STUDIA GEOMORPHOLOGICA CARPATHO-BALCANICA
VOL. XXV—XXVI KRAKOW 1991—1992 PL ISSN 0081-6434

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THE STRUCTURE AND AGE OF THE DRWIEŃ DEPRESSION INTERRUPTING THE VISTULA FLOOD-PLAIN EAST OF CRACOW (SOUTH POLAND)

Flat-floored depressions, 1—3 km wide, attaining a width of several to more than 10 km, occur frequently on the Vistula flood-plain within the Sandomierz Basin. Little is known of their origin. In contrast to the other areas showing numerous palaeomeanders of the Vistula, there are no traces of the latter in the depressions. These are drained by rivulets. Such landforms have been described as the Drwinka and Drwień depressions from the Niepołomice Forest and in the Cracow area (Gębica, Starkel 1987; Kalicki, Starkel 1987). Another depression is used by the Breń downstream of the Dunajec river mouth (Sokołowski 1987). Two other depressions — those of the Trześniówka and the Mokrzeszówka are found in the Tarnobrzeg area (Mycielska-Dowgiałło 1987). Analogous depressions drained by the Gróbka and the Uszewka are at the Raba river mouth (Gębica 1989), and that of the Kisielina is at the Dunajec river mouth (Sokołowski 1987).

Those landforms were already reported by Łomnicki (1903), Łoziński (1935), Połtowicz (1967) and Bzowski (1973). The Drwinka depression has been identified by them as the braided Vistula river channel dating from the close of the Pleistocene. The first radiocarbon datings seem to confirm this view and indicate the late glacial age of the above depressions (Gębica, Starkel 1987; Kalicki, Starkel 1987; Mycielska-Dowgiałło 1987; Gębica 1989). Air photo interpretation made of the Drwinka depression re-vealed numerous troughs laid across each other which indicate fashioning by a braided river (Baumgart-Kotarba 1991).

A detailed study of the evolution of the Vistula valley between Cracow and Niepołomice (Kalicki 1988, 1991) included the detailed examination of the Drwień depression. Its aim was to recognize both structure and age of this landform.

MORPHOLOGY

Between Cracow and Niepołomice the Vistula valley floor increases eastward in width from 3 to 7 km (Fig. 1). The whole flood-plain is interrupted by numerous palaeomeanders of differing age (Kalicki 1988, 1991). Along most the southern valley-side there extends a

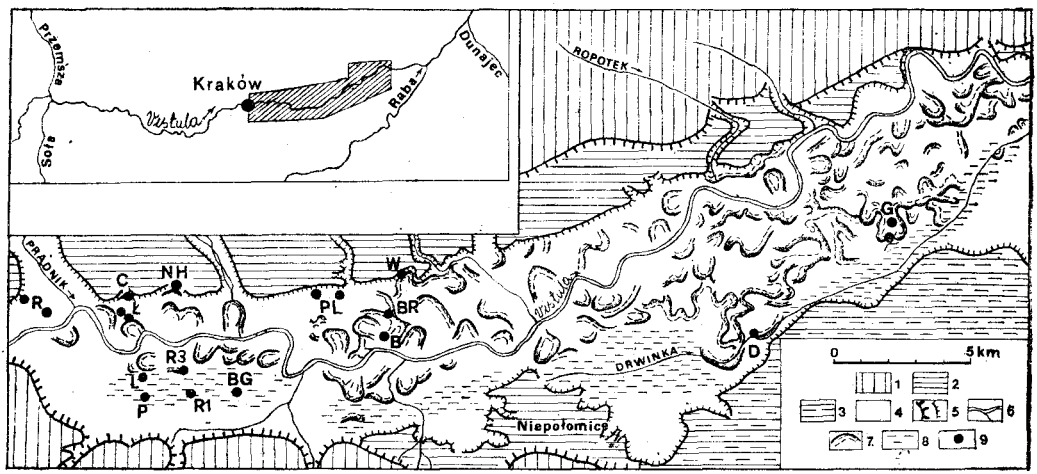


Fig. 1. Sketch to show location of the Vistula valley between Cracow and Trawniki in the Sandomierz Basin: 1 — Proszowice Divide and Gdów Plateau, 2 — Vistula terraces, 3 — alluvial fan laid down by the Raba river, 4 — Vistula flood-plain, 5 — edges, 6 — rivulets, 7 — palaeomeanders, 8 — wide depression interrupting the flood-plain, 9 — sites: B — Branice—Stryjów, BG — Brzegi i Przewóz, BR — Branice, C — Czyżyny, D — Drwinka, G — Grobla Forest, L — Lasówka, Ł — Łęg, NH — Nowa Huta, P — Płaszów, PL — Pleszów, R — Rondo Mogilskie and Przy Rondzie, R1 — Rybitwy (profiles R1 and R/87), R3 — Rybitwy (profile R3), W — Wyciąże

Ryc. 1. Szkic sytuacyjny doliny Wisły pomiędzy Krakowem a Trawnikami: 1 — Działy Proszowskie i Wysoczyzna Gdowska, 2 — terasy Wisły, 3 — stożek Raby, 4 — równina zalewowa Wisły, 5 — krawędzie morfologiczne, 6 — cieki, 7 — paleomeandry, 8 — szerokie obniżenia na równinie zalewowej, 9 — stanowiska: B — Branice—Stryjów, BG — Brzegi i Przewóz, BR — Branice, C — Czyżyny, D — Drwinka, G — Las Grobla, L — Lasówka, Ł — Łęg, NH — Nowa Huta, P — Płaszów, PL — Pleszów, R — Rondo Mogilskie i Przy Rondzie, R1 — Rybitwy (profil R1 i R/87), R3 — Rybitwy (profil R3), W — Wyciąże

flat-floored depression, c. 1.5 km wide, without traces of the Vistula palaeomeanders. It lies at 199—192 m a.s.l., i.e. c. 4 m above Vistula river level. Thus, this zone is by c. 1 m lower than the surrounding flood-plain with superficial cutoffs termed „wiśliska". East of the gravel pit at Brzegi and in the Niepołomice area the depression contains alluvial fans laid down by the Zabawka and the Podłężówka which are draining the depression, together with the Drwinka. West of the

gravel pit there extends the depression of the Drwień rivulet which flows alongside of the Vistula for more than 10 km to join it c. 1 km east of the gravel pit. This depression was subject of detailed investigation.

THE EASTERN PART OF THE DRWIEŃ DEPRESSION

YOUNGER DRAYS AND PREBOREAL DEPOSITS AT PRZEWÓZ AND BRZEGI

The sites at Przewóz and in the gravel pit at Brzegi are located in the eastern part of the Drwień depression. They were already briefly discussed by Kalicki and Starkel (1987) and by Kalicki (1989). To the north the Drwień depression is bordered by a zone with large, presumably Subatlantic palaeomeanders accompanying the present Vistula river channel (Fig. 1). The depression is drained by the Drwień and the Seraf to the south. Both rivulets join in the eastern part of the depression. Old maps show the presence of a meander at the place of the gravel pit at Brzegi. Its radius was c. 400 m. Thus it appears that this meander was larger than those dating, from Boreal and Atlantic times.

The top of Miocene deposits at 185—186 m a.s.l. (Fig. 2) is rather flat. The thickness of alluvia attains 11—12 m. Their basal part is formed of a gravel series with interbedded silts which was disclosed in six borings. These silts reach as deep as 8.3 m below Vistula river level. The gravel top shows marked height differences exceeding 7 m, although in general it is rather flat and rises to high elevations (up to 196 m a.s.l.), especially in the gravel pit at Brzegi. Three well defined culminations are separated by a deep depression (up to 190 m a.s.l.) in the central part (Fig. 3). Farther south they are accompanied by a very deep trough with a maximum depth of below 193 m a.s.l. to the west and of 189 m a.s.l. to the east. Over a long distance its course corresponds to that of the Drwień rivulet. Between the Przewóz site and the gravel pit at Brzegi this trough is joined by a side trough to the north which also reaches below 193 m a.s.l. In the gravel pit at Brzegi, a well preserved reindeer antler was found in gravels at a depth of 6—7 m. A radiocarbon dating on this antler gave its age as 24 600 ± 300 yr BP (Gd-5010).

The gravel series is overlain by sands which vary in thickness, with a maximum thickness of 5 m inside the semicircular cut-off channel seen on the old maps. These sands tend to smooth the sub-„mada" surface rising above 195 m a.s.l., locally attaining 196 m a.s.l. (Fig. 4). The sand series is also dissected by the above mentioned deep trough

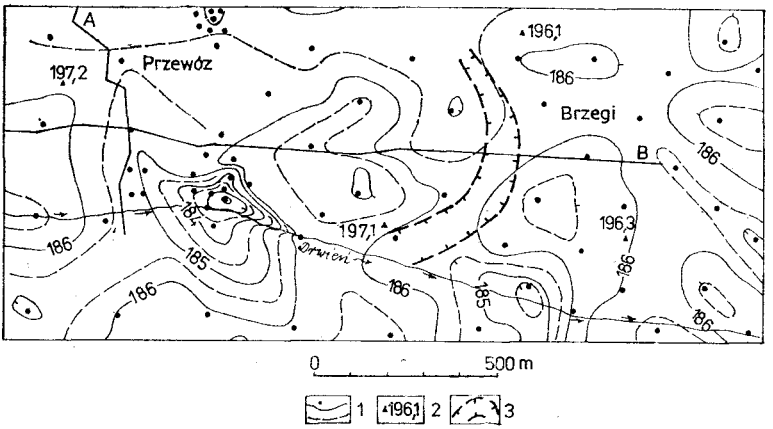


Fig. 2. The sub-Quaternary relief at Przewóz and Brzegi: 1 — contour lines and borings, 2 — altitudes, 3 — cutoff edges, A, B — sections (see Figs 5 and 12)

