Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

Disappearing lignite seam in the Tomisławice opencast (Konin Basin, central Poland) – the case study based on field and borehole data

***Marek WIDERA*[1]*, *Paweł URBAŃSKI*[2] and *Robert WACHOCKI*[3]**

Authors' affiliations and addresses:
[1] Institute of Geology, Adam Mickiewicz University, Krygowskiego 12, 61-680 Poznań, Poland
e-mail: widera@amu.edu.pl

[2] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland
e-mail: purb@pgi.gov.pl

[3] Konin Lignite Mine, 600-lecia 9, 62-540 Kleczew, Poland
e-mail: robert.wachocki@vp.pl

***Correspondence:**
Marek Widera, Institute of Geology, Adam Mickiewicz University, Krygowskiego 12, 61-680 Poznań, Poland
e-mail: widera@amu.edu.pl

Funding information:
Adam Mickiewicz University, Poznań, Poland

Acknowledgement:
The authors are warmly grateful to Miloš Markič (Ljubljana, Slovenia) and Sławomir Mazurek (Warsaw, Poland) for their valuable comments and suggestions that improved the quality of this paper.

How to cite this article:
Widera, M., Urbański, P. and Wachocki, R. (2024). Disappearing lignite seam in the Tomisławice opencast (Konin Basin, central Poland) – the case study based on field and borehole data. *Acta Montanistica Slovaca,* Volume 29 (3), 703-711

DOI:
https://doi.org/10.46544/AMS.v29i3.16

Abstract
This geological study is devoted to an interesting cognitive issue regarding a large mining problem. A narrow, so-called 'lignite-free' zone occurs in the Tomisławice opencast in central Poland. This surprising disappearance of an exploited lignite seam posed a threat to the proper operation of a nearby Pątnów lignite-fired power plant. Therefore, the Konin Lignite Mine carried out geological studies into the 'lignite-free' area, as designated in the field.
During the investigation, it turned out that, in the 'lignite-free' zone, there was, in fact, a continuous lignite seam, but it was at least 11 m lower than the surrounding part of the 'Tomisławice' deposit. This phenomenon can be explained in two ways. First, it could result from greater peat-to-lignite compaction in the zone where the lignite seam is at least twice thicker. Secondly, the zonal lowering of the lignite seam could be caused by post-depositional tectonics, most likely of Quaternary age. The latter hypothesis seems more probable at the current stage of research.
Regardless of the reasons for such a large hypsometric lowering of the exploited lignite seam, it is lost to the Konin Lignite Mine. Its extraction is technically possible but would involve lowering the mine water table in the cone depression by at least 11 m. Leaving aside the formal and legal aspects, such action would be too costly and, therefore, lignite from the examined 'lignite-free' zone will remain as mining losses in the Tomisławice deposit.

Keywords
peat accumulation; peat-to-lignite compaction; tectonics; opencast mining; Konin Lignite Mine

Introduction

From June 2023, the Tomisławice opencast is the only mine in the Konin Basin (central Poland) where lignite is still exploited (Fig. 1). This lignite is characterised by the following average chemical and technological parameters: calorific value (Q_i^r) – 9.1 MJ/kg, ash yield (A^d) – 23.4 wt% and sulphur content (S_t^d) – 1.0 wt% (Widera, 2021). It is used almost entirely to produce electricity at the Pątnów lignite-fired power plant owned by ZE PAK S.A. Hence, a regular and continuous supply of lignite to this power plant is of great importance for the region's energy security by supporting the high-voltage power grid of central Poland.

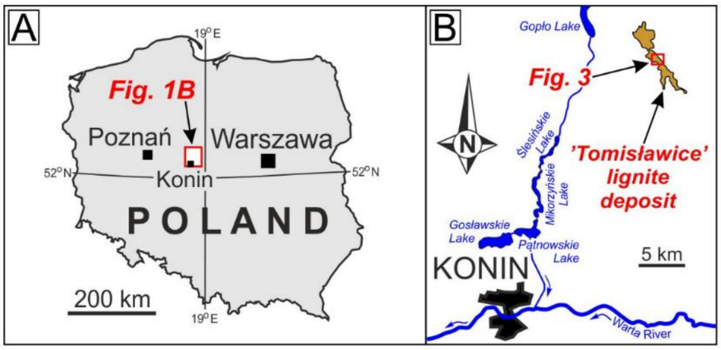

Fig. 1. Location map of the study area

Everything was in accordance with the exploitation plan and knowledge of the deposit's geology until the second half of 2022, when a lack of lignite was noticed during the cleaning and levelling of the roof of the mined lignite seam. This (disastrous) information was soon confirmed at the exploitation front (lignite wall), as well as in dewatering channels and basins.

