Geological Quarterly, Vol. 38, No. 1, 1994, p. 133–154

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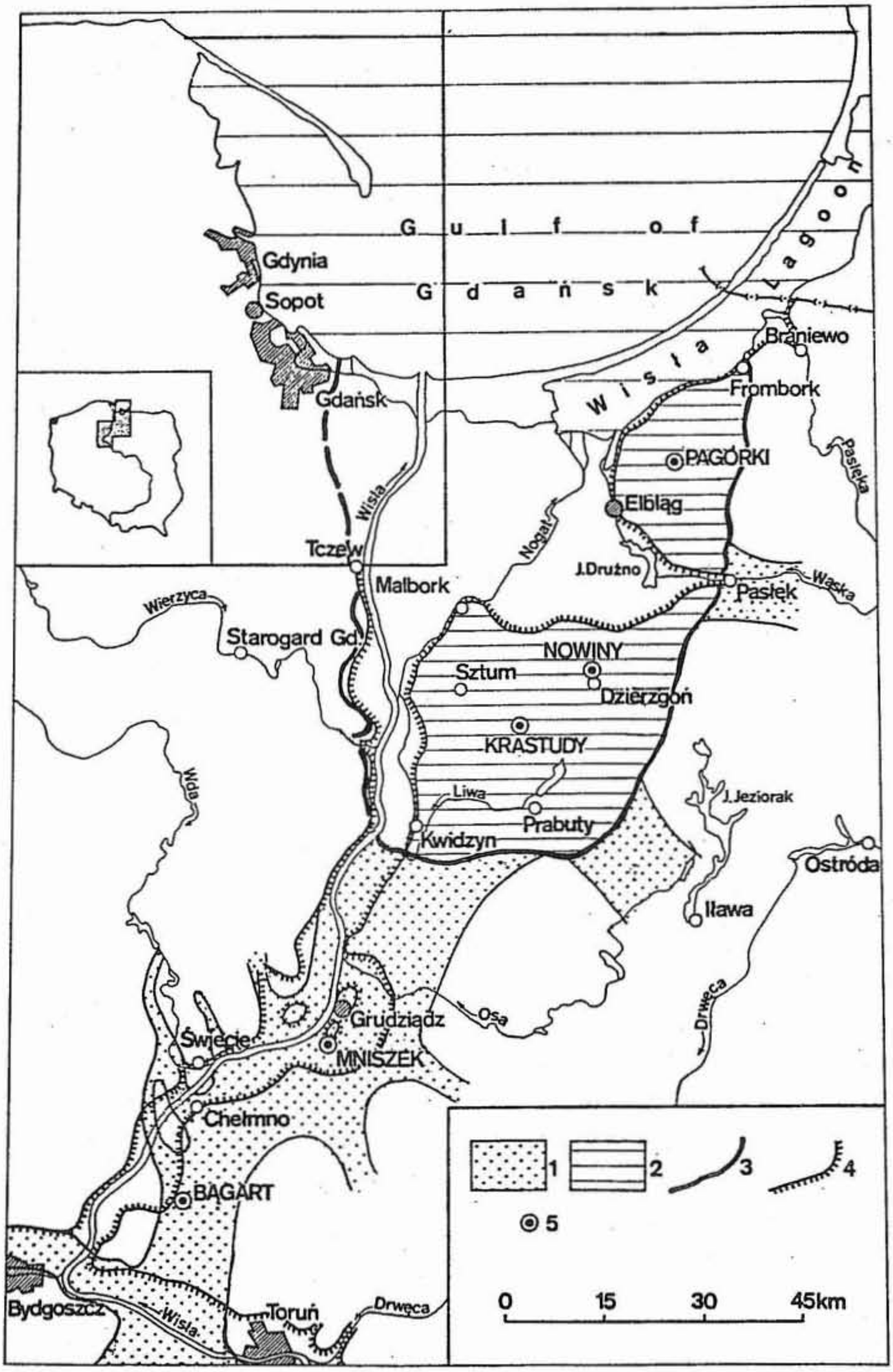
Climatic variation in the pre-glacial part of the Toruń Glaciation in the Lower Vistula Region and the Elbląg Elevation (preliminary report)

In the upper part of the Lower Vistula formation in the Lower Vistula Region and the Elbląg Elevation a cyclic deposition of fluvial and fluvial-deltaic-lacustrine sediments was noted. It reflects successive climatic changes at the turn of the Eemian Interglacial and the Toruń Glaciation. These changes comprised at least three successive coolings and warmings. The oldest warming has been palynologically determined as the Amersfoort–Brörup. Following cool and warm waves are to be correlated with the Early Vistulian stadials and interstadials, distinguished in pollen sites from Poland by K. Mamakowa (1989) and at Władysławów by K. Tobolski (1991). Studies carried out in the Lower Vistula Region and the Elbląg Elevation prove that all these intervals were climatically connected with the pre-glacial part of the Toruń Glaciation.

INTRODUCTION

Previous examination of a borehole core at Pagórki near Elbląg (A. Makowska, W. Rabek, 1990; A. Makowska, 1991) in which, not only the Eemian Interglacial but also sediments of the Amersfoort–Brörup were recorded (Z. Janczyk-Kopikowa, 1991), allows broader comparative analysis of the Late Eemian and the Early Torunian series in the Lower Vistula Region and the Elbląg Elevation.

Sediments of this age also occur in the upper part of the Lower Vistula formation that forms a principal key horizon in the area. This formation was recognized by me at the turn of the sixties and the seventies as the Eemian series *sensu lato* (A. Makowska, 1979). It is composed of terrigenous sediments that fill buried river valleys in the Lower Vistula Region, and of bipartite marine sediments of an ancient sea bay in the northern part of the area.


G u l f o f
G d a ń s k
Wisła Lagoon
Gdynia
Sopot
Gdańsk
Wisła
Tczew
Malbork
Braniewo
Frombork
PAGÓRKI
Pasłęka
Elbląg
Nogat
J. Drużno
Pasłęk
Wąska
Wierzyca
Starogard Gd.
NOWINY
Sztum
Dzierzgoń
KRASTUDY
Liwa
Prabuty
Kwidzyn
J. Jeziorak
Ostróda
Iława
Wda
Osa
Drwęca
Grudziądz
Świecie
MNISZEK
Chełmno
BAGART
Bydgoszcz
Wisła
Toruń
Drwęca
1
2
3
4
5
0 15 30 45km

