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PHASES OF PALAEOGENE AND NEOGENE TECTONIC EVOLUTION OF SELECTED GRABENS IN THE WIELKOPOLSKA AREA, CENTRAL-WESTERN POLAND

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Abstract: In the Wielkopolska (Great Poland) area, there occur numerous tectonic grabens which were active in the Palaeogene and Neogene. The similarities and differences between their development are presented on the example of the Czempiń, Szamotuły, Lubstów, and Władysławów Grabens. Using various methods of palaeotectonic analysis, the stages of accelerated subsidence of the grabens, i.e. tectonic phases, were indicated. The extent of vertical movement in the studied grabens were compared and it was affirmed that there is a connection between the occurrence of older dislocations and salt structures in the deep basement. From among the examined grabens, the Lubstów Graben is the deepest one, and shows the most complex geological structure. The Czempiń and Szamotuły Grabens are characterized by relatively simple geological structure, where the stratigraphic completeness and tectonic style are very legible. These three grabens were active in different tectonic stages from the turn of the Eocene/Oligocene till the end of the Neogene, and perhaps also in the Prepleistocene. The Władysławów Graben is a very shallow tectonic structure and its evolution lasted for the shorter period of time. The time of its development extended from the Early through the Middle Miocene.

These grabens provide a good example of the relationship between the fault throw and graben location. The Czempiń, Szamotuły, and Lubstów Grabens, connected with deeply-rooted dislocations, came to existence in the Pyrenean phase (latest Eocene – Early Oligocene). However, the Władysławów Graben was affected mainly by salt structure activity. Thus, its first stage of tectonic evolution took place in the Savian phase (Early Miocene).

Key words: tectonic phases, grabens, Palaeogene, Neogene, Wielkopolska area, central-western Poland.

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INTRODUCTION

More than twenty Palaeogene and Neogene tectonic grabens have been distinguished within administrative borders of the Wielkopolska area (Piwocki, 1991; Widera, 2002a). It is impossible to discuss all these grabens in this short paper. Therefore, four grabens have been chosen, being the most representative for all the grabens in this area. The Czempiń, Szamotuły, Lubstów, and Władysławów Grabens have been studied in detail (Fig. 1).

In the last ten years, I have examined all negative tectonic structures, i.e. grabens in the eastern Wielkopolska area (Widera, 1998, 2000, 2001) and, lately, also grabens located in the nearest vicinity of Poznań (Widera & Cepińska, 2003; Widera *et al.*, 2004). The important pieces of information about geological structure and tectonic activity of the other grabens in Wielkopolska have been taken mainly from the papers by Ciuk (1965, 1967, 1978), Walkiewicz (1968, 1979, 1984), Piwocki (1975, 1991), Kasiński (1984), and Walkiewicz & Skoczylas (1989). Moreover, to compare the age and origin of deformations in the Wiekopolska grabens as well as in other parts of Poland and Europe, the papers by Malkovsky (1987), Bergerat (1989), Ziegler (1992), Dyjor (1995), Ziegler *et al.* (1995), Fodor (1995), Kovác *et al.* (1995), Hippolyte & Sandulescu (1996), Oszczypko (1996, 1999, 2001), Peterek *et al.* (1997), Sissingh (1998), Krysiak (2000), ten Veen & Kleinspehn (2000), Poprawa *et al.* (2001), and Michon *et al.* (2003) have been taken into consideration.

The main aim of this work is to show that in the Palaeogene and Neogene, in the area of Czempiń, Szamotuły, Lubstów, and Władysławów Grabens, phases of increased tectonic activity took place. Another task is to compare the intensity of the distinguished phases in the area of the above grabens, and, finally, to show the connection between the Palaeogene and Neogene tectonics with older manifestations of tectonic activity of the studied parts of Wielkopolska area.

Fig. 1. Location map (mainly after Walkiewicz, 1984; Piwocki, 1991; and Widera, 2002a). Grabens: 1 – Naramowice, 2 – Poznań Town, 3 – Mosina, 4 – Krzywiń, 5 – Chróścina-Nowa Wieś, 6 – Gostyń, 7 – Chobienia-Rawicz, 8 – Młodzikowo-Czarnotki, 9 – Sulmierzyce, 10 – Uciechów, 11 – Sieroszewice, 12 – Kępno, 13 – Kleczew, 14 – Niesłusz-Gosławice, 15 – Bilczew-Drzewce, 16 – Piaski, 17 – Adamów; Dislocation Zones: P-SzDZ – Poznań-Szamotuły, P-ODZ – Poznań-Oleśnica, P-KDZ – Poznań-Kalisz, G-P-PDZ – Gopło-Ponętów-Pabianice

GEOLOGICAL SETTING

The Czempiń Graben is situated in the area of the Fore-Sudetic Monocline, whereas the other grabens are located within the Szczecin-Łódź-Miechów Trough. Describing their location more precisely, one can say that the Szamotuły Graben lies in the area of the Oborniki Elevation (Pożaryski, 1971), and that the Lubstów and Władysławów Grabens are located in the area of the Konin Elevation (Krygowski, 1952; Widera, 1998).

The Mesozoic basement of the discussed grabens is stratigraphically diversified. In the substratum of the Lubstów and Władysławów Grabens and on their fault sides, the top of the Mesozoic rocks is represented by the Maastrichtian–Upper Cretaceous strata only (Dadlez & Marek, 1974; Marek, 1977). The sub-Cenozoic basement of the Szamotuły Graben and its fault sides consists of different stages of the Cretaceous and Jurassic (Stemulak, 1959; Jaskowiak-Schoeneichowa, 1981), whereas the top of the Mesozoic in the Czempiń Graben and on its fault sides is represented only by different stages of the Jurassic (Sokołowski, 1967; Ciuk, 1978; Deczkowski & Gajewska, 1977, 1979, 1980; Grocholski, 1991). It is a result of the Mesozoic tectonic activity in the Szamotuły and Czempiń Grabens. Thus, in this case we should even say about the Cenozoic phases of rejuvenation of both the grabens.

The Czempiń, Szamotuły, and Lubstów Grabens are situated in the Permian–Mesozoic fault zones in central-western Poland (Sokołowski, 1967; Marek, 1977; Deczkowski & Gajewska, 1977, 1979, 1980; Dadlez, 1980;

Karnkowski, 1980; Knieszner *et al.*, 1983; Marek & Pajchlowa, 1997). These grabens came into being along the pre-Palaeogene discontinuity surfaces. In case of the Władysławów Graben, pre-Cenozoic faults have not been found yet. The first tectonic movements in this area, which led to an uplift, took place at the turn of the Palaeogene and Neogene. The relatively small size and the shape of the Władysławów Graben were controlled by the occurrence of the Turek salt pillow in the deep basement (Marek, 1977; Widera, 1998).

MATERIALS AND METHODS

Geological recognition of the studied grabens is very differentiated. In a fragment of the Szamotuły Graben, subjected to detailed studies, only 25 boreholes were made. Within the other grabens the following numbers of boreholes were drilled: the Czempiń Graben – 42, the Lubstów Graben – 362, and the Władysławów Graben – 454 boreholes. The 884 boreholes mentioned above were used to mark the outlines of the grabens. However, simplified cross-sections were made on the basis of only 39 borehole logs. It must be added that cross-section lines were chosen in such a way that they are: (a) approximately perpendicular to the orientation of the graben, (b) the longest lines, (c) include the greatest number of boreholes that reached the top of the Mesozoic rocks. Moreover, to make structural maps of the lignite seams, data derived from the area of the Lubstów Graben from 279 boreholes, and from the Władysławów Graben from 193 boreholes, were used. Direct observations of the exposures were taken into account, as well.

The lithology, thickness, and position of formations and lithostratigraphic members occurring within the mentioned grabens and on their fault sides required different research methods. For the Czempiń and Szamotuły Grabens, the aggradation coefficient was estimated. It qualifies how many times the average thickness of the sediments within the graben is bigger than the average thickness of the sediments outside the graben. The aggradation coefficient can be calculated only for this area whereupon litostratigraphic units are widely spread, i.e. both in the graben and on its bordering fault sides. This condition is only fulfilled for the Czempiń and Szamotuły Grabens. The method was already used to indicate the Mesozoic tectonic phases in the Poznań-Kalisz Dislocation Zone (Kwolek, 2000), as well as in northern part of the Poznań-Oleśnica Dislocation Zone to characterize Tertiary tectonic phases (Widera *et al.*, 2004).

In the Lubstów Graben, the Palaeogene formations occur only in the deepest part of this structure. The other Neogene lithostratigraphic units, like in the Władysławów Graben, are partially destroyed. The Pleistocene Scandinavian ice-sheets played here a really destructive role (Widera, 1998, 2001). Thus, the values of aggradation coefficient in the Lubstów and Władysławów Grabens would be strongly biased. Therefore, the bottom surfaces of main lignite seams were subjected to palaeotectonic analysis. In this way, the major faults which were active during the sedimentation of the peat, were localized. Then, the faults in question were compared to those faults that had already shown previous activity. Their location was defined on the basis of: cross-sections, thickness maps of sub-coal sediments, and the topography of the Mesozoic surface. Numerous cross-sections and maps are not included in this paper; they are enclosed only in an archival study by Widera (1997). Only the best documented structural maps of the bottom of the main lignite seams, i.e. the 2nd Lusatian Lignite Seam in the Lubstów Graben, and the 1st Middle-Polish Lignite Seam in the Władysławów Graben, have been chosen (Widera, 1997).

