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Devonian depositional architecture in central segment of the Lublin Trough: preliminary results of integrated seismic and borehole study

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Seismostratigraphic analysis of two selected seismic lines coupled with sedimentological and stratigraphic investigations of four deep wells allows for putting forward a revised depositional model for the Middle to Upper Devonian predominantly carbonate succession in the central part of the Lublin Trough. The upper Frasnian carbonate ramp prograded towards the north-east over the relatively thin and widespread Middle Devonian to lower Frasnian cycles. The lower Famennian shelf-basin fill consists of carbonate-shaly clinoforms also prograding towards the depocentral axis. The proposed model has important implications for a distribution of source-rocks related to distal condensed portions of the lower Famennian clinoforms and, probably, to distal part of the upper Frasnian ramp.

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Key words: Devonian, Lublin Trough, carbonates, seismic stratigraphy, T-R cycles, source rocks.

INTRODUCTION

In the following paper we would like to address selected problems of reconstruction of depositional architecture of the Middle and Upper Devonian sediments in the central segment of the Lublin Trough. This analysis was based on results of seismostratigraphic interpretation of selected seismic lines coupled with results of sedimentological and facies studies of logs and cores from key wells located in their vicinity.

Interpretation of seismic data from the Lublin Trough completed so far was mainly devoted to tectonic problems (i.a. A. M. Żelichowski, 1972*a*, *b*, 1979, 1983) and usually not to detailed analysis of internal depositional architecture of the Palaeozoic sedimentary succession. In case of the Devonian sediments such an analysis seemed particularly difficult due to generally low quality of seismic data for Devonian section, related to attenuation of seismic energy caused by overlying thick Carboniferous predominantly built of terrigenous deposits. During this study two industrial seismic lines acquired by the Polish Oil and Gas Company (Geofizyka–Kraków Geophysical Company), and four research wells drilled by the Polish Geological Institute, were selected for seismostratigraphic interpretation (Fig. 1). The study area is located in central segment of the Lublin Trough to the south of Lublin city. This area is particularly suitable for such a study as Carboniferous sediments are only partly preserved in axes of synclines and are relatively thin, in order of few hundred metres. This preferable situation is due to regional uplift and shallowing of axes of main tectonic units within the Palaeozoic structural complex. Such a geological situation allowed for acquisition of seismic data that fairly precisely imaged internal structure of the Devonian sediments.

GEOLOGICAL SETTING

Lublin Trough is a prominent Devonian–Carboniferous depocenter which developed along southern edge of Laurussia (Old Red Continent) in palaeogeographical continuity

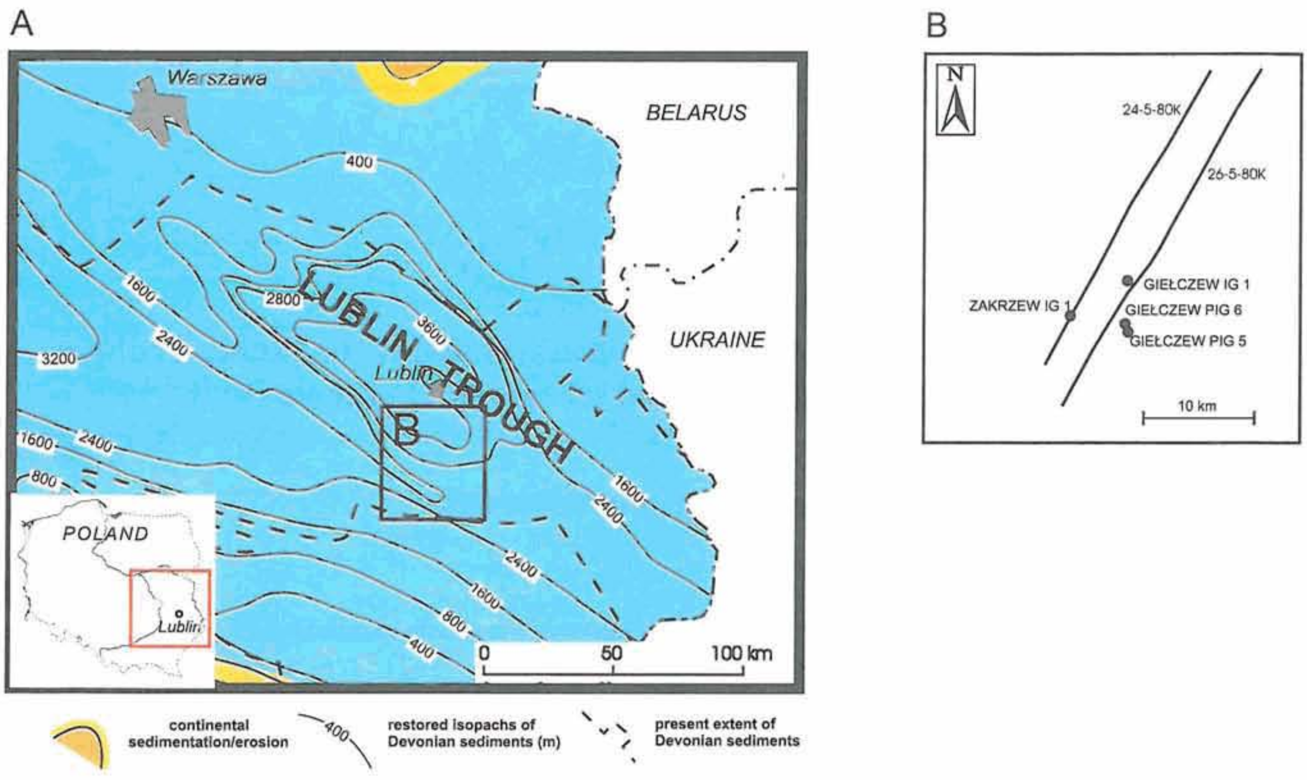

Fig. 1. A. Location map of the study area against the restored Devonian geometry of the Lublin Trough
B. Location of investigated seismic lines and wells

