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Crevasse splays within a lignite seam at the Tomisławice opencast mine near Konin, central Poland: architecture, sedimentology and depositional model

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Abstract

The present article focuses predominantly on sandy deposits that occur within the Middle Miocene lignite seam at the Tomisławice opencast mine, owned by the Konin Lignite Mine. As a result of mining activity, these siliciclastics were available for direct observation in 2015–2016. They are situated between two lignite benches over a distance of ~500 m in the lower part and ~200 m in the higher part of the exploitation levels. The maximum thickness of these sandy sediments, of a lenticular structure in a S–N cross section, is up to 1.8 m. With the exception of a thin lignite intercalation, these siliciclastics comprise mainly by fine-grained and well-sorted sands, and only their basal and top layers are enriched with silt particles and organic matter. Based on a detailed analysis of the sediments studied (i.e., their architecture and textural-structural features), I present a discussion of their genesis and then propose a model of their formation. These siliciclastics most likely formed during at least two flood events in the overbank area of a Middle Miocene meandering or anastomosing river. Following breaching of the natural river levee, the sandy particles (derived mainly from the main river channel and levees) were deposited on the mire (backswamp) surface in the form of crevasse splays. After each flooding event, vegetation developed on the top of these siliciclastics; hence, two crevasse-splay bodies (here referred to as the older and younger) came into existence. As a result, the first Mid-Polish lignite seam at the Tomisławice opencast mine is currently divided in two by relatively thick siliciclastics, which prevents a significant portion of this seam from being used for industrial purposes.

Key words: backswamp area, facies analysis, siliciclastic deposition, Neogene

1. Introduction

Crevasse splays are commonly found in the valleys of both meandering and anastomosing rivers (Smith et al., 1989; Makaske, 2001; Zieliński, 2014). They are created by the breaching of natural levees that extend along the river banks during the initial phase of flooding (e.g., Bristow et al., 1999; Farrell, 2001). Crevasse-splay bodies can vary significantly in size, their maximum thickness usually being between 2.5 and 6.0 metres in the proximal part (i.e., in close proximity to the levee), while their length and width may even exceed 2 kilometres (Smith et al., 1989; Mjøs et al., 1993; Boggs, 2012).

Deposits of crevasse splays are well known from around the world, including lignite/coal areas, both in the rock record and from modern sedimentary environments (e.g., Horne et al., 1978; Zwoliński, 1985; Kasiński, 1986; Fielding, 1986; Kurowski, 1999; Pérez-Arlucea & Smith, 1999; Słomka et al., 2000; Szponar, 2000; Davies-Vollum & Kraus, 2001; Gębica & Sokołowski, 2001; Farrell, 2001; Stouthamer, 2001; Kordowski et al., 2014; Burns et al., 2017). In Polish geological literature, however, numerous crevasse-splay deposits are interpreted mainly on the basis of data from boreholes that penetrate the coal-bearing Carboniferous succession (e.g., Gradziński et al., 1995, 2005; Kędzior, 2001, 2016; Doktor, 2007).

In Poland, crevasse-splay sediments in the rock record are available for direct observation only at four exposures. The first of these is the Brynów brickyard, in the city of Katowice, where standing trunks of horsetails (*Calamites*) have been documented within sandy clay deposits of Late Carboniferous (Westphalian A) age. These strata were interpreted by Brzyski et al. (1976) as typical of crevasse splays which were formed by several depositional cycles. The second outcrop, located at Sołtyków, in the vicinity of the city of Skarżysko Kamienna (northern part of the Holy Cross Mountains), includes sandy lithosomes within muddy silt deposits of Early Jurassic age. These sandy bodies were also recognised as deposits that represent fossil crevasse splays (Pieńkowski, 2004). The Tomisławice opencast mine is the third site to expose a crevasse splay in Poland; it was accessible in 2015 and 2016, and actually the first one to be discovered within Miocene lignite-bearing strata (Widera et al., 2017). These crevasse-splay sediments were one of the subjects covered in my Master's thesis; the current research revolves around them as well. It is worth adding here that in 2018 a new crevasse splay was exposed in the nearby Jóźwin IIB opencast mine (Fig. 1). These deposits and deformational structures are currently being investigated and results obtained have been published and discussed in separate papers (Chomiak et al., 2019a, b; Van Loon, 2019).

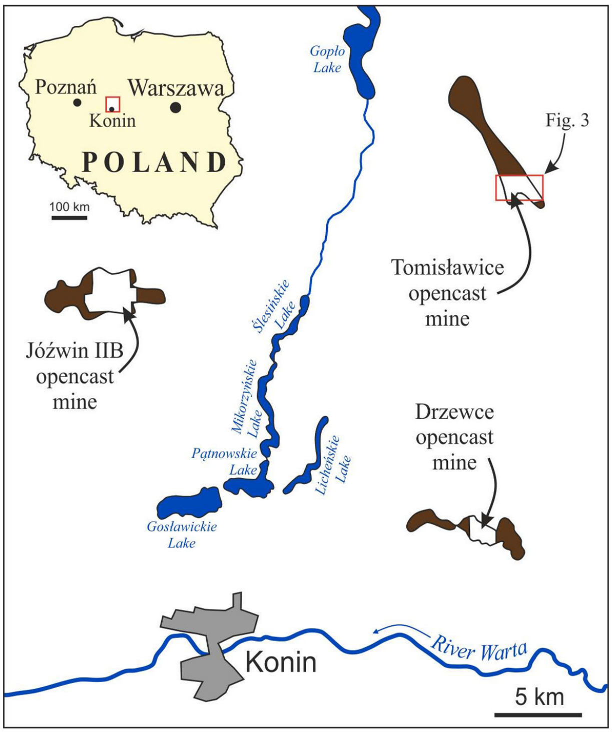


Fig. 1. Location map of the study area

In the present paper, only the crevasse-splay strata from the Tomisławice opencast mine are characterised, as these were the first to be described directly from the entire Miocene sequence in Poland. Some sedimentological issues that are in need of clarification have not yet been analysed. Therefore, the main aims of the present study are threefold: 1) to explain briefly the differences in cross-sectional shape of the crevasse-splay bodies; 2) to describe and interpret facies that represent the crevasse-splay deposits examined and 3) to propose, for the first time, a depositional model that comprises the formation stages of the two superimposed crevasse splays.

