-Crinoid Limestone Level for illustration of the intershoal small-scale cyclicity. Numbers refer to conodont samples (Tab. 1). Numbering of beds is given for the western Zamkowa Góra (cf. Racki & Baliński 1981) and Jaźwica profiles. For other explanations see Fig. 25.

ing local carbonate productivity (laterally shifting tidal flat islands; see review in Strasser 1991 and Tucker & Wright 1991: pp. 62-66). However, high-frequency eustatic oscilations of a few meters, which may result from minor climatic variation driven by orbital perturbations (Milankovitch cyclicity; Goodwin & Anderson 1985; Playford *et al.* 1989; Hering 1992), are commonly proposed as significant allogenic mechanism. Only high resolution event stratigraphy may to clarify roles of both the processes in the sedimentary record (see also Kauffman 1986; Einsele *et al.* 1991).

Intershoal cycles.– Rhythmic patterns in essentially open shelf, inter-reef Devonian environments are poorly known. Cyclicity seems to be common in the Chęciny Beds, although it is fully expressed only in the three cycles of set F at Góra Zamkowa section (Fig. 27), as well as in the oxygen-deficient Dębnik basin (Racki & Baliński 1981). The complete succession up to 4 m thick is a transition from winnowed crinoid grainstone through an atrypid, rarely bivalve, bioclastic-peloidal packstone to a calcispheroid wackestone; the highest unit is capped with coral biostromal layers (set G).

Similar upward-fining tendency from the Facies M-2 to variants of the Facies M-6, sometimes with erosional features at the bottom, has been identified also in other portions of the Chęciny sequence, especially those with atrypid shelly partings (sets B, E, I). Sequential changes possibly reflect lateral migration of high-energy crinoidal mounds and bars into more sheltered areas during heavy storms, and such event stratification (Seilacher & Aigner 1991) may be differently developed in the intershoal successions. A reduced marine circulation is apparent from the biotic replacement trend, but usually assumed shallowing is not supported by any evidence with possible exception of the set D of Góra Zamkowa where gastropod-rich or unfossiliferous fine-grained layers are repeatedly capped by laminated units bearing even emergence features (Facies M-1). The shoaling episodes are recorded particularly in edgewise conglomerates with reddish, ferrugineous groundmass (Fig. 17B) representing current fill of tidal channels and pot holes with clasts derived from dried mud on levees and microbial mats (cf. Wilson 1975: p. 82). The depositional pattern is less distinct in more muddy laminite sequence of Stokówka, probably developed in more sheltered setting.

Biostratigraphically-based age correlation

Except for isolated occurrences of *Stringocephalus* (Baliński 1973), the only fossils of time correlation value in the Kowala Formation are conodonts. Eighty two samples from ten sites (Tabs 1-3) have yielded conodonts useful for stratigraphic inferences, typically below 25 specimens per kilogram and frequently juvenile. Samples from fossiliferous, especially crinoid-bearing variant of the micrite Facies M-3 were the most productive, with frequencies above 200 elements per kilogram. The collected material comprises about one thousand variably preserved specimens representing at least 19 species (Figs 29-33). Some conodont elements from the nodular varietes of the Chęciny Limestone show a red-cherrish coloration, the feature being usually linked with deformations by compaction and partial crushing. Samples from the spiculite micrites of the Facies M-4 are exceptional, containing many delicate ramiforms, and clusters are found in one sample.

The conodonts enable dating of main transgressive levels, but in the strata traditionally ascribed as 'Upper Givetian Limestones', developed in the lagoonal and reef facies, the microfossils are virtually lacking (Racki 1980). As shown above (Figs 15A-C; 19A-C, 28), the faunas largely probably belong to the polygnathid biofacies (Klapper & Lane 1985; Sandberg *et al.* 1989), which is of very limited correlative value. The broad-plat-

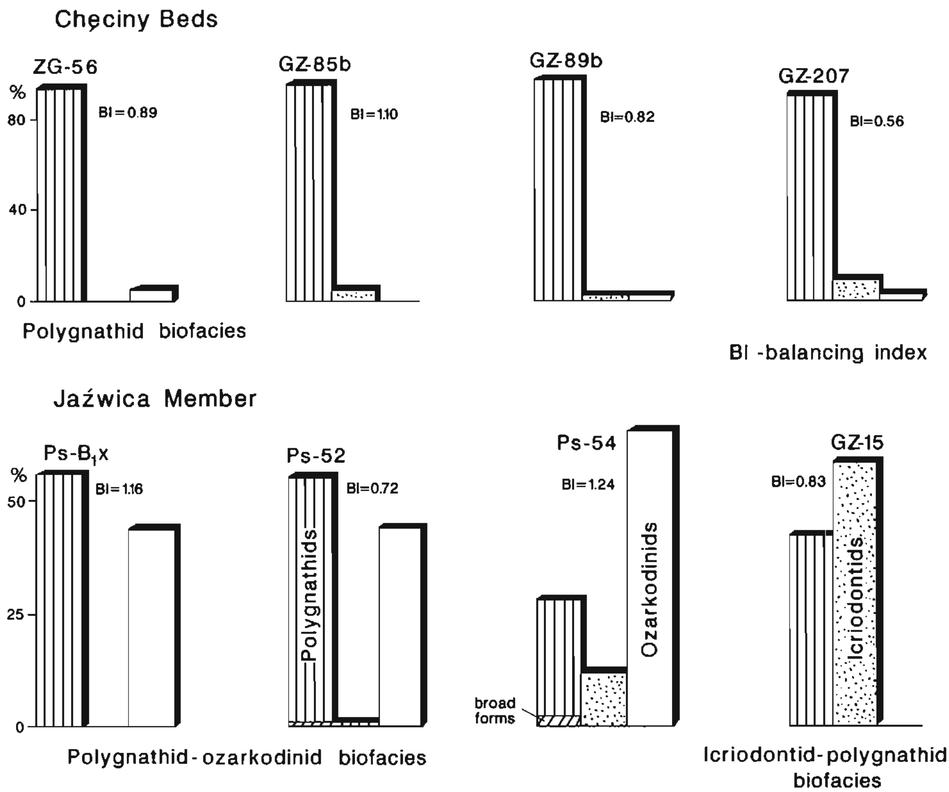


Fig. 28. Frequency distribution of conodonts diagnostic for particular biofacies in representative samples from the Jaźwica Member and Chęciny Beds.

formed elements, as well as reef-related *Belodella*, are extremely scarce in the faunas from the southern Holy Cross Mountains. This is in contrast with data from the northern periphery of the Kielce Region and the Kostomłoty basin (Racki & Bultynck in preparation). All the data argue for a complex nature of the ecologic relationships within the analysed bank-dwelling conodont faunas, difficult to evaluate in terms of the simple depth-stratification model, as it is known for polygnathid/icriodontid separation pattern (see summary in Pohler & Barnes 1990 and Belka & Wendt 1992). The role of local ecologic patchiness seems to be still underestimated in conodont biogeography. Some conodont species, especially icriodontids might be in fact nektobenthic or benthic(?) creatures sensitive to subtle environmental and biotic influences at the sea floor (Sweet 1988).

Age of the *Stringocephalus* Beds.– The lower part of the Kowala Formation is dolomitized, with few fossils preserved, especially in the unit I of Narkiewicz (1991). Even the relatively open shelf deposits of set A at Jurkowice-Budy, representing the basal portion of the subcycle G-Ia, have yielded juvenile icriodontids only. The oldest ?pre-*Stringocephalus* macrofauna in this section, also found in the set A, and possibly in the Dziewki Limestone (Racki *et al.* in press b), includes crinoid ossicles of the 1st Faunal Interval with *Stenocrinus-Noctuicrinus*(?) Assemblage of Głuchowski (1993) and fragmented brachiopods (Racki 1986a: Pl. 1: 1). Columnal-based *Gurjevskocrinus punctulatus* Dubatolova 1971 is limited in the region to the Skały Beds (the Eifelian/Givetian transition), while common *Stenocrinus raricostatus* Głuchowski 1992 appears as low as in the Middle Givetian Laskowa Góra Beds.

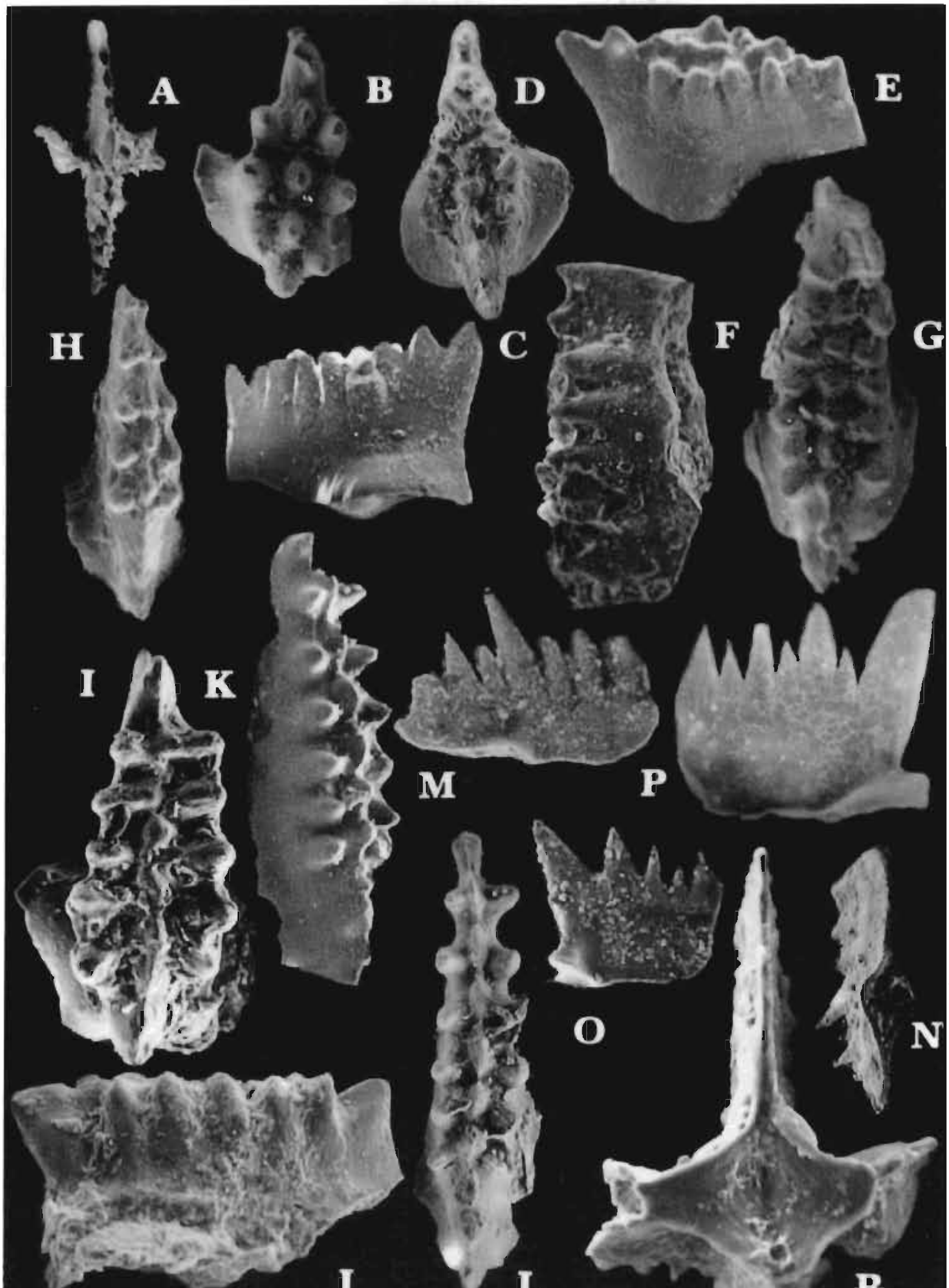
Determinable brachiopods comprise *Rensselandia* cf. *circularis* Holzapfel 1912. Representatives of this genus range in the Rheno-Ardennian area, according to data of Struve (1982), from the late *Polygnathus ensensis* Zone (*sensu* Weddige 1988) to the Middle *Polygnathus varcus* Subzone. A similar rensselandiid was identified also e.g. in the middle part of the Skały Beds (Biernat 1966). The closely related Moravian species *R. gregaria* Ficner & Havliček 1978 was quoted from the Eifelian/Givetian transition beds (Čelechowice cycle; Galle *et al.* 1988).

The higher *Stringocephalus*-bearing suite of the fossiliferous Jurkowice-Budy section was a subject of several paleontological studies, without reference, however, to the more detailed set subdivision. In all likelihood, the most of the data come from the severely weathered well-exposed fossiliferrous strata of the set E (Fig. 9B) representing the basal part of the subcycle G-Ib. Their late, but not the latest Givetian age, was generally accepted (Kaźmierczak 1971b; Baliński 1973; Olempska 1979).

Coral assemblages of the *Stringocephalus* Beds, including data from their equivalents in the Silesia-Cracow area, comprise many distinctive Givetian species (Nowiński 1976, 1993; Wrzołek 1988, 1993). However, their ranges within this stage are crudely recognized as exemplified by apparently equivalent *'Hexagonaria' laxa*-Upper *Caliapora battersbyi* Zone in the 'mid'-Givetian strata of Moravia (Galle *et al.* 1988). Rich ostracod associations of together 33 species (Olempska 1979) also include species markedly characteristic for the Eifelian and/or early Givetian of both the Variscan Europe and the East European Platform (cf. Żbikowska 1983: Tab. 5). It is well exemplified by the most abundant *Coelenellina minima* (Kummerow 1953).

Brachiopods typical of the set E at Jurkowice-Budy, as well as of the higher Dziewki Limestone (Brachiopod Interval Ib-R of Racki 1993), are marked by *Rhynchospirifer hians* (von Buch 1836) that in the Rhenish

Fig. 29. ❑A, R. *Ancyrodella* sp., juvenile specimen in upper view (A) and details of the rhombic basal cavity (R); Góra Zamkowa GZ 157. ❑B-F. *Icriodus subterminus* Youngquist 1947, upper (B, D), oblique-lateral (E), and lateral (C, F) views, note variable height of the posteriomost denticles (cf. Uyeno in Norris & Uyeno 1983: Pl. 1: 9-22, 25-27) and length of the spindle; Jaźwica Jz 6 (B-C), Zamkowa Góra GZ 15 (D-E) and Sowie Górki SG C_2 (F). ❑G. *Icriodus expansus* Branson & Mehl 1934, upper view, Jaźwica Jz 7. ❑H and K-L. *Icriodus* ex gr. *brevis* Stauffer 1940, upper (H, L) and oblique-lateral (K) views of different-size specimes; Sowie Górki SG Cx (H) and Trzemoszna TZ x_2 (K-L). ❑I-J. *Icriodus* aff. *latecarinatus* Bultynck 1979, upper (I) and lateral (J) views, note relatively weakly developed posterior cusp; Marzysz Mz x_2.



□M-P. *Ozarkodina brevis* (Bischoff & Ziegler 1957), lateral (M) and oblique-lower (N) view of the Pb element (cf. Nicoll 1985), and lateral views of the Pa elements (O-P): Góra Zamkowa GZ 97b (M-N) and GZ 89b (O), and Posłowice Ps 54 (P). All × 100 except for B, G (× 75), P (× 130) and R (× 300).

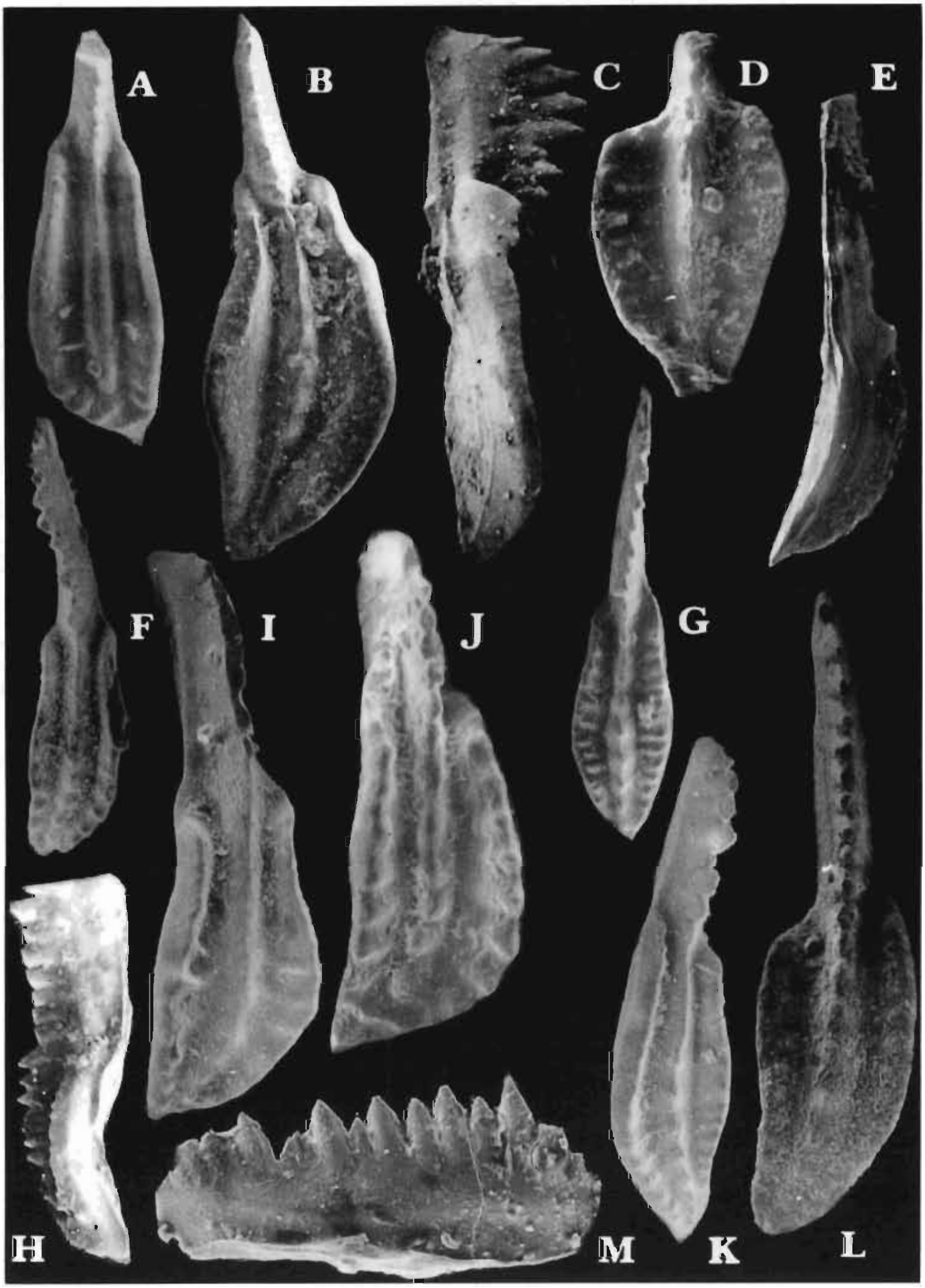
Slate Mountains probably does not occur above the *P. ensensis* Zone (Struve 1982). In fact, Baliński (1973: p. 271) noticed the faunal similarity of the Jurkowice-Budy section to the Rodert Formation that falls within the Early Givetian. The associated species *Ambothyris infima* (Whidborne 1893) was originally described from the *P. varcus* Zone (Lummaton Shell Bed; Austin *et al.* 1985). The presence of *Ozarkodina brevis* (Bischoff & Ziegler 1957) in impoverished fauna of Siewierz is of little value due to a broad range of the species (Klapper & Johnson 1980), evidenced also by data from the Holy Cross Mountains.

Furthermore, *Rensselandia gibbosa* (Cloud 1942) at Jurkowice-Budy, and particularly *Parastringocephalus* at Siewierz that pre-dates the *Rhynchospirifer* association, are strongly suggestive of a higher Givetian position (level 'CaPlat 11' of Struve 1992). Thus, a relic nature of this *Rhynchospirifer hians* occurrence in southern Poland can be proposed (cf. Racki 1988) and this refers to several coral (see also Hladil 1988), as well as ostracod species. The Middle Givetian position of the subcycle G-Ib is consistent with the crinoid succession (Głuchowski 1993), which suggests correlation with the well-dated Laskowa Góra Beds (3rd Faunal Interval with *Anthinocrinus brevicostatus*).

Position of the Eifelian/Givetian boundary.– The stage boundary is recently defined within the *P. ensensis* Zone, and, as underlined by Bultynck *et al.* (1991), in the neritic facies realm the traditional *Stringocephalus*-based boundary has been drawn distinctly higher in the sequence. As the Early Givetian span is undoubted at Jurkowice-Budy for the set C where the first *Stringocephalus* was encountered (Fig. 12A), the boundary must be somewhere in the underlying strata, e. g. in the unit I of Narkiewicz (1991).

Base of the Jaźwica Member.– The transgressive set of the cycle G-II was a source of numerous conodonts. The most abundant fauna of at least 14 species has been collected from the subset B_2 at Posłowice (Fig. 15A-C). First appearances of such species as *Icriodus subterminus* Youngquist 1947, *Polygnathus* cf. *dengleri* Bischoff & Ziegler 1957, *P. pollocki* Druce 1976, and particularly *P. webbi* Stauffer 1938 are significant, and their co-occurrence with *Polygnathus latifossatus* Wirth 1967 in sample Ps 54 indicates the *Mesotaxis falsiovalis* Zone (cf. Klapper & Johnson 1980; Bultynck 1982, 1986; Feist & Klapper 1985). Sequences representing Bolechowice facies yield less diverse but similar faunas with *I. subterminus* (the most common species), *P. pollocki*, and *Mehlina gradata* (Youngquist 1945).

Fig. 30. ❑A-C. *Polygnathus alatus* Huddle 1934, upper (A-B) and lateral (C) views; Marzysz Mz x_2 (A) and Sitkówka-Kostrzewa SK 21 (B-C). ❑D. *Polygnathus* cf. *dengleri* Bischoff & Ziegler 1957, upper view of incomplete specimen corresponding likely to the more primitive morphotypes; Posłowice Ps 54. ❑E-H. *Polygnathus dubius* Hinde 1879, upper (F-G), oblique-lower (E) and lateral (H) views; Góra Zamkowa GZ 85e (E, G-H) and Posłowice Ps 52 (F). ❑ I-K. *Polygnathus denisbriceae* Bultynck 1979, upper views; Góra Zamkowa GZ 84b (I), GZ 90d (J) →



and Sitkówka-Kostrzewa SK 110 (K). ❑L. *Polygnathus* aff. *dubius* Hinde 1879 (*P. decorosus*-trend *sensu* Bultynck 1982), upper view of element exhibiting saggitate platform outline; Góra Zamkowa GZ 78c. ❑M. *Mehlina gradata* (Youngquist 1945), lateral view; Jaźwica Jz 36. All × 100 except B-C, E-G (× 65) and H (× 50).

