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Depositional evolution of the Holy Cross Mts. (Poland) in the Devonian and Carboniferous — a review

The Devonian and Early Carboniferous succession in the Holy Cross Mts. records a steady sea level rise and is bounded by major angular unconformities. The Lower Devonian is developed as a terrigenic sequence of complex, continental and shallow-marine facies. Growth of a shallow-marine carbonate platform in the Middle to Upper Devonian resulted in separation of two adjacent intrashelf basins. This central swell was stepwise transformed in a pelagic carbonate platform and influenced a pattern of facies and thickness after its completed drowning in the Viséan. An impressive progress is noticed in understanding of sedimentation and stratigraphy of the carbonate succession, while recognition of depositional environments and regimes in the Devonian and Carboniferous clastics still remains a subject of several basic questions.

INTRODUCTION

The Holy Cross Mountains (HCM) are the area of Central Europe, where Palaeozoic stratigraphic succession emerges to the surface in the closest proximity of the East European Platform. Although they are situated beyond the Variscan fold belt, the facies development of the Palaeozoic reveals many similarities with this realm. This particular position makes the HCM important for palaeogeographical and palaeotectonical reconstructions, which extend far from this region. The aim of this article is to offer an outline of depositional history of the HCM in the Devonian and Carboniferous and to review the existing literature, in order to facilitate understanding geology of this region. Only selected positions could be included in references, since the literature concerning these topics is very abundant. This paper is a slightly modified and updated version of the presentation prepared for the Trans-European Suture Zone Workshop of EUROPROBE PROJECT, held in Kielce in 1994 (M. Szulczewski, 1994).

The Devonian and the Early Carboniferous make together a coherent chapter of a depositional history in the HCM area, since this stratigraphic succession is bounded by the major angular unconformities. They correlate with the late Caledonian and the Variscan orogenies, but effects of the two tectonic events are much more mild than in regions of their typical development. The stratigraphic succession records a steady sea-level rise since the Early Devonian till the Early Carboniferous. Particularly, no remarkable regression is noticeable in the Famennian, in contrast to the Rheinisches Schiefergebirge and the Ardennes, and even to the corresponding portion of the eustatic sea-level curve proposed by J. G. Johnson *et al.* (1985).

A striking feature of the depositional pattern in the Palaeozoic of the HCM is its twofold regional diversification (Fig. 1). It resulted from a different palaeotectonical behaviour of the two regions. The northern of them is called Łysogóry region and the southern one — the Kielce region. The regions are, however, regarded in the two ways: (1) as recent regional tectonic entities and (2) as palaeogeographical units. According to their first understanding their boundary is positioned precisely along the Holy Cross Fault (HCF). This definition is adopted in this paper because of its explicity. The boundary defined in the second way shifted in time and during the Devonian was situated more or less south of the HCF.

THE LOWER DEVONIAN CLASTIC DEPOSITION

The Lower Devonian in the area of the HCM is developed mainly as a distinct terrigenous sequence, composed predominantly of fine clastics. It reveals significant differences in its thickness, completeness of stratigraphic record and vertical facies succession when comparing the Łysogóry and the Kielce regions. In the Łysogóry region it follows conformably the marine Silurian and displays a complete sequence of stratigraphic stages. Its thickness is remarkably higher there and a record of marine facies at least better readable than in the Kielce region, where it is two times or more thinner, conspicuously incomplete at its base and unconformable to the folded Lower Palaeozoic. The Lower Devonian stratigraphic pattern is usually regarded as the most illustrative feature of the twofold palaeogeographical subdivision of the Holy Cross area in the Palaeozoic.

LOWER DEVONIAN IN THE ŁYSOGÓRY REGION

In the Łysogóry region marine facies continues from the Silurian up to the lowermost Devonian Bostów Beds. They pronouncely interfinger with the base of the terrigenous complex and disappear westward. Consequently, the lower boundary of the terrigenous complex is diachronous within the Gedinnian.

The terrigenous complex (Gózd Group in the Łysogóry region) is up to about 550 m in thickness (H. Łobanowski, 1981). It displays a vertical facies evolution expressed in a generally upward increasing participation and thickness of sandstones, an increasing maturity of their mineral composition and a change of colouring from usually brown and cherry to more light. It is associated with an evolution of a fossils content, vertically increasing in amount, diversity and participation of marine components. The commonly accepted threefold principal subdivision of the complex, into the Klonów, Barcza and Zagórze Formations, reflects the main phases of its facies development.

The lack of sufficient biostratigraphic control in a substantial part of the Lower Devonian sequence hampers an accurate chronostratigraphic subdivision of the Lower Devonian succession even at the stage level. The best dated are its lowermost and the uppermost stratigraphic units, which were deposited in marine environments. Accordingly, an attribution of the Bostów Beds to the Gedinnian is afforded by benthic fossils, particularly trilobites (e.g. E. Tomczykowa, H. Tomczyk, 1981). The age of the Klonów and Barcza Formations is vaguely determined. A difference of at least a half of a stage is postulated by various authors as to the chronostratigraphic position of these units. The Klonów Formation is regarded as belonging solely to the Gedinnian (J. Malec, 1993*b*), the Siegenian (E. Tomczykowa, H. Tomczyk, 1981) or to both Gedinnian and Lower Siegenian (H. Łobanowski, 1990). Consequently, the Barcza Formation is assigned to the Upper Siegenian-Lower Emsian interval (H. Łobanowski, 1990) or solely to the Lower Emsian (E. Tomczykowa, H. Tomczyk, 1981). The Zagórze Formation is attributed to the Upper Emsian, again on the sound foundation of direct palaeontological evidences (H. Łobanowski, 1971).

