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The Frasnian/Famennian transition: the sequence of events in southern Poland and its implications

ABSTRACT: Detailed analysis of the facies sequences on the Late Devonian shelf in southern Poland allows for a reconstruction of geological events at the Frasnian/Famennian transition. This reconstruction can be extrapolated on the global scale *via* conodont zonation. Rapid regression occurred in the late Frasnian Lower gigas Zone and was shortly followed by a transgressive pulse. These events — perhaps glacieustatic in nature — resulted in termination of the growth of Late Devonian reef complexes. A crisis in carbonate production occurred at the Frasnian/Famennian boundary and was roughly associated in time with extinction of pelagic faunas.

INTRODUCTION

The Frasnian/Famennian (F/F) transition has for long attracted attention of geoscientists, but it still poses a challenge. The authors here undertake to analyse the lithological record of this stratigraphic interval. The aim of this analysis is global in scope. The record is always local, however, and one therefore has to begin with a local sequence which necessarily reflects the net result of an interplay of local and worldwide processes. Extrapolation from a local to the global scale demands that these influences be disentangled from each other. This can be only achieved where reliable global-scale time correlation tools exist. The authors here assume that conodont biostratigraphy indeed provides such tools for the F/F transition (*see* SANDBERG & *al.* 1988).

The focus is here on the Late Devonian carbonate shelf in southern Poland. This area is particularly suited for our purposes because (*i*) its lithofacies pattern is well recognized and includes monotonous deeper-shelf (= "basinal") facies which are precisely dated by means of conodont biostratigraphy (NARKIEWICZ 1985, 1987, 1988); (*ii*) its paleogeographic position is typical of the tropical to subtropical regions which harbor all the best studied records of the F/F transition (Text-fig. 1); and (*iii*) the facies development is generally concordant with other Late Devonian epicontinental basins, including North America and Australia (WILSON 1975).

GEOLOGICAL SETTING

The Late Devonian shelf in southern Poland made part of a large pericratonic basin that rimmed from the south the Old Red Continent (Text-fig. 2). This part of the basin sloped into deeper areas of the Moravo-Silesian branch of the Variscan geosyncline. In terms of paleolatitude, the considered shelf was comparable to the Rhenish Slate Mountains in Germany, the Ardennes in Belgium, Alberta in Canada, and Canning Basin in Australia (*see* Text-fig. 1). It underwent stable epicontinental development throughout the Devonian and Early Carboniferous cycle and was only negligibly affected by the Variscan orogeny. Its cratonic basement, however, was heterogeneous and consisted of several blocks with varying consolidation and subsidence histories (for overview *see* ZNOSKO 1984). This variation allows for sorting out purely local effects on facies development from those controlled at least regionally if not globally.

Facies development was studied in detail in the following areas (*see* Text-fig.2): (*i*) Dębnik-Zawodzie area, mostly subcrops situated in a narrow tectonic zone with Caledonian consolidation, not far from the pre-Carpathian Land in the south; (*ii*) Kielce area in the Holy Cross Mountains, outcrops in the central part of the shelf, remote from land areas, underlain by the northern flank of the Baikalian Małopolska Massif; and (*iii*) Lublin area, subcrops, located close to the Belorussian Land near the margin of the Precambrian East-European Platform, showing increased subsidence during the Devonian.

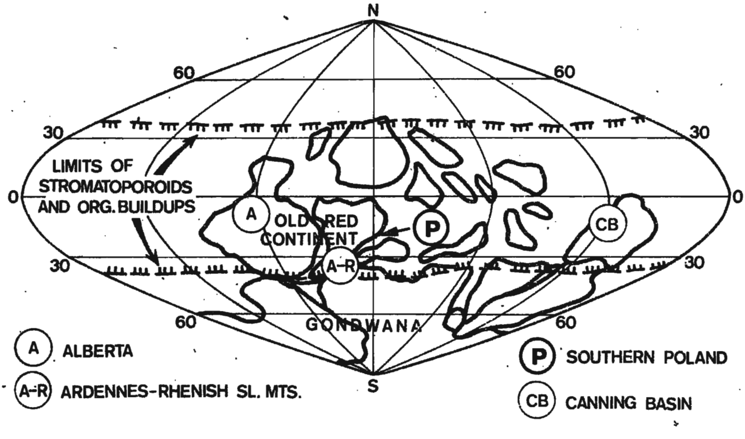


Fig. 1. Paleogeographic position of southern Poland; the Devonian world reconstruction *after* HECKEL & WITZKE (1979; simplified)

LOCAL SEQUENCE OF EVENTS

Time correlation of the facies patterns in these areas (Text-fig. 3) leads to the following interpretation of the sequence of events at the F/F transition:

The basal Frasnian transgression in the Lower asymmetricus Zone drowned the Middle Devonian carbonate platform, which was built chiefly of coral-stromatoporoid biostromes and occupied almost the entire shelf area. The prevailing lithofacies became dark, poorly fossiliferous, marly deposits of a shelf basin, while biogenic sedimentation continued only in restricted areas, as isolated coral-stromatoporoid buildups and a nearshore platform rimming the pre-Carpathian Land. The smaller buildups were soon eliminated by the rapid rise of the sealevel, and only some more prominent reef complexes, several kilometers in diameter, survived into the Late Frasnian. These structures, known from the Kielce and Lublin areas, show much similarity in facies pattern to their equivalents from Germany and Canada.

