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Mrongovian and Brokian, new stratigraphic units of the Middle Pleistocene in northeastern Poland

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Results of palynologic and lithologic analyses of 6 key sections from northeastern Poland have been reinterpreted. Two new stratigraphic units within the Middle Pleistocene were defined, the warm Mrongovian and the cold Brokian. A completely new interstadial pollen succession, named the Mrongovian one, was distinguished. Lake and lake-fluvial deposits of the Mazovian Interglacial (upper series) and Mrongovian Interstadial (lower series) are separated with a till. Stratigraphic rank of the separating till results from determination of a new palynostratigraphic unit. Petrographic character of its lithologic type and stratigraphic location suggest correlation of this till either to a younger stadial of the Wilgian Glaciation or to a new glaciation.

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INTRODUCTION

In several dozen test-cartographic boreholes, done in northeastern Poland for the *Detailed Geologic Map of Poland* in scale of 1:50 000, there were also interglacial lake, bog and lake-fluvial deposits. Basing on palynological examination, these sediments were mostly connected with the Mazovian Interglacial. Their lithology and occurrence made, however, univocal stratigraphic interpretation difficult. Interglacial deposits were unusually thick, containing till or locally glaciofluvial sands with gravels from several to a dozen metres. They were examined in the key section at Goleń (H. Winter, S. Lisicki, 1998). In this paper the other sections are also presented (Fig. 1): Koczarki (Z. Borówko-Dłużakowa, W. Słowański, 1991) in the Mrągowo Lakeland, Węgorzewo III (W. Słowański, 1975) and IV in the northern Mazury Lakeland, Gawrych Ruda (A. Ber, 1998) in the Suwałki Lakeland and Śniadowo (A. Bałuk, in print) in the Łomża Interfluve.

194 samples of the Quaternary deposits were collected from the section Koczarki, among them 65 samples for pollen analyses (Z. Borówko-Dłużakowa, W. Słowański, 1991). The section Węgorzewo III supplied with 332 samples of the Quaternary deposits and palynological examination was done for 69 samples (M. Sobolewska, 1975). From the section Gawrych Ruda, 95 samples of the Quaternary deposits were collected and 21 of them were subjected to pollen analysis (Z. Janczyk-Kopikowa, 1986). The section Śniadowo gave 109 samples, with palynological examination of 22 ones (H. Winter, unpubl.). Petrographic analysis of gravels, 5–10 mm in diameter, was done for 54 samples of till from the section Koczarki (J. Czerwonka *et al.*, 1984), 43 samples from the section Węgorzewo III (J. Rzechowski *et al.*, 1975), 38 samples from the section Gawrych Ruda (K. Kenig, 1987) and 33 samples from the section Śniadowo (B. Gronkowska-Krystek, 1993).

PALYNOLOGY

In northeastern Poland, the pollen succession of the Mazovian Interglacial (i.e. the so-called Mazovian pollen succession according to Z. Janczyk-Kopikowa, 1991) is known from numerous sections. However, only the diagram from Krzyżewo (Z. Janczyk-Kopikowa, 1996) presents a complete vege-

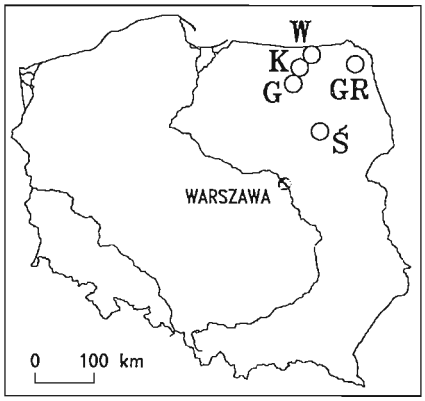


Fig. 1. Location of the study sections in northeastern Poland

G — Goleń, K — Koczarki, W — Węgorzewo III and IV, GR — Gawrych Ruda, Ś — Śniadowo

tational development which is typical for this succession and recorded in typical lake-bog sediments, represented by lake silts, gyttjas and peats.

Among the characteristic features of the Mazovian pollen succession from Krzyżewo, there are: predominant pollen of *Picea* and *Alnus*, then common occurrence of *Taxus* pollen during the pollen period II. The period III is predominated by pollen of *Abies* and *Carpinus*, and the highest content of *Quercus* among the thermophilous deciduous trees, presence of such termophilous taxa as *Ilex, Buxus* and *Ligustrum.*

In the section Goleń (H. Winter, S. Lisicki, 1998) there are lake series with palynological examination and separated by a till. Pollen succession of the upper series (depth 35.10–36.92 m) is typical for the pollen periods II–IV of the Mazovian pollen succession. Pollen succession recorded in sediments from depth 50.31–53.21 m indicates high content of *Picea* (to 45%), at first with abundant *Alnus* and *Abies* (to 14%), and low content of *Carpinus* (over 4%), *Quercus* and *Corylus*, but also presence of *Taxus*. The following rise of *Betula* (to 40%) is accompanied by increasing of values of NAP (over 29%). Still abundant is pollen of *Abies*, and *Pinus* pollen reaches its maximum, accompanied by significant content of *Picea*. Pollen spectra of this series do not correspond to any known interglacial or interstadial succession. It presents fragment of specific interstadial-like succession as indicated by low content of pollen of thermophilous deciduous trees as *Quercus, Ulmus, Tilia*, and also *Corylus*. Due to presence of pollen of *Taxus, Pterocarya, Juglans, Viscum* and microspores of water plants *Azolla filiculoides* and *Salvinia*, the climate could be warm and mild, and permitted development of plants with higher thermic demands.

A till between two series of lake sediments of the Mazovian Interglacial was noted also in the sections Gawrych Ruda (Z. Janczyk-Kopikowa, 1986) and Śniadowo (H. Winter, unpubl.).

In the section Gawrych Ruda (Fig. 2) there three pollen series were analysed. The lower one (depth 134.95–145.00 m) is represented by silts. Pollen spectra from these sediments are predominated by *Pinus*, accompanied by *Picea, Betula, Alnus* and *Abies* (to 9%), with small admixture of thermophilous deciduous trees and *Carpinus*. There are also microspores of *Azolla filiculoides*. The spectra from the overlying series of silts and clays (depth 99.90–104.95 m) represent similar vegetation as the one from the lower series. There is pollen of *Pterocarya*. These spectra contain quite a lot of pollen of herbs, particularly of *Artemisia* (to 4%). Z. Janczyk-Kopikowa (1986) suggested affiliation of both series to the pollen period II (*Picea-Alnus*) of the Mazovian Interglacial. However, correlation of the pollen spectra with the zone Krz6 — *Pinus-Betula-Picea* of the pollen period IV of the Mazovian Interglacial from the upper series at Krzyżewo seems possible, whereas the lower spectrum from Krzyżewo can be referred to the lower one from Goleń.

