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# SAND- AND MUD-FILLED FLUVIAL PALAEOCHANNELS IN THE WIELKOPOLSKA MEMBER OF NEOGENE POZNAŃ FORMATION, CENTRAL POLAND

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**Abstract:** This study focuses on the single- and multi-storey fluvial palaeochannel lithosomes encased in mud-rich floodplain deposits in the alluvial succession of the late Neogene Wielkopolska Member of the Poznań Formation, central Poland, well-exposed in the lignite mining pits of the region. The fluvial lithosomes include both sand-filled and mud-filled channel varieties. The channel-fill facies are not diagnostic for any particular type of fluvial system, as the fine- to very fine-grained sandy deposits are massive to trough cross-stratified and also the muddy deposits are massive to weakly flat-laminated. The scarcity of lateral accretion bedding precludes the possibility of meandering rivers, whereas the low width/thickness ratios of the palaeochannels preclude braided rivers. The width/thickness ratio is in the range of 4.5–14 (averaging 7.5) for sand-filled channels and in the range of 6–10 (averaging 9) for mud-filled ones, which indicates narrow ribbons in general classification of fluvial channel belts. The origin of the alluvial succession is attributed to a W-/NW-directed anastomosing river system characterized by laterally inactive cut-and-fill channels with cohesive and vegetated banks. The sand-filled channels conveyed water and sediment discharges on a perennial basis, whereas the mud-filled conduits are thought to have been the cut-and-abandoned branches of the system, filled by overbank flooding from adjacent active channels. Minor lateral migration of channels occurred probably during periods of minimum subsidence rate, when the fluvial system was forced to develop lateral accommodation for its discharges.

**Key words:** fluvial lithosomes, floodplain deposits, channel-fill facies, channel width/depth ratio, hyperconcentrated flow, anastomosing river system.

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## INTRODUCTION

Alluvial successions, as the infill of small and large continental basins, are generally divided into fluvial (channel-fill) and floodplain (overbank) sedimentary domains (Schumm, 1977; Miall, 1996; Bridge, 2003). The relative proportion of fluvial to floodplain deposits in an alluvial succession depends both on the basin subsidence rate (Leeder, 1977; Bridge & Leeder, 1979) and the type of river system, varying from > 90% in some braidplain systems (Nemec, 1992; Miall, 1996) to around 50% and even < 5% in meandering or anastomosing river systems (Allen, 1965, 1978; Schumm, 1968; Rust, 1978, 1981; Smith, 1983, 1986; Harwood & Brown, 1993; Miall, 1996; Gibling *et al.*, 1998; Makaske, 2001). Fluvial deposits have generally received more research interest, as they are more crucial for the recognition of alluvial system type and also as potential petroleum reservoirs or their outcrop analogues. A large amount of data on the width and thickness (depth) of modern and ancient fluvial channels is available in the literature (Gibling, 2006), collected primarily as a database for the possible prediction of channel-belt widths from their thicknesses measured in exploration wells.

Apart from gravel-filled or mixed sand-gravel channels, typical of highland and proglacial settings, the majority of studies from lowland fluvial systems have documented sand-filled channels (e.g., Horne *et al.*, 1978; Friend *et al.*, 1979; Friend, 1983; Stear, 1983; Nemec, 1984; Lorenz *et al.*, 1985; Gibling & Rust, 1990; Törnqvist *et al.*, 1993; Nadon, 1994; Gradziński *et al.*, 1995, 2000, 2003; Kraus, 1996; Bridge *et al.*, 2000; Davies-Vollum & Kraus, 2001; Makaske, 2001; Stouthamer, 2001; Gibling, 2006; Doktor, 2007; Gouw, 2007; González-Bonorino *et al.*, 2010; Gross *et al.*, 2011; Widera, 2012). Less commonly reported are mud-filled channels (e.g., Eberth & Miall, 1991; Gibling *et al.*, 1998; Kraus & Davies-Vollum, 2004; Gruszka & Zieliński, 2008), probably because such palaeochannels – where encased in muddy floodplain deposits – are difficult to recognize in outcrops, borehole cores and seismic or GPR sections.

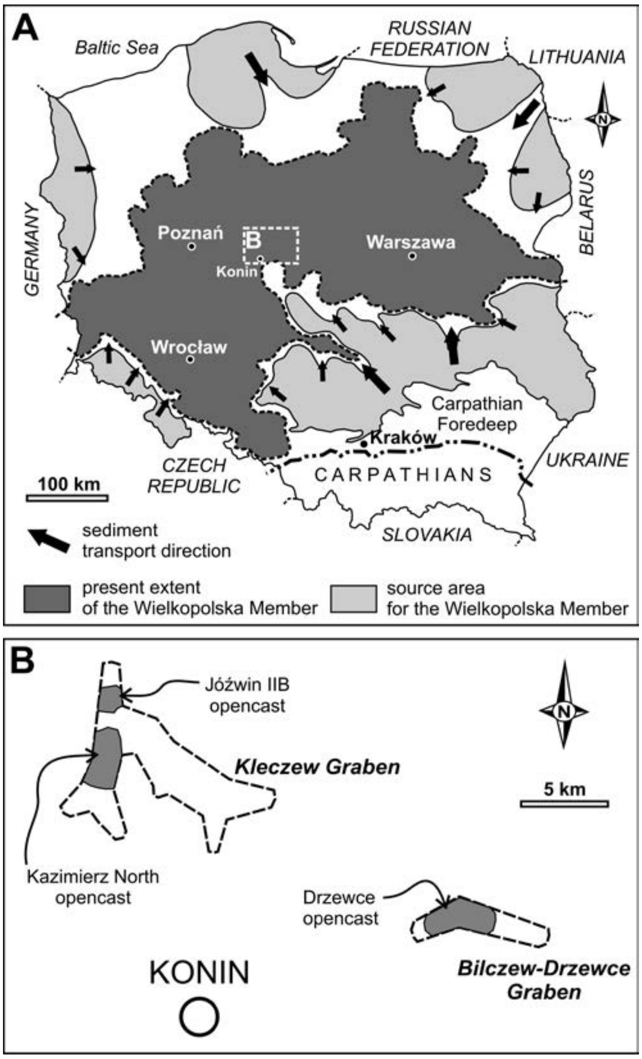


**Fig. 1.** Study area. **A** – Location of the study area (frame B) with the present-day areal extent of the Wielkopolska Member (modified from Piwocki, 1992, 1998; Czapowski & Kasiński, 2002); **B** – Location of the lignite opencast mining pits in the study area