Ryc. 2. Rzeźba podczwartorzędowa w Przewozie i Brzegach: 1 — izohipsy i wiercenia, 2 — punkty wysokościowe, 3 — krawędzie starorzecza, A, B — linie przekrojów (patrz Ryc. 5 i 12)

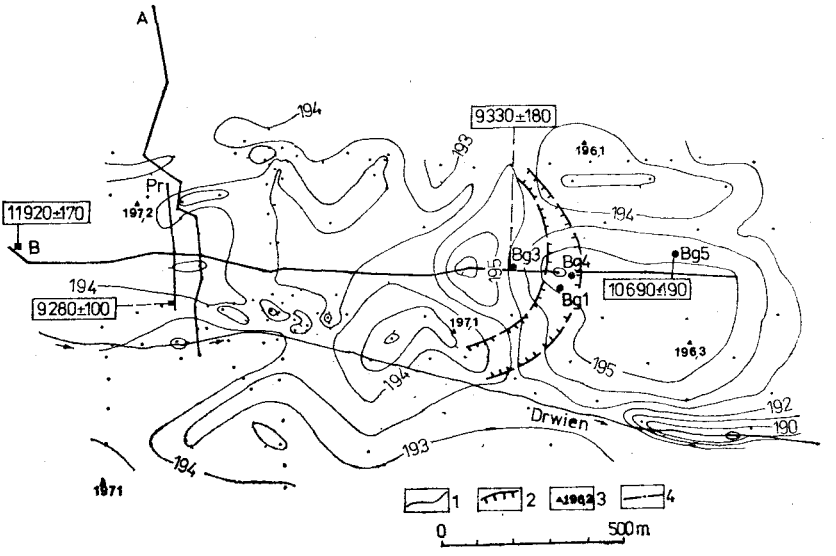


Fig. 3. Configuration of the top of channel deposits at Przewóz and Brzegi: 1 — contour lines, 2 — cutoff edges, 3 — altitudes, 4 — borings and sections A and B (see Figs 5 and 12)

Ryc. 3. Rzeźba stropu osadów korytowych w Przewozie i Brzegach: 1 — izohipsy, 2 — krawędzie starorzecza, 3 — punkty wysokościowe, 4 — wiercenia i linie przekrojów A i B (patrz Ryc. 5 i 12)

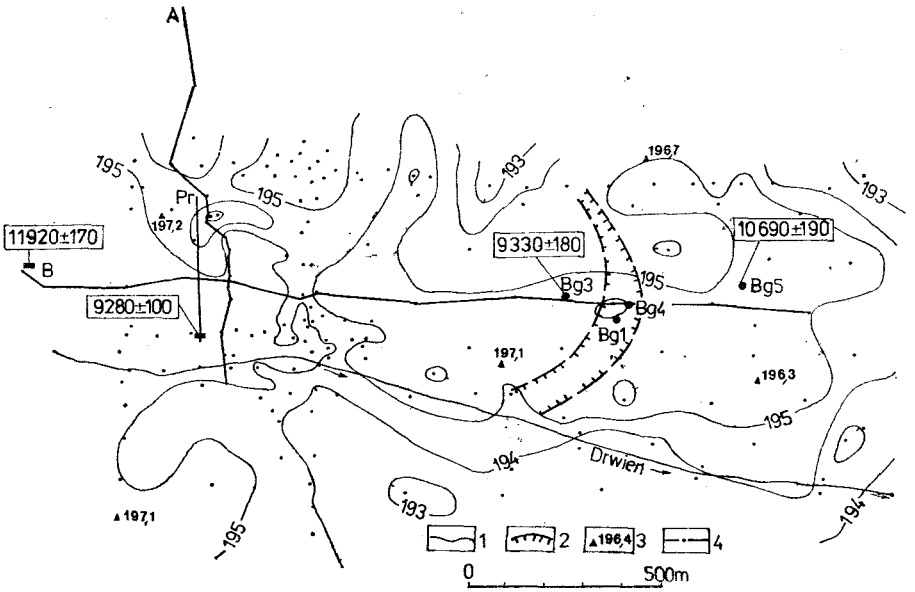


Fig. 4. Configuration of both the base of the channel fill and the "mada" at Przewóz and Brzegi: 1 — contour lines, 2 — cutoff edges, 3 — altitudes, 4 — borings and sections A and B (see Figs 5 and 12)

Ryc. 4. Rzeźba spągu osadów wypełniających starorzecza i mad w Przewozie i Brzegach: 1 — izohipsy, 2 — krawędzie starorzecza, 3 — punkty wysokościowe, 4 — wiercenia i linie przekrojów A i B (patrz Ryc. 5 i 12)

(below 193 m a.s.l.). The top series of the Quaternary deposits consists of „mada", 1—2 m thick.

The individual series of deposits were described in several profiles. A N—S section across the Przewóz site (Fig. 5) revealed the presence of a twofold „mada" (Pr1, Pr2) to the north. This „mada" is clayey at top (Mz = 8.4—9.2 ϕ) and sandy at the base (Mz = 4.6—7.0 ϕ) and very poorly sorted. Beneath the „mada" there is exposed the characteristic fill of a trough, together with a depression cut into the gravels, up to 3 cm in diameter, and into poorly sorted sands (Mz = = −0.7 to 0.5 ϕ). This 1 m complex (in archivel borings up to 2 m thick) consists of alternating silty and sandy layers. It contains frequently 10 layers of a very poorly sorted silt (Mz = 5.5—6.2 ϕ), 0.5—20 cm thick, with intercalations of a medium-grained (Mz = 1.9—2.0 ϕ), well sorted sand showing cross bedding. These strata are 1—14 cm thick and have southward dips of 15° (Fig. 6).

Farther south, toward the Drwień rivulet the top of the gravel series lies well higher, up to 1.5 m. This series includes sands and gravels (Mz = −0.6 to 0.6 ϕ) which are poorly and very poorly sorted and capped by a twofold „mada" (Fig. 7). Close to the Drwień a deep, sand-filled trough is cut into the gravels (Fig. 8). The gravel

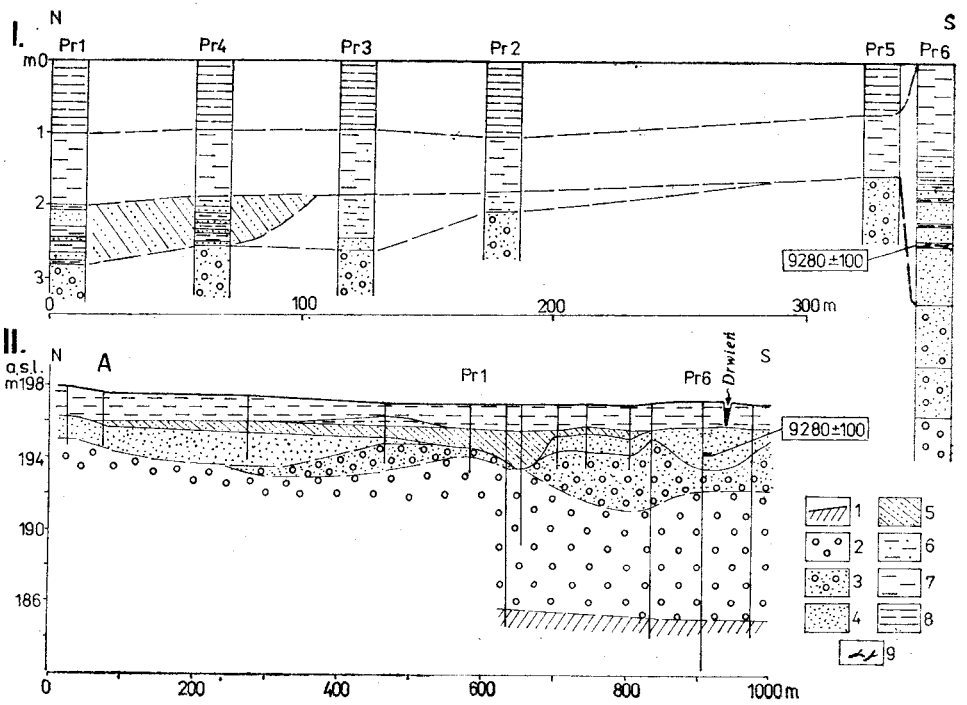
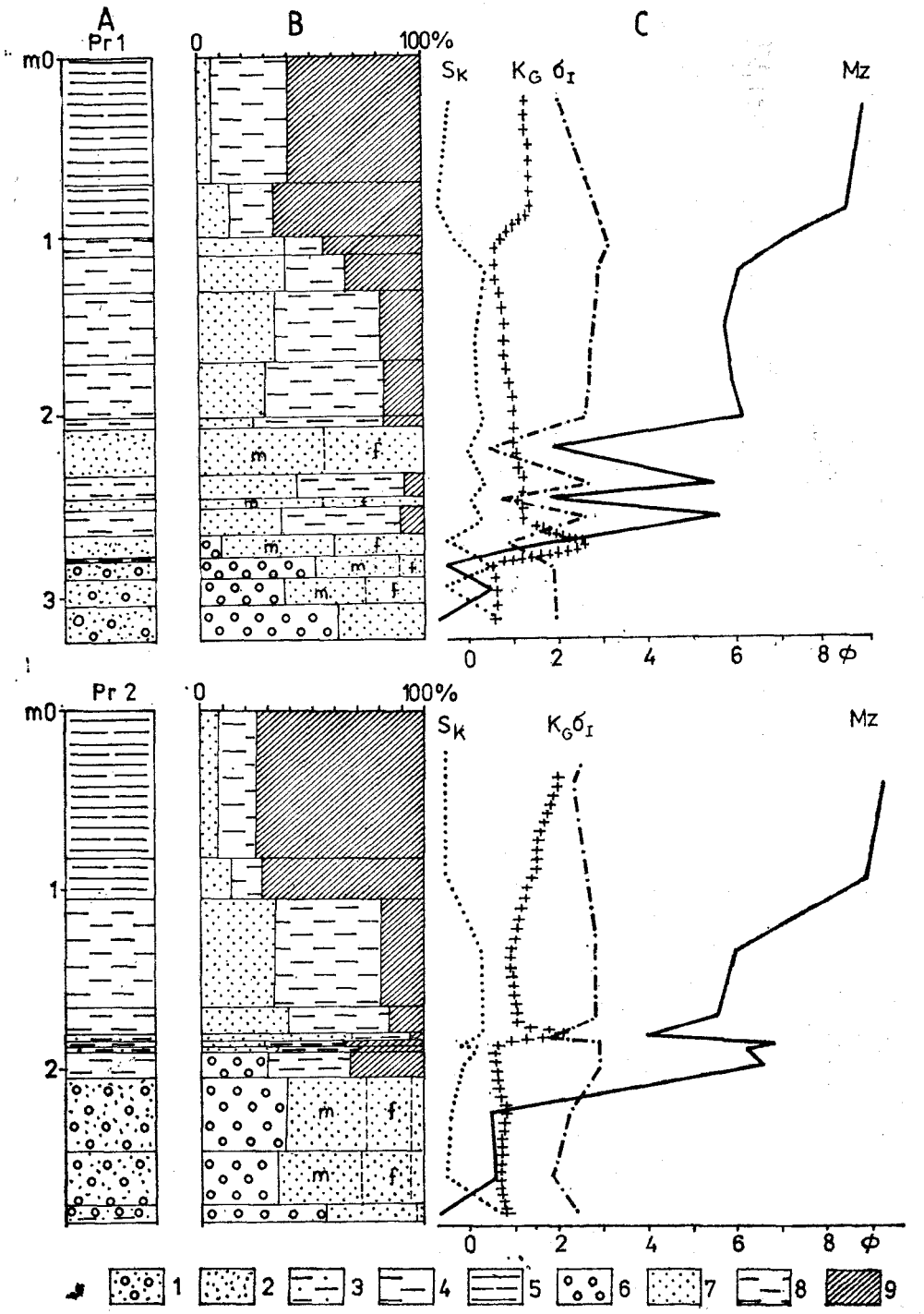


