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Mazovian Interglacial at Cząstkowo near Stężyca — the first site in Pomerania

In the profile of the borehole at Cząstkowo at the depth of 105.8–128.5 m on the basis of lithology and pollen studies one identified sediments of the Mazovian Interglacial. The sediments occur within a thick intermoraine series, between tills of the San 2 and Odra glaciations. The series comprises ice-dam lake sediments and cyclic-layered valley sediments. The interglacial deposits consisting of fluvial sands and lake silts formed in the first (or one of the first) cycle of the valley sedimentation. Above, there occur similar sediments of the subsequent valley cycle, and on their basis one distinguished the first stadial and interstadial of the Odra Glaciation, following directly the Mazovian Interglacial.

INTRODUCTION

During elaboration of the Stężyca sheet of the *Detailed geological map of Poland* in the scale 1:50 000 by Gdańsk Department of the Geological Enterprise from Warsaw, one drilled three boreholes for mapping purposes, namely: at Cząstkowo, at Kamienica Szlachecka and at Bukowa Góra. All the boreholes pierced the Quaternary complex and achieved its substratum. The borehole at Cząstkowo appeared the most interesting, because it yielded well-formed sediments of the Mazovian Interglacial, described in the present publication.

The area covered by the Stężyca sheet occurs in the northeastern part of the Pomerania Lakeland. The borehole at Cząstkowo is localised in the Kaszuby Lakeland 5 km to the south of Stężyca, in the area of a denudated upland, limited in its northern margin with a broad channel of the Raduńskie Lakes (Fig. 1). The depth of the borehole achieved 259.0 m. At the depth of 253.0 m the borehole pierced the Quaternary sediments and entered the top of Tertiary deposits. The borehole was completely cored, similarly to the two other ones.

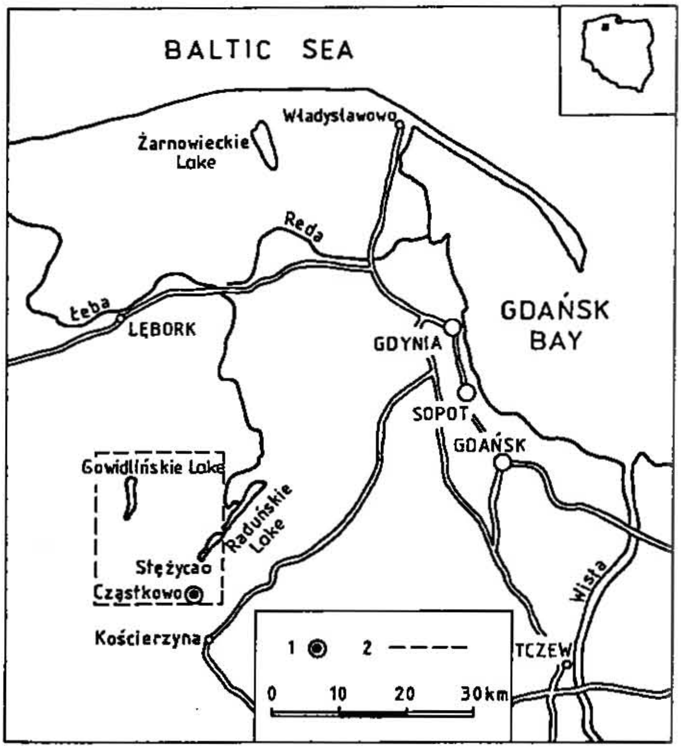


Fig. 1. Localisation sketch map
1 — Cząstkowo borehole, 2 — borders of the Stężyca sheet of the *Detailed geological map of Poland* in the scale 1:50 000 (L. Jurys, in press)
Szkic lokalizacyjny
1 — otwór wiertniczy Cząstkowo, 2 — granice arkusza Stężyca *Szczegółowej mapy geologicznej Polski* w skali 1:50 000 (L. Jurys, w druku)

L. Jurys is the author of the elaboration of the Stężyca sheet and the project of the distribution and location of the drillings (in press). The sediments, obtained from the drilling cores, were investigated lithologically and petrographically in the extent that was a standard for *Detailed geological map of Poland* (J. B. Nowak, A. Szelewicka, 1995), and the obtained results were used for the preparation of the map. They will not be discussed in details in the present report, because they are appropriate for a separate publication. B. Noryśkiewicz performed the pollen studies of the interglacial sediments from Cząstkowo and palynologic determinations for individual samples from the discussed profile and from the other two boreholes. A. Makowska is the author of the lithologic, genetic and stratigraphic, with regard to other studies, of the intermoraine series, bearing the interglacial sediments in the profile from Cząstkowo. For selected samples one performed the dating of the sediments by means of the thermoluminescence method (I. J. Olszak, S. Fedorowicz, 1993), which, however, correlate in a very limited degree with the results, obtained by other methods, and thus we will not discuss them in the present paper.

The elaboration of the profile from Cząstkowo became the basis of the lithogenetic and stratigraphic interpretation of the Pleistocene sediments in the whole area of the Stężyca sheet. Without recognition this location the orientation in the Quaternary stratigraphy would be distinctly more difficult, because the sediments of this age are poorly investigated here, and, as appears from the drillings for mapping purposes, they display large lithological differences and extensive disturbances caused by glaciotectonics and other processes that occurred in various periods of Quaternary.

The importance of profile from Cząstkowo is not limited to the area of one sheet of the map, but it may be extended to the entire Pomerania, because it is the first site in northwestern Poland with palynologically documented sediments of the Mazovian Interglacial. Moreover, beyond the interglacial deposits they also contain the younger, interstadial strata.

OUTLINE OF THE GEOLOGIC STRUCTURE

PRE-QUATERNARY SUBSTRATUM

Morphology and geologic structure of the pre-Quaternary substratum within the limits of the Stężyca sheet (Fig. 2) was obtained on the basis of four boreholes that pierced Quaternary beds, and, on the other hand, in relation to the area of the Egiertowo sheet (G. Hrynkiewicz-Moczulska, in preparation).

The borehole at Cząstkowo reached the largest depression of the pre-Quaternary substratum, occurring here at the altitude of 76.0 m b.s.l. In the other boreholes the substratum occurs higher and achieved a maximum height of 79.4 m a.s.l. at Bukowa Góra and 82.6 m a.s.l. at Sulęczyno. The depression from extends Cząstkowo meridionally along the channel of the Raduńskie Lakes and through Łączyno (78.0 m b.s.l.) heads northwards. In the area of Stężyca another depression separates from the previous one, extending to the region of Szymbark. The remaining part of the substratum has a poorly variable upper surface inclined eastwards and achieving maximum height of 70–80 m a.s.l. The origin of the substratum morphology is complex, because it was modelled by Quaternary processes of various age. The deepest depression, as it is indicated by the glacial sediments at Cząstkowo, is of the exaration nature. Its origin should be related to the oldest Quaternary. Higher slopes could be eroded by the rivers of the Mazovian Interglacial, as it is visible e.g. at Kamienica Szlachecka (Fig. 3). The morphology of the remaining part of the pre-Quaternary substratum is younger. It was formed both during the Mazovian Interglacial and during the periods younger than this interglacial.

On the surface of the pre-Quaternary substratum there occur only Tertiary deposits, as one may infer from the drilling cores. In the prevailing part of this area the sediments are of Miocene age and they are beige-to-dark brown dusty sands with admixture of brown coal dust. Their supposed thickness equals c. 55 m. The bottom of these sediments occurs at the height of 25 m b.s.l. Below, there appear Oligocene sediments drilled at Cząstkowo. They crop out probably along the both exaration depressions, extending from Cząstkowo to the

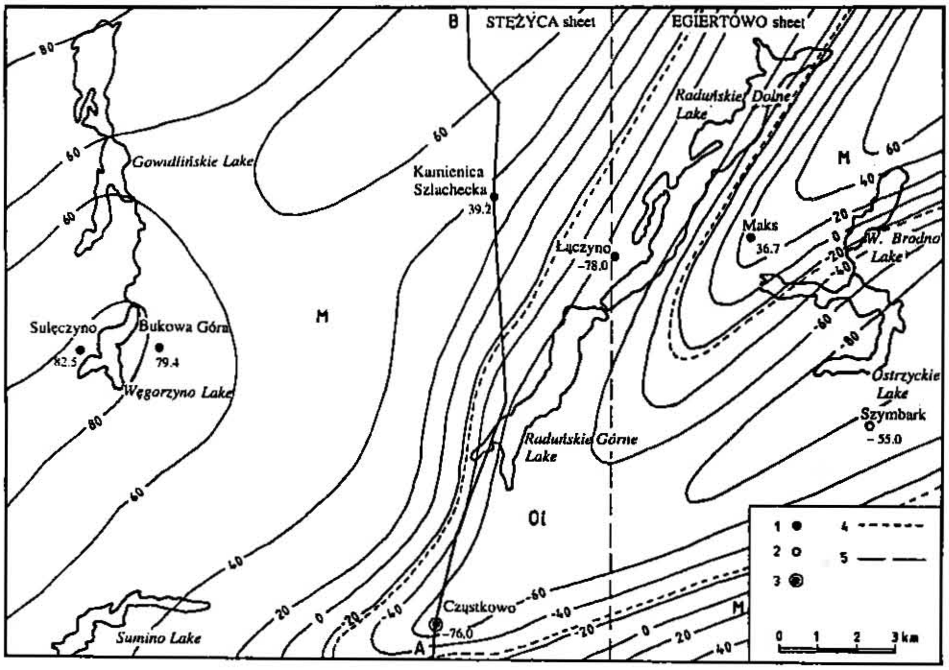


Fig. 2. Sketch map of the pre-Quaternary substratum

Boreholes: 1 — piercing Quaternary, the number means the height of the pre-Quaternary substratum, m a.s.l., 2 — not reaching the Quaternary bottom, the number means the height of the borehole bottom, m a.s.l.; 3 — Cząstkowo borehole; 4 — geologic borders; 5 — borders between the Stężyca and Egiertowo sheets (G. Hrynkiewicz-Moczulska, in preparation), A–B — line of the geologic cross-section; M — Miocene, Ol — Oligocene

Szkic podłoża czwartorzędu

Otwory wiertnicze: 1 — przebijające czwartorzęd, liczba oznacza wysokość podłoża czwartorzędu w m n.p.m., 2 — nie przebijające czwartorzędu, liczba oznacza wysokość dna otworu w m n.p.m.; 3 — otwór Cząstkowo; 4 — granice litologiczne; 5 — granica między arkuszami Stężyca i Egiertowo (G. Hrynkiewicz-Moczulska, w przygotowaniu); A–B — linia przekroju geologicznego; M — miocen, Ol — oligocen

north-east. At Cząstkowo their thickness equals 6 m. The Oligocene sediments are hiatal dark green glauconitic and clayey sands with poorly visible parallel lamination. The bottom of the Oligocene sediments is unknown.

