sciendo

CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

E-ISSN 2450-8594

CEER 2020; 30 (1): 018-032
DOI: 10.2478/ceer-2020-0002
*Original Research Article*

# NEW INSIGHTS INTO THE GENESIS OF THE "POZNAŃ CLAYS" – UPPER NEOGENE OF POLAND

Piotr MACIASZEK[1], Lilianna CHOMIAK[2], Paweł URBAŃSKI[3], Marek WIDERA[2*]
[1] Polish Geological Institute – National Research Institute, Marine Geology Branch, Gdańsk, Poland
[2]Adam Mickiewicz University, Poznań, Poland
[3]Polish Geological Institute – National Research Institute, Warszawa, Poland

Abstract

The present study focuses on the upper Neogene deposits, called the "Poznań Clays", that cover more than 75,000 km$^2$ of Poland. They are situated between the first mid-Polish lignite seam and the glaciogenic deposits of the Pleistocene age. Lithostratigraphically, the "Poznań Clays" belong to the uppermost portion of the lignite-bearing Grey Clays Member and the whole Wielkopolska Member (Poznań Formation). The examined fine-grained sediments include mud-rich floodplain deposits with palaeosol remnants and large sandy-muddy or muddy palaeochannel bodies. Therefore, taking into account facies analysis, cross-sectional geometry, and the planform of the palaeochannels, it can be stated that the "Poznań Clays" formed in the environment of a late Neogene anastomosing river.

Keywords: overbank deposits, palaeosols, palaeochannels, anastomosing river, Neogene of central Poland

## 1. INTRODUCTION

The Mio-Pliocene "Poznań Clays" are sometimes exposed in the field or rest relatively close to the terrain surface, and cover over a quarter of Poland (Fig. 1);

[2*] Corresponding author: Adam Mickiewicz University, Institute of Geology, 12 Krygowski Street, PL-61-680 Poznań, Poland, e-mail: widera@amu.edu.pl, tel. +48618296030

hence, they can be easily mined in shallow outcrops for brick production [6, 32]. This practical use of the "Poznań Clays" dates back to at least the sixteenth century in the vicinity of Jarocin and Krotoszyn (~80–105 km southeast of Poznań) and to the first half of the nineteenth century near Wronki (~60 km northwest of Poznań). Moreover, a great number of cities in central and western Poland are settled on glaciotectonically disturbed "Poznań Clays," including those at high elevation, for example: Chodzież, Kalisz, Kcynia, Poznań, Warszawa, Zielona Góra, and Żerków. Because these clays are very expansive [6, 11, 32], their shallow occurrence creates serious problems, mainly in the foundations of buildings [13, 21]. Furthermore, the "Poznań Clays" are underlain by widely spread lignites, which is why they were/are often mined together [31].

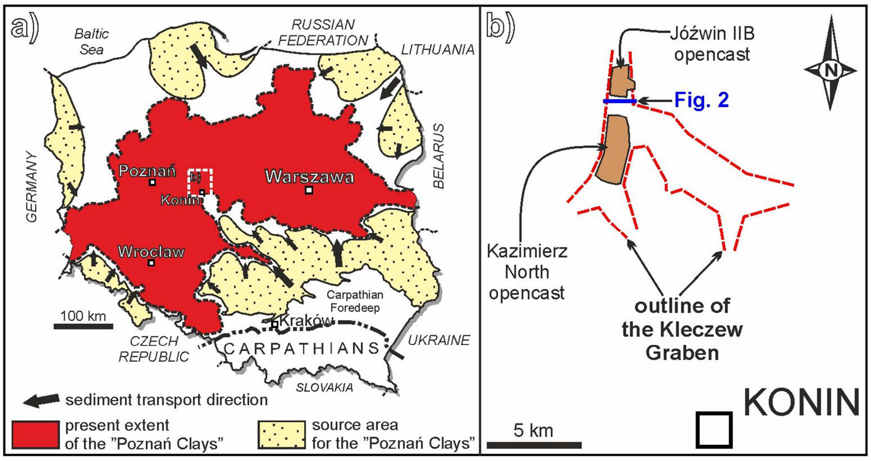


Fig. 1. Location map of the study area: a) extent of the "Poznań Clays" in the background of Polish territory and possible source area for them [1, 5, 26], b) location of the Jóźwin IIB and Kazimierz North lignite opencast mines examined in this paper; note location of the cross-section line depicted in Fig. 2

The increased demand for clayey raw materials, exploration for lignite deposits, and the rapid development of building on the clayey substrate has led to accelerated research on the "Poznań Clays". This began in the second half of the nineteenth century and continues today. Lithostratigraphic, palaeontological, mineralogical, and technological studies were first conducted by German and then Polish researchers. The examined sediments were originally named, inter alia, as: "Posener Septarientone" by Berendt in 1987, "Posener Flammentone" by Jentzsch in 1897, "Posener Flammenon" by Mass in 1903, and "Posener Ton" by Menzel in 1913, who carried out their pioneering investigations in the vicinity of Poznań [19] (Fig. 1a).

