Geological Quarterly, 2024, 68, 27
DOI: http://dx.doi.org/10.7306/gq.1755

# Development of a non-perennial to ephemeral fluvial system in a continental fault-bounded basin – an example from the early Permian Krajanów Formation of the Intra-Sudetic Basin (NE Bohemian Massif) – discussion

Paweł Henryk KARNKOWSKI [1, *]

[1] University of Warsaw, Faculty of Geology, Department of Georesources and Economic Geology, Żwirki i Wigury 93, 02-089 Warszawa, Poland; ORCID: 0000-0003-1168-3786

Karnkowski, P.H., 2024. Development of a non-perennial to ephemeral fluvial system in a continental fault-bounded basin – an example from the early Permian Krajanów Formation of the Intra-Sudetic Basin (NE Bohemian Massif) – discussion. Geological Quarterly, 68, 27; https://doi.org/10.7306/gq.1755

One of the problems of the article discussed appears in the first sentence: The term "member" is not used in the text, although it should be. This is explained further in the discussion. Numerous problematic issues are present in this article, which have prompted this discussion, aimed at helping to clarify and organise many of the issues identified.

Kowalski and Furca (2023) used a sedimentological analysis as a primary research method, applied extensively to seven field stratigraphic profiles (their figs. 4–10). In addition, a geological profile from the Świerki IG 1 borehole, located in the study area, was used (their figs. 2, 5 and 11C). A detailed examination of the location of these points on figures 2 and 11C (Kowalski and Furca, 2023) shows discrepancies in their relative positions. For example, point 2 is shown to the west of the Świerki IG 1 borehole in one figure, while it is positioned to the north-east in another figure. The overlay of figures 2 and 11C (Kowalski and Furca, 2023) using *ArcGIS* software makes these inconsistencies even clearer. Although figure 11C is labelled "not to scale", the discrepancies are so great that neither figure provides a reliable way to accurately locate these points in the field. Fortunately, Kowalski and Furca, 2023 were meticulous enough to include topographic sketches of the sedimentological profiles studied. I successfully transferred the locations to a detailed topographical base map and confirmed that the positions of sampling points 1–7 are accurate based on the topographical sketches provided. With the exact coordinates in hand, I correlated these points with those shown in figures 2 (Kowalski and Furca, 2023) and 11C (Kowalski and Furca, 2023). The results can be seen in Figure 1, where both maps (Kowalski and Furca, 2023, figs. 2 and 11C) are overlaid with the locations derived from the topographic sketches. These two maps are fitted into the frame of points 1–7 using *ArcMAP*, thereby matching the existing maps as closely as possible to the exact frame of the sample points. This process inevitably leads to a deformation of the input maps, depending on the misalignment of the base points on these maps with the reference points. The resulting image (Fig. 1) contains three groups of sample points: points from figure 2 (Kowalski and Furca, 2023) (large numbers on yellow oval background), points from figure 11C (Kowalski and Furca, 2023) (small numbers on yellow oval background) and points based on the detailed site sketches (small numbers on green background).

The extent of these discrepancies can be determined by comparing the different locations. The discrepancies between the points on the palaeogeographic map (Kowalski and Furca, 2023, fig. 11C) and the points on the location sketches are relatively small. To achieve this harmonisation, the software had to transform the original map (Kowalski and Furca, 2023, fig. 11C), mainly by vertically shifting the edges. Is this "deformed" map (Fig. 1) – palaeogeographic map accurate? Two arguments speak for this: the almost congruent position of the points from the sketches and the palaeogeographic map as well as the central positioning of the "Anthracosia Lake" within the Intra-Sudetic Basin, which correlates with known lacustrine deposits in the form of the Walchia Shale (Wołkowicz, 1988). In addition, the transport directions marked on the map as "axial drainage" correspond well with established palaeogeographic models. On this "deformed" map (Fig. 1), transport directions have been slightly altered, suggesting that transport direction considerations based on field studies may need to be revised with respect to the original palaeogeographic map (Kowalski and Furca, 2023, fig. 11C).

All further discussion in this analysis will be based on maps with verified locations of sampling points 1–7. In this context, the Świerki IG 1 borehole plays a crucial role in Kowalski and Furca (2023). This borehole provides a geological profile delineating the Krajanów Formation together with the underlying and overlying strata, including the lower and upper Anthracosia Shale layers. These layers position the profile under investigation, which has a thickness of >400 m. In contrast, the combined thickness of the seven profiles analysed in Kowalski and Furca (2023) is ~40 m, which is ~10% of the thickness of the Krajanów Formation.

* E-mail: Karnkowski@uw.edu.pl

Received: June 20, 2024; accepted: June 21, 2024; first published online: September 20, 2024

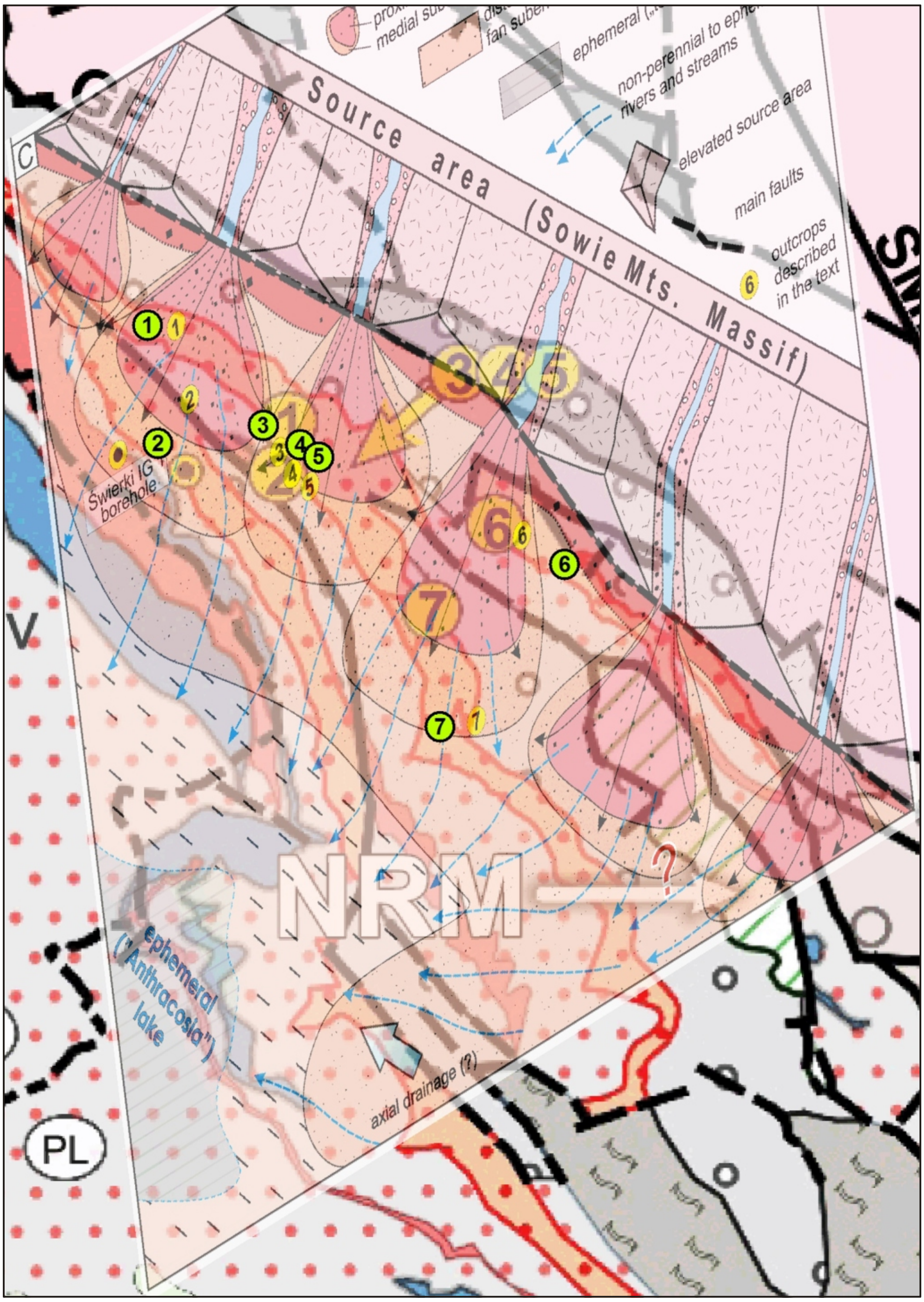


**Fig. 1. Location of the same research points (outcrops) placed on the maps in the paper by Kowalski and Furca (2023, figures 2, 6, 7, 11C)**