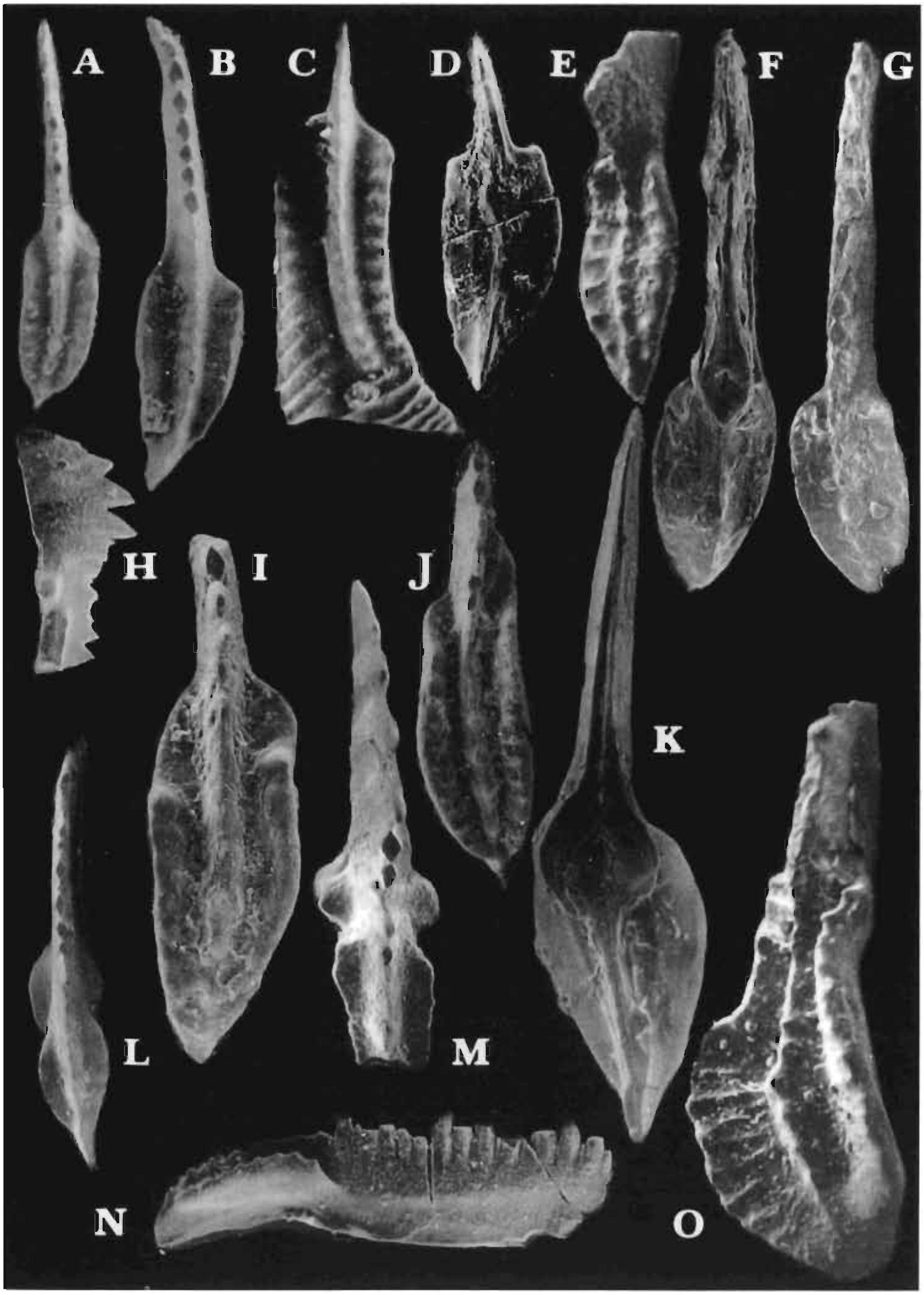
Data from the Jaźwica section (Figs 8) point that the boundary between *Stringocephalus* Beds and Jaźwica Member occurs within the range of the *I. subterminus*-dominated association. Thus, it is not older than the *Klapperina disparilis* Zone, like *I. subterminus* Fauna of North America (Braun *et al.* 1988; Witzke *et al.* 1988), and possibly near the boundary of *K. disparilis/M. falsiovalis* Zones. This time interval is especially difficult to precise conodont dating in the shelf domains, as discussed below. Noteworthy, the local acmes of *O. brevis* (Posłowice) and *P. linguiformis linguiformis* (Sowie Górki) represent the highest (late Givetian) parts only of their total ranges; similar distribution was recorded in the Ardennes (Bultynck 1982: Fig. 7) and North America (Witzke *et al.* 1988).

Considering all the conodont evidences, the Jaźwica Member represents largely the Early *M. falsiovalis* Zone. Slightly older age of the basal part in case of the Bolechowice-type succession can not be excluded. Due to above mentioned scarce conodont record (*O. brevis* fauna), a broader uncertainty interval, ranging to the *P. varcus* Subzone, marks the initiation of the Posłowice-type deposition.

Position of the Givetian/Frasnian boundary.– As shown by Sandberg *et al.* (1989), the Middle/Late Devonian boundary had been fixed in the early part of the newly established *M. falsiovalis* Zone, considered to be an aproximate standard equivalent of the former 'Lowermost *P. asymmetricus*' Zone [or the 'Upper *P. dengleri* Subzone' (Klapper & Johnson 1980; Johnson *et al.* 1985) or the '*S. norrisi*' Zone of Klapper & Johnson (*in* Johnson 1990) in more shallow-water facies realm]. Unfortunately, some uncertainty remains due to difficult correlation with the global stratotype level defined on the first appearance of poorly known primitive ancyrodellids (see discussion in Sandberg *et al.* 1989). In the studied succession this is coupled with a weak paleontological basis of biostratigraphic correlations.

Among the polygnathid-dominated associations of the Sitkówka and Chęciny Beds (*P. dubius* fauna), there are some samples with more abundant and/or diverse, large-sized and robust polygnathids (*Polygnathus* sp. A; ZG 30, GZ 207). *Polygnathus angustidiscus* Youngquist 1945 has been found firstly in the Atrypid-Crinoid Level of Sitkówka. In the

Fig. 31. ❑A, N. *Polygnathus xylus xylus* Stauffer 1940, upper (A) and lateral (N) views; Posłowice Ps B_1x . ❑ B, K-L. *Polygnathus latifosssatus* Wirth 1967, upper (B, L; L - juvenile from) and lower (K; note enlarged basal cavity) views; Posłowice Ps 54. ❑C. *Polygnathus linguiformis linguiformis* Hinde 1879 gamma morphotype Bultynck 1970, upper view; Sowie Górki SG C_1. ❑D-E. *Polygnathus pennatus* Hinde 1879, lower (D) and oblique-upper (E) views; Góra Zamkowa GZ 77. ❑F-G. *Polygnathus varcus* Stauffer 1940, lower (F) and upper (G) views; Posłowice Ps 25 (F-G). ❑ H, M. *Schmidtognathus(?)* sp., lateral (H) and upper (M) views of juvenile specimen; Posłowice Ps 52. ❑ I. *Polygnathus* cf. *timorensis* Klapper, Philip & Jackson 1970, upper view of specimen with broken free blade, visible not opposite geniculation points and junction of two anterior through margins with the blade at close position; Trzemoszna Tz x_2. ❑J. *Polygnathus* sp. aff. *P. hemiansatus* Bultynck 1987, upper view of incomplete slender specimen with the platform characterized by a weak constriction of the outer geniculation point, junction of two anterior through margins at different position and deep



adcarinal throughs; Posłowice Ps Bx (J). ❑O. *Polygnathus webbi* Stauffer 1938, upper (O) view of large element with considerable constriction near the anterior end of the platform (cf. *P.* sp. A of Uyeno 1974); Góra Zamkowa GZ-III/5. All × 100 except B-C, H (× 75), D-E, O (× 50) and M (× 150).

Tab. 1. Conodont distribution and frequency in the Góra Zamkowa succession at Chęciny. *P - Polygnathus, I - Icriodus, O - Ozarkodina, A - Ancyrodella; disp. - K. disparilis, trans. - P. transitans.* Samples signed by 'x' are pilot ones, without acurrate placement within the set.

	12	15	16	25a	33b	39	77	78a	78c	81b	84b	85a	85b	85c	Fx	85a	89b	89c
	disp.- trans.			*M. falsiovalis - P. transitans*														
P. pollocki	2	26	1	?2	?1	5	-	3	3	3	-	-	1	-	-	-	-	-
I. subterminus	-	38	?1	-	-	10	-	-	-	?1	-	2	-	-	7	-	1	-
P. dubius	-	2	-	-	3	-	-	-	-	-	-	-	-	?1	3	2	5	2
P. denisbriceae	-	1	-	-	-	-	-	?2	-	-	5	?2	7	4	4	4	?2	2
P. xylus	-	2	-	-	-	-	-	?7	3	-	-	-	?1	-	2	-	-	-
P. webbi	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-
I. expansus	-	-	-	-	2	-	-	2	-	-	-	-	2	-	-	1	-	-
P. pennatus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
P. alatus	-	-	-	-	-	-	-	?1	-	-	-	-	-	-	1	-	2	4
P. aff. *dubius*	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-
P. sp. indet.	-	22	1	1	-	8	2	12	10	4	3	6	20	40	15	40	55	27
I. sp. indet.	-	12	-	1	2	-	-	-	-	-	-	-	-	1	-	1	-	-
oz-ne elements	5	25	-	8	5	3	10	1	-	4	4	7	25	24	6	45	50	25

	89d	92	94	95a	95b	97a	97b	124	157	167	207	I/3	I/4	III/3	III/5	III/7	III/10
	M. falsiovalis - P. transitans								*P. transitans - P. punctata*								
I. subterminus	-	-	-	-	-	-	-	1	-	-	15	-	-	-	-	-	-
O. brevis	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
P. pollocki	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
P. dubius	?1	6	1	?1	-	-	-	-	1	-	-	-	- 1	-	-	2	-
P. denisbriceae	-	-	2	8	7	-	?1	-	-	-	2	-	?1	-	?1	-	-
P. xylus	-	-	1	?1	-	-	1	1	1	2	-	1	-	-	2	-	-
P. webbi	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	2	-
P. alatus	-	-	-	-	-	-	-	-	-	-	7	-	-	2	?1	-	2
P. aff. *dubius*	?1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
P. varcus	-	?2	-	-	-	-	-	-	-	-	-	-	-	-	-	?1	-
A. sp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
P. sp. A	-	-	-	-	-	-	-	-	-	-	3	?1	4	-	-	-	-
I. ex gr. *brevis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
P. sp. indet.	14	9	2	15	12	12	6	19	-	10	15	12	-	1	10	4	4
I. sp. indet.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
oz-ne elements	30	8	4	10	5	2	5	25	15	10	20	-	-	2	8	1	5

classical Chęciny section, *Polygnathus pennatus* Hinde 1879 appears in set E, and is succeeded by an ancyrodellid (Fig. 29A, R) in the higher part of set H representing post-*A. soluta* stage of phylogeny (*sensu* Sandberg *et al.* 1989).

No significant macrofaunal changes have been identified in the Chęciny Beds in the critical (G/F-III to IC) interval due to severe facies hindrances, and the transition from the lower to upper Sitkówka Beds represents generally similar case (but see tetracoral data in Wrzołek 1988, 1993). Brachiopod distribution at Chęciny (Fig. 7) can be summarized in two principal points: (1) the subset F-I (Racki & Baliński 1981) is marked by the appearance of *Uchtospirifer nalivkini* (Lyashenko 1959), and (2) the characteristic atrypid *Iowatrypa timanica* (Markovsky 1938) entries in the middle portion of set I. This species pair marks the Middle-Late Devonian passage, as recently defined, in Russia and the Urals (Lyashenko 1973).

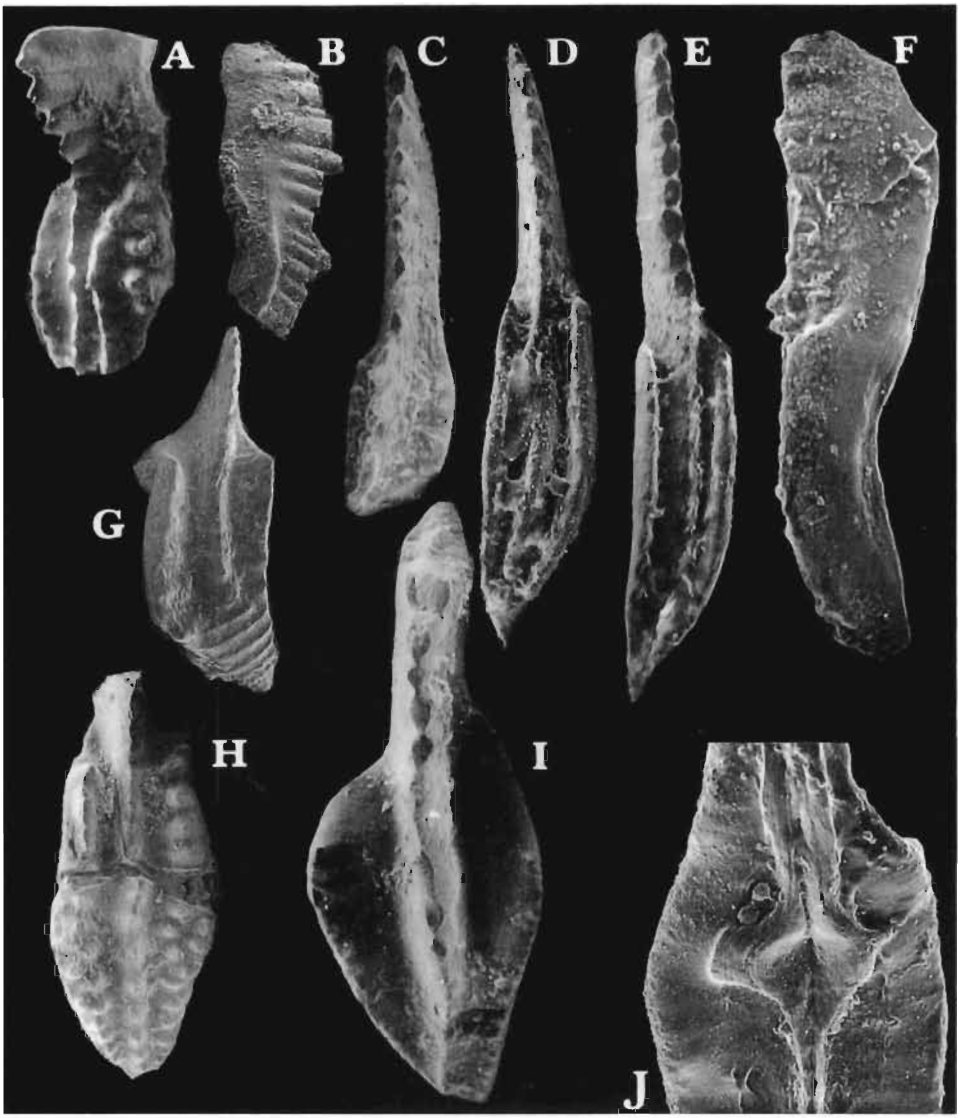


Fig. 32. ❑A, J. *Schmidtognathus* cf. *wittekindi* Ziegler 1966, oblique-upper (A) and partial lower (J) view of damaged specimen; Posłowice PS 54. ❑B. *Polygnathus* cf. *angustidiscus* Youngquist 1945, lateral view of incomplete specimen with strongly reduced platform; Sitkówka-Kostrzewa SK 21 (B). ❑C. *Polygnathus angustidiscus* Youngquist 1945, upper view of specimen with broken posterior end; SK Bx . ❑D-F. *Polygnathus pollocki* Druce 1976, upper (D-E) and lateral (F) views, note elongated and weakly ornamented platform with passages toward *P. xylus* ; Góra Zamkowa GZ 15. ❑G. *Polygnathus linguiformis linguiformis* Hinde 1879 gamma morphotype Bultynck 1970, upper view; Trzemoszna Tz x. ❑H. *Polygnathus* cf. *ordinatus* Huddle 1934, fragmentary specimen in upper view; Posłowice Ps 50. ❑I. *Polygnathus* cf. *elegantulus* Klapper & Lane 1985, upper view; Zegzelogóra ZG 41. All × 100 except for A-B and G-H that are taken × 50.

Tab. 2. Conodont distribution and frequency in sections of the Jaźwica Member. Tz - Trzemoszna, Mz - Marzysz, Łg - Łagów; *S* - *Schmidtognathus*, *B* - *Belodella*, E - Early, M - Middle, L - Late, *v* - *P. varcus*, *h* - *P. hermanni*, *d* - *K. disparilis*, *f* - *M. falsiovalis*, *t* - *P. transitans*, *p* - *P. punctata*; for other abbreviations see Tab. 1.

	Tz		Mz	Posłowice								Sowie Górki C						Stokówka			Łg
	x_1	x_2	x_2	30	43	45	46	B_1 x	50	52	54	1	2	3	4	5	x	17	18	24	32
	E*v*-*t*	M*v*-*f*	*h*-*p*	E*v*-*f*	L*v*-*f*	*h*-*f*			?*f*		*f*	?E*v*-*t*			*d*-*t*		E*v*-*t*	E*v*-*p*	*d*-*p*		?*f*-*p*
P. xylus xylus	1	-	-	1	-	-	1	2	10	-	-	5	-	-	-	-	-	-	1	-	-
P. ling. linguiformis	2	10	-	-	-	-	-	-	-	-	-	1	1	3	-	1	6	-	-	-	-
P. ling. cf. *weddigei*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. denisbriceae	-	1	-	-	-	-	?1	-	-	-	1	?1	-	-	-	-	-	-	-	-	-
P. cf. *timorensis*	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. aff. *hemiansatus*	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
I. ex. gr. *brevis*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
P. varcus	-	-	?1	-	?1	-	-	?3	?2	-	-	-	-	-	-	-	1	-	-	1	-
P. dubius	-	-	1	-	-	2	-	2	-	12	12	-	-	-	-	-	-	-	-	-	-
P. alatus	-	-	2	-	-	-	-	?2	-	-	2	-	-	-	-	-	-	-	-	-	-
I. expansus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	?1
I. aff. *latecarinatus*	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O. brevis	-	-	-	-	-	-	-	38	-	10	24	-	-	-	-	1	-	-	-	-	-
P. webbi	-	-	-	-	-	-	-	-	?1	-	2	-	-	-	-	-	-	-	-	-	?2
P. cf. *ordinatus*	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
S. cf. *wittekindi*	-	-	-	-	-	-	-	-	-	?1	2	-	-	-	-	-	-	-	-	-	-
P. dengleri	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
P. latifossatus	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
I. subterminus	-	-	-	-	-	-	-	-	-	-	12	-	-	-	3	-	-	-	1	-	-
P. pollocki	-	-	-	-	-	-	-	-	-	-	2	-	-	-	6	-	-	-	-	-	-
P. sp. indet.	-	3	4	-	-	-	-	15	-	-	9	1	-	-	-	-	-	-	3	2	3
I. sp. indet.	1	-	1	-	-	-	2	-	-	1	2	-	-	-	1	-	2	1	3	-	-
oz-ne elements	2	8	1	-	-	2	-	35	-	1	7	-	2	1*B*	-	2+1*B*	5	-	1	-	5

Tab. 3. Conodont distribution and frequency of conodonts in sections of the Jaźwica Member and Chęciny Beds. *M* - *Mehlina*; for other abbreviations see Tabs 1-2.

	Jaźwica							Zegzelogóra					Sosnówka			Sitkówka-Kostrzewa									
	6	7	9	Bx	27	28	36	7	10	30	40	56	10	16	23a	21	43	Bx	73	110	111	131	I/3	I/4	II/1
	d-*t*				*d*-*p*			*h*-*p*			*d*-*p*	?*d*-?*t*			M*v*-?*t*	?*f*-?*t*	*f*-*t*			*f*-*p*			*f*-*t*		
I. subterminus	11	20	11	32	29	7	-	-	-	-	-	-	-	-	-	-	?2	9	72	1	-	1	1	4	1
P. pollocki	?1	31	3	3	10	3	-	-	-	-	-	?2	?1	-	-	-	-	-	-	-	-	-	-	-	-
M. gradata	2	2	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I. expansus	-	15	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O. brevis	-	4	-	-	-	-	-	-	-	-	-	1	?1	-	-	-	-	-	-	-	-	-	-	-	-
P. xylus	-	-	1	5	-	?5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. denisbriceae	-	-	-	4	-	-	-	?1	-	-	-	-	?2	-	-	-	-	-	-	1	-	-	-	?4	-
P. alatus	-	-	-	-	-	?1	-	-	-	-	-	-	-	-	-	?1	1	1	?1	-	1	-	-	1	-
P. dubius	-	-	-	-	-	-	-	-	2	-	10	4	-	5	1	-	2	5	-	-	-	-	-	-	-
P. sp. A	-	-	-	-	-	-	-	-	-	8	12	4	?2	1	-	-	-	-	-	-	1	-	-	-	2
P. cf. *elegantulus*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. varcus	-	-	-	-	-	-	-	-	-	-	-	?1	-	-	-	-	-	-	-	-	-	-	-	-	-
P. aff. *dubius*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
P. angustidiscus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?1	1	-	-	-	-	-	-	-
P. webbi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?1	-	-	-	-	-	2	2
P. sp. indet.	2	5	2	20	10	6	-	3	-	-	-	12	2	7	1	-	9	12	7	1	1	1	-	20	1
I. sp. indet.	10	5	3	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	-	1	-	-
oz-ne elements	14	31	-	15	4	2	-	1	1	-	-	16	-	5	2	-	8	23	4	4	-	4	-	8	3

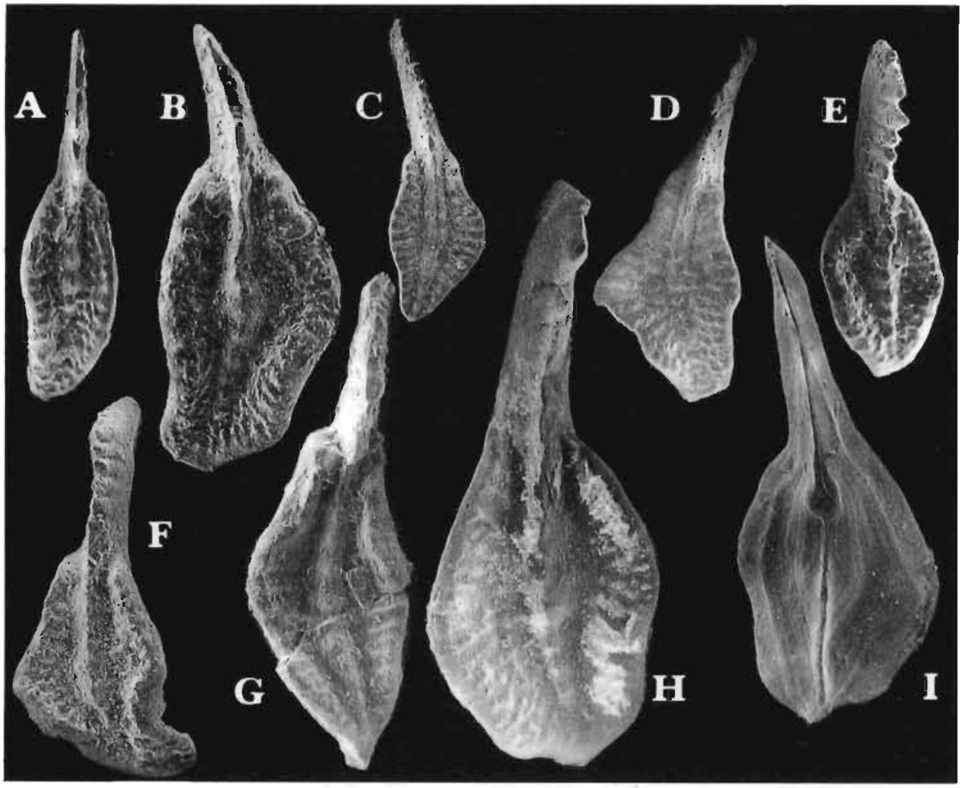


Fig. 33. *Polygnathus* sp. A, upper (A-H) and lower (I) views; Sosnówka Sn 23a (A), Sitkówka-Kostrzewa SK-II/1 (B), Zegzelogóra ZG 30 (C), ZG 56 (D-E), ZG 40 (F, H-I), Góra Zamkowa GZ 207 (G). All × 48 except for H-I that is × 57. The specimens are marked by more conspicuous, infrequently asymmetrical flaring of platform than even most broad in outer part (*P. foliatus*-type) varietes of widespread *P. dubius*, the neotype including (Huddle 1970: Pl. 10: 5-6; also Bultynck 1982: Pl. 3: 9). From *P. ovatinodosus* Ziegler & Klapper 1976 they differ in having much shorter free blade and frequently asymmetrical platform with incomplete carina. Forms from the sample GZ 207 (G) in more upturned margins and the 'waist' of the almost symmetrical, ribbed platform are somewhat similar to *P.* sp. A *sensu* Uyeno (1974: p. 41, Pl. 4: 9 only), and *P. aequalis* Klapper & Lane 1985.