A. Lokalizacja obszaru badań na tle odtworzonej pierwotnej geometrii dewońskiego rowu lubelskiego
B. Lokalizacja badanych linii sejsmicznych i wierceń

with other peri-cratonic basins stretching from Western Canada to Eastern Europe (see e.g. M. Narkiewicz, 1988). It developed in southeastern Poland along the Trans-European Suture Zone (TESZ), i.e. zone of a major crustal discontinuity between the Precambrian East European Craton and Palaeozoic crust of Western Europe (T. Pharaoh *et al.*, 1996; P. Ziegler, 1990). TESZ forms southwestern border of the Lublin Trough, while from the north-east it is bordered by another deeply-rooted tectonic discontinuity — the Kock Fault Zone (i.a. A. M. Żelichowski, 1972*b*, 1979). Recently completed subsidence analysis suggests that Early to Middle Devonian sedimentation in this area was governed by gradually decreasing thermal subsidence, similarly as in the remaining area of the Devonian epicontinental basin in southern Poland. More localized development of the Lublin Trough as a separate depocenter started in the Frasnian. This is evidenced by increased subsidence rate probably controlled by extensional or transtensional tectonic regime (M. Narkiewicz *et al.*, 1997). In late Westphalian time tectonic activity related to Variscan orogeny led to development of several rather gentle folds and other structures, that can be presently clearly observed on numerous seismic lines. Period of tectonic activity was followed by strong erosion that removed, especially in southeastern part of the Lublin Trough, large part of Carboniferous sediments. During late Permian and Mesozoic the studied area was located closely to margins of intracontinental or epicontinental basins whose depocenters (collectively termed the Mid-Polish Trough) extended along the TESZ further to the north and west (R. Dadlez, 1989; P. Ziegler, 1990).

In the study area two structural complexes can be distinguished in the investigated seismic sections. Older complex is built of deformed Palaeozoic rock series of the Devonian and Carboniferous age. Devonian section is fairly complete and consists of the Lower to Upper Devonian sediments (Fig. 2). Carboniferous (Viséan) deposits are only partly preserved in axial parts of synclines. Younger structural complex is built of undeformed, nearly horizontal Middle Jurassic to Cretaceous sediments deposited closely to southeastern part of the Mid-Polish Trough. These two complexes are separated by prominent, widespread angular unconformity that can be traced on long distances on numerous seismic lines.

AVAILABLE DATA AND METHODS OF INTERPRETATION

Analysis of internal depositional architecture of the Middle and Upper Devonian sediments of the investigated part of the Lublin Trough was based on interpretation of two

Table 1

Depths of upper boundaries of the Devonian and Carboniferous chronostratigraphic units in the studied wells (after L. Miłaczewski)

Chronostratigraphic unit	Giełczew PIG 5 (J_2 over Fa)	Giełczew PIG 6 (J_2 over Fa)	Giełczew IG 1 (J_2 over Fr)	Zakrzew IG 1 (J_2 over V)
Viséan (V)	–	–	–	1460.0
Famennian (Fa)	1465.0	1453.0	–	1480.5
Frasnian (Fr)	1508.0	1563.5	1481.0	2090.
Givetian	1960.5	2009.4	1966.0	2553.5
Eifelian	2106.5	–	2150.0	2618.0
Lower Devonian	2140.5	–	2262.5	2725.5
	TD 2150.5	TD 2009.6	TD 2344.0	TD 2798.0

J_2 — Middle Jurassic

industry seismic lines (24-5-80K and 26-5-80K) acquired in early '80 by the Polish Oil and Gas Company (Geofizyka-Kraków Geophysical Company) and located perpendicularly to axes of main fold structures present within the Palaeozoic complex. These seismic lines were calibrated by data from four research wells drilled by the Polish Geological Institute (Giełczew IG 1, PIG 5 and PIG 6 and Zakrzew IG 1). Table 1 presents depths of tops of particular chronostratigraphic units distinguished in these wells. Carboniferous sediments were drilled in only one well (Zakrzew IG 1) and are relatively thin, while the Devonian section is complete and of sufficient thickness in order to properly image its internal architecture on seismic data. Pre-Middle Devonian sediments are poorly resolved on seismic data. Devonian stages form continuous stratigraphic succession, whereas boundary between the Famennian and Viséan is marked by stratigraphic gap and can be described as a parallel unconformity. In the well Giełczew IG 1 post-Variscan erosion removed not only Carboniferous sediments but also Famennian and topmost part of Frasnian section, therefore Frasnian is covered directly by flat-lying Middle Jurassic sediments.

Detailed sedimentological investigations have been based on two fully cored wells: Giełczew PIG 5 and PIG 6. As a result of the investigations, depositional systems have been interpreted and the Devonian succession has been subdivided into several transgressive-regressive cycles (Fig. 2; M. Narkiewicz *et al.*, in prep., see also further in the text).

For all the wells a complete suite of digital well logs (LAS format) was available. The only exception was lack of sonic logs for the wells Zakrzew IG 1 and Giełczew IG 1. Sonic log for the Giełczew PIG 6 was of low quality and with numerous errors caused by acquisition procedure. For all the wells synthetic sonic logs were constructed using in-house software GEOFLOG developed in the Polish Geological Institute and designed for advanced qualitative and quantitative analysis of well data (J. Szewczyk, D. Gientka, 1996). Synthetic sonic logs were calculated using radiometric and electric logs and results of lithological studies of cores. Seismic lines were time-migrated and provided in SEG-Y format, along with location data (UKOOA format).

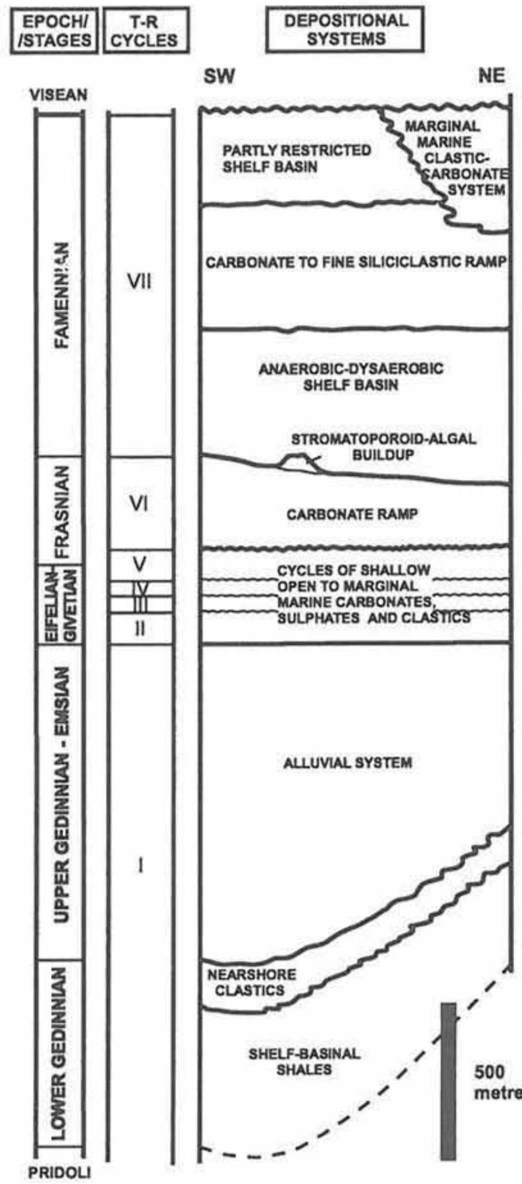

Fig. 2. Summary of Devonian chronostratigraphy, transgressive-regressive cycles and depositional systems in the central segment of the Lublin Trough