QUATERNARY

The Quaternary sediments their greatest thickness (253 m) achieved at Cząstkowo and they represent the most complete Quaternary profile for the whole Stężyca sheet (Figs. 3, 4A).

The sediments of the Mazovian Interglacial, occurring only in this profile and studied palynologically, which split the Quaternary complex in the parts older and younger than this interglacial, are the basis of the stratigraphic division of the Quaternary deposits. Further division was made on the basis of the lithostratigraphic horizons. Below the Mazovian

Interglacial one distinguished sediments of the following glaciations: the oldest one (Narew Glaciation) with one bipartite till horizon, and the South-Polish Glaciations with three main till horizons (Nida, San 1 and San 2). Above the Mazovian Interglacial deposits there occur the sediments of the Mid-Polish Glaciations with two till horizons (Odra and Warta), locally separated by the sediments of the Eemian Interglacial from the overlying sediments of the North-Polish Glaciations, with two or three till horizons belonging to the Baltic Glaciation (the Świecie and Pomerania-Leszno stadials with two phases).

The sediments of the older Pleistocene have been recognised only at Cząstkowo, where they fill an exaration depression in the pre-Quaternary substratum and probably extend along its whole length. The sediments younger than the Mazovian Interglacial are also known from other localities, including the two boreholes made for mapping purposes, and they occur in the whole area of the Stężyca sheet.

THE OLDEST GLACIATION (NAREW)

Sediments of this glaciation differ from the upper part of the Pleistocene profile in their lithological features and disturbances in upper layers. The sediments occur at the depth of 218.0 to 253.0 m. Clayey and dusty sands form the bottom, covered with till horizon of the thickness of 28.5 m. In the lower part it is a 10 m thick layer of homogeneous, compact, gray till with abundant admixture of gravel and pebbles. Above, similar gray till is intercalated with gray clay of distinctly disturbed layers, oriented obliquely to the drilling core axis.

The overlying 4 m thick layer of gray-blue clay intercalated with till shows similar disturbances. This clay finishes the glacial cycle and indicates the total glacial recess. The disturbances of the layers, that affected an almost 20 m thick depth zone, developed due to pressure of a subsequent inland ice. The displacement of the sediments occurred in a local exaration depression, limited by margins and probably strongly flooded.

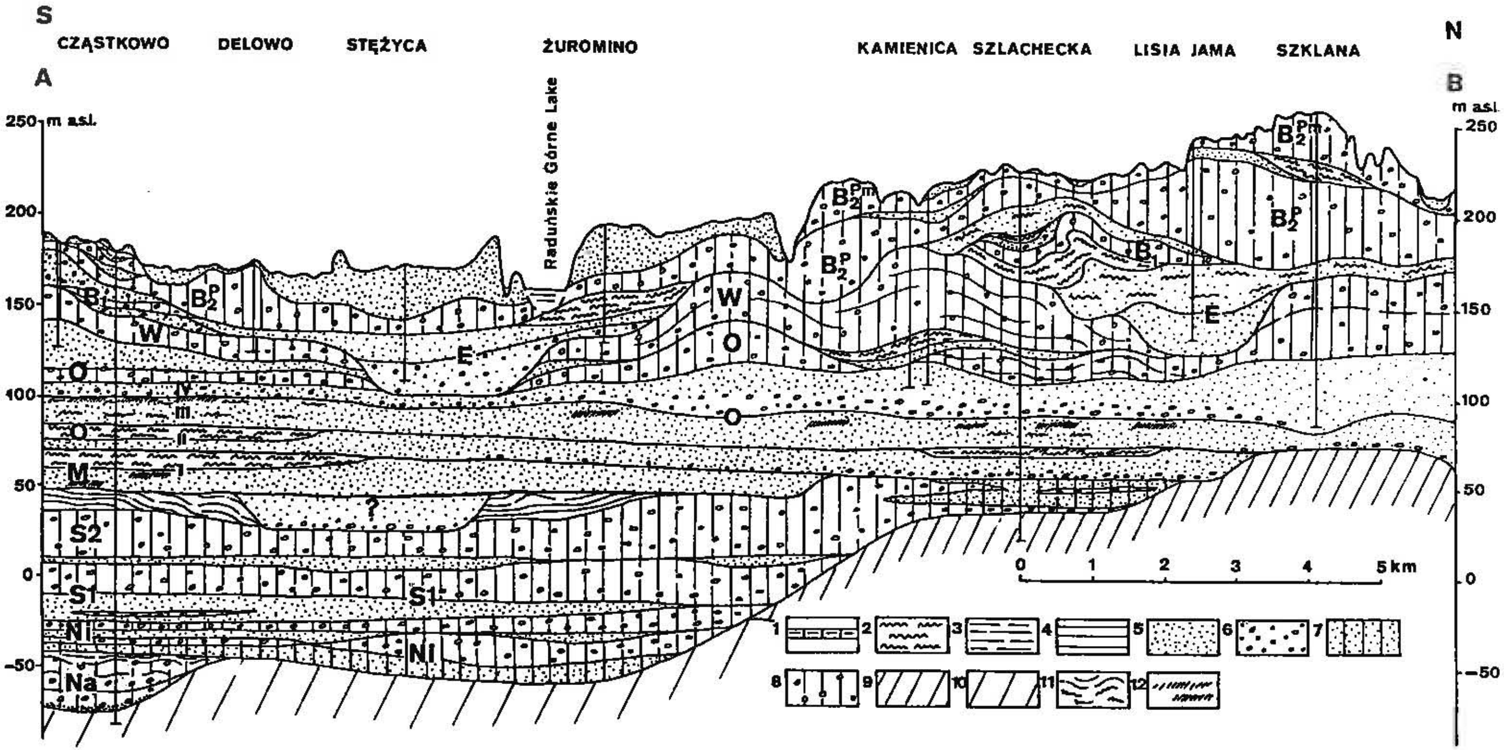
THE SOUTH-POLISH GLACIATIONS

Erosion and denudation that started after the oldest glaciation, removed the oldest Pleistocene sediments as well as probably in part Tertiary ones. The glacial sediments of the oldest glaciation remained only in distinct depressions of this area. The younger Pleistocene complex typically bearing many till horizons separated by irregular sandy intercalations, covered afterwards the remnants of the oldest glaciation sediments.

On the basis of the analysis of the macroscopic lithologic and structural features, and petrographic investigations, this complex was divided into three parts: lower, middle and upper, that were attributed to separate glaciations: Nida, San 1 and San 2.

The sediments of the Nida Glaciation, forming the lower part of the complex, occur at the depth of 205.0–218.0 m. They consist of clayey sands with intercalations of till, splitted to two parts by a 1.5 m thick layer of clay. The sediments bear a significant admixture of the pre-Pleistocene substratum rocks, namely crushed Cretaceous marls with cherts that occur in the lower part of the sandy sequence, and glauconite sand trails in till, what makes the difference with respect to the overlying middle part of the complex. Inland ice of that glaciation had to exarate strongly the pre-Quaternary substratum till then.

The sediments from the depth of 170.8–205.0 m that form the middle part of the complex are attributed to the San 1 Glaciation. They consist of gray, compact, sandy till,


S
N
CZĄSTKOWO
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250
200
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0 1 2 3 4 5 km
1 2 3 4 5 6 7
8 9 10 11 12

in their lower part intercalated and underlain by fine- and vari-grained sands. Unlike the underlying sediments of the Nida Glaciation, this part of the profile bears none of the admixtures derived from the pre-Quaternary substratum. This feature proves, that during this inland ice transgression, the pre-Quaternary substratum was still covered by sediments from the previous glaciation.

Above, at the depth of 128.5–170.8 m, there occurs subsequent glacial complex, attributed to the San 2 Glaciation. This complex begins from clayey sands covered by vari-grained sands then overlain (depth 143.8–167.4 m) by a 23.6 m thick bed of gray, sandy, compact till, bearing in its bottom part intercalations of the Tertiary calcareous-free sandy clays of green colour. This till is covered by a series of clayey and silty sediments of an ice-dam lake, gradually altering upwards to a regular lake deposit (depth 128.5–143.8 m), formed at the decline of the glaciation. Sediments of this series are partly disturbed due to charge and flowage processes.

THE MAZOVIAN INTERGLACIAL

Fluvial and lacustrine deposits of one cycle (I) of the valley sedimentation form the interglacial series. They were exclusively recognised in the profile from Cząstkowo. The fluvial sediment consists of fine-grained sands, occurring at the depth of 116.5–128.5 m. The sands are overlain by lacustrine sediment, the actual interglacial deposit, consisting of calcareous silts of the thickness of 10.9 m (depth 105.8–116.7 m) with organic remnants. A detailed description of this deposit will be presented in the further part of the present text.

THE MID-POLISH GLACIATIONS

The sandy and silty sediments, occurring at Cząstkowo directly on the interglacial series at the depth of 68.5–105.8 m and two horizons of till from the depth of 28.5-68.5 m separated by a more than 20 m thick series of sands and gravels, and covered with similar sands, are considered as formed during this period. One reckons them the sediments of the Odra and Warta glaciations.