The genesis and age of the "Poznań Clays" are still debatable. However, their origin was associated with the lacustrine environment by German researchers, and their age was referred to as Pliocene [19]. This interpretation lasted until the early 1960s when these "clays" were attributed mainly to the so-called "Pliocene lake" [1]. Between the late 1960s and early 1980s, it was suggested that the lacustrine basin was influenced by short-lasting marine ingressions [3, 4, 7, 8]. Then, from the first years of the twenty-first century, some researchers postulated an alluvial origin of the "Poznań Clays" [2, 19, 25, 26]. The most recent contributions have additionally provided previously unknown evidence for their deposition, predominantly in a fluvial environment [12, 15-17, 29, 30].
The main goal of this research is to present the newest results of sedimentological studies on the so-called "Poznań Clays". This will be achieved through the description and interpretation of overbank muds, with layers of palaeosols, and channel-fill sands and muds.

## 2. OUTLINE OF GEOLOGY

This paper presents research results obtained in the Kazimierz North and Jóźwin IIB opencast mines, owned by the Konin Lignite Mine. They are located in the western branch of the Kleczew Graben, ~10–20 km north of Konin in central Poland (Fig. 1b). This fault-bounded shallow tectonic depression is up to a few tens of metres deep, and its Late Cretaceous bedrock is made up of limy sandstone (Fig. 2).

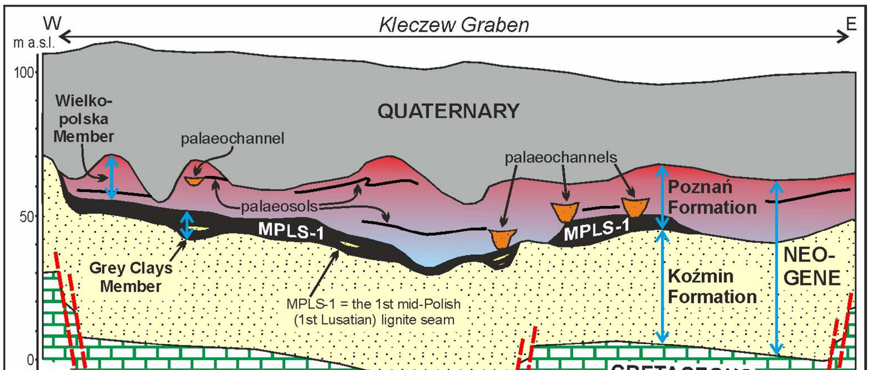


Fig. 2. Idealised cross-section through the area between the Jóźwin IIB and Kazimierz North lignite opencast mines (based on borehole data and field observations [26, 27, 29]); MPLS-1 – the first mid-Polish lignite seam; for the location of the cross-section line see Fig. 1

The Cenozoic in the study area consists of Neogene and Quaternary successions. This is due to the fact that the entire Paleogene covers a great stratigraphic gap caused by a regional tectonic uplift of this area [27, 30]. Thus, the Cenozoic evolution of the Kleczew Graben began at the turn of the Paleogene and Neogene [24]. The Neogene is divided into two lithostratigraphic formations, the lower Koźmin Formation and the upper Poznań Formation (Fig. 2).

The Koźmin Formation (earliest to Mid-Miocene) is made up of fluvio-lacustrine sand and silt deposits with lignite interbeddings, while the Poznań Formation is bipartite [20, 24]. Due to its genetic diversity, it is divided into two lithostratigraphic members: the Grey Clays and Wielkopolska members (Fig. 2).

The Grey Clays Member (middle Mid-Miocene) contains, in its majority, the first mid-Polish lignite seam (MPLS-1, <10 m thick on average) with remnants of the so-called "grey clays" at the top. These "grey clays," including fossilised wood fragments (xylites), belong to the investigated "Poznań Clays."

The remaining part of the "Poznań Clays" (from late Mid-Miocene to earliest Pliocene [20, 22, 24]) comprises the Wielkopolska Member (Fig. 2), which is actually the subject of the study presented in this paper. This lithostratigraphic member consists of predominantly muddy sediments. The overbank deposits (with the palaeosol horizons) are the more clayey-silty ones, while the more sandy-muddy sediments are typical of the palaeochannel fill. Their maximum thickness ranges from ~20 m [25, 26] in the Jóźwin IIB mine to ~50 m in the Kazimierz North lignite mine [29, 30]. Such a large variation in the thickness of the "Poznań Clays" was caused by the destructive processes of the Scandinavian ice sheets and their meltwaters in the Pleistocene [23, 24, 28].

## 3. DATA AND METHODS

Long-term fieldwork has been conducted in the Kazimierz North and Jóźwin IIB lignite opencast mines (Konin Lignite Mine), where the studied "Poznań Clays" are especially well exposed (Fig. 1). The geology of these areas is also relatively well known due to the intensive exploration of the lignite deposits. Thus, the representative geological cross-section (Fig. 2), located between the two aforementioned lignite opencasts, is based on data from 24 boreholes and field observations.

