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Geologic setting and palynologic examination of the Vistulian sediments at Koźmin near Turek, central Poland

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Several alternating organic-mineral and mineral beds of the Vistulian, accumulated by a braided river, are recorded from outcrops of the Adamów open-cast mine. They have considerable lateral extension and are underlain by the Wartanian till. Sedimentary structures and lithologic analyses prove varying-energy conditions during formation of the mineral series. The organic-mineral series (organic silts and peats) is an effect of a low-energy flow. Palynologic examination does not allow to establish the age relationship between these sediments and particular warmings during the Vistulian.

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INTRODUCTION

The Koźmin outcrop in the Adamów open-cast mine is located in an extensive alluvial plain in western part of the Uniejów Basin, where a meridional segment of the Warta River valley flows into the Warsaw–Berlin Pradolina (Fig. 1). The plain is occupied by numerous small streams that join the Kiełbaska and Teleszyna Rivers; these in turn are the tributaries of the Warta River. The following Cainozoic deposits are displayed in the outcrop: the Tertiary series (about 20 m thick) with a brown coal bed, covered by sands and silts, and the Quaternary series (about 30 m thick), a composition of which is predominated by the Neopleistocene and the Holocene sediments. Investigations at Koźmin have been conducted since 1995 by a team led by Professor Halina Klatkowa. Initial information, interpretation and stratigraphic suggestions came out in 1996 (H. Klatkowa, 1996; H. Klatkowa *et al.*, 1996). The paper presents geologic records and results of palynologic analysis of organic-mineral deposits of the Vistulian (J. Forysiak *et al.*, 1998).

Outcrops at the Adamów opencast mine, along with numerous geologic records, provided a base for a study concerning geologic structure of the area surrounding Uniejów and Turek. According to J. Czarnik (1972), the coal horizon in the vicinity of Turek is covered by the Pliocene grey-green clays, fine grey sands, grey clays with organic remains and grey-green clays. Among the Quaternary deposits, he noted relic tills of the South Polish Glaciation and two series of the Holsteinian Interglacial. The Middle Polish Glaciation was represented by varved clays, fluvioglacial sands and gravels, tills of the maximum stadial and interstadial deposits, followed by varved clays, glaciofluvial sands and gravels, and the Wartanian tills. During the maximum stadial, intensive glaciotectonic deformations occurred but they probably disappeared during the Wartanian. The Eemian Interglacial was represented by few phases of erosion and valley accumulation of vari-grained, mostly sandy deposits. During the Vistulian Glaciation, erosion and accumulation of glaciolacustrine and fluvial deposits occurred, accompanied by aeolian processes.

Geologic record at the Koźmin outcrop is close to the sequence presented by J. Czarnik (1972), although his sequence presents a general picture of geology in the vicinity of Turek. The Koźmin outcrop displays the Quaternary sequence, 30 m thick, predominated by the Neopleistocene and the Holocene sediments. The Tertiary deposits above the brown

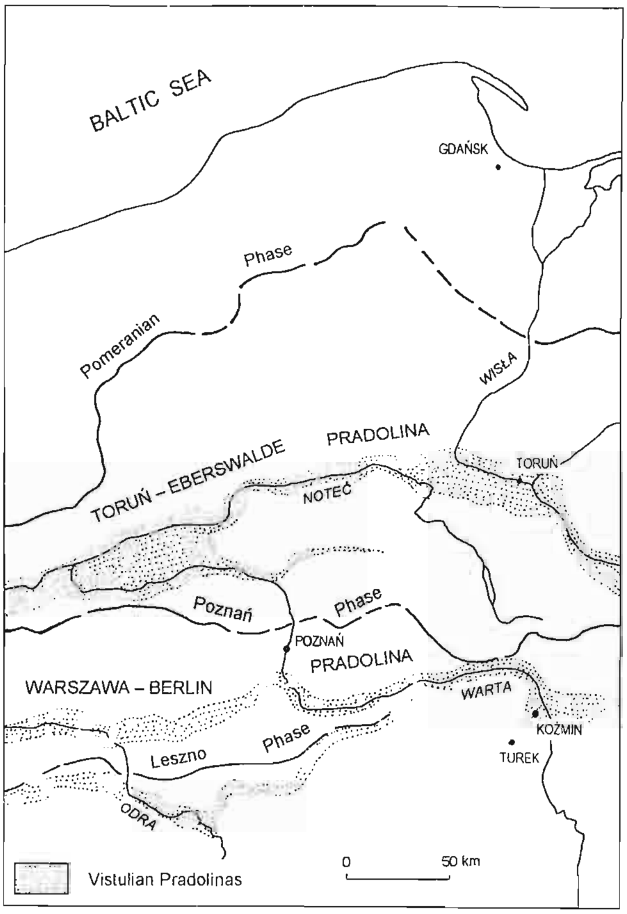

Fig. 1. Location of the site Koźmin against limits major of the last ice sheet and pradolinas (after S. Kozarski, 1988)

coal bed are glaciotectonically deformed. A subsequent significant erosive tendency is evidenced by truncation of these deformed deposits. The erosive surface is mantled with sandy and sandy-gravelly or silty deposits, or individual patches of the Wartanian tills. A till in the Koźmin outcrop is grey and is usually 2–5 m thick. In some profiles a till concordantly overlies the older, mostly the Tertiary deposits. Deposition of a till was followed by intensive erosion, which resulted in considerable reduction or even complete destruction of the till itself.

In a southern part of the Uniejów Basin, within the Teleszyna valley which adjoins the Warta valley, there are the Wartanian tills to over 20 m thick (H. Klatkowa, M. Załoba, 1991). At Smulsko near Koźmin there are three tills, in total about 18 m thick (H. Klatkowa, 1992, 1993). The till in the Koźmin outcrop seems to correspond to the Wartanian till at Smulsko. Petrographic coefficients O/K, K/W and A/B (after J. Rzechowski, 1991) for the till at Koźmin are equal to 1.51, 0.7 and 1.31, respectively, and content of $CaCO_3$ is equal to 10.5–14.5% (Fig. 2). Values for a till from Smulsko are almost the same (H. Klatkowa, 1992, 1993). Long axes of clasts in tills have also a similar orientation. The Wartanian age of a till from Koźmin is confirmed by thermoluminescence dating at 160.1±24.0 ka BP.