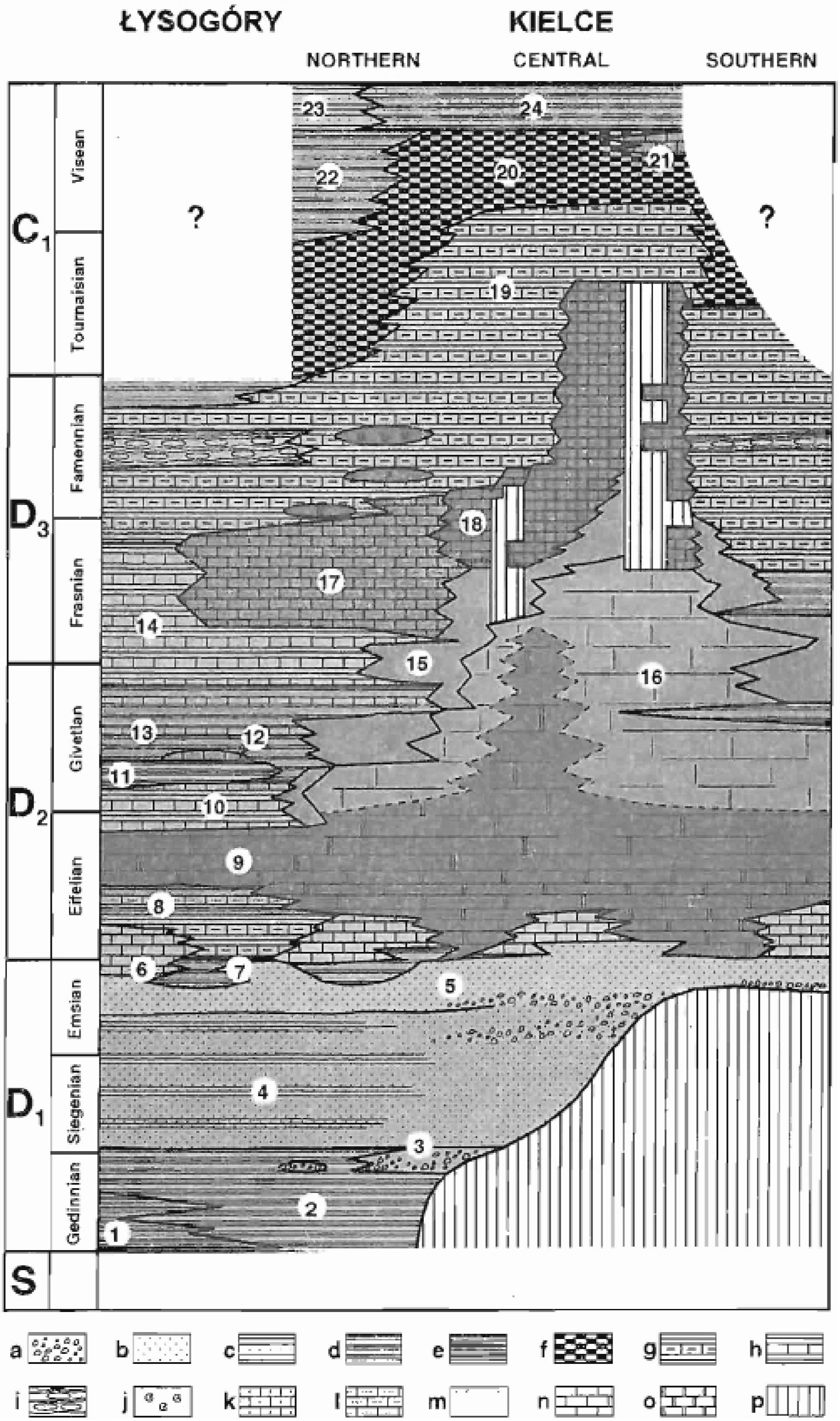
The depositional environments of the Klonów and Barcza Formations are not sufficiently understood. In their characteristic development the two stratigraphic units are very sparsely fossiliferous. They commonly contain only scarce placoderm fishes and additionally sporadic bivalves or plant remains.

The Klonów Formation is brown-reddish, thin-bedded and contain fine-grained graywackes. They were for long ascribed to the continental Old Red Sandstone (e.g. J. Czarnocki 1936), and recently H. Łobanowski (1990) regarded them as fluvial overbank or flood plain deposits.

The Barcza Formation is more sandy and contains well individualised sandstone sets (Z. Kowalczewski *et al.*, 1989). Quartzites are also more frequent in this unit. According to H. Łobanowski (1990) the formation comprises continental deposits of meandering streams, although previously its lagoonal origin was suggested (e.g. J. Czarnocki, 1936).

Nevertheless, there are palaeontological indications that marine depositional environments have also contributed to the accumulation of both stratigraphic units. The deposition of the Klonów Formation was probably affected only by intermittent ingressions, as evidenced by the three marine intercalations reported by H. Łobanowski (1990, Tab. 1). J. Czarnocki (1936) listed also several stenohaline marine taxa from the Barcza Formation. These findings, together with his observation that bivalves are scattered throughout the unit, suggest that a rather significant portion of the Barcza Formation was deposited in the marine environments, presumably not only restricted, but also open marine.

The Devonian marine transgression definitely overflooded the Łysogóry region during deposition of the Zagórze Formation (J. Czarnocki, 1936; H. Łobanowski, 1971, 1981, 1990). This formation is sandstone dominated, with its overall ratio to the other terrigenous deposits of about 4.5:1. The vertical sequence reveals repetition of several lithofacies associations, representing the shallow-marine, nearshore, storm-dominated depositional setting. They encompasse a broad range of depositional environments from an offshore-transition up to a back-barrier lagoon (M. Szulczewski, 1993). The fossils are distinctive of the Rheinisch magnafacies.


ŁYSOGÓRY
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LOWER DEVONIAN IN THE KIELCE REGION

The thickness of the Lower Devonian in the eastern part of the Kielce region attains 260 m, but commonly is about 130–150 m (M. Tarnowska, 1981). In the western part of the region it is usually no more than 30 m thick. Locally it is even attenuated to 2–3 m (J. Głazek *et al.*, 1981; Z. Kowalczewski, 1971; M. Tarnowska, 1987).

