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# STRATIGRAPHY OF THE VISTULIAN ALLUVIAL FILLS IN THE WISŁOKA VALLEY NORTH OF DĘBICA

## STATE OF THE STUDIES

Studies on the Vistulian alluvial fills near Dębica have a long history. At the beginning of the 20-th century W. Friedberg (1903) distinguished "diluvial" (Pleistocene) higher terrace covered by eolian sands and two Holocene fills with fossil trunks (8 and 4 m terrace).

Later K. Konior (1936) classified the two Holocene terraces as the upper Pleistocene, and then M. Klimaszewski (1948) connected only 8 m terrace with last cold stage (overlain by Holocene loams). L. Starkel (1957, 1960) in his preliminary studies documented Holocene age of several fills and argued the pre-Alleröd erosion, cutting through the lower Vistulian deposits. Then, A. Środon (1965) and W. Laskowska-Wysoczańska (1971) described the silty-sand deposits of the 15 m high terrace with Dryas flora and Brörup peat at their base (Laskowska-Wysoczańska and Niklewski 1969) that were connected with the last pleniglacial.

Several years later, based on 3 fills in Brzeźnica, a geological transect was elaborated (Mamakowa and Starkel 1974). In the middle silty-sandy unit of 15 m high terrace the cold flora was dated at c. 28 ka BP (4 datings), and beneath the lateglacial paleomeander fills of the 9 m terrace an older outlier was exposed with partly eroded paleochannel fill, the peaty part of which was dated between 36 and >48 ka BP. In other section at Podgrodzie (Mamakowa and Starkel 1977) below the early Holocene sequence and erosional surface the alluvial and colluvial deposits were found just above the present river channel indicating the low position of the channel about 33,350 ± 750 BP and still about 22,450 ± 340 BP.

In the monograph on the evolution of the Wisłoka valley (Starkel [in:] Alexandrowicz et al. 1981) the opinion was presented, based on several sites with higher bottoms of abandoned lateglacial meanders, that the late Vistulian erosion has not reached the present-day level. The intermediate level, 10–12 m high, without paleomeanders and overbank loams but with several spurs of shallow parallel channel depressions was distinguished on the left bank of the Wisłoka river.

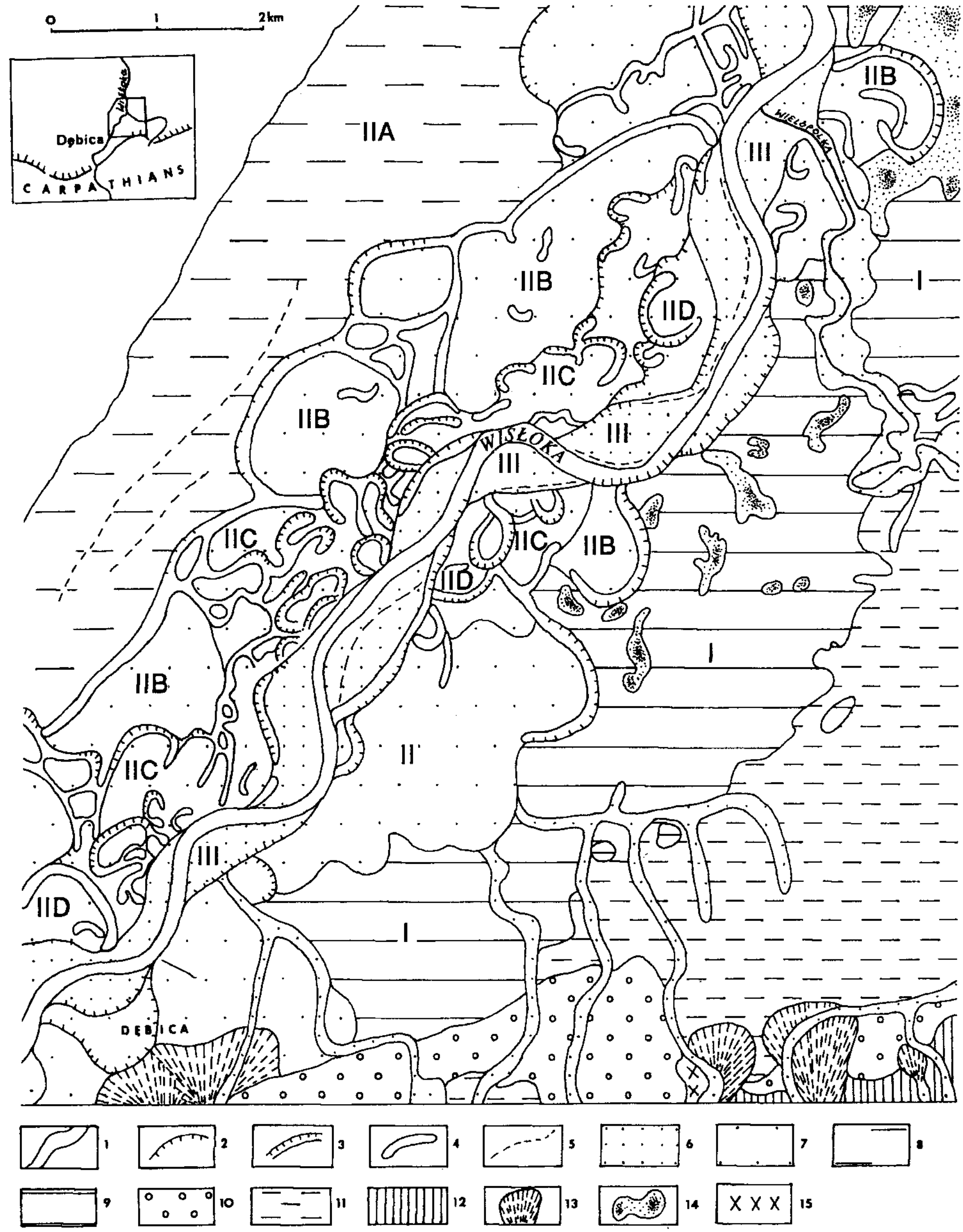


Fig. 1. Geomorphological map of studied reach of Wisłoka valley (based on map by L. Starkel et al (1982) and geological survey by J. Boratyn and S. Brud). 1 — Wisłoka channel with bars, 2 — terrace edges, 3 — paleochannel well preserved, 4 — paleochannel less preserved, 5 — shallow paleochannel depression, 6 — low floodplain level III (3–6 m high), 7 — Holocene terraces 8–10 m high, level IIB–D, 8 — Vistulian terrace 10–12 m, level IIA, 9 — Vistulian terrace 15 m, level I, 10 — fluvioglacial level (Sanian glaciation), 11 — Vistulian terrace with banket of Holocene alluvial loams, 12 — Vistulian loess, 13 — Holocene alluvial fan, 14 — eolian sands with dunes, 15 — Sanian glacial till

In the 1980s, in several valleys of the Carpathian foreland were documented channels sloping below the present ones, dated in the Vistula valley > 13 ka BP (Kalicki 1991) and in the San valley > 15 ka BP (Klimek 1992). To the north of the main elevation of the South Polish Upland the dissection of the highest Vistulian terrace fills started at least 2–5 ka before the maximum extent of the ice sheet (Rotnicki 1987, Harasimiuk 1991).