Fig. 5. Geological cross section at the Przewóz site (see Figs 3 and 4): 1 — Miocene clays, 2 — gravels, 3 — gravels and sands, 4 — sands, 5 — sands interbedded with silts, 6 — sandy silts, 7 — silts, 8 — clasy, 9 — pieces of wood and boughs

Ryc. 5. Przekroje geologiczne przez stanowisko w Przewozie (patrz Ryc. 3 i 4): 1 — iły mioceńskie, 2 — żwiry, 3 — żwiry z piaskami, 4 — piaski, 5 — piaski przewarstwione mułkami, 6 — mułki piaszczyste, 7 — mułki, 8 — iły, 9 — drewna i gałęzie

series shows two members there. At the base, at a depth of 5 m there rest coarse gravels, up to 8 cm in diameter (Mz = −1.1 ϕ) which are poorly sorted. Overlying are coarse and medium-grained-poorly sorted sands exhibiting cross bedding and single, poorly sorted, fine gravels, up to 2 cm in diameter (Mz = −0.1 to 0.3 ϕ). The gravelly member is overlain by a series of white, coarse and medium-grained sands (Mz = 0.9—1.8 ϕ), the thickness of which exceeds 1.5 m. Sands show cross bedding and they are either well sorted or moderately well sorted (δ_I = 0.5—0.9). An interbed of silt contains single gravels, plant detritus and branches. Studies by Z. Tomczyńska revealed *Pinus silvestris* (1 piece) and *Salix sp.* (1 piece) which have been dated

Fig. 6. Profiles of deposits Pr1 and Pr2 (A) at Przewóz, grain size composition (B) and parameters of Folk's and Ward's (1957) grain size distribution (C): 1 — gravels and sands, 2 — sands, 3 — sandy silts, 4 — silts, 5 — clays; fractions: 6 — gravelly, 7 — sandy: m — medium, f — fine, 8 — dusty, 9 — clayey



Ryc. 6. Profile osadów Pr1 i Pr2 (A) z Przewozu, skład mechaniczny (B) i parametry rozkładu uziarnienia (C) Folka i Warda (1957): 1 — żwiry z piaskami, 2 — piaski, 3 — mułki piaszczyste, 4 — mułki, 5 — iły; frakcje: 6 — żwirowa, 7 — piaszczysta: m — średnioziarnista, f — drobnoziarnista, 8 — pylasta, 9 — ilasta

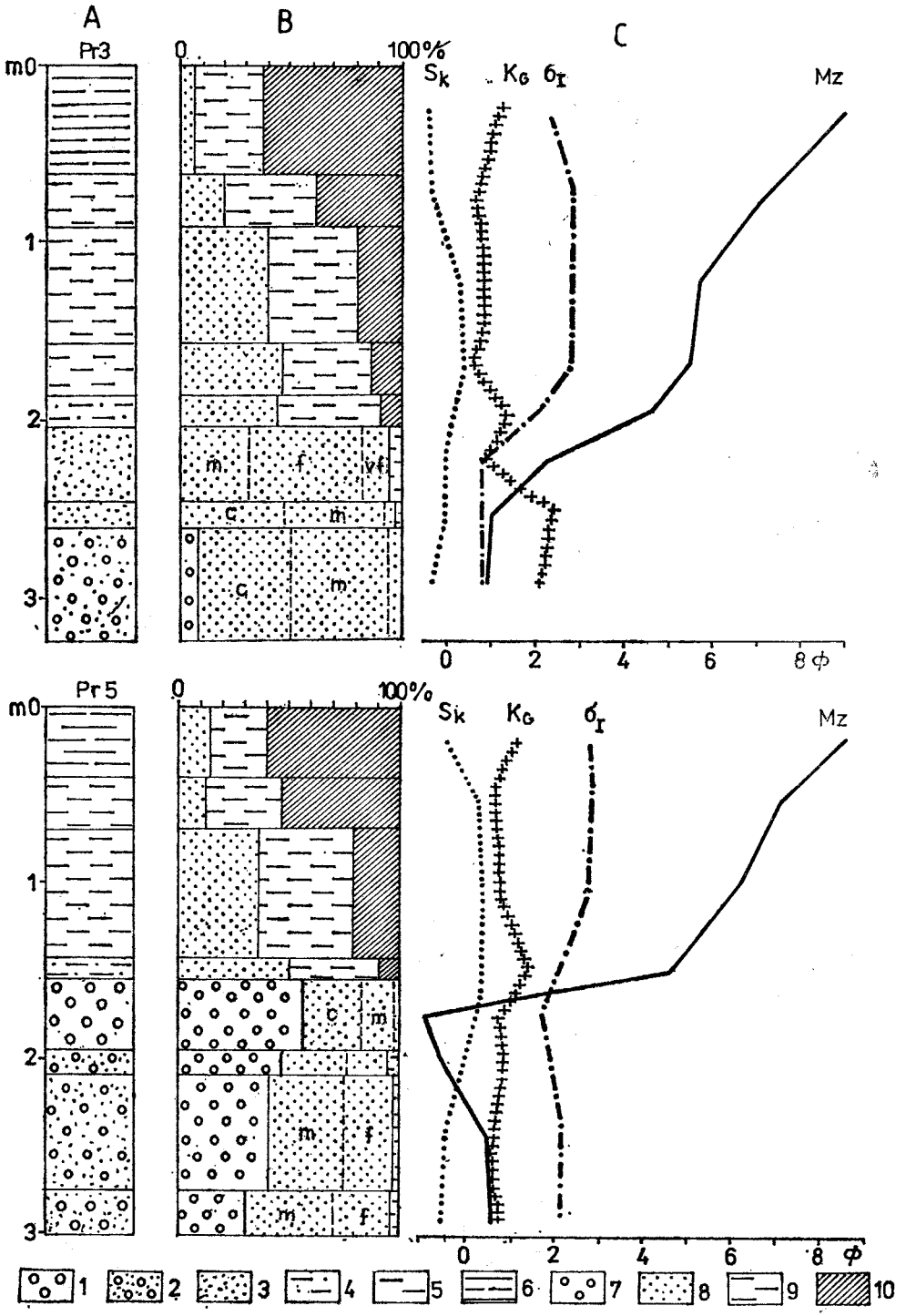


Fig. 7. Profiles of deposits Pr3 and Pr5 (A) at Przewóz, grain size composition (B) and parameters of Folk's and Ward's (1957) grain size distribution (C): 1 — gravels, 2 — gravels and sands, 3 — sands, 4 — sandy silts, 5 — silts,

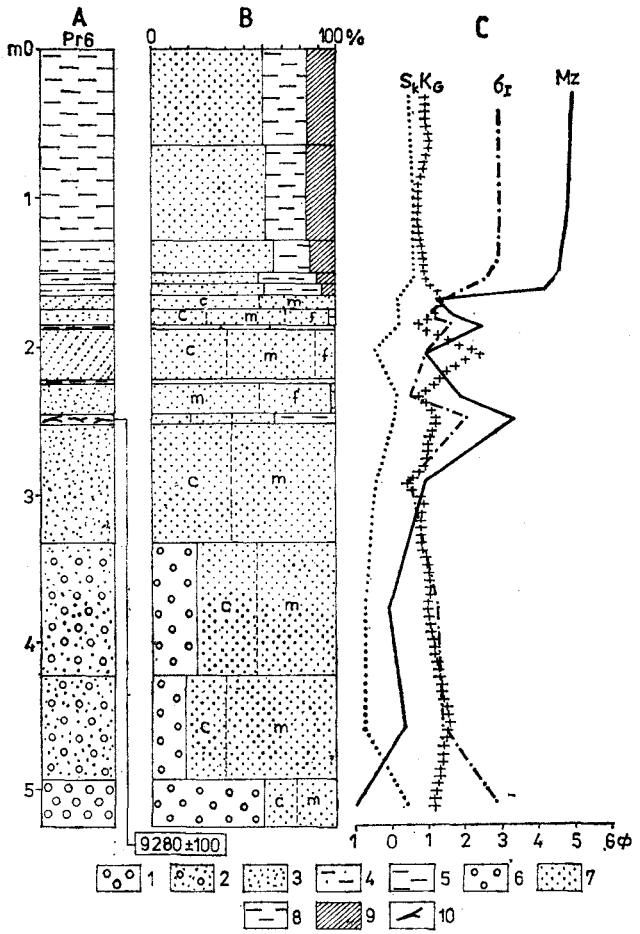


Fig. 8. Profile of deposits Pr6 (A) at Przewóz, grain size composition (B) and parameters of Folk's and Ward's (1957) grain size distribution (C): 1 — gravels, 2 — gravels and sands, 3 — sands, 4 — sandy silts, 5 — silts; fractions: 6 — gravelly, 7 — sandy: c — coarse, m — medium, f — fine, 8 — dusty, 9 — clayey, 10 — boughs

