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# VISTULIAN TERRACE WITH LOESS COVER IN THE VISTULA VALLEY NEAR NOWE BRZESKO (SOUTHERN POLAND)

Abstract

The paper presents the trial of new genetic, age and accumulation conditions interpretation of the 20 m thick Vistulian deposits building loess terrace in the Vistula valley (35 km east of Cracow). Discovered during drillings peat layer 1 m thick and situated above fossil soil has been dated with the help of radiocarbon method. Sedimentological researches supplemented with palaeontological analyses and radiocarbon dating make the base for stratigraphy of the distinguished elements of deposits.

The lowest situated river channel alluvia come from the Lower Plenivistulian. Lower series of deposits which are mainly dusty with organic matter and peat were formed on flood plain and they represent extra channel facies of meandering or anastomosing river. They were formed on the area of park tundra under the wet climate conditions. These deposits have been dated at 31–28 ka BP and they represent Denekamp interstadial.

Since ca. 28 ka BP, increase of fluvial accumulation took place and then the river entirely left the plain. Fossil soil dated for 23 ka BP developed and then loesses were deposited. These deposits represent the upper series of the loess terrace. Change of alluvial sedimentation into loessic one probably means that erosion occurred in the river valley or/and decrease of high water reach in the result of climatic aridization. Malacological sequence points out that loess accumulated both in subaeral conditions and in small water reservoirs of thermokarst type in periglacial zone. In the Holocene chernozem and loess deluvia were formed.

## INTRODUCTION

Terraces with loess cover are commonly the best preserved forms among polygenic ones, from the Last Glaciation (Vistulian) in river valleys. They are common in river valleys on loess areas of Małopolska Upland making the system of several terraces described as middle terraces

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(JAHN, 1956; JERSAK *et al.*, 1992). In the Wieprz valley 20 m thick series of middle terrace was connected with river aggradation in periglacial conditions of either Middle Plenivistulian (HARASIMIUK, SZWAJGIER, 1985) or the Upper Plenivistulian (JERSAK, 1991). At the beginning of the Upper Plenivistulian erosion in the valley bottom and loess accumulation on the terrace occurred (HARASIMIUK, 1991). In the premontane segment of the San valley in Przemyśl region, the middle terrace (loess terrace) is built of thick series of younger loess (Vistulian) lying on older loess and alluvia from the Warta Glaciation (ŁANCZONT, 1994).

In the Carpathian foreland, along the left bank of the Vistula valley, east of Cracow, there is a terrace well visible in landscape terrace. It has been distinguished and described by some authors as the higher terrace level, overflood terrace, middle terrace or loess (ŁOZIŃSKI, 1909; TYCZYŃSKA, 1968; STARKEL, 1972; JERSAK, 1976; GĘBICA, STARKEL, 1987; PŁONCZYŃSKI, 1993; LINDNER, SIENNICKA, 1994; GĘBICA, 1993, 1995). The width of the terrace reaches 2 km and it rises ca. 15 m above the river bottom. The main element of that terrace are dusty deposits which were thought to be eolian material deposited in water environment (ŁYCZEWSKA, 1948; JERSAK, 1976) or loess deluvia (POŻARYSKI, 1956). It has been lately stated that they were accumulated by slowly flowing flood waters (ALEXANDROWICZ, JERSAK, 1991; JERSAK *et al.*, 1992). Sands and gravels building the lower part of the terrace are of fluvial origin. They were dated for Middle Polish Glaciation (TYCZYŃSKA, 1968), Early Vistulian (KOZŁOWSKI *et al.*, 1970) and Lower Plenivistulian (JERSAK, 1976; MYCIELSKA-DOWGIAŁŁO, 1978). Sands and river silts are probably stratigraphical equivalent of sands with gravels and silt occurring in the southern edge of the Vistula valley (Fig. 1 A). In some localities on the same terrace there were "underloess" silts with fossil flora dated by radiocarbon from more than 40 000 years BP to 25 000 years BP, e.g. Zator (KOPEROWA, ŚRODOŃ, 1965), Nowa Huta (MAMAKOWA, ŚRODOŃ, 1977), Ściejowice (MAMAKOWA, RUTKOWSKI, 1989), Opatowiec (ALEXANDROWICZ, JERSAK, 1991). Frequent inversions of radiocarbon dating occurring at these sites and imperfection of thermoluminescent method make sometimes divergences in dating of deposits and sedimentation changes in pleniglacial series of the Last Glaciation.

Researches on relief and age of young Quaternary deposits existing in the zone of the northern edge of the Vistula valley have been undertaken within the researches carried out by Department of Geomorphology and Hydrology of the Mountains and Uplands, Polish Academy of Sciences in Cracow (research task B.1.2. "The Quaternary Evolution of the Vistula Valley in Sandomierz Basin").

The basic material was collected during the detailed geomorphological mapping and during 8 geological drillings, 12–17 m deep which were made in the years 1995–97. The boreholes were drilled with the help of "Geomeres" gadder (patent of the Quaternary Research Institute UAM in Poznań). Samples of deposits for sedimentological and palaeontological analyses were taken with φ=8 cm spiral plummet.

In some boreholes on the terrace in Nowe Brzesko there was discovered a layer of peat nearly 1 m thick which together with the upper fossil soil makes the base for valley deposits stratigraphy of the Vistula stage on that area. Interpretation of the collected materials takes into account obtained by the drillings geological profiles. They were supplemented with the results of granulometric analyses made with the help of laser method, graphic ratios of granulation by FOLK and WARD (1957) and contents of carbonates (M. Sc. A. LASEK) and the results of palaeobotanic analyses (prof. K. SZCZEPANEK) and malacological (dr A. SAŃKO). Within the grant no. 6. PO4E 10 "Geochronology of the Upper Quaternary of Poland" (the head prof. A. PAZDUR) 5 radiocarbon datings were done. On the basis of the obtained analyses results and earlier published materials (GĘBICA, 1995; ALEXANDROWICZ, GĘBICA, 1997) an attempt of new interpretation of origin, age and palaeogeographic conditions of dusty deposits accumulation, building the terrace in Nowe Brzesko, was undertaken.

## LOCALITIES AND MORPHOLOGY OF THE LOESS TERRACE

Stated during the drillings series of Pleniglacial organic material covered with silty deposits is located on the loess terrace in Nowe Brzesko (35 km east of Cracow centre). Nowe Brzesko profile I/8 was assumed as key borehole for the whole site; it is located 1.1 km west of Nowe Brzesko centre and 40 m south of Cracow–Koszyce road (φ=50°07'45"N, λ=20° 23'00"E; Fig. 1 B).

The loess terrace in that place is from 0.2 to 1.3 km wide and 13–17 m high above the Vistula river channel. The edge of the terrace 10 m high is undercut by the Holocene oxbows. They are within the flood plain 3–4 m high above the river channel. Parts of the terrace with rectilinear edge were probably shaped by the braided river at the end of the Last Glaciation. Along the edge of the terrace there are accumulation loess banks 1–1.5 m high. They mark primary border of the loess cover and the extent of the terrace in the valley bottom. Its slightly inclined area (1–3°) becomes smooth underslope plain covered with deluvia. Above, there spreads out hillslope of Działy Proszowickie belonging to Małopolska Upland. The hillslope is covered with continuous loess mantle.