During fieldwork, the overburden walls above the exploited lignite seam were successively observed, and the most interesting deposits, structures, and palaeoforms were documented. In those days, the basic sedimentological (sedimentary logging, description of sedimentary structures, measurements of palaeotransport directions, sediment sampling, etc.) and cartographic studies (geological mapping) were carried out. Some photographs depicting the analysed deposits are included in the current paper (Figs. 3–6).

The standard division of clastic rocks was used to describe the sediment fraction; however, clayey-silty particles was used when the content exceeded 50 wt.% and the silt content was in the range of 33–66 wt.%. In this case, the name "mud" was applied [14]. During geological mapping, the width (W) and thickness (T) of the palaeochannel-fill deposits were measured first and then the W/T ratio was calculated [9, 10]. Furthermore, the intersection points (channel margins), marked on overburden walls built of "Poznań Clays", were used to reconstruct the palaeochannels pattern in plan view.

## 4. RESULTS

The upper Neogene "Poznań Clays" are presented here in the context of their fluvial genesis. Therefore, the extra-channel sediments that contain fossil soil horizons will be described first, then the morphometry of the palaeochannels and deposits filling them will be characterised. Finally, the river type will be discussed.

### 4.1. Overbank deposits

**Description**. Muddy (>50 wt.% clay and silt) deposits predominate (>95 vol.%) within the "Poznań Clays", while the remaining parts (<5 vol.%) are channel-fill deposits, palaeosols and lignite beds as well as lignite seams [23, 25, 26]. These widely spread muds are extremely various in colour, that is, from dark blue to blood red, interbedded with grey-black (Fig. 3).
Similarly, based on field observations and laboratory analyses, the "Poznań Clays" are comprised of grains of clay, silt, and sand in approximately equal proportions [24]. Most often, it is a mixture of these fractions; hence, when the share of clay and silt is >50 wt.%, such a deposit can be called a mud [14]. Nevertheless, it must be noted that purely clayey samples and beds (in the form of lenses between several and several hundred metres in size) are also present within the characterised "Poznań Clays" [24, 31].
**Interpretation**. The above-described muddy deposits have not yet been studied sedimentologically because they seem to be monotonous in the context of their genesis. However, the results of mineralogical studies support a fluvial depositional environment. Deposition of these fine-grained sediments took place mainly sub-aerially on the alluvial plain with significant fluctuations in the level of groundwater. This is evidenced in the clay mineral content, especially with a predominance of smectite over illite and kaolinite, and in the colour diversity of the interpreted sediments [6, 11, 32]. Of course, such alternating layers of varicoloured muds, representing the overbank deposits, are also documented in the studied lignite opencasts (Fig. 3).

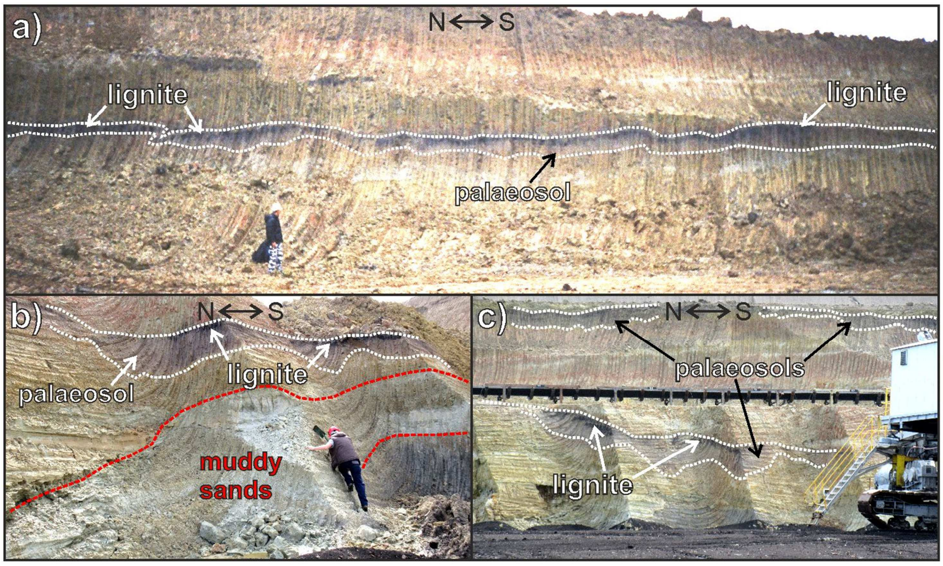


Fig. 3. Broad eastward view of the “Poznań Clays” in outcrops belonging to the Konin Lignite Mine: a) overbank muds including a palaeosol layer with a slightly glaciotectonically deformed lignite at the top, exposed in the Kazimierz North opencast, b) compactionally deformed channel muddy sands and overbank muds with the paleosol and lignite remnants exposed in the Jóźwin IIB opencast, c) overbank muds including two compactionally deformed palaeosol layers and remnants of lignite exposed in the Jóźwin IIB opencast

### 4.2. Palaeosols

**Description**. On overburden walls within the “Poznań Clays”, grey-black layers are clearly visible. They are a few metres to over 1 km in length, and up to 1 m in thickness. Moreover, these layers are more or less continuous, and often more or less lenticular in shape (Figs. 3, 4). In most cases, the described deposits are enriched in organic matter, trending upwards in the sedimentary profile. Thus, the top-most beds can be called lignite when the organics content is >60 wt.% (Fig. 3).