Chronostratygrafia, cykle transgresywno-regresywne i systemy depozycyjne w dewonie centralnego segmentu rowu lubelskiego

All the interpretation of geophysical data was completed using Landmark Graphics Corporation software. Well logs were converted to LAS format and loaded into the database, along with other well information including location, elevation information and depth of drilled formation tops. In order to tie well information to seismic data synthetic seismograms were calculated using SynTool package. Interpretation of seismic data was completed using SeisWorks2D package.

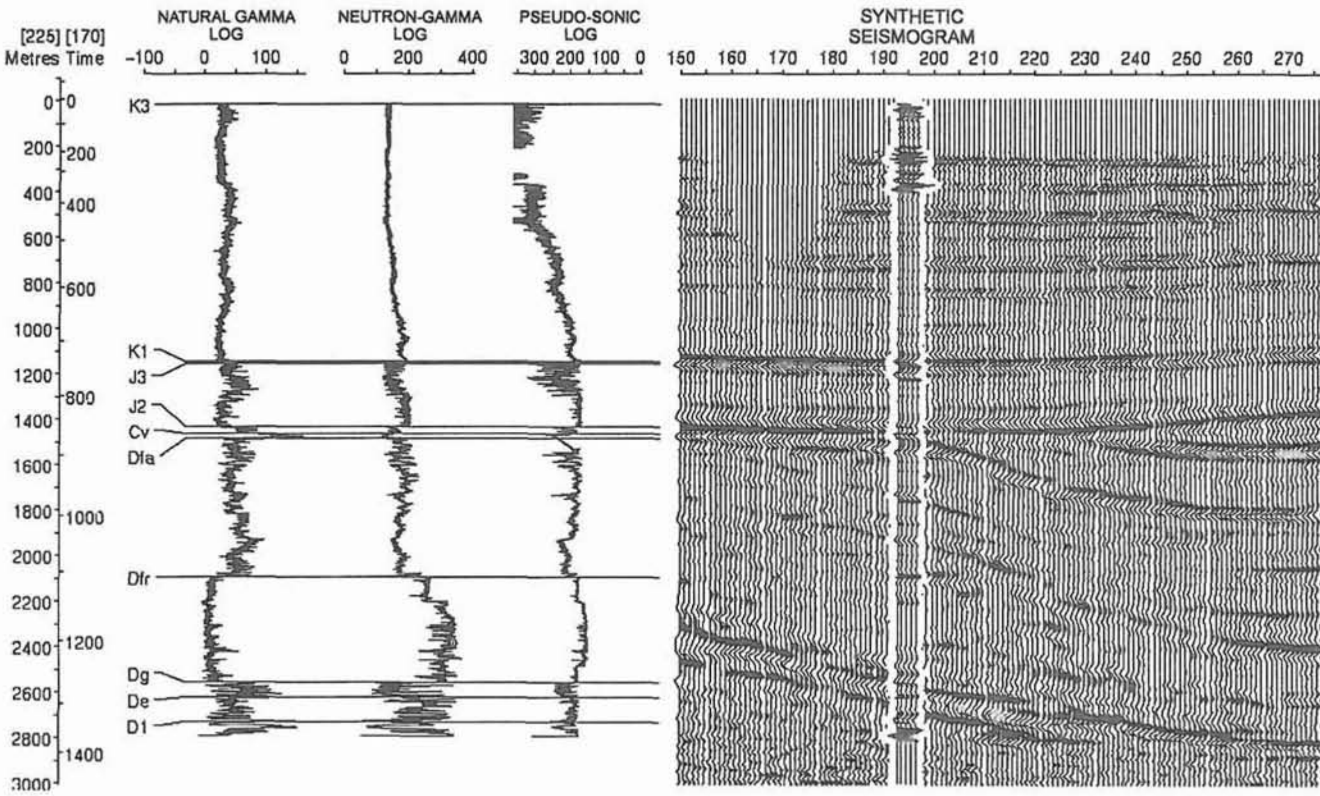

Fig. 3. Well Zakrzew IG 1 — natural gamma-ray log, sonic log, synthetic seismogram and its correlation with part of seismic line 24-5-80K

Otwór Zakrzew IG 1 — krzywe karotażowe gamma i akustyczna, sejsmogram syntetyczny i jego korelacja z fragmentem linii sejsmicznej 24-5-80K

CORRELATION OF BOREHOLE AND SEISMIC DATA

In order to precisely calibrate recorded seismic wave field it is necessary to tie available well information to seismic data. This can be achieved by calculation of synthetic seismograms, i.e. theoretical seismic response along the well due to variations of velocities and densities within the drilled rock succession. Synthetic seismogram can be calculated using sonic and density logs measured in a well. It can then be correlated with recorded seismic data, and particular maxima and minima observed on seismic lines can be correlated with particular lithological and stratigraphic boundaries (N. S. Neidell, 1984). Such a correlation is regarded as a first and indispensable step in stratigraphic interpretation of seismic data (P. Krzywiec, 1993; P. R. Vail, 1987).