The present study reports on sand- and mud-filled palaeochannels recognizable in the extensive open-pit mine faces of the lignite-bearing Wielkopolska Member of the Neogene Poznań Formation in central Poland. The sedimentary succession has been studied since the mid-19$^{th}$ century, but its mud-filled channels were not recognized and also its origin remained controversial (see Piwocki *et al.*, 2004). Three main successive palaeoenvironmental interpretations were offered. Until the early 1960s, the deposits were attributed mainly to a "Pliocene lake" environment (e.g., Areń, 1957, 1964). In the late 1960s to early 1980s, the lacustrine basin was considered to have been marine-influenced, paralic (Dyjor, 1968, 1970; Ciuk & Pożaryska, 1982). More recent interpretations postulate an alluvial origin for the Wielkopolska Member (Badura & Przybylski, 2004; Piwocki *et al.*, 2004; Widera, 2012) and its stratigraphic equivalents (Kasiński, 2000), and the present study concurs with this notion. The aims of this study are: (1) to describe the sedimentary characteristics of channel-belt deposits; (2) to quantify the geometrical width/thickness aspect of sand- and mud-filled palaeochannels; and (3) to assess the style of fluvial drainage system in the basin by comparing the palaeochannels with those of braided, meandering and anastomosing rivers.

## GEOLOGICAL SETTING

The Wielkopolska Member is laterally extensive, covering an area of ~75,000 km$^2$ in central Poland (Fig. 1A). The original extent of these deposits was probably much larger, reduced by the erosional effect of the Pleistocene Scandinavian ice-sheet (Piwocki, 1992; Piwocki *et al.*, 2004). The depth of glacial erosion and deformation locally extends to the Neogene deposits, as evidenced in the open-pit lignite mines Kazimierz North, Jóźwin IIB and Drzewce (Fig. 1B). These mining areas are in shallow tectonic grabens (Fig. 1B), with the first two pits located in the western branch of the Kleczew Graben, formed in the early to middle Miocene, and the last pit located in the central part of the Bilczew-Drzewce Graben, which began to form in the early Oligocene (Widera, 2004, 2007).

The Wielkopolska Member represents the upper part of the Poznań Formation, which is the uppermost Neogene stratigraphic unit in central Poland (Fig. 2). The underlying part of the Poznań Formation is the lignite-bearing muddy Middle-Polish Member, earlier referred to as the Grey Clays unit, which contains the First Mid-Polish Lignite Seam (Piwocki & Ziembińska-Tworzydło, 1995, 1997), known earlier as the Henryk Seam (Dyjor, 1968, 1970). The age estimates for the Wielkopolska Member indicate a time span from the late mid-Miocene to the latest early Pliocene (Piwocki & Ziembińska-Tworzydło, 1995, 1997; Ważyńska, 1998; Troć & Sadowska, 2006).

The Wielkopolska Member is presently thought to have been deposited in an alluvial environment (Badura & Przybylski, 2004; Piwocki *et al.*, 2004; Widera, 2012), with supporting evidence from mineralogical and geochemical studies of channel-surrounding floodplain mudstones (e.g., Wyrwicki & Wiewióra, 1981; Górniak *et al.*, 2001; Duczmal-Czernikiewicz, 2010, 2011; and other references therein). In the late Neogene, central Poland is thought to have hosted an endohoric alluvial basin, with a centripetal pattern of fluvial drainage (Fig. 1A; Widera, 2012).

## METHODS AND TERMINOLOGY

The study is based on fieldwork conducted in the region's open-pit lignite mines in 2004–2012. The outcrop walls, up to 40–60 m high, were mapped over a lateral distance of tens of kilometres with the use of binocular and high-resolution photomosaics, and the channel-fill and floodplain deposits were sampled and documented in close- up detail wherever they were accessible. In total, 25 palaeochannels were recognized and documented for further analysis, 19 of them sand-filled and 6 mud-filled. The deposits are poorly compacted and only weakly cemented, and hence are referred to by the soft-sediment names sand, silt, mud and clay.