In the early 1990s L. Starkel (1995) looked for documents from the Wisłoka valley and performed supplementary investigation (in the project KBN no 6–0783–91–01–P2) documenting that the lateglacial fills go deeper into the present-day channel. The first borings on 10–11 m high terrace at Wola Żyrakowska showed at 1.5–4 m depth silty-clay deposits with organic intercalations dated at >33,500 BP and 21,300 ± 1,200 BP. This indicate that the upper sandy-gravel units are younger.

## AIM AND METHODS OF RESEARCH

The still open question on the sequence of Vistulian evolution of the Wisłoka valley needed further studies. And thus the co-operation of two research teams begun. In 1995 L. Starkel continued the exploration and made next 8 borings of the 10–12 m high terrace, the study was performed within the framework of the IGCP project No 253 (partly sponsored by the KBN grant no 6P–202–034–07). Detail grain size analyses were made by J. Sala in the laboratory of the Geomorphology and Hydrology Department. Two further radiocarbon datings were kindly made by A. Pazdur from the Radiocarbon Laboratory in Gliwice. J. Boratyn and S. Brud from the Geological Enterprise carried parallel detail geological mapping for the Geological Survey. Six samples from three profiles sampled in detail on the right bank of Vistula were also dated in Gliwice: 2 samples by radiocarbon method (by A. Pazdur) and 4 samples by TL method (by A. Bluszcz). K. Mamakowa from the Botanical Institute elaborated several samples from the cores at 11 m terrace in Wola Żyrakowska and a single sample from the eastern 15 m terrace, and compared them with the previous diagrams from Brzeźnica.

Ryc. 1. Mapa geomorfologiczna badanego odcinka doliny Wisłoki (na podstawie mapy L. Starkel i in. (1982) i zdjęcia geologicznego J. Boratyn i S. Brud). 1 — koryto Wisłoki z odsypami, 2 — krawędzie teras, 3 — paleokoryta dobrze zachowane, 4 — paleokoryta słabo zachowane, 5 — płytkie obniżenia paleokoryt, 6 — niska równina zalewowa, poziom III (3–6 m wys.), 7 — terasy holoceńskie 8–10 m, poziom IIB–D, 8 — vistuliańska terasa 10–12 m, poziom IIA, 9 — vistuliańska terasa 15 m, poziom I, 10 — poziom fluwioglacjalny (zlodowacenia sanu), 11 — terasa vistuliańska z pokrywą holoceńską glin aluwialnych, 12 — less vistuliański, 13 — holoceński stożek napływowy, 14 — piaski eoliczne z wydmami, 15 — glina morenowa zlodowacenia sanu

We express our thanks to all who helped us in the field work, in various laboratory works as well as in preparation of figures and English text.

## TERRACE SEQUENCE AT THE VALLEY TRANSECT NORTH OF DĘBICA

In the described reach we made the transect, that crosses all main terrace units described in the Wisłoka valley (Fig. 1, 3). Following the monograph (Alexandrowicz et al. 1981) and papers in this domain (Starkel et al. 1982, Starkel 1995) the following terraces were distinguished:
terrace I — 15 m high with single dunes, developed on the right bank of Wisłoka, rising upto 20 m to the east and to the south slowly submerged under the blanket of deluvial and proluvial sediments,
terrace IIA — 10–12 m high, flat with remains of shallow parallel channels,
terrace IIB — 8–10 m high, bordered by large paleomeanders lateglacial in age (Mamakowa, Starkel 1974, Alexandrowicz et al. 1981, Starkel and Granoszewski 1995),
terrace IIC–D — 8–10 m high with many remains of small radius paleochannels, sometimes separated in 2–3 various fills, Holocene in age (Starkel [in:] Alexandrowicz et al. 1981),
terrace III — 3–6 m high floodplain, formed in last two centuries (cf. Klimek and Starkel 1974).

In the present paper we concentrate on the structure of two terrace levels: I and IIA.

## THE SUB-QUATERNARY RELIEF OF THE WISŁOKA VALLEY FLOOR

The sub-Quaternary substratum elevated about 200–210 m a.s.l. near Tarnów Hills forms a 25–30 m high scarp, sloping towards the Wisłoka valley. Under the alluvial cover of the valley floor, the height of the Miocene substratum fluctuates between 163 and 184 m a.s.l., e.g. goes down to 20 m below the present river channel. In this surface two different zones may be distinguished (Fig. 2). Between Tarnów Hills and the present river course, a relatively flat erosional plain extends. The plain slopes gently to the north–east, and is elevated to 178–174 m a.s.l. with an outlier rising to 180–184 m a.s.l. near Żyrakow village. A wide incised valley runs to the south–east. The axis of the valley slopes from 175 metres near the outlet of the left tributary Czarna to the east and then, turns towards the north to 163 m a.s.l.

In the earlier reconstructions (Laskowska-Wysoczanska 1971, Starkel [in:] Alexandrowicz et al. 1981) only the fragments of this buried valley were recognised, and its either more latitudinal or longitudinal directions were suggested.

