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Depositional history of the Devonian succession in the Pomeranian Basin, NW Poland

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Evolution of the Pomeranian Basin (NW Poland) during the Devonian saw the development of a characteristic siliciclastic and mixed siliciclastic-carbonate marginal marine-to-open marine carbonate sedimentary succession. This was controlled via proximity of the land areas representing uplifted parts of the East European Craton (EEC): the Fennoscandian High extending in the north, and the Mazury–Belarus High, situated in the east. The depositional history of the Pomeranian Basin began not earlier than at the end of the Emsian or possibly in the Eifelian, after a long break spanning the Lochkovian, Pragian and much of the Emsian when the area was subjected to erosion. Sedimentation started in the northeastern part with marginal-marine clastic deposits with local evaporites which are dated as uppermost Emsian?–Eifelian, passing upwards into lower–middle Givetian marginal-marine siliciclastic and carbonate deposits; these are followed by upper Givetian marginal-marine siliciclastic rocks. In the southwestern part of the area, the Devonian succession started with marginal-marine carbonates and siliciclastics which belong to the uppermost Emsian?–Eifelian, followed by lower and middle Givetian carbonates, passing upwards into upper Givetian marginal-marine siliciclastics. During the Late Devonian the Pomeranian Basin underwent evolution from a marginal-marine in the earliest Frasnian, through carbonate ramp or platform/shelf basin settings during the rest of the Frasnian and early Famennian, up to a reappearance of shallow subtidal and marginal-marine environments in late Famennian time. At the end of the Famennian an open shelf environment became prevalent almost over the whole area and continued up to the Mid Tournaisian. The lateral relationships of the lithofacies during the Givetian, Frasnian and Famennian are portrayed on 11 maps, showing relatively short time-intervals, selected to depict the most significant environmental changes. Transgressive-regressive depositional cycles observed in the Pomeranian Basin seem to have been strongly controlled by sea level variations, probably of eustatic nature; however, tectonic activity of some structural elements locally modified the sedimentary record.

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INTRODUCTION

The main aim of this paper is to summarize current knowledge of the stratigraphy and sedimentological development, and to recognize some control mechanisms on observed spatial and vertical facies changes, in the Pomeranian Basin during Devonian times.

Almost 100 boreholes have penetrated Devonian deposits in the Western Pomerania area (NW Poland). Of these, about 70 have been studied in detail. Unfortunately, most of these boreholes penetrated only part of the Devonian succession. A few boreholes have penetrated an almost complete Devonian succession but none are represented as continuous drillcore section. However, thanks to many years of biostratigraphic analyses, based mainly on conodonts and miospores, and of facies analyses, it has been possible to reconstruct the most probable mutual lateral relations among lithostratigraphic units, to show their succession, and to relate them to particular depositional settings. The characteristics of the Devonian lithostratigraphic units and the pattern of their mutual spatial and temporal relationships, along with a general assignation to particular depositional settings, as well as the history of facies development, include a number of modifications, especially in the Middle Devonian part, as compared to those proposed earlier (Matyja, 1987, 1988, 1993, 1998, 2006). These modifications have been introduced in response to new analytical data which have enabled the formations, as well as turning points in the sedimentary development of the area, to be dated more precisely. These data are sufficient to enable the construction of successive depositional stages of the Pomeranian Basin, although most of the geological data used in the spatial and temporal reconstructions of the lithofacies pattern during the Devo-

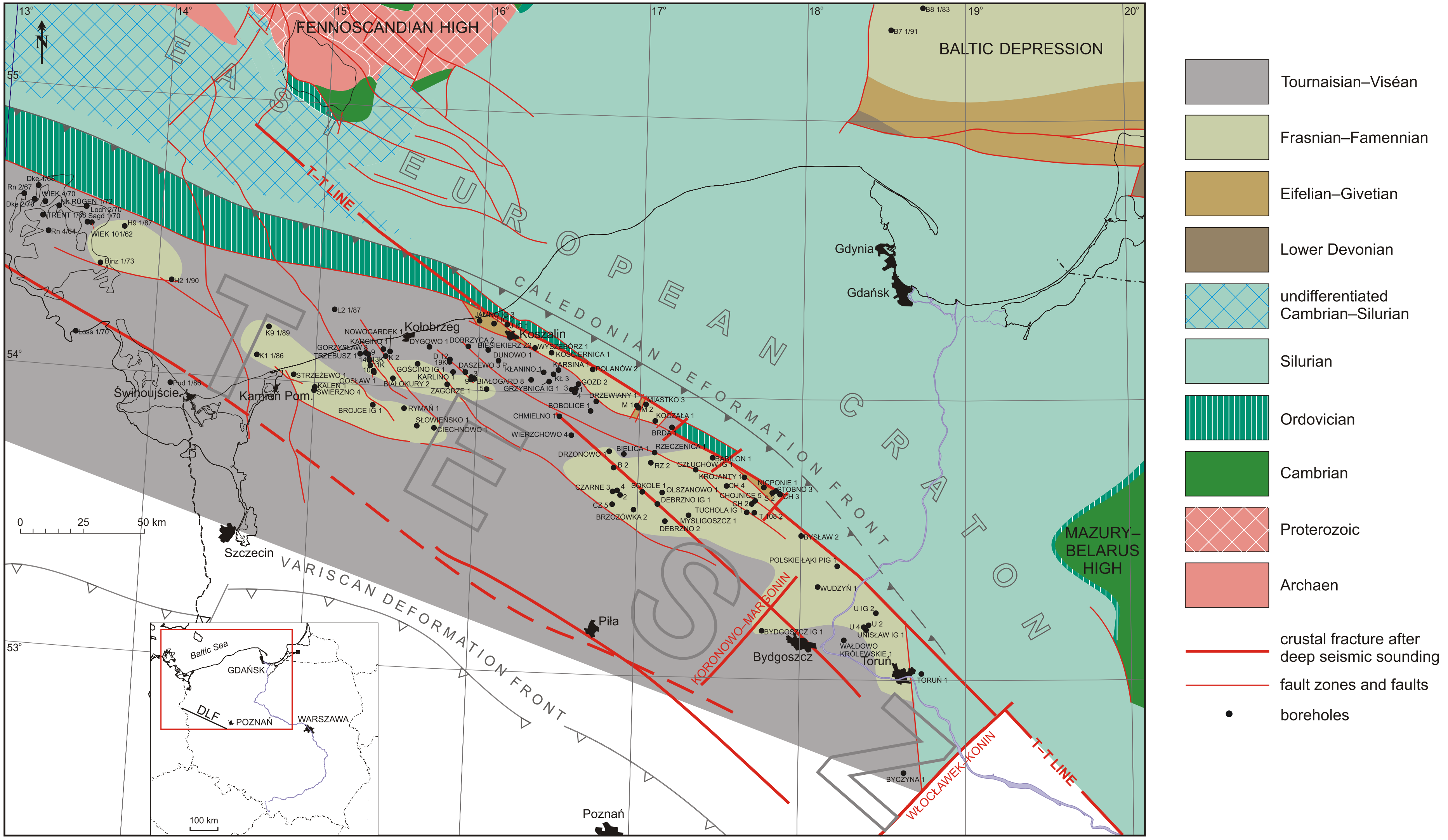

Fig. 1. Location of boreholes on the sub-Pennsylvanian map of Western Pomerania, modified after Matyja (2006); location of some deep crustal fractures and important faults after Królikowski *et al.* (1996, 1999), Dadlez (1997, 2000, 2006) and Kramarska *et al.* (1999)

TESZ — Trans-European Suture Zone; DLF — Dolsk Fault, SW boundary of TESZ (Dadlez, 2006) nian originates from a relatively narrow belt of deposits extending NW–SE, between Koszalin–Kołobrzeg–Kamień Pomorski and Toruń–Bydgoszcz (Fig. 1).

The lateral relationships of the lithofacies during the Devonian are portrayed on 11 maps. The results are presented below following the "standard" conodont and local (Pomeranian) miospore zonations and the recent Devonian stratigraphic scheme (House and Gradstein, 2004).

REGIONAL FRAMEWORK

The Pomeranian Basin during its Devonian and Mississippian history was situated within the Trans-European Suture Zone (TESZ), and located along the margin of the stable East European Craton (EEC) to the north and north-east, and the Variscan-influenced areas to the south-west.

A deep crustal fracture — the Teisseyre-Tornquist Zone (TTZ) — marks the profound crustal boundary between the East European Craton and the typical Trans-European Suture Zone crust. The northeastern part of the TTZ coincides more or less (Fig. 1) with the northeastern extent of deformed Lower Palaeozoic strata (Caledonian Deformation Front — CDF), with the present-day northeastern erosional margin of Devonian and Carboniferous deposits, and with the Koszalin–Chojnice Fault Zone that has been repeatedly reactivated during the Permian–Mesozoic evolution of the Polish Basin and during the Late Cretaceous–Palaeocene inversion of the Mid-Polish Trough (Dadlez, 2006). The Koszalin–Chojnice Zone has been interpreted by some authors as a crustal fragment detached from the northern margin of Gondwana and subsequently docked alongside Baltica during the Early Palaeozoic (e.g., Franke, 1995). Following the studies of Krzemiński and Poprawa (2006), and Poprawa *et al.* (2006), its Early Palaeozoic history seems to have been connected with the East European Craton (Baltica), as earlier suggested by Dadlez (Dadlez *et al*., 1994; Dadlez, 2000). The SW boundary of the TESZ, marked by the Dolsk Fault (inset map on Fig. 1), across which the consolidated crustal layer is replaced by crystalline Variscan upper crust, is evident only on two deep seismic profiles, LT-7 and P4, and the deformation front of the Variscan Externides (VDF) is located some 100 km north-eastwards of the Dolsk Fault within the confines of the TESZ crust (Dadlez, 2006).

Significant lateral and thickness changes of the crystalline crust as well as differences in the composition of its sedimentary cover were noted on the individual crustal blocks within the TESZ, i.e. on the Pomeranian, Kuiavian and Holy Cross Mts. segments. These changes in the crustal configuration appear to be controlled by deep crustal fractures, such as the Koronowo–Margonin or Włocławek–Konin faults (Dadlez, 1997, 2000; Fig. 1) or the Poznań–Bydgoszcz–Toruń tectonic zone, that separates the Pomeranian and the Kuiavian segments (Dadlez, 2006). Whether these faults separated individual terranes or individual blocks of the same terrane is unknown (Dadlez, 2006). The deep seismic profiles performed within the TESZ indicate that this specific mosaic of crystalline crustal blocks is covered to a depth of 7–8 km (Guterch *et al*., 1994; Grad *et al*., 1999) by a Palaeozoic sedimentary succession. None of the boreholes drilled in the Western Pomerania region (located on the Pomeranian segment) reached the TESZ crystalline crust. The oldest identified sedimentary rocks belong to the Ordovician, to the upper part of the Llanvirnian and to Caradocian series of the British succession (Podhalańska and Modliński, 2006). Devonian rocks lie unconformably on Ordovician or Silurian deposits, and are overlain by a Carboniferous succession. The boreholes have penetrated only part of the Carboniferous sequence, that shows an almost complete Tournaisian and Viséan succession; the uppermost Mississippian, including a part of the Brigantian?, the Serpukhovian, as well as the lowermost Pennsylvanian, including part of Bashkirian, are not recognized in any of the sections studied. Thus it might be supposed that the latest Mississippian–earliest Pennsylvannian was a period of regional non-deposition and erosion throughout the area (Matyja, 2008*a*). The Devonian and Carboniferous strata are buried under the thick younger Permian and Mesozoic/Cenozoic-age sequences of the Polish Basin.

The name Pomeranian Basin may be used in two ways. In the conventional sense of a sedimentary basin it includes the entire depositional area of the NW Polish Variscan foreland during Devonian and Mississippian times. However, it will be used throughout in a more restricted sense as that part of the Pomeranian Basin *sensu lato* which has been recognized in the Western Pomerania area (NW Poland). All of the available data originates from a relatively narrow belt of Devonian subcrops, extending NW–SE between Koszalin–Kołobrzeg–Kamień Pomorski and Toruń–Bydgoszcz, and situated in the immediate proximity to the Teisseyre-Tornquist Line (TTL). The present-day range of Devonian and Carboniferous deposits to the north and north-east is not a natural northern and eastern limit of the Pomeranian Basin. Devonian and Mississippian strata must have been originally extended far on to the East European Craton, taking into account the spatial and temporal reconstructions of the facies pattern (Matyja, 1993, 2006, 2008*a*). The extent of the Pomeranian Basin to the south-west is approximately coincident with the Variscan Deformation Front as suggested by Dadlez (1997). Unfortunately, there is no information from the area extending south-west of Kamień Pomorski–Bydgoszcz line, as no borehole has penetrated the Devonian succession (Fig. 1).

LITHOSTRATIGRAPHIC SUCCESSION

The first attempt to outline the arrangement of the Devonian lithological units and their general depositional environments was made by Dadlez (1978). He subdivided the Devonian strata into 10 informal units referred to as "complexes", *i.e.* Jamno, Miastko, Sianów, Wyszebórz, Koczała, Stobno, Tuchola, Silno, Chojnice and Człuchów; the Człuchów complex was subdivided into 4 subcomplexes, the uppermost one having been recognized as partly Famennian, partly Tournaisian. The Kłanino complex was also introduced by Dadlez (*op. cit.*) as a Famennian or Tournaisian unit recognized in the Kłanino 1 section. Later on, the Studnica complex was proposed by Miłaczewski (1986) as the lowermost Devonian unit in the Miastko 1 section, and the Sąpolno complex was established by Żelichowski (1987) as the lowermost lithological unit of the Tournaisian. The scarcity of biostratigraphical data for the "complexes" was a major problem at that time.

More recently, Matyja (1993, 1998, 2006, 2007*a*, 2008*b*, *c*) has refined the Dadlez (1978) scheme using new biostratigraphical and sedimentological data. Major modifications have been proposed, involving more detailed assessment of one particular unit, its hierarchy, and the erection of several new lithostratigraphic units (Fig. 2). Dadlez's (1978) and Miłaczewski's (1986) informal stratigraphic divisions, the Jamno, Studnica, Miastko, Sianów, Wyszebórz, Koczała, Tuchola, Silno, Chojnice, Człuchów and Kłanino complexes, were classified as formations. The Człuchów formation was subdivided into the Unisław, Strzeżewo, Gorzysław, Gościno and Bielica members, and one new formation was defined (the Krojanty formation). The uppermost part of the Człuchów complex (= the upper marly subcomplex) *sensu* Dadlez (1978) and the Sąpolno complex of Żelichowski (1983) together constitute the Sąpolno formation *sensu* Matyja (1993). This formation was later named the Sapolno Calcareous Shale Formation by Lipiec and Matyja (1998). It is widely distributed and represents the uppermost part of the Famennian and part of the Tournaisian (Matyja, 2006, 2008*a*).

Conodonts and miospores have been used to achieve precise dating of the Devonian formations in the study area (Turnau, 1978, 1995, 2007, 2008; Matyja, 1993, 2006, 2007*a*, 2008*b*, *c*; Turnau and Matyja, 2001; Matyja and Turnau, 2008). The pattern of their mutual spatial and temporal relationships presented here (Fig. 3) include the above-mentioned modifications. It must be stressed, however, that the informal status of all of these lithostratigraphic units still remains. Specific rules and a detailed procedure should be followed to propose formal changes in stratigraphic nomenclature and this is outside the scope of this paper.

The Upper Devonian lithostratigraphic units such as the Koczała, Człuchów, Krojanty, Kłanino and Sapolno formations have already been described and illustrated in details (Matyja,

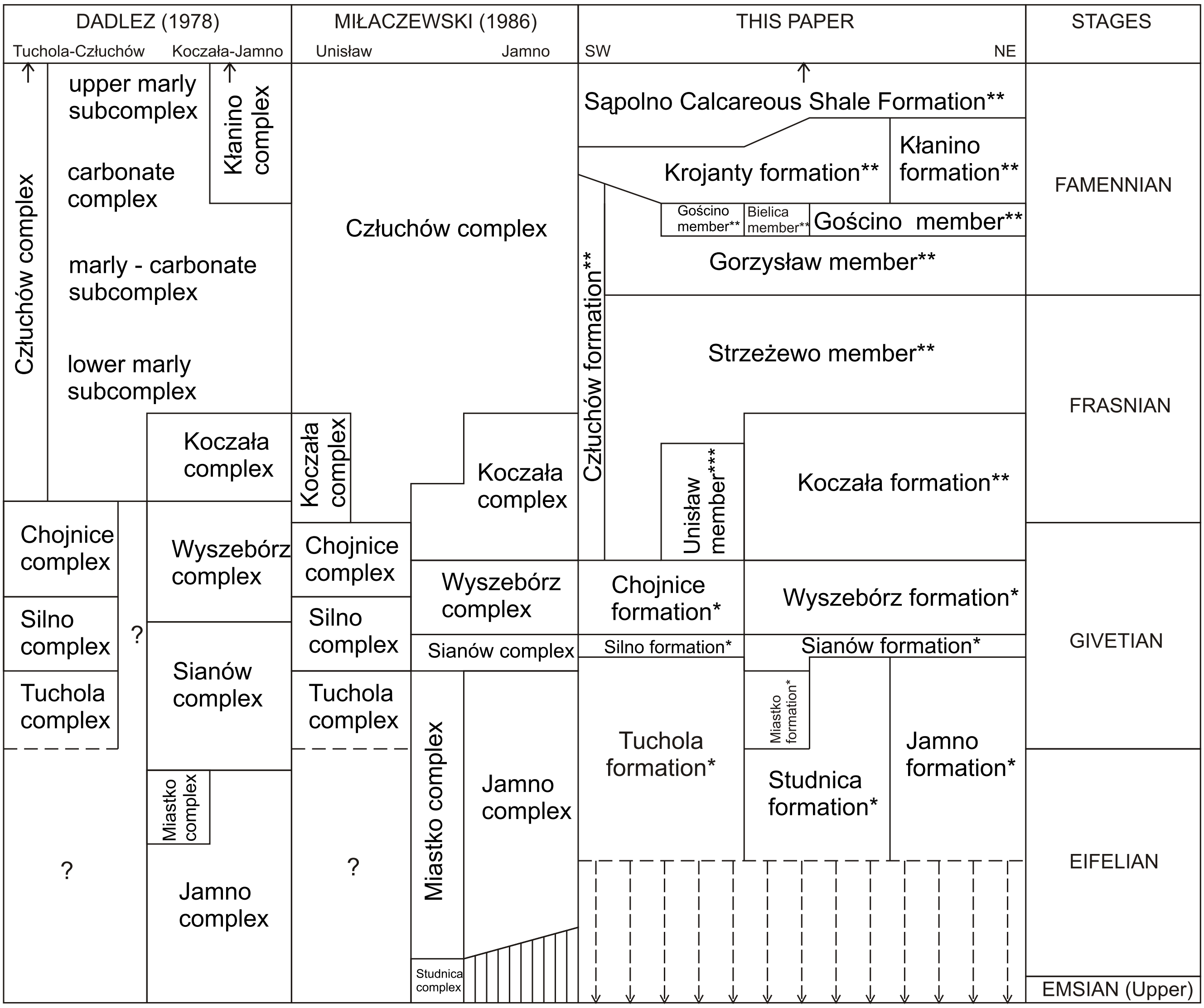

Fig. 2. Revised lithostratigraphy of the Devonian in the Western Pomerania, based on Matyja (1993, 1998, 2006), with the previous stratigraphic succession of Dadlez (1978) and Miłaczewski (1986)

Relation of lithosratigraphic units to Devonian stages based on papers by: * — Turnau (1995, 2004, 2007, 2008), Turnau and Matyja (2001), Matyja (2007*a*, 2008*b*, *c*) and Matyja and Turnau (2008); ** — Matyja (1993); *** — Matyja (1998)

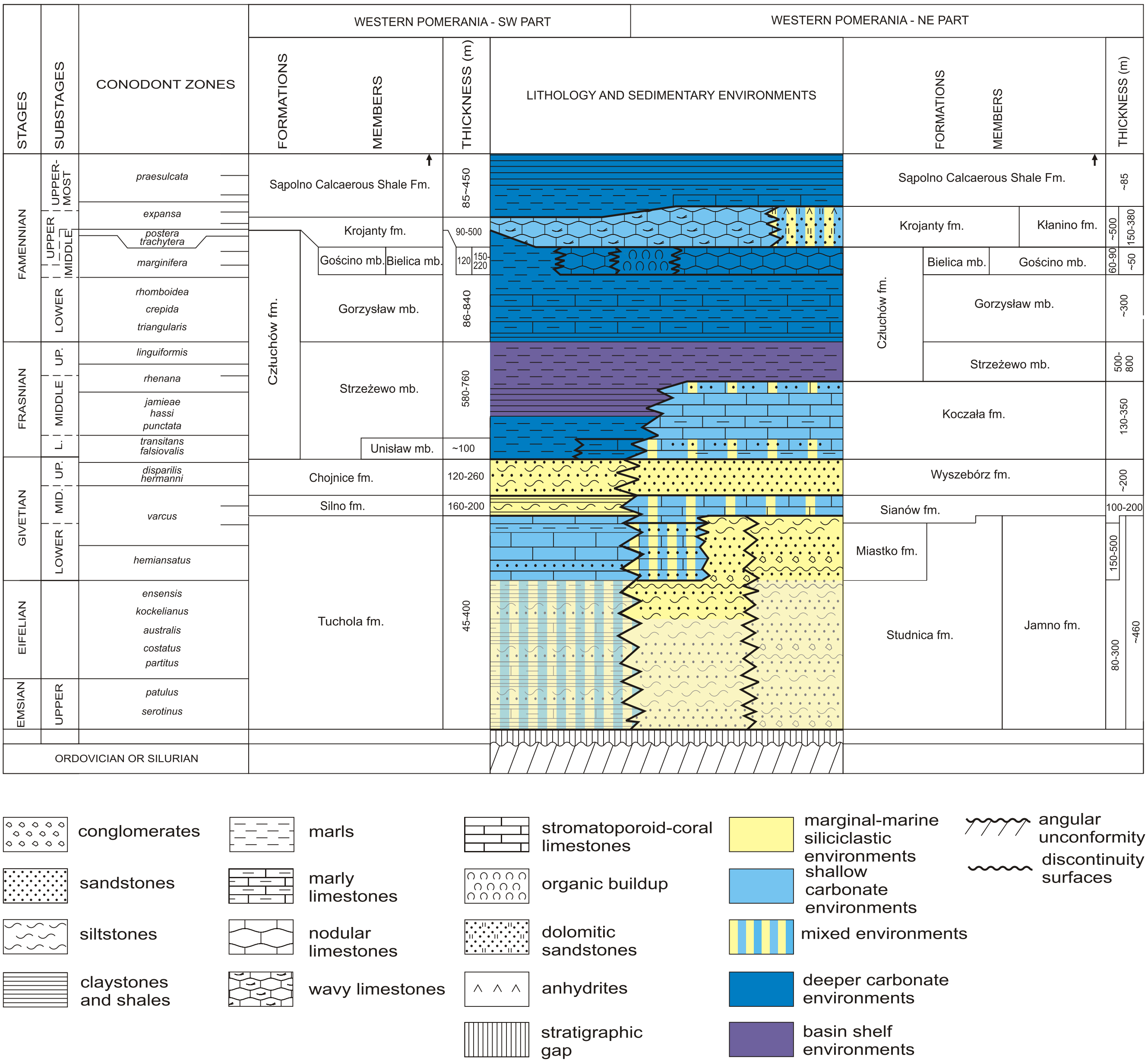

Fig. 3. Devonian lithostratigraphic units and the pattern of their spatial and temporal relationships in the Pomeranian Basin from the basin margin (NE) through to the central part of the basin (SW) (Matyja 2006, modified)

Devonian Substages after proposition of the Subcommission on Devonian Stratigraphy (Bultynck, 2004; Becker, 2007); relation of lithostratigraphic units to conodont zones in the Middle Devonian based on papers by Turnau (1995, 2004, 2007, 2008) and Matyja and Turnau (2008), in the Upper Devonian in part on Matyja (1993); lower parts of the Jamno, Studnica and Tuchola formations (a paler colouring) have not been adequately defined by biostratigraphy

1993). The Middle Devonian lithostratigraphic units, i.e. Jamno, Studnica, Tuchola, Miastko, Sianów, Silno, Wyszebórz and Chojnice formations, will be described and illustrated in a separate paper, thought some details based on a few boreholes were earlier published (Matyja, 2007*a*, *b*, 2008*b*, *d*; Pacześna, 2007, 2008*b*). Therefore, only a brief description of formations and members will be given in this paper, and this will begin with the oldest unit first, followed by younger units.