Younger loesses (Vistulian) make the essential part of loess cover of Działy Proszowickie. They are lying on older loess (Middle Polish Glaciation) or even on the older Quaternary deposits or directly on the

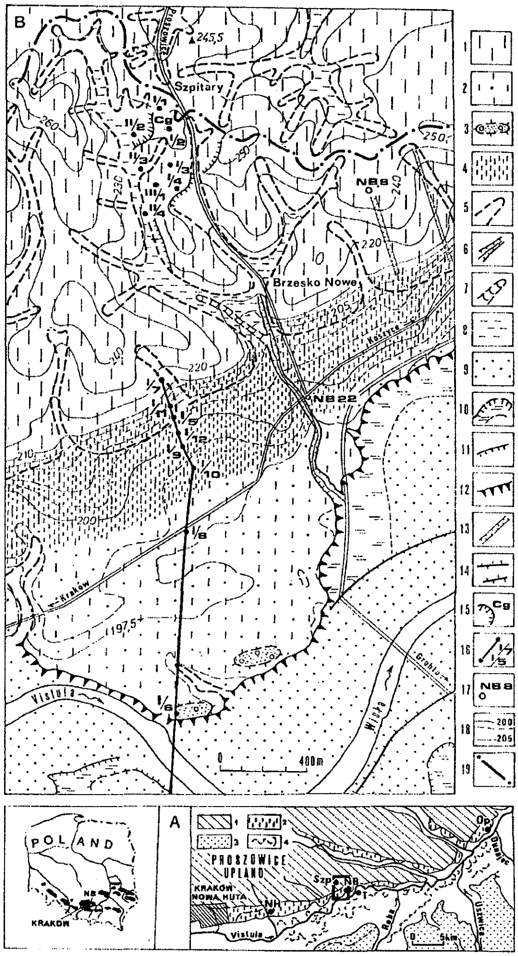


Fig. 1. A – Situation of Nowe Brzesko profile against a background of distribution of loesses in Poland and geomorphology of the western part of Sandomierz Basin

1. loess-cover mantling older relief (4–27 m thick); 2. Pleniglacial terrace, loess covered; 3. Vistulian terraces and alluvial fans; 4. Late Glacial and Holocene floodplains with paleochannels. Localities described in text: N.B. – Nowe Brzesko; Szp.– Szpitary; T – Trawniki; N.H.– Nowa Huta; Op – Opatowiec

B – Geomorphological map of the surroundings of Nowe Brzesko site.

1. plateaus and slopes covered by Vistulian loesses and older loesses; 2. Pleniglacial terrace plain, loess-covered; 3. natural loess embankments; 4. footslope covered by washed loess (deluvia); 5. denudational valleys (dellen); 6. V-shape valleys; 7. loess gullies; 8. flat floored of dry valleys; 9. floodplain; abandoned channels; 11. erosional edges, below 6 m; 12. erosional edges, 6–10 m; 13. road cuts; 14. flood-control embankments; 15. brickyard pit; 16. line of the geological transect with numbers of drillings; 17. archival bores; 18. contour lines; 19. watershed between Vistula and Szreniawa basins

Miocene deposits. Thickness of loess is different and varies from some to several metres with maximum thickness 21 m (archival borehole NB 8) or even 27 m (Płonczyński, 1993). In the region of Szpitary brick field which is located on the plateau 255 m a.s.l. thickness of younger loess is only 4.5 m. However, the older loess cover in that region is 12 m thick (Gębica, 1998).

Slope of Proszowice Plateau in Nowe Brzesko region is dissected by valleys, Vistulian in age, reaching 0.5 km in length and by system of dry valleys 1–2 km long. The main parts of valleys have flat accumulation bottoms, which in their lower parts are dissected by the Holocene ravines. At valley outlets in the contact zone with plain, there are lacking talus cones which can suggest that their deposits have been put in the loess terrace roof (Fig. 1 B). In the present relief of loess terrace on its wide surfaces there are elongated basins and closed depressions. The first, according to JERSAK and others (JERSAK *et al.*, 1992) are connected with braided river channels, the next – with thermokarst. Some elongated depressions e.g. those described from Śmiłowice region, make continuation of side valleys ending in the plain. They produced huge sand and silt series which builts present roof of the loess terrace (GĘBICA, 1995).

On the right bank of the Vistula below Niepołomice, two meander hills occur – Trawnik and Skała near Grobla. They are residual patches of the loess terrace separated from it in the result of erosional activity of the Vistula after changing its run into northen part of the valley (STARKEL, 1967; GĘBICA, STARKEL, 1987).

## SEQUENCE AND LITHOLOGY OF DEPOSITS

Sequence of deposits ca. 20 m thick, distinguished in the terrace cross-section consists of the following series (description of series from the bottom upwards, Fig. 2).

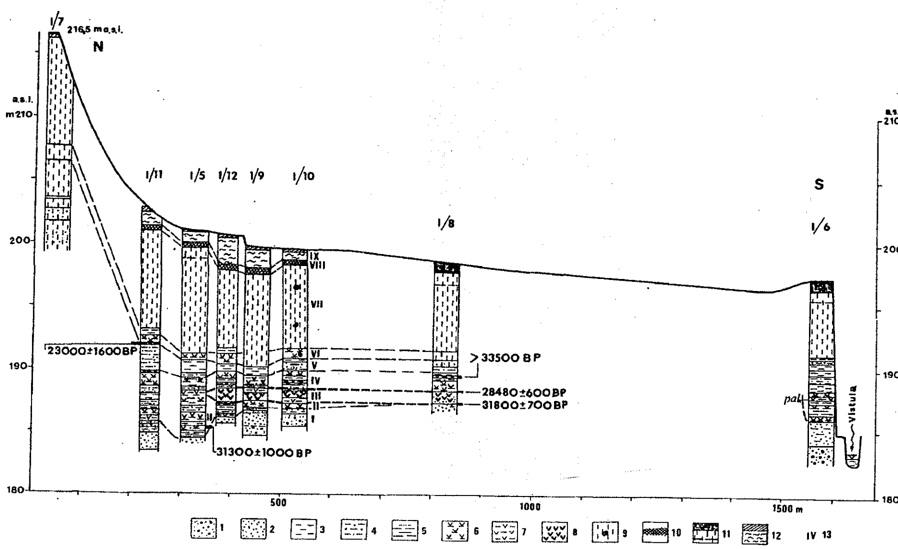


Fig. 2. Geological cross-section and radiocarbon datings of terrace with loess cover in the Vistula valley near Nowe Brzesko

1. sand with gravel; 2. sand; 3. silt; 4. sandy silt; 5. clay; 6. silt with organic matter; 7. peaty mud; 8. peat; 9. loess with malacofauna shells; 10. chernozem soil (fossil); 11. chernozem under cultivation; 12. deluvia; 13. number of series

Sandy – gravel series (I) – contains sands and gravels 4–7 m thick lying on the Sarmatian clays. In the drilling profiles containing the alluvia roof, there is noticeable a sequence of the size decreasing up the profile material: sands with gravel till 3 cm in diameter become differently grained sands and then silty sands. Denivelations within the top of the series reaching 2.5 m are probably connected with existence of fossil river channel on the alluvial plane. Sands are poorly sorted and they do not present features of eolian abrasion. On the surface of quarz grains there are clear marks of chemical weathering (oral information from M. Sc. B. Woronko from Sedimentology Laboratory U. W). It confirms short transportation and poor abrasion of sandy material.