In the section Śniadowo (Fig. 3) two series of lake-fluvial deposits, separated by a till, were examined. The lower series (depth 90.02–91.55 m) is composed of sandy silts and silty sands. Pollen spectra of this series are predominated by pollen of *Pinus* (to 55%), with abundant pollen of *Picea, Abies, Alnus* and *Betula*, and small admixture of thermophilous deciduous trees, including *Carpinus*. Relatively high content of herbs (to 30%) is due to high share of Cyperaceae. Basing on data from the section Goleń, the lower series from Śniadowo should be correlated with the lower series from Goleń.

Pollen spectra of the upper series (depth 80.70–82.60 m) composed of silts are predominated by *Pinus*, and abundant *Picea* and *Abies*, low *Betula, Alnus* and *Taxus*. There is a low content of pollen of thermophilous trees and NAP is below 20%. Similar pollen spectra can be referred to the termination of the pollen period III or the beginning of the pollen period IV of the Mazovian Interglacial.

Analysis of sediments and pollen diagrams from other sections in this area indicated particular significance of the section Węgorzewo III (M. Sobolewska, 1975). W. Słowański (1975) connected the sediments from depth 91.5–166.9 m with the Mazovian Interglacial, subdivided them into the series A and B, and with an erosive contact between them. He stated also that in most sections in central Poland there are no equivalents of the series A. M. Sobolewska (1975) correlated deposits of the series B from Węgorzewo III with the phases II–IV of the Mazovian Interglacial, but she has not determined the age of the samples from the series A. Pollen spectra from the series A indicate their similarity to the spectra from the lower pollen succession at Goleń. It is proved by high content of *Picea* and *Alnus*, accompanied by *Abies* and *Carpinus*.

The section Koczarki contains very thick sediments of the Mazovian Interglacial. In a pollen diagram from this section, Z. Borówko-Dłużakowa and W. Słowański (1991) distinguished two series: A and B, ascribed to this interglacial. In the series A, three pollen periods (I–III) were distinguished. Typical for the period I there are high contents of *Betula* and *Pinus*, medium of *Alnus*, and at the end high contents of *Picea* and presence of *Pterocarya.* During the period II there are high contents of *Picea*, medium of *Alnus*, early appearance of *Abies, Carpinus* and thermophilous *Celtis*. Presence of *Pterocarya* is distinct. Pollen spectra of the period II of the Mazovian succession from Krzyżewo are slightly diffrent. In this period there is no pollen of such thermophilous taxa as *Celtis* and *Pterocarya*, whereas *Taxus* is relatively abundant, and *Abies* and *Carpinus* appear at the end of this period.

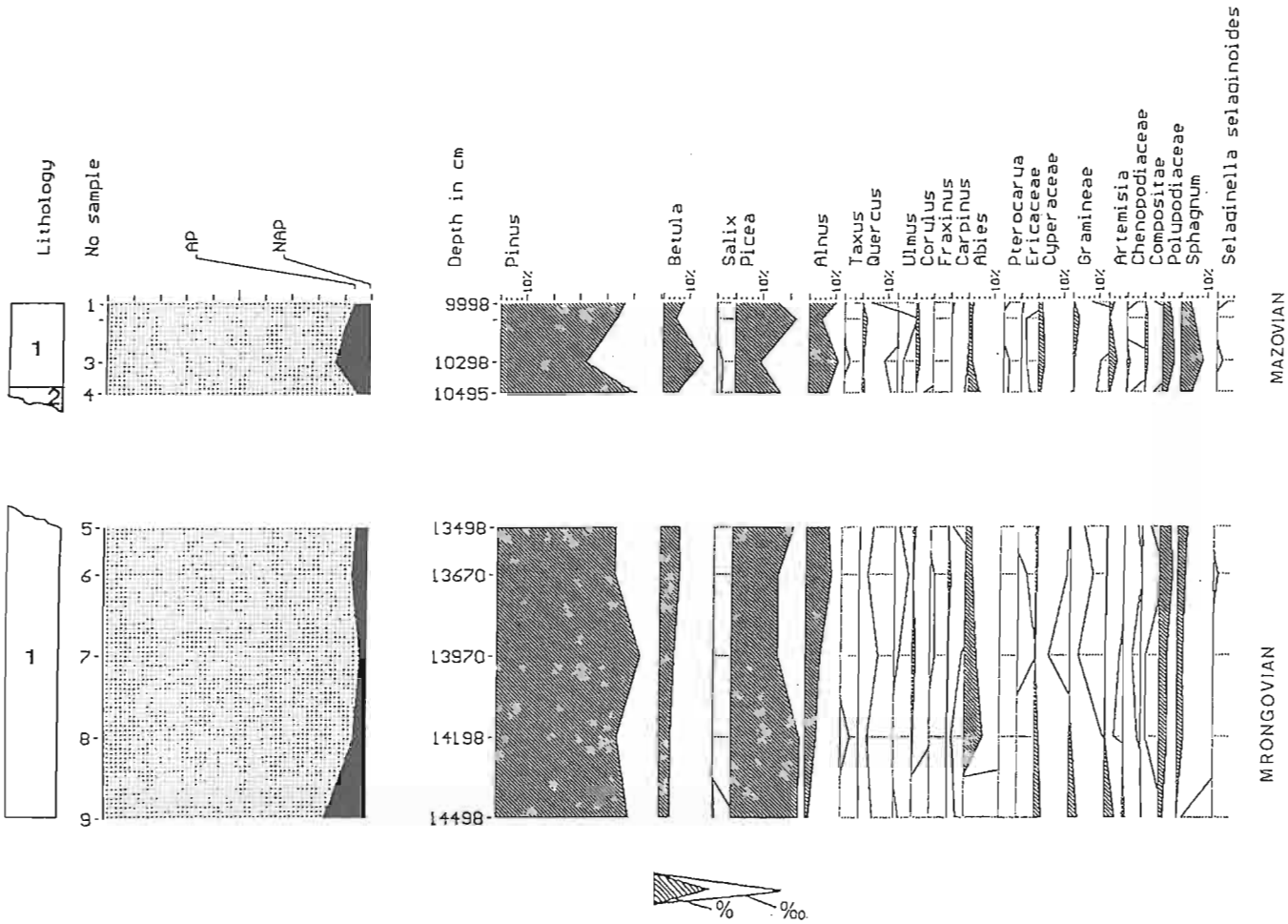


Fig. 2. Gawrych Ruda, pollen diagram

1 — silt, 2 — clay

Variation in pollen spectra in deposits at depth 166.4–175.8 m in the section Koczarki and in spectra of the pollen period I–II in the section Krzyżewo, their similarity to pollen spectra from the lower series at Goleń, as well as presence of sands at depth 166.4–169.0 m, speak for two pollen successions in the section Koczarki. The lower series (samples 1–17 at depth 166.4–175.8 m) should be correlated with the interstadial pollen succession from the section Goleń rather, and the upper series — with pollen periods II–IV of the Mazovian Interglacial.

In the section Goleń the intra-till series at depth 50.31–53.21 m represents an interstadial-like pollen succession. The succession itself, its possible equivalent in other sites and reliable connection with deposits that precede the Mazovian Interglacial, speak for establishment of a separate interstadial succession — named the Mrongovian one.

