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Stratigraphy of the Devonian in the Szwejki IG 3 deep well, Central Poland

Detailed biostratigraphic investigations of conodonts and ostracods indicate the presence of the late Eifelian *kockelianus* Zone in the lower part of the Devonian sequence. Its upper portion has been ascribed to the earliest Frasnian (not older than the upper part of the *falsiovalis* Zone). However, boundaries of the Givetian have not been precisely defined due to a poor biostratigraphic control. The studied section reveals many similarities to the development of the Devonian succession in the northern Łysogóry Region (Holy Cross Mts.) located ca. 90 km to the south-east. Both the sequences display similar litho- and biofacies development and comparable thicknesses of the chronostratigraphic units.

INTRODUCTION

The Szwejki IG 3 well was drilled for the Polish Geological Institute during 1986–1988 in Kaleń village near Nowe Miasto town at Pilica river (Fig. 1). The occurrence of an up to 1250 m thick Devonian epicontinental succession has been found at depth 4226.0 to 5501 m (J. Malec *et al.*, 1991). The section is of considerable regional importance as it represents the northwesternmost well record of the southern Polish Devonian shelf area (M. Narkiewicz, 1985). About 100 km to the west of the section one may expect a transition from continental slope to deeper basinal facies related to the Devonian passive margin of the Old Red Continent (Laurussia).

The aim of the present paper is to establish a chronostratigraphic framework of the Devonian deposits in the Szwejki IG 3 well basing almost exclusively on the micropalaeontological studies of conodonts and ostracods. It is planned that these studies will provide a starting point for more detailed stratigraphic correlations based on precise reconstruction of sedimentary events recorded in the Devonian depositional sequences. Here, we will restrict our considerations to general comparisons with the Devonian succession of the

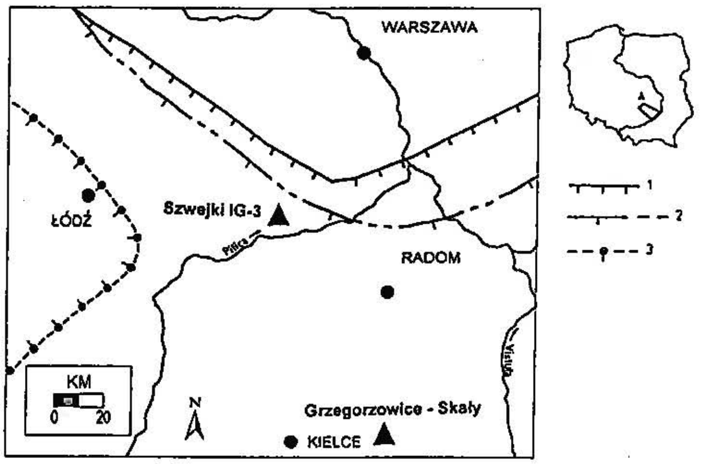

Fig. 1. Location of the Szwejki IG 3 well section and the Grzegorzowice – Skały section

The map of Poland (upper right) shows the location of the studied section and the outline of the Holy Cross Mts; 1 — interpreted limit of the continental Lower Devonian deposits of the Zwoleń Formation; 2 — interpreted limit of the Givetian deposition; 3 — probable boundary between deeper basinal and epicontinental sedimentation

Lokalizacja profilu otworu wiertniczego Szwejki IG 3 i Grzegorzowice – Skały w północnej części Gór Świętokrzyskich

1 — interpretowany zasięg lądowych osadów dolnodewońskich formacji zwoleńskiej; 2 — zasięg osadów żyweckich; 3 — przypuszczalna granica między sedymentacją epikontynentalną a głębszego basenu

Łysogóry Region in the northern Holy Cross Mts. some 90 km to the south-east of the studied well section. The above succession is the nearest reference area with a detailed stratigraphic subdivision of the entire Devonian succession.

LITHOSTRATIGRAPHIC FRAMEWORK

Following informal lithostratigraphic subdivision (Fig. 2) has been established basing on both wireline logs (gamma and neutron-gamma) and core descriptions. Details of lithology and fossil content have been interpolated between cores which obviously casts some doubt on the representativeness of short descriptions given below. However, gross lithological patterns have been certainly reflected in the diagnoses of the following units (in ascending order):

1. **Calcareous-Dolomitic Marls Unit** (depth interval 5501.0–5305.0 m; thickness 196 m, not pierced). The unit consists of dark grey and grey-brownish marls with intercalations of marly limestones and dolostones. Dolomite content varies irregularly from insignificant admixture to total replacement of primary calcareous deposits by fine-crystalline dolosparite. In general, the rocks are developed as clayey-carbonate skeletal mudstones to packstones. Fossil assemblage, abundant in places, includes i.a. brachiopods, solitary and colonial corals, crinoids, cephalopods, plant detritus, gastropods and trilobites.

2. **Marls and Limestones Unit** (5305.0–5156.0 m; 149 m). The unit is characterized by variable succession of carbonate-clayey deposits with changing proportion of terrigenous clay admixture: from almost pure limestone (depth 5255 to 5270 m) passing upwards into calcareous marls and downwards (lower 25 m of the unit) into clayey marls. The above changes are clearly expressed on the gamma log (Fig. 2). The described unit differs from the lower one in overall increased clay admixture, insignificant dolomite content (which seems to be, however, secondary in origin) and less abundant and less diverse fossil assemblage. The latter includes Articulata and Inarticulata brachiopods, uncommon crinoids, small bivalves, cephalopods, conularids and imprints of non-skeletal algae. Moreover, rare branching and massive corals have been found in more calcareous beds.

3. **Claystones, Marls and Limestones Unit** (5156.0–5048.0 m; 108 m). Wireline logs indicate a characteristic bipartite development of the unit. Lower part is built of black to dark grey claystones and dolomitic-calcareous marls with subordinate carbonate-rich intercalations containing more abundant skeletal material of brachiopods, crinoids, branching and massive corals. In places, ostracods, bivalves and lingulids form abundant shell accumulations on bedding surfaces of claystones and marls. Upper part of the unit, from ca. 5100 m upwards, represents intercalations of black to grey claystones, marls and limestones. The latter contain, in addition to Articulata brachiopods, also solitary corals and domal stromatoporoids, particularly in the uppermost part of the unit.

4. **Sandy Unit** (5048.0–5036.5 m; 11.5 m). Although rather thin, this unit has been separately distinguished as it represents a unique lithofacies in the whole described section. Lower 7.5 m are formed of continuous light grey quartz arenites with cross-bedding, ripple and flat horizontal laminations. Upwards in the section there occur intercalations of dark grey dolosparites and clayey-dolomitic marls with a bioturbation.

5. **Calcareous-Clayey Unit with Stromatoporoid Biostromes** (5036.5–4673.0 m; 363.5 m). Lower part, up to a depth 4806.0 m, is built of dark grey limestones, partly dolomitized mudstones to skeletal wackestones with a variable although generally insignificant clay admixture. Near the base of the unit the limestones show a nodular appearance whereas upwards they commonly display biostromal development, with abundant branching stromatoporoids. Other skeletal constituents include gastropods, domal stromatoporoids and crinoids. Dark clayey-dolomitic marls represent a less important lithology. In the upper part of the unit biostromes decrease in proportion and are partly replaced by black marls and marly limestones, greenish claystones and even some terrigenous mudstones with muscovite, and rare quartz arenites. Near the top of the unit, grey fine- to medium-grained calcarenites have been found intercalated within more clayey deposits.

6. **Middle Claystones Unit** (4673.0–4529.0 m; 144 m). Typical for the unit are dark grey marly claystones with intercalations of brownish to grey-greenish claystones. Near the top, there is a few-metres thick intercalation of black clayey limestones with crinoids and corals. The claystones contain remains of brachiopods, crinoids, phyllopod test accumulations and plant detritus. Present are also rare intercalations of redeposited skeletons of branching and domal stromatoporoids.