JAMNO FORMATION

The Jamno formation comprises pink, green and grey, very coarse to fine-grained quartz sandstones, variegated siltstones, heterolithic sandstones and siltstones with occasional horizons of claystone. Numerous horizons of conglomerate, 10 to 30 centimetres thick, composed of well rounded and not very well sorted quartz pebbles have been identified. Near the base of some sandstone beds, shale and siltstone clasts have been noted. Thin beds of primary or early diagenetic dolomite, as well as anhydrite nodules, have been recognized. Some evidence of possibly periodic subaerial exposure (thin brecciated units, conspicuous red and green clay seams) have been identified throughout the formation.

Sedimentary structures, as horizontal, large scale cross- and trough-bedding, as well as horizontal, flaser, ripple cross- and climbing ripple cross-lamination have been recognized (Pacześna, 2008*b*; Matyja, 2008*b*, figs. 14–16).

A sparse skeletal fauna is limited to thin interbeds within microbial laminites, where microconchids have been observed, and to a few beds, possibly of tempestite origin, where abraded crinoid and bryozoan skeletal particles have been identified. Numerous trace fossils have been recognized (Pacześna and Sarnecka, 2003; Pacześna, 2008*b*). Microspores have been noted only in some siltstone and claystone beds.

The formation reflects a siliciclastic marginal-marine phase of sedimentation, and represents tidal flat and tidal channel environments (Pacześna, 2004, 2008*a*, *b*; Matyja, 2006, 2008*d*, *e*), contrary to opinion of Dadlez (1978) and Matyja (1998) that these deposits reflect mainly a fluvial environment.

STUDNICA FORMATION

The Studnica formation is composed of red and pale grey siliciclastic deposits, dominated by fine-grained sandstones and siltstones, displaying large scale cross-, trough and horizontal bedding, as well as ripple cross- and horizontal lamination (Pacześna, 2004). Claystone interbeds occur subordinately. Several horizons of carbonate conglomerates have been identified, composed of well rounded but not very well sorted micritic lithoclasts. Anhydrite nodules have been noted, especially in the lower part of the formation.

Numerous trace fossils have been recognized throughout the formation (Pacześna and Sarnecka, 2003; Pacześna, 2004), as well as macrospores and plant fragments (Fuglewicz and Prejbisz, 1981). A sparse skeletal fauna is limited to thin interbeds within microbial laminites, where microconchids have been observed and to a few beds where abraded crinoid, gastropod, stromatoporoid and bryozoan skeletal particles have been identified. Claystones contain also rare ostracodes and lingulids (Łobanowski, 1968), as well as miospores (Turnau, 1995, 2004, 2007).

The Studnica formation is similar to its lateral equivalent, the Jamno formation, in some lithofacies. The exact contact is impossible to determine in known borehole sections, but overall the formation differs in some respects. The Studnica formation contains only horizons of medium- and fine-grained sandstones; it does not contain horizons of quartz conglomerate, and there is no evidence of subaerial exposure, as it is observed within the Jamno formation.

The Studnica formation also reflects a siliciclastic marginal-marine phase of sedimentation and represents tidal flat and lagoonal environments (Matyja, 2004, 2006; Pacześna, 2004).

TUCHOLA FORMATION

This formation is mainly composed of dark grey marls and calcareous claystones, and skeletal limestones.

Plant fragments, benthic ostracodes, and miospores are typical of the marls and claystones; thin interbeds of microbial laminite and oncolite wackestone, as well as siderite, were also here recognized. Skeletal wackestones, packstones and floatstones, as well as rudstones and boundstones, are relatively more frequent in the upper part of the formation. Skeletal limestones are rich in large bioclasts, the most frequent are massive stromatoporoid fragments and tabulate corals; relatively rare are articulate brachiopods.

Interbeds of calcareous fine-grained quartz sandstone and siltstone have also been noted (Matyja, 1998, 2006, 2007*a*, *b*).

The Tuchola formation reflects a dominantly carbonate marginal-marine (represented by tidal flat and lagoonal environments) and shallow-water carbonate ramp phase of sedimentation (Matyja, 2004, 2007*b*, *c*; Pacześna, 2004, 2007).

MIASTKO FORMATION

The Miastko formation consists of a sequence of marls and limestones interbedded with siliciclastic deposits, represented by variegated fine-grained sandstones, siltstones, and occasionally claystones.

Marls and limestones contain corals, stromatoporoids, crinoids, and rare brachiopods. Microorganisms are represented by ostracodes and microspores (Turnau, 1995, 2004, 2007). Thin interbeds of microbial laminite have been noted both in siliciclastic and carbonate parts of the formation (Matyja, 2004, 2007*b*).

Horizontal bedding, occasionally large scale cross-bedding, as well as wave, ripple cross- and flaser lamination, are observed in some siliciclastic beds. Numerous thin horizons of conglomerate, composed of well rounded, not very well sorted siltstone and claystone pebbles have been identified (Pacześna, 2004, 2007). Numerous trace fossils and plant fragments have been recognized from the siliciclastic parts of the formation (Pacześna and Sarnecka, 2003; Pacześna, 2004).

The Miastko formation reflects a mixed siliciclastic-carbonate marginal-marine (represented by tidal flat, and lagoonal-barrier environments), as well as shallow-water carbonate ramp phase of sedimentation (Matyja, 2004, 2007*b*, *c*; Pacześna, 2004, 2007).

SIANÓW FORMATION

The Sianów formation is composed of carbonate and marly carbonate lithofacies.

A variety of lithotypes can be seen, including microbial laminites with microconchids, oncolite wackestones, massive stromatoporoid-coral boundstones, skeletal floatstones, marly packstones and wackestones with stromatoporoids and, dispersed throughout the rock, corals, large crinoid ossicles, and brachiopods, and dark marls with a weak nodular fabric, containing rare ostracodes, plant fragments and small crinoid ossicles.

Interbeds of fine-grained quartz sandstones and siltstones have been also noted.

The Sianów formation reflects a dominantly carbonate marginal-marine (represented by lagoonal environments), and shallow-water carbonate ramp phase of sedimentation (Matyja, 2004, 2007*b*, *c*, 2008*d*, *e*; Pacześna, 2004, 2007, 2008*b*).

SILNO FORMATION

The Silno formation is predominantly composed of alternating dark gray claystones, calcareous in some parts, and calcareous fine-grained quartz sandstones and siltstones.

The presence of thin interbeds of siderite, as well as pyrite aggregates, has been observed within some claystone beds.

Plant fragments, benthic ostracodes and miospores are characteristic of the claystone beds. The macrofauna is limited to thin interbeds of skeletal limestone, probably of tempestite origin, where corals, stromatoporoids, and very worn crinoid fragments have been identified.

The formation reflects a siliciclastic-carbonate, marginal-marine phase of sedimentation and represents tidal flat and lagoonal environments (Matyja, 2004; Pacześna, 2004).

WYSZEBÓRZ FORMATION

The Wyszebórz formation comprises grey and pink, fine-to medium-grained, quartz sandstones and siltstones. Conglomerates, several to 10 millimetres thick, composed of well rounded, not very well sorted quartz pebbles, have been identified in some sections. Thin interbeds of primary or early diagenetic dolomite have been noted. Repeated evidence of possibly periodic exposure (thin brecciated units, conspicuous red and green clay seams) have been identified throughout the formation.

A diversity of sedimentary structures were recognized throughout the formation, i.e., horizontal, large scale cross- and trough bedding, as well as horizontal, flaser, ripple cross- and climbing ripple cross-lamination (Pacześna, 2008*b*; Matyja, 2008*b*, figs. 14–16).

Numerous trace fossils have been recognized throughout the formation (Pacześna, 2008*b*).

The Wyszebórz formation reflects a siliciclastic marginal-marine phase of sedimentation and represents tidal flat and tidal channel environments (Matyja, 2004, 2008*d*, *e*; Pacześna, 2004, 2008*a*, *b*).

CHOJNICE FORMATION

The formation is mainly composed of dark grey bioturbated siltstones and claystones with thin interbeds of siderite, alternating with gray fine-grained quartz sandstones with large scale cross-bedding and flaser lamination. In some sections coarse-grained sandstones have been identified in the middle part of the formation.

Thin interbeds of skeletal limestone with stromatoporoids, tabulate corals, crinoids, ostracodes and fish teeth occur rather subordinately (except for the Bydgoszcz IG 1 section).

The formation reflects a dominantly siliciclastic marginal-marine phase of sedimentation, and represents tidal flat, and lagoonal-barrier environments (Matyja, 2004; Pacześna, 2004) contrary to the opinion of Dadlez and Dadlez (1986) that these deposits reflect in part fluvial and deltaic environments.

KOCZAŁA FORMATION

A variety of carbonate lithotypes characterizes the Koczała formation. Its lowermost parts are dominanted by calcareous fine-grained quartz sandstones and siltstones, sandy limestones and shales with rare bivalves, inarticulate brachiopods and ostracodes, as well as thin interbeds of microbial laminites and marly limestones with ostracodes, fish scales and teeth, algae, crinoid remains, stromatoporoid, coral and articulate brachiopod fragments. The upper part of the formation is characterized mainly by skeletal limestones (Dadlez and Dadlez, 1986; Matyja, 1993, 2008*d*).

The skeletal limestones are considerably differentiated in their composition and grain size; they are usually unsorted and bioclasts vary from sand to gravel size: the most frequent are massive stromatoporoid fragments and tabulate corals. Microorganisms are represented by conodonts, benthic ostracodes, unilocular foraminifera, calcispheres, charophyta, small green algae and miospores.

The formation reflects a carbonate marginal-marine (recognized as lagoonal) environment, as well as a shallow-water, carbonate ramp and carbonate platform phase of sedimentation (Matyja, 1993, 2004, 2006, 2008*d*, *e*).

CZŁUCHÓW FORMATION

The Człuchów formation consists of open-marine shales and carbonates, displaying a shallowing-upwards sequence. The formation was divided into five lithostratigraphic units. They are, in ascending order, the Unisław, Strzeżewo, Gorzysław, and Gościno members, the latter of which interfingers with the Bielica member (Fig. 2; Matyja, 1993, 1998, 2006).

UNISŁAW MEMBER

The Unisław member is predominantly composed of thinly-bedded calcareous claystones, marls and marly limestones. Rare fossils are represented by cephalopods, thin-shalled bivalves, articulate and inarticulate brachiopods, crinoids, solitary corals, tentaculitoids, pelagic ostracodes and conodonts. Thin interbeds of skeletal limestones with microconchids and worn fragments of massive stromatoporoids occur subordinately.

This part of the Devonian succession has been referred to an open shelf environment (Matyja, 1998, 2006).

STRZEŻEWO MEMBER

The Strzeżewo member is composed of thinly-bedded dark shales, often finely-laminated. Rare fossils are represented by conodonts, pelagic ostracodes and tentaculitoids. Interbeds of grey, thinly-bedded or nodular limestones contain in addition rare cephalopods, thin-shelled bivalves (*Buchiola*), lingulids, and subordinate shell debris with occasional whole articulate brachiopods. The presence of pyrite aggregates has also been noted.

This part of the Devonian succession has been referred to a shelf basin environment (Matyja, 1993, 1998, 2006).

GORZYSŁAW MEMBER

The Gorzysław member consists mainly of alternating grey marls and nodular limestones. Interbeds of shales are less frequent than in the Strzeżewo member. An increasing number of benthic organisms, a progressive loss of fine lamination and a paler coloration of the rocks up-section, characterize this member. The benthic fauna is represented by crinoid debris, articulate brachiopods, ostracodes and encrusting foraminifers. Subordinately, interbeds of crinoid-bryozoan wackestone with rare coral debris and chaetetid fragments were observed.

Small-scale brecciation, as well as the presence of intraclasts and fine fissure-fillings, was also noted there.

Cephalopods, pelagic ostracodes, tentaculitoids and relatively abundant conodonts were also reported. Some of the nodular limestone beds are just rich enough in skeletal remains to be described as cephalopod and tentaculitoid wackestones (Matyja, 1993).

This part of the Devonian succession has been referred to an open shelf environment (Matyja, 1993, 1998, 2006).

GOŚCINO MEMBER

The Gościno member is composed of dark grey, rather thickly-bedded nodular limestones. Marly crinoid wackestones, marly bryozoan-ostracode wackestones and crinoid-brachiopod wackestones to packstones prevail in the succession. Relatively abundant conodonts have also been reported. Subordinate, thin, sharp-based beds which are grainstones with an abundant platform-derived fauna, have been noted. Allochthonous grains include bioclasts of shallow-water organisms (*Girvanella*, microconchids, and palaeoberesellid algae) and lithoclasts of micritic limestones.

This part of the Devonian succession has been referred to a shallow open shelf environment (Matyja, 1993, 1998, 2006).

BIELICA MEMBER

This member is predominately of bioclastic limestones rich in crinoids, stick bryozoans, benthic ostracodes, and shell debris with occasional large whole brachiopods. These limestones alternate with massive limestones, where small-scale brecciation and fissure fillings have been found. The fauna is well represented by crinoids, fenestrate bryozoans, colonies of dendroid tabulate corals and stromatoporoids.

This part of the Devonian succession was related to a carbonate buildup setting (Matyja, 1993, 1998, 2006).

KROJANTY FORMATION

This formation is predominantly of pale grey, thickly bedded and shale-free limestones with irregular wavy bedding planes. The grain components are mainly represented by skeletal remains that vary in size, the amount of bioclastic sands being relatively high. Skeletal components include small green algae, plurilocular foraminifera, calcispheres, benthic ostracodes, *Girvanella* fragments, and conodonts. Small palaeoberesellid green algae are the dominant fossils here, often creating a bafflestone texture. Micritized bioclastic grains have also been noted. Brachiopods and crinoid remains are not very abundant.

Deposits of the Krojanty formation reflect a shallow subtidal carbonate environment of open or partly restricted? shelf (Matyja, 1993).

KŁANINO FORMATION

This formation is composed of a great variety of mixed carbonate-siliciclastic and siliciclastic-evaporite lithofacies and there are few sections where one lithological type is dominant over another.

The mixed carbonate-siliciclastic succession consists mainly of cross-bedded and shale-free, well sorted skeletal-intraclastic grainstones rich in foraminifera, benthic ostracodes, microconchids, palaeoberesellid algae and worn crinoid debris. Subordinate interbeds of microbial laminites occur, as well as thin interbeds of fine-grained quartz sandstone and siltstone.

A siliciclastic-dominated part of the succession is characterized by red, pink, green and grey dolomitic, fine-grained quartz sandstones and siltstones with intergranular anhydritic cement, displaying ripple cross-lamination and subordinate shales. The top of the siliciclastic unit includes "red-beds", *i.e.* dolomitized sandstones and siltstones with anhydrite occurring as thin beds with a characteristic "chicken-wire" texture or as nodules and crystal rosettes.

Deposits of the Kłanino formation reflect a mixed siliciclastic-carbonate, marginal-marine phase of sedimentation (Matyja, 1993, 1998, 2006).

THE SĄPOLNO CALCAREOUS SHALE FORMATION

The Sąpolno Formation belongs partly to the Famennian and partly to the Tournaisian (Matyja, 1993, 2006, 2008*a*). The Famennian part consists of dark fossiliferous marly limestones (with crinoids, small palaeoberesellid green algae, calcareous and encrusting foraminifers, benthic ostracodes, rare brachiopods and laminar stromatoporoids) in the shallower part of the Pomeranian Basin, and dark fossiliferous marls (with brachiopods, bivalves, gastropods, rare ammonoids, trilobites and solitary corals, as well as conodonts, pelagic ostracodes and miospores) in the deeper part of the basin (Matyja, 1993; Matyja and Stempień-Sałek, 1994).

The Devonian part of the formation reflects an open-marine, middle/outer ramp phase of sedimentation and was probably widespread throughout the whole Pomeranian area as indicated by its depositional setting (Matyja, 1993, 2006).

BIOSTRATIGRAPHY

GENERAL REMARKS

Much of the early work on biostratigraphy in Western Pomerania was carried out by geologists, working on macrofossil groups (Tokarski, 1959; Łobanowski, 1968, 1969; Stasińska, 1969; Różkowska and Fedorowski, 1972; Korejwo, 1975; Różkowska, 1979). In the past twenty years, however, the distribution of macrofossils has not been investigated intensively (Nowiński and Prejbisz, 1986; Kłapciński and Muszer, 1995*a*, *b*, *c*; Muszer, 1998; Chwediuk, 2003). Significant macrofaunal remains are relatively rare in the marginal-marine and shallow subtidal deposits of the Lower? and Middle Devonian part of the succession. Brachiopods, bryozoans and crinoids are quite abundant in some parts of the Upper Devonian succession (Matyja, 1976; Kłapciński and Muszer, 1995*a*, *b*, *c*; Muszer, 1998) but require fresh systematic study to realize their biostratigraphic potential. Cephalopods and trilobites are too rare within Upper Devonian shelf facies to be of more than occasional use (Korejwo, 1975; Kłapciński and Muszer, 1995*a*, *c*).

Higher precision has been achieved by using different microfossil groups, notably conodonts, pelagic ostracodes, benthic ostracodes, foraminifers, and palynomorphs. However, benthic ostracodes are very sensitive to facies and do not appear, from the limited amount of research done, to provide a basis for detailed stratigraphy (Żbikowska, 1983). Foraminifers occur sporadically in the Upper Devonian, and are facies-controlled in their distribution. Moreover, the assemblages are generally of low diversity (Matyja and Tomaś, unpubl. data).

The recognition of diagnostic microfossil taxa and their use in defining Devonian stage and zone boundaries in the Western Pomerania area has already been discussed in detail elsewhere (Turnau, 1978, 1979, 1995, 1996, 2007, 2008; Matyja and Turnau, 1989, 2008; Matyja, 1993, 1998, 2006, 2007*a*, 2008*b*, *c*; Matyja and Stempień-Sałek, 1994; Turnau and Matyja, 2001; Stempień-Sałek, 2002).

CONODONTS

Conodonts are the only microfossil group in the Devonian whose distribution is known in as much detail as that of the cephalopods, and the only group which at present provides the basis for a comparatively refined biostratigraphy within the basinal and shelf facies. The Middle and Upper Devonian "standard" conodont zonation, originally proposed by Weddige (1988) for the Middle Devonian and by Ziegler (1962) for the Upper Devonian, and considerably revised during the last four decades (Ziegler and Sandberg, 1990; Clausen *et al*., 1993; Weddige and Ziegler, 1996; Bultynck, 2007), is now based mainly on taxa that were distinguished globally in the pelagic realm. The standard zones are named mainly after species or subspecies of *Polygnathus* and *Icriodus* in the Middle Devonian, *Mesotaxis* at the beginning of the Frasnian, *Palmatolepis* during most of the Frasnian and Famennian, and *Siphonodella* at the end of the Famennian. The start of each conodont zone is defined by the first occurrence of a diagnostic species or subspecies, preferably the next phyletically younger taxon (Ziegler and Sandberg, 1990, 1994). The conodont faunas of each zone are characterized by a distinctive association of conodont elements which includes the diagnostic taxon defining the base of the zone. Despite the absence of the diagnostic taxon, a zone can be recognized by the remaining fauna, and zonal limits can be approximately defined by overlaps in ranges of taxa within the successive faunas.

There are no conodonts in the uppermost Emsian? and Eifelian part of the Devonian succession in Western Pomerania, reflecting unfavourable conditions for conodont faunas in marginal-marine environments. The Givetian part is documented by some representatives of the genera *Eognathodus, Pandorinellina, Icriodus* and *Polygnathus* which enable recognition of the Lower, Middle and Upper *varcus* subzones (Matyja and Turnau, 2008). The Upper Devonian succession is documented in much more detail by conodonts, reflecting the widespread development of open-marine environments within the Pomeranian Basin, which created more suitable conditions for conodont faunas. Conodont analysis permitted recognition of much of the Upper Devonian "standard" conodont zones (Fig. 4), but the age of some samples has been only broadly determined to represent intervals of 2–3 zones (Matyja, 1993). It should be also noted that the base of a conodont zone has almost nowhere been adequately defined because of the paucity of diagnostic conodonts. Therefore, application of original zone definitions, based on index taxa, was not possible in most cases, and ranges of accompanying taxa, correlated with the "standard" conodont zonation, have been usually employed.