The Odra Glaciation deposits began from preglacial sediments. They are fluvial fine-grained and dusty sands of the total thickness of c. 27.0 m (depth 79.0–105.8 m) separated by a 7 m thick layer of lacustrine silts. These sediments are a continuation of the deposits of the Mazovian Interglacial and they represent two further cycles of the valley

Fig. 3. Geological cross-section A–B

1 — lake marl, 2 — silts, 3 — clays, 4 — varved clays, 5 — sands, 6 — chads and gravels, 7 — clayey sands, 8 — till, 9 — Miocene sediments, 10 — Oligocene sediments, 11 — disturbances and cracks of layers, 12 — plant detritus; glaciations: Na — Narew, Ni — Nida, S1 — San 1, S2 — San 2; M — Mazovian Interglacial; glaciations: O — Odra, W — Warta; E — Eemian Interglacial; Baltic Glaciation: B_1 — Świecie Stadial; B_2 — Leszno-Pomerania Stadial: B_2^P — Leszno-Poznań Phase, B_2^{Pm} — Pomerania Phase; I–IV — valley sedimentation cycles

Przekrój geologiczny A–B

1 — kreda jeziorna, 2 — mułki, 3 — iły, 4 — iły warwowe, 5 — piaski, 6 — żwirki i żwiry, 7 — piaski gliniaste, 8 — glina zwałowa, 9 — osady mioceńskie, 10 — osady oligoceńskie, 11 — zaburzenia i spękania warstw, 12 — detrytus roślinny; zlodowacenia: Na — narwi, Ni — nidy, S1 — sanu 1, S2 — sanu 2; M — interglacjał mazowiecki; zlodowacenia: O — odry, W — warty; E — interglacjał eemski; zlodowacenie bałtyckie: B_1 — stadiał świecia, B_2 — stadiał leszczyńsko-pomorski: B_2^P — faza leszczyńsko-poznańska, B_2^{Pm} — faza pomorska; I–IV — cykle sedymentacji dolinnej

sedimentation (II, III). They are the evidence of cyclic climate changes at the beginning of the Odra Glaciation. Above, there occur the sediments of a subsequent cycle (IV), comprising fluvial and glacifluvial fine- and vari-grained sands with fine gravels, related to approaching inland ice. The glacial part of the sediments consists of gray clayey-sandy compact till covering the sands. The till in its upper part is strongly outwashed, thus altered to clayey sands with gravels. Thickness of the till at Cząstkowo is small and equals c. 3.5 m. Such till occurs at many places of the described area, e.g. at Kamienica Szlachecka, where it achieves the thickness up to 20 m (Fig. 3). Outwashing of the till top at Cząstkowo occurred in the period, which may be connected to the Lublin Interglacial, however, there lack any distinct sediments that would confirm the rank of this period. The following sandy layer, occurring on the latter till, does not display recognisable features of a fluvial sediment. Thickness of this layer exceeds 25 m. This sandy layer occurs as well in other localities except for Cząstkowo, where it separates two beds of the Mid-Polish tills.

At Cząstkowo, above the sand there occurs a subsequent till bed of the thickness of 14.0 m, reckoned the Warta Glaciation. The till appears commonly in the whole described area; locally its thickness significantly exceeds the thickness at Cząstkowo. At Kamienica Szlachecka it is disturbed glaciotectonically jointly with the underlying till of the Odra Glaciation, as one could distinctly recognise in the drilling core (Fig. 3).

THE EEMIAN INTERGLACIAL

At Cząstkowo the sediments of this period are absent. In other locations there are known sandy-gravel, sandy or muddy-sandy sediments of the thickness achieving 40 m, which filled the depressions of the river valley type in the surface of the Odra Glaciation tills (Stężyca, Lisia Jama). These sands are most pronounced inter-moraine series of the younger part of the Pleistocene complex, thus they were reckoned the Eemian Interglacial.

THE NORTH-POLISH GLACIATIONS

At Cząstkowo, like in the remaining parts of the Stężyca sheet, this period is represented by two and at places by three beds of till, separated and underlain by fluvioglacial sediments. As resulted from a general analysis, these sediments were related to two stadials of the Baltic Glaciation: Świecie and Leszno-Pomerania, with two phases distinguished in the latter, i.e. Leszno-Poznań and Pomerania ones (Fig. 3).

Thickness of the tills as well as thickness of the separating and underlying fluvioglacial sediments is variable. The Leszno-Poznań till achieved the greatest thickness; locally, e.g. at Kamienica Szlachecka and at Szklana it reached 40 to 60 m. Inland ice that sedimented this till, moved on uneven substratum and thus it was very active. It caused great disturbances of the sediments in its substratum at Kamienica Szlachecka, forming there a kind of a large squeezing moraine. In the disturbed structures there occur the sediments of the Odra and Warta glaciations, Eemian Interglacial and Świecie Stadial. Splitting of the two upper Baltic tills of the Leszno-Pomerania Stadial is not everywhere distinct, however, at many places they form separate horizons, proving individual character of the Pomerania Phase in this area. During the inland ice recess of this phase, the present-day terrain morphology with the whole variability of sediments and recess forms developed, however, their characteristics exceeds the limits of the current publication.

THE MAZOVIAN INTERGLACIAL AT CZĄSTKOWO

CHARACTERISTICS OF THE INTERMORAINE SERIES

The sediments of the Mazovian Interglacial occur in the middle part of the 74 m thick intermoraine series, located between tills of the San 2 and Odra glaciations (depth 68.5–142.5 m), as shown in Figure 4A, B, F. The lower part of this series formed at the decline of the San 2 Glaciation, whereas the upper part was connected with the preglacial period of the Odra Glaciation.

D e c l i n e o f t h e S a n 2 G l a c i a t i o n . The series started from ice-dam lake and lacustrine sediments (depth 128.5–142.5 m), occurring directly on till of the San 2 Glaciation. In the lower part there occurs a 6 m thick layer of typical gray varved clay, intercalated by thin silt laminae, and in the bottom indented with till. Above, one observed clayey or sandy silts of the thickness of 1.6 m, bearing trails or abundant intercalations of plants detritus, that caused black colour of the sediments. Palynologic analysis of one sample from these sediments shown the presence of mixed pollens of Quaternary and Tertiary plants. On the silts there lie again compact, gray clays 6.3 m thick, irregularly intercalated by light beige silts, and with trails of organic matter in the top. An overlying half-metre-thick layer of gray clay intercalated with gray-greenish silt with distinct admixtures of organic matter evidenced that the lake became grown over with plants.

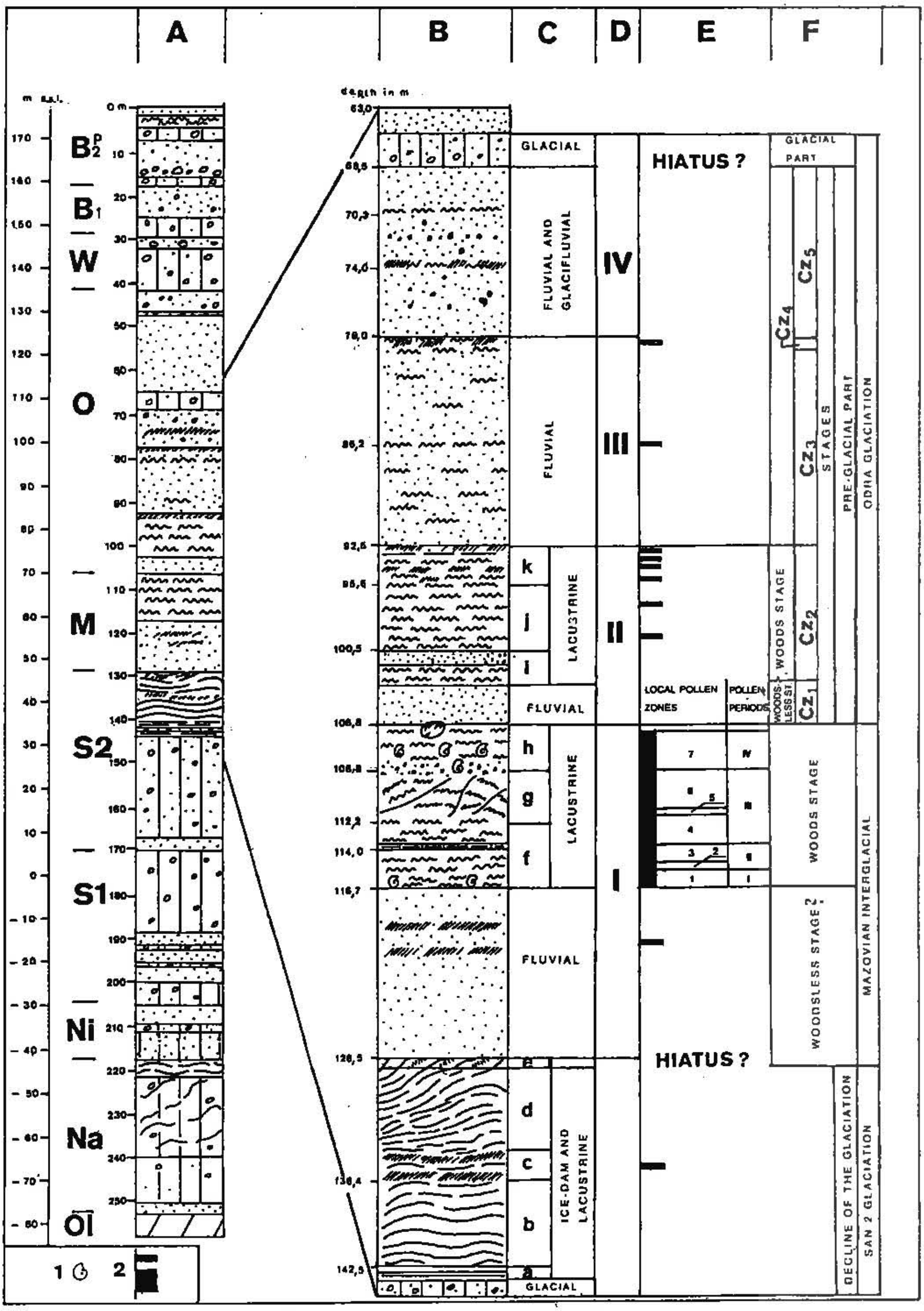
The complex of the layers characterised above recorded the evolution of the ice-dam lake and its change in a regular lake during climate warming on the decline of the San 2 Glaciation (Fig. 4C). In the evolution one may distinguish five phases:

a — glacial-ice-dam lake with an inflow of moraine material,
b — typical still and deep ice-dam lake,
c — shallowed reservoir with inflow of silt with detrital plant matter,
d — deep lake reservoir,
e — shallowed lake, in part becoming grown over with plants.

The above-described ice-dam lake and lacustrine layers are squeezed and fairly strongly disturbed, because locally they are almost vertically oriented in the drilling core. The most probable explanation of the origin of these disturbances is, that they were of the slide-flow type and formed on the slopes of valleys at the beginning of the Mazovian Interglacial during an intensive, bottom-eroding river activity (Fig. 3).

T h e M a z o v i a n I n t e r g l a c i a l . Thickness of the interglacial sediments equals 22.7 m (depth 105.8–128.5 m). These sediments formed in one simple cycle of the valley sedimentation (I), consisting of two parts: lower one, comprising fluvial deposits of the thickness of 11.8 m and upper one, being lacustrine deposits of the thickness of 10.9 m (Fig. 4B, C).

The fluvial deposits are fine- and equi-grained selected sands of horizontal lamination. In the lower part they are gray-brown, higher — brown-gray. In the upper part of the layer the sands become silty and bear trails of humus and seams of plant detritus. All these features as well as the results of the lithologic-petrographic studies indicate their fluvial origin. The sediment are a deposit of an apparently meandriform river with slow, gradually extincting flow.