7. **Stromatoporoid-Coral Unit** (4529.0–4351.0 m; 178 m). Typical lithology is represented by pure lime mudstones to Amphipora wackestones displaying grey-beige colour. Important are also biostromal limestones with variable proportion of domal stromatopo-

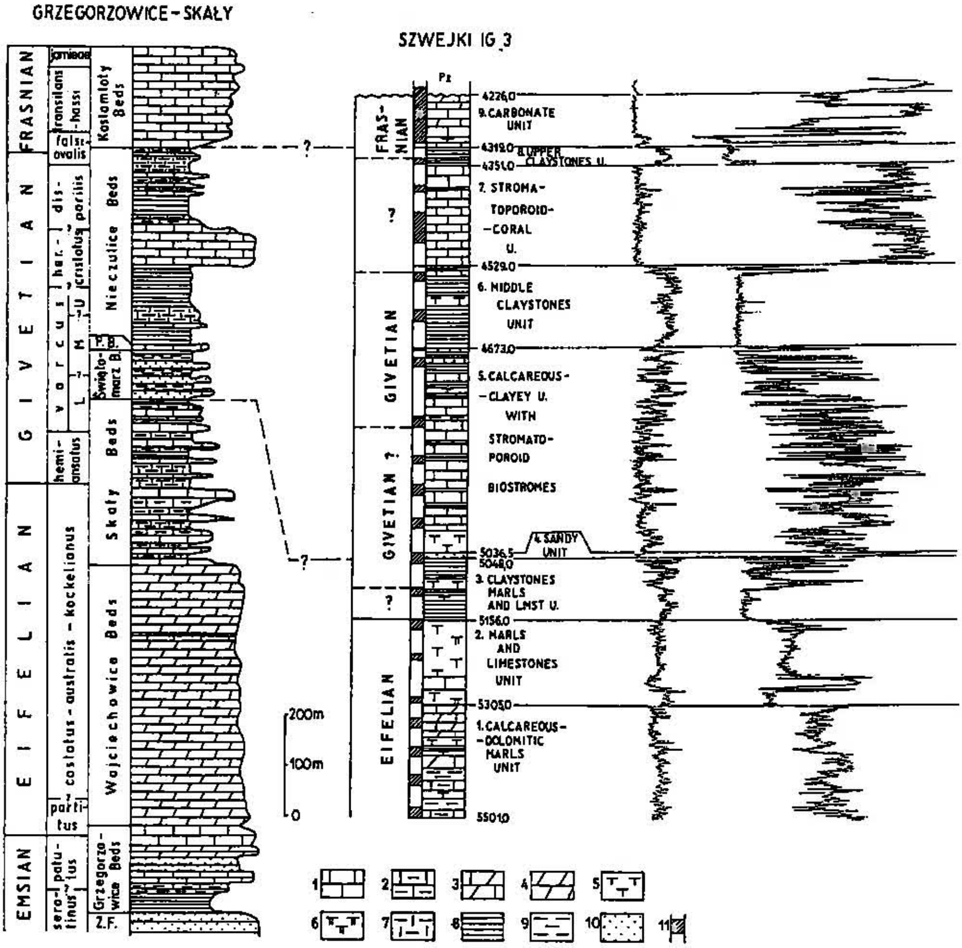

Fig. 2. Comparison of the Szwejki IG 3 section with the Grzegorzowice – Skały section in the northern Holy Cross Mts.; stratigraphic division of the Devonian in the Szwejki IG 3 well shown against general lithology and gamma (left) and neutron-gamma logs; conodont zonation after C.-D. Clausen *et al.* (1993)

Pz — Zechstein; 1 — limestones, 2 — marly limestones, 3 — dolomitic limestones and/or calcareous dolostones, 4 — dolostones, 5 — marls, 6 — dolomitic marls, 7 — calcareous claystones, 8 — claystones, clay shales, 9 — mudstones, 10 — sandstones, 11 — cored interval

Porównanie profilu Szwejki IG 3 z profilem Grzegorzowice – Skały w północnej części Gór Świętokrzyskich; podział stratygraficzny dewonu w otworze Szwejki IG 3 przedstawiono na tle ogólnego wykształcenia litologicznego oraz krzywych karotażowych gamma (lewa) i neutron-gamma; poziomy konodontowe według C.-D. Clausen i in. (1993)

Pz — cechsztyn; 1 — wapienie, 2 — wapienie margliste, 3 — wapienie dolomityczne i/lub dolomity wapniste, 4 — dolomity, 5 - margle, 6 — margle dolomityczne, 7 — iłowce wapniste, 8 — iłowce, łupki ilaste, 9 — mułowce, 10 — piaskowce, 11 — interwały rdzeniowane

roids, branching corals, gastropods, crinoids and brachiopods. Less important are fenestral mudstones, and quite subordinate — calcareous marls, claystones and nodular limestones.

8. **Upper Claystones Unit** (4351.0–4319.0 m; 32 m). The unit is built of grey and brownish marly claystones with rare brachiopods and with accumulations of ostracod and phyllopod valves. Some more calcareous intercalations contain redeposited skeletons of brachiopods, branching and platy corals and/or stromatoporoids, and crinoids.

9. **Carbonate Unit** (4319.0–4226.0 m; 93 m — reduced due to pre-Zechstein erosion). The lower boundary of the unit is placed at the base of the limestone intercalation being 8 m thick and clearly expressed on the wireline logs. Above, there occur 10 m of almost black to greyish-greenish claystones with ostracods and lingulids. These are succeeded by characteristic light purely carbonate deposits. They have been developed originally as stromatoporoid-coral boundstones with stromatactis structures and with detrital intercalations of rudstones and skeletal calcarenites. The biolithites are irregularly replaced by light porous fine-crystalline dolosparite whose thicker packages are distinctly expressed as lowered values on the neutron-gamma log (Fig. 2).

BIOSTRATIGRAPHY

CONODONTS

Overall, 39 samples have been processed with an average weight of 0.5 to 3.0 kg. Ten positive samples yielded ca. 130 conodont elements ascribed to 12 form-taxa. In general, frequency is low and ranges from 2 to 7 specimens per sample. Only one sample from the depth 5172.5 m yielded ca. 100 conodonts. Biostratigraphical analysis has been carried out basing on platform elements in six samples (Tab. 1). Stratigraphic ranges of particular taxa were related to the recent subdivision of the Devonian in the Rhenish Slate Mts. (C.-D.Clausen *et al.*, 1993; O. H. Walliser *et al.*, 1995; see Fig. 2).

In the lowermost sample from 5279.5 m only two specimens have been found and were determined as *Icriodus regularicrescens* Bultynck. This species ranges from the *costatus* Zone to the lowermost part of the Lower *varcus* Zone (P. Bultynck, 1989, 1995/1996). It has a widespread occurrence and has been found in Europe, northern Africa, North America and China. Diverse assemblage comprising eight taxa has been found in the sample from depth 5172.5 m. Most abundant is genus *Icriodus* (67% of all specimens) with two species: *I. regularicrescens* Bultynck (Pl. I, Fig. 1) and *I. introlevatus* Bultynck (Pl. I, Figs. 6, 7, 8). Precise range of the latter species has not been established yet. P. Bultynck and H. Hollard (1980) found it in the Bou Tchafrine section, beds 1 to 14 (Marocco). The youngest bed can be correlated with the *kockelianus* Zone (P. Bultynck, 1987). On the other hand, C. Y. Wang and W. Ziegler (1981) found *I. introlevatus* Bultynck in the Huobshan Formation (northern part of China, locality 1, mountain SE of Wunur). The age of the cited formation is interpreted as Givetian. *Polygnathus angustipennatus* Bischoff et Ziegler (Pl. I, Fig. 2) is an Eifelian species and does not range into the Givetian (P. Bultynck, 1987, 1989; K. Weddige, W. Struve, 1988). Its occurrence determines the upper age limit of the sample as the *kockelianus* Zone. Presence of *P. alexanderensis* Savage (Pl. I, Figs. 3, 4) and *P.* cf. *P. ensensis* Ziegler et Klapper (Pl. I, Fig. 9) constrains the sample age to this very zone. The former species is known from southeastern Australia where its occurrence is limited to the *kockelianus* Zone (N. M. Savage, 1995). Within this zone also early rare representatives of