As indicated by the prograding fore-reef talus (Kielce area) and by detrital deposits associated with the nearshore platform (Dębnik area), a shallowing trend began in the basin as early as in the Middle to Upper asymmetricus Zone. This trend could be caused either by sediment accumulation during a sealevel stillstand, or by a slow regression. The regression was considerably

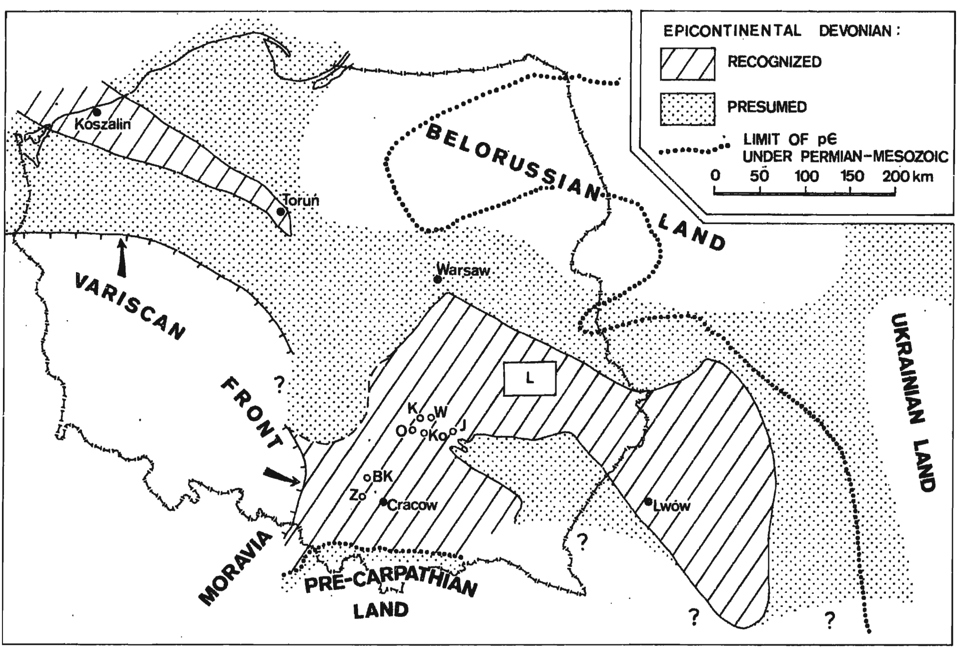
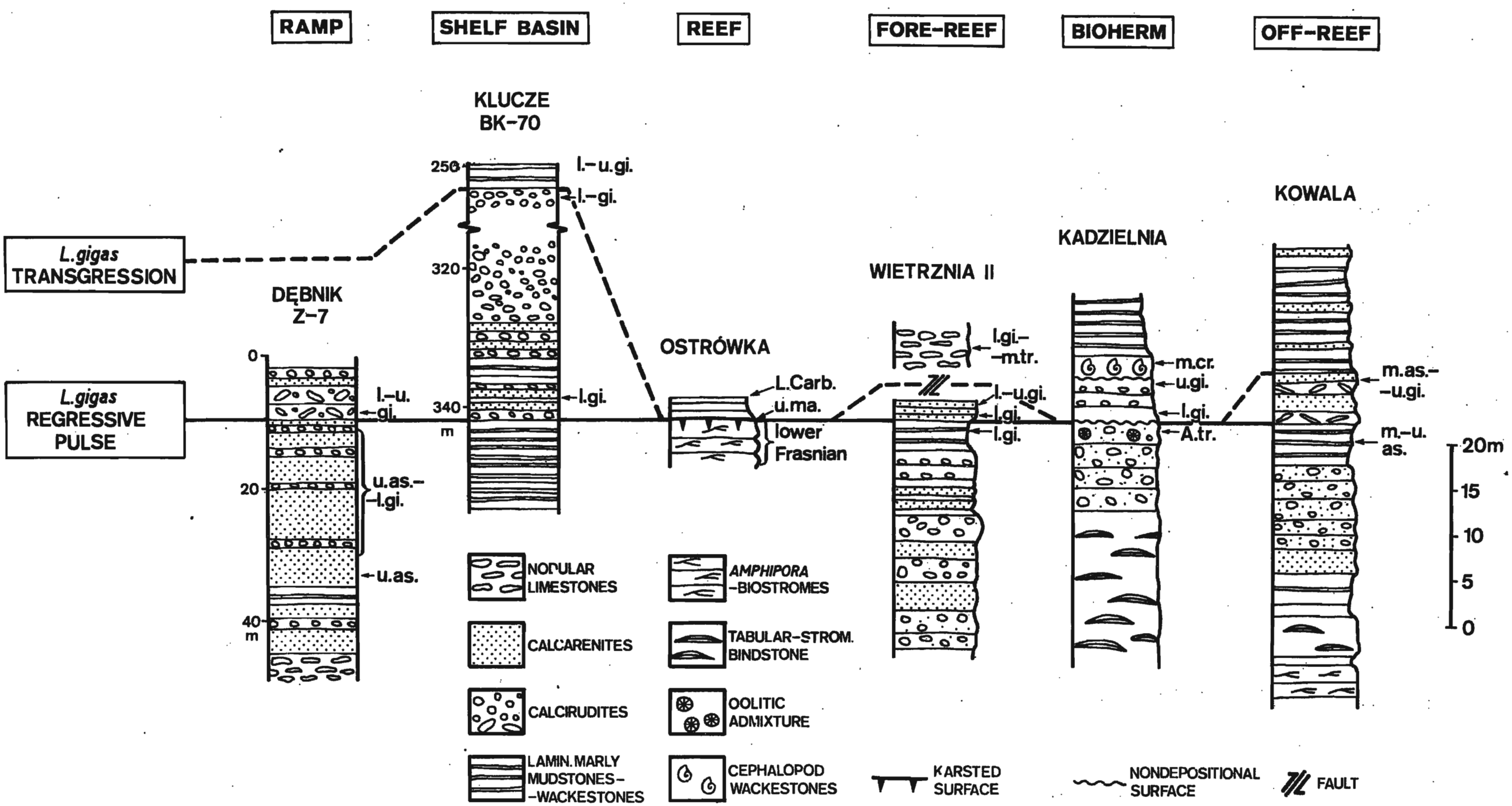