Large points with a yellow background from figure 2, small dots with green background from figures 6 and 7, small dots with yellow background – figure 11C; other explanations in the text

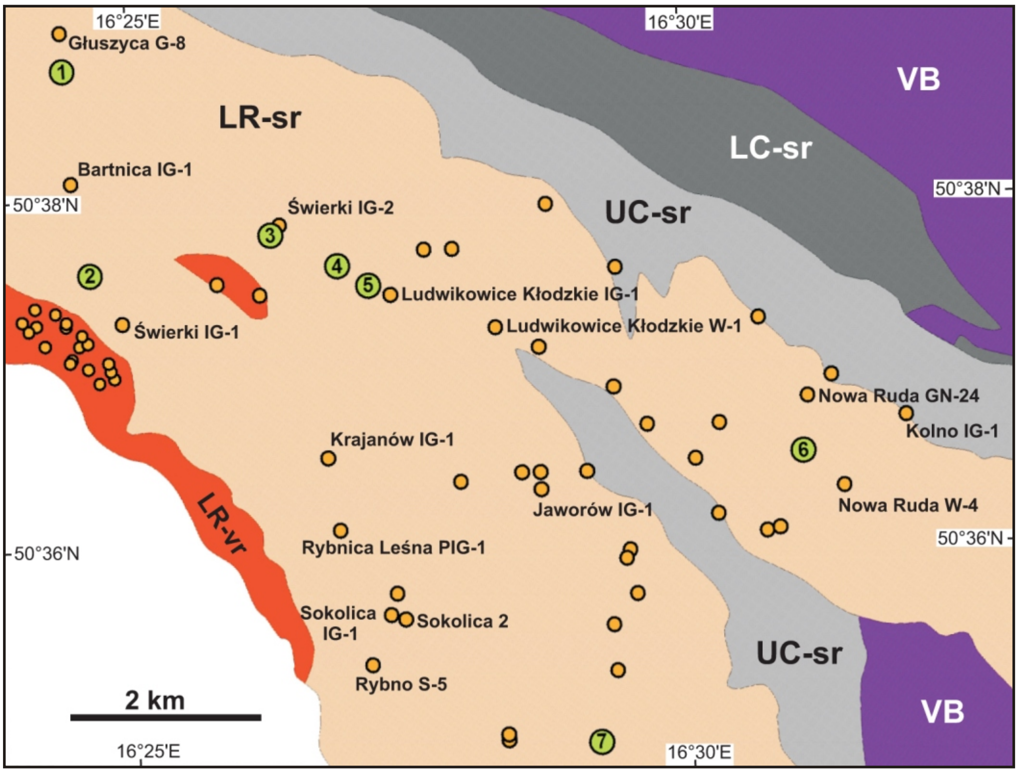


**Fig. 2. Location of research points (1–7) from the paper of Kowalski and Furca (2023) and boreholes penetrating Rotliegend formations against the background of a simplified geological map of the research area discussed**

Named boreholes are usually fully cored and are ideal for regional, quantitative and qualitative geological studies; VB – Variscan basement, LC-sr – Lower Carboniferous sedimentary rocks, UC-sr – Upper Carboniferous sedimentary rocks, LR-sr – Lower Rotliegend sedimentary rocks, LR-vr – Lower Rotliegend volcanic rocks; other explanations in the text

In addition, I have marked all boreholes in the study area (Fig. 2). Some boreholes are shallow and were drilled primarily to document volcanic rocks for quarrying. Others were drilled to explore and document coal deposits. However, there are several boreholes with complete coring that comprehensively document the Rotliegend strata. Among these, Świerki IG 1 is particularly noteworthy, as are the boreholes labelled by name on the map. The profiles from these boreholes not only facilitate qualitative sedimentological analysis, but also enable the creation of quantitative isopach and lithofacies maps for individual formations.

Thanks to these boreholes (planned, supervised, described and analysed mainly by Mieczník, 1988, 1989) it is possible to extend our geological understanding of the Rotliegend strata of the Intra-Sudetic Basin. Given the extensive documentation provided by the complete geological profiles of the Rotliegend strata in the study area, it seems illogical to integrate partial surface profiles of points 1–7 (Kowalski and Furca, 2023, fig. 5) into the complete profile of the Świerki IG 1 borehole. For example, the Świerki IG 2 borehole is located near point 3, the Głuszyca G-8 borehole near point 1 and the Nowa Ruda GN-24 and Nowa Ruda W-4 boreholes near point 6.

The surface sedimentological measurement points (1–7) represent only a very small part of the overall profile. For regional and palaeogeographical considerations, it makes more sense to use complete profiles than partial profiles. This is shown by the palaeogeographic map (Kowalski and Furca, 2023, fig. 11C), which is only supported by surface sedimentological investigations with a focus on conglomeratic and sandy lithofacies. Meanwhile, the map also includes clayey lithofacies described as playa and Lake Anthracosia environments. On the basis of figure 11C (Kowalski and Furca, 2023), I created a palaeogeographic map (Fig. 3PM), which was used to create two conceptual palaeogeographic cross-sections. The first cross-section (Fig. 3CS-1) is based directly on the data from the palaeogeographic map (Fig. 3PM). This cross-section shows the time window of the palaeogeographic framework corresponding to the map, where the lithofacies (sedimentary environment) comprises the clayey lake deposits labelled "ephemeral Anthracosia Lake." However, the palaeogeographic map (Fig. 3PM) represents only the lower and middle part of the Krajanów Formation profile.

If this representation were correct, the " Anthracosia Lake" would have existed during the sedimentation of the middle part of the Krajanów Formation and would have continued to the level of the upper Anthracosia Shale. In reality, however, things are different. The Anthracosia layers (lower and upper) have a small thickness, but a considerable lateral extension (Wójcik-Tabol et al., 2021; Dąbek-Głowacka et al., 2024). This situation is illustrated in the second palaeogeographic cross-section (Fig. 3CS-2), in which the " Anthracosia Lake" cannot be considered for the palaeogeographic time window of the middle part of the Krajanów Formation profile. The central part of the basin of the Krajanów Formation was occupied by lake deposits, but these were playa-type lakes filled with red clay deposits. The extent of these deposits was smaller in the early phase of