Table 1

Conodont occurrence in the Szwejki IG 3 well section

Conodonts	Chronostratigraphy					
	Upper Eifelian		Givetian-Frasnian			
	conodont zone					
	costatus-kockelianus	*kockelianus*	Lower *varcus*-Early *falsiovalis*		Early *falsiovalis*	
	sample depth [m]					
	5279.5	5172.5	4546.4	4542.0	4343.8	4343.0
Icriodus regularicrescens Bultynck, 1970	2	25				
Icriodus introlevatus Bultynck, 1970		19				
Icriodus subterminus Youngquist, 1947					1	1
Icriodus sp. indet.		24	2	1		
Polygnathus angustipennatus Bischoff et Ziegler, 1957		1				
Polygnathus alexanderensis Savage, 1995		3				
Polygnathus sp. n.		1				
Polygnathus cf. *P. ensensis* Ziegler et Klapper, 1976		1				
Polygnathus xylus xylus Stauffer, 1940				1	1	
Polygnathus l. linguiformis Hinde, 1879 gamma morphotype Bultynck, 1970		5				
Polygnathus cf. *P. timorensis* Klapper, Philip et Jackson, 1970			1			
Polygnathus cf. *P. ordinatus* Bryant, 1921					1	
Polygnathus sp. indet.		20				
Belodella devonica (Stauffer, 1940)		2				1
Mehlina sp.						1
Ramiform elements	2	4	2		4	3

P. ensensis Ziegler et Klapper have been found (P. Bultynck, 1987, 1989). The investigated specimen displays three weak serrations on the outer margin and none on the inner one (Pl. I, Fig. 9). Typical representatives of *P. ensensis* Ziegler et Klapper with distinctly serrated margins of the anterior platform appear as late as in the *hemiansatus* Zone.

Sample from the depth 4546.4 m yielded 5 conodonts, including a single specimen determined as *P.* cf. *P. timorensis* Klapper, Philip et Jackson. Its range represents the interval from the Lower *varcus* Zone (Givetian) to the Early *falsiovalis* Zone (Givetian/Frasnian). Single specimen of *P. xylus xylus* Stauffer from the upper sample is a long-ranging form and thus unimportant for biostratigraphic considerations.

Two successive samples from depths 4343.8 and 4343.0 m are discussed collectively as they are located very closely in the section. Upper age limit is defined by the upper range of *P.* cf. *P. timorensis* Klapper, Philip et Jackson as the Early *falsiovalis* Zone whereas appearance of *I. subterminus* Youngquist (Pl. I, Fig. 11) constrains the age to this very zone (P. Bultynck, 1995/1996). The specimen described as *P.* cf. *P. timorensis* Klapper, Philip et Jackson (Pl. I, Fig. 10) is a juvenile form hardly discernible from juvenile specimens of *P. ansatus* Ziegler et Klapper (W. Ziegler *et al.*, 1976). The latter species is characteristic for the Middle *varcus* Zone (P. Bultynck, 1987) although R. Mawson and J. A. Talent (1989) found it higher, namely in the Early *hermanni-cristatus* Zone. The taxonomic determination of the above specimen as *P.* cf. *P. timorensis* Klapper, Philip et Jackson was based i.a. on the assumption that an occurrence of *P. ansatus* Ziegler et Klapper in such a high stratigraphical position seems rather unlikely.

In summary, two lowermost samples represent the late part of the Eifelian. The age of the sample from depth 5172.5 m can be narrowed to the *kockelianus* Zone. The deposits from the depth interval between 4546.4 and 4343.0 m can be attributed to the wide age interval spanning Givetian and, possibly, also earliest Frasnian. Stratigraphic range of conodonts found at depths 4546.4 and 4542.0 m is wide: from the Lower *varcus* Zone to the Early *falsiovalis* Zone. On the other hand, the age of two uppermost samples is limited to the Early *falsiovalis* Zone.

OSTRACODS

In general, 38 samples have been processed of which 17 yielded determinable ostracod material. From the lower part of the section, below depth 5165.1 m, only few indeterminable poorly preserved specimens have been obtained. More abundant assemblages occur within the depth interval 4307.0 to 5156.0 m, where nearly 300 specimens belonging to 31 genera have been found. Twenty taxa have been determined on a species level, 23 forms on a generic level and some specimens have been generally ascribed to *Ostracoda* indet. because of a poor preservation (Tab. 2). Illustrated on Plates II to IV are stratigraphically important taxa and/or those interesting from the systematic point of view.

The oldest of more diverse ostracod assemblages has been found at depth 5156.0 m (Tab. 2). Species *Polyzygia trigonata* (Gürich), *P. insculpta insculpta* Becker, *Bufina schaderthalensis* Zagora are known to range from the late Eifelian to early Givetian (K. Zagora, 1968; H. Groos, 1969; F. Adamczak, 1971, 1976; M. P. Michel, 1972; G. Becker, 1988; J. G. Casier *et al.*, 1992). *Poloniella tertia* Krömmelbein (Pl. II, Fig. 6) is documented from the deposits of early Eifelian to late Givetian age (K. Krömmelbein, 1953; H. Groos, 1969; B. Żbikowska, 1983; J. Malec, 1989). In turn, *Bythocyproidea puschi* Adamczak (Pl. III, Figs. 3, 4) has been found in the Grzegorzowice – Skały section (Łysogóry Region, Holy Cross Mts., see Fig. 1 for a locality) where it occurs in the lower part of the Skały Beds in complexes XIII to XIV, according to the stratigraphic subdivision by M. Pajchlowa (1957; *cf.* Fig. 2) (F. Adamczak, 1976; J. Malec, 1984, 1988; J. Malec *et al.*, 1995). *Ponderodictya aggeriana* Groos has been first described from the lower Eifelian of the Rhenish Slate Mts. (H. Groos, 1969). In the Holy Cross Mts. this species occurs in the lower part of the Skały Beds in complexes XIII to XIV (A. Přibyl, 1953; F. Adamczak, 1976; J. Malec, 1984, 1988; J. Malec *et al.*, 1995). The above assemblage is characteristic for the lower part of the Skały Beds in the Łysogóry Region. According to the conodont zonation those deposits represent the lower part of the *kockelianus* Zone of the late Eifelian (J. Malec,

Occurrence of the ostracods

Ostracods	Chronostratigraphy			
	Eifelian	Givetian		
	sample depth [m]			
	5156.0	5105.1	4975.5	4924.2
Ostracoda indet.	8	11	4	5
Poloniella sp.		5	1	
Poloniella tertia Krömmelbein, 1953	3			
Polyzygia trigonata (Gürich, 1900)	1			
Polyzygia insculpta insculpta Becker,1964	1			
Bufina schaderthalensis Zagora, 1968	1			
Ponderodictya aggeriana Groos, 1969	1			
Bythocyproidea puschi Adamczak, 1976	2			
Evlanella mirabilis Adamczak, 1968		1		
Cytherellina sp. 1		3		
Balantoides sp.		1		
Jenningsina sp.		3		
Cryptophyllus sp.		3		
Punctoprimitia sp.		2		
Graphiadactyllis? sp.		1		
Fellerites sp.			1	
Leperditia sp.				2
Parapribylites hanaicus (Pokorny, 1950)				
Orthocypris sp.				
Cavellina devoniana Egorov, 1950				
Healdianella resima (Rozhdestvenskaya, 1959)				
Cytherellina obliqua (Kummerow, 1953)				
Bairdiocypris sp.				
Bairdia paffrathensis Kummerow, 1953				
Microcheilinella sp.				
Kozlowskiella sp.				
Praepilatina sp.				
Sulcella (*Postsulcella*) sp.				
Poloniella trisinuata (Van Pelt, 1933)				
Quasillites (*Q.*) *quasillitiformis* (Polenova, 1952)				
Microcheilinella fecunda (Přibyl et Šnajdr, 1950)				
Jenningsina cavernosa (Polenova, 1952)				
Bufina sp.				
Jefina sp.				
Quasillites sp.				
Semilukiella polita Żbikowska, 1983				
Orthocypris perlonga Kummerow, 1953				
Cytherellina sp. 2				
Polyzygia symmetrica Gürich, 1896				
Polyzygia neodevonica (Matern, 1929)				
Favulella sp.				
Hollinella sp.				
Uchtovia sp.				
Acratia sp.				