These research methods include only some elements of a very popular geohistory analysis quantifying tectonic subsidence, i.e. the backstripping method (Van Hinte, 1978; ten Veen & Kleinspehn, 2000; Michon *et al.*, 2003). In the Wielkopolska area, chronostratigraphy is not well estimated. In contrast, lithostratigraphic formations or members are better defined and much more important (Piwocki & Ziembińska-Tworzydło, 1995; Piwocki *et al.*, 1996). We do not know the time intervals during which the lithostratigraphic units have been deposited. That is why the backstripping method, in its original range where precision depends highly on chronostratigraphy, can not be applied to tectonic analysis of the Wielkopolska grabens (Widera *et al.*, 2004). Thus, in the present study decompaction (deconsolidation of lignites), as a component of the backstripping method, was used. This approach has made it possible to determine the tectonic subsidence apart from the total subsidence.

OUTLINE OF STRATIGRAPHY

The lithostratigraphy of the studied grabens has been characterized on the basis of individual borehole logs (Fig. 2). These boreholes are not always the deepest ones, but they are most representative for all the boreholes from a given cross-section. Lithostratigraphic units determined in these boreholes have been correlated and their stratigraphic position has been presented against the background of the present chronostratigraphic scheme (Steininger & Rögl, 1983; Steininger *et al.*, 1987; Remane *et al.*, 2000). The terminology of lithostratigraphic units was taken from Ciuk (1965, 1967, 1970), including supplements provided by Piwocki (1991, 2001), Piwocki and Ziembińska-Tworzydło (1995), as well as Widera (2001, 2002a).

The Czempiń and Szamotuły Grabens have very similar Tertiary lithostratigraphy. The only differences include the thickness and/or absence of some formations and members in particular boreholes. The Palaeogene is represented by the following formations: the Lower Mosina Formation – LMF, Czempiń Formation – CF, and Upper Mosina Formation – UMF. In the Neogene, in turn, the following formations can be distinguished: the Rawicz – RF, Ścinawa – ŚF, Adamów – AF, Pawłowice – PF, and Poznań Formations (Fig. 2). The last-mentioned one is divided into two members: the Middle-Polish Member – MM, and the Wielkopolska Member – WM (Piwocki & Ziembińska-Tworzydło, 1995; Piwocki *et al.*, 1996).

The complex tectonic structure of the Lubstów Graben has had a significant influence on the lithology of its infill-

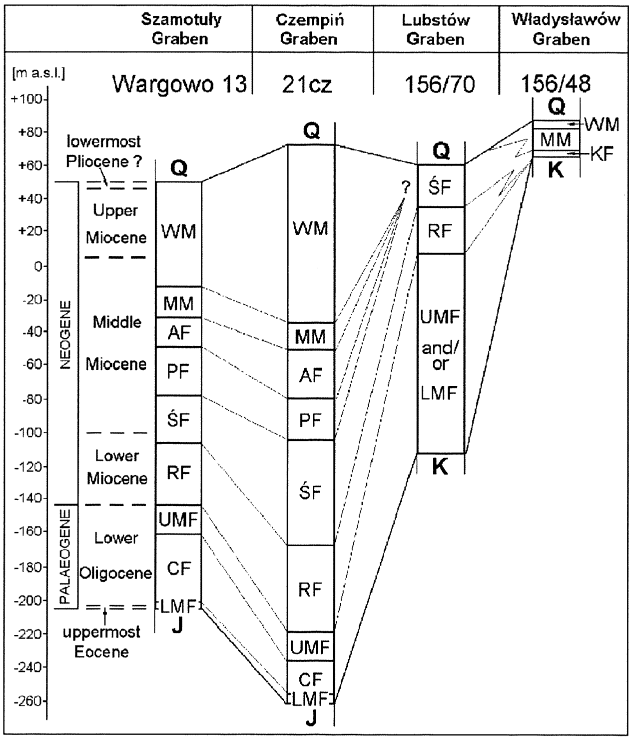

Fig. 2. Compilation of lithostratigraphic logs of the studied grabens (location in Figs 3, 4, 5, 7). Formations: LMF – Lower Mosina, CF – Czempiń, UMF – Upper Mosina, RF – Rawicz, KF – Koźmin, ŚF – Ścinawa, PF – Pawłowice, AF – Adamów; Members of the Poznań Formation: MM – Middle-Polish, WM – Wielkopolska; J – Jurassic; K – Cretaceous; Q – Quaternary

ing sediments (Widera, 1998, 2000). Therefore, it is difficult and sometimes even impossible to assign these sediments to a particular lithostratigraphic unit. It refers mainly to the Palaeogene, and, in part, to the Neogene deposits. In some boreholes, sediments of the Lower Oligocene formations may be distinguished: the Lower Mosina Formation, Czempiń Formation, and Upper Mosina Formation. On the basis of phytoplankton analyses, Ciuk and Grabowska (1991) distinguished even the Upper Oligocene sediments of the Leszno Formation, which seems to be unfounded methodologically (Alexandrowicz *et al.*, 1975). Therefore, the Palaeogene is represented by sediments of the uppermost Eocene–Lower Oligocene (Fig. 2). Sediments younger than the Ścinawa Formation occur only in the SE part of the Lubstów Graben in residual forms (Ciuk & Grabowska, 1991; Widera, 1998, 2000, 2001). Their origin and preservation were not the effect of tectonic movements but apparently resulted from consolidation of thick deposits lying below the 2nd Lusatian Lignite Seam (Widera, 2000, 2002a). In the Lubstów Graben, sediments of the Rawicz Formation – mainly sands/sandstones, and the Ścinawa Formation including coals show the most complete development (Fig. 2). It is necessary to remember that the top of the Ścinawa Formation (inside the graben), and the top of the Rawicz Formation (outside the graben) were significantly eroded in the Pleistocene.

In the area of the Władysławów Graben, only sediments of the Neogene Koźmin Formation and the Poznań Formation with the Middle-Polish and Wielkopolska Members do occur (Fig. 2). The lithological and stratigraphic position of the Poznań Formation are very similar as in other areas which have been studied in detail. Recently, distinguishing of the Koźmin Formation in the western Wielkopolska area has been suggested (Widera, 2001, 2002a). It has to be added that the mentioned sediments were distinguished earlier, according to the present chronostratigraphy, as the Middle Miocene Adamów Formation (Ciuk, 1967, 1970), or the Lower Miocene Rawicz Formation (Widera, 1998). The change of view was caused by verification of borehole logs and cross-sections which were made on either side of the extent of the 2nd Lusatian Seam (Walkiewicz, 1979, 1984), and between the Lubstów lignite deposit and other lignite deposits in the area of Konin and Turek (Widera, 2001, 2002a). It turned out that in the eastern Wielkopolska area, widely spread sediments of the Koźmin Formation couple laterally with sediments of the Rawicz, Ścinawa, and Adamów/Pawłowice Formations, and even with the Middle-Polish Member. Therefore, to the east of the Gniezno – Września – Pyzdry – Jarocin – Kalisz – Ostrów Wielkopolski line (Fig. 1), beyond the Lubstów Graben where the 2nd Lusatian Seam of the Ścinawa Formation occurs, the Koźmin Formation should be distinguished. In the area lacking the above-mentioned seam or its facies equivalents, the Rawicz and Adamów Formations cannot be distinguished because of their lithological similarities (Widera & Cepińska, 2003). The age of sedimentation of the Koźmin Formation should be extended from the Early Miocene (sedimentation of the Rawicz Formation) till the Middle Miocene (sedimentation of the Middle-Polish Member; Fig. 2).

PALAEOTECTONIC ANALYSIS

The **Czempiń Graben** is a negative tectonic structure, approximately orientated N–S (Fig. 3A). Its length is about 8 km and its width is ca. 2–2.5 km. In its deepest part, which includes the central part of the graben, the top of the Mesozoic rocks occurs at about –320 m b.s.l., whereas the most southern and northern areas of the graben reveal depths ranging from –250 to –300 m b.s.l. On the basis of data derived from all the 42 boreholes it may be affirmed that the depth of the Czempiń Graben is about 170–180 m. The cross-section line was drawn perpendicularly to the southern part of this graben (Fig. 3A, 3B). This cross-section shows the most complete log of the sediments. Stratigraphic equivalents of sediments occurring in the axial part of the Czempiń Graben (boreholes 20cz and 21cz) appear also on its bordering fault sides (boreholes 18cz, 19cz, and 22cz). Only in boreholes 18cz and 19cz there is a lack of lithological basis to distinguish the Lower Mosina and Czempiń Formations (Fig. 3B). It may be supposed that this was caused either by the lack of sedimentation, or by redeposition of not very thick sediments from the fault sides towards the axial part of the graben. Similar situations were observed in the vicinity of nearby tectonic structures, like the Krzywiń Graben (Kasiński, 1984), Mosina and Naramowice Grabens (Widera *et al.*, 2004), as well as around all tectonic grabens