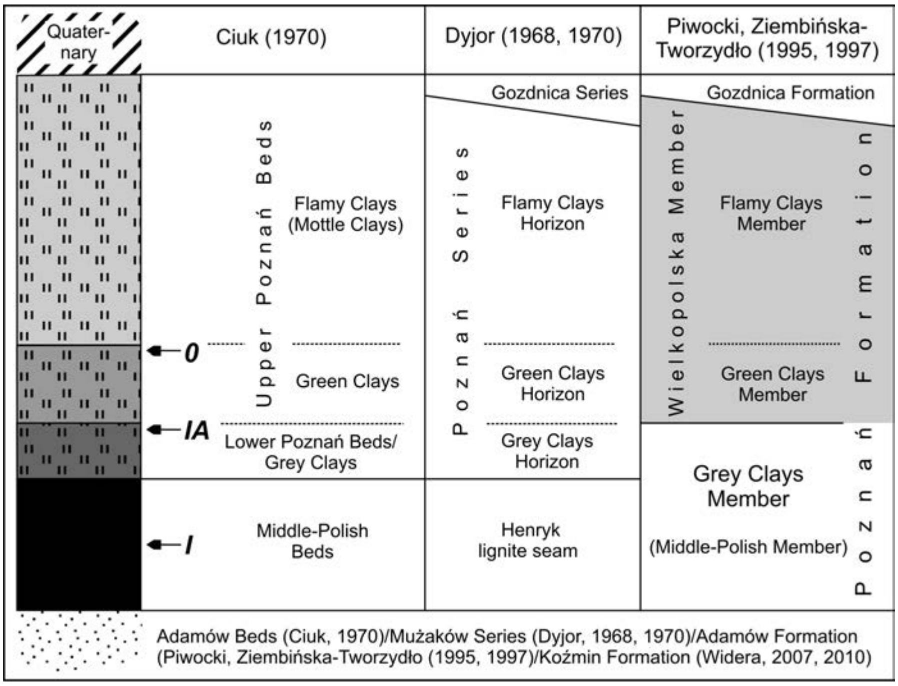


**Fig. 2.** Compiled lithostratigraphy of the Neogene Poznań Formation (after Ciuk, 1970; Dyjor, 1968, 1970; Piwocki & Ziembińska-Tworzydło, 1995, 1997); note the stratigraphic position of the late Neogene Wielkopolska Member in the right-hand column. The letter code in the left-hand column indicates: O – the Orłowo lignite seam group; IA – the Oczkowice lignite seam group; and I – the Mid-Polish lignite seam group

Three main lines of detailed research were carried out in this study. Firstly, the width and thickness (depth) of the fluvial palaeochannels were measured and their width/thickness aspect ratios were calculated. A modified terminology of Friend (1983) and Nadon (1994) is used for channel-belt geometry. Channel belts with an aspect ratio of 15–30 are considered to be medium ribbons, whereas those with a ratio of < 15 are referred to as narrow ribbons and those with a ratio of > 30 as wide ribbons. Aspect ratios may help to identify the plan-form of an ancient fluvial system, such as braided, meandering or anastomosing (Makaske, 2001; Gibling, 2006). Secondly, the sedimentary facies of channel-fill and overbank deposits are identified and described, using the letter code of Miall (1977). The terminology for sedimentary structures is after Collinson & Thompson (1982). Thirdly, 79 sediment samples were collected for grain-size analysis, including 34 from sand-filled and 5 from mud-filled channels and an additional 40 from overbank deposits. The standard Udden (1914) grain-size scale modified by Wentworth (1922) is used. Clayey deposits with a silt admixture of > 50 vol. % are referred to as mud (Lundegard & Samuels, 1980).

## RESULTS

On the basis of outcrop mapping, the relative volumetric proportion of fluvial lithosomes in the Wielkopolska Member is estimated to be less than 5%, one of the lowest reported from alluvial successions. Observations on the internal characteristics and cross-sectional geometric aspect of the palaeochannels are reviewed in this section.

### Sand-filled channels

These are single- and multi-storey channels, filled predominantly with fine-grained sand (see channels 1–19 in Figs 3–9). They form concave-upwards lenses encased in floodplain deposits. The latter comprise mud interlayered with clay, silt and very fine-to fine-grained sand sheets (Table 1), including varicoloured palaeosols with plant-root traces, carbonate nodules, gypsum crystals, slickensides and sporadic lignite layers (Figs 3–9). Most of these palaeochannels, in the upper part of the succession, are affected by the Pleistocene glacitectonic deformation and partial erosion (see channels 1, 2 and 7 in Figs 3 & 5; channels 5 and 6 in Fig. 4; channels 3, 4 and 8 in Figs 4 & 6; channels 9–12 in Fig. 7A, B; and channels 13–19 in Figs 7C & 8).

The sandy channel-fill deposits are poorly stratified and appear to be mainly massive, with the exception of channel 4 (Fig. 4) that is filled with a moderately- to very well-sorted sand showing trough cross-stratification. The stratification in recognizable owing to the presence of mud and/or fine plant detritus on strata interfaces (Fig. 4B–G) and indicates transport towards the W and NW (Fig. 4). This channel is exceptional also in that its infill, although dominated by fine- to very fine-grained sand, includes mud at the base and at the top (Fig. 4).

The sandy channel-fill in most cases shows a fining-upwards trend, although the trend is poorly defined in fine-grained sand and recognizable only by grain-size analysis of sediment samples (e.g., see channels 2 and 13 in Figs 3B & 7C). Most of the palaeochannels appear to have been filled by vertical accretion (Figs 3, 7 & 8), but some also show subordinate lateral accretion indicative of point bars with

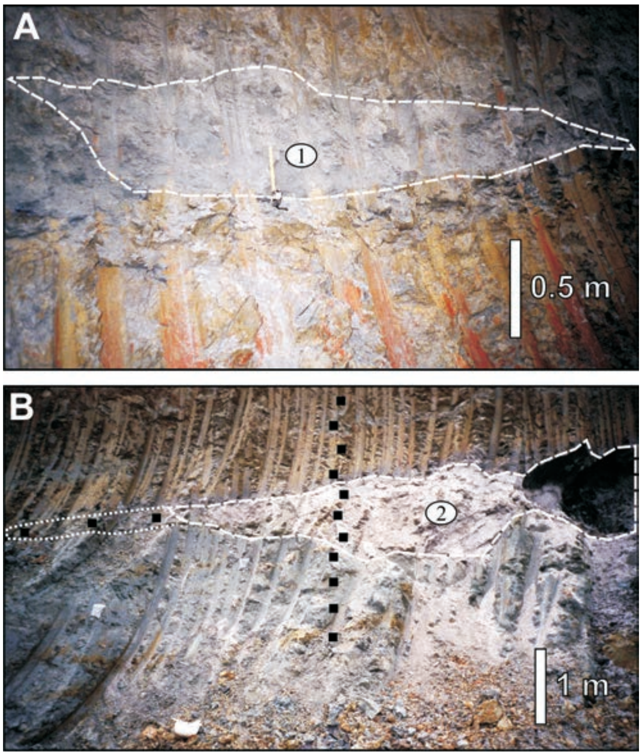


**Fig. 3.** Non-deformed, sand-filled single-storey channels in the Wielkopolska Member. **A** – Palaeochannel exposed in the Kazimierz North lignite pit (Fig. 1B), view to the east; **B** – Palaeochannel with a levee "wing" attached to its left-hand margin, exposed in the Jóźwin IIB lignite pit (Fig. 1B), view to the east. Numbers in circles refer to the numbering of palaeochannels in Table 1; the black squares in B indicate sediment sampling for grain-size analysis

relatively steep (15–20°) to gently inclined flanks (Figs 4E–G, 5). Channel-bank levees in the geometrical form of lateral "wings" are only locally recognizable (e.g., see channels 2 and 12, Figs 3B & 7A, B). It is uncertain whether such lateral overbank ridges are in reality more common, as the low-relief levees, composed of interlayered sand, silt and mud, are poorly distinguishable from the surrounding floodplain deposits.