Mineral – organic series (II) – consits of laminated dust, sandy and argillaceous dust, grey with dispersed oganic matter. These deposits are deprived of carbonates and their thickness in the old river channel is from 0.5 to 2.2 m (in the borehole NB I/5). The analysed deposits present great diversity of granulation ratio. Bedded sequences with smaller and smaller, up the profile, particles are probably connected with seasonal flooding of the plain during high water (Fig. 3).

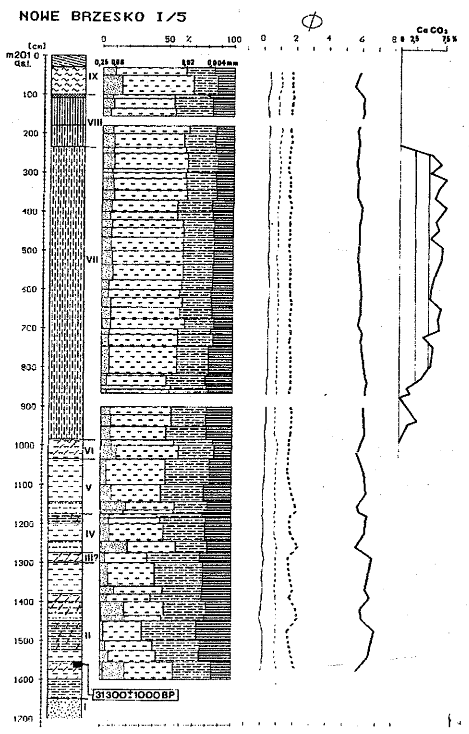


Fig 3. Nowe Brzesko I/5 profile. Lithology, granulometric composition, grain size indices after Folk and Ward (1957) and carbonate content (Scheibler method). Explanations of signs see Fig. 4

Organic series (III) – is made of peat and peaty silts found in four boreholes. Thickness of peat varies from 0.65 m (borehole NB I/9) to 1.05 m (borehole NBI/12). Peat is dark brown, strongly decomposed with admixture of mineral material. In the borehole NB I/8 peat is situated directly on river channel alluvia.

Mineral – organic series (IV) – contains dusty-clayey deposits 1.25–2.75 m thick, grey and greyish-olive. These deposits are completely deprived of carbonates or sometimes they are slightly carbonated. In silt striped with organic matter there are insertions of peaty silt. The deposit is poorly and very poorly sorted. Great participation clay of fraction, 18–47%, and increase of medium diameter of grains up to 8φ indicates significant share of extra channel sedimentation in oxbows (profile NB I/6) or in post flood basins.

Mineral series (V) – is made of bedded deposits with great textural diversity. These are: dust, sandy dust and dusty sands, grey in colour, without organic matter. Thickness of these deposits is from 1 to 3 m. They are non-carbonate or slightly carbonate in the top part. They were deposited by slowly flowing flood waters in the zone close to river channel banks (profile NB I/6) and adjoining flood plain (profile NB I/8; Fig. 4).

Fossil soil (VI) – dusty and argilaceous dusty deposits with organic matter, with clear signs of pedogenesis. Soil is greyish-brown or grey without carbonates or slightly carbonate with malacofauna shells. In profiles NB I/7 and NB I/8 it is marked as the level of loess decalcification. Mean thickness of fossil soil on the terrace is 0.6 m.

Cover dust (loess, VII) series – dusty deposits with massive structure, thickness 6–8 m. Grain size distribution analysis of the dusty deposits, made by laser method, showed content of: fraction 0.06 mm 46–56% (predominant componenent), clay fraction (below 0.004 mm) 13–21% and sandy fraction (above 0.06 mm) – 4–11%. Share of mentioned fractions is comparable to granulometric composition of the typical loess. It is carbonate loess and contains numerous malacofauna shells. Mean diameter of grains corresponds to fine grained dust and increases up the profile from 6.2φ to 5.6φ, also sorting becomes much better, from 1.9φ to 1.6φ. Values of skewness and kurtosis increase as well (Fig. 3). In the eolian environment the described above parameters confirm increase of dynamics and strength of wind which were also stated in other areas built of dusty covers (HARASIMIUK, 1986, NIEDZIAŁKOWSKA, SZCZEPANEK, 1993–94). Increase of carbonate contents up the profile from 1% to 8% $CaCO_3$ confirms increase of humidity of the substratum and increase of climate aridization. Loess in the top is changed by the soil forming processes and is decalcified. In profiles NB I/9 and NB I/12 thickness of decalcification reaches 9 m which can be connected with poor flow in natural depressions at the foot of the slope presently covered with deluvia.

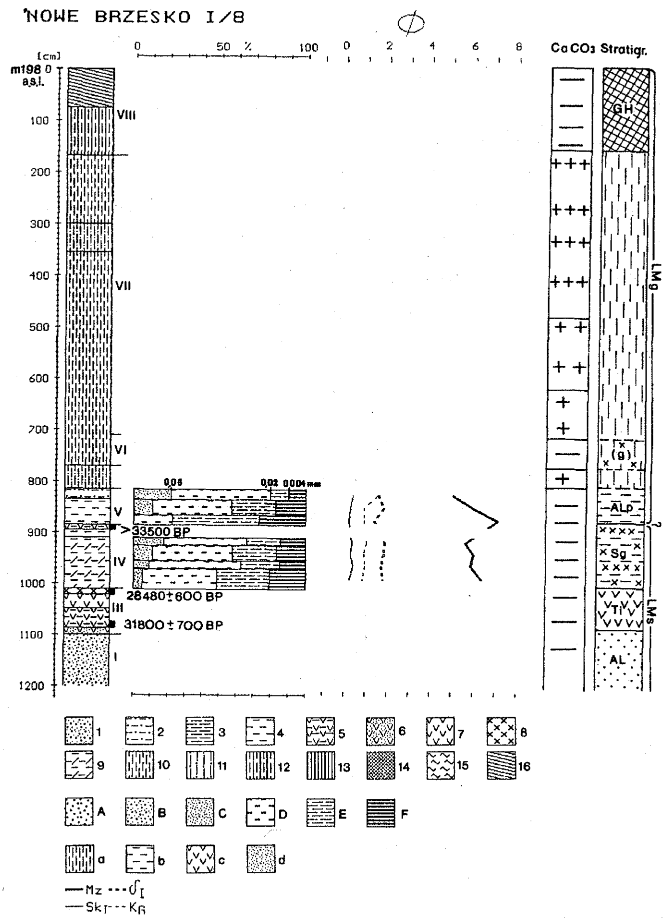


Fig. 4. Nowe Brzesko I/8 profile. Lithology and chronostratigraphy of the Pleniglacial deposits

