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MIDDLE PLEISTOCENE FLUVIAL, LACUSTRINE AND GLACIOLACUSTRINE SEDIMENTS OF THE CZYŻÓW AND KUCÓW FORMATIONS (KUCÓW 9, 10 AND 16 SECTIONS), BEŁCHATÓW OUTCROP, CENTRAL POLAND – THE PROBLEM OF STRATIGRAPHICAL INTERPRETATION

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Abstract:

The article presents results of research of three sections (Kuców 9, 10 and 16). Two of them record fluvial and lacustrine interglacial sediments and the third, cold-stage glaciolacustrine sediments. They were formed inside the Miocene–Pliocene syncline depressions in a central part of the southern horst within the Kleszczów Graben. Fluvial and lacustrine deposits of the Middle Pleistocene Interglacial (Mazovian or Ferdynandovian in the Czyżów Formation) are described from the Kuców 9 and 10 sections. Their sediments are located in marginal parts of a buried river valley and within an oxbow palaeolake, then covered by glaciofluvial deposits of the Ławki (Early Saalian) and Rogowiec (Late Saalian) Formations. The Kuców 16 section comprises ice-dam sandy lithofacies (Kuców Formation, Elsterian) of a marginal part in a proglacial lake. Two pollen diagrams of K65/15 and Kuców 9 sections represent the Mazovian (Holsteinian) succession, although in the Kuców 9 section some features are typical for the Ferdinandovian succession.

Key words: lake deposits, fluvial deposits, oxbow, Mazovian, Ferdynandovian, Kleszczów Graben, central Poland

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INTRODUCTION

A long sequence of the Pleistocene sediments in the Kleszczów Graben, central Poland (Fig. 1), with the Mazovian (Holsteinian) Interglacial limnic and fluvial deposits are an important link in Polish Quaternary stratigraphy (Baraniecka, 1971; Mojski, 2005). The Czyżów Formation, stratigraphically part of the Czyżów Complex, provides a lithostratigraphic sequence of the central part of the Kleszczów Graben in the Bełchatów outcrop that comprises fluvial sand and gravel, and also gyttjas, clay, silt and peat (cf. Krzyszkowski, 1989, 1992, 1996; Krzyszkowski and Czerwonka, 1992; Balwierz *et al*., 2006, 2008; Allen and Krzyszkowski, 2008). Palynological investigations of the organic deposits showed their affinity with the Mazovian? Interglacial (Holsteinian).

In the 1990s, during removal of overburden in the central part of the Bełchatów outcrop, a sequence of deposits of the Czyżów Formation was revealed in the southern part of the Kleszczów Graben (Krzyszkowski, 1992; Figs 1 and 2). Results of the studies conducted in the 1990s were only partially published and this paper presents the unpublished

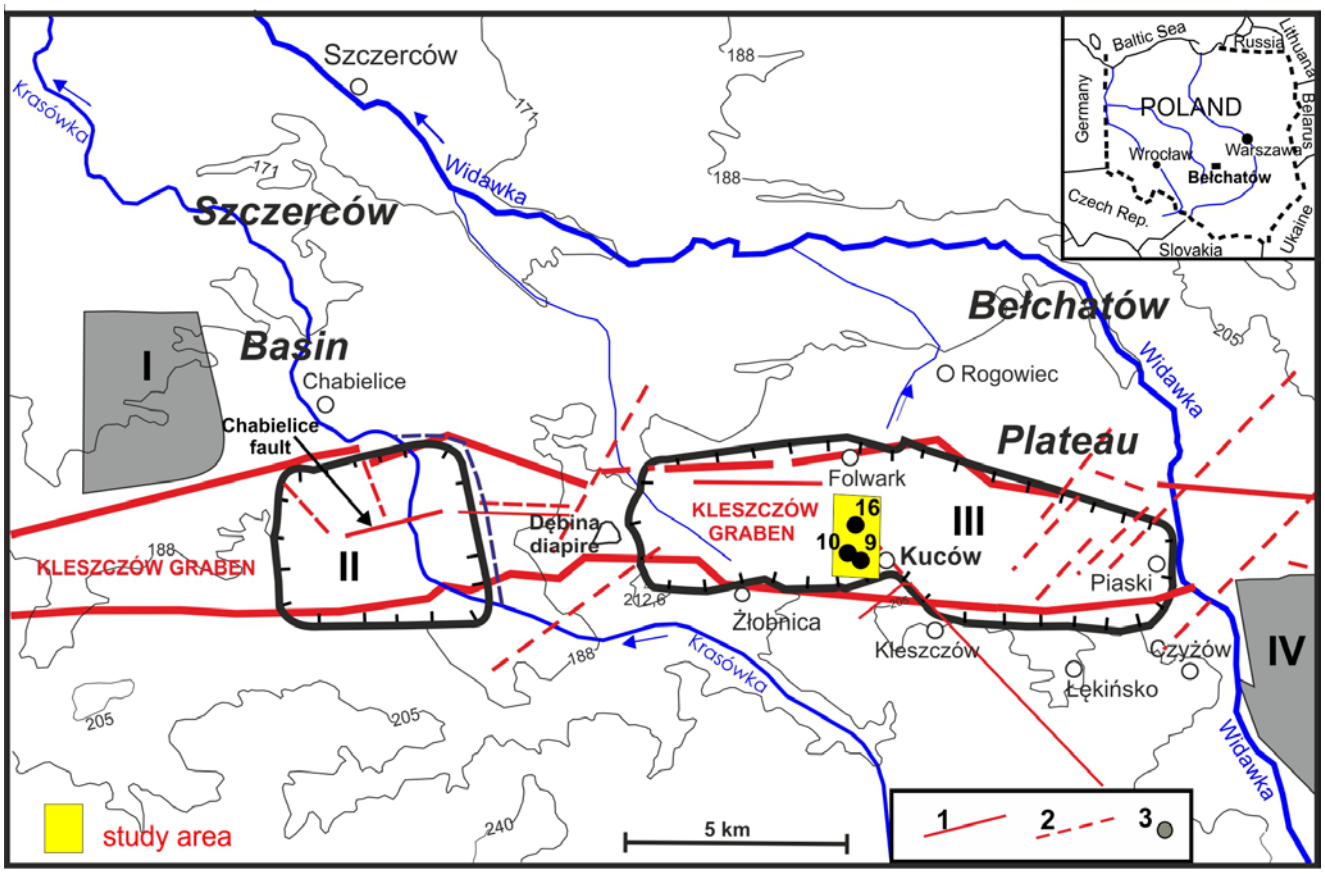

Fig. 1. Study area. 1 – faults; 2 – probable faults; 3 – examined sections (Kuców 9, Kuców 10, Kuców 16); I and IV – outside-mine piles, II – Szczerców outcrop, III – Bełchatów outcrop.

data. The deposits comprise limnic and fluvial, as well as glaciolacustrine sediments from the lower structural unit in the Kleszczów Graben revealed in the sections Kuców 9, 10 and 16.

Research material and results of lithological-structural and textural analyses of sediments (Krzyszkowski, 1992), and palynological studies complement a palaeogeographical reconstruction of fluvial, lacustrine and glaciolacustrine deposits that filled the Miocene/Pliocene depressions (Krzyszkowski and Czerwonka, 1992) during the Middle Pleistocene. The main problem is the age of organic sediments that fill oxbow lakes and the stratigraphic setting of the adjacent deposits. Such stratigraphical problem is important because more recent studies reinterpreted and rejuvenation setting of the Holsteinian Interglacial (Balwierz *et al*., 2006, 2008; Pawłowska *et al*., 2014) if referred to older studies of the Czyżów Formation (Krzyszkowski, 1992, 1996; Allen and Krzyszkowski, 2008; Krzyszkowski *et al*., 2016a, b, 2017) (see Table 1).