PELAGIC OSTRACODES

Since the comprehensive work of Rabien (1954) the great value of the pelagic entomozoacean ostracodes with fingerprint sculpture for European and Chinese Devonian biostratigraphy, is undisputed (Gross-Uffenorde and Wang, 1989; Gross-Uffenorde and Schindler, 1990; Gross-Uffenorde *et al*., 2000). After speciation during the Late Silurian and Early Devonian, little is known about Middle Devonian occurrences in Europe, whereas Frasnian and Famennian pelagic ostracode faunas have been reported from many places. The entomozoacean zonation is mainly based on partial ranges of species and the beginning of a zone or subzone is generally defined by the first occurrence of a new index species. The entomozoacean zonation is more or less correlated with the conodont one, although precise correlations with the standard conodont zonation have still to be verified (Gross-Uffenorde and Schindler, 1990; Gross-Uffenorde *et al*., 2000).

Entomozoaceans are thought to have been planktic and to characterize a pelagic environment; however, representatives of this ostracode group sometimes entered the shelf facies, where their presence indicates a rather deep shelf environment.

The Upper Devonian deposits of Western Pomerania bear rare entomozoaceans. They are only limited to some horizons; however, it was possible to recognize some of the "standard" entomozoid zones (Żbikowska, 1986, 1992; Fig. 4).

PALYNOMORPHS

The local Pomeranian Middle and Upper Devonian miospore zonation was established by Turnau (1978, 1979, 1995, 1996, 2007, 2008; Fig. 4) and is based on interval zones. In Turnau's opinion, it is difficult to adopt any of the zonal schemes for western (Streel *et al*., 1987) or eastern Europe (Avkhimovitch *et al*., 1993) because of important quantitative and qualitative differences between the Pomeranian miospore assemblages and those from other regions. There are some similarities in the composition of miospore assemblages and their succession between the East European Craton and the study area, especially in the Middle Devonian part (comp. Avkhimovitch *et al*., 1993). Unfortunately, the pertinent part of the scheme by Avkhimovitch *et al*. (1993) cannot be employed for the Pomerania area, as most of its zones and subzones are defined using quantitative criteria (they are acme zones). Moreover, important species, that define the boundaries of some miospore zones have not been found in the Pomerania area.

The base of the Devonian has nowhere in Pomerania been adequately defined because of the paucity of diagnostic

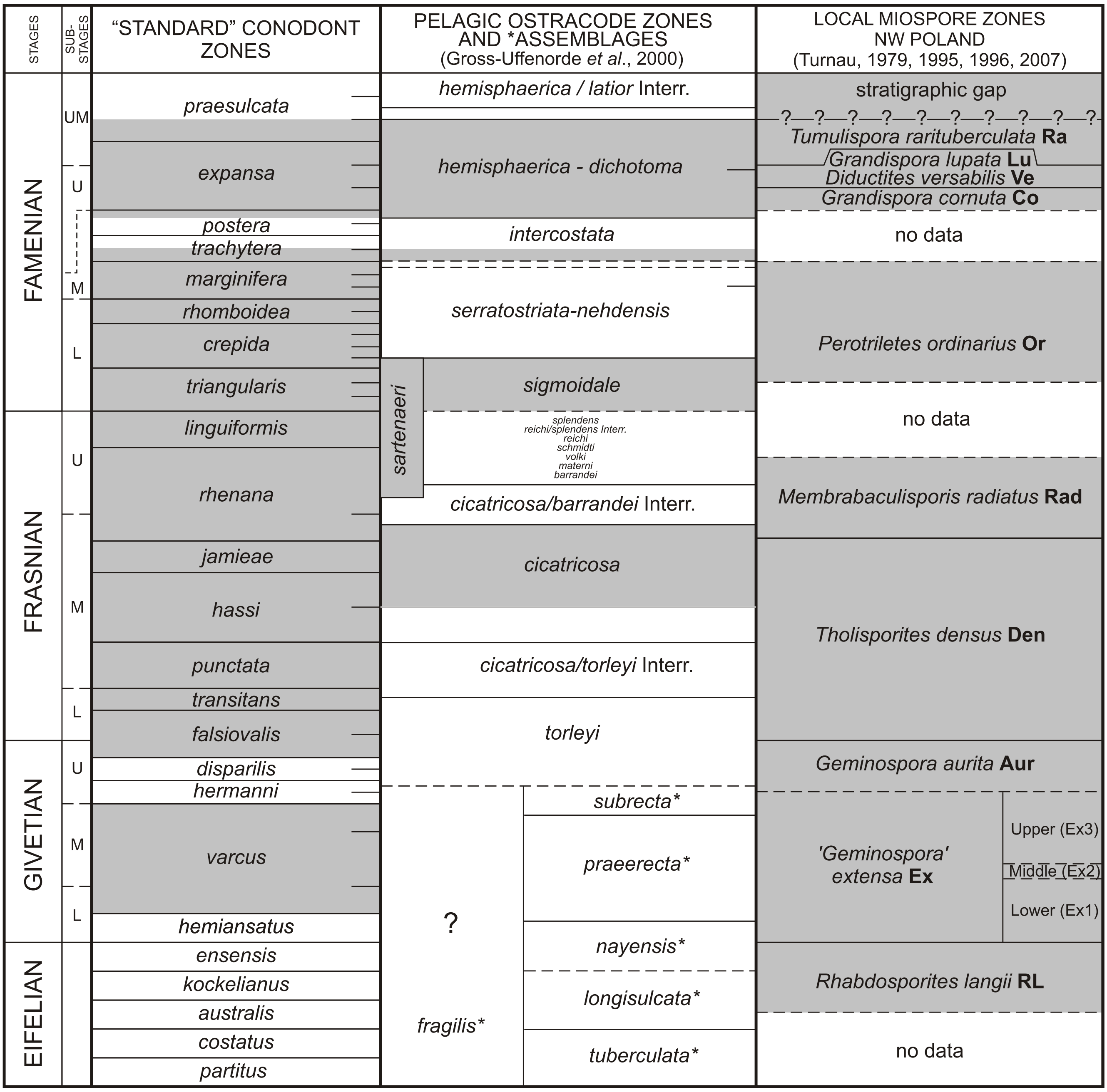

Fig. 4. Devonian chronostratigraphy and its correlation with the "standard" conodont and pelagic ostracode zones, and with local miospore zones

Zones identified in Western Pomerania are shaded in grey

palynomorphs; moreover, the mixed character of some miospore assemblages was recognized and this has led to biostratigraphical uncertainty (Turnau and Matyja, 2001). Miospore analysis enabled distinction of 13 local miospore zones and subzones, from the Eifelian *Rhabdosporites langi* Zone, up to the Famennian *Tumulispora rarituberculata* Zone; however, it is necessary to note that palynomorphs have not been analysed in the uppermost Frasnian and in the middle Famennian (Fig. 4).

LOWER? AND MIDDLE DEVONIAN BIOSTRATIGRAPHICAL DATA

There are no conodonts in the lowermost part of the Devonian succession in Western Pomerania; however, palynomorph "assemblages" of low taxonomic diversity are recorded in some boreholes. These "assemblages" contain both autochtonous and reworked taxa. Taking into account the autochthonous palynomorphs, it might be suggested that a position not below the uppermost Emsian (not below the *serotinus* conodont Zone) is indicated for the base of the Devonian succession in Pomerania, but a lower or middle Eifelian age cannot been ruled out. Redeposited small spores and cryptospores, represented by tetrads, diads and monads, as well as acritarchs, were derived from Silurian (Ludlow or Pridoli) or Lower Devonian (Lochkovian) deposits (Turnau and Matyja, 2001).

The most useful biostratigraphic tools, to subdivide and correlate the upper Eifelian and Givetian deposits in Western Pomerania, are diverse and abundant miospore assemblages and relatively sparse conodonts. The Eifelian part of the succession is less well documented, reflecting unfavourable conditions for conodont faunas in marginal-marine environments, and miospores were rare and poorly preserved. However, the lower and middle Givetian part of the Devonian succession is better documented (Fig. 4), reflecting the widespread development of shallow-water marine environments, which created more suitable conditions for conodont faunas over relatively large areas. The preservation of miospores was also better in such environments.

Miospore analysis by Turnau (1995, 1996, 2007, 2008) permitted distinction of five local Middle Devonian miospore zones and subzones: *Rhabdosporites langii* (RL), "*Geminospora*" *extensa* (Ex1–Ex3), and *Geminospora aurita* (Aur).

The base of the *Rhabdosporites langii* Zone has been defined in eastern Europe (Belorussia) by the first occurrence of *Densosporites devonicus* and *Cirratriradites monogrammos* (Turnau, 1995, 1996). Conodonts of the Eifelian *kockelianus* and the lower part of the *ensensis* zones were found within the RL Zone in Belorussia (Avkhimovitch *et al*., 1993). Unfortunately, the base of this Zone has not been identified in Pomerania; however, a typical assemblage here includes *Rhabdosporites langii, Densosporites devonicus* and *Cirratriradites monogrammos.* There are no conodonts in this part of Pomeranian succession (Matyja and Turnau, 2008). Thus, it might only be supposed that the local *Rhabdosporites langii* (RL) Zone in Pomerania also could belong to the upper Eifelian (Turnau, 1995, 1996).

The "*Geminospora*" *extensa* Zone embraces part of the Givetian, and should be situated not below the *hemiansatus* conodont Zone and not above than the lowermost parts of the Lower *hermanni* conodont Zone (Turnau, 2007; Matyja and Turnau, 2008). The first appearance of the species *Geminospora lemurata*, which marks the base of the local Lower *extensa* Subzone, is generally accepted as roughly coincident with the Eifelian/Givetian boundary (Loboziak *et al*., 1991, *fide* Turnau, 2007). Conodonts are relatively rare in the Lower *extensa* Subzone, where only *Eognathodus bipennatus bipennatus, Icriodus* cf. *liliputensis* and *Pandorinellina* sp. have been noted. *Chelinospora concinna* marks in Pomerania the base of the Middle *extensa* Subzone. In this Subzone the presence of *Polygnathus varcus*, *Polygnathus linguiformis linguiformis* and *Belodella resima* has been established. The miospore species *Samarisporites triangulatus* marks the base of the Upper *extensa* Zone. In the lower and middle parts of this subzone the presence of relatively rich conodont assemblages has been noted: *Icriodus* cf. *liliputensis*, *Icriodus difficilis*, *Icriodus brevis*, *Icriodus eslaensis*, *Icriodus platyobliquimarginatus*, *Icriodus arkonensis arkonensis, Icriodus arkonensis walliserianus, Polygnathus varcus* and *Polygnathus linguiformis linguiformis*. The composition of this conodont assemblage does not change much through the Upper *extensa* miospore Subzone.

Thus, the base of the Lower *extensa* miospore Subzone may be correlated with the base of the *hemiansatus* conodont Zone, and the top of the Subzone belongs to the Lower *varcus* conodont Subzone or to a part of it. The Middle *extensa* miospore Subzone may be correlated with the lower part of the Middle *varcus* conodont Zone, and the Upper *extensa* Zone belongs to the upper part of the Middle, as well as to the Upper *varcus* conodont subzone (Turnau, 1996; Turnau and Racki, 1999; Matyja and Turnau, 2008).

The base of the uppermost Givetian *Geminospora aurita* (Aur) local Zone is defined by the last occurrence of "*Geminospora*" *extensa* (Turnau, 2008). The miospore assemblage of this zone is impoverished, as at this level many species disappeared (Turnau, *op. cit.*). A sudden decrease in taxonomic diversity of miospore assemblages and the extinction of most representatives of the genera *Geminospora* and *Aneurospora* at the boundary between "*Geminospora*" *extensa* and *Geminospora aurita* in Pomerania (Turnau, 1996), has its analogues over the whole East European Craton, as well as in France (Obukhovskaya, 2000, *fide* Turnau, 2008). A position not below the *hermanni* conodont Zone and not above the lowermost Lower *falsiovalis* conodont Zone was suggested by Turnau (2004, 2008) for this miospore zone. Sparse conodonts, represented by *Icriodus subterminus, Icriodus* aff. *subterminus and Icriodus eslaensis*, have been identified in the *Geminospora aurita* (Aur) miospore Zone (Matyja and Turnau, 2008). In general, these conodonts confirm the view of Turnau (2004, 2008) regarding the position of the *Geminospora aurita* miospore Zone in relation to conodont zonation.

UPPER DEVONIAN BIOSTRATIGRAPHICAL DATA

The most useful stratigraphic tools to subdivide and correlate the Upper Devonian shelf deposits in Pomerania are relatively diverse and abundant conodonts and palynomorphs, and less abundant pelagic ostracodes.

Conodont analysis permitted recognition of much of the Upper Devonian "standard" conodont zones, up to the Uppermost *marginifera* or even Lower *trachytera* Zone (Fig. 4; see also Matyja, 1993). The last palmatolepids, which are the basis for the Upper Devonian standard zonation, definitively retreat from the Pomeranian shelf at the end of the *marginifera* or early in the *trachytera* Chron, owing to palaeoecological reasons (Matyja, 1993).

The Upper *trachytera* and Lower *postera* zones have not been identified (Matyja, *op. cit.*). On the basis of borehole data, it became clear that the inability to recognize these zones within the very shallow-water Krojanty and Kłanino formations may be associated with the paucity or even absence of diagnostic conodonts (Ziegler and Sandberg, 1984*a*, *b*).

The Lower and Middle *expansa* zones were recognizable owing to the presence of numerous bizzare forms characteristic of extremely shallow environments (Matyja, *op. cit.*). Their vertical ranges have been correlated with the standard conodont zonation given by Sandberg and Ziegler (1979). The Upper *expansa* and Lower *praesulcata* zones were recognizable owing the presence of numerous species of *Bispathodus* (Matyja, *op. cit.*).

The Middle and Upper *praesulcata* zones have not been found in Western Pomerania. The results of detailed conodont studies (Matyja, 1993; Matyja and Stempień-Sałek, 1994; Matyja *et al*., 2000) suggest the presence, on a regional scale, of a stratigraphic gap that comprises the uppermost Famennian (Middle and Upper *praesulcata* conodont zones) and the lowermost Mississippian, Hastarian (the *sulcata, duplicata*, and the lower part of the *sandbergi* conodont zones).

Miospore analysis permitted distinction of seven local Upper Devonian miospore zones and subzones: *Membrabaculisporis radiatus* (Rad), *Perotriletes ordinarius* (Or), *Grandispora cornuta* (Co), *Diductites versabilis* (Ve), *Grandispora lupata* (Lu) and *Tumulispora rarituberculata* (Ra1–Ra2) (Turnau, 1978, 1979; Stempień-Sałek, 2002). Unfortunately, there is no miospore data on the uppermost Frasnian and lowermost Famennian part of the Pomeranian succession, and the lower and middle part of the Famennian is poorly recognized by miospores (Fig. 4). A stratigraphic gap close to the Devonian–Carboniferous boundary is also indicated by the miospore data, as the equivalents of the western European miospore zones *lepidophyta–explanatus* (LE), *lepidophyta–nitidus* (LN), and *verrucosus–incohatus* (VI) zones are missing (Matyja and Turnau, 1989; Matyja and Stempień-Sałek, 1994).

The Upper Devonian deposits of Pomerania bear also rare pelagic ostracodes, usually poorly preserved. Nevertheless, 16 species have been recognized by Żbikowska (1992). They are limited to some horizons only, and represent six zones and subzones: *cicatricosa, sartenaeri, sigmoidale, intercostata*, Lower and Upper *hemisphaerica–dichotoma* (Fig. 4). The ages of almost all entomozoacean-bearing intervals have been confirmed by conodonts (Matyja, 1993, figs. 3–4).

BIOSTRATIGRAPHICAL DATA AND AGE OF THE LITHOSTRATIGRAPHICAL UNITS

It is worth of note that one of the most significant advances in Devonian biostratigraphy in Pomerania has been in utilizing many different microfossil groups in an integrated analysis. The microfaunal and palynological samples were collected from the same boreholes, and, if possible, from the same depth interval. Such combined studies provide more precise age determinations for those parts of the Devonian succession which were hitherto unfavourable as regards individual fossil groups (Matyja and Turnau, 1989, 2008; Matyja, 1993; Matyja and Stempień-Sałek, 1994; Stempień-Sałek, 2002; Turnau, 2007, 2008).

"Standard" conodont zones and local miospore zones have been used to characterize the Devonian litostratigraphic units and to recognize the pattern of their spatial and temporal relationships (Matyja, 1993, 1998; Turnau, 1995, 1996; Matyja *et al*., 2000; Matyja and Turnau, 2001). Recently, however, some modifications, concerning a more detailed assessment of the Middle Devonian formations, have been proposed, based on new analytical data (Turnau, 2004, 2007, 2008; Matyja, 2007*a*, 2008*a*, *b*, *c*; Matyja and Turnau, 2008). The relationships presented here between lithostratigraphic units include these modifications (Fig. 3).

DEPOSITIONAL HISTORY

Global palaeogeographical and palaeoclimatical reconstructions by Witzke and Heckel (1988), and Witzke (1990) place northern and central Europe, during the Mid and Late Devonian times, in close proximity to the Old Red Continent along its southern margin, and the northwestern part of Poland occupies a position within the southern arid belt, in latitudes between about ~10–30° S. Such a position in the tropical dry belt was indicated by the widespread occurrence of red deposits and evaporites (mainly sulphates, varying from isolated anhydrite nodules sparsely scattered in terrigenous sediment to very thick sequences of anhydrite), noted in many areas of Europe (overview in Heckel and Witzke, 1979; Bless *et al*., 1984, 1986; Paproth *et al*., 1986; Thorez and Dreesen, 1986), as well as in in Poland (Miłaczewski, 1981; Matyja, 1993).

Evolution of the Devonian epicontinental basin of Western Pomerania (NW Poland), and the development of a characteristic siliciclastic and mixed siliciclastic-carbonate marginal marine-to-open marine carbonate sedimentary succession, was controlled via proximity of the land areas representing uplifted parts of the EEC: the Fennoscandian High extending in the north, and the Mazury–Belarus High situated in the east. The sedimentary evolution and lithofacies pattern observed within the Pomeranian Basin followed these main structural outlines and was generally associated with a gradual northward and eastward expansion of the marine basins (Figs. 1 and 5–15).

In general, the morphology of the shelf depends on relative rates of subsidence, sediment supply, eustatic change and shoreline progradation, and on wave and tidal regimes. In the Pomeranian model the configuration of the shelf area corresponds rather to a relatively gentle ramp, where facies belts were rather wide, and where the zone of highest energy was probably quite close to the shoreline. In the south-east, however, close to the Polskie Łąki, Unisław and Wałdowo Królewskie sections, a rimmed carbonate shelf formed in the early and mid Frasnian, separated probably by one or more sharp breaks in slope, possibly related to fault lines (Figs. 8–9).

The Western Pomeranian region consisted of two parts (?sub-regions) during its Devonian and Early to Mid Mississippian history: a northeastern and a southwestern one. These corresponded to two very roughly defined facies zones, a relatively shallow water facies zone in the north-east and a deeper water one in the south-west (Pajchlowa, 1964, 1968; J. Dadlez, 1975, 1976), and their mutual relationships follow more or less the natural depositional slope in the basin (Matyja, 2006). Analysis of facies and thickness distribution shows (Matyja, 1993; Świdrowska and Hakenberg, 1996) that the Teisseyre-Tornquist Zone played an important role both as regards variable subsidence of the basement in individual Pomeranian Basin segments, and as regards lithofacies distribution. The highest Upper Devonian thickness of *ca*. 3500 m (in relation to about 1500 m in the rest of the area) is recorded in boreholes, which lies in an area located between the Chmielno 1, Wierzchowo 4, Człuchów IG 1, Chojnice 5 and Tuchola IG 1 sections. This marks a local depocentre, which probably was a synsedimentary depositional trough. This is expressed by continued persistence of higher subsidence in this area, starting from the Middle Devonian (Givetian?) and continuing, with some breaks, at least until the end of the Devonian. Therefore, the faults limiting this trough appear to be old and long-lived structural elements in the region. This was also the passage by which open-marine facies might extend into shallow-water environments. Thus, the criteria used to identify a synsedimentary activity of this unit include both thickness variation across this structure, as well as facies variation. Detailed geometry of this depositional trough with its framing crustal fractures remains unknown. Its axis is aligned approximately NE–SW, and the northern margin may possible be related to the area south to the Koczała 1 section and the southern margin to the area north to the Nicponie 1 section (comp. Figs. 1, 4–10 and 13, 14). The previously used term "Chojnice-Gdańsk palaeostructural trough" (Miłaczewski, 1980; Narkiewicz *et al*., 1998) is here replaced by a more descriptive "Człuchów Gate". It is because the possible prolongation of the trough to the NE and SW remains unknown, and only part of the Chojnice area, represented by the Chojnice 2, Chojnice 4 and Chojnice 5 sections, was located within this unit. Moreover, the most representative section, Człuchów IG 1, was located in the central part of this structure.

The lateral relationships of the lithofacies during the Givetian, Frasnian and Famennian are portrayed on 11 maps (Figs. 5–15), showing relatively short time-intervals, selected to depict the most significant environmental changes, which were controlled both by eustatic transgressive and regressive episodes, and by relative sea level changes caused by tectonic activity of the hinterland area (East European Craton) and the Pomeranian Basin floor. The pattern of their mutual spatial and temporal relationships, along with a general assignation to particular depositional settings, is presented on Figure 3. The results are presented according to the "standard" conodont and local miospore zones and to Devonian chronostratigraphy (Fig. 4).

EARLY GIVETIAN: SILICICLASTIC (NE)/CARBONATE (SW) MARGINAL-MARINE PHASE OF SEDIMENTATION (FIG. 5)

Devonian sedimentation started not earlier than at the end of Emsian or possibly in Eifelian time (Turnau and Matyja, 2001), after a long break spanning the Lochkovian, Pragian and much of the Emsian when the area was subjected to erosion. Due to sparse borehole evedence and the scarcity of analytical data for the latest Emsian? and Eifelian interval, the early Mid Devonian depositional history is difficult to reconstruct in detail. In general, the northeastern area extending around Jamno, Miastko, Kłanino and Koczała, and close to Nicponie, was dominated by clastic marginal marine sedimentation (lowermost parts of the Jamno and Studnica formations). Towards the south-west and south-east, between Chojnice, Tuchola and Bydgoszcz, nearshore clastic deposits laterally pass into nearshore carbonates (lowermost parts of the Tuchola formation).