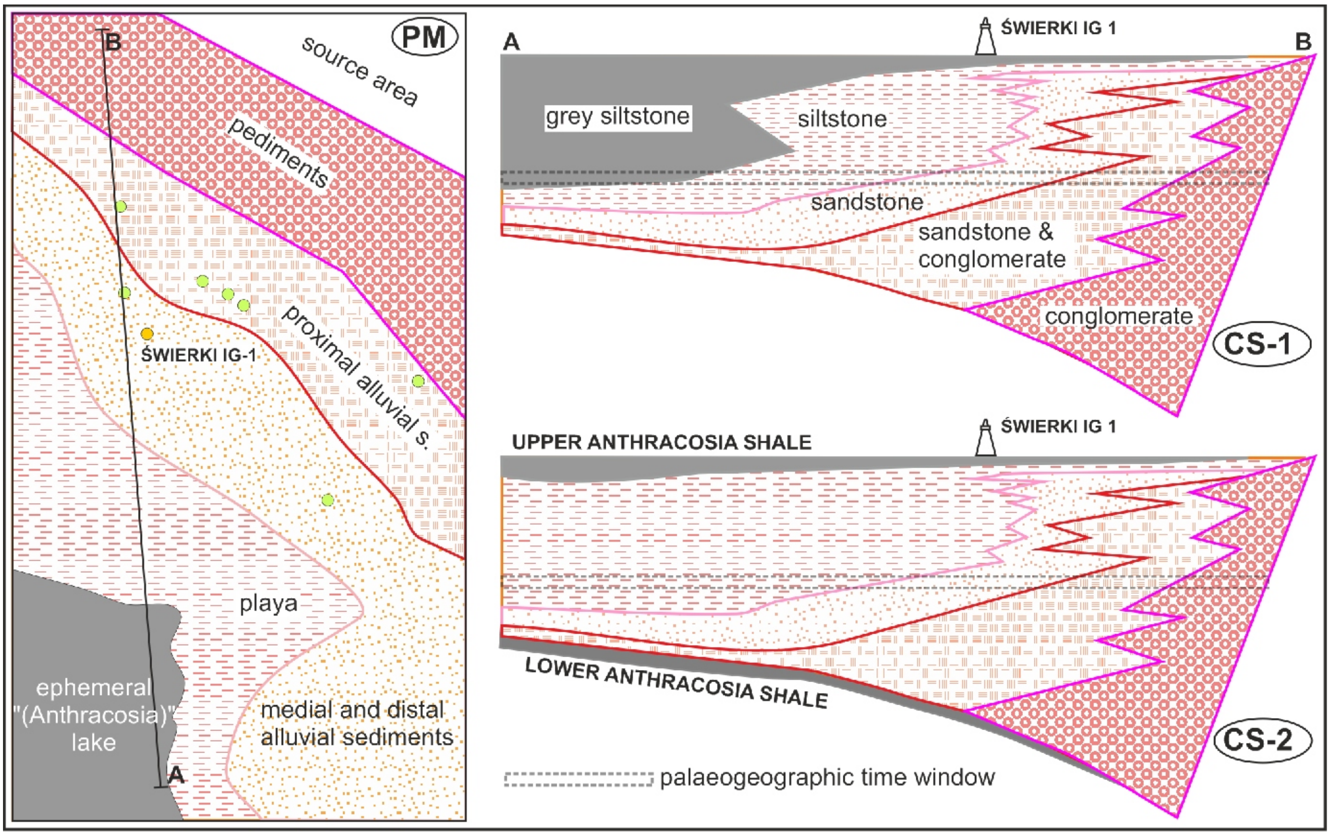


**Fig. 3. Simplified palaeogeographic map (PM) adapted from Kowalski and Furca (2023, fig. 11C), with two conceptual palaeogeographic cross-sections (CS-1 and CS-2) derived from the same map and data from the Świerki IG 1 borehole cores**

Additional explanations are provided in the text

the Krajanów Formation development, but had a much larger lateral extent in the late and final phase. This can be easily seen by comparing the borehole profiles of Świerki IG 1 and Świerki IG 2, which are very similar in both cases.

Therefore, the palaeogeographic map of the upper part of the Krajanów Formation would primarily represent a playa environment. Alluvial deposits are overlain by lake deposits, and a comprehensive palaeogeographic map of the Anthracosia Lake period (which is short-lived but significant) would complete this picture. To show the variability and evolution of the Krajanów Formation, at least three palaeogeographic maps should be shown.

It is appropriate to return to the first sentence of this discussion, in which I emphasised the use of the lithostratigraphic term "member" in the context of the Krajanów Formation. This formation is delineated by the extent of the lower and upper Anthracosia Shale. The primary lithological types constituting this formation are predominantly sandstones with subordinate conglomerates in the lower part and predominantly clayey lithofacies in the upper part. This bipartite division is reflected in the geological map for the Ludwikowice Kłodzkie sheet (Krechowicz and Kisielewski, 1964). The map describes the units as follows: "lower unit – quartzite conglomerates with lydites at the base; and upper unit – sandstones and shales with intercalations of Anthracosia shales and limestones (horizon of upper Anthracosia shales)." From a lithostratigraphic point of view, the Krajanów Formation comprises these two different components. Despite their practical application in the geological mapping of the Ludwikowice Kłodzkie sheet (Krechowicz and Kisielewski, 1964), these members have never been formally or informally named. As mentioned above, a single palaeogeographic map is not sufficient to illustrate the development of the Krajanów Formation. Therefore, at least two palaeogeographic maps are required. One map should depict the playa-dominated environment, with annotations indicating that at times this environment transformed into an organic-rich lake (algal blooms) and the surrounding areas developed soil horizons. This concept is illustrated in Figure 4, where the lithofacies are colour-coded and the boundaries of the allostratigraphic units are delineated by lake horizons rich in organic matter (Anthracosia Shale). The corresponding soil horizons should be identified in the areas surrounding the lake environment.

In the early 1980s, the American Stratigraphic Code was published, which prompted me to advocate the inclusion of allostratigraphic units in the Polish stratigraphic guidelines (Karnkowski, 1986a, 1987a). However, Dadlez (1987) argued that the simultaneous use of lithostratigraphic and allostratigraphic units was unnecessary. By contrast, Szulczewski (1986) recognised the rational potential for the use of allostratigraphic units.These discussions enabled me to publish a formalised version of almost all the previously proposed lithostratigraphic units (Karnkowski, 1987c). I also presented the results of a facies analysis of the Wielkopolska Subgroup (Karnkowski, 1987b) in the northern part of the Fore-Sudetic Monocline, based on the lithostratigraphic framework I had initially proposed (Karnkowski, 1977, 1981). My views on the stratigraphy of the Rotliegend were finally summarised (Karnkowski, 1999) and complemented the formalisation of the lithostratigraphic units in the Polish Basin that had been started earlier (Karnkowski, 1994).