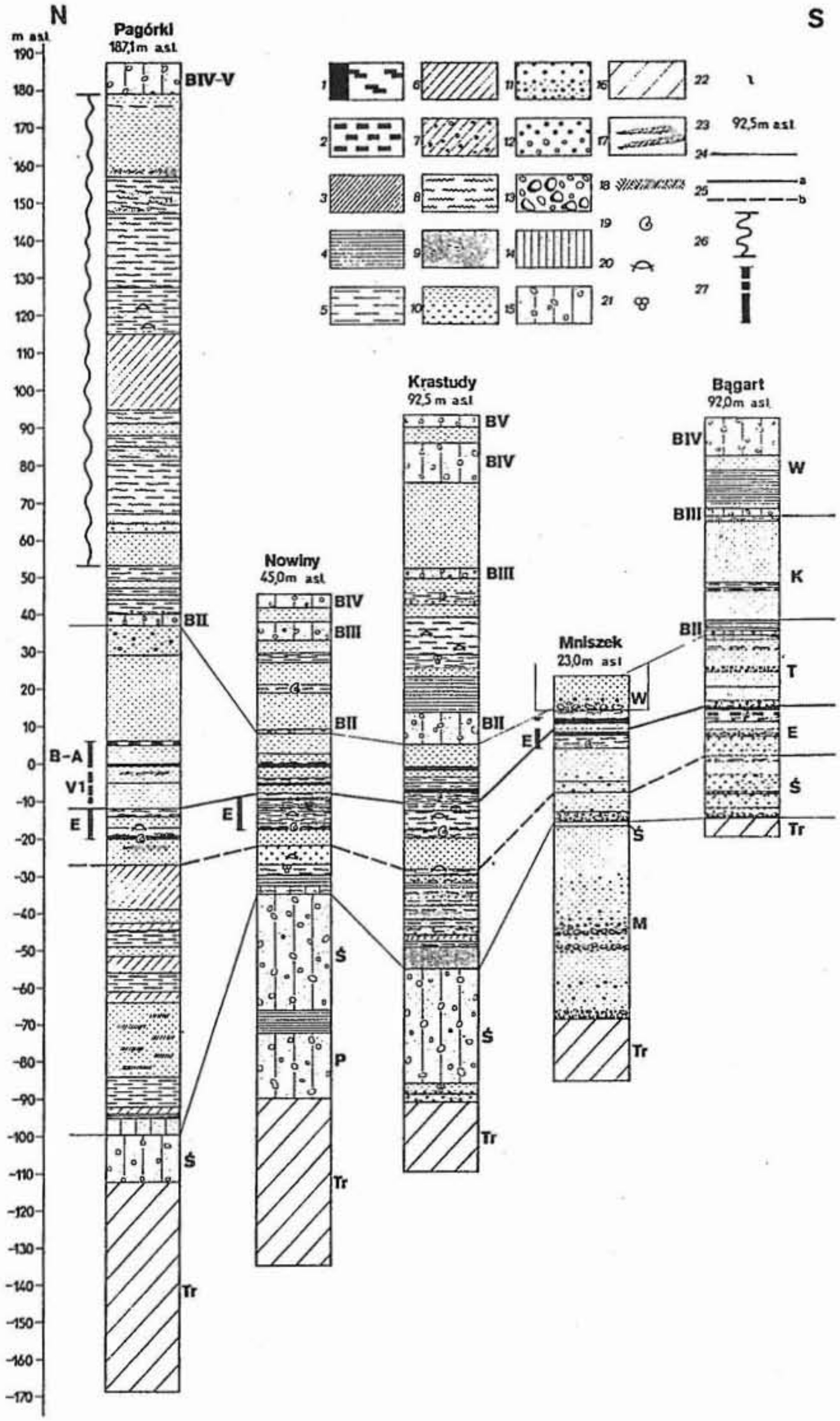
My very first studies have already proved that noted bed cyclicity in the sediments resulted from climatic variation during deposition. Several sedimentary cycles were distinguished in the upper part of the series, above sediments from the Eemian Interglacial optimum. I considered them as an effect of climatic changes that occurred at the end of Eemian Interglacial and at the beginning of the Baltic (Vistulian) Glaciation. They had, however, no palaeobotanical documentation, except for a single site at Mniszek near Grudziądz. K. Tobolski (E. Drozdowski, K. Tobolski, 1972) suggested, on the basis of a single sample — after examination of organic sediments of the Eemian Interglacial, the presence of a post-optimum climatic warming (interstadial). The latter was named afterwards by me the Mniszek Warming (A. Makowska, 1979, 1980). Since this work on the Eemian series was submitted for publication in 1975, information about the Lower Vistula Region and the Elbląg Elevation has been enriched during mapping of the area from numerous new boreholes (A. Makowska, 1992), some of them passed through the Lower Vistula formation. These boreholes generally support the results of the first studies of the Eemian series. In many places they enrich this series with new sediments and, locally, call for revision of some previous investigations. The complete list of new results, however, needs a separate examination. But at present, after investigations of the borehole at Pagórki have been completed, there is a serious demand for an up-to-date interpretation of this part of the Lower Vistula formation that contains the sediments of the decline of the Eemian Interglacial and the pre-glacial part of the Toruń Glaciation. Interpretation of these sediments, in addition to completing a stratigraphical scheme of the Late Pleistocene of the Lower Vistula Region and the Elbląg Elevation, also acts as important element in stratigraphical correlation with other areas of Poland. Comparative analyses were done by me in five selected and published sections, distributed in marine as well as terrigenous zones of the Lower Vistula formation (Fig. 1). These sections are representative not only for the problems discussed here but also for the whole Pleistocene complex of described areas. They come from boreholes at Pagórki near Elbląg (A. Makowska, W. Rabek, 1990; Z. Janczyk-Kopikowa, 1991; A. Makowska, 1991), Nowiny near Dzierzgoń (Z. Janczyk-Kopikowa, 1976; A. Makowska, 1980, 1984, 1986*b*), Krastudy near Mikołajki Pomorskie (A. Makowska, 1986*a*, *b*), Mniszek near Grudziądz (Z. Borówko-Dłużakowa, Z. Janczyk-Kopikowa, 1965; A. Makowska, 1970, 1979, 1980; E. Drozdowski, K. Tobolski, 1972) and Bągart near Unisław (A. Makowska, 1977). In the upper part of the Lower Vistula formation some of them contain very interesting organic sediments that have not been discussed in detail, mainly due to lack of palynological documentation. These sediments can now be presented in a new way.

Fig. 1. Geological setting

Sediments of the Lower Vistula formation: 1 — inland (fluvial), 2 — marine; 3 — maximum extent of the Eemian (Tychnowy) sea; 4 — escarps of the Vistula valley and delta; 5 — boreholes (presented in the text)

Szkic sytuacyjny

Osady formacji dolnopowiślańskiej: 1 — lądowe (dolinne), 2 — morskie; 3 — maksymalny zasięg eemskiej transgresji morskiej (morza tychnowskiego); 4 — krawędzie doliny i delty Wisły; 5 — otwory wiertnicze (omawiane w tekście)


N
S
m asl
Pagórki
187,1m asl
BIV-V
BII
B-A
V1
E
Ś
Tr
Nowiny
45,0m asl
BIV
BIII
BII
E
Ś
P
Tr
Krastudy
92,5 m asl
BV
BIV
BIII
BII
Ś
Tr
Mniszek
23,0m asl
W
E
Ś
M
Tr
Bągart
92,0m asl
BIV
W
BIII
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92,5m asl

LOWER VISTULA FORMATION IN THE LOWER VISTULA REGION AND THE ELBLĄG ELEVATION

The Lower Vistula formation is a distinct and spatially well defined lithostratigraphical unit (Fig. 2). It comprises sediments formed since the decline of the Middle Polish Glaciation up to the Toruń Glaciation (Early Vistulian). They spread along the Vistula valley and delta from the Toruń Basin as far as the Vistula Lagoon, creating a strip about 170 km long and from a dozen kilometres wide in the south to several dozen kilometres in the north (Fig. 1). The base of the sediment occurs from about 0–20 m b.s.l. in the south to about 90–100 m b.s.l. in the north whereas the top — up to about 40 m a.s.l. These sediments are located beneath the bottom of the Vistula valley and are not exposed, with only occasional exceptions, at the surface. The whole formation is overlain with glacial and intermorainic sediments, locally up to 80–100 m thick, formed during three separate ice sheet advances (Fig. 2). During each advance an ice sheet occupied the whole area and each time retreated beyond its limits to the north. Two of these advances also indicated smaller oscillations. As a result, an extensive sedimentary complex was formed which comprises five till beds determined in the authoress' publications by symbols BI–BV These till beds are separated by four intermorainic series (A. Makowska, 1992).

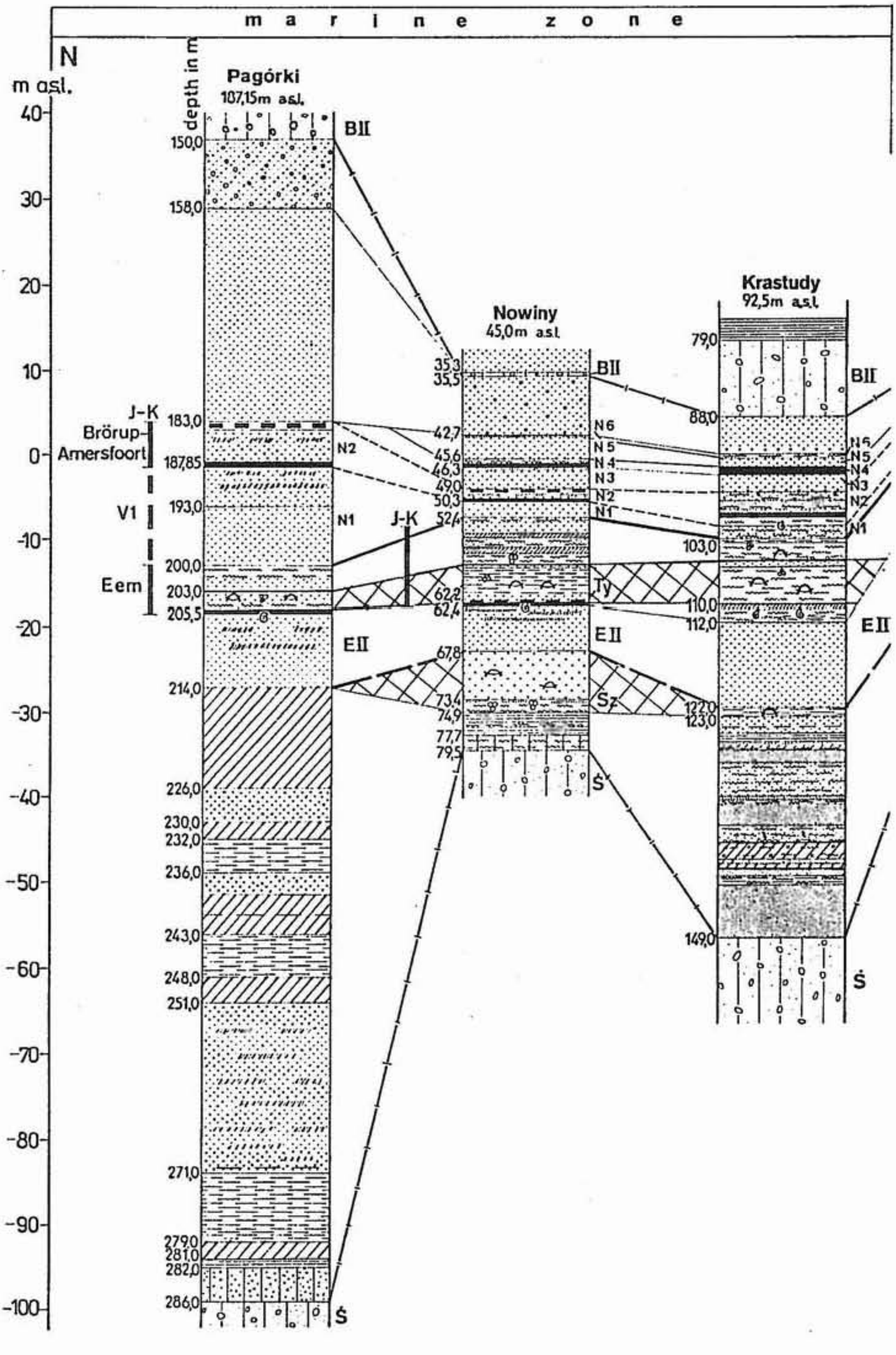
Three main tills (BII–BIV) occur in all or almost all the area, the two others are noted locally, only in its northern part. The tills BII–BIV are separated by two main intermorainic series (formations): the lower — the Gniew one and the upper — the Grudziądz one (Fig. 2). In the Elbląg Elevation they are the Kadyny and the Łęcze formations respectively. The whole post-Eemian complex has been previously referred by me to the North Polish (Baltic, Wisła, Vistulian) Glaciation; at present the lower tills BI and BII are