In the case of four wells located in the Giełczew–Zakrzew area, either sonic or synthetic sonic logs were available, but no density logs were recorded. In order to achieve best correlation between synthetic seismograms and recorded seismic wavefield several seismic wavelets (Ormsby, Butterworth, Ricker, bandpass) with different parameters were tested. Ricker wavelet with 35 Hz dominant frequency was selected as the one that provided best results. With this wavelet all the analyzed synthetic seismograms were calculated. On Figure 3 a synthetic seismogram calculated for the well Zakrzew IG 1 is presented along with natural gamma log, neutron-gamma log, as well as with correlation between synthetic seismogram and seismic data. Additionally, location of particular stratigraphic boundaries is presented, including tops of Viséan, Famennian, Frasnian, Middle Jurassic and Lower Cretaceous. Similar correlation between geological and geophysical data was completed for other wells. Zakrzew IG 1 is the only well located directly on the investigated seismic lines. As can be inferred from different thicknesses of Carboniferous and Devonian intervals for all the studied wells, significant thickness variations perpendicular to studied seismic lines exist, and superposition of wells other then Zakrzew IG 1 on the seismic lines could lead to some error. Therefore, the well Zakrzew IG 1 was regarded as a key well for the present study. Correlation of the well Zakrzew IG 1 with the seismic line 24-5-80K via calculated synthetic seismogram enabled location of particular stratigraphic boundaries on recorded seismic wavefield.

In the study area seven T-R cycles can be distinguished within the Devonian succession, which are also characterized by different well log response. Detailed analysis of Devonian depositional systems, transgressive-regressive cycles and their correlation will be presented elsewhere (M. Narkiewicz *et al.*, in prep.). For the purpose of this study the results can be summarized as follows (see also Fig. 2). Upper part of the Lower Devonian sediments (Zwoleń Formation) belonging to middle Gedinnian–Emsian and attaining total thickness about 1300 m, can be interpreted as alluvial depositional system. Middle and Upper Devonian are represented by marine sediments. In the lower part (Eifelian) these are terrigenous,

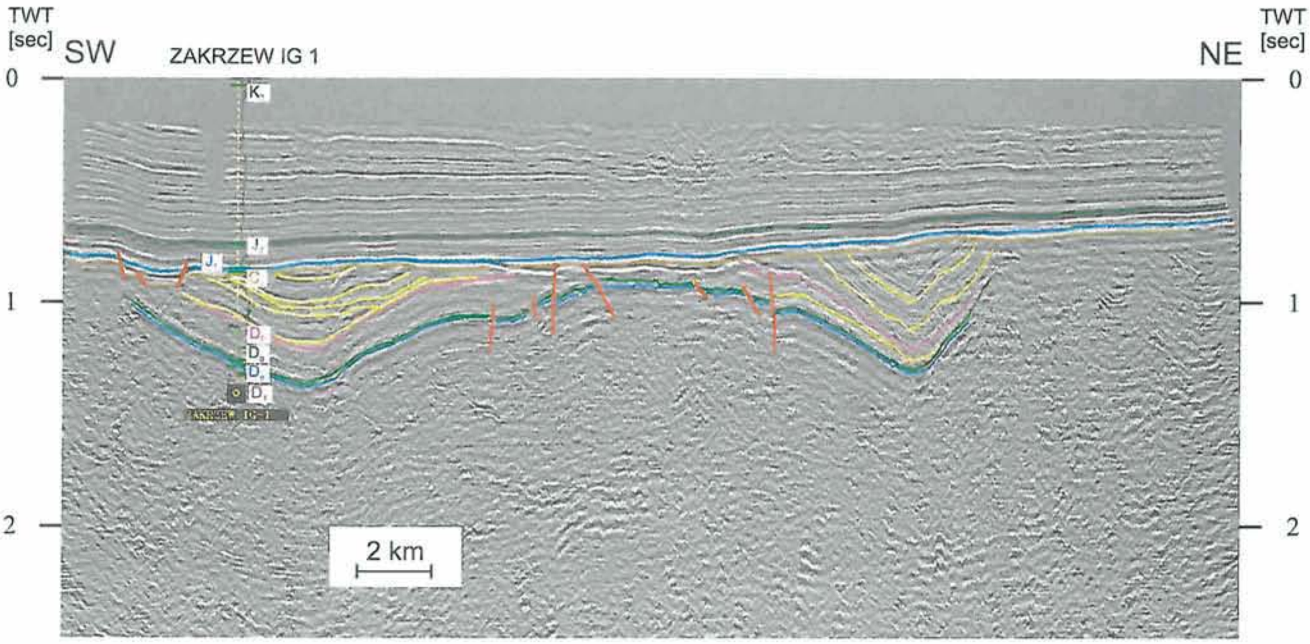

Fig. 4. Interpreted time seismic line 24-5-80K
Interpretacja czasowego profilu sejsmicznego 24-5-80K

mostly sandy sediments representing nearshore siliciclastics. They are overlain by almost pure carbonates deposited on a carbonate subtidal to supratidal platform and shallow-water carbonate ramp. Four relatively thin T-R cycles can be distinguished within the Givetian and lower Frasnian sediments being characterized by prominent lateral continuity and attaining up to 300 m of total thickness. Successive T-R cycle developed within the upper part of Frasnian (Zubowice Member; L. Miłaczewski, 1981) is of much higher thickness (up to 300 m) and can be interpreted largely as a shallow subtidal platform or middle ramp. Beginning of this cycle can be related to increase in a sedimentation and subsidence rate which reached its maximum in the Famennian. During that time, after a short period of regression in latest Frasnian, thick (up to 1000 m in study area, and about 1800 m in vicinity of Lublin) shaly-carbonate series of the single T-R cycle have been deposited. Sedimentation took place in sedimentary basin with strong, tectonically-controlled subsidence. This basin was filled first by sediments of dys-anaeorobic shelf-basin (Bychawa Formation), that were subsequently replaced by deposits of a carbonate ramp (Firlej Formation). During the late Famennian, sediments of the Niedrzwica Formation were most probably deposited in study area, but they are absent today due to later erosion. In other places they consist of fine siliciclastics and carbonates related to sedimentation of (partly isolated?) shelf-basinal depositional system.

Analysis of calculated synthetic seismogram for the well Zakrzew IG 1 (Fig. 3) clearly shows that characteristic packages of seismic reflectors can be distinguished and correlated with particular lithological intervals. For example, strong reflectors present within the topmost part of the Fammenian can be correlated with shale and mudstone intercalations in carbonates, prominent reflector is related to the bottom of the Frasnian shaly-carbonate sediments, also package of strong reflectors can be correlated with siliciclastics of the Eifelian and uppermost part of the Lower Devonian. For the well Zakrzew IG 1 high degree of correlation has been achieved between calculated syntethic seismogram and seismic wavefield of seismic line 24-5-80K. In case of wells located in vicinity of Giełczew village correlation was less reliable. This was due to the fact that all these wells were projected on seismic line from some distance. For the wells Giełczew PIG 5 and PIG 6 synthetic seismograms were calculated based on both measured and calculated (synthetic) sonic logs. In case of the well Giełczew PIG 5 obtained results were nearly identical and for further considerations synthetic seismogram calculated from measured sonic data was used. High degree of correlation between both synthetic seismograms was also regarded as a direct proof that methodology developed for construction of synthetic sonic logs adopted in the GEOFLOG software (J. Szewczyk, D. Gientka, 1996) yields reliable results. In the case of the well Giełczew PIG 6 well synthetic sonic log was used for construction of synthetic seismogram as several errors were identified on measured sonic log that were most probably related to acquisition failures.