The sand-filled channels in cross-section are up to 4.5 m thick and 63 m wide (Table 1), with the width/thickness ratio ranging from 4.5 for channels 12 and 19 (Figs 7B & 8A) to 14 for channel 7 (Fig. 5). The average *w/t* ratio calculated for the 19 sand-filled channels is ~7.5. All these palaeochannels are thus classified as narrow ribbons. Most of them are, in fact, very narrow by comparison with fluvial channel belts in general (Friend, 1983; Nadon, 1994; Bridge, 2003).

### Mud-filled channels

Six palaeochannels of this type have been documented (Figs 8 & 9), 5 of them filled with mud and one also with a sand admixture. These are multi-storey channels, comprising 2 (Fig. 8) to 4 storeys (Fig. 9) and generally showing little or no recognizable glacitectonic deformation. Their concave-upwards erosional bases are key features allowing channel identification.

**Table 1**

Summary of data on the channel-fill type, channel width and channel thickness (depth) in the Wielkopolska Member

| Channel number [Figs 3-9] | Sediment type | Channel-fill width [m] | Channel-fill thickness [m] | Width/thickness ratio [w/t] |
|---|---|---|---|---|
| 1 | v.f. sand, mud | 6.5 | 0.7 | 9.3 |
| 2 | f. sand | 10 | 1 | 10 |
| 3 | f. sand | >4 | >0.5 | ? |
| 4 | v.f. to f. sand, mud, organic material | 25 | 2.5 | 10 |
| 5 | v.f. sand | 9 | 0.8 | 11.3 |
| 6 | v.f. sand | 4 | 0.6 | 6.7 |
| 7 | v.f. to f. sand, mud | 63 | 4.5 | 14 |
| 8 | v.f. to f. sand, mud, organic material | 30 | >3 | <10 |
| 9 | v.f. sand, mud | 7.8 | 1.2 | 6.5 |
| 10 | f. sand | 6.7 | 1.1 | 6.1 |
| 11 | f. sand | 4 | 0.8 | 5 |
| 12 | f. sand | 5.7 | 1.2 | 4.5 |
| 13 | f. sand | 5.8 | 0.9 | 6.4 |
| 14 | v.f. sand | 2.2 | 0.3 | 7.3 |
| 15 | v.f. sand | 5.3 | 0.8 | 6.6 |
| 16 | v.f. sand | 3 | 0.5 | 6 |
| 17 | v.f. sand | 3.6 | 0.6 | 6 |
| 18 | v.f. sand | 2.5 | 0.4 | 6.3 |
| 19 | v.f. sand | 1.8 | 0.4 | 4.5 |
| 20 | mud, v.f. sand | 16 | 2 | 8 |
| 21 | mud | 7.8 | 1.3 | 6 |
| 22 | mud | 12.5 | 1.3 | 9.6 |
| 23 | mud | 10 | 1 | 10 |
| 24 | mud | 11.8 | 1.2 | 9.8 |
| 25 | mud | 10.7 | 1.1 | 9.7 |

Sand grain-size abbreviations: f. – fine-grained; v.f. – very fine-grained

The muddy channel-fill deposits are mainly massive, only locally showing weak, irregular, flat lamination (Fig. 9B). Grain-size analyses revealed upward fining, and the basal part of channel-fill in some cases is enriched in silt and/or very fine- to fine-grained sand admixture. There is no evidence of lateral accretion, and these channels were apparently filled by episodic vertical aggradation (Fig. 9B).

The mud-filled channels have thicknesses in the range of 1–2 m and their widths range from 7.8 to 16 m (e.g., see channels 20, 21 and 23 in Figs 8 & 9). The *w/t* ratio of these channels varies from 6 to 10 (Table 1), averaging ~9.0. Accordingly, the palaeochannels of this category are similarly classified as narrow ribbons.

## INTERPRETATION

Field observations indicate that both the sand-filled and mud-filled palaeochannel varieties in the Wielkopolska