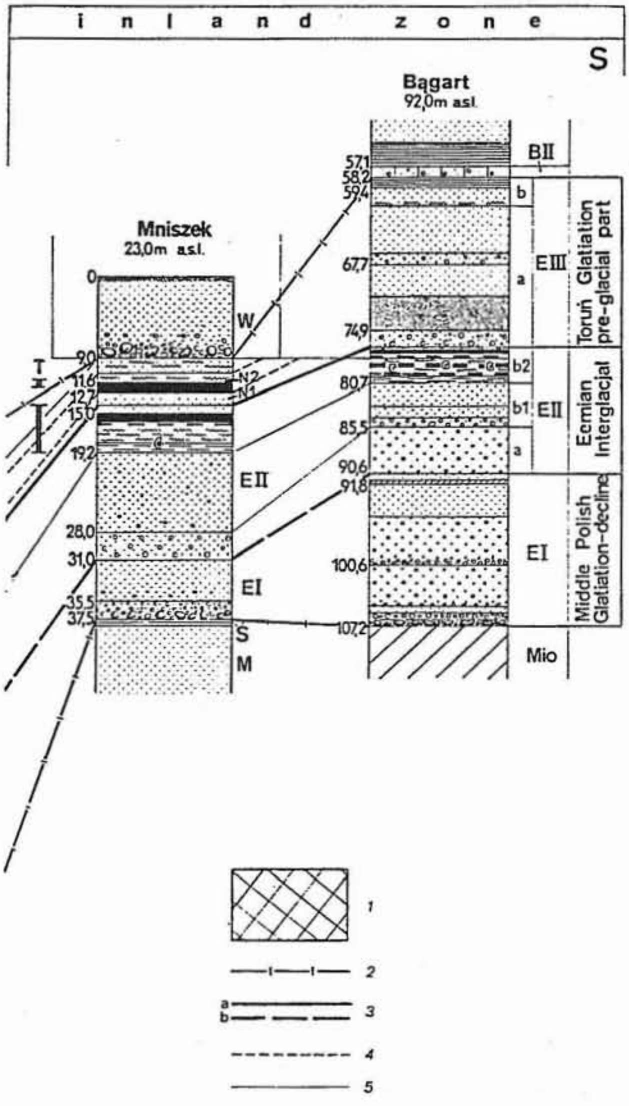
Fig. 2. Borehole sections (presented in the text)

1 — peats; 2 — gyttjas; 3 — silts with organic matter; 4 — varved clays; 5 — clays; 6 — red clays; 7 — red clays with gravel; 8 — silt; 9 — silty sands; 10 — fine- and medium-grained sands; 11 — coarse- and vari-grained sands; 12 — gravel and chad; 13 — boulders; 14 — clayey sands; 15 — tills; 16 — Tertiary sediments; 17 — humus, admixture of organic matter, plant detritus; 18 — soil; 19 — freshwater molluscs; 20 — marine molluscs; 21 — foraminiferae; 22 — glauconite; 23 — borehole altitude; 24 — boundaries of the Lower Vistula formation; 25 — boundaries of sediments of the Eemian Interglacial: a — upper, b — lower (probable); 26 — glaciotectonic deformations; 27 — palynologically-examined fragments of sections; Tr — Tertiary; P — South Polish Glaciation; M — Mazovian Interglacial; Ś — Middle Polish Glaciation; E — Eemian Interglacial; T — Toruń Glaciation; K — Krastudy Interglacial; W — Wisła Glaciation; V1 — Vistulian 1; B–A — Brörup–Amersfoort Interstadial; BII–BV — tills of the Late Pleistocene age

Profile otworów wiertniczych (omawianych w tekście)

1 — torfy; 2 — gytie; 3 — mułki z substancją organiczną; 4 — iły warwowe; 5 — iły; 6 — iły czerwone; 7 — iły czerwone ze żwirami; 8 — mułki; 9 — piaski pylaste; 10 — piaski drobno- i średnioziarniste; 11 — piaski grubo- i różnoziarniste; 12 — żwirki i żwiry; 13 — głaziki i głazy; 14 — piaski gliniaste; 15 — gliny zwałowe; 16 — osady trzeciorzędowe; 17 — humus, domieszki substancji organicznej, detrytus roślin; 18 — gleba; 19 — mięczaki słodkowodne; 20 — mięczaki morskie; 21 — otwornice; 22 — glaukonit; 23 — rzędna otworu wiertniczego; 24 — granice formacji dolnopowiślańskiej; 25 — granice osadów interglacjału eemskiego: a — górna, b — dolna (przypuszczalna); 26 — glacitektoniczne zaburzenia warstw; 27 — odcinki profilu zbadane palinologicznie; Tr — trzeciorzęd; P — zlodowacenie południowopolskie; M — interglacjał mazowiecki; Ś — zlodowacenie środkowopolskie; E — interglacjał eemski; T — zlodowacenie toruńskie; K — interglacjał krastudzki; W — zlodowacenie wisły; V1 — vistulian 1; B–A — interstadiał brörup-amersfoort; BII–BV — poziomy glin zwałowych młodszego plejstocenu


marine zone
N
m asl.
depth in m
Pagórki
107,15m a.s.l.
Nowiny
45,0m a.s.l.
Krastudy
92,5m a.s.l.
J-K
Brörup
Amersfoort
V1
Eem
BII
N1
N2
N3
N4
N5
N6
Ty
EII
Sz
Ś


inland zone
S
Bągart
92,0m asl.
Mniszek
23,0m asl.
BII
b
a
EIII
Toruń Glatiation pre-glacial part
b2
b1
EII
a
Eemian Interglacial
EI
Middle Polish Glatiation-decline
Mio
W
N2
N1
EII
EI
S
M
1
2
3
4
5

connected with the Toruń Glaciation and only the upper tills (BIII, BIV and BV — with the Wisła Glaciation (A. Makowska, 1986*b*, 1992). The ice sheet of the Toruń Glaciation occupied a smaller area in comparison with the two younger ice sheets of the Wisła Glaciation. In the Lower Vistula Region it occurred in post-Eemian depressions, reaching at least as far as the Toruń Basin in the south along the Eemian valleys. It moved only slightly to the west and a little more to the east where it reached Warmia and western Mazury. The till of the Toruń Glaciation (till BII) overlies the Lower Vistula formation in almost the whole area, but pre-glacial sediments are included in this formation (Figs. 2, 3).

In general, the Lower Vistula formation is composed of terrigenous and marine sediments. The former comprise mainly valley deposits that fill widespread river valleys (Fig. 1). The main valley runs from the south northwards along the present Vistula valley, from the Toruń Basin to Kwidzyn where, covered with marine sediments, it forms branches and runs towards the Vistula Lagoon. To the south of Kwidzyn three series were distinguished in the valley sediments i.e. lower (EI), middle (EII) and upper (EIII) ones, composed of cyclic-bedded fluvial sediments of channel and overbank facies (oxbow and flood or larger valley lakes included). Deposition ends with an ice-dam series. All these sediments are known, among others from Mniszek and are best visible in the section at Bągart (Fig. 3).

To the north of Kwidzyn there is a vast depression formed in the top of the Lower Vistula formation and filled with marine and terrigenous (fluvial) sediments. Marine sediments form two separate beds: lower one — the Sztum and upper one — the Tychnowy, separated by fluvial sediments of the middle valley series (EII) covered with fluvial, fluvial-deltaic or lake sediments of the upper valley series (EIII). In the top of the latter there are locally — in place of ice-dam sediments — glaciofluvial deposits. Sections from Nowiny, Krastudy and Pagórki, described in this paper, can be considered representative of this zone (Figs. 1–3).

