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CHRONOSTRATIGRAPHY OF LATE PLEISTOCENE FLUVIAL DEPOSITS IN THE WISŁOK RIVER VALLEY BETWEEN RZESZÓW AND ŁAŃCUT, SOUTH POLAND

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Abstract: **This paper presents results of absolute dating of alluvial sedimentary series forming a rendzina terrace (higher floodplain) 7-8 m high above the Wisłok River channel and a sandy terrace 8-10 m high in the Subcarpathian Pradolina section of the Wisłok River valley. The organic mud infilling fossil depressions (palaeochannels?) in the lower part of the rendzina terrace have been dated by the radiocarbon method to more than 38,500 BP. The organic series occurring within the sandy terrace yielded three ages >36,000 BP. Results of palynological analyses carried out on both sites indicate tundra or forest-tundra environments with water-filled depressions at the time of organic sediments deposition. The top of the 8-10 m high sandy terrace is built of fluvial sands and eolian cover sands with dunes in the uppermost part. Their age has been established by means of the OSL method to 11.2±0.9 ka BP. The younger alluvial inset fill is formed of sands and silts with involutions occurring under Holocene muds. They were deposited by a braided river during the Upper Plenivistulian as indicated by two other OSL dates of 22.2±2.2 ka BP and 14.0±1.5 ka BP. Within the rendzina terrace the youngest series of Vistulian age is built with peats and silts, infilling the wide depression at the foots of sandy hillocks, dated to about 11,800 BP.**

1. INTRODUCTION

The geological survey of the Wisłok River valley started at the beginning of the 20th century when Friedberg (1903) elaborated Rzeszów and Łańcut sheets of the Geological Atlas of the former Austrian Galicia. Friedberg (1903) described grey-blue clays underlying glacial gravels in the lower part of rendzina terrace in Terliczka and Łukawiec. He assigned them to the Young Pleistocene or early Holocene period. Klimaszewski assigned the middle terrace (up to 20 meters above the river bed) loess-covered to the Middle Polish (Saalian) Glaciation, and the lower-lying terrace (up to 10 meters) with overbank loams in the top to the Last Glaciation. The structure and age of the Wisłok terraces in Rzeszów were studied by Jahn (1957), Laskowska-Wysoczańska (1971) and Starkel (1972 and 1980) who dated the higher terrace sediments bearing a cover of loess or dunes to the North Polish (Vistulian) Glaciation. According to Jahn (1957) and Starkel (1960) the 6-8 m high rendzina terrace is apparently inserted in the loess-covered terrace. Starkel (1960) provided evidence for the Holocene age of the rendzina terrace in Rzeszów, which comprise alluvial inset fills of different age. It also hides remnants of older alluvia as, for example, documented by the profile in Brzeźnica in the neighbouring Wisłoka River valley, where paleochannel deposits have been dated to between 46 and 36 ky BP (Mamakowa and Starkel, 1974). Starkel (1980) cited a date of 43.9±2.1 ky for peat sample taken by himself in Łukawiec and obtained by M. Geyh in 1975. Several years ago, in the frame of the Detailed Geologic Map of Poland 1:50,000 project, geological mapping of the Rzeszów, Łańcut and Jarosław sheets has been undertaken. Results of geological mapping have been published in the form of several notes and presented during the VI Conference on Stratigraphy of Pleistocene in Poland, Czudec 1999 (Wójcik *et al.*, 1999; Zimnal, 1999).

During spring freshets of the year 2000, with the highest water level reaching 5 m above the river bed, Wisłok River made numerous undercuts in banks in the section behind Łąka where the river runs within the Subcarpathian Pradolina. When floodwaters subsided, P. Gębica found in several new exposures in the lower part of the rendzina terrace a cohesive layer of silty clay and organic mud, truncated in the upper part and covered with younger alluvial series. A similar organic series and silts were found nearby in Czarna-Podbór, in the open sand pit located on the higher 8-10 m terrace.

Undertaken researches aimed at finding an age of different sequences of Vistulian fluvial sediments. Geomorphological mapping of the Wisłok River valley bottom between Rzeszów and Łańcut was performed by P. Gębica. On the same occasion a number of accessible exposures, presenting different stratigraphical units was profiled. Information related to the range and thickness of terrace sequences have been supplemented with data obtained through geological drillings and taken from rich archive documentation on earlier boring projects. The fieldwork was also an occasion for taking samples for palynological and granulometric analyses, and for radiometric dating. Radiocarbon dating was performed on samples of peat and organic silt sediments while OSL (optically stimulated luminescence) dating was made on samples of mineral sediments.