In the western part of the area, A. Mańkowska (1980) noted glaciofluvial sands of the Vistulian. As an alternative opinion, these sands have been correlated by P. Kłysz (1980, 1981), and P. Kłysz and W. Stankowski (1986) to the Middle Polish Glaciation. The latter would agree with the idea of B. Krygowski (1975) that during maximum extent of the Vistulian Glaciation (the Leszno Phase), the meltwaters flew westwards as far as possible and directly within a marginal zone; otherwise, they flew through a pradolina. Most meltwater sediments remained in a marginal zone, and generated inside many various landforms. Hence, small alluvial fans in foreland of the Leszno Phase ice sheet and small extent of glaciofluvial deposits southwards are typical. The present studies at Koźmin confirm a lack of glaciogenic deposits of the Vistulian. Geological maps (A. Mańkowska, 1980) and geomorphological sketches display terrace deposits of the Vistulian, cut by narrow belts of alluvia of the Holocene.

GEOLOGY AND PALYNOLOGY

Morphogenesis of the Vistulian is manifested in the vicinity of Koźmin by fluvial deposits, achieving a thickness of several metres. The Vistulian series is composed largely of sands, and is interbedded with numerous mineral-organic deposits with considerable lateral extent (a few square kilometres). The alternating mineral and organic beds are numbered from 5 to 9, and only these are a subject of the present study (Fig. 2); the others are of the Holocene age. However, due to a clear palynological individuality, the horizon 9 is presented for three separate sections (9/10, 9/A, 9/B).

The lowest part of the Vistulian sequence is composed of mineral-organic sediments, which fill an incision in sandy-gravelly series and in a till (Fig. 2: 9/10). Results of a pollen analysis indicate that pollen spectrum of the entire profile is slightly varied and characterized by considerable content of trees (AP equal to 80%): mainly *Pinus, Betula, Alnus, Carpinus, Picea, Corylus* and *Quercus*, also *Tilia, Ulmus* and *Salix*. Such pollen spectrum points out to a temperate warm climate, favouring development of forest habitats. On the other hand, relatively large and constant content of pollen of herbaceous plants (Rosaceae, Umbelliferae, Compositae, Cruciferae), including heliophilous ones (e.g. *Helianthemum,* Chenopodiaceae), proves climatic deterioration in the early Vistulian.

However, a considerable content of the redeposited Tertiary material (*Nyssa, Pterocarya, Neogenespores*) suggests that some other pollen grains might have been redeposited as well. Hence, deposits in this profile should be associated with existence of a closed depression and therefore, it does not seem possible to determine the age of the studied basin (K. Dyakowska, 1956). For this reason, a diagram of this profile is not attached to this paper.

Deposits of the **series 9** and the profiles 9/A, 9/B have a considerable extension and, unlike the above described sediments, they are not confined to the basin. They form a continuous series with a relatively constant thickness of about 2 m (Pl. I, Fig. 1). These deposits are underlain by a thin series of