The base of the Lower Devonian truncates the Lower Palaeozoic succession down to the Lower Cambrian. It is, however, noteworthy that the gap associated with this unconformity is a cummulative effect of the erosional episode following the post-Cambrian uplift as well as the post-Silurian one. A differentiation of the Lower Devonian facies, thickness and probably also completness of stratigraphic record reflects the morphology of the inundated land (cf. J. Głazek *et al.*, 1981).

Drill record reveals that, in its more expanded development the sequence consists of alternating complexes dominated by sandstones or by mudstones and clays (e.g. Z. Kowalczewski, 1971; M. Tarnowska, 1981). Over the eastern part of the region, where its stratigraphy is better understood, it consists of two mudstone complexes sandwiched with two sandstone ones. Conglomerates are subordinate to finer clastics and almost confined to the western part of the Kielce region (J. Czarnocki, 1936; Z. Kowalczewski, 1971). They are mostly basal conglomerates, but another level is situated within the unit (Bieliny conglomerate).

Fig. 1. Simplified diagrammatic cross-section through the Holy Cross Mts. from the Lower Devonian to Lower Carboniferous times

1 — Bostów Beds; 2 — Klonów Formation; 3 — Miedziana Góra Conglomerate; 4 — Barcza Formation; 5 — Zagórze Formation; 6 — Bukowa Góra Shale Formation; 7 — Kapkazy Formation; 8 — Grzegorzowice Formation; 9 — Wojciechowice Formation; 10 — Skały Formation; 11 — Świętomarz Formation.; 12 — Pokrzywianka Beds; 13 — Nieczulice Beds and Śniadka Formation; 14 — Szydłówek Beds; 15 — Laskowa Góra Beds; 16 — Kowala Formation; 17 — Kostomłoty Beds; 18 — Manticoceras Limestone; 19 — Radlin Beds; 20 — Zaręby Formation; 21 — Gałęzice Debrite Member of Lechówek Formation; 22 — Górno Beds; 23 — Gułaczów Member of Lechówek Formation; 24 — remaining portion of Lechówek Formation; a — conglomerates; b — dominating coarse-grained clastics; c — coarse- and fine-grained clastics; d — dominating fine-grained clastics; e — clayey and marly shales; f — siliceous shales; g — marly limestones and shales; h — limestones and shales; i — nodular limestones; j — cephalopod limestones; k — condensed cephalopod and crinoidal limestones; l — micrites, calcarenites and calcirudites; m — calcirudites; n — massive and bedded limestone; o — dolomites; p — stratigraphic gaps

Uproszczony przekrój przez Góry Świętokrzyskie od dolnego dewonu do dolnego karbonu

1 — warstwy bostowskie; 2 — formacja klonowska; 3 — zlepieniec miedzianogórski; 4 — formacja barczańska; 5 — formacja zagórzańska; 6 — formacja łupków z Bukowej Góry; 7 — formacja kapkazka; 8 — formacja grzegorzowicka; 9 — formacja wojciechowicka; 10 — formacja skalska; 11 — formacja świętomarska; 12 — warstwy pokrzywiańskie; 13 — warstwy nieczulickie i formacja śniadkowska; 14 — warstwy szydłóweckie; 15 — warstwy Laskowej Góry; 16 — formacja z Kowali; 17 — warstwy kostomłockie; 18 — wapień mantikocerasowy; 19 — warstwy radlińskie; 20 — formacja zarębiańska; 21 — ogniwo debrytów gałęzickich formacji z Lechówka; 22 — warstwy z Górna; 23 — ogniwo gułaczowskie formacji z Lechówka; 24 — pozostała część formacji z Lechówka; a — zlepieńce; b — skały klastyczne z przewagą gruboziarnistych; c — grubo- i drobnoziarniste skały klastyczne; d — skały klastyczne z przewagą drobnoziarnistych; e — łupki ilaste i margliste; f — łupki krzemionkowe; g — wapienie margliste i łupki; h — wapienie i łupki; i — wapienie gruzłowe; j — wapienie głowonogowe; k — skondensowane wapienie głowonogowe i krynoidowe; l — wapienie mikrytowe, kalkarenity i kalcyrudyty; m — kalcyrudyty; n — wapienie masywne i warstwowane; o — dolomity; p — luki stratygraficzne

Formerly, the Lower Devonian sequence in this region was termed the lagoonal "placoderm sandstone" and attributed entirely to the Lower Emsian (J. Czarnocki, 1936). Accordingly, it was supposed to be substantially incomplete and deposited in the shore proximal environments, generally more shallow than its stratigraphic counterparts in the Łysogóry region (J. Czarnocki, 1936). According to recent papers, those differences seem not to be so profound. M. Tarnowska (e.g. 1981) suggests that the Devonian deposition commenced in the southern region earlier than it was supposed, probably in the Siegenian. She relies on the tephrocorrelation and regards one of the several found tephra horizons as a marker bed, relevant for its correlation with the topmost part of the Barcza Formation in the Łysogóry region.

M. Tarnowska (1976, 1981, 1987) also claims that the sequence accumulated in recurrent alluvial and marine nearshore environments. The southern succession indeed yields numerous and diversified open marine biota, but almost solely in the northernmost belt of the region, and only in the Upper Emsian (J. Czarnocki, 1936; J. Studencka, M. Studencki, 1986). The fossils and lithology are closely related to those in the Zagórze Formation in the Łysogóry region. Farther to the south psammosteid agnathans and placoderm fishes are indeed the most characteristic fossils. They are locally accompanied by eurypterids and bivalves (J. Czarnocki, 1936; M. Tarnowska, 1981). Depositional environment of this "placoderm facies", yielding locally unusual vertebrate fossil concentrations (e.g. L. B. N. Tarlo, 1964), is not yet adequately recognised. Marine environments are, however, indicated by trace fossils found by M. Tarnowska (1987, 1990) far to the south, beyond the limit of known occurrence of marine body fossils and even beyond the margin of the HCM.