**Interpretation**. The grey-black layers within the “Poznań Clays”, which often contain organics, are interpreted in this paper as fossil soils. These palaeosols developed on an alluvial plain in conditions of a relatively-high groundwater level. However, the palaeosol horizons, due to their suitability for the reconstruction of climatic conditions in the late Neogene, require more detailed studies. It is worth adding that in other parts of the same sedimentary basin, for example in the area of the Oczkowice lignite deposit (~100 km S of Poznań), the thickness of lignite within the “Poznań Clays” exceeds 10 m [23].

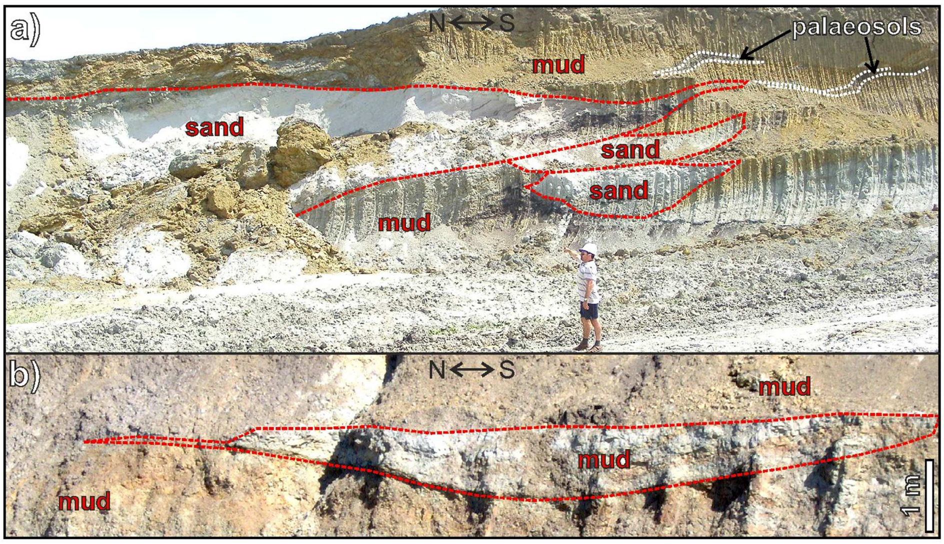


Fig. 4. Palaeochannels within the "Poznań Clays" in the Kazimierz North lignite opencast mine: a) palaeochannels filled predominantly with sand, b) palaeochannel filled predominantly with mud

### 4.3. Palaeochannels

**Description**. There are a great number of palaeochannels filled with sand, sand-mud, and mud in the opencasts belonging to the Konin Lignite Mine [12, 16, 17, 24, 26, 29, 30]. Some of them are multi-storey (Fig. 4a), while others are single-storey (Figs. 4b, 5). They are lenticular in shape with an erosional base. Their maximum height (channel-fill thickness) is ~12 m, and their apparent cross-sectional width is up to 160 m (Fig. 5). These palaeochannels are incised into the muddy floodplain (overbank) deposits (Fig. 4) or even into the underlying lignite seam – MPLS-1 (Fig. 5). In the case of the palaeochannel shown in Figure 5, the true W was calculated at ~150 m. Taking into consideration the fact that the T of these channel-fill deposits range up to 12 m, a W/T=12.5 was obtained [15, 16]. Similarly, the W/T values (5–15) were calculated for all palaeochannels from the Jóźwin IIB opencast [12, 29, 30], as well as for the majority of the palaeochannels from the Kazimierz North and other opencasts belonging to the Konin Lignite Mine [25, 26].

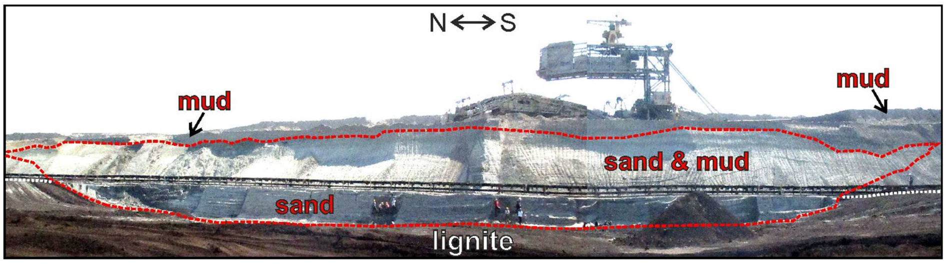


Fig. 5. Broad eastward view of the biggest palaeochannel outcropped in 2018 in the Jóźwin IIB lignite opencast mine; note that the palaeochannel is deeply incised in the underlying lignite seam