Fig. 2. Paleogeographic and structural framework of the Upper Devonian in Poland
Section locations: **Z** — Dębnik *Z-7* borehole. **BK** — Klucze *BK-70* borehole, **O** — Ostrówka quarry, **Ko** — Kowala section, **K** — Kadzielnia quarry, **W** — Wietrznia *II* quarry, **J** — Janczyce *I* borehole; **L** — Lublin area

Correlation of the investigated Upper Devonian sections in Poland



Conodont datings are given on the right of each section: **as.** — asymmetricus Zone, **A. tr.** — A. triangularis Zone, **gi.** — gigas Zone, **tr.** — Pa. triangularis Zone, **ma.** — marginifera Zone, **cr.** — crepida Zone; all with indication of their: l — lower, m — middle, u — upper parts

For location of the sections *see* Text-fig. 2

accelerated in the Lower gigas Zone, which bears clear signs of sealevel drop. Quartz-bearing, coarse-grained calcirudites occur in the Dębnik area, and the inventory of redeposited fossils shows their derivation from the coral-stromatoporoid biostromal complex. In the Klucze section nearby, some tens of meters of calcirudites are intercalated in the marly basinal sequence; they contain massive stromatoporoids and corals along with detrital quartz and laminated, dark marly intraclasts with oxidation halos and embedded in red shaly matrix, which clearly indicate subaerial weathering (NARKIEWICZ 1978). In the Kielce area, a few meters of peritidal tempestites occur in a sequence generally representing a moderately deep-basinal setting (KAŹMIERCZAK & GOLDRING 1978). In the central part of the reef complex, back-reef amphiporoid biostromes are topped by erosional surface with indications of subaerial exposure (karst and caliche; Dr. Z. BEŁKA, *pers. comm.*). An earlier drowned stromatoporoid mud-mound ("Kadzielnia reef" of SZULCZEWSKI 1971) is partly overlain by an upward-shallowing sequence of biodetrital limestones with oolitic admixture, and terminated by a discontinuity (subaerial?) surface.

The most conservative estimate of the magnitude of sealevel drop in the central part of the reef complex gives 20 meters. This figure is based on the minimum depth of erosion (10 m according to SZULCZEWSKI 1978) plus minimum depositional depth plus emersion allowing for karst phenomena to develop. In the Klucze section, intraclasts representative of anaerobic basinal facies bear evidence of emersion. General sedimentary models of epicontinental anaerobic facies suggest that such conditions develop at depths of at least 50 meters (BYERS 1977). This figure gives therefore the minimum estimate of sealevel fall in this area.