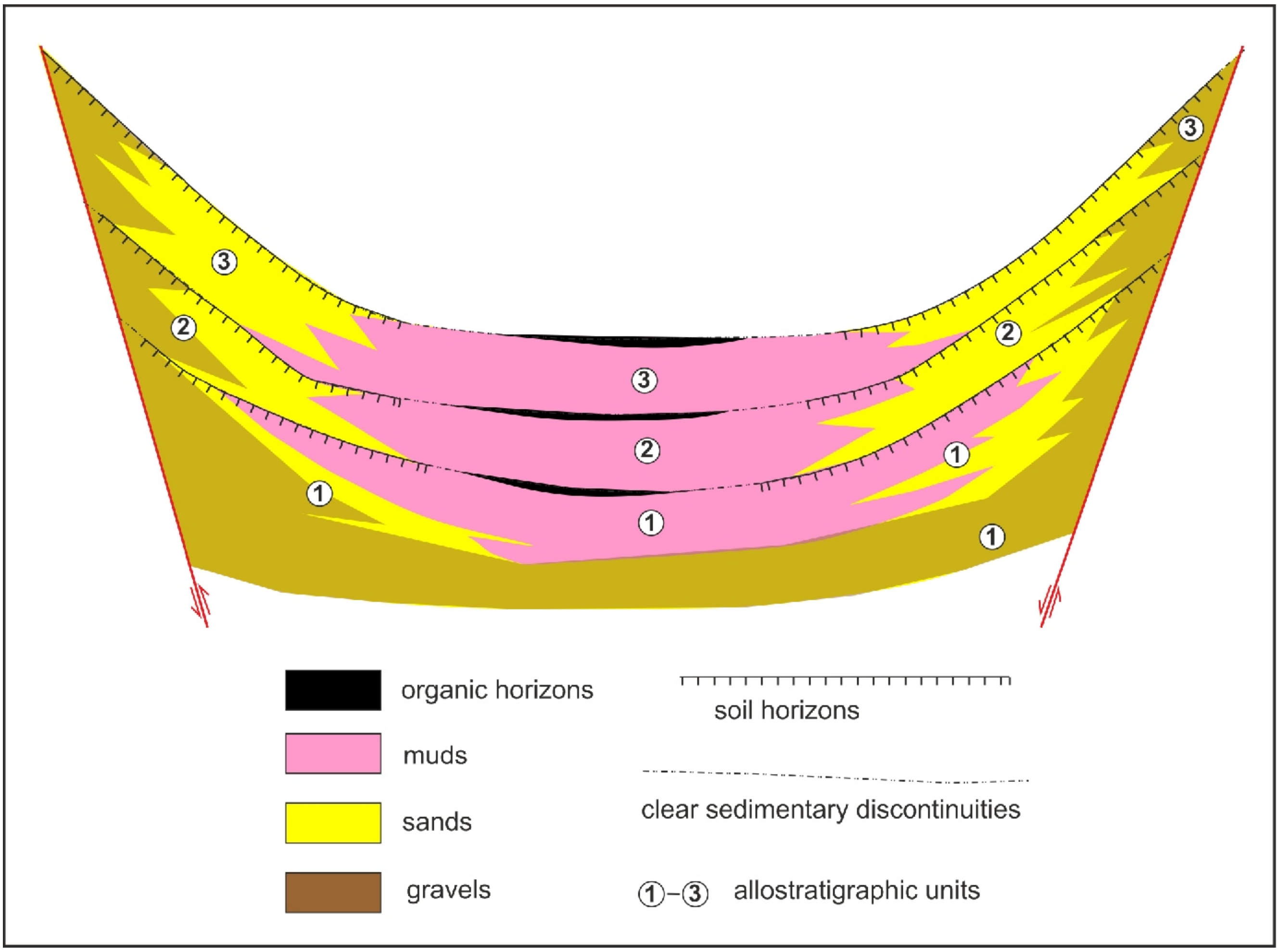


**Fig. 4. The conceptual model of lithofacies distribution and deposition of fluvial and lacustrine sediments in the Intra-Sudetic Basin during the Stephanian C-Autunian**

The Wielkopolska Subgroup, which corresponds to the upper part of the Rotliegend in the Polish Basin, was not only analysed lithostratigraphically, but also divided into six depositional sequences based on climatic and tectonic influences. A palaeogeographic map was created for each sequence (Karnkowski, 1999). These sequences are described in several steps: first as allostratigraphic units, followed by the identification of depositional systems between the boundaries of the allostratigraphic units (dynamic stratigraphy) and finally the sedimentological characterisation of the formation and development of the individual depositional sequences. A depositional system is defined as a three-dimensional ensemble of genetically related lithofacies that requires lithological characterisation.

At this level of detail, formal lithostratigraphic units are not required; working units (dynamic stratigraphy methodology) are sufficient to create a model of the depositional sequence.

In the Intra-Sudetic Basin, stratigraphic questions of the Rotliegend have been intensively investigated, especially in the 1980s and 1990s. During this period, several articles were published in which a differentiation of the lithostratigraphic units was proposed (Nemec, 1978; Nemec et al., 1982; Miecznik, 1989; Dziedzic and Teisseyre, 1990). A common feature of these proposals is the naming of cyclic sedimentary units (sedimentary sequences) with lithostratigraphic terms (formations, members). For example, the Krajanów Formation was defined (Nemec et al., 1982), which was recognised in the publication by Dziedzic and Teisseyre (1990) as the Świerki Formation in the Nowa Ruda region and as the Unisław Formation in the Wałbrzych region. In addition, the Świerki Formation was divided into two parts by Miecznik (1989): the Ludwikowice Member and the Krajanów Member.

In my opinion, all these complications and ambiguities are due to the attempt to force cyclic sedimentation units into the framework of lithostratigraphy. This probably explains the efforts of Kowalski and Furca (2023) to represent the complex sedimentation of the Krajanów Formation (after Nemec et al., 1982) on a single palaeogeographic map (Kowalski and Furca, 2023, fig. 11C).

In view of these observations, two review papers dealing with the question of the simultaneous application of lithostratigraphic and allostratigraphic (depositional sequences) units are relevant. The first is by Porębski (1996), who stated that “The key aspects of sequence stratigraphy are to understand the role of chronostratigraphic units in correlation, the role of cyclicity in sedimentary sequences, and the fundamental importance of fluctuations in the position of the erosional base for understanding the stratigraphic architecture of sedimentary basins”. Furthermore, figure 2 in Porębski (1996) is entitled: “Categorisation of the sedimentary sequence in terms of lithostratigraphy, allostratigraphy and sequence stratigraphy”.

In the second publication, Pieńkowski (2009) emphasised that "the integration of lithostratigraphy – a common practice in the geological sciences, fundamental for geological mapping and resource exploration – with the description of correlatable boundaries, essential for the identification of sedimentary cycles and depositional sequences, represents one of the great syntheses of the geological sciences in recent decades." In the same publication, Pieńkowski (2009) referred to the work of Dadlez (1987), who criticised the simultaneous use of lithostratigraphy and allostratigraphy. To illustrate his point, he added a figure (Dadlez, 1987, fig. 1) to show the identification of sedimentary cycles as lithostratigraphic units. This very figure was included in Pieńkowski's work (2009) entitled "Diagram of the principles of allostratigraphy".

In the description of figure 1 of Kowalski and Furca (2023), entitled "Generalised facies map and extent of the Lower Permian in the NE Bohemian Massif and Central Western Europe", names are not used for facies (lithofacies), but for sedimentary environments. It is therefore essentially a palaeogeographical map of the Lower Permian (Rotliegend), which lasted almost 40 million years, and shows the extent of the sedimentary basins of this interval. The basins in the Bohemian Massif (their extent and lithofacies are taken from Pešek et al., 1998) represent the maximum extent of the Upper Carboniferous (Stephanian C) and Autunian lithofacies. By contrast, the Polish Rotliegend Basin represents the final phase of clastic sedimentation in terrestrial environments, shortly before the Zechstein transgression. This is evidenced by the dune fields, that show their greatest extent during this time. Therefore, the palaeogeographic map (Kowalski and Furca, 2023, fig. 1) combines images from different time periods. Kowalski and Furca (2023) focused on the beginning of the Rotliegend (Krajanów Formation) and extended their palaeogeographic map beyond the Intra-Sudetic Basin.

It is important to keep to the time frame relevant to the emergence of the Krajanów Formation. The starting point for this analysis is the works of Czech geologists (Holub, 1972; Pešek et al., 1998; Martinek and Štolfová, 2009; Zajic, 2014; Opluštil et al., 2016), especially the palaeogeographic maps they have produced. The most useful map is the palaeogeographic map for the Stephanian C-Autunian period (Pešek et al., 1998) which covers the entire Czech region, essentially the entire Bohemian Massif. In this discussion I have used data from these maps and included a simplified version in Figure 5.

As is easy to see, I have distinguished only two palaeogeographic environments for the Czech territory: the playa and the fluvial sedimentation environment. The fluvial sediments consist mainly of sandy and conglomeratic lithofacies. The present map (Fig. 5) may appear somewhat unusual, as it clearly consists of two parts. The southern part (Czech) was created by Czech geologists, while the northern part (Polish) was prepared by me (Karnkowski, 1999), although it also incorporated my earlier works (Karnkowski, 1977; Karnkowski and Rdzanek, 1982). The maps used in this compilation (Fig. 5) correspond to a similar time window: Stephanian C – Autunian.

Why have I not created a unified map in a similar manner? Drawing such a map would require a separate article to explain the many details that distinguish the Polish and Czech territories. Firstly, in Poland most of the data comes from deep boreholes. Only the outcrops around the Intra-Sudetic Synclinorium and the southern outcrops of the North Sudetic Synclinorium are accessible for field studies. Therefore, I have marked the areas where the Dolsk Formation (corresponding to the Świerzawa Formation in the North-Sudetic Basin) is documented, as well as the probable extents of the local Late Carboniferous and Early Permian sedimentary basins.

This explanation and warning is necessary because the current extent of the Dolsk Formation is much smaller than its original boundaries in the local sedimentary basins. This is due to the strong erosion before and after the Permian volcanism and during the formation of the Wielkopolska Subgroup (Upper Rotliegend). This erosion mainly affected the area of the Wolsztyn Ridge, which did not yet exist at the time of the transition from the Carboniferous to the Permian. Its formation and palaeotectonic activity led to considerable erosion not only of the Permian volcanic rocks, but also of the deposits of the Dolsk Formation protected by them. Therefore, the separation between the Wielkopolska Basin and the Lower Silesian Basin shown on the map (Fig. 5) is hypothetical. A similar situation exists between the North Sudetic Basin and the Lower Silesian Basin. Here, too, there were active palaeotectonic elements during the Upper Rotliegend (known today as the Żary Pericline). The separately labelled Pomeranian Basin correlates with the profiles of the Dolsk Formation and is therefore also included here.