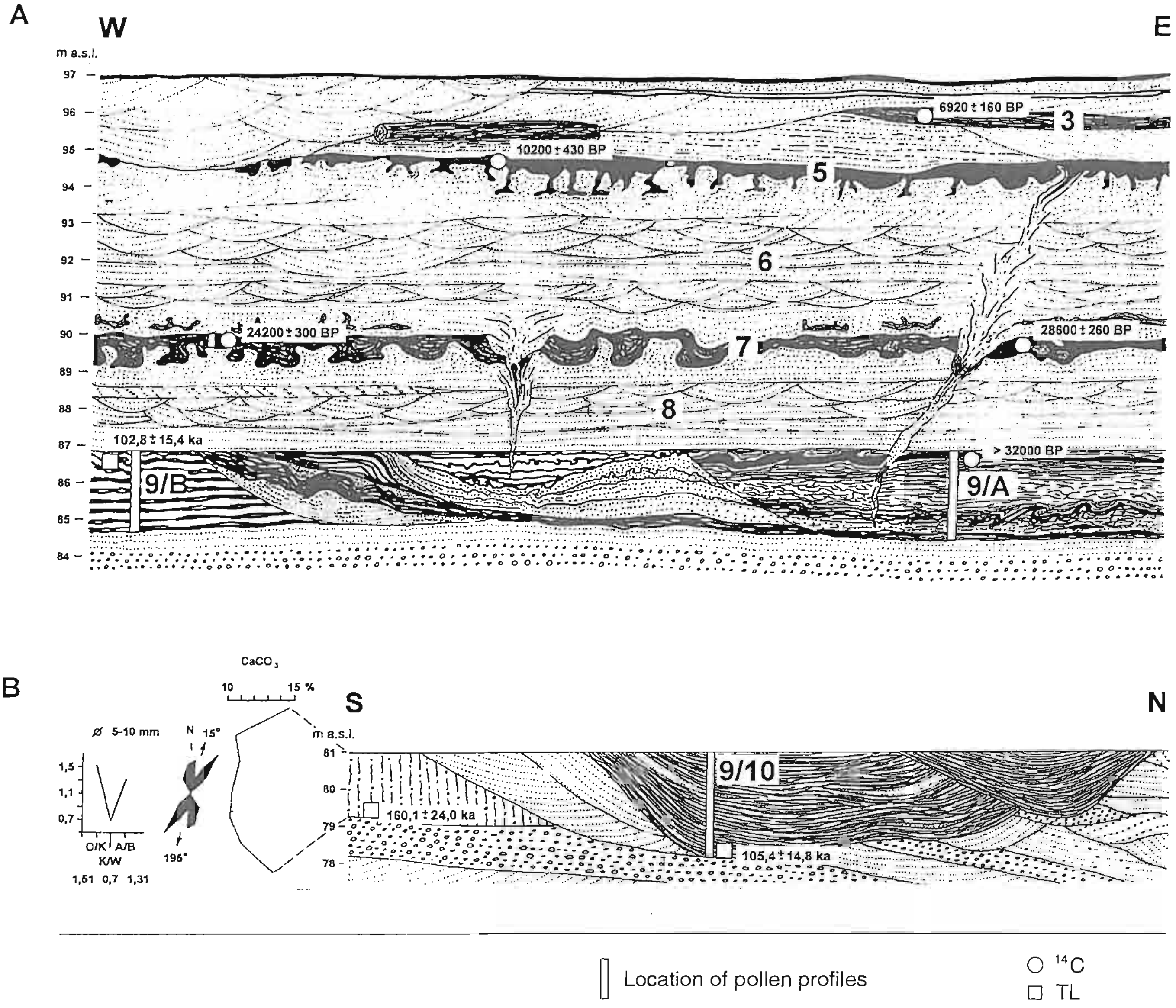

Fig. 2. Koźmin, organic (3, 5, 7, 9A, 9B, 9/10) and mineral (6, 8) series in the open-cast brown coal mine

A — Holocene and Vistulian organic and mineral series at the first exploitation level, B — the lowest organic horizon at the second exploitation level; petrographic coefficients O/K, K/W and A/B, long-axis azimuth of clasts and content of $CaCO_3$ in the Wartanian till

medium-grained sands and gravels. Flaster bedding is the most common sedimentary structure, with distinct alternating dark brown layers containing organic matter, and with lighter, more sandy layers. Such deposits are characteristic for deposition in a closed basin or an open basin with a limited water discharge. Infillings underwent cutting; afterwards, similar mineral-organic deposits were collected within intrenchments. Except for stratified structures, there is massive packing of structure-less material. Quartz-grain analysis by the method of A. Cailleux (1942) indicates that in fraction 0.6–0.8 mm, there is a similar content of grains RM and EL grains, equal to 20–24%, whereas M grains reach about 46–48% (Fig. 3).

Within the lowest organic horizon, synsedimentary or post-sedimentary disturbances were found. Sometimes there are slightly undulated structures only, then again layers are more deflected. Elsewhere, deposits of the series 9 are developed as folds, attaining a height of several centimetres. Sediments from a top of the series 9 are TL dated to 102.8±15.4 ka BP, and radiocarbon dated to 32 ka BP. Pollen analysis of the profile 9A (Fig. 4) clearly points out to three individual parts. The lower one presents a high content of trees (AP), ca. 90%. There are abundant pollen of *Pinus* and *Picea*, whereas *Alnus*, *Carpinus* and *Quercus* are common. Herbaceous plants are rare. This part of the diagram is similar to the profile 9/10, however, a total of AP is higher, and there is no redeposited Tertiary material.