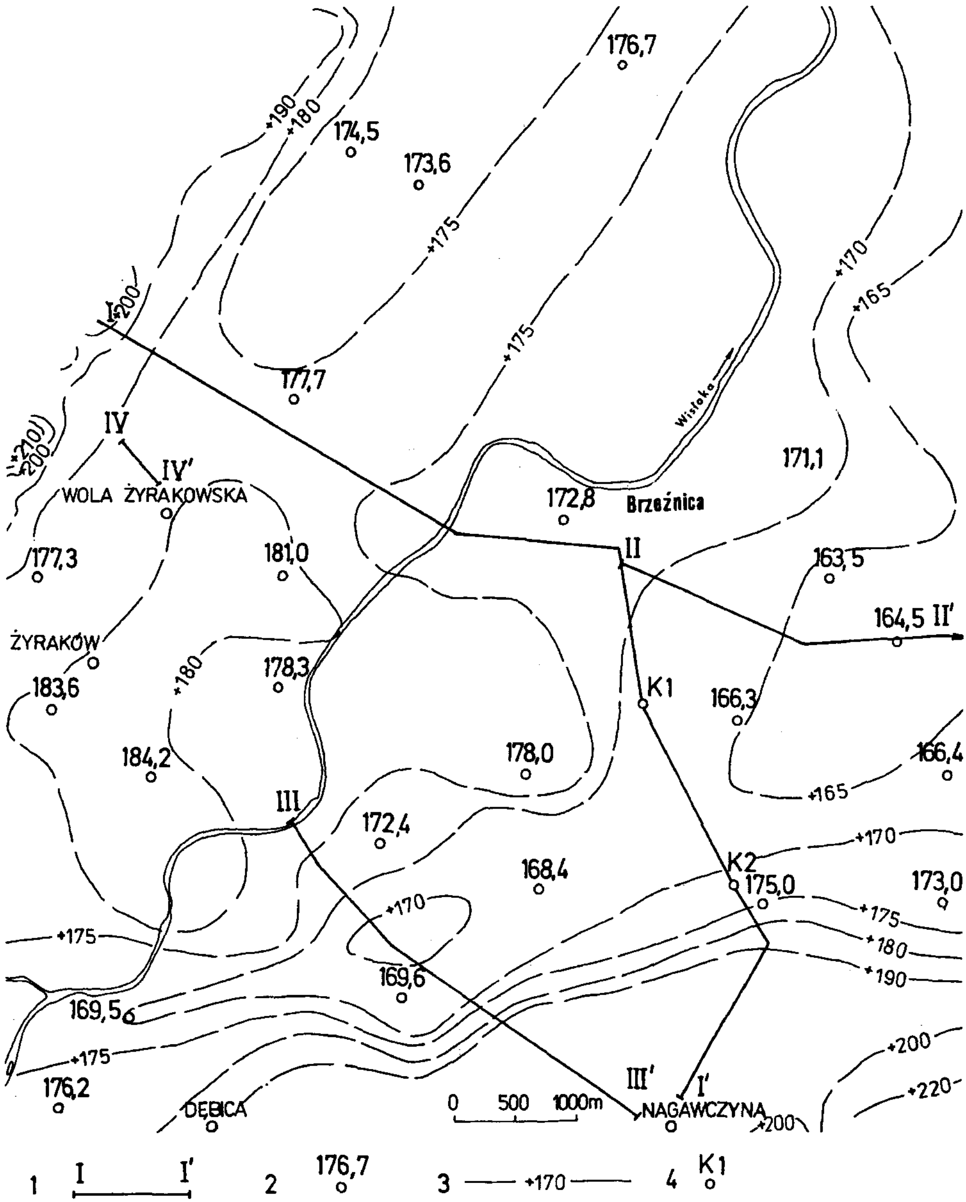


Fig. 2. Map of sub-Quaternary surface (by J. Boratyn and S. Brud). 1 — cross-sections (Fig. 3, 5, 6), 2 — elevation of Miocene deposits in borings, 3 — isohypses of Sub-Quaternary relief, 4 — K1 and K2 borings presented on Fig. 3 and 4

Ryc. 2. Mapa rzeźby podczwartorzędowej (oprac. J. Boratyn i S. Brud). 1 — linie przekrojów (ryc. 3, 5, 6), 2 — wysokość stropu osadów miocenu w wierceniach, 3 — izolinie rzeźby podczwartorzędowej, 4 — wiercenia K1 i K2 przedstawione na ryc. 3 i 4

The formation of this deep valley was connected with erosion either during the great (Masovian) interglacial (Starkel [in:] Alexandrowicz et al. 1981) or during the Eemian interglacial (Laskowska-Wysoczańska 1971). Distinct erosional benches, existing the valley sides, suggest a very complex origin and a complex age of the sub-Quaternary relief beneath the sequence of the Vistulian and Holocene terraces.

To the south, the Miocene substratum rises to the elevation of c. 192–194 m a.s.l. forming an erosional socle of the glacifluvial terrace connected with an outflow along the Carpathian front during the recession of the Sanian ice sheet (Starkel 1957).

## LITHOLOGY AND AGE OF RIGHT-BANK TERRACE I

The right-bank middle terrace elevated 12–15 meters above the mean water level of the Wisłoka river is separated from the Holocene lower terraces by a scarp being up to 5 m high. The transition to the glacifluvial terrace in the south is masked by the Holocene loams of small tributaries or deluvial covers (Fig. 1). The terrace plain descends from 195 m a.s.l. east of Dębica to 190 m near Brzeźnica in the north, where its surface is modulated by fields of eolian sands culminating in small dunes. Closer to the Carpathian escarpment the deluvial-proluvial cover is thinner and the exposed denuded surface is built of several meters of glacifluvial gravels and sands with patches of glacial till, discovered during the new geological survey in recent years. These remains of the ice marginal outflow during the retreat of Sanian glaciation are partly buried by the Carpathian foothills or under the deluvial glacis.

The lowest member of the Quaternary fill under the 15 m terrace is represented by coarse gravels 2–5 meters thick, filling the deepest part of buried valley elevated 163–170 m a.s.l. The admixture of sand is rather low. The petrographic composition of gravels in borings K1 and K2 (Fig. 3, 4), different from glacifluvial sediments and Holocene fills, shows the dominance of flysch sandstones (64–73%) and quartz (12–17%) with admixture of igneous rocks (3–6%), Palaeozoic sandstones (4–10%), flints (3–6%) and hornfels (2–5%). In the heavy mineral spectrum prevail the grains of syderite (73–77%), also present are micas and chlorite (7–13%), opaque ore minerals (3–7%), garnet (3–5%) and zircon (2%). The analysis of the roundness of grains 0.5–1 mm in diameter in Powers' scale indicates presence of 60–70% of sharpedged and semi-sharpedged grains, 20–30% of semi-rounded and rounded grains and less than 10% of very sharpedged and well rounded grains. The content of quartz in this fraction reach 75–85%, the others represent aggregates of quartz, iron concretions, dark silica rocks, feldspars. The described gravel member was formed probably at the transition Eemian–early Vistulian (cf. Laskowska-Wysoczańska 1971), but one may not exclude that it might represent the