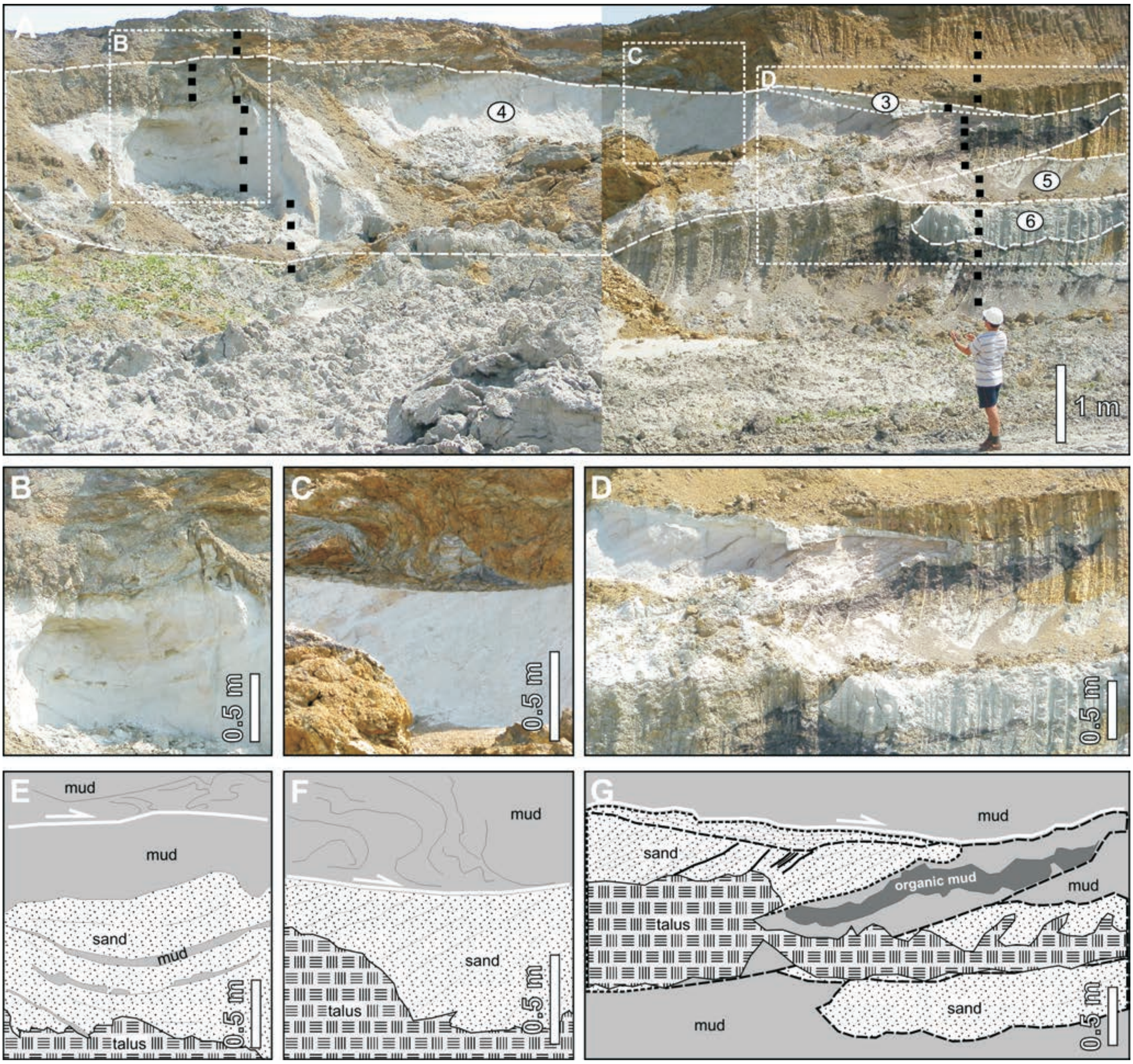


**Fig. 4.** Glacitectonically deformed, sand-filled multi-storey channels in the Wielkopolska Member. **A** – Broad eastward view of outcrop section showing at least four palaeochannels in the Kazimierz North lignite pit (Fig. 1B) with the black squares indicating sediment sampling for grain-size analysis; **B**–**D** – Photographic outcrop details; **E**–**G** – The corresponding line-drawings of palaeochannels. Note the vertical channel-fill accretion in E and the limited lateral accretion in F and G. The arrows indicate direction of glacitectonic deformation in the overlying, muddy floodplain deposits

Member are quite narrow ribbons in the general classification fluvial channel belts. The sandy channel-fill deposits are massive and/or trough cross-stratified. Trough cross-stratification represents migration of linguoid 3-D dunes in the upper part of lower flow regime (Collinson & Thompson, 1982; Bridge, 2003), whereas the non-tractional deposition of massive sand is attributed to a rapid dumping of sediment directly from turbulent suspension (Lowe, 1988), which is indicative of hyperconcentrated flows (Pierson, 2005; Nemec, 2009). These sedimentary facies are not diagnostic for any particular river type, as they may occur in virtually all fluvial systems (cf. Allen, 1965, 1978; Schumm, 1968; Miall, 1977, 1996; Rust, 1978; Bridge, 2003). Similarly non-diagnostic are the internal facies of mud-filled channels, which indicate slack-water deposition of mud from suspension fall-out in an abandoned conduit, with possible incursions of heavily mud-laden flows (Baas & Best, 2002; Baas *et al.*, 2009), all of which can be attributed to overbank flooding from adjacent active channels (Bridge, 2003). In short, the channel-fill facies alone are not diagnostic for any specific river type.

The bedding architecture of channel-fill deposits in most cases indicates simple cut-and-fill conduits plugged by vertical sediment accretion, but shows evidence of minor lateral accretion in some of the sand-filled channels (Fig. 4E–G). At least some of the channels were thus laterally active, migrating sideways and forming incipient point bars. Therefore, it is the low width/thickness ratio of the palaeo-

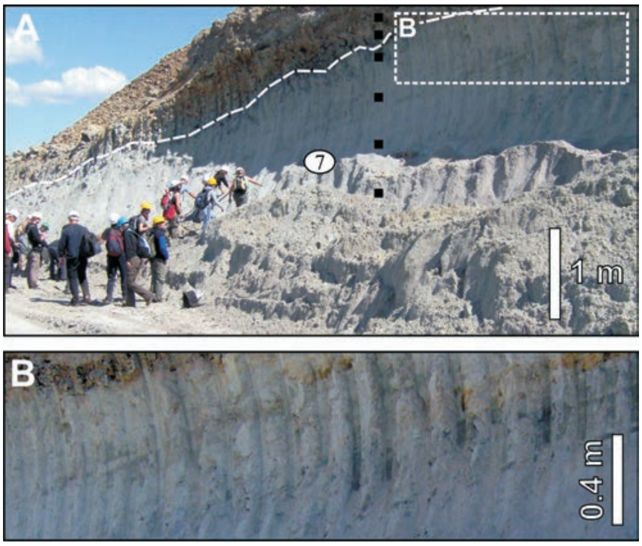


**Fig. 5.** Sand-filled channel exposed in the Kazimierz North lignite pit (Fig. 1B). **A** – Broad view of the outcrop, looking towards the NE, with the dashed line indicating palaeochannel top; **B** – Close-up detail showing a lateral to vertical pattern of accretion bedding, highlighted by muddy intercalations (darker-colour bands)