Fig. 3. Lower Vistula formation (in sections presented in the text)

1 — correlation of marine sediments; 2 boundaries of the Lower Vistula formation; 3 — boundaries of the Eemian Interglacial: a — upper, b — lower (probable); 4 — boundaries of the Brörup–Amersfoort Interstadial; 5 — correlation of other lithostratigraphical horizons; Mio — Miocene; valley series: EI — lower, EII — middle, EIII — upper; a, b, b1, b2 — fragments of valley series; marine horizons: Sz — Sztum, Ty — Tychnowy; N1–N6 — climatic intervals in pre-glacial part of the Toruń Glaciation; authors of palynological analyses: J-K — Z. Janczyk-Kopikowa (1976, 1991), T — K. Tobolski (E. Drozdowski, K. Tobolski, 1972); for other explanations see Fig. 2

Formacja dolnopowiślańska (w profilach omawianych w tekście)

1 — korelacja osadów morskich; 2 — granice formacji dolnopowiślańskiej; 3 — granice osadów interglacjału eemskiego: a — górna, b — dolna (przypuszczalna); 4 — granice osadów interstadiału brörup-amersfoort; 5 — korelacja innych poziomów litostratygraficznych; Mio — miocen; serie dolinne: EI — dolna, EII — środkowa, EIII — górna; a, b, b1, b2 — części serii dolinnych; poziomy morskie: Sz — sztumski, Ty — tychnowski; N1–N6 — okresy klimatyczne przedglacjalnej części zlodowacenia toruńskiego; autorzy opracowań palinologicznych: J-K — Z. Janczyk-Kopikowa (1976, 1991), T — K. Tobolski (E. Drozdowski, K. Tobolski, 1972); for other explanations see Fig. 2

DECLINE OF THE EEMIAN INTERGLACIAL AND PRE-GLACIAL PART OF THE TORUŃ GLACIATION

Pollen examination of the Lower Vistula formation of organic sediments in valleys and marine zones in the sites Przyłubie, Zła Wieś Wielka, Bajerze, Kaniczki, Białki, Grabówka, Kwidzyn-Nicponie (Z. Janczyk-Kopikowa, 1970; A. Makowska, 1979), Mniszek (Z. Borówko-Dłużakowa, Z. Janczyk-Kopikowa, 1965; A. Makowska, 1970; E. Drozdowski, K. Tobolski, 1972; A. Makowska, 1979), Nowiny (Z. Janczyk-Kopikowa, 1976; A. Makowska, 1980, 1984, 1986*b*) and Pagórki (A. Makowska, W. Rabek, 1990; Z. Janczyk-Kopikowa, 1991; A. Makowska, 1991) indicated that the middle valley series (EII) and the Tychnowy marine horizon with the overlying brackish sediments of relic lakes constitute an interglacial sequence *sensu stricto*. The upper limit of the interglacial was defined in these sediments on the basis of pollen analyses whereas its lower limit is still arbitrary (Fig. 3). Above, there are the pre-glacial sediments of the Toruń Glaciation. In many sites they comprise basal inserts of organic sediments. Amongst these sites with organic remains the most complete palynological examinations were done for the sections at Mniszek, Nowiny and Pagórki, these can form a basis for the interpretation and correlation of other sites. Pollen analysis of a single sample from the Mniszek section by K. Tobolski (E. Drozdowski, K. Tobolski, 1972) enabled the distinction of a renewed warming after the optimum and the post-optimum cooling of the Eemian Interglacial. This warming could be interpreted approximately by the author as the first post-Eemian interstadial. The possible occurrence of this warming as well as of the several following ones, has been also indicated by my analyses of sedimentary sections from the whole investigated area. Therefore, climatic curves based on this analyses enabled me to distinguish the climatic variation at Mniszek as the distinct post-optimum Mniszek Warming (A. Makowska, 1979, 1980). At present the Mniszek Warming can be related to a warming noted at Pagórki by Z. Janczyk-Kopikowa who correlates it with the Amersfoort–Brörup (Z. Janczyk-Kopikowa, 1991; Fig. 3). A similar correlation for Mniszek is also suggested by K. Mamakowa (1989) in her paper on the Eemian and the Early Vistulian sites in Poland. Both at Mniszek as well as at Pagórki the section of organic sediments ends with this warming and there is no palynological evidence for further climatic changes. In both these sites organic sediments are erosively cut and then overlain by sediments without plant remains (Figs. 2, 3). At Mniszek the overlying organic sediments could have been removed during the Late Pleistocene due to the erosion that preceded deposition of the suprainundation terrace of the present Vistula valley. At Pagórki a similar role could have been played by erosion before deposition of sandy deltaic sediments of the third valley series. In addition to these two sections, several others have been recorded in the described area, in which organic sediments retained a more complete sequence as demonstrated by the published sections of boreholes at Nowiny and Krastudy (Figs. 1–3). Both these boreholes are located within the limits of the Eemian seas. They were drilled in 1974 (Nowiny) and 1985 (Krastudy) (A. Makowska, 1980, 1984, 1986*a*, *b*). These sections within them correlated because the Lower Vistula formation is overlain by, an almost complete (from a stratigraphical point of view) complex of glacial and intermorainic sediments (Fig. 2). In this context a particular significance is played by these fragments of sections that comprise the Late Eemian Interglacial and the pre-glacial part of the Toruń Glaciation (Fig. 3). Below they will be described in detail.

Nowiny. The composition of the Lower Vistula formation at Nowiny has already been presented in detail in my earlier publications (A. Makowska, 1980, 1984, 1986*b*), together with the results of pollen analyses by Z. Janczyk-Kopikowa (1976) and of faunal studies. Here I would like to pay attention, once again to the Late Eemian and the Early Torunian part of this section (Fig. 4). Sediments of the Lower Vistula formation occur at Nowiny at depths from 35.5 to 79.5 m i.e. from 9.5 m a.s.l. to 34.5 m b.s.l. (the borehole was located at about 45 m a.s.l.). This location agrees completely with the occurrence of the whole formation, spreading at similar altitude from the south northwards across the whole Lower Vistula Region and part of the Elbląg Elevation (Figs. 1–3), and suggests their primary sedimentary position.

Previous description of this formation at Nowiny indicated (A. Makowska, 1986*b*) the presence of five lithogenetical members. They are (from the bottom): ice-dam sediments (NI), marine sediments of the Sztum member (NII), fluvial-deltaic sediments (NIII) corresponding to the middle valley series (EII), marine sediments of the Tychnowy member (NIV) and lake-deltaic, deltaic and fluvial sediments (NV) of the upper valley series (EIII). At a depth of 45.5–77.7 m in the section, a pollen examination was done by Z. Janczyk-Kopikowa (1976). It indicated that sediments at a depth of 53.9–62.4 m belong to the Eemian Interglacial (after Jessen and Milthers comprising the phases Ed–Ei). Other sediments, which were palynologically analysed, contained an admixture of Tertiary pollen that made it imposible to obtain a pure Quaternary spectrum. The Eemian pollen diagram (Z. Janczyk-Kopikowa *fide* A. Makowska, 1986*b*) comprises, from the bottom, oxbow or lacustrine organic sediments with freshwater fauna of the middle valley series (EII), then sediments of the Tychnowy sea in its complete sedimentary cycle and sediments of the following brackish relic lakes (layers NIII2, NIV1–7 and NV1). If we compare this part of the section with the respective, palynologically studied part of the section at Pagórki (Fig. 3), we can easily find that in both cases they comprise the same lithostratigraphical horizons. Z. Janczyk-Kopikowa (1991) obtained a complete Eemian succession at Pagórki for sediments at a depth of 200.0 to 205.5 m. They are similar in their composition, origin (fluvial sediments and marine sediments of the Tychnowy member), thickness and even altitude if compared to the above described Eemian sediments from Nowiny, although the boreholes were a large (about 30 km) distance apart (Fig. 1). It indicates a significant regularity in the deposition of these sediments, which have not been disturbed by local conditions but only influenced by external factors such as climatic variation. It proves also that the Lower Vistula formation occurs at Pagórki, together with the overlying till of the Toruń Glaciation, in its primary position and is not affected by the glaciotectonic deformations of the upper part of the section (Fig. 2; A. Makowska, W. Rabek, 1990; A. Makowska, 1991). On this basis the section at Pagórki can be considered as a representative of the Lower Vistula formation in the Elbląg Elevation and it can be freely used for correlation with other sections. Z. Janczyk-Kopikowa (1991) sets the upper palynological limit of the Eemian Interglacial at Pagórki at depth of 200 m and she ascribes the overlying sediments to the first cooling of the Vistulian (V1) and to the Amersfoort–Brörup Warming (Fig. 3). These fluvial and lacustrine fine-grained sands, 12 m thick, are overlain by organic sediments (peats, peaty silts or gyttjas), separated by a thin layer of fine-grained sands. The bipartition of the organic layers to mine mind presumably corresponds to two warm intervals (Amersfoort and Brörup), separated by a slight cooling.