2. GEOMORPHOLOGICAL AND GEOLOGICAL SETTING

The Wisłok River beyond Rzeszów flows within an erosional depression of the Subcarpathian Pradolina. The pradolina is distinctively bordered from the south and the north (**Fig. 1**). To the south an edge of the Kańczucka Plateau (220-280 m a.s.l.) rises, which is covered with a sequence of alluvial and glacial sediments, frequently overlain by loess, deposited on a Miocene clays (Laskowska-Wysoczańska, 1971; Zimnal, 1999). The edge of the Kolbuszowski Plateau constitutes the north border. It is built with Miocene clays, covered with preglacial alluvial sediments, fluvioglacial sands, and glacial till from the Sanian 2 (Elsterian) Glaciation. In the Subcarpathian Pradolina near Jasionka at the elevation of 210-213 m a.s.l. fluvioglacial deposits and washed glacial till cover an interstadial organic series from the Sanian 2 Glaciation (Laskowska-Wysoczańska, 1971). The bottom of the Wisłok River valley is terraced and filled with alluvia of the thickness up to 20 m. Between Rzeszów and Trzebownisko, a slightly inclined terrace plain ranges at

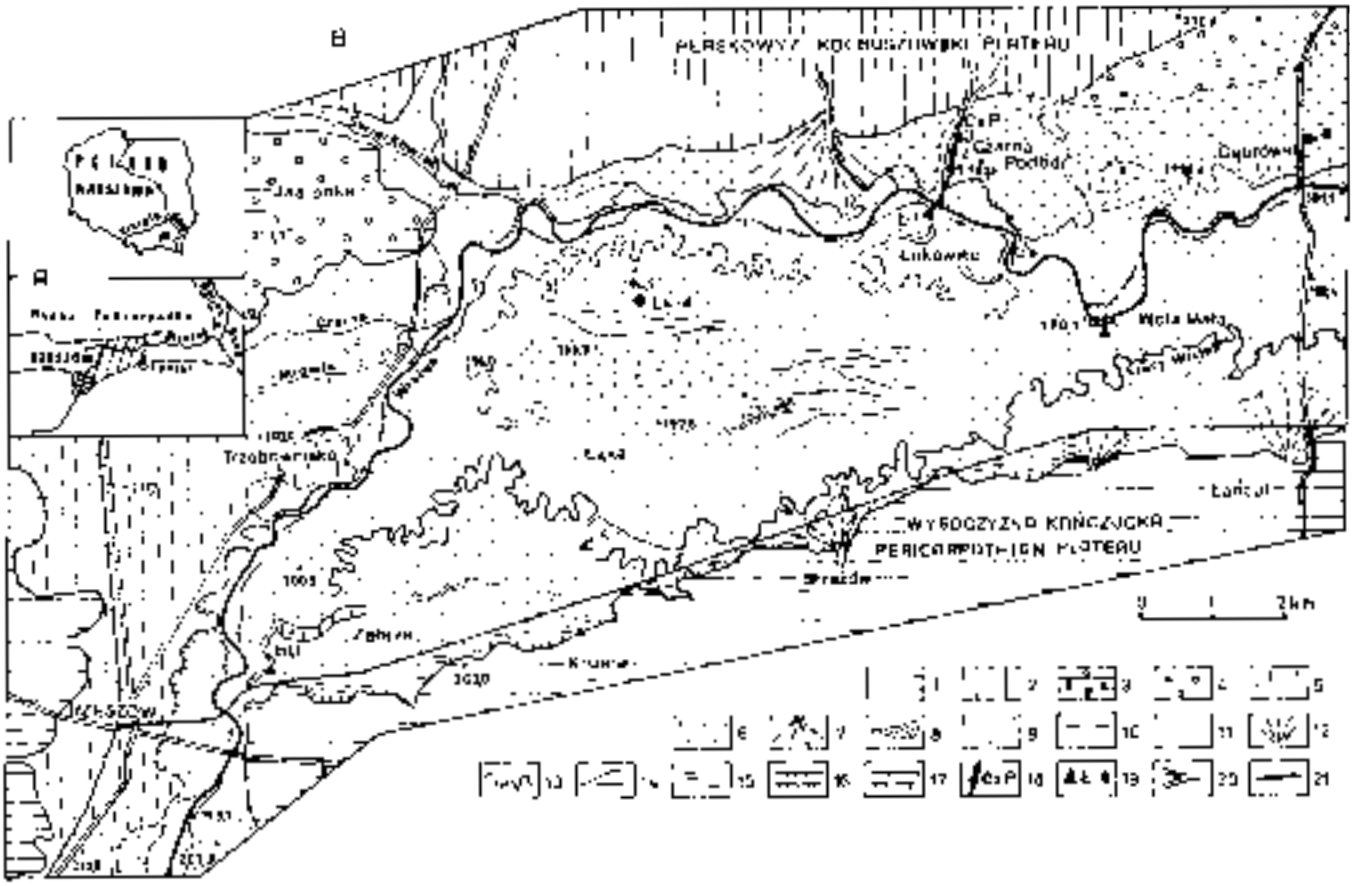

Fig. 1. *Geomorphological map of the Wisłok River valley between Rzeszów and Łańcut:*
1 – PeriCarpathian Loess Plateau, 2 –- Kolbuszowski Plateau, 3 – fluvioglacial level from the Sanian 2 Glaciation, 4 – alluvial terrace from the Middle Polish Glaciation?, 5 – loess-covered terrace plain from the Vistulian Glaciation, 6 – sandy terrace 8-10 m high, 7 – alluvial fan of the Vistulian age, 8 – dune ridges, 9 – higher floodplain (rendzina terrace) 7-10 m high, 10 – flatbottomed depressions (floodbasins), 11 – lower floodplain 3-5 m high, 12 – alluvial fan of Holocene age, 13 –- paleochannel system, 14 – traces of braided river (Late Vistulian age), 15 – peatbogs, 16 – erosional edges below 10 m, 17 – erosional edges above 10 m, 18 – geological transect with borehole numbers, 19 – excavations, 20 – roads, 21 – railway.