The first species indicates the Lower Kyn subhorizon of the Late Givetian (*K. disparilis* or *M. falsiovalis* Zone; cf. Khalymbadzha *et al.* 1985; Rzhonsnitskaja 1988), while the atrypid is typical for the basal Frasnian Sargaievo horizon. *Uchtospirifer* is reported also from the Givetian-Frasnian transition ('F2a') of the Ardenne and Boulonnais successions (Brice 1982).

In consequence, the bottom part of the cycle G/F-III exhibits, with reservations noted above, the latest Givetian biostratigraphic features, while the oldest Frasnian attribute comes from the basal IC-Complex, i.e. the ancyrodellid from the set H of Chęciny. The stage boundary may be located just below or near bottom of the latter unit, e.g. in the middle part of the Chęciny Beds, somewhere within the sets F-G. Unfortunately, this inference may be only crudely supported by the correlation with more accurately dated Wietrznia sections due to obscured cycle record in the coarse-grained sequences.

Base of the *Phlogoiderhynchus* Marly Level.– The Detrital Beds, occurring directly below the *Phlogoiderhynchus* Level in the Chęciny sequence (set J), belong already to the *Palmatolepis punctata* Zone (Narkiewicz 1973) as shown by the index palmatolepid (Fig. 34). The following transgressive set of the cycle F-I certainly represents the same zone, as evidenced by the occurrence of *Ancyrodella gigas* Youngquist 1947 in the Kowala section (see also Szulczewski & Racki 1981).

Eustatic framework of the depositional history

In the face of generally weak biostratigraphic evidence (the almost complete lack of any pelagic fossils), the sections in the southwestern part of the Holy Cross Mountains can be correlated and non-directly dated by attribution to regional sedimentary cycles of mostly eustatic nature (Figs 7, 35-36; Racki 1985b, 1988). Johnson, Klapper & Sandberg (1985) constructed a qualitative sea-level curve for the Devonian (see also House 1985; Johnson & Sandberg 1988) that may serve as the reference standard.

Thus, the main factor of extrabasinal control on vast Middle and Late Devonian carbonate shelves was the sea level movement, with little contribution of local tectonics. In the Givetian to early Frasnian epeiric sea of the Holy Cross Mountains area, an influence of synsedimentary tectonics can be recognized mainly in the Wietrznia subregion (Szulczewski 1989; Racki & Bultynck in preparation).

The eustatic standard was originally derived from five widely disjunct Euramerican platform areas. A lot of information emerged subsequently, also from Poland and Russia, which enables some refinement of the scheme (see also Hladil 1986). The major pulses are correlatable with global bio-events (House 1985; Walliser 1985; Weddige 1988; Boucot 1990). The biotic response for the Late Givetian transgression is called herein '*Mesotaxis* Event' as an alternative for the '*asymmetricus* Event' proposed by Walliser (1992). *Manticoceras* Event (Frasne Event of House 1985) is arbitrarily assigned to the Cycle IIc.

Two prominent late Givetian and early Frasnian deepening pulses are recognized in the sequences of the Kowala Formation, and they can be traced northward, too. Otherwise, two stratigraphically older significant deepening events are apparent in the Middle Devonian fossiliferous succession of the Bodzentyn Syncline (Pajchlowa 1957): (1) the platform (lagoonal and dolomitic) Wojciechowice Beds were abruptly transgreded by open-shelf, marly-limy deposits of the Skały Beds, and (2) the shaly Nieczulice Beds (Śniadka Formation of Kłossowski 1985) overlie the Pokrzywianka-type buildup or clastic Świętomarz Beds. The first onlap

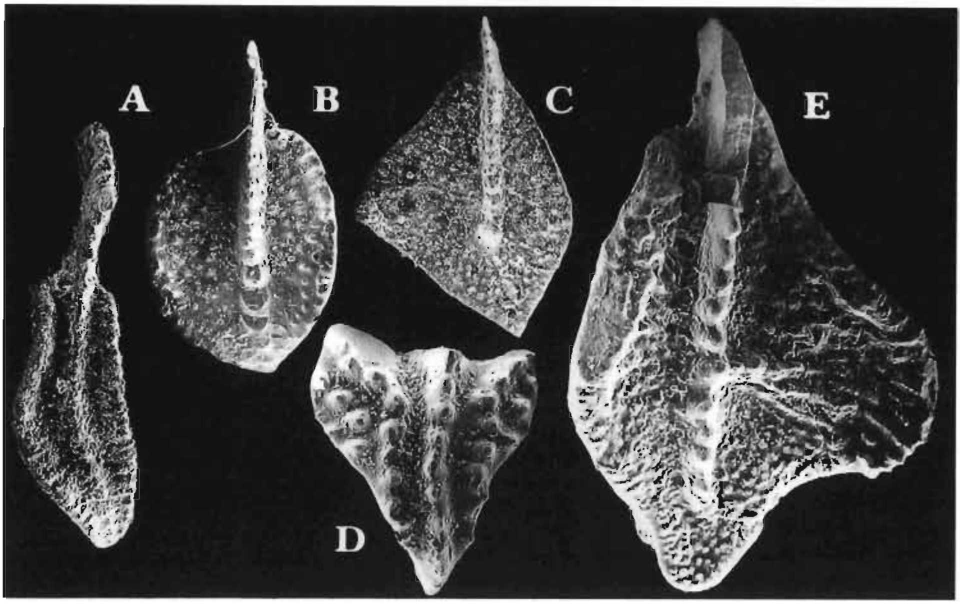


Fig. 34. Frasnian conodonts of the *Phlogoiderhynchus* Level at Kowala (A-D; see Fig. 24 for sample location), and underlying Detrital Beds of Chęciny (E); upper views. ❑A. *Polygnathus webbi* Stauffer 1938; Wl D-2. ❑B. *Mesotaxis asymmetrica* (Bischoff & Ziegler 1957); Wl D-2. ❑C. *Palmatolepis transitans* Müller 1956; Wl D-1. ❑D. *Ancyrodella gigas* Youngquist 1945; Wl D-2. ❑E. *Palmatolepis punctata* (Hinde 1879); GZ-V Jx. All × 48.

begins at or near the *Tortodus kockelianus* - *P. ensensis* zonal boundary, the second one is in the Middle *P. varcus* Subzone (Malec 1984, Kowalczewski & Malec 1990). The latter profound Middle Givetian facies shift is also indicated by drowning of the carbonate bank portion in the Kostomłoty area at the top of the *Stringocephalus* Beds in the Laskowa sequence (Racki *et al.* 1985).

The overall cyclic pattern may extend much eastward to the Lublin area (cf. Narkiewicz 1988), but more accurate dating of eastern sequences is prerequisite. The Dębnik Limestone of the Cracow Devonian exhibits only a weak transgressive facies trend across the Givetian-Frasnian passage interval, culminating in a distinct early Frasnian deepening pulse, probably in the *M. transitans* Zone (Narkiewicz & Racki 1987; Narkiewicz 1988).

T-R Cycles If-IIa (*Nowakia otomari* and Taghanic Events)

Regional setting.– The latest Eifelian and Middle Givetian worldwide transgressions are expected to influence deposition on the Kielce platform as it was well evidenced for the adjacent Kostomłoty-Łysogóry intrashelf basin. Despite several biostratigraphic indications gathered from the Kielce Region and Siewierz area, discussed in the previous chapter, only somewhat speculative correlation of these events with the bipartite cycle

G-I of the *Stringocephalus* Beds can be proposed (Figs 3, 37). A lot of uncertainty remains in such interpretated eustatic framework and the three main alternatives have to be considered within the limits of possible dating errors:

(1) An initial phase of the Cycle If may be recorded in the basal biostromal-dolomitic unit of the Kowala Formation, and thus responsible for a gradual decline of strictly hypersaline sedimentation (cf. Narkiewicz 1991).

(2) The base of the Kowala Formation correlates with the Middle Givetian onlap, which would imply an extraordinary relic character of the faunas.

(3) Possible extension of the lower part of the Jaźwica Member in the Posłowice facies as low as the Middle *P. varcus* Subzone would indicate that the mid-Givetian sea-level rise had drowned some portions of the Kielce biostromal platform. This scenario would imply similar deposition in the Kostomłoty slope area, manifested in the Laskowa Góra Beds, and this more submerged bank fragment corresponding to widened variant of the Górno-Daleszyce depressional area, which was indicated later by southward spreading of the deeper water sedimentation of the Szydłówek Beds ('basin tongue'; Figs 2, 15D). According to this interpretation, the Jaźwica Member would record two superimposed Givetian deepening pulses in the continuosly open shelf Posłowice-type successions, but only the later one in the Bolechowice facies area.

Notably, large regressions documented for many Givetian successions (Hladil 1986; Braun *et al.* 1988; Johnson & Sandberg 1988), are difficult to recognize in the Givetian of the Kielce Region. However, Kowalczewski & Malec (1990) emphasized the significance of intra-Givetian block uplifts in the adjacent areas, that are recorded also in a terrigenous influx to the Łysogóry basin (Świętomarz Beds; Czarnocki 1950).

Supra-regional aspects. – Despite the somewhat unclear nature of the *N. otomari* Event (Truyols-Massoni *et al.* 1990), the base of the Skały Beds corresponds to the original concept of this global event (Walliser 1985) being lastly regarded as 'natural' middle of the Middle Devonian (Bultynck *et al.* 1991). The transgressive pulse seems to be connected also with the base of the Mosolovo horizon of Russia that is not very reliably dated as the *P. ensensis/P. varcus* zonal boundary interval (Aristov 1988; Rzhonsnitskaja 1988: Tab. 2).

The Middle Givetian Taghanic inundation, only broadly synchronous, followed a regressive episode and is belived to be of paramount importance in Euramerica as the beginning of the second Devonian major depositional cycle (*sensu* Johnson *et al.* 1985). It may be identified in the erosional base of the Staryi Oskol horizon of Russia, dated with the *Icriodus difficilis* fauna by Aristov (1988), and in Bohemia (Chlupač 1988). Nevertheless, the trangressive pulse is difficult to detect not only in some offshore localities of Johnson *et al.* (1985), but also on the whole Australian and Siberian continental blocks (Talent & Yolkin 1987). This resembles the situation in

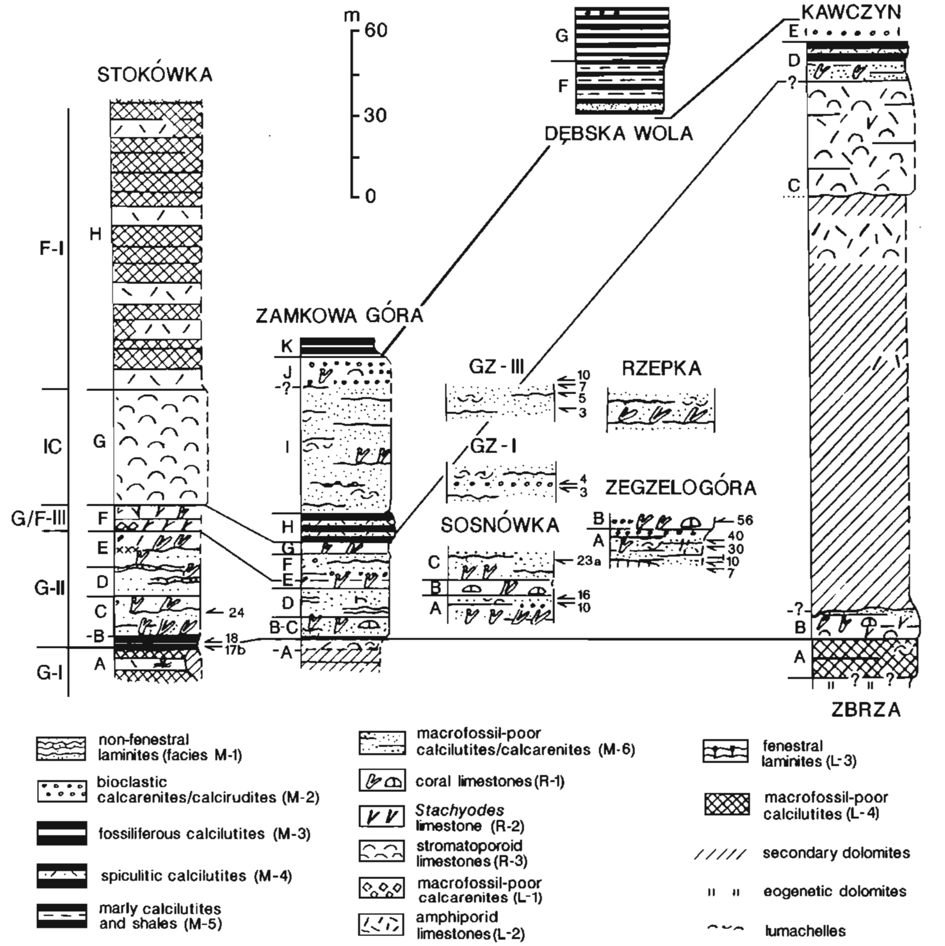


Fig. 35. Major depositional cyclicity as the basis for correlation of the sections within the paleolow area of Chęciny-Zbrza. Transitional Stokówka section (see Fig. 36) is included too. Succession of the Zbrza Anticline modified after Kucia (1987). Numbers refer to conodont samples (Tabs 1, 3). Facies are coded as in the 'Facies types account'.

Marocco (O.H. Walliser, letter communication), Moravia (Galle *et al.* 1988) and Rhenish Slate Mountains (cf. Clausen & Ziegler 1989), as well as in southern Poland shelf. Hence, it is an additional suggestion in favour of the T-R Cycle If as being responsible for the drastic facies changes toward biostromal-type deposition initiating the *Stringocephalus* Beds, even if the Taghanic transgressive event led to the far more extensive organic frame-building preceding accelerated early Frasnian reef accretion (House 1992).

T-R Cycle IIb (*Mesotaxis* Event)

Regional setting.– The Late Givetian inundation is undoubtedly indicated by the incursion of the open shelf Jaźwica Member, replaced by the

Tenticospirifer Level eastward, into the Kielce platform, but also by a southward shift of this platform margin between the time of deposition of the Laskowa Góra and Szydłówek Beds. The sedimentary response is slightly diachronous in the differentiated platform slope setting (Racki & Bultynck in preparation), but always within the range of broadly defined *K. disparilis* to *K. falsiovalis* zonal passage. As noted by House (1985) in eustatic events, depth maxima of local sequences correlate more exactly with each oter than transgressive pulse signatures which depend too much on local hypsography (see also summary in Vail *et al.* 1991).

Supra-regional aspects.– Originally, the initial diachronous inception was arbitrarily separated by Johnson *et al.* (1985) from the main cluster of the early Frasnian onlaps, and recognized with some doubts in four reference areas of Euramerica. The finally established pattern of the T-R Cycle IIb was based on two quite different conodont lines of evidence:

(1) In North America, the Waterways transgression in Canada, and the Devils Gate Limestone overlapping Bay State Dolomite barrier in Nevada, are guided chiefly by shallow-water *Pandorinellina insita* biofacies that only indirectly, via *Skeletognathus norrisi* (Uyeno 1967), is correlative with the pelagic standard (former 'Lowermost *P. asymmetricus* Zone') in its oldest part (Johnson *et al.* 1980: p. 97). Nevertheless, the lower boundary of this biofacies range is not very precisely known (Bultynck 1986: p. 273). The *P. insita* Fauna is preceded in shelf settings by the two more restricted *I. subterminus* Faunas (Witzke *et al.* 1988) ultimately assigned to the *K. disparilis* Zone (Braun *et al.* 1988). Thus, the basal transgressive signal or signals would be difficult to identify in areas where *P. insita* Stauffer 1938 and *S. norrisi* were eliminated due to biogeographic and/or ecologic constraints which is the frequent case for the Holy Cross Mountains, Russian and Rhenish conodont faunas.

(2) Basal Frasnian ('F2a') transgression in Belgium begins with facies-controlled (Bultynck 1982) entry of earliest ancyrodellids, possibly near the Givetian/Frasnian boundary level of the global stratotype (Sandberg *et al.* 1989) in the Early *M. falsiovalis* Zone, viz. later than in the North American sites. Noticeably, however, the conodont-bearing basal set of the upper Fromelennes Formation ('F1c'; Fort du Hulobiet Member *in* Bultynck *et al.* 1991) is marked by thin-layered lime-marly lithologies with poor brachiopod ('*Martinia*') and gastropod fauna (Coen & Coen-Aubert 1971; Bultynck 1974: Figs 3, 5), and scarce conodonts (Bultynck 1982), comprising predominantly *I. subterminus* and *P. insita*. The data are strongly suggestive that this very segment of the Fromelennes succession corresponds to rather obscured inception of the T-R Cycle IIb. It is assumed to be equivalent to the Jaźwica Member; this maybe refers also to '*Crurithyris*?-Hauptlager' of the upper Wallersheim Formation in the Eifel Mts (Struve 1964), but its correlation with the Fort du Hulobiet Member remains uncertain. Thus, the abrupt facies change at the bottom of the Frasnes Group represents rather a regional event of epeirogenic origin possibly recorded also in the basal Oos Formation of the Rhenish

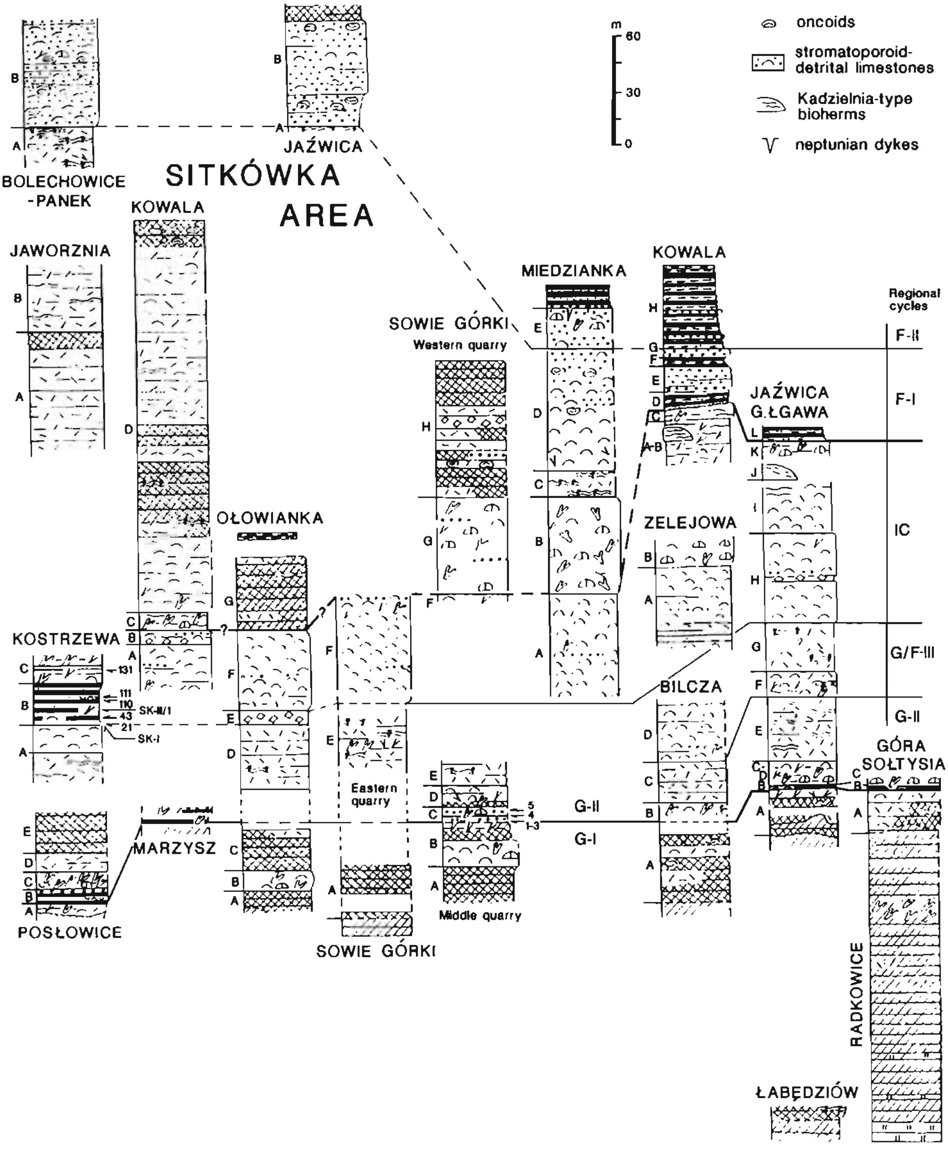


Fig. 36. Major cyclicity as the basis for correlation of the sections of the paleohigh Kielce Region in the western Holy Cross Mts. Profiles of the Sitkówka-Bolechowice area (Kowala, Jaźwica, Panek) mostly after Kaźmierczak (1971b). Stromatoporoid-detrital limestones comprise talus-like variety of the Facies R-3r. Numbers refer to conodont samples (Tab. 3).