Of particular interest is the Laskowice Graben, also known as the Eastern Sudetic Basin, where the thickness of the Permian clastic deposits exceeds 1000 m, with the sequences corresponding to the Dolsk Formation exceeding 400 m in thickness. The depocentre was located in the southern part of the basin, and its depositional architecture reflects a multi-stage tectonic and climatic evolution. Four sequences can be distinguished, the first two of which are dated to the latest Carboniferous and Autunian (Kiersnowski, 1983). This basin is relatively well documented by numerous boreholes, so that the outline of a playa lake from the earliest Permian can be described (Fig. 5).

The Intra-Sudetic Basin, probably formed by tectonic movements during the Bretonian phase, is a geological structure ~60 km long and 25 km wide (Augustyniak and Grocholski, 1968). Its infill consists mainly of Carboniferous strata, with Permian rocks constituting up to 10% of the total sedimentary succession. The Rotliegend basin in the Intra-Sudetic Basin overlies an older, intermontane basin of Carboniferous age (Dziedzic and Teisseyre, 1990). The Glinik Formation (Ihnatowicz, 2005) is considered the beginning of the Rotliegend deposits and represents a transitional element between the typical coal-bearing Namurian-Westphalian deposits and red beds of the Stephanian C-Autunian stages (Jerzykiewicz, 1987). The Rotliegend deposits in the Intra-Sudetic Basin form megacycles with a thickness of 250–300 m (Bossowski and Ihnatowicz, 1994). A complete megacyclic sequence consists of alluvial fan deposits (occurring only at the basin margins), fluvial and lacustrine deposits (Dziedzic, 1959, 1961; Wojewoda and Mastalerz, 1989). These megacyclothems are interpreted as products of uneven, episodic subsidence associated with tectonic events (Aleksandrowski et al., 1986). In times of tectonic stability, when the basin floor subsided gradually and slowly, autocyclic processes determined the sedimentation rates. The effects of slow climatic changes, which are well reflected in the successive levels of lacustrine deposits, indicate a gradual aridification of the climate (Dziedzic, 1961; Wojewoda and Mastalerz, 1989).

Although the North Sudetic Basin formed much later than the Intra-Sudetic Basin, the characteristics of the Stephanian C and Autunian deposits are very similar in both basins (Ostromęcki, 1973; Milewicz, 1985; Mastalerz et al., 1993). Again, two megacycles are distinguished beneath the volcanic rocks, which are overlain by a lacustrine facies known as the Lower and Upper Anthracosia Shale (Świerzawa Formation). The main components of the two megacycles are fluvial and lacustrine deposits (Mastalerz and Nehyba, 1997). The Świerzawa Formation is overlain by volcanic rocks of the Wielisławka Formation.

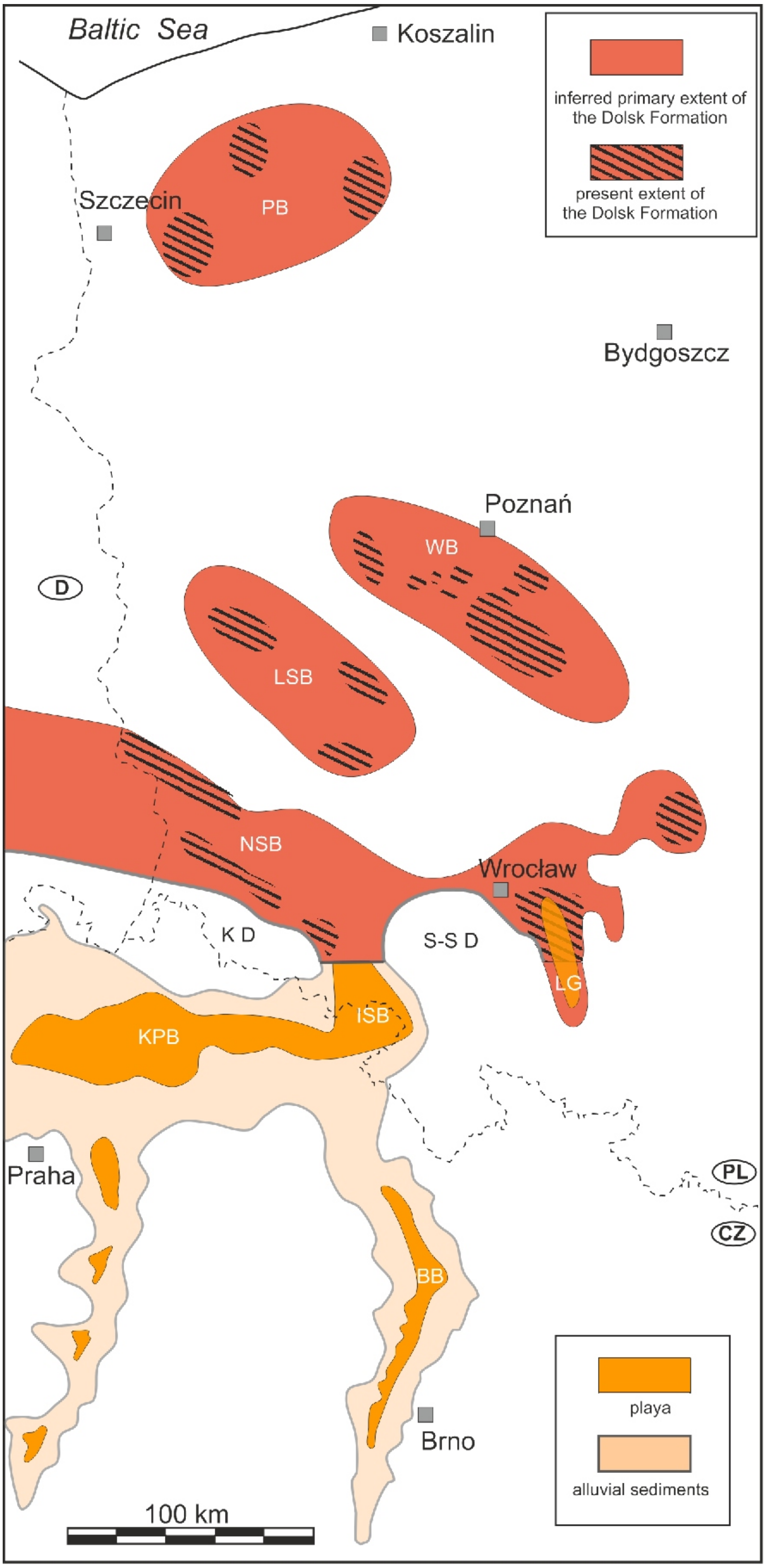


**Fig. 5. Palaeogeographic map of the latest Carboniferous (Stephanian C) and Autunian (Gzehlian\Asselian, ~299–297 Ma)**

Sedimentary basins: BB – Boskovice, KPB – Krkonoše Piedmont, ISB – Intra-Sudetic, NSB – North-Sudetic, LG(ESB) – Laskowice Graben (East-Sudetic), LSB – Lower Silesia, WB – Wielkopolska, PB – Pomerania; Palaeotectonic uplifts: KD – Krkonoše Dome, S-SD – Strzegom-Strzelin Dome (Polish Basin after Karnkowski, 1999; Bohemian basins after Holub, 1972; Pešek et al., 1998; Zajic, 2014; Opluštil et al., 2016); additional explanations are provided in the text

The Lower Silesian Basin is located to the north of the North Sudetic Basin, between the Wielkopolska Basin and the North Sudetic Basin. During the pre-volcanic Rotliegend period, when the Wolsztyn Ridge and the Fore-Sudetic Block did not yet appear in the palaeomorphology, similar sedimentary conditions probably prevailed in these basins. The megacycles identified in the Lower Silesian Basin are not as evident, which could be due to later erosion or incomplete core data. Nevertheless, there is a clear transition from grey and black to red and brown deposits at the beginning of Rotliegend sedimentation in the Late Stephanian.

North of the Lower Silesian Basin, I have also identified the Wielkopolska Basin (the stratotype area for the Dolsk Formation) and the Pomeranian Basin (Fig. 5). In all these regions, sequences of grey and black clastic deposits gradually change to red and dark brown colours under the volcanic rocks.