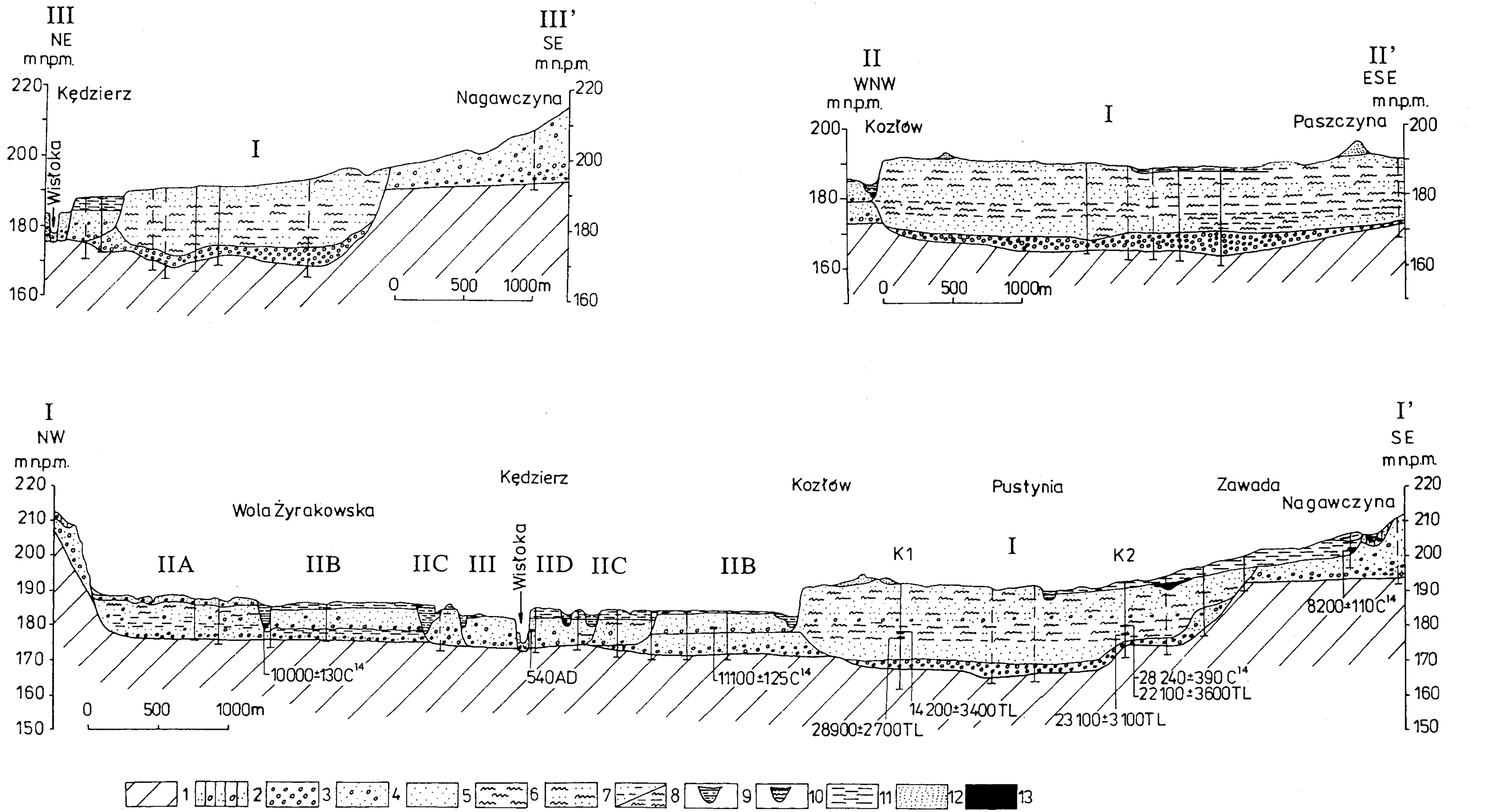


Fig. 3. Geological cross-sections I–I', II–II' and III–III' (compiled by J. Boratyn and S. Brud). 1 — Miocene substratum, 2 — glacial till from Sanian glaciation, 3 — gravel, 4 — sand with gravel, 5 — sand, 6 — silty muds, 7 — sandy muds, 8 — sandy clays interbedded with silty clays, 9 — paleochannel fills, 10 — muddy fills of tributary valleys, 11 — alluvial loams, 12 — eolian sand, 13 — peat

Ryc. 3. Przekroje geologiczne I–I', II–II', III–III' (opr. przez J. Boratyn i S. Brud). 1 — podłoże mioceńskie, 2 — glina zwałowa ze zlodowacenia sanu, 3 — żwiry, 4 — piaski ze żwirami, 5 — piaski, 6 — mułki pylaste, 7 — mułki piaszczyste, 8 — iły na przemian piaszczyste i pylaste, 9 — wypełnienia starorzeczy, 10 — wypełnienia mułkowe bocznych dolin, 11 — gliny aluwialne (mady), 12 — piaski eoliczne, 13 — torf

Masovian interglacial (Starkel 1972). Similar gravels were indicated by Laskowska-Wysoczańska (1971) in the N–S transect at the eastern border of discussed area, but this is probably the same valley bending towards north.

Over these gravels was deposited the 17–21 meters thick (to the north in Pustków even 27 m) very monotonous series of laminated silts indicated with more sandy or clayey beds and fine sands, described for the first time by W. Laskowska-Wysoczańska (1971) and L. Starkel (1972). Their upper member consists of fine and coarser sands. These sediments were recognised in detail in two cores K1 and K2 during elaboration of new detail geological map, as well as in several tens of hydrological borings. The fraction 0.5–1.0 mm contains 50–80% of quartz and small amounts of quartz aggregates, feldspars, silica rocks, and Fe concretions. Most of quartz grains are rounded. At the depth of 11–12 m in both borings the sandy-gravely horizon is marked. Below it were made several TL and $^{14}C$ datings and one palynological spectrum. The dating of wood remains from the sandy layer at 13.8 m depth in the boring K2 (Fig. 3 ) gave the age 28,240 ± 390 BP. However the TL datings from the silty horizons in the same K2 profile fluctuate about 22.1 ± 3.6 ka BP (13.9 m depth) and 23.1 ± 3.1 ka BP (15.9 m depth) and in other K1 boring are even more dispersed: 14.2 ± 3.4 ka BP (14.1 m) and 28.9 ± 2.7 ka BP (16.2 m). All of them indicate the upper pleniglacial age. The palynological expertise only tells that this sediment represent a cold pleniglacial phase.

In the former undercutting SW of Brzeźnica village in the 14–15 meters high profile (Mamakowa and Starkel 1974) were exposed the following members (from bottom to the top): 0–2 m gravels and sands, 2–4 m silty clays with unclear lamination, 4–9 m rhythmically bedded silts and fine sand with lenticles of organic matter, 9–14 m cross bedded fluvial sands with gradual transition to fine eolian sands on the top. From the layer c. 5.5 m above the water level were taken 4 samples dated by $^{14}C$ method and two oldest gave an age 27,805 ± 330 BP and 28,200+1,350–1,100.

In the adjacent 9 m high terrace under the lateglacial channel deposits there is buried the 4 m high outlier of older alluvial fill — with remains of paleochannel organic sediments dated between 35 and > 48 ka BP and interstadial flora (Mamakowa and Starkel 1974, Alexandrowicz et al. 1981).

The plain of 15 m high terrace is slowly rising to 195 m a.s.l. to the south, where it is buried under 1–4 m thick blanket of loamy alluvial deposits, formed during the local floods of Wielopolka and other small streams draining the margin of the Carpathian foothills. At several places under these loams are buried Holocene peats. In Nagawczyna (3 km east of Dębica) on the flat alluvial fan of small creek beneath 5 m of alluvial loams were found sandy organic muds overlying next 5 meters of loams and 11 m of fluvioglacial coarse sediments. This organic horizon was dated at 8,200 ± 110 BP, what correlates very well with other localities with distinctly expressed phase of frequent flooding about 8,400–7,700 BP (Niedziałkowska et al. 1977).