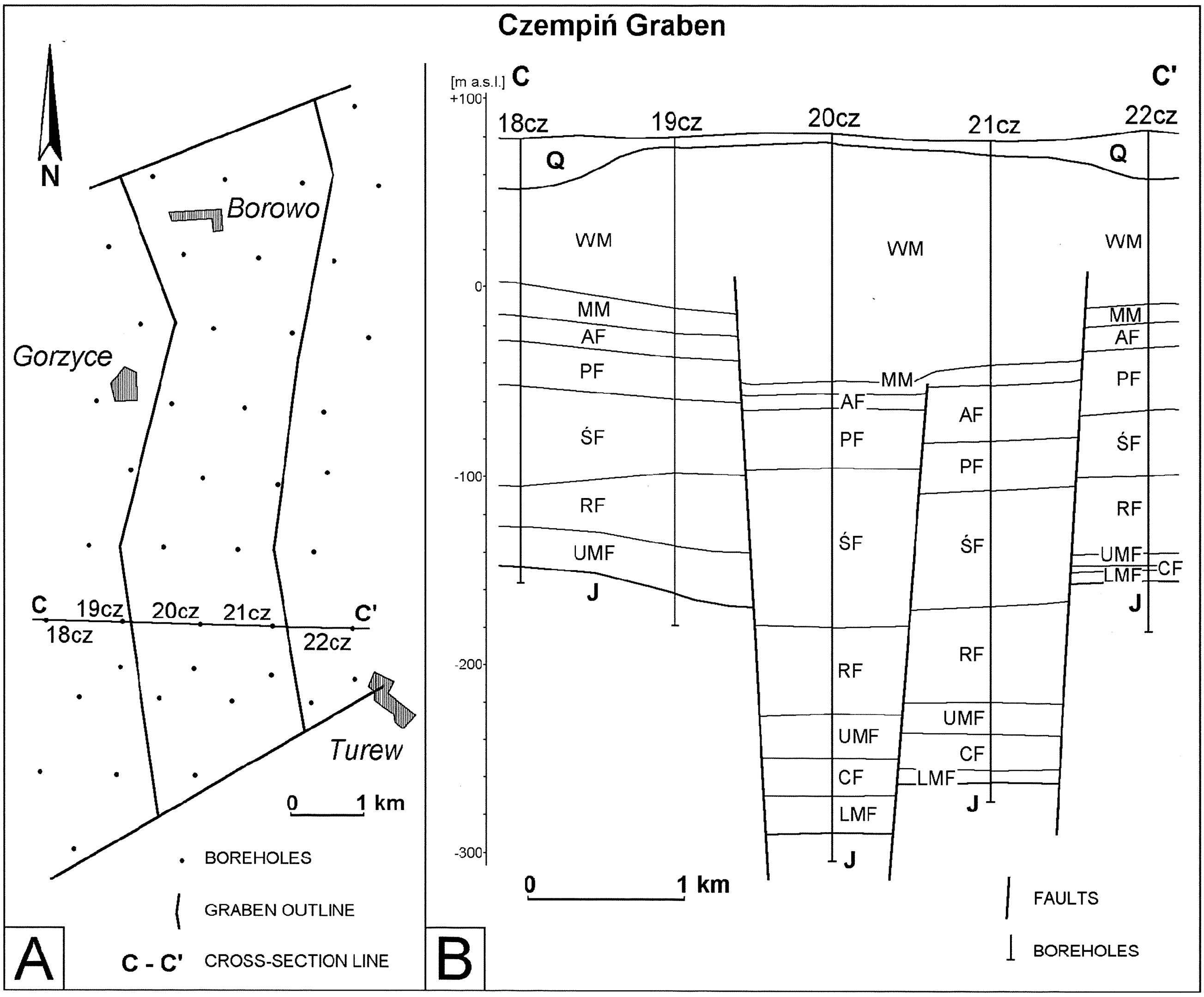

Fig. 3. Czempiń Graben: **A** – graben outline and cross-section location; **B** – cross-section along line C – C'; for other explanations – see Fig. 2

in the eastern Wielkopolska area (Widera, 1998, 2000, 2001).

The main fault throw at the bottom of the Palaeogene exceeds 120 m, and at the top of the Middle-Polish Member it is only 25–40 m (Fig. 3B). Both the main faults were active for the longest time throughout all the phases of graben development. The outlines of the Czempiń Graben, formed in the Palaeogene, did not change significantly in Neogene times. The other faults were active throughout a shorter period of time; e.g., the fault between boreholes 20cz and 21cz (Fig. 3B). On the basis of an analysis of cross-section it may be affirmed that the Palaeogene development of the Czempiń Graben was initiated at the time of sedimentation of the Lower Mosina Formation. However, the last vertical dislocations were present after the sedimentation of the Middle-Polish Member with the 1st Middle-Polish group of lignite seams, but before the glacial Pleistocene. It could have taken place during the Wielkopolska Member deposition, between the Wielkopolska Member and the Pleistocene, or during the Prepleistocene (= before the glacial Pleistocene).

The aggradation coefficient is the most objective method of subsidence measurement between the graben and its fault sides. The calculation has been made on the basis of data derived from boreholes which lie along the line of cross-section C-C' (Fig. 3B; Table 1). The value of aggradation coefficient which exceeds 150% testifies to tectonic subsidence of the graben bottom. The value lower than 150% might have been caused by compaction and consolidation of underlying sediments (Widera *et al.*, 2004). Therefore, for the part of the Czempiń Graben which was studied in detail, three main phases of tectonic activity can be distinguished. They include the time of sedimentation of the following formations: Lower Mosina Formation – 543%, Czempiń Formation – 2,814%, Ścinawa Formation – 183%, and Wielkopolska Member – 169% (Table 1). In the case of the Wielkopolska Member it must be remembered that the high value of aggradation coefficient may be a result of the Late Neogene and even pre-Pleistocene tectonic movements (Ciuk, 1978; Walkiewicz, 1984; Widera *et al.*, 2004). The described phases of the Czempiń Graben development may

Table 1

Values of aggradation coefficient calculated along cross-section line C – C' (Fig. 3A)

Formation (Fm.) or Member (Mb.)		Thickness in boreholes [m]					Aggradation coefficient [%]
		18cz	19cz	20cz	21cz	22cz	
Poznań Fm.	Wielkopolska Mb.	**51.7**	**88.4**	124.8	105.8	**65.0**	169
	Middle-Polish Mb.	**17.0**	**9.2**	6.6	15.0	**10.3**	89
Adamów Fm.		**14.1**	**14.5**	8.1	30.8	**14.8**	134
Pawłowice Fm.		**23.4**	**20.5**	29.8	25.1	**38.9**	100
Ścinawa Fm.		**51.3**	**38.4**	85.3	59.7	**29.0**	183
Rawicz Fm.		**22.6**	**39.2**	46.7	51.6	**40.5**	144
Upper Mosina Fm.		**21.3**	**24.8**	23.5	18.2	**5.0**	123
Czempiń Fm.		**0.0**	**0.0**	20.2	19.2	**2.2**	2814
Lower Mosina Fm.		**0.0**	**0.0**	18.1	4.6	**6.4**	543

Data derived from boreholes situated outside the Czempiń Graben are typed in bold (Fig. 3B)

be correlated with the stages of tectonic activity in the Alpine and Carpathian areas (Stille, 1952; Bergerat, 1989; Hippolyte & Sandulescu, 1996; Oszczypko, 1996, 1999, 2001; Dyjor; 1995; Krysiak, 2000; Poprawa *et al.*, 2001). These are, in stratigraphic succession, the Pyrenean, Styrian, and one of post-Moldavian phases. The first phase of the Czempiń Graben evolution strictly corresponds to the latest Eocene – Early Oligocene inversion in the North Sea Rift System (Ziegler, 1992). During this period of the Palaeogene, also a major tectonic activity was the most intensive and legible in the main Cenozoic grabens of Western Europe (Malkovsky, 1987; Peterek *et al.*, 1997; Ziegler *et al.*, 1995; Sissingh, 1998; Michon *et al.*, 2003).

The **Szamotuły Graben** is orientated NW–SE. In the studied section its length is about 12 km, and its width changes from 3.5 to 5.5 km (Fig. 4A). In the axial part of the graben, the Mesozoic basement is inclined towards the NW. The top of Mesozoic rocks lies at a depth of –210 m b.s.l. in the SE part, to below –270 m b.s.l. in the NW part of this graben. The maximum depth of the Szamotuły Graben exceeds 150–160 m. A cross-section line orientated WSW–ENE was drawn through the central part of the study area. Borehole Geo5, which reached the Mesozoic basement in the axial zone of the graben, was used as an auxiliary source of data (Fig. 4A, 4B).

Stratigraphic completeness in the Szamotuły Graben is almost the same as in the Czempiń Graben. On the graben sides all three Palaeogene formations, whose thickness is 40 m, occur (Fig. 4B). Two main faults have been distinguished between Nieczajna 1/62 and Nieczajna 21/63, and between Wargowo 4/62 and Świerkówki 5/62 boreholes. The other faults were active throughout shorter time. Vertical dislocations between boreholes Przecław IG-1 and Nieczajna 2/62, as well as between Wargowo 13 and Wargowo 3/62 were active only in the Palaeogene. Moreover, minor faults between boreholes Nieczajna 21/63 and Przecław IG-1, as well as between Nieczajna 2/62 and Wargowo 13 were formed also in the Neogene (Fig. 4B).

The throw of the top of Mesozoic rocks changes from 20 m to about 80 m between the boreholes Wargowo 4/62 and Świerkówki 5/62. It should be noticed that the top of the Middle-Polish Member is thrown by about 25–30 m only along the main faults (Fig. 4B). It is one of the criteria of distinguishing the main faults. In this case, the duration of their activity is more important than these fault throws. Thus, the beginning of tectonic subsidence of the grabens is marked by sedimentation of the Lower Mosina Formation, and the end took place after the sedimentation of the Middle-Polish Member, but before the glacial deposition of the Pleistocene.

The values of aggradation coefficient calculated for the Szamotuły Graben are similar to those obtained for the Czempiń Graben (Table 2). In the studied area, four phases of intensified tectonic subsidence of the graben bottom have been distinguished. Each phase includes the time of sedimentation of two or three lithostratigraphic units. The first phase is marked by deposition of the following formations: Lower Mosina – 148%, Czempiń – 168%, and Upper Mosina – 160%. The maximum of the second phase occurred during sedimentation of the Ścinawa Formation – 789%, and continued till the end of deposition of the Pawłowice Formation – 159%. The next phase corresponds with the origin of the Middle-Polish Member – 161%. The last phase was probably initiated during the sedimentation of the Wielkopolska Member and might have continued also in pre-Pleistocene times (Table 2). In this case, in comparison to the Czempiń Graben, one more phase of tectonic development of the Szamotuły Graben, i.e. the Moldavian phase, must be distinguished.