GEOLOGICAL SETTING

The studied deposits occur in a southern part of the graben at shallow depth, *ca* 20 m below the surface of the morainic Bełchatów Plateau) within a tectonic (structural) unit, located above faults that delimiting the Kleszczów Graben (Fig. 1). This structural unit is located within the Kleszczów Graben (Krzyszkowski, 1992) and is composed of glacial sand and gravel, and sandy silt, silt, clay and till (glaciofluvial, glacial, glaciolacustrine and fluvial in origin) of the Folwark, Kuców and Ławki Formations (Krzyszkowski, 1992, 1993, 1994, 1995; Krzyszkowski and Czerwonka, 1992; Gruszka *et al*., 2004) (Table 1). A non-disturbed upper structural unit lies at the top and comprises glacial and glaciofluvial (Rogowiec Formation: Late Saalian), lacustrine (Aleksandrów Formation: Eemian), fluvial (Piaski and Widawka Formation: Weichselian and Holocene) and organic (Szerokie Formation: Holocene) sediments.

The thicknesses of these deposits are: 1–10 m (Folwark Formation); 25–45 m (Kuców Formation); 15–55 m (Ławki Formation); 2–15 m (Rogowiec Formation, in upper structural unit) (Krzyszkowski and Czerwonka, 1992; Gruszka *et al*., 2004). Previous work identified glacilimic and glacideltaic sediments (Hałuszczak, 1982), separated by tills (T1–T7) (see Table 1) of varying thickness and lithology (Krzyszkowski and Czerwonka, 1992). Fluvial deposits are interbedded with ice-dam sediments (e.g. within the Czyżów and Piaski Formations) (see Table 1 and Figs 2 and 3).

Table 1. Quaternary stratigraphy of the Kleszczów Graben after different authors.

Tectonics	Lithostratigraphy (formations)	Glacial beds or other data: Szczercow outcrop	Glacial beds or other data: Bełchatów outrop	Chronostratigraphy	MIS
		acc. to Krzyszkowski (1996); Allen and Krzyszkowski (2008); Krzyszkowski et al. (2016 a,b, 2017); correlation with MIS acc. Krzyszkowski (2010), Krzyszkowski and Wachecka-Kotkowska (2013)			
UPPER STRUCTURAL UNIT (UNDISTURBED)	WIDAWKA* / SZEROKIE*			HOLOCENE	1
	PIASKI*			WEICHSELIAN Upper / Middle / Lower	2 - 5d
	?				
	ALEKSANDRÓW*		palaeosoil?	EEMIAN	5e
	ROGOWIEC	TILL 7	TILL 7	SAALIAN: WARTANIAN 2	6
		?	TILL 6		
			palaeosoil?	interstadial?	
		?	TILL 5	WARTANIAN 1	
	CHOJNY*			PILICIAN	
LOWER STRUCTURAL UNIT (DISTURBED)	STAWEK			?	
	ŁAWKI	TILL 4	TILL 4	ODRANIAN	
	ROKITY	?	TILL 3	?	
	CZYŻOW*	Czyżów Interstadial / Podlesie Interstadial / Mazovian Interglacial ? Ferdynandovian Interglacial		CZYŻÓW COMPLEX	8 / 9 / 10 / 11
	KUCÓW	TILL 2B	HIATUS ?	ELSTERIAN: SANIAN	12
		TILL 2	TILL 2		
		TILL 2A	TILL 2A		
	FOLWARK	TILL 1	TILL 1	NIDANIAN	
	hiatus	no data		?	13-?
	ŁEKIŃSKO*			LOWER PLEISTOCENE	?
	P L I O C E N E				

MIS	Litho-stratigraphy (formations)	Chronostratigraphy: acc. to Pawłowska et al. (2014) - and correlation with MIS		
1	Widawka* & Szerokie*	Holocene		
2 - 5d	Piaski*	Vistulian (Weichselian) Glaciation		North-Polish Complex
5e	Aleksandrów*	Eemian Interglacial		
6 - 8	Rogowiec	Odranian Glaciation (with Wartanian recessive stadial) / Krznanian Glaciation		Middle-Polish Complex
9? or 11?	Chojny*	Zbójnian (Reinsdorf) Interglacial? / Mazovian (Holsteinian) Interglacial		
12 - ?	Stawek Ławki Rokity / Czyżów* / Kuców Folwark	Nidanian & Sanian Glaciations (Cromerian Complex and Elsterian)		South-Polish Complex
hiatus		Praetiglian?	?	
?-103	Łękińsko*		Preglacial Complex	
P L I O C E N E				

MIS	Stratigraphic subdivision of the Quaternary of Poland: acc. to Marks et al. (2016)	
1	Holocene	
2 - 5d	Vistulian Glaciation	North Polish Complex
5e	Eemian	
6	Odranian Glaciation	Middle Polish Complex
7	Lublinian Interglacial	
8	Krznanian Glaciation	
9	Zbójnian Interglacial	
10	Liwiecian Gl.	
11	Mazovian Interglacial	
12	Sanian 2 Gl.	South Polish Complex
13-15	Ferdynandovian In.	
16	Sanian 1 Gl.	
17-21	Podlasian In.	
22	Nidanian Gl.	
23-103	Preglacial	K & K series
Older substratum		

Deposits of the Czyżów Formation are sandwiched between the Sanian (Elsterian) and Odranian–Wartanian (Saalian) beds. They are located between the Kuców Formation and Rokity and/or Ławki Formations (Table 1, Fig. 2) in the southern part of the Bełchatów outcrop. The formation is 20–60 m thick and its deposits occur at 140–180 m a.s.l., about 25–60 m beneath the Bełchatów Plateau. The Czyżów Formation consists of sand, sandy silt and silt as well as the organic sediments (e.g. peat, organic detritus-rich silt, diatomite, lake marl), grouped in several sedimentary members (A–F) of different age and origin: member A at the top (Upper Member), member B below (Middle Member) and members B, D and E at the bottom (Lower Members). Moreover, the sixth member (F) was identified in borings in the western foreland of the Bełchatów outcrop (Krzyszkowski, 1992, 1993; Krzyszkowski and Czerwonka, 1992).

MATERIAL AND METHODS

Fieldworks

The sediments were exposed at the first and second mining levels in 1993–1995, on the western wall in the central part of the Bełchatów outcrop (Fig. 1). The sections Kuców 9, 10 and 16 were described by Krzyszkowski and subsequently, examined by a team of authors (Krzyszkowski *et al*., 2016a, b, 2017).

A geological cross-section and a detailed sketch of exposed deposits of the Czyżów Formation were compiled from sketches of open pits, field drawings of pit walls, recording of structural (lithofacies) analysis according to Miall (1978) and modified by Krzyszkowski (1993), supported by photographic record of deposits and landforms. Palaeoflow directions were determined from directional (palaeocurrent) measurements in stratified and structurally undisturbed deposits.

Textural analysis

Alluvial and limnic samples were collected for textural analyses from the sections Kuców 9, 10 and 16. Textural features of mineral deposits were examined by grain-size, heavy mineral composition, and morphoscopy (shape and roundness by a quartz grain analysis). Basic grain size analyses were performed in the laboratories of the Institute of Geology and Geography of the University of Wrocław.