The channel-fill sediments from the Kazimierz North lignite opencast mine are characterised predominantly by their massive structure [25, 26]. In contrast, those palaeochannels from the Jóźwin IIB lignite opencast mine contain a large variety of sedimentary structures [15-17, 29]. Some of them, stratified both at large and small scale, are shown in this paper (Fig. 6). Generally, the examined deposits represent an upward-fining succession starting from channel lag (massive), through the domination of large-scale stratification (trough, planar, horizontal), with small-scale lamination (ripple, climbing-ripple, and heterolithic bedding: flaser, wavy, lenticular/nodular) appearing upwards in the palaeochannels [15-17, 29]. Sandy layers, most often stratified at a large scale, are interbedded with mud (Fig. 6c), which is characterised by small-scale lamination, including the aforementioned heterolithic bedding (Fig. 6e, f).

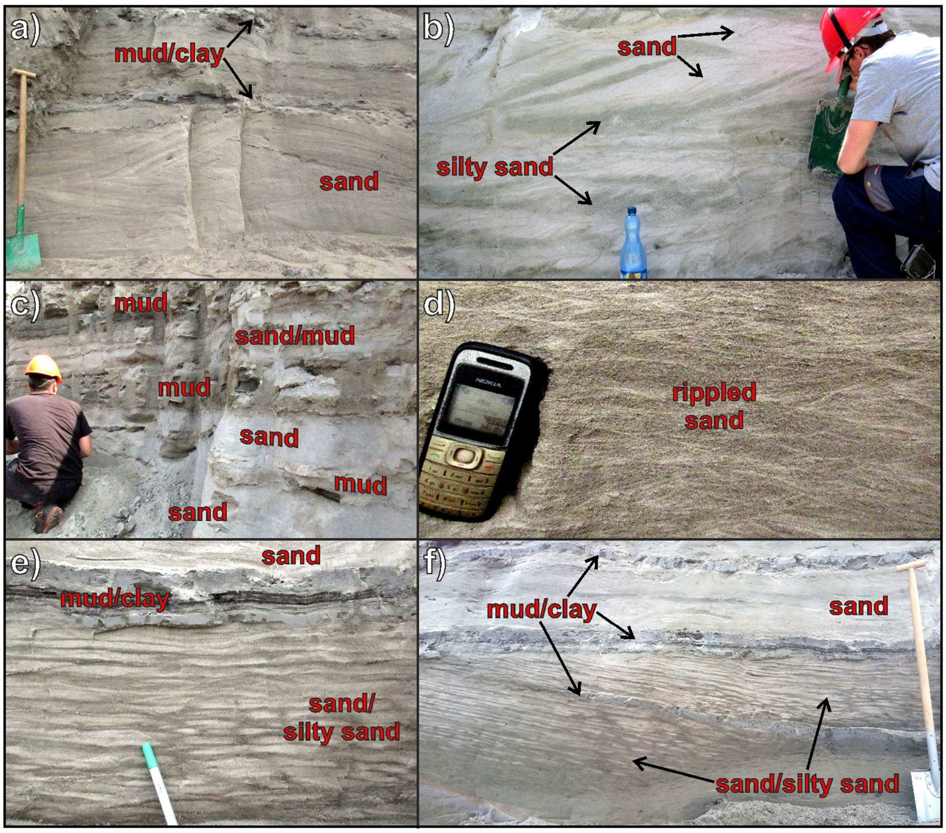


Fig. 6. Most common facies documented within the palaeochannels in the Jóźwin IIB lignite opencast mine in 2016–2018: a) and b) large-scale cross-stratified sands and silty sands, c) sands interbedded with muds, d) small-scale sands with rippled lamination, e) and f) heterolithic bedding (lenticular bedding) covered by muddy-clayey layers

**Interpretation**. Most of the palaeochannels from the Kazimierz North and Jóźwin IIB opencast mines are tilted, thrust or eroded, and sediments that fill them are sometimes disturbed. All these deformations took place postdepositionally and were caused by glaciotectonic and compactional processes [25, 26, 28, 30]. On the other hand, the largest of the investigated palaeochannels is incised more than 4 m into the mined lignite seam (Fig. 5). This deep erosion should be combined with the process of avulsion in the initial phase of the flood when the muds and underlying lignites were eroded [17, 29].

The channels with cross-sectional geometry described above, where the average W/T value is in the range of 5–15, are defined as broad ribbons [9, 10]. This means that the examined palaeochannels were laterally inactive and the deposition was dominated by vertical accretion. The lack of point bars confirms that their lateral migration was restricted or even absent due to strongly cohesive (muds) riverbanks. Thus, they are typical of cut-and-fill palaeoriver channels [9, 10, 18, 29].