2. Study area

2.1. Location

The crevasse-splay deposits examined are situated in the southern part of the Tomisławice lignite opencast mine, which is ~30 km north of the city of Konin in central Poland (Fig. 1). The siliciclastics studied occur between two lignite benches on the lower exploitation level and between sands that are below the lignite seam and remains of the upper lignite bench or Quaternary deposits on the upper overburden level (compare Figs. 2–4 and 5).

2.2. Geology and lithostratigraphy

The research area is in the eastern part of the Mogilno–Łódź Basin, above the southeastern slope of a deeply rooted salt structure, the so-called 'Gopło Anticline' (Dadlez et al., 2000). According to the subdivision of Poland into tectonic units, the territory of the Tomisławice opencast mine is located in the Szczecin–Miechów Synclinorium and, more precisely, in the eastern part of the Mogilno–Łódź Segment (Żelaźniewicz et al., 2011).

The Mesozoic top in the study area comprises marls of Late Cretaceous age (Fig. 2; Dadlez et al., 2000). The Cenozoic succession starts with Paleogene strata, most likely of Early Oligocene age, which locally fill a shallow tectonic depression. Deposits formed at that time comprise greenish glauconitic sands of marine origin (Widera & Kita, 2007).

After Late Oligocene uplift and erosion in central Poland, Neogene deposition commenced. This is dominated by fluvial sediments, interbedded with carbonaceous/coaly layers. Thus, the Neogene in the area of the 'Tomisławice' deposit starts with a 12-m-thick layer of sands, often enriched with organics, which belong to the Koźmin Formation of Early–Middle Miocene age. Overlying is the Poznań Formation (Middle Miocene to earliest Pliocene), which terminates the Neogene succession in this part of Poland. The Poznań Formation is divided into two members, i.e., the older, Grey Clay Member, and the younger, Wielkopolska Member (Piwocki & Ziembińska-Tworzydło, 1997). The former unit includes the first Mid-Polish lignite seam (Kasiński & Słodkowska, 2016), which reaches an average thickness of ~6.5 m in the study area; the latter member, comprising the so-called 'Poznań Clays', is preserved only locally in residual form (Fig. 2; see Widera 2016a, 2017).

The Neogene deposits described above are capped by Quaternary strata which vary in thickness between 35 and 60 metres in the area of the Tomisławice opencast mine. These Quaternary deposits consist mainly of glacial tills, gravels and sands as well as fluvioglacial gravels, sands and muds (Fig. 2; see Widera et al., 2017).