A similar complex determined by palynological analysis and located directly above the Eemian sediments, has also been noted at Nowiny (Fig. 4). Marine and lacustrine sediments of the member NIV and the lower layer of the member NV (NV1) are overlain by a successive second layer of the member NV (NV2) which comprises lacustrine-deltaic and fluvial sediments composed of three cycles. The latter have already been distinguished by me, during the first macroscopic lithological determination of the section, as cycles of the upper valley series (EIII) and defined by symbols a_1, a_2 and a_3. At this time, I expected the organic sediments of these cycles to correspond to the warmings Amersfoort and Brörup (A. Makowska, 1980). Each cycle (marked in Fig. 4 also with letters a_1, a_2 and a_3) starts with sands and ends with organic sediments. The sediments of the lower cycle (a_1) are very similar to the sediments of the first cooling during the Vistulian (V1) and to the Amersfoort–Brörup at Pagórki. They are composed of fine-grained sands, overlain by two organic layers (peats and gyttjas), separated by sand. At present we can take them, similarly to Pagórki, for equivalents of the first post-Eemian cooling and the following bipartite

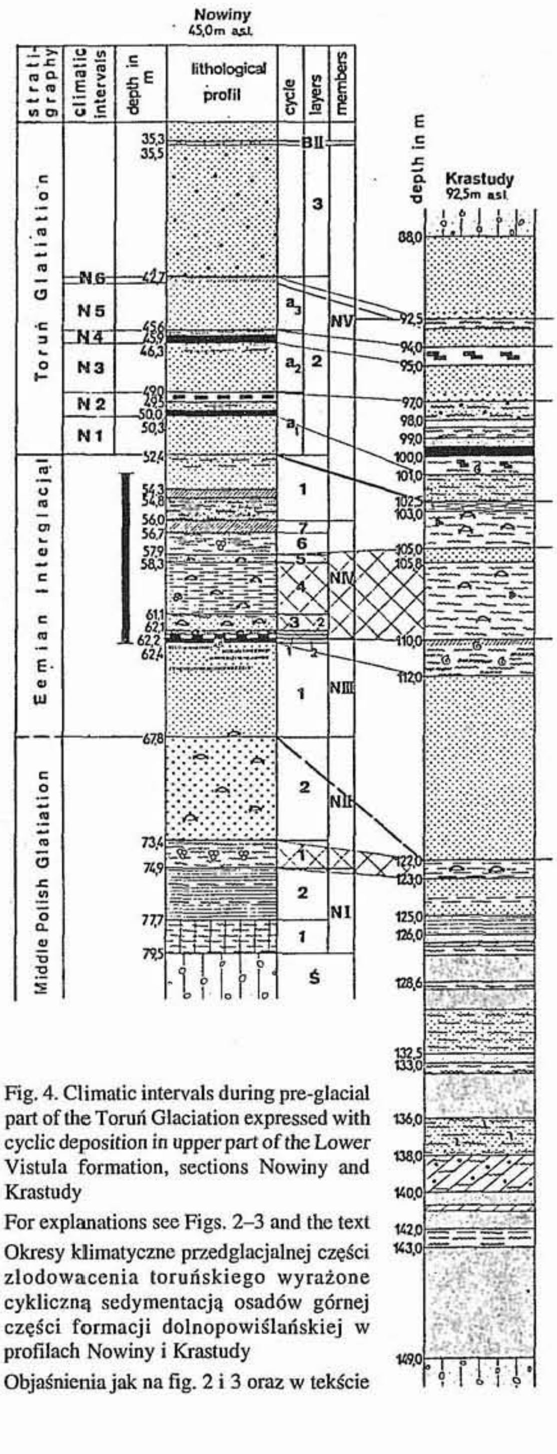


Fig. 4. Climatic intervals during pre-glacial part of the Toruń Glaciation expressed with cyclic deposition in upper part of the Lower Vistula formation, sections Nowiny and Krastudy

For explanations see Figs. 2–3 and the text

Okresy klimatyczne przedglacjalnej części zlodowacenia toruńskiego wyrażone cykliczną sedymentacją osadów górnej części formacji dolnopowiślańskiej w profilach Nowiny i Krastudy

Objaśnienia jak na fig. 2 i 3 oraz w tekście warming i.e. if referred to the interpretation of Z. Janczyk-Kopikowa, for the cooling V1 and the warming (interstadial) Amersfoort–Brörup. A boundary between the Eemian Interglacial and the cooling V1 presumably occurs at a depth of 52.4 m where silty sands pass into fine-grained sands. The sediments of the lower cycle (a_1) are overlain at Nowiny by sediments of the middle cycle (a_2) which is already absent at Pagórki (Fig. 3). At Nowiny they form a fine-grained sand layer, 2.7 m thick, overlain by peat and sandy silts, 0.7 m thick. Sediments of this cycle are to be interpreted similarly to the lower cycle as being deposited during a cool (sands) and then a warm interval (peats and sandy silts). At Nowiny we have, therefore, evidence for successive cooling and warming, present neither at Pagórki nor at Mniszek. Silts of the middle cycle (a_2) are overlain at Nowiny by sediments of the next, still younger cycle (a_3) that comprises fine-grained sands, 2.9 m thick, with very thin organic layer on the top, comprising an agglomeration of plant detritus. This cycle, similarly to the older ones, should be also treated as evidence of successive climatic cooling and warming.

Summing up the above description, sediments above the palynologically examined Eemian series at Nowiny comprise three distinct sedimentary cycles. Each of them ends at the top with organic sediments. Sediments of all these cycles occur above the palynological boundary of the Eemian Interglacial and belong to the pre-glacial part of the Toruń Glaciation. The overlying layer of sands with individual gravels (NV3) suggests a distinct ice sheet advance, indicated by the subsequent deposition of the till of the Toruń Glaciation (BII). Sediments with cyclic bedding were formed under the influence of oscillating climatic changes that comprised three successive coolings, separated by three warmings. For correlative purposes these intervals can be marked at Nowiny with symbols N1–N6 (Fig. 4). The oldest ones (N1, N2) are correlated, in connection to Pagórki, to the cooling (stadial) V1 and to warming (interstadial) Amersfoort–Brörup. Two younger climatic waves (N3, N4 and N5, N6) correspond to the waves which have been previously distinguished by me on the basis of analysis of cyclic-bedded sediments of the third valley series (EIIIa) and indicated on a curve of climatic variation (A. Makowska, 1979). At that time they were already correlated to the steppe-tundra period, distinguished by S. Z. Różycki (1972) at the beginning of the Baltic Glaciation.

Krastudy. This section also presents a complete sequence of sediments from the decline of the Eemian Interglacial and the pre-glacial part of the Toruń Glaciation (Figs. 1–3). No pollen analyses were done for this section but its lithology is so similar to the one of the Nowiny section that it enables correlation between the two (Fig. 4). The Lower Vistula formation occurs at Krastudy at a depth of 88.0–149.0 m and, similarly to Nowiny, is mostly located below sea level — from 4.5 m a.s.l. to 56.5 m b.s.l. (Fig. 3). The lower part of this formation is more complete and slightly different than at Nowiny and therefore, makes future supplementation or correction of the present opinion on this interval possible. From a depth of 122 m upwards there are sediments which are entirely comparable to the Nowiny section (Fig. 4). They comprise (from the bottom) fluvial (channel and over bank) sediments of the second valley series (EII) and end at the top with silts and peaty silts with freshwater molluscs. Above — from 110.0 to 102.5 m — there are silts with a layer of fine-grained and silty sands in the middle and with a layer of clay on top. In the lower silt layer there is an abundant admixture of marine mollusc shells and foraminifers, which also appear in smaller amounts in the upper silts. The lower silt layer and overlying sands form the marine Tychnowy horizon, corresponding to a similar horizon at Nowiny (member NIV, layers 3–5). Upper silts and clays were formed similarly to those at Nowiny, in relic brackish lakes after the recession of the Tychnowy sea. All these sediments still belong to the Eemian Interglacial as known from the section at Nowiny. The upper limit of the interglacial is probably located in the top of a clay layer at a depth of 102.5 m whereas overlying sediments were formed at the beginning of the Toruń Glaciation. They comprise three sedimentary cycles: two lower ones with sands or sandy silts at the bottom and with organic sediments on top (they can be connected with the cycles a_1 and a_2 of the layer NV2 at Nowiny), and the third — highest one, which is not so well expressed and is connected with the cycle a_3 at Nowiny. The oldest cycle comprises sediments from a depth of 97.0–102.5 m. They are (from the bottom) sandy silts, silts with inserts of peat and a peat layer, 0.5 m thick, covered by four layers of silty sands and silts. Silts that underlie the peat contain fine, unfortunately indeterminable shell remains of freshwater molluscs. Sediments of this cycle, similarly to sediments of the cycle a_1 at Nowiny, are connected with the cooling V1 and the Amersfoort–Brörup Warming. They are overlain (depth 94.0–97.0 m) by sediments of the next cycle, composed of fluvial fine- and medium-grained sands mantled with peat, 1 m thick. This cycle is very distinct and diverse. It can be connected with the cycle a_2 at Nowiny as well as with successive climatic cooling and warming. Sediments of this cycle are overlain by a successive, poorly expressed sedimentary cycle (depth 92.5–94.0 m) that can be connected with the cycle a_3 at Nowiny. Fine- and medium-grained sands on top correspond to the layer NV3 at Nowiny and indicate ice sheet advance.

A considerable similarity in sediments was, therefore, noted at Krastudy when compared with the section at Nowiny. Deposition could have occurred under the influence of climatic oscillations at the turn of the Eemian Interglacial and the Toruń Glaciation. Once again, there were at least three cool intervals, similar to N1, N3 and N5 distinguished at Nowiny, separated and terminated by warm periods corresponding to the intervals N2, N4 and N6. When comparing these two sections, similarities in their composition are also noted in the post-Eemian complex (Fig. 2), with the exception that the latter is thicker at Krastudy and contains extra marine sediments of the Krastudy member and the till BV which is absent at Nowiny.