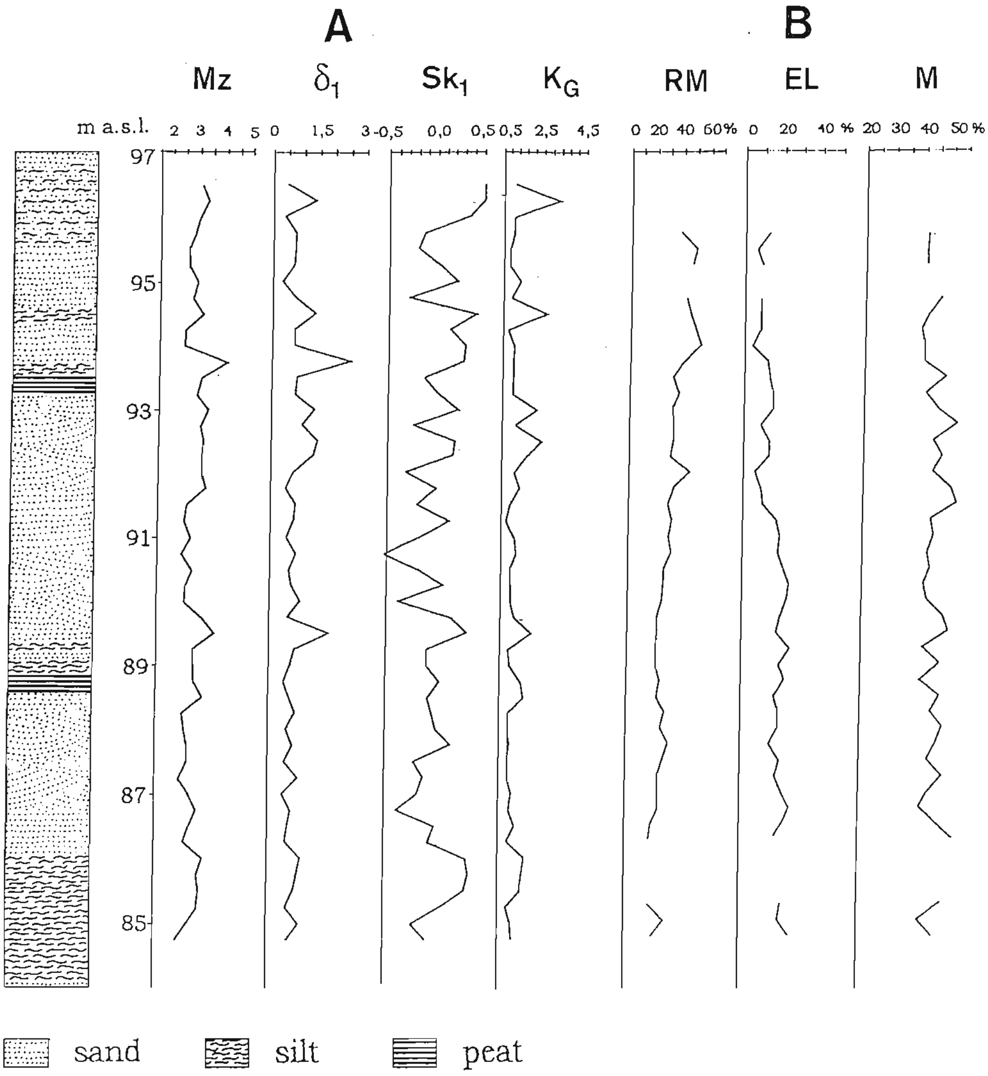

Fig. 3. Grain size distribution and quartz-grain abrasion at the Koźmin section

A — grain size coefficients after R. L. Folk and W. C. Ward (1957): Mz — mean grain diameter, δ_1 — standard deviation, Sk_1 — skewness, K_G — curtosis; B — quartz grain abrasion of the grain size 0.63–0.80 mm after A. Cailleux (1942): RM — rounded mat, EL — rounded glittering, M — mat

An evident change in a palynologic record is connected with a shift from sandy deposits to silts with an organic admixture. Curves of deciduous trees visibly disappear, and contents of *Pinus* and *Picea* drops rapidly. A quantity of trees (AP) decreases to 30%, whereas a content of herbs (NAP) increases: mainly of Gramineae, Cyperaceae and heliophilous plants (*Artemisia,* Chenopodiaceae, Caryophyllaceae) as well as Compositae, *Thalictrum* and Umbelliferae. Such vegetation changes indicate a climatic cooling. An increasing content of AP at the end of this period is due to more pollen of *Betula*, most likely *Betula nana*. Development of a treeless tundra in cool climatic conditions is also supported by occurrence of plants as *Helianthemum* and *Juniperus*. A climatic cooling might have been referred to a stadial of the early Vistulian. Although the curves of trees are similar to the ones of the early Vistulian from Władysławów near Turek (K. Tobolski, 1986), Zgierz–Rudunki (M. Jastrzębska-Mamełka, 1985) and Imbramowice (K. Mamakowa, 1989), both too low values of NAP (K. Tobolski, 1991) and a further course of curves seem to exclude such interpretation from consideration.

Pollen-free sandy deposits at the top of the section are overlain by a thin (8 cm) peat layer, covered with mineral deposits. There is high content of *Pinus* (up to 76%), *Betula* (14–20%), and less *Corylus* and *Alnus*. There is sporadic pollen of other deciduous trees. At the top of the profile, pollen of trees almost completely disappears. There are great quantities of spores of *Sphagnum* and of pollen of herbs: mainly Gramineae, Cyperaceae and heliophilous plants. Such pollen composition indicates a slight climatic warming and development of an open pine-birch forest which, with progressing cooling, were replaced by peatbogs and a treeless tundra. High values of AP suggest that this climatic amelioration should be referred to the next interstadial than to an interphase rather.