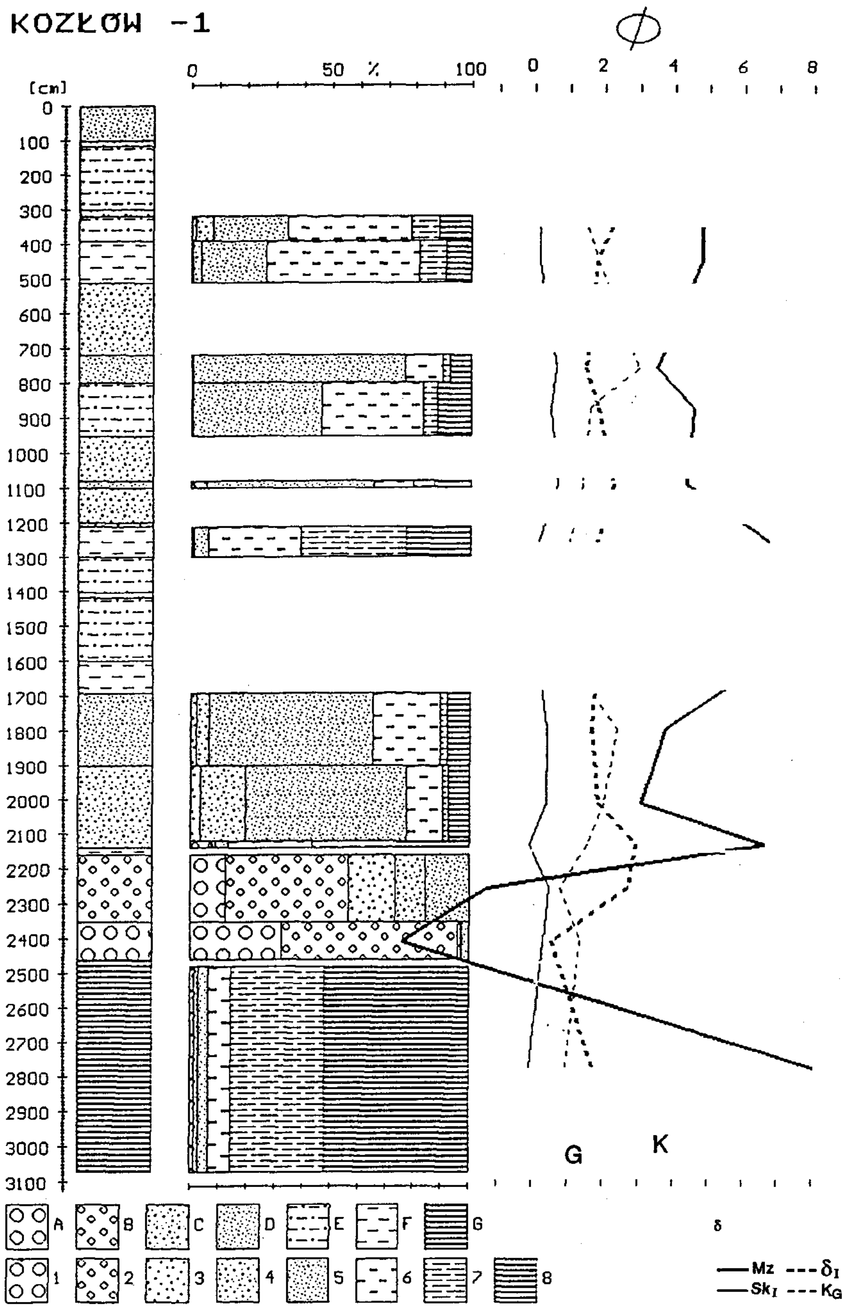


Fig. 4. Lithology and granulometry of the profile Kozłów 1 (K1) on the cross-section I (by J. Boratyn and S. Brud, compiled by A. Lasek). A — coarse gravel, B — fine gravel, C — middle-grain sand, D — fine sand, E — sandy-silt mud, F — silty mud, G — clay; 1 — coarse gravel, 2 — mid- and fine gravel, 3 — coarse sand, 4 — middle-grain sand, 5 — fine sand, 6 — coarse silt, 7 — fine silt, 8 — clay, Mz — mean grain size, $\delta_I$ — standard deviation, $Sk_I$ — skewness, $K_G$ — kurtosis

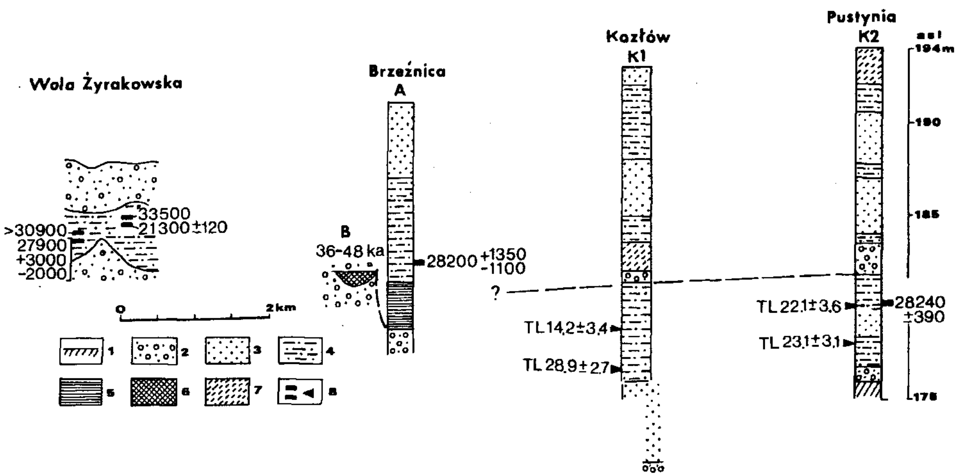


Fig. 5. Main Vistulian localities on the W–E transect including Brzeźnica elab. by K. Mamakowa and L. Starkel (1974). 1 — Miocene substratum, 2 — gravels with sand, 3 — sand, 4 — sandy mud, 5 — clay, 6 — organic sediments, 7 — Holocene alluvial loams, 8 — position of radiocarbon datings and TL datings

Ryc. 5. Główne stanowiska vistulianu na przekroju W–E włączając Brzeźnicę, opracowaną przez K. Mamakowa i L. Starkel (1974). 1 — podłoże mioceńskie, 2 — żwiry z piaskiem, 3 — piasek, 4 — mułek piaszczysty, 5 — ił, 6 — osady organiczne, 7 — holoceńskie gliny aluwialne, 8 — położenie datowań radiowęgla i TL

The all datings and palynological records support the opinion about the Vistulian pleniglacial age of the whole sequence (Fig. 5). But the Brzeźnica profile informs about existence of more than one fill in similar elevation. The existence of gravely horizon at 11–12 m depth in borings K1 and K2 suggests that the sediments below should represent older members of the last pleniglacial. Therefore all the TL datings as well as one radiocarbon date seem to be rejuvenated. In any case the dating 14.2 ± 3.4 ka from 14 m depth can not be accepted if in the Brzeźnica exposure the horizon several meters higher is not younger than 28 ka BP.

Ryc. 4. Litologia i granulometria profilu Kozłów 1 (K1) na przekroju I (oprac. J. Boratyn i S. Brud, zestawienie A. Lasek). A — gruby żwir, B — drobny żwir, C — średnioziarnisty piasek, D — drobnoziarnisty piasek, E — mułek piaszczysto-pylasty, F — mułek pylasty, G — ił; 1 — gruby żwir, 2 — średnioziarnisty i drobny żwir, 3 — gruby piasek, 4 — średnioziarnisty piasek, 5 — drobnoziarnisty piasek, 6 — gruboziarnisty pył, 7 — drobnoziarnisty pył, 8 — ił; Mz — średnie uziarnienie, $\delta_I$ — odchylenie standardowe, $Sk_I$ — skośność, $K_G$ — kurtoza

## LITHOLOGY AND DATING OF TERRACE IIA AT WOLA ŻYRAKOWSKA

The 11–12 m high terrace occupies the western margin of the Wisloka valley floor. It is 1–2 km wide, elevated 188–189 m a.s.l. As it was stated earlier (Starkel 1995) the terrace near the valley side is covered by deluvial loam upto 1 m thick. Closer to the river, fragments of the terrace semicircular scarp are connected with large Younger Dryas paleomeanders (Starkel and Granoszewski 1995). Upto 0.5 m deep, discontinuous strips of the channels, characteristic of the braided pattern, are visible on the flat surface.