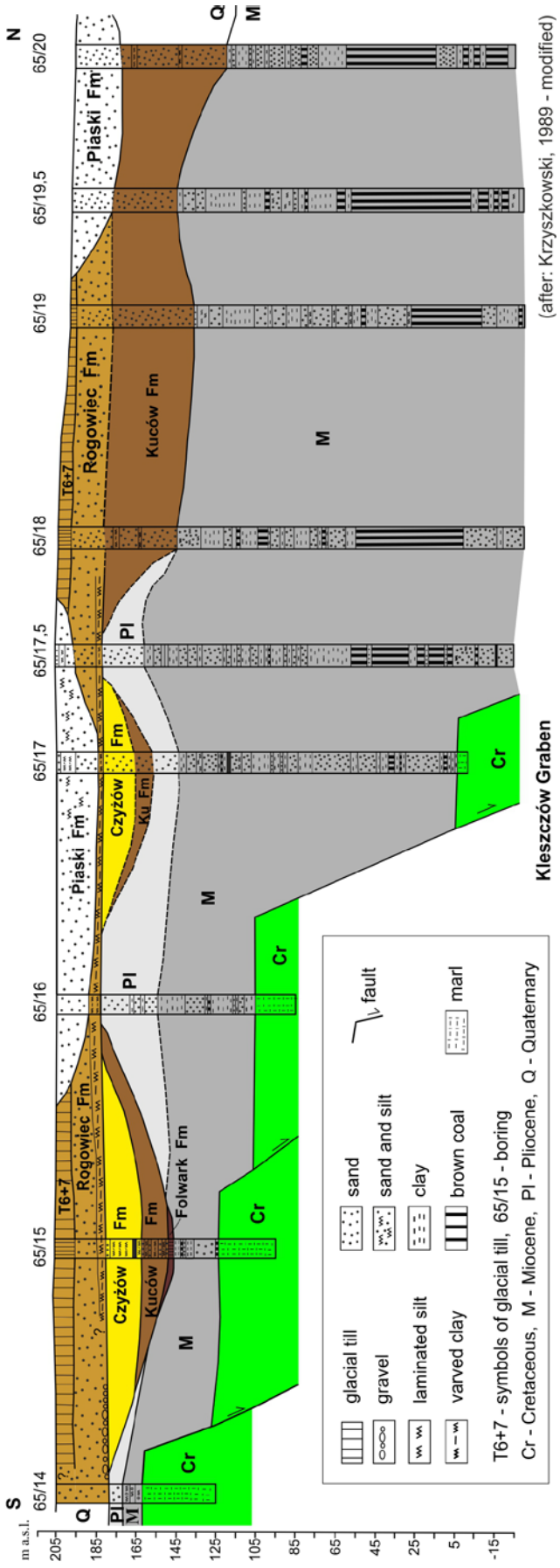

Fig. 2. Examined sites in the Kleszczów Graben (central part of the southern horst).

Gravel petrography analyses were carried out at the Geological Enterprise PROXIMA S.A. in Wrocław, using samples collected at research sites (Czerwonka, 1998a).

Opaque and transparent heavy minerals were examined in grain size 0.1–0.25 mm, with 300 grains analyzed, and such methodology was adopted by the Polish Geological Institute – National Research Institute as a standard survey for the Detailed Geological Map of Poland, scale 1:50,000. Minerals were separated in bromoform (2.89 g/cm^3). The analysis of heavy minerals was done with the «SZERL» software, written for the ZX-SPEKTRUM microcomputer (Czerwonka, 1998b).

Roundness of quartz grains (0.5–1.0 mm) was determined using a simple photographic method (Morawski, 1955; Racinowski and Rzechowski, 1960). Partially rounded grains were interpreted as sculpture by «normal» fluvial processes and long transport. The well rounded grains in the preglacial series were considered to be highly re-worked sediments, either due to chemical weathering or periglacial processes during the Quaternary (Goździk, 1980). When present, the series with increased well rounded quartz grains was investigated additionally using the method of Cailleux (1961) and modified by Goździk (1980, 1995), in order to determine more precisely a nature of grain weathering.

Lithological and especially sedimentological studies, have provided data for a palaeoenvironmental reconstruction. Sedimentological analysis allowed to identify depositional sub-environments, for which a mutual spatial relationship was determined and depth and stratigraphic correlations were made.

Pollen analysis

Alluvial and limnic samples were also collected for a palynological analysis from the section Kuców 9. Samples designed for pollen analysis were macerated with 10% KOH, 10% HCl, $ZnCl_2$ and subjected to the Erdtman's acetolysis. Sporomorphs were counted to at least 500 pollen grains of trees and shrubs. The POLPAL programme was used to prepare and draw both diagrams (Walanus and Nalepka, 1999). Pollen diagrams are presented (Figs 9 and 11).

RESULTS

Lithology

Section Kuców 16 (Folwark and/or Kuców Formations)

Description. The section Kuców 16 is located in the central part of the Kleszczów Graben at 155−175 m a.s.l. (Fig. 1).

At the base there is trough cross-bedded sand and gravel (*SGt*, *St*), overlain in succession by sandy silt (*Vc4*) and varved clay (*Vs* − varved clay with silt and sandy silt), and by trough cross-bedded sand and gravel (*St*, *SGt*), sand and silt with subordinate varved clay (*Vc4*, *Vc3*, *Vc2*, *Vc3*, *Vc4*)