During the early Givetian the northeastern region (between the Jamno and Gozd sections) was also dominated by clastic marginal-marine sedimentation (Fig. 5). Conglomerates and coarse- and medium-grained quartz sandstones of the Jamno formation were mainly deposited both in tidal flat and tidal channel environments (Pacześna, 2004, 2008*b*), whereas fine-grained sandstones and siltstones of the Studnica formation were deposited in tidal flat and brackish, lagoonal environments, and to a lesser extent in a high-energy shallow-water barrier-island system (Pacześna, 2004, 2007). Associated with the siliciclastic deposits, thin interbeds of irregularly laminated limestone with some fenestral structures (Matyja, 2004, 2008*d*), indicates a microbial mat origin and in general suggests an intertidal type setting (e.g., Flügel, 2004) for some parts of the succession. Thin interbeds of primary or early diagenetic dolomite, and fine-grained sandstone with anhydrite nodules, as well as the presence of low-diversity trace fossil assemblages, suggest a

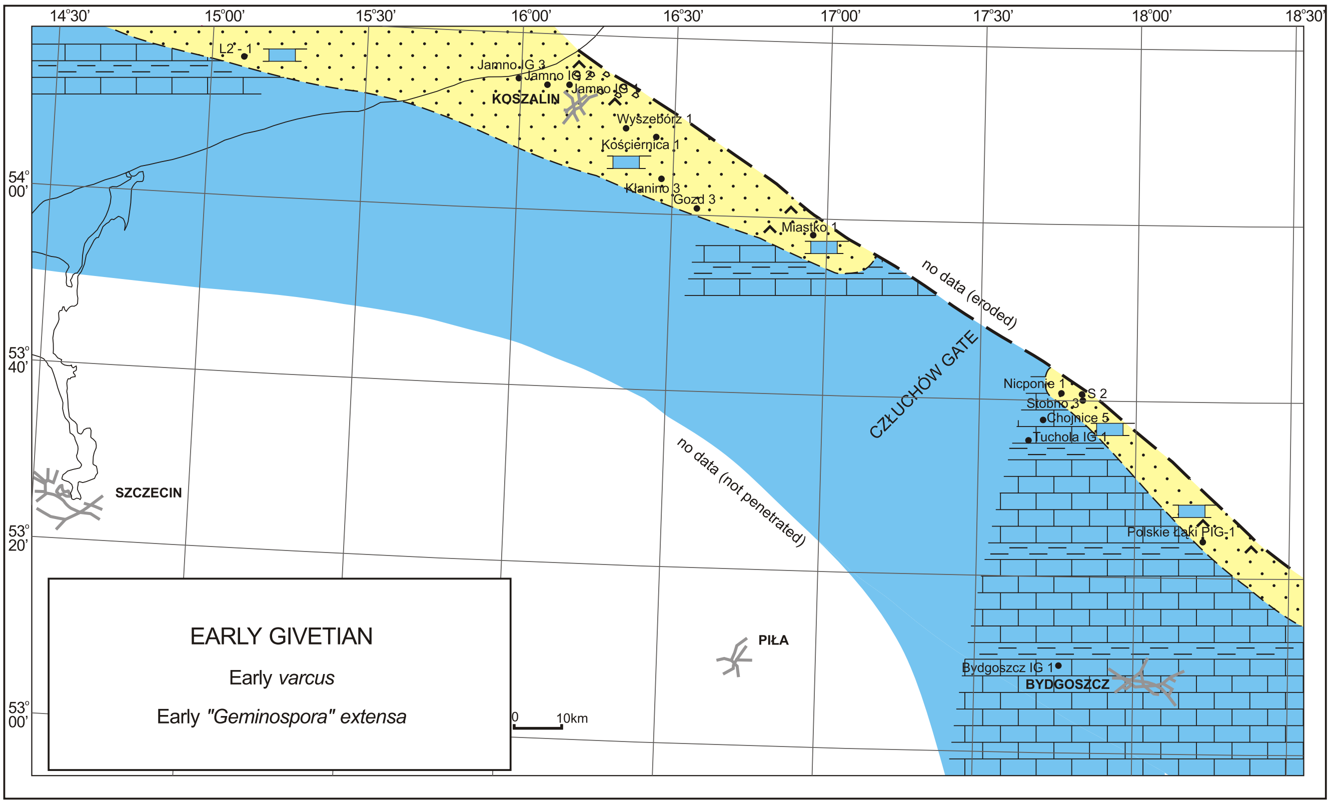

Fig. 5. Lithofacies pattern for the early Givetian (approximately Early *varcus* conodont Chron = Early "*Geminospora*" *extensa* miospore Chron) in Western Pomerania

Explanations as in Figure 3

supratidal type setting (?sabkha) (Pacześna, 2008*a*), and positively correlates with Devonian global palaeogeographical and palaeoclimatical reconstructions by Witzke and Heckel (1988), and Witzke (1990, figs. 5–6). Thus, it seems that the observed sedimentological and palaeontological features within this part of Devonian sequence indicate a predominance of intertidal and supratidal rather than subtidal deposition for the Jamno and Studnica formations.

At the same time, the area close to the Miastko section and extending between the Nicponie, Stobno and Polskie Łąki sections was covered by mixed siliciclastic-carbonate deposits of the Miastko formation. Numerous thin horizons of conglomerate with siltstone and claystone pebbles, variegated fine-grained sandstones, siltstones and occasionally claystones are interbedded with thin horizons of microbial laminite. Rather thick interbeds of stromatoporoid-coral marl and limestone (noticeably sandy in many intervals) with rare crinoids and brachiopods, have been identified throughout the formation. It is worth noting, that the area extending close to the Miastko sections is characterized by a higher proportion of carbonates throughout the formation than in the area between the Nicponie, Stobno and Polskie Łąki sections. Mixed siliciclastic-carbonate deposits of the Miastko formation documents a sedimentary succession believed to have formed mainly in an intertidal, mixed siliciclastic-carbonate depositional environment, along a barred coastline (Pacześna, 2004, 2007), and in a shallow subtidal environment, located to the south-west, and related to the proximal part of a carbonate ramp or platform (Matyja, 2004, 2007*b*, *c*).

During the early Givetian the southwestern part of Pomerania was dominated by carbonate shallow subtidal sedimentation. Dark gray marls and calcareous claystones of the Tuchola formation with plant fragments, benthic ostracodes, phyllopods and miospores, were mainly deposited in a lagoonal environment, whereas stromatoporoid-coral marls and limestones with rare crinoids and brachiopods may be related to the more open part of the carbonate ramp or platform located to the south-west (Matyja, 2004, 2007*b*, *c*).

In general, the latest Emsian?–early Givetian phase of deposition in Pomerania is characterized by depositional settings restricted to intertidal and very shallow subtidal, occasionally supratidal, siliciclastic and mixed siliciclastic-carbonate environments. Peritidal cyclic deposition is a common feature of the siliciclastic deposits of this phase (Pacześna, 2004).

MIDDLE GIVETIAN: CARBONATE (NE)/SILICICLASTIC (SW) MARGINAL-MARINE PHASE OF SEDIMENTATION (FIG. 6)

The first change in this pattern was associated with a gradual north-eastward spreading of carbonate environments. This trend manifested itself by the occurrence of shallow-marine carbonate facies (deposits of the Sianów formation) at the beginning of the mid Givetian (early Mid *varcus* Chron) in the area located close to the Miastko, and in the area extending be-

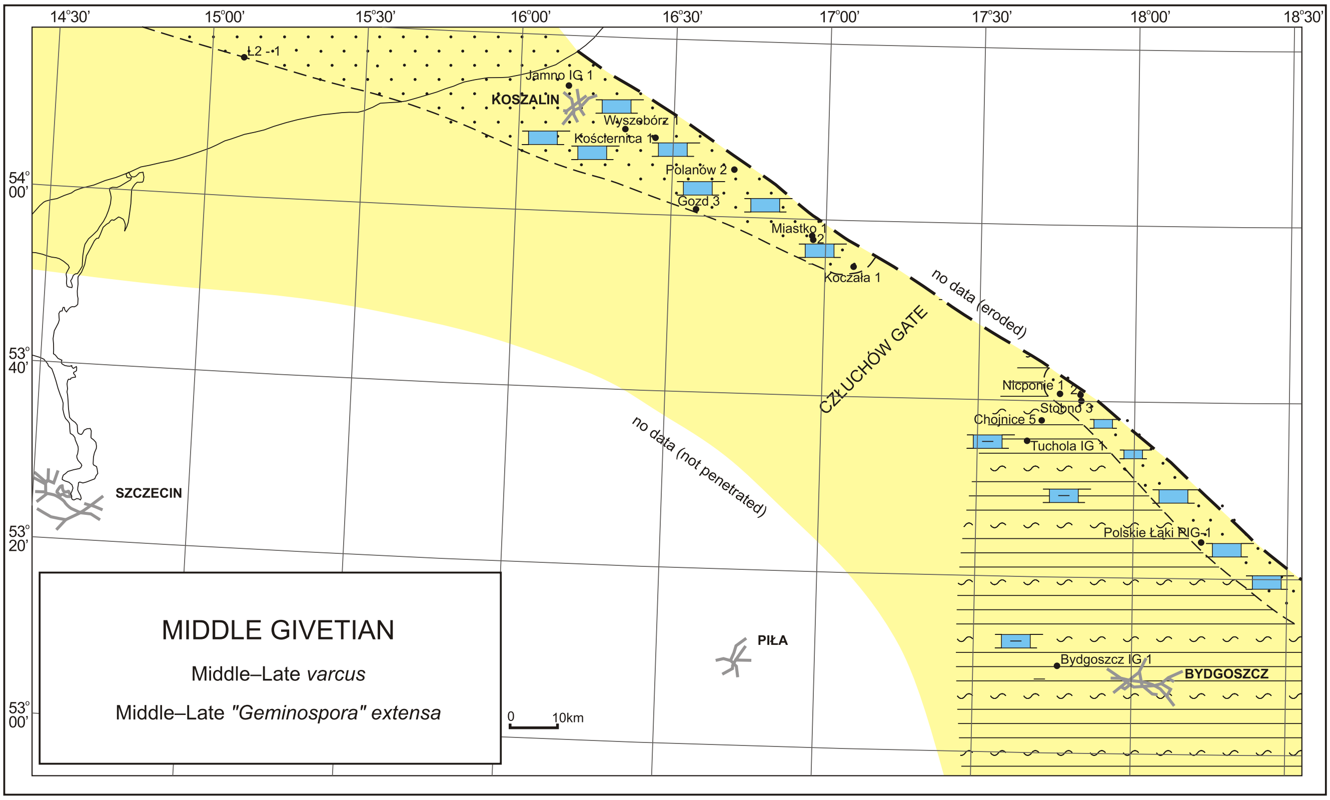

Fig. 6. Lithofacies pattern for the mid Givetian (approximately Mid–Late *varcus* conodont chrons = Mid–Late "*Geminospora*" *extensa* miospore chrons)

Explanations as in Figure 3

tween Nicponie, Stobno and Polskie Łąki, where marginal marine siliciclastic-carbonate sedimentation predominated previously (deposits of the Miastko formation). In the late Mid *varcus* Chron the shallow-marine carbonate facies (deposits of the Sianów formation) spread also onto the areas located further north-eastwards between Jamno, Wyszebórz, Kościernica, Kłanino, Polanów and Gozd, where marginal-marine clastic deposits of the Jamno and Studnica formations predominated previously (Figs. 5 and 6).

The middle Givetian carbonate deposits represent a wide spectrum of microfacies, associated with very shallow-marine, mainly subtidal depositional environments. Charophyte wackestones, *Amphipora* wackestones/packstones, *Amphipora*-dasyclad algae-ostracode-wackestones/packstones, ostracode wackestones, calcisphere-ostracode wackestones, oncolite-microconchid wackestones (Matyja, 2008*d*, figs. 33A–C, 31C, E, H), are noted in the Jamno IG 1 section situated in the north-east. Specific biota and the presence of fine-grained deposits point here to a lagoonal environment. Rare peloidal-skeletal or skeletal grainstone (Matyja, 2008*d*, figs. 31F, 33E) interbeds may indicate a periodic, more dynamic sedimentary environment. Marly stromatoporoid-coral limestones (packstones and wackestones) with rare brachiopods, bryozoan fragments and crinoid ossicles, stromatoporoid-coral floatstones and massive stromatoporoid-coral boundstones (Matyja, 2008*d*) make up the bulk of the carbonate ramp or platform setting, and have been recognized to the south-east (e.g., in the Miastko 1, Koczała 1 and Polskie Łąki PIG 1 sections).

At the same time the southwestern part of the Pomerania (close to the Chojnice and Tuchola sections) was dominated by siliciclastic deposits associated with very shallow subtidal sedimentation. Dark gray claystones with thin interbeds of siderite, and calcareous fine-grained quartz sandstones and siltstones of the Silno formation were mainly deposited in a quiet, brackish lagoonal environment, where plant fragments, benthic ostracodes, miospores, and some trace fossils only have been identified (Paczeŝna, 2004, 2008*a*). Rare, thin interbeds of marly limestone with worn skeletal fragments of coral, stromatoporoid and crinoid may possibly be related to tempestites.

LATE GIVETIAN: SILICICLASTIC MARGINAL-MARINE PHASE OF SEDIMENTATION (FIG. 7)

At the end of mid and during late Givetian times the entire region was again dominated by siliciclastic, marginal-marine sedimentation. Conglomerates, variegated coarse- and medium-grained quartz sandstones of the Wyszebórz formation were mainly deposited both in tidal channel and tidal flat environments, subordinately in a high-energy shallow-water barrier-island system, whereas fine-grained sandstones and siltstones were deposited in tidal flat and lagoonal environments (Paczeŝna, 2004, 2008*b*). Repeated evidence of possibly periodic exposure (brecciation, conspicuous red and green clay seams) have been identified throughout the succession. Associated with the siliciclastics, thin interbeds of irregularly fine-laminated limestone with subordinately fenestral structures (Matyja, 2004, 2008*d*), indicate a microbial mat origin and in general also suggest an intertidal setting for the succession. Siltstone and thickly-bedded grey fine-grained quartz sandstones with large-scale cross-bedding and flaser lamination of the Chojnice

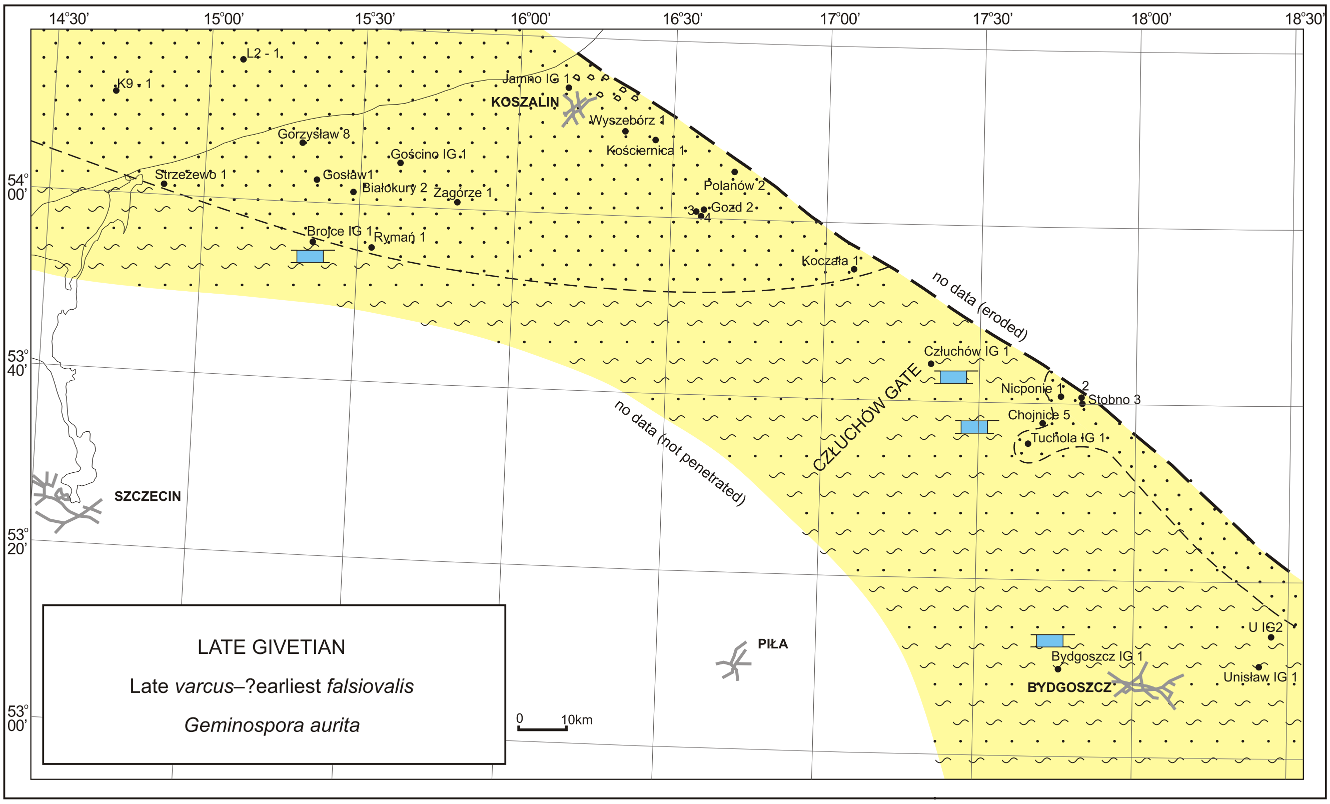

Fig. 7. Lithofacies pattern for the late Givetian (approximately Late *varcus–falsiovalis* conodont chrons = Geminospora aurita miospore Chron)

Explanations as in Figure 3

formation were also deposited in a tidal flat environment, whereas dark grey bioturbated siltstones and claystones with thin interbeds of siderite were deposited in a quiet, probably dysaerobic environment, where plant fragments, benthic ostracodes, miospores, and some trace fossils only have been identified (Pacześna, 2004). Rare, thin interbeds of marly limestone with worn skeletal fragments of tabulate corals, stromatoporoids and crinoids may be related to tempestites.

It seems that the late Givetian phase of sedimentation is characterized by a predominance of intertidal and shallow subtidal siliciclastic environments.

EARLIEST FRASNIAN (?*FALSIOVALIS* CHRON): CARBONATE-SILICICLASTIC MARGINAL-MARINE (NE)/ OPEN-SHELF (SW) PHASE OF SEDIMENTATION (FIG. 8)

Late Givetian siliciclastic marginal marine deposits of the Wyszebórz and Chojnice formations were drowned in a Late Devonian transgressive episode, which took place probably in the *falsiovalis* Chron. The northeastern part of the Pomeranian Basin (extending between Jamno, Koczała, Polanów, Polskie Łąki and Bydgoszcz) was a zone of nearshore, marginal-marine carbonate-siliciclastic sedimentation, where calcareous fine-grained quartz sandstones and siltstones with rare bivalves, inarticulate brachiopods and ostracodes, and marly nodular limestones, marls and shales with crinoid remains, stromatoporoids, coral and articulate brachiopods were deposited (lower part of the Koczała formation). Towards the south-east, i.e. into the basin centre (between Człuchów, Chojnice and Tuchola) it passed into an open-shelf environment (Fig. 8), characterized by thinly-bedded marls, marly limestones and siliciclastic deposits (deposits of the Unisław member of the Człuchów formation) with an open-marine fauna of rare cephalopods, tentaculitoids, pelagic ostracodes, conodonts, thin-shalled bivalves, inarticulate and articulate brachiopods, solitary corals and crinoids. This unit reflects the first episode of open shelf sedimentation in the Pomeranian Basin.

EARLY–MIDDLE FRASNIAN (*TRANSITANS?* OR *PUNCTATA*–EARLY *RHENANA* CHRONS): CARBONATE RAMP OR PLATFORM (NE)/SHELF-BASIN (SW) PHASE OF SEDIMENTATION (FIG. 9)

There was a distinct change to carbonate ramp or platform and shelf-basin sedimentation in the early Frasnian when two panecontemporaneous successions are recognized.