After reliable tie between synthetic seismograms and seismic profiles had been achieved for all the considered wells, time-depth tables were calculated and stored in database. This enabled well data transfer from depth to time domain and consequently detailed stratigraphic interpretation of seismic data.

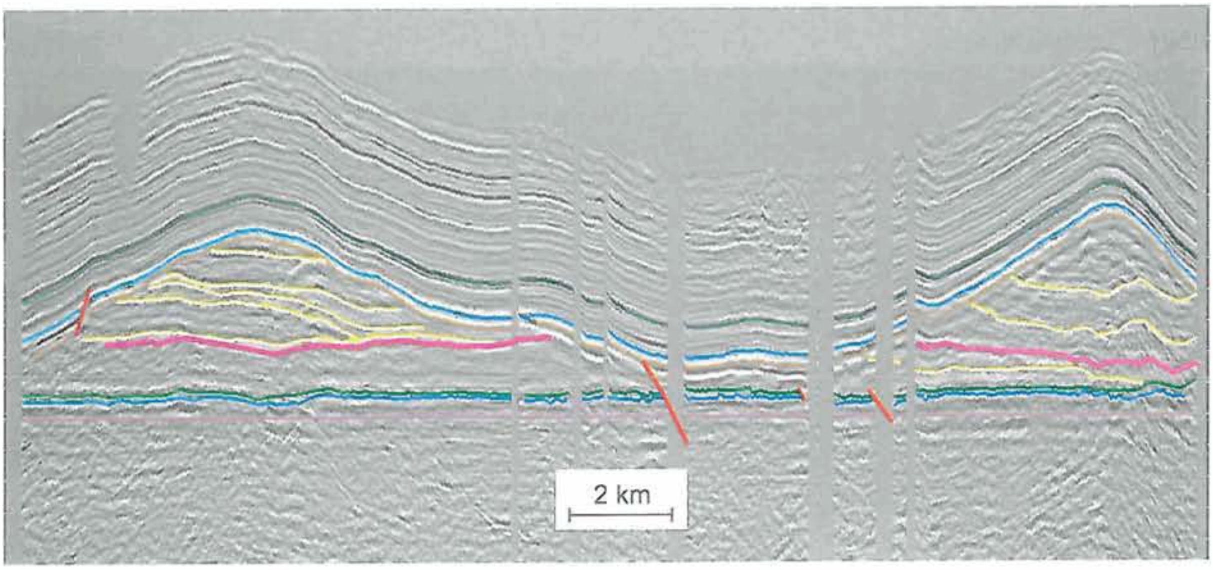

Fig. 5. Interpreted time seismic line 24-5-80K flattened on seismic horizon related to top of the Lower Devonian

Interpretacja sejsmicznego profilu czasowego 24-5-80K wypłaszczonego względem horyzontu sejsmicznego związanego ze stropem dewonu dolnego

INTERPRETATION OF SEISMIC DATA

Well Zakrzew IG 1 was the only well located directly on seismic line 24-5-80K. Owing to a very good tie between synthetic seismogram and seismic data (Fig. 3) the following stratigraphic horizons were identified on this seismic line: top of the Lower Devonian, top of the Eifelian, top of the Givetian, top of the Frasnian, top of the Palaeozoic (in the well Zakrzew IG 1 this boundary was correlated with the top of the Famennian together with Viséan due to a very low thickness of the latter), top of the Middle Jurassic, and finally top of the Upper Jurassic. Within the Devonian section, several intra-Famennian reflectors were picked, that visualize internal depositional architecture of these sediments. As can be seen on Figure 4, seismic horizons related to tops of the Lower Devonian, Eifelian, Givetian and Frasnian are — at least within the syncline drilled by well Zakrzew IG 1 — nearly parallel. This