Ryc. 8. Profil osadów Pr6 (A) z Przewozu, skład mechaniczny (B) i parametry rozkładu uziarnienia (C) Folka i Warda (1957): 1 — żwiry, 2 — żwiry z piaskami, 3 — piaski, 4 — mułki piaszczyste, 5 — mułki; frakcje: 6 — żwirowa, 7 — piaszczysta: c — gruboziarnista, m — średnioziarnista, f — drobnoziarnista, 8 — pylasta, 9 — ilasta, 10 — gałęzie

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6 — clays; fractions: 7 — gravelly, 8 — sandy: c — coarse, m — medium, f — fine, vf — very fine, 9 — dusty, 10 — clayey

Ryc. 7. Profile osadów Pr 3 i Pr 5 (A) z Przewozu, skład mechaniczny (B) i parametry rozkładu uziarnienia (C) Folka i Warda (1957): 1 — żwiry, 2 — żwiry z piaskami, 3 — piaski, 4 — mułki piaszczyste, 5 — mułki, 6 — iły; frakcje: 7 — żwirowa, 8 — piaszczysta: c — gruboziarnista, m — średnioziarnista, f — drobnoziarnista, vf — bardzo drobnoziarnista, 9 — pylasta, 10 — ilasta

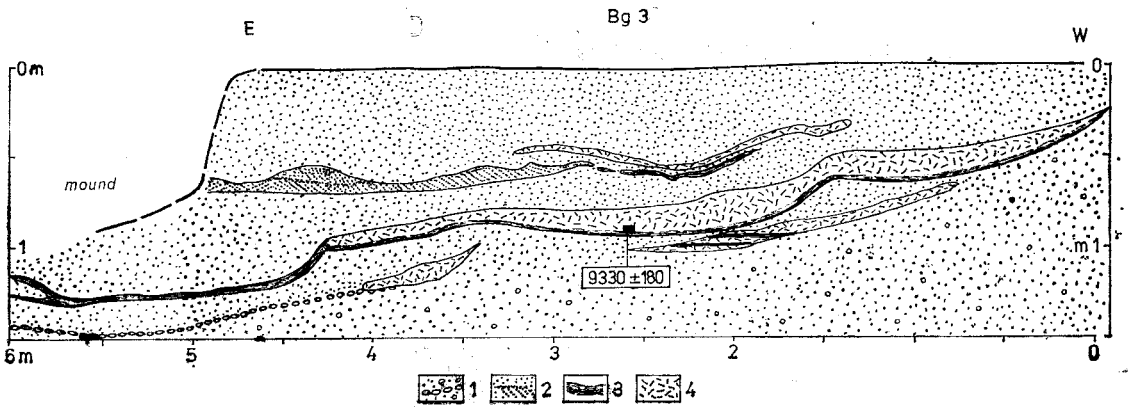

Fig. 9. Detailed section across the interbeds of plant detritus contained in the sandy bars at the Bg3 site at Brzegi (see Figs 3 and 4): 1 — sands with gravels and lag horizon, 2 — sands and ripplemarks, 3 — silty layers, 4 — interbeds of plant detritus

Ryc. 9. Szczegółowe przekroje wkładek sieczki roślinnej w piaszczystych odsypach na stanowisku Bg3 w Brzegach (patrz Ryc. 3 i 4): 1 — piaski ze żwirami i poziom bruku, 2 — piaski i riplemarki, 3 — warstwy mułków, 4 — wkładki sieczki roślinnej

at 9280 ± 100 yr BP (Gd-5428). The top series comprises a sandy „mada" (Mz = 4.2—4.9 ϕ) which is very poorly sorted (δ_I = 2.1—2.9).

In the gravel pit at Brzegi lying some 0.5 km east of Grabie the profiles described are characteristic of channel deposits rising to great heights. In the thick sandy series occupying the interior of the loop shown on the old maps plant detritus layers have been exposed. Plant remains underlain by grey sandy silts are contained in the northeasterly trending troughs cut into sands with lag stones at the base as well as in some depressions separating the sandy bars. Here only *Salix sp.* (3 pieces) and *Pinus sp.* (1 piece) were identified by Z. Tomczyńska. A piece of *Salix sp.* has been dated at 9330 ± 180 yr BP (Gd-2517). This indicates an age close to that of plant remains at Przewóz.

The channel seen on the maps is cut into gravels with sands (Mz = = −0.8 to 1.4 ϕ) being poorly sorted (δ_I = 1.2—1.7). The channel fill has been dated at 3290 ± 110 yr BP (Gd-4072). It is likely that this (δ_I = 3.2) (Fig. 10, 11). A piece of wood found in the loamy channel fill has been dated at 3290 ± 110 yr BP (Gd-4072). It is likely that this piece of young wood was deposited by the later floods when the Vistula river channel again was located close to the Drwień depression.

In the easternmost part of the gravel pit, within the highest gravelly culmination two tree trunks with diameters of 25 cm, turned 95° and 135°, have been found. One of the trunks has been dated at 10 690 ± 190 yr BP (Gd-2351) (Fig. 1).

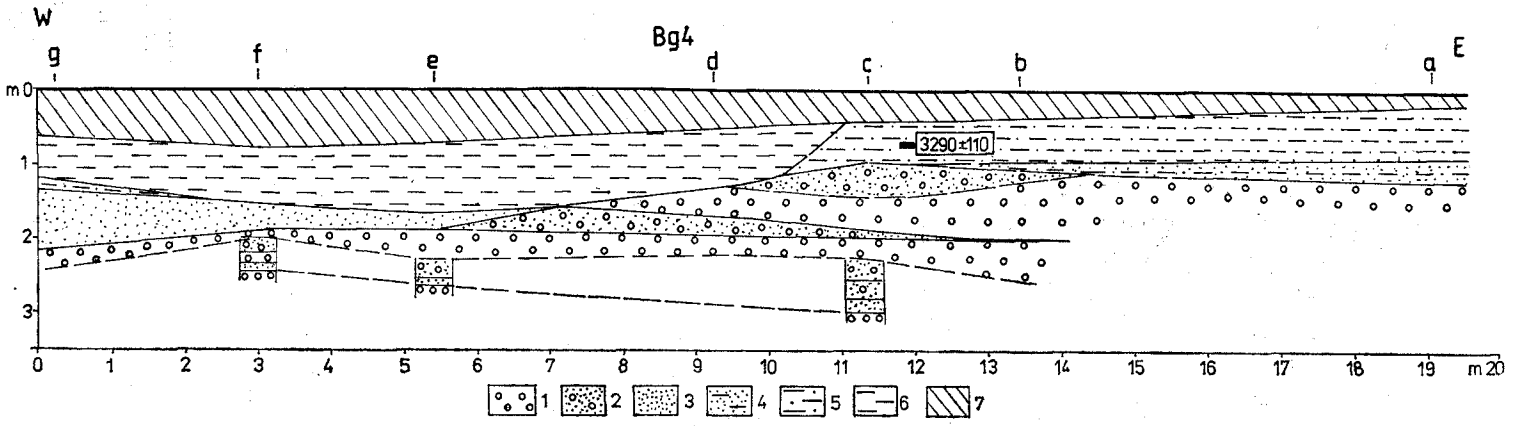

Fig. 10. Section across the channel at the Bg4 site at Brzegi (see Figs 3 and 4): 1 — gravels, 2 — gravels and sands, 3 — sands, 4 — sands with clay admixture, 5 — sandy silts, 6 — silts, 7 — embankment

Ryc. 10. Przekrój przez koryto na stanowisku Bg4 w Brzegach (patrz Ryc. 3 i 4): 1 — żwiry, 2 — żwiry z piaskami, 3 — piaski, 4 — piaski zaglinione, 5 — mułki piaszczyste, 6 — mułki, 7 — nasypy