It is important to emphasise that during the latest Carboniferous and early Permian (Stephanian C–Autunian) palaeotectonic structures such as the Wolsztyn Ridge, the Mid-Polish Trough and the Fore-Sudetic Block did not yet exist. At the border between Poland and the Czech Republic, the palaeotectonic and palaeogeographic landscape was dominated by two large massifs and their Paleozoic sedimentary and metamorphic cover layers, referred to here as the Karkonoše Dome and the Strzegom-Strzelin Dome (Fig. 5). These massifs are of fundamental importance for the Permian palaeogeography at the southwestern border between Poland and the Czech Republic.

The reconstruction of the development of the Polish Permian Basin during the Rotliegend period begins with the pre-volcanic and volcanic phases that precede the formation of the Polish Basin. The Silesian Subgroup, which includes the Dolsk Formation and the Wyrzeka Volcanic Formation, formed before the establishment of the structural framework of the Polish Basin. A detailed analysis of these formations and their transformations sheds light on the successive phases that marked the transition from the Variscan geological pattern to the new Permo-Mesozoic basin. The early Rotliegend period was characterised by extensive restructuring of Late Carboniferous structures, which eventually led to the formation of epicontinental sedimentation within the Polish Permian Basin (Karnkowski, 1999). Recently, detailed petrological studies by Lützner et al. (2020) and Awdankiewicz (2022) have shown that volcanic processes in the Lower Rotliegend started almost at the beginning of the Permian and lasted only a few million years. In such a situation, the Krajanów Formation, which lies beneath the Lower Permian volcanics in the Intra-Sudetic Basin, can be fully assigned to the Stephanian C and the oldest part of the Autunian (Gzhelian\Asselian).

Having discussed figure 1 (Kowalski and Furca, 2023) in a palaeogeographic and temporal context (Stephanian C–Autunian) in this article, it is also important to consider this map in the context of the Late Rotliegend period to illustrate how different the landscape was at the end compared to the beginning. This map corresponds to Sequence 6, referred to as the Pre-Zechstein Sequence (Karnkowski, 1999), as it is associated with the final phase of clastic sedimentation in the Polish Rotliegend Basin. It is overlain by marine Zechstein deposits. During this phase of Polish Basin development, the paleogeography of the basin changed significantly: the extent of aeolianites distinctly enlarged towards the Lower Silesia area (Fig. 6). In my opinion (Karnkowski, 1999), this change was not due to an exceptional event (aeolian sedimentation had continued since the beginning of the main dry sequence in the Poznań region), but resulted from an increased subsidence rate in the eastern part of the Lower Silesian sub-basin. This subsidence created a favourable hydrological system (linked with the Intra-Sudetic Basin) with a shallow underground water table, which enabled the former dune fields to be preserved by their overburden. The invading Zechstein Sea flooded various older deposits, including the clayey sediments of the central lake, dune fields with dunes several tens of metres high, fluvial deposits and areas devoid of Rotliegend deposits such as the Wolsztyn Ridge (Karnkowski, 1986b, 1995, 1999). The rapidly transgressing sea only partially destroyed the former landscape. Remnants of this preserved landscape are visible in copper mines in the Lower Silesia region and can be reconstructed on the basis of seismic and drilling data in the Wielkopolska region (Karnkowski et al., 1997). The area of the Intra-Sudetic Basin was probably a catchment area in which the water flowing and infiltrating north of Wrocław stabilised the emerging dune fields. These dune fields extended to the south beyond the present-day extent of the Fore-Sudetic Block, which only became a significant palaeogeomorphological feature in the Late Cretaceous.

The extent of the dune fields in the southern part of the Polish Basin shown in figure 1 (Kowalski and Furca, 2023) is based on the paper of Kiersnowski (2013). However, it is inappropriate to limit the extent of these dune fields to the northern fault of the Fore-Sudetic Block, as this block did not exist as a palaeotectonic element during the Permian. This question is well addressed in studies on the palaeogeography of the Late Rotliegend, which show the extension of the dune fields not only in Lower Silesia, but also in the Wielkopolska area (Pokorski, 1989, 1998; Karnkowski, 1986b, 1995, 1999). In addition, studies on the evolution of the early Zechstein in Poland provide evidence for the distribution of different cyclothems, which show that the Fore-Sudetic Block had no influence on facies differentiation and thickness variations as the early Zechstein deposits formed (Peryt, 1978; Wagner, 1994; Kowalski et al., 2018a, b). In the meantime, evidence of the formation of alluvial deposits of lesser thickness can be observed in the Bohemian Massif for this time interval (cf. Fig. 6).

Finally, I would like to draw attention to certain terms used in the title of the article, specifically: "ephemeral," "non-perennial," and "continental fault-bounded basin." "Ephemeral" and "non-perennial" are terms used to describe water bodies or streams based on the duration of their flow and the presence of water. Ephemeral streams are temporary bodies of water that only flow in response to specific weather events. Their flow rate is highly dependent on seasonal weather patterns and they can be dry for extended periods between rainfall events. Non-perennial streams flow sporadically but over a longer period of time and may have more stable channels and water levels during dry periods. Non-perennial water bodies are common in regions with seasonal rainfall fluctuations or in areas with intermittent groundwater sources. Kowalski and Furca (2023) used only once the term "non-perennial" – in the title of the article, and the term 'ephemeral' is used only as 'ephemeral lake' in relation to the study area "(also only once). Is the illustration of these differences in figure 11A and 11B shown without the terms that play a role in the title of the article? Since the distinction between these two states depends on the "duration of flow and the presence of water, it is not necessarily shown in figure 11A and 11B, which could explain the absence of the terms "non-perennial" and "ephemeral" in the captions and explanations.

A "continental fault- bounded basin" can be defined as "a large-scale depression typically surrounded by higher features such as mountain ranges. This basin can have been formed by tectonic processes such as faulting" The inclusion of terms in the title that refer to the influence of climate and tectonics on the