A nearshore carbonate ramp with typical widespread stromatoporoid-coral limestone facies (upper part of the Koczała formation) accumulated in the north-east (Fig. 9). A stromatoporoid-coral limestone facies is dominated by skeletal limestones, wackestones, packstones and floatstones, as well as by massive rudstones and boundstones. Skeletal limestones are predominantly rich in large bioclasts of stromatoporoid and tabulate coral, while solitary rugose corals, articulate brachiopods and gastropods are sparse (Matyja, 2008*d*, fig. 33D). They represent a shallow subtidal, rather open-marine environment of carbonate ramp or platform. Rare interbeds of bioclastic (algal-ostracode)-peloidal and algal-foramini-

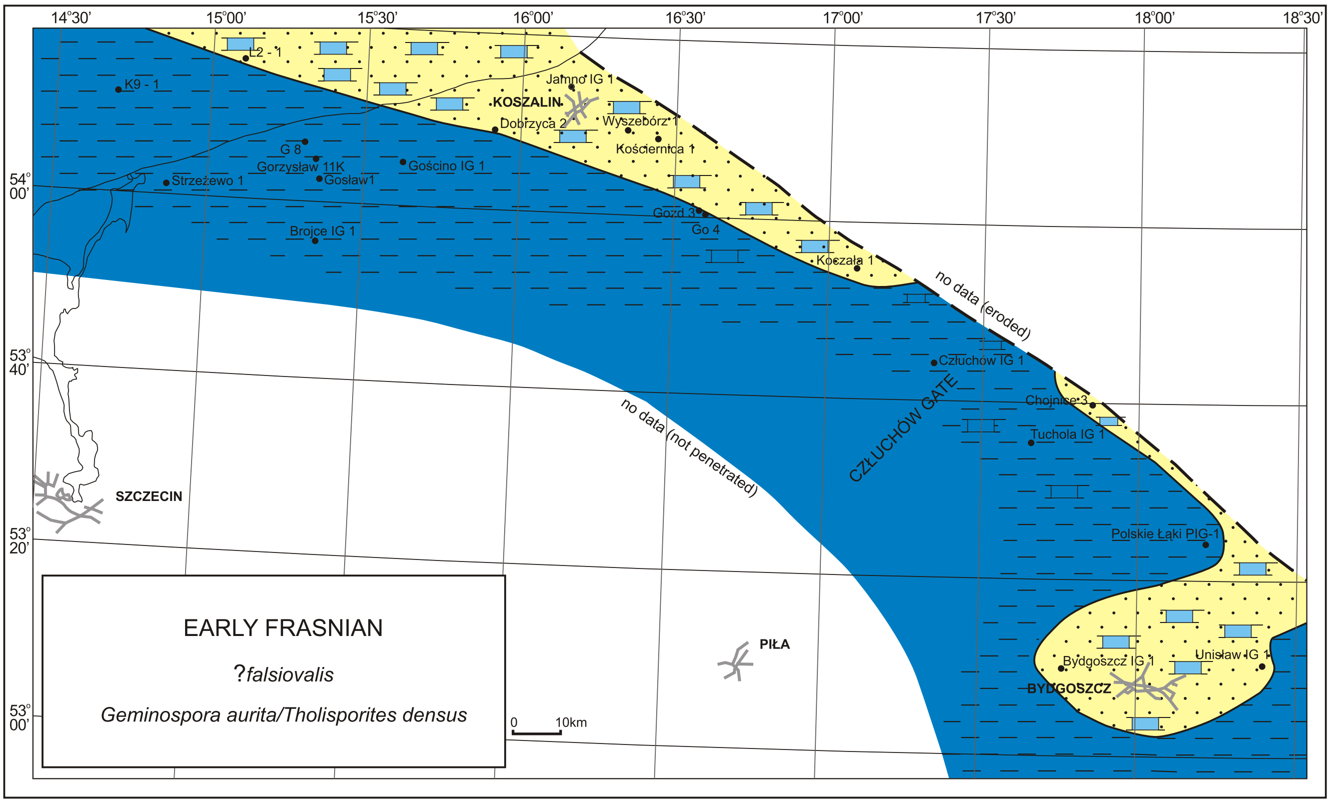

Fig. 8. Lithofacies pattern for the early Frasnian (approximately *falsiovalis* conodont Chron = uppermost *Geminospora aurita*–lowermost *Tholisporites densus* miospore chrons)

Explanations as in Figure 3

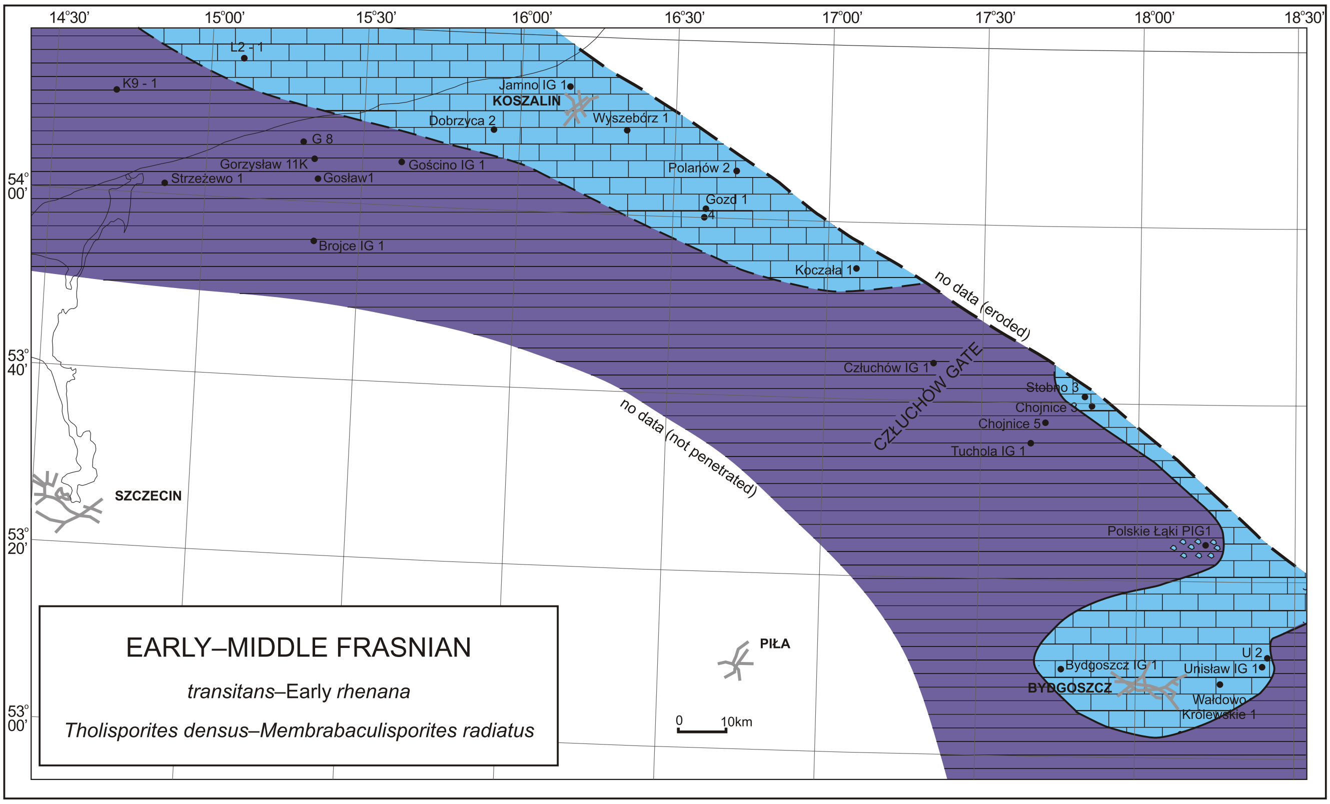

Fig. 9. Lithofacies pattern for the early–mid Frasnian (*transitans*–Early *rhenana* conodont chrons = *Tholisporites densus–Membrabaculisporites radiatus* miospore chrons), modified after Matyja (1993)

Explanations as in Figure 3

feral-crinoidal grainstone (Matyja, 2008*d*, figs. 33F and E) characterized more dynamic episodes within this environment. Interbeds of dark wackestone with *Amphipora*, unilocular foraminifera, benthic ostracodes, calcispheres, charophyta and small green algae have also been noted (Matyja, 2008*d*, figs. 31C, E–H, 33A–C). The low-diversity biota and the presence of fine-grained sediments point to a restricted, lagoonal environment for these microfacies types.

At the same time the southwestern part of the Pomeranian Basin (Tuchola, Chojnice and Człuchów region) turned into a poorly oxygenated shelf basin environment, presumably of dysaerobic sedimentary conditions. Deposits of the Strzeżewo member are thinly-bedded, and display monotonous alternation of a few lithological types: black shales are characterized by millimetre-scale lamination and the presence of pyrite aggregates and rare fossils represented by pelagic ostracodes and tentaculitoids, whereas thinly-bedded and nodular limestones contain rare cephalopods, conodonts, pelagic ostracodes, tentaculitoids, thin-shelled bivalves (*Buchiola*), lingulids, and articulate brachiopods (Matyja, 1993, 1998, 2006).

Such sedimentation persisted through the early and mid Frasnian.

In some sections located in the south-easternmost part of the study area, close to the Polskie Łąki section, relatively thickly-bedded intraformational conglomerates have been recognized in the upper part of the Unisław member. These are composed of *Amphipora* wackestones, peloid wackestones, stromatoporoid-coral wackestones and packstones, as well as limestones with *Renalcis* clasts (Matyja, 2007*b*; Radlicz, 2007). As most of the clasts represent shallow, carbonate platform environments of unknown location at this time, it is possible that these deposits represent pebble-debris flows, triggered at the platform-edge by its collapse and deposited at the toe-of-slope on the adjacent basin plain.

LATE FRASNIAN–EARLY FAMENNIAN (LATE *RHENANA*–MID *TRIANGULARIS* CHRONS): SHELF-BASIN PHASE OF SEDIMENTATION (FIG. 10)

A nearshore carbonate ramp or platform with widespread stromatoporoid-coral limestone facies (upper part of the Koczała formation) that accumulated in the north-east was definitively drowned and covered by a poorly oxygenated shelf-basin environment, presumably dysaerobic (deposits of the Strzeżewo member) at the end of the Early *rhenana* Chron (Matyja, 1993). Thus, in the late Frasnian a shelf-basin environment become prevalent over the whole area, and persisted up to the early Famennian (to the Mid *triangularis* Chron) (Matyja, 1993).

There is no marked facies turnover at the Frasnian/Famennian boundary. The critical interval is, however, accentuated by a reduction in the rate of carbonate sedimentation and/or a decrease in the carbonate/clay ratio, and, in some sections located in the south-easternmost part of the study area close to the Unisław and Wałdowo Królewskie sections, by the presence of shales and limestones alternating with relatively thickly-bedded intraformational conglomerates composed of

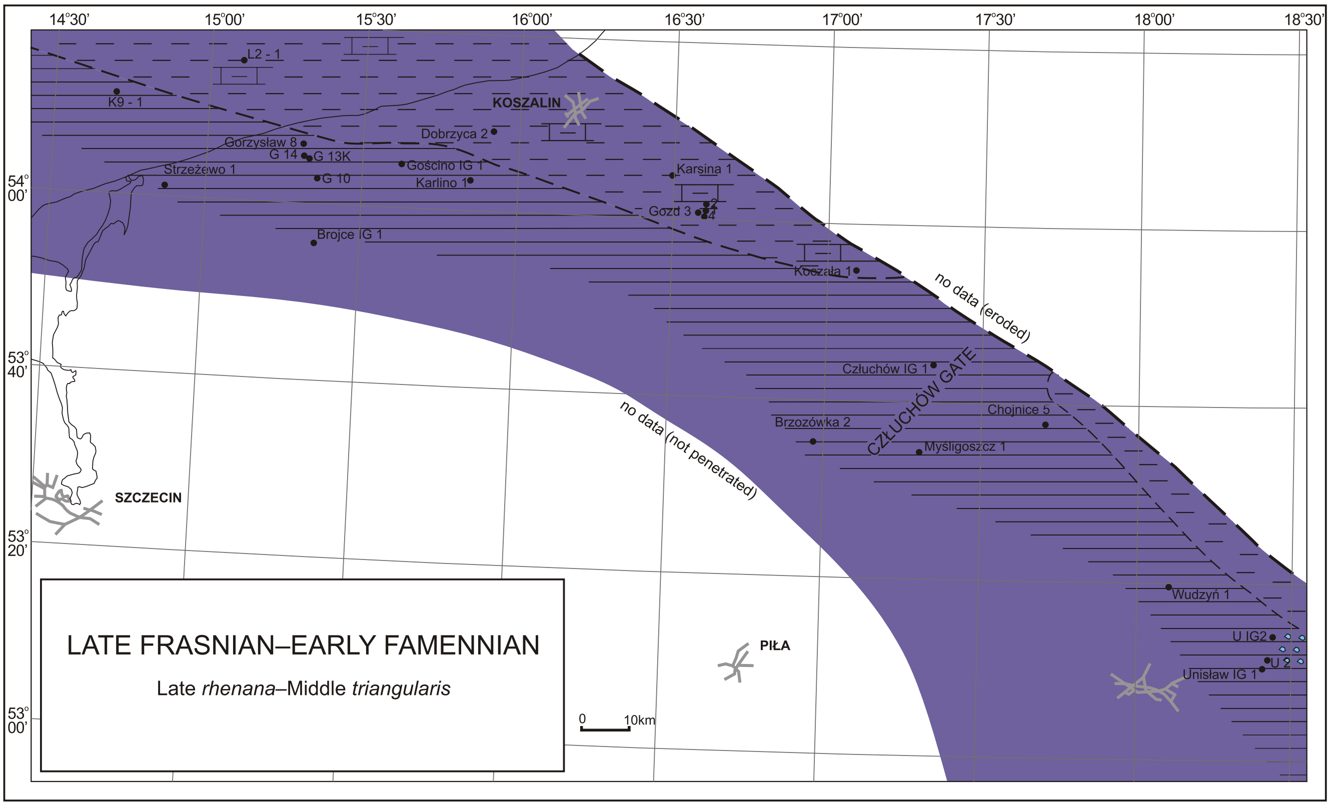

Fig. 10. Lithofacies pattern for the late Frasnian–early Famennian (Late *rhenana*–Mid *triangularis* conodont chrons), modified after Matyja (1993)

Explanations as in Figure 3

lime mudstone and grainstone clasts (Matyja and Narkiewicz, 1992; Matyja, 1993). As most of the clasts represent shallow, near-shore carbonate platform environments of unknown location at this time, it is possible that these deposits represent pebble-debris flows, triggered at the platform-edge by its collapse and deposited at the toe-of-slope on the adjacent basin plain.

EARLY FAMENNIAN (LATE *TRIANGULARIS–RHOMBOIDEA* CHRONS): OPEN SHELF PHASE OF SEDIMENTATION (FIG. 11)

A change in sedimentary conditions took place during the early Famennian, beginning with the Late *triangularis* Chron. This resulted in a gradual shallowing of sedimentary environments through the whole early Famennian, up to the *rhomboidea* Chron (Matyja, 1993). This phase of sedimentation is characterized by a progressive loss of fine lamination, a paler colour, as well as by an increasing number of benthic fossils up section. Marls and marly limestones of the Gorzysław member contain crinoid debris, articulate brachiopods, benthic ostracodes, agglutinated foraminifers, as well as cephalopods, styliolinids, pelagic ostracodes and relatively abundant conodonts; however, its uppermost part (marly limestones of the *rhomboidea* conodont Zone) is already relatively rich in benthic fauna and conodonts, and cephalopods, pelagic ostracodes and styliolinids are absent.

EARLY MID FAMENNIAN (EARLY–LATE *MARGINIFERA* CHRONS): OPEN SHELF WITH CARBONATE BUILDUPS PHASE OF SEDIMENTATION (FIG. 12)

Deposits of the Gościno member are characterized by dark gray, thickly-bedded nodular limestones with a few thin grainstone intercalations. Marly crinoid wackestones, marly bryozoan-ostracode wackestones and crinoid-brachiopod wackestones to packstones prevail in the succession and do not show strong evidence of high depositional energy. Thin interbeds of grainstone, are usually non-graded, exhibit sharp lower contacts, good sorting and horizontal textures, and consist of bioclasts of shallow-water organisms, *i. e. Girvanella,* microconchids, palaeoberesellid algae, as well as well-rounded lithoclasts of micritic limestone. Nodular limestones were deposited in a relatively shallow open marine shelf environment, whereas litho- and bioclasts in the grainstone interbeds were probably derived from and adjacent carbonate platform, located possibly to the east.

Within this open-shelf environment, isolated elevations were formed by carbonate buildups of mudmound type (Matyja, 1993). The Bielica member consists of pale micritic limestones with accumulations of crinoid debris, scattered ramose and stick bryozoans, ostracodes, patchily distributed brachiopod shells, and massive lime mudstones with scattered crinoid debris, fenestrate bryozoan fronds, colonies of dendroid

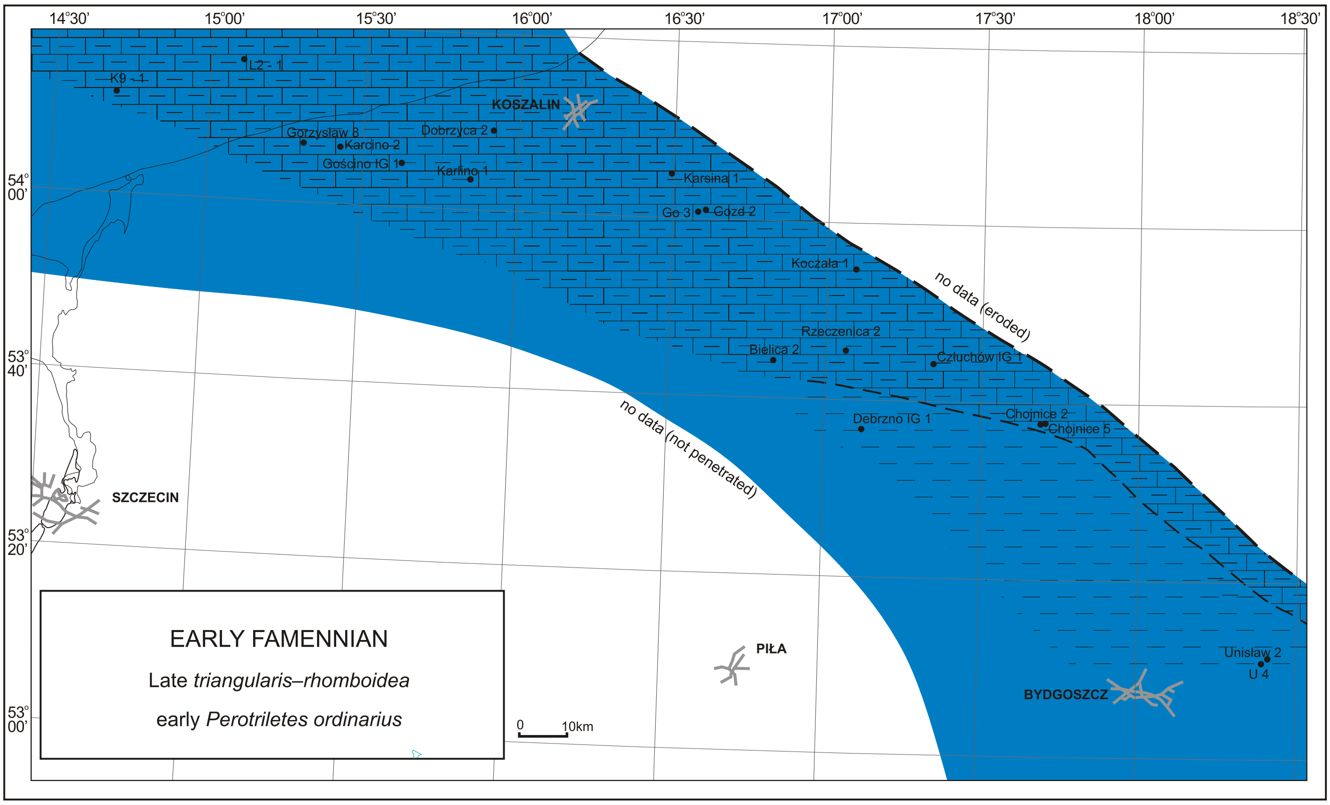

Fig. 11. Lithofacies pattern for the early Famennian (Late *triangularis–rhomboidea* conodont chrons = early *Perotriletes ordinarius* miospore Chron), modified after Matyja (1993)

Explanations as in Figure 3

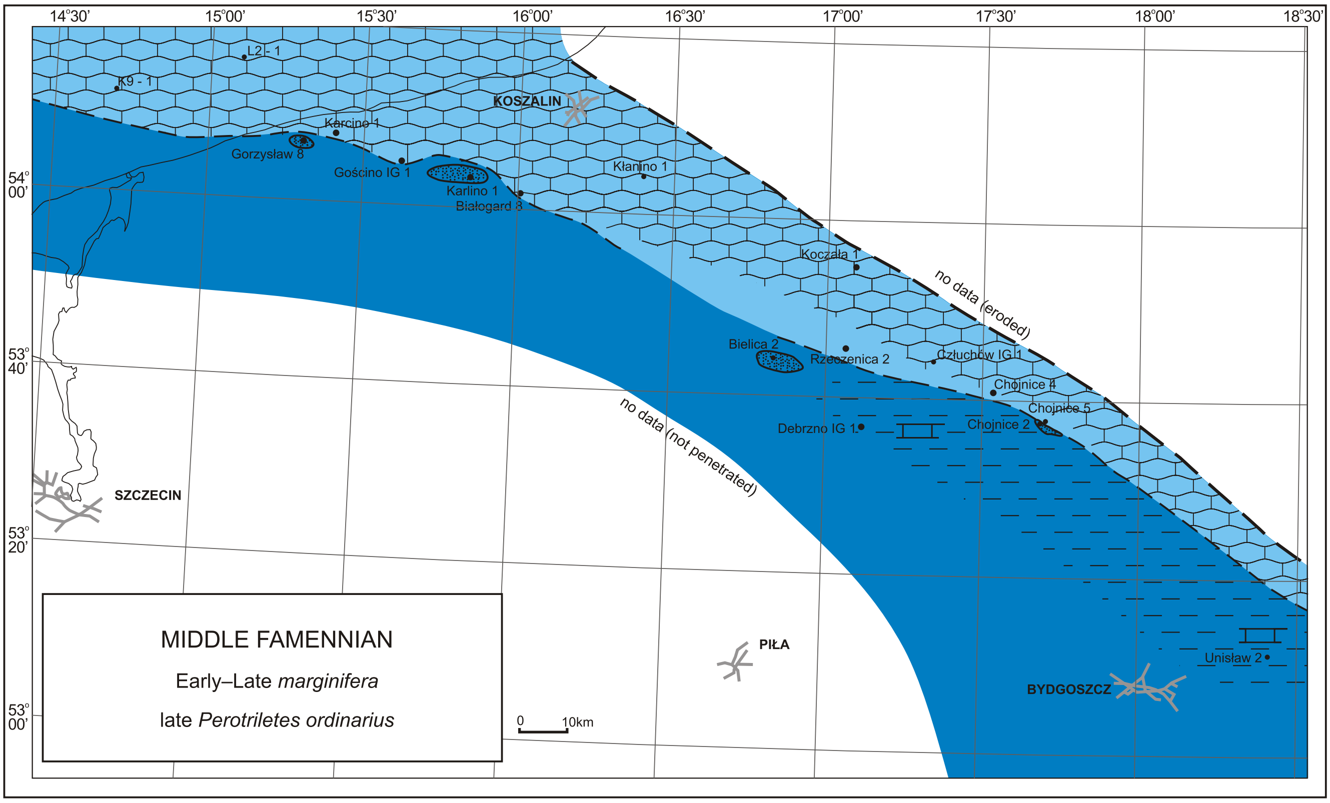

Fig. 12. Lithofacies pattern for the mid Famennian (Early–Late *marginifera* conodont Chron = late *Perotriletes ordinarius* miospore Chron), modified after Matyja (1993)

Explanations as in Figure 3

tabulate corals, rare stromatoporoids and palaeoberesellid green algae, noted in the upper part of the buildup succession. Different microfacies types are noted here: crinoid wackestones and packstones, crinoid-brachiopod-bryozoan wackestones to packstones, stromatoporoid floatstones with *Amphipora*, *Baculella* bindstones, bryozoan bindstones with *Fenestella*, tabulate coral bafflestones and lime mudstones with stromatactis structures, and peloidal micritic crusts of probable microbial origin. Small-scale brecciation and fissure-fillings related to neptunian dykes have also been found in some sections. Although the core material does not provide conclusive evidence for the spatial geometry of the deposits, it is likely that they are fragments of carbonate buildups. Such an interpretation is confirmed by the presence of particular biota not found in other contemporaneous facies and by the occurrence of sites of increased carbonate productivity (Matyja, 1993). The deposits of the Bielica member constitute probably an off-mound facies comparable to the Waulsortian mound facies. It is generally believed (Lees, 1964, 1988; Lees *et al.*, 1985; Lees and Miller, 1985; Somerville *et al.*, 1992) that the Waulsortian mudmounds were initiated in relatively deep water but grew rapidly to reach the photic zone. Analysis of the successive components of the Pomeranian buildups have also suggested a final phase of shallowing and breakthrough into the photic zone. A significant indicator of such shallowing event is the presence of peloids, particularly as geopetal fills, plurilocular foraminifera and small green algae (Skompski, 1987) all of which have been found at the top of the supposed buildups. The Pomeranian mudmounds had probably grown on tectonically controlled intrabasinal highs connected with the Teisseyre-Tornquist Tectonic Zone, as suggested by their linear north-west–south-east striking arrangement (Matyja, 1993).