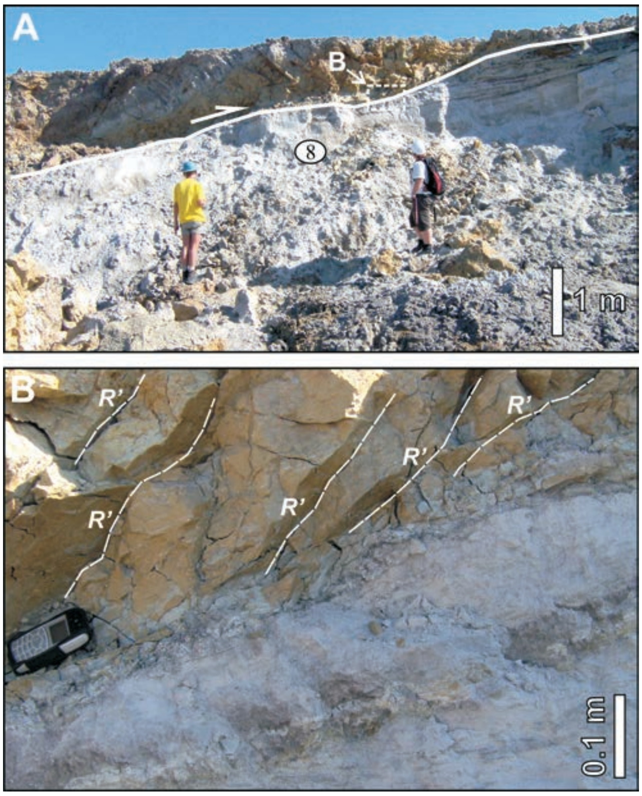


**Fig. 6.** Glacitectonic deformation of palaeochannels in the Wielkopolska Member in the Kazimierz North lignite pit (Fig. 1B). **A** – Broad eastward view of a glacitectonically tilted and top-truncated palaeochannel, with the arrows indicating the southward direction of strain; **B** – Close-up view of muddy floodplain deposits with steep Riedel shears (*R'*), thrust southwards over a palaeochannel lithosome (Fig. 6A)

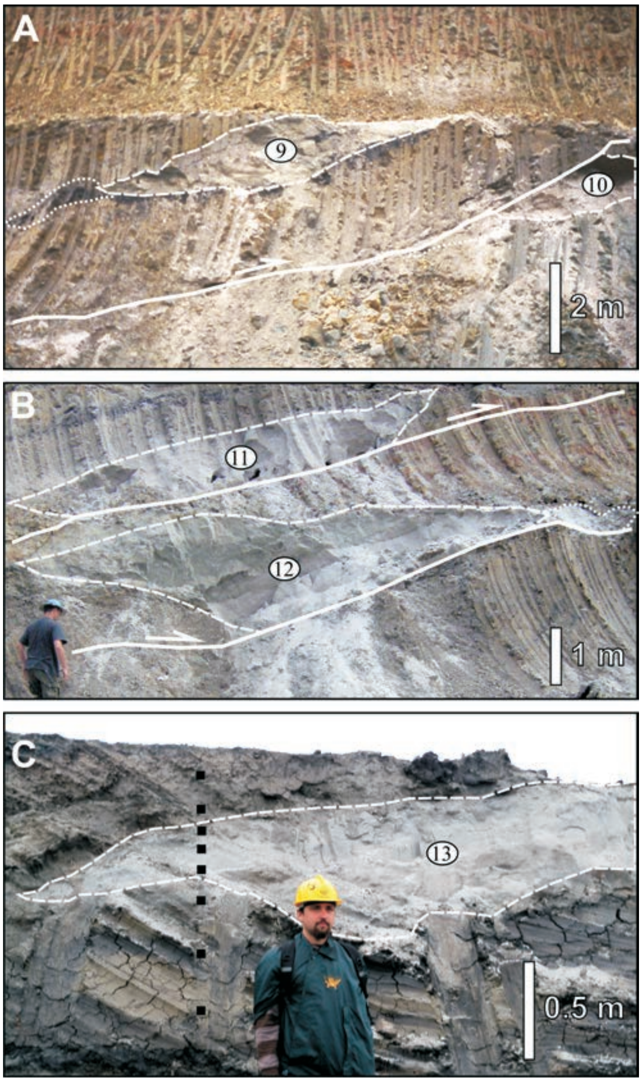


**Fig. 7.** Glacitectonically thrust-tilted sand-filled channels in the Kazimierz North lignite pit (Fig. 1B); view towards the east. **A** – Palaeochannels separated by a thrust fault, with the arrows indicating direction of glacitectonic strain; **B** – Palaeochannels displaced by a thrust duplex structure, with the arrows indicating direction of glacitectonic strain; **C** – Palaeochannel lithosome slightly north-tilted by glacitectonic deformation; the apparent oblique bands on outcrop wall are scratches left by bucket-wheel excavation machine

channels that would appear to be most diagnostic of the fluvial system type, as discussed further in the next section.

## DISCUSSION

Laterally inactive sand- and mud-dominated channels with low width/thickness ratios and a vertically accreted infill are generally characteristic of anastomosing river systems (Rust, 1981; Friend, 1983; Smith, 1983, 1986; Nadon, 1994; Makaske, 2001). Such channel systems require for their formation stable banks composed of cohesive and/or vegetated sediment (McCarthy *et al.*, 1991; Gibling *et al.*, 1998; Gradziński *et al.*, 2003), which is consistent with the field evidence in the present case.