Table 2

in the Szwejki IG 3 well section

Chronostratigraphy								
Givetian						Givetian?-Frasnian?	Frasnian	
sample depth [m]								
4811.1	4800.1	4796.0	4616.5	4605.1	4551.0	4546.0	4345.0	4307.0
				2	22			5
					1			
9								
2						1	4	
2								
3		31			1			
4								
1						1		
1								
	1							
		3						
		2						
		1						
			1					
			2					
			3					
			2					
			1					
			2					
			3					
				1				
				1				
					4			
					10			
							1	
							92	
								1
								1
								2

1988). The same age can be ascribed to the sample from depth 5156.0 m in the Szwejki IG 3 well.

The assemblage containing i.a. *Evlanella mirabilis* Adamczak and *Balantoides* sp. (Pl. II, Fig. 2) has been found at depth 5105.1 m. In the Holy Cross Mts., the former species occurs in the lower to middle part of the Skały Beds, mostly in the upper Eifelian but also in the lowermost Givetian (F. Adamczak, 1968, 1976; J. Malec, 1984, 1988). However, characteristic specimens belonging to genus *Balantoides*, virtually the same as those from the studied well, appear only in the lowermost Givetian of the Skały section (complex XX) attributed to the *hemiansatus* Zone (J. Malec, 1984, 1988). Sample from depth 5105.1 m can be ascribed to the boundary interval between the stages or, what is more probable, to the lower Givetian.

Among the taxa described in the sample from depth 4811.1 m, *Bairdia paffrathensis* Kummerow (Pl. IV, Fig. 11) ranges from the late Eifelian to the middle Frasnian. However, it is most ubiquitous in the middle to late Givetian (G. Becker, 1965*a, b*, 1971; H. Groos, 1969; J. G. Casier, 1987; J. G. Casier, A. Preat, 1991). In Poland, this species has been described from the middle and upper Givetian of the Holy Cross Mts. (E. Olempska, 1979; J. Malec, 1984, 1988) and upper Givetian of Pomerania (B. Żbikowska, 1983). Two other species, *Cytherellina obliqua* (Kummerow) (Pl. IV, Fig. 1) and *Healdianella resima* (Rozhdestvenskaya) are known from the upper Givetian in Pomerania (B. Żbikowska, 1983), whereas the latter is also known from the upper Givetian of Russia (A. A. Rozhdestvenskaya, 1959). In the Eifel Mts. and Rhenish Slate Mts., the former species occurs in the Eifelian and Givetian deposits (G. Becker, 1965*a, b*; H. Groos, 1969). Representatives of *Cavellina devoniana* Egorov (Pl. II, Fig. 15) are known from the middle to upper Givetian of northern France and the Ardennes Mts. (M. Coen, 1985; B. Milhau, 1988). *Parapribylites hanaicus* (Pokorny) (Pl. II, Fig. 1) is characteristic for the Givetian (V. Pokorny, 1950; H. Groos, 1969; B. Żbikowska, 1983; M. Coen, 1985). In the Łysogóry Region of the Holy Cross Mts. this species first appears in the middle part of the Skały Beds (complex XX) in the *hemiansatus* Zone (J. Malec, 1984, 1988). Above described ostracod assemblage from depth 4811.1 m points to the Givetian, probably middle Givetian age.

In the stratigraphically important assemblage from depth 4616.5 m seven taxa have been determined, including four species: *Poloniella trisinuata* (Van Pelt) (Pl. II, Fig. 7), *Quasillites (Q.) quasillitiformis* (Polenova) (Pl. III, Figs. 5, 6), *Microcheilinella fecunda* (Přibyl et Šnajdr) (Pl. IV, Figs. 4, 5) and *Jenningsina cavernosa* (Polenova) (Pl. II, Figs. 4, 5). The above species have been described in the Polish Devonian from the upper Givetian of Pomerania (B. Żbikowska, 1983). In other areas, such as European Russia, Czech Republic, U.S.A., Holy Cross Mts., particular species mentioned above are cited from the upper Givetian or, more generally, from the Middle Devonian (G. A. Stewart, 1936; A. Přibyl, M. Šnajdr, 1950; E. N. Polenova, 1952; E. Kummerow, 1953; R. V. Kesling, R. B. Chilman, 1978). One can suppose that the assemblage indicates the late Givetian age of the deposits at depth 4616.5 m.

At depth 4605.1 m two ostracod species have been determined: *Orthocypris perlonga* Kummerow (Pl. III, Fig. 14) and *Semilukiella polita* Żbikowska (Pl. II, Fig. 14). The former species is known from both the Eifelian and Givetian deposits (E. Kummerow, 1953; G. Becker, 1965*a, b*; H. Groos, 1969; B. Żbikowska, 1983). In the Polish Devonian, both species have been described from the upper Givetian of Pomerania (B. Żbikowska, 1983).

At depth 4551.0 m there occurs an assemblage comprising the following taxa: *Polyzygia symmetrica* Gürich, *Healdianella resima* (Rozhdestvenskaya) (Pl. IV, Fig. 10) and *Cytherellina* sp. 2 (Pl. III, Figs. 11, 12). The first of above mentioned taxa is known in the Łysogóry Region from the upper Eifelian to upper Givetian, spanning the conodont zones from the lower *kockelianus* to *disparilis* (F. Adamczak, 1976; J. Malec, 1984, 1988; J. Malec *et al.*, 1995). In the Kielce Region, however, *Polyzygia symmetrica* Gürich has been noted in the middle and upper Givetian (G. Racki *et al.*, 1985; J. Malec, G. Racki, 1992). In the European Devonian this species is widely known from the Eifelian and Givetian (M. P. Michel, 1972; G. Becker, M. J. M. Bless, 1974; G. Becker, 1988; J. G. Casier, A. Preat, 1991). Its presence in the studied section indicates that the age of the sample from depth 4551.0 m is not younger than Givetian and most probably is limited to a late part of the Givetian.

At depth 4345.0 m there occurs *Polyzygia neodevonica* (Matern) known in the European Devonian from the uppermost Givetian to Famennian. However, it is most characteristic and widespread in the lower Frasnian (F. Adamczak, 1971; G. Becker, 1971, 1988; M. P. Michel, 1972; M. Coen, 1982; F. Lethiers, 1982; F. Lethiers *et al.*, 1985; B. Milhau, 1983, 1988; J. G. Casier, 1987, 1988, 1989; J. G. Casier, X. Devleeschouwer, 1995; S. Crasquin-Soleau *et al.*, 1994). At the same depth also specimens of *Orthocypris* sp. have been found (Pl. IV, Fig. 12) as well as abundant assemblage of *Favulella* sp. (Pl. II, Figs. 8–11). In the European Devonian, rare representatives of this genus (*F. lecomptei* Becker, *F. spissa* Żbikowska) occur in the lower and middle Frasnian (G. Becker, 1971; F. Lethiers, 1982; F. Lethiers *et al.*, 1985; B. Żbikowska, 1983; J. G. Casier, 1987). *F. lecomptei* Becker co-occurs with *P. neodevonica* (Matern). Basing on this species the ostracod zone has been established which is comprised within the conodont *transitans* to Early *hassi* Zones (F. Lethiers, 1982; J. G. Casier, 1987).