This regressive episode is hard to detect in the proximal fore-reef and in deeper-basinal settings. It has thus far not been observed in subcrops in the Lublin area, presumably due to sparse coring and insufficiently detailed sedimentological analysis.

All the sections with regressive deposits of the Lower gigas Zone provide also unambiguous record of a transgressive pulse in the same zone. The detrital facies are overlain by lime mudstones, often marly, with a pelagic fauna of cephalopods, fish, conodonts, and ostracods but without benthic fossils in situ; some non-reefal benthos occurs only in rare tempestite and/or turbidite intercalations. There is no direct or indirect evidence for continuing reef growth on the considered shelf. The submerged reef complexes in the Kielce and Lublin areas were mostly the sites of either non-deposition or pelagic sedimentation, chiefly of the cephalopod limestone type.

This transgressive event is less readily detectable in shallow submerged portions of the organic buildups and in the deepest shelf areas. The former settings are exemplified at Psie Górki site in Kielce (*see* SZULCZEWSKI 1971), the section of which represents continuous sedimentation of reef-cap type beginning with the Lower gigas Zone and straddling the F/F boundary between the linguiformis and Lower triangularis Zones. These well-sorted grainstones comprise mostly crinoid and brachiopod remains, but also an admixture of reworked rugose corals and, in minor amounts, small massive stromatoporoids in the lower part of the section.

In the sections that represent drowned organic buildups, the F/F boundary usually falls within a stratigraphic gap spanning at least the Lower triangularis Zone and comprising in extreme cases the Upper Frasnian to the uppermost Famennian (SZULCZEWSKI 1978, 1989). A crisis in carbonate sedimentation is also detectable in marginal parts of the basin. It is here reflected by a marked increase in the carbonate-to-clay ratio in the uppermost linguiformis to Middle triangularis Zones (Dębnik-Zawiercie area) and roughly near the F/F boundary in the Lublin area (NARKIEWICZ 1987, 1988; MATYJA & NARKIEWICZ, *in press*).

The carbonate crisis is less evident in the central, presumably deepest, part of the basin, which is represented in the investigated material by the borehole Janczyce *I* (Text-fig. 4). Nevertheless, detailed observations in this section also suggest a slowdown in carbonate sedimentation in the uppermost linguiformis Zone. A FeS_2-impregnated discontinuity surface is overlain by pyritized intraclasts and mudstone lenses, while a marked increase in conodont

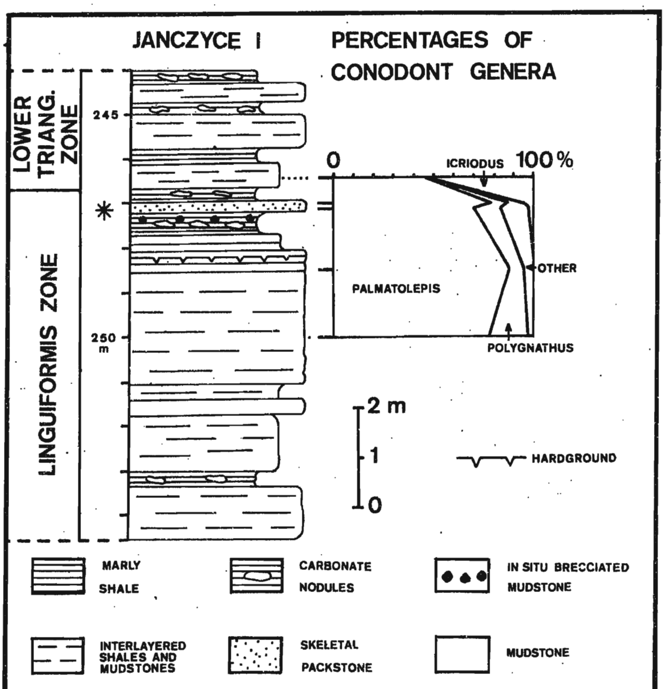


Fig. 4. Frasnian/Famennian transition in the Janczyce *I* borehole, with conodont biofacies sequence (*inset*) and the last occurrence of tentaculitoids (*asterisk*) shown; scale on the left represents the actual depth in the borehole, whereas the scale bar shows the actual thickness of the strata (*after* MATYJA & NARKIEWICZ: *submitted*)

frequency points to a drop in the rate of sediment accumulation. SZULCZEWSKI (1989) notes gaps and stratigraphic condensation comprising the triangularis Zones in other basinal sequences of the Holy Cross Mountains (Kostomłoty, Śluchowice). MATYJA & NARKIEWICZ (*in press*) and SZULCZEWSKI (1989) report also a clear shift in conodont biofacies sequence near the linguiformis/triangularis Zone boundary in several basinal as well as condensed sections in Poland (*see* Text-fig. 4). This shift seems to represent the "Icriodus peak" of SANDBERG & *al.* (1988), which has been interpreted by these authors as evidence of a eustatic shallowing at the F/F boundary.