Lithology: 1. medium sand; 2. sandy silt; 3. clay; 4. silt; 5. peaty mud; 6. peat with sand; 7. clayey peat; 8. peat; 9. silt with organic matter; 10. loess; 11. sandy loess; 12–14. chernozem soil (fossil): 12. illuvial horizon (B); 13. transitory horizon (A1/B); 14. humus horizon ($A_1$); 15. loess deluvia; 16. chernozem soil under cultivation. Granulometric composition and Folk-Ward's parameters distribution: A – coarse sand ($M_z$= (1 to +1φ); B – medium sand (+1 to +2φ); C – fine sand ($M_z$=+2 to +4φ); D – coarse and medium silt ($M_z$=+4 to +6φ); E – fine silt ($M_z$=+6 to +8φ); F – clay (>8φ); $M_z$ – mean diameter; $\delta_I$ – standard deviation; $Sk_I$ – skewness; $K_G$ – kurtosis; Carbonate content (approximately): "+++" – strong and long emission of $CO_2$ (>5% $CaCO_3$); "++" – short and strong emission of $CO_2$ (3–5% $CaCO_3$); "+" – weak emission of $CO_2$ (1–3% $CaCO_3$); "–" – missing of emission of $CO_2$ (<1% $CaCO_3$); Stratigraphy: letter symbols of stratigraphic units of loesses and soil units: L – loess; M – younger; g – upper; s – middle; G – soils with well developed genetic horizons; H – Holocene soil; sg – soil sediments; (g) – symptoms of the development of pedogenesis. Graphic and letter signatures of sediments: a – non-weathered, carbonate loesses; b – overbank facies (Alp); c – interstadial peat (Ti); d – channel facies (AL.)

Chernozem (fossil, VIII) – the Holocene soil, non-carbonate, with dark grey horizon of humus layer, 0.4–0.55 m thick, and yelow-brown illuvial zone. At the foot of the hill chernozem is covered with deluvia. In boreholes NB I/8 and NB I/6 soil appears on the surface and thickness of humus horizon reaches 0.95 m. Depth of decalcification of loess connected with development of soil processes in the Holocene is 1.7–3.3 m.

Loess deluvia (IX) – greyish-brown dust, not bedded with admixture of sand and humus material, non-carbonate. Thickness of deluvia ranges from 0,6 to 2.2 m. Deluvia were formed in the result of soil washout from the slope mainly during intensive development of agriculture. Fragments of enamel ceramics and bricks found in these deposits confirm that at least part of the deposits were formed in the Mediaeval Ages and even later (GĘBICA, 1995).

## PLANT COMPOSITION IN THE LOCALITY SURROUNDING

Deposits samples for pollen analysis come from two boreholes: Nowe Brzesko I/8 (11 samples from 10.11 to 10.98 m of depth) and Nowe Brzesko I/6 (5 samples from 9.15 to 9.29 m of depth) (Fig. 2, 5). All samples were boiled in potassium hydroxide and then hot hydrofluoride and Erdtman acetolise were used. There were defined and counted from 100 to 900 grains of pollen on the area of 150 sq. mm of microscopic slide.

The results of microscopic analyses from NB I/8 borehole were presented in pollen diagram prepared with the help of computer programme POLPAL (Fig. 5). Countings were made on the basis of sum of trees, bushes and herbs pollens (100%), excluding pollens of swampy and spore plants. Moss spores (*Bryales*) and coenobia of algae from *Pediastrum* kind were not counted though in some samples they were present in great number. In the sample NB I/8–13 the following taxa were defined: *Pediastrum kavraiskyi* (the most common), *P. boryanum* var. *Pseudoglabratum* (common), *P. cornutum* (sporadic), *P. boryanum* var. *longicorne* (occasional) and *P. integratum* (very occasional).

Prof. K. MAMAKOWA from Botany Institute of Polish Academy of Sciences in Cracow made all designations of algae from *Pediastrum*. Defined taxa of *Pediastrum* indicated for the presence of periodical olitrophic or poorly eutrophic water reservoires and severe climatic conditions (borealsubarctic).

Taxonomic and quantity composition of pollen spectra (Fig. 5) point out that in vegetation of the closest vicinity of the studied localities, prevailed communities of herbaceous plants with a small share of trees (17–36%) and they had wide habitat requirements. These were: *Pinus silvestris* (pine), *Pinus cembra* (Swiss stone pine), birch trees (*Betula* s. *"albae"*), *Betula nana* (dwarf birch), *Larix* (larch), *Salix "alba"* (willow) and maybe also *Alnus* (alder) and *Picea* (spruce). It concerns mainly the samples from borehole NB I/8 except for the roof samples (I/8–11). Spectra of samples from the NB I/6 borehole are clearly of non forest character. The significant feature of spectra from the I/8 borehole (except for the roof sample) is great share of grass pollen (*Gramineae*) clearly exceeding share

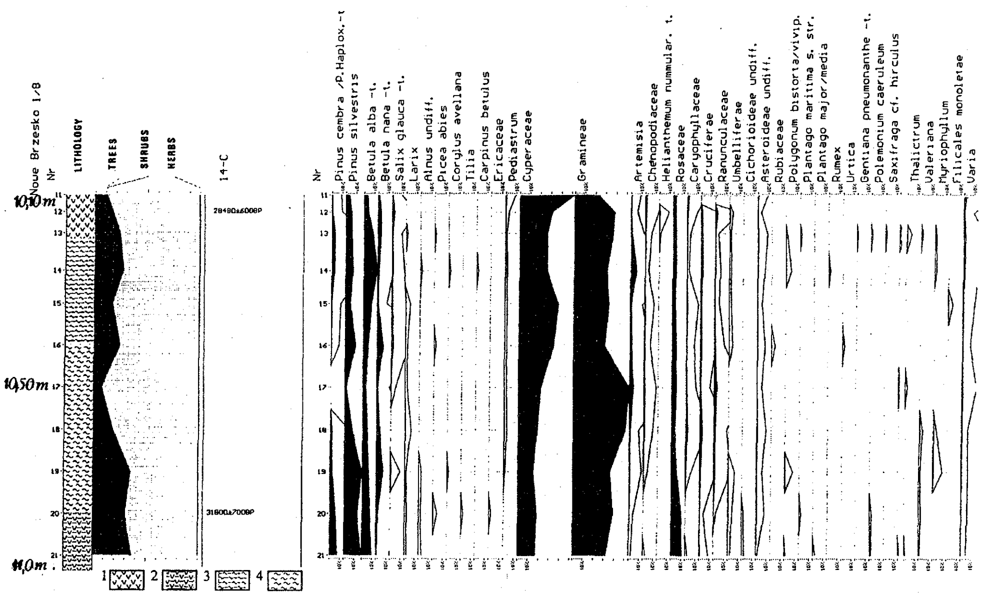


Fig. 5. Palynological diagram showing the tundra vegetation development during the deposition of peat in Nowe Brzesko I/8 profile.