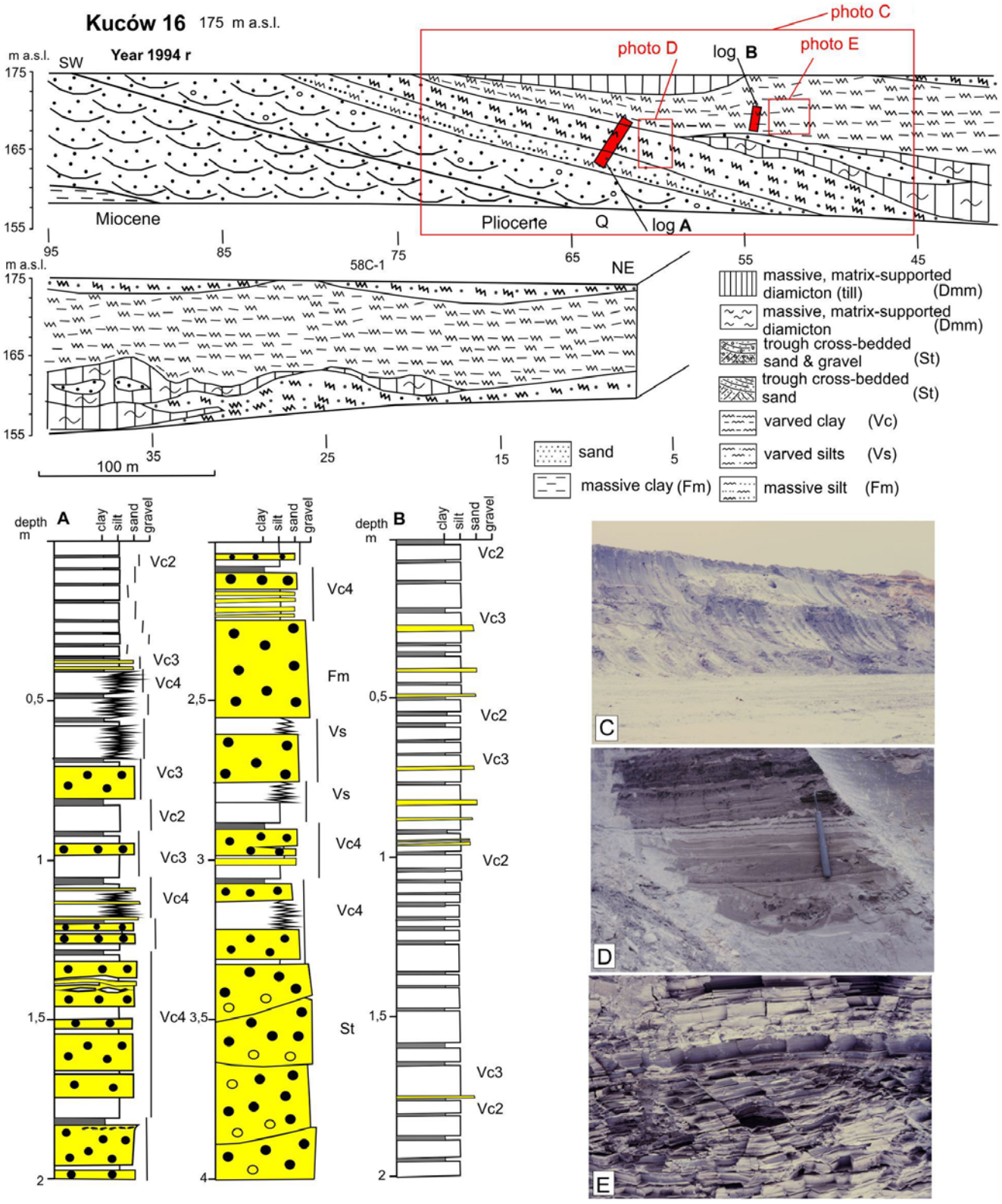

Fig. 3. Kuców 16 section: geology (top) and structure of deposits (bottom).

and finally, silt and clay, subordinately fine-grained sand (*Vc3, Vc4*) (Fig. 3). No facies related to gravitational flows were observed (*Dmm*), although they occur nearby.

Interpretation. Ice-dam sediments of the section Kuców 16 are located on the Pliocene sediments. The basal part of *SGt* and *St* facies may include glacioflu-

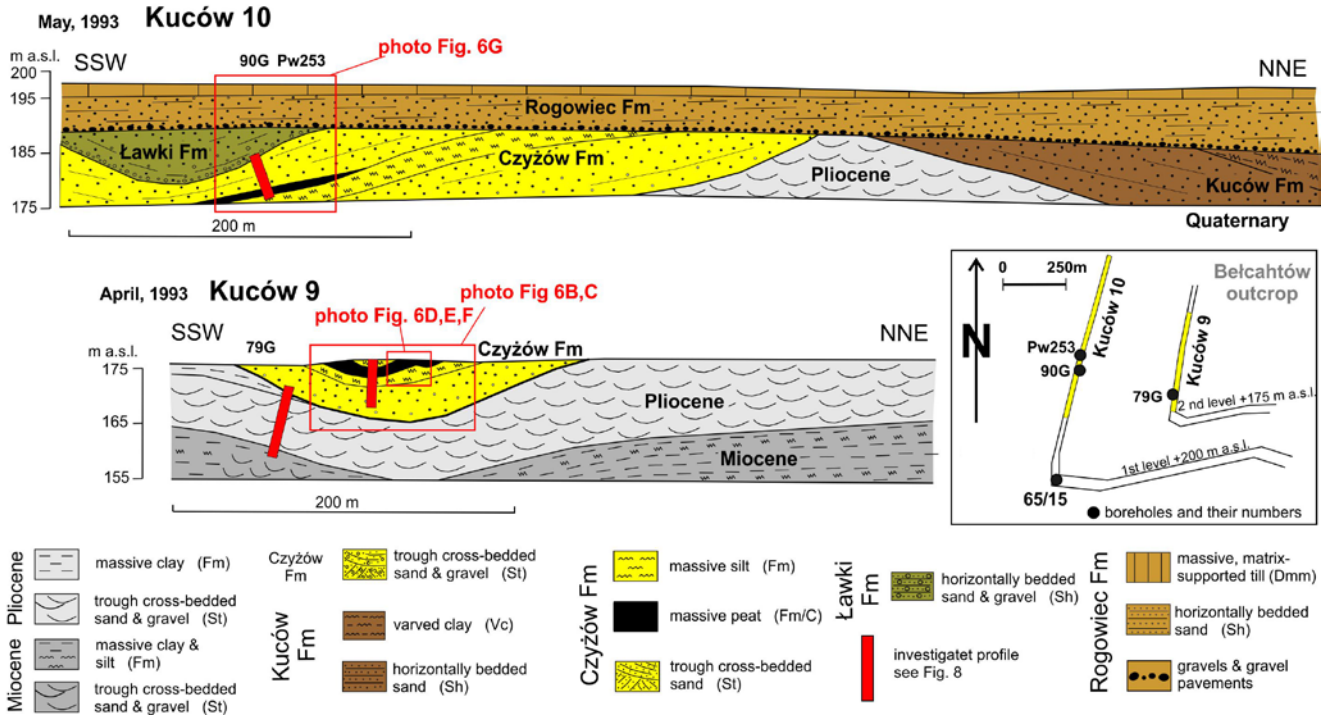

Fig. 4. Geological cross-section of the sections Kuców 9 and 10.

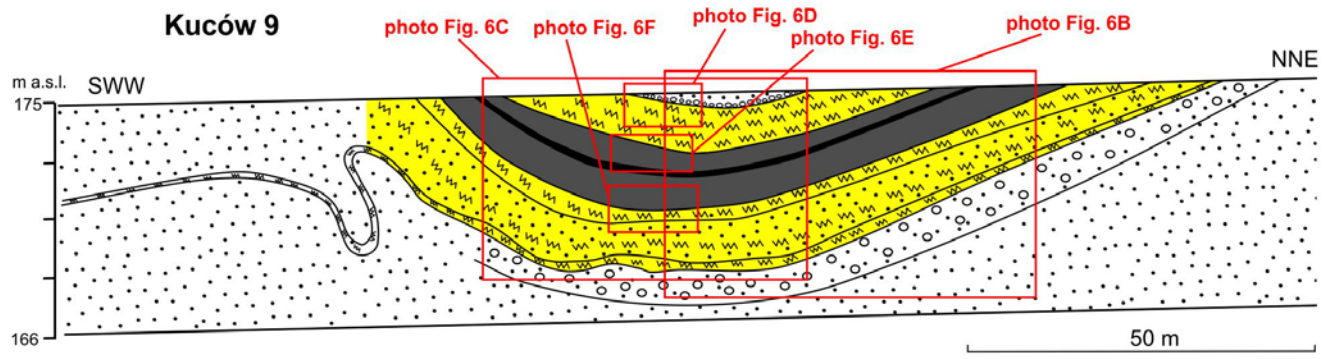

Fig. 5. Detailed geological cross-section near the section Kuców 9.

vial formations, while glaciodeltaic (fragment with more sand) and glacilimnic formations (mainly silt and clay) are at the top (Fig. 3). Deposition occurred without a direct participation of gravitation runoff processes, indicating a higher-flow episode (rapid flow of material). Such sequence is characteristic for marginal parts of a proglacial palaeolake.

Sections Kuców 9 and 10 (Czyżów Formation)

Description. The section Kuców 9 is located in the middle part of the Kleszczów Graben at 166–175 m a.s.l. and the section Kuców 10 at 175–205 m a.s.l. within a palaeovalley (syncline?) form (Figs 4−6). At the bottom there are sand, gravel and till of the Kuców Formation, accompanied by Miocene and Pliocene variegated sand and clay that form wide-synclines and anticlines. Deposits of the Czyżów Formation are overlain uncomfortably by sandy gravel and gravel of the Ławki and Rogowiec Formations (Early Saalian, MIS 6). Organic and fluvial sediments from the lower structural unit were examined, located at 155–175 m a.s.l. (see the section Kuców 16). The Czyżów Formation sediments were characteristic for greenish and yellowish silt and yellow-brownish or greenish sand.