LITHOLOGY AND STRATIGRAPHY

Stratigraphic subdivision of the Pleistocene of north-eastern Poland was based on detailed analysis of 32 sections of test-cartographic boreholes from the central part of the Mrągowo Lakeland (S. Lisicki, 1996, 1997). Petrographic analysis of gravels (size 5–10 mm) from over 1200 samples of tills (after the method of J. Rzechowski, 1971, 1974) and palynological examination of interglacial deposits (Z. Borówko-Dłużakowa, W. Słowański, 1991; M. Sobolewska, 1975) created foundations to distinguish 14 lithologic types of tills (S. Lisicki, 1996, 1997).

The oldest deposit of the Pleistocene in the analyzed sections are lag concentrates. They are presumably residuals of tills of the older Narevian Glaciation, present in the sections

Śniadowo and Węgorzewo III (Fig. 4). The oldest analysed till, i.e. **lithotype *A2*** of the younger stadial of the Narevian Glaciation, occurs at Gawrych Ruda and Śniadowo. Its mean petrographic coefficients are equal to 1.06–1.03–0.93 (6 samples) and 1.02–1.28–0.64 (2 samples). A boulder-gravel lag concentrate at depth of about 200 m in the section Węgorzewo III is presumably a relic of a till of the older stadial of the Nidanian Glaciation. A till of the **lithotype *N2***, i.e. of the younger stadial of the Nidanian Glaciation, is represented by the following mean petrographical coefficients: at Koczarki 1.17–0.93–0.98 (4 samples), Węgorzewo 1.20–0.89–1.03 (1 sample), and Gawrych Ruda 1.59–0.67–1.46 (4 samples). It is overlain by tills of the Sanian Glaciation. A till of the **lithotype *S1***, i.e. of the older stadial, has mean petrographic coefficients equal to 0.77–1.69–0.55 at Goleń (3 samples), 0.91–1.29–0.70 at Węgorzewo (4 samples), and 0.96–1.37–0.62 at Śniadowo (10 samples). In both latter sections, large thickness of a till suggest its glaciotectonic (scaly?) push. Mean petrographic coefficients of a till with the **lithotype *S2***, i.e. of the younger stadial of the Sanian Glaciation, are equal to 1.20–1.05–0.79 at Goleń (2 samples), 1.01–1.09–0.89 at Koczarki (2 samples) and 1.08–1.08–0.80 at Śniadowo (2 samples). The next, younger till of the **lithotype *G*** is of the Wilgian Glaciation. It is 2 m thick at Goleń, and 3.1 and 4.8 m thick at Śniadowo. Mean petrographic coefficients of this till are respectively: 1.51–0.72–1.23 (2 samples), 1.33–0.86–1.01 (1 sample) and 1.20–0.89–1.04 (1 sample).

Above there is a red clay complex, composed of clayey flow tills, and reservoir clays with single, small gravels. These deposits are red due to content of trivalent iron, derived together with clay from the Lower Triassic sediments. It is a marker stratigraphic bed in the whole northeastern Poland, considered previously for the ice-dam lake complex formed at decline of the Wilgian Glaciation (S. Lisicki, 1997). In the section Węgorzewo III (Fig. 4) such deposits occur at 44.6 m b.s.l. on a till of the lithotype ***G*** and are 30.7 m thick. Red and brown-red ice-dam clays contain interbeds of beige and grey silt, and also plant remains and pieces of mollusc shells. Pollen analyses of 10 samples (M. Sobolewska, 1975) noted predominance of tree pollen (AP) of boreal forest over pollen of herbs (NAP) in lake clays, and almost their complete absence in flow tills. Varying contents of pollen in deposits suggest climatic changes (varied temperature and precipitation) and in vegetation cover (W. Słowański, 1975). In this part of the section, a new interglacial pollen succession was recorded.

In the section Węgorzewo IV, brown silty clays of the red clay complex occur at 51.2 m b.s.l., probably on a till of the Sanian Glaciation and are in total 6.5 m thick. In the section Koczarki there is a 14.1 m thick series of dark brown-red limy clays with single gravels, to 4 cm in diameter. They overlie a till of the lithotype ***S2***. 2 samples of clays from the top were palynologically-examined (Z. Borówko-Dłużakowa, W. Słowański, 1991), indicating predominance of pine-birch forest. Therefore, the red clay complex seems to be composed of periglacial-lake and lake sediments of cooler part of the Mrongovian period (**R**). Gravels in clays could be derived form perennial floating pack ice, presumably incorporated in winter into ice in a coastal zone.

In the section Goleń, a till of the lithotype ***G*** is overlain by a till which is 0.6 m thick. Although grey, it was included into the red clay complex. Similarly as most tills of this complex (in 11 sections in the Mrągowo Lakeland), it contains more (if compared with ordinary tills) northern dolomites (Dp), even to 19%. In two other sections, deposits of the red complex are absent but they occur in similar geologic setting in sections of the Augustów Plain (to the south of Gawrych Ruda) and in the section Przasnysz (to the west of Śniadowo). In sections of the Augustów Plain, tills of the red clay complex contain abundant (to 47.5%) dolomites (J. Czerwonka, D. Krzyszkowski, 1995).

In all the sections (except from Węgorzewo III, in which there are sediments of the red clay complex only), among deposits of warmer part of the Mrongovian warm period (**R**) there are the ones in lake, bog and lake-fluvial facies (Fig. 4). In the section Goleń, a grey flow till is overlain by dark brown peat, 1.5 m thick. It has sandy interbeds in the top, and is covered with grey and dark brown silt with plant remains and single fine gravels, mantled in turn in the very top by very limy silty sand. In total, these sediments are 3.2 m thick. Basing on palynological examination, the Mrongovian succession was distinguished older than the Mazovian Interglacial (H. Winter, S. Lisicki, 1998).

Lake and bog sediments are 8.4 m thick in the section Koczarki. They were palynologically-examined (Z. Borówko-Dłużakowa, W. Słowański, 1991). Analysis of 15 samples proved deposition directly after development of the red clay complex. There is limy grey-brown clay in the top, overlain by grey sandy silts with peaty inserts. These sediments contain numerous remains of mollusc shells. They are overlain by grey-green fine-grained and silty sands with pieces of wood. In the section Węgorzewo IV, this series is presumably represented by green-grey fine-grained fluvial sands with pieces of wood and interbeds of humus, and with a layer of green-grey silts in the middle. These sediments have not been palynologically-examined. They are in total 17.4 m thick. In the section Gawrych Ruda, a bed of fine-grained sands, 2 m thick, is overlain by grey and green-grey sandy lake silts, 16.5 m thick, with abundant plant remains in the middle. In the section Śniadowo, the Mrongovian warm period (**R**) is recorded by two cycles of lake-fluvial deposits, in total 15 m thick. Lower part of each cycle are coarse-grained to fine-grained sands, covered with much thicker grey silts and inserts of humus.