The latest Devonian sedimentation in southern Poland ended with a regression initiated by shallowing pulse in the crepida Zone. Carbonates gradually regained dominance on the entire shelf area. The process culminated in the Late Famennian development of a shoal-rimmed platform with stromatoporoid patch-reefs in the vicinity of the pre-Carpathian Land.

THE F/F TRANSITION: A LOCAL SCENARIO

During the earliest Frasnian, a strong transgression terminated development of the vast, shallow-shelf biostromal platform. As a result, organic structures with their highly diverse biotas persisted only in localized areas, as nearshore ramps and platforms or as isolated reef complexes within a poorly-oxygenated shelf basin ranging perhaps to 100–300 meters in depth.

Under these conditions, the rapid regressive pulse in the Lower gigas Zone could have lethal effects on many reef communities, even if the sealevel drop was on the order of no more than some tens of meters, which is a rather conservative estimate. The frame-builders and reef-dwellers could in principle migrate downslope the former fore-reef apron. The reefs, however, were surrounded by muddy and poorly-oxygenated bottom environments. Moreover, the sealevel drop further limited water circulation in the shelf basin,

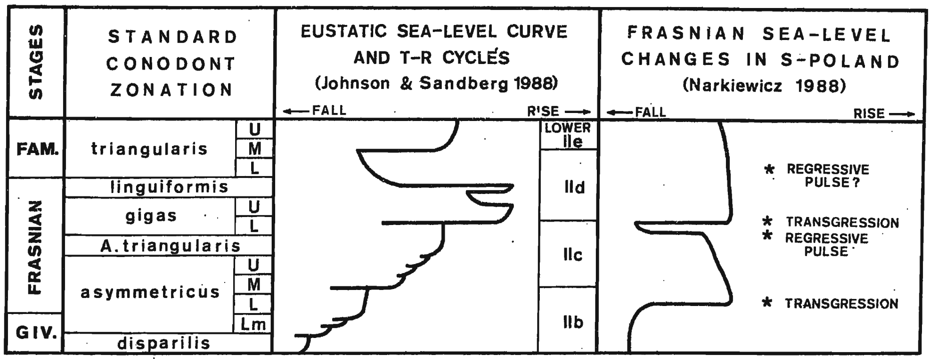


Fig. 5. Frasnian sealevel changes in southern Poland, as compared to the eustatic curve compiled by JOHNSON & SANDBERG (1988); conodont zonation *after* KLAPPER & ZIEGLER (1979)

leading to elevated salinity. The local occurrences of oolites in southern Poland and the presence of sulphates in peritidal deposits in the easternmost Lublin area (MIŁACZEWSKI 1981) support this scenario, while they contradict a development of brackish conditions, the other possible sequence of events in regressive continental basins (*see* HALLAM 1981). Thus, the reef communities migrating away from the progressively exposed buildups often encountered hostile habitats of the restricted basin. The subsequent rapid transgression in the Lower gigas Zone drowned the remaining reef structures and thus led to at least local extermination of both frame-building and reef-dwelling faunas.

Although large reef structures deceased at that time, however, corals and stromatoporoids locally persisted, confined to the facies of reef-cap type (*e.g.*, at Psie Górki). In the latest linguiformis Zone, a basinwide crisis of carbonate sedimentation set on and persisted until the crepida Zone. The beginning of this crisis was roughly coeval with the latest occurrence of tentaculitoids and with a change in conodont biofacies which is suggestive of a shallowing.

The F/F transition in southern Poland thus seems to include at least three separate events (*see* Text-fig. 5): (*i*) decimation of the reef biotas by rapid regression in the Lower gigas Zone, which trapped many communities between subaerial and anaerobic conditions; (*ii*) ultimate termination of the reefs due to drowning still in the Lower gigas Zone; and (*iii*) carbonate crisis at the linguiformis/triangularis Zone boundary, which is roughly associated in time with extinction of pelagic fauna.

IMPLICATIONS FOR THE GLOBAL SEQUENCE

The sequence of events in the shelf basin in southern Poland includes many components which are generally regarded as typical of the facies development encompassing the F/F transition in tropical to subtropical regions. These are: (*i*) the basal Frasnian transgression which drowned vast coral-stromatoporoid biostromal platforms; (*ii*) subsequent development of carbonate ramps and nearshore platforms and isolated reef complexes surrounded by poorly-oxygenated basins, typically with marly sedimentation; and (*iii*) rapid and strong transgression in the Lower gigas Zone (WILSON 1975, JOHNSON & *al.* 1985).