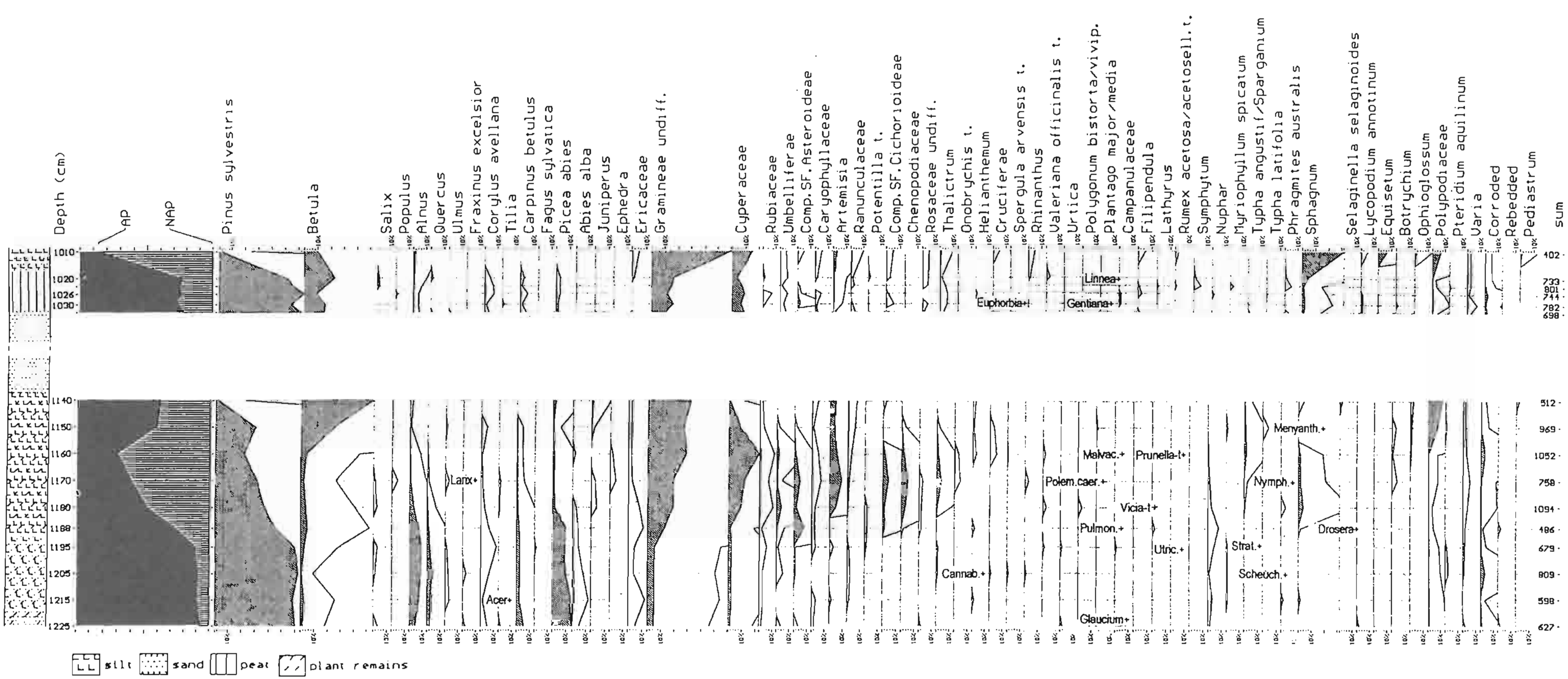

Fig. 4. Koźmin 9/A, percentage pollen diagram

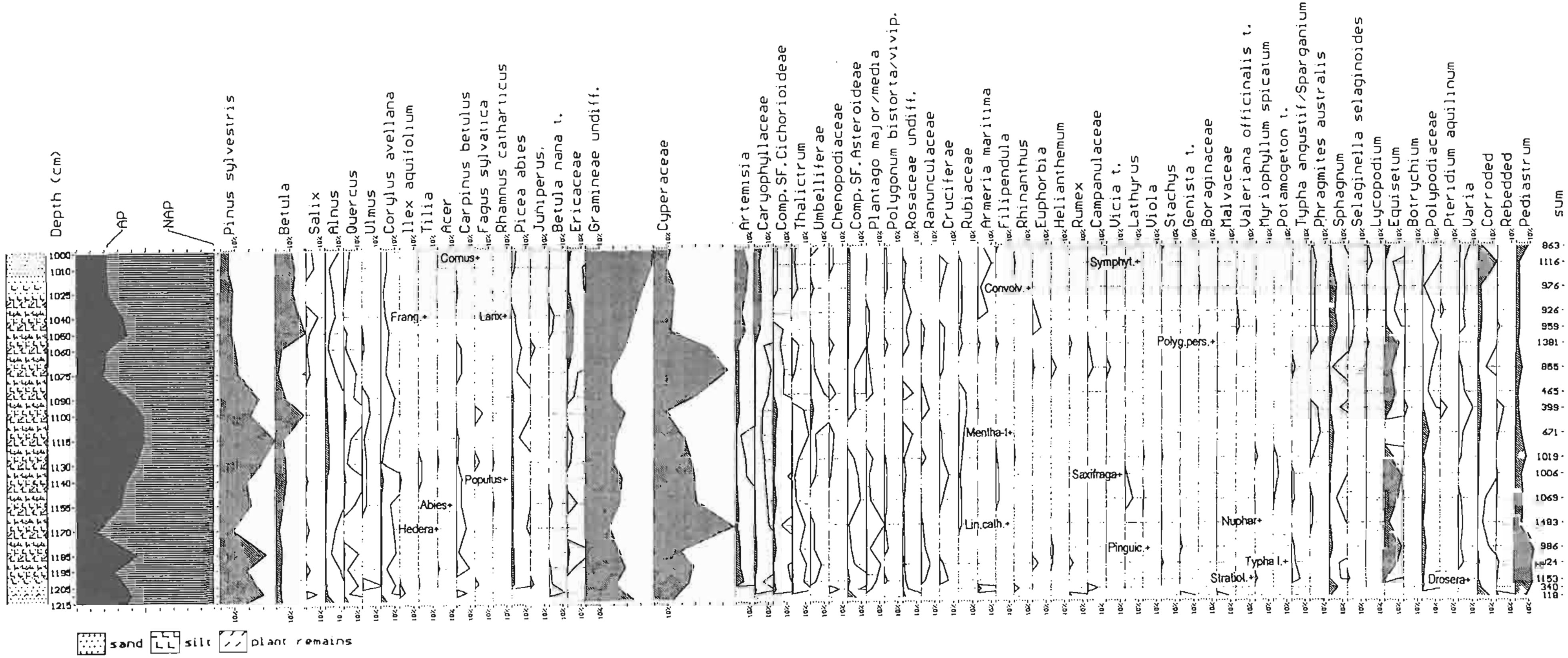

Fig. 5. Koźmin 9/B, percentage pollen diagram

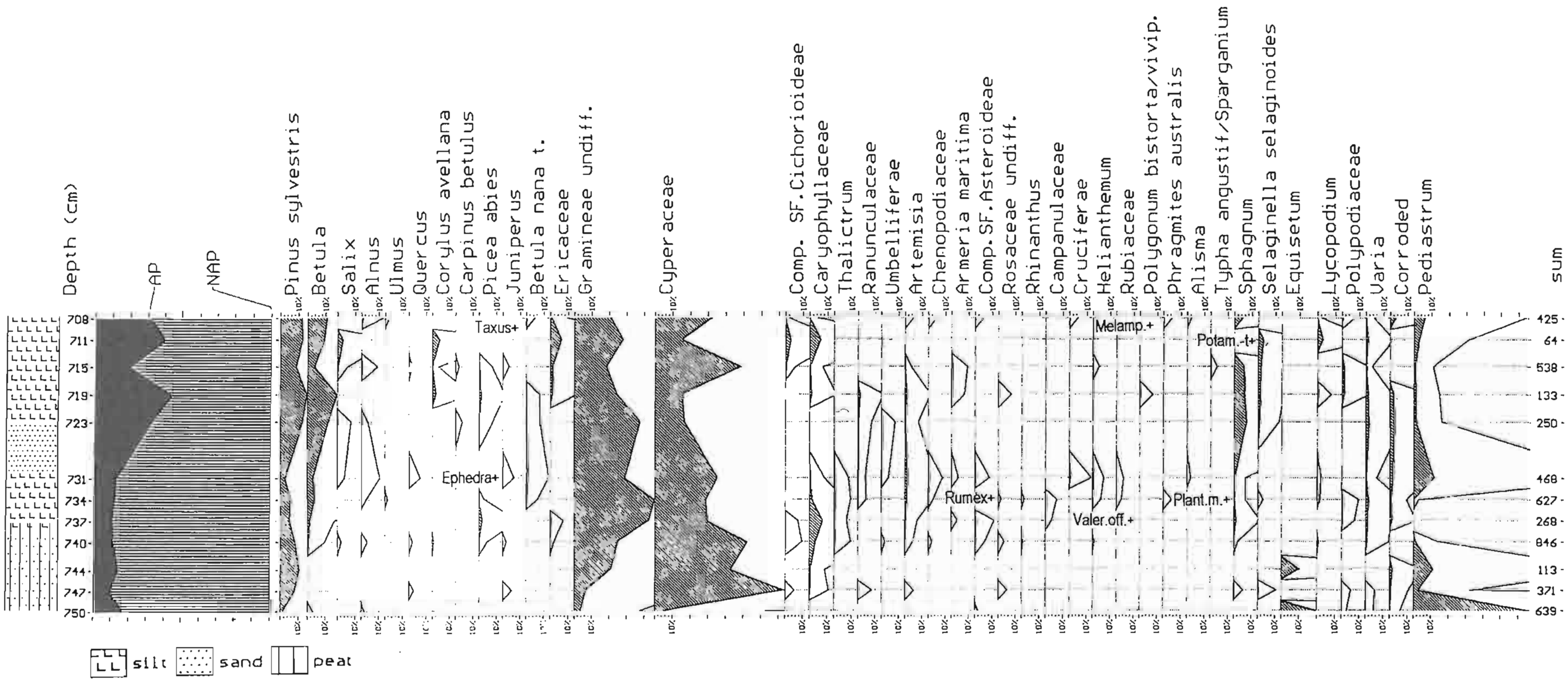

Fig. 6. Koźmin 7, percentage pollen diagram

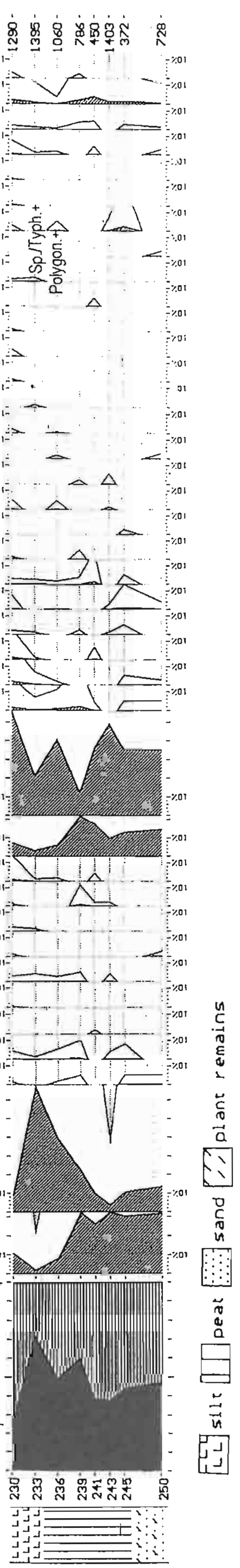

Fig. 7. Koźmin 5, percentage pollen diagram

The picture that emerges from a pollen analysis of deposits in the section 9/B (Fig. 5) is completely different from the one for the profile 9/A. Pollen spectrum of all samples contains more herbaceous plants (NAP 50–85%). The lower NAP values were recorded in a middle part of deposits, where content of trees increases, i.e. mainly of *Quercus, Alnus, Pinus* and *Betula.* Higher content of Ericaceae, *Artemisia,* Compositae and Caryophyllaceae was recorded at the bottom and at the top. Thus, both the bottom and the top of these deposits could have been formed under cooler climatic conditions than their middle part. However, particularly at the bottom, single grains of *Ilex aquifolium* and *Hedera*, which are "incompatible" with a general pollen spectrum, indicate contamination by extraneous matter. This is also supported by a type of deposits, containing well-pronounced layer disturbances. Thus, this picture reflects no climatic conditions in deposition of the studied sequence.

The surface between the organic-mineral series 9 and the overlying mineral **series 8** reveals erosional features (Fig. 2; Pl. I, Figs. 1 and 2). Organic-mineral deposits are truncated, so a bottom of the series 8 occurs at more or less constant altitude, about 88 m a.s.l.