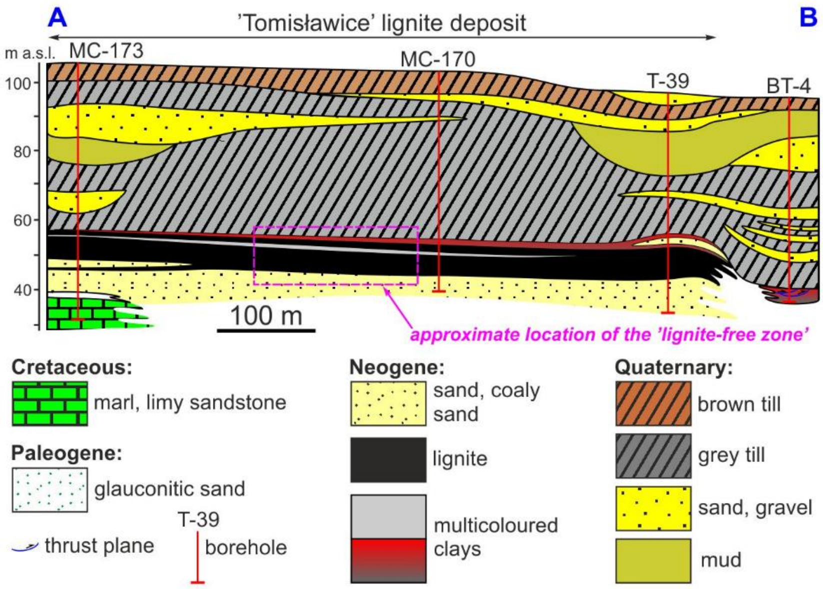

Fig. 2. Geological cross-section A–B through the 'Tomisławice' lignite deposit based on data from deep boreholes
See Figure 3 for the location of the cross-section line A–B

In such a situation, the Konin Lignite Mine was forced to urgently determine the 'lignite-free' area because the aforementioned Pątnów power plant operation was at risk. Therefore, the relevant geological works (including drilling and geological mapping) were carried out between 2022 and 2023.

This study does not cover formal, legal, economic, or technological issues but focuses on geological ones. Therefore, the main aim of the current paper is to try to explain the reason for the disappearance of the lignite seam in the Tomisławice opencast. Unfortunately, this issue has not been definitively resolved, but the two most likely scenarios are presented. They relate to peat-to-lignite compaction and/or tectonics, although they occur at different times.

Geological setting of the study area

The Tomisławice lignite opencast is located approximately 30 km NNE of the town of Konin in central Poland. It is operating on a deposit of the same name, i.e. the 'Tomisławice' lignite deposit. This deposit covers a shallow tectonic depression: a graben up to 20–30 m in depth and with a NNW–SSE orientation (Fig. 1). In the tectonic division of Poland, the graben belongs to the Szczecin-Miechów Synclinorium (Żelaźniewicz et al., 2011) and, more precisely, it occupies the most north-easterly part of the Konin Elevation (Widera, 2022).

In the study area, the sub-Cenozoic surface, i.e. the top of the Mesozoic, is made up of fractured and/or faulted marls and carbonate sandstones of Late Cretaceous age (Dadlez et al., 2000). Due to periodic tectonic upward movements, the Cenozoic succession contains some long-term stratigraphic hiatuses. Therefore, the oldest Paleogene sediments are marine glauconite sands of early Oligocene age, which are preserved locally (Fig. 2; Widera, 2021; Wachocki et al., 2023).

The Neogene only includes two lithostratigraphic formations in the territory of the 'Tomisławice' lignite deposit. The lower Koźmin Formation (Lower–Middle Miocene), previously called the Adamów Formation (Piwocki and Ziembińska-Tworzydło, 1997), consists of fluvial sands and coaly sands, as well as thin lignite lenses up to 1 m thick. The upper Poznań Formation is divided into the Grey Clay Member and the Wielkopolska Member (Fig. 2; Piwocki and Ziembińska-Tworzydło, 1997; Widera, 2007, 2021).

The Grey Clay Member contains the examined lignite seam. It is the first Mid-Polish lignite seam (MPLS-1) and the so-called 'grey clays' that rest locally on its top. In the study area, the MPLS-1 is up to 11.8 m thick (6.9 m on average) and includes siliciclastic interbeddings (Fig. 2). They represent crevasse-splay sands, up to 5 m thick (Widera et al., 2017, 2023; Chomiak, 2020; Dziamara et al., 2023), as well as lacustrine clays, up to 0.8 m thick (Chomiak et al., 2020). On the contrary, the Wielkopolska Member comprises multicoloured clays, i.e.' green clays' and 'flamy clays' (Klęsk et al., 2022, 2023, 2024), which occur as a thin (from decimetres to several metres) and discontinuous layer, often glaciotectonically deformed, between the studied lignite seam (MPLS-1) and the Quaternary overburden (Fig. 2; Wachocki et al., 2024).

In the area of the 'Tomisławice' lignite deposit, the thickness of the Quaternary succession ranges from 35–60 m due to Pleistocene erosional and glaciotectonic processes. Sediments of Pleistocene age (tills, sands and gravels, and muds) are typical of glacial, fluvioglacial and glaciolacustrine environments, respectively (Fig 2; Chomiak, 2020; Chomiak et al., 2020; Widera, 2017, 2020; Wachocki et al., 2024). The Holocene contains locally occurring sands and muds of surface streams, peats and soil layers.