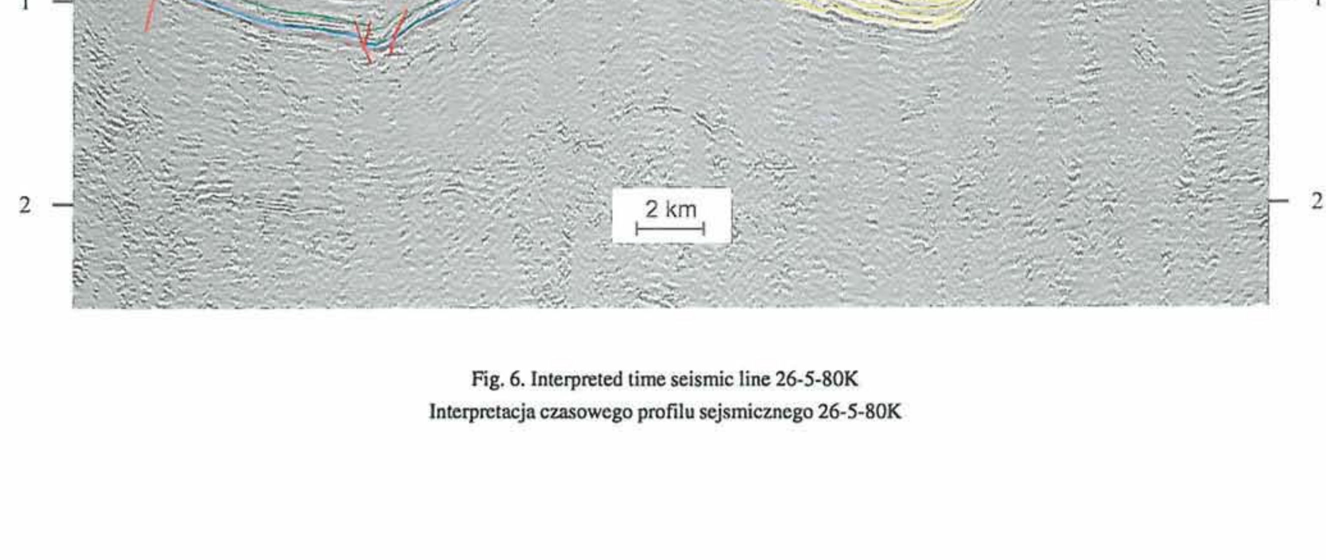

Fig. 6. Interpreted time seismic line 26-5-80K

Interpretacja czasowego profilu sejsmicznego 26-5-80K

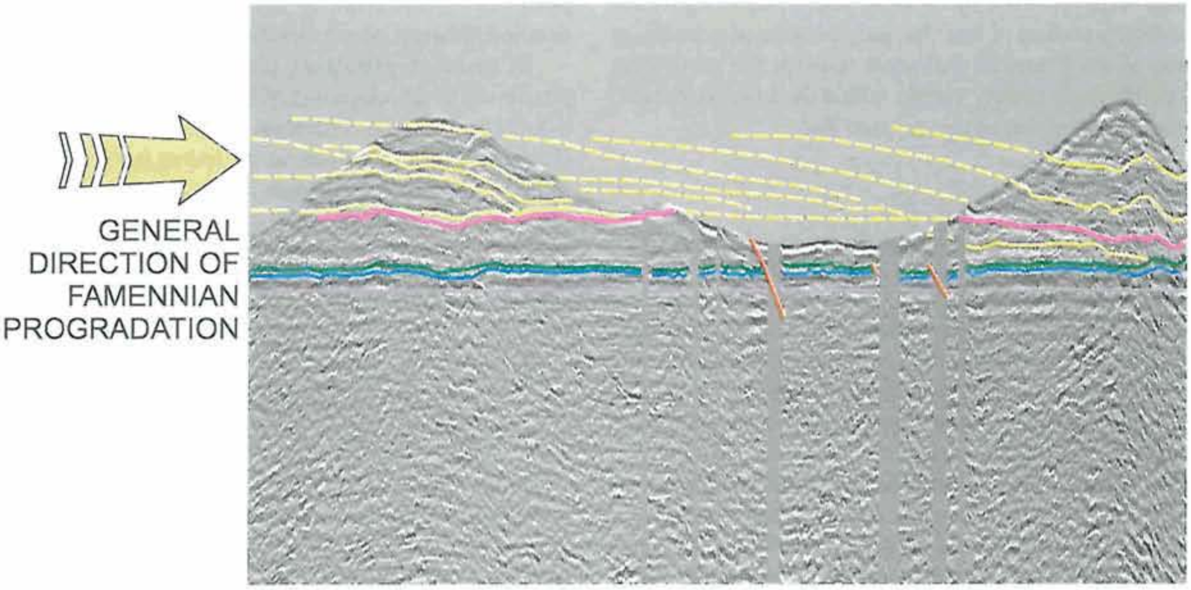

Fig. 7. Lower Famennian depositional model based on seismic line 24-5-80K
Model depozycji famenu dolnego na podstawie profilu sejsmicznego 24-5-80K

situation is in agreement with assumed development of relatively thin, laterally-continuous depositional systems forming widespread T-R cycles. Analysis of the top of Frasnian in another syncline reveals that thickness of the stage is increasing towards the north-east (see also below).

Interesting configuration of seismic horizons can be observed within the Famennian section. Despite same disturbances of seismic wavefield, related most probably to not-fully migrated diffraction waves, several truncations of intra-Famennian reflectors can be clearly distinguished (Fig. 4). These truncations are interpreted as tilted downlap configuration which developed due to progradation of Famennian sediments towards the north-east, followed by tectonic movements which created array of synclines and anticlines. In order to better visualize pre-tectonic, syn-depositional seismic configuration entire seismic section was flattened on the Lower Devonian horizon (Fig. 5). This procedure shifts all the seismic traces in such a manner, that picks of given horizon on all the traces are aligned along horizontal line. As the Lower Devonian sediments were deposited on alluvial plain it is plausible to assume that their regional initial, syn-depositional configuration was nearly horizontal and hence such a flattened seismic line in fact approximates post-Early Devonian depositional architecture of this part of the Lublin Trough. It can be observed on flattened seismic line 24-5-80K that Frasnian sediments progressively decrease their thickness towards the NE and that general configuration can be regarded as resulting from progradation of a wedge of Frasnian sediments above Middle Devonian deposits. Taking into account also studies of cores from the Giełczew wells, such a Frasnian internal geometry could be interpreted as related to a development of a carbonate ramp shallowing towards the south-west. Within the Famennian sediments distinct downlap pattern was described (compare P. Krzywiec, 1993). Its origin was interpreted as caused by progradation of Famennian shales and carbonates towards the NE (D. B. Macurda, 1987; J. F. Sarg, 1988; compare similar model of a shelf-basin fill proposed by F. A. Stoakes, 1980). This interpretation is also supported by:

— general type of Famennian sedimentation representing stage of a basin infill within the single T-R cycle (M. Narkiewicz *et al.*, in prep.);

— tectonically controlled subsidence (and hence palaeobathymetry) of the Lublin Trough with its maximum located towards the north-east from the study area.

It should be mentioned, however, that there also exists alternative interpretation postulating sediment supply to the Lublin Trough from its eastern flanks, i.e. from elevated areas of the East European Craton towards the west and south-west (L. Miłaczewski, 1981). Further comparison and discussion of these two models will require more detailed facies-sedimentological studies and more comprehensive interpretation of seismic data, in particular based on much more dense grid of seismic lines.

Analysis of another seismic line located in the study area (Fig. 6) provided only information on depositional pattern of the Lower Devonian to Frasnian sediments. This line was calibrated by the wells Giełczew PIG 5, PIG 6, and, to a lesser extent by the Giełczew IG 1 well which is significantly removed from this line. Identified and correlated seismic horizons included tops of the Lower Devonian, Eifelian, Givetian, Frasnian, Middle Jurassic and Upper Jurassic. Also, similarly to the line 24-5-80K, the boundary between Palaeozoic and Mesozoic complexes was identified and picked. This boundary in the wells Giełczew PIG 5 and PIG 6 can be correlated with erosional top of the Famennian, and in the well Giełczew IG 1 with erosional top of the Frasnian. Line 26-5-80K is located in the area where nearly all the Famennian sediments were removed by erosion. Therefore seismostratigraphic interpretation of this line only confirmed decreasing thickness of the Frasnian sediments towards the north-east. This is particularly clearly visible within the syncline located in the northeastern part of this seismic line.