This level is built of 9–12 m thick alluvial sediments overlying the relatively flat surface of the Miocene clays, slightly higher than the present water level of the Wisłoka river. In the alluvial sequence, five various members may be distinguished. Three of these members have been reached by the recent borings and have been subjected to examination.

At the base, there is a 1–3 m thick gravel body, followed by mixed series of silty-sandy deposits or clays, upto 7 m thick at some places. Yet, along the transect line there are two main, silty-clay horizons separated by middle gravels. On the 305 m long transect (Fig. 6) with 8 borings, these middle gravels are dissected and several depressions are upto 2–3 m deep. The deepest part is elevated to 181.9 m a.s.l. and the upper silty-clays in their highest position reach 185.6 m. The discussed upper silts are laminated, with peaty intercalations, characteristic of extensive backswamps filling up an old channel system. The organic layers from 3 borings were sampled for palynological analyses (WŻ 4, 18, 22).

The 2–3 m thick, top member consists of layers of sands and gravels to 3 cm in diameter, usually with a thin lag horizon at the base. This clear, erosional surface fluctuates by about 1 m and evidences the strips of braided pattern on the surface.

The first radiocarbon datings of organic matter from WŻ 4 have shown a distinct inversion (upper > 33,500 BP, lower one 21,300 ± 1,200 BP) and suggest an interpleniglacial age. A phase of erosion was followed by upbuilding of the channel deposits, long before the lateglacial was exposed on a much lower level (Starkel 1995). The repeated two datings from WŻ 22 (Fig. 7) show the inversion again: > 30,900 BP and below 27,900 ± 3,000 BP. Comparing the elevations of organic horizons above the mean water level between 15 m high terrace in Brzeźnica (Mamakowa and Starkel 1974) and Wola Żyrakowska we find that their elevations are similar and the organic lenticles occur on both the banks (184 m a.s.l. in Brzeźnica and 184–185 m a.s.l. in Wola Żyrakowska).

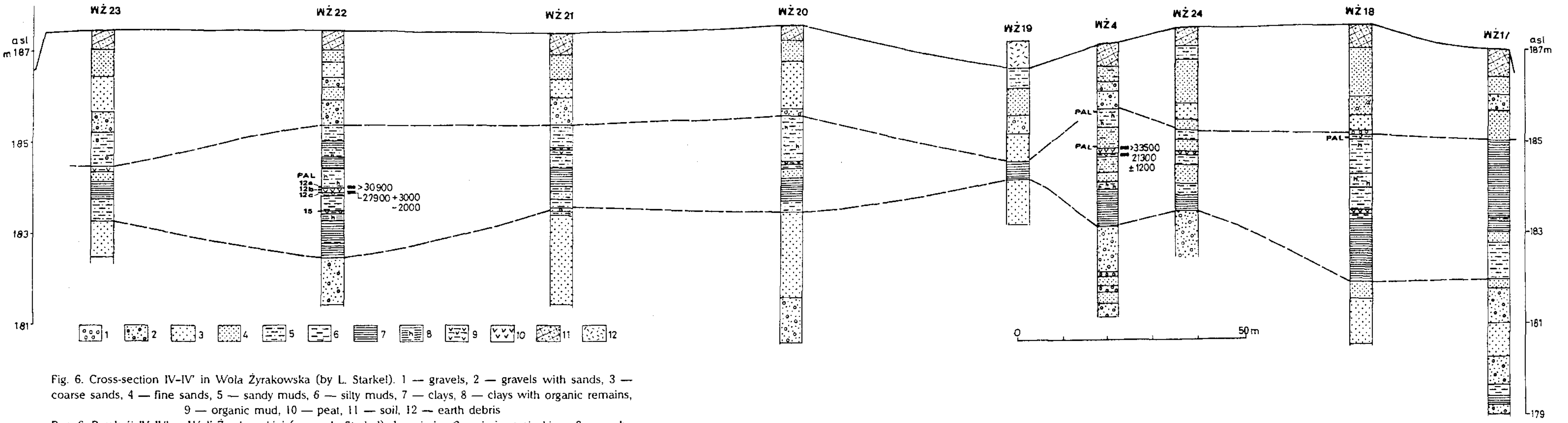


Fig. 6. Cross-section IV–IV' in Wola Żyrakowska (by L. Starkel). 1 — gravels, 2 — gravels with sands, 3 — coarse sands, 4 — fine sands, 5 — sandy muds, 6 — silty muds, 7 — clays, 8 — clays with organic remains, 9 — organic mud, 10 — peat, 11 — soil, 12 — earth debris

Ryc. 6. Przekrój IV–IV' w Woli Żyrakowskiej (oprac. L. Starkel). 1 — żwiry, 2 — żwiry z piaskiem, 3 — grube piaski, 4 — drobne piaski, 5 — mułki piaszczyste, 6 — mułki pylaste, 7 — iły, 8 — iły z materiałem organicznym, 9 — mułek organiczny, 10 — torf, 11 — gleba, 12 — nasyp