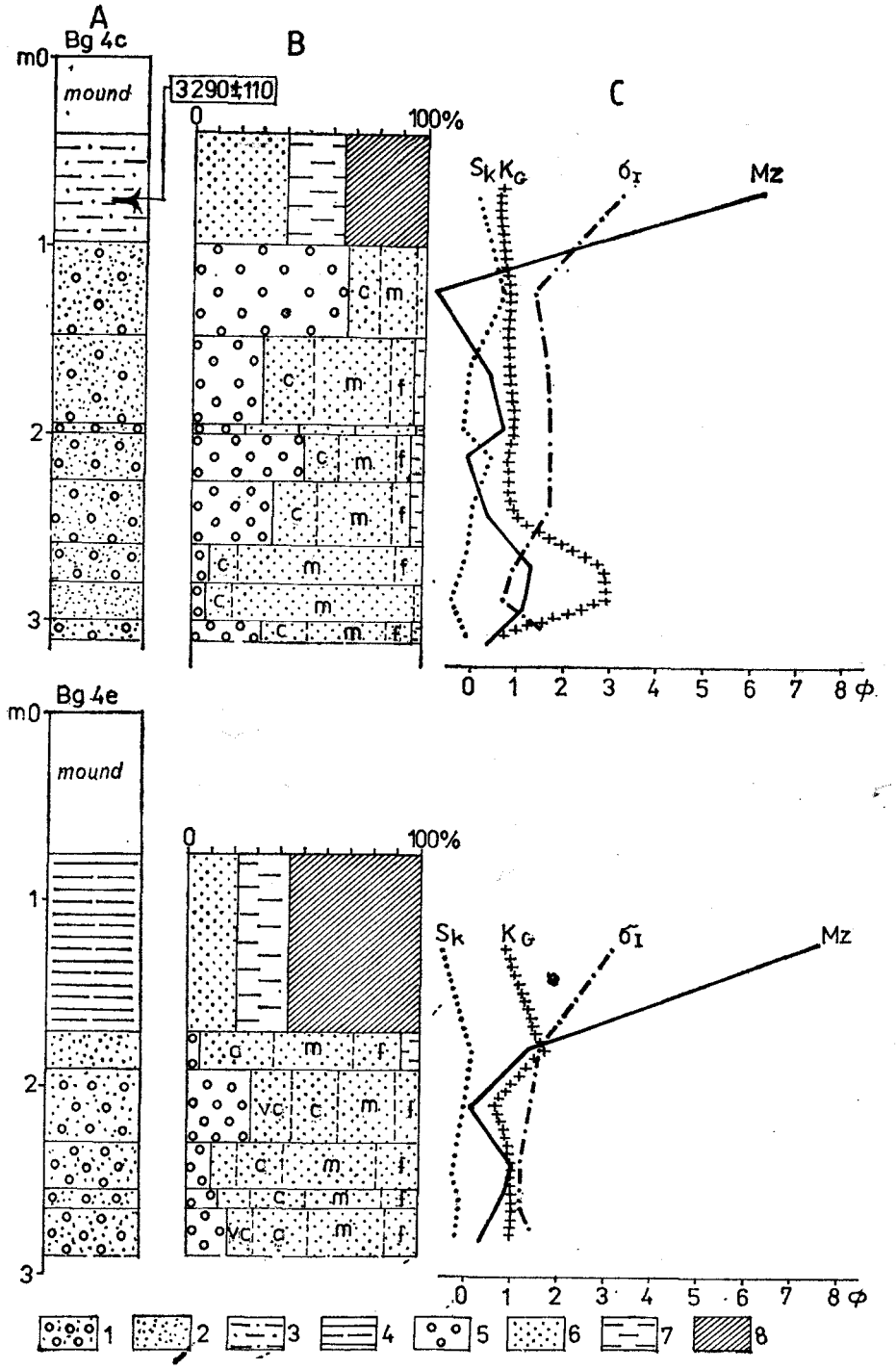

Fig. 11. Profiles of deposits Bg4 (A) identified from the channel at Brzegi, grain size composition (B), parameters of Folk's and Ward's (1957) grain size distribution (C): 1 — gravels and sands, 2 — sands, 3 — sandy silts, 4 — clays; fractions: 5 — gravelly, 6 — sandy: vc — very coarse, c — coarse, m — medium, f — fine, 7 — dusty, 8 — clayey

Ryc. 11. Profile osadów Bg4 (A) z przekroju koryta w Brzegach, skład mechaniczny (B), parametry rozkładu uziarnienia (C) Folka i Warda (1957): 1 — żwiry z piaskami, 2 — piaski, 3 — mułki piaszczyste, 4 — iły; frakcje: 5 — żwirowa, 6 — piaszczysta: vc — bardzo gruboziarnista, c — gruboziarnista m — średnioziarnista, f — drobnoziarnista, 7 — pylasta, 8 — ilasta

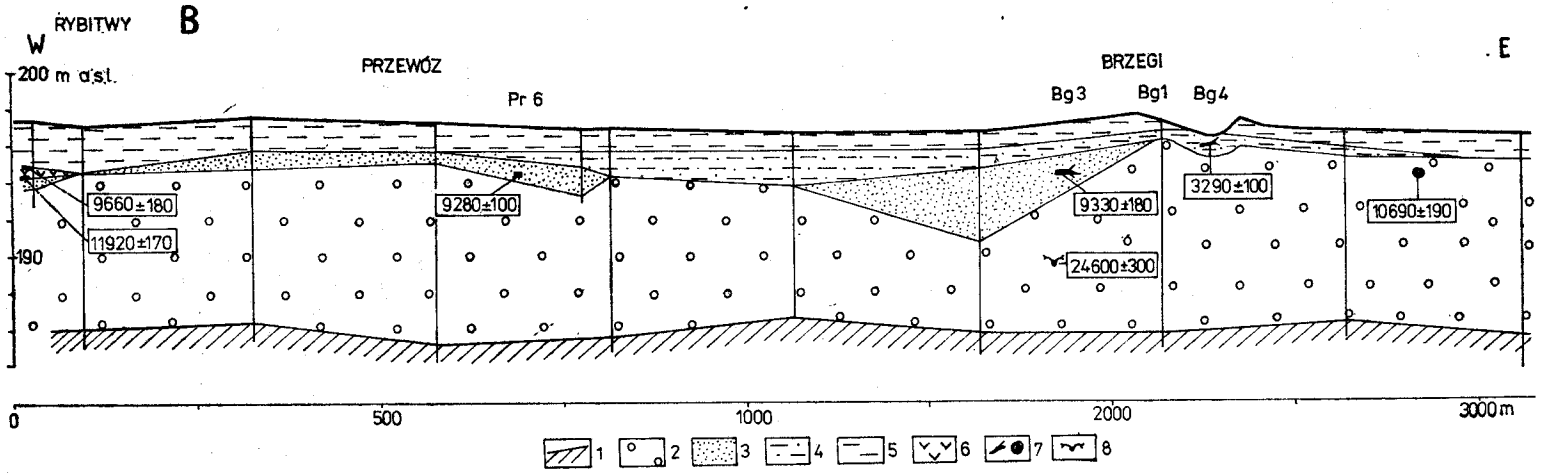

Fig. 12. Geological section across the gravel pit at Brzegi (see Figs 3 and 4): 1 — Miocene clays, 2 — gravels, 3 — sands, 4 — sandy silts, 5 — silts, 6 — peats, 7 — boughs and tree trunks, 8 — reindeer antler

Ryc. 12. Przekrój geologiczny przez żwirownię w Brzegach (patrz Ryc. 3 i 4): 1 — iły mioceńskie, 2 — żwiry, 3 — piaski, 4 — mułki piaszczyste, 5 — mułki, 6 — torfy, 7 — gałęzie i drzewa, 8 — róg renifera

At both sites Late Glacial and early Holocene deposits are exposed. A characteristic feature is the very high position of the top channel deposits dating from the Younger Dryas. Such a position has nowhere been observed in the Vistula valley reach discussed. This fact indicates that the Younger Dryas was a period of distinct aggradation. In all probability the deposits examined were laid down by the braided Vistula river. Evidence may be yielded by both structure and sedimentation type.

Several cross troughs are cut into the Younger Dryas deposits. They are mostly filled with sandy deposits containing organic sediments which date from Preboreal times. These deposits were laid down in the meandering Vistula river channel which again began to develop at this time. This channel is traceable in the gravel pit at Brzegi. The functioning of great meanders as early as 9520 ± 110 yr BP (Gd-5055) is confirmed by the Drwinka site located 10 km east of Brzegi (Gębica, Starkel 1987; Nalepka 1991).

Channel deposits are capped by a twofold „mada" the sandy basal part of which dates from the late glacial/Holocene transition. Its top part is clayey and probably dates from the Atlantic period of maximum extent of woodland in the Vistula drainage basin (Kalicki 1988, 1991). Subsequent flood incursions in the Drwień depression are indicated by a piece of wood with a date of 3290 yr BP (i.e. the close of the Subboreal) which has been found in the „mada". Flood incursions were probably aided by the repeated Vistula channel avulsion to the south, close to the depression. Increased frequency and magnitude of floods being associated with a cooler and moister climate then was also favourable (Kalicki 1988, 1991; Kalicki, Krąpiec 1991).

THE WESTERN PART OF THE DRWIEŃ DEPRESSION

LATE—GLACIAL DEPOSITS AT RYBITWY

The Rybitwy site lies some 2 km to the west of Brzegi and Przewóz (Fig. 1, 12). There occurs a flat plain interrupted by cutoffs of the Drwień rivulet. These are up to 5 m deep with a maximum width of 10 m. Here the Drwień depression is undercut by the Boreal systems of small cutoffs at Lasówka and Rybitwy to the north (Kalicki 1988). To the south an alluvial fan was laid down by the Seraf in the depression. The great amount of archival borings provided information on the general geological structure and revealed the homogeneity of the area, 2.5 km long and 1.5 km wide.