Slate Mountains (see dating in Sartenaer 1980), and, maybe in the cycle G/F-III within the Sitkówka biostromal complex.

The inception of the eustatic cycle under discussion is restricted to the *K. disparilis* to *M. falsiovalis* zonal passage (pre-ancyrodellid span), but because of crude correlation in the shelf successions, stepwise nature of the superimposed transgressive pulses can not be excluded (see e.g. Upper *Pharciceras* horizon of Ebert 1992, subcycle IIa-3 of Witzke *et al.* 1988).

It is quite probable that this post-*Stringocephalus* deepening event was far more significant than assumed by Johnson *et al.* (1985). Overstepping facies progressions are well documented not only in North America (Braun *et al.* 1988; Witzke *et al.* 1988) but also in the progressive Kyn flooding in Russia and the Urals (Rzhonsnitskaja 1988). This profound event has a variable sedimentary record (Kliuzhina 1981: Fig. 1) and, judging from current conodont datings, corresponds to *K. disparilis* and/or *M. falsiovalis* Zones (Khalymbadzha *et al.* 1985). The deepening pulse can be seen in the bottom of the Moravian Ochoz Cycle (Galle *et al.* 1988). Likewise, Talent & Yolkin (1987) claimed that the transgression at the base of the T-R Cycle IIb was noticeably important for the southern Siberian, and possibly Australian successions, although their dating remains somewhat ambiguous.

T-R Cycle IIc sensu lato (*Manticoceras* Event)

Regional setting.– The early Frasnian deepening is well established in the area (Narkiewicz 1988). The base of the transgressive *Phlogoiderhynchus* Marly Level falls within the *P. punctata* Zone in the southern Kielce and Chęciny-Zbrza areas, which is in accordance with the dating of the inundation elsewhere (Johnson *et al.* 1985). Nonetheless, a similar facies changeover in the Wietrznia-Kostomłoty transect is dated precisely by Racki & Bultynck (in preparation) as the early *P. transitans* Zone, being aided by the entry of *Ancyrodella rugosa* Branson & Mehl 1934 (cf. Sandberg *et al.* 1989), and marked by the appearance of a cephalopod fauna with *Manticoceras* (see Racki *et al.* 1985). This initial flooding is followed in the area by a continuing deepening in the *P. punctata* Zone, expressed in reduction of debris influx from the Kadzielnia reef, paired with periodic anoxic conditions expansion in the deeper-water setting (see e.g. set C of Kostomłoty). Therefore, the final drowning of the southern periphery of the incipient Dyminy reef most probably coincides with the repeated transgressive signal on its northern flank.

Supra-regional aspects.– The renewed sea-level rise in the early Frasnian *P. transitans* Zone is evident over areas of the Russian Platform and Urals from fully marine carbonate strata of the Sargaievo horizon. The trend starts already in the *M. falsiovalis* Zone, corresponding to the local *Ancyrodella rotundiloba* zone (Rzhonsnitskaja 1988), and was considerably sustained at least to the *P. hassi* Zone as shown by appearance of deep-marine, bituminous-shaly Domanik suite (Kirikov 1988). The likely worldwide transgression in the former 'Lower *P. asymmetricus* Zone' was already underlined by Narkiewicz (1988) and Racki (1988), and evidence from Poland, and other areas was cited (for new supporting data see Kirchgasser *et al.* 1988; Reissner 1989; Belka & Wendt 1991; Ebert 1992).

Remarkably, the early Frasnian goniatite break (House 1985; Walliser 1985) coincides with this very zone.

The Holy Cross Mountains sections prove either the sustained deepening in the Kostomłoty area or drowning event on the Kielce platform in the *P. punctata* Zone. Hence, the preceding onlap in the *P. transitans* Zone is considered as a prelude to T-R Cycle IIc instead a retarded step of the Cycle IIb (Narkiewicz 1988) and designed as the Subcycle IIb/c.

The broadly defined Givetian to Frasnian boundary interval is thus marked by a continuous series of deepening events. Complex large-scale tectonic effects, jointly with orogenic activity (see Ziegler 1988 for summary), were taken by Talent & Yolkin (1987) as seriously biasing effects of eustasy by this time and such situation is described e.g. from the Cantabrian zone (Raven 1983). Dessication of evaporite basins could also contribute to sea-level rises (cf. Schlager 1981; Johnson *et al.* 1985), especially in the Givetian epicontinental seas.

Late Frasnian events

The largest Devonian transgressive anoxic pulse in the early Late *P. rhenana* Zone (T-R Cycle IIe) is well recorded in the depositional history of the Kielce Region (Narkiewicz 1988; Szulczewski 1989). This is best shown by bituminous marly strata with pelagic fauna overlying detrital foreslope deposits containing variable microbial-metazoan mounds and knolls (Hoffmann & Paszkowski 1992). Nevertheless, the coarse-grained deposits, with much evidence of rapid intraformational erosion, correspond chiefly to the preceding regressive/epeirogenic event (Narkiewicz 1988, Racki 1991). This pattern seems recognizable across almost the whole western Holy Cross Mountains region, maybe extending even to the Łysogóry basin (Czarnocki 1950), marking also the top of the Kowala Formation (Fig. 3).

The latest Frasnian displays a serious submergence of the Dyminy reef and the final sedimentation phase is characterized by presence of coral-bearing, chiefly grained deposits of the assumed cap-type. Protected areas still populated by *Amphipora* meadows lasted locally, maybe e.g. in the elevated Miedzianka area (cf. Malec & Racki 1993), until the final reef demise just prior to the Frasnian-Famennian boundary (cf. Szulczewski 1971: p. 75; compare also Kaźmierczak & Goldring 1978 and Mikłas *in* Racki *et al.* in press b). This event was connected with major sea-level changes (main Kellwasser Event of Walliser 1985; see summary in Racki 1990), and related climatic and oceanographic phenomenes (cf. autocyclic model of Buggisch 1991).

An influence of several active tectonic blocks within the Święty Krzyż Fracture zone may be implied from abrupt lateral changes of the later Frasnian sedimentation within the Kostomłoty area, according to data of Szulczewski (1971) and Małkowski (1981). The extermination of the reef was also partly associated with movement and uplift of some blocks

(Szulczewski 1989; Racki 1991), maybe as a response to intensified extensional tectonics coupled with isostatic compensation (cf. Cocozza & Gandin 1990).

Conclusions

Geobiological history.– The local ecostratigraphic bioevents (*sensu* Kauffman 1986) recognized in the Devonian of the Holy Cross Mountains (Fig. 37) led to a stepwise colonization of the backstepping carbonate platform after a dolomitic hypersaline phase (see Figs 12, 16, 22; Racki 1988). Euryhaline biota of varied micro-organisms and amphiporids represented the pioneer settlement pre-G-I phase. The possibly late Eifelian two-step facies changeover is likely to correspond to the climatic evolution from arid to more humid conditions and/or an inundation, recording e.g. T-R Cycle Ie, and reflected in rhythmically changing sedimentary conditions (Narkiewicz 1991).

The proposed major extra-regional colonization is a local expression of two following, latest Eifelian and Middle Givetian sea-level rises of T-R Cycles If and IIa. The resultant immigration waves spread over the whole *Stringocephalus* biostromal bank across southern Poland and Moravia. A regressive trend culminated in mudflat growth and caused also a first total demise of the specialized biostromal and lagoonal biotas. It was a reflection of the global extinctions in the late phase of the T-R Cycle IIa (Stringocephalid Event of Talent *et al.* 1991; Ebert 1992).

The Late Givetian flooding of T-R Cycle IIb had the most drastic biotic response. Two opposing processes took place: (1) inter-regional immigration of normal marine species derived chiefly from the survivors of the stratigraphically older Łysogóry-type biotas, followed by (2) second extinction pulse due to seaward bank progradation of the Givetian-type species, especially among coral and perhaps also crinoid associations. This transgressive event coincides with the highest Givetian peak of terminal extinction percentage (Ebert 1992) which resembles the pattern around the Permo-Triassic boundary (Hallam 1992).

The sea-level rise produced an incipient drowning of the shelf and the shallow-water Miedzianka area appears to be an unique refuge for prolific shallow-water faunas. With the flooding sea they migrated to this site from the northern periphery of the Kielce platform via hypothetical western route. The most abundant echinoderm-brachiopod-sponge biota was localized in the northwestern part of the studied area, possibly owing to open-sea influences from the Kostomłoty basin on one side, and temporary growth of the charophyte algal meadows in shallowing parts (Racki & Racka 1981).

After this facies turnover, the Givetian to Frasnian passage was an interval of ecologically depauperate ecosystem in generally regressive regime (cf. closed ecological system *sensu* McGhee *et al.* 1992; see also

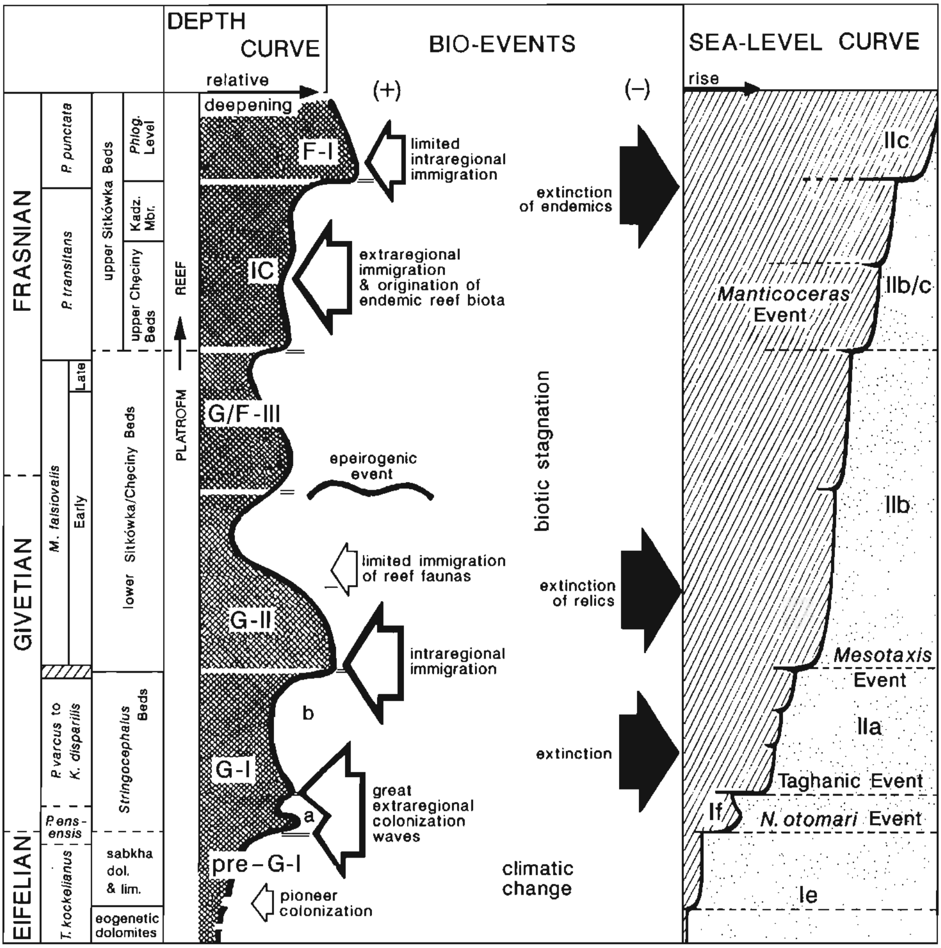


Fig. 37. Regional bioevent pattern of the Givetian to early Frasnian carbonate shelf of the southwestern Holy Cross Mts (cf. Racki 1988: Fig. 7, modified). Sea-level curve based on Johnson *et al* (1985: Fig. 12).

Johnson 1990). This was only for a brief time reversed by epeirogenic movements (cycle G/F-III), which resulted in atrypid-crinoid biota thriving.

Initiation of the Dyminy reef growth was connected with a third large wave of colonizers, with massive stromatoporoids and the cyanobacteria, chiefly renalcids, as important constructors of reef communities. The chiefly extra-regional influx of the Frasnian-type species is also involved in origination of very rich, although mostly endemic bioherm biotas quickly extinguished by an accelerated sea-level rise. Biotic responses to the Middle Frasnian (IIc) flooding are limited to an appearance of several new shelly level-bottom and pelagic faunas (*Styliolina*, conodonts) of distinctly Kostomłoty-Łysogóry affinities. This is also recorded in the temporary growth of coral muddy biostromes in reef interior areas. The shallowing Chęciny-Zbrza intrashelf basin was subsequently marked by wide distribution of flank, crinoid-brachiopod assemblages.

Climate.– The predominance of micritic matrix in the Kowala Formation points to intensive precipitation of calcium carbonate by non-skeletal green algae and bacteria in subtropical realm (cf. Hladil 1986: p. 7; Preat & Mamet 1989). The absence of early dolomites and sulphates, and moderate diversity algal biotas with dasyclads in tidal systems suggest rather rainy, semi-humid conditions (Boulvain & Preat 1987; Tucker & Wright 1991: pp. 154-155; see also Racki 1986a).

As discussed by Boucot (1988, 1990) the progressive smoothing of global climatic gradient linked with the sustained eustatic rise were one of the main reasons for the Middle Devonian biotic changeovers. In the shelf of southern Poland, the warming event proposed by the cited author for the Eifelian/Givetian boundary interval, might coincide with two-step termination of hypersaline deposition (Fig. 37). The Łysogóry sections should be examined in this respect, especially the cyclic sequence ending the Eifelian Wojciechowice Beds. However, the Holy Cross Mountains area was placed in the southern arid belt by Witzke & Heckel (1988), which require additional factors to be taken into account to explain climatic evolution of this part of the Laurasian shelf (see example for the Ardenne Givetian by Boulvain & Preat 1987).

Trophic structure.– In general terms, the Devonian bank- to-reef shelf ecosystems represented a highly productive carbonate factory (Wilson 1975; Schlager 1981), especially if the main reef-formers possessed zooxanthellae (Risk *et al.* 1987). Its trophic interpretations (see Fagerstrom 1987 for summary) remain still speculative because of doubtful taxonomic affiliation of many members of its inferred nucleus.

High primary production is inferred for restricted lagoon areas. It is suggested by both taxonomic diversity of the benthic algae and phytoplankton, and the structure of biotas suggestive of eutrophic environment (Kaźmierczak *et al.* 1985). This source supported extensive development of rich epifaunal suspension-feeders communities in reef and open shelf settings. Lagoon-derived micritized grains and, consequently, also particulate matter, were abundantly transported to adjacent areas (see Facies M-6). It seems also reasonable that plentiful soft-bodied deposit-feeders, probably mostly polychaetes, and scavengers thrived in lagoonal and intershoal habitats where their presence was recorded by trace fossils and pellets. Nevertheless, the most abundant fossilized herbivorous and detritus-feeding benthic communities in the Posłowice intershoal (Racki & Racka 1981) and Kadzielnia-type mud mounds utilized rather local plant resources.

The highest levels of the trophic pyramid were largely occupied by diverse nektonic vertebrates (Liszkowski & Racki 1993) and rarely by nautiloid cephalopods. The former are believed to depend on variety of diets in the Devonian and ranged from detritus-feeders and scavengers (some placoderms) to active predators (acanthodians, elasmobranchs). Also conodonts were represented probably by both small-size nektobenthic (in case of icriodontids), and pelagic elements. The only well established example of zooplankton was the Frasnian styliolinid community.

In regional perspective, the prominent differences in biotic diversity between northern (Wietrznia-Kadzielnia) and southern periphery of the Kielce shoal region reflect differences in oceanographic/topographic setting (windward versus leeward, strenght of contour-following currents, slope profile etc.; Klovan 1974; Read 1985; Kenter 1990) forcing varying biological productivity dependent e.g. on upwelling of nutrient-rich waters near the edge of the northern intrashelf basin.

Acknowledgements

I wish thank all the persons that have assisted me with the study, in particular all the authors of articles in the volume. Several colleagues reviewed early drafts and their criticisms guided me in final version. Especially, I am grateful to Professor M. Narkiewicz, and Dr. T. Wrzołek for their constructive discussions. Some problems were consulted with Professors O.H. Walliser, J.G. Johnson, P. Bultynck and A. Preat, Dr. W. Struve and J. Ebert, MSc. Various technical works done by Mrs L. Wawro, E. Kozik, G. Łakomy, A. Śliwicka D. Lis and E. Teper are kindly acknowledged. I thank my wife, Maria Racka, for field assistance, tolerance, and perseverance. Core material was studied through the courtesy of the Directorate of the State Geological Institute at Kielce.

References

Ager, D.V., 1973. *The Nature of the Stratigraphical Record.* 114 pp. The Macmilian Press, London.

Aristov, V.A. (Аристов, В.А.) 1988. Девонские конодонты Главного Девонского Поля. *Труды Геологического Института Академии Наук СССР* **432**, 1-119.

Austin, R.L., Orchard, M.J., & Stewart, I.J. 1985. Conodonts of the Devonian System from Great Britain. In: A.C. Higgins & R.L. Austin (eds) *A Stratigraphical Index of Conodonts*, 93-166. Lelus Harwood, Chichester.

Baliński, A. 1973. Morphology and paleocecology of Givetian brachiopods from Jurkowice-Budy, Poland. *Acta Palaeontologica Polonica* **18**, 269-297.

Baliński, A. 1979. Brachiopods and conodonts from the Frasnian of the Dębnik Anticline, southern Poland. *Palaeontologia Polonica* **39**, 3-95.

Bandel K. & Meyer D.E. 1975. Algenriffkalke, allochtone Riff-blocke and autochtone beckenkalke im Südteil der Rheinischen Eugeosynklinale. *Mainzer geowissenschaftliche Mitteilungen* **4**, 5-65.

Bathurst, R.G.C. 1991. Pressure-dissolution and limestone bedding: the influence of stratified cementation. In: G., Einsele, A., Seilacher, & W., Ricken (eds) *Cycles and Events in Stratigraphy*, 450-463. Springer, Berlin.

Belka, Z. & Wendt, J. 1992. Conodont biofacies patterns in the Kellwasser Facies (upper Frasnian/lower Famennian) of the eastern Anti-Atlas, Marocco. *Palaeogeography, Palaeoclimatology, Palaeoecology* **91**, 143-173.

Biernat, G. & Szulczewski, M. 1975. The Devonian brachiopod *Phlogoiderhynchus polonicus* (Roemer, 1866) from the Holy Cross Mountains, Poland. *Acta Palaeontologica Polonica* **20**, 199-221.

Boucot, A.J. 1982. Ecostratigraphic framework for the Lower Devonian of the North American Appohimichi Subprovince. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* **163**, 1-22.

Boucot, A.J. 1988. Devonian biogeography: an update. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 211-228.

Boucot, A.J. 1990. Silurian and pre-Upper Devonian bio-events. In: E.G. Kauffman & O.H. Walliser (eds) *Extinction Events in Earth History. Lecture Notes in Earth Sciences* **35**, 125-132. Springer, Berlin.

Boulvain, F. & Preat, A. 1987. Les calcaires laminaires du Givétian Superieur du bord sud du Bassin de Dinant (Belgique, France): témoins d'une évolution paléoclimatique. *Annales de la Société Géologique de Belgique* **109**, 609-619.

Braithwaite, C.J.R. 1967. Carbonate environments in the Middle Devonian of South Devon, England. *Sedimentary Geology* **1**, 283-320.

Braun, W.K., Norris, A.W., & Uyeno, T.T. 1988. Late Givetian to early Frasnian biostratigraphy of western Canada: The Slave Point; Waterways boundary and related events. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 93-112.

Brenner, R.L. & McHargue, T.R. 1988. *Integrative Stratigraphy Concepts and Applications.* 419 pp. Prentice Hall, New Haven.

Brett, C.A., Dick, V.B., & Baird, G.C. 1991. Comparative taphonomy and paleoecology of Middle Devonian dark gray and black shale facies from western New York. *New York State Museum Bulletin* **469**, 5-36.

Brice, D. 1982. Comments on the distribution of some selected brachiopods for the latest Givetian and early Frasnian periods in the Boulonnais (Ferques) and the Massif Armoricain (Rade de Brest). In: P. Sartener (ed.) *Papers on the Frasnian-Givetian boundary*, 5-16. Geological Survey of Belgium, Brussels.

Buggisch, W. 1991. The global Frasnian-Famennian 'Kelwasser Event'. *Geologische Rundschau* **80**, 49-72.

Bultynck, P. 1974. Conodontes de la Formation du Fromelennes du Givetien de l'Ardenne franco-belge. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre* **50** (10), 1-30.

Bultynck, P. 1982. Conodont succession and general faunal distribution across the Givetian-Frasnian boundary beds in the type area. In: P. Sartenaer (ed.) *Papers on the Frasnian-Givetian boundary*. 34-59, Geological Survey of Belgium, Brussels.

Bultynck, P. 1986. Accuracy and reliability of conodont zones: the Polygnathus asymmetricus Zone and the Givetian-Frasnian boundary. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre* **56**, 269-280.

Bultynck, P., Coen-Aubert, M., Dejonghe, L. *et al.* 1990. Les Formations du Devonien Moen de la Belgique. *Mémoires pour servir à l'Explication des Cartes Géologiques et Minièr de la Belgique, Mémoire* **30**, 1-106.

Bultynck, P., Walliser, O.H., & Weddige, K. 1991. Conodont based proposal for the Eifelian-Givetian boundary. In: *Marocco Field Meeting of the SDS, Guide-Book*. 13-15.

Burchette, T.P. 1981. European Devonian reefs: a review of current concepts and models. *Society of Economic Paleontologists and Mineralogists, Special Publication* **30**, 85-142.

Chlupač, I. 1988. The Devonian of Czechoslovakia and its stratigraphic significance. *Canadian Society of Petroleum Geologists, Memoir* **14** (1), 481-498.