Material and methods

The main sources of information for preparing the current article were field observations in the Tomisławice lignite opencast and data from boreholes (Fig. 3,4 and 5). Fieldwork was conducted for one year between September 2022 and September 2023. Profiles of deep boreholes (occasionally reaching the Cretaceous bedrock, up to 68 m deep) come from older geological documentation (Kozula, 1999, 2001), while shallow (up to 20 m deep) boreholes were drilled between December 2022 and March 2023 (Fig. 3). All of the mentioned borehole data and geodetic maps were obtained from the Konin Lignite Mine.

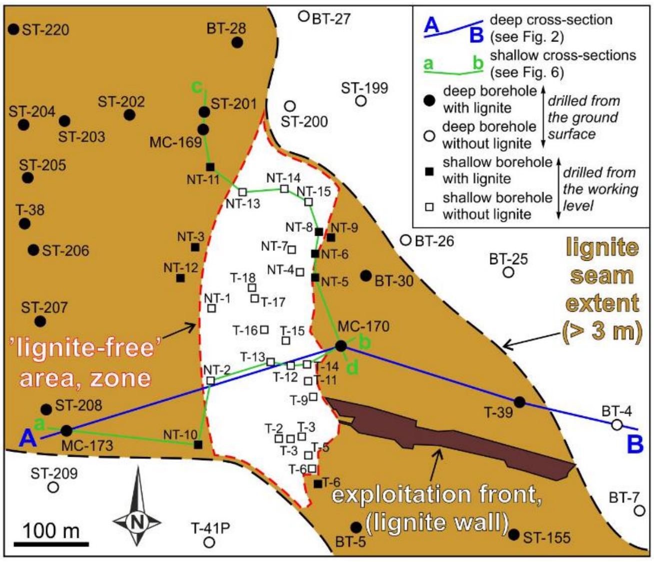

Fig. 3. Documentation map of the middle part of the 'Tomisławice' lignite deposit with the examined 'lignite-free 'zone
Note the location of the cross-section lines A–B, a–b and c–d; See Figure 2 for cross-section A–B;
See Figure 6 for cross-sections a–b and c–d

Results

In a general way, the geology of the vicinity of the Tomisławice opencast is presented in the geological cross-section A–B in this paper (Fig. 2). It was prepared using data from four deep boreholes with depths of 61–68 m. On the other hand, the extent of the 'lignite-free' zone, as well as the simplified geological cross-sections a–b and c–d, were determined on the basis of data from four deep and twelve shallow (5–20 m deep) boreholes (Fig. 3 and Fig. 6). During the interpretation of the obtained results and the creation of conceptual models explaining the formation of the investigated 'lignite-free' zone, both the tectonic movements of the sub-Cenozoic basement and the compaction of lignite were taken into account (Widera et al., 2007; Widera, 2013, 2015).

Description of field observations and cross-sections

A 'lignite-free' area was mapped, up to 500 m long and 150 m wide (Fig. 3). The titular disappearance of the lignite seam was very clearly visible in the Tomisławice opencast. Observations of walls along dewatering channels and basins, as well as the lignite exploitation front, provided evidence of the discontinuity of the lignite seam in the same elevation range (Fig. 4 and 5). In other words, lignite passes laterally into overlying clays in two ways. In the first case, the lignite seam is flexurally bent (folded), sometimes very steeply, with preserved layer continuity (Fig. 4A). Moreover, small high-angle faults were also documented in the top lignite layers (Fig. 4B) and even low-angle normal faults were seen at the lignite–clay contact and in the overburden clays (Fig. 4C). In the second case, the lignite seam is evidently faulted at an angle of 45–75°. The magnitude of the throw of the lignite roof is in the range of a few decimetres (Fig. 5A) to >3 m, as seen in the field (Fig. 5B).