A
B
C
D
E
F
m a.s.l.
depth in m
GLACIAL
FLUVIAL AND GLACIFLUVIAL
FLUVIAL
LACUSTRINE
FLUVIAL
LACUSTRINE
FLUVIAL
ICE-DAM AND LACUSTRINE
GLACIAL
IV
III
II
I
HIATUS ?
LOCAL POLLEN ZONES
POLLEN PERIODS
HIATUS ?
GLACIAL PART
PRE-GLACIAL PART
ODRA GLACIATION
STAGES
WOODS STAGE
WOODLESS STAGE ?
MAZOVIAN INTERGLACIAL
DECLINE OF THE GLACIATION
SAN 2 GLACIATION
1
2

The overlying silt is a lacustrine sediment. The silt layers are variegated, thus indicating an evolution of the lake in three main phases (Fig. 3C):

f — that yielded the sediments from the borehole at the depth of 112.2–116.7 m. The sediments consist of horizontally laminated gray-beige, locally whitish sandy silts that are calcareous-rich, at places even with seams of lake marl. As resulted from lithologic-petrographic studies (J. Nowak, A. Szelewicka, 1995), they may be considered calcareous gyttja. Their bottom part bears single, crushed mollusc shells. This type of sediments is known from initial formation stages of lakes in cool climate.

g — represented by silts, present in the borehole at the depth of 108.8–112.2 m. The silts are sandy, gray and gray-brownish, compact and squeezed, and typically in part fractured and brecciated, thus they formed probably in two different periods. In the first one they precipitated quietly at the lake bottom, in the second one they emerged and submerged periodically due to the changes of the water level in the lake as caused by local changes of the hydrologic conditions.

h — (depth 105.8–108.8 m) in which the filling of the lake with fluvial sediments started and the process of shallowing continued. It is proved by sands, chads and gravels with very finely crushed mollusc shells, occurring in the bottom of the silty layers at the depth of 108.7–108.8 m. Above there occur again silts up to the depth mark of 105.8 m; they are horizontally laminated, brittle, more sandy than the lower silts, and upwards becoming gray, increasingly porous and calcareous-rich. At the depth of 107.0–108.2 m the silt bears very fine chips of mollusc shells, among which one determined only a fragment of the *Valvata* sp. apex and *Ostracoda*. The top of these sediments was outwashed, as evidenced by a pebble of diameter of 10 cm.

The deposits of all the phases indicate that the lake was variable in time and not deep, despite accumulation of the appreciable amount of the sediments.

The pollen analysis, performed for the whole lacustrine series showed, that the series formed during a full development and extinction of the forest vegetation of the Mazovian Interglacial (Fig. 4E). Fluvial sands underlying the silty series, formed at an earlier stage, supposedly in the beginning of the first pollen period, not recorded in the sediments, or in climatic conditions, unfavourable yet for the forest development. Presence of the well-formed river valley, in which these sediments deposited, indicates already the interglacial period.

Preglacial part of the Odra Glaciation. Above the interglacial sediments, the upper part of the intermoraine series occurs, consisting of more than 37

Fig. 4. Profile of the sediments of the Mazovian Interglacial on the background of the San 2–Odra intermoraine series

A — lithologic profile of the drilling core; B — lithologic profile of the intermoraine series; C — sedimentation environment: **a–k** — phases of the lake development; D — valley sedimentation cycles I–IV; E — palynologic studies: 1–7 — local pollen zones, I–IV — pollen periods; F — stratigraphy: Cz_1, Cz_3, Cz_5 — stadials, Cz_2, Cz_4 — interstadials; 1 — molluscs, 2 — profile sections studied palynologically; other explanations as in Fig. 3

Profil osadów interglacjału mazowieckiego na tle serii międzymorenowej san 2–odra

A — profil litologiczny otworu; B — profil litologiczny serii międzymorenowej; C — środowisko sedymentacyjne: **a–k** — fazy rozwoju jezior; D — I–IV — cykle sedymentacji dolinnej; E — badania pyłkowe: 1–7 — poziomy pyłkowe, I–IV — okresy pyłkowe; F — stratygrafia: Cz_1, Cz_3, Cz_5 — stadiały, Cz_2, Cz_4 — interstadiały; 1 — mięczaki, 2 — odcinki profilu badane palinologicznie; pozostałe objaśnienia jak na fig. 3

m sands and silts, where one may distinguish at least three further valley sedimentation cycles (Fig. 4D).

The lowest cycle II of the valley sedimentation (depth 92.5–105.8 m) comprises the sediments similar to those of the Mazovian Interglacial. The cycle started from a layer of fine- and equi-grained brown decalcified fluvial sands of the thickness of 3.3 m. A series of silts of the thickness of 10.0 m (depth 92.5–102.5 m) lies in this layer. The silts are similar to those in the underlying interglacial series. They are sandy or sandy-clayey, horizontally layered, in the lower part intercalated with a thick seam of sand, and in the upper part close to the top they bear trails and appreciable dispersed admixture of organic matter and humus as well as plant detritus. The silts are gray in the bottom part, upper beige and light beige, and in the top part dark gray due to organic matter admixtures.

The features of the sediment indicate the reservoir of different phases of development (Fig. 4C). Initially, it was an oxbow (phase **i**) with a periodical river flow, later a vast, clean lake (phase **j**), afterwards shallowed and grown over with plants (phase **k**). On the basis of lithology one may conclude (irrespectively of the results of the pollen analysis, which will be discussed in the further part of the text, see Fig. 4E) — that the deposits of the valley sedimentation cycle II formed in climate close to the climatic conditions of formation of the underlying interglacial series. In the beginning there was a cool period, which left fluvial sands, afterwards a warmer one when a series of the lacustrine silts formed.

In the following valley sedimentation cycle III (depth 79.0–92.5) a consecutive thick sand layer finished with a thin layer of a clayey silt of the thickness of 0.7 m, bearing abundant plant detritus. These sediments are different than those of the two older cycles. First and foremost, one may recognise a significant prevailing of sands over silts, what proves, that the sediment formed in a flowing environment, though the flow was very slow. Sands are very fine-grained or silty, in the bottom part intercalated with very thin seams of silt, extincting upwards.

The river, that transported sandy material, overflew broadly and its water was dammed up periodically. In the final period of this sedimentation shallow flood-waters formed, that were filled then by clayey silt. Palynologic analyses of the sediments showed the presence of mixed Tertiary and Quaternary pollens.

During the last valley sedimentation cycle IV (depth 68.5–79.0 m), the grain size of the sediments displayed further changes. The material becomes more coarse-grained. In addition to fine-grained sands, there occur medium-grained and hiatal ones and chads of the grain size up to 1.0 cm in diameter, and scarce layers of gravels of pebble diameter up to 2.0 cm. Locally, single trails of silt still occur. This sequence indicates an increase of the water flow velocity, which could be caused by an inflow of water from the north, from the approaching inland ice. The fluvial sedimentation, that replaced the fluvioglacial one, finally filled and smoothed the river valley existing from the beginning of the Mazovian Interglacial (Figs. 3, 4E).

POLLEN ANALYSIS

METHODS

One performed a detailed analysis of 46 samples taken from the organic-matter-bearing sediments of the thickness of 10.4 m from the depth of 106.0–116.4 m (Fig. 4E).

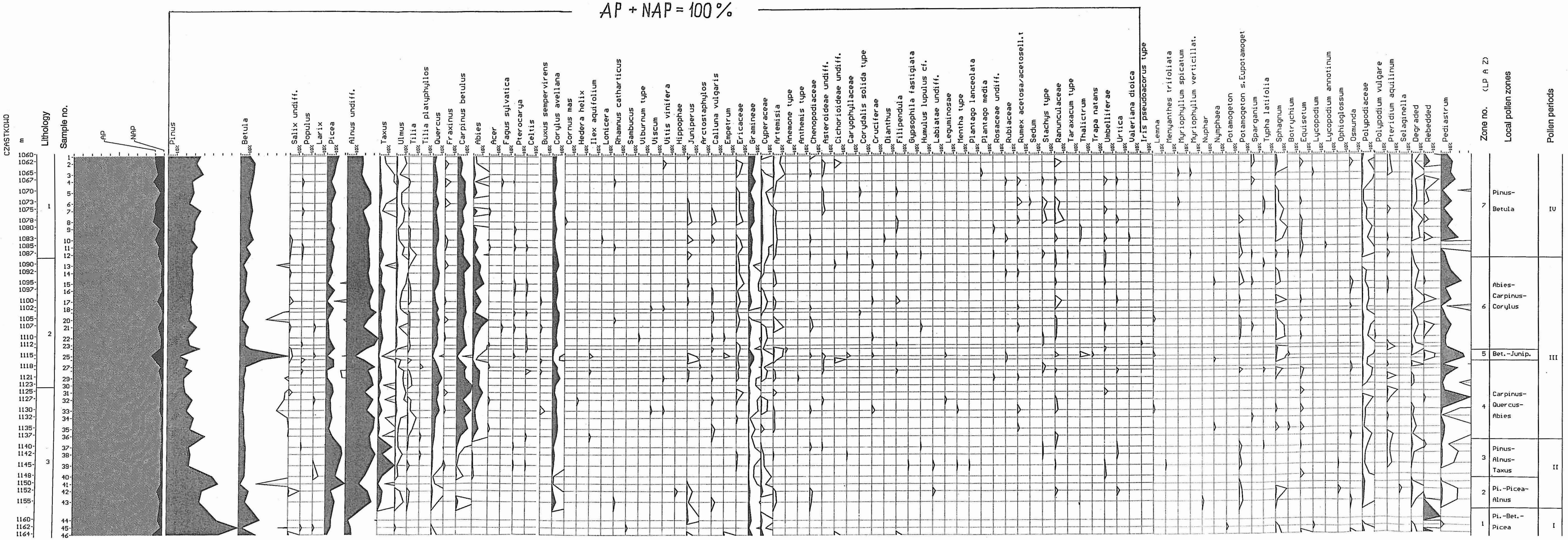


Fig. 5. Pollen diagram of the sediments from Cząstkowo

Lithology: 1 — sandy silts, 2 — gray, partly brecciated sandy silts, 3 — whitish clayey-sandy silts (calcareous gyttja)

Diagram pyłkowy osadów z Cząstkowa

Litologia: 1 — mułki piaszczyste, 2 — mułki piaszczyste szare, częciowo zbrekcjowane, 3 — mułki ilasto-piaszczyste białawe (gytia wapienna)

One macerated the analysed samples by means of various methods, depending on the kind of sediments. Most of the samples required a 48-hour-treatment with HF for the clay fraction separation. Removal of calcium carbonate with HCl and humus dissolution by boiling in 10% KOH were the subsequent stages of the laboratory treatment. All samples were macerated at the final stage by the acetolysis method.