CLIMATIC VARIATION AT THE TURN OF THE EEMIAN INTERGLACIAL AND THE TORUŃ GLACIATION

Cyclic bedding of sediments, noted in the illustrated sections at Nowiny and Krastudy, occurs in the Lower Vistula Region and in the Elbląg Elevation on a considerably wider scale. It is observed not only in the Eemian marine zone, where it is accentuated by the presence of organic sediments (as at Pagórki, Nowiny or Krastudy), but also inland where it is frequently expressed in grain size variations within purely fluvial channel sediments as at Bągart. Cyclic bedding of sediments is so distinct that it had already been observed during preliminary studies of the Eemian series, although at that time samples from percussion borings were the only ones accessible (A. Makowska, 1979). At present cyclic bedding is also noted in the new sites which have not been presented in publications yet.

Table 1

Climatic variation in pre-glacial part of the Toruń Glaciation against stratigraphy of the Late Pleistocene in the Lower Vistula region and the Elbląg Elavation

Wisła Glaciation	Late	Oldest Dryas — Younger Dryas		
	Upper	Leszno-Pomorze Stadial		Pomorze Phase Poznań Phase Leszno Phase
	Middle	Grudziądz (Łęcze) Interstadial		
	Lower	Świecie Stadial		
Krastudy Interglacial				
Toruń Glaciation	glacial part	Glacial Stadial		Toruń Phase Knibawa and Suchacz Interphase Malbork Phase
	pre-glacial part	Warming	N6	(Wła6 — Oerel?)*
		Cooling	N5	(EV5)
		Warming	N4	(EV4 — Odderade)
		Cooling	N3	(EV3)
		Warming	N2	— Brörup-Amersfoort
		Cooling	N1	
Eem Interglacial		Cooling Tychnowy Optimum Cooling with warm waves		
Middle Polish Glaciation (decline)		Sztum Warming		

*In brackets there is correlation with subdivision of K. Mamakowa (1989) and K. Tobolski (1986, 1991)

Common occurrence of this phenomenon proves that it could have been created under the influence of an external factor, whether referred to varied inland or marine sedimentary environments. This factor could only be represented by the variation of climatic conditions. The latter were of oscillating character, typical for the transition from an interglacial into a glacial period, in agreement with a climatostratigraphical idea of S.Z. Różycki (1964). They comprised successive, larger and larger coolings (N1, N3, N5), separated by less intensive warmings (N2, N4, N6) until complete disappearance of the latter and progression into a full glaciation. It is quite clearly visible in the development of sediments of successive sedimentary cycles at Nowiny, where gradual decrease in the number and thickness of organic layers, corresponding to warm intervals, is observed. The palynologically defined limit of the interglacial puts all these climatic waves within the Toruń Glaciation, although from a geological point of view they can be also entirely or partly set within the Eemian Interglacial, because deposition of sediments of the third valley

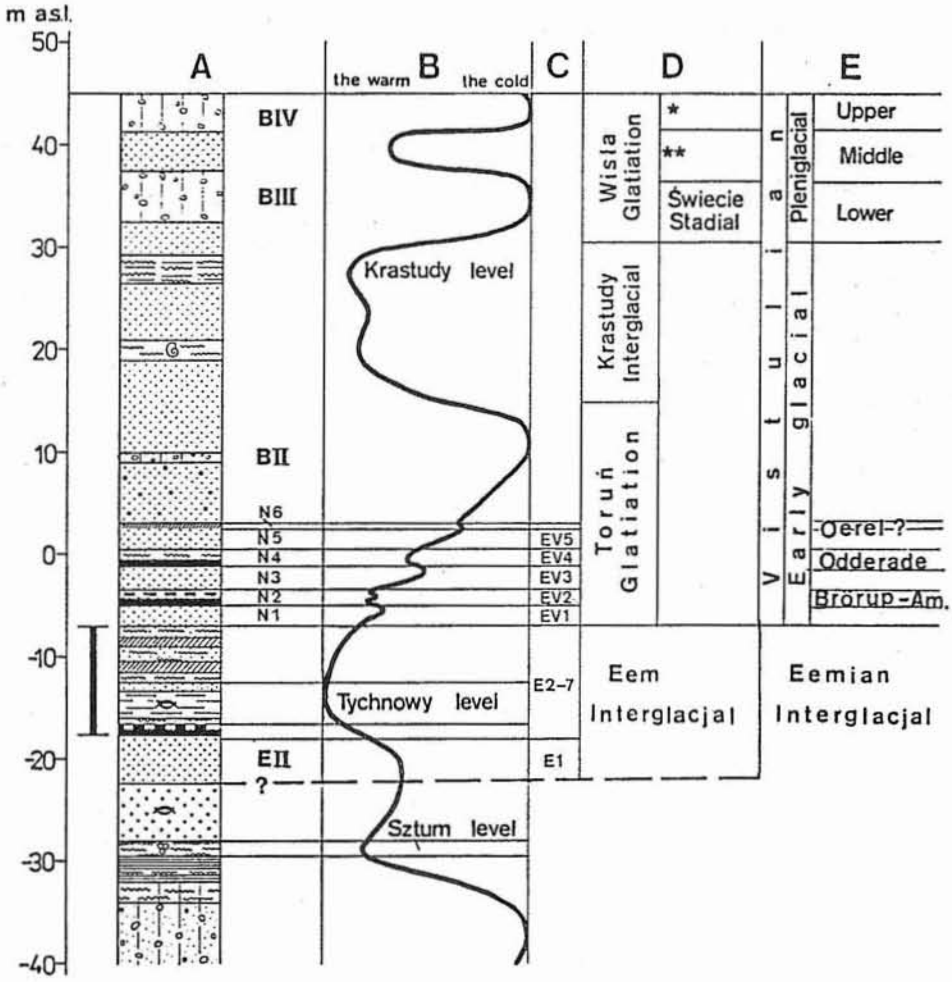


Fig. 5. Climatic variation in the Late Pleistocene, based on lithological sections at Nowiny

A — lithological section; B — curve of climatic changes; C — Eemian Interglacial and Early Vistulian after K. Mamakowa (1989); D — stratigraphy of sediments; E — correlation to the Danish-Dutch-German subdivision; * — Leszno–Pomeranian Stadial; ** — Grudziądz Interstadial; for explanations see Figs. 2 and 3

Zmiany klimatyczne w młodszym plejstocenie na podstawie profilu litologicznego w Nowinach

A — profil litologiczny; B — krzywa zmian klimatycznych; C — interglacjał eemski i wczesny vistulian według K. Mamakowej (1989); D — stratygrafia osadów; E — korelacja z podziałem duńsko-holendersko-niemieckim;* — stadiał leszczyńsko-pomorski; ** — interstadiał Grudziądza; pozostałe objaśnienia jak na fig. 2 i 3

series (EIII) was connected with a large river, flowing from the south (A. Makowska, 1979). When making reference to palynological subdivisions, these climatic waves can be distinctly correlated to the post-Eemian warm and cool intervals, distinguished by K.

Mamakowa (1989) after re-interpretation of 99 palynological sites of the Eemian and the Early Vistulian sediments from Poland. The two earliest intervals i.e. the cooling EV1 and the warming EV2, connected by K. Mamakowa with the first stadial of the Vistulian and the Amersfoort–Brörup Interstadial, have been documented at Pagórki with a pollen analysis (Z. Janczyk--Kopikowa, 1991). Further climatic changes, resulting from geological interpretation of the sections at Nowiny and Krastudy as a continuation of the transformations at the turn of the Eemian Interglacial and the Toruń Glaciation, can be naturally correlated to the coolings EV3 and EV5, and to the separating warming EV4 of K. Mamakowa (Fig. 5C, Table 1).

At Nowiny and Krastudy there is still another, poorly expressed interval, represented by an organic layer or silt (N6) which reflects a successive poor warming before the ice sheet advance of the Toruń Glaciation. This warming is absent in sites listed by K. Mamakowa but presumably corresponds to the youngest warming in the section from Władysławów in Kujawy (Wła6), examined by K. Tobolski (1986, 1991). Such correlation, although based only on succession of geological strata, seems logical and considerably probable.

The above confrontation suggests that all post-Eemian warm and cool intervals, distinguished by K. Mamakowa for Poland and also by K. Tobolski for Władysławów, were connencted with ice sheet advance in the Lower Vistula Region during the Toruń Glaciation. The presence of this ice sheet was very distinctly indicated as the till BII, that usually mantles the whole Lower Vistula formation, spreads southwards at least to the Toruń Basin. In the marginal part of the Vistula Delta it is underlain by the till BI.