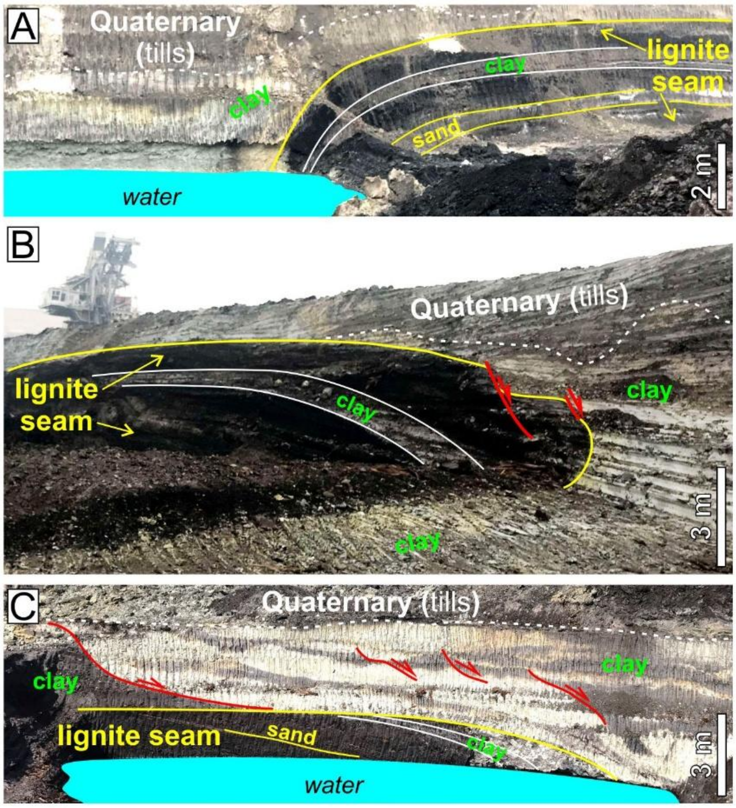

Fig. 4. Folded (flexurally bent) lignite seam adjacent to the 'lignite-free 'zone (Tomisławice opencast, autumn 2022) Note the clayey and sandy interbeddings present in the lignite seam (A–C). Note traces of discontinuities (faults) in the top layers of lignite and its overburden (B, C)

In turn, the shallow geological cross-sections a–b and c–d do not provide much information about where the studied lignite seam is located (Fig. 6). The exception here are the data from boreholes NT-6 and NT-8, in which the top layers of lignite were drilled below the overburden clays (Fig. 6B). In the remaining cases, these clays were not pierced to a depth of more than 44.5 m a.s.l. (e.g. shallow borehole T-14), although in the adjacent deep borehole MC-170, the lignite roof was found at 55.5 m a.s.l. This means that over a distance of ca. 70 m, the lignite seam is lower by >11 m (Fig. 6A). It is worth paying attention to the fact that the base of the Quaternary glacial tills is also lower by >5–10 m in the 'lignite-free' zone, i.e. between boreholes NT-10 and MC-170, as well as between NT-11 and NT-5 (Fig. 6).

Interpretation of the obtained results

The field observations and shallow geological cross-sections characterised above prove that the examined lignite seam (MPLS-1) from the Tomisławice opencast is strongly hypsometrically diversified in the 'lignite-free' zone. This is in contradiction to data from deep geological cross-sections (see Fig. 2). Thus, the obtained results indicate, at least in part, that the lignite seam has been subjected to zonal subsidence by flexure and/or vertical throw along normal faults (Fig. 4 and 5). Numerous relatively shallow boreholes and the geological cross-sections based upon them do not allow us to precisely determine the architecture of the seam in the 'lignite-free' zone (cf. Fig. 3 and 6). Therefore, its genesis can only be explained by putting forward at least two hypotheses.

The first hypothesis connects the formation of the studied 'lignite-free' zone with the transformation of peat into lignite, in other words, with the peat-to-lignite compaction process (Fig. 7). At the first stage, under conditions of syn-depositional tectonics (during the middle part of the Mid-Miocene), peat beds with a thickness approximately twice as thick as the current thickness of the lignite seam (ca. 10 m) were accumulated. In this case, it should also be assumed that, in the 'lignite-free' zone, peat's thickness was at least twice as thick as in the surroundings. This means that the thickness of the peat before becoming covered with mineral overburden (i.e. Neogene clays) was in the range of ca. 25–55 m (Fig. 7A). The second stage of deformation included uneven compaction, depending on the varying thickness of the peat. As a result, in the place of its greatest thickness (>50 m), the roof of the lignite seam subsided by >12.5 m more than in the place where the peat thickness was >25 m.

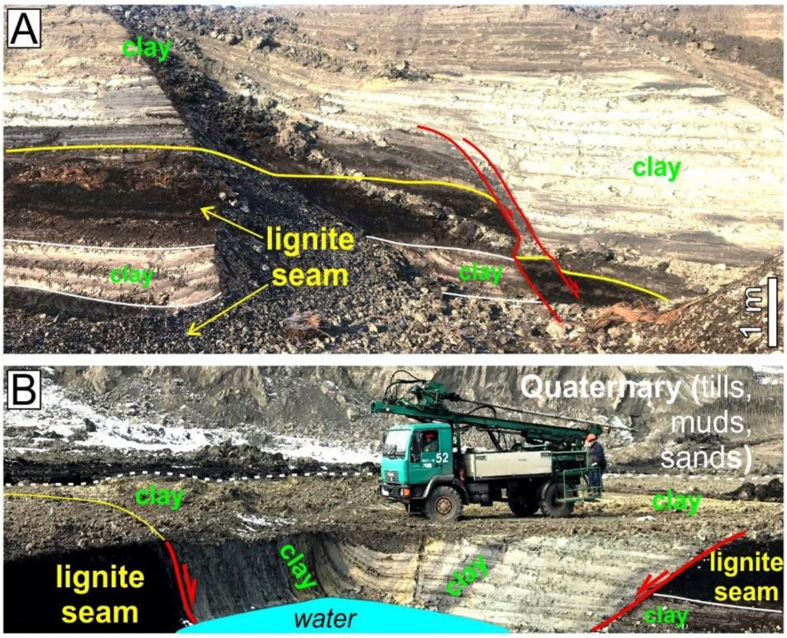

Fig. 5. Faulted lignite seam adjacent to the 'lignite-free' zone (Tomisławice opencast, winter 2023)
Note the step faults in the lignite seam and its overburden (A); Note the steeply sloping overburden clays (B)