The **Lubstów Graben**, orientated NNW–SSE, is about 6 km long and about 2–3 km wide (Fig. 5A). The deepest depression occurs in the SE part of the graben, where the

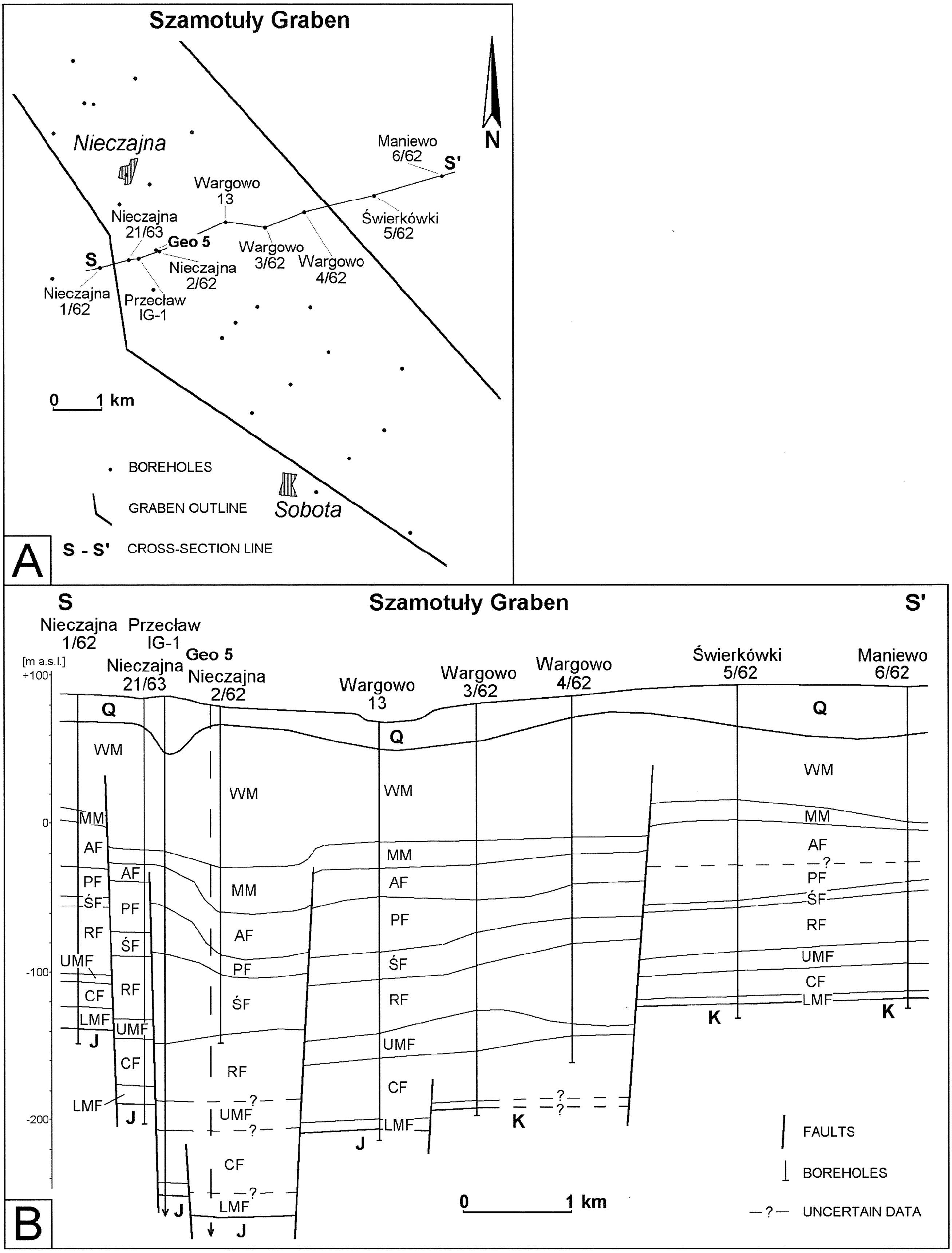

Fig. 4. Szamotuły Graben: **A** – graben outline and cross-section location; **B** – cross-section along line S – S'; for other explanations – see Fig. 2

Table 2

Values of aggradation coefficient calculated along cross-section line S – S' (Fig. 4A)

Formation (Fm.) or Member (Mb.)		Thickness in boreholes [m]									Aggradation coefficient [%]
		Nieczajna 1/62	Nieczajna 21/62	Przecław IG-1	Nieczajna 2/62	Wargowo 13	Wargowo 3/62	Wargowo 4/62	Świerkówki 5/62	Maniewo 6/62	
Poznań Fm.	Wielkopolska Mb.	**47.0**	77.5	69.6	95.9	61.9	60.5	78.8	**48.7**	**61.0**	142
	Middle-Polish Mb.	**8.5**	10.7	~2.0	~27.3	16.6	19.5	13.6	**15.3**	4.0	161
Adamów Fm.		**~31.0**	13.7	~14.0	~30.0	18.5	25.5	19.6	**~32.7**	**~20.5**	72
Pawłowice Fm.		**~20.0**	33.8	~50.0	~13.0	32.5	22.2	24.9	**~21.8**	**~13.7**	159
Ścinawa Fm.		**~3.0**	16.2	~62.0	37.9	25.4	22.8	15.5	**1.5**	**6.8**	789
Rawicz Fm.		**~50.0**	46.0	~29.0	-	36.8	29.0	56.9	**31.5**	**32.4**	103
Upper Mosina Fm.		**~2.0**	12.3	~22.0	-	15.3	28.1	5.5	**12.5**	**16.6**	160
Czempiń Fm.		**~24.0**	30.7	~32.0	-	43.2	33.6	>15.2	**18.6**	**19.7**	168
Lower Mosina Fm.		**~8.5**	13.0	~8.0	-	1.8	3.3	-	**2.4**	**2.3**	148

Data derived from boreholes located outside the Szamotuły Graben are typed in bold (Fig. 4B)

Mesozoic basement lies at a depth below –180 m b.s.l. In the northernmost, southern, and western parts of the graben, the top of Mesozoic rocks occurs at depths ranging between +10 m a.s.l. and +40 m a.s.l. The maximum depth of the graben exceeds 220 – 240 m. The cross-section line runs approximately W–E, goping through the central part of the Lubstów Graben (Fig. 5A, 5B). This cross-section does not show very complex tectonic pattern of the Lubstów Graben (Widera, 1997, 1998, 2000), and crosses those lithostratigraphic members which are most common within the discussed graben. It is easy to notice that the thickness of the Palaeogene in the axial part of the graben is nearly two times bigger than that of the Neogene (Fig. 5B). However, along the cross-section line, the Neogene is represented

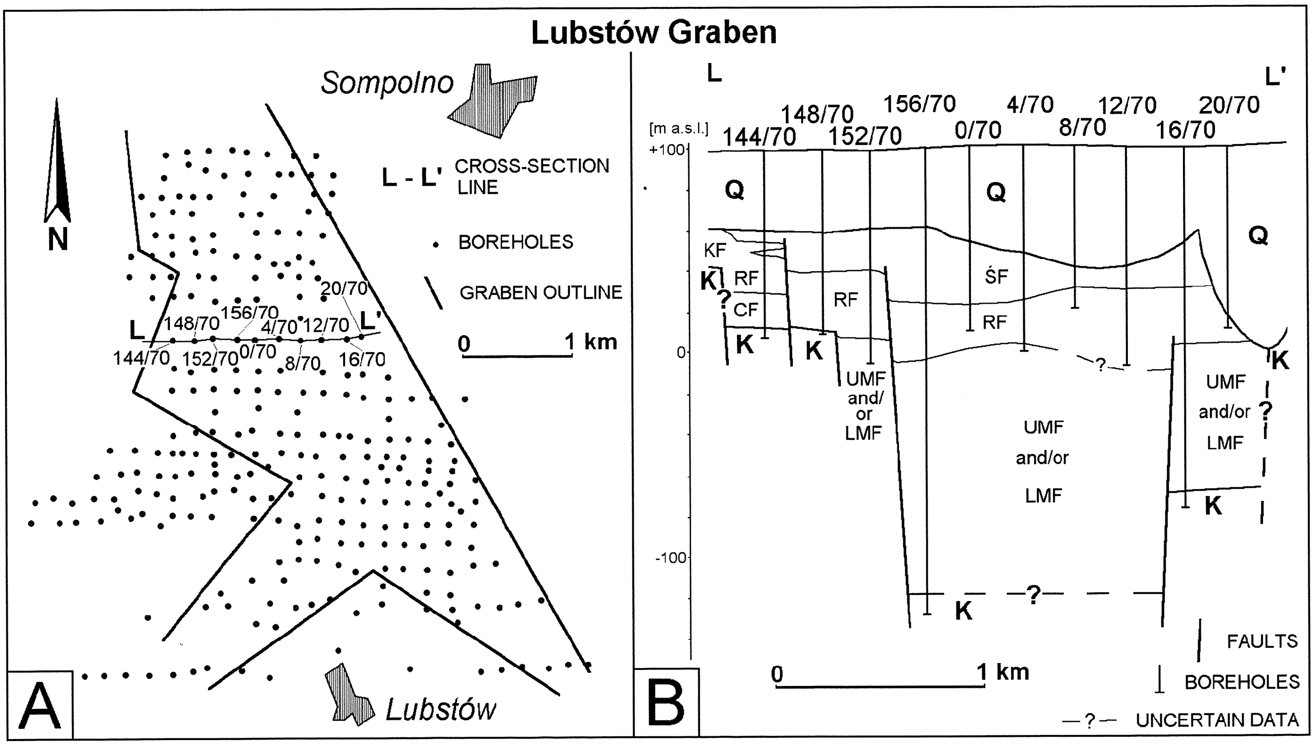

Fig. 5. Lubstów Graben: **A** – graben outline and cross-section location; **B** – cross-section along line L – L'; for other explanations – see Fig. 2