The mineral series consists largely of sandy sediments. Horizontal or low-angle tabular cross-bedding are prevailing usually at the bottom of the series. Above, sets of trough cross-bedding occur more frequently. Generally, all sorts of stratification which are typical for a high-energy environment of a braided river, can be observed there. Occasionally, there are silty-sandy layers. A lack of erosional surfaces proves that probably erosion has not occurred. A quartz-grain analysis (Fig. 3) indicates a higher content of RM (up to 30%) and EL (ca. 18%) grains than in the series 9. Such values may testify an increased supply of wind-abraded grains to a river system; furthermore, glacial debris could have been involved.

The next organic-mineral **series 7** occurs at 90 m a.s.l. (Fig. 2). Sands of the overlying mineral series are covered by peat, followed by sands and silts. These deposits comprise the described series and are seriously deformed (Pl. II, Fig. 1). Downsinking caused undulations of organic sediments, the overlying silty material was in turn updomed and resulting deformations frequently formed small diapirs. Sandy deposits beneath and above were involved in deformations, and their original sedimentary structures have been destroyed. The organic-mineral series was sampled to radiocarbon datings. The samples were collected wide apart, and gave the two different ^{14}C dates of 24 200±300 and 28 600±260 years BP.

Pollen analysis of the series 7 (Fig. 6) indicates a small content of trees (AP 10–15%) at the bottom. *Pinus* is the most common tree. It seems, however, possible that in such a treelees environment, some pollen could have been derived from a long-distance transport. Among herbaceous plants there are mainly Cyperaceae, Gramineae, Caryophyllaceae and *Thalictrum.* Abundant spores of *Equisetum* and *Pediastrum* are common too. Thus, especially during growing of peat, there was a cool and humid climate.