This formation in both sections is 13 m thick, comprising the lower, strictly mineral unit (5.5 m), the middle organic-mineral unit (2.5 m) and the upper mineral unit (5 m). The middle part of the section Kuców 9 documented more details than the section Kuców 10 (Figs 4, 6, 7).

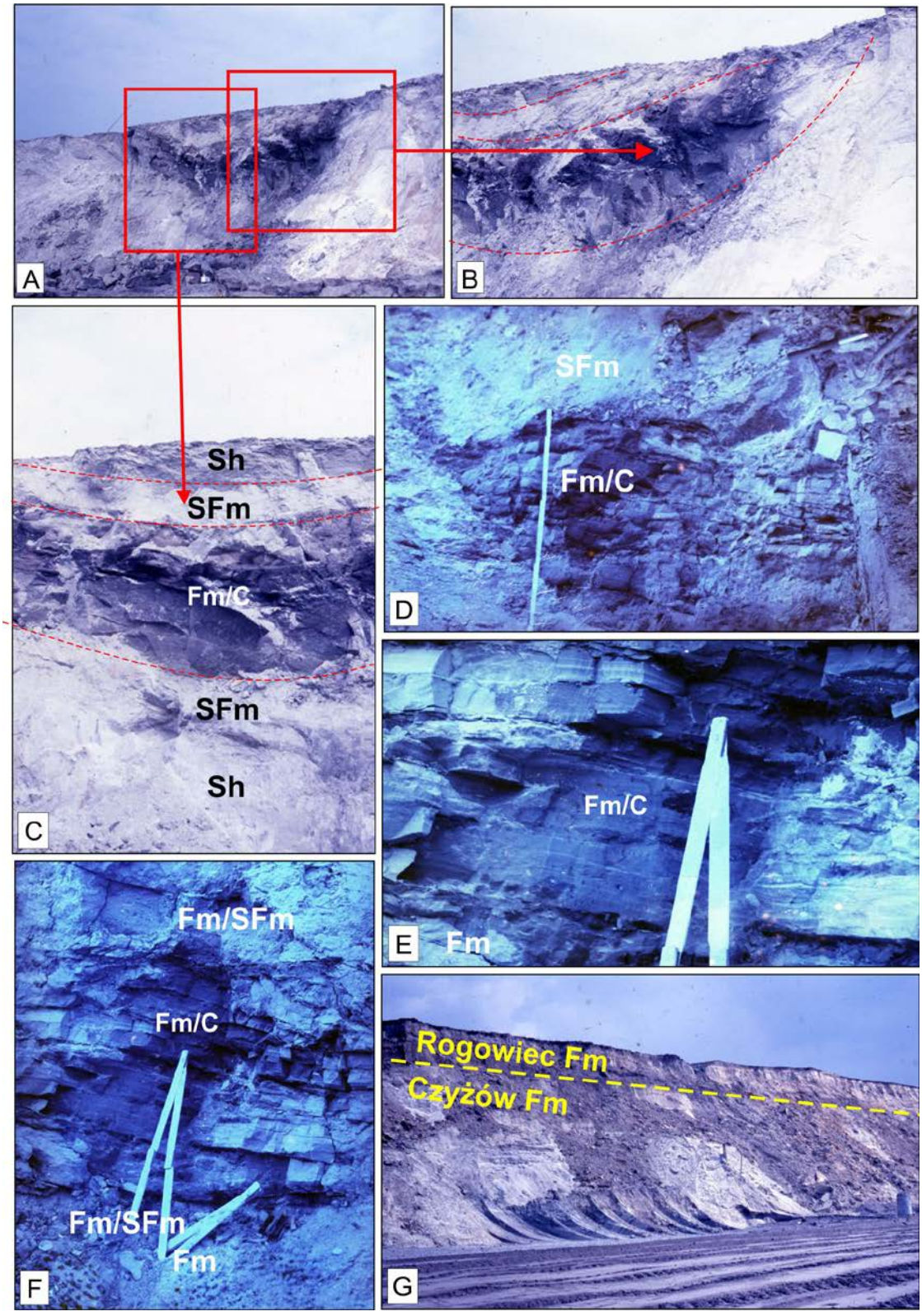

Fig. 6. Limnic deposits in the sections Kuców 9 and 10.

In the floor there are sand and gravel *St*, *Sh* and *Sp*. In the middle member, sand *St/Sh* passed upwards into gyttja, silt and clay *Fm, FmC* and peat (*C*). At the top, *Sh* facies (pale yellow) predominate (Figs 6, 7).

Interpretation. In the section Kuców 9, fluvial and limnic material inside a syncline located in the Pliocene top set, and in this section similar sediments filled a valley form, with an erosional contact (Figs 4–6). The sequences of the Kuców 9

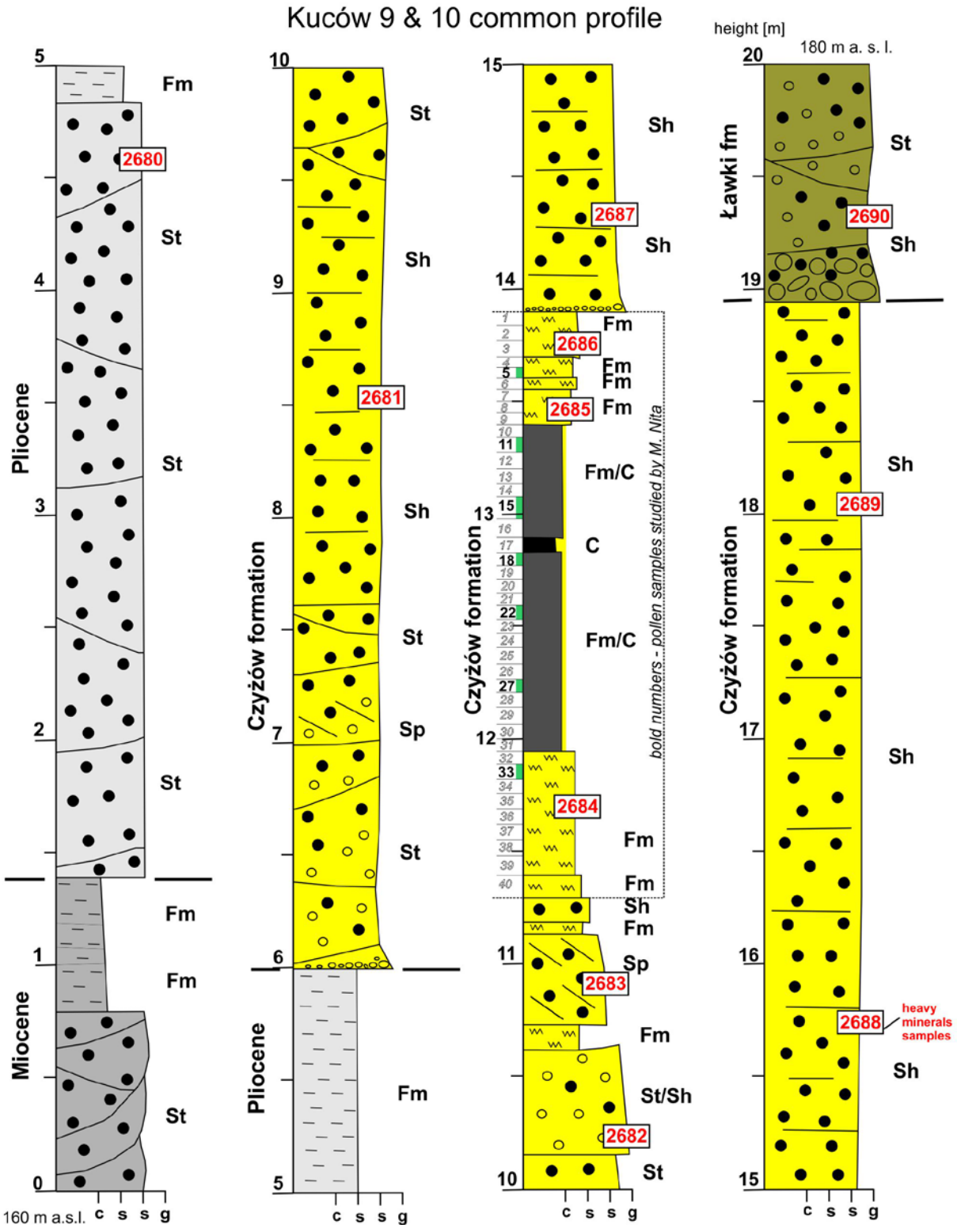

Fig. 7. Lithology in the sections Kuców 9 and 10.