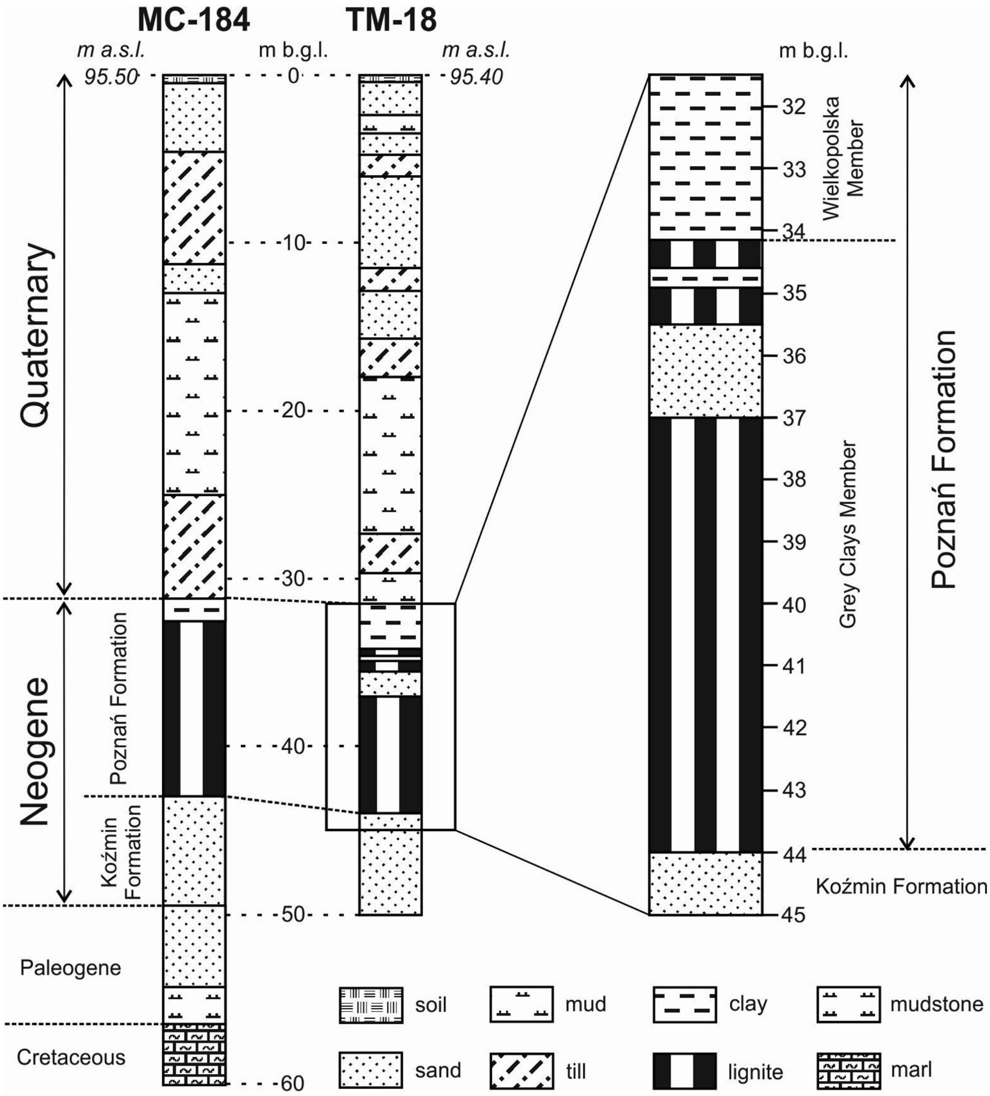


Fig. 2. Compilation of boreholes MC-184 and TM-18 in the area of the 'Tomisławice' lignite deposit, depicting the lithostratigraphy of the Cenozoic succession and the position of the crevasse splay(s) examined within the first Mid-Polish lignite seam. For the location of boreholes, reference is made to Figure 3

3. Material and methods

3.1. Field data

The results of the present study are based mainly on field observations carried out in the southern part of the Tomisławice lignite opencast mine (Fig. 3) in the autumn of 2015. The sandy deposits analysed were visible over a distance of ~500 m between two lignite benches on the lower exploitation level. The summarised thickness of these siliciclastics reached a maximum of 1.4 metres (Fig. 4A). However, they

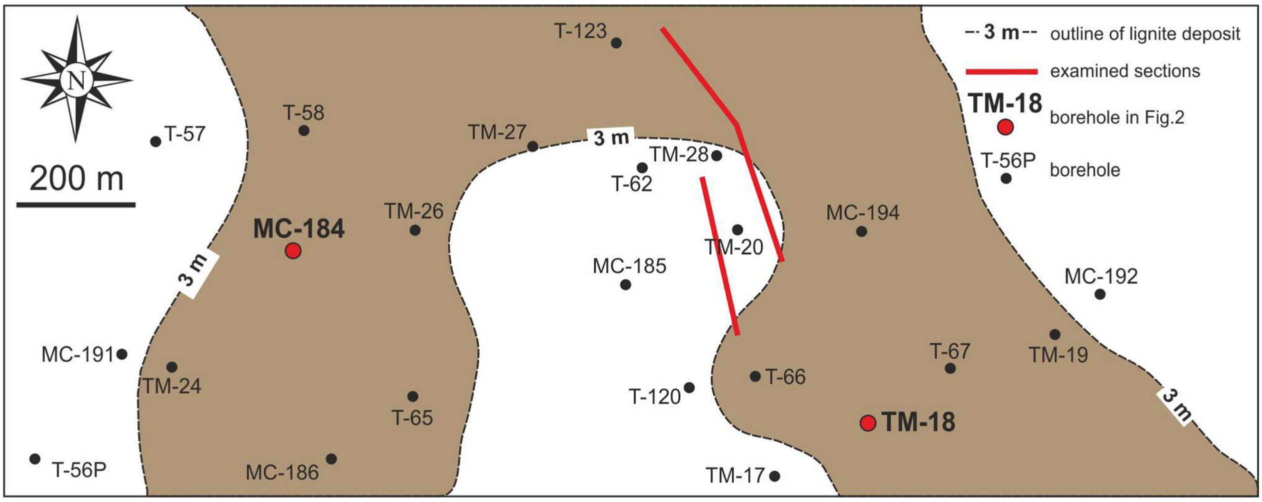


Fig. 3. Documentation map of the southern part of the 'Tomisławice' lignite deposit, showing location of lignite and overburden faces with crevasse-splay interbeddings boreholes MC-184 and TM-18 (compare Fig. 2) examined in more detail. For location of the area covered by this map see Figure 1