Pollen spectrum of the younger part of deposits points to presence of *Betula*; besides, there are some pollen of *Alnus, Salix, Picea, Betula nana, Artemisia,* Chenopodiaceae, Ranunculaceae, *Helianthemum* and other heliophilous plants. Such spectrum might indicate slight warming, which is reflected in development of treeless tundra communities with birch and dwarf willow, and with heaths in the youngest period. Continued cool climatic conditions are indicated by occurrence of microspores of *Selaginella selaginoides*, which is an arctic-alpine species characteristic for a tundra. Deposition of this series should be associated with a warming during an interphase. The radiocarbon date of 24 200±300 years BP for a peat at the bottom of the series, points out to an interphase of the Vistulian Glaciation.

This organic-mineral series is covered with a mineral **series 6** (Fig. 2). As the series 8, it is mostly composed of vari-grained sands, though it contains presumably more finer fractions (Fig. 3). There are common sedimentary structures, typical for sandy material deposited in an aqueous environment. Horizontal lamination as well as tabular and trough bedding appear. At the boundary with the neighbouring organic series, deformation caused failure of the original structure of sandy sediments. These deposits do not display any erosional surfaces. Quartz-grain analysis indicates more RM grains, from 25% at the bottom up to 46% at the top, whereas contents of EL grains decreases from 23 to 8%, respectively (Fig. 3). Grain-size distribution supports varied sedimentary conditions.

The youngest organic **series 5** that represents a decline of the Vistulian is located at 95 m a.s.l. It is composed of sand with organic admixture of peat and silt. This series is also seriously deformed. However, in this case, deformations are fashioned in different way. Drop structures, resulting from downsinking of organic deposit, become flat at certain depth, as if spreading over a flat surface below was impossible (Pl. II, Fig. 2). This boundary reveals no lithologic features — within a mineral series, where drop structures sunk, there is no change in the sediment. Presumably, the boundary coincided with a permafrost table. Also crack structures, occurring in the Vistulian deposits and covering often the entire profile (Fig. 2), provide evidence for presence of permafrost. These structures were described by H. Klatkowa (1996) as syngenetic ones. The youngest organic-mineral series of the Vistulian is radiocarbon dated to 10 200±430 years BP.

Pollen analysis indicates that open pine forest with a slight admixture of *Betula* occurred at the beginning of deposition (Fig. 7). It is supported by low content of AP (below 50%), and some pollen could have been derived from a long-distance transport. Vegetation was predominated by herbaceous plants, mainly Cyperaceae and Gramineae, and was subjected to a cool climate which has not favoured development of more compact forest communities. Abundant spores of *Selaginella selaginoides* also indicate such conditions.

Later on, pine forest was replaced by open birch forest with patches of heliophilous plants. These conditions are supported by occurrence of *Artemisia,* Cruciferae, Chenopodiaceae and Ericaceae, and particularly by a rise of *Betula* and simultaneous drop of *Pinus*. In spite of poor preservation of pollen, distinction between *Betula* and *Betula* f. *nana* was impossible, yet it could be assumed that most grains represent a dwarf birch, therefore an increase of AP does not indicate forest expansion. This pollen spectrum is typical for a cool subarctic climate. Deposits of this series were probably produced during a decline of the Vistulian, thus a radiocarbon dating gave somewhat a younger age.

The top of the series 5 displays an erosional surface which was formed probably in the Holocene. Abundant erosional intrenchments in the outcrop extend downwards to the series 6 and 7. Erosional intrenchments are filled up with sandy deposits, enriched in organic remains. Besides, the Holocene deposits are represented by peats, alluvia and vari-grained mineral sediments.

CONCLUDING REMARKS

Studies in the outcrop at Koźmin prove that stratigraphic role of the Vistulian organic-mineral deposits is smaller than preliminary assumed. The present state of investigations makes difficult a precise connect of the organic series with decided warmings. Exclusively, earlier ideas (H. Klatkowa, 1996; H. Klatkowa *et al.*, 1996) on the early Vistulian age of the lowest organic-mineral series 9 have been supported. However, lack of relations to the Eemian deposits as well as contamination by extraneous matter do not allow for a more precise dating of the sediment. Also, the phase of erosion which followed accumulation of this series does not enable a stratigraphic reconstruction. Pollen spectrum of the organic series 7 does not reveal features which would permit accurate determination of age of its development. Radiocarbon age estimations from this series indicate that it was formed during an interphase, prior to the ice sheet advance during the Leszno Phase of the Vistulian Glaciation. Pollen analysis and radiocarbon datings of the youngest organic series 5 indicate that it was formed during an interphase of the Vistulian decline. Palaeobotanic and lithologic investigations as well as recorded erosional surfaces point out breaks in deposition during the Vistulian.

In spite of a lack of reliable stratigraphic data, the studies at Koźmin provide a base for reconstruction of environmental changes in the Uniejów Basin. Further examination which has been already started may give new information on geologic structure and sedimentary conditions of the Vistulian sequence.

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STRATYGRAFIA I ANALIZA PALINOLOGICZNA OSADÓW ZLODOWACENIA WISŁY W KOŹMINIE KOŁO TURKA

Streszczenie

Odkrywka Koźmin KWB Adamów znajduje się na rozległej równinie aluwialnej w zachodniej części basenu uniejowskiego (fig. 1). Powierzchnię równiny pokrywają osady tarasowe vistulianu pocięte wąskimi strefami aluwiów holoceńskich. W zachodniej części obszaru A. Mańkowska (1980) wyróżniła piaski glacifluwialne zlodowacenia wisły, natomiast P. Kłysz (1981) i P. Kłysz, W. Stankowski (1986) wiek piasków wiążą ze zlodowaceniem środkowopolskim.

Osady czwartorzędowe odsłaniają się na długości 30 m profilu. Dominują utwory neoplejstocenu i holocenu. Podścielają je zdeformowane glacitektonicznie a następnie ścięte erozyjnie osady trzeciorzędowe. Nad nimi leżą osady różnofrakcyjne, m.in. izolowane płaty gliny zwałowej zlodowacenia warty. Płaty gliny zwałowej w odkrywce Koźmin odpowiadają dolnemu poziomowi gliny zlodowacenia warty z pobliskiego stanowiska Smulsko (H. Klatkowa, 1992, 1993).