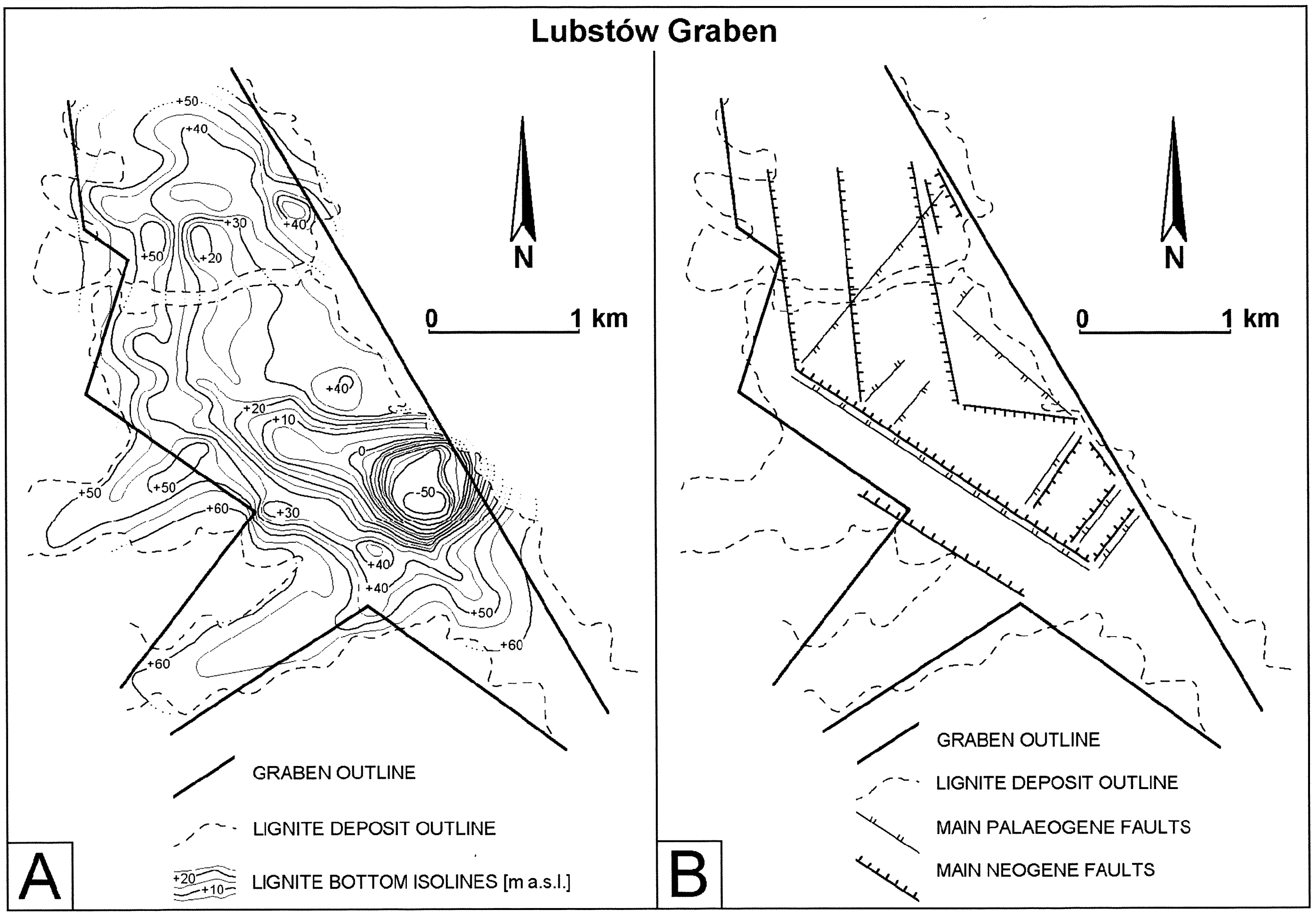

Fig. 6. Lubstów Graben: **A** – structural map of the bottom of the 2nd Lusatian Lignite Seam; **B** – main faults active before and during the peat sedimentation

only by the Rawicz and Ścinawa Formations, which outside the graben pass laterally into the Koźmin Formation (Fig. 5B).

The outlines of the Lubstów Graben are marked by faults which were active either in Palaeogene or Neogene times, or throughout the entire Tertiary (Fig. 5A). None of dislocations shown on the cross-section can be named the main fault. It is clearly seen that the Lubstów Graben bottom was subjected to the great deformations during the Palaeogene, at the time of dposition of the Lower and/or Upper Mosina Formations. Differences in the depth to the top of Mesozoic rocks between boreholes 148/70 and 156/70 exceed 120 m (Fig. 6B). It is a good example of a fault which was reactivated during the sedimentation of the Ścinawa Formation; the throw of its bottom amounts to 20 m. The fault which was interpreted between 12/70 and 16/70 boreholes, of throw ca. 40 m, was active mainly in the Palaeogene. During the time of sedimentation of the Rawicz Formation, this fault was active but its activity was not significant; the fault is not marked in the topography of the bottom of the Ścinawa Formation (Fig. 5B). It has to be added that the relief of the top of Mesozoic strata, between the deepest part of the Lubstów Graben and its surroundings, exceeds 220–240 m. It is not only the deepest graben from among those described in this work, but also the deepest Cenozoic graben in the Wielkopolska region (Widera, 2000).

An analysis of the above cross-section enables one to distinguish at least two phases of tectonic development of the Lubstów Graben. The third phase is described in the following part of this work because its distinguishing is based on other premises. The first, Pyrenean, phase includes the time of sedimentation of the Palaeogene formations, and the second, Styrian phase is contemporaneous with sedimentation of the Ścinawa Formation. During the deposition of the Rawicz Formation, with its levelled thickness along the entire cross-section line, one can conclude about the pause in tectonic subsidence of the graben bottom (Fig. 5B).

In case of the Lubstów Graben, the aggradation coefficient can not be used for quantitative estimation of the size of tectonic activity. Few reason can be mentioned here: (a) too small number of boreholes within the graben reach the top of the Mesozoic rocks, (b) most of boreholes end in sub-coal sediments of the Rawicz Formation, (c) the Paleogene lithostratigraphy is uncertain, (d) in the Pleistocene, the top of the Ścinawa Formation (both within and outside the graben), and the top of the Rawicz Formation (outside the graben) were destroyed. Therefore, the bottom of the 2nd Lusatian Lignite seam (= the bottom of the Ścinawa Formation) was subjected to palaeotectonic analysis (Fig. 6A). The interpreted faults that were active at that time were compared with faults active in the Palaeogene. These faults have been interpreted (Fig. 6B) on the basis of numerous

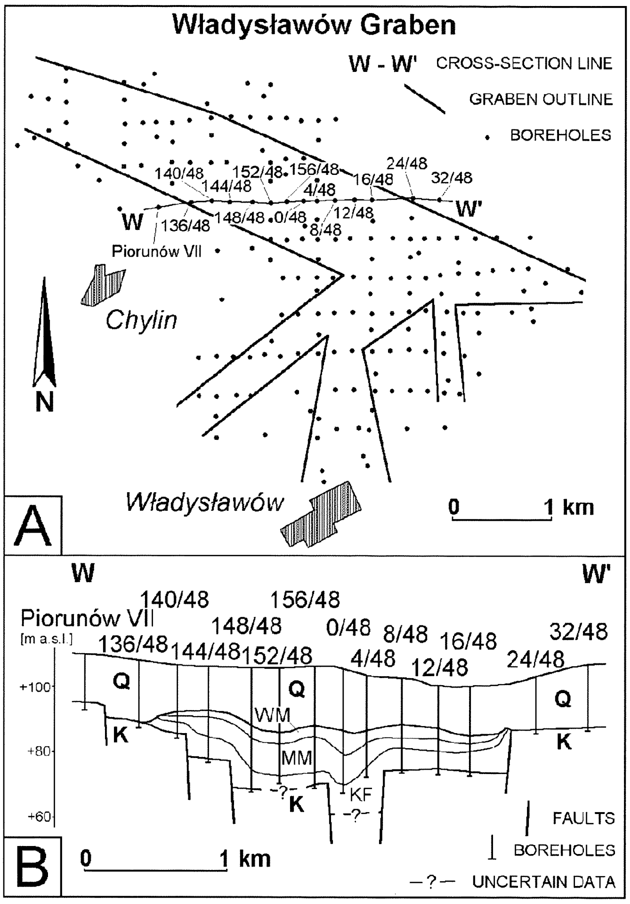

Fig. 7. Władysławów Graben: **A** – graben outline and cross-section location; **B** – cross-section along line W – W'; for other explanations – see Fig. 2

cross-sections and the thickness of Palaeogene sediments (Widera, 1997).

During sedimentation of the Ścinawa Formation, including the 2nd Lusatian Lignite Seam, the bottom of the Lubstów Graben was subjected to strong, although very slow and long-lasting subsidence. On one hand, it was recorded in the topography of the top of the lignite seam which is characterized by differences in the depth of occurrence exceeding 110 m (Fig. 6A). On the other hand, such a thickness of a continuous lignite seam, which is rare in Wielkopolska and reaches 86.2 m in the Lubstów Graben, provides some pieces of evidence (Widera, 1998, 2000). Isolines of the top of the discussed lignite seam are arrange into three main tectonic directions. In the deepest SE part, two sets are orientated NW–SE or NE–SW, whereas another one in the central and norhern parts of the graben strikes N–S (Fig. 6B). All these faults were active during the Neogene. In the Palaeogene, however, the main faults were orientated NW–SE and NE–SW (Fig. 6B). An analysis of fault orientation determines the existence of two stages of the Lubstów Graben development. In the first stage, two perpendicular faults, i.e. NW–SE and NE–SW, were active. In the second stage these two fault sets became rejuvenated, and a new, N–S-orientated fault set did appear in the Lubstów Graben (Fig. 6B).