Several other points of the local scenario need a discussion, however, prior to its extrapolation on the global scale. These include: (*i*) the timing of reef extinction relative to the F/F boundary; (*ii*) the global scale of the regressive pulse in the Lower gigas Zone, and the nature of the regression/transgression couplet; (*iii*) the mechanism of reef extinction; and (*iv*) the carbonate crisis at the F/F boundary.

TIMING OF REEF EXTINCTION

Recognition of the time of the ultimate extinction of Upper Devonian coral-stromatoporoid reefs is quite a difficult task. First of all, conodonts rather scarcely occur in reef facies, and conodont dating of reef structures often is further obscured by the commonness of minor neptunian dykes of post-reefal age. Second, many reef structures were terminated as early as in the Late Givetian to Early Frasnian due to local geological factors, *e.g.*, burial under terrigenous sediments (STOAKES 1980, EDER & FRANKE 1982). While seeking to determine the time and causes of the ultimate extinction of coral-stromatoporoid reefs, such early terminations due to local factors must be somehow sorted out. Third, various data purporting to establish the timing of reef extinction may in fact concern notasmuch the reef structures themselves as later accumulations of reef-cap type, such as the one recorded at Psie Górki. It is therefore necessary to distinguish between the termination of reef structures and the extinction of organisms which presumably had a potential to form reefs. Clearly, many potentially reef-building taxa (rugose corals, tabulates, stromatoporoids) could survive some time after the termination of reef structures and succumb later to some other extinction agents.

There are at least two instances of well-dated Late Frasnian organic buildups — *viz.*, the Belgian Neuville (*F2j*) bioherms terminated in the Upper gigas Zone (TOURNEUR 1982), and the Canadian Nisku "reefs" which developed after the Lower gigas transgression (JOHNSON & *al.* 1985). Description of these structures leaves no doubt that they substantially differ in ecology from the earlier Frasnian reef complexes, *i.e.*, the *F2h* bioherms and Peechee buildups, respectively (TOURNEUR 1982, WATTS 1987). This difference is also reflected in a change in the stromatoporoid assemblage (STEARN 1987), for the stromatoporoid diversity decreased from 19 species in *F2h* bioherms to merely 5 species in *F2j* bioherms in Belgium and from 13 species in the early Frasnian Ancient Wall Reef Complex to 8 species in the Arcs Member which post-dates the Lower gigas transgression in Canada.

Thus, it seems that large reef complexes with full ecological zonation and significant synbiosedimentary erosion (*i.e.*, true reefs according to our definition; *see* HOFFMAN & NARKIEWICZ 1977) do not range into the Late Frasnian. Wherever their termination can be determined more precisely (Poland, Canada), it occurs in the Lower gigas Zone. In Germany, they appear to persist until the Upper gigas Zone (EDER & FRANKE 1982), but field observations by one uf us (M. N.) on the Rodheim Reef (*i.e.*, one of the three buildups analyzed by these authors) suggest that the critical conodont datings may here refer to crinoid-brachiopod accumulations of reef-cap type rather than to the reef sensu stricto. Later Frasnian organic buildups represent another ecological category. These are deeper-water mounds or bioherms with reduced diversity of frame-builders and without the ecological zonation typical of true, waveresistant reef structures. Evidently, then, reef ecosystems underwent a serious crisis as early as in the Lower gigas Zone, though it did not cause a total extinction of the reef-associated biotas.

LOWER GIGAS REGRESSION

The global nature of the transgression in the Lower gigas Zone is well established but the eustatic curve for the Devonian lacks a preceding regressive pulse (JOHNSON & *al.* 1985, Fig. 12). There is nevertheless some evidence (Table 1) to corroborate the hypothesis that this regression also was a eustatic event.

Table 1

Evidence for worldwide regression in the Lower gigas Zone

Locality	Evidence	Dating	Reference
Erfoud section, Morocco	angular unconformity	pre-Upper gigas	WENDT & *al.* 1984; BUGGISCH 1972, p. 16
Devils Gate, Nevada	erosional surface	Lower gigas	SANDBERG & POOLE 1977, Fig. 7
Visé, Belgium	karsted surface	late Frasnian	POTY 1980
South England	deep crevassing	A. triangularis – gigas	ORCHARD 1978, pp. 918, 923
New York	retreat of black shale deposition (pre-Rhinestreet Shale)	Lower gigas	KIRCHGASSER & *al.* 1985; HOUSE 1983
Adorf section, West Germany	detrital layers in pelagic condensed sequence	Lower gigas	HOUSE & ZIEGLER 1977
Caunes-Minervois section, Montagne Noire, France	intraformational breccias	Lower gigas (?)	BOYER & *al.* 1968, Fig. 2
Ancient Wall Reef Complex, Alberta	megabreccias (reef margin), debris flows (basin)	Lower gigas	GELDSETZER 1987; WEISSENBERGER 1987