These sediments with typical Mrongovian warm period (**R**) are commonly overlain by a till or gravel-boulder accumulation, covered in turn by sediments of the Mazovian Interglacial (**M**) (Fig. 4). A till of the new cold episode — Brokian cold period (**D**) — is noted in the sections Goleń and Węgorzewo IV. This till was correlated in the section Goleń with the Liviecian Glaciation (S. Lisicki, 1997; H. Winter, S. Lisicki, 1998), and in the section Śniadowo — with the older stadial of the Sanian Glaciation (A. Bałuk, in print). The **lithotype *D*** of this till is represented by mean petrographic coefficients equal to 1.46–0.73–1.29 at Goleń (4 samples) and 1.53–0.75–1.12 at Śniadowo (1 sample with 61 gravel grains only). This till is 2.8–6.6 m thick. In the section Węgorzewo

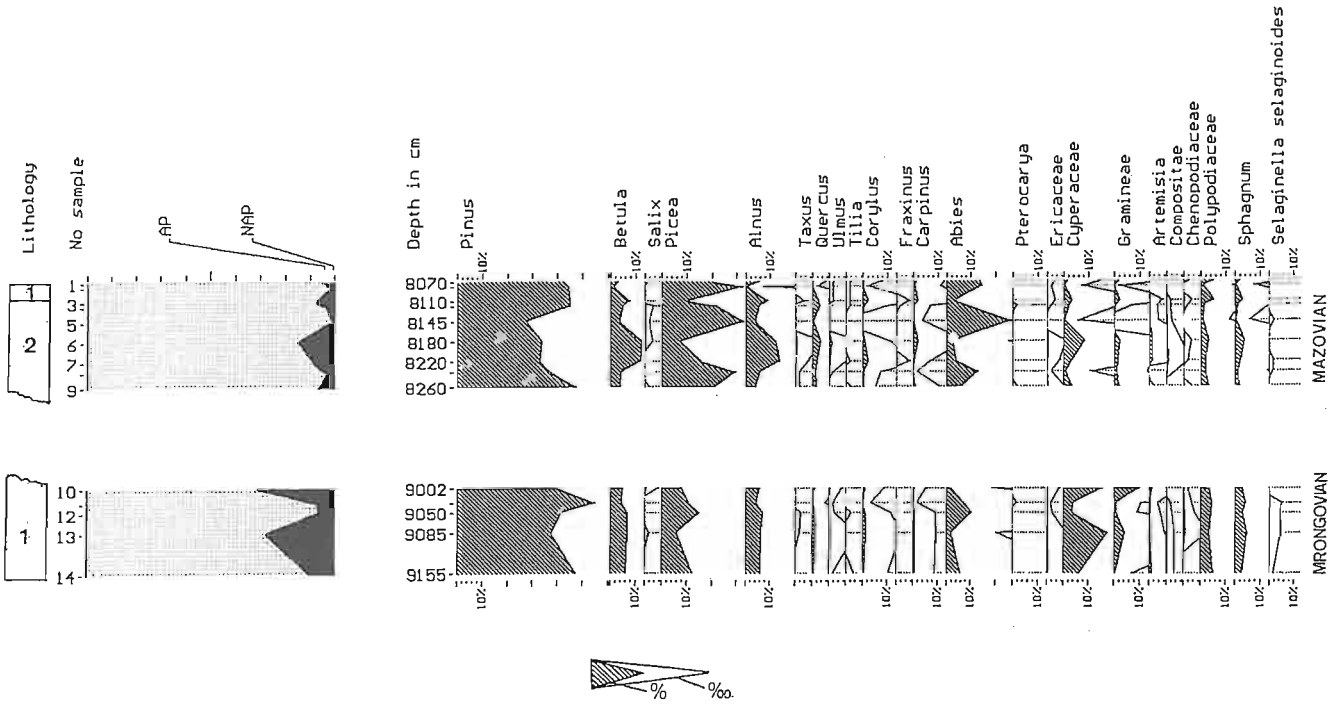


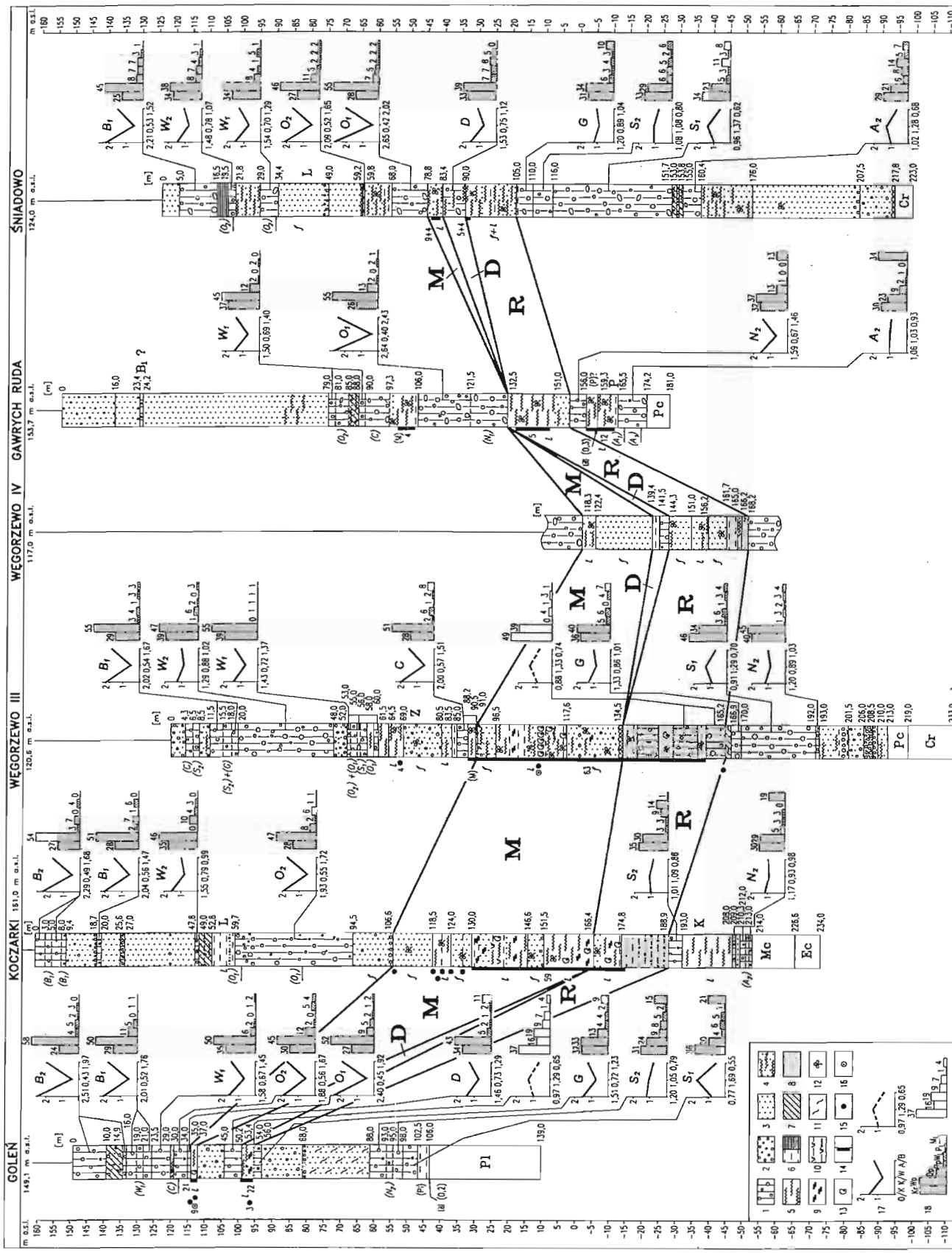
Fig. 3. Śniadowo, pollen diagram

1 — silt, 2 — sandy silt

III, this till is presumably represented by a gravel-boulder lag concentrate on the red clay complex (Fig. 4).