1. peat; 2. peat with sand; 3. peat with clay; 4. peaty mud

of cyperaceous (*Cyperaceae*), which MAMAKOWA and ŚRODOŃ (1977) interpreted as the fact of greater density of vegetation. The presence of sporomorphes from the kinds *Ranunculaceae (Ranunculus flammula* t., *R. trichophyllus* t.), *Cruciferae, Rosaceae (Comarum* t., *Filipendula), Polygonum* and others point out for poor tree cover and small density, and great diversity of herbaceous communities of wet biotopes.

In spectra from the NB I/6 borehole and the roof sample from NB I/8–11 drillings the number of pollen clearly decreases especially of tree pollen (10–20%), coenobia of *Pediastrum* were very rare, more common are spores of brown moss, share of grass pollen (*Graminaeae*) decreases as well whereas cyperaceous pollen (*Cyperaceae*) increases. Taxonomic diversity of pollen spectra decreased too. It may confirm that plant cover became less continuous and climate of the area might be more continental. It is reflected in lithology, from peat to clayey-dust deposits. Floristic composition and position in the profile of analysed samples and radiocarbon dating of peat from NB I/8 profile point out that the age of analysed peat can be estimated at Denekamp Interglacial for which GEY and ROHDE (1972) give the time from 33 200 to 28 800 years BP.

## RESULTS OF THE MALACOLOGICAL ANALYSIS

Samples for malacological analyses were taken from NB I/10 borehole. Shortened lithological description is as follows:

| | |
|---|---|
| 0.00–0.80 m | light brown dust (deluvium), HCl– |
| 0.80–1.90 | fossil chernozem, HCl– |
| 1.90–7.85 | yellowish grey dust changing into yellow-grey dust with red stripes and shells (loess), HCl+++/HCl++ |
| 7.85–8.45 | slightly clayey dust, grey, changing towards the base into steel-grey material with dispersed organic matter and malacofauna shells (fossil soil), HCl+ |
| 8.45–9.60 | bedded dust and dusty sands, grey and olive in colour, HCl+/HCl– |
| 9.60–10.38 | grey dust with organic matter stripes, HCl– |
| 10.38–10.48 | peaty silt with clay, HCL– |
| 10.48–10.80 | clayey dust, dark grey, with organic matter stripes, HCl– |
| 10.80–11.05 | bedded dusty sands and dust steel-grey, HCl– |
| 11.05–11.20 | peaty silt with clay, HCL– |
| 11.20–12.20 | dark brown peat well decomposed, changing into peaty silt with argil and greyish-brown dust with organic matter, HCl– |
| 12.20–12.60 | sandy dust steel-grey with organic matter, HCl– |
| 12.60–13.00 | fine grained dusty sand changing into sandy dust, dark grey |
| 13.00–14.00 | grey sand |

Samples for the analyses were taken from the following depths: 2.0–2.4 m, 3,6–4.0 m, 4.5–5.0 m, 8.1–8.4 m. In the first two samples there is a complex of mollusca consisting only of *Succinea oblonga elongata* SANDBERGER. That fauna points out for land environment of wet but not swampy meadows and steppes with different stage of shade. In the layear at 4.5–5.0 m depth besides shells of the above mentioned mollusca there are also water species *Gryaulus laevis* (ALDER) – the specimen characteristic for a very shallow, permanently filled with water – thermokarst lake. There were also present sporadic shells of ostracod (*Ostracoda*) living only in water environment. At the depth of 8.1–8,4 m in the layer of fossil soil there were numerous *Succinea oblonga elongata*, some shells of *Gyraulus laevis* (ALDER), occasional shells of ostracode, fragments of insects and remains of small rodents teeth.

Malacological analyses point out for changeable sedimentation conditions of loess dust. Fossil soil developed in a short time on the wet tundra which was getting more and more swampy. Dusty deposits occurring above the fossil soil were deposited in swampy tundra with existing sporadically shallow thermokarst lakes. These deposits can be interpreted as loess of water facies (facies of subaqual loess). Dust accumulation at the 2.0–4.0 m of depth took place in wet tundra environment. That loess can be included into loesses of subaeral facies. In the same terrace at Trawniki, in the top of loess there are nearly only water mollusca with predominant specimen *Gyraulus laevis* (ALEXANDROWICZ, GĘBICA, 1997). It confirms changing conditions of loess accumulation in the valley bottom. Mollusca complexes distinguished in valley loess reflect in the greater stage differentiation of local conditions and development and disappearing of water reservoirs than changes in climatic conditions (ALEXANDROWICZ, GĘBICA, 1997).

## RESULTS OF RADIOCARBON DATING

Samples of strongly disintegrated peat and peaty silt with mineral substances and fossil soil were radiocarbon dated. Reliable material which can be used for 14C concentration and dating in that type of deposits is insoluble part of a sample which is left after removing of soluble fractions in hydrochloric (HCl) and sodium hydroxide (NaOH). In practice, use of such a porocedure is sometimes difficult as the mass of the sample, after removing the HCl–SOL (fulvic acids) and NaOH–SOL (humic acids), is too small to make the measurements in the standard conditions. Such situation is typical while dating of samples obtained from plummets with a small diameter when the sample mass for dating is limited and practically impossible to be supplemented, like in the described above situation. So the introductory preparations of the Nowe Brzesko samples aimed at removing fulvic acids. The rest of organic matter was changed into carbon dioxide in which the concentration of 14C isotope was measured using gas proportional counting technique, counters L1 and L4 (PAZDUR, A., PAZDUR, M. F., 1986).

Comparison of dating results for NaCH–SOL and RES (humic) fractions as to the Holocene samples leads to the conclusion that there is a lack of systematic age difference of those fractions, showing only slightly less date dispersion in comparison to the values of laboratory errors (PAZDUR, 1982). It means that it is not necessary to use intensive extraction of humic acids. For samples older than ca. 20 ka BP it can be stated that particularly important for proper sample dating older than 30 ka BP is complete removal of humic acids in the process of hydrochloric solution treatment. It is required to measure age of NaOH–SOL and RES fractions at the same time if only the amount of organic matter is sufficient.