The studied samples had relatively good frequency and satisfactory preservation state of sporomorphs. In certain spectra, mainly in the bottom and to lesser extent in the top parts of the layer, one found an admixture of older forms, relatively easy to distinguish visually (in the pollen diagram the item *Rebedded*). One distinguished the pollens of *Tsuga*, *Taxodium*, cf. *Podocarpus* and *Nyssa*. The spectra from the depths of 111.5 and 111.6 m displayed poor preservation state and low frequency of pollens.

The results of the palynological analysis are presented on the extended pollen diagram (Fig. 5). The total of the tree pollens (AP) and herbaceous plant pollens (NAP) equal 100% were the basis of the calculations. The percentage shares of aquatic plant pollens and spores were calculated with respect to this total.

INVESTIGATION RESULTS

Analysis of the pollen diagram of the profile from Cząstkowo caused, that on the basis of the vegetation changes, one distinguished 7 local zones, in 4 periods characterising the interglacial succession (Z. Janczyk-Kopikowa, 1987).

Zone 1 *Pinus-Betula-Picea* (samples 44–46; depth 115.5–116.4 m). Pine (*Pinus*) max. 79.9% and birch (*Betula*) max. 23.7% were the dominating trees. They were associated with spruce (*Picea*) max. 6.8%, alder (*Alnus*) max. 7.1% and juniper (*Juniperus*) max. 1.7%. The total of herbaceous plants (NAP) achieves 10.4%. In the zone 1 there was the highest number of the redeposited grains in the whole profile (*Rebedded* max. 18.6%, not included to the 100% total).

Zone 2 *Pinus-Picea-Alnus* (samples 40–43; depth 114.8–115.5 m). In this zone the mixed forests dominated with still prevailing pine (*Pinus*) max. 57.1% and the first maximum of spruce (*Picea*) 22.3%. In this zone the alder curve reaches its maximum of 29.5% earlier than spruce. The listed species are associated with yew (*Taxus*) max. 5.8%, oak (*Quercus*) max. 1.8%, elm (*Ulmus*) max. 1.0%, hornbeam (*Carpinus*) max. 2.6% and hazel (*Corylus*) max. 4.6%. At this time in the water reservoir there occurred submerged plants, e.g. pond-weed (*Potamogeton*) and these with floating leaves, e.g. waterlily (*Nuphar*), as well as planktonic algae (*Pediastrum*), and on the reservoir sides — peat moss (*Sphagnum*) and ferns (*Polypodiaceae*).

Zone 3 *Picea-Alnus-Taxus* (samples 37–39; depth 113.7–114.8 m) is characterised by pollen spectra with maximum values of yew (19.5%) and spruce (19.0%) for the whole profile. The lowest values of the total herbaceous plants (NAP) fall here, what proves a compact forest around this assemblage. Yew probably occurred in the lower height assemblage of the trees. The values for pine decrease in this zone from 50.6 to 24.4%. Oak, elm and hornbeam display low, but still continuous curves.

Zone 4 *Carpinus-Quercus-Abies* (samples 27–36; depth 111.6–113.7 m) is distinguished by increase of stenothermal species of deciduous trees (elm max. 15.8%, oak 11.4%, hornbeam 2.4% and hazel 8.7%) associated with fir (*Abies*), achieving in this zone maximum 11.4%. As hitherto, alder occurs at humid habitats, maintaining — like in the previous zone — high shares (mean for the whole zone 28.3%). The compact shady forests (low NAP curve) did not permit to expand the photophilous birch. Its curve does not exceed 5%. Waterlily (*Nymphaea*), duckweed (*Lemna*), pond-weed (*Potamogeton*) and algae (*Pediastrum*) grew in the water reservoir, and on the lake shore — cattail (*Typha latifolia*) and bur reeds (*Sparganium*).

Zone 5 *Betula-Juniperus* (samples 25–26; depth 111.3–111.6 m). The pollen spectra of the samples present a distinctly different plant succession, untypical for the interglacial optimum. Birch dominated utterly (54.2%), the curves of the other trees decreased, juniper (*Juniperus*) appeared, and the total of the herbaceous plants increased several times to the values of 9.8 and 12.9%. Such pollen spectra are typical of boreal climate and would indicate rapid, transitory coolness. The rapid increase of birch from 6.8 to 26.3% suggests redeposition of this sediment. The kind of sediment in this zone, determined as brecciated silt, confirms this conclusion. The pollen grains, found in this zone and indicating climate optimum, like caltrop (*Trapa*) and holly (*Ilex*), support the opinion about mixing of pollens of the plants from various climatic conditions.

Zone 6 *Abies-Carpinus-Corylus* (samples 12–24; depth 108.7–111.3 m). In its set of sporomorphs, this zone is similar to the zone 4. The decreasing curve of spruce draws the distinction between the two zones (a minimum in the sample 17 equals 0.9%), as well as the higher fir values (max. 17.0%). Alder continuously maintains high values, to achieve even the absolute maximum (35.5%), occurring probably in the same humid habitats as in the older zone. Pine occurs in the whole zone in the constant, but a little higher values than in the zone 4. The occurrence of the pollens of grape-vine (*Vitis*), mistletoe (*Viscum*) and box (*Buxus*) proves that climate during this phase was humid and warm.

Zone 7 *Pinus-Betula* (samples 1–12; depth 106.0–108.7 m). The curves of pine and birch gradually increase from the beginning of this zone. Herbaceous plants become more numerous as well. The NAP curve usually exceeds 10% (max. 11.9%), and its main components are plants of the heath family (*Ericaceae*), grass (*Gramineae*), sedge (*Cyperaceae*), motherwort (*Artemisia*) and ragwort type (*Stachys* type). Most of them are taxons of the photophilous plants, evidencing the less compact forest type of this part of the interglacial. The water reservoir exists continuously with aquatic and rush plants. As shown by pollens, this kind of plants includes water nimfoil (*Myriophyllum spicatum, M. verticillatum*), pond-weed (*Potamogeton*), cattail (*Typha latifolia*) and bur reeds (*Sparganium*). In the spectra the curve of peat moss (*Sphagnum*) increases, spores of horsetail (*Equisetum*) are more frequent as well. In the top samples the curves of all deciduous trees but birch decrease, and the shares of pine and spruce increase; the sporomorphs occurring in the secondary deposit are more numerous as well.

AGE OF FLORA IN THE SEDIMENTS FROM THE PROFILE OF THE CZĄSTKOWO BOREHOLE

When compared with the periods, distinguished in the typical interglacial diagrams, one may ascertain, that the elaborated pollen diagram from Cząstkowo bears all the distinguished periods (I–IV) and it records the interglacial plant succession (W. Szafer, 1953, and others). The zone 1 in the diagram from Cząstkowo may be related to the pollen period I, characterising the moderately cold (boreal) climate partly temperate (Z. Janczyk-Kopikowa, 1991). Changes of the plant assemblage in this zone are of progressive nature. The zones 2 and 3 may be correlated with the period II, and the zones 4 and 6 — with the period III.

The periods II and III are typical forest ones, characteristic for the interglacial optimum climate (Z. Janczyk-Kopikowa, 1991). The vegetation in this zone is of the climax type. The zone 7 displays plant assemblage similar to that one of the period IV, in which the vegetation is of the regressive type.

The site of the interglacial sediments from Cząstkowo, has distinct diagnostic features and represents a succession, typical for the Mazovian Interglacial. It is of great importance for recognition of the plant succession during this interglacial in the area of Poland and occupies a very important position among the hitherto identified findings from that period. The described profile is the only representative of the discussed interglacial in the Pomerania Lakeland and unique in northwestern Poland. In the belt of the lake districts relatively far to the east (Mazury Lakeland) one described the sediments of this period only at Węgorzewo (M. Sobolewska, 1975) and at Koczarki (Z. Borówko-Dłużakowa, W. Słowański, 1991).

Most of the known flora, representing the Mazovian Interglacial in Poland is localised in the eastern part of the country, whereas in the western part (to the west from the line: Gdańsk–Łódź–Kraków) the profile from Cząstkowo is barely the fourth known site from that period (Boczów — Z. Janczyk-Kopikowa, S. Skompski, 1977; Wieluń Upland — Z. Borówko-Dłużakowa, 1981; Gościęcin — A. Środoń, 1957).

The plant succession of the Mazovian Interglacial at Cząstkowo in the pollen spectra is characterised by great shares of conifers and expansion of deciduous trees in the following sequence: initially pine dominated, and in turn alder, spruce and yew did. Hornbeam increased its share contemporaneously with fir, and the stenothermal deciduous trees (oak, elm, linden and ash) occurred in small but constant amounts in the whole period. The share of alder in the spectra at Cząstkowo is significant, like at Boczów (the first increase of the value it achieves earlier than spruce, unlike the most of the diagrams from the eastern Poland).

The occurrence of yew is correlated with the increase of the alder and spruce values and with the barely marked in the diagram presence of sporomorphs of the stenothermal deciduous trees. After the yew maximum (but before the increase of the values of hornbeam and fir) at Cząstkowo, as well as in the most diagrams with the flora of the Mazovian Interglacial, one observes the increase of pine. K. M. Krupiński *et al.* (1988) pays the attention to this phenomenon in the profile from Biała Podlaska, explaining the decrease of the yew values by an influence of the climatic soil factors. Taking into account the significant distance between these two locations, one should consider rather the climatic factor than the soil one (limited to small areas), as responsible for the decrease of the yew curve and the increase of the pine curve. The share of hornbeam in the forest assemblages, which in the period considered is smaller among the vegetation of the described area than in eastern Poland, may be accepted as a regional feature. The maximum hornbeam contents in the spectra from Cząstkowo and from further to the west located Boczów do not exceed 15.8 and 10.0%, respectively, whereas in the most profiles from the locations occurring to the east of Cząstkowo the maxima achieve values from 20 to 50% (Adamówka: 50% — K. Bińka *et al.*, 1987; Poznań near Kock: 40.1% — H. Winter, 1991; Biała Podlaska: above 40% — K. M. Krupiński *et al.*, 1988).