& 10 sections present deposits located in marginal parts of a fossil river valley and a palaeolake, covered by glaciofluvial deposits of the Ławki and Rogowiec Formations. Deposition occurred in a channel with varied flow − from very energetic through waning flow in probable oxbow lakes filled with organic sediments (peat and gyttja). In a final stage, there was a very low-energy flow (almost dying), which was then resumed and intensified. A resumption of the flow resulted in occurrence of organic sediments being covered by mineral, overbank and flood deposits.

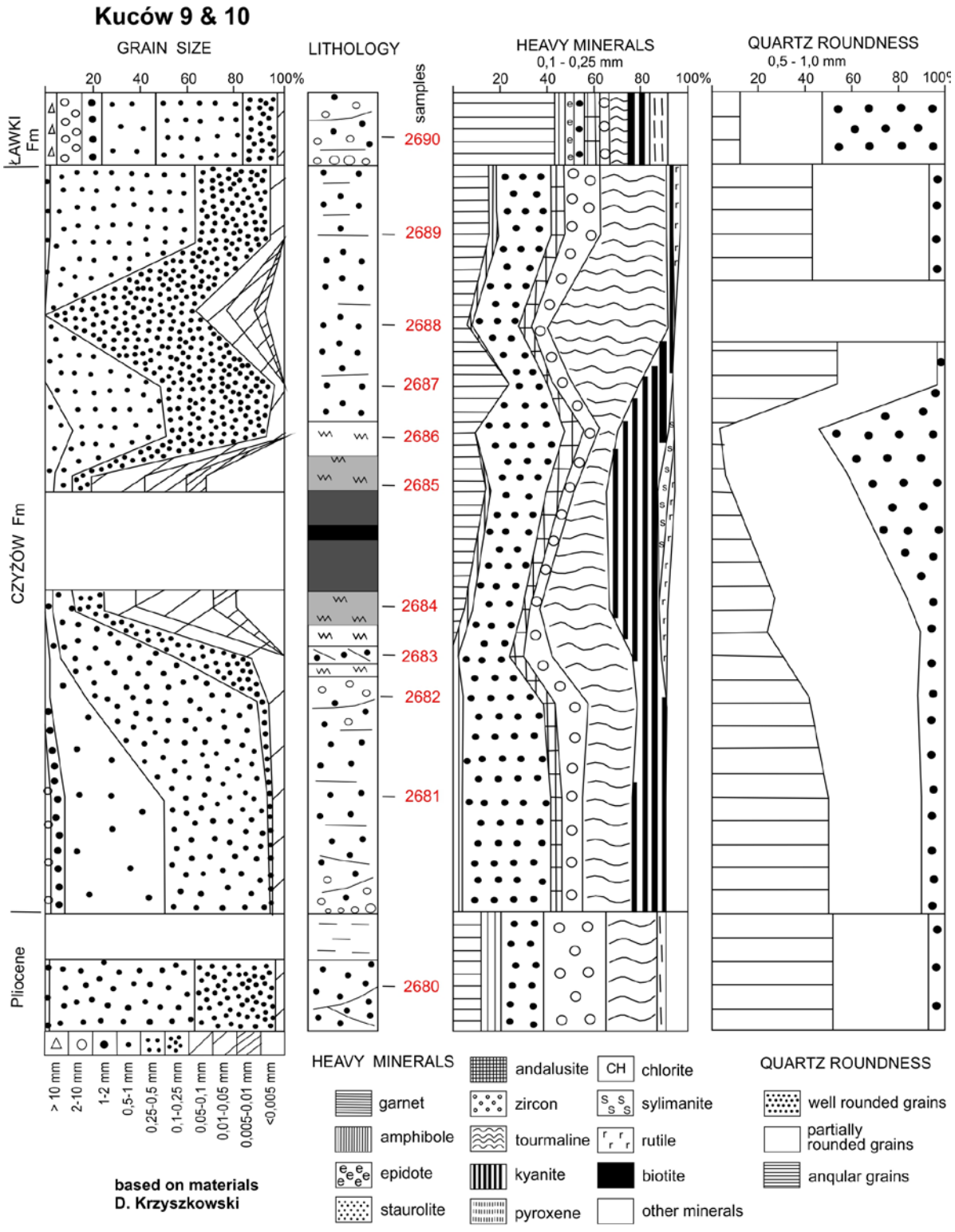

Fig. 8. Texture and petrography features of deposits in s central part of the Bełchatów Field (sections Kuców 9 and 10).

Textural and petrographic features

In the sections Kuców 9 and 10, coarse and medium-grain sand (80%) turn upwards into fine sand (50%). In the middle part of the section there are peat and gyttja that pass upwards into silt and silty sand (60%) and then into vari-grained sand (30–50%). At the top, sediments of the Ławki Formation are composed of vari-grained sand, with predominance of medium-grained one (30%).

Results of mineralogical analysis indicated differences

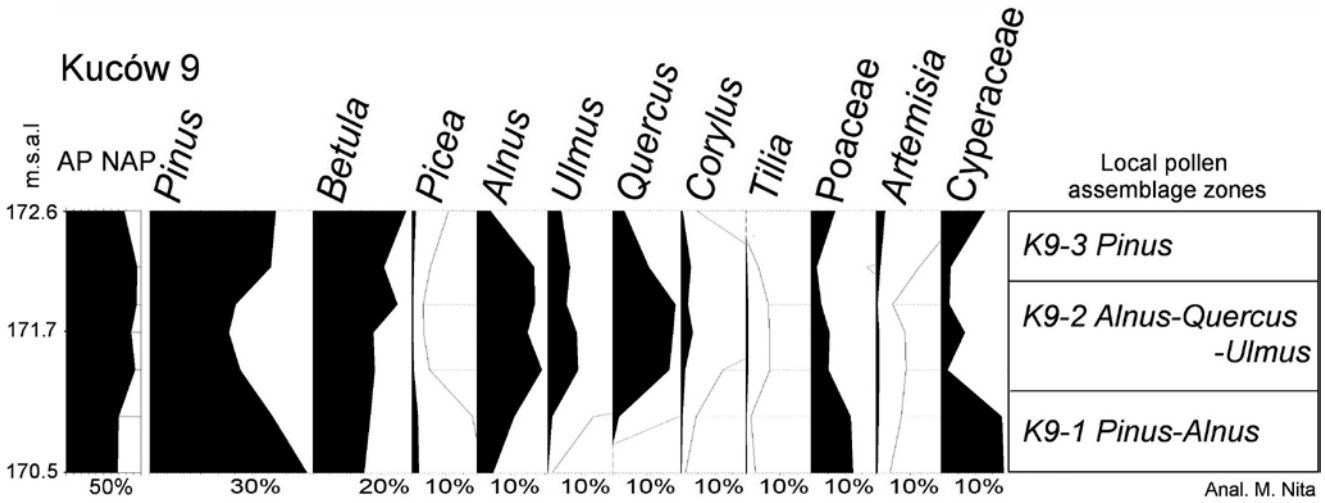

Fig. 9. Percentage pollen diagram from the section Kuców 9.

between lithostratigraphic units (Fig. 8). In the lower part, within the Pliocene sediments incorporated into the basal Pleistocene deposits, resistant minerals predominate (staurolite 30%, zircon 40% and tourmaline 30%). Fluvial sediments of the Czyżów Formation contain a larger variety of minerals (tourmaline 20–40%, staurolite 20–40%, kyanite 10–20% and zircon 10–15%). However, above the interglacial deposits in the upper part, spectrum of heavy minerals from glacial sediments of the Ławki Formation with moderately resistant minerals (garnet 40% and amphiboles 5%) over those that are more resistant to weathering (staurolite 10%, tourmaline 10%, kyanite 10%, zircon 5%).