In the post-Eemian complex of the Lower Vistula Region the Toruń till (BII) is still underlain by two or three tills (BIII, BIV and BV) and two intermorainic series. An almost complete set of these main lithostratigraphical units is noted in sections at Nowiny and Krastudy. The former, having been more precisely examined, can be considered at this point as a key section. If an approximate climatic curve is drawn only on the basis of this section for the decline of the Eemian Interglacial and for younger periods, then the curve presents three glacial intervals, separated by two warmer ones (Fig. 5B). They correspond to the Toruń Glaciation, the Krastudy Interglacial and the Wisła Glaciation with the Świecie and Leszno-Pomorze stadials, separated by the Grudziądz Interstadial (Fig. 5D). Climatic changes at the end of the Eemian Interglacial and the beginning of the Toruń Glaciation are very small on the curve from Nowiny, which depends on the place occupied by corresponding sediments in a lithological section of this site. They do not indicate, however, the absolute values but undoubtedly express general time relations between the pre-glacial part of the Toruń Glaciation and the following interval that comprises all remaining Late Pleistocene processes in the studied area. In general stratigraphical schemes (A. Makowska, 1986*b*, 1992) the pre-glacial part of the Toruń Glaciation forms a relatively short time span between the end of the Eemian Interglacial determined at about 115 ka and the beginning of ice sheet advance during the Malbork Phase of the Toruń Glaciation, defined at 110 ka. This short period is in contradiction with stratigraphical subdivisions from other parts of Poland where corresponding warmings and coolings extend into a broad part of the post-Eemian Pleistocene, as far as the so-called Inter-Plenivistulian. It seems obvious that ascription of such a significant time rank to these units results mainly from stratigraphical gaps that exist within the Late Pleistocene sediments in other areas of Poland if referred to the Lower Vistula Region. From the other side, the applied stratigraphical scheme of the Late Pleistocene for the Lower Vistula Region and the Elbląg Elevation seems to leave too little place for the pre-glacial part of the Toruń Glaciation where not only the described climatic units should be located but presumably also the others which have not yet been distinguished. It seems possible that both tills of this glaciation (BI and BII) should be slightly younger and partly dislocated in time towards the upper boundary of previous age determinations i.e. to about 90–80 ka. This problem can be discussed in more detail only with the use of further datings of sediments — not only in the Lower Vistula Region or the Elbląg Elevation but also in other parts of Poland.

Last but not least, one should also mention the connections of the Late Pleistocene of the described areas to the mid-northern European stratigraphical schemes that form the reference for many Polish scientists. Described climatic waves from the pre-glacial part of the Toruń Glaciation correlate, after K. Mamakowa (1989), to the two Early Vistulian stadials and separating interstadials Amersfoort–Brörup and Odderade. The third, youngest stadial seems to already belong to the Middle Vistulian. Climatic changes, noted at Władysławów, were precisely correlated by K. Tobolski (1991) to the changes found at Oerel in Lower Saxony (K. E. Behre, U. Lade, 1986). They comprise the interstadials Brörup, Odderade and Oerel, and stadials Herning, Redestal, Schalkholz and Ebersdorf. In this connection two older stadials and separating interstadials, according to the interpretation of K. E. Behre and U. Lade (1986) for the site Oerel, belong to the Early Vistulian whereas two younger stadials and the Oerel Interstadial are to be included within the Middle Vistulian. After these interpretations, the upper limit of the Early Vistulian would occur above, the sediments of the Odderade Interstadial. Referring these interpretations to the sections from the Lower Vistula Region, there is, however, no support for the introduction of this boundary in a similar place. The boundary between the Early Vistulian and the Pleni-Vistulian seems to have been connected with a more distinct climatic deterioration that should be indicated in deposition. In the Lower Vistula Region the latter occurred in cycles in all the environments, marine as well as inland ones, but without great disturbances — in a way that indicates regular climatic evolution from the Eemian optimum towards the glacial part of the Toruń Glaciation. This evolution comprised the three cool and warms waves distinguished, but even more cannot be excluded. All would belong to the same interval, i.e. the pre-glacial part of the Toruń Glaciation. Based on these facts, the upper boundary of the Early Vistulian from the Danish-Dutch-German stratigraphical schemes (in which it has still no certain location) should be dislocated at least to beyond the glacial part of the Toruń Glaciation. This interval also includes the Krastudy Interglacial (Fig. 5E). On the other hand, the upper part of the Late Pleistocene complex — comprising sediments referred, by me, to the Vistulian Glaciation *sensu stricto* and including two main tills (BIII and BIV with BV), separated by formation of Grudziądz and Łęcze — can be correlated to the so-called Pleni-Vistulian. Such correlation is supported by numerous datings of these sediments, among others presented for the Lower Vistula valley near Grudziądz by E. Drozdowski (1980, 1986) and E. Drozdowski, S. Fedorowicz (1985, 1987), indicating that this part of the Late Pleistocene complex is younger than about 60 ka.

CONCLUSIONS

1. In the Lower Vistula Region and in the Elbląg Elevation, cyclic fluvial and fluvial-deltaic-lacustrine deposition occurred during the decline of the Eemian Interglacial and the beginning of the Toruń Glaciation. It was indicated in buried river valleys as well as in a bay of the Eemian sea. The cycles comprise gravel-sandy sediments with upwards-decreasing grain size or sandy sediments with organic layers on the top. They occur in the upper part of the Lower Vistula formation that constitutes a principal key horizon in the described area. They are to be noted in sections, among others at Pagórki, Nowiny, Krastudy, Mniszek and Bągart.

2. Sedimentary cyclicity reflected oscillating climatic variation at the turn of the Eemian Interglacial and the Toruń Glaciation. Gravels and sands were deposited during cool, whereas organic sediments — during warm intervals. Examination of these sediments enables us to distinguish at least three larger post-Eemian climatic oscillations, composed of successive coolings and warmings. The changes resulted in gradual climatic cooling until the final disappearance of warm intervals and permanent predominance of arctic conditions.

3. Described climatic changes occurred during the pre-glacial part of the Toruń Glaciation. The palynologically defined boundary between the Eemian Interglacial and the Toruń Glaciation occurs beneath the oldest of the distinguished post-Eemian cycles. It has been documented with pollen examination at Pagórki and partly also at Mniszek.

4. Sediments of the oldest sedimentary cycle at Pagórki were correlated by Z. Janczyk-Kopikowa (1991), on the basis of pollen analysis, to the first stadial of the Vistulian (V1) and the Amersfoort–Brörup Interstadial. Similar sediments from Mniszek were interpreted by K. Mamakowa (1989) in the same way. Sediments of two younger cycles that reflect two successive cool intervals separated and terminated by two warmings, can be correlated in a natural way to stadials and interstadials younger than the Amersfoort–Brörup, distinguished by K. Mamakowa (1989) and at Władysławów by K. Tobolski (1991). This correlation suggests that cool and warm intervals distinguished by these authors were connected with ice sheet advance during the Toruń Glaciation in the Lower Vistula Region.

5. Transition of the Eemian Interglacial into the Toruń Glaciation with enclosed oscillating climatic changes occupied a relatively short time during other post-Eemian processes. The latter are to be examined in a general section of the Late Pleistocene sediments in the Lower Vistula Region and the Elbląg Elevation. The short duration of this interval, when referred to the remaining part of the post-Eemian Pleistocene, is noted among others in climatic variation from the section at Nowiny, typical for a marine zone of the Eemian Interglacial in this area.

6. Warmings and coolings of the pre-glacial part of the Toruń Glaciation in the Lower Vistula Region and the Elbląg Elevation, correlated by K. Mamakowa (1989) and K. Tobolski (1991) partly to the Early and partly to the Middle Vistulian, should be entirely referred to the Early Vistulian. The latter should also comprise the glacial part of the Toruń

Glaciation and the Krastudy Interglacial. On the other hand, datings of sediments from the upper part of the Late Pleistocene complex in the Lower Vistula Region and the Elbląg Elevation enabled their correlation to the so-called Pleni-Vistulian.

Translated by Leszek Marks

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Received: 15.06.1993

REFERENCES

BEHRE K. E., LADE U. (1986) — Eine Folge von Eem und 4 Weichsel-Interstadialen in Oerel/Niedersachsen und ihr Vegetationsablauf. *Eiszeitalter u. Gegenwart*, **36**, p. 11–36.

BORÓWKO-DŁUŻAKOWA Z., JANCZYK-KOPIKOWA Z. (1965) — Orzeczenie dotyczące dwu próbek z Mniszka. Arch. Państw. Inst. Geol. Warszawa.

DROZDOWSKI E. (1980) — Chronostratygraphy of the Vistulian Glaciation on the Lower Vistula River. Quatern. Stud. Pol., no. 2, p. 13–20.

DROZDOWSKI E. (1986) — Stratygrafia i geneza osadów zlodowacenia Vistulian w północnej części dolnego Powiśla. Pr. Geogr. Inst. Geogr. Przestrz. Zagospod. PAN, no. 146.

DROZDOWSKI E., FEDOROWICZ S. (1985) — Nowe datowania termoluminescencyjne osadów zlodowacenia vistulian nad dolną Wisłą. Prz. Geogr., **57**, p. 599–609, no. 4.

DROZDOWSKI E., FEDOROWICZ S. (1987) — Stratigraphy of Vistulian glaciogenic deposits and corresponding TL dates in the Lower Vistula region, northern Poland, Boreas, **16**, p. 139–156.

DROZDOWSKI E., TOBOLSKI K. (1972) — Sites of Eem Interglacial in Grudziądz Basin (Preliminary Information). Bad. Fizjogr. nad Pol. Zach., Ser., **25**, p. 75–81.

JANCZYK-KOPIKOWA Z. (1970) — Analiza pyłkowa osadów z obszaru doliny dolnej Wisły. Arch. Państw. Inst. Geol. Warszawa.

JANCZYK-KOPIKOWA Z. (1976) — Analiza pyłkowa osadów w Nowinach. Arch. Państw. Inst. Geol. Warszawa.

JANCZYK-KOPIKOWA Z. (1991) — Pollen analysis of deposits from the borehole Pagórki. Prz. Geol., **39**, p. 269–271, no. 5–6.

MAKOWSKA A. (1970) — Osady organiczne interglacjału eemskiego w Mniszku koło Grudziądza. Kwart. Geol., **14**, p. 567–571, no. 3.