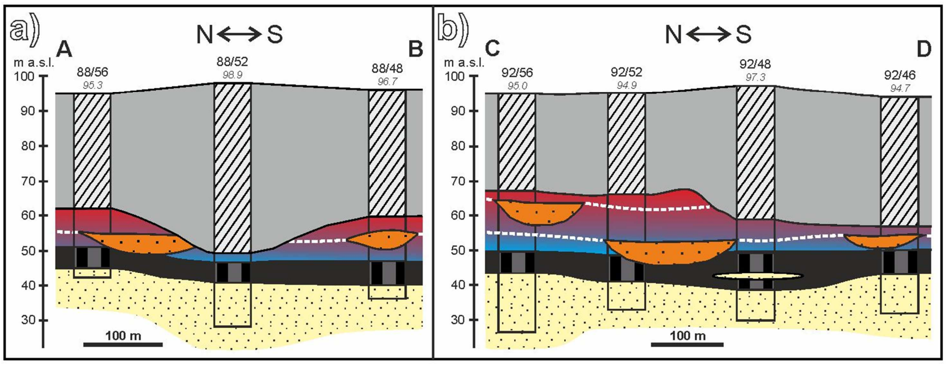


Fig. 7. Cross-sections through the studied palaeochannels in the Jóźwin IIB lignite opencast mines [15, 16]; for lithostratigraphic explanations see Fig. 2; for the location of the cross-section lines A–B and C–D see Fig. 8

The alternating occurrence of sandy, sandy-muddy, and muddy facies, stratified at large and small scale, indicate frequent changes in the palaeoriver flow regime. Most sandy facies were deposited by tractional turbulent flow during high and low water stages, while most muddy ones were deposited in the lower part of the lower flow regime by both traction and suspension in various proportions [17, 29]. However, the ripple-derived sedimentary structures, mainly heterolithic bedding (flaser, wavy, and lenticular/nodular), are of great interpretational significance when determining the type of palaeoriver. Simply speaking, the preservation of heterolithic bedding is the best evidence of alternating deposition during intervals of slow flow (<0.5 m/s) to extremely slow flow and almost stagnant water [17, 29].

### 4.4. River type

**Description**. The cross-sectional and plan view of the channels play an important role in determining the morphological type of the river, which may be braided, meandering or anastomosing [10, 18]. First, more than one palaeochannel occurs at the same stratigraphic level (Fig. 7). These palaeochannels, in some cases, may be multi-storey (Fig. 7b). The late Neogene river system, studied in the Jóźwin IIB opencast, consists of palaeochannels that are relatively short (Fig. 8). Their length is in the range of 0.3–0.5 km and the palaeoriver reaches merge and split, that is, they are tributive and distributive. The inter-channel areas form the islands that are comprised of very cohesive overbank muds. The location of the palaeochannels (studied in detail [12, 15, 17, 29, 30]) with the measured directions of palaeotransport are depicted on the map (Fig. 8).

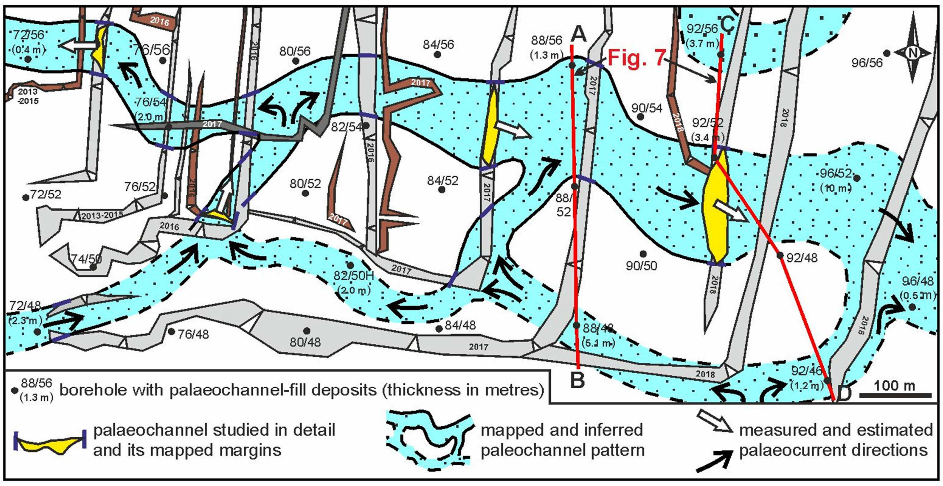


Fig. 8. Palaeochannel pattern reconstructed in 2013-2018 on the basis of geological mapping and sedimentological study in the Jóźwin IIB lignite opencast mines [15, 29]; cross-sections A–B and C–D are shown in Fig. 7; note, that the late Neogene fluvial system is multi-channel with tributive and distributive reaches