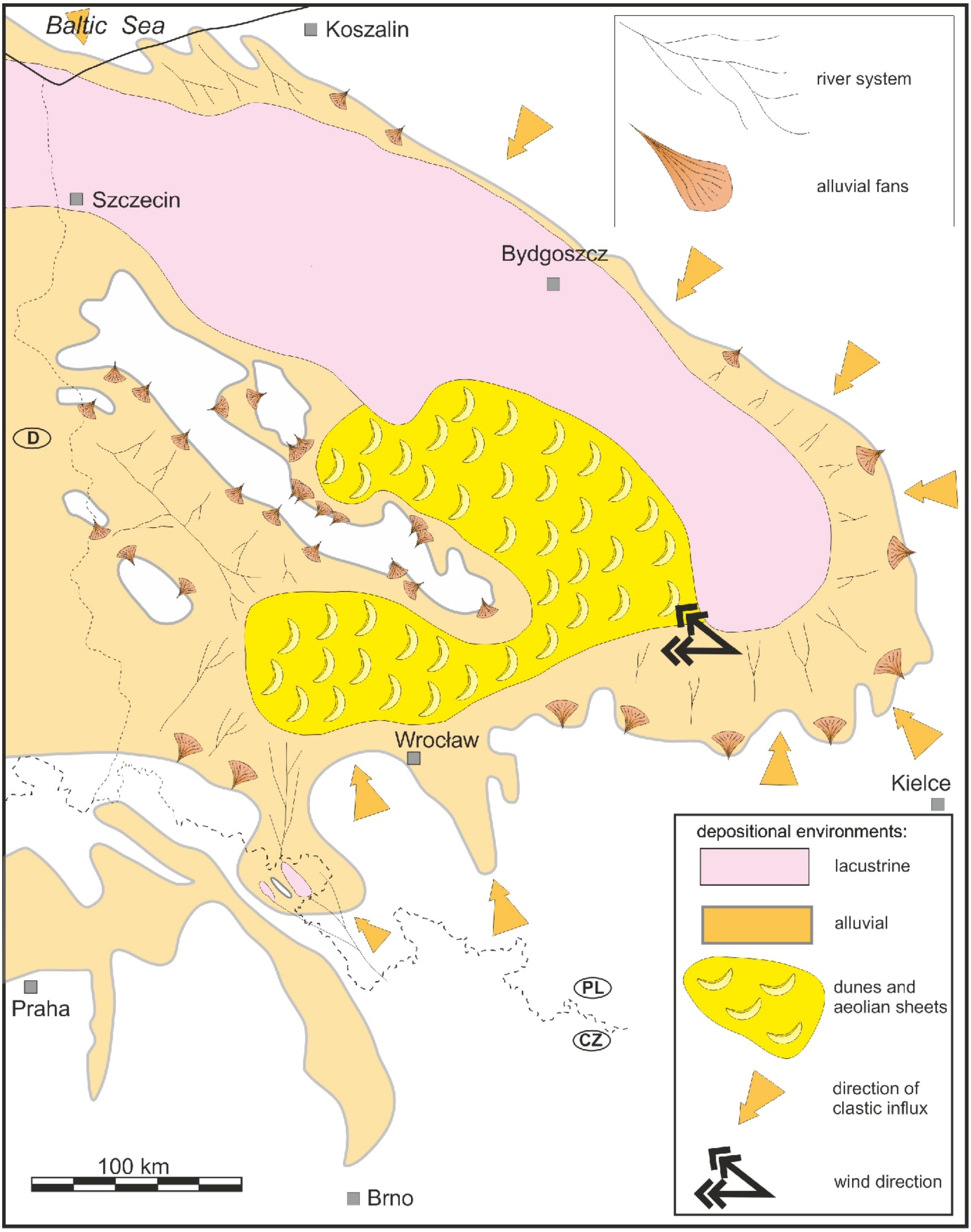


**Fig. 6. Palaeogeographic map of the decline of the Rotliegend (Middle Wuchiapingian, ~259–257 Ma) in the Polish Permian Basin (pre-Zechstein sequence *sensu* Karnkowski, 1999) and basins in the area of the Bohemian Massif (according to Holub, 1972; Pešek et al., 1998; Zajic, 214; Opluštil et al., 2016)**

Additional explanations are provided in the text shaping of the fluvial system during one of the Rotliegend episodes in the development of the Intra-Sudetic Basin does not, in my opinion, reflect their mutual role in shaping the evolution of the basin fill. Kowalski and Furca (2023) mainly emphasised the tectonic factor, although the fluvial system is always significantly influenced by the climatic factor as well. The coexistence of these two factors (tectonics and climate) has been repeatedly emphasised in connection with the deposition of the fluvial sediments of the Rotliegend in the Sudetic region (Wojewoda and Mastalerz,1989).

The discussion presented has only touched on some of the issues raised by Kowalski and Furca (2023). In this discussion I have tried to emphasise them in the context of the direct statements of the article, but I have also addressed methodological issues (which are extremely important in this article) that have accumulated a considerable layer of inaccuracies and omissions over the last 50 years. Geologists are faced with the challenge of developing the most accurate regional palaeogeographic maps of the Permian. However, it all has to start with geological maps that need to be remapped in detail.

## REFERENCES


**Aleksandrowski, P., Śliwiński W., Wojewoda J., 1986.** Frontally and surficially fluidized slump to debris flow sheets in an alluvial sequence, Lower Permian, Intra-Sudetic Basin. In: IAS 7th European Regional Meeting, Excursion Guidebook, Kraków-Poland, Excursion A-1 (ed. A.K. Teisseyre): 9–29. Ossolineum, Wroclaw.

**Augustyniak, K., Grocholski, A., 1968.** Geological structure and outline of the development of the Intra-Sudetic depression (in Polish with English summary). Biuletyn Instytutu Geologicznego, **227**: 87–111.

**Awdankiewicz, M., 2022.** Polyphase Permo-Carboniferous magmatism adjacent to the Intra-Sudetic Fault: constraints from U-Pb SHRIMP zircon study of felsic subvolcanic intrusions in the Intra-Sudetic Basin, SW Poland. International Journal of Earth Sciences, **111**: 2199–2224; https://doi.org/10.1007/s00531-022-02232-y

**Bossowski, A., Ihnatowicz, A., 1994.** Palaeogeography of the uppermost Carboniferous and lowermost Permian deposits in the NE part of the Intra-Sudetic Depression. Geological Quarterly, **38** (4): 709–726.

**Dadlez, R., 1987.** Allostratigraphy, cyclicity of sedimentation, lithostratigraphy (in Polish with English summary). Kwartalnik Geologiczny, **31** (4): 673–678.

**Dąbek-Głowacka, J., Wójcik-Tabol, P., Nowak, G.J., 2024**. Influence of Late Carboniferous–Early Permian climate change on the sedimentary evolution – a case study of the lacustrine Lower Anthracosia Shales (Intra-Sudetic Basin, SW Poland). Geological Quarterly, **68**, 5; https://doi.org/10.7306/gq.1728

**Dziedzic, K., 1959.** Comparison of Rotliegendes sediments in the region of Nowa Ruda and Świerzawa (in Polish with English summary). Kwartalnik Geologiczny, **3** (4): 831–846.

**Dziedzic, K., 1961.** Lower Permian in the Intrasudetic Basin (in Polish with English summary). Studia Geologica Polonica, **6**: 1–124.

**Dziedzic, K., Teisseyre, A.K., 1990.** The Hercynian molasse and younger deposits in the Intra-Sudetic Depression, SW Poland. Neues Jahrbuch für Geologie und Paläontologie, **179**: 285–305.

**Holub, V., 1972.** Permian of the Bohemian Massif. International Sedimentary Petrographical Series, **15**: 137–188.

**Ihnatowicz, A., 2005.** Depositional conditions of the Glinik Formation (Intra-Sudetic Basin) (in Polish with English summary). Biuletyn Państwowego Instytutu Geologicznego, **415**: 101–151.

**Jerzykiewicz, J., 1987.** Latest Carboniferous (Stephanian) and Early Permian (Autunian) palynological assemblages from the Intrasudetic Basin, Southwestern Poland. Palynology, **11**: 117–131; https://doi.org/10.1080/01916122.1987.9989324

**Karnkowski, P.H., 1977.** Facies analysis of the Rotliegendes in the northern part of the Fore-Sudetic monocline (Poznań-Śrem region) (in Polish with English summary). Acta Geologica. Polonica, **27**: 481–495.

**Karnkowski, P.H., 1981**. The current lithostratigraphic subdivision of the Rotliegendes in Poland and proposition of its formalization (in Polish with English summary). Kwartalnik Geologiczny, **25** (1): 59–66.

**Karnkowski, P.H., 1986a.** Allostratigraphic units – proposal new formal units in the Polish Stratigraphic Classification (in Polish with English summary). Przegląd Geologiczny, **34**: 255–257.

**Karnkowski, P.H., 1986b.** The nature of Zechstein transgression versus origin of the Weissliegendes in the Wielkopolska area (northern Fore-Sudetic Monocline, western Poland (in Polish with English summary). Geologia Sudetica, **21**: 101–122.

**Karnkowski, P.H., 1987a.** Allostratigraphy and lithostratigraphy of the Rotliegend in Poland (in Polish with English summary). Kwartalnik Geologiczny, **31** (1): 43–56.

**Karnkowski, P.H., 1987b.** Facies analysis of the Wielkopolska Subgroup (Upper Rotliegend) in the northern part of the Fore-Sudetic Monocline (in Polish with English summary). Przegląd Geologiczny, **35**: 187–192.

**Karnkowski, P.H., 1987c.** Lithostratigraphy of the Rotliegend in the Wielkopolska region, W Poland (in Polish with English summary). Kwartalnik Geologiczny, **31** (4): 643–672.

**Karnkowski, P.H., 1994.** Rotliegend lithostratigraphy in the central part of the Polish Permian Basin. Geological Quarterly**, 38** (1): 27–42.

**Karnkowski, P.H., 1995.** Upper Rotliegend – Zechstein: Terrestial-marine sedimentary succession in the Wielkopolska region. XIII International Congress on Carboniferous-Permian, Guide to Excursion A-3: 23–37, Kraków.

**Karnkowski, P.H., 1999.** Origin and evolution of the Polish Rotliegend Basin. Polish Geological Institute Special Papers, **3**: 1–93.