Clausen, C.D. & Ziegler, W. 1989. Die neue Mittel-/Oberdevon-Grenze - ihre Anwendungsmoglichkeiten im Rheinischen Schiefergebirge. *Fortschritte der Geologie Rheinland und Westfalen* **35**, 9-30.

Cocozza, T. & Gandin, A. 1990. Carbonate deposition during early rifting: the Cambrian of Sardinia and the Triassic-Jurassic of Tuscany, Italy. *Special Publications of the International Association of Sedimentologists* **9**, 9-37.

Coen, M. & Coen-Aubert, M. 1971. L'Assise des Fromelennes aux bords sud et est du Basin de Dinant et dans le Massif de la Vesdre. *Annales de la Société Géologique de Belgique* **94**, 5-20.

Cook, H.E. 1972. Miette platform evolution and relation to over-lying bank ('reef') localization, Upper Devonian, Alberta. *Bulletin of Canadian Petroleum Geology* **20**, 439-497.

Copper, P. 1988. Ecological succession in Phanerozoic reef ecosystems: is it real? *Palaios* **3**, 136-151.

Coppold, M.P. 1976. Buildup to basin transition at the Ancient Wall Complex (Upper Devonian), Alberta. *Bulletin of Canadian Petroleum Geology* **24**, 154-192.

Cutler, W.G. 1983. Stratigraphy and sedimentation of the Upper Devonian Grosmont Formation, northern Alberta. *Bulletin of Canadian Petroleum Geology* **31**, 282-325.

Czarnocki, J. 1927. Sprawozdanie z badań, wykonanych w r. 1926, w związku z ogólnym poglądem na budowę mas mezozoicznych regionu chęcińskiego. *Posiedzenia Naukowe PIG* **17**, 4-14.

Czarnocki, J. 1948. Przewodnik XX zjazdu Polskiego Towarzystwa Geologicznego w Górach Świętokrzyskich w r. 1947. *Rocznik Polskiego Towarzystwa Geologicznego* **17**, 237-299.

Czarnocki, J. 1950. Geologia regionu łysogórskiego w związku z zagadnieniem złoża rud żelaza w Rudkach. *Prace Państwowego Instytutu Geologicznego* **1**, 1-404.

Czarnocki, J. & Samsonowicz, J. 1911. O dewonie górnym na górze Miedziance. *Sprawozdania Towarzystwa Naukowego Warszawskiego* **4**, 314-321.

Czermiński, J. 1960. Rozwój litologiczny serii węglanowej dewonu południowej części Gór Świętokrzyskich. *Prace Instytutu Geologicznego* **30**, 31-121.

Dolphin, D.R. & Klovan, J.E. 1970. Stratigraphy and paleoecology of the Upper Devonian carbonate bank, Saskatchewan River Crossing, Alberta. *Bulletin of Canadian Petroleum Geology* **18**, 289-331.

Dott, R.H. 1982. Episodic seimentation-How normal is average? How rare is rare? Does it matter? *Journal of Sedimentary Petrology* **53**, 5-23.

Ebert, J. 1992. Events around the *Pharciceras* Stufe. *Fifth International Conference on Global Bioevents Abstract Volume*, 128. Göttingen.

Einsele, G., Seilacher, A., & Ricken, W. (eds) 1991. *Cycles and Events in Stratigraphy*. 955 pp. Springer, Berlin.

Embry, A.F. & Klovan, J.E. 1971. A Late Devonian reef tract on north-eastern Banks Island, Northwest Territories. *Bulletin of Canadian Petroleum Geology* **19**, 730-781.

Fagerstrom, J.A. 1987. *The Evolution of Reef Communities*. 600 pp. J. Wiley, New York.

Feist, R. & Klapper, G. 1985. Stratigraphy and conodonts in pelagic sequence across the Middle-Upper Devonian boundary, Montaigne Noire, France. *Palaeontographica A* **188**, 1-18

Ficner, F. & Havlíček, V. 1978. Middle Devonian brachiopods from Čelechowice, Moravia. *Sbornik Geologiceských Věd, Paleontologie* **21**, 49-106.

Filonowicz, P. 1967. Wapienie ze *Stringocephalus* w Czarnowie k/Kielc. *Kwartalnik Geologiczny* **11**, 958.

Filonowicz, P. 1969. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski. Arkusz Bodzentyn*. 86 pp. Wydawnictwa Geologiczne, Warszawa.

Filonowicz, P. 1973. *Budowa geologiczna SW części Gór Świętokrzyskich*. Unupublished Doctoral Thesis. State Geological Institute, Warszawa.

Filonowicz, P. 1976. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski. Arkusz Daleszyce*. 77 pp. Wydawnictwa Geologiczne, Warszawa.

Galle, A., Friakova, O., Hladil, J., Kalvoda, J., Krejci, Z., & Zukalova, V. 1988. Biostratigraphy of Middle and Upper Devonian carbonates of Moravia, Czechoslovakia. *Canadian Society of Petroleum Geologists, Memoir* **14**, 633-645.

Galli, G. 1986. Ecology and dispersion of the fauna of the Cima Ombladet carbonate succession (Devonian, Carnic Alps, Northern Italy). *Palaeogeography, Palaeoclimatology, Palaeoecology* **49**, 265-275.

Gekker, R.F. (Геккер, Р.Ф.) 1980. Экология населения древних бассейнов геологического прошлого. In: *Экостратиграфия и Экологические Системы Геололического Прошлого*, 12-20. Наука, Ленинград.

Gekker, R.F. (Геккер, Р.Ф.) 1983. Тафономические и экологические особенности фауны и флоры Главного Девонского Поля. *Труды Палеонтологического Института АН СССР* **190**, 1-141.

Głazek, J., Karwowski, D., Racki, G., & Wrzołek, T. 1981. The early Devonian continental/marine succession at Chęciny in the Holy Cross Mts, and its paleogeographic and tectonic significance. *Acta Geologica Polonica* **31**, 233-251.

Głazek, J. & Romanek, A. 1978. Jaworznia. In: *Zechstein of the Holy Cross Mts. Guide of Excursions, Symposium on Central European Permian.* 41-49. Wydawnictwa Geologiczne, Warszawa.

Głuchowski, E. (in press) Crinoid assemblages in the Polish Givetian and Frasnian. *Acta Palaeontologica Polonica* **38**.

Godefroid, J. & Racki, G. 1990. Frasnian gypidulid brachiopods from the Holy Cross Mountains (Poland). Comparative stratigraphic analysis with the Dinant Synclinorium (Belgium). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre* **60**, 43-74.

Gogolczyk, W. 1956. Rodzaj *Amphipora* w dewonie Polski. *Acta Paleontologica Polonica* **1**, 211-240.

Gogolczyk, W. 1959. Rodzaj *Stachyodes* (Stromatoporoidea) w dewonie Polski. *Acta Palaeontologica Polonica* **4**, 353-387.

Goldhammer, R.K. & Elmore, R.G. 1984. Paleosols capping regressive carbonate cycles in the Pennsylvanian Black Prince Limestone, Arizona. *Journal of Sedimentary Petrology* **54**, 1124-1137.

Goodwin, P.W. & Anderson, E.J. 1985. Punctuated aggradational cycles: a general hypothesis of episodic stratigraphic accumulation. *Journal of Geology* **93**, 515-553.

Gürich, G. 1896. Das Paläozoikum des Polnischen Mittelgebirge. *Verhandlungen der Russischen Kaiserlichen Gesselschaft zu St. Petersburg II* **32**, 1-539.

Hallam, A. 1992. The Permo-Triassic boundary event. *Fifth International Conference on Global Bioevents Abstract Volume*, 43. Göttingen.

Havard, C. & Oldershaw, A. 1976. Early diagenesis in back-reef sedimentary cycles, Strip Lake Reef Complex, Alberta. *Bulletin of Canadian Petroleum Geology* **24**, 27-69.

Heckel, P.H. 1983. Diagenetic model for carbonate rocks in Midcontinent Pensylvanian eustatic cyclothems. *Journal of Sedimentary Geology* **53**, 733-759.

Hering, G. 1992. Cycles and rhytms in a Middle Devonian back-reef environment. *Fifth International Conference on Global Bioevents Abstract Volume*, 130. Göttingen.

Hladil, J. 1986. Trends in the development and cyclic patterns of Middle and Upper Devonian buildups. *Facies* **15**, 1-34.

Hladil, J. 1988. Structure and microfacies of Middle and Upper Devonian Carbonate buildups in Moravia, Czechoslovakia. *Canadian Society of Petroleum Geologists, Memoir* **14**, 607-618.

Hoffmann, M. & Paszkowski, M. 1992. Mikrobialne budowle organiczne górnego dewonu w synklinie kieleckiej. *Przegląd Geologiczny* **40**, 606-607.

House, M.R. 1985. Correlation of mid-Paleozoic ammonoid evolutionary events with global sedimentary perturbations. *Nature* **313** (5997), 17-22.

House, M.R. 1992. Nature and interpretation of the Devonian Taghanic Event. *Fifth International Conference on Global Bioevents Abstract Volume*, 53. Göttingen.

Huddle, J.W. 1971. Revised descriptions of some Late Devonian polygnathid conodonts. *Journal of Paleontology* **44**, 1029-1040.

Jamieson, E.R. 1971. Paleoecology of Devonian reefs of western Canada. *North American Paleontological Convention Proceedings J*, 1300-1340.

Jansa, L.F. & Fischbuch, N.R. 1974. Evolution of a Middle to Upper Devonian sequence from a clastic coastal-deltaic complex into overlying carbonate reef complexes and banks, Sturgeon Mitsue area, Alberta. *Geological Survey of Canada Bulletin* **234**, 1-105.

Johnson, J.G. 1990. Lower and Middle Devonian brachiopod-dominated communities of Nevada, and their position in a biofacies-province-realm model. *Journal of Paleontology* **64**, 902-941.

Johnson, J.G., Klapper, G., & Sandberg, C.A. 1985. Devonian eustatic fluctuations in Euramerica. *Geological Society of America Bulletin* **96**, 567-587.

Johnson. J.G., Klapper, G., & Trojan, W.R. 1980. Brachiopod and conodont successions in the Devonian of the northern Antelope Range, central Nevada. *Geologica et Palaeontologica* **14**, 77-116.

Johnson, J.G. & Sandberg, C.A. 1988. Devonian eustatic events in the Western Unites States and their biostratigraphic responses. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 171-179.

Kaljo, D.D. & Klaaman, E. (Кальо, Д.Д. и Клааман, Э.) (eds) 1986. *Теория и Опыт Экостратиграфии.* 295 pp. Валгус, Таллин.

Karczewski, L. 1988. Ślimaki i małże dewońskie z Gór Świętokrzyskich. *Biuletyn Państwowego Instytutu Geologicznego* **363**, 97-133.

Kauffman, E.G. 1986. High resolution event stratigraphy: regional and global Cretaceous bio-events. In: O.H. Walliser (ed.) *Global Bio-Events. Lecture Notes in Earth Sciences* **8**, 279-335. Berlin, Springer.

Kaźmierczak, J. 1971a. Kamieniołom na Górze Zamkowej. Bolechowice, kamieniołom Panek. In: H. Żakowa (ed.) *Przewodnik 43 Zjazdu Polskiego Towarzystwa Geologicznego*, 26-30. Wydawnictwa Geologiczne, Warszawa.

Kaźmierczak, J. 1971b. Morphogenesis and systematics of the Devonian Stromatoporoidea from the Holy Cross Mountains, Poland. *Paleontologia Polonica* **26**, 1-150.

Kaźmierczak, J. & Goldring, R. 1978. Subtidal flat-pebble conglomerate from the Upper Devonian of Poland: a multiprovenant high-energy product. *Geological Magazine* **15** 359-366.

Kaźmierczak, J., Ittekot, V., & Degens, E.T. 1985. Biocalcification through time: environmental challenge and cellurar response. *Paläontologische Zeitschrift* **59**, 15-33.

Kenter, J.A.M. 1990. Carbonate platform flanks: slope angle and sediment fabric. *Sedimentology* **37**, 777-794.

Khalymbadzha, V.G., Chernysheva, N.G., & Baryshev, V.N. (Халымбаджа, В.Г, Чернышева, Н.Г и Барышев, В.Н.) 1985. Биостратиграфия среднего девона западнего скона Урала по конодонтам. In: *Средний Девон СССР, его границы и ярусное расчленение*, 69-74. Наука, Москва.

Kidwell, M.S. 1991. Taphonomic feedbeck (live/dead interactions) in the genesis of bioclastic beds: keys to reconstructing sedimentary dynamics. In: G. Einsele, A., Seilacher, & W., Ricken (eds) *Cycles and Events in Stratigraphy*, 268-282. Springer, Berlin.

Kirchgasser, W.T., Baird, G.C., & Brett, C.E. 1985. Regional placement of Middle/Upper Devonian (Givetian-Frasnian) boundary in Western New York State. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 113-118.

Kirikov, V.P. 1988. Devonian Period in evolution of the Russian Platform. *Canadian Society of Petroleum Geologists, Memoir* **14** (1), 513-526.

Klapper, G., Feist, R., & House, M.R. 1987. Decision for the Middle/Upper Devonian Series boundary. *Episodes* **10**, 97-101.

Klapper, G. & Johnson, J.G. 1980. Endemism and dispersal of Devonian conodonts. *Journal of Paleontology* **54**, 400-455.

Klapper, G. & Lane, H.R. 1985. Upper Devonian (Frasnian) conodonts of the *Polygnathus* biofacies, N.W.T., Canada. *Journal of Paleontology* **59**, 904-951.

Kliuzhina, M.L. (Клюжина, М.Л.) 1981. Палеотечения в доманиковом бассейне. In: *Литология и условия образования докембрийских и палеозойских отложении Урала*, 27-37. Академия Наук СССР, Свердловск.

Kłossowski, J. 1985. Sedymentacja środkowego dewonu w regionie łysogórskim (profil Świętomarz/Śniadka). *Przegląd Geologiczny* **33**, 264-167.

Klovan, J.E. 1964. Facies analysis of the Redwater reef complex, Alberta, Canada. *Bulletin of Canadian Petroleum Geology* **12**, 1-100.

Klovan, J.E. 1974. Development of western Canadian Devonian reefs and comparison with Holocene analogies. *American Association of Petroleum Geologists Bulletin* **58**, 787-799.

Kotański, Z. 1959. *Przewodnik Geologiczny po Górach Świętokrzyskich* I-II. 448 pp. Wydawnictwa Geologiczne, Warszawa.

Kowalczewski, Z. 1963. Transwersalne założenia w budowie cokołu paleozoicznego antyklinorium świętokrzyskiego. *Kwartalnik Geologiczny* **7**, 571-586.

Kowalczewski, Z. & Malec, J. 1990. Regionalne aspekty badań skał dewonu z otworu Podgace IG 1 w Górach Świętokrzyskich. *Kwartalnik Geologiczny* **34**, 561-563.

Krebs, W. 1974. Devonian carbonate complexes of Central Europe. *Society of Economic Paleontologists and Mineralogists Special Publication* **18**, 155-208.

Krebs, W. 1979. Devonian basinal facies. *Special Paper in Palaeontology* **23**, 125-139.

Kucia, W. 1987. *Żywet i dewon górny antykliny Zbrzy (Góry Świętokrzyskie).* Unpublished MSc. thesis, Silesian University, Sosnowiec.

Kulicka, R. & Nowiński, A. 1983. The Devonian Tabulata of the southern part of the Świętokrzyskie/Holy Cross Mts. *Acta Palaeontologica Polonica* **28**, 467-490.

Laevitt, E.M. 1968. Petrology, paleontology, Carson Creek North Reef Complex, Alberta. *Bulletin of Canadian Petroleum Geology* **16**, 298-413.

Lane, N.G. 1981. A nearshore sponge spicule mat from the Pennsylvanian of west-central Indiana. *Journal of Sedimentary Geology* **51**, 197-202.

Lecompte, M. 1970. Die Riffe im Devon der Ardennen und ihre Bildungsbedingungen. *Geologica et Palaeontologica* **4**, 25-71.

Lenkiewicz, J. 1981. *Wykształcenie i stratygrafia utworów dewonu środkowego wschodniej części Gór Świętokrzyskich okolic Krępy.* Unpublished MSc. thesis, Silesian Univesity, Sosnowiec.

Lindholm, R.C. 1969. Carbonate petrology of the Onondaga Limestone (Middle Devonian), New York: a case of calcisiltite. *Journal of Sedimentary Petrology* **39**, 268-275.

Liszkowski, J. & Racki, G. 1993. Ichthyoliths and deepening events in the Devonian carbonate platform of the Holy Cross Mountains. *Acta Palaeontoogica Polonica* **37**, 407-426.

Longman, M.W. 1981. A process approach to recognizing facies of reef complexes. *Society of Economic Paleontologists and Mineralogists Special Publication* **30**, 9-40.

Lyashenko, A.I. (Ляшенко, А.И)1973. *Брахиоподы и стратиграфия нижнефранских отложении Тимана и Волго-Уральской нефтегазоносной Провинции*. 279 pp. Недра, Москва.

Machielse, S. 1972. Devonian algae and their contribution to the Western Canadian sedimentary basin. *Bulletin of Canadian Petroleum Geology* **20**, 187-237.

Malec, J. 1984. Nowe dane o stratygrafii dewonu w profilu Grzegorzowice-Skały. *Kwartalnik Geologiczny* **23**, 782.

Malec, J. 1991. Uwagi o stratygrafii utworów dewonu dolnego i środkowego w zachodniej części Gór Świętokrzyskich. *Kwartalnik Geologiczny* **35**, 525-526.

Malec, J. & Racki, G. 1993. Givetian and Frasnian ostracod associations from the Holy Cross Mountains. *Acta Palaeontologica Polonica* **37**, 359-384.

Małkowski, K. 1981. Upper Devonian deposits at Górno in the Holy Cross Mts. *Acta Geologica Polonica* **31**, 223-232.

Martinsson, A. 1980. Ecostratigraphy: limits of applicability. *Lethaia* **13**, 363.

McGhee, G.R., Bayer, U., & Seilacher, A. 1991. Biological and evolutionary responses to transgressive-regressive cycles. In: G. Einsele, A., Seilacher, & W., Ricken (eds) *Cycles and Events in Stratigraphy*, 696-708. Springer, Berlin.

Miller, K.B., Brett, C.E., & Parsons, K.M. 1988. The paleoecologic significance of storm-generated disturbance within a Middle Devonian muddy epeiric sea. *Palaios* **3**, 35-52.

Modliński, Z. 1982. Rozwój litofacjalny i paleotektoniczny ordowiku na obszarze platformy prekambryjskiej w Polsce. *Prace Instytutu Geologicznego* **102**, 1-66.

Narkiewicz, M. 1973. *Dewon Pasma Góry Zamkowej w Chęcinach.* Unpublished MSc. Thesis, Warsaw University, Warsaw.

Narkiewicz, M. 1981. Budy-kamieniołom dolomitów i wapieni środkowego dewonu. Sobiekurów - odsłonięcie wapieni gruzłowych franu. In: H. Żakowa (ed.) *Przewodnik 53 Zjazdu Polskiego Towarzystwa Geologicznego*, 276-284, 289-291. Wydawnictwa Geologiczne, Warszawa.

Narkiewicz, M. 1988. Turning points in sedimentary development in the Late Devonian in southern Poland. *Canadian Society of Petroleum Geologists, Memoir* **14** (2), 619-636.

Narkiewicz, M. 1991. Procesy dolomityzacji mezogenetycznej na przykładzie żywetu i franu Gór Świetokrzyskich. *Prace Państwowego Instytutu Geologicznego* **132**, 1-54.

Narkiewicz, M. & Racki, G. 1984. Stratygrafia dewonu antykliny Dębnika. *Kwartalnik Geologiczny* **28**, 513-546.

Narkiewicz, M. & Racki, G. 1987. Korelacja i rozwój sedymentacji dewonu górnego między Dębnikiem i Zawierciem. *Kwartalnik Geologiczny* **31**, 241-256.

Narkiewicz, M., Racki, G., & Wrzołek, T. 1990. Litostratygrafia dewońskiej serii stromatoporoidowo-koralowcowej w Górach Świętokrzyskich. *Kwartalnik Geologiczny* **34**,433-456.

Neumann, A.C. & Macintyre, I. 1985. Reef response to sea-level rise: keep-up, catch-up or give-up. *Proceedings of the Fifth International Coral Reef Congress* **3**, 105-110.

Nicoll, R.S. 1985. Multielement composition of the conodont species *Polygnathus xylus xylus* Stauffer, 1940 and *Ozarkodina brevis* (Bischoff & Ziegler, 1957) from the Upper Devonian of the Canning Basin, western Australia. *BMR Journal of Australian Geology and Geophysics* **9**, 133-147.

Noble, J.P.A. 1970. Biofacies analysis, Cairn Formation of Miette Reef Complex (Upper Devonian), Jasper National Park, Alberta. *Bulletin of Canadian Petroleum Geology* **18**, 493-543.

Norris, A.W. & Uyeno, T.T. 1981. Stratigraphy and paleontology of the lowermost Upper Devonian Slave Point Formation on Lake Claire and the lower Upper Devonian Waterways Formation on Birch River, northeastern Alberta. *Geological Survey of Canada Bulletin* **334**, 1-53.

Norris, A.W. & Uyeno, T.T. 1983. Biostratigraphy and paleontology of Middle-Upper Devonian boundary beds, Gypsum Cliffs area, Northeastern Alberta. *Geological Survey of Canada Bulletin* **313**, 1-125.

Nowiński, A. 1976. Tabulata and Chaetetida from the Dévonian and Carboniferous of southern Poland. *Palaeontologia Polonica* **35**, 1-125.

Nowiński, A. 1993. Tabulate corals from the Givetian and Frasnian of the Holy Cross Mountains and Silesian Upland. *Acta Palaeontologica Polonica* **37**, 183-216.

Olempska, E. 1979. Middle to Upper Devonian Ostracoda from the southern Holy Cross Mountains, Poland. *Palaeontologia Polonica* **40**, 57-162.

Ozonkowa, H. 1961. Dewon w profilu Iwaniska-Piskrzyn (Góry Świętokrzyskie). *Rocznik Polskiego Towarzystwa Geologicznego* **31**, 85-102.

Pajchlowa, M. 1957. Dewon w profilu Grzegorzowice-Skały. *Biuletyn Instytutu Geologicznego* **122**, 145-254.

Pajchlowa, M. & Stasińska, A. 1965. Formations récifales du Devonien des Monts de Sainte-Croix (Pologne). *Acta Palaeontologica Polonica* **10**, 249-260.

Playford, P.E. 1980. Devonian 'Great Barrier Reef' of Canning Basin, Western Australia. *American Association of Petroleum Geologists Bulletin* **64**, 814-840.