The roundness coefficient is varied. Content of angular grains decreases from the bottom to the top. About 60% of grains are angular in the Pliocene sand. They are succeeded by untreated sands; at the base 58% of them are angular, 8–20% in the central part but reaching 45% in the topmost part of the Czyżów Complex. Well-rounded grains are common (60%) above organic deposits and their content decreases to the top of the Czyżów Complex. A high content (55%) of well roundness grains occurs in younger sediments of the overlying Rogowiec Formation.

Palynology

The pollen diagram from section Kuców 9 (Fig. 9) was divided into three local pollen assemblage zones (K9-1 to K9-3). Arboreal pollen dominates in the oldest part of the section (K9-1 *Pinus–Alnus*) (AP, 70%); *Pinus* (max. 46%), *Alnus* (11%) and very low *Picea* (2%). Among herbaceous plants (NAP), Cyperaceae are the most common (18%). In K9-2 *Alnus–Quercus–Ulmus* pollen exceeds 94%, *Alnus* (19%), *Quercus* (19%) and *Ulmus* (9%) reaches its maximum. The youngest pollen level K9-3 *Pinus* is characterized by an increase of *Pinus* and a decrease of *Alnus, Quercus* and *Ulmus*. In the entire section, a share of *Picea* pollen is very low (max. 2%).

DISCUSSION

Limnic and fluvial sediments are recognised in the sections Kuców 9 and 10. In the section Kuców 16, ice-dam sediments occur as a repeating stack in a basal part of the Czyżów Complex, suggesting cyclic tectonic activity of the Cainozoic substrate and associated lowering of the bottom of the Kleszczów Graben during successive glaciations (Krzyszkowski, 1995). Deposition occurred, among others as a result of mass runoff, indicating that the underwater slope of a proglacial palaeolake was periodically quite steep (e.g. Krzyszkowski, 1993, 1995; Gruszka *et al*., 2004).

A lack of till of Elsterian and Sanian 2 glaciations makes accurate determination of lithostratigraphy of the Czyżów Complex difficult. However, the examined borehole 65/15 indicates presence of clay and till of this age (Krzyszkowski, 1989), similarly as the Radziechowice site (Borówko-Dłużakowa, 1981). Sequences of the sections Kuców 9 and 10 in the Czyżów Complex comprise only a fragment of interglacial or interstadial sediments. A stratigraphic setting of these deposits was discussed extensively by Krzyszkowski (1989).

Problem of age interpretation may result from a lot of hiatuses associated with erosive phases during Early and Middle Pleistocene in the Kleszczów Graben (Krzyszkowski, 1991a; Krzyszkowski and Czerwonka, 1992; Krzyszkowski, 1996) and impact of neotectonics (Krzyszkowski, 1992). Furthermore, fluvial and organic deposits were accumulated during interglacials in erosive forms, inherited depressions (Krzyszkowski, 1989) or in an oxbow lake.

Finally, the main problems are in age of subsurface of the Middle Pleistocene Interglacials (Holsteinian or Ferdynandovian) deposits, distance from the Saalian (Odranian) ice sheet (Marks *et al*., 2018) and new data concerning the age of tills (Czubla *et al*., 2019). Additionally, lack of undisturbed and continuous glacial series makes stratigraphic interpretation difficult.

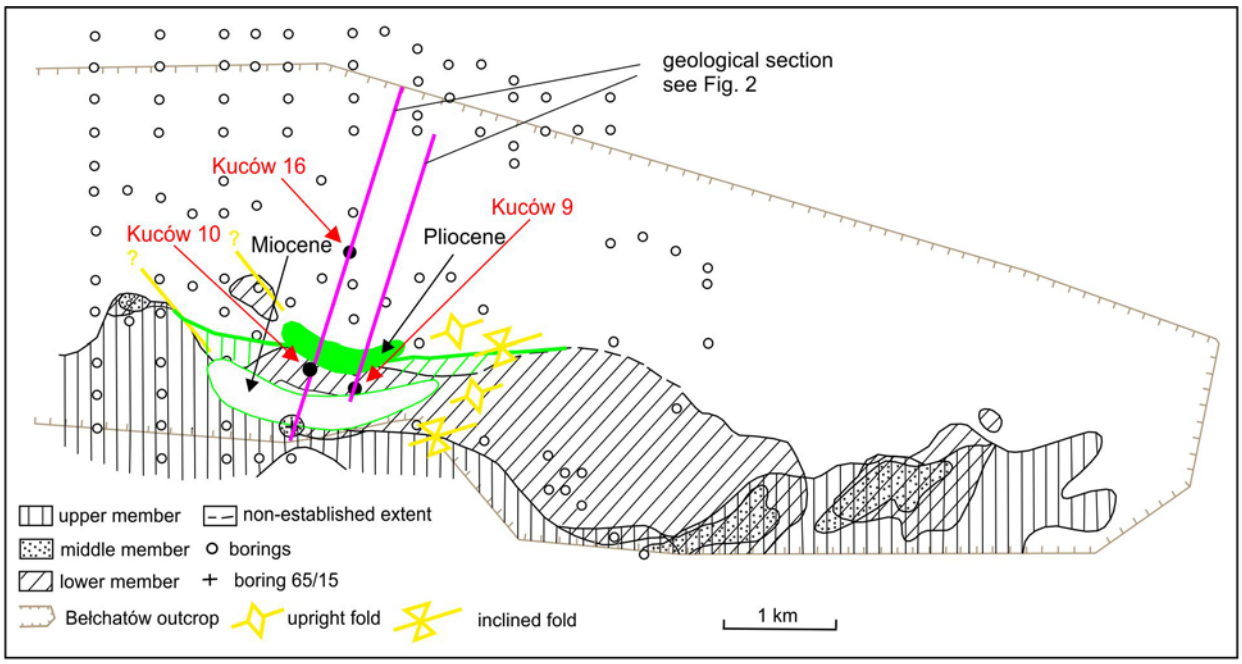

Fig. 10. Deposits of the Czyżów Formation in a central part of the southern horst of the Kleszczów Graben; according to Krzyszkowski (1989), modified.

The Czyżów Complex is located between the Folwark – Kuców (Elsterian) and Ławki – Rogowiec (Saalian) Complexes (Table 1; Fig. 2). Fluvial deposits were probably formed after the Elsterian (Sanian Glaciation). They are covered by the Saalian (Odranian and Wartanian) tills, glaciofluvial sand and gravel.