Deposits of the Mazovian Interglacial (**M**) are known from all the analysed sections. In the section Goleń they are olive-grey and usually clayey compact silts with mollusc shells, occurring at depth 35.0–36.5 m on a till of the new cold episode. These deposits are underlain by lake-deluvial sandy silts, 0.5 m thick, with single gravels. These silts are located at 112.6 m a.s.l. Interglacial series was subjected to pollen analysis (H. Winter, S. Lisicki, 1998). In the section Koczarki, sediments of the Mazovian Interglacial (**M**) occur at depth 106.6–166.4 m, and their bottom was noted at 5.4 m b.s.l. These sediments represent two sedimentary cycles. Lake and bog series in each cycle were covered by fluvial sediments. They were described in detail by W. Słowański (Z. Borówko-Dłużakowa, W. Słowański, 1991). A successful pollen analysis was done for deposits at depth below 130 m (Z. Borówko-Dłużakowa, W. Słowański, 1991). Pollen material in the upper part of the sequence was considerably redeposited. In the section Węgorzewo III, sediments of the Mazovian Interglacial (**M**) are composed of fluvial (deltaic?), lake and bog series at depth 91.0–134.5 m. Their bottom is located at 13.9 m b.s.l. A complex of these sediments was described in detail by W. Słowański (1975). 45 samples from the interglacial series were palynologically-examined and 8 samples from the overlying (depth 88.2–90.5 m) raft of light grey silts (M. Sobolewska, 1975). In the neighbouring section Węgorzewo IV (Fig. 4), presumable non-examined palynologically sediments of the Mazovian Interglacial (**M**) are the fluvial or deltaic blue-grey non-limy fine- and medium-grained sands above a grey ice-dam clay, overlain by probable oxbow sediments: very fine-grained and silty sands with brown organic matter. These sediments are 21.1 m thick and occur at 22.4 m b.s.l. In the section Gawrych Ruda at depth 97.3–106.0 m, there are lake sediments with plant remains. They are located at 47.7 m a.s.l. Pollen analysis ascribes these sediments to the Mazovian Interglacial (Z. Janczyk-Kopikowa, 1986). They are, however, underlain by a till of the **lithotype** ***O*$_1$**, ascribed in northeastern Poland to the Odranian Glaciation and covered by glacial complex of the Wartanian Glaciation. The described lake sediments from the section Gawrych Ruda should be therefore interpreted as a glacial raft. In the section Śniadowo, sediments of the Mazovian Interglacial (**M**) occur on a till of the cold episode of Brokian cold period (**D**). At depth 78.8–83.4 m there are lake silts with dark humus inserts at 40.6 m a.s.l. In northeastern Poland, sediments of the Mazovian Interglacial (**M**) are commonly covered with tills of the lithotypes ***C*** or ***O*$_1$**.

A till of the **lithotype *C*** (Liviecian Glaciation) occurs *in situ* in the section Węgorzewo III only and presumably in the section Węgorzewo IV. Its mean petrographic coefficients in the former are equal to 2.00–0.57–1.51 (3 samples). A till of the lithotype ***O*$_1$** (older stadial of the Odranian Glaciation) was noted in three sections. Mean petrographic coefficients of this till are equal to 2.40–0.45–1.92 at Goleń (1 sample), 2.65–0.42–2.02 at Śniadowo (3 samples) and 1.34–0.82–1.10 (2 samples) in the upper weathered part, and 2.64–0.40–2.43 at Gawrych Ruda (8 samples) and 2.41–0.43–2.36 (6 samples) for a till raft of the **lithotype *N*$_1$** in the lower part. Both tills in the latter section are firstly different for their contents of


GOLEŃ
KOCZARKI
WĘGORZEWO III
WĘGORZEWO IV
GAWRYCH RUDA
ŚNIADOWO

local siltstones (M_L): 1.1% for the lithotype ***O1***, and 10% for the lithotype ***N1***. A till of the **lithotype *O2*** (younger stadial of the Odranian Glaciation) occurs in three sections. Its petrographic coefficients are equal to 2.09–0.52–1.65 at Śniadowo (1 sample) and 1.88–0.56–1.67 at Goleń (3 samples). At Koczarki, a till of the younger stadial of the Odranian Glaciation is the thickest (34.8 m) and could be glaciotectonically deformed. Its mean petrographic coefficients are equal to 1.93–0.55–1.72 (32 samples). A till of the **lithotype *W1*** (older stadial of the Wartanian Glaciation) was noted in four sections. Its mean petrographic coefficients are equal to 1.54–0.70–1.29 at Śniadowo (2 samples), and 1.58–0.67–1.45 at Goleń (3 samples). At Węgorzewo mean petrographic coefficients of a till of the Wartanian Glaciation are equal to 1.43–0.72–1.37 (3 samples). At Gawrych Ruda, a till of this age contains rafts of tills of the lithotypes ***C*** and ***O2***. Beneath the described glacial sediments in this section, there is a raft of lake sediments of the Mazovian Interglacial, 8.7 m thick. Mean petrographic coefficients for a till of the lithotype ***W1*** are equal to 1.50–0.69–1.40 (4 samples), and for rafts of a till of the lithotype ***O2*** they are 1.93–0.53–1.77 in the upper part and 2.28–0.45–2.10 for a till of the lithotype ***C*** in the lower part. A till of the lithotype ***C*** contains abundant northern dolomites (D_P), equal to 21% (12% in a till of the lithotype ***W1***). Such high content of dolomites is a diagnostic feature for this till in the whole Suwałki Lakeland, i.e. for the lithotype T5 according to J. Czerwonka, D. Krzyszkowski (1995) in the Augustów Plain. In the central Mazury Lakeland, a till of the lithotype ***C*** contains considerably less dolomites (Fig. 4). Mean petrographic coefficients for a till of the **lithotype *W2*** (younger stadial of the Wartanian Glaciation) are equal to 1.55–0.79–0.99 at Koczarki (1 sample), 1.48–0.78–1.07 at Śniadowo (1 sample) and 1.29–0.88–1.02 at Węgorzewo III (10 samples). A till of the older stadial of the Vistulian Glaciation is represented by the **lithotype *B1***. It occurs in all the analysed sections. Its mean petrographic coefficients are equal to 2.04–0.56–1.47 at Koczarki (1 sample), 2.01–0.52–1.76 at Goleń (2 samples), 2.02-0.54-1.67 at Węgorzewo III (4 samples) and 2.21–0.53–1.52 at Śniadowo (5 samples). The youngest till of the **lithotype *B2***, i.e. of the younger stadial of the Vistulian Glaciation, is noted in two sections only. In the section Goleń, it forms the upper part of the Pleistocene complex. Its mean petrographic coefficients are equal to 2.51–0.43–1.97 (3 samples). In the section Koczarki, this till occurs also at land surface, and its mean petrographic coefficients are equal to 2.29–0.49–1.68 (5 samples). In the section Węgorzewo III, the youngest glacial bed under the outwash cover is composed of rafts of tills only of the lithotypes ***C*** and ***S2***. Thus, the youngest till (of the lithotype ***B2***) in this area has been presumably eroded by meltwaters.