**Interpretation.** The reconstructed palaeochannel pattern occupies only a small part of the Kleczew Graben area. Hence, the interpretation is limited to the mapped area, that is, to the axial and northernmost zone of this tectonic structure (Fig. 1b). The analysed river system consists of at least two (in meridional section) or three (in latitudinal section) palaeochannels situated at the same or very similar altitudes (cf. Figs. 7 and 8). The filling of these palaeochannels was more vertical than lateral as indicated by small values of the aspect ratio W/T<15 and the lack of point bars. The islands, being remnants of the muddy floodplain, are large in relation to the width of the palaeochannels (Fig. 8). Furthermore, the palaeochannels studied are filled with a significant amount of sandy-muddy and muddy facies. This proves that the water in the analysed palaeochannels flowed slowly and even extremely slowly for a long time [15, 16, 28]. Thus, all of the features listed above, according to the criteria included in the literature [10, 18], indicate an anastomosing river type for the late Neogene river system in the area of the Jóźwin IIB lignite opencast mine [12, 15-17, 25, 26, 29, 30].

## 5. FINAL REMARKS

In recent years, there has been a significant acceleration of research on the genesis of the “Poznań Clays”. These late Neogene deposits belong lithostratigraphically to the Poznań Formation, in fact, they cover the uppermost part of the Grey Clays Member (above the first mid-Polish lignite seam) and the entire Wielkopolska Member. Thus, the age of the “Poznań Clays” is between the late Mid-Miocene and the earliest Pliocene.

In total, more than 30 palaeochannels were mapped and documented in opencasts owned by the Konin Lignite Mine. They are filled with sand, sand-mud, and mud. The greatest diversity of facies was found in those that are sandy-muddy in the Jóźwin IIB lignite opencast mine. They clearly show that the palaeochannel-fill sediments were largely deposited in an extremely low-energy fluvial environment when the water was slow-flowing to almost stagnant. The examined palaeochannels are single- and multi-storey, and they can be classified as broad ribbons because they are relatively deep/thick with respect to their width (5<W/T<15). Additionally, no facies typical of point bars, which are found in sediments of meandering rivers, were documented in the field. This means that vertical rather than lateral accretion dominated the filling of these palaeochannels. Moreover, the pattern of the palaeochannels from the Jóźwin IIB opencast is multi-channel in plan view.

The origin of the majority of the “Poznań Clays” should be combined with a river environment as indicated by the presence of the overbank sediments with palaeosol horizons and palaeochannel-fill deposits. Therefore, the results obtained in this paper indicate an anastomosing type of late Neogene river system, at least in the study area. This conclusion is confirmed both by the facies and the shape of the palaeochannels as seen in the cross-sections and plan-view map.

Finally, a better knowledge of the “Poznań Clays” fluvial genesis can be helpful in geotechnical activity, for example, at the stage of planning and implementation of various construction projects. In such cases, postdepositional deformations, mainly compactional and glaciotectonic, must be taken into consideration.

## ACKNOWLEDGEMENTS

The authors would like to warmly thank the anonymous reviewers for their efforts to evaluate the typescript. This paper is supported by the National Science Centre, Poland, through research project no. 2017/27/B/ST10/00001.

## REFERENCES


1. Areń, B 1957-1964. *Atlas geologiczny Polski. Zagadnienia stratygraficzno-facjalne. Trzeciorzęd 1:3000000.* Wydawnictwa Geologiczne, Warszawa.
2. Badura, J and Przybylski, B 2004. Evolution of the Late Neogene and Eopleistocene fluvial system in the foreland of the Sudetes Mountains, SW Poland. *Annales Societatis Geologorum Poloniae* **74**, 43-61.
3. Ciuk, E 1970. Schematy litostratygraficzne trzeciorzędu Niżu Polskiego. *Kwartalnik Geologiczny* **14**, 754-771.
4. Ciuk, E and Pożaryska, K 1982. On paleogeography of the Tertiary of the Polish Lowland. *Prace Muzeum Ziemi* **35**, 81-88.
5. Czapowski, G and Kasiński, JR 2002. Facje i warunki depozycji utworów formacji poznańskiej. *Przegląd Geologiczny* **50**, 256-257.
6. Duczmal-Czernikiewicz, A 2013. Evidence of soils and palaeosols in the Poznań Formation (Neogene, Polish Lowlands). *Geological Quarterly* **57**, 189-204.
7. Dyjor, S 1968. Poziomy morskie w obrębie serii iłów poznańskich. *Kwartalnik Geologiczny* **12**, 941-955.
8. Dyjor, S 1970. Seria poznańska w Polsce zachodniej. *Kwartalnik Geologiczny* **14**, 819-835.
9. Friend, PF, Slater, MJ and Williams, RC 1979. Vertical and lateral building of river sandstone bodies, Ebro Basin, Spain. *Geological Society of London Journal* **136**, 39-46.
10. Gibling, MR 2006. Width and thickness of fluvial channel bodies and valley fills in the geological record: a literature compilation and classification. *Journal of Sedimentary Research* **76**, 731-770.
11. Górniak, K, Szydłak, T, Sikora, WS, Gaweł, A, Bahranowski, K and Ratajczak, T 2001. Minerały ilaste w różnobarwnych odmianach skał występujących nad pokładem węgla brunatnego w rejonie Konina. *Górnictwo Odkrywkowe* **43**, 129-139.
12. Kowalska, E 2016. *Charakterystyka litofacjalna osadów korytowych w obrębie iłów poznańskich (odkrywka Jóźwin IIB, PAK KWB Konin S.A.).* Archiwum Instytutu Geologii UAM, Poznań, 1-73.
13. Kumor, MK 2008. Selected geotechnical problems of expansive clays in the area of Poland. *Architecture Civil Engineering Environment* **4**, 75-92.
14. Lundegard, PD and Samuels, ND 1980. Field classification of fine-grained sedimentary rocks. *Journal of Sedimentary Petrology* **50**, 781-786.
15. Maciaszek, P 2019. *Charakterystyka litofacjalna neogeńskich osadów mineralnych w odkrywce Jóźwin IIB (KWB Konin).* Archiwum Instytutu Geologii UAM, Poznań 1-104.