MID–LATE FAMENNIAN (LATEST *MARGINIFERA*–MID *EXPANSA* CHRONS): MIXED SILICICLASTIC-CARBONATE AND CARBONATE MARGINAL-MARINE (N)/SHALLOW OPEN SHELF (S AND SW) PHASE OF SEDIMENTATION (FIG. 13)

A gradual change in tectonic constraints on the Pomeranian Basin began during the mid–late Famennian. This resulted in a restructuring of the facies and subsidence pattern in the basin (Matyja, 1993; Świdrowska and Hakenberg, 1996). The uplifting Fennoscandian part of the EEC probably constrained development of the latitudinal facies and subsidence pattern. These palaeogeographic and tectonic trends, established at the end of Devonian times, were maintained also in the Early Carboniferous (Matyja, 2008*a*).

A distinct and relatively rapid regressive event affected the study area probably at the beginning of the Latest *marginifera* Chron. The northern part of the area was then dominated by peritidal siliciclastic-carbonate deposition with local evaporites. A great variety of facies characterizes the Kłanino formation but there are only few sections when one lithological type is dominant over another. Generally, siliciclastic facies with evaporites prevail in the area between Trzebusz and Kłanino, whereas carbonate-siliciclastic deposits, mainly sandy

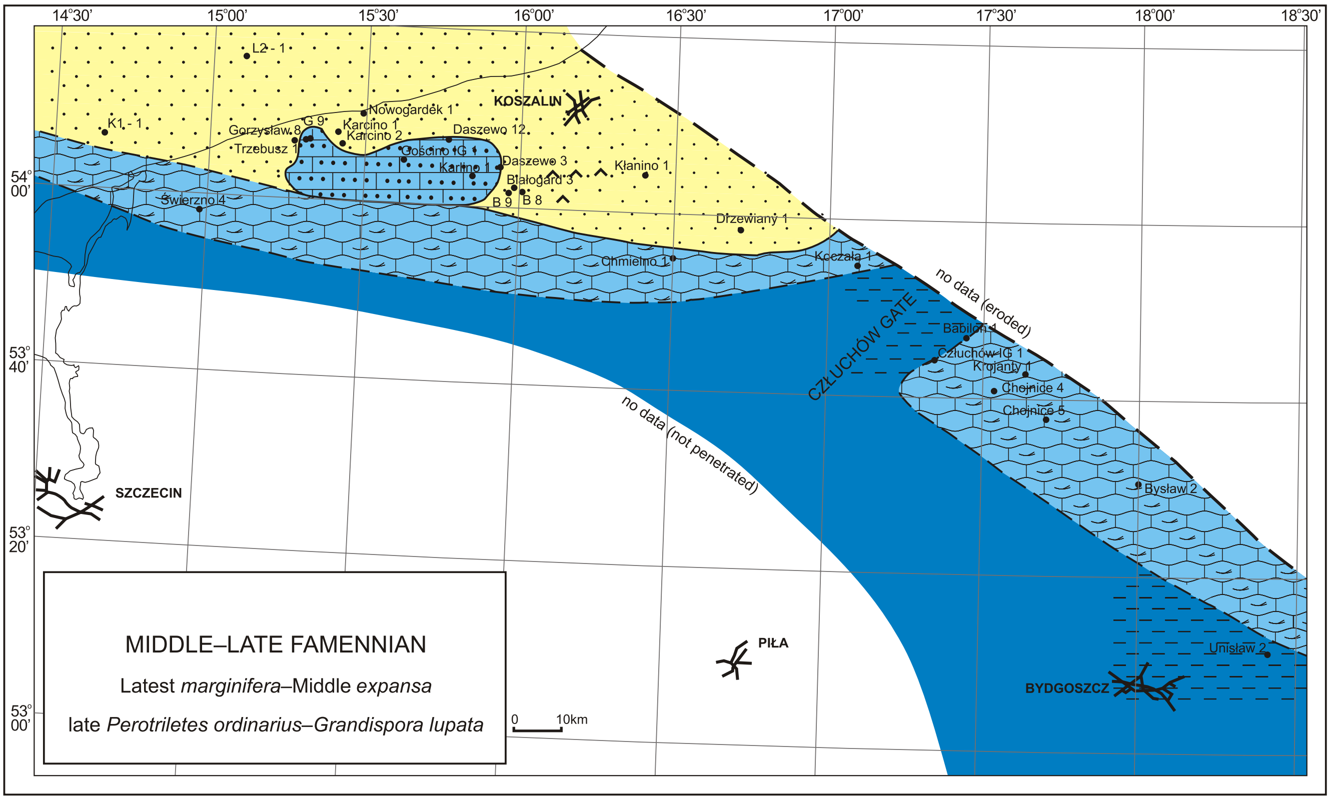

Fig. 13. Lithofacies pattern for the mid–late Famennian (Latest *marginifera*–Mid *expansa* conodont chrons = late *Perotriletes ordinarius*–*Grandispora lupata* miospore chrons), modified after Matyja (1993)

Explanations as in Figure 3

grainstones, are more abundant in the Gorzysław–Karlino area. The siliciclastic-dominated part of succession is characterized by red, pink, green and gray, well-sorted and fine-grained dolomitic quartz sandstones and siltstones with intergranular anhydritic cement, displaying horizontal and large-scale cross-bedding, as well as horizontal, flaser and ripple cross-lamination. Interbeds of claystone occur subordinately. The top of the siliciclastic unit includes "red-beds", *i.e.* red and pink dolomitic sandstones and siltstones with anhydrite occurring as thin beds with a characteristic "chicken-wire" texture or as nodules and crystal rosettes being pseudomorphs after gypsum. This is a typical shallowing-upwards succession. The carbonate-dominated succession of the Kłanino formation consists mainly of cross-bedded and shale-free, well sorted peloidal and intraclastic grainstones rich in foraminifera, benthic ostracodes, microconchids, palaeoberesellid algae and worn crinoid debris. Such features indicate a high-energy and very shallow-water barrier-shoal environment. There are subordinate finely-laminated limestones (microbialites) and fine-grained interbeds of limestones with microconchids. Microfacies analysis indicates the presence of laminoid-fenestral fabrics within some laminae. Laminoid fenestral fabrics occur preferentially in shallow near-coast supratidal and upper intertidal environments. Erect and gregarious forms of "microconchids" (formerly considered to be "vermetid gastropods" or spirorbid worms, now assigned to a separate group of molluscs), are frame builders in peritidal schizohaline lagoonal settings (Burchette and Riding, 1977; Wright and Wright, 1981; Flügel, 2004).

Thus, the Kłanino formation is made up of a variable suite of facies which includes supratidal siliciclastics with evaporites, as well as intertidal and shallow subtidal carbonates (including fenestral and intraclastic-algal micrites) and siliciclastic deposits. In contrast, grainstones probably resulted from current activity which caused the accumulation of the coarser material in a form of narrow, elongate bars, deposited as carbonate sand shoals in a high energy environment (e.g., Halley *et al*., 1983).

To the south and south-west a shallow subtidal environment developed, probably related to an inner carbonate ramp or platform. Deposits of the Krojanty formation consist of pale gray nodular and wavy bioclastic limestones. The grain components are represented by organic remains varying in size though the amount of bioclastic sands is relatively high. The depositional texture varies from wackestone to packstone. Green algae represented by issinellids and palaeoberesellids, plurilocular foraminifers represented by endothyrids and tournayellids, as well as calcispheres, *Girvanella* fragments and benthic ostracodes are particularly common. Issinellids and palaeoberesellids are the dominant fossils here, often creating a bafflestone texture. Palaeoberesellids were the most important carbonate-producing organisms in a shallow, low-energy environment recognized in the late Dinantian of South Wales (e.g., Adams *et al*., 1992). The organisms requiring more open marine conditions, such as brachiopods and echinoderms, are not very abundant. Thus, microfacies analysis (Matyja, 1993) points to a partly restricted?, shallow subtidal environment.

In the upper part of the unit, the algal-foraminiferal wackestones and packstones are often interbedded with algal-foraminiferal-peloidal grainstones in which lime mudstone and algal wackestone intraclasts occur. Horizontal grain orientation is often observed within some grainstone beds, as well as poor sorting. This is also a record of shallowing-upwards succession.

At the same time, the shallowing-upwards tendency has also been observed in the conodont biofacies shift, from the deeper polygnathid–palmatolepid biofacies during the Early–Late *marginifera* chrons to the very shallow-water polygnathid one in the Latest *marginifera* Chron (comp. Matyja, 1993, figs. 9–10). This bioevent was also related with the final (definitive) retreat of the offshore genus *Palmatolepis* from the Pomeranian Basin at the end of the *marginifera* Chron.

There is no evidence of the *trachytera* and *postera* conodont zones throughout the entire Pomeranian area. Some fragments of the succession contain a conodont fauna indicative of the Lower *expansa* Zone but with admixture of older elements representative of the Upper and Uppermost *marginifera* or possibly the Lower *trachytera* zones (Matyja, 1993). Taking into account the very shallow-water character of the succession and the low net sedimentation rate during the *trachytera* and *postera* chrons (Matyja, 1993, figs. 3B and 4), it is not certain whether deposition was more or less continuous between the Latest *marginifera* (or Early *trachytera*) and Late *postera* (or Early *expansa*) chrons.

The first signs of deepening, although short-lived, appeared in the Late *postera* or more probably in the Early *expansa* Chron. The trend manifested itself by the occurrence of grainstones in the area extending between Gorzysław and Białogard, where siliciclastic sedimentation with evaporites predominated previously. At the same time, open marine marls with an open-marine fauna, even with rare pelagic ostracodes, occurred to the south-west (for example in the Człuchów IG 1 and Babilon sections; Matyja, 1993, fig. 3B).

LATE FAMENNIAN (LATEST *EXPANSA*–EARLY *PRAESULCATA* CHRONS): OPEN SHELF, MIDDLE TO OUTER RAMP PHASE OF SEDIMENTATION (FIG. 14)

Slightly later, at the beginning of the Late *expansa* Chron, both the peritidal siliciclastic-carbonate environments situated in the north, and the shallow-marine subtidal environment of probable inner carbonate ramp extending to the south, fell within a deeper subtidal open-marine sedimentary environment (Matyja, 1993, 1998, 2006, 2008*a*). Dark fossiliferous marly limestones with crinoids, palaeoberesellid algae, calcareous and encrusting foraminifers, benthic ostracodes, rare brachiopods and laminar stromatoporoids were deposited in the shallower part of the basin situated in the north, whereas dark fossiliferous marls with ammonoids, pelagic ostracodes, conodonts, trilobites, bivalves, gastropods, brachiopods and solitary corals characterized the deeper part of the basin (Matyja, 1993; Matyja and Stempień-Sałek, 1994). Thus, the Devonian part of the Sąpolno Formation is a succession of open-marine carbonate and clayey deposits, formed well below wave base, periodically under conditions of oxygen deficiency and probably reflecting a middle/outer ramp phase of sedimentation.

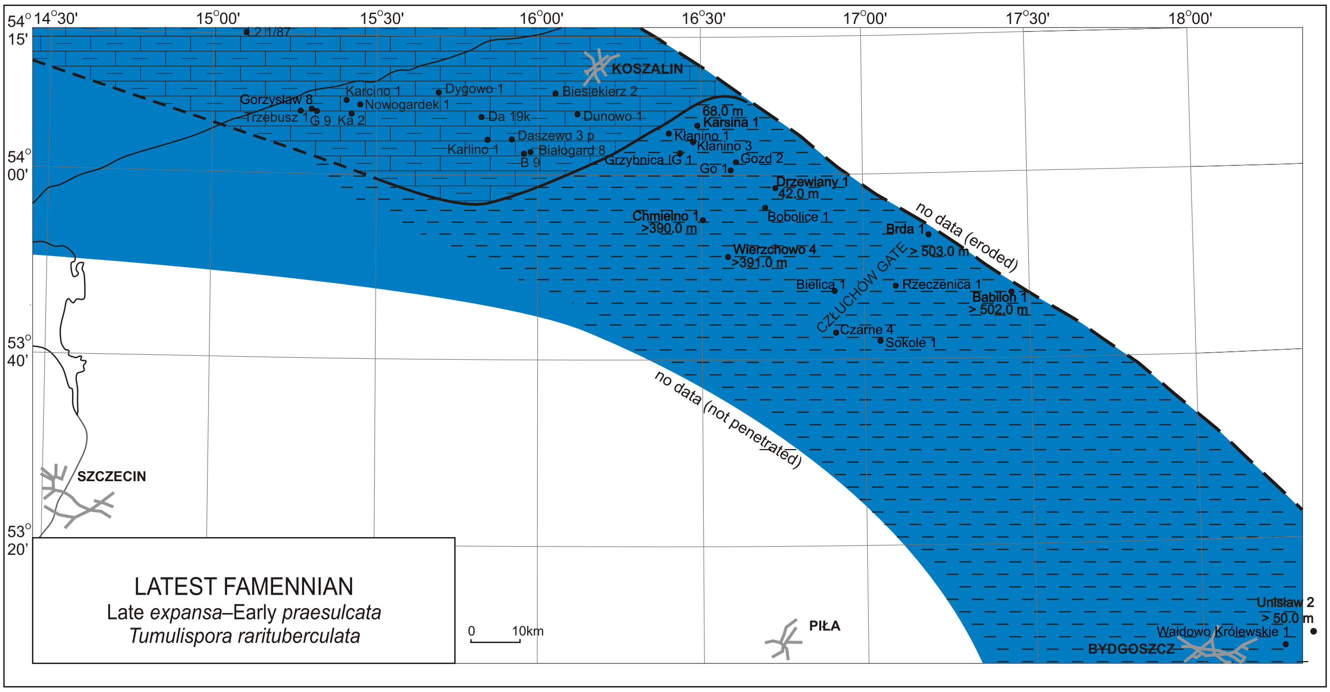

Fig. 14. Lithofacies pattern for the latest Famennian (Late *expansa*–Early *praesulcata* conodont chrons = *Tumulispora rarituberculata* miospore Chron), modified after Matyja (2088*a*)

Explanations as in Figure 3

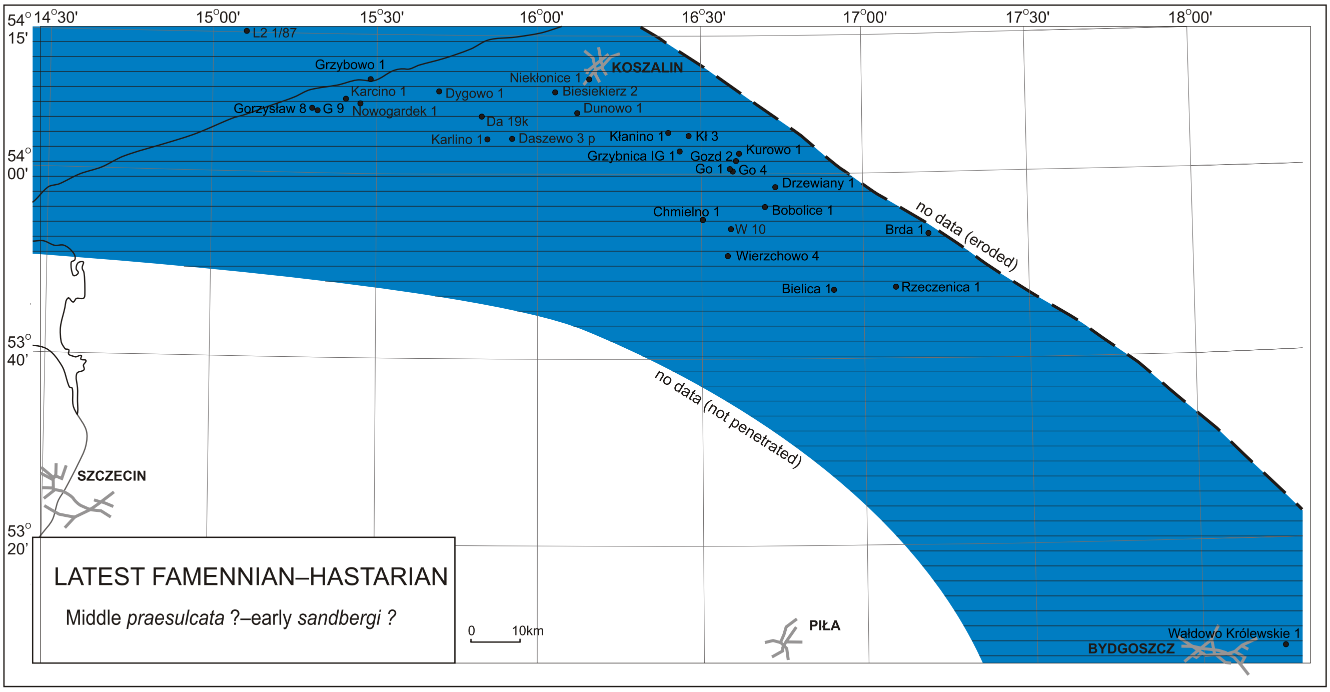

Fig. 15. Lithofacies pattern for the latest Famennian–Hastarian (Mid *praesulcata*?–early *sandbergi*? conodont chrons), modified after Matyja (2008*a*)

Explanations as in Figure 3

LATE FAMENNIAN–HASTARIAN (MID *PRAESULCATA–SANDBERGI* CHRONS): OPEN SHELF, ANOXIC PHASE OF SEDIMENTATION (FIG. 15)

The Devonian/Carboniferous passage interval is marked by black anoxic shales which show a general absence of fossils (Matyja, 1993, 2008*a*; Matyja and Stempień-Sałek, 1994). The Sąpolno Calcareous Shale Formation is a succession of open-marine carbonate and clayey deposits, formed well below wave base, under conditions of periodic oxygen deficiency. The formation probably reflects an outer ramp phase of sedimentation (Matyja, 2006).

PALAEOGEOGRAPHIC, EUSTATIC AND TECTONIC CONTROLS OF SEDIMENTARY EVOLUTION OF THE POMERANIAN BASIN

Evolution of the Devonian epicontinental basin of NW Poland, and the development of a characteristic marine-to-continental, mainly carbonate-siliciclastic sedimentary succession, were controlled by proximity of the land areas representing uplifted parts of the EEC: the Fennoscandian High extending in the north, and the Mazury–Belarus High, situated in the east. These continental areas probably formed a more or less continuous land mass during the relatively low stand of sea level which influenced sedimentation by supplying terrigenous material (with affinity to granitoid-type rocks: a predominance of quarz, and low contents of feldspar and heavy minerals), however, they were probably separated by straits during the maximum transgression.

The sedimentary evolution and lithofacies pattern observed within the Pomeranian Basin followed these main structural outlines and was generally associated with a gradual northwards and eastwards expansion of the marine basins. It seems, however, that through much of the Mid and Late Devonian time the Mazury–Belarus High must have played a significant role in the palaeogeography of the study area, whereas the Fennoscandian High was more active at the end of the Famennian and during the Mississippian (Figs. 1 and 5–15; Matyja, 2008*a*, figs. 5–12).

A sequence of a dozen or so Late Devonian events and faunistic crises has been described in the Pomeranian Basin and some of them, using the criteria of House (1983, 1985) and Johnson *et al*. (1985), were characterized as short-termed eustatic and hypoxic events (Matyja, 1993). The Mid–Late Devonian interval has been subdivided (Matyja, 1998) into 7 transgressive-regressive depositional cycles correlated, with varying degrees of precision, with the “standard” conodont zonation as well as with the global sea level curve of Johnson *et al*. (1985). One difference consists of a single rapid regressive episode initiated at the onset of the Late *marginifera* Chrone, and continuing till the Early *expansa* Chron. This was probably triggered by uplift of the Fennoscandian part of the East European Craton. This also forced changes of the facies pattern from the earlier NE–SW trends to, starting from the Late *marginifera* Chron, a more or less latitudinal pattern (Figs. 5–15; Matyja, 1993). Such facies relationships persisted until the end of the Tournaisian (Matyja, 2008*a*).

It is worth of note, however, that the currently accepted global sea level curve for the Devonian (Johnson *et al*., 1985) came mostly from North American and a few European section. With progress and increased knowledge it became evident that some of the “global” Devonian events were, in fact, not synchronous and some were probably multi-phased. Thus, Devonian events may have a more complex history as previously suggested (see examples in Belka and Wendt, 1992; Barnes *et al*., 1996; Walliser, 1996; House and Ziegler, 1997; House, 2002; Hartenfels and Becker, 2008). Some of Devonian events, such as the Late Kellwasser Event at the Frasnian/Famennian boundary and the Hangenberg Event close to the Devonian/Carboniferous boundary, have received the most detailed analyses (for example Baliński *et al*., 2002; Racki and House, 2002; Brand *et al*., 2004). Analyses of other Devonian events are still in progress (Baliński *et al*., 2006; Van Geldern *et al*., 2006; Racki *et al*., 2008; Hartenfels and Becker, 2008). As noted by Becker (2008), an integration of biostratigraphic data with modern stratigraphic techniques into Devonian multidisciplinary schemes is required, from as many sedimentary basins as possible, in order to produce a more detailed, high-resolution Devonian eustatic curve.

Although transgressive-regressive depositional cycles observed in the Pomeranian Basin seem to have been strongly controlled by sea level variations, probably of a eustatic nature, the tectonic activity of some structural elements (blocks) locally modified the sedimentary record (for example the Człuchów Gate). Two time intervals, the Givetian — earliest Famennian (Figs. 5–10) and the mid–late Famennian (Fig. 13) appears to have been of particular significance in the evolution of the Człuchów Gate. Synsedimentary tectonic activity of this palaeostructure is observed as thickness and facies variation. In the early–mid Famennian interval (Figs. 11–12) the Człuchów Gate was inactive both as regards variable thickness, and as regards facies variation. In the latest Famennian (Fig. 14) only the thickness variation is observed here. At the end of the Famennian (Fig. 15) tectonic activity of this palaeostructure ceased.