The top of Miocene clays occurs at 186—187 m a.s.l. The thickness of Quaternary deposits varies from 11 to 12 m. Their basal part consists of a gravel-and-sand series without interbeds of silt. The flat top of

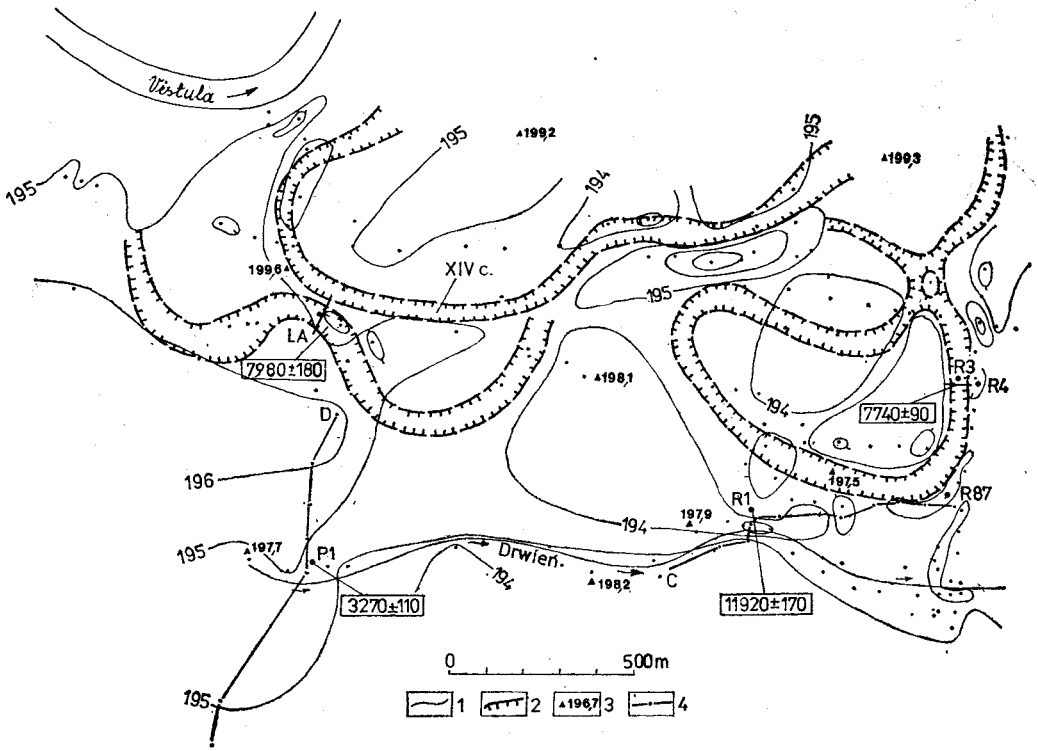

Fig. 13. Configuration of the top of channel deposits in the surroundings of Lasówka, Rybitwy and Płaszów: 1 — contour lines, 2 — cutoff edges, 3 — altitudes, 4 — borings and sections C and D (see Figs 15 and 18)

Ryc. 13. Rzeźba stropu osadów korytowych w rejonie Lasówki, Rybitw i Płaszowa: 1 — izohipsy, 2 — krawędzie starorzeczy, 3 — punkty wysokościowe, 4 — wiercenia i linie przekrojów C i D (patrz Ryc. 15 i 18)

this series rises to 194—195 m a.s.l. Only in one boring located close to the Drwień rivulet its top was below 193 m a.s.l. (Fig. 13, 14). Roughly parallel to the present Drwień channel there extends a very wide depression containing locally sand and sandy silts. Channel deposits are covered with 20—40 cm of organic deposits whose top conforms in planform to that of the underlying series. Overlying are about 2 m of a clayey „mada" (Fig. 15).

Two additional borings were sunken in this area: the first one R1 was made nearby the greatest depression present on the gravel top, the second one (R/87) was made in the marginal part of the Drwień depression (Fig. 13, 14), i.e. 200 m and 50 m south of the Boreal palaeomeander at Rybitwy. In both cores the sequence of deposits is very similar (Fig. 16, 17).

The first boring disclosed at the base 50 cm of sandy silts (Mz = = 5.2—6.2 ϕ) which are very poorly sorted. These are capped by 20

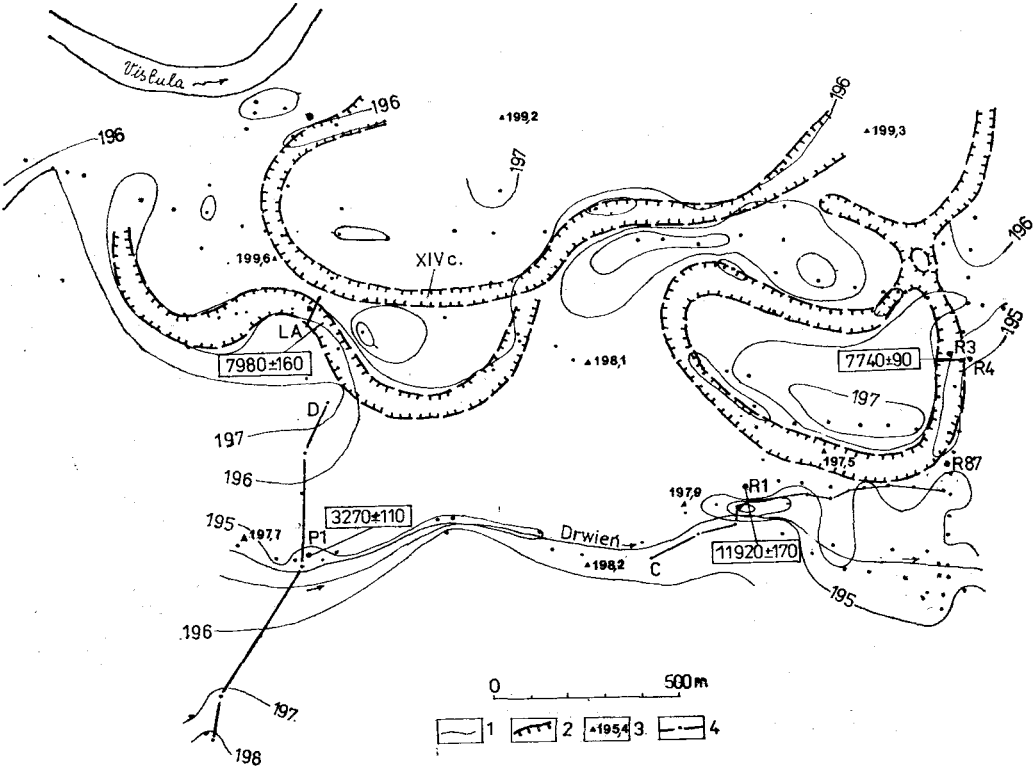

Fig. 14. Configuration of both the base of the cutoff fill and the „mada" in the surroundings of Lasówka, Rybitwy and Płaszów: 1 — contour line, 2 — cutoff edges, 3 — altitudes, 4 — borings and sections C and D (see Figs 15 and 18)

Ryc. 14. Rzeźba spągu osadów wypełniających starorzecza i mad w rejonie Lasówki, Rybitw i Płaszowa: 1 — izohipsy, 2 — krawędzie starorzeczy, 3 — punkty wysokościowe, 4 — wiercenia i linie przekrojów C i D (patrz Ryc. 15 i 18)

cm of fine (Mz = 2.7 ϕ), poorly sorted sand. In the second boring sandy silts (Mz = 5.3—7.3 ϕ) rest on sands with gravels. Sandy silts are very poorly sorted. At the top they contain organic remains. Overlying are organic deposits. In the boring R1 the latter comprise three peat layers with much clay and peaty silts, 3 cm, 1 cm and 6 cm thick. Interbeds of grey sand are up to 1 cm thick. The upper layer of rusty, heavily decomposed peats with clay has been dated at 11 920 ± 170 yr BP (Gd-2409). This is succeeded by 10 cm of rusty, heavily decomposed peats with less clay and 30% of organic substance. The uppermost layer is composed of organic silts, 25 cm thick. Their top part has been radiocarbon dated at 9660 ± 180 yr BP (Gd-2412). In the boring R/87 the organic layer attaining a thickness of 30 cm includes brownish-grey peaty silts which pass upward into brown peats with clay. In both borings on the organic horizon there rest dusty (Mz = 6.1—7.2 ϕ),

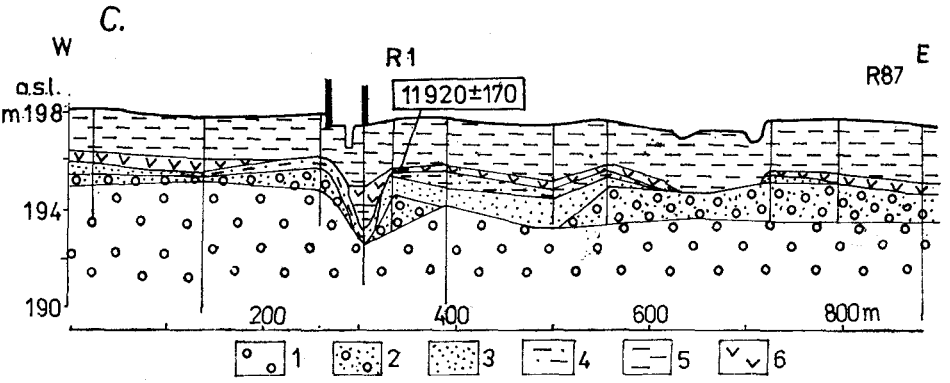

Fig. 15. Geological cross section at Rybitwy (see Figs 13 and 14): 1 — gravels, 2 — gravels and sands, 3 — sands, 4 — sandy silts, 5 — silts, 6 — peats

Ryc. 15. Przekrój geologiczny przez stanowisko w Rybitwach (patrz Ryc. 13 i 14): 1 — żwiry, 2 — żwiry z piaskami, 3 — piaski, 4 — mułki piaszczyste, 5 — mułki, 6 — torfy

very poorly sorted silts, up to 40 cm thick. The upper 1.8 m of deposits is a twofold clayey silt. Its lower member is formed either of clay or of clayey silts (Mz = 7.4—9.7 ϕ) which are very poorly sorted. The percentage of the finest fraction increases upward from 54—65 to 72—78. In both cases its content clearly decreases to 30—40% at a depth of 1.0—1.5 m. The upper member, about 0.5 m thick, consists of a still finer „mada" (Mz = 7.6—8.5 ϕ) which shows a worse sorting than the underlying clays. Here the content of the finest fractions decreases upward from 58% to 41%.