Playford, P.E., Hurley, N.F., Kerans, C., & Middleton, M.F. 1989. Reefal platform development, Devonian of the Canning Basin, Western Australia. *Society of Economic Paleontologists and Mineralogists, Special Publication* **44**, 187-202.

Pohler, S.M.L. & Barnes, C.R. 1990. Conceptual models in conodont paleoecology. *Courier Forschungsinstitut Senckenberg* **118**, 409-440.

Pożaryski, W., Grocholski, A., Tomczyk, H., Karnkowski P., & Moryc, W. 1992. Mapa tektoniczna Polski w epoce waryscyjskiej. *Przegląd Geologiczny* **40**, 643-651.

Pratt, B.R. 1982. Stromatolitic framework of carbonate mud mounds. *Journal of Sedimentary Petrology* **52**, 1202-1227.

Preat, A. & Mamet, B. 1989. Sédimentation de la plate-forme carbonatée givétienne Franco-Belge. *Bulletin des Centres Rechearche Exploration-Production Aquitaine* **13**, 47-86.

Preat, A. & Racki, G. (in press) Small-scale cyclic sedimentation in the Lower Givetian of the Holy Cross Mountains: comparison with the Ardenne sequence. *Annales Societatis Geologarum Poloniae.*

Purdy, E.G. 1964. Sediments as substrates. In: J. Imbrie & N.D. Newell (eds) *Approaches to Paleoecology*, 230-271. J. Wiley. New York.

Racki, G. 1980. Znaczenie konodontów dla biostratygrafii wapieni stromatoporoidowo-koralowcowych dewonu Gór Świętokrzyskich. *Przegląd Geologiczny* **28**, 215-219.

Racki, G. 1981. Stratygrafia i tektonika utworów dewonu środkowego i górnego w kamieniołomach Jaźwica. In: H. Żakowa (ed.) *Przewodnik 53 Zjazdu Polskiego Towarzystwa Geologicznego*, 171-178. Wydawnictwa Geologiczne, Warszawa.

Racki, G. 1985a. A new atrypid brachiopod, *Desquamatia macroumbonata* sp. n., from the Middle to Upper Devonian boundary beds of the Holy Cross Mts. *Acta Geologica Polonica* **35**, 61-72.

Racki, G. 1985b. Cykliczność sedymentacji a podział stratygraficzny dewońskiej serii stromatoporoidowo-koralowcowej Gór Świętokrzyskich. *Przegląd Geologiczny* **33**, 267-270.

Racki, G. 1986a. Brachiopod ecology of the Devonian carbonate complex, and problem of brachiopod hyposalinity. *Biostratigraphie du Paléozoique* **4**, 363-373.

Racki, G. 1986b. Middle to Upper Devonian boundary beds of the Holy Cross Mts: brachiopod responses to eustatic events. In: O.H. Walliser (ed.) *Global Bio-Events, Lecture Notes in Earth Sciences* **8**, 203-212. Springer, Berlin.

Racki, G. 1988. Middle to Upper Devonian boundary beds of the Cross Mts, Central Poland: introduction to ecostratigraphy. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 119-131.

Racki, G. 1990. Frasnian/Famennian event in the Holy Cross Mts, Central Poland: stratigraphic and ecologic aspects. In: E.G. Kauffman & O. Walliser (eds) *Extinction Events in Earth History, Lecture Notes in Earth Sciences* **30**, 169-181. Springer, Berlin.

Racki, G. 1991. O eustatyce, tektonice i innych zdarzeniach w późnym dewonie Gór Świętokrzyskich. *Przegląd Geologiczny* **39**, 193-198.

Racki, G. 1993. Brachiopod assemblages in the Devonian Kowala Formation of the Holy Cross Mountains. *Acta Palaeontologica Polonica* **37**, 297-357.

Racki, G. & Baliński, A. 1981. Environmental interpretation of the atrypid shell beds from the Middle to Upper Devonian boundary of the Holy Cross Mts and Cracow Upland. *Acta Geologica Polonica* **31**, 177-197.

Racki, G., Głuchowski, E., & Malec, J. 1985. The Givetian to Frasnian succession at Kostomłoty in the Holy Cross Mts, and its regional significance. *Bulletin of Polish Academy of Sciences, Earth Sciences* **33**, 159-171.

Racki, G., Makowski, I., Mikłas, J., & Gawlik, S. (in press a) Brachiopod biofacies in the Frasnian reef-complexes: an example from the Holy Cross Mts. *Prace Naukowe Uniwersytetu Śląskiego, Geologia* **12-13**.

Racki, G., Nowak, B., Wrzołek, T., & Słupik, A. (in press b) Nowe dane o dewonie antykliny Siewierza na podstawie wiercenia WB-12. *Prace Naukowe Uniwersytetu Śląskiego, Geologia* **12-13**.

Racki, G. & Racka, M. 1981. Ecology of the Devonian charophyte algae from the Holy Cross Mts. *Acta Geologica Polonica* **31**, 213-222.

Racki, G. & Soboń-Podgórska, J. 1993. Givetian and Frasnian calcareous microbiotas of the Holy Cross Mountains. *Acta Palaeontologica Polonica* **37**, 255-289.

Raven, J.G.M. 1983. Conodont biostratigraphy and depositional history of the Middle Devonian to Lower Carboniferous in the Cantabrian Zone (Cantabrian Mountains). *Leidse Geologische Mededelingen* **12**, 265-339.

Read, A.F. 1973. Paleo-environments and paleogeography Pillara Formation (Devonian), Western Australia. *Bulletin of Canadian Petroleum Geology* **21**, 344-394.

Read, A.F. 1985. Carbonate platform facies models. *American Association of Petroleum Geologists Bulletin* **69**, 1-21.

Reissner, B. 1989. The Givetian-Frasnian boundary at the southern border of the Inde Synclinorium. *Annales de la Societe Geologique de Belgique* **112**, 165-170.

Risk, M.J., Pagani, S.E., & Elias, R.J. 1987. Another internal clock: preliminary estimates of growth rate based on cycles of algal boring activity. *Palaios* **2**, 323-331.

Roche, J.E. & Carozzi, A.V. 1970. Petrography of back-reef carbonates: Traverse Group (Givetian) of the northern part of southern peninsule of Michigan. *Bulletin des Centres Rechearche Pau-SNPA* **4**, 137-189.

Roemer, F. 1866a. Geognostische Beobachtungen im Polnischen Mittelgebirge. *Zeitschrift der Deutsche geologische Gesselschaft* **18**, 667-690.

Roemer, F. 1866b. Über die Auffindung devonischer Kalksteinschichten bei Siewierz im Königreich Polen. *Zeitschrift der Deutsche geologische Gesselschaft* **18**, 433-438.

Rollins, H.B., West, R.R., & Busch, R.M. 1990. Hierarchical genetic stratigraphy and marine paleoecology. *Paleontological Society Special Publication* **5**, 273-308.

Romanek, A. & Rup, M. 1990. Podział litostratygraficzny dewonu w profilu otworu wiertniczego Kowala 1. *Kwartalnik Geologiczny* **34**, 221-242.

Różkowska, M. & Fedorowski, J. 1972. Genus *Disphyllum* de Fromentel (Rugosa) in the Devonian of Poland and its distribution. *Acta Palaeontologica Polonica* **18**, 265-340.

Rubinowski, Z. 1971. Rudy metali nieżelaznych w Górach Świętokrzyskich i ich pozycja metalogeniczna. *Biuletyn Instytutu Geologicznego* **247**, 1-166.

Rzhonsnitskaja, M.A. 1988. Biostratigraphic scheme of the Devonian of the Russian Platform. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 691-702.

Samsonowicz, J. 1917. Utwory dewońskie wschodniej części Gór Świętokrzyskich. *Prace Towarzystwa Naukowego Warszawskiego* **20**, 1-69.

Sandberg, C.A., Ziegler, W., & Bultynck, P. 1989. New standard conodont zones and early *Ancyrodella* phylogeny across Middle-Upper Devonian boundary. *Courier Forschungsinstitut Senckenberg* **110**, 195-230.

Sartenaer, P. 1980. Appartence de l'espèce *Terebratula formosa* de l'Eifel au genere *Phlogoiderhynchus* du dèbut du Frasnien. *Senckenbergiana Lethaea* **61**, 17-43.

Schlager, W. 1981. The paradox of drowned reefs and carbonate platforms. *Geological Society of America Bulletin* **92**, 197-211.

Schlager, W. 1989. Drowning unconformities on carbonate platforms. *Society of Economic Paleontologists and Mineralogists Special Publication* **44**, 15-25.

Seilacher, A. & Aigner, T. 1991. Storm deposition at the bed, facies and basin scale: the geologic perspective. In: G. Einsele, A., Seilacher, & W., Ricken (eds) *Cycles and Events in Stratigraphy*, 249-267. Springer, Berlin.

Śliwiński, S. 1960. O występowaniu wapieni i dolomitów dewońskich koło Siewierza oraz możliwościach ich użytkowania. *Prace Naukowe Akademii Górniczo-Hutniczej* **1**, 91-117.

Słupik, A. (in press) Rodzaj *Amphipora* (Stromatoporoidea) z franu Jaworzni w Górach Świętokrzyskich. *Prace Naukowe Uniwersytetu Śląskiego, Geologia* **12-13**.

Sobolev, D. (Соболев, Д.)1909. Средний девон Келецко-Сандомирского Кряжа. *Материялы по Геологии России* **24**, 41-536.

Sobolev, D. (Соболев, Д.) 1911. Путеводитель гля геологической экскурсии в Келецко-Сандомирский Кряж. *Известья Варшавского Политехнического Института* **1**, 1-55.

Sokolov, B. (Соколов, Б.) 1986. Экостратиграфия, ее место и роль в севоднящей стратиграфии. In: Д.Д. Кальё и Э. Клааман (eds) Теория и Опыт Экостратиграфии, 9-18. Валгус, Таллин.

Stanton, R.J. & Flügel, E. 1989. Problems with reef models: the Late Triassic Steinplatte 'Reef' (northern Alps, Salzburg/Tyrol, Austria). *Facies* **20**, 1-138.

Stoakes, F.A. 1980. Nature and control of shale basin fill and its effect on reef growth and termination: Upper Devonian Duverney and Ireton Formations of Alberta, Canada. *Bulletin of Canadian Petroleum Geologists* **28**, 345-410.

Strasser, A. 1991. Lagoonal-peritidal sequences in carbonate environments: autocyclic and allocyclic processes. In: G. Einsele, A., Seilacher, & W., Ricken (eds) *Cycles and Events in Stratigraphy*, 709-721. Springer, Berlin.

Straszak, G. 1986. *Opracowanie mikropaleontologiczne wapieni żywetu okolic Siewierza.* Unpublished MSc. thesis, Silesian University, Sosnowiec.

Struve, W. 1964. Bericht über geologischen Exkursionen in der Prümer Mulde (20. 5. 1964) und in der Eifeler Kalkmulden Zone (20. 5. 1964). *Decheniana* **117**, 224-244.

Struve, W. 1982. The Eifelian the Devonian frame; history, boundaries, definitions. *Courier Forschungsinstitut Senckenberg* **55**,401-433.

Struve, W. 1992. Nueues zur Stratigraphie und Fauna der rhenotypen Mittel-Devon. *Senckenbergiana Lethaea* **73**, 503-624.

Stupnicka, E. 1989. *Geologia Regionalna Polski.* 286 pp. Wydawnictwa Geologiczne, Warszawa.

Sweet, W.C. 1988. *The Conodonta: Morphology, Taxonomy, Paleoecology and Evolutionary History of a Long-extinct Animal Phylum.* 212 pp. Clarendon, Oxford.

Szulczewski, M. 1971. Upper Devonian conodonts, stratigraphy and facies development in the Holy Cross Mts. *Acta Geologica Polonica* **21**, 1-129.

Szulczewski, M. 1973. Famennian-Tournaisian neptunian dykes and their conodont fauna from Dalnia in the Holy Cross Mts. *Acta Geologica Polonica* **23**, 15-52.

Szulczewski, M. 1977. Główne regiony facjalne w paleozoiku Gór Świętokrzyskiech. *Przegląd Geologiczny* **25**, 428-432.

Szulczewski, M. 1978. The nature of uncorformities in the Upper Devonian-Lower Carboniferous condensed sequence in the Holy Cross Mts. *Acta Geologica Polonica* **28**, 283-298.

Szulczewski, M. 1979. Devonian carbonate platform of the Holy Cross Mts. In: *Third International Symposium on Fosil Cnidaria Guidebook*, 5-36, Wydawnictwa Geologiczne, Warszawa.

Szulczewski, M. 1981. Stratygrafia franu wzgórz kostomłockich. In: H.Żakowa (ed.) *Przewodnik 53 Zjazdu Polskiego Towarzystwa Geologicznego*, 222-225. Wydawnictwa Geologiczne, Warszawa.

Szulczewski, M. 1989. Światowe i regionalne zdarzenia w zapisie stratygraficznym pogranicza franu z famenem Gór Świętokrzyskich. *Przegląd Geologiczny* **37**, 551-557.

Szulczewski, M. & Racki, G. 1981. Early Frasnian bioherms in the Holy Cross Mts. *Acta Geologica Polonica* **31**, 147-162.

Talent, J.A., Mawson, R., Andrew, A.S., Hamilton, P.J., & Whitford, D.J. 1991. Middle Paleozoic extinction events: quest for isotopic signatures. In: *Research Symposium on Event Markers in Earth History Abstracts*, 69. Calgary.

Talent, J.A. & Yolkin, E.A. 1987. Transgression-regression patterns for the Devonian of Australia and southern West Siberia. *Courier Forschungsinstitut Senckenberg* **92**, 235-249.

Truyols-Massoni, M., Montesinos, R., Garcia-Alcalde, J.L., & Leyva, F. 1990. The Kačak-*otomari* event and its characterization in the Palentine domain (Cantabrian Zone. NW Spain). In: E.G. Kauffman & O.H. Walliser (eds) *Extinction Events in Earth History, Lecture Notes in Earth Sciences* **30**, 133-143.

Tsien, H.H. 1981. Ancient reefs and reef carbonates. *Proceedings of 4th International Coral Reef Symposium* **1**, 601-609.

Tsien, H.H. 1988. Devonian paleogeography and reef development of northwestern and central Europe. *Canadian Society of Petroleum Geologists, Memoir* **14** (1), 341-358.

Tucker, M.E. & Wright, V.P. 1990. *Carbonate Sedimentology*. 482 pp. Blackwell, Oxford.

Uyeno, T.T. 1974. Conodonts of the Waterways Formation (Upper Devonian) of northeastern and central Alberta. *Geological Survey of Canada Bulletin* **232**, 1-93.

Vail, P.R., Audemard, F., Bowman, S.A., Eisner, P.N., & Perez-Cruz, C. 1991. The stratigraphic signature of tectonics, eustacy and sedimentology: an overview. In: G. Einsele, A., Seilacher, & W., Ricken (eds) *Cycles and Events in Stratigraphy*, 617-659. Springer, Berlin.

Van Steenwinkel, M. 1990. Sequence stratigraphy from 'spot' outcrops - example from a carbonate-dominated setting: Devonian-Carboniferous transition, Dinant synclinorium (Belgium). *Sedimentary Geology* **69**, 259-280.

Walliser, O.H. 1985. Natural boundaries and Commission boundaries in the Devonian. *Courier Forschungsinstitut Senckenberg* **75**, 401-408.

Walliser, O.H. 1986. Toward a more critical approach to bio-events. In: O.H. Walliser (ed.) *Global Bio-Events, Lecture Notes in Earth History*, 5-16. Springer, Berlin.

Walliser, O.H. 1992. Devonian global events. *Fifth International Conference on Global Bioevents Abstract Volume*, 116. Gottingen.

Weddige, K. 1988. Eifel conodonts. *Courier Forschungsinstitut Senckenberg* **102**, 103-110.

Wendt, J. & Belka, Z. 1991. Age and depositional environment of Upper Devonian (Early Frasnian to Early Famennian) black shales and limestones (Kellwasser Facies) in the Eastern Anti-Atlas, Marocco. *Facies* **25**, 51-90.

Wilson, J.L. 1975. *Carbonate Facies in the Geologic History*. 410 pp. Springer, Berlin.

Witzke, B.J., Bunker, B.J., & Rogers, F.S. 1988. Eifelian through Lower Frasnian stratigraphy and deposition in the Iowa area, Midcontinent, U.S.A. *Canadian Society of Petroleum Geologists, Memoir* **14** (1), 221-230.

Witzke, B.J. & Heckel, P.H. 1988. Paleoclimatic indicators and inferred Devonian paleolatitudes of Euramerica. *Canadian Society of Petroleum Geologists, Memoir* **14** (1),49-66.

Wrzołek, T. 1988. Tetracoral zonation of the Devonian stromatoporoid-coral limestones in the SW Holy Cross Mountains, Poland. *Canadian Society of Petroleum Geologists, Memoir* **14** (3), 413-424.

Wrzołek, T. 1993. Rugose corals from the Devonian Kowala Formation of the Holy Cross Mountains. *Acta Palaeontologica Polonica* **37**, 217-254.

Żakowa H., Szulczewski, M., & Chlebowski, R. 1983. Dewon górny i karbon synkliny borkowskiej. *Biuletyn Instytutu Geologicznego* **345**, 5-134.

Żbikowska, B. 1983. Middle to Upper Devonian ostracods from northwestern Poland and their stratigraphic significance. *Palaeontologia Polonica* **44**, 1-108.

Ziegler, A.P. 1988. Laurassia - the Old Red Continent. *Canadian Society of Petroleum Geologists, Memoir* **14** (1), 15-48.

Register of localities

The listed localities (Figs 2-3) are refered to in all papers of this volume. Lithologic subunits are designated by letters.

Łysogóry (northern) region

Skały.– Exposures on the eastern slope of the Dobruchna river valley, ca. 4.5 km N of Nowa Słupia, within the Grzegorzowice-Skały section. Wojciechowice Beds to Nieczulice Beds; Eifelian to Middle Givetian (Pajchlowa 1957; Malec 1984).

Świętomarz.– Exposures in the Psarka river valley, 5.5 km NE of Bodzentyn, within the Świętomarz-Śniadka section. Wojciechowice Beds to Nieczulice Beds (Śniadka formation); Eifelian to Middle Givetian (Czarnocki 1950; Kłossowski 1985).

Kostomłoty transitional zone

Czarnów.– Non-continuous exposures in an overgrown railway cut (mostly only as rubble) and a largely covered road cut near Kielce-Czarnów station, three trenches in the northeastern slope of the Grabinowa hill, abandoned peasant quarries along the southern slope of the this hill. Partly dolomitized Stringocephalus Beds (A), Szydłówek Beds (B) to Wietrznia Beds (C-D); Early(?) Givetian to Early Frasnian (Filonowicz 1967; Szulczewski 1971; Racki & Bultynck in preparation).

Domaszowice.– Overgrown peasant quarry localized N of the Kielce-Opatów road, E of the village. A few meters of fossiliferous (silicified coral-bearing) detrital limestones, presumably higher Kostomłoty Beds; Late Frasnian (*P. rhenana* Zone).

Górno.– Poor outcrops in the road cut Górno-Daleszyce and two quarries (one of them large and active) on the Józefka hill 1.4 km S of the village; several exposures at the village by the road Kielce-Opatów and in the Warkocz stream valley. Dolomitized *Stringocephalus* Beds, Laskowa Góra Beds (A), Szydłowek Beds (B), to varied Detrital/Marly Beds (a variety of Kostomłoty Beds) with the lowest organodetrital set C referred to the Wietrznia Beds; ?Late Givetian to Frasnian (Filonowicz 1969; Małkowski 1981; Racki & Bultynck in preparation).

Kostomłoty-East (Kostomłoty-IV).– Outcrops along the Kostomłoty hills with five exposures enable reconstruction of a composite section. Sets A-B represent Laskowa Góra Beds and Szydłówek Beds, respectively, whereas sets C-H corespond to units A-F of Szulczewski (1981) within the Kostomłoty Beds. This easternmost exposure is represented by several old pits in the western and middle part of the eastern Kostomłoty hill. Higher Kostomłoty Beds (?F-H); Late Frasnian (Szulczewski 1971) .

Kostomłoty-West (Kostomłoty-III).– An abandoned peasant quarry in the eastern part of the western Kostomłoty hill. Middle Kostomloty Beds (?E-F); Late Frasnian (Szulczewski 1971).

Krzemucha (Kostomłoty-I).– Mostly covered quarry in the westernmost part of the hill, by the Kielce-Strawczyn road. Middle Szydłówek Beds to lower Kostomłoty Beds (units B_2-?D only); Frasnian (Racki *et al.* 1985).

Laskowa (Laskowa Góra).– Active quarry on a hill N of the village Laskowa. Dolomitized *Stringocephalus* Beds to lower Szydłówek Beds (units A-B_1 of the composite Kostomłoty section); Givetian (Racki *et al.* 1985).

Małe Górki (Kostomłoty-II; Laskowa *in* Biernat & Szulczewski 1975).– Small active quarry adjacent to both the Laskowa and Krzemucha exposures, with the eastern wall being a protected area. Middle Szydłówek Beds to lower Kostomłoty Beds (units B_2-D); Early through Middle Frasnian (Racki *et al.* 1985; Racki & Bultynck in preparation).

Mogiłki (Kostomłoty-V).– A small quarry in the northeastern part of the Kostomłoty hills, and nearby pits. Large part of the Kostomłoty Beds (?C-?F); later Frasnian.

Radlin.– Rural quarries and loose blocks of waste on the hill, 1.3 km S of the village (Kielce-Opatów road). Szydłówek Beds (A) to Kostomłoty Beds (chiefly marly-nodular variety, B); latest(?) Givetian to the later Frasnian.

Śluchowice (Ślichowice).– A spectacular inactive protected quarry near the Kielce-Herby railroad station, northwestern part of Kielce. Basal Wietrznia Beds (A-B) to Kostomłoty Beds (C); complete(?) Frasnian (Szulczewski 1971; Racki & Bultynck in preparation).

Szydłówek.– Temporary pits and dugs by Manifest Lipcowy Street, and cut of this street across the Szydłówek hill; poor exposures occur also along the foot of the hill (N of the Bocianek quarter), and in the road cut by Warszawska Street (Sz-I). Szydłówek Beds, subdivided into lower (A), middle (B) and upper (C) parts; Late Givetian to Early Frasnian (Biernat & Szulczewski 1975; Racki & Bultynck in preparation).

Wola Jachowa.– Minute exposures on a low hill, 200 m W of the village. Upper Szydłówek Beds; earliest Frasnian (Racki & Bultynck in preparation).