For a variety of reasons, such evidence is not easy to find in literature. First, the precision of lithofacies descriptions is highly variable, and sometimes there is no sedimentological characteristics of the sequence at all; yet although evidence for a shallowing can be unequivocal (*e.g.*, subaerial erosion, karst), it can often be highly ambiguous (*e.g.*, gravity flow). Second, the precision of biostratigraphic dating is often low, so that potentially good lithological evidence cannot be employed for the purpose of global-scale analysis. This is generally the case with the Upper Devonian reef complexes of Australia and Asia (TALENT & YOLKIN 1985). Third, local tectonic events can obscure the record of eustatic sealevel changes. And fourth, the envisaged extent of sealevel drop in the Lower gigas Zone (about 50 meters) makes it unlikely to be reflected in offshore depositional environments at depths greater than, say, 200 meters.

The 8 localities referred to herein (Table 1) range nonetheless from West Europe and North Africa to North America, from epicontinental to geosynclinal settings, and from reefal to deep-basinal environments. There is a geographic bias in these references for the Old Red Continent and its margins, but this bias is due to the concentration of detailed facies and conodont studies on the Upper Devonian in this area. In every locality we cite, indications of a regression are present. The biostratigraphic datings are of variable precision; understandably, the longer was subaerial exposure, the wider the time gap and hence the less precise is time correlation. The Lower gigas age of the regressive pulse, however, is strongly indicated in several sections (Nevada, Alberta, New York, West Germany). Thus, the geological evidence from southern Poland for a regression/transgression couplet in the Lower gigas Zone is supported by data from other countries and continents.

The average duration of Late Devonian conodont zones approximates 0.7 – 0.8 Myr (ZIEGLER 1979). The eustatic sealevel fall and subsequent rise in the Lower gigas Zone appear therefore to be separated by no more than several hundred thousand years. The rate of eustatic sealevel change was very rapid on the geological timescale. It was much too rapid to be accounted for by a mechanism referring to changes in spreading rates or, as JOHNSON & *al.* (1985) put it, by a "combination of the growth and decay of oceanic ridge systems with mid-plate thermal uplift and volcanism."

The rate of the regressive-transgressive change in the Lower gigas Zone is such that it might, in principle, be explained as a result of desiccation and refilling of a huge marine basin, several times greater than the Mediterranean Sea in the Messinian. On the one hand, however, there is no plausible candidate for such a basin in the Upper Devonian; and on the other, this model can hardly account for a regression preceding rather than succeeding transgression.

The only remaining causal explanation for the global-scale sealevel changes observed in the Lower gigas Zone is glacieustacy. The authors therefore conclude that development and melting of continental icesheests as early as during the Late Frasnian provides the best currently available explanation for the geological evidence. This process could also account for the subsequent eustatic sealevel changes around the F/F transition, as observed by JOHNSON & *al.* (1985) and SANDBERG & *al.* (1988). This explanation is rather speculative at the moment due to absence of direct evidence for glaciation in this stratigraphic interval. Glacial deposits are only known from the Famennian (CAPUTO & CROWELL 1985); though new discoveries may push the onset of the Late Paleozoic glaciation further back in time, as it has indeed been the case with the Cenozoic glaciation.

MECHANISM OF REEF-COMPLEX EXTINCTION

The Lower gigas regressive event certainly could have exterminated many reef communities by destruction of their local habitats, as envisaged by JOHNSON (1974), though it did not cause the ultimate demise of all reef biotas. In particular, it could not have any devastating effects on non-cratonic Late Devonian reefs, similar to those described from Germany (FRANKE 1973, KREBS 1974), surrounded by deeper basins and developed, for instance, on volcanic seamounts; such non-cratonic settings provide reef biotas with ample opportunities for downslope migration and survival during regression (*see* JABLONSKI 1985).

The reef biotas which survived the regression were subsequently affected by the transgressive event described by JOHNSON & *al.* (1985) as "the maximum of the Devonian transgressions". Could this be the cause of the final extermination of the reef complexes?