At the Rybitwy site there are preserved channel deposits of the Vistula having an age greater than 12 000 years. The absence of meander traces, the very flat top of the gravel-and-sand series being unlike that of the meander zone, the lack of a well developed sandy series being characteristic of the meandering river provide indirect evidence of channel deposits laid down by a braided river. Channel deposits are overlain by a thin layer of peats and peaty silts, the deposition of which was initiated at the Older Dryas /Allerød transition. Initially, organic sedimentation was interrupted by sand deposition on the Vistula flood-plain. In Allerød times deposition became stabilized due to constriction of the Vistula river channel (Kalicki, Starkel 1987; Kalicki 1988, 1991). At this time, the Vistula was flowing in great loops at the foot of both the loess-covered terrace edge and the alluvial fan laid down by the Dłubnia river (sites: Nowa Huta, Łęg) (Kalicki 1987, 1991). Such conditions induced organic sedimentation on an older segment of the flood-plain which was preserved far off the active river channel. The Younger Dryas saw the first changes and the deposition of organic silts due to reactivation of the fluvial

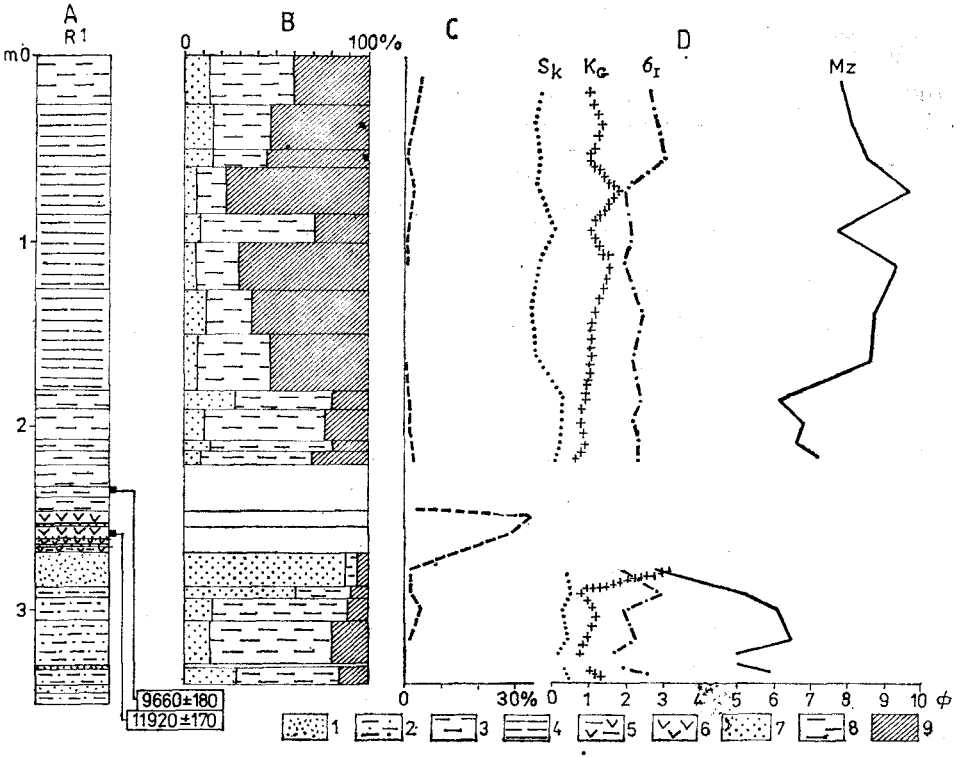

Fig. 16. Profile of deposits R1 (A) at the Rybitwy site, grain size composition (B), content of organic substance (C) and parameters of Folk's and Ward's (1957) grain size distribution (D)

1 — sands, 2 — sandy silts, 3 — silts, 4 — clays, 5 — peaty silts, 6 — peats; fractions: 7 — sandy, 8 — dusty, 9 — clayey

Ryc. 16. Profil osadów R1 (A) ze stanowiska w Rybitwach, skład mechaniczny (B), zawartość substancji organicznej (C) i parametry rozkładu uziarnienia (D) Folka i Warda (1957): 1 — piaski, 2 — mułki piaszczyste, 3 — mułki, 4 — iły, 5 — mułki torfiaste, 6 — torfy; frakcje: 7 — piaszczysta, 8 — pylasta, 9 — ilasta

processes. This is indicated by increased aggradation. The meandering Vistula channel became replaced either by a braided channel (at the Brzegi site) or by an anastomosing one. At the Drwinka site this may be indicated by a large meander which became cut off in Preboreal time (Gębica, Starkel 1987; Kalicki, Starkel 1987; Kalicki 1991). Organic sedimentation came to an end during the Preboreal (9660 yr BP) when the Vistula river channel again was close to the Rybitwy and Przewóz sites. Peat initiation in the large cutoffs occurring at the foot of the Dłubnia alluvial fan indicates that by this time (9660 ± 110 yr BP) the connection between them and the active river channel (Kalicki 1987) became interrupted. This also provides indirect evidence of a Vistula channel avulsion toward the south. It

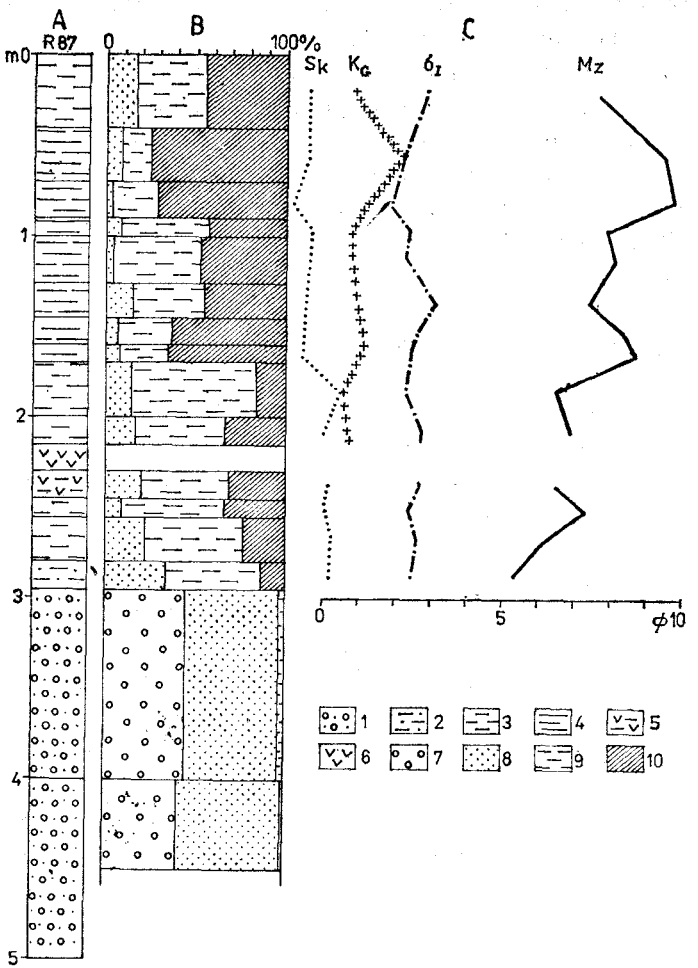

Fig. 17. Profile of deposits R 87 (A) at the Rybitwy site, grain size composition (B) and parameters of Folk's and Ward's (1957) grain size distribution (C) 1 — gravels and sands, 2 — sandy silts, 3 — silts, 4 — clays, 5 — peaty silts, 6 — peats; fractions: 7 — gravelly, 8 — sandy, 9 — dusty, 10 — clayey

Ryc. 17. Profil osadów R/87 (A) ze stanowiska w Rybitwach, skład mechaniczny (B) i parametry rozkładu uziarnienia (C) Folka i Warda (1957): 1 — żwiry z piaskami, 2 — mułki piaszczyste, 3 — mułki, 4 — iły, 5 — mułki torfiaste, 6 — torfy; frakcje: 7 — żwirowa, 8 — piaszczysta, 9 — pylasta, 10 — ilasta

may well be that about 9300 yrs BP there functioned the shallow, already sinuous Vistula river channel as is indicated by traces of such a channel at Przewóz and Brzegi. At this time, sandy „mada" deposition took place at Przewóz and Brzegi, and dusty „mada" deposition occurred at Rybitwy farther off the active river channel. In Boreal and Atlantic times of maximum extent of woodland in the Vistula drainage basin, and of rather uniform stream discharges a clayey „mada" was laid

down in the Drwień depression. At Lasówka and Rybitwy, cutoff fills with dates of 7980 and 7740 yr BP show that in the close vicinity of the Boreal Vistula river channel the „mada" became finer over a short period. The youngest, more dusty „mada" must already be refrred to the last millenia of increased human activity. At this time, dusty-sandy „mada" deposition has taken place close to the active Vistula river channel, whereas a dusty „mada" was laid down in the far off Drwień depression (Kalicki 1988, 1991).

THE SUPERFICIAL SUBBOREAL PEAT BOG AT PŁASZÓW

The Płaszów site lies in the westernmost part of the Drwień depression, some 2 km west of Rybitwy and 400 m south of the Boreal system of palaeomeanders at Lasówka (Fig. 13, 14). The southern part of the Drwień depression contains alluvial fans laid down by the small tributaries of the Vistula which are draining the Gdów Plateau. The original relief is not seen because of the industrial building-up of the depression. Numerous archival borings allow the original relief and geological structure to be reconstructed there.

In this area the top of Miocene clays is at 188 m a.s.l. Tertiary deposits are overlain by 7 m of gravels-and-sands whose top rises little above 195 m a.s.l. (Fig. 13). Only close to the Drwień channel there extends a smooth and wide depression the bottom of which reaches 194 m a.s.l. It is well seen on a map showing the sub-„mada" surface (Fig. 14). This depression extends between the zone of the Boreal point bars at Lasówka to the north (up to 197 m a.s.l.) and the sandy alluvial fans to the south (198 m a.s.l.). The uppermost Quaternary deposits consist of „mada" whose thickness exceeds 2.5 m in the depression. On the alluvial fans it is up to 1 m thick (Fig. 18).