MAKOWSKA A. (1977) — Revision of the stratigraphic setting of deposits of so-called Chełmno Interglacial from Bągart near Unisław. Kwart. Geol., **21**, p. 105–117, no. 1.

MAKOWSKA A. (1979) — Interglacjał eemski w Dolinie Dolnej Wisły. Stud. Geol. Pol., **63**, p. 1–90.

MAKOWSKA A. (1980) — Late Eemian with preglacial and glacial part of Vistulian Glaciation in the Lower Vistula Region. Quatern. Studies, no. 2, p. 37–56.

MAKOWSKA A. (1984) — Osady morskie i rzeczne w rejonie doliny dolnej Wisły. In: Budowa geologiczna Polski, **1** — Stratygrafia, cz. 3b — Kenozoik. Czwartorzęd. Inst. Geol. Warszawa.

MAKOWSKA A. (*1986a*) — New Pleistocene marine horizon and traces of the Holstein sea in the Lower Powiśle area. Kwart. Geol., **30**, p. 609–628, no. 3/4.

MAKOWSKA A. (1986*b*) — Pleistocene seas in Poland — sediments, age and palaeogeography. Pr. Inst. Geol., **120**.

MAKOWSKA A. (1991) — Geologic section of the borehole at Pagórki near Elbląg and significance of pollen analysis of its deposits to a stratigraphy of the Late Pleistocene in Poland. Prz. Geol., **39**, p. 262–269, no. 5–6.

MAKOWSKA A. (1992) — Stratigraphy of the Younger Pleistocene in the Dolne Powiśle and the Elbląg Elevation based on mapping and boreholes. Kwart. Geol., **36**, p. 97–120, no. 1.

MAKOWSKA A., RABEK W. (1990) — Marine deposits of the Eemian Interglacial and stratigraphic position of the Elbląg clays (Yoldia) on the base of boreholes in Pęklewo and Pagórki (the Elbląg Elevation). Kwart. Geol., **34**, p. 305–324, no. 2.

MAMAKOWA K. (1989) — Late Middle Polish Glaciation, Eemian and early Vistulian vegetation at Imbramowice near Wrocław and the pollen stratigraphy of this part of the Pleistocene in Poland. Acta Paleobot., **29**, p. 11–176, no. 1.

RÓŻYCKI S. Z. (1964) — Klimatostratygraficzne jednostki podziału plejstocenu. Acta Geol. Pol., **14**, p. 321–334, no. 3.

RÓŻYCKI S. Z. (1972) — Plejstocen Polski Środkowej na tle przeszłości w górnym trzeciorzędzie. Wyd. II. PWN. Warszawa.

TOBOLSKI K. (1986) — Paleobotanical studies of the Eemian interglacial and early Vistulian at Władysławów in the vicinity of Turek (preliminary report). Quatern. Stud. in Poland, 7, p. 91–101.

TOBOLSKI K. (1991) — Biostratygrafia interglacjału eemskiego i vistulianu Niziny Wielkopolsko-Kujawskiej (Eemian and Vistulian biostratigraphy of Great Poland Kujawy Lowland). In: Geneza, litologia i stratygrafia utworów czwartorzędowych (red. A. Kostrzewski). Geografia, **50**, p. 573–583. Wyd. Nauk. Uniw. im. A. Mickiewicza. Poznań.

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OSCYLACJE KLIMATYCZNE W PRZEDGLACJALNEJ CZĘŚCI ZLODOWACENIA TORUŃSKIEGO NA DOLNYM POWIŚLU I WZNIESIENIU ELBLĄSKIM (WIADOMOŚĆ WSTĘPNA)

Streszczenie

Na podstawie wyników badań uzyskanych w Pagórkach koło Elbląga, gdzie ponad eemem ujawniły się osady amersfoortu-brörupu (Z. Janczyk-Kopikowa, 1991; A. Makowska, 1991), przeprowadziłam szerszą analizę porównawczą dla osadów tego wieku z górnej części formacji dolnopowiślańskiej Dolnego Powiśla i Wzniesienia Elbląskiego. Analiza wykazuje, że w czasie powstawania tej części formacji — oprócz pierwszego poeemskiego ochłodzenia i ocieplenia amesfoortu-brörupu — miały miejsce dalsze oscylacje klimatyczne. Problem został omówiony na przykładzie wybranych i publikowanych już profili otworów wiertniczych z Pagórków, Nowin, Krastud, Mniszka i Bągartu (fig. 1). Oprócz formacji dolnopowiślańskiej obejmują one cały lokalny kompleks plejstoceński docierając do podłoża trzeciorzędowego (fig. 2).

Formacja dolnopowiślańska na Dolnym Powiślu i Wzniesieniu Elbląskim stanowi przewodnią, dobrze określoną przestrzennie jednostkę litostratygraficzną, rozciągającą się szerokim pasem wzdłuż doliny i delty Wisły od Kotliny Toruńskiej po Zalew Wiślany (A. Makowska, 1979, 1986*b*) — fig. 1, 2. W jej składzie znajdują się osady lądowe i morskie powstałe w okresie od schyłku zlodowacenia środkowopolskiego, poprzez interglacjał eemski i przedglacjalną część zlodowacenia toruńskiego do jego części glacjalnej (fig. 3).

Osady lądowe wchodzące w skład formacji, to osady dolinne, wypełniające sieć kopalnych dolin rzecznych przebiegających wzdłuż współczesnej doliny Wisły od Kotliny Toruńskiej po Kwidzyn, a następnie pod przykryciem osadów morskich w kierunku Zalewu Wiślanego (fig. 1). W dolinach wyróżniono trzy wzajemnie nadległe serie dolinne (EI, EII, EIII), składające się z osadów rzecznych, korytowych i pozakorytowych, w tym starorzeczy i jezior dolinnych, które w najwyższej serii przykryte są przez osady zastoiskowe (fig. 3).

Osady morskie wypełniają dno kopalnej zatoki morskiej rozciągającej się na północ od Kwidzyna (fig. 1). Tworzą one dwa odrębne poziomy — sztumski i tychnowski rozdzielone osadami środkowej serii dolinnej (EII) i przykryte osadami rzecznymi, rzeczno-deltowymi i jeziornymi wiążącymi się z trzecią serią dolinną (EIII) — fig. 3.

Ekspertyzy i badania pyłkowe wykonane w wielu stanowiskach (Z. Borówko-Dłużakowa, Z. Janczyk-Kopikowa, 1965; Z. Janczyk-Kopikowa, 1970, 1976, 1991; E. Drozdowski, K. Tobolski, 1972) wykazały, że środkowa część formacji dolnopowiślańskiej powstała w interglacjale eemskim. Są to osady rzeczne środkowej serii dolinnej oraz osady morza tychnowskiego i pozostałych po nim jezior reliktowych (fig. 2, 3). Górna granica interglacjału została określona badaniami pyłkowymi w Pagórkach (Z. Janczyk-Kopikowa, 1991). Granica dolna jest jeszcze umowna. Ponad osadami eemskimi leżą osady przedglacjalnej części zlodowacenia toruńskiego, które obejmują trzecią serię dolinną (EIII), a w strefie morskiej — osady rzeczne, rzeczno-deltowe i jeziorne, odpowiadające tej serii. Osady te w dolnej części, podobnie jak w całej formacji, wykazują cykliczne warstwowania, na podstawie których można wnioskować o zmianach klimatycznych zachodzących w czasie ich sedymentacji. Szczególnie wyraźnie jest to widoczne w profilach Nowiny i Krastudy (fig. 4), gdzie ponad osadami eemskimi występują na przemian osady piaszczyste i organiczne zgrupowane w trzech cyklach sedymentacyjnych (a_1, a_2, a_3), wskazujące na poeemskie oscylacje klimatyczne obejmujące trzy ochłodzenia rozdzielone i zakończone trzema ociepleniami. Dla celów korelacyjnych oznaczono je w Nowinach symbolami N1–N6 (fig. 4, 5A, B). Najstarsza fala klimatyczna (N1, N2) została udokumentowana palinologicznie w Pagórkach jako ochłodzenie V1 i ocieplenie amersfoort-brörup (Z. Janczyk-Kopikowa, 1991) — fig. 3. Młodsze oscylacje klimatyczne (N3–N5) korelują się z dwiema dalszymi falami chłodu i falą ciepła, wyróżnionymi dla obszaru Polski przez K. Mamakową (1989) i określonymi jako stadiały EV3 i EV5 oraz interstadiał EV4 (odderade). Ocieplenie N6, nie mające odpowiednika w podziale K. Mamakowej, koreluje się prawdopodobnie z ociepleniem Wła6 (oerel) wyróżnionym we Władysławowie przez K. Tobolskiego (1986, 1991) obok innych fal klimatycznych (tab. 1, fig. 5C). Z analizy przeprowadzonej dla Dolnego Powiśla i Wzniesienia Elbląskiego wynika, że wszystkie te okresy klimatyczne związane były z przedglacjalną częścią zlodowacenia toruńskiego. W nawiązaniu do podziałów duńsko-holendersko-niemieckich należałoby je w całości korelować z tzw. wczesnym vistulianem, do którego trzeba byłoby też włączyć glacjalną część zlodowacenia toruńskiego oraz interglacjał krastudzki (fig. 5E).