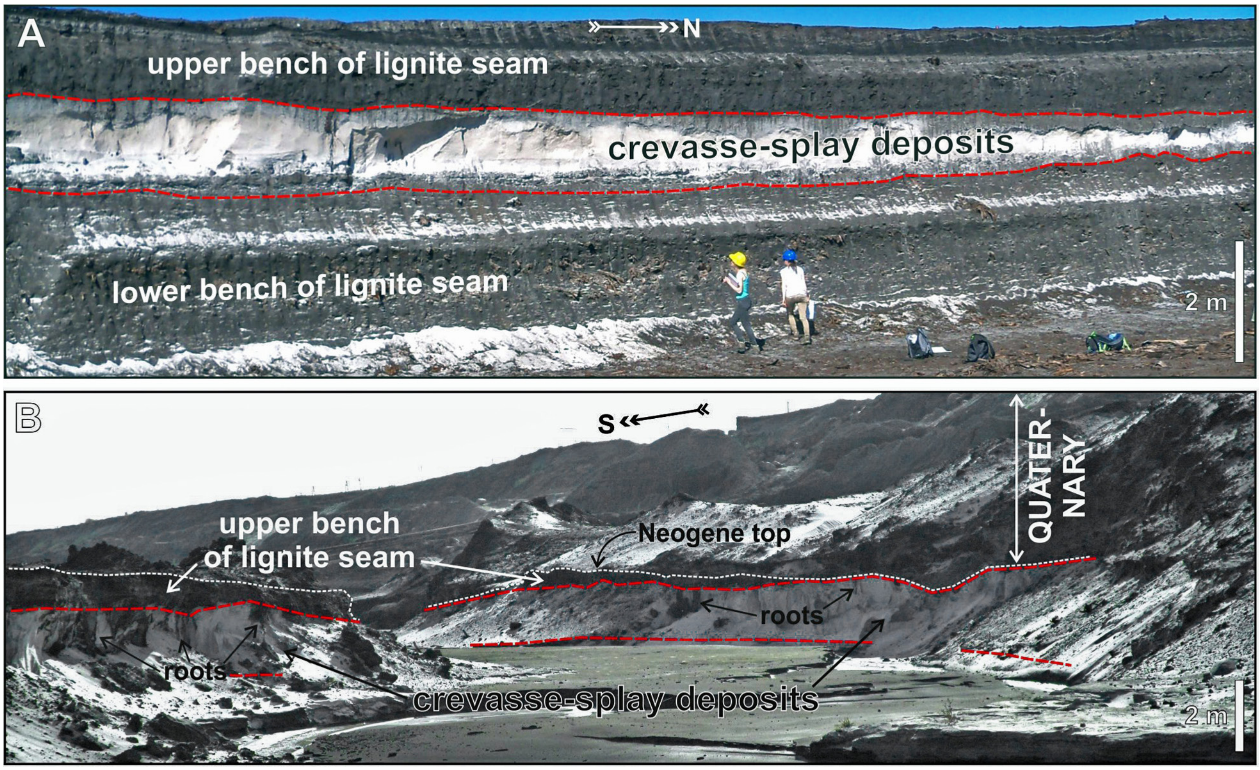


Fig. 4. Broad view of the crevasse-splay deposits within the First Mid-Polish lignite seam outcropping at the Tomisławice mine
A – distal part of the crevasse splay; **B** – proximal part of the crevasse splay. For location of the area covered by this map see Figure 3

outcropped over a distance of ~200 m, with a maximum total thickness of 1.8 m on the upper overburden level (Fig. 4B). The height of the mine faces examined ranged from 2 to 6 metres and extended over a length of between 200 and 500 metres in a north-south direction and over more than 100 m in an east-west direction (Fig. 3). Furthermore, during fieldwork, 50 samples of sands, silty sands and coaly sands were collected for laboratory analysis.

3.2. Geological mapping

In order to characterise the architecture of the crevasse-splay bodies (dimensions, shape, etc.), the lignite and overburden faces were mapped. Data from boreholes MC-184 and TM-18 were also used to describe the geology, including the lithostratigraphical subdivision, of the study area (compare Figs. 2 and 3). All the necessary data were obtained from the archives of the Konin Lignite Mine.

3.3. Facies analysis

During fieldwork, firstly the facies within the crevasse-splay bodies were distinguished. Subsequently, these facies were described using the facies codes of Miall (1977), Rust (1978) and Zieliński (1995, 2014). The lithotype code proposed

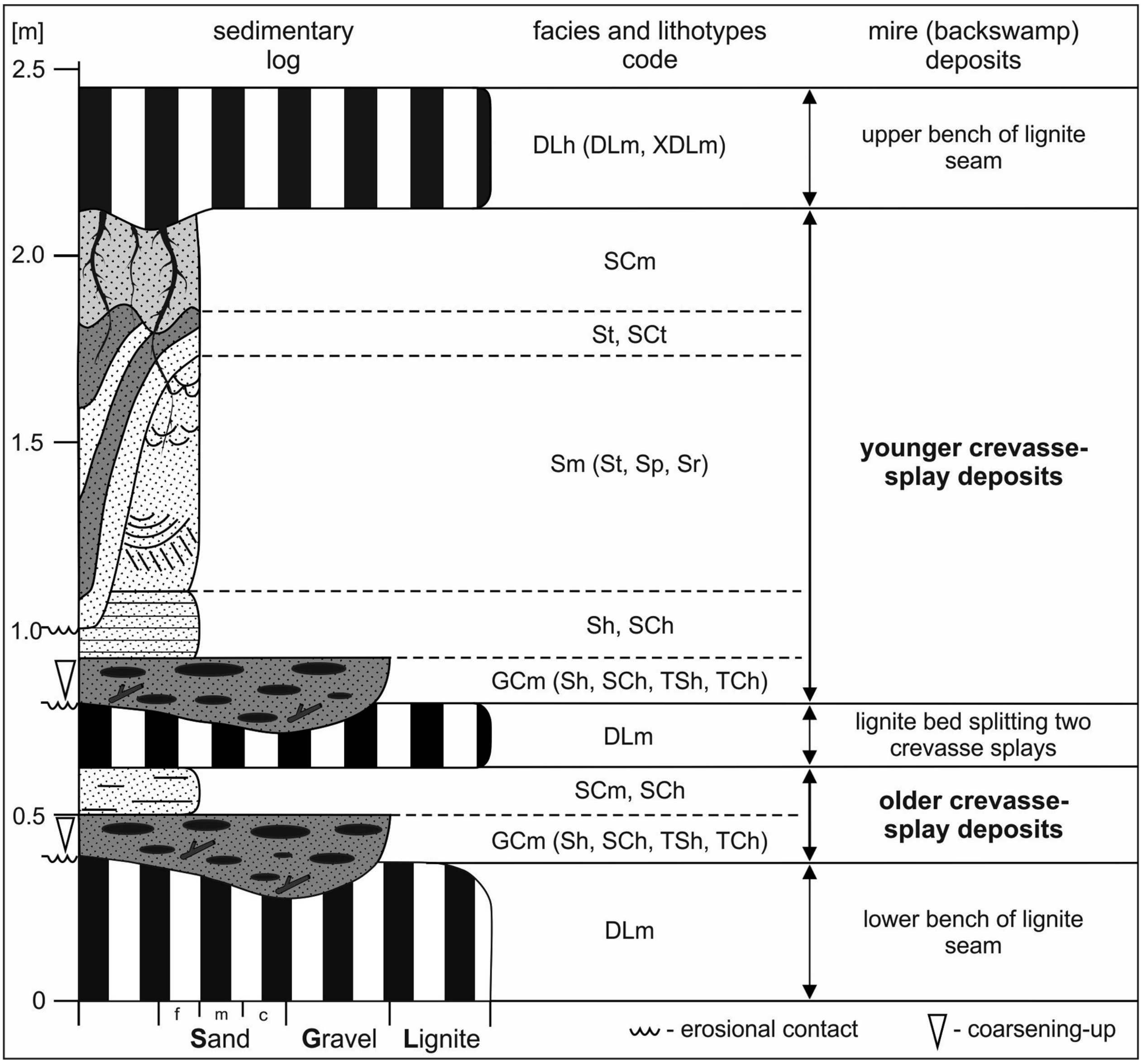


Fig. 5. Idealised sedimentary log of two superimposed crevasse-splay deposits situated between benches of the lignite seam at the Tomisławice opencast mine. For description of facies and lithotype codes see Table 1