Flexural bending and even faulting of both overburden clays, lignite, and clastic interbeddings (sands, clays) into the lignite have been well documented in the field (cf. Fig. 4 and 5). Finally, the Neogene deposits were subjected to Quaternary erosion by Scandinavian ice sheets and/or their meltwaters (Fig. 7C and 7D). Due to the massive, homogeneous structure of the Quaternary deposits (mainly tills at the base), it is difficult to determine the formation age of the studied 'lignite-free' zone. This could have occurred in the Neogene (Fig. 7C) and the Quaternary (Fig. 7D).

The second hypothesis assumes that peat accumulation took place under conditions of equal tectonic subsidence in the studied part of the 'Tomisławice' lignite deposit. Then, ca. 20 m of peat could have formed (Fig. 8A). Of course, uniform compaction (with a ratio of ca. 2.0; Widera et al., 2007; Widera, 2015) led to the creation of the lignite seam with a very uniform thickness, currently ca. 10 m, and lying horizontally under the Neogene overburden clays (cf. Fig. 2, 6, and 8B). In the final stage of forming the 'lignite-free' area, the lignite seam was zonally subsided due to post-depositional tectonic movements (after the middle part of the Mid-Miocene). Similar to the interpretation presented above, it is currently impossible to say with certainty whether the analysed tectonic deformations occurred already in the Neogene or later in the Quaternary (Fig. 8C and 8D).

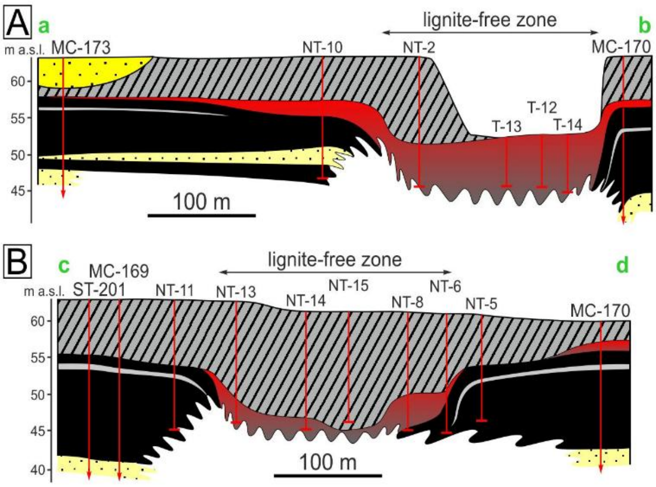

Fig. 6. Geological cross-sections through the 'lignite-free' zone in the Tomisławice opencast based mainly on data from shallow boreholes See Figure 3 for the location of the cross-section lines a–b and c–d; See Figure 2 for explanations.

Discussion

The scenarios for developing the 'lignite-free' zone in the Tomisławice opencast presented in this paper should be considered hypothetical but possible. The lack of lignite in this zone is also of great practical importance. Therefore, the following three questions need to be discussed and answered. First, what should be done to verify the above hypotheses? Second, which one is more likely? And third, whether the unexpected appearance of the 'lignite-free' zone constitutes a real problem for the Konin Lignite Mine?

Similar zones, where the lignite seam is much thicker (twice or more between adjacent boreholes) than in the surroundings and is strongly subsided (even by several dozen metres), are known from many lignite deposits. In Poland, the best examples are the 'Bełchatów' and 'Lubstów' deposits (e.g., Gotowała and Hałuszczak, 2002; Widera and Hałuszczak, 2011; Widera, 2013, 2021, 2024a, 2024b). Such a zone, where the lignite seam was hidden under the Neogene clays, was previously found in the Tomisławice opencast. In this case, however, the borehole data indicated that the lowered lignite roof was related to the compaction of lignite of a greater thickness (Wachocki et al., 2024). Thus, making deeper boreholes in the axial part of the investigated 'lignite-free' zone would allow both hypotheses to be verified. If a bed of lignite >20 m thick was pierced, the first hypothesis would be positively verified (see Fig. 7). On the contrary, if the thickness of the lignite was ca. 10 m, i.e. the same as in the surrounding area, the second proposed hypothesis would be positively verified (see Fig. 8).