The Lower Devonian in the northern marginal belt of the Kielce region, adjacent to the HCF, deserves particular attention. Possibly its development would contribute to the vital question of the territorial consolidation of the HCM area in the Early Devonian times (cf. M. Lewandowski, 1993). The development of the Lower Devonian in this belt has definitely much more in common with the pattern characteristic of the Łysogóry region than that of the Kielce one. It overlies conformably the uppermost Silurian (J. Czarnocki, 1936; J. Malec, 1993*b*). Also, at least several of regional stratigraphic units seem to extend to this belt from the Łysogóry region, straddling the HCF. The commonly accepted example is the Klonów Formation (e.g. J. Czarnocki, 1936; J. Malec, 1993*b*), but J. Malec (1993*b*) recognised here as well the Barcza Formation, and the facies of the Upper Emsian is also akin its northern counterpart (i.e. Zagórze Formation).

The particular feature of the Lower Devonian of the western part of this belt is the Miedziana Góra Conglomerate. It is situated within the Klonów Formation and interfinger with its topmost part. The conglomerate is developed as a main straticform body (attaining its maximum thickness in excess of 45 m), and as its satellite lenses. It consists of predominantly rounded cobbles and boulders of the Cambrian quartzites (with identified trilobite *Paradoxides*), and the exceptionally rare Ordovician glauconitic sandstones (J. Czarnocki, 1936).

Depositional setting of this particular conglomerate, provenance of its cobbles as well as its palaeotectonic meaning are disputable. Three depositional setting were proposed for it: submarine fan (J. Malec, 1993*b*), alluvial fan (M. Szulczewski, 1994) and scree fan, which consists of residual gravel of the Silurian age (E. Stupnicka, 1995). My suggestion was based solely on the description by J. Malec and on the position of conglomerate within the Klonów Formation of continental origin. The opinion of E. Stupnicka (1995) is too complicated and improbable to be accepted.

There is a prevailing opinion that a source area of components of the Miedziana Góra Conglomerate were the Cambrian rocks in the northern, Łysogóry region (J. Czarnocki, 1936; Z. Kowalczewski, 1968, 1971; J. Malec, 1993*b*). However, this possibility obviously contradicts another observation of J. Czarnocki, that the Cambrian in this region is overlain by stratigraphically complete succession of Palaeozoic systems. Consequently, as far as we know, there is no possibility that it was available for erosion in the Devonian. Far more probable is that the Miedziana Góra Conglomerate is composed of material deriving from the Kielce region, where the Middle Cambrian was exposed at the surface and a land morphology could be conspicuously sculptured at the beginning of the Devonian (M. Szulczewski, 1994).

According to J. Malec (1993*b*), the Miedziana Góra Conglomerate would have been accumulated in the regressive phase of the post-Silurian marine basin, prior to the folding in the Erian phase, responsible for the sub-Devonian angular unconformity in the Kielce region. This unconformity would be plausibly demonstrated by the suggested truncation of the depicted fan and capping it unconformably with a veneer of another conglomerate (Conglomerates from Gruchawka). However, the Gruchawka Conglomerate seems to blanket concordantly the depositional surface of the fan. Consequently, the Miedziana Góra Conglomerate should be regarded as deposited after a folding and uplift in the southern Kielce region.

THE LOWER/MIDDLE DEVONIAN BOUNDARY: CESSATION OF CLASTIC DEPOSITION

The deposits directly overlying the Lower Devonian clastic sequence exhibit fairly variable lithologies (J. Czarnocki, 1950). The corresponding phase of particularly differentiated facies pattern is attributed to the latest Emsian and the Early Eifelian. This turnover is generally caused by a significant rise of the relative sea level. J. Malec (1990; cf. S. Skompski, M. Szulczewski, 1994) supposed that it reflects the eustatic sea leval rise of the Ic cycle proposed by J. G. Johnson *et al.* (1985). The transgression introduced a domination of clay (e.g. Bukowa Góra Shale Formation) and carbonate deposition instead of hitherto common clastics. However, significant recurring shifts of depositional environments resulted in interfingering of the transgressive clays with the clastic wedge (Kapkazy Formation) in the confines of the Lower/Middle Devonian in the Łysogóry region.

The differentiation of the facies pattern of transgressive deposits seems to be affected by the depositional palaeotopography of the top surface of the clastic sequence. Discontinuously distributed clay deposits would be confined to the palaeomorphological depressions, while the areas where clastics are directly blanketed by carbonates would suggest the elevations.

The clays and limestones of this transgressive phase of deposition often contain abundant fossils of open marine biota. The possibly endemic brachiopod *Chimaerothyris* *dombroviensis* (Gürich) is characteristic of the Lower Eifelian of both the Kielce and Łysogóry regions (J. Studencka, 1983).

The black clays with pyrite locally overlie the clastic succession (e.g. J. Malec, 1991), suggesting an existence of sub-basins with restricted circulation. In such deposits the sideritic ore was exploited in past at the northwestern margin of the Kielce region.

J. Malec (e.g. 1991) argues in his preliminary report that the top of the terrigenous sequence is diachronous over the HCM, and that the Lower/Middle Devonian is situated fairly above it, diagonally cutting the overlying clays and even usually succeeding them carbonate rocks. M. Tarnowska (1983, 1990) regards her "tuff bed T4" as a regional correlative horizon situated close to the Lower/Middle Devonian boundary in the Kielce region and farther to the south.