Northern-Kielce subregion

Białogon.– Almost completely covered old quarry near railway station. Dark amphiporid biostromes; Givetian (Gürich 1896).

Daleszyce.– Small outcrops and rubble on hills W and N of the town, and on the church hill. Detrital Beds (including renalcid varieties, and intraformational brecciae) to *Manticoceras* Limestone (coral- and crinoid-bearing cherrish- grey micrites); Frasnian (Filonowicz 1976).

Góra Cmentarna.– Mostly filled old quarry and small natural exposures near a cemetery by Ściegiennego Street. Topmost Sitkówka Beds (A) grading into the Kadzielnia Limestone (B); Early Frasnian (Gawlik *in* Racki *et al.* in press a).

Grabina.– Abandoned quarry on the hill, 1 km W of the Karczówka monastery; similar-age rocks were uncovered in the nearby Dalnia (Szulczewski 1971, 1973) and Karczówka hills. Highest Sitkówka(?) Beds (stromatoporoid limestones, A) and Detrital Beds (set B comprising renalcid-stromatolite-*Stachyodes* boundstones; calcarenites with the basal coral-bearing bed, set C); Middle(?) and Later Frasnian (Wrzołek 1988; Godefroid & Racki 1990).

Jaworznia.– Large abandoned quarry adjoining to lime-kilns at the village (Głazek & Romanek 1978); older strata are partly visible in a pit on the Moczydło hill in western part of the village (Kaźmierczak 1971b, Rubinowski 1971). Upper Sitkówka Beds (dark amphiporid biostromes, A; light amphiporid-laminite rhythmic series, set B); Frasnian (Kaźmierczak 1971b; Słupik 1993).

Kadzielnia.– Inactive protected quarry. Kadzielnia Limestone Member (A), Detrital Beds (B) to *Manticoceras* Limestone (C); Frasnian (Kaźmierczak 1971b; Szulczewski 1971, 1979; Szulczewski & Racki 1981).

Psie Górki.– A few abandoned small quarries on a hill by Zakopiańska Street. Detrital Beds (sets C-H as a continuation of the Cmentarna Góra section); later Frasnian (Szulczewski 1971; Racki 1990; Gawlik *in* Racki *et al.* in press a).

Szczukowskie Górki.– Quarry on the Kopaczowa hill beside the Kielce-Piekoszów road (Rubinowski 1971). Uppermost(?) Sitkówka Beds and Detrital Beds (undivided); Early-Middle(?) Frasnian (Sobolev 1909; Godefroid & Racki 1990).

Wietrznia.– Large exposure comprising three joined inactive quarries and small pits on the hill E of quarry. Two sections are distinguished after Szulczewski (1971): Wietrznia-I (western quarry) and Wietrznia-II (Eastern Międzygórz). Partly dolomitized at the bottom

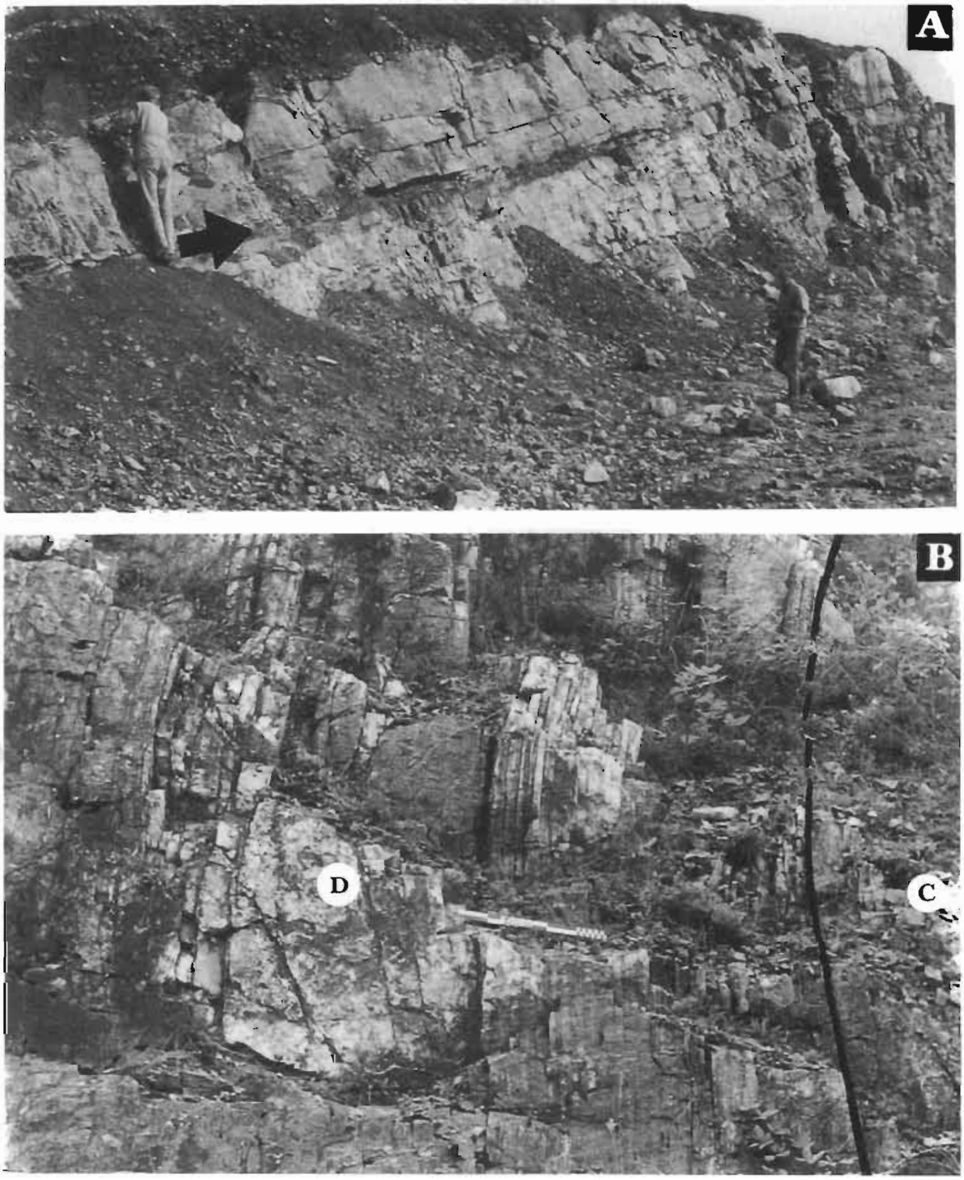


Fig. 38. ❑A. Frasnian part of the Kowala Formation in contact with the condensed Famennian-Carboniferous strata in the Ostrówka Quarry, arrowed is a wedging paleokarstic horizon. ❑B. Middle part of the southern Stokówka quarry showing a laminite-bearing complex D (Fig. 35); bar scale 0.5 m.

Wietrznia Beds intertwined with the *Phlogoiderhynchus* Level (set C) and tentatively subdivided into lower (A-B) and upper (D and higher sets) portions; Late Givetian to Frasnian (Szulczewski 1971; 1989; Makowski *in* Racki *et al.* in press a).

Central Kielce subregion

Miedzianka.– Abandoned quarries and natural exposures on the hill grouped along the western slope (Fig. 39B), 200 m N of the village (Rubinowski 1971). Upper Sitkówka Beds

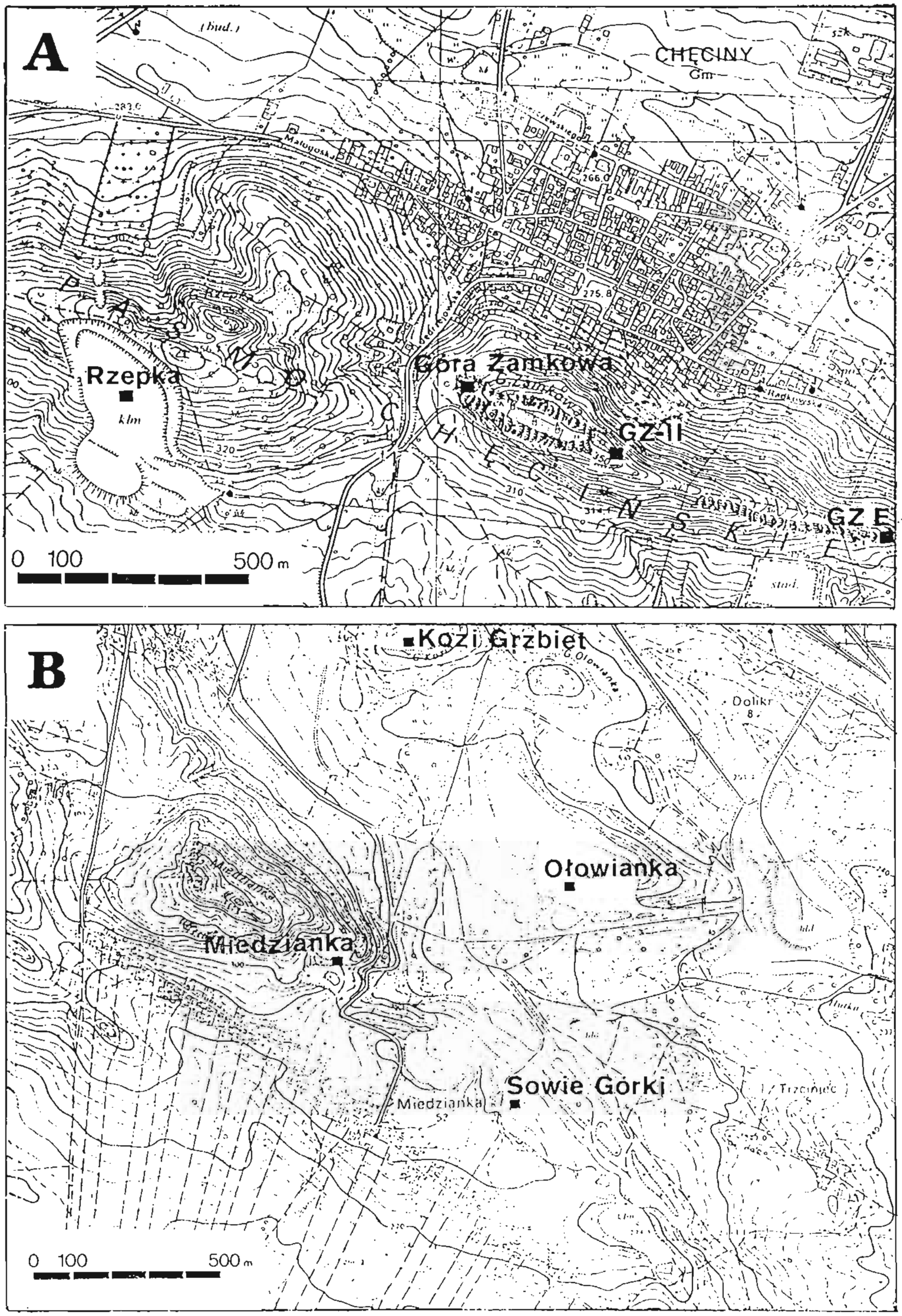


Fig. 39. Location of sections (see Fig. 2B) in Chęciny (A) and Miedzianka (B) areas.

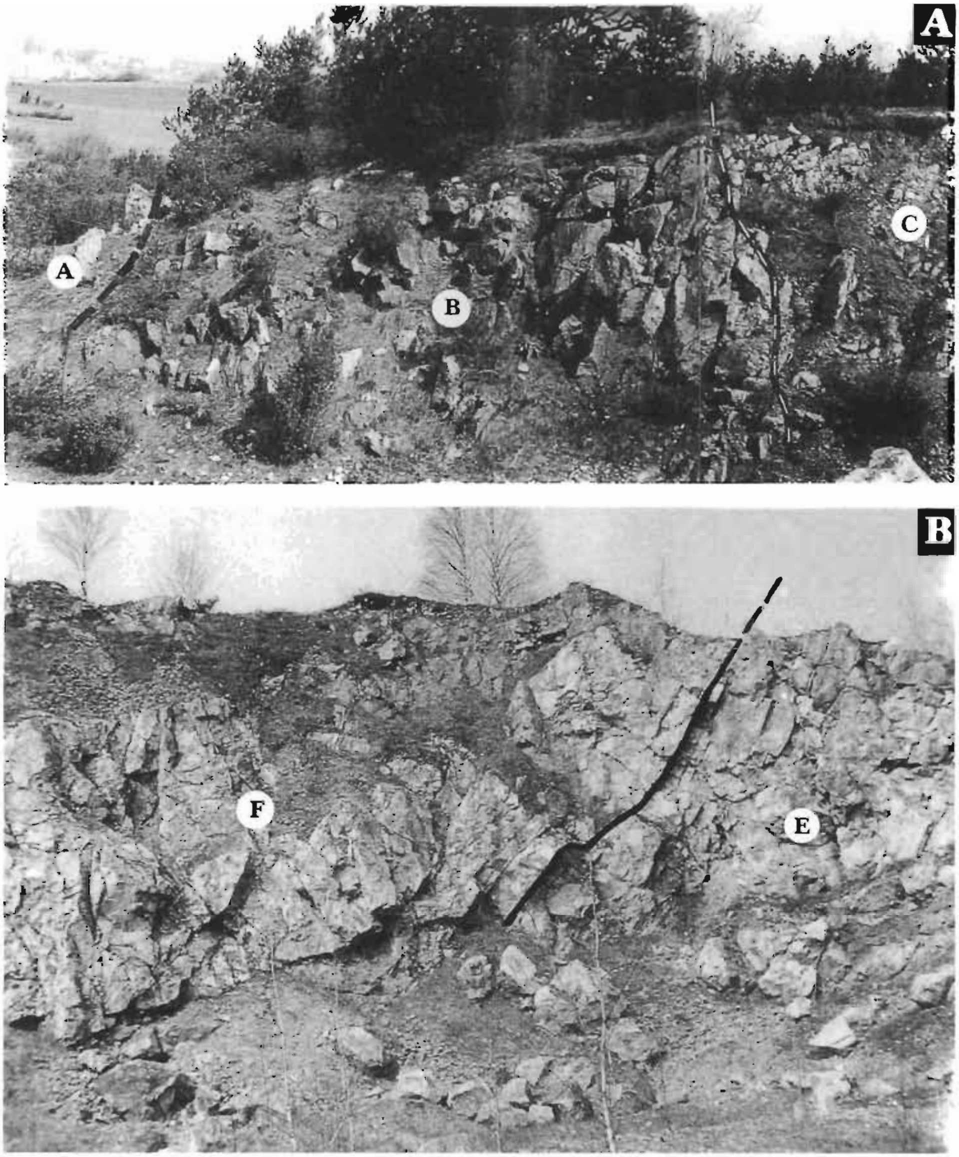


Fig. 40. Outcrops in the Miedzianka area (see Figs 36, 39B). ❑A. Most northwestern part (cut) of the Ołowianka quarry, the oldest sets A-C cropping out. ❑B. Southwestern fragment of the eastern Sowie Górki quarry, with visible tectonic contact within higher part of the Kowala Formation (sets E-F).

(A-C), Detrital-Stromatoporoid (D-E) Beds; Frasnian (Czarnocki & Samsonowicz 1911; Szulczewski 1989).

Marzysz.– Obscured pits and trenches, and a debris in waste on hillock, ca. 600 m S of the eastern part of the village; younger strata are poorly outcropped at the Jabłonna hill, N of the Kielce-Daleszyce road (Żakowa *et al.* 1983). Jaźwica Limestone Member, and unstudied dolomites and lower Sitkówka Beds; Givetian (Filonowicz 1973).

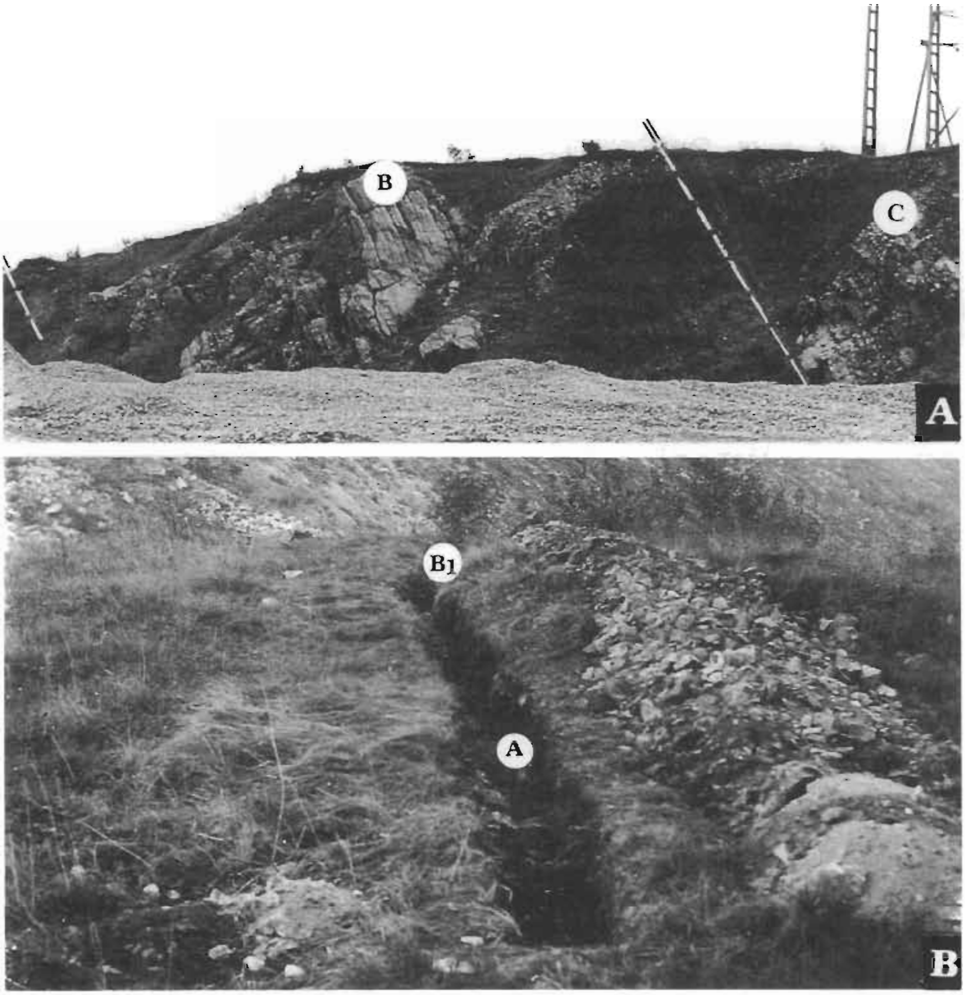


Fig. 41. ❑A. Fragment of the eastern wall of the old Sitkówka quarry near railway station (Kostrzewa hill) in 1979, with outcropping the middle part of the section marked by abundant Chęciny-type shelly faunas (sets B-C; Fig. 36). ❑B. Northwestern portion of the Posłowice hill (Fig. 42) showing trench exposing the lower boundary of the Jaźwica Member (A-B - lithologic sets, Fig. 14).

Ostrówka.– Very large active quarry on the Ostrówka and Jaźwiny hills, S of the Gałęzice village; the exposure accessible to studies only in the western part (Fig. 38A). Mostly upper Sitkówka Beds (thick laminite-amphiporid rhythmic series); ?Givetian to Frasnian (Szulczewski 1978; Malec & Racki 1993).

Ołowianka.– Abandoned quarry on the hill 500 m N of Miedzianka village (Figs 39A, 40A); fragments of the sequence are poorly available in the nearby former Kozi Grzbiet quarry. *Stringocephalus* Beds (A-C), lower (D-E) and upper (F-G) Sitkówka Beds; Givetian to Middle(?) Frasnian.

Panek (Bolechowice).– Small 'marble' quarry on the western slope of hill, 500 m N of Bolechowice (near the highway E-7); lower amphiporid-laminite complex crops out to the W, mainly at the old Szewce quarry, while a more complete Frasnian sequence is visible in the abandoned Zgórsko quarry, 1 km to E, by the 'Nowiny' cement factory. Topmost Sitkówka

Beds (A) and Detrital-Stromatoporoid Beds (B); Middle-Upper(?) Frasnian (Kaźmierczak 1971a, b; Wrzołek 1988).

Posłowice.– Rural quarries and trench dug in 1984 in NW part of a low hill, partly covered by dump (Figs 41B, 42). Highest *Stringocephalus* Beds (A), Jaźwica Member (B) to Lower Sitkówka Beds (C-D); Middle-Late Givetian (Filonowicz 1973; Racki & Racka 1981).

Sowie Górki (Sowi Grzbiet).– Extensive (ca. 1 km in length) three-partite inactive quarry on hills immediately along the SE part of Miedzianka village (Figs 39B, 40B); fossil-rich rubble was found on the small hill, SE of the quarry, just by the Hutka stream. Dolomites, *Stringocephalus* Beds (A-B), Coral-Crinoid Level (with reduced Jaźwica Member, C) to Lower (D) and Upper (E-G) Sitkówka Beds; Givetian to Middle Frasnian.

Sitkówka-Jaźwica (Sitkówka I in Kaźmierczak 1971b).– Abandoned quarry used as an industrial depositional reservoir on a hill between the Sitkówka and Kowala villages (Fig. 42); similar but macrofossil-poor strata are exposed on hills eastward in abandoned quarries and ditches. Topmost Sitkówka Beds (A) and Detrital-Stromatoporoid Beds (B); later Frasnian (Sobolev 1909; Mikłas *in* Racki *et al.* in press a).

Sitkówka-Kostrzewa (Sitkówka III in Kaźmierczak 1971b).– Old, mostly covered quarry near the railway-station Sitkówka (Fig. 41A); in a minute pit (SK-I) E of the quarry a lower atrypid-rich fragment of the set B is exposed. Lower Sitkówka Beds (A and C) interfingering with the Chęciny Beds (B; Atrypid-Crinoid Level); Givetian-Frasnian passage beds (Sobolev 1911; Kotański 1959; Pajchlowa & Stasińska 1965).

Sitkówka-Kowala Quarry (Sitkówka V in Kaźmierczak 1971b).– Large active quarry beside the lime factory, NE of the village; the corresponding section has been completely buried in the nearby Bełkowa quarry (Sitkówka IV in Kaźmierczak 1971b). Upper Sitkówka Beds (A-D); Early-Middle Frasnian.

Słopiec.– Peasant quarry on a hill beside Kielce-Daleszyce road, NW of the village; smaller outcrops are also known westward near Borków. Sitkówka Beds; Late Givetian-Frasnian (Gürich 1896).

Trzemoszna.– Rubbles in waste on hillock, E of the village (near forester's lodge); the series was pierced by borehole Szczecno 1 and 2 (Narkiewicz 1991), 4 km to SW. Jaźwica Member and possibly adjacent coral-rich strata; Givetian (Filonowicz 1973).