Five radiocarbon datings were made at Nowe Brzesko locality. In the profile NB I/8 stated as key section one, were done 3 radiocarbon datings. The conventional radiocarbon age of the sample taken from peat base from the depth of 10.8–10.87 m is 31 800 ± 700 years BP (Gd-10485) and the sample taken from peat top from the depth of 10.10–10.15 m is 28 480 ± 600 years BP (Gd-7813). Dating results show proper sequence in the profile. But the age of the sample from the insertion of peaty silt from the depth 8.85–8.95 m with a small content of organic matter is older than 33 500 years BP (Gd-9628). It should be stated that the obtained age of silt when the amount of organic carbon was small is accordant to the reach of dating possible to obtain on the measurement locality. Because the age Gd-9628 is infinished it cannot be excluded that the obtained age is the result of redeposition of older organic material. In the same terrace in Nowa Huta inversion of radiocarbon dating is explained by MAMAKOWA and ŚRODOŃ (1997) as humus substances rejunvenation by flowing underground waters. Age of silt sample with organic matter in the base of old river chanel filling in the I/5 profile, from the depth of 15.55–15.65 m is 31 300 ± 1000 years BP (Gd-10393). All the above presented results of radiocarbon datings correlated to the period of "Komorniki" soil development, distinguished in valley loess profiles (JERSAK *et al.*, 1992). Age of fossil soil (layer with signs of pedogenesis) from the NB I/11 profile, from the depth 10.60 – 10.75 m was determines as 23 000 ± 1600 years BP (Gd-9838). According to some scientists age of swampy soils dated by radiocarbon method is lowered (MARUSZCZAK, 1989). These soils paralleled with interstadial Denekamp should be corelated to the distinguished in West Europe (BEHRE, 1989) older interstadial Glinde or Oerel. Obtained with the 14C method results of the top and base of peat datings are not lowered – they are related to Denekamp insterstadial, for which GEYH and ROHDE (1972) estimated the period of lasting from 33 200 to 28 800 years BP.

Additional factor limiting precision of dating of deposits older than 20 ka BP are changes of radiocarbon concentration in atmosphere in the past, amounts of which and final reasons have not been recognized yet. That fact makes impossible calibration of radiocarbon dates of "old" samples and makes that the systematic error of radiocarbon age is higher than laboratory error. First systematic researches on these changes were made for 75 m core of laminated deposit from Suigetsu Lake in Japan which contains nearly all reach of radiocarbon chronometry (KITAGAWA, VAN DER PLICHT, 1998). Deposits from that lake seems to confirm earlier observed increase of differences between the calendar and radiocarbon age, back to 32 ka BP and the difference changed particularly in the 27–32 ka BP interval reaching value even of ca. 5 000 years.

## RECAPITULATION AND CONCLUSIONS

On the basis of observed in geological profiles sedimentation changes and radiocarbon dating, the process of fluvial and eolian accumulation on the Nowe Brzesko terrace is as follows (Fig. 6):

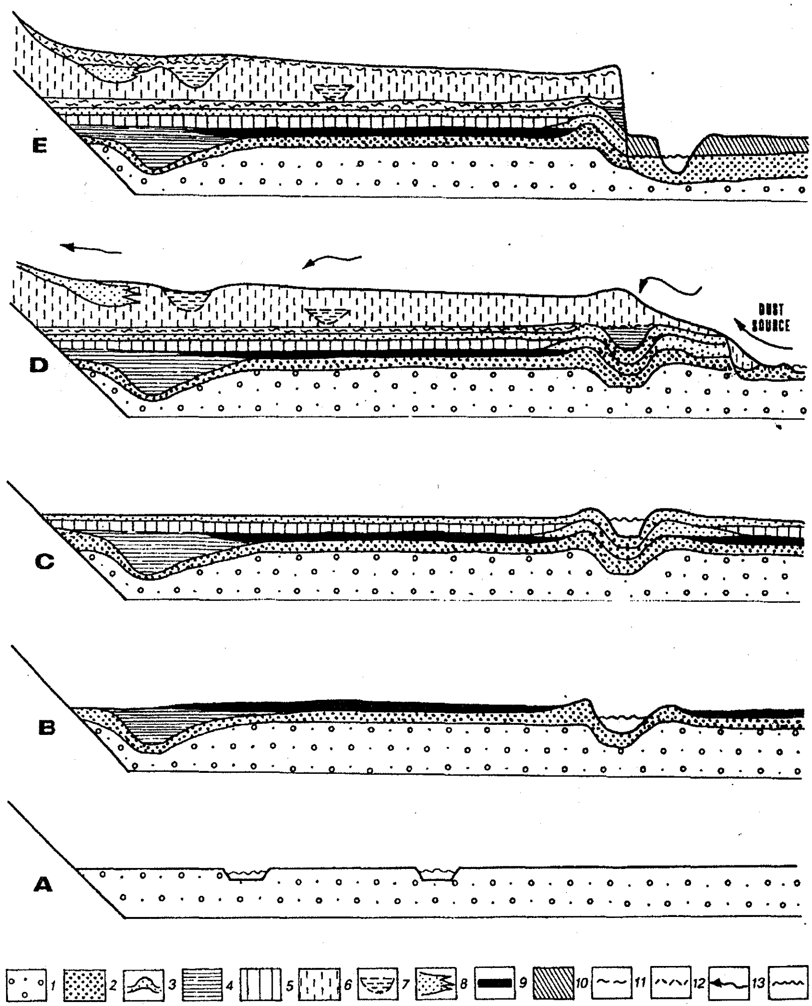


Fig. 6. Paleogeographical reconstruction of the fluvial depositional system and loess accumulation during the Middle and Upper Pleniglacial in the Vistula river valley, South Poland

A – Accumulation of sands and gravels in the braided river system during Lower Pleniglacial. B – Erosion and stabilization of river channel, peat growth starts in the floodbasin ca 31 ka BP; C – Overbank accumulation, levee and crevasse splay development in the anastomosing river system ca 28–23 ka BP. D – Erosion and stabilization of river channel, soil development ca 23 ka BP and loess accumulation on stabilized terrace surface till ca 14 ka BP; E – Development of chernozem in Early Holocene, soil erosion and deposition of loess deluvia in Middle Ages. 1. sand with gravel (channel deposits); 2. sand (channel deposits); 3. sandy silts (overbank deposits of levees and crevasse splays); 4. channel fill deposits; 5. silts (flood basin deposits); 6. loess; 7. thermokarst depressions; 8. alluvial fan deposits; 9. peat; 10. Holocene muds; 11. soils; 12. loess deluvia; 13. direction of winds; 14. water level

There have not been stated older than Plenivistulian deposits so it can be stated that erosion took place during Eemian interglacial or during the Early Vistulian. River sands and gravels accumulated during the Lower Plenivistulian and age of them was counted in Trawniki with the thermoluminescent method (GĘBICA, 1995) for 69 ± 9 ka BP (GdTL–251).

Left by the river alluvial plain and change of sedimentation type took place directly before 31 ka BP. From ca. 31 ka BP increase extra channel accumulation in oxbows and swampy-organic sedimentation in flood basins. Vegetation of swampy grass-sedge communities with small complexes of trees and bushes predominated in the landscape. Vegetation cover was dense and continuous. It points out for cool and rather wet climate. That period of time is interpreted as warmer Denekamp oscillation within Pleniglacial of Vistulian (STARKEL, 1980; KOZARSKI, 1991). Peat accumulation on the plain evidenced river channel stabilization. The river channel was probably of a meander or anastomosing character. Similar conditions of fluvial sedimentation from that times were noticed in river valleys in Holland and Germany (HUISSTEDEN, 1990; MOL, 1997).

On the turn of the Midle and Upper Plenivistulian (ca. 28,5 ka BP) peat was covered with extra channel silt. It points out for slow increase of fluvial sedimentation. During the phase of the Upper Plenivistulian (before ca. 23 ka BP) there is a clear increase of fluvial activity and extra channel sedimentation but without vegetation participation. In pollen spectra amount of pollen especially of trees decreases what can suggest loosening of plant cover and gradually increasing continentalisation of climate.