THE GROWTH OF THE MIDDLE-UPPER DEVONIAN CARBONATE PLATFORM

A substantial advance of transgressing sea in the Early Eifelian was followed by a fall of the relative sea level late in the Eifelian. The facies pattern became simplified and a ubiquitous carbonate deposition was established over the vast Fennosarmatian shelf, to which the area of the HCM belonged. The "carbonate factory" commenced its long-lived activity, which resulted in a growth of the shallow-marine carbonate platform. The carbonate platform has been developing until the Frasnian and attained a thickness of about 1400 m (cf. G. Racki, 1993). The principal trends in an evolution of the carbonate platform were its progressive areal restriction, topographic differentiation and an increasing significance of organic buildups. Three phases of its development are to be distinguished.

The first phase correlates with the Late Eifelian, although the location of the Eifelian/Givetian boundary in this facies setting creates serious difficulties. This phase is characterised by a low depositional topography, a scarcity of organic buildups and a depositional setting restricted to shallow subtidal and tidal environments. Meter-scale, non-reefal peritidal cyclic deposition and early diagenetic dolomites are common features of carbonates deposited late in this phase (M. Narkiewicz, 1991; S. Skompski, M. Szulczewski, 1994). Sabkha environment was recognised by M. Narkiewicz (1991) in the cyclic deposits of this phase in the Kielce region. It is the only phase of development of the carbonate platform when it was also extended over the Łysogóry region, the latter being governed by intra-shelf basinal facies.

The second and the third phases of development of the carbonate platform are similar to the bank and reef phases distinguished by W. Krebs (1974) in the Devonian carbonate platforms of the Variscan realm (cf. G. Racki, 1993). In the HCM the bank phase is attributed approximately to the Givetian and the reef phase to the Frasnian. Both phases are represented mostly by the stromatoporoid-coral limestones. They make up a bulk of the carbonate platform and are distinguished as the Kowala Formation by M. Narkiewicz *et al.* (1990). Its thickness ranges from 330 to above 800 m and it comprises primarily skeletal accumulations *in situ* (G. Racki, 1993). At least four deepening pulses were recognised by G. Racki (1988, 1993) during its accumulation, resulting in intermittent drowning of the platform. He proposes an astonishingly synchronous correlation of the relative sea level changes within the platform and the adjacent basins with the curve of global sea level changes presented by J. G. Johnson *et al.* (1985).

The bank phase commenced with accumulation of undifferentiated *Stringocephalus* biostromal bank which was subsequently replaced by the Sitkówka bank complex (J. Kaźmierczak, 1971; A. Preat, G. Racki, 1993). The reef phase has been attained by the carbonate platform early in the Frasnian. The carbonate depositional system developed in this phase was called Dyminy reef by M. Narkiewicz (1988) or Dyminy reef complex by G. Racki (1993). However, what the platform became in the Frasnian is rather a reef- and shoal-rimmed isolated carbonate platform. In this phase the platform shrinked to the central part of the Kielce region and was flanked to the north and south by two intra-shelf basins.

This phase of development of the carbonate platform is characterised by the most complex facies pattern. Its stratigraphic anatomy was enabled by conodont zonation, applicated to majority of facies (M. Szulczewski, 1971; G. Racki, 1993; G. Racki, P. Bultynck, 1993). G. Racki (1993; cf. M. Szulczewski *et al.*, in press) found that the platform interior was occupied by an extensive lagoon, where the "reefal" peritidal small-scale cyclic deposits aggraded. This facies evidences that the platform interior was sheltered by a reef-rim. The elevated morphology of the platform margins is also indicated by its thick slope deposits. However, only at the southern platform margin they contain significant amount of possible reef debris (M. Szulczewski, 1968, 1971; J. Kaźmierczak, R. Goldring, 1978; A. Romanek, M. Rup, 1990), while at the northern one they derive largely from canibalisation of the slope deposits themselves. It is possible that a syndepositional block-faulting or associated seismicity contributed to the fragmentation of slope deposits and induced gravity debris flow.

In the Middle Frasnian the external parts of the carbonate platform were covered with detrital carbonate deposits, containing skeletal debris, ooids and sediment binding *Renalcis* (M. Szulczewski, 1971; M. Hoffmann, M. Paszkowski, 1992). This facies is evidently regressive to the underlying deposits. It is especially evident where these deposits overstep the peripheral Lower Frasnian quiet-water reef mound of the Kadzielnia Limestone Member (M. Szulczewski, 1981; M. Szulczewski, G. Racki, 1981; cf. M. Narkiewicz, 1988).

According to M. Szulczewski (1971), the Devonian reef from the HCM lasted out to the Lower Famennian. However, M. Narkiewicz (1988) and G. Racki (1990) pointed out that a stromatoporoid-coral community was seriously influenced by transgressive pulse in the Early *gigas* Zone and did not exceed here the Frasnian/Famennian boundary. Nevertheless, the known remnants of the carbonate platform persisted to the Lower Famennian (M. Szulczewski, 1971) and the fossil content of the limestone turbidites intercalating basinal deposits reveals that *Renalcis* organic buildups were active at least to the Upper *crepida* Zone.

A considerable part of the carbonate platform is composed of dolomites. The eogenetic dolomites are confined to the earliest phase of its development. The prevailing are mesogenetic dolomites, which locally reach the Frasnian, but are more common in the lower part of the platform. There is a common understanding that the dolomitization process was ascending and active before the Zechstein. Recently M. Narkiewicz (1991) proposed for it a sophisticated model of compactional-convective circulation of hyposaline solutions. Its suggested timing is placed before the Variscan tectonic event. An alternative and controversial solution was presented by Z. Migaszewski (1991) who regarded these dolomites as hydrothermal synsedimentary deposits involved with hot springs activity.