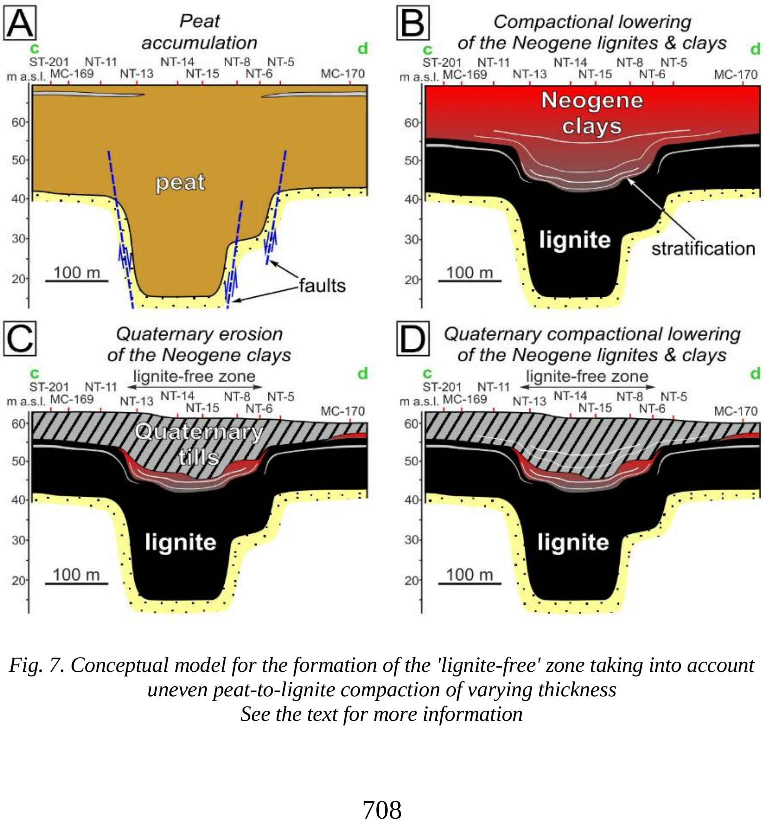

Fig. 7. Conceptual model for the formation of the 'lignite-free' zone taking into account uneven peat-to-lignite compaction of varying thickness See the text for more information

At the current stage of the study, without boreholes piercing the Neogene overburden clays and lignites in the 'lignite-free' zone, the hypothesis of post-depositional tectonic subsidence seems more likely. This opinion is partially supported by at least two facts. Firstly, no lignite thicker than 11.8 m (in borehole MC-170) has been found in the entire area of the 'Tomisławice' deposit (Kozula, 1999, 2001). Secondly, the concave shape of the top of the overburden clays and the Quaternary base indicates post-Neogene tectonic movements (cf. Fig. 6 and 8). However, the erosion along the examined zone during the Pleistocene cannot be ruled out in this case.

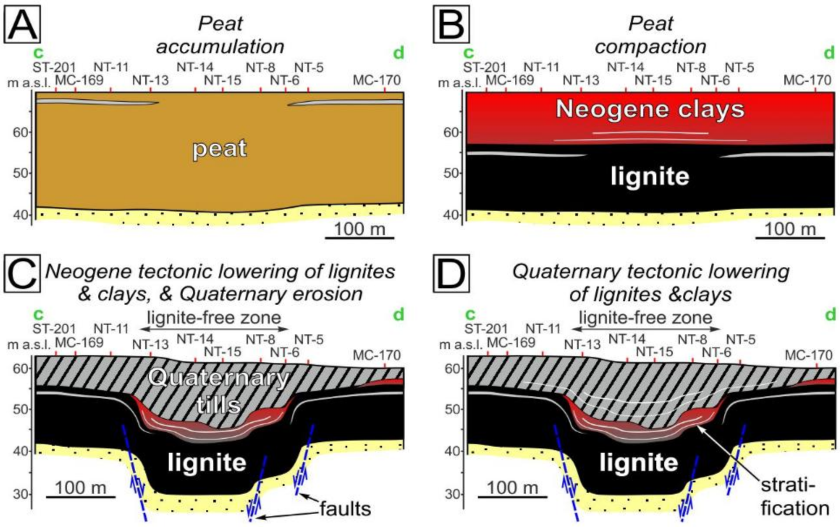

Fig. 8. Conceptual model for the formation of the 'lignite-free' zone taking into account post-depositional tectonic subsidence
See the text for more information

As late as mid-2022, the Konin Lignite Mine operated three opencasts, from which lignite was supplied to the aforementioned Pątnów power plant. At the time when the 'lignite-free' zone in the Tomisławice opencast was identified (at the end of 2022), only two opencasts were operating, one of which finished its mining activity in June 2023. Hence, among other things, the lack of continuous lignite supplies to this power plant has become a very real problem. Therefore, over the last two years (i.e. in 2022 and 2023), significant amounts of lignite (ca. 0.5–1 Mt) have been imported from the Sieniawa Lignite Mine (western Poland), which is over 230 km away from Konin (Widera et al., 2024a, 2024b). It is expensive, although cheaper than lowering the water table by >10 m and potential lignite mining from the studied 'lignite-free' zone. As a result, the electricity produced by the Pątnów power plant is costlier than it could have been if not for the surprising disappearance of the lignite seam in the Tomisławice opencast.