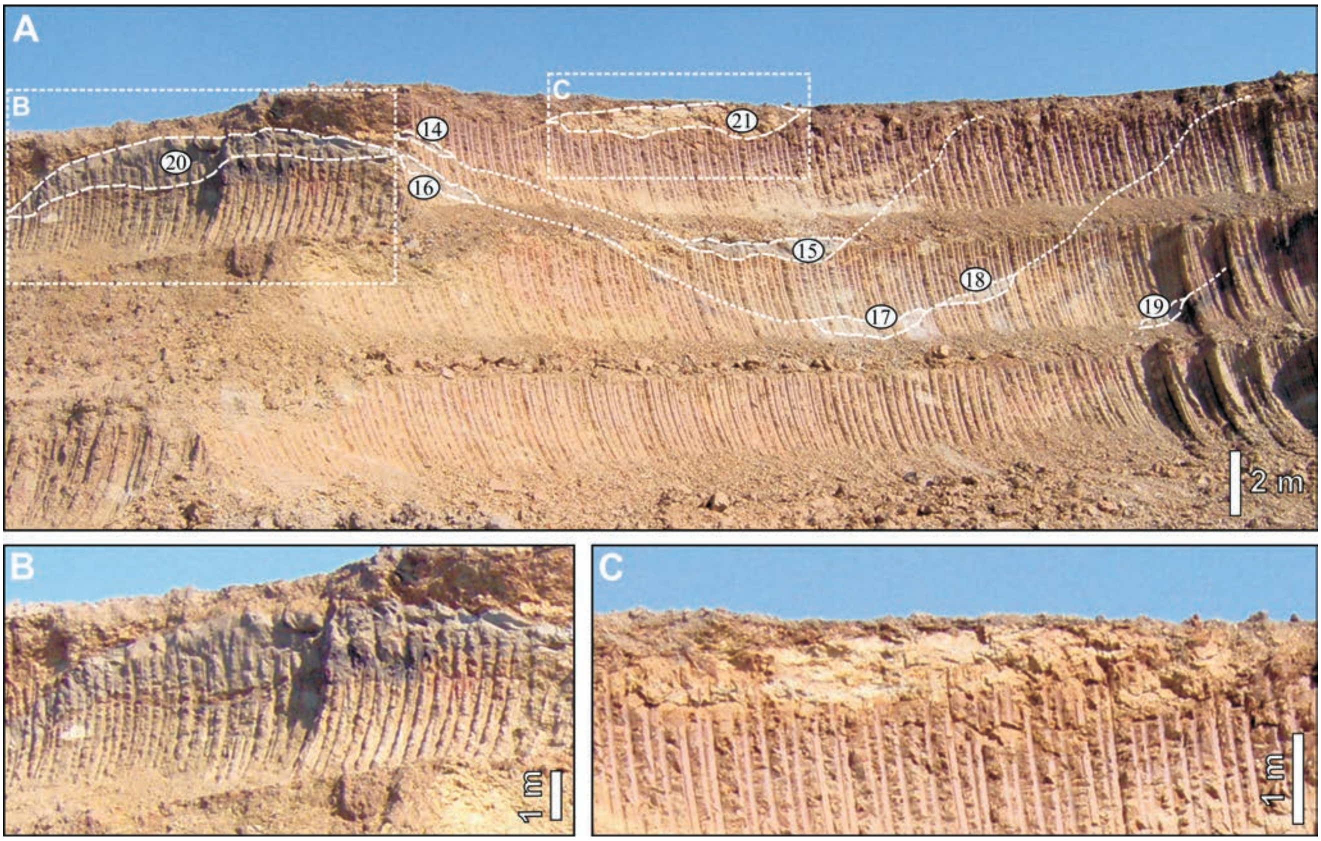


**Fig. 8.** Multi-storey sand- and mud-filled channels in the Kazimierz North lignite pit (Fig. 1B), affected by glacitectonic deformation. **A** – Broad view of outcrop section, looking towards the east; **B**, **C** – Close-up views of mud-dominated palaeochannels filled by vertical accretion

The channel width/thickness ratios reported from interpreted ancient anastomosing fluvial systems are characteristically low, but show considerable variation. For example, the reported aspect ratios of sandy palaeochannel ribbons in the Palaeogene Willwood Formation of Wyoming are in the range of 3–13 (Davies-Vollum & Kraus, 2001), but are in the range of 5.5–15 in other cases (Friend *et al.*, 1979; González-Bonorino *et al.*, 2010). The aspect ratio of anastomosing river channels may exceed 15 and possibly even 100 in some cases (Gibling *et al.*, 1998), but these would be instances involving considerable lateral migration or braiding of the conduit.

For comparison, the mud-filled channels in the Willwood Formation have reported width/thickness ratios in the range of 3–55, with an average of less than 20 (Kraus & Davies-Vollum, 2004). In the Triassic of southern Poland, the aspect ratios of mud-filled channels of an inferred anastomosing river system are in the range of 27–60 (Gruszka & Zieliński, 2008), which has been attributed to a combination of such factors as the low energy of channel-filling flow; a resistant, cohesive substrate; and a high load of suspended mud. However, the exact role of these factors in rendering the channel *w*/*t* ratio high remains unclear, and the mud-filled channels there may represent abandoned branches of a braided river system (cf. Mroczkowski, 1977; Mroczkowski & Mader, 1982).

The width/depth ratios of modern anastomosing fluvial systems, such as the Polish Narew River, are in the range of 2–10 (Gradziński *et al.*, 2000, 2003). The anastomosing river channels on the Holocene Rhine-Meuse delta plain of northern Germany and in the lower Mississippi Valley of U.S.A. have width/thickness ratios significantly lower than 25 (Törnqvist *et al.*, 1993; Stouthamer, 2001; Gouw, 2007).

In summary, the low width/thickness aspect ratios of the palaeochannels in the present study (Table 1) are the strongest interpretive argument for an anastomosing fluvial system. There is no evidence of significant channel meandering, whereas the possibility of a braided fluvial system can be precluded, because the boundary between meandering and braided rivers corresponds to an aspect ratio between 200 and 500 or even higher (Horne *et al.*, 1978; Eberth & Miall, 1991; Törnqvist *et al.*, 1993; Gradziński *et al.*, 1995; Makaske, 2001; Gibling, 2006; Doktor, 2007; Gouw, 2007). Some of the sand-filled channels were subject to minor lateral migration, probably during phases of negligible subsidence rate, when the conduits were forced to develop lateral accommodation for their discharges. The muddy interlayers in some of the sand-filled channels (Figs 4E & 5B) indicate that many conduits probably conveyed sand only during high stages of the fluvial system, with an intervening transport of mud during slack-water stages. This kind of alternation of high sand discharges and episodic slack-water conditions in some channel branches is consistent with the notion of an anastomosing fluvial system (Smith, 1983, 1986; McCarthy *et al.*, 1991; Nadon, 1994; Miall, 1996; Gibling *et al.*, 1998; Makaske, 2001).