Southern Kielce subregion

Bilcza.– Several mostly more or less filled rural quarries and ditches on the three small hills in the vicinity of Bilcza-Podgórze village; the best exposures occur on the hill Bilcza-1 adjacent to the eastern part of the village, and the nearby hills Bilcza-2 and Bilcza-3 localized S and W of the village, respectively. Topmost *Stringocephalus* Beds (A) to lower Sitkówka Beds (B-D); Middle-Upper Givetian.

Góra Łgawa (eastern Jaźwica Quarry).– Active quarry situated S of Bolechowice, presently joined with the smaller western quarry, and minute pits along the hill, E of the quarry. Dolomicrites, mainly dolomitized *Stringocephalus* Beds to *Phlogoiderhynchus* Level (sets A–L), Detrital Beds to nodular-marly beds (sets M–R); Eifelian through Frasnian (Racki 1981).

Góra Sołtysia.– Obscured trenches and peasant ditches on the small hill, E of Wola Murowana, by Bobrza river; older dolomitic series are outcropped in the adjacent Radkowice quarry (Czermiński 1960). *Stringocephalus* Beds to lower Sitkówka Beds (Kaźmierczak 1971b); Middle-Late Givetian.

Jaźwica.– Temporally inactive (till 1986) western quarry of the stone plant 'Jaźwica', 0.5 km S of the Bolechowice village, presently joined with the eastern part in one large quarry (Figs 6, 8A). Topmost *Stringocephalus* Beds (A), Jaźwica Member (B), lower (D-G) and upper (H-I and K) Sitkówka Beds (locally Kadzielnia Member, J), and *Phlogoiderhynchus* Level (L); Middle Givetian to Middle Frasnian (Racki 1981; 1985a).

Kowala Mała hill (Kowala-III).– Several small, mostly overgrown rural pits, and natural outcrops along the hill situated between the Kowala and Kowala Mała villages. Upper Sitkówka Beds to Detrital Limestones (undivided); Frasnian (Wrzołek 1988).

Kowala-railroad cut.– Reference section for the set of outcrops along the hill range, S of the Kowala village (Fig. 42); the exposure 0.8 km from the village (Szulczewski & Racki 1981: Fig. 2). Upper Sitkówka Beds (A-B), Kadzielnia Member (C), *Phlogoiderhynchus* Level (D), Detrital Beds to rhythmic marly deposits (E-H); Frasnian (Czermiński 1960; Szulczewski 1971).

Kowala-road cut (Kowala-II).– Roadside exposure along industrial highway to cement plant, 300 m SW of the railroad cut. Detrital Limestones to marly strata, equivalents of sets G(?) and H, from the railroad cut; Late Frasnian (Kaźmierczak & Goldring 1978; Wrzołek 1988; Miklas *in* Racki *et al.* in press a).

Kowala Quarry (Wola Quarry, Kowala-I).– Large active quarry (Fig. 8B). Upper Sitkówka Beds to varied marly deposits (sets as in the railroad cut); Frasnian (Szulczewski & Racki 1981).

Łabędziów .– Small active quarry, S of the village, near the Czarna Nida river. Mostly dolomitized *Stringocephalus* Beds; Middle Givetian.

Stokówka.– Inactive, two-level quarry at the western part of the hill (Fig. 38B), 1 km SE of Gałęzice. Topmost *Stringocephalus* Beds (A), Jaźwica Member (B), Chęciny Beds (C-D), lower (E-F) to upper (G-H) Sitkówka Beds; Middle Givetian to early Frasnian (Rożkowska & Fedorowski 1972).

Zelejowa.– Abandoned quarries (the largest one in the western part) and extensive natural exposures along the hill, 1.5 km N of Chęciny. Upper Sitkówka Beds (A-B); Early Frasnian.

Chęciny-Zbrza area

Dębska Wola (Zielona).– Trenches dug in 1986 and obscured pits on the southern slope of hill, beside the road Kawczyn-Dębska Wola and railway station, 500 m SW of the village. *Phlogoiderhynchus* Level (sets F-G in composite section of the Zbrza Anticline; ?Middle Frasnian (Czarnockl 1927; Filonowicz 1973; Kucia 1987).

Góra Zamkowa.– Several exposures along the hill with castle ruin (Fig. 39A; Racki & Baliński 1981: Fig. 2); the reference section is based on the inactive western quarry passing into natural outcrops on the rocky southern slope (Figs 4B, 5), and other small exposures comprising a trench in the middle part of the hill (GZ-I), excavation in a ridge above the old Jewish cemetery (GZ-II). Eastern outcrops (GZ-E) include escarpment of the secondary road to Stare Chęciny (GZ-III), as well as obscured small quarries in the easternmost (GZ-IV) and southeastern (GZ-V) endings. Dolomitized *Stringocephalus* Beds (A_1; set terminology consequently follows Racki & Baliński 1981), Jaźwica Member (A_2), Chęciny Beds (B-I), Detrital Beds (J) to *Phlogoiderhynchus* Level (K); Middle Givetian to Middle Frasnian (Kotański 1959; Kaźmierczak 1971a; Narkiewicz 1973; Szulczewski 1979).

Kawczyn.– Mostly overgrown ditches, and rubble on a hill extending westward from the village; continuation of the Zbrza section. Sitkówka Beds (C), upper Chęciny Beds (D), Detrital Beds (E) to *Phlogoiderhynchus* Level (F); Givetian(?) to Middle Frasnian (Filonowicz 1973; Kucia 1987).

Radkowice.– An overgrown ditch, 300 m S of the western part of the village. Detrital Beds (unit L in the composite Chęciny section); later Frasnian.

Rzepka.– Abandoned quarry in the southern part, small pits and natural exposures on the vast hill adjacent from SW to Chęciny. Dolomicrites to Chęciny Beds (to marly strata); Eifelian to Frasnian (Narkiewicz 1991).

Sosnówka.– Mostly natural exposures, buried trench, and debris on the hill, 1 km W of Chęciny, by road to Zajączków (Fig. 4A). Chęciny Beds (A-C), *Phlogoiderhynchus* Level (D) to ?marly strata; Late Givetian through Frasnian (Narkiewicz 1973; Wrzołek 1988).

Zbrza.– Minute pits along a low hill, 0.7 km SW of the village, by secondary road to Łukowa. *Stringocephalus* Beds (A) to strongly dolomitized Lower Sitkówka(?) Beds (B-C); Givetian (Filonowicz 1973; Kucia 1987).

Zegzelogóra.– Old peasant quarries and a trench dug in 1984 on the western slope of thw hill, 400 m SE of Żebrownica and S of the Gościniec village. Chęciny Beds (A-B); Late Givetian (Narkiewicz 1973; Wrzołek 1988).

Żebrownica.– Mostly covered trenches in the middle part of the hill, 2 km W of Chęciny, near the road Chęciny-Zajączków. Dolomitized higher *Stringocephalus* Beds; Givetian (Narkiewicz 1973).

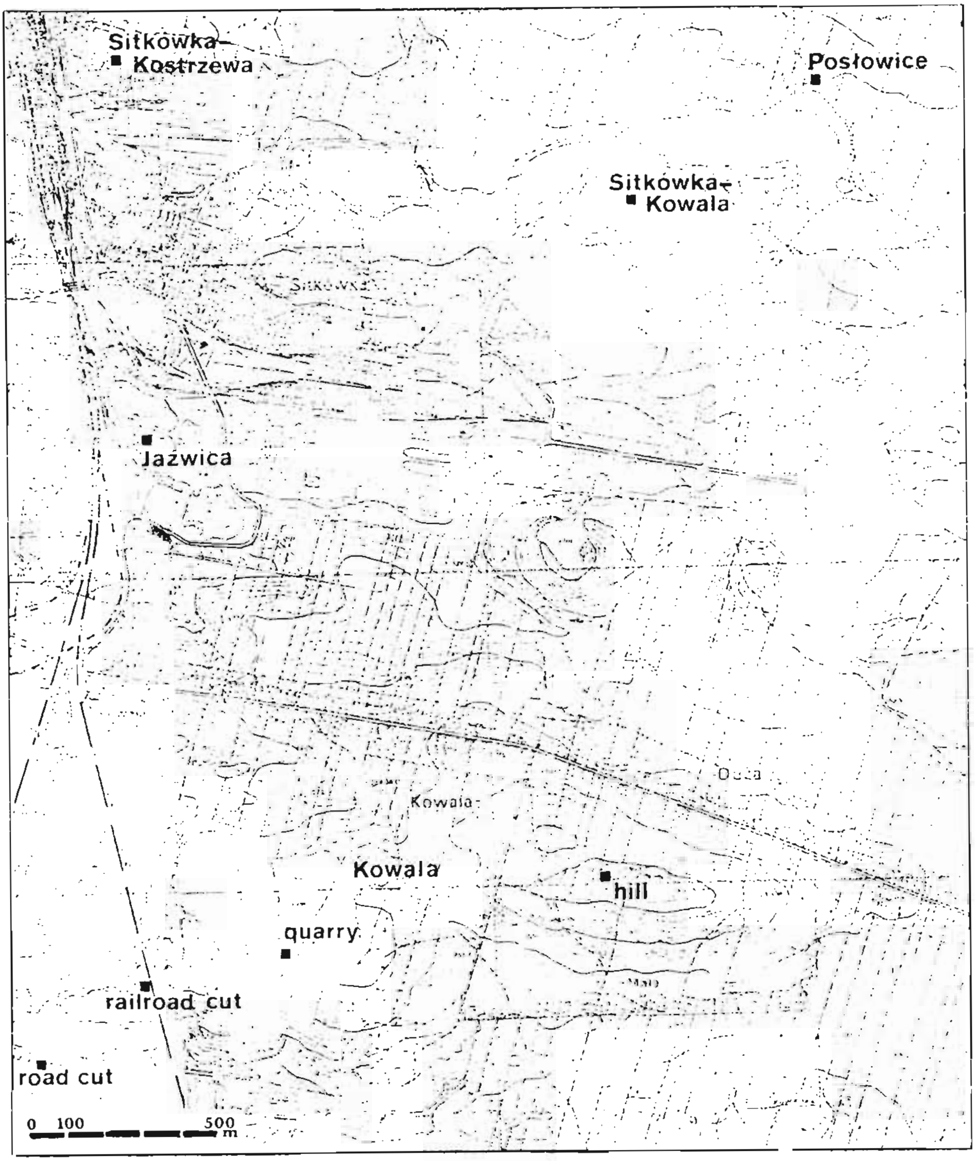


Fig. 42. Location of sections (see Fig. 2B) in the Sitkówka-Kowala area.

Eastern Holy Cross Mountains

Jurkowice-Budy.– Active quarry on the hill between the Jurkowice and Budy villages, near the road to Smerdyna. Dolomicrites to middle *Stringocephalus* Beds (A-F; Figs 9-10); Eifelian(?) to Middle Givetian (Pajchlowa & Stasińska 1965; Kaźmierczak 1971b; Baliński 1973; Narkiewicz 1981; Preat & Racki in press).

Karwów.– Small active quarry and adjacent pits in ravine, S of the village. Upper(?) Sitkówka Beds to Detrital Limestones; Frasnian (Samsonowicz 1917; Godefroid & Racki 1990).

Łagów.– Natural exposures along the eastern escarpment of the Łagowica river valley, and several rural quarries near Kielce-Opatów road. Dolomitized *Stringocephalus* Beds to upper Sitkówka Beds and marly strata; Givetian to Famennian (Samsonowicz 1917; Czermiński 1960; Narkiewicz 1991).

Sobiekurów.– Small abandoned quarry beside the Opatów-Staszów road, 2.5 km NE of Iwaniska. Nodular Limestones; Late Frasnian (Narkiewicz 1981).

Tudorów.– Overgrown peasant quarries in the ravine, S of the village. Detrital Limestones to Platy(?) Limestones; later Frasnian (Samsonowicz 1917; Godefroid & Racki 1990).

Wojnowice.– Natural exposures in the eastern rocky slope of the Koprzywianka river valley, SW of the Wojnowice-Podgórze village (Iwaniska-Piskrzyn section: Ozonkowa 1961); similar strata are visible eastward near Krępa (Lenkiewicz 1981). *Stringocephalus* Beds(?) to Sitkówka Beds; Givetian to Frasnian (Samsonowicz 1917; Ozonkowa 1961).

Silesia-Cracow region

Dębnik.– Several quarries, pits, and boreholes within the Dębnik Ridge between the villages Dębnik, Siedlec and Czatkowice. Dolomites, Platy Limestones, Stromatoporoid-Detrital Limestones; Givetian(?) through Frasnian to Famennian (Nowiński 1976; Baliński 1979; Narkiewicz & Racki 1984).

Siewierz (Dziewki).– Dozens of small quarries and ditches on the hill between the Dziewki and Brudzowice villages, as well as nearby borehole WB 12 (Racki *et al.* in press b). Dziewki Limestone (Fig. 10), eguivalent to the *Stringocephalus* and lower(?) Sitkówka Beds, represented by unfossiliferous calcilutites (A), wavy-bedded spiculitic (-crinoid) calcarenites (B), stromatoporoid-coral (-crinoid) reefoid limestones (C), and amphiporid biostromes (D), and amphiporid-laminite complex (E); Givetian (Gürich 1896; Śliwiński 1960).

Facies types account

The thirteen main facies types are briefly summarized below and confronted either with the standard (SMF) or type Devonian (D) microfacies in the scheme of Wilson (1975; see also Preat & Mamet 1989).

Intershoal (open shelf) facies

Non-fenestral laminated limestones (Facies M-1).– Platy, thin- to medium-layered (Figs 17A, 38B), grey to brown-yellowish units formed by dense microsparry, and rarer mudstone to bioclastic-peloid packstone laminae (up to 400 μm) grading into cm-sized ribbon-type intercalations (Narkiewicz 1973; Szulczewski 1979). For similar facies see Cook (1972), Machielse (1972), Bandel & Meyer (1975).

Bioclastic limestones (Facies M-2).– Variously bedded and grained, light grey limestones (neomorphozed and/or partly washed, bioturbated crinoid packstones/grainstones to well-sorted biolithoclastic grainstones with frequent micritized bioclast rims; Figs 12A, 16D, 22D) marked by more or less distinct wavy-bedding, with tendency to subnodular appearance in some cases (e.g. unit F-II of Racki & Baliński 1981; Fig. 11B). Corresponds to SMF-12 (see also Krebs 1974; Galli 1986).

Fossiliferous subnodular calcilutites (Facies M-3).– Distinctly-bedded, medium-grey to reddish micritic limestones, mostly bioclastic bioturbated wackestones (Figs 13D-E, 16C, 17C, 23B-C) with changing clay admixture that display various types of wavy to nodular bedding, and are markedly rich in open-marine faunal remains. Corresponds to 3D.

Platy calcilutites (Facies M-4).– Medium-grey, thin and rhythmically bedded, cherty, frequently finely-laminated micritic limestones (spiculitic wackestones) with sparse macrofauna and thin shaly interlayers in some parts (Figs 11C, 13A and C). This is a 'siliceous variety' of SMF-9 (see also Dolphin & Klovan 1970; Roche & Carozzi 1970).

Platy marly limestones and shales (Facies M-5).– Dark-grey to black, rhythmically bedded sequence of micritic to marly limestones (burrowed mudstones/bioclastic wackestones) and argillaceous shales, with pelagic tentaculite- and brachiopod-bearing levels (Fig.

22C). This is a more calcareous variety of 1D-2D, comparable with the Flinz Limestones (Krebs 1974).

Macrofossil-poor calcilutites and calcarenites (Facies M-6).– Micritic to fine-grained limestones (neomorphozed and bioturbated bioclastic-peloidal wackestones/packestones; Figs 13B, 16F, 23A), characterized by variously grey to brownish colors, medium- to thick-bedding of less or more distinct wavy appearance and macrofossils limited mostly to scattered gastropods. This is a special ('restricted marine') variant related to 10D (see also Braithwaite 1967; Jansa & Fischbuch 1974; Coppold 1976).

Organic buldups facies

Coral limestones (Facies R-1).– Coral-rich, typically platy to wavy bedded and medium-grey strata, with bioclastic wackestone to packstone matrix, and variably comminuted, unsorted coral skeletons as the main component. Subdivided into dendroid coral bafflestones (Facies R-1b; Figs 17D, 18A-B, D), massive coral bindstones/floatstones (R-1bf; Figs 17E, 18C, 21A), and coral rudstones with overturned and/or fragmented coralla (R-1r; Fig. 16B). Corresponds to 5D.

***Stachyodes* limestones** (Facies R-2).– Largely thin stromatoporoid beds characterized by two contrasting subfacies: *Stachyodes* bafflestones (R-2b), with whole skeletons preserved in bioclastic-peloidal wackestone/packstone matrix (Fig. 18B), and *Stachyodes* rudstones (R-2r), composed of poorly-sorted closely packed angular bioclasts, with transitions into unsorted intraclastic grainstones (Fig. 16F). Corresponds to 7D, and possibly 5D.

Massive stromatoporoid limestones (Facies R-3).– The three varietes cover the bulk of the observed variability (see also Kaźmierczak 1971b; Szulczewski 1971):

(1) Stromatoporoid bindstones (Facies R-3b; Figs 11A, 17E, 18D) are markedly abundant in laminar (sheet-like) stromatoporoids, accompanied mainly by varied alveolitid coralla and other skeletal grains, in micrite matrix locally with stromatactoid and umbrella sparry infillings (Szulczewski & Racki 1981). This facies is close to 6D.

(2) Reefoid stromatoporoid (-coral) limestones (R-3r) include to a various degree reworked, but only rarely strongly fragmented bulbous, domal, tabular, as well as dendroid coenostea, densely packed in variable micrite-sparry interstitial matrix (Figs 21C, 22E). The large skeletons are associated with diverse bioclasts and non-skeletal particles, with micritic encrustations and occassionally oncoids around skeletal nuclei, and micritized rinds and borings. The Frasnian stromatoporoid-detrital limestones are marked by higher frequency of various intraclasts and broken reef-builders in sparry-bioclastic matrix, enriched in crinoid-shelly debris. This is an equivalent of 8D.

(3) Bulbous stromatoporoid floatstones (R-3f) are typified by concentrations of bulbous coenostea up to 30 cm in diameter, 'floating' in a bioturbated peloidal-bioclastic wackestone/packstone matrix locally rich in problematic microfossils, mostly calcispheroids (Figs 16A, 22A). This variety corresponds to 9D.

Lagoonal facies

Macrofossil-impoverished calcarenites (Facies L-1).– These thick-bedded, light-grey fine-grained deposits with very sparse macrofossils, mostly well-sorted intrabioclastic grainstones grade into unsorted rudstones. Micrite coatings (even oncolite partings), composite grains and fragmented *Stachyodes* coenostea are represented in various proportions (Figs 12B, 16F). This is a grainy variant of 12D, related to SMF-18 (see also Noble 1970; Jansa & Fischbuch 1974).

Amphiporid limestones (Facies L-2).– These well-layered units, with individual beds rarely exceeding 50 cm in thickness, are characterized by dense concentrations of tiny spaghetti-like amphiporid skeletons (Fig. 26). Two extreme subfacies are bafflestones (L-3b) with well-preserved, intact peripheral epitheca of fragmented stromatoporoid branches in primary peloidal-micrite calcispheroid-rich groundmass (Figs 12F, 20B), and rudstones (L-2r), composed mainly of sticks rimmed with sparry calcite cement (Fig. 16E). This facies type corresponds to 11D.

Fenestral laminated calcilutites (Facies L-3).– Their laminated layers, usually up to 40 cm thick (but see Fig. 20C), commonly contain spar-filled fenestrae in horizontal sheet-like units, and consists of more or less regularly alternating peloid-rich micritic and sparry laminae (Figs 12D, 20A, 21B, 22F; see also Preat & Racki in press). This is an equivalent of 13D (cf. types 1-3 of Boulvain & Preat 1987).

Macrofossil-poor calcilutites (Facies L-4).– These mostly thick-bedded, medium- to light grey micritic limestones (bioturbated mudstone-wackestone to bioclastic-peloidal packstone) contain very rich and well-preserved calcareous problematic microfossils, green algae and ostracods (Fig. 12E). Locally sponge spicules are abundant (Preat & Racki in press). Macrofossils are rare, represented mostly by amphiporids, as well as infrequent coquinite levels. This is a micritic variety of 12D (see also Krebs 1974).

Streszczenie

Żywecko-frańska seria stromatoporoidowo-koralowcowa Formacji z Kowali w południowej części Gór Świętokrzyskich została podzielona stratygraficznie i skorelowana z innymi sekwencjami na podstawie cykli sedymentacyjnych o charakterze sekwencji spłycających się ku stropowi (shallowing upward). Datowanie podstawowych poziomów transgresywnych przez konodonty oraz wybrane skamieniałości bentoniczne (ramienionogi, koralowce) wskazuje, że cykliczność ta odzwierciedla głównie eustatyczne zmiany poziomu morza. Zakończenie eifelskiej fazy hypersalinarnej depozycji typu „sabkha" było przypuszczalnie wynikiem zmian klimatu na bardziej humidny i (lub) pulsów transgreswnych. Rozległa dwuetapowa kolonizacja platformy węglanowej Regionu Kieleckiego nastąpiła na pograniczu eiflu i żywetu oraz w środkowym żywecie. Co najmniej 4 pulsy pogłębień spowodowały skokowe zatapianie wielkiej platformy węglanowej i zastąpienie niezróżnicowanej stringocefalowej ławicy biostromalnej („biostromal bank") przez sitkówczański kompleks ławicowy, a następnie – dymiński kompleks rafowy.

Wymieranie pod koniec żywetu w regionie świętokrzyskim zachodziło w warunkach destabilizacji ekosystemu szelfowego przez raptowne zmiany eustatyczne. Późnożywecki zalew miał najbardziej rozległe skutki, powodując zatopienie części platformy oraz napływ nowej grupy gatunków ze strefy łysogórsko-kostomłockiej. Okres pewnej stagnacji biotycznej w interwale przejściowym żywetu i franu był urozmaicony jedynie zdarzeniem epejrogenicznym. Rzutowało ono m.in. na przejściową poprawę cyrkulacji wód i rozwój bardziej bogatych zespołów bentosu w śródpłyciznowym obszarze chęcińskim. Wzrost rafy w centralnej strefie dymińskiej był efektem rosnącego tempa transgresji we wczesnym franie oraz dopływu trzeciej fali imigrantów, w tym unikatowej biocenozy kopców mułowych typu kadzielniańskiego oraz rafotwórczych zaspołów stromatoporoidów i cjanobakterii. Ostateczny upadek rafy był następstwem połączonych ruchów eustatycznych i tektonicznych, zintensyfikowanych w trakcie wielkiego kryzysu późnofrańskiego.