DEPOSITIONAL MODEL AND TECTONIC HISTORY

Present stratigraphic interpretation of the seismic lines located in the central part of the Lublin Trough coupled with results of analysis of the research wells allows for putting forward the following depositional scenario of geological development of the study area.

Stage 1. Initial deposition of marine Eifelian siliciclastic sediments (nearshore sandstone bodies) was followed by several cycles of deposition of Givetian and lower Frasnian carbonates characterized by fairly uniform and small thicknesses (flat-lying sedimentary bodies that can be correlated on long distances). Devonian sedimentary basin was characterized by relatively small tectonic subsidence and was dominated by widespread sea-level changes.

Stage 2. Late Frasnian deposition was taking place in a carbonate ramp environment shallowing towards the southwest. Thickness of the deposits markedly decreases towards the north-east. The ramp was most probably prograding in that direction. Significant influence of tectonic subsidence can be assumed.

Stage 3. Filling up of the basin by shaly-carbonate Famennian sediments is represented by the sedimentary wedge prograding towards the north-east. This wedge developed within the single T-R cycle in the basin to a large degree controlled by a tectonic subsidence. Geoseismic sketch representing this stage and based on flattened seismic line 24-5-80K is presented on Figure 7. Late Devonian deposition was followed by uplift and development of parallel unconformity overlain by the upper Viséan carbonates to Upper Carboniferous siliciclastics attaining thickness up to 2 km.

Stage 4. Tectonic movements (folding) after deposition of the Carboniferous sediments led to formation of several synclines and anticlines.

Stage 5. Erosion (most probably of latest Carboniferous and post-Carboniferous age) removed most of the Carboniferous and part of the Devonian sediments (A. Zdanowski, H. Żakowa, 1995).

Stage 6. This stage embraced deposition of the Mesozoic sediments starting in the Middle Jurassic.

It must be stressed out, however, that the scenario presented above is based on a relatively small amount of seismic observations, that in fact allowed only for preliminary seismostratigraphic interpretation of the Devonian internal depositional architecture. Further seismic stratigraphic investigations should be based on denser net of seismic lines, which in turn should provide information on three-dimensional depositional architecture of the studied sediments and more detailed information on directions of sediment progradation.

In terms of petroleum prospectivity of the study area, possibility of development of highly condensed sediments of a distal ramp (upper Frasnian) and deeper anoxic shelf basin (Famennian, in particular in its lower part) is of particular importance. These sediments might have developed towards the north-east, i.e. in the axial part of the Lublin Trough. These sediments could have been significantly enriched in primary organic matter and hence form good source rocks.

SUMMARY AND CONCLUSIONS

In the course of the present study we attempted to assess if the quality of seismic data available from the Lublin Trough is high enough to apply concepts of seismic stratigraphy to unravel more detailed Devonian depositional history of this area. In this respect we can conclude that resolution of seismic data is appropriate to complete seismic stratigraphic interpretation, and that the Devonian sediments are of sufficient thickness to be subjected to such an analysis. Therefore it can be concluded that interpretation of all the seismic lines available from this area should provide new information on three-dimensional distribution of seismic facies and sequences and hence would allow to formulate new — possibly different from accepted so far — depositional scenario of the Devonian sedimentation. Another goal of the present study was to complete preliminary integrated seismic stratigraphic and geologic interpretation of selected seismic lines and wells. It appears that such an interpretation coupled with results of detailed studies of well data provides important clues to distribution of source and reservoir rocks within the sequence stratigraphic framework. Based on results described in this paper it can be inferred that it would be possible to construct maps of distribution of particular seismic facies that can be correlated with source and reservoir series. Also, full seismostratigraphic interpretation would clarify relationship between bio- and lithostratigraphic subdivisions and their relationship to sequence stratigraphic framework.

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REFERENCES

DADLEZ R. (1989) — Epicontinental Permian and Mesozoic basins in Poland (in Polish with English summary). Geol. Quart., **33**, p. 175–198, no. 2.

KRZYWIEC P. (1993) — Seismic stratigraphy (in Polish only). Prz. Geol., **41**, p. 745–751, no. 11.

MACURDA D. B. (1987) — Seismic stratigraphy of carbonate platform sediments, southwest Florida. In: Atlas of seismic stratigraphy (ed. A. W. Bally). Am. Ass. Petrol. Geol. Stud. Geol., **27**, p. 240–247, no. 2.

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

NARKIEWICZ M. (1988) — Turning points in sedimentary development in the Late Devonian in southern Poland. In: Devonian of the World (eds. N. J. McMillan *et al.*). Can. Soc. Petrol. Geol. Mem., **14** (II), p. 619–635.

NARKIEWICZ M., POPRAWA P., MIŁACZEWSKI L., ŻELICHOWSKI A. M. (1997) — Devonian to Carboniferous subsidence history and tectonic evolution of the Lublin Trough (SE segment of the TESZ in Poland). Terra Nostra, **97/11**, p. 95–102. EUROPROBE TESZ-Meeting, Potsdam.

NEIDELL N. S. (1984) — Stratigraphic modelling and interpretation: geophysical principles and techniques. Am. Ass. Petrol. Geol. Educat. Course Note Series, **13**.

PHARAOH T. and TESZ collegues (1996) — Trans-European Suture Zone. Phanerozoic accretion and the evolution of contrasting continental lithospheres. In: EUROPROBE 1996 — Lithosphere dynamics: origin and evolution of continents (eds. D. G. Gee and H. J. Zeyen). Published by the EUROPROBE Secretariate, Uppsala University, p. 41–54.

SARG J. F. (1988) — Carbonate sequence stratigraphy. In: Sea-level changes: an integrated approach (eds. C. K. Wilgus *et al.*). Soc. Econ. Paleont. Miner. Spec. Publ., **42**, p. 155–181.

STOAKES F. A. (1980) — Nature and control of shale basin fill and its effects on reef growth and termination: Upper Devonian Duvernay and Ireton Formations of Alberta, Canada. Bull. Can. Petrol. Geol., **28**, p. 345–410, no. 3.

SZEWCZYK J., GIENTKA D. (1996) — Opis profilu litologicznego w systemie GEOFLOG. Prz. Geol., **44**, p. 555–556, no. 6.