The **Władysławów Graben** is 6 km long and its width very rarely exceeds 1 km (Fig. 7A). It is a very shallow, 40 m deep, tectonic palaeostructure which is orientated WNW–ESE. The cross-section line was drawn obliquely to the strike of the graben (Fig. 7A, 7B). This cross-section can

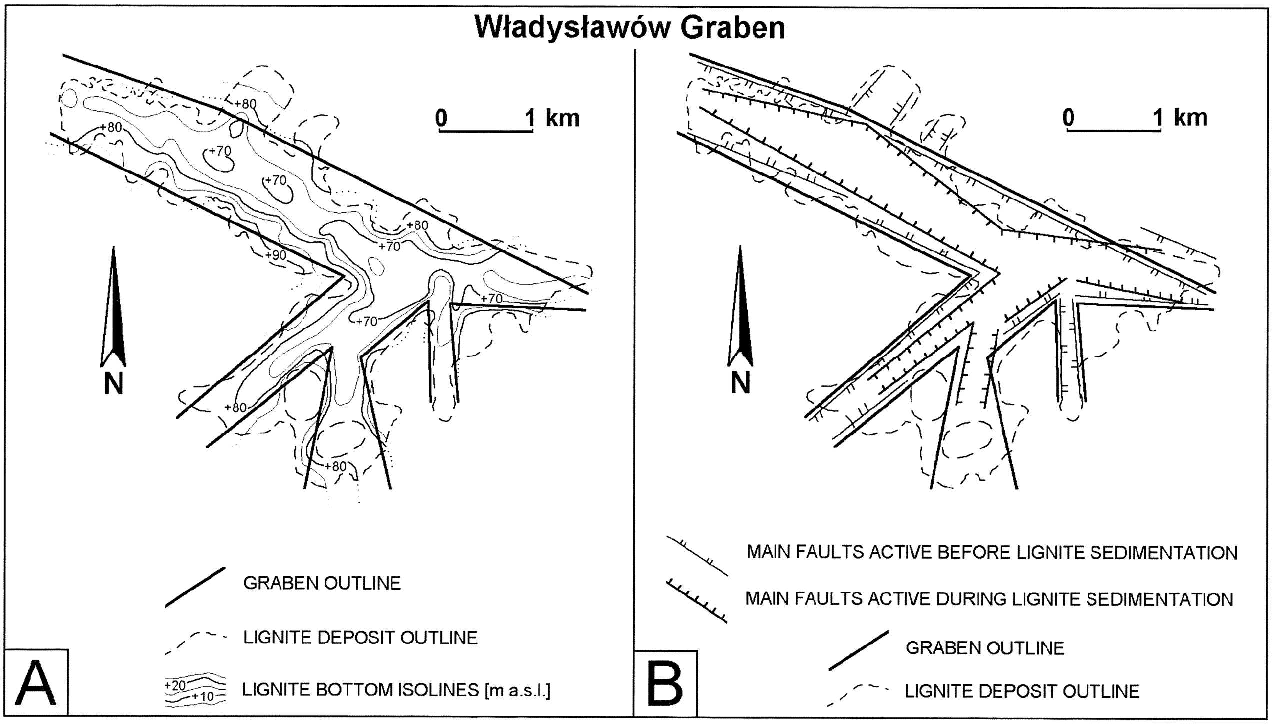

Fig. 8. Władysławów Graben: **A** – structural map of the bottom of the 1st Middle-Polish Lignite Seam; **B** – main faults active before and during peat sedimentation

Table 3

Compilation of the average thickness of strata inside and outside of the studied grabens

Formation (Fm.) or Member (Mb.)		Average thickness inside and outside grabens (G.) [m]												Formation (Fm.) or Member (Mb.)	
		Czempiń G.			Szamotuły G.			Lubstów G.			Władysławów G.				
		in	out	diff.	in	out	diff.	in	out	diff.	in	out	diff.		
Poznań Fm.	Wielkopolska Mb.	115.3	68.4	**+46.9 ?**	74.0	52.2	**+21.8 ?**	–	–	–	3.0	0.0	+3.0	Wielkopolska Mb.	Poznań Fm.
	Middle-Polish Mb.	10.8	12.2	–1.4	15.0	9.3	**+5.7**	–	–	–	7.0	0.1	**+6.9**	Middle-Polish Mb.	
Adamów Fm.		19.5	14.5	+5.0	20.1	28.1	–8.0	–	–	–	4.9	1.8	**+3.1**	Koźmin Fm.	
Pawłowice Fm.		27.5	27.6	–0.1	29.4	18.5	**+10.9**	–	–	–					
Ścinawa Fm.		72.5	39.6	**+32.9**	30.0	3.8	**+26.2**	~20.3	~0.0	**+20.3**					
Rawicz Fm.		49.2	34.1	+15.1	39.3	37.9	+1.4	~30.0	<30.0	>0.0					
Upper Mosina Fm. Czempiń Fm. Lower Mosina Fm.	Palaeogene	52.0	19.9	**+32.1**	58.0	35.9	**+22.1**	~82.0	~0.0	**+82.0**					

Tectonic phases recorded in thickness are typed in bold; in – inside graben, out – outside graben, diff. – difference

be treated as a typical one for the entire Władysławów Graben. The Poznań Formation, including the Middle-Polish and Wielkopolska Members, rests on sediments of the Koźmin Formation. The Wielkopolska Member is preserved residually. Here, likewise in the Lubstów Graben, the role of Pleistocene destruction was significant, especially in the graben surroundings (Widera, 1998, 2001). Therefore, in many cases, Pleistocene strata overlie directly Mesozoic rocks, like in boreholes Piorunów VII, 136/48, 24/48, and 32/48 (Fig. 7B). The faults cutting the Mesozoic basement most often display throws of 10–15 m. They were interpreted on the basis of denivelation of the top of the Mesozoic and, in part, on the basis of morphology of the bottom of coal seams, e.g., the bottom of the Middle-Polish Member (Widera, 1997, 1998). The cross-section analysis enables one to distinguish two Neogene phases of the Władysławów Graben development. The first (Savian) phase, which initiated the origin of the graben, was coeval with sedimentation of the Koźmin Formation. The second (Moldavian) phase took place during sedimentation of the Middle-Polish Member, including the 1st Middle-Polish Lignite Seam (Fig. 7B).

All the limitations of using the aggradation coefficient in palaeotectonic analysis of the Władysławów Graben are the same as in case of the Lubstów Graben. Therefore, the layout of the bottom of the main lignite seam in the Władysławów Graben was used (Fig. 8A). The differences in the depth of occurrence of the lignite bottom between the graben and its surroundings reach 20–25 m. It is evident that isolines are arranged parallel to the strike of the graben. The faults that were active during the lignite sedimentation fit to those which were active during the time of deposition of the Koźmin Formation. Here, likewise in the Lubstów Graben, three generations of faults which were active in different times can be distinguished: (a) those which were active before sedimentation of the 1st Middle-Polish Lignite Seam, (b) during that time, and (c) before and during that time (Fig. 8A, 8B). As compared to the Lubstów Graben, the only difference is that in the Władysławów Graben the faults active in different times have a very similar orientation, i.e. are approximately parallel. The Władysławów Graben is characterized by very simple geological structure. This graben was developing only in the Neogene during two tectonic phases: the Savian and Moldavian ones. The first phase is marked by unconstant subsidence during deposition of mainly mineral deposits of the Koźmin Formation. In the second phase, the subsidence of the bottom of the basin was steady and monotonous, during deposition of the Middle-Polish Member with the 1st Middle-Polish Lignite Seam.

TECTONIC PHASES

Graphic confrontation of tectonic phases, expressed in a quantitative way, is difficult. On one hand, subsidence of the basement in the Czempiń and Szamotuły Grabens, compared to their surroundings, was defined qualitatively and quantitatively by the use of aggradation coefficient (Table 1, 2). On the other hand, in the Lubstów and Władysławów Grabens tectonic phases were defined only qualitatively. Therefore, for the purpose of this work, I suggest to compare the thickness of sediments which occur both inside and outside the grabens. In order to compare the results, sediments of the Palaeogene formations from the Czempiń and Szamotuły Grabens should be treated as one unit, as in the case of Palaeogene strata in the Lubstów Graben. The calculations have only been made for the data obtained from boreholes which are located along the earlier-analyzed cross-section lines (Table 3). However, a graphic comparison of the distinguished tectonic phases in a qualitative way, is possible (Fig. 9).

The obtained results enable one to confirm that the Palaeogene subsidence of the Lubstów Graben, in compari-