EVOLUTION OF THE SEDIMENTATION BASINS

Processes, that led to the formation of the discussed intermoraine series, took place in fairly distinctly defined palaeomorphologic conditions. During the whole time of the formation of the series the area was depressed with respect to its surroundings. Initially the area was occupied by ice-dam lakes and regular lakes, and afterwards by well-formed river valley, which was active from the beginning of the Mazovian Interglacial, or maybe earlier, till the covering of this area by inland ice of the Odra Glaciation (Fig. 3).

The original formation of the depression could be predisposed by the occurrence of the exaration channel in the pre-Quaternary substratum, which influenced the origin of the analogous depressions on the subsequent Pleistocene surfaces in older Quaternary. Probably, along this channel during destruction of the inland ices, deep fissures formed, afterwards filled by fissure or ice-dam lake sediments. The ice-dam lake at Cząstkowo started to form in such a fissure simultaneously with the destruction of the inland ice of the San 2 Glaciation to blocks, what is evidenced by intercalations of till in the bottom layers of varved clays (Fig. 4C, phase **a**).

Later, after melting of ice, the ice-dam lake enlarged its extension and changed to a large dammed lake, limited in the north by the regressing inland ice, maybe beyond the discussed area. The lake extended probably meridionally according to the pre-Quaternary substratum depression. The depth of the ice-dam lake should be significant, because it produced sediments of the thickness of several metres (phase **b**). The sediments were very fine-grained, mainly clayey, well-laminated in the varve style.

In certain period there occurred changes of the sedimentation conditions and somewhat coarser material entered the ice-dam lake, resulting in sedimentation of silts with seams of abundant plant detritus (phase **c**). The change of sedimentation was probably connected with the complete retreat of inland ice from the area of Pomerania. It is not excluded, that the shores of the former ice-dam lake started to become grown over that time, what could indicate a periodic, maybe interphase warming of climate, however, distinct evidences still lack. Palynologic analysis of one sample (depth 135.5 m) showed a low frequency of pollen and poor state of its preservation, but in single cases the following Quaternary trees were distinguished: pine, spruce, elm, alder and hornbeam. Exotic taxons occurred as well, namely *Nyssa*, *Sequoia* and *Taxodium*. The pollen occurs in a secondary deposit and its origin might have been various. It could be transported together with the plant detritus to the lake from the immediate surrounding, not excluded that from the coast zone overgrown by vegetation.

Later the lake lost its ice-dam character and it altered in a regular, initially relatively deep post-glacial lake (phase **d**). The level of lake water lowered and the lake gradually shallowed. The shallowest parts of the lake and its shores became muddy and grown over by aquatic and marsh vegetation, what is evidenced by the presence of organic matter in the uppermost, top clay layer (phase **e**). Apparently, it was as well the result of a short climate warming. After filling of the lake basins by sediments, the area was partly smoothed, but it was still depressed with respect to the surrounding post-glacial uplands.

During the next stage a sharp change of the sedimentation conditions took place, because the depression started to transform to a river valley. It was a valley of the upland area. Its bottom in the initial period was at the height of c. 50 m a.s.l. or a little lower, and in the final period — c. 100 m a.s.l., what was a very high position for this region, if one take into account an adjacent location of the erosion basis, the Holstein Sea, occurring below the present-day sea level. The river flowing here did not head directly to sea, but it was probably a tributary of a greater river. At Cząstkowo only a fragment of the valley is preserved from its later mature development stage, which probably took place in the beginning of the interglacial. Early fragments from the period of deep fluvial erosion are not known. They could occur at other places and present earlier cycle (cycles) of fluvial erosion and accumulation (Fig. 3). At that time deluvial flows and landslides of the valley slopes developed, causing at Cząstkowo the disturbances of the varved clays in the bottom of the valley sedimentation cycle I. The conclusion on the earlier bottom erosion comes from the analysis of the fluvial sediments of this cycle. They are fine-grained sands without any coarser material, deposited by slowly flowing waters. Traces of the bottom erosion are absent. One should suppose, that the lateral erosion of the meandering river played the main role in formation of the river valley, resulting in a broad, mature valley with a vast flood terrace. On this terrace, oxbows formed initially, then probably altered to lakes. Sandy sedimentation occurred in a cool period, when the conditions did not stimulate the vegetation development. Animal remnants are absent in the sediments, and the traces of plants appear only in the upper part of the layer as trails of humus and plant detritus. Palynologic analysis of the sample from the depth of 119.7 m revealed here numerous but strongly destroyed pollen grains of Quaternary and Tertiary plants, occurring undoubtedly in a secondary deposit. On the other hand, the depressions of the future lakes from the beginning of their existence started to fill with mineral and organic sediments, what lasted long time during the Mazovian Interglacial, associated by full development and then by decline of the tree vegetation.

As it appears from the palynologic analysis, the sedimentation of the lacustrine deposits at Cząstkowo began in boreal climate, in the pollen period I, when in the surroundings of the reservoirs the pine-birch forests dominated with subordinate spruce, and herbaceous plant comprised only 10.4% of the total plant assemblage (Fig. 4C, E — phase **f** of the lake development). Initially, the depth of the lake was small and the sediments were calcareous-rich. In the pollen period I the waters were inhabited by molluscs. In the pollen period II in the beginning of the climatic optimum of the interglacial, when the forests changed to mixed ones with pine, spruce and alder (pollen zone 2), and subsequently with yew (pollen zone 3), calcareous silts precipitated in the lake, locally intercalated with lake marl. Mollusc shells are absent, what probably indicates nonfavourable ecological conditions. In the following pollen period III, characterised by domination of stenothermal species of deciduous trees (pollen zones 4 and 6), when climate was warm and humid, increase of the lake depth occurred and lake waters bear less calcium carbonate. Silts precipitated continuously on the bottom. The palynologic studies indicate, that the lake was surrounded that time by compact, shadowy forests, in which elm, oak, hornbeam and hazel prevailed. In the marshy areas alder grew abundantly. In the shallow parts of the lake waterlilies, duckweed and pond-weed grew, and along the shores — cattail and bur reeds. In the second half of this period the lake shallowed again (phase **g**). The silty sediments periodically emerged above the water level, what caused local disturbances of their structures. In this process the sediments could displace within small ranges due to e.g. rainfalls running from the shore to the lake. Such displacement of the sediments could occur in the layer from the depth of

111.3–111.6 m, where in the palynologic analysis one observed an incorrect pollen composition in the optimum part of the interglacial (the pollen zone 5).

The lowering of the water level in the lake was not connected with the change of the climate humidity. As hitherto, climate was warm and humid, as it appears from the presence of the pollens of such plants as *Vitis*, *Viscum* and *Buxus*. The changes of the lake basin limits had to have a local character. However, one could connect a change of the climate humidity with the shallowing of the lake, that was marked at the decline of the climatic optimum by sedimentation of sands with gravels, occurring at the depth of 108.8 m (phase **h**), brought to the shallow zone of the lake by a river current.

Simultaneously a distinct cooling of climate occurred, as indicated by the pollen zone 7. In the forest assemblages there occur changes of the regressive type. The share of all deciduous trees except for birch decreases, and the share of pine and spruce increases. The forests are thinned out, and the share of the photophilous and herbaceous plants increases.

At the lake bottom silts deposited, which became gradually more sandy. Waters were again inhabited by molluscs. The lake shores were grown over by aquatic and rush plants. The sedimentation of silts ceased in the period of a significant climate cooling, coinciding with the end of the Mazovian Interglacial. Maybe, the lake reservoir evolved further, but its sediments display in the top traces of limited fluvial erosion, that possibly removed the upper part of the sediments. Thus, in the Cząstkowo profile the Mazovian Interglacial caused the origin of the deposits of a single cycle of the valley sedimentation, including the fluvial sedimentation and subsequently the lacustrine one.

In the later periods, however, further changes of the sedimentation environments occurred in the river valley, which, at least in the beginning, took place in similar palaeogeographic conditions and were an immediate continuation of the valley sedimentation that started in the Mazovian Interglacial. After filling of the interglacial lake with silty sediments, the overburden of the valley with the fluvial sediments began again. The river bed was that time c. 20 m higher than in the Mazovian Interglacial beginning (Fig. 3). In the region of Cząstkowo a new flood terrace formed, afterwards relatively quickly left by the river. An oxbow developed in the place of the former river bed, being initially at times flooded by the river (Fig. 4C, phase **i**), then altered in a relatively large lake, apparently of the size similar to the size of the interglacial lake. The evolution of the new lake was close to that of the previous one. Initially, it was a relatively deep reservoir of clean water (phase **j**), afterwards strongly shallowed and grown over (phase **k**). In the lake silts remnants of mollusc shells are absent, what indicates the conditions less appropriate to live for these animals. However, the vegetation developed undoubtedly, as is evidenced by trails and admixtures of organic matter in the upper layers of silts.

The range of the climate warming, which occurred during the sedimentation of silts, is recognised on the basis of the palynologic analysis performed for six samples from the depth of 93.0–99.0 m (Fig. 4E). The analysis showed generally low frequency of pollen and its irregular distribution. From presence of the individual distinguished taxons one may make a number of conclusions. The highest part of the sediments, where from one sample was studied, was washed out in the top and contains mixed pollens. The best preserved pollen grains occurred in the following layer from the top, which is thin and consists of clay with organic matter, and formed in the shallowed lake (phase **k**, depth 93.8 m). One found there scarce pollens of pine, birch, spruce, hazel and alder together with pollens of *Gramineae*, *Cyperaceae, Artemisia, Cichorioideae undiff., Ericaceae* and spores of ferns and *Sphagnum*. They indicate, that the sediment formed in a forest-free landscape, but with herbaceous plants present, under conditions of cool, boreal climate. Similar conditions are evidenced by the following samples, taken from the underlying silts. One may conclude, that the whole silty series formed in relatively cool climate, quite different than the interglacial climate and prefering the development of the herbaceous plant and shrubs as well as scarce arborescent plants. On this basis, and taking into account the lithologic profile, one may accept that it was an interstadial warming of climate, the first one after the Mazovian Interglacial. It was preceded by a stadial cooling, marked by sedimentation of fluvial sands underlying silts.