Specimens of *Favulella* from the Szwejki IG 3 well most probably represent a new species. Taking into account the known stratigraphic range of *Favulella* in the Upper Devonian of Europe one may assume that an age of the studied *Favulella* assemblage overlaps with this range. This would indicate indirectly that the part of section at depth 4345.0 m can be attributed to the *transitans* to Early *hassi* Zones of the lower Frasnian.

OTHER FOSSILS

Among other organic groups found in the Szwejki IG 3 well only tetracorals have been studied in more detail (J. Fedorowski, 1990). Moreover, some scattered observations have been made with respect to brachiopods and crinoids.

Investigations of tetracorals enabled J. Fedorowski to distinguish three distinct assemblages. The older one, found within the interval 5336.3 to 5498.1 m, is composed of the following taxa: *Favosites goldfussi* d'Orbigny, *Thamnophyllum caespitosum* (Goldfuss), *Heliolites porosus* (Goldfuss), *Syringopora* cf. *vulgaris* Yanet, *Grypophyllum* cf. *primum* (Wedekind), *Alveolites* sp. and *Pterorrhiza* sp. According to J. Fedorowski, the age of the assemblage is limited to the Givetian (its early part?). Second assemblage, described from depth 4538.4 to 4545.5 m, contains the following taxa: *Alveolites obtortus* Lecompte, ?*Thamnopora* sp., *Ceratophyllum* cf. *kielcensis* Różkowska, *Thamnophyllum* cf. *germanicum* Scrutton, *Thamnophyllum* sp., *Disphyllum* sp., *Pterorrhiza bathycalyx* (Frech). The age of the assemblage is upper Givetian. Uppermost assemblage, from the depth interval 4297.7 to 4300.3 m, is composed of *Pterorrhiza* sp., *Crassialveolites evidens* Dubatalov and *Disphyllum* cf. *caespitosum* (Goldfuss). The above taxa indicate, according to J. Fedorowski, a boundary interval between the Givetian and Frasnian.

Two preliminarily described brachiopod forms appear to have a certain stratigraphic significance. *Emanuella* sp., found at depth 5158.7 m is characteristic for the lower part of the Givetian in the eastern Lublin area and in Podolia (Ukraine) (L. Miłaczewski, 1981). Moreover, *Uchtospirifer* sp. (4613 m) is known from the lowermost Frasnian of the Ardennes and Timan.

Lastly, one should mention the occurrence of the crinoid remains identified as *Cupressocrinites gracilis* Goldfuss at depths 5335.0 to 5344.0 m. The stratigrahic range of this species is Eifelian-lower Givetian (E. Głuchowski, 1993).

CHRONOSTRATIGRAPHIC CONCLUSIONS

Biostratigraphic conclusions have been based upon the investigations of different organic groups and have different levels of precision. They cover the section not uniformly, and, moreover, they are to some degree contradictory. The most consistent are the results of micropalaeontological studies of conodonts and ostracods. In particular, studies of both the groups are in agreement with the late Eifelian age of the topmost part of the Unit 2 (Marls and Limestones). The uppermost ostracod sample attributed to the Eifelian is located at depth 5156.0 m. In view of those results, the Givetian age of the lowermost coral assemblage from depth interval 5336.3 to 5498.1 m (J. Fedorowski, 1990) is regarded as problematic here.

The lowermost presumable occurrence of the Givetian deposits is indicated by ostracods at depth 5105.1 m, whereas firmly established Givetian has been found at 4811.1 m. Thus, the boundary between the Eifelian and Givetian runs probably within the interval 5156.0 to 5105.1 m, and certainly between the former depth and 4811.1 m. The latter interval corresponds to the Unit 3 and a lower part of the Unit 4 (Fig. 2).

Ostracod samples from the depth interval 4616.5 to 4551.0 m have been attributed to the Givetian. The conodont samples localized few metres above the latter depth indicate the age interval spanning a considerable part of the Givetian up to the *falsiovalis* Zone which comprises the upper boundary of the stage. The narrow age represented by this very zone has been found in two samples from the Upper Claystones Unit (8). The age of the closely localized ostracod sample (depth 4345.0 m) suggests the early Frasnian age of the discussed interval. This conclusion is not contradicted by the age of the coral assemblage from the depth interval 4300.3 to 4297.7 m, interpreted by J. Fedorowski as a boundary interval between the Givetian and Frasnian. In the light of the above results one may suppose that the Middle/Upper Devonian boundary runs closely to the depth 4345.0 m and thus near the base of the Upper Claystones Unit (8). However, when rigorously applying principles of age determination one should regard the entire interval between the 4542.0 and 4345.0 m as a probable range of the above stratigraphic boundary. The deposits above the latter depth belong to the Frasnian with a highest degree of confidence.

COMPARISONS WITH THE ŁYSOGÓRY REGION

The Devonian sections with detailed stratigraphic control and at the same time located as close as possible to the Szwejki IG 3 well have been investigated about 90 km to the south, in surface exposures of the Łysogóry Region in the northern Holy Cross Mts. (Fig. 1). More precise correlation appears however difficult due to uncertain age of several lithostratigraphic units in the investigated well section. It is only possible to indicate here certain general differences and similarities reflecting disparities and analogies in palaeogeographic location of both localities against the epicontinental shelf of southern Poland during the Middle to Late Devonian.

The comparison to the Grzegorzowice – Skały section (Fig. 2; J. Malec, in press) reveals a general similarity in a lithological development of the interval correlatable with the Skały to Kostomłoty Beds. In both sections this interval is represented by carbonate-clayey deposits with abundant and diverse benthic fauna dominated in places by rich brachiopod assemblages, and with intercalations of pure carbonates of biostromal nature. In the investigated section we did not find any facies equivalents of the thick carbonate platform system with a considerable proportion of peritidal dolomites, typical for the Wojciechowice Beds in the Łysogóry Region (Fig. 2). This may suggest that the investigated section spans only the upper part of the Eifelian sequence i.e. the age equivalent of a lower part of the Skały Beds. Alternatively, the age equivalent of the Eifelian carbonate platform of the Łysogóry Region may be developed here as subtidal but still shallow-marine deposits of the Unit 1, and, probably, also part of the Unit 2.

Comparison of sediment thicknesses seems to confirm analogies between both locations. Total thickness of the Middle Devonian in the Grzegorzowice – Skały section is estimated as ca. 1400 m, while in the Szwejki IG 3 section thickness of the series (without a lower part of the Eifelian) probably ranges to ca. 1150 m. When comparing both the sections in more detail it seems rather striking that both include a unique intercalation of thicker siliciclastic deposits developed as the Świętomarz Beds in the Łysogóry Region and as the Sandy Unit (4) in the Szwejki IG 3 well. The present investigations do not preclude the age-equivalence of both the units, however, further detailed biostratigraphic analyses are required to confirm this supposition. Another striking feature common to both the sections is a similar development of the Middle to Upper Devonian boundary interval displaying a lithological contrast between the marly-clayey deposits and the overlying pure carbonate facies of the Kostomłoty Beds and the Carbonate Unit (9) (Fig. 2).