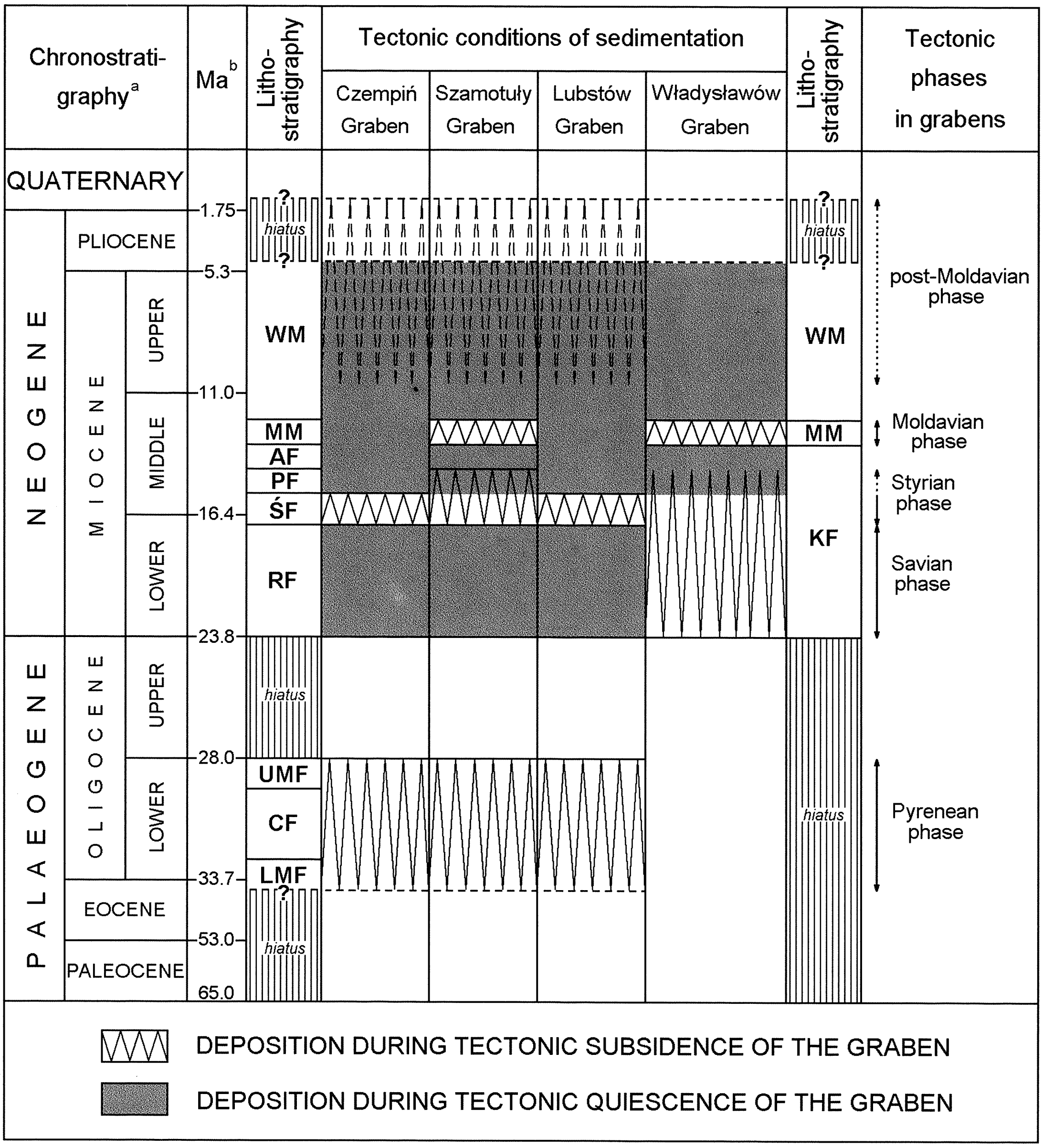

Fig. 9. Sketch of the Palaeogene and Neogene tectonic phases in the Czempiń, Szamotuły, Lubstów, and Władysławów Grabens: a – according to Steininger & Rögl (1983), and Steininger *et al.* (1987); b – according to Steininger *et al.* (1987), and Remané *et al.* (2000)

son to its surroundings, was about 2.5 times greater than that in the Czempiń Graben, and about 4 times greater than in the Szamotuły Graben. The Władysławów Graben did not exist at that time (Fig. 9). The beginning of its evolution should be connected with the Early Miocene (Widera, 1998, 2001).

During deposition of the Ścinawa Formation in the Czempiń and Lubstów Grabens, and in the Szamotuły Graben also at the time of deposition of the Pawłowice Formation, the next phase of their tectonic development took place (Table 3, Fig. 9). The subsidence in the Czempiń and Szamotuły Grabens had a similar extent. Although the analysed cross-section line does not testify to this, during the sedimentation of the Ścinawa Formation in the Lubstów Graben the greatest vertical movement took place. The thickness of a continuous lignite seam, up to 86.2 m, a rare feature in other Wielkopolska grabens, confirms the presence of vertical movements (Widera, 1998, 2000). On the basis of author's calculation, the consolidation coefficient for the studied lignite seam in the Lubstów Graben may be assumed as 2.34 (Widera, 2002b). Thus, the size of subsidence during the time of peat deposition exceeded 200 m, whereas for the Czempiń and Szamotuły Grabens the differences between the subsidence within the graben and upon its surroundings would have reached up to 100 m, even though the lithology of sediments and their compaction/consolidation are taken into account.

At the time of sedimentation of the Middle-Polish Member, the subsequent tectonic phase was marked in the Władysławów and Szamotuły Grabens (Fig. 9), while the

Lubstów Graben did not show tectonic activity, and in the Czempiń Graben relatively fast subsidence of the graben surroundings took place (Table 3).

Following the sedimentation of the Middle-Polish Member, and before the glacial Pleistocene (= Prepleistocene), the main faults in the Czempiń and Szamotuły Grabens became reactivated, as shown by the nearly 40 m throw of the Middle-Polish Member. After sedimentation of this member in the Władysławów Graben ceased, no signs of tectonic activity have been detected (Fig. 9). However, sedimentation of the Wielkopolska Member can be explaned by consolidation of lignites of the Middle-Polish Member (Widera, 2002b). After deposition of this member, the deepest, SE parts of the Lubstów Graben underwent uplift. Basing on the depth to the peat-bog (> 200 m) and denivelation of the bottom of lignite seam (> 110 m) it may be supposed that the extent of vertical displacements reached about 90 m. This problem demands further, more detailed studies, and it will not be discussed in this paper.

At a regional scale, numerous similarly developed structures were affected by several periods of subsidence and/or inversion at the same time. All these stages of tectonic evolution of the grabens and basins are indicated in the Carpathian-Alpine orogen and its foreland (Ziegler *et al.*, 1995; Hippolyte & Sandulescu, 1996), including the Sudetes, Carpathians, and Carpathian Foredeep (Dyjor, 1995; Oszczypko, 1996, 1999, 2001; Krysiak, 2000; Poprawa *et al.*, 2001). These episodes are also well marked in the Pannonian Basin (Bergerat, 1989; Fodor, 1995; Kovác *et al.*, 1995). At a European scale, tectonic phases distinguished in the Wielkopolska grabens are synchronous with main periods of tectonic activity recorded in the largest Cenozoic grabens of the Western Europe (Malkovsky, 1987; Peterek *et al.*, 1997; Sissingh, 1998; Michon *et al.*, 2003), and in the North Sea Rift System (Ziegler, 1992).

Moreover, the grabens' shape was directly controlled by the pre-existing fault zones and/or salt structures. In this case, the Czempiń Graben corresponds to the Variscan dislocations which were very active in the Mesozoic (Sokołowski, 1967; Deczkowski & Gajewska, 1977, 1979, 1980; Karnkowski, 1980; Knieszner *et al.*, 1983; Grocholski, 1991; Marek & Pajchlowa, 1997). In contrast, the Władysławów Graben can be linked with salt activity alone. The Szamotuły and Lubstów Grabens were affected by both mentioned processes, i.e. reactivation the pre-Cenozoic faults, and the uplift of salt structures (Stemulak, 1959; Pożaryski, 1971; Marek, 1977; Karnkowski, 1980; Ciuk & Grabowska, 1991; Widera, 1998, 2000).

CONCLUSIONS

Five tectonic phases can be distinguished in the Palaeogene and Neogene evolution of the studied grabens. Referring to the Alpine and Carpathian areas, these are the Pyrenean, Savian, Styrian, Moldavian, and one uncertain post-Moldavian phases. Usually, two, three or four phases within individual grabens can be identified. In the Władysławów Graben, the Savian and Moldavian phases have been reconstructed. In the Lubstów and Czempiń Grabens, three phases: Pyrenean, Styrian, and post-Moldavian left their traces, whereas in the Szamotuły Graben four stages of subsidence are clearly marked, being related to the Pyrenean, Styrian, Moldavian, and post-Moldavian phases.

The Lubstów Graben was subjected to the strongest vertical movements. Basing on the existing geological data, it can be concluded that in the Pyrenean phase the deepest part of this graben became subsided by 130 m, and in the Styrian phase – by the next 200 m. In the post-Moldavian phase, inversion of up to ca. 100 m took place. As far as the other grabens are concerned, no traces of significant uplift has been detected. In the Czempiń and Szamotuły Grabens, likewise in the Lubstów Graben, movements of the Styrian phase, when the Ścinawa Formation with the 2nd Lusatian Lignite Seam had been formed, were marked very distinctly. In both these grabens, the post-Moldavian displacements of amplitudes ranging 25–40 m, are to be found. The origin of the Władysławów Graben is correlated with the Savian phase. The most important event in the evolution of this graben, similarly as in the other grabens of the Konin Elevation area situated outside the Lubstów Graben, was the Moldavian phase, during which the Middle-Polish Member, bearing the 1st Middle-Polish Lignite Seam, was formed.

In the Palaeogene development of the Władysławów, Lubstów, and Szamotuły Grabens, the activity of salt structures occurring in the basement played a significant role. It is worth emphasizing that in case of the Lubstów and Szamotuły Grabens some older faults became reactivated. In the Władysławów Graben, new faults came into being after the onset of the Neogene. The origin of the Czempiń Graben cannot be explained by halokinesis and halotectonics. It is assumed that the outlines of this graben, likewise the other grabens of the Fore-Sudetic Monocline, are associated with those fault zones which had been active before the Cenozoic, and then became rejuvenated in the Tertiary.

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Streszczenie

FAZY PALEOGEŃSKIEGO I NEOGEŃSKIEGO ROZWOJU TEKTONICZNEGO WYBRANYCH ROWÓW NA OBSZARZE WIELKOPOLSKI

Marek Widera

Na obszarze Wielkopolski znajduje się szereg rowów tektonicznych, spośród których ponad 20 wykazywało aktywność jeszcze w kenozoiku. Część z nich funkcjonowała już w mezozoiku, a inne rozpoczęły swój rozwój w paleogenie, albo nawet w neogenie. W prezentowanej pracy omówiono jedynie trzeciorzędowe fazy rozwoju czterech rowów tektonicznych: Czempinia, Szamotuł, Lubstowa i Władysławowa (Fig. 1), reprezentatywnych dla analogicznych struktur tektonicznych Wielkopolski.