RECAPITULATION

Basing on pollen analysis two lake, bog and lake-fluvial series in the sections Gawrych Ruda, Goleń and Śniadowo, separated by a till and sands, were connected with the Mazovian Interglacial: the lower series to the stage II, and the upper to stage III of the scheme of W. Szafer (1953). The fact that these series were separated by a till was hardly interpreted, and the younger series of lake sediments was expected to have been a raft in the lower part of the younger tills (S. Lisicki, 1997).

Petrographic composition of tills in the Mrągowo Lakeland is considerably varied (S. Lisicki, 1996, 1997). However, this variation is much smaller for a definite lithotype (its chronostratigraphic position was determined on the basis of palaeogeographic reconstruction), equal to 25% if referred to mean values of each lithotype (S. Lisicki, 1998). Only tills of the Wilgian (**G**) and Liviecian (**C**) Glaciations were described with two different sublithotypes. Such changing petrographic characterstics of tills was explained (S. Lisicki, 1997) by different directions of glacial lobes and streams, advancing onto the central part of the Mazury Lakeland, both during the Wilgian and Liviecian Glaciations. It has not been, however, concordant with a general picture of advance of the Scandinavian ice sheets. These geologic problems are solved by introduction of a new interstadial pollen succession (H. Winter, S. Lisicki, 1998), interpreted in the discussed sections as the pollen stage II of the Mazovian Interglacial (*cf.* W. Szafer, 1953).

The idea of a pollen succession of at least the interstadial-rank and located beneath deposits of the Mazovian Interglacial is not a new one. Already J. Dyakowska (1952), basing on the pollen diagram from Nowiny Żukowskie, suggested a possible warm interval at the termination of the Cracovian Glaciation (Elsterian). It is indicated by pollen spectra in a bottom part of the section, with *Picea* to 21.9%, *Abies* to 18.3%, and *Carpinus* to 8.5%.

A similar phenomenon was also noted by M. Brem (1953) in the diagram from Ciechanki Krzesimowskie II. Also A. Środoń (1954) when presenting the section from Tarzymie-

Fig. 4. Stratigraphic correlation of the study sections

1 — till, 2 — gravel, 3 — sand, 4 — silty sand or sand with silt, 5 — silt, 6 — clay and varved clay, 7 — glaciofluvial-flow till deposits, 8 — red clay complex, 9 — peat, 10 — gyttja, 11 — glauconite (large concentrations), 12 — fossil flora, 13 — fossil fauna, 14 — pollen diagram, 15 — pollen expertise, 16 — palaeozoological expertise, 17 — petrographic coefficients of tills of the red clay complex (O — total of sedimentary rocks, K — total of crystalline rocks and quartz, W — total of carbonate rocks, A — total of rocks non-resistant to destruction, B — total of resistant rocks), 18 — mean content (in %) of gravels in tills of the red clay complex (groups of Scandinavian rocks: Kr — crystalline rocks, W_P — limestones of northern origin, D_P — dolomites of northern origin, P_P — sandstones and quartzites of northern origin; local rocks: W_L — limestones and marls, P_L — sandstones, M_L — siltstones and claystones); lithologic symbols: f — fluvial sediments, l — lacustrine sediments; chronostratigraphic symbols: **Cr** — Cretaceous, **Pc** — Paleocene, **Ec** — Eocene, **Mc** — Miocene, **Pl** — Pliocene, **P** — Podlasian (Augustovian) Interglacial, **K** — Malopolanian Interglacial, **R** — Mrongovian warm period, **D** — Brokian cold period, **M** — Mazovian Interglacial, **Z** — Zbójnian Interglacial, **L** — Lublinian Interglacial; lithostratigraphic symbols are in italics; chrono- and litostrathigraphic symbols in brackets are for glacial rafts

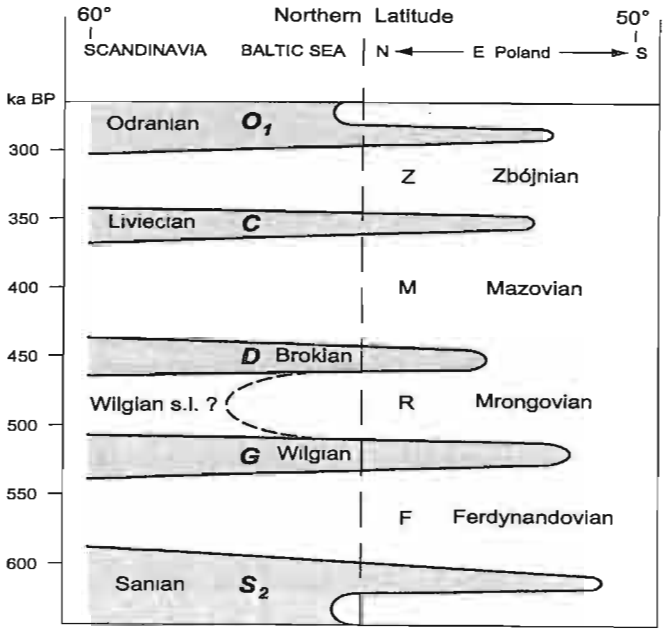


Fig. 5. Stratigraphic subdivsion of the Middle Pleistocene of northeastern Poland

Lithostratigraphic symbols in italics; others are chronostratigraphic symbols; time scale after L. Lindner (1992), modified

chy, confirmed the opinion of J. Dyakowska (1952) on presence of "...traces of interstadial warming against oscillations of a retreating ice sheet edge. This interstadial would be separated from the proper interglacial by a cool stadial, indicated in bottoms of the sections from Nowiny Żukowskie and Ciechanki Krzesimowskie by a period with predominant pine-birch forest with spruce...". A. Środoń (1957) repeated also his opinion in the paper on the sediments from Gościęcin in the Lower Silesia. There he distinguished the phase IV, represented by pine-birch forest with spruce, alder, elm and hazel, and with traces of other thermophilous trees, and with *Stratiotes aloides* and *Najas marina* f. *ovata* in the lake. He considered this phase for an interstadial at the end of the Cracovian Glaciation.