In the central part of the depression, close to the Drwień channel there occurred a small superficial peat bog being almost completely covered with waste now. In an additional boring (P1) 1 m of peat with clay was penetrated. The content of organic substance decreases downward from 30% to 26% (Fig. 18). The basal part of the peat has been dated at 3270 ± 110 yr BP (Gd-2413). Underlying is a 0.5 m series of peaty silts alternating with clayey sands and fine sands. Clayey sands occur at the base.

The initiation of organic sedimentation must be related to rising ground-water levels which were favourable for peat growth in a natural depression interrupting the Vistula flood-plain. In all probability the Vistula became reactivated the evidence of which are cutoffs and series of „black oak" trunks found in the environs of Cracow (Kalicki 1988, 1991; Kalicki, Krąpiec 1991).

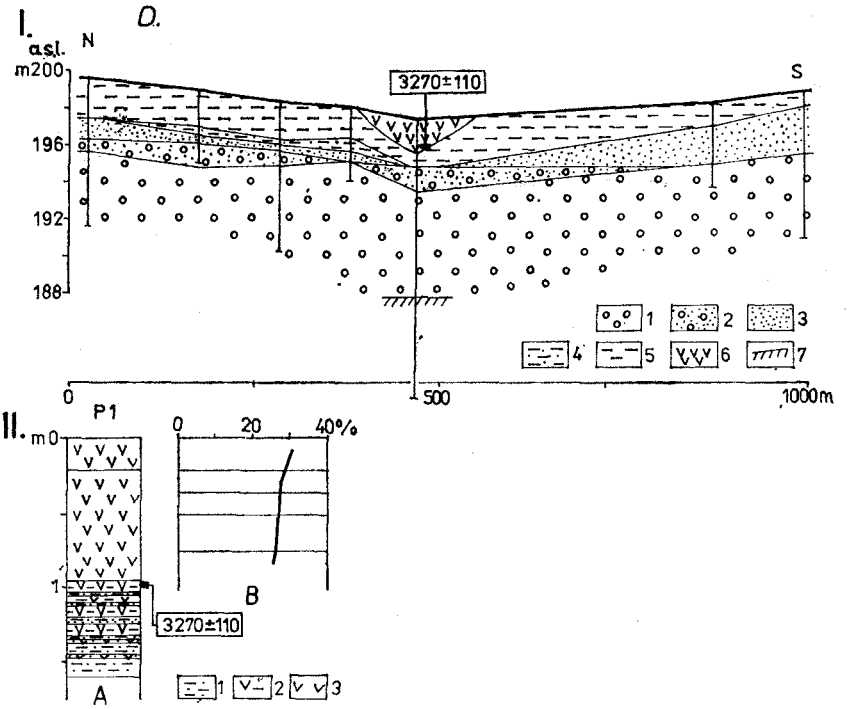

Fig. 18. Geological cross section at Płaszów (I) (see Figs 13 and 14): 1 — gravels, 2 — gravels and sands, 3 — sands, 4 — sandy silts, 5 — silts, 6 — peats, 7 — Miocene clays. Profile of deposits P1 (IIA) obtained from the peat bog at Płaszów and content of organic substance (IIB): 1 — sandy silts, 2 — peaty silts, 3 — peats with clay

Ryc. 18. Przekrój geologiczny przez stanowisko w Płaszowie (I) (patrz Ryc. 13 i 14). 1 — żwiry, 2 — żwiry z piaskami, 3 — piaski, 4 — mułki piaszczyste, 5 — mułki, 6 — torfy, 7 — iły mioceńskie. Profil osadów P1 (IIA) z torfowiska w Płaszowie i zawartość substancji organicznej (IIB): 1 — mułki piaszczyste, 2 — mułki torfiaste, 3 — torfy zailone

CONCLUSIONS

In the Drwień depression there survived channel deposits laid down by the braided Vistula during the Late Glacial. However, the structure of the landform discussed is not uniform, and its various parts have functioned at different times. To the west, in the Rybitwy area this depression was used by the Vistula still prior to 12 000 years BP, whereas near Przewóz and Brzegi it was used during the Younger Dryas and in early Holocene times. Thus, the age of functioning of the Drwień depression appears to be the same as that of the other depressions occurring in the Vistula valley, namely: pre-Allerød in the Trześniówka and Mokrzyszówka depressions — 11 640 ± 100 yr BP (M y-

cielska-Dowgiałło 1987) and in the Uszewska depression — 11 300 ± 140 yr BP (Gębica 1989); either pre-Younger Dryas or Younger Dryas in a depression extending north of the Grobla Forest — 10 520 ± 110 yr BP (Gębica, Starkel 1987) as well as in the Drwinka depression — 9840 ± 140 yr BP (Starkel *et al.* 1988).

All of these depressions also show a similar geological structure: sandy-gravelly channel deposits underlie a thin layer of organic sediments. Radiocarbon datings indicate that organic deposition took place on the older flood-plain segments during periods of a rather low dynamics of the fluvial processes (Allerød, onset of the Holocene) when the Vistula river channel became constricted to a meandering one. As the Vistula channel was at these times located far off the older flood-plain segments, organic sedimentation occurred there. During the Younger Dryas peat growth has been noted only in a depression extending north of the Grobla Forest. This example illustrates the important role played by distance from the active river channel in the sedimentation type, since fluvial processes have been reactivated during the Younger Dryas. In all probability, the Vistula used at this time the Drwinka depression so that the great distance from the braided Vistula river channel facilitated organic sedimentation north of the Grobla Forest. At the Płaszów site peat bogs also developed in the Drwień depression toward the close of the Subboreal under cooler and wetter climatic conditions which were responsible for the rising ground-water tables. The great distance from the active Vistula river channel is also believed to have been a cause of it.

In all of the depressions examined organic deposits have a capping of a clayey „mada". „Mada" initiation took place at different times: during the Younger Dryas (10 440 ± 200 yr BP) in the Uszewka depression (Gębica 1989), in Preboreal time (9660 ± 180 yr BP) in the Drwień depression (this paper) and in Atlantictime (8010 ± 140 yr BP) in the Drwinka depression (Starkel, *et al.* 1988). These are periods of increased fluvial activity (Kalicki 1988, 1991). In this case a very important role was played by distance from the active Vistula channel as indicated by detailed analyses of the Vistula channel changes between Cracow and Niepołomice (this paper), and of the Drwinka depression (Starkel *et al.* 1988).

A detailed analysis of the „mada" contained in the Drwień depression revealed changes of both age and facies. The early Holocene „mada" is sandy-dusty, „mada" of Atlantic age is clayey, and the youngest one dating from the last millenia again is dusty. This differentiation is due to climatic and vegetational changes and to the activities of man (Kalicki 1988, 1991). However, facies changes in the „older mada" like those in the „younger mada" (Kalicki 1988, 1991) were also controlled by distance from the active Vistula river channel. Consequently,

the early Holocene „mada" laid down close to the active channel (at the Przewóz site) is sandy-dusty (Mz = 5—6 ϕ), whereas that located far from the active channel (at the Rybitwy site) is dusty (Mz = 6—7 ϕ). At Rybitwy and Przewóz again there is evidence of facies changes in the Boreal-Atlantic „mada". Close to the active channel, at Rybitwy and Lasówka, there occurs a dusty-clayey „mada" (Mz = 7—8 ϕ), whereas far off the channel a clayey „mada" (Mz = 8—9 ϕ) was found.

The evidence presented shows that wide depressions are a characteristic feature of the flood-plains developed in the Sandomierz Basin. These depressions were active until the Late Glacial times, and they were fashioned by the braided rivers. At analogous landform (Riedzone) has also been described by Schirmer (1988) from the Rhine valley north of Strasbourg. This landform is 4 km wide and by 1—3 m lower than the adjacent part of the flood-plain. Peats found there indicate that the depression functioned during the late Würmian. Here alluvial loam deposition has still taken place in the Subboreal period, and probably even in later times. Other depressions being similar to those described have been reported from the middle Vistula valley between Magnuszewo and Karczew. These depressions were active until the Allerød (11 190 ± 65 yr BP). They occur, however, on the lowermost supra-flood terrace named the Praga terrace, which became dissected at the beginning of the Holocene (Sarnacka 1987).

In all probability the wide depressions without traces of palaeomeanders may be considered typical of the extensive flood-plains of the large central-European rivers being favourable for their preservation. Such depressions are the oldest elements of the flood-plains that date well back to the late glacial. They were fashioned by the braided rivers.

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STRESZCZENIE

T. Kalicki

BUDOWA I WIEK OBNIŻENIA DRWIENIA NA RÓWNINIE ZALEWOWEJ WISŁY NA WSCHÓD OD KRAKOWA

Szerokie obniżenia bez śladów paleomeandrów są często spotykaną formą na równinach zalewowych rzek w Kotlinie Sandomierskiej. Obniżenie Drwienia ciągnie się w dolinie Wisły pomiędzy Krakowem a Niepołomicami (Ryc. 1). We wschodniej części obniżenia występują młododryasowe i preborealne osady korytowe składane najpierw przez rzekę roztokową, a później zakolową w czasie organizacji odpływu meandrowego (Ryc. 2—12). W zachodniej części znajdują się osady korytowe starsze niż 12 000 lat BP składane przez rzekę roztokową. Przykryte są one cienką warstwą torfów, których sedymentacja skończyła się w preboreale. Od tego czasu w obniżeniu Drwienia osadzały się ilaste mady (Ryc. 12—17). W zachodniej części usytuowane jest także powierzchniowe torfowisko w Płaszowie powstałe w okresie ochłodzenia i zwilgotnienia klimatu pod koniec subboreału.

Mady obniżenia Drwienia wykazują zróżnicowanie wiekowe i facjalne. Nawiązuje ono z jednej strony do zmian klimatyczno-roślinnych oraz działalności człowieka (mady wczesnoholoceńskie i subatlantyckie — pylaste, atlantyckie — ilaste), z drugiej do odległości od czynnego koryta Wisły.