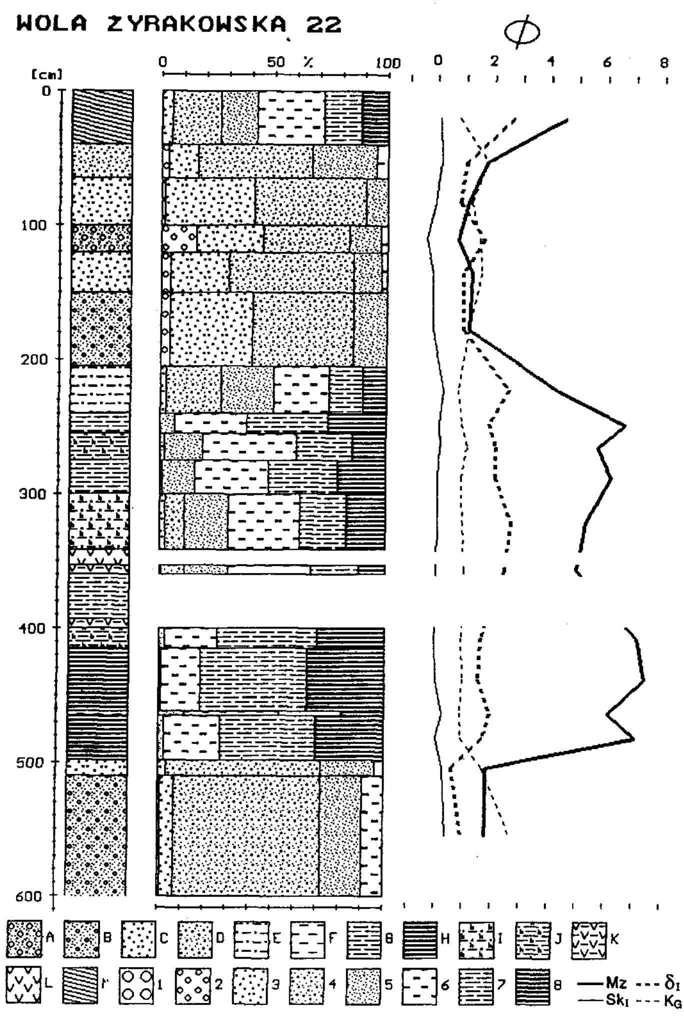


Fig. 7. Profile WŻ 22 on the 11 m high terrace IIA at Wola Żyrakowska (elab. by L. Starkel and J. Sala). A — coarse gravel, B — sand with gravel, C — coarse sand, D — middle-grain sand, E — sandy-silty loam, F — silty mud, G — clayly mud, H — clay, I — sandy organic mud, J — clayly organic mud, K — peaty mud, L — peat, Ł — humus horizon (soil), 1 — coarse gravel, 2 — fine gravel, 3 — coarse sand, 4 — middle-grain sand, 5 — fine sand, 6 — coarse silt, 7 — fine silt, 8 — clay, Mz — mean grain diameter, $\delta_I$ — standard deviation, $Sk_I$ — skewness, $K_G$ — kurtosis

Ryc. 7. Profil WŻ 22 na terasie 11 metrowej IIA w Woli Żyrakowskiej (oprac. L. Starkel i J. Sala). A — żwir gruby, B — piasek ze żwirem, C — gruby piasek, D — średnioziarnisty piasek, E — glina pylasto- piaszczysta, F — mułek pylasty, G — mułek ilasty, H — ił, I — mułek piaszczysty, organiczny, J — mułek ilasty, organiczny, K — mułek torfiasty, L — torf, Ł — gleba (poziom humusowy), 1 — gruby żwir, 2 — drobny żwir, 3 — gruby piasek, 4 — piasek średnioziarnisty, 5 — piasek drobnoziarnisty, 6 — pył gruboziarnisty, 7 — pył drobnoziarnisty, 8 — ił, Mz — średnia średnica ziarna, $\delta_I$ — odchylenie standardowe, $Sk_I$ — skośność, $K_G$ — kurtoza

## RESULTS OF POLLEN ANALYSIS

Pollen analysis was applied to study seven samples from three profiles at Wola Żyrakowska: four samples from profile 22, two from profile 4 and one from profile 18. Apart from them one pollen spectrum was also obtained from profile K1 at Kozłów.

The nature of the pollen spectrum of sample 15 from Wola Żyrakowska profile 22 lets us infer that the organic mud from which this sample was taken (depth: 3.94–3.98 m) had been deposited in a period when a parkland landscape predominated in this area. Dominant were undoubtedly various types of open communities with prepondering sedge swamps, wet and moist meadows with which pollen of *Caltha* type, *Chamaenerion*, *Comarum*, *Filipendula* (if *F. ulmaria*), *Polygonum bistorta/viviparum*, *Polygonum viviparum*, *Valeriana* and others is associated. There were also communities corresponding to shrub tundra, with dwarf birch (*Betula nana*) and shrub willows (*Salix glauca* type), and perhaps also some thickets with green alder (*Alnus viridis*). Pollen of cf. Dryas is an important indicator of grasslands.

The communities of dry habitats are represented apart from *Gramineae* pollen also by such taxa as *Artemisia*, *Centaurea jacea* type, *C. scabiosa* type, *Elymus* type, *Rumex acetosella* type, and *Chenopodiaceae*. Stands of trees, chiefly with stone pine (*Pinus cembra*), larch (*Larix*) and birches (*Betula alba* type) were scattered in that open landscape, but single specimens of *Populus*, *Sorbus* and tree willows (*Salix pentandra* type) may have occured as well.

The pollen spectra of samples 12c, 12b, 12a from profile 22 and 8 and 4a from profile 4 point to the domination of a considerably more open landscape at the time when this series of organic muds was being deposited. The high pollen values of herbs (81.6%–90.1%), dominated by pollen of *Cyperaceae* and *Gramineae* but with a very large variety of taxa, evidence that floristically very rich sedge-grass and grass communities prevailed at that time. In addition to the plants found in spectrum 15, some other indicator taxa of wet and moist but also dry habitats occur in these samples. As regards wet and moist habitats, they are *Chrysosplenium*, *Hydrocotyle*, *Knautia*, cf. *Lotus*, *Menyanthes*, *Parnassia*, *Plantago major*, *Rumex acetosa* type, *Sanguisorba officinalis*, *Saxifraga oppositifolia* type, *S. nivalis* type, *S. hirculus* type, *Succisa* and *Urtica dioica*, whereas *Armeria* B type, *Helianthemum nummularium* type, *Jasione*, *Plantago media* come from drier habitats. The shrubby communities with *Betula nana*, *Salix* (*Salix glauca* type), *Alnus viridis*, *Sambucus racemosa*, *S. nigra*, *Juniperus*, *Hippophae* and *Ephedra* (*E. distachya* type and *E. fragilis* type) were an essential element of this landscape.

A proportion of tree pollen 9.9%–18.4% would allow the statement that it was a period of the domination of treeless vegetation. However, in spite of sporadic pollen grains, it seems that at least single specimens of *Larix*, *Populus*, *Sorbus* and tree willows (*Salix pentandra* type) were present in situ or in the close vicinity. The same may be true of *Pinus cembra*, especially in the period represented by sample 12a from profile 22, in which the proportion of its pollen comes to 6.4%. Pollen of the remaining trees surely comes from the long-distance transport or from redeposition. The possibility of redeposition is suggested by a vestigial presence of Pre-Quaternary sporomorphs in sample 12c from profile 22 and in sample 4a from profile 4.

The single pollen spectrum from profile 18 shows a somewhat different vegetation. The high herbaceous pollen values (53.7%), with the predominance of *Cyperaceae*, evidence that at the time when sediment was deposited, the open habitats were covered by sedge swamps, floristically relatively poor and by communities of a grassland nature, where *Selaginella selaginoides* found favourable conditions. Grassland communities were however of minor importance. *Sphagnum* spores comparatively often noted and the presence of *Betula nana* pollen may evidence that at that time raised bogs originated, in which dwarf birch (*Betula nana*) found suitable habitats. A significant role played willow communities. So high pollen values of *Salix glauca* type (26.9%) suggest that the river activity, forming sand and gravel banks — provided favourable conditions for the shrub willow communities at that time. The activation of the river is also indicated by the presence of *Dinoflagellata* cysts and several metamorphous Pre-Quaternary sporomorphs.

The presence of *Linum catharticum* type, *Artemisia* and *Chenopodiaceae* pollen proves the occurrence of drier habitats in the surroundings, supporting, among others, steppe-like grassland communities.

Nevertheless, as regards trees, there grew single specimens of *Larix*, while the sporadic occurrence of tree birches (*Betula alba* type) and *Pinus cembra* cannot be utterly excluded either. Pollen of other trees comes from the long--distance transport or from the redeposited Tertiary sediments.