Osady vistuliańskie reprezentowane są głównie przez piaski, poprzedzielane poziomami organiczno-mineralnymi, charakteryzującymi się znacznym rozprzestrzenieniem lateralnym (fig. 2, 3). Najniższy kompleks organiczny 9 (tabl. I, fig. 1, 2) ma największą miąższość i w głównej mierze składa się z laminowanych faliście, częściowo zaburzonych piasków i mułów organicznych. Obraz palinologiczny (fig. 4, 5) nie pozwala jednak na stwierdzenie czy osady powstały w początkowym okresie vistulianu, czy też można je łączyć z którymś z późniejszych interstadiałów. Nadległa seria osadów mineralnych (8) zbudowana jest z różnofrakcyjnych piasków warstwowanych horyzontalnie i przekątnie (fig. 2). Wyżej zalega poziom osadów mineralno-organicznych z torfem (7), zaburzonych postsedymentacyjnie (tabl. II, fig. 1). Wyniki analizy palinologicznej wyraźnie wskazują, że w czasie powstawania tej serii panował klimat zimny, uniemożliwiający rozwój lasów (fig. 6). Należy to łączyć najprawdopodobniej z jakąś interfazą. Serię mineralno-organiczną przykrywają osady piaszczyste i mułkowe, wykazujące zróżnicowane warstwowanie. Najwyższy poziom vistuliański w stanowisku Koźmin to seria osadów organiczno-mineralnych (5) utworzonych z piasku, torfu i mułku. Wyniki analizy palinologicznej wskazują, że badane osady powstały w zimnym interstadiale bądź interfazie (fig. 7). Serie organiczno-mineralne 5 oraz 7 mają znacznie mniejszą miąższość (tabl. II, fig. 1, 2). Podlegały intensywnym deformacjom o charakterze niestatecznego warstwowania gęstościowego. W obrębie serii vistuliańskiej rozwinęły się liczne struktury szczelinowe.

Przeprowadzone badania wskazują, że rola stratygraficzna osadów vistuliańskich jest mniejsza niż zakładano pierwotnie. Obraz palinologiczny nie pozwala na odniesienie poziomów organicznych do konkretnych okresów ciepłych vistulianu, ale może być podstawą do rekonstrukcji ewolucji paleośrodowiska basenu uniejowskiego. Kontynuowane są prace w celu określenia specyfiki osadów oraz warunków ich sedymentacji w vistulianie i holocenie.

EXPLANATIONS OF PLATES

PLATE I

Figs. 1, 2. Koźmin. The lowest organic-mineral series 9, truncated and covered with mineral series 8; photo H. Klatkowa

PLATE II

Fig. 1. Koźmin. Organic-mineral horizon 7 with deformations; photo H. Klatkowa

Fig. 2. Koźmin. The uppermost Vistulian organic series 5 with deformations, underlain by the mineral series 6 and covered by the Holocene series 3; photo H. Klatkowa

Fig. 1

Fig. 2

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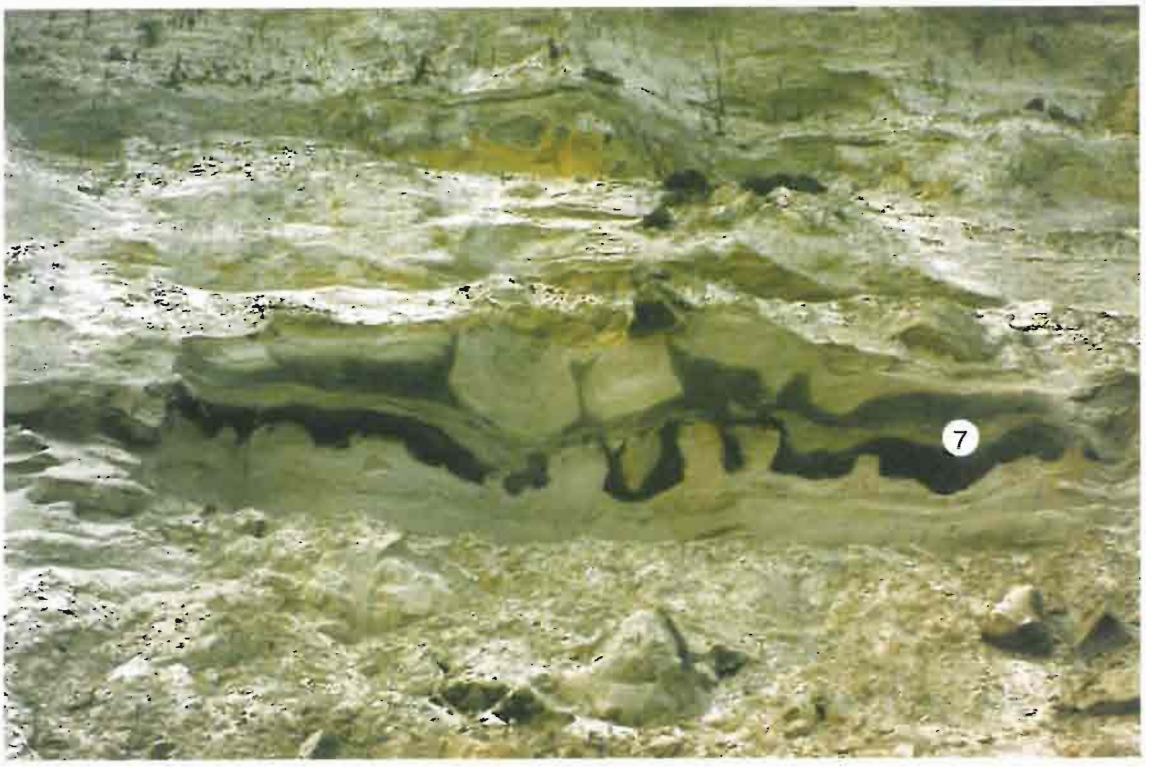

Fig. 1

Fig. 2

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