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STRATYGRAFIA DEWONU W OTWORZE WIERTNICZYM SZWEJKI IG 3, POLSKA CENTRALNA

Streszczenie

Otwór wiertniczy Szwejki IG 3 koło Nowego Miasta nad Pilicą obejmuje najdalej ku północnemu zachodowi położony profil dewonu epikontynentalnego, reprezentujący środkowo- i późnodewoński szelf południowej Polski (fig. 1). W badanym profilu wydzielono 9 nieformalnych jednostek litostratygraficznych odznaczających się charakterystycznym zapisem karotażowym (fig. 2). Są to od dołu:

1. Seria margli wapienno-dolomitycznych (miąższość 196 m, nie przewiercona).
2. Seria margli z wapieniami (149 m).
3. Seria iłowców, margli i wapieni (108 m)
4. Jednostka piaszczysta (11,5 m)
5. Seria wapienno-iłowcowa z biostromami stromatoporoidowymi (363,5 m).
6. Seria iłowców środkowych (144 m).
7. Seria stromatoporoidowo-koralowcowa (178 m).
8. Seria iłowców górnych (32 m).
9. Seria węglanowa (93 m, erozyjny kontakt z cechsztynem).

Badania konodontów i małżoraczków pozwoliły na zaliczenie najniższej części profilu do wyższego eiflu (poziom *kockelianus*), natomiast najwyższej — do najniższego franu (górny poziom *falsiovalis*). Granice piętra żyweckiego biegną w obrębie grubych przedziałów niepewności korelacyjnej, odpowiednio, dolna między 5156,0 a 4811,1 m, i górna między 4542,0 a 4345,0 m.

Najbliższym rejonem o szczegółowo opracowanej stratygrafii dewonu środkowego i górnego jest północna część Gór Świętokrzyskich. Porównanie tamtejszego profilu Grzegorzowice - Skały z utworami badanymi ujawnia analogie w ogólnym wykształceniu i miąższości osadów (fig. 2). W szczególności, charakterystyczne jest występowanie w środkowym dewonie zwartego kompleksu utworów silikoklastycznych, wydzielonych jako jednostka piaszczysta w profilu Szwejki IG 3, natomiast z regionu łysogórskiego znanych jako warstwy świętomarskie. Również najniższy fran ma porównywalne wykształcenie w obu profilach.

PLATE I

Fig. 1. *Icriodus regularicrescens* Bultynck, 1970
Depth 5172.5 m; x 52
Fig. 2. *Polygnathus angustipennatus* Bischoff et Ziegler, 1957
Depth 5172.5 m; x 112
Figs. 3, 4. *Polygnathus alexanderensis* Savage, 1995
Depth 5172.5 m; Fig. 3 — x 74; Fig. 4 — x 72
Fig. 5. *Polygnathus* sp. n.
Depth 5172.5 m; x 63
Figs. 6, 7, 8. *Icriodus introlevatus* Bultynck, 1970
Fig. 6 — x 62; Fig. 7 — side view (widok platformy z boku), depth 5172.5 m, x 62; Fig. 8 — x 65
Fig. 9. *Polygnathus* cf. *P. ensensis* Ziegler et Klapper, 1976
Depth 5172.5 m; x 86
Fig. 10. *Polygnathus* cf. *P. timorensis* Klapper, Philip et Jackson, 1970
Depth 4343.0 m; juvenile specimen (okaz młody); x 76
Fig. 11. *Icriodus subterminus* Youngquist, 1947
Depth 4343.0 m; x 70
Figs. 12, 13. *Polygnathus* cf. *P. ordinatus* Bryant, 1921
Fig. 12 — x 94; Fig. 13 — lower view (widok platformy od strony dolnej), depth 4343.8 m, x 94

All views are upper unless otherwise stated (widoki górnej platformy, z wyjątkami opisanymi)

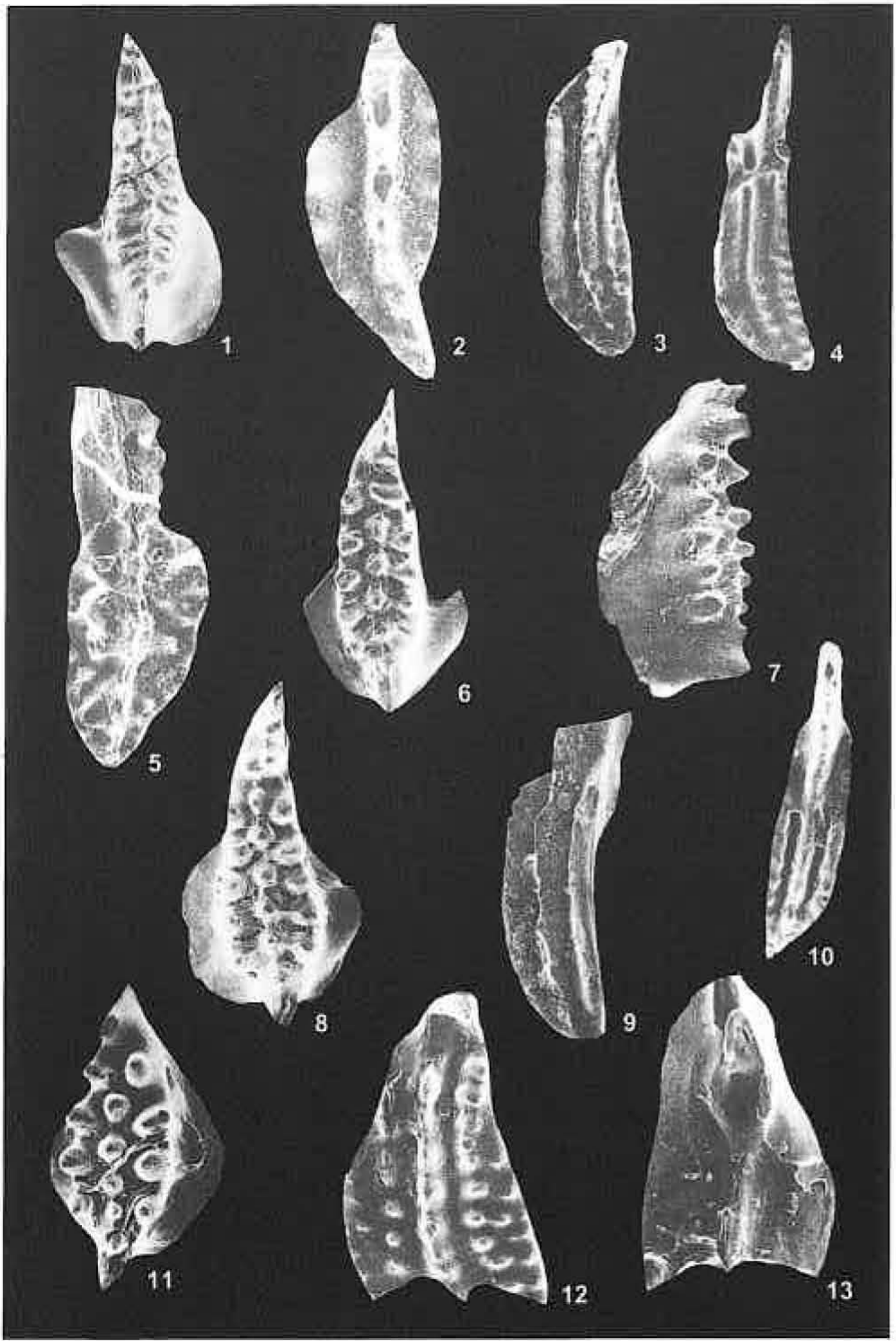

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PLATE II

Fig. 1. *Parapribylites hanaicus* (Pokorny, 1950)
Right valve (skorupka prawa); depth 4811.1 m
Fig. 2. *Balantoides* sp.
Left valve (skorupka lewa); depth 5105.0 m
Fig. 3. *Punctoprimitia* sp.
Right valve (skorupka prawa); depth 5105.0 m
Figs. 4, 5. *Jenningsina cavernosa* (Polenova, 1952)
Fig. 4 — right valve (skorupka prawa), Fig. 5 — dorsal view (widok strony grzbietowej); depth 4616.5 m
Fig. 6. *Poloniella tertia* Krömmelbein, 1953
Left valve (skorupka lewa); depth 5156.0 m
Fig. 7. *Poloniella trisinuata* (Van Pelt, 1933)
Right valve (skorupka prawa); depth 4616.5 m
Figs. 8–11. *Favulella* sp.
Figs. 8, 10 — right valve (skorupka prawa), Figs. 9, 11 — dorsal view (widok strony grzbietowej); depth 4345.0 m
Figs. 12, 13. *Jenningsina* sp.
Fig. 12 — left valve (skorupka lewa), Fig. 13 — dorsal view (widok strony grzbietowej); depth 5105.0 m
Fig. 14. *Semilukiella polita* Żbikowska, 1983
Right valve (skorupka prawa); depth 4605.1 m
Fig. 15. *Cavellina devoniana* Egorov, 1950
Right valve (skorupka prawa); depth 4811.1 m