Table 1. Codification of crevasse-splay facies (after Miall, 1977; Rust, 1978; Zieliński, 1995, 2014) and lignite lithotypes (after Widera, 2012, 2016b) used in the present paper; secondary facies are shown in brackets

Crevasse-splay facies	
Code	Description
GCm, (GCh)	massive coaly, carbonaceous gravel (horizontally stratified coaly gravel)
Sh, (SCh)	horizontally laminated sand, (horizontally laminated sand with coaly strings)
Sm, (St, Sp, Sr)	massive sand, (trough, planar and ripple cross-laminated sand)
St, SCt	trough cross-stratified sand and coaly sand
SCm	massive coaly sand
Lignite lithotypes	
Code	Description
DLm	detritic lignite with a massive structure
DLh, (DLm, XDLm)	horizontally stratified detritic lignite, (massive detritic and xylodetritic lignite)

by Widera (2012, 2016b; see Table 1; Figs. 5 and 6) was then applied to lignite. First of all, 25 samples were analysed for their organic matter content, using a 30% hydrogen peroxide solution to dissolve organic matter. Finally, all 50 samples were sieved in order to determine the grain size of the deposits examined.

3.4. Depositional model

A depositional model was created to fulfil one of the main goals of the present research; this covers the formation of both the older and younger crevasse-splay bodies within the first Mid-Polish lignite seam at the Tomisławice opencast mine (Fig. 7).

4. Results

4.1. Cross-sectional shape of the crevasse-splay body

The crevasse-splay body, which actually comprises two superimposed splays, is of a lenticular shape at both the lower exploitation and the upper overburden levels. However, their shapes differ significantly in a north-south cross section, at these levels (compare Figs. 3 and 4). In the former, the top of the lens is nearly flat, while its base is concave up (Fig. 4A), while in the latter, the lens shape mirrors the one described above, i.e., its top is convex up and its base flat (Fig. 4B).

4.2. Interpretation of the cross-sectional shape of the crevasse splay body

Differences in the shape of the crevasse-splay bodies examined were observed along two cross-sectional lines; these can be explained by variable compaction of the underlying lignite and sands. The compaction ratio for the first Mid-Polish lignite seam is ~2.0 (Widera, 2015), whereas sands can be considered as being almost non-compactible in comparison with lignite. Thus, where sands follow directly on lignite (i.e., originally on peat), the base of the crevasse-splay body is strongly concave up due to peat/lignite compaction (Fig. 4A). In contrast, the initial shape of the crevasse-splay body is preserved when its substratum consists of non-compactible sands, i.e., the convex-up top remains preserved (Fig. 4B; see Widera, 2016a; Widera et al., 2017).

4.3. Description of the crevasse-splay facies

A detailed facies analysis has been made of the sandy sediments and, more locally, of the sandy-organic strata, at five sites along both sections studied (Figs. 3 and 4). As a result, six primary and numerous secondary facies have been distinguished within the crevasse-splay facies associations (Table 1; Figs. 5 and 6).

The first main facies (GCm) forms the basis of the sedimentary succession of both the older and younger crevasse-splay bodies (Fig. 5). It is composed largely of massive, occasionally crudely stratified, gravel-sized components that consist of sandy-silty particles with an organic admixture. Within this facies, in some parts of the exposure, other fine-grained sands, horizontally stratified secondary facies can be distinguished: Sh, SCh, TSh and TCh. Moreover, fossilised wood fragments (xylites) and compacted fragments of turf with rootlets are also easily visible within this facies (Fig. 6).

Horizontally stratified sands (Sh), which are locally enriched in organic matter, create the secondary facies SCh (Figs. 5 and 6). These deposits consist of fine-grained, well-sorted sands. Their mean grain size is ~0.16 mm; the organic content is in the range of 0.1 to 0.45 wt%.

In some places of predominantly massive sands (Sm) traces of small-scale stratification are visible in the form of trough, planar and ripple cross-laminated sand, i.e., facies Sp, St and Sr (Figs. 5 and 6). These sandy deposits are well and very well sorted, with a mean grain size between 0.14 and 0.17 mm. In the sands described, organic content is negligible or (as in most of the laboratory tested samples) even lacking (Fig. 6).

The next facies consists of trough, cross-stratified sands (St) and coaly sands (SCt) at a large scale, i.e., the set thickness attains up to 0.6–0.7 m (Figs. 5 and 6). These sediments fill the erosional channel that cuts facies Sh and Sm, and is covered by the next facies, SCm (Table 1). The dip of the layers is 15 to 25° towards ENE.

The uppermost facies (SCm), just below the upper bench of lignite, is also distinguished in the lower crevasse splay (Figs. 4A, 5 and 6). It is made up of coaly sands with a massive structure that are poorly