THE PELAGIC CARBONATE PLATFORM

A drowning of the shallow-marine carbonate platform and its transformation into a pelagic platform (*sensu* M. Santantonio, 1994) was prolonged and stepwise. The northern margin of the platform was almost completely drown in the late Frasnian Early *rhenana* Zone (M. Szulczewski, 1981; M. Narkiewicz, 1988). It is largely covered with the Upper Frasnian pelagic limestones traditionally called Manticoceras Limestones. They compensate a palaeomorphology previously created by organic buildups and small-scale block-faulting. The oldest known Frasnian cephalopod condensed limestones are confined to the elevation of this palaeorelief (M. Szulczewski, 1981, 1989). These pelagic limestones also fill the oldest generation of neptunian dykes penetrating the carbonate platform. Over several palaeotopographic highs, however, a submarine nondeposition prevailed, locally remaining during the entire Late Frasnian, a considerable part of the Famennian or even up to the Tournaisian.

The encroachment of a low-rate pelagic deposition over the shallow-marine carbonates was completed late in the Famennian, when it invaded the remaining known part of the platform. Hence, the Famennian palaeogeography was dominated by the central pelagic carbonate platform which separated two intra shelf basins.

A thickness of the condensed limestones is strikingly contrasting with a thickness of the coeval basinal deposits, which are up to one thousand times thicker. The condensed sequences are developed in two principal facies: crinoidal and cephalopod. The crinoidal limestones occur mainly in the Lower Famennian. The cephalopod ones are more commonly distributed, especially in the Upper Famennian.The mixed crinoid-cephalopod facies reveals physical segregation of biotic components by storm events (M. Szulczewski *et al.*, in press).

In several places the Famennian condensed deposits are a continuation of similar Upper Frasnian deposits (M. Szulczewski, 1981, 1989). More commonly they unconformably abruptly overlay the carbonates of the shallow-marine platform, locally with an angular unconformity (M. Szulczewski, 1978; M. Szulczewski *et al.*, in press). Over a large part of the pelagic platform a condensed deposition persisted to the end of the Famennian or even terminated in the Tournaisian (M. Szulczewski, 1978; H. Żakowa *et al.*, 1984; M. Szulczewski *et al.*, in press). Near the northern margin of the platform the condensed sequence is restricted to the Lower Famennian and then is vertically replaced by basinal deposits (M. Szulczewski, 1971, 1981, 1989).

THE MIDDLE TO UPPER DEVONIAN INTRA-SHELF BASINS

The Middle to Upper Devonian evolution of a palaeotopography in the area of the HCM is largely a history of intra-shelf basins expanding in expense of the separating them carbonate platform. The two basins differ, however, substantially from each other in their extent and persistency. It makes a pensymmetrical appearance of the resulting facies distribution. The depth of the basins did not exceed several hundreds metres, but often was less, especially in the Middle Devonian. The lithology of basins-fill is dominated by clay and carbonate rocks, clastic rocks being exceptionally rare.

THE NORTHERN BASIN

The northern basinal area of the HCM was only the southernmost marginal fragment of the broad basin, stretching far to the north. The basinal setting appeared just after cessation of the Lower Devonian clastic deposition. It persisted throughout the Devonian, interrupted only during several regressive episods by basinward shift of more shallow and margin-proximal depositional environments .The noteworthy examples are the Eifelian tong of the early carbonate platform (Wojciechowice Formation) the Givetian buildups of the Pokrzywianka Beds and the Frasnian complex of slope deposit (Kostomłoty Beds).

The Middle Devonian basin-fill is informally termed "a shaly facies", since it consists mainly of shales, intercalated with variable limestones and marls (Grzegorzowice Formation, Skały Formation, Nieczulice Beds, Śniadka Beds). They often contain abundant and diversified fossil assemblages, mostly benthonic, but nektonic fossils are also encountered, goniatites including. The Świętomarz Formation is the exceptional stratigraphic unit within the basinal sequence, since it comprises fine clastics. J. Kłossowski (1985) demonstrated that sedimentological indicators point to their westward transportation.

In the Upper Givetian and Frasnian the basinal facies (Szydłówek Beds) significantly shifted southward (G. Racki, 1985; G. Racki *et al.*, 1985). Finally, late in the Early Famennian, they encroached over the marginal part of the isolated carbonate platform, succeeding the condensed cephalopod limestones. The Upper Devonian basinal deposits mostly represent deeper depositional settings compared to the Middle Devonian ones (M. Narkiewicz, I. Olkowicz-Paprocka, 1983; H. Matyja, M. Narkiewicz, 1992, 1995). They are less fossiliferous, and contain impoverished fauna. It consists of nektonic, planktonic and oxygen deficiency tolerating benthonic assemblages. Different and far more differentiated fauna is included in the crinoidal beds, resedimented from the central swell by gravity debris flow (G. Biernat, M. Szulczewski, 1992).

In the eastern part of the Kielce region (Płucki, Janczyce, Łagów) thin lenticles of cephalopod limestone are inserted within the basinal deposits (H. Makowski, 1971, 1991; H. Matyja, M. Narkiewicz, 1995). They precisely correlate with rises of the global sea proposed by J. G. Johnson *et al.* (1985). The lowermost cephalopod limestone is situated at the Frasnian/Famennian boundary and is representative of the well-known Kellwasserkalk.

The thickness of the Middle to Upper Devonian, overlying Eifelian extension of the carbonate platform (i.e. Wojciechowice Formation), probably exceeds 1000 m. It includes the Famennian, which is up to roughly 300 m thick.

THE SOUTHERN BASIN

The appearance of the southern basin is closely related with an isolation of the central carbonate platform. The basinal deposition commenced in the Upper Givetian by drowning of a portion of the carbonate platform, which attained its bank phase of development. The basin enlarged in the Frasnian, but nevertheless it remained only about 10 km wide, since its southern margin was identified still at the southern border of the HCM (G. Racki, 1993; cf. Z. Bełka, S. Skompski, 1988).