The spectrum from Kozłów K1 shows 76.9% of herbaceous pollen, among which *Cyperaceae* (46.2%) and *Gramineae* (14.4%) dominate. The diversity of taxa is not large but still there are some indicator taxa of wet meadow communities, among them such as *Sanguisorba officinalis* and *Filipendula* (to be sure, *F. ulmaria*). Among tree pollen, the presence of five well-preserved pollen grains of *Pinus cembra* is conspicuous.

On the basis of this spectrum may be suggested that the sediment from which it comes was deposited in a period of the domination of an open landscape with patches of floristically poor moss-sedge-grass swamps in that region. The percentage values of tree pollen (23.1%), characterized by a very low frequency, are too low to permit the inference that they represent the trees growing in situ. This pollen probably comes from the long-distance transport, or — in spite of good preservation — from redeposition. The high proportion of redeposited Pre-Quaternary sporomorphs (43%) and the presence of *Dinoflagellata* cysts point to the unsteadiness of the substratum covered by very scanty vegetation and the intensive fluvial processes.

## STRATIGRAPHIC POSITION OF FOSSIL FLORAS

All the pollen spectra from Wola Żyrakowska and the spectrum from Kozłów K1 permit the statement that the sediments from which they come were deposited in the cold stage. This conclusion is supported by both the type of vegetation with dominating open communities and a series of indicator taxa of arctic-boreal communities (*Selaginella selaginoides*, *Betula nana*, etc.) as well as the occurrence of communities with *Pinus cembra*, *Larix* and *Alnus viridis*, which now occur by or above the timber line in the Carpathians.

The nature of vegetation unfortunately has not diagnostic characters of a definite glacial period.

The $^{14}C$ date > 30,900 BP from the level of sample 12a of profile 22 rules out the Vistulian part younger than the middle part of the Denekamp Interstadial and the date > 33,500 BP from the level of sample 8 of profile 4 rules out the whole Denekamp and a part of the cold section between the Denekamp and Hengelo Interstadials. Anyway, these dates do not allow us to assume the origin of this sediment from the Vistulian. Such a suggestion is supported by a comparison of these spectra with the results of palynological studies from Brzeźnica near Dębica (Mamakowa and Starkel 1974) and Jasło-Bryły (Mamakowa and Wójcik 1987, Mamakowa and Wójcik in prep.). Organic deposits from both these sites are being investigated in a continuous manner and the $^{14}C$ dates (and TL at Jasło-Bryły) permit refering these deposits to the Pleni-Vistulian.

The results of the palynological analyses from Wola Żyrakowska and Kozłów show that the flora of these regions included many such taxa as those occuring at Brzeźnica B (see Fig. 8) and Jasło-Bryły. The percentage relations between the pollen values of trees and shrubs and herbs suggest that the organic mud from which sample 15 from profile 22 comes may represent the Hengelo Interstadial, the age of which is assumed to be about 36–39 ka or some older units of Pleni-Vistulian. Samples 12c, 12b, 12a from profile 22 and 4a and 8 from profile 4 presumably represent a cold oscillation between the Hengelo and Denekamp Interstadials. It may well be however that all these samples represent the older part of the Pleni-Vistulian just as does the profile from Brzeźnica B, from which a series of datings performed by M. Geyh in the 70s lie between 35 and > 48 ka BP (Kowalkowski et al. [in:] Alexandrowicz et al. 1981).

The pollen spectrum from sample 7a from profile 18 has no counterpart in the pollen sequence from Brzeźnica and Jasło-Bryły. The position of this sediment directly under gravels in the top part of this terrace lets us assume the age of this sample as younger than that of the top samples from profiles 22 and 4 (Fig. 8).

The pollen spectrum from a depth of 14 m at Kozłów K1 points to considerably poorer vegetation than that represented by samples from profile 4 and samples 12c–a from profile 22. At the same time, this vegetation is also poorer than that represented by the pollen spectrum from the 15 metre terrace at Brzeźnica A, from a thin peat layer dated to 27,805 ± 330 BP. It is probable that the sediment from Kozłów comes from the older part of the Pleni-Vistulian, which agrees with its position about 6.5 m below both the sediments at Brzeźnica A and the Pleni-Vistulian sediments at Brzeźnica B.

## DISCUSSION

The lithology, datings and palynological records support the opinion about the Vistulian age of the 20 m thick sequence (Fig. 3, 5). However, the Brzeźnica profile informs about that more than one interpleniglacial fill exist at similar elevations (Mamakowa and Starkel 1974, Starkel 1994). The presence of gravel horizon at the depth of 11–12 m in boreholes K1 and K2 suggests that the sediments below may represent the older members of the last pleniglacial. Therefore, all the TL datings and one $^{14}C$ date in K1 seem to be rejuvenated. Date 14.2 ± 3.4 ka BP from the depth of 14 m is particularly difficult to accept, if in the Brzeźnica outcrop the horizon, not younger than 28,000 BP, is located at least 5–6 m higer.

Comparing all the profiles on the right bank of the Wisłoka river and all the cores in Wola Żyrakowska, one might conclude that the interpleniglacial period was characterised by a very diverse vegetation, both in space and time, as well as by several changes in the vertical position of the river channel, its lateral shifting and avulsions.

The final stage of formation of the 15 m high terrace ended several millenia after 28 ka BP. The channel deposits inbedded over the 11 m high left-bank terrace (IIA) represent probably the fragment of the maximum cooling and the braided pattern (Fig. 6, 7). The next deep incision preceded the formation of the late Vistulian paleomeanders on terrace IIB.

Our present records show how difficult is to work out a more detail stratigraphy of the alluvial sequences in the Carpathian foreland, where continuous shifting of the channels and intercalations are not sufficiently supported by datings. Both the radiocarbon and TL datings, the latter to much higher degree, give reduced ages. Nevertheless, the existing records on the thick Vistulian sequencies in the Wisłoka valley show a perspective for finding of more complete sequences of fills with well dated horizons in future investigations.

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## STRESZCZENIE

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### STRATYGRAFIA VISTULIAŃSKICH SERII ALUWIALNYCH W DOLINIE WISŁOKI NA PÓŁNOC OD DĘBICY

Nowe wiercenia w obrębie dna doliny pozwoliły rozpoznać szczegółowiej budowę vistuliańskich teras wys. 15 i 10–12 m n.p. Wisłoki. Wykonane nowe analizy pyłkowe i datowania $^{14}C$ wykazały związek szeregu ogniw z interpleniglacjałem, w którym w warunkach przewagi zbiorowisk bezleśnych, następowały liczne zmiany położenia koryta zarówno wysokościowe, jak i w planie. Terasa 15 metrowa kryje w sobie ok. 20 metrową złożoną serię pleniglacjalną, natomiast terasę 11 metrową budują osady korytowe rzeki roztokowej, ścinające starorzeczne osady interpleniglacjalne.

Większość dat radiowęgla jak i wszystkie datowania TL wykazują wiek zaniżony, co wskazuje na potrzebę znacznej ostrożności przy interpretacji stratygraficznej poszczególnych datowań.