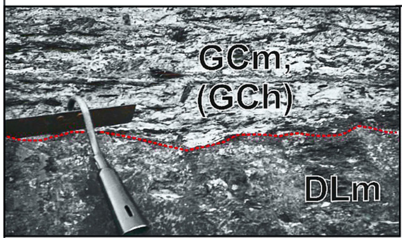
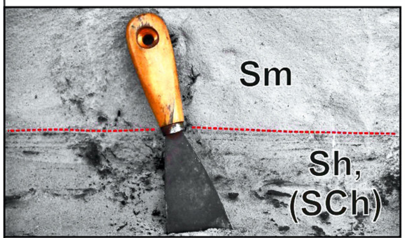
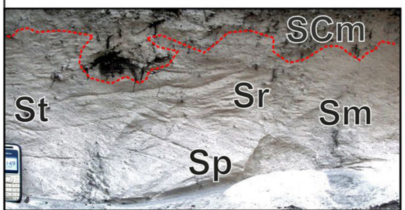
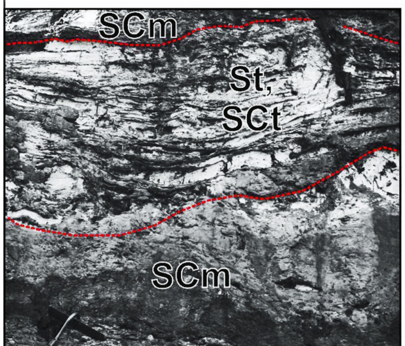
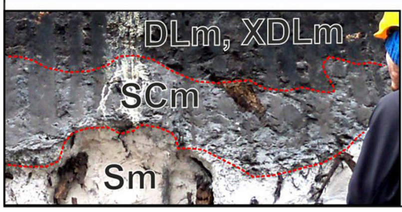
	Code	Description	Interpretation
	GCm, (GCh)	discontinuous layers of massive to horizontal coaly gravel-sized clasts; 10-50 cm long; gravel rip-up clasts enriched in organic particles; matrix-supported by coaly sand; very poorly sorted; base is always sharp and erosional; this facies is underlain by detritic lignite of lower bench of lignite seam	erosion of channel levees or proximal parts of the backswamp; redeposition by high energy slurry flows in the backswamp (overbank) area
	Sh, (SCh)	continuous layers of horizontally laminated fine sand; 10-20 cm thick; strings of horizontally laminated coaly sand	sheet flow in middle and distal parts of the crevasse splay; upper-stage plane bed; supercritical flow
	Sm, (Sr, St, Sr)	mainly massive structure with crude visible lithofacies (St, Sr, Sp) at small-scale; very well sorted; mineral-organic aggregates of plant roots; slightly fining-upward trend; both gradational and erosional bases; up to 1 m thick	migration of bedforms - ripples (Sr), 2-D dunes (Sp); 3-D dunes (St); upper part of lower flow regime; middle to distal parts of the crevasse splay
	St, (SCt)	dominant trough cross-stratification at large-scale; regularly interbedded both lithofacies (St, SCt); evidently erosional base; up to 0.6 m thick	crevasse distributary channel fills; tractional deposition; varying flow energy; resedimentation of organic matter; middle part of the crevasse splay
	SCm	mainly massive structure; abundant well-preserved roots; poorly to very well sorted; gradational base; up to 0.5 m thick	pedogenesis; strong bioturbation by roots of herbaceous vegetation; massive; all parts of the crevasse splay

Fig. 6. Compilation of characteristic features of crevasse-splay facies studied with brief environmental interpretations; compare with Table 1 and Figure 5

to very well sorted. Moreover, this facies is enriched in organic matter content, ranging from 0.03 to 12.20 wt%. Its characteristic feature is the presence of roots of bushes and trees, often also penetrating the underlying facies (Figs. 5 and 6).

The last primary facies comprises only massive sands (Sm); this was exposed exclusively on the upper overburden level at the Tomisławice lignite opencast (compare Figs. 3 and 4B). These siliciclastics are very well sorted and fining upwards, fine-grained sands with a mean grain size from 0.14 to 0.17 mm.

4.4. Interpretation of crevasse-splay facies

Facies GCm is the most important for my interpretation of its sedimentary environment, regardless of the fact that it occupies a small part of both crevasse-splay bodies examined. Its typical features, i.e., the massive structure with horizontally arranged fragments of xylites and fossilised turf at the top, allow them to be interpreted as the result of a mudflow (Carter, 1975; Lowe & Guy, 2000). Most likely, the above-mentioned plant fragments (xylites and turf) were derived from the channel levee and/or the proximal zone of the overbank area (backswamp) during the initial phase of each flood (e.g., Fielding, 1986; Farrell, 2001; Gębica & Sokołowski, 2001; Widera, 2016a; Widera et al., 2017).

The next facies (Sh) is characterised by horizontal stratification over the entire length of the exposure. This may indicate that sedimentation occurred as a continuous layer over the entire surface of the crevasse splay. Hence, facies Sh could have formed under conditions of the upper plane bed as a sheetflow (Gradziński et al., 1976; Mjøs et al., 1993; Zieliński, 2014; Burns et al., 2017; Chomiak et al., 2019a).

The interpretation of facies Sm is difficult, because the sands are very well sorted and do not reveal lamination underlined by organic matter. Therefore, most likely this facies can be attributed to sudden deposition from a hyperconcentrated flow (Nemec, 2009). However, in some places small-scale structures (Sp, Sr, St) are visible (Fig. 6). This clearly indicates low energy and slow water flow, which resulted in the formation of small-scale bedforms (e.g., ripples) in the distal parts of the crevasse splay (Bristow et al., 1999; Zieliński, 2014; Burns et al., 2017). Facies Sm, on the upper exploitation level (compare Figs. 4b and 6), can be similarly interpreted. This is proved by the common massiveness of all crevasse-splay deposits in their proximal part. However, occasionally documented traces of trough cross-stratification provide evidence of a channelised flow, typical of the migration of large-scale bedforms such as 3-D dunes (Gradziński et al., 1976; Bristow et al., 1999).

Facies St and SCt is a record of infill of the distributary channel that existed on the surface of the crevasse splay studied (Fig. 6). The symmetrical stratification within the channel is typical of a gradually decreasing flow velocity of the water, while the alternating occurrence of facies St and SCt points to rhythmic changes in flow competence (Gradziński et al., 1976; Widera, 2016a; Widera et al., 2017). Thus, facies St formed under conditions of higher flow energy and facies SCt formed when the energy of the flow was relatively lower (Fig. 6).