The central carbonate platform influenced deposition in the basin (1) as a source of resedimented carbonate debris and (2) as a sill, which restricted water circulation. The carbonate turbidites are common in the Frasnian deposits (M. Szulczewski, 1968), but the last distal ones occur in the Early Famennian. A poorly oxigenated conditions strongly influenced biota in the basin (G. Biernat, G. Racki, 1986; B. Berkowski, 1991). The main feature of the evolution of depositional environments in the Famennian is their progressing transformation from anaerobic to well oxygenated ones, accompanied by shallowing up. Near the end of the Famennian the basin and the adjacent central swell became almost levelled, as evidenced by condensed cephalopod limestones, known from vicinity of Kowala village (J. Czarnocki, 1989; J. Malec, 1993*a*), which completed the basin filling.

THE LOWER CARBONIFEROUS BASIN

The Lower Carboniferous deposits are commonly soft and easily weathering, so they are hardly accessible at the surface. They were nowhere encountered in the Łysogóry region, where they probably have been largely eroded. However, in the Kielce region they are known through drill record. The correlation of particular sections is difficult, since fossils adequate for reliable age determination are often scarce. Hence, the here presented reconstruction of stratigraphic relationships will be more simplified than those proposed by H. Żakowa (1970, 1980, 1981) and H. Żakowa and Z. Migaszewski (1995).

In the Early Carboniferous the general pattern of principal facies or regional stratigraphic units is relatively simple. Apparently it does not follow the Upper Devonian trifold pattern reflecting a basins — swell topography. However, a thickness distribution and diachronism of facies boundaries indicates that the swell affected the regional depositional pattern until the Viséan.

Over the pelagic carbonate platform the Carboniferous is known from very limited localities. Nevertheless, it has been found that the condensed limestones of the pelagic carbonate platform locally include the Lower and Middle Tournaisian at its summit (Nasiłowski, 1975 *vide* M. Szulczewski, 1978; H. Żakowa *et al.*, 1984; M. Szulczewski *et al.*, in press). The existence of the low-rate deposition in this time-span was earlier evidenced by the palaeontological content of the unusually fossiliferous neptunian dyke (M. Szulczewski, 1973). Elsewhere this stratigraphic interval often falls, however, into a broad nondepositional gap.

The Famennian and Lower Carboniferous succession evidences progressing and stepwise foundering of the carbonate platform. The facies of the succeeding lithosomes reflects progressive deepening, decreasing oxygenation and increasing rate of accumulation. The condensed sequence is vertically replaced by the red to variegated complex of alternating limestones and shales (Radlin Beds). Commonly it belongs to the Upper Tournaisian *anchoralis* Zone and reaches to equivalent of the lowermost Viséan *texanus* Zone, although locally it may commence much earlier. Sedimentological and palaeontological features of this complex indicate its deposition in a well aerated environment situated at the swell-to-basin transition (M. Szulczewski *et al.*, in press).

The drowning was completed in the Viséan with onset of deposition of black siliceous shales (Zaręby Formation). They are here attributed to the Lower and Middle Viséan (M. Szulczewski *et al.*, in press). The black shales are laminated and organic rich. They contain abundant radiolarians and subordinate sponge spicules. Their features point to an anoxic depositional environment at a depth of several hundred metres.

The lithologies typifying the two above described units, which follow the condensed sequence over the buried carbonate platform, continue beyond it to the former basinal area, but their thickness increases conspicuously in this direction. The alternating limestones and shales are only about 3.5 m thick over the platform but outside it a thickness of the corresponding Radlin Beds attains up to 20 m (H. Żakowa, 1981). The black shales of the Zaręby Formation are respectively from 25 (or possibly up to 60 m) to about 250 m thick (H. Żakowa, 1981). Moreover, beyond the platform at least the lowest 90 m of the black shales belong still to the Tournaisian (H. Żakowa, 1981; H. Żakowa, M. Paszkowski, 1989), while above the platform their base is situated within the Viséan.

The Lower and Middle Viséan was a period of the most unificated and the deepest depositional environments in the Upper Palaeozoic history of the HCM. The accumulated deposits are hemipelagic noncarbonate clays. They are laterally differentiated only into aforementioned more siliceous facies (Zaręby Formation), akin to Kiesellschiefer, and the nonsiliceous one (former Górno Beds, included in Lechówek Formation by H. Żakowa and Z. Migaszewski, 1995). Although their depositional setting remind of "bathyal lull", governing penecontemporaneously many regions in the Variscan realm, their accumulation rate was relatively high, since the Górno Beds attain 75 to more than 400 m in thickness (H. Żakowa, 1981).

Appreciably contributing to the accumulation of the all above described Carboniferous units were tephra deposits (H. Żakowa *et al.*, 1984; Z. Migaszewski, 1995; R. Chlebowski, 1995). They appear as early as in the uppermost Famennian. Over the swell peaks of volcanic activity coincide with several boundaries between the units reflecting successive phases of its drowning. It confirms that the foundering was significantly affected by extensional tectonics (M. Szulczewski *et al.*, in press).

Conspicuous turnover in the depositional regime is marked within the Upper Viséan by onset of siliciclastics upon hemipelagic deposits of the Zaręby Formation and Górno Beds. The clastic deposits are some hundred metres thick, generally fine-grained and contain more clay and mudstones than sandstone intercalations. They belong to the Lechówek Formation, the Gułaczów Member including (H. Żakowa, Z. Migaszewski, 1995), the latter more sandy and containing thicker sandstone intercalations than the former. They still wait for sedimentological analysis.

This transformation of depositional regime was heralded by an abrupt deposition of the coarse-grained lenticular carbonate bodies (Gałęzice Debrite Member of H. Żakowa and Z. Migaszewski, 1995). They occur in the southwestern corner of the HCM, close to the Middle/Upper Viséan boundary. According to Z. Bełka and S. Skompski (1988) they are carbonate gravity flow deposits. They were deposited as submarine fans, situated in a deep lower-slope environment of Zaręby Formation. Their Frasnian to Viséan debris derive from another, hypothetic, more long-lived carbonate platform. Z. Bełka *et al.* (in press) suppose that it was situated about 10 km to the south and name it the Nida Platform.