The importance of eustatic versus tectonic events in the Devonian of Pomerania is still difficult to ascertain in detail, and further refinement of the biostratigraphy, as well as improved stratigraphic correlation between the study area and the neighbouring areas is needed.

POMERANIAN BASIN AND NEIGHBOURING AREAS

The evolution of Devonian facies in the Pomeranian sedimentary basin may be compared with the history of neighbouring areas. These are: (1) the intracratonic Baltic Basin in the east, located on the East European Craton and covering territories of the Baltic countries, the Kaliningrad region, Lithuania, Latvia, Estonia and the eastern part of the Baltic Sea, and (2) the area of Vorpommern (NE Germany) in the west, including Usedom, Rügen and Hiddensee Islands, and the environs of Greifswald. The latter area is situated, like the Western Pomerania region, within the Trans-European Suture Zone (TESZ).

The scope of detailed investigations, including a biostratigraphic study as a starting point for precise and well documented regional considerations, was different for each of the areas. Thus, of necessity, many geological aspects were compared at the level of stage or its subdivision, although much data concerning the Devonian of the Pomeranian area could be examined with higher stratigraphic resolution based on the conodont or miospore zonation.

As thus described, sedimentation began in the Pomeranian Basin not earlier than at the end of Emsian or possibly in the Eifelian, after a long break spanning the Lochkovian, Pragian and much of the Emsian, when the area was subjected to erosion. Sedimentation started in the northeastern part with marginal-marine clastic deposits with local evaporites which are dated as uppermost Emsian?–Eifelian, passing upwards into lower–middle Givetian marginal-marine siliciclastic and carbonate deposits, followed by upper Givetian marginal-marine siliciclastic rocks. In the southwestern part of the area, the Devonian succession started with marginal-marine carbonates and siliciclastic deposits which belong to the uppermost Emsian?–Eifelian, followed by lower and middle Givetian carbonates, passing upwards into upper Givetian marginal-marine siliciclastic deposits. The Late Devonian, in general, was a time of predominance of shallow and deeper subtidal, open-marine carbonate sedimentation. During the Late Devonian the Pomeranian Basin underwent evolution from marginal marine in the earliest Frasnian, through carbonate ramp or platform/shelf basin settings during the rest of the Frasnian and early Famennian, up to reappearance of shallow subtidal and marginal marine environments in the late Famennian. At the end of the Famennian an open shelf environment became prevalent over almost the whole area and continued up to the Mid Tournaisian (Matyja, 2008*a*).

The Hercynian structural complex of the Baltic Basin begins with Lower Devonian terrigenous deposits representing the Pragian and lower Emsian (Kemeri regional stage), and ends with Tournaisian terrigenous-carbonate sediments belonging to the Klykoliai Group. The succession is characterized by a number of stratigraphic gaps, especially within the Lower and Middle Devonian section, and is overlain by Upper Permian rocks (Paškevičius, 1997; Ūsaitytė, 2000; Matyja, 2006, fig. 3). During Devonian and Early Carboniferous times, the Baltic Basin was a typical epicratonic, partly isolated sedimentary basin of considerable salinity. Details concerning lithologies, stratigraphy and the history of facies development during the Devonian and Early Carboniferous of the onshore part of the Baltic Basin (encompassing parts of Estonia, Latvia and Lithuania) (Sorokin *et al*., 1981; Paškevičius, 1997), allows the conclusion that the Hercynian complex is bipartite. The lower part contained between the Lower Devonian and lower Frasnian (excluding the Narva marly dolomites) is composed mainly of sandstones and claystones representing terrestrial and marginal marine environments fed by material derived from the Fennoscandian land at that time. In the upper part, between the mid Frasnian and Early Tournaisian, lagoonal environments were dominant, with periodic carbonate sedimentation in open marine conditions, as was the case during the mid Frasnian (corresponding to the Plavinas stage) or during the early and mid Famennian (between the Kruoja and Kuršiai stages; Matyja, 2006, fig. 3).

The history of facies development in the Baltic and Pomeranian Basins seems to indicate that these were probably separate sedimentary basins, although located relatively close to each other, through most of Devonian time. Only during the early and mid Famennian, when the Baltic Basin turned from an isolated into a marine one open to the south-west (Paškevičius, 1997), there might have been some communication between the Pomeranian and Baltic basins, possibly via the Człuchów Gate. At the end of the Early Tournaisian the Baltic Basin came to its end and denudation processes dominated over the area until the Early Permian.

Devonian deposits of NE Germany were encountered in a dozen boreholes drilled both in the western part of the Baltic Sea (H2-1, H9-1) and on Rügen, Hiddensee and Usedom Island (Fig. 1). Devonian deposits are underlain by tectonically deformed Ordovician and Llanvirn rocks, and are overlain by Tournaisian or Viséan deposits. In places they are erosionally truncated and overlain by upper Carboniferous or Permian rocks. The Rügen Devonian succession (Schmidt and Franke, 1977; I. Zagora, 1993; K. Zagora, 1993, 1995; McCann, 1996, 1999; Zagora and Zagora, 1999, 2004) begins with upper Emsian basal conglomerates unconformably overlying deformed Ordovician rocks. They are typicaly bipartite. The lower portion, contained between the upper Emsian and lower Givetian, is represented by Old Red facies. The Middle Devonian is composed of sedimentary cycles consisting of red and grey sandstones and mudstones interbedded with conglomerates. The Lower and Middle Devonian sequence is a fining-upwards succession indicating a progressive marine transgression gradually changing sedimentary conditions from continental (alluvial environment) through brackish to marine. The first intercalations of marine limestone are observed in the uppermost Givetian. The upper part of the Rügen Devonian succession, contained between the upper Givetian and Famennian, is represented by marine facies. The Upper Devonian section is conspicuous by the presence of marls and limestones deposited in nearshore and shallow-marine depositional settings. The Famennian section is probably incomplete. The Devonian deposits conformably pass into Mississippian represented by the relatively shallow-marine Carboniferous Limestone facies (Hoffmann *et al*., 1975, 2006).

The comparison of facies development of the Pomeranian and NE Germany basins during its Devonian evolution (Matyja, 2006, figs. 2 and 4, 5) does not lead to unequivocal interpretation. Taking into account the short distances between these areas one could expect the same or at least a similar sedimentary evolution at that time. The main feature in common to the two areas is the similar timing of the beginning of Devonian sedimentation (late Emsian?). The most important difference is the considerably “more marine and open-marine” nature of the Devonian deposits in Pomerania as compared to Rügen (Aehnelt and Katzung, 2007; Aehnelt *et al*., 2008).

SUMMARY

Evolution of the Pomeranian Basin (NW Poland) during the Devonian, and the development of a characteristic siliciclastic and mixed siliciclastic-carbonate marginal marine-to-open marine carbonate sedimentary succession, was controlled via proximity of the land areas representing uplifted parts of the EEC: the

Fennoscandian High extending in the north, and the Mazury–Belarus High, situated in the east. The sedimentary evolution and lithofacies pattern observed within the Pomeranian Basin followed these main structural outlines and was generally associated with a gradual northwards and eastwards expansion of the open marine facies. It seems, however, that through much of the Mid and Late Devonian the Mazury–Belarus High must have played a significant role in the palaeogeography of the study area, whereas the Fennoscandian High was more active at the end of Famennian and during the Mississippian.

The depositional history of the Pomeranian Basin began not earlier than at the end of Emsian or possibly in the Eifelian, after a long break spanning the Lochkovian, Pragian and much of the Emsian when the area was subjected to erosion.

Sedimentation started in the northeastern part with marginal-marine clastic deposits with local evaporites which are dated as uppermost Emsian?–Eifelian, passing upwards into lower–middle Givetian marginal-marine siliciclastics and carbonates, followed by upper Givetian marginal-marine siliciclastic strata.

In the southwestern part of the area, the Devonian succession started with marginal-marine carbonates and siliciclastics which belong to the uppermost Emsian?–Eifelian, followed by lower and middle Givetian carbonates, passing upwards into upper Givetian marginal-marine siliciclastics.

During the Late Devonian the Pomeranian Basin underwent evolution from marginal-marine in the earliest Frasnian, through carbonate ramp or platform/shelf basin settings during the rest of the Frasnian and early Famennian, up to reappearance of shallow subtidal and marginal marine environments in the late Famennian. At the end of the Famennian an open shelf environment became prevalent over almost the whole area and continued up to the Mid Tournaisian.

Transgressive-regressive depositional cycles observed in the Pomeranian Basin seem to have been strongly controlled by sea level variations, probably of eustatic nature; however, tectonic activity of some structural elements (for example the Człuchów Gate) locally modified the sedimentary record.

The sedimentary succession presented and characteristic episodes observed in the Pomeranian Basin during its Devonian history display a pattern partly different from that observed in other areas in Poland and in Europe. Distinct facies differences are observed between the Western Pomerania area and, located further to the NNW, the Rügen and Hiddensee islands. The Devonian evolution of the Western Pomerania area presumably owes its distinct structural and depositional development to a proximal position with respect to the land-mass of the East European Craton and to a distal position with respect to the evolving Variscan orogen.

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REFERENCES

ADAMS A. E., HORBURY A. D. and RAMSAY A. T. S. (1992) — Significance of palaeoberesellids (Chlorophyta) in Dinantian sedimentation, UK. Lethaia, **25** (4): 37–582.

AEHNELT M. and KATZUNG G. (2007) — Lithology of the covered Old Red Succession (Middle Devonian) in Western Pomerania (NE Germany). In: Geology cross-bordering the Western and Eastern European Platform (eds. H.-G. Röhling, Ch. Breitkreuz, Th. Duda, W. Stackebrandt, A. Witkowski and O. Uhlmann). Joint Meeting DGG-PTG Geo-Pomerania Szczecin 2007, Poland. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, **53**: 38.

AEHNELT M., ZAGORA K. and HÜNEKE H. (2008) — Middle to Upper Devonian sea-level evolution in the Rügen area, Western Pomerania. In: From Gondwana and Laurussia to Pangea: Dynamics of Oceans and Supercontinents (eds. P. Königshof and U. Linnemann): 149–151. 20th International Senckenberg Conference and 2nd Geinitz Conference (Final Meeting of IGCP 497 & IGCP 499), September 30–October 10 2008, Frankfurt, Germany. Abstracts and Programme.

AVKHIMOVITCH V. I., TCHIBRIKOVA E. V., OBUKHOVSKAYA T. G., NAZARENKO A. M., UMNOVA V. T., RASKATOVA L. G., MANTSUROVA V. N., LOBOZIAK S. and STREEL M. (1993) — Middle and Upper Devonian miospore zonation of Eastern Europe. Bull. Centres Rech. Explor.-Prod. Elf Aquitaine, **17**: 79–147.

BALIŃSKI A., OLEMPSKA E. and RACKI G. eds. (2002) — Biotic responses to the Late Devonian global events: introductory remarks. Acta Palaeont. Pol., **47** (2).

BALIŃSKI A., OLEMPSKA E. and RACKI G. eds. (2006) — Early-Middle Frasnian transition. Acta Palaeont. Pol., **51** (4).

BARNES Ch., HALLAM A., KALJO D., KAUFFMAN E. G. and WALLISSER O. H. (1996) — Global event stratigraphy. In: Global Events and Event Stratigraphy in the Phanerozoic (ed. O. H. Walliser): 319–333. Springer-Verlag: Berlin Heidelberg.

BECKER R. T. (2007) — Message from the chairman. Subcomm. Devonian Stratigraph. Newslett., **22**.

BECKER R. T. (2008) — Annual report to ICS, 2007. Subcomm. Devonian Stratigraph. Newslett., **23**: 5–11.

BELKA Z. and WENDT J. (1992) — Conodont biofacies pattern in the Kellwasser Facies (upper Frasnian/lower Famennian) of the eastern Anti-Atlas, Morocco. Palaeogeogr., Palaeoclimatol., Palaeoecol., **91**: 143–173.

BLESS M. J. M., BOUCKAERT J. and PAPROTH E. (1984) — Migration of facies belts as a response to continental drift during the Late Devonian and Carboniferous. Bull. Soc. Belge Géol., **93**: 189–195.

BLESS M. J. M., BOUCKAERT J., PAPROTH E. and STOPPEL D. (1986) — Evaporites of Devono-Dinantian age in the southeastern Netherlands? Bull. Soc. Belge Géol., **95**: 83–87.

BRAND U., LEGRAND-BLAIN M. and STREEL M. (2004) — Biochemostratigraphy of the Devonian-Carboniferous boundary global stratotype section and point, Griotte Formation, La Serre, Montagne Noire, France. Palaeogeogr., Palaeoclimat., Palaeoecol., **205**: 337–357.

BULTYNCK P. (2004) — Message from the chairman. Subcomm. Devonian Stratigraph. Newslett., **20**.

BULTYNCK P. (2007) — Limitation on the application of the Devonian standard conodont zonation. Geol. Quart., **51** (4): 339–344.

BURCHETTE T. P. and RIDING R. (1977) — Attached vermiform gastropods in Carboniferous marginal marine stromatolites and biostromes. Lethaia, **10** (1): 17–28.

CLAUSEN C-D., WEDDIGE K. and ZIEGLER W. (1993) — Devonian of the Rhenish Massif. Newslett. Subcomm. Devonian Stratigraph., **10**: 18–19.

CHWEDIUK E. (2003) — Late Devonian and early Carboniferous Rugosa from Western Pomerania, northern Poland. Acta Geol. Pol., **55** (4): 392–443.

DADLEZ J. (1975) — Petrography of the Devonian sediments in the Gościno-Człuchów zone of the Pomerania trough (north-western Poland) (in Polish with English summary). Kwart. Geol., **19** (3): 515–536.

DADLEZ J. (1976) — Petrography of the Devonian sediments in the Jamno-Miastko zone of the Pomerania trough (north-western Poland) (in Polish with English summary). Kwart. Geol., **20** (3): 503–523.

DADLEZ J. and DADLEZ R. (1986) — Late Devonian transgression in the Unisław sequence, central Poland (in Polish with English summary). Kwart. Geol., **30** (3–4): 445–472.

DADLEZ R. (1978) — Sub-Permian rock complexes in the Koszalin–Chojnice Zone (in Polish with English summary). Kwart. Geol., **22** (2): 269–301.

DADLEZ R. (1997) — Epicontinental basins in Poland: Devonian to Cretaceous — relationships between the crystaline basement and sedimentary infill. Geol. Quart., **41** (4): 419–432.

DADLEZ R. (2000) — Pomeranian Caledonides (NW Poland), fifty years of controversies: a review and a new concept. Geol. Quart., **44** (3): 221–236.

DADLEZ R. (2006) — The Polish Basin — relationship between the crystalline, consolidated and sedimentary crust. Geol. Quart., **50** (1): 43–58.

DADLEZ R., KOWALCZEWSKI Z. and ZNOSKO J. (1994) — Some key problems of the pre-Permian tectonics of Poland. Geol. Quart., **38** (2):169–190.

FLÜGEL E. (2004) — Microfacies of carbonate rocks, Analysis, Interpretation and Application. Springer-Verlag: Berlin, Heidelberg.

FRANKE D. (1995) — The North Variscan Foreland. In: Pre-Permian Geology of Central and Eastern Europe (eds. R. D. Dallmeyer, W. Franke and K. Weber): 554–593. Springer-Verlag: Berlin, Heidelberg.

FUGLEWICZ R. and PREJBISZ A. (1981) — Devonian megaspores from NW Poland. Acta Palaeont. Pol., **26** (1): 55–72.

GRAD M., JANIK T., YLINIEMI J., GUTERCH A., LUOSTO U., TIIRA T., KOMMINAHO K., ŚRODA P., HÖING K., MAKRIS J. and LUND C-E. (1999) — Crustal structure of the Mid-Polish Trough beneath TTZ seismic profile. Tectonophysics, **314** (1–3): 145–160.

GROSS-UFFENORDE H., LETHIERS F. and BLUMENSTENGEL H. (2000) — Ostracodes and Devonian stratigraphy. Cour. Forsch.-Inst. Senckenberg, **220**: 99–111.

GROSS-UFFENORDE H. and SCHINDLER E. (1990) — The effect of global events on entomozoacean Ostracoda. In: Ostracoda and Global Events (eds. R. Whatley and C. Maybury): 11–112. British Micropalaeont. Soc. Ser. London.

GROSS-UFFENORDE H. and WANG S. (1989) — The entomozoacean succession of China and Germany (Ostracoda, Devonian). Cour. Forsch.-Inst. Senckenberg, **110**: 61–79.

GUTERCH A., GRAD M., JANIK T., MATERZOK R., LUOSTO U., LÜCK E., SCHÜLZE A. and FÖRSTE K. (1994) — Crustal structure of the transition zone between Precambrian and Variscan Europe from new seismic data along LT-7 profile (NW Poland and eastern Germany). Géophysique/Geophysics, C.R. Acad. Sc. Paris, **319** (sér. II): 1489–1496.

HALLEY R. B., HARRIS P. M. and HINE A. C. (1983) — Bank margin environment. In: Carbonate Depositional Environment (eds. P. A. Scholle, D. B. Bebout and C. H. Moore). Amer. Ass. Petrol. Geol. Mem., **33**: 463–506.

HARTENFELS S. and BECKER R. T. (2008) — Timing of sea-level changes in the Upper Famennian (Devonian) Effenberg quarry, northern Rhenish Massif, Germany. In: Global Alignments of the Lower Devonian Carbonate and Clastic Sequences (eds. A. I. Kim, F. A. Salimova and N. A. Messhchankina): 179–181. IGCP Project 499/Subcommission on Devonian Stratigraphy Joint Field Meeting August 25–September 9 2008, Kitab State Geol. Res., Uzbekistan.

HECKEL P. H. and WITZKE B. J. (1979) — Devonian world palaeogeography determined from distribution of carbonates and related lithic palaeoclimatic indicators. In: The Devonian System (eds. M. R. House, C. T. Scrutton and M. G. Basset). Spec. Pap. Palaeont., **23**: 99–123.

HOFFMANN N., LINDERT W., WEYER D. and WILLERS K. H. (1975) — Zum Unterkarbon-Vorkommen auf den Inseln Rügen und Hiddensee. Z. Geol. Wiss., **3**: 851–873.

HOFFMANN N., LINDERT W. and WEYER D. (2006) — Süd-Westrand der Osteuropäischen Platform (Inseln Rügen, Hiddensee, Usedom; Mecklenburg-Vorpommern). In: Deutsche Stratigraphische Komission. Stratigraphie von Deutschland VI Unterkarbon (Mississippium) (eds. M. R. W. Amler and D. Stoppel). Schriftenreihe der Deutschen Gesselschaft für Geowiss., **41**: 480–493.

HOUSE M. R. (1983) — Devonian eustatic events. Proc. Ussher Soc., **5**: 396–405.

HOUSE M. R. (1985) — Correlations of mid-Palaeozoic ammonoid evolutionary events with global sedimentary perturbations. Nature, **313**: 17–22.

HOUSE M. R. (2002) — Strength, timing, setting and cause of mid-Palaeozoic extinctions. Palaeogeogr., Palaeoclimat., Palaeoecol., **181**: 5–25.

HOUSE M. R. and GRADSTEIN F. M. (2004) — The Devonian Period. In: A Geological Time Scale 2004 (eds. F. M. Gradstein, J. G. Ogg and A. G. Smith): 202–221. Cambridge Univ. Press.

HOUSE M. R. and ZIEGLER W. eds. (1997) — On sea-level fluctuations in the Devonian. Cour. Forsch.-Inst. Senckenberg, **199**: 1–146.

JOHNSON J. G., KLAPPER G. and SANDBERG C. A. (1985) — Devonian eustatic fluctuations in Euramerica. Geol. Soc. Amer. Bull., **96**: 567–587.

JOHNSON J. G., KLAPPER G. and SANDBERG C. A. (1986) — Late Devonian eustatic cycles around margin of Old Red Continent. Ann. Soc. Géol. Belgique, **109**: 141–147.

KŁAPCIŃSKI J. and MUSZER J. (1995*a*) — Under-Permian rocks from selected wells in Pomorze Zachodnie area (Szczecin synclinotium, Pomorze synclinorium and antyclinorium) (in Polish with English summary). Acta Univ. Wratisl., Pr. Geol.-Miner., **48**: 15–25.

KŁAPCIŃSKI J. and MUSZER J. (1995*b*) — Stratigraphic division of the basement of the Permian in the Kłanino 3 borehole based on microfossils (Pomorze Zachodnie, NW Poland) (in Polish with English summary). Acta Univ. Wratisl., Pr. Geol.-Miner., **50**: 191–198.

KŁAPCIŃSKI J. and MUSZER J. (1995*c*) — Upper Devonian and Lower Carboniferous rocks from the Brzozówka 2, Myśligoszcz 1, Rzeczenica 2 and Wałdowo Królewskie 1 boreholes (Pomorze Zachodnie, NW Poland) (in Polish with English summary). Acta Univ. Wratisl., Pr. Geol.-Miner., **50**: 209–217.

KOREJWO K. (1975) — The lowermost Dinantian from the Babilon 1 column (Western Pomerania) (in Polish with English summary). Acta Geol. Pol., **25** (4): 451–504.

KRAMARSKA R., KRZYWIEC P., DADLEZ R., JEGLIŃSKI W., PAPIERNIK B., PRZEZDZIECKI P. and ZIENTARA P. (1999) — Geological Map of the Western and Central Part of the Baltic Depression without Permian and younger formations (in Polish with English summary). Państw. Inst. Geol. Warszawa–Gdańsk.

KRÓLIKOWSKI C., PETECKI Z. and DADLEZ R. (1996) — Vertical discontinuities in the Earth's crust of the TESZ in Poland — gravity data. Geol. Quart., **40** (2): 155–168.

KRÓLIKOWSKI C., PETECKI Z. and ŻÓŁTOWSKI Z. (1999) — Main structural units in the Polish part of the East European Platform in the light of gravimetric data (in Polish with English summary). Biul. Państw. Inst. Geol., **386**: 5–58.

KRZEMIŃSKI L. and POPRAWA P. (2006) — Geochemistry of the Ordovician and Silurian clastic sediments of the Koszalin–Chojnice zone and the western Baltic Basin (N Poland) (in Polish with English summary). In: Facies, Tectonic and Thermal Evolution of the Pomeranian Sector of Trans-European Suture Zone and Adjacent Areas (eds. H. Matyja and P. Poprawa). Pr. Państw. Inst. Geol., **186**: 123–148.

LEES A. (1964) — The structure and origin of the Waulsortian (Lower Carboniferous) "reefs" of west-central Eire. Philosophical Transaction of the Royal Society London, **247B**: 483–531.