Establishment of a new pollen succession permits for reinterpretation of the pollen diagrams for the sections Węgorzewo III and Koczarki. In both these sections, sediments of the Mazovian Interglacial are found to be of different age. In the upper series (B) at Węgorzewo and in sediments at depth 130.0–166.4 m at Koczarki, there is evidence for the Mazovian Interglacial. On the other hand, pollen spectra from the lower series (A) at Węgorzewo and from a depth 166.4–175.8 m at Koczarki, can to be referred to the Mrongovian succession. Consequently, establishment of the interstadial-rank Mrongovian succession results in a new lithotype of a till which separates deposits of the Mrongovian period from the ones of the Mazovian Interglacial. This till can belong to a new glaciation or to a younger stadial of the Wilgian Glaciation (Fig. 5). S. Lisicki speaks for the first version rather.

A renewed analysis of the pollen examination of M. Sobolewska (1975) for the section Węgorzewo III, the red clay complex is of periglacial-lake and lake origin. Its deposition should be connected with the Mrongovian warm period after the Wilgian Glaciation.

Considering the new geologic data from the Suwałki Lakeland, the section Gawrych Ruda was the most difficult to interpretation in its fragment above a till of the lithotype O_1 (Fig. 4). Because lake silts of the Mazovian Interglacial, 8.7 m thick, are underlain by a till of the lithotype O_1 (the older stadial of the Odranian Glaciation), and are overlain by a till of the lithotype C, i.e. interpreted in this section as a raft of an older till of the lithotype W_1 (of the older stadial of the Wartanian Glaciation), the lake sediments at Gawrych Ruda could be incorporated into a glacial raft only. Such interpretation corresponds with conclusions of A. Ber (1998).

CONCLUSIONS

Results of pollen and petrographic analyses, and their interpretation formed the basis to distinguish a new chronostratigraphic unit, i.e. the Mrongovian warm period. It could be introduced due to:

— individuality of the Mrongovian pollen succession if compared with other interglacial and interstadial ones;

— its equivalents in other sections;

— consequent overlying of sediments in which it is recorded, by the ones of the Mazovian Interglacial;

— separation of sediments of these two warm intervals by a till or gravel-boulder accumulation;

— common occurrence of the red clay complex in bottom sediments of the Mrongovian warm period.

At present, sediments of the Mrongovian warm period can be distinguished as the Mrongovian substage within the Wilgian Stage (according to H. Winter) or as the Mrongovian Stage, being a short interglacial (according to S. Lisicki). In northeastern Poland, sediments of the Mrongovian warm period are separated from deposits of the Mazovian Interglacial by a till or its gravel-boulder remains. This new cold episode, presumably a short glaciation, during which deposition of till occurred, is postulated to be a substage (Brokian Stadial) within the Wilgian Stage or a stage, named the Brokian, after the right tributary of the Bug River.

REFERENCES

BAŁUK A. (in print) — Szczegółowa mapa geologiczna Polski 1:50 000, ark. Śniadowo. Państw. Inst. Geol. Warszawa.

BER A. (1998) — Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Krasnopol. Państw. Inst. Geol. Warszawa.

BORÓWKO-DŁUŻAKOWA Z., SŁOWAŃSKI W. (1991) — Results of pollen analysis of interglacial deposits of Koczarki near Mrągowo (in Polish with English summary). Kwart. Geol., **35** (3): 323–336.

BREM M. (1953) — Flora interglacjalna z Ciechanek Krzesimowskich. Acta Geol. Pol., **3** (3): 475–480.

CZERWONKA J. A., KRZYSZKOWSKI D. (1995) — Szczegółowa mapa geologiczna Polski w skali 1:50 000 (opracowanie specjalne). Badania litostratygraficzne, ark. Wieliczki i Augustów. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

CZERWONKA J., CHOMA-MORYL J., KRYZA R., MORYL J. (1984) — Geneza i stratygrafia osadów występujących na obszarze Szczegółowej mapy geologicznej Polski w skali 1:50 000, ark. Mrągowo. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

DYAKOWSKA J. (1952) — Pleistocene flora of Nowiny Żukowskie on the Lublin Upland (in Polish with English summary). Biul. Państw. Inst. Geol., **67**: 115–174.

GRONKOWSKA-KRYSTEK B. (1993) — Badania litologiczno-petrograficzne osadów czwartorzędowych. Szczegółowa mapa geologiczna Polski w skali 1:50 000, ark. Śniadowo. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

JANCZYK-KOPIKOWA Z. (1986) — Orzeczenie dotyczące próbek z miejscowości Gawrychruda, ark. Krasnopol i Zielone Królewskie, ark. Suwalki. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

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

JANCZYK-KOPIKOWA Z. (1996) — Temperate stages of the Mesopleistocene in Northeastern Poland (in Polish in English summary). Biul. Państw. Inst. Geol., **373**: 49–66.

KENIG K. (1987) — Badania litologiczno-petrograficzne osadów czwartorzędowych. Szczegółowa mapa geologiczna Polski w skali 1:50 000, ark. Krasnopol. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

LINDNER L. (1992) — Stratygrafia (klimatostratygrafia) czwartorzędu. In: Czwartorzęd: osady, metody badań, stratygrafia (ed. L. Lindner): 441–633. Wyd. PAE. Warszawa.

LISICKI S. (1996) — Stratigraphy of Pleistocene deposits in the central Mazury Lakeland (in Polish with English summary). In: Stratygrafia plejstocenu Polski (ed. L. Marks): 55–58.

LISICKI S. (1997) — Pleistocene of Mrągowo Lakeland. Geol. Quart., **41** (3): 327–346.

LISICKI S. (1998) — Interpretacja wyników analizy petrograficznej frakcji żwirowej glin zwałowych w nawiązaniu do ich genezy. Prz. Geol, **46** (5): 410–416.

RZECHOWSKI J. (1971) — Granulometric-petrographic properties of the till in the drainage basin of the middle Widawka (in Polish with English summary). Biul. Inst. Geol., **254**: 111–155.

RZECHOWSKI J. (1974) — On lithotypes of lower and middle Pleistocene tills in Polish Lowland (in Polish with English summary). Zesz. Nauk. Uniw. A. Mickiewicza w Poznaniu, Geogr., **10**: 87–99.

RZECHOWSKI J., GRONKOWSKA B., KENIG K., SOBCZUK B. (1975) — Litostratygrafia osadów glacjalnych z profilów wiertniczych na Pojezierzu Mazurskim. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

SŁOWAŃSKI W. (1975) — The Quaternary at Węgorzewo and its vicinity (in Polish with English summary). Biul. Inst. Geol., **288**: 99–136.

SOBOLEWSKA M. (1975) — A palynological analysis of the interglacial deposits at Węgorzewo (in Polish with English summary). Biul. Inst. Geol., **288**: 137–165.

SZAFER W. (1953) — Stratygrafia plejstocenu w Polsce na podstawie florystycznej. Rocz. Pol. Tow. Geol., **22** (1): 1–99.

ŚRODOŃ A. (1954) — Pleistocene floras from Tarzymiechy on the river Wieprz (in Polish with English summary). Biul. Państw. Inst. Geol., **69**: 5–78.

ŚRODOŃ A. (1957) — Interlacial flora from Gościęcin near Koźle (Sudetic Foreland) (in Polish with English summary). Biul. Państw. Inst. Geol., **118**: 7–60.