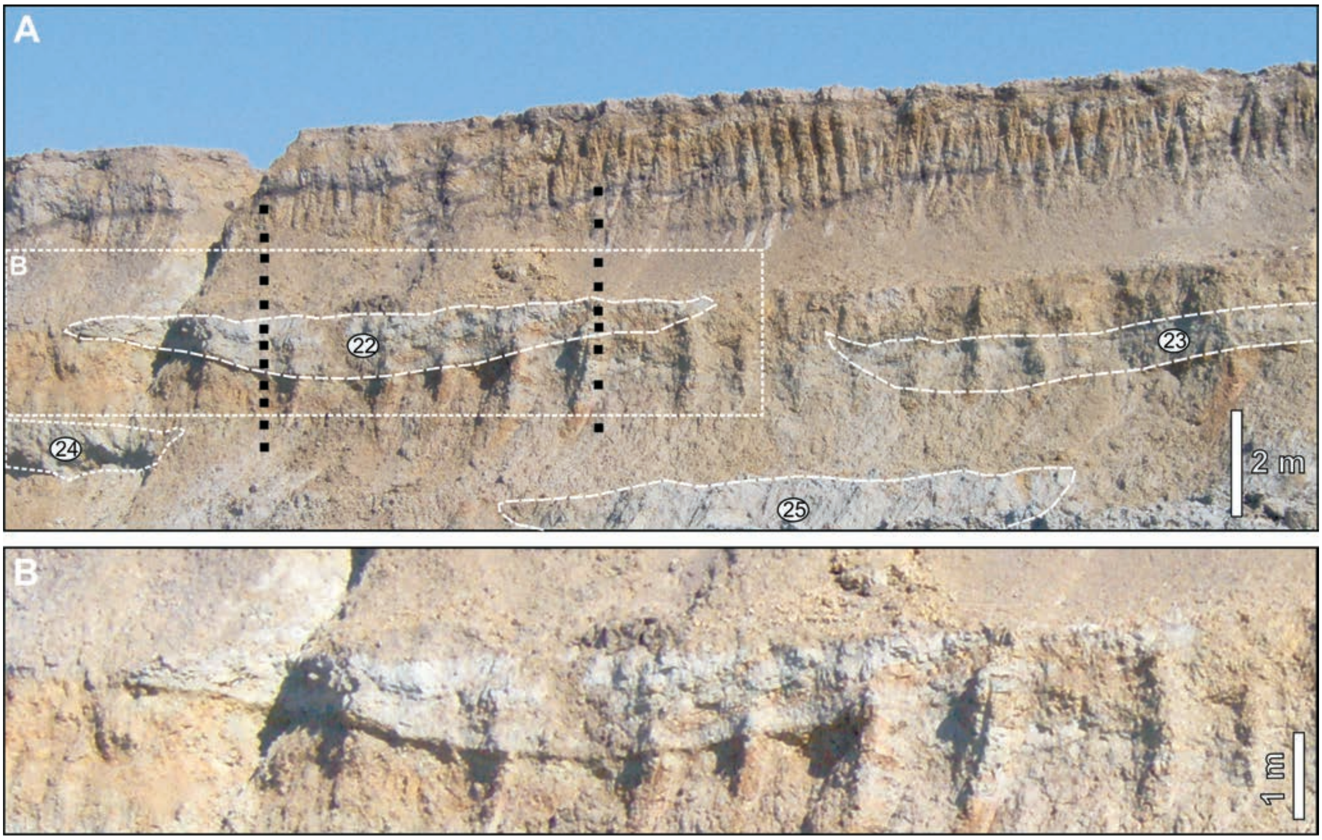


**Fig. 9.** Multi-storey mud-filled channels exposed in the Kazimierz North lignite pit (Fig. 1B). **A** – Broad eastward view of outcrop section, showing four single-storey isolated palaeochannels with glacitectonically deformed floodplain deposits at the outcrop top; **B** – Close-up view of a palaeochannel filled by vertical accretion

## CONCLUSIONS

1. The Wielkopolska Member of the Neogene Poznań Formation in central Poland consists of single- and multi-storey palaeochannel lithosomes encased in mud-rich floodplain deposits and is interpreted to have formed in an alluvial environment with a westward to north-westward direction of fluvial drainage.

2. Two types of palaeochannels were distinguished: sand-filled and mud-filled. Both show an upward fining trend, although it is often recognizable only by the grain-size analysis of sediment samples, rather than at a macroscopic level.

3. The fine- to very fine-grained sandy channel-fill deposits are mainly massive, but include trough cross-stratification. The muddy channel-fill deposits are massive to faintly laminated. The origin of the channel-fill facies was interpreted. The sedimentary facies alone are not diagnostic for any particular type of fluvial system, but the lack of systematic lateral accretion bedding precludes the possibility of meandering rivers.

4. The cross-sectional geometry of the palaeochannels was studied in terms of their width/thickness ratio, which is in the range of 4.5–14 for the sand-filled channels and in the range of 6–10 for the mud-filled ones. Therefore, the palaeochannels are considered to be narrow ribbons in the general classification of fluvial channel belts, and this evidence precludes braided rivers.

5. The origin of the Wielkopolska Member is attributed to an anastomosing river system characterized by cut-and-fill channels with cohesive and vegetated banks. Some of the sand-filled channels were laterally active, subject to limited meandering. The mud-filled conduits are thought to have been the cut-and-abandoned branches of the system, whereas the sand-filled conduits were those conveying the main discharge and sand load on perennial basis.

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