The new, revised maximum Saalian ice sheet limit is (from west to east): northern edge of the Sudetes (Krzyszkowski *et al*., 2019), Moravian Gate (Břizová, 1994), northern slopes of the South Polish Uplands (Terpiłowski *et al*., 2014; Marks *et al*., 2018; Czubla *et al*., 2019). The study area was located north of the maximum limit of the Saalian (Odranian) ice sheet.

Setting of a till of MIS 8 (Older Saalian, Ławki Formation?) and of the oldest glaciofluvial sediments of the Rokity Formation, previously referred to the Odranian (Krzyszkowski, 1992, 1996 *versus* Pawłowska *et al*., 2014 – see Table 1) is essential. Petrographic analysis of this till suggested an age of the underlying interglacial sediments. According to Czubla *et al*. (2019) tills ascribed to MIS 8 in central-eastern Poland are generally correlated with MIS 12 (Elsterian, Sanian 2). It is a fundamental issue to decide about the age of the examined organic sediments as of the Mazovian or the Ferdinandovian Interglacial or of the Middle Pleistocene interstadial (Czyżów or Podlesie?). Theoretically, all these possibilities can be taken into account.

Interglacial peats and gyttjas within the Czyżów Complex are presented (Fig. 10). Their location and sickle shape indicates existence of the Middle Pleistocene oxbow lake inside a W-E river valley on a southern slope of a horst within the Kleszczów Graben. Fast deposition in the oxbow lake resulted in a short and incomplete record of a warm period of the Middle Pleistocene. Palynological analysis of organic sediments in this palaeolake supplied with evidence on climatic conditions.

Initially, the section K65/15 was correlated with the Mazovian Interglacial (Janczyk-Kopikowa, 1987; Krzyszkowski, 1989). More recent studies, including the Mazovian Interglacial succession at the Folwark site (Balwierz *et al*., 2006, 2008) called into question the previous arrangements. In the pollen succession, there are no basic features that would correlate it with the Mazovian Interglacial, among them a high content of *Taxus* pollen, a coexistence of high contents of *Picea* and *Alnus*, as well as of *Carpinus* and *Abies*, that occurred in the nearby Folwark site (Balwierz *et al*., 2006, 2008). The pollen curves in the K65/15 section indicate convergence with the older Ferdinandovian Interglacial climatic optimum pollen succession, which is represented at Bełchatów by the section from Buczyna Pod Brukiem (Janczyk-Kopikowa, 1985). The almost complete absence of *Carpinus* pollen (single pollen grains), low *Picea* content, quite high of *Ulmus* and presence of *Abies* in the upper part of the section are the most important features of this correlation. The pollen spectra from the section Kuców 9 are a fragment of a pollen succession. The pollen curves in the lower and middle part of the section are similar to a central fragment of the pollen succession from the site K65/15 (Fig. 11). This allows for correlation of this section with the Ferdinandovian Interglacial.

Furthermore, the Czyżów Complex comprises deposits of two interglacials (Mazovian and Ferdynandovian) and two interstadials (Czyżów and Podlesie) (Krzyszkowski, 1991a–c; Krzyszkowski *et al*., 1996). A lack of glacial material and presence of organic deposits from at least two in-

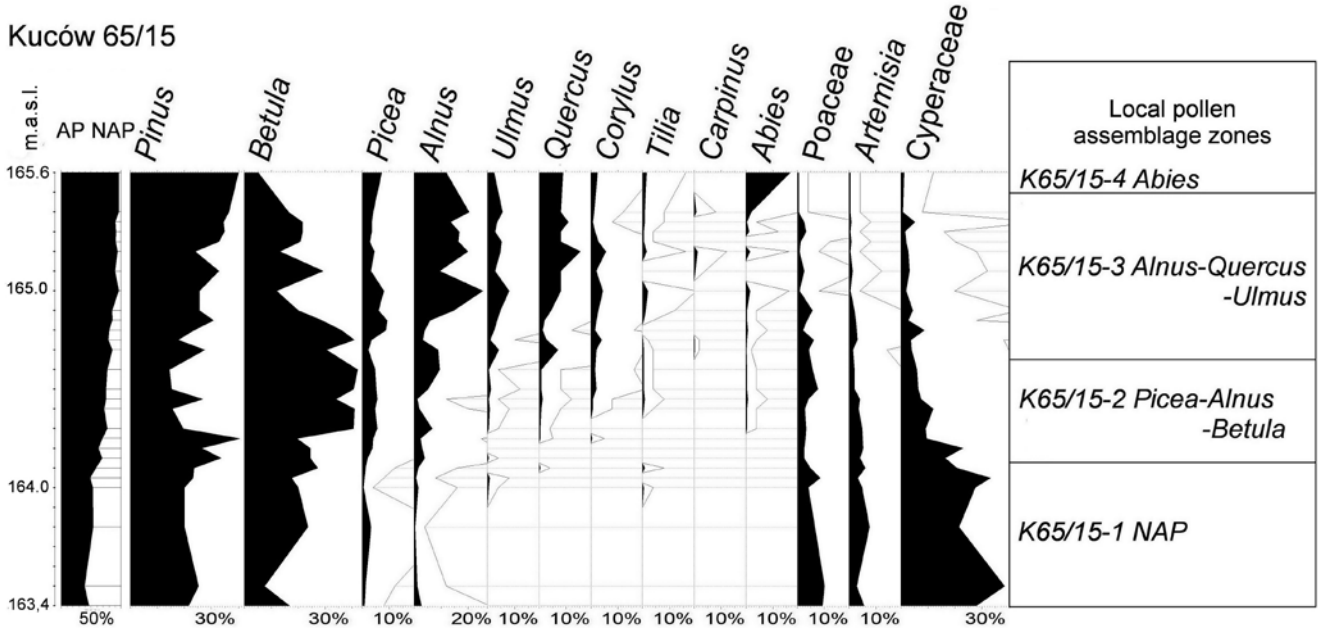

Fig. 11. Percentage pollen diagram from the section Kuców 65/15 according to Janczyk-Kopikowa (1987), modified and simplified.

terglacials indicates that the Czyżów Complex represents a long interval (Kuszel, 1991a,b). Based on this study, it is not possible to present strong evidence for a stratigraphic location of the Ferdinandovian related to the Mazovian, as it is clearly presented in the stratotype area (see: Rzechowski, 1996; Mojski, 2005; Lindner *et al*., 2013).

SUMMARY

Deposits of the Kuców 9 and 10 sections are located in the middle part of the Kleszczów Graben, inside the Miocene/Pliocene synclinal depressions. The basal Sanian (Elsterian) glaciolacustrine deposits (Kuców Formation) are described from Kuców 16, followed by glaciofluvial deposits of the Saalian Ławki and Rogowiec Formations (Odranian and Wartanian glaciations respectively).

The basal part of the section comprised trough cross-bedded fluvial deposits, overlain by limnic (deltaic) deposits. At the top there are generally sandy fluvial overbank facies. At the beginning of a warm period, and maybe even at the termination of the preceding glaciation, deposition of fluvial sand and gravel occurred. This was followed by oxbow lake and/or deltaic sedimentation, and then by periodic flooding of a valley bottom.

Deposition of organic sediments in the filling of the oxbow lake is generally short, so it is not possible to determine this episode, either the Mazovian or the Ferdinandovian Interglacial or the interstadial (Czyżów or Podlesie) of the Middle Pleistocene. The Kuców 9 pollen diagram probably presents an initial phase of the Ferdinandovian Interglacial.

In addition, lack of a clear stratigraphic setting of the bottom and covering tills, disturbances in sediments of the lower structural unit of the graben, many hiatuses related to the neotectonics and erosional phases do not allow for a clear determination of the moment of climate warming and overgrowing of oxbow lakes in a meandering river system in the Kleszczów Graben during the Middle Pleistocene.

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