As argued by SCHLAGER (1981), the rate of eustatic sealevel rise can hardly be expected to exceed the rate of growth of all reefs and hence to cause extinction of all reef biotas by drowning. This Late Frasnian transgression, however, clearly was associated with a strong expansion of the oxygen minimum water layer over shelf areas, discernible in the form of *Kellwasserkalk* horizons in the lithological record at least in West Europe, North Africa, and North America (BUGGISCH 1972, HOUSE 1985). There are in fact serveral *Kellwasserkalk* horizons in the record, ranging in age from the Lower gigas to Upper triangularis Zones, of which the lowermost was the most prominent and widespread (BUGGISCH 1972, Tables 10—13). They reflect pulses of expansion of anoxic waters onto the craton, depending on local tectonic, paleogeographic, and paleoceanographic settings. The Late Frasnian reef-complex extinction apparently coincided with the onset of *Kellwasser* regime in the Lower gigas Zone (BUGGISCH 1972, p. 46), rather than with the so-called Upper *Kellwasserkalk* horizon considered by some authors as the *Kellwasser* Event (*e.g.*, McGHEE & *al.* 1986). It seems, on the other hand, evident that some deeper-water coral-stromatoporoid mud-mounds survived and fell victim to a later pulse.

CARBONATE CRISIS

Stratigraphic gaps and condensations abound in the Upper Devonian (*e.g.*, SZULCZEWSKI 1978, 1989; PLAYFORD & *al.* 1984; WENDT 1988), thus making it very difficult to determine the rate of carbonate deposition on the global scale. Nevertheless, the maximum of condensation and/or nondeposition seems to fall in the lowest Famennian triangularis Zones. In the Rhenoherzynicum, for example, a ubiquitous stratigraphic gap begins after the linguiformis Zone and sedimentation returns only in the Middle triangularis Zone (BUGGISCH 1972). According to WENDT (1988), stratigraphic condensation in the Moroccan Devonian "is most widespread during the early Famennian". BECKER & *al.* (1988, Fig. 3) give the total thickness of the triangularis and crepida Zones in El Atrous (Morocco) as 4 meters, whereas the gigas Zones exceed 10 meters. The Lower triangularis Zone is unusually thin also in the Montagne Noire in France, where its base "seems to lie in all sections at or immediately above a sedimentary break" (HOUSE & *al.* 1988). The Lower triangularis to Lower crepida Zones represent the most condensed part of the Upper Devonian sequence also in the Canning Basin, Australia (PLAYFORD & *al.* 1984). These are indications of a considerable slowdown in carbonate production.

This carbonate crisis is also reflected by a drop in the carbonate-to-clay ratio; for example, in the Middle to Upper triangularis Zones in Germany and Morocco (BUGGISCH 1972) and in the Middle triangularis Zone of the Fore-Kolyma Uplift in the Soviet Union (GAGIEV 1985).

These data suggest that the carbonate crisis, which began in Poland in the uppermost part of the linguiformis Zone and had its maximum in the triangularis Zone, was worldwide in scope (*cf.* WALLISER 1985). It is very unlikely that its association in time with the extinction of trilobites, cephalopods, ostracodes, and tentaculitoids at the F/F boundary (*see* BECKER 1987, HOUSE & *al.* 1988, McGHEE 1988, WALLISER & *al.* 1988) is due to nothing but accidental coincidence.

CONCLUSIONS

Conodont biostratigraphic correlations indicate that three physical events recognizable on the Late Devonian carbonate shelf in southern Poland have their equivalents on the global scale, or at least in epicontinental tropical to subtropical basins with good geological record. These events are: rapid regression and transgression in the Lower gigas Zone and a carbonate crisis at the linguiformis/triangularis Zone boundary. The regression/transgression couplet was so rapid that it seems to be best explained by glacieustatic mechanism. The record also indicates that although some corals and stromatoporoids survived beyond the Lower gigas transgression, large coral-stromatoporoid reef complexes did not. Their growth was terminated, apparently in association with the onset of *Kellwasser* regime which denotes incursions of anoxic waters onto the craton. The pelagic fauna, however, underwent heavy extinction only substantially later, roughly at the time of the carbonate crisis at the F/F boundary.

Consequently, the so-called F/F extinction involved in fact a number of separate episodes rather than a single "mass extinction" event.

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POGRANICZE FRANU I FAMENU: NASTĘPSTWO WYDARZEŃ W POŁUDNIOWEJ POLSCE I ICH ZNACZENIE GLOBALNE

(Streszczenie)

Analiza następstwa facji na górnodewońskim szelfie południowej Polski (fig. 1–4) pozwala na rekonstrukcję wydarzeń geologicznych zachodzących na tym obszarze na pograniczu franu i famenu (fig. 5). Dzięki biostratygrafii konodontowej rekonstrukcję tę można ekstrapolować na skalę globalną. Górnofrański poziom *dolny gigas* zawiera świadectwa szybkiej regresji (fig. 3 oraz tab. 1), po której nastąpił wkrótce puls transgresywny. Wydarzenia te miały zapewne charakter glacieustatyczny, a w ich efekcie załamaniu uległ rozwój górnodewońskich kompleksów rafowych. Na granicy franu i famenu nastąpił kryzys sedymentacji węglanowej, a mniej więcej równocześnie z nim miało miejsce wymieranie fauny pelagicznej.