Conclusions

The current paper is both cognitive and practical in nature. The results presented allow the following conclusions to be drawn:

1) During mining activity, the sudden disappearance of the lignite seam occurred at the exploitation level in the Tomisławice opencast (central Poland). As a result of geological mapping, it was determined that the extent of the so-called 'lignite-free' zone was ca. 500 m long and up to 150 m wide. This means that about 0.9 Mt of lignite will not be mined.
2) Available data (mainly too shallow boreholes and mine exposures) did not allow for a clear explanation of the origin of the examined 'lignite-free' zone. Therefore, two scenarios for its creation were proposed – both related to the post-depositional lowering of the roof of the exploited lignite seam by >11 m. The first was associated with peat-to-lignite compaction, and the second concerned late Neogene or Quaternary tectonics.
3) The lack of lignite, which threatens the continuity of its supplies to a nearby power plant, is currently being supplemented with purchases from distant deposits. Of course, this increases electricity production costs, but it is cheaper than mining deep-lying lignite in the so-called 'lignite-free' zone. For the latter, lowering the water table to>10 m should be achieved.
4) Ultimately, the hypotheses for the formation of the 'lignite-free' zone examined in this paper can be verified by deep drillings. Therefore, the authors do not rule out any possibility at this stage of their research.

References

Chomiak, L. (2020). Crevasse splays within a lignite seam at the Tomisławice opencast mine near Konin, central Poland: architecture, sedimentology and depositional model. *Geologos*, 26 (1), pp. 25–37, DOI: 10.2478/logos-2020-0002.

Chomiak, L., Urbański, P. and Widera, M. (2020). Architektura i geneza iłów w górnym poziomie węgli brunatnych formacji poznańskiej (środkowy miocen) – odkrywka Tomisławice k. Konina w środkowej Polsce [Architecture and origin of clays within the upper part of lignites of the Poznań Formation (Middle Miocene) – the Tomisławice lignite opencast mine near Konin, central Poland]. *Przegląd Geologiczny*, 68 (6), pp. 526–534, DOI: 10.7306./2020.19.

Dadlez, R., Marek, S. and Pokorski J. ed. (2000). Mapa geologiczna Polski bez utworów kenozoiku [Geological map of Poland without Cenozoic sediments]. Państwowy Instytut Geologiczny, Warszawa.

Dziamara, M., Kaczmarek, P., Klęsk, J., Wachocki, R., Widera, M., 2023. Facies and statistical analyses of a crevasse-splay complex from the Tomisławice lignite opencast, central Poland. *Geologos*, 29 (3), pp. 173–181, DOI: 10.14746/logos.2023.29.3.17.

Gotowała, R. and Hałuszczak, A. (2002). The Late Alpinie structural development of the Kleszczów Graben (Central Poland) as a result of a reactivation of the pre-existing, regional dislocation. *European Geoscience Union, Stephan Mueller Special Publication Series*, 1, pp. 137–150, DOI: 10.5194/smsps-1-137-2002.

Klęsk, J., Błachowski, A., Diduszko, R., Kruszewski, Ł. and Widera, M. (2022). Iron-bearing phases affecting the colour of upper Neogene clayey sediments from Dymaczewo Stare, west-central Poland. *Geologos*, 28 (2), pp. 129–139, DOI: 10.2478/logos-2022-0010.

Klęsk, J., Błachowski, A., Kruszewski, Ł., Kubiak, M. and Widera, M. (2024). Main colouring minerals in the 'Poznań Clays': Case studies from the upper Neogene in the Polish Lowlands. *Inżynieria Mineralna – Journal of the Polish Mineral Engineering Society*, 53 (1), pp. 145-152, DOI: 10.29227/IM-2024-01-17.

Klęsk, J., Błachowski, A., Kruszewski, Ł., Michalska, D., Mrozek-Wysocka, M. and Widera M. (2023). Colours of the upper Neogene "Poznań Clays" in light of sedimentological, mineralogical and nuclear methods. *Geological Quarterly*, 67 (4), 49, DOI: 10.7306/gq.1719.

Kozula, R. (1999). Dokumentacja geologiczna złoża węgla brunatnego „Tomisławice" w kategorii C1 i C2 , Cześć I – tekst [Geological documentation of the 'Tomisławice' lignite deposit in categories C1 and C2, Part I – text] . Przedsiębiorstwo Geologiczne we Wrocławiu PROXIMA S.A., Wrocław. (in Polish).

Kozula, R. (2001). Dokumentacja geologiczna złoża węgla brunatnego „Tomisławice" w kategorii B i C1 w Tomisławicach, Część I – tekst [Geological documentation of the 'Tomisławice' lignite deposit in categories B and C1 in Tomisławice, Part I – text]. Przedsiębiorstwo Geologiczne PROXIMA S.A., Wrocław. (in Polish).