Figs. 1, 3–15 — x 60, Fig. 2 — x 90

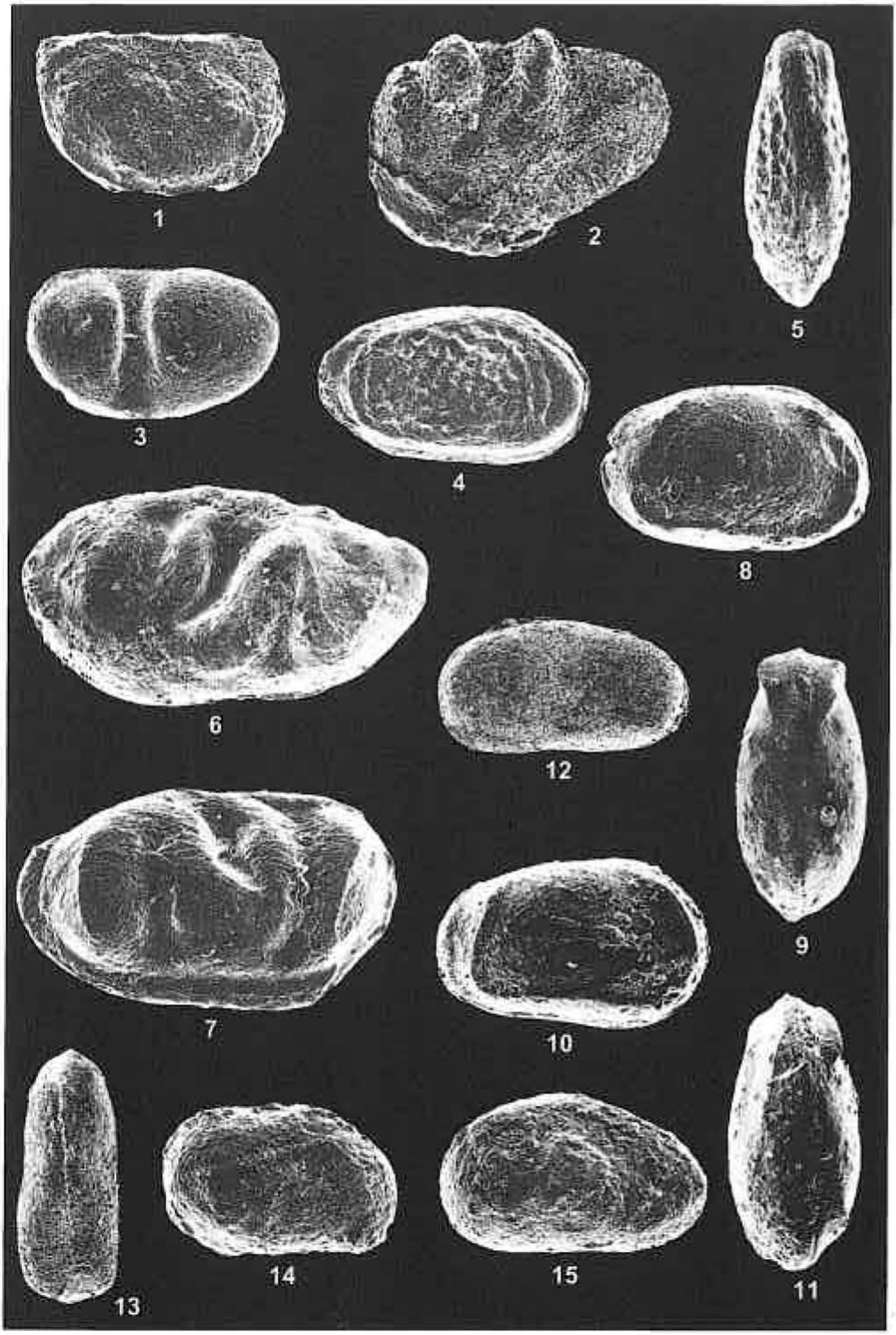

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PLATE III

Figs. 1, 2. *Jefina* sp.

Fig. 1 — right valve (skorupka prawa), Fig. 2 — dorsal view (widok strony grzbietowej); depth 4616.5 m

Figs. 3, 4. *Bythocyproidea puschi* Adamczak, 1976

Fig. 3 — left valve (skorupka lewa), Fig. 4 — dorsal view (widok strony grzbietowej); depth 5156.0 m

Figs. 5, 6. *Quasillites* (*Q.*) *quasillitiformis* (Polenova, 1952)

Fig. 5 — right valve (skorupka prawa), Fig. 6 — dorsal view (widok strony grzbietowej); depth 4616.5 m

Figs. 7, 8. *Graphiadactyllis*? sp.

Fig. 7 — right valve (skorupka prawa), Fig. 8 — dorsal view (widok strony grzbietowej); depth 5105.0 m

Figs. 9, 10. *Bufina* sp.

Fig. 9 — right valve (skorupka prawa), Fig. 10 — dorsal view (widok strony grzbietowej); depth 4616.5 m

Figs. 11, 12. *Cytherellina* sp. 2

Fig. 11 — right valve (skorupka prawa), Fig. 12 — dorsal view (widok strony grzbietowej); depth 4551.0 m

Fig. 13. *Sulcella* (*Postsulcella*) sp.