16. Maciaszek, P, Chomiak, L, Urbański, P and Widera, M 2019. *The "Poznań Clays" in the light of the latest geological research.* CGE-2019 – Proceedings of the third International Conference "Challenges in Geotechnical Engineering." September 10th–13th 2019, Zielona Góra, Poland, 19.
17. Maciaszek, P, Chomiak, L, Wachocki, R and Widera, M 2019. The interpretive significance of ripple-derived sedimentary structures within the late Neogene fluvial succession, central Poland. *Geologos* **25**, 1-13.
18. Makaske, B 2001. Anastomosing rivers: a review of their classification, origin and sedimentary products. *Earth-Science Reviews* **53**, 149-196.
19. Piwocki, M, Badura, J and Przybylski, B 2004. Neogen. [W:] Peryt, TM and Piwocki, M (red.). *Budowa Geologiczna Polski, t. 1, Stratygrafia, część 3a, Kenozoik – paleogen, neogen.* Państwowy Instytut Geologiczny, Warszawa, 71-133.
20. Piwocki, M and Ziembińska-Tworzydło, M 1997. Neogene of the Polish Lowlands – lithostratigraphy and pollen-spore zones. *Geological Quarterly* **41**, 21-40.
21. Superczyńska, M, Józefiak, K and Zbiciak, A 2016. Numerical analysis of diaphragm wall model executed in Poznań clay formation applying selected fem codes. *Archives of Civil Engineering* **62**, 207-224.
22. Troć, M and Sadowska, A 2006. Wiek utworów formacji poznańskiej rejonu Poznania. *Przegląd Geologiczny* **54**, 588-593.
23. Urbański, P and Widera, M 2016. Geologia złóż węgla brunatnego w południowo-zachodniej Wielkopolsce, *Przegląd Geologiczny* **64**, 791-798.
24. Widera, M 2007. *Litostratygrafia i paleotektonika kenozoiku podplejstoceńskiego Wielkopolski.* Seria Geologia, 18, Wydawnictwo Naukowe UAM, Poznań.
25. Widera, M 2012. Fluwialna geneza ogniwa wielkopolskiego na podstawie danych z obszaru środkowej Polski. *Górnictwo Odkrywkowe* **53**, 109-118.
26. Widera, M 2013. Sand- and mud-filled fluvial palaeochannels in the Wielkopolska Member of the Neogene Poznań Formation, central Poland. *Annales Societatis Geologorum Poloniae* **83**, 19-28.
27. Widera, M 2014. Lignite cleat studies from the first Middle-Polish (first Lusatian) lignite seam in central Poland. *International Journal of Coal Geology* **131**, 227-238.
28. Widera, M 2018. Tectonic and glaciotectonic deformations in the areas of Polish lignite deposits. *Civil and Environmental Engineering Reports* **28**, 182-193.
29. Widera, M, Chomiak, L and Zieliński, T 2019. Sedimentary facies, processes and paleochannel pattern of an anastomosing river system: an

example from the Upper Neogene of Central Poland. *Journal of Sedimentary Research* **89**, 487-507.
30. Widera, M, Kowalska, E and Fortuna, M 2017. A Miocene anastomosing river system in the area of Konin Lignite Mine, central Poland. *Annales Societatis Geologorum Poloniae* **87**, 157-168.
31. Widera, M and Szczurek, M 2014. Złoża antropogeniczne w wielkopolskich odkrywkach węgla brunatnego – stan aktualny. *Gospodarka Surowcami Mineralnymi – Mineral Resources Management* **30**, 21-38.
32. Wyrwicki, R and Wiewióra, A 1981. Clay minerals of the Upper Miocene sediments in Poland. *Bulletin Polish Academy of Science, Earth Sciences* **29**, 67-71.

*Editor received the manuscript: 14.09.2019*