Piwocki, M. and Ziembińska-Tworzydło, M. (1997). Neogene of the Polish Lowlands – lithostratigraphy and pollen-spore zones. *Geological Quarterly*, 41 (1), pp. 21–40.

Wachocki, R., Dziamara, M., Klęsk, J. and Widera, M. (2024). Comparison of the geology presented in a cross-section and that observed in the field – a lesson from the Tomisławice lignite opencast mine, Konin Basin in central Poland. *Inżynieria Mineralna – Journal of the Polish Mineral Engineering Society*, 53 (1), pp. 417-425, DOI: 10.29227/IM-2024-01-47.

Widera, M. (2007). Litostratygrafia i paleotektonika kenozoiku podplejstoceńskiego Wielkopolski [Lithostratigraphy and palaeotectonics of the sub-Pleistocene Cenozoic of Wielkopolska]. Wydawnictwo Naukowe UAM, Poznań. (in Polish).

Widera, M. (2013). Changes of the lignite seam architecture – a case study from Polish lignite deposits. *International Journal of Coal Geology*, 114, pp. 60–73, DOI: 10.1016/j.coal.2013.02.004.

Widera, M. (2015). Compaction of lignite: a review of methods and results. *Acta Geologica Polonica*, 65 (3), pp. 367–368, DOI: 10.1515/agp-2015-0016.

Widera, M. (2017). Sedimentary breccia formed atop a Miocene crevasse-splay succession in central Poland. *Sedimentary Geology*, 360, pp. 96–104, DOI: 10.1016/j.sedgeo.2017.09.006.

Widera, M. (2020). Slump folds within mid-Miocene crevasse-splay deposits: a unique example from the Tomisławice lignite opencast mine in central Poland. *Geological Quarterly*, 64 (3), pp. 711–722, DOI: 10.7306/gq.1545.

Widera, M. (2021). Geologia polskich złóż węgla brunatnego [Geology of Polish lignite deposits]. Bogucki Wydawnictwo Naukowe, Poznań. (in Polish).

Widera, M. (2022). Zarys geologii okolic Poznania, Turku i Konina [An outline of the geology in the vicinity of Poznań, Turek and Konin]. Bogucki Wydawnictwo Naukowe, Poznań. (in Polish).

Widera, M. (2024a). Cenozoic tectonic evolution of the main lignite-rich grabens in Poland. Part 1. Tectonic stages. *Acta Geologica Polonica*, 74 (1), e2, DOI: 10.24425/agp.2023.148021.

Widera, M. (2024b). Cenozoic tectonic evolution of the main lignite-rich grabens in Poland. Part 2. Tectonics versus autocompaction and compaction. *Acta Geologica Polonica*, 74 (2), e7, DOI: 10.24425/agp.2024.150000.

Widera, M., Jachna-Filipczuk, G., Kozula, R. and Mazurek, S. (2007). From peat bog to lignite seam: a new method to calculate the consolidation coefficient of lignite seams, Wielkopolska region in central Poland. *International Journal of Earth Sciences*, 96, pp. 947–955, DOI: 10.1007/s00531-006-0137-z.

Widera, M. and Hałuszczak, A. (2011). Stages of the Cenozoic tectonics in central Poland: examples from selected grabens. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, 162 (2), pp. 203–215, DOI: 10.1127/1860-1804/2011/0162-0203.

Widera, M., Chomiak, L., Gradecki, D. and Wachocki, R. (2017). Osady glifu krewasowego z miocenu Polski środkowej w okolicach Konina [Crevasse splay deposits from the Miocene of central Poland near Konin]. *Przegląd Geologiczny*, 65 (4), pp. 251–258.

Widera, M., Chomiak, L. and Wachocki, R. (2023). Distinct types of crevasse splays formed in the area of Middle Miocene mires, central Poland: Insights from geological mapping and facies analysis. *Sedimentary Geology*, 443, 106300, DOI: 10.1016/j.sedgeo.2022.106300.

Widera, M., Naworyta, W. and Urbański, P. (2024a). Polish energy sector's dependence on lignite industry: The process of transition. *Journal of Sustainable Mining*, 23 (4), pp. 397-406, DOI: 10.46873/2300-3960.1432.

Widera, M., Urbański, P., Mazurek, S. and Naworyta, W. (2024b). Polish lignite resources, mining and energy industries – what is next? *Gospodarka Surowcami Mineralnymi – Mineral Resources Management*, 40 (2), pp. 5-28, DOI: 10.46873/2300-3960.1432.

Żelaźniewicz, A., Aleksandrowski, P., Buła, Z., Karnkowski, P.H., Konon, A., Ślączka, A., Żaba, J. and Żytko, K. (2011). Regionalizacja tektoniczna Polski [Tectonic subdivision of Poland]. Komitet Nauk Geologicznych Polskiej Akademii Nauk, Wrocław. (in Polish).