Ewolucja rowów tektonicznych w Wielkopolsce nie jest dobrze poznana. Dotychczas tylko kilka prac poświęcono wyłącznie kenozoicznej tektonice tego obszaru (Karnkowski, 1980; Kasiński, 1984; Widera, 1998, 2000; Widera *et al.*, 2004). W innych opracowaniach zagadnienia tektoniczne są traktowane drugorzędnie, jako informacje dodatkowe lub uzupełniające (Walkiewicz, 1968, 1979, 1984; Piwocki, 1975, 1991; Walkiewicz & Skoczylas, 1989; Ciuk, 1978; Ciuk & Grabowska, 1991). Poza tym, rozwój kenozoicznych rowów zasygnalizowano albo w szerszym kontekście stratygraficznym – od prekambru do czwartorzędu (Grocholski, 1991), albo na tle większego obszaru Polski (Deczkowski & Gajewska, 1980; Kniesner *et al.*, 1983). Dlatego też uzasadnione wydaje się opracowanie rozwoju wielkopolskich rowów tektonicznych w paleogenie i neogenie.

Analizowane trzeciorzędowe rowy Wielkopolski położone są na obszarze różnych jednostek strukturalno-tektonicznych. Rów Czempinia znajduje się na monoklinie przedsudeckiej (Sokołowski, 1967). Pozostałe rowy występują na elewacjach w obrębie synklinorium szczecińsko-łódzko-miechowskiego. Rów Szamotuł zlokalizowany jest na elewacji obornickiej (Stemulak, 1959; Pożaryski, 1971), a rowy Lubstowa i Władysławowa położone są na obszarze elewacji konińskiej (Krygowski, 1952; Widera, 1998).

Rozpoznanie geologiczne przebadanych rowów jest bardzo zróżnicowane. Liczba otworów wiertniczych dla poszczególnych rowów mieści się w przedziale od 25 (rów Szamotuł), do 454 (rów Władysławowa). Z uwagi na zróżnicowany stopień rozpoznania osadów wypełniających badane rowy zastosowano różne metody badawcze. Dla rowów Czempinia i Szamotuł obliczono tzw. współczynnik agradacji, który określa ile razy średnia miąższość osadów wewnątrz rowu jest większa niż w jego otoczeniu. Natomiast dla rowów Lubstowa i Władysławowa etapy tektonicznej aktywności wyznaczono na podstawie analizy przekrojów geologicznych, map miąższościowych i map strukturalnych spągu głównych pokładów węglowych.

Przed przystąpieniem do analizy paleotektonicznej przyporządkowano wydzielenia w kartach otworów wiertniczych odpowiednim formacjom i ogniwom. Terminologię litostratygraficzną przyjęto za Ciukiem (1965, 1967, 1970), z korektami i uzupełnieniami Piwockiego (1991, 2001), Piwockiego & Ziembińskiej-

Tworzydło (1995) oraz Widery (2001, 2002a). Natomiast pozycję wiekową jednostek litostratygraficznych przedstawiono na tle aktualnej chronostratygrafii paleogenu i neogenu (Steininger & Rögl, 1983; Steininger *et al.*, 1987; Remané *et al.*, 2000).

Skutki trzeciorzędowych deformacji osadów omówiono na podstawie przekrojów geologicznych, które skonstruowano w oparciu o dane z 39 otworów wiertniczych (Fig. 3B, 4B, 5B, 7B). Wskazano uskoki główne i uskoki drugorzędne, jak i określono przybliżone wielkości pionowych przemieszczeń oraz wiek deformacji. Dla rowów Czempinia i Szamotuł, które charakteryzują się stosunkowo prostą budową i łatwą do skorelowania litostratygrafią, wyznaczono fazy rozwoju tektonicznego w sposób ilościowy, obliczając współczynnik agradacji (Tabele 1, 2). W przypadku rowów Lubstowa i Władysławowa fazy tektoniczne określono jakościowo, ponieważ nie można tutaj obliczyć współczynnika agradacji. Jest to spowodowane nie do końca rozpoznaną litostratygrafią osadów paleogeńskich, zwłaszcza w rowie Lubstowa, a przede wszystkim brakiem litostratygraficznych odpowiedników wewnątrz i na zewnątrz obu rowów. Poza przyczynami tektonicznymi należy także uwzględnić niszczącą działalność lądolodów skandynawskich w plejstocenie (Widera, 1998, 2001). Dlatego też, dla rowów Lubstowa i Władysławowa wykorzystano inne metody wyznaczania faz tektonicznych. Posłużono się analizą paleotektoniczną map miąższościowych i strukturalnych spągu głównych pokładów węgla brunatnego: drugiego łużyckiego (lubstowskiego) w Lubstowie i pierwszego środkowopolskiego (konińskiego) we Władysławowie (Fig. 6, 8).

Zastosowane metody badawcze pozwoliły na wyznaczenie trzeciorzędowych faz tektonicznych na obszarze rowów Wielkopolski, a także na szacunkowe porównanie rozmiarów ruchów pionowych (Tabela 3). Łącznie wyróżniono pięć faz ewolucji tektonicznej badanych rowów (Fig. 9); w tym: jedną fazę podczas paleogenu i cztery neogeńskie. Kolejno, według terminologii Stillego (1952), są to fazy tektoniczne: pirenejska, sawska, styryjska, mołdawska i bliżej nieokreślona faza post-mołdawska. Niemniej jednak, czas ich trwania jest znacznie dłuższy niż przedstawiał to Stille (1952). Bardziej wskazane, nie budzące większych kontrowersji, jest jednak łączenie etapów rozwoju rowów z sedymentacją odpowiednich jednostek litostratygraficznych. Pierwszy, paleogeński etap obejmuje zatem sedymentację takich formacji, jak: mosińskiej dolnej, czempińskiej i mosińskiej górnej (najwyższy eocen – dolny oligocen). Drugi etap może być korelowany z rozpoczęciem sedymentacji formacji koźmińskiej w rowie Władysławowa (dolny miocen). W trzecim etapie doszło do największej subsydencji, czego zapisem są osady formacji ścinawskiej z drugą łużycką grupą pokładów węgla brunatnego (najniższy środkowy miocen). Kolejny, czwarty etap obejmuje czas sedymentacji ogniwa środkowopolskiego z pierwszą środkowopolską grupą pokładów węgla brunatnego (środkowa część środkowego miocenu). Natomiast piąty, ostatni etap rozwoju tektonicznego rowów jest trudny do określenia. Można jedynie stwierdzić, że mógł mieć on miejsce w czasie sedymentacji ogniwa wielkopolskiego, a być może nawet w plejstocenie przedglacjalnym – preplejstocenie (Widera *et al.*, 2004).

Na obszarze badanych rowów nie zaznaczyły się wszystkie wymienione fazy tektoniczne (Fig. 9). W rowie Władysławowa wyróżniono tylko 2 fazy, w rowach Lubstowa i Czempinia odnotowano 3 fazy, a w rowie Szamotuł stwierdzono 4 fazy paleogeńsko-neogeńskiej aktywności tektonicznej. W przeważającej mierze kolejne fazy tektoniczne zaznaczyły się w postaci ruchów obniżających osiowe części rowów. Wyjątek stanowi rów Lubstowa, gdzie w fazie post-mołdawskiej najgłębsze partie rowu uległy ruchom wznoszącym. Rozmiary pionowych przemieszczeń inwersyjnych wstępnie oszacowano na około 100 m.

Znaczne urozmaicenie w trzeciorzędowej ewolucji rowów tektonicznych w Wielkopolsce powiązano z ich lokalizacją. W rozwoju rowów Władysławowa, Lubstowa i Szamotuł zaznaczyła się w różnym stopniu aktywność struktur solnych. Neogeńskie ruchy wznoszące tzw. poduszki solnej Turku należy uznać za główną przyczynę powstania rowu Władysławowa (Widera, 1998). W przypadku rowów Lubstowa i Szamotuł najprawdopodobniej reaktywacji uległy również dyslokacje przedkenozoiczne (Stemulak, 1959; Marek, 1977; Widera, 1998, 2000). Dlatego też, m.in. oba rowy były już aktywne w paleogenie, tj. w fazie pirenejskiej. Położenie rowu Czempinia nie upoważnia do łączenia jego paleogeńsko-neogeńskiego rozwoju z tektoniką solną (Deczkowski & Gajewska, 1977, 1979, 1980; Knieszner *et al.,* 1983). Zarysy rowu, podobnie jak innych rowów na monoklinie przedsudeckiej, nawiązują do przebiegu nieciągłości w starszym podłożu. Można stwierdzić, że główne paleogeńsko-neogeńskie uskoki w rowie Czempinia rozwinęły się wzdłuż dyslokacji bardzo aktywnych już w mezozoiku (Sokołowski, 1967; Grocholski, 1991).

Fazy tektonicznego rozwoju rowów na terenie Wielkopolski są porównywalne z etapami zwiększonej aktywności innych obszarów Polski, a nawet Europy. Każda z wyróżnionych faz może być korelowana z tektoniczną aktywnością orogenu alpejsko-karpackiego (Stille, 1952; Hippolyte & Sandulescu, 1995). Pierwszy, paleogeński etap rozwoju rowów Wielkopolski – faza pirenejska – jest izochroniczny z początkiem kenozoicznej ewolucji największych rowów tektonicznych zachodniej Europy (Malkovsky, 1987; Peterek *et al.*, 1997; Ziegler *et al.*, 1995; Sissingh, 1998; Michon *et al.*, 2003) i systemu ryftowego Morza Północnego (Ziegler, 1992). Natomiast pozostałe, neogeńskie etapy aktywności tektonicznej badanych rowów korelują się lepiej z fazami tektonicznymi wyróżnianymi w Sudetach, Karpatach i zapadlisku przedkarpackim (Dyjor, 1995; Oszczypko, 1996, 1999, 2001; Krysiak, 2000; Poprawa *et al.*, 2001) oraz na obszarze basenu panońskiego (Bergerat, 1989; Fodor, 1995; Kováč *et al.*, 1995).