Further development of the valley occurred already in distinctly cooler climate. The depression, that remained after the interstadial lake, was filled by fluvial sediments of the cycle III of the valley sedimentation. The ongoing widening of the valley took place. The river flew slowly with periodical standstills, when on the flood terrace there appeared shallow overflows with precipitating silts that bore admixtures of plant detritus. Palynological analyses of samples from two silt layers (depth 79.6 and 86.0 m) showed presence of numerous fragments of coal and coal dust as well as large amount of strongly destroyed pollen grains, among which pine prevails, occurring with spruce, oak, hazel and birch and sporomorphs of the heath family. Moreover, in the studied material there occurred numerous Tertiary forms, what proves, that the whole pollen material occurs in the secondary deposit, and the river which transported sandy and silty material eroded in its upper flow both sediments of the Mazovian Interglacial in the same valley and, during the valley broadening, Miocene sediments from the pre-Quaternary substratum. At that time, there already occurred significant though not complete filling of the valley with sediments. Afterwards, a change of the sedimentation environment appeared, resulting in the change of grain size of the sediments of the valley sedimentation cycle IV. More coarse-grained material was present, indicating the change of the sediments from fluvial to fluvioglacial ones. The direction of the water flow in the valley changed. Instead of the river flowing slowly from the south or almost stagnating, the fluvioglacial waters appeared, quickly running from the north, from the forefield of the approaching inland ice, which afterwards covered the valley, finishing its development lasting from the beginning of the Mazovian Interglacial.

STRATIGRAPHIC CORRELATIONS — THE MAZOVIAN INTERGLACIAL AND THE FIRST INTERSTADIAL OF THE ODRA GLACIATION

Lacustrine reservoirs of the type present at Cząstkowo, formed in fluvial valleys of the Mazovian Interglacial, are known from the area of Poland in numerous palynologically documented sites. The profile from Cząstkowo is distinguished by the feature, that in addition to the sediments of the Mazovian Interglacial, it also includes the adjacent younger sediments that formed in the valley till the inland ice of the Odra Glaciation covered this area. Such sediments are rarely found in other sites and less investigated.

The most complete pattern of sedimentation in the fluvial valleys of the Mazovian Interglacial was presented by S. Z. Różycki (1961, 1972). The concept of the four-cycle valley sedimentation during the Mazovian Interglacial was confirmed in this region of

Poland by various detailed studies (e.g. J. Nowak, 1974; Z. Sarnacka, 1977, 1978). Presently, other concepts exist, according to which only two lower cycles of the sediments that filled valleys, originated in the Mazovian Interglacial, but the upper cycles are connected with the Liwiec Glaciation and the Zbójno Interglacial (L. Lindner, 1984, 1992). If we add the possibility, that certain fluvial valleys considered till now as the Mazovian ones, may be connected with the Ferdynandów Interglacial, the problem of the correlation of the sediments filling these valleys becomes very complicated.

As to their lithological type, the sediments from Cząstkowo are to be bound convincing enough to the valley cycles of S. Z. Różycki and other authors confirming the analogous structure of the fluvial valleys of the Mazovian Interglacial (J. Nowak, 1974; Z. Sarnacka, 1977, 1978; M. Brzeziński, Z. Janczyk-Kopikowa, 1991). Supposing, that the profile from Cząstkowo does not comprise the earliest phases of the valley development, it seems to be most probable to connect the three lower cycles (I, II, III) of the valley sedimentation from Cząstkowo with the second, third and fourth cycle according to S. Z. Różycki. By this mode we achieve the coincidence of the position of the upper border of the Mazovian Interglacial. After S. Z. Różycki this border occurs in the top of the sediments of the second cycle, though this position is conventional, because the latter author accepted smooth transitions of the glacials in the interglacials both in time and in space, without sharp borders. At Cząstkowo this border is determined on the basis of the results of the pollen studies and it occurs in the top of the sediments of the cycle I of the valley sedimentation. The overlying sediments belong to the preglacial part of the Odra Glaciation and they are not of the interglacial sediment type, but they are interstadial (and stadial ones)[1].

The most distinct units of this range appear in the sediments of the valley sedimentation cycle II. Immediately after the Mazovian Interglacial, a cool stadial (Cz_1) followed there (Fig. 4F), marked by sedimentation of fluvial sands, and afterwards the interstadial (Cz_2), when sediments formed, very similar to the underlying interglacial deposits. It was the first interstadial after the Mazovian Interglacial. That period was cooler than the Calidostadial J II/III*3 of S. Z. Różycki in the central Poland, because it did not comprise the warm optimum with mixed forests, similar to the interglacial optimum attributed to this calidostadial. For this reason one cannot correlate it with the Zbójno Interglacial and the underlying sands — with the Liwiec Glaciation. As it seems presently, any place for these two units lacks in that profile.

The interstadial apparent in the valley sedimentation cycle II at Cząstkowo (Cz_2) is thus the first interstadial of the Odra Glaciation, occurring immediately after the Mazovian Interstadial.

The second interstadial (Cz_4) appeared probably in the top of the valley sedimentation cycle III, but it is only a thin silt layer with plant detritus. Organic sediments are absent there. This interstadial was best recognised at Żabieniec near Warsaw (Z. Sarnacka, 1977), where Z. Janczyk-Kopikowa after performing the pollen studies in a 1.7 m thick layer of sediments from an oxbow of the valley sedimentation cycle IV, obtained the diagram of the vegetation of a cool, interstadial or interphase period. This period Z. Sarnacka included then to the Mazovian Interglacial (the Calidostadial J II/III*4 of S. Z. Różycki). On the basis of

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[1] Maybe the phase and interphase ones, but the correct rank of these periods one could determine only due to an analysis of the Odra Glaciation in large areas.

the above discussed correlation of the valley sedimentation cycle III from Cząstkowo, one may consider the interstadial from Żabieniec as the second interstadial of the Odra Glaciation, coming directly after the Mazovian Interglacial and after the first interstadial from Cząstkowo (Cz_2). The sediments of the upper cycle of the valley sedimentation (IV) at Cząstkowo are already connected with the inland ice transgression of the Odra Glaciation.

In recapitulation one may ascertain, that the sediments of the three lower cycles of the valley sedimentation (I, II and III) at Cząstkowo correspond with the second, third and fourth cycle by S. Z. Różycki. They formed in the Mazovian Interglacial as well as in the beginning of the Odra Glaciation during the two earliest interstadials (Cz_2 and Cz_4), preceded and separated by the subsequent stadials (Cz_1, Cz_3 and Cz_5; see Fig. 4D, F).

After the present paper has been prepared for press, the K. M. Krupiński (1995) publication was issued. The latter author on the basis of the studies of the sediments at Ossówka in Podlasie distinguished a number of warm and cool climate oscillations during the early period of the glaciation following the Mazovian Interglacial. The possible correlation of these oscillations with the climate changes in the preglacial part of the Odra Glaciation resulting from the analysis of the profile at Cząstkowo is not easy, because in each of the both cases the conclusions based on different criteria. At Cząstkowo the conclusions stem mainly from the sediment lithology, because palynological analyses yielded very little data, whereas at Ossówka the results of the pollen studies are the main criterion. The lithology of the sediments is uniform there, because the sediments formed in a stable lacustrine environment. Climatic changes distinguished in the both elaborations could appear at different time and comprise various periods. It is possible, that the climate oscillations distinguished by K. M. Krupiński and estimated as phases, could precede the first stadial and interstadial of the Odra Glaciation at Cząstkowo, where these periods yielded an abundant valley sedimentation, comparable with analogous sedimentation, which occurred there during the whole Mazovian Interglacial. The climate changes of the early period of the Odra Glaciation distinguished in Podlasie, in the profile from Cząstkowo could appear in the highest part of the lacustrine sediments of the valley sedimentation cycle I, which were probably destroyed by a younger river erosion.

Marginally to these correlations, it is worth noting, that the profile at Cząstkowo generally displays significant analogy with the profiles of the sediments of well-developed river valleys of the Eemian Interglacial in the Lower Powiśle (A. Makowska, 1979, 1994). Like at Cząstkowo, the interglacial sediments occupy there only small, middle part of a large intermoraine Lower Powiśle Formation, occurring between tills of the Mid-Polish (Warta) and North- Polish (Toruń) Glaciations. Below the interglacial sediments there occur the sediments from the decline of the Warta Glaciation, and above — the series of the preglacial sediments of the Toruń Glaciation, in which the sediments of the Brörup, Odderade and Oerel interstadials appear.

The first interstadial at Cząstkowo occupies a similar position with respect to the Mazovian Interglacial like the Brörup Interstadial with respect to the Eemian on the Lower Powiśle. Analogies exist probably in the shape of the valleys as well. Development of the river valleys of the Eemian Interglacial started at the decline of the Warta Glaciation, and in the interglacial optimum the valleys were already mature with vast terraces. On the basis of the profile from Cząstkowo one could suppose, that the valleys of the Mazovian

Interglacial developed by a similar mode, and that the beginning of their development one should not relate to the optimum of that interglacial, as it was accepted by S. Z. Różycki (1961, 1972), but to the decline of the San 2 Glaciation.

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REFERENCES

BIŃKA K., MARCINIAK B., ZIEMBIŃSKA-TWORZYDŁO M. (1987) — Palynologic and diatomologic analysis of the Masovian Interglacial deposits in Adamówka (Sandomierz Lowland) (in Polish with English summary). Kwart. Geol., **31**, p. 453–474, no. 2–3.

BORÓWKO-DŁUŻAKOWA Z. (1981) — The Mazovian Interglacial in Wieluń Upland (in Polish with English summary). Biul. Inst. Geol., **321**, p. 259–275.

BORÓWKO-DŁUŻAKOWA Z., SŁOWAŃSKI W. (1991) — Results of pollen analysis of interglacial deposits at Koczarki near Mrągowo (in Polish with English summary). Geol. Quart., **35**, p. 323–336, no. 3.

BRZEZIŃSKI M., JANCZYK-KOPIKOWA Z. (1991) — Mazovian Interglacial at Jamno (in Polish with English summary). Prz. Geol., **39**, p. 292–298, no. 5–6.

HRYNKIEWICZ-MOCZULSKA G. (in preparation) — Szczegółowa mapa geologiczna Polski 1:50 000, ark. Egiertowo, objaśnienia do mapy.

JANCZYK-KOPIKOWA Z. (1987) — Remarks on palynostratigraphy of the Quaternary (in Polish with English summary). Kwart. Geol., **31**, p. 155–161, no. 1.

JANCZYK-KOPIKOWA Z. (1991) — Palynostratigraphy of the Pleistocene in Poland and the problem of the age of deposits from Besiekierz (Central Poland). Ann. UMCS, Sect. B, **46**, p. 111–128.

JANCZYK-KOPIKOWA Z., SKOMPSKI S. (1977) — Interglacial deposits from Boczów near Rzepin (Western Poland) (in Polish with English summary). Kwart. Geol., **21**, p. 789–801, no. 4.