VAIL P. R. (1987) — Seismic stratigraphic interpretation using sequence stratigraphy, Part 1: Seismic stratigraphy procedure. In: Atlas of seismic stratigraphy (ed. A. W. Bally). Am. Ass. Petrol. Geol. Stud. Geol., **27**, p. 1–10, no. 1.

ZDANOWSKI A., ŻAKOWA H. eds. (1995) — The Carboniferous system in Poland. Pr. Państ. Inst. Geol., **148**.

ZIEGLER P. (1990) — Geological atlas of Western and Central Europe. Shell Int. Petrol. Co. and Geol. Soc. Publ. House.

ŻELICHOWSKI A. M. (1972*a*) — Anticline Opole Lubelskie–Zakrzew (central Lublin region) (in Polish with English summary). Geol. Quart., **16**, p. 291–300, no. 2.

ŻELICHOWSKI A. M. (1972*b*) — Evolution of the geological structure of the area between the Góry Świętokrzyskie and the river Bug (in Polish with English summary). Biul. Inst. Geol., **263**.

ŻELICHOWSKI A. M. (1979) — Geological cross-section through marginal part of the Precambrian Platform in the Lublin–Podlasie area (Cenozoic excluded) (in Polish with English summary). Geol. Quart., **23**, p. 291–307, no. 2.

ŻELICHOWSKI A. M. (1983) — The tectonics of the Marginal Trough and its substrate in the zone of the Grójec Fault (Warsaw–Dęblin area) (in Polish with English summary). Biul. Inst. Geol., **344**.

DEWOŃSKA ARCHITEKTURA DEPOZYCYJNA W ŚRODKOWYM SEGMENCIE ROWU LUBELSKIEGO: WSTĘPNE WYNIKI POŁĄCZONYCH BADAŃ SEJSMICZNYCH I OTWOROWYCH

Streszczenie

Zintegrowana analiza danych sejsmicznych i otworowych z obszaru Lubelszczyzny pozwoliła na skonstruowanie wstępnego, odmiennego od przyjmowanych dotychczas, modelu sedymentacji osadów dewońskich na tym obszarze. W pracy wykorzystano dwa profile sejsmiczne pomierzone przez ośrodek Geofizyka-Kraków i znajdujące się w ich pobliżu otwory Giełczew IG 1, PIG 5, PIG 6 oraz Zakrzew IG 1, odwiercone przez Państwowy Instytut Geologiczny (fig. 1). Obszar badań znajduje się w SE części Lubelszczyzny, gdzie osady karbonu występują tylko szczątkowo, a osady dewońskie przykryte są bezpośrednio przez osady mezozoiku platformowego. Osady dolnodewońskie (formacja zwoleńska), zaliczane do górnego żedynu-emsu, reprezentują aluwialny system depozycyjny. Dewon środkowy i górny składa się z utworów morskich. W niższej części (eifel) są to osady terygeniczne, przeważnie piaszczyste, zaliczone tu do systemu przybrzeżnych klastyków. Wyżej występują niemal wyłącznie utwory węglanowe, reprezentujące rytmiczne następstwo utworów szelfu niżejpływowego (lub rampy) i płytkowodnej platformy węglanowej. W obrębie żywetu i franu niższego można wyróżnić 4 cykle transgresywno-regresywne (T-R), których poszczególne ogniwa charakteryzują się znaczną oboczną ciągłością przy ogólnie niewielkich miąższościach (4 cykle łącznie ok. 300 m miąższości). Kolejny cykl T-R w obrębie wyższej części franu (ogniwo zubowickie) osiąga większą miąższość (ok. 300 m) i odpowiada w większości środowisku płytkiego niżejpływowego szelfu lub środkowej rampy węglanowej. Początek tego cyklu wiąże się prawdopodobnie z przyspieszeniem tempa sedymentacji i subsydencji, które osiąga kulminację w famenie. Wtedy to, po krótkotrwałym epizodzie regresywnym w najpóźniejszym franie, osadzają się miąższe (ok. 1000 m w tym rejonie, a ok. 1800 m koło Lublina) serie marglisto-wapienne tworzące pojedynczy cykl T-R. W warunkach silnej subsydencji, niewątpliwie o podłożu tektonicznym, następowało zasypywanie zbiornika przez utwory, początkowo, dys-anaerobowego niżejpływowego basenu szelfowego (formacja bychawska), a następnie — rampy węglanowej (formacja firlejska).

Przy wykorzystaniu danych karotażowych (pomierzone oraz syntetyczne krzywe akustyczne) dla opracowanych otworów skonstruowano sejsmogramy syntetyczne, które pozwoliły na precyzyjne dowiązanie stratygrafii przewierconych osadów do obrazu sejsmicznego (fig. 3). W obrębie osadów dewońskich zidentyfikowano i skorelowano na profilach sejsmicznych horyzonty sejsmiczne związane ze stropem dewonu dolnego, eiflu, żywetu, franu i famenu (fig. 4 i 6). W obrębie interwału frańskiego stwierdzono wyraźne cienienie poszczególnych pakietów osadowych w kierunku NE, natomiast w obrębie pakietu fameńskiego zidentyfikowano kilka niezgodności kątowych między refleksami sejsmicznymi. Ponieważ dolny interwał osadów dewońskich reprezentowany jest przez osady generalnie płytkowodne, przyjęto zatem, że dla odtworzenia dewońskiej syn-depozycyjnej geometrii tej części basenu można wypłaszczyć interpretowane profile sejsmiczne wzdłuż horyzontu związanego ze stropem dolnego dewonu (fig. 5). Na tak przekształconym profilu sejsmicznym wyraźnie widać, iż osady franu, a szczególnie famenu, wykazują progradacyjny charakter. Pozwoliło to na postawienie tezy, że osady ilasto-węglanowe famenu reprezentują etap zasypywania basenu i migrację pryzmy osadów ku NE. Model depozycji tych osadów pokazuje fig. 7.

Przedstawiona interpretacja oparta była na stosunkowo skąpym materiale sejsmicznym. Z tego też względu powinna być traktowana jako wstępna propozycja modelu depozycyjnego dla osadów dewońskich w tej części Lubelszczyzny. Jego weryfikacja i uszczegółowienie powinno nastąpić poprzez interpretację gęstszej siatki profili sejsmicznych z tego rejonu oraz wykorzystanie większej liczby otworów.