The uppermost facies, SCm, can be distinguished on the lower exploitation level and formed under similar conditions as Sm (Fig. 6). In contrast to the white colour of facies Sm, the grey colour of facies SCm comes from the roots of the vegetation, of which the overlying lignite bench was formed. The presence of well-preserved roots proves that the water level was close to the depositional surface. Under these conditions, the crevasse splay body was covered predominantly by herbaceous and bushy vegetation, which later turned into detritic and xylodetritic lignite (Kwiecińska & Wagner, 1997; Markič & Sachsenhofer, 1997; Widera, 2012, 2016b).

4.5. Depositional model of the succession studied

The depositional processes in the overbank area (floodplain, backswamp) are not constant in time and space. In short-term cycles, shorter periods or stages can be distinguished, corresponding to subsequent phases of deposition (Zwoliński, 1985; Pérez-Arlucea & Smith, 1999; Zieliński, 2014). Similarly, six phases in the formation of the crevasse-splay bodies, which appear in superposition at the Tomisławice opencast mine, are proposed here (Fig. 7), as follows:

4.5.1. Phase 1

Clastic deposition was restricted to the river channel during the first phase, i.e., prior to the first flood. At that time, peat-forming vegetation developed intensively in the overbank area, creating a backswamp (Fig. 7A, B).

4.5.2. Phase 2

During the first flood, the natural levee was breached. At this time the river water, which carried the clastic load from the main channel and the levee, spilled onto the surface of the mire (backswamp) (Fig. 7C, D).

4.5.3. Phase 3

When the water level dropped, clastic sediments in the form of an older crevasse-splay lobe, appeared in the backswamp area in close proximity to the main river channel (Fig. 7E, F). Their thickness, as observed in the field, did not exceed 0.5 metres.

4.5.4. Phase 4

Following the formation of the older crevasse-splay body, there was a period without floods, the rock

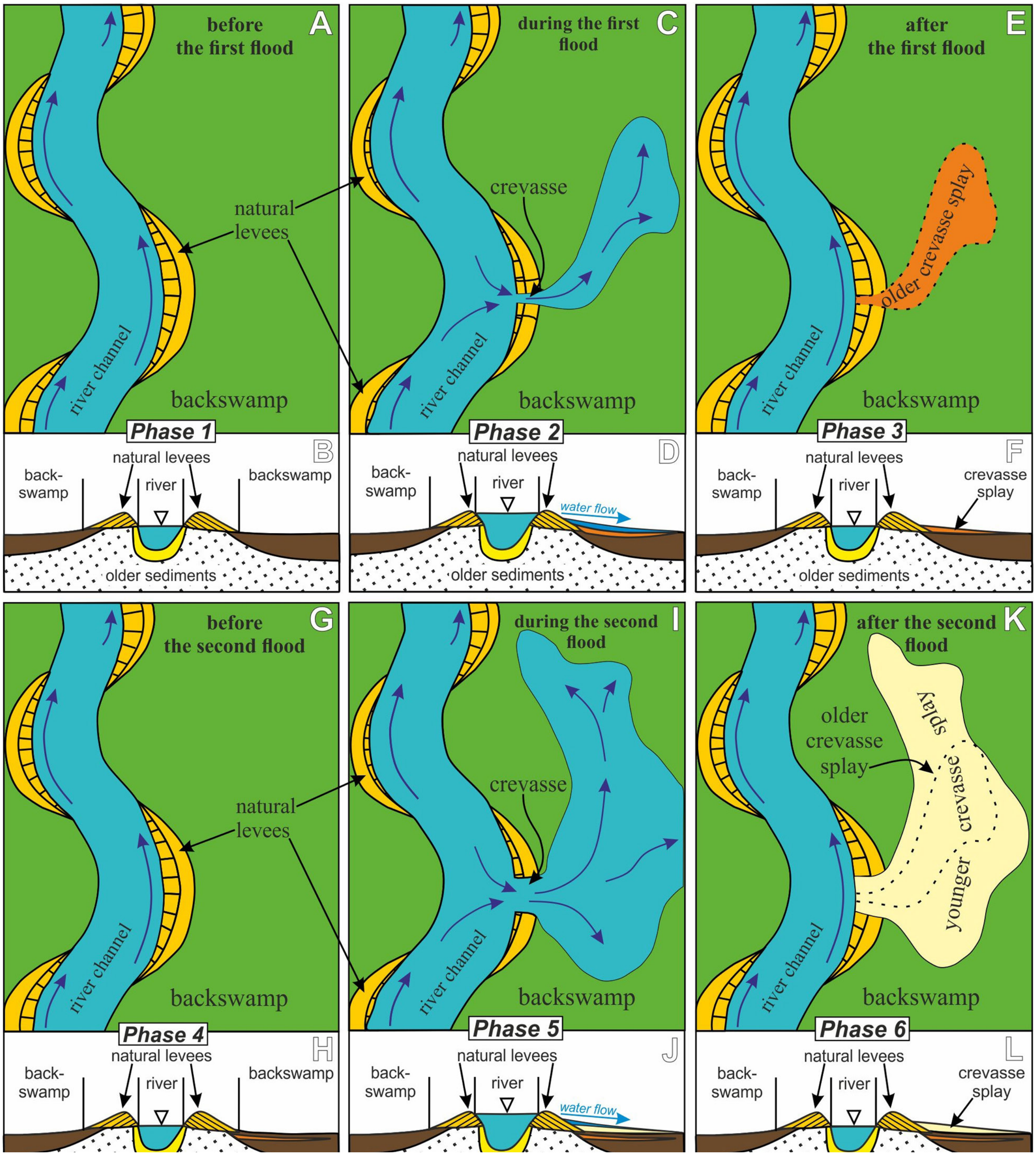


Fig. 7. Conceptual model depicting phases in the formation of the crevasse splays and accompanying peat transformation into lignite

A, C, E, G, I, K – plan views; **B, D, F, H, J, L** – cross-sectional views. For other explanations see text record of which would be clastic interbedding within the lignite seam. In other words, a relatively long period of mire development at the top of the above-mentioned splay started (Fig. 7G, H). As a result, approximately 0.2 metres of lignite formed, separating both crevasse-splay bodies studied.