Right valve (skorupka prawa); depth 4796.0 m

Fig. 14. *Orthocypris perlonga* Kummerow, 1953

Right valve (skorupka prawa); depth 4605.1 m

Figs. 1–14 — x 60

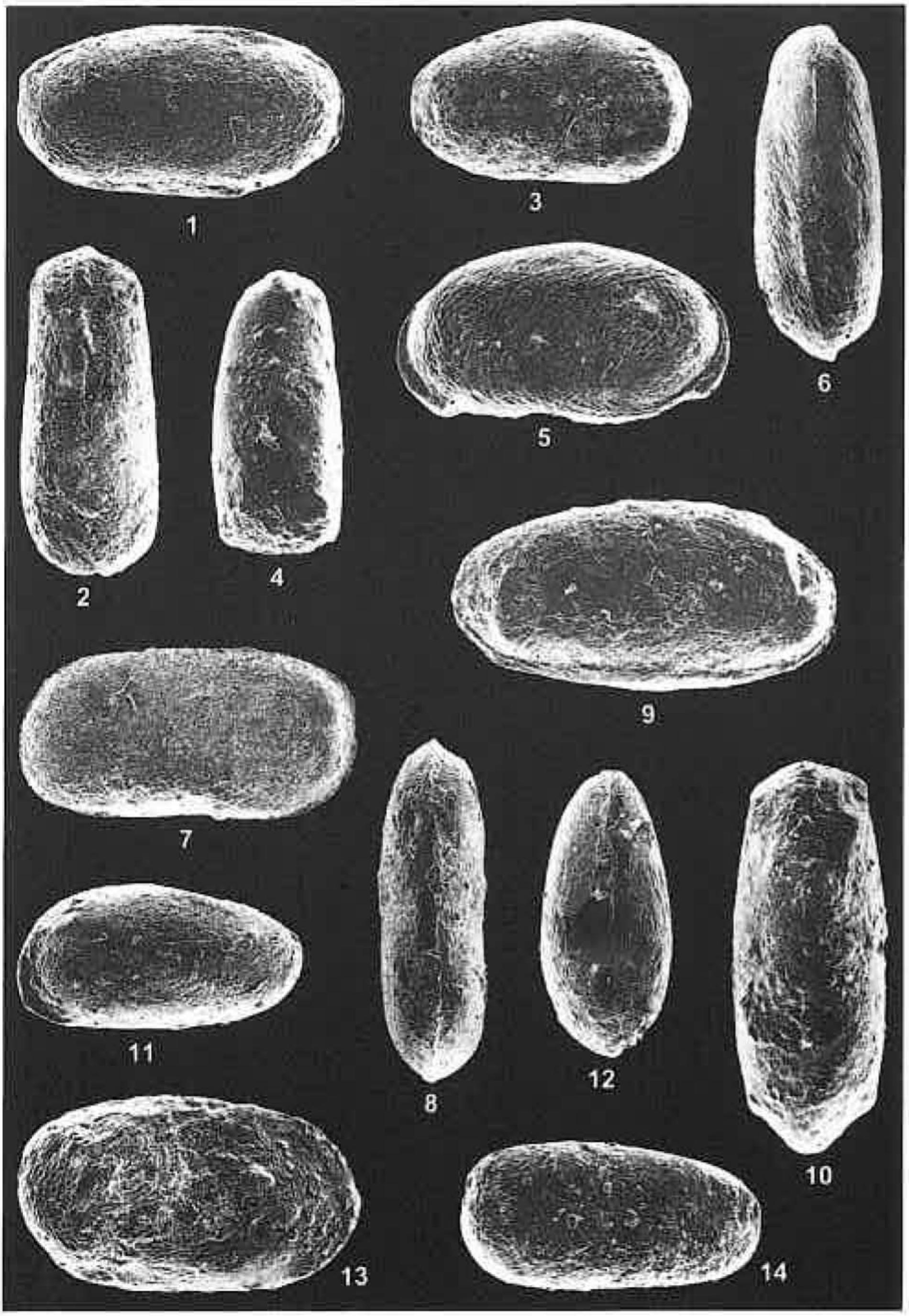

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PLATE IV

Fig. 1. *Cytherellina obliqua* (Kummerow, 1953)

Right valve (skorupka prawa); depth 4811.1 m

Figs. 2, 3. *Cytherellina* sp. 1

Fig. 2 — left valve (skorupka lewa), Fig. 3 — dorsal view (widok strony grzbietowej); depth 5105.0 m

Figs. 4, 5. *Microcheilinella fecunda* (Přibyl et Šnajdr, 1950)

Fig. 4 — right valve (skorupka prawa), Fig. 5 — dorsal view (widok strony grzbietowej); depth 4616.5 m

Figs. 6, 7, 10, 13, 14. *Healdianella resima* (Rozhdestvenskaya, 1959)

Fig. 6, 10, 13 — right valve (skorupka prawa), Fig. 7, 14 — dorsal view (widok strony grzbietowej); Figs. 6, 7, 13, 14 — depth 4796.0 m, Fig. 10 — depth 4551.0 m

Figs. 8, 9. *Microcheilinella* sp.

Fig. 8 — right valve (skorupka prawa), Fig. 9 — dorsal view (widok strony grzbietowej); depth 4800.1 m

Fig. 11. *Bairdia paffrathensis* Kummerow, 1953

Right valve (skorupka prawa); depth 4811.1 m

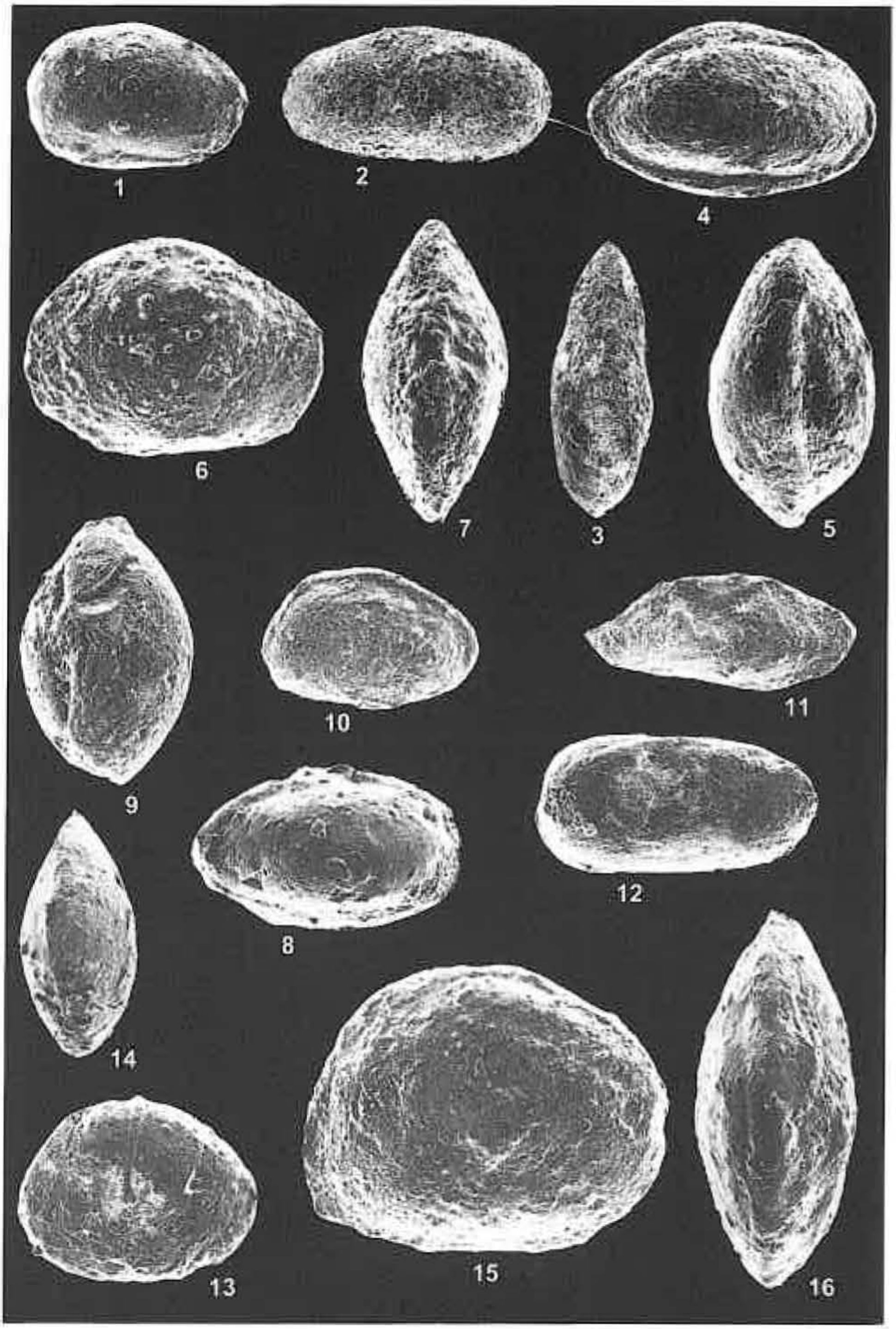
Fig. 12. *Orthocypris* sp.

Right valve (skorupka prawa); depth 4345.0 m

Figs. 15, 16. *Praepilatina* sp.

Fig. 15 — right valve (skorupka prawa), Fig. 16 — dorsal view (widok strony grzbietowej); depth 4796.0 m

Figs. 1–4, 6–10 — x 60, Fig. 5 — x 90



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