WINTER H., LISICKI S. (1998) — New palyno- and lithostratigraphic interpretation of the Cenozoic lake sediments in the section Goleń, Mazury Lakeland. Geol. Quart., **42** (1): 87–98.

NOWE JEDNOSTKI STRATYGRAFICZNE ŚRODKOWEGO PLEJSTOCENU POLSKI PÓŁNOCNO-WSCHODNIEJ

Streszczenie

W artykule przedstawiono reinterpretację wyników badań palinologicznych i litologiczno-stratygraficznych osadów z profili Gawrych Ruda, Goleń, Koczarki, Śniadowo, Węgorzewo III i IV (fig. 1). Szczególną uwagę zwrócono na osady jeziorne, bagienne i jeziorno-rzeczne. Osady te, przedzielone gliną zwałową, a miejscami piaskami i żwirami wodnolodowcowymi, zostały początkowo na podstawie badań palinologicznych zaliczone do interglacjału mazowieckiego (S. Lisicki, 1997). Jednak powtórna analiza wyników badań palinologicznych i litologiczno-petrograficznych w profilu Goleń (H. Winter, S. Lisicki, 1998) pozwoliła na wyróżnienie dwóch odrębnych sukcesji pyłkowych.

W Goleniu seria górna obejmuje osady interglacjału mazowieckiego, czyli okresy pyłkowe II–IV, natomiast seria dolna prezentuje fragment nowej, interstadialnej sukcesji pyłkowej — sukcesji mrągowskiej. Do cech charakterystycznych tej sukcesji należą: duża rola świerka (*Picea*) w całej sukcesji ze znaczącym udziałem olchy (*Alnus*) na początku, wczesne pojawienie się jodły (*Abies*) wraz z grabem (*Carpinus*), niski udział procentowy ciepłolubnych drzew liściastych, głównie dębu (*Quercus*), obecność pyłku *Taxus*, kulminacja brzozy (*Betula*) łącznie z roślinami zielnymi i jodłą (*Abies*), a następnie z sosną (*Pinus*) i świerkiem (*Picea*).

Występowanie dwóch różnych sukcesji pyłkowych — mazowieckiej i mrągowskiej — stwierdzono również w profilach: Gawrych Ruda (fig. 2), Śniadowo (fig. 3), Węgorzewo III i Koczarki. Jedną z podstaw opracowania podziału stratygraficznego plejstocenu Polski północno-wschodniej było szczegółowe zbadanie 32 profilów otworów kartograficzno-badawczych z centralnej części Pojezierza Mazurskiego (S. Lisicki, 1996, 1997). Na podstawie badań litologiczno-petrograficznych, w tym głównie analizy składu petrograficznego żwirów (średnica 5–10 mm) z próbek glin zwałowych i badań palinologicznych osadów interglacjalnych (Z. Borówko-Dłużakowa, W. Słowański, 1991; M. Sobolewska, 1975), wyodrębniono 14 litotypów glin morenowych. Ważnym poziomem stratygraficznym w Polsce północno-wschodniej są osady czerwonego kompleksu ilastego. Wykształcone są one w facji ilastych glin spływowych i iłów zbiornikowych z pojedynczymi małymi ziarnami żwiru. Są to utwory jeziorno-peryglacjalne i jeziorne chłodniejszego odcinka ciepłego okresu mrągowskiego (**R**).

W omawianych profilach do cieplejszego odcinka tego okresu należy zaliczyć osady wykształcone w facji jeziornej, bagiennej i jeziorno-rzecznej (fig. 4). W profilu Goleń na Mazurach na szarej glinie spływowej spoczywają osady bagienne i jeziorne o miąższości 3,2 m. Zostały one zbadane palinologicznie, a otrzymane wyniki ponownie zinterpretowane przez H. Wintcr (H. Winter, S. Lisicki, 1998). W profilu Koczarki osady jeziorne i bagienne opracowane palinologicznie (Z. Borówko-Dłużakowa, W. Słowański, 1991) są kontynuacją utworów czerwonego kompleksu ilastego. W profilu Węgorzewo IV serii tej odpowiadają prawdopodobnie piaski rzeczne z fragmentami szczątków roślinnych. Osady te nie były badanc palinologicznie. Na

Suwalszczyźnie w profilu Gawrych Ruda osady jeziorne w środkowej części zawierają liczny detrytus roślinny. W profilu Śniadowo, między Łomżą a Ostrołęką, do ciepłego okresu mrągowskiego (**R**) zaliczono osady jeziorno-rzeczne wykształcone w dwóch cyklach akumulacyjnych.

Na osadach ciepłego okresu mrągowskiego zalega najczęściej glina zwałowa lub rezyduum żwirowo-głazowe, przykryte utworami interglacjału mazowieckiego (fig. 5). Występują one w profilach: Goleń, Węgorzewo IV i Śniadowo. Litotyp gliny charakteryzują średnie współczynniki petrograficzne wynoszące 1,46–0,73–1,29 w Goleniu (4 próbki), a 1,53–0,75–1,12 w Śniadowie (1 próbka — tylko 61 żwirów). W profilu Węgorzewo III rezyduum po tej glinie stanowi zapewne bruk żwirowo-głazowy, leżący na osadach czerwonego kompleksu ilastego.

Utwory interglacjału mazowieckiego występują we wszystkich analizowanych profilach (fig. 5). Są to osady bagienne, jeziorne, jeziorno-rzeczne i rzeczne. W profilu Gawrych Ruda na głębokości 97,3–106,0 m występują zbadane palinologicznie jeziorne mułki interglacjału mazowieckiego. Jednak w tym profilu znajdują się one w pozycji porwaka (kry lodowcowej) w spągowej części glacjalnego kompleksu zlodowacenia warty.

Powtórna analiza dokumentacji paleobotanicznej i litologiczno-petrograficznej dała podstawy do wyróżnienia nowego, ciepłego okresu mrągowskiego (**R**), interpretowanego dawniej w niektórych dyskutowanych profilach jako Szaferowski II okres pyłkowy interglacjału mazowieckiego. Do podstaw tych należy odrębność sukcesji mrągowskiej w stosunku do innych znanych sukcesji interglacjalnych i interstadialnych, konsekwentny związek osadów tego okresu z utworami reprezentującymi interglacjał mazowiecki, rozdzielność osadów obu okresów ciepłych w postaci gliny zwałowej lub bruku żwirowo-głazowego oraz częste występowanie w spągu osadów okresu mrągowskiego utworów czerwonego kompleksu ilastego.

Nowo odkryty okres jest chłodnym interglacjałem albo ciepłym interstadialem. W takiej sytuacji glinę zwałową o nowym litotypie, rozdzielającą osady okresu mrągowskiego od utworów interglacjału mazowieckiego należy określić jako należącą do nowego zlodowacenia albo do młodszego stadiału zlodowacenia wilgi (fig. 5). S. Lisicki przychyla się do pierwszej wersji interpretacji i nazywa nowy zimny okres zlodowaceniem broku (**D**) — od nazwy prawego dopływu Bugu na Międzyrzeczu Łomżyńskim, a nowy litotyp oznacza literą ***D*** (fig. 4 i 5).