LEES A. (1988) — Waulsortian "reefs": the history of a concept. MPm. Inst. GPol. Univ. Louvain, **34**: 43–55.

LEES A., HALLET V. and HIBO D. (1985) — Facies variation in Waulsortian buildups. Part 1: A model from Belgium. Geol. J., **20**: 133–158.

LEES A. and MILLER J. (1985) — Facies variation in Waulsortian buildups. Part 2: Mid/Dinantian buildups from England and North America. Geol. J., **20**: 159–180.

LIPIEC M. and MATYJA H. (1998) — Depositional architecture of the Lower Carboniferous sedimentary basin in Pomerania (in Polish with English summary). Pr. Państw. Inst. Geol., **165**: 101–112.

ŁOBANOWSKI H. (1968) — Preliminary notes on the Devonian in the structural zone of the Chojnice — NW Poland (in Polish with English summary). Acta Geol. Pol., **18** (4): 765–786.

ŁOBANOWSKI H. (1969) — Upper Devonian from borehole Stobno 3 in the vicinity of Chojnice (NW Poland) (in Polish with English summary). Acta Geol. Pol., **19** (4): 793–803.

LOBOZIAK S., STREEL M. and WEDDIGE K. (1991) — Miospores, the *lemurata* and *triangulatus* levels and their faunal indices near the Eifelian/Givetian boundary in the Eifel (F.R.G.). Ann. Soc. Géol. Belge, **113**: 299–313.

MATYJA H. (1976) — Biostratigraphy of the Devonian–Carboniferous passage beds from some selected profiles of NW Poland. Acta Geol. Pol., **26** (4): 489–539.

MATYJA H. (1987) — Conodont biofacies in the Famennian Stage of Pomerania, nothwestern Poland. In: Conodonts: Investigative Techniques and Applications (ed. R L. Austin): 363–381. British Micropalaont. Soc. Ser. Harwood Ltd. Chichester.

MATYJA H. (1988) — Famennian facies of Pomerania, northwestern Poland and the paleogeography of Northern Europe. In: Devonian of the World, vol. II. Sedimentation (eds. N. J. McMillan, A. F. Embry and D. J. Glass). Canad. Soc. Petrol. Geol. Mem., **14**: 637–647.

MATYJA H. (1993) — Upper Devonian of Western Pomerania. Acta Geol. Pol., **42** (1–2): 27–94.

MATYJA H. (1998) — Depositional architecture of the Devonian Basin in the Pomorze–Kujawy area (in Polish with English summary). In: Sedimentary Basin Analysis of the Polish Lowlands (ed. M. Narkiewicz). Pr. Państw. Inst. Geol., **165**: 73–88.

MATYJA H. (2004) — Stratygrafia, węglanowe systemy depozycyjne dewonu środkowego i franu, architektura facjalna. In: Rozwój transgresji środkowodewońskiej i wczesnofrańskiej i jej zapis w mieszanych, klastyczno-węglanowych środowiskach marginalno-morskich (modele facjalne, stratygrafia sekwencji). Unpubl., Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.

MATYJA H. (2006) — Stratigraphy and facies development of Devonian and Carboniferous deposits in the Pomeranian Basin and in western part of the Baltic Basin, and palaeogeography of the northern TESZ during Late Palaeozoic times (in Polish with English summary). In: Facies, Tectonic and Thermal Evolution of the Pomeranian Sector of Trans-European Suture Zone and Adjacent Areas (eds. H. Matyja and P. Poprawa). Pr. Państw. Inst. Geol., **186**: 79–122.

MATYJA H. (2007*a*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Lito- i biostratygrafia. In: Polskie Łąki PIG 1. Profile Głębokich Otworów. Państw. Inst. Geol., **122**: 54–62.

MATYJA H. (2007*b*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Osady węglanowe i środowiska ich depozycji. In: Polskie Łąki PIG 1. Profile Głębokich Otworów. Państw. Inst. Geol., **122**: 73–74.

MATYJA H. (2007*c*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Uwagi o rozwoju facjalnym obszaru pomorskiego w dewonie wczesnym, środkowym i na początku późnego In: Polskie Łąki PIG 1. Profile Głębokich Otworów. Państw. Inst. Geol., **122**: 80–81.

MATYJA H. (2008*a*) — Pomeranian basin (NW Poland) and its sedimentary evolution during Mississippian times. In: Carboniferous Platforms and Basins (eds. M. Aretz., H-G. Herbig and I. D. Somerville). Geol. J., **43** (2–3): 123–150.

MATYJA H. (2008*b*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Lito- i biostratygrafia osadów dewonu obszaru pomorskiego. Profile Głębokich Otworów Państwowego Instytutu Geologicznego, Jamno IG 1, Jamno IG 2, Jamno IG 3 (ed. H. Matyja), **124**: 117–124.

MATYJA H. (2008*c*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Biostratygrafia osadów franu na podstawie fauny konodontowej. Profile Głębokich Otworów Państwowego Instytutu Geologicznego, Jamno IG 1, Jamno IG 2, Jamno IG 3 (ed. H. Matyja), **124**: 136–138.

MATYJA H. (2008*d*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Osady węglanowe i środowiska ich depozycji. Profile Głębokich Otworów Państwowego Instytutu Geologicznego, Jamno IG 1, Jamno IG 2, Jamno IG 3 (ed. H. Matyja), **124**: 160–164.

MATYJA H. (2008*e*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Rozwój facjalny pn. wsch. części obszaru pomorskiego w dewonie ?wczesnym, środkowym i na początku późnego. Profile Głębokich Otworów Państwowego Instytutu Geologicznego, Jamno IG 1, Jamno IG 2, Jamno IG 3 (ed. H. Matyja), **124**: 174–176.

MATYJA H. and NARKIEWICZ M. (1992) — Conodont biofacies succession near the Frasnian/Famennian boundary: some Polish examples. Cour. Forsch-Inst. Senckenberg, **154**: 125–147.

MATYJA H. and STEMPIEŃ-SAŁEK M. (1994) — Devonian/Carboniferous boundary and the associated phenomena in Western Pomerania (NW Poland). Ann. Soc. Belgique, **116** (2): 249–263.

MATYJA H. and TURNAU E. (1989) — Conodonts and spores from the Devonian/Carboniferous boundary beds in Poland. XI CongrPs International de Stratigraphie et de Géologie du CarbonifPre Bejing, Compte Rendu, **3**: 61–72. Bejing.

MATYJA H. and TURNAU E. (2008) — Integrated analysis of miospores and conodonts: a tool for correlation of shallow-water, mixed siliciclastic-carbonate succession of Lower? and Middle Devonian (Pomeranian basin, NW Poland). In: Global Alignments of the Lower Devonian Carbonate and Clastic Sequences (eds. A. I. Kim, F. A. Salimova and N. A. Messhchankina): 67–71. IGCP Project 499/Subcommission on Devonian Stratigraphy Joint Field Meeting August 25–September 9 2008, Kitab State Geol. Res., Uzbekistan.

MATYJA H., TURNAU E. and ŻBIKOWSKA B. (2000) — Lower Carboniferous (Missisippian) stratigraphy of northwestern Poland: conodont, miospore and ostracod zones compared. Ann. Soc. Geol. Pol., **70** (3–4): 193–217.

McCANN T. (1996) — Pre-Permian of the north-east German Basin. Geol. J., **31**: 159–177.

McCANN T. (1999) — Middle to Late Devonian basin evolution in the Rügen area, NE Germany. Geol. Mijnb., **78**: 57–71.

MIŁACZEWSKI L. (1980) — Dewon na Pomorzu. Kwart. Geol., **24** (4): 944–945.

MIŁACZEWSKI L. (1981) — The Devonian of the south-eastern part of the Radom-Lublin area (eastern Poland) (in Polish with English summary). Pr. Inst. Geol., **101**: 1–90.

MIŁACZEWSKI L. (1986) — Dewon na Pomorzu. Konferencja Naukowa, Tuczno: 77–88. Piła.

MUSZER J. (1998) — Makrofauna i stratygrafia osadów górnego dewonu i dolnego karbonu północnej części Pomorza Zachodniego. Pr. Geol.-Miner., **66**: 1–153.

NARKIEWICZ M., POPRAWA P., LIPIEC M., MATYJA H. and MIŁACZEWSKI L. (1998) — Palaeogeographic and tectonic setting and the Devonian–Carboniferous subsidence development of the Pomerania and Radom–Lublin areas (TESZ, Poland) (in Polish with English summary). In: Sedimentary Basin Analysis of the Polish Lowlands (ed. M. Narkiewicz). Pr. Państw. Inst. Geol., **165**: 31–46.

NOWIŃSKI A. and PREJBISZ A. (1986) — Devonian tabulate corals from Western Pomerania, Poland. Acta Palaeont. Pol., **31** (3–4): 237–251.

OBUKHOVSKAYA T. G. (1999) — Zonalnaje rozczlienienie sredne devonskich odkladow uschodnoj Belarusi na miosporach (in Russian). Litasfera, **10–11**: 76–85.

PACZEŚNA J. (2004) — Klastyczne systemy depozycyjne dewonu środkowego. In: Rozwój transgresji środkowodewońskiej i wczesnofrańskiej i jej zapis w mieszanych, klastyczno-węglanowych środowiskach marginalnomorskich (modele facjalne, stratygrafia sekwencji). Unpubl., Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.

PACZEŚNA J. (2007) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Środowiska depozycji środkowodewońskich utworów klastycznych. In: Polskie Łąki PIG 1. Profile Głębokich Otworów. Państw. Inst. Geol., **122**: 74–80.

PACZEŚNA J. (2008*a*) — Lagoon-barrier complex trace fossil assemblages from the Middle Devonian of the Western Pomerania (northwestern Poland). In: The Seconds International Congress on Ichnology, Cracow, Poland, August 29–September 8, 2008. Abstract Book and the Intra-Congress field trip guidebook (ed. A. Uchman): 97. Pol. Geol. Inst.

PACZEŚNA J. (2008*b*) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Środowiska depozycji osadów klastycznych. In: Jamno IG 1, Jamno IG 2, Jamno IG 3. Profile Głębokich Otworów. Państw. Inst. Geol., (ed. H. Matyja), **124**: 165–174.

PACZEŚNA J. and SARNECKA E. (2003) — Ichnofauna. In: Budowa Geologiczna Polski. Atlas skamieniałości. Dewon (ed. L. Malinowska). Państw. Inst. Geol., **III 1b**, (1): 607–612.

PAJCHLOWA M. (1964) — Preliminary data on Devonian in the Polish Lowlands area (in Polish with English summary). Kwart. Geol., **8** (2): 224–251.

PAJCHLOWA M. (1968) — Wstępne dane o dewonie zachodniego Pomorza. Kwart. Geol., **12** (4): 1039–1040.

PAPROTH E., DREESEN R. and THOREZ J. (1986) — Famennian paleogeography and event stratigraphy of northwestern Europe. Ann. Soc. Géol. Belgique, **109** (10): 175–186.

PAŠKEVIČIUS J. (1997) — The geology of the Baltic Republics. Lietuvos Geologijos Tarnyba. Vilnius.

PODHALAŃSKA T. and MODLIŃSKI Z. (2006) — Stratigraphy and facies characteristics of the Ordovician and Silurian deposits of the Koszalin-Chojnice zone; similarities and differences to the western margin of the East European Craton and Rügen area (in Polish with English summary). In: Facies, Tectonic and Thermal Evolution of the Pomeranian Sector of Trans-European Suture Zone and Adjacent Areas (eds. H. Matyja and P. Poprawa). Pr. Państw. Inst. Geol., **186**: 39–78.

POPRAWA P., PASZKOWSKI M., FANNING M. C., PÉCSKAY Z., NAWROCKI J. and SIKORSKA-JAWOROWSKA M. (2006) — Geochronological characteristics of source areas for the Lower Palaeozoic sediments from the NW East European Craton and Koszalin-Chojnice zone; dating of detrital mica (K/Ar) and zircon (U/Pb SHRIMP) (in Polish with English summary). In: Facies, Tectonic and Thermal Evolution of the Pomeranian Sector of Trans-European Suture Zone and Adjacent Areas (eds. H. Matyja and P. Poprawa). Pr. Państw. Inst. Geol., **186**: 149–164.

RABIEN A. (1954) — Zur Taxionomie und Chronologie der Oberdevonischen Ostracoden. Abh. Hess. L.-A. Bodenforsch., **9**.

RACKI G. and HOUSE M. R. eds. (2002) — Late Devonian biotic crisis: ecological, depositional and geochemical records. Palaeogeogr., Palaeoclimat., Palaeoecol., **181** (1–3).

RACKI G., JOACHIMSKI M. M. and MORROW J. R. eds. (2008) — A major perturbation of the global carbon budget in the Early-Middle Frasnian transition (Late Devonian). Palaeogeogr., Palaeoclimat., Palaeoecol., **269** (3–4).

RADLICZ K. (2007) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Petrografia oraz diageneza osadów dewonu. Profile Głębokich Otworów Państwowego Instytutu Geologicznego, Jamno IG 1, Jamno IG 2, Jamno IG 3 (ed. H. Matyja), **124**: 139–160.

RÓŻKOWSKA M. (1979) — Contribution to the Frasnian tetracorals from Poland. Palaeont. Pol., **40**.

RÓŻKOWSKA M. and FEDOROWSKI J. (1972) — Genus *Disphyllum* de Fromentel (Rugosa) in the Devonian of Poland and its distribution. Acta Geol. Pol., **17** (3): 265–335.

SANDBERG C. A. and ZIEGLER W. (1979) — Taxonomy and biofacies of important conodonts of Late Devonian *styriacus*-Zone, United States and Germany. Geol. Palaeont., **13**: 173–212.

SCHMIDT K. and FRANKE D. (1977) — Zur litologisch-faziellen Entwicklung des Präperms in Nordteil der DDR. Zeitschrift für Angewandte Geologie, **23** (11): 541–548.

SKOMPSKI S. (1987) — The dasycladacean nature of late Paleozoic palaeoberesellid algae. Acta Geol. Pol., **37** (1–2): 21–31.

SOMERVILLE I. D., STROGEN P. and JONES G. Ll. (1992) — Mid-Dinantian Waulsortian buildups in the Dublin Basin, Ireland. Sediment. Geol., **79**: 91–116.

SOROKIN V. S., ŁARSKAJA L. A., NARBUTAS W. W. and ŻEIBA S. I. *et al.* (1981) — Dewon i karbon Pribaltiki. Zinatne. Riga.

STASIŃSKA A. (1969) — Devonian Tabulata corals from borehole Miastko 1 (NW Poland) (in Polish with English summary). Acta Geol. Pol., **19** (4): 765–778.

STEMPIEŃ-SAŁEK M. (2002) — Miospore taxonomy and stratigraphy of Upper Devonian and lowermost Carboniferous in Western Pomerania (NW Poland). Ann. Soc. Geol. Pol., **72** (2): 163–190.

STREEL M., HIGGS K., LOBOZIAK S., RIEGEL W. and STEEMANS P. (1987) — Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenne-Rhenish regions. Rev. Palaeobot. Palynol., **50**: 211–229.

ŚWIDROWSKA J. and HAKENBERG M. (1996) — Palaeotectonic evolution of the Koszalin–Chojnice Late Devonian basin (Western Pomerania, Northern Poland). Bull. Pol. Acad. Sc. Earth Sc., **44** (1): 17–36.

THOREZ J. and DREESEN R. (1986) — A model of a regressive depositional system around the Old Red Continent as exemplified by a field trop in the Upper Famennian “Psammites du Condroz” in Belgium. Ann. Soc. Géol. Belgique, **109** (1): 285–323.

TOKARSKI A. (1959) — The profile of the Zechstein at Chojnice (in Polish with English summary). Rocz. Pol. Tow. Geol., **29** (2): 129–163.

TURNAU E. (1978) — Spore zonation of uppermost Devonian and lower Carboniferous of Western Pomerania. Mededelingen Rijks Geologische Dienst, **30** (1): 1–34.

TURNAU E. (1979) — Correlations of Upper Devonian and Carboniferous deposits of Western Pomerania based on miospore study (in Polish with English summary). Rocz. Pol. Tow. Geol., **49** (3–4): 231–269.

TURNAU E. (1995) — Palynological stratigraphy and correlation of the Middle Devonian deposits of Central Pomerania (in Polish with English summary). Prz. Geol., **43** (3): 211–214.

TURNAU E. (1996) — Miospore stratigraphy of Middle Devonian deposits from Western Pomerania. Rev. Palaeob. Palynol., **93**:107–125.

TURNAU E. (2004) — Korelacja klastyczno-węglanowych utworów dewonu środkowego i franu na obszarze Pomorza Zachodniego na podstawie analizy palinologicznej. In: Rozwój transgresji środkowodewońskiej i wczesnofrańskiej i jej zapis w środowiskach marginalnomorskich obszaru północno-zachodniej Polski. Unpubl., Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.

TURNAU E. (2007) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Palinostratygrafia. In: Polskie Łąki PIG 1. Profile Głębokich Otworów. Państw. Inst. Geol., **122**: 62–69.

TURNAU E. (2008) — Wyniki badań stratygraficznych, sedymentologicznych i petrograficznych. Dewon. Wyniki badań palinostratygraficznych. In: Jamno IG 1, Jamno IG 2, Jamno IG 3. Profile Głębokich Otworów. Państw. Inst. Geol., **124**: 125–135.

TURNAU E. and MATYJA H. (2001) — Timing of the onset of Devonian sedimentation in northwestern Poland: palynological evidence. Ann. Soc. Geol. Pol., **71** (2): 67–74.

TURNAU E. and RACKI G. (1999) — Givetian palynostratigraphy and palynofacies: new data from the Bodzentyn Syncline (Holy Cross Mountains, central Poland). Rev. Palaeobot. Palynol., **106**: 237–271.

ŪSAITYTĖ D. (2000) — The geology of the southeastern Baltic Sea: a review. Earth Sc. Rev., **50**: 137–225.

Van GELDERN R., JOACHIMSKI M. M., DAY J., JANSEN U., ALVAREZ F., YOLKIN E. A. and MA X.-P. (2006) — Carbon, oxygen and strontium isotope records of Devonian brachiopod shell calcite. Palaeogeogr., Palaeoclimat., Palaeoecol., **240**: 47–67.

WALLISER O. (1996) — Global events in the Devonian and Carboniferous. In: Global Events and Event Stratigraphy in the Phanerozoic (ed. O. H. Walliser): 225–250. Springer-Verlag: Berlin, Heidelberg.

WEDDIGE K. (1988) — Eifel conodonts. In: Guide to Field Trips. Part 1 (ed. W. Ziegler). Cour. Forsch.-Inst. Senckenberg, **102**: 103–110.

WEDDIGE K. and ZIEGLER W. (1996) — Mitteldevon Cnodonten-Zonen, globale; actueller Stand. In: Devon-Korrelationstabelle (ed. K. Weddige). Senckenberg. Leth., **76** (1–2): 278–279.

WITZKE B. J. (1990) — Palaeoclimatic constraints for Palaeozoic palaeolatitudes of Laurentia and Euramerica. In: Palaeozoic Palaeogeography and Biogeography (eds. W. S. McKerrow and C. R. Scotese). Geol. Soc. Mem., **12**: 57–73.

WIETZKE B. J. and HECKEL P. H. (1988) — Palaeoclimatic indicators and inferred Devonian paleolatitudes of Euramerica. In: Devonian of the World, I: Regional Synthesis (eds. M. J. McMillan, A. F. Embry and D. J. Glass). Canadian Soc. Petrol. Geol. Mem., **14**: 49–63.

WRIGHT V. P. and WRIGHT E. V. G. (1981) — The palaeoecology of some algal-gastropod bioherms in the Lower Carboniferous of South Wales. N. Jb. Geol. Paläont. Mh., **9**: 554–558.

ZAGORA I. (1993) — Zur Teufenabhängigkeit der Nutzporosität mitteldevonischer Sandsteine von Rügen/Vorpommern. Geologisches Jahrbuch A, **131**: 401–406.

ZAGORA K. (1993) — Sedimentationsablauf und Speicherentwicklung im Oberdevon der Insel Rügen. Geologisches Jahrbuch A, **131**: 389–399.

ZAGORA K. (1995) — Devonian of the Isle Rügen. Stud. Geoph. Geod,. **39**: 298–301.

ZAGORA I. and ZAGORA K. (1999) — Zur biostratigraphie des Oberdevons und Unterkarbons der Forschungsbohrung Pudagla 1/86 auf der Insel Usedom (NE Deutschland). Greifswalder Geowissenschaftliche Beiträge, **6**: 347–365.

ZAGORA I. and ZAGORA K. (2004) — Devon. In: Geologie von Mecklenburg–Vorpommern (ed. G. Katzung): 70–79. E. Schweizerbart'sche Verlagsbuchhandlung. Stuttgart.

ZIEGLER W. (1962) — Taxionomie und Phylogenie oberdevonischer Conodonten und ihre stratigraphische Bedeutung. Abh. Hessischen Land. Bodenforsch., **38**: 1–166.

ZIEGLER W. and SANDBERG C. A. (1984*a*) — Important candidate sections for stratotype of conodont based Devonian–Carboniferous boundary. Cour. Forsch.-Inst. Senckenberg, **67**: 231–239.

ZIEGLER W. and SANDBERG C. A. (1984*b*) — *Palmatolepis*-based revision of upper part of standard Late Devonian conodont zonation. In: Conodont Biofacies and Provincialism (ed. D. L. Clark). Geol. Soc. Amer. Spec. Paper, **196**: 179–194.

ZIEGLER W. and SANDBERG C. A. (1990) — The Late Devonian Standard Conodont Zonation. Courier Forsch.-Inst. Senckenberg, **121**.

ZIEGLER W. and SANDBERG C. A. (1994) — Conodont phylogenetic-zone concept. Newsl. Stratigr., **30**: 105–123.

ŻBIKOWSKA B. (1983) — Middle to Upper Devonian ostracods from northwestern Poland and their stratigraphic significance. Palaeont. Pol., **44**: 3–108.

ŻBIKOWSKA B. (1992) — Entomozoidy (małżoraczki) górnego dewonu i najniższego karbonu Pomorza Zachodniego. Prz. Geol., **40** (10): 612.

ŻELICHOWSKI A. M. (1983) — The Carboniferous in Western Pomerania. Prz. Geol., **31** (6): 356–364.

ŻELICHOWSKI A. M. (1987) — Stratygrafia i rozwój sedymentacji; karbon. In: Budowa geologiczna wału pomorskiego i jego podłoża (ed. A. Raczyńska). Pr. Inst. Geol., **119**: 26–51.