Changes of alluvial sedimentation into loess means probably that erosion began in valley bottom or/and reach of high water decreased in the result of slow increase of climate aridization (HARASIMIUK, 1991; STARKEL, 1995). In the result of erosion on the terrace the swampy soil developed, dated for 23 ka BP. Accumulation of the main series of loess is younger than 23 ka BP and probably lasted till ca. 14 ka BP what is confirmed by dating of younger loess in other localities in Cracow region (ALEXANDROWICZ, 1988, 1991; KONECKA-BETLEY, MADEYSKA, 1985).

Loess which is above the soil belongs to eolian facies. Loess sedimentation took place in continental climate – dry and cool. During loess deposition on the terrace, dimension of grains gradually increased and sorting of the material become much better. Carbonate contents was increasing. In the eolian environment it means increase of wind strength and confirms decrease of the ground humidity. Thickness and sedimentological variety of loess are, to a great extent, results of morphological variety of the valley bottom of that time. During seasonal high water, lower situated alluvial plain made good conditions for mud acumulation. During low water, dried deposits not covered with plants and rich calcium carbonate, underwent intensive deflation under periglacial conditions. In the edge zone of the terrace, within higher, close to the channel banks of the Vistula, elongated loess banks were accumulated by wind. The layer of loess in that zone is thinner and carbonate. In the marginal zone of the terrace, often swampy, the layer of loess is thicker, and material is finer and practically decalcified. Flowing from the valley slopes streams redeposited older terrigenic material and deposited it on the terrace. It caused washing and sanding up of the loess together with gravel insertions existence in the terrace top.

During the Holocene, in the result of vegetation development and increase of precipitation loess leaching and soil processes development took place. In the result of these processes chernozem soil developed and covered valley slopes and terrace. Humus dating from that soil outcropped in Hebdów gave the result 6 240 ± 120 years BP (Gd-2953) what probably indicates its upper age limit (GĘBICA, 1995). Soil was covered with deluvial sediments, deposited by slope wash-outs mainly in the period of increased agriculture development. Fragments of enameled ceramics and bricks found in these deposits mean that greater part of them was formed in the Middle Ages or later (GĘBICA, 1995). Deluvial deposits covering the foot--slopes caused formation of concave subslope flattening characteristic for the terrace.

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References

ALEXANDROWICZ, S. W., EVIN, J., 1988 – O wieku lessów w Bibicach koło Krakowa (On Age of loess series in Bibice near Kraków). Spraw. Pos. Kom. PAN, Oddział Kraków, 30, 1–2; p. 338–340.

ALEXANDROWICZ, S. W., 1991 – Malakofauna i wiek lessów z Maszkowa w dolinie Dłubni (summary: Malacofauna and age of loess series at Maszków in the Dłubnia River Valley, South Poland) Wyd. Nauk. UAM, ser. *Geografia,* 50, Poznań; p. 379–387.

ALEXANDROWICZ, S. W., GĘBICA, P., 1997 – Malakofauna lessów i osadów holocenu średniej terasy Wisły w Hebdowie koło Krakowa (Malacofauna in loess series and Holocene sediments on the middle terrace of the Vistula river in Hebdów near Kraków). Geologia. *Kwartalnik AGH,* 23; p. 9–28.

ALEXANDROWICZ, S. W., JERSAK, J., 1991 – Profil lessów w Opatowcu nad Wisłą (Loess section at Opatowiec on the Vistula river). *In:* H. MARUSZCZAK (ed.), Podstawowe profile lessów w Polsce, UMCS, Lublin; p. 91–93.

BEHRE, K. E., 1989 – Biostratigraphy of the Last Glacial period in Europe. *Quatern. Science Reviews,* 8–1; p. 25–44.

FOLK, R. L., WARD, W. C., 1957 – Brazos River bar: A study in the significance of grain size parameters. *Jour. Sed. Petrology,* 27; p. 3–26.

GĘBICA, P., 1993 – Vistulian Kotliny Sandomierskiej między Niepołomicami a Opatowcem (Vistulian of the Sandomierz Basin between Niepołomice and Opatowiec). *Spraw. Pos. Kom. Nauk. PAN* Oddział Kraków, 35; p. 310–314.

GĘBICA, P., 1995 – Ewolucja doliny Wisły pomiędzy Nowym Brzeskiem a Opatowcem w vistulianie i holocenie (summary: Evolution of the Vistula valley between Nowe Brzesko and Opatowiec in the Vistulian and Holocene). *Dokumentacja Geograficzna* 2; p. 1–89.

GĘBICA, P., 1998 – Szpitary koło Nowego Brzeska – osady środkowego i górnego plejstocenu (Szpitary near Nowe Brzesko – the Middle and Upper Pleistocene deposits). *In:* T. KALICKI (ed.), Paleogeografia górnego plejstocenu i holocenu wschodniej Polski i Białorusi, Polsko-Białoruskie seminarium, 5–7 października 1998, Kraków. Przewodnik wycieczki; p. 1–4.

GĘBICA, P., STARKEL, L., 1987 – Evolution of the Vistula river valley at the northern margin of the Niepołomice Forest during the last 15 000 years. *Geogr. Stud., Spec Issue* 4; p. 71–86.

GEYH, M. A., ROHDE P., 1972. – Weichselian chronostratigraphy, C-14 datings and statistics. *XXIV I.G.C., Section 12,* Montreal.

HARASIMIUK, M., 1991 – Vistulian Glacial cycle of the fluvial processes development in the valley of the Middle Wieprz river (SE Poland), *Annales UMCS,* Lublin, 46; p. 81–109.

HARASIMIUK, M., SZWAJGIER, W., 1985 – Section of fluvial loesses at Latyczów in the Wieprz valley, Quide book Inter. Symp. "Problems stratigr. paleogeogr. of loesses" UMCS, Lublin; p. 138–147.

VAN HUISSTEDEN, J., 1990 – Tundra rivers of the Last Glacial: sedimentological and geomorphological processes during the Middle Pleniglacial in Twente, Eastern Netherlands. Meded. Rijks Geol. Dienst. H. W. J. Amerom (ed.), 44–3; p. 3–138.

JAHN, A., 1956 – Wyżyna Lubelska – rzeźba i czwartorzęd (summary: Geomorphology and Quaternary history of Lublin Upland). *Prace Geogr. Inst. Geogr. PAN,* 7; 454 pp.

JERSAK, J., 1976 – Związek akumulacji lessu z rozwojem procesów rzecznych w dolinach przedpola Karpat i na wyżynach południowej Polski (summary: Interrelation between the loess accumulation and development of fluvial processes in the valleys of the Carpathian foreland and on the southern Polish Uplands). *Acta Geogr. Lodziensia, 37*; p. 25–52.

JERSAK, J., 1991 – Osady rzeczne fazy pełni piętra zimnego Wisły w dolinie Wieprza między Szczebrzeszynem a Łańcuchowem (summary: Plenitade phase fluvial sediments of the cold Vistula stage in the Wieprz river valley between Szczebrzeszyn and Łańcuchów). *In:* J. JERSAK (ed.) Less i osady dolinne. *Prace Nauk. Uniw. Śl.,* Katowice, 1107; p. 51–92.