JURYS L. (in press) — Szczegółowa mapa geologiczna Polski 1:50 000, ark. Stężyca, objaśnienia do mapy.

KRUPIŃSKI K. M. (1995) — Stratygrafia pyłkowa i sukcesja roślinności interglacjału mazowieckiego. Acta Geogr. Lodz., **70**.

KRUPIŃSKI K. M., LINDNER L., TUROWSKI W. (1988) — Geologic-floristic setting of the Mazovian Interglacial sediments at Biała Podlaska (E Poland). Acta Palaeobot., **28**, p. 29–47, no. 1–2.

LINDNER L. (1984) — An outline of Pleistocene chronostratigraphy in Poland. Acta Geol. Pol., **34**, p. 27–49, no. 1–2.

LINDNER L. (1992) — Stratygrafia (klimatostratygrafia) czwartorzędu. In: Czwartorzęd. Osady, metody badań, stratygrafia (ed. L. Lindner), p. 513–522. Wyd. PAE S. A. Warszawa.

MAKOWSKA A. (1979) — Eemian Interglacial in valley of Lower Vistula River (in Polish with English summary). Stud. Geol. Pol., **63**, p. 1–90.

MAKOWSKA A. (1994) — Climatic variation in the pre-glacial part of the Toruń Glaciation in the Lower Vistula Region and the Elbląg Elevation (preliminary report). Geol. Quart., **38**, p. 133–154, no. 1.

NOWAK J. (1974) — Stratigraphy of the Pleistocene in the northern part of the Warsaw Depression (in Polish with English summary). Biul. Inst. Geol., **286**, p. 91–160.
NOWAK J. B., SZELEWICKA A. (1995) — Badania litologiczno-petrograficzne i sedymentologiczne osadów czwartorzędowych (w materiałach ark. Stężyca). Arch. Państw. Inst. Geol. Warszawa.
OLSZAK I. J., FEDOROWICZ S. (1993) — Sprawozdanie z wykonanych datowań TL (w materiałach ark. Stężyca). Arch. Państ. Inst. Geol. Warszawa.
RÓŻYCKI S. Z. (1961) — Sub-stages of the Great Interglacial Stage. In: Studies of the Pleistocene of middle Poland under the direction of prof. dr S. Z. Różycki. Special issue VI INQUA Congress, Warsaw, p. 13–34. Wyd. Geol. Warszawa.
RÓŻYCKI S. Z. (1972) — Plejstocen Polski Środkowej na tle przeszłości w górnym trzeciorzędzie. PWN. Warszawa.
SARNACKA Z. (1977) — Organic sediments in Masovian (Great) Interglacial fluvial series from Żabieniec south of Warsaw (in Polish with English summary). Kwart. Geol., **21**, p. 141–151, no. 1.
SARNACKA Z. (1978) — Pleistocene deposits in the area of the Vistula Valley between Magnuszew and Góra Kalwaria (in Polish with English summary). Biul. Inst. Geol., **300**, p. 5–88.
SOBOLEWSKA M. (1975) — A palynological analysis of the interglacial deposits at Węgorzewo (in Polish with English summary). Biul. Inst. Geol., **288**, p. 137–165.
ŚRODOŃ A. (1957) — Interglacial flora from Gościęcin near Koźle (Sudetic Foreland) (in Polish with English summary). Biul. Inst. Geol., **118**, p. 7–60.
SZAFER W. (1953) — Pleistocene stratigraphy of Poland from the floristical point of view (in Polish with English summary). Rocz. Pol. Tow. Geol., **22**, no. 1.
WINTER H. (1991) — Results of pollen analysis of the Poznań 1 profile (Kock vicinity, eastern Poland). Geol. Quart., **35**, p. 133–140, no. 1.

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INTERGLACJAŁ MAZOWIECKI W CZĄSTKOWIE KOŁO STĘŻYCY — PIERWSZE STANOWISKO NA POMORZU

Streszczenie

Osady interglacjału mazowieckiego stwierdzono na głębokości 105,8–128,5 m w profilu otworu wiertniczego w Cząstkowie. Otwór został wykonany przy opracowaniu *Szczegółowej mapy geologicznej Polski* w skali 1:50 000, ark. Stężyca, w Gdańskim Zakładzie Przedsiębiorstwa Geologicznego w Warszawie przez L. Jurysa (fig. 1).

W wyniku przeprowadzonych prac badawczych profil z Cząstkowa będzie pierwszym na Pomorzu i w Polsce północno-zachodniej stanowiskiem z udokumentowanymi palinologicznie osadami interglacjału mazowieckiego.

Otworem z Cząstkowa, po przebiciu utworów czwartorzędowych, dotarto do podłoża trzeciorzędowego. W miejscu jego lokalizacji w podłożu przebiega głębokie egzaracyjne obniżenie, rozchodzące się od Stężycy dwoma ramionami w kierunku północno-wschodnim (fig. 2).

Miąższość utworów czwartorzędowych osiąga w Cząstkowie 253,0 m (fig. 3, 4A). Podział stratygraficzny całego kompleksu oparty jest na występowaniu osadów interglacjału mazowieckiego, które dzielą ten kompleks na część starszą i młodszą od tego interglacjału. Dalszy podział został dokonany na podstawie poziomów litostratygraficznych. W starszym czwartorzędzie, poznanym tylko w Cząstkowie, wyróżniono osady zlodowacenia najstarszego (narwi) oraz zlodowaceń południowopolskich z trzema głównymi poziomami glin zwałowych (nidy, sanu 1 i sanu 2). W czwartorzędzie młodszym, występującym na całym omawianym obszarze, wyróżniono osady zlodowaceń środkowopolskich z dwiema glinami zwałowymi (odry i warty) oraz zlodowaceń północnopolskich z dwoma lub trzema poziomami glin zwałowych.

Osady interglacjału mazowieckiego w Cząstkowie znajdują sie między glinami zwałowymi zlodowacenia sanu 2 i odry. Występują w zróżnicowanej serii międzymorenowej o miąższości 74,0 m, złożonej z osadów zastoiskowych oraz z cyklicznie warstwowanych osadów dolinnych (fig. 4B, C, D i F). Dolna część serii, obejmująca osady zastoiskowe, powstała w schyłkowym okresie zlodowacenia sanu 2. W interglacjale mazowieckim utworzyły się osady dolinne stanowiące pierwszy cykl sedymentacji dolinnej o miąższości 22,7 m, obejmujące piaski rzeczne oraz gytie i wapniste mułki jeziorne ze szczątkami roślin i ułamkami skorupek mięczaków. Górna część serii międzymorenowej spoczywająca na osadach interglacjalnych powstała na początku zlodowacenia odry. Obejmuje ona utwory trzech kolejnych cykli sedymentacji dolinnej (II, III, IV) złożone z piasków, mułków i piasków ze żwirami. Osady cyklu II są wykształcone analogicznie jak osady interglacjału mazowieckiego i obejmują piaski rzeczne oraz mułki jeziorne ze szczątkami roślin. Powstały one w czasie pierwszego stadiału (Cz_1) oraz interstadiału (Cz_2) następującego bezpośrednio po interglacjale mazowieckim, na początku zlodowacenia odry. W podobnych okresach (Cz_3, Cz_4) powstały rzeczne osady cyklu III. W cyklu IV sedymentacja zmieniła się na rzeczno-wodnolodowcową, związaną ze zbliżającym się lądolodem.

Badaniami pyłkowymi objęto osady jeziorne I cyklu sedymentacji dolinnej z głębokości 106,0–116,4 m. Ponadto wykonano ekspertyzy pyłkowe dla 10 innych próbek z różnych głębokości (fig. 4E). Na podstawie badań pyłkowych uzyskano rozwinięty diagram pyłkowy (fig. 5), którego analiza pozwoliła wyróżnić 7 lokalnych poziomów pyłkowych, zawartych w czterech okresach cechujących sukcesję interglacjalną (Z. Janczyk-Kopikowa, 1987). Mają one wyraźne cechy diagnostyczne i reprezentują charakterystyczną sukcesję dla interglacjału mazowieckiego. Jest to jedyny profil z osadami tego interglacjału na Pojezierzu Pomorskim.

Wykształcenie omówionej serii międzymorenowej wskazuje na konsekwentne przemiany środowisk sedymentacyjnych, jakie odbywały się w czasie tworzenia się jej w rejonie Cząstkowa. Po wycofaniu się lądolodu zlodowacenia sanu 2 obszar został zajęty przez zastoisko, które przeszło kilka faz ewolucji (**a**, **b**, **c**, **d**) (fig. 4C), aby przekształcić się w płytkie, zarastające roślinnością jezioro. Następnie obszar został przekształcony w dolinę rzeczną.

Początkowy okres rozwoju doliny nie zaznaczył się w Cząstkowie. W interglacjale mazowieckim była to już dolina dojrzała, z szerokim tarasem zalewowym, zajętym przez meandrującą rzekę. Na tarasie tworzyły się starorzecza, przekształcające się miejscami w większe jeziora. W jednym z takich jezior powstały osady mułkowe z Cząstkowa. Jezioro przechodziło szereg faz ewolucyjnych (**f**, **g**, **h**), aby u schyłku interglacjału spłycić się i zarosnąć roślinnością. Dolina rzeczna funkcjonowała w dalszym ciągu w następnym, przedglacjalnym okresie, aż do nasunięcia się na ten obszar lądolodu zlodowacenia odry. W tym czasie została wypełniona osadami następnych trzech cykli sedymentacji dolinnej, początkowo osadami rzecznymi i jeziornymi, a w końcu rzeczno-wodnolodowcowymi. W pierwszym okresie zapełnianie doliny odbywało się w warunkach zbliżonych do interglacjalnych. Po początkowym ochłodzeniu nastąpiło wyraźne ocieplenie, co wpłynęło na ponowne utworzenie się jeziora na tarasie zalewowym. Miało ono zbliżony zasięg i głębokość do jeziora interglacjalnego. Ekspertyza pyłkowa z kilku próbek osadów jeziornych wykazuje, iż panował wówczas klimat borealny. Okres ten wyróżniono jako pierwszy interstadiał zlodowacenia odry (Cz_2), następujący bezpośrednio po interglacjale mazowieckim.

Osady cyklów sedymentacji dolinnej w Cząstkowie można skorelować z odpowiednimi cyklami wyróżnionymi przez S. Z. Różyckiego (1961, 1972) w dolinach interglacjału mazowieckiego Polski Środkowej z założeniem, że pierwszy cykl Cząstkowa odpowiada II cyklowi S. Z. Różyckiego (*op. cit.*).