The source of the Upper Viséan siliciclastic deposits seems, on the other hand, to be situated to the north or north-west of the HCM. It was probably created by the approaching front of the Variscan orogeny. The Palaeozoic succession of the HCM was folded during this orogeny. The youngest folded strata belong to the Upper Viséan, and the oldest unconformably overlying them are the Permian. Hence, a broad and significant time-span of geological history of the HCM is devoid of its direct stratigraphic record.

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EWOLUCJA DEPOZYCJI W GÓRACH ŚWIĘTOKRZYSKICH W DEWONIE I KARBONIE — PRZEGLĄD PROBLEMATYKI

S t r e s z c z e n i e

Prędki przyrost wiedzy o dewonie i karbonie Gór Świętokrzyskich skłania do podjęcia próby przeglądu ważniejszych publikacji, składających się na obraz głównych zjawisk i problemów rozwoju facjalnego w tym przedziale stratygraficznym. Niniejszy artykuł, temu poświęcony, jest nieco zmodyfikowaną i unowocześnioną wersją opracowania przedstawionego na konferencji międzynarodowego projektu EUROPROBE, która odbyła się w Kielcach w 1994 r.

Dewon i dolny karbon Gór Świętokrzyskich tworzą spójny rozdział historii sedymentacji, podporządkowany długotrwałej transgresji i ograniczony dwiema niezgodnościami kątowymi, korelującymi się z orogenezą późnokaledońską i waryscyjską.

Dolny dewon jest wykształcony głównie jako sukcesja klastyczna. W jej depozycji uczestniczyły środowiska lądowe i morskie, aż po ostateczną transgresję morską w górnym emsie. Wzór geograficznego zróżnicowania jej miąższości, kompletności zapisu stratygraficznego i facji jest wyrazistą ilustracją odmienności reżimu depozycyjnego w regionie łysogórskim i kieleckim. Facjalne ograniczenia występowania skamieniałości powodują jednak niepewność podziału chronostratygraficznego tego oddziału dewonu nawet na poziomie piętra. Środowiska sedymentacji poszczególnych formacji są wprawdzie identyfikowane, ale brakuje pogłębionych studiów uzasadniających deklarowane zapatrywania. Stąd znaczne czasem rozbieżności poglądów, jak w sprawie środowiska depozycji i regionalnego znaczenia zlepieńca miedzianogórskiego. Niejasny obraz paleogeografii poprawiają sygnały M. Tarnowskiej, że facje morskie w górnej partii dolnego dewonu sięgają daleko na południe, poza granice Gór Świętokrzyskich.

Transgresywny skok poziomu morza na przełomie wczesnego i środkowego dewonu wywołał zanik sedymentacji klastycznej i wprowadził na krótko zróżnicowane środowiska morskie, z udziałem środowisk pełnomorskich. Rychłe spłycenie i unifikacja środowisk depozycji zapoczątkowały z kolei długotrwały rozwój płytkowodnej platformy węglanowej. Bogactwo zespołów skamieniałości i zjawisk fizycznych spowodowało, że jej aspekty stratygraficzne, sedymentologiczne i paleontologiczne od lat skupiają na sobie najwięcej uwagi badaczy. Głównymi znamionami ewolucji platformy było stopniowe zmniejszanie się jej obszaru, wzrost zróżnicowania reliefu i rosnące znaczenie budowli organicznych. Z trzech faz rozwoju platformy pierwsza charakteryzuje się dominacją facji wokółpływowych i ubóstwem budowli organicznych, a dwie kolejne odpowiadają fazie ławicowej i rafowej z dewonu frańskiego. W fazie rafowej platforma osiągnęła najbardziej złożony układ facji, odpowiadający systemowi depozycyjnemu izolowanej platformy węglanowej, obramowanej rafami i płyciznami (rafa dymińska

M. Narkiewicza, dymiński kompleks rafowy G. Rackiego). Stromatoporoidowo-koralowcowy zespół organizmów zanikł przed końcem franu, ale oznaki istnienia płytkowodnej platformy pojawiają się jeszcze długo w famenie.

Na północy i południu z płytkowodną platformą sąsiadowały baseny śródszelfowe. Basen północny sięgał daleko poza Góry Świętokrzyskie i wyodrębnił się już u schyłku wczesnego dewonu. Powstanie węższego, południowego basenu jest równoznaczne z izolacją platformy w jej stadium rafowym. Centralnie usytuowana platforma wpływała na sedymentację w basenach jako źródło resedymentowanego materiału oraz jako próg ograniczający cyrkulację.

Część platformy węglanowej zatopiona w górnym dewonie przekształciła się w pelagiczną platformę węglanową. Stanowią ją skondensowane wapienie głowonogowe i krynoidowe, sięgające lokalnie nawet środkowego turneju. Spoczywają one często na węglanach platformy niezgodnie i wnikają w nią w formie różnowiekowych żył neptunicznych.

W dolnym karbonie wzór facjalny ulega uproszczeniu. Sukcesja stratygraficzna zwykle rozpoczyna się naprzemianległymi wapieniami i łupkami, a przykrywają je czarne łupki krzemionkowe oraz ilaste. Wpływ pogrążonej platformy węglanowej wyraża się już tylko w różnicach miąższości tych formacji i w diachronizmie dzielącej je granicy. Zasadniczy zwrot w reżimie sedymentacyjnym nastąpił w górnym wizenie wraz z pojawieniem się kompleksu silicyklastycznego, zamykającego zachowaną sukcesję karbońską. Poprzedziła go lokalna depozycja soczewek wapiennych, uważanych obecnie za stożki podmorskie, utworzone z materiału grawitacyjnie przemieszczonego z dłużej trwającej, hipotetycznej platformy węglanowej, położonej na południe od Gór Świętokrzyskich. Zdarzenia te wiąże się już z aktywnością tektoniczną, która wkrótce przyniosła emersję i wywołała niezgodność waryscyjską.