4.5.5. Phase 5

This phase corresponds to the next flood. Firstly, the natural levee was breached after which river water spilled onto the surface of the backswamp through the crevasse (Fig. 7I, J). Thus, the development of the mire in the overbank area was interrupted for some time, when the younger crevasse splay formed.

4.5.6. Phase 6

The last phase (following the second flood) in crevasse splay formation can be combined with a lowering of the levels of river water and groundwater in the overbank area. The siliciclastic deposits of the younger crevasse splay were exposed in close proximity to the main river channel (Fig. 7K, L). Phase 6 is a repetition of phase 3 outlined above (compare Fig. 7E, F and K, L). Subsequently, peat vegetation covered the surface of the younger crevasse splay. In this way, a new layer of peat was formed, which was then transformed into an upper bench of lignite (compare Figs. 4 and 5).

5. Discussion

Direct observation and investigation of crevasse-splay deposits in the rock record are very rare, not only in Poland, but also worldwide. Therefore, exposures of crevasse splays from the relatively large opencast mine have proved very valuable. However, at least three issues, not discussed so far, are still debatable. These concern mainly the rate of flooding as well as the accumulation time of crevasse-splay siliciclastics and of the thin lignite layers separating them.

It appears that the upper crevasse-splay body records a large flood, i.e., larger than the one accountable for the lower body. This is supported by the fact that the most diagnostic facies GCm (silty sands with gravel-sized xylites and turf; secondary facies: Sh, SCh, TSh, TCh) occurs only in the basal parts of these two bodies (see Fig. 5). Moreover, the upper crevasse-splay represents a more complete sedimentary profile, indicating a weakening flow energy from the mudflow (facies SCm), through the sheetflow (facies Sh and SCh), to the channelised flow at various scales (facies St, SCt, Sp and Sr). Deposits discussed are characteristic of a single, catastrophic flood for at least two reasons. First, none of the main facies mentioned above is repeated in the sedimentary section (compare Figs. 5 and 6). Secondly, the thickness of the crevasse-splay deposits examined exceeds the 0.5 metres typical of a catastrophic flood (e.g., Gębica & Sokołowski, 2001; Makaske, 2001; Zieliński, 2014).

The duration of crevasse splay deposition may vary widely. Simply put, it depends on the duration of the flood, specifically on the time of outflow of channel water (which carries a mineral load) into the overbank (backswamp) area. In the case of present-day, individual, short or long-lived floods, it can be counted in hours, days or even weeks (Zwoliński, 1985; Gębica & Sokołowski, 2001). Of course, floods recorded in modern times can recur and intervals between them can be from tens to hundreds of years (Smith et al., 1989; Pérez-Arlucea & Smith, 1999; Farrell, 2001; Stouthamer, 2001; Kordowski et al., 2014).

Taking into account field data, the question arises as to how much time was involved in deposition of the lignite layer which separates the older and younger crevasse-splay bodies. The maximum thickness of this lignite bed reaches about 0.2 metres. In the literature it has been indicated that the approximately 100 metres of the Main Seam in the Lower Rhine Graben (Germany) accumulated for ~6 million years, i.e., one metre of lignite per 60 thousand years (Zagwijn & Hager, 1987). Obviously, this Main Seam here is more compacted than the first Mid-Polish lignite seam at the Tomisławice opencast mine. The average compaction ratio for the deposits mentioned is ~3.0 and ~2.0, respectively (compare Widera, 2015). Thus, the 0.2 metres of lignite interbedding could have formed over a period of about 8,000 years (60,000 x 0.2 x 2/3 = 8,000). However, this result should be considered an estimate because both the base and top of the lignite layer in the study area cannot be dated precisely.

Borehole data from the 'Tomisławice' lignite deposit provide information on relatively thick layers of mineral matter within the lignite seam. These may indicate the presence of other crevasse splays in the study area. Unfortunately, during fieldwork these deposits were not observed (lack of exposure).

At the present time, the formation of crevasse splays is often associated with sudden and catastrophic destruction of flood protection measures. The deposition of such forms covers both the natural river sediments and those coming from those artificial constructions (e.g., Gębica & Sokołowski, 2001). Therefore, differences in deposition dynamics should be taken into account when comparing contemporary and ancient crevasse splays.

6. Conclusions

The current research determines the sedimentological characteristics of crevasse splays exposed within all lignite-bearing successions in Poland. The major conclusions drawn here can be briefly summarised as follows:

– Two superimposed crevasse-splay bodies were revealed at the Tomisławice opencast mine (Konin Lignite Mine; central Poland) during mining activity. These bodies divided the lignite seam of Middle Miocene age in two.
– The crevasse splays are lenticular in shape and mirror imaged, on the exploitation and overburden levels. This significant difference is explained by varying compaction of the underlying, strongly compactible lignites and almost non-compactible sands.
– Facies analysis shows that the siliciclastic deposits studied are typical of a crevasse splay, which accumulated in close proximity to the river channel, i.e., in the overbank (backswamp) area. The sediments are well-sorted, fine-grained sands, locally with an organic admixture. Massive and horizontal structures are commonest, while crudely stratified and gravel-sized clasts are the most characteristic facies within the crevasse-splay deposits studied.
– A depositional model of crevasse splays formation is proposed. It includes six phases that correspond to the creation of both splays (older and younger) and the thin layer of lignite separating them, i.e., before, during and after two floods. Most likely, the break in clastic sedimentation, recorded in peat accumulation, lasted for a few thousand years.
– The results presented here may be useful for mining activity, particularly at the stage of mapping the extent of exploitation of the lignite seam. Therefore, a better knowledge of the mechanisms of deposition of the siliciclastic beds within the lignite seams (crevasse splays) is highly desirable.

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