**Karnkowski, P.H., Rdzanek K., 1982.** Some remarks on the Permian basement in the Wielkopolska region (in Polish with English summary). Kwartalnik Geologiczny, **26** (2): 327–340.

**Karnkowski, P.H., Kiersnowski, H., Czapowski, G., 1997**. Sedimentological and geophysical data as a tool for prediction of the Rotliegend stratigraphic gas traps (Polish Permian Basin). Prace Państwowego Instytutu. Geologicznego **157**: 353–360.

**Kiersnowski H., 1983.** Development of sedimentation of latest Palaeozoic clastic deposits in the vicinity of Brzeg city, SW Poland (in Polish with English summary). Przegląd Geologiczny, **31**: 475–479.

**Kiersnowski, H., 2013.** Late Permian aeolian sand seas from the Polish Upper Rotliegend basin in the context of palaeoclimatic periodicity. Geological Society Special Publications, **376**: 431–456; https://doi.org/10.1144/sp376.20

**Kowalski, A., Furca, M., 2023.** Development of a non-perennial to ephemeral fluvial system in continental fault-bounded basin – an ex ample from the early Permian Krajanów Formation of the Intra-Sudetic Basin (NE Bohemian Massif). Geological Quarterly, **67**, 31; https://doi.org/10.7306/gq.1701

**Kowalski, A., Raczyński, P., Wojewoda, J., 2018a.** The extent of the Zechstein Sea in the area of the North Sudetic Synclinorium in the light of new sedimentological data from the Wleń tectonic graben (in Polish). In: Polska Konferencja Sedymentologiczna POKOS 7. Góra Św. Anny, 4–7 czerwca 2018 r. Materiały konferencyjne (eds. M. Kędzierski and M. Gradziński). Polskie Towarzystwo Geologiczne, Kraków.

**Kowalski, A., Durkowski, K., Raczyński, P., 2018b.** Zechstein marine deposits in the Wleń Graben (North Sudetic Synclinorium, SW Poland) – new insights into the palaeogeography of the southern part of the Polish Zechstein Basin. Annales Societatis Geologorum Poloniae, **88**: 321–339; https://doi.org/10.14241/asgp.2018.021

**Krechowicz, J., Kisielewski, F., 1965.** Szczegółowa Mapa geologiczna Sudetów w skali 1:25 000, arkusz Ludwikowice Kłodzkie (in Polish). Instytut Geologiczny, Warszawa.

**Lützner, H., Tichomirowa, M., Käßner, A., Gaupp, R., 2021.** Latest Carboniferous to early Permian volcano-stratigraphic evolution in Central Europe: U–Pb CA–ID–TIMS ages of volcanic rocks in the Thuringian Forest Basin (Germany). International Journal of Earth Sciences, **110**: 377–398; https://doi.org/10.1007/s00531-020-01957-y

**Mastalerz, K., Nehyba, S., 1997.** Comparison of Rotliegende lacustrine depositional sequences from the Intrasudetic, North-Sudetic and Boskovice basins (Central Europe). Geologia Sudetica, **30**: 21–57.

**Mastalerz, K., Kurowski, L., Wojewoda, J., 1993.** Lithostratigraphy and evolution of the Intra-Sudetic Basin in the Carboniferous and Permian (in Polish). II Krajowe Spotkanie Sedymentologów. Baseny sedymentacyjne – procesy, osady, architektura. Wrocław, Sudety, 4–7 września: 65–73. Instytut Nauk Geologicznych Uniwersytetu Wrocławskiego, Wrocław.

**Miecznik, J.B., 1988.** Diastrophic-sedimentary evolution of the Intra-Sudetic Basin in the Late Silesian and Early Autunian (in Polish with English summary). Przegląd Geologiczny, **36**: 211–213.

**Miecznik, J.B., 1989.** The Upper Silesian and Lower Autunian from NE limb of the Intra-Sudetic Depression (in Polish with English summary). Biuletyn Państwowego Instytutu Geologicznego, **363**: 5–39.

**Milewicz J., 1985.** Development of the Rotliegend in southwestern Poland (in Polish with English summary). Kwartalnik Geologiczny, **29** (3–4): 679–690.

**Nemec, W., 1978.** Tectonically controlled alluvial sedimentation in the Słupiec Formation (Lower Permian) of Intrasudetic Basin. In: Proceedings of International Symposium Central European Permian. Jabłonna, April 27–29, 1978: 294–311.

**Nemec, W., Porębski, S.J., Teisseyre, A.K., 1982.** Explanatory notes to the lithotectonic molasse profile of the Intra-Sudetic Basin, Polish part (Sudety Mts., Carboniferous-Permian). Veröffentlichungen des Zentralinstituts für Physik der Erde, **66**: 267–278.

**Opluštil, S., Pešek, J., 1998.** Stratigraphy, palaeoclimatology and palaeogeography of the Late Palaeozoic continental deposits in the Czech Republic. Geodiversitas, **20**: 597–620.

**Opluštil, S., Schmitz, M., Kachlík, V., Štamberg, S., 2016.** Reassessment of lithostratigraphy, biostratigraphy, and volcanic activity of the Late Palaeozoic Intra-Sudetic, Krkonoše-Piedmont and Mnichovo Hradiště basins (Czech Republic) based on new U-Pb CA-ID-TIMS ages. Bulletin of Geosciences, **91**: 399–432; https:// doi.org/10.3140/bull.geosci.1603

**Ostromęcki, A., 1973.** Development of the Late Paleozoic sedimentary basins of the Kaczawa Mts. Annales Societatis Geologorum Poloniae, **43**: 319–362.

**Peryt, T., 1978**. Outline of the Zechstein stratigraphy in the North Sudetic Trough (in Polish with English summary). Kwartalnik Geologiczny, **22** (1): 59–82.

**Pešek, J., Opluštil, S., Kumpera, O., Holub, V., Skoček, V. Dvořák, J., Prouza, V., Tásler, R., 1998.** Paleogeographic Atlas, Late Paleozoic and Triassic Formations, Czech Republic. 56 pp. Czech Geological Survey, Prague.

**Pieńkowski, G., 2009.** From lithostratigraphy to cyclostratigraphy – innovative directions in the research of Professor Ryszard Dadlez (1931–2008) (in Polish). Przegląd Geologiczny, **57**: 387–392.

**Pokorski, J., 1989.** Evolution of the Rotliegendes Basin in Poland. Bulletin of the Polish Academy of Science, Earth Sciences, **37**: 49–55.

**Pokorski, J., 1998.** Plate 3, Late Rotliegend, Noteć Subgroup palaeogeography. In: Palaeogeographical atlas of the epicontinental Permian and Mesozoic in Poland (eds. R. Dadlez, S. Marek and J. Pokorski). Państwowy Instytut Geologiczny, Warszawa.

**Porębski, S., 1996**. Fundamentals of sequence stratigraphy in clastic successions (in Polish). Przegląd Geologiczny, **44**: 995–1006.

**Szulczewski, M., 1986.** Concepts and reality of stratigraphic classification (in Polish with English summary). Przegląd Geologiczny, **34**: 233–237.

**Wagner, R., 1994.** Stratigraphy and evolution of the Zechstein basin in the Polish Lowlands (In Polish, with English summary). Prace Państwowego Instytutu Geologicznego, **146**: 1–75.

**Wojewoda, J., Mastalerz, K., 1989.** Climate evolution, allo- and autocyclicity of sedimentation: an example from the Permo-Carboniferous continental deposits of the Sudetes, SW Poland (in Polish with English summary). Przegląd Geologiczny, **37**: 173–180.

**Wołkowicz, S., 1988.** On the sedimentation of the Lower Permian Walchia Shales from Ratno Dolne (Intra-Sudetic depression) (in Polish with English summary). Przegląd Geologiczny, **36**: 214–218.

**Wójcik-Tabol, P., Dąbek, J., Nowak, G., 2021.** Preliminary mineralogical characteristics of the Anthracosia Shales from the Intra-Sudetic Synclinorium (in Polish with English summary). Przegląd Geologiczny, **69**: 389–392; https:// doi.org/10.7306/2021.23