JERSAK, J., SENDOBRY K., ŚNIESZKO Z., 1992. Postwarciańska ewolucja wyżyn lessowych w Polsce (Evolution of loess covers in Poland during the post-Warta period). *Prace Nauk. Uniw. Śl.,* 1227, Katowice; 198 pp.

KITAGAWA H., VAN DER PLICHT J., 1998 – Atmospheric radiocarbon calibration to 45,000 yr BP.: Late Glacial fluctuations and cosmogenic isotope production. *Science,* 279; p. 1187–1190.

KONECKA-BETLEY, K., MADEYSKA, T., 1985 – Loess section at Kraków–Zwierzyniec. Guide--book intern. symp. Problems Stratigr. Paleogeogr. Loesses, UMCS, Lublin.

KOPEROWA, W., ŚRODOŃ, A., 1965 – Pleniglacial deposits of the Last Glaciation at Zator (West of Cracow). *Acta Palaeobotanica,* 6; p. 1–31.

KOZARSKI, S., 1991 – Paleogeografia Polski w Vistulianie. *In:* L. STARKEL (ed.), Geografia Polski, Środowisko przyrodnicze. Warszawa, PWN; p. 80–105.

KOZŁOWSKI, J., KUBIAK, H., WELC, A., 1970. A palaeolithic site with mammoth remains at Nowa Huta (Cracow, Poland). *Folia Quatern.,* 36; p. 1–20.

LINDNER, L., SIENNICKA, A., 1994 – Osady czwartorzędowe w strefie północnej krawędzi doliny Wisły na wschód od Brzeska Nowego (Wyżyna Miechowska) (Quaternary deposits in the northern zone of the Vistula River edge east of Brzesko Nowe, Miechów Upland, South Poland). *Przegl. Geol.,* 42; p. 105–111.

ŁANCZONT, M., 1994 – Terasa lessowa w dolinie Sanu u wylotu z Karpat (Loess terrace in the San valley on the Karpaty Foreland). Litologia i stratygrafia czwartorzędowych utworów pyłowych, *Georama 2,* Uniw. Śl., Sosnowiec; p. 49–58

ŁOZIŃSKI, W., 1909 – Glacyalne zjawiska u brzegu północnego dyluwium wzdłuż Karpat i Sudetów. (Glacial occurrence in the border of northern diluvium along the Carpathian and Sudetic Mts.). *Spraw. Kom. Fizjograf.,* Kraków, 43; p. 3–50.

ŁYCZEWSKA, J., 1948 – Sprawozdania z badań geologicznych w północno-zachodniej części arkusza Brzesko Nowe (1:100 000), (Report on the geological research in the northwest part of Brzesko Nowe sheet). *Biul. Państw. Inst. Geol.,* 42; p. 46–75.

MAMAKOWA, K., ŚRODOŃ, A., 1977 – O pleniglacjalnej florze z Nowej Huty i osadach czwartorzędu doliny Wisły pod Krakowem (summary: On the Pleniglacial flora from Nowa Huta and Quaternary deposits of the Vistula valley near Cracow). *Rocz. Pol. Tow. Geol.,* 47; p. 485–511.

MAMAKOWA, K., RUTKOWSKI, J., 1989 – Wstępne wyniki badań paleobotanicznych profilu ze Ściejowic (Preliminary results of paleobotanical studies the geological profile from Ściejowice). Przewodnik LX Zjazdu Pol. Tow. Geol., 14–16 września, Kraków; p. 113–117.

MARUSZCZAK, H., 1991 – Zróżnicowanie stratygraficzne lessów polskich (Stratigraphical differentiation of Polish loesses). *In:* H. MARUSZCZAK (ed.) Podstawowe profile lessów w Polsce, UMCS, Lublin; p. 13–35.

MOL, J., 1997 – Fluvial response to climate variations. The Last Glaciation in eastern Germany. Ph–D thesis Vrije Universiteit, Amsterdam; 100pp.

MYCIELSKA-DOWGIAŁŁO, E., 1978 – Rozwój rzeźby fluwialnej w północnej części Kotliny Sandomierskiej w świetle badań sedymentologicznych (The development of fluvial relief in the northern part of Sandomierz Basin in the light of sedimentological studies). *Rozpr. Uniw. Warsz.;* p. 7–148.

NIEDZIAŁKOWSKA, E., SZCZEPANEK, K., 1993–1994 – Utwory pyłowe vistuliańskiego stożka Wisły w Kotlinie Oświęcimskiej (summary: Vistulian silty sediments of the Vistula river fan in the Oświęcim Basin). *Studia Geomorph. Carpatho-Balcanica,* 27–28; p.29–44.

PAZDUR, M .F., 1982 – Badanie dokładności datowania metodą 14C północnoplejstoceńskich holoceńskich osadów organogenicznych (summary: A study of the accuracy of radiocarbon dating of the Holocene and Late Pleistocene organogenic sediments). *Zesz. Nauk. Pol. Śląskiej, Ser. Mat-Fiz.,* 41; 81pp.

PAZDUR, A., PAZDUR, M. F., 1986 – Aparatura pomiarowa Laboratorium 14C w Gliwicach. Doświadczenia konstrukcyjne i eksploatacyjne (Measuring instruments in 14C Laboratory in Gliwice. Constructional and utilization experience). *Zesz. Nauk. Pol. Śląskiej, Ser. Mat-Fiz.* 46, Geochronometria, 1; p 55–69.

PŁONCZYŃSKI, J., 1993 – Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, Arkusz Nowe Brzesko (Explanations to the Geological Map of Poland 1:50 000, sheet Nowe Brzesko). Państw. Inst. Geol., Warszawa; p. 5–44.

POŻARYSKI, W., 1956 – Stratygrafia plejstocenu w Polsce w świetle badań wschodniej części wyżyn środkowopolskich (Stratigraphy of Pleistocene in Poland in the light of studies from eastern part of Middle Polish Uplands). *Przegl. Geogr.*, 28; 2.

STARKEL, L., 1967 – Wisła wśród gór i wyżyn. Przewodnik geologiczny z biegiem Wisły, Warszawa; p. 31–159.

STARKEL, L., 1972 – Kotlina Sandomierska. *In:* M. KLIMASZEWSKI (ed.) Geomorfologia Polski, PWN, Warszawa, 1; p. 138–163.

STARKEL, L., 1980 – Stratigraphy and chronology of the Vistulian in the Polish Carpathians and in the subcarpathians basins. *Quater. Stud. in Poland,* 2; p.121–135.

STARKEL, L., 1995 – Evolution of the Carpathians valleys and the forecarpathians basins in the Vistulian and Holocene. *Studia Geomorph. Carpatho-Balcan.*, 29; p. 5–40.

TYCZYŃSKA, M., 1968 – Rozwój geomorfologiczny terytorium miasta Krakowa (summary: Geomorphological evolution of the city of Cracow). *Prace Geogr. UJ,* 17; p. 5–70.