the elevation about 20 m above the Wisłok River level. Its upper part consists of dozen-metre-thick loess, and its lower part contains alluvial sands with organic mud insets and gravels lying on the Miocene clays. These deposits are 20 m thick and they date to the Vistulian Glaciation (Jahn, 1957). Along the left border of the valley, at the height of 8-13 m above the Wisłok River channel, a sandy terrace stretches, 0.5 to 1.5 km wide, with a wind-blown sands on the top. In places, undercut by paleomeanders, it is separated from the rendzina terrace by a 1-2 m high edge. Circular, wet depressions (thermokarstic?) and natural levees with wind-blown sands on the top have been profiled on the terrace surface. The contemporary bottom of the Wisłok River valley, 4-6 km wide, is occupied by a Holocene rendzina terrace, which is cut 10 m deep in the vicinity of Rzeszów and 7-8 m deep near Łańcut (**Fig. 1**). It forms a higher level of a floodplain that currently is not flooded even during the highest freshets. It forms an alluvial fan beyond Rzeszów, with several abandoned (due to avulsion processes) palaeomeander systems of the Wisłok River and its tributary Czarna River. The best known is a narrow and sinuous paleochannel system called Stary Wisłok abandoned after one of catastrophic floods in the half of the 18th century (Strzelecka, 1958). The rendzina terrace is built of gravels with sands in the lower part, and sands with alluvial loams and 2-4 m thick clays in the upper part. In the Łąka locality a Pleistocene sandy terrace occurs in isolated patches and it rises 1-3 meters above the floodplain (**Fig. 1**). This is probably a fragment of an alluvial fan formed by the Wisłok River during the Vistulian time, which is indicated by an archaeological findings of Mesolithic settlements (Czopek and Podgórska-Czopek, 1995). The lower level of the floodplain makes narrow bench of swampy meadow terrace at the elevation of 3-5 meters above the river channel, being several tens to 500 m wide. It is covered with meadows and brush and it is flooded almost every year during higher freshets. It is mainly built of sandy loams overlying sands with gravel. It has probably been formed during the last 150-200 years, similarly like the swampy meadow terrace of the San River (Szumański, 1986). The channel of the Wisłok River underwent partial regulation in the beginning of the 20th century, but it is not embanked. The present width of the river is about 25-35 m.

3. SITE DESCRIPTIONS

Łukawiec-1

A very interesting profile, exposing two series of alluvial deposits (**Figs 1** and **2**), was found during the geomorphological mapping of the 7 m high terrace on the right bank of the Wisłok river. The lower series consisted of fine sands covered with alternately stratified silt and yellow-olive sand. In the upper part of the sequence sand distinctively graded into blue silty clays which in turn gradually graded into organic silts and peaty mud of 0.6 metre thickness. At the contact between the organogenic layer and the underlying silts and sands numerous sedimentary involutions and cryogenic fissure structure filled with organic material, had developed. The top of organogenic series has been truncated and covered with the younger series of alluvial sediments of 5 m thickness. This younger series consists mainly of sands with coarse gravel (channel deposits) and sets of cross-bedded sands with sandy silt insets (meander point bar deposits) and of overbank alluvial loams in the top. The peaty mud sample taken at the elevation of 2 m above the present water level in the river channel yielded the radiocarbon age >38,500 BP (Gd-15157). Pollen analyses made on eight samples taken from peaty mud organic silts in the profile Łukawiec-1 (**Fig. 3**) revealed large amounts of herbaceous plants (NAP), particularly *Cyperaceae* and grasses (*Poaceae*). Tree pollen percentage reaches almost 25% of the total pollen count only in the top sample; in other samples it varies between 9.8% and 20.2%. The taxonomic composition of samples is not much diversified. Among the trees only pollen of common pine (*Pinus silvestris*) and of stone pine (*Pinus cembra*) are abundant in all samples. Among the bushes relatively high scores have been recorded for dwarf birch (*Betula nana*). A few pollen grains of willow (*Salix*), sporadic pollen grains of alder (*Alnus viridis*) and abundant colonies of *Pediastrum* algae have been found. They indicate the presence of shallow water depressions, at least periodic. The results enable stating that the most characteristic feature of the landscape of the area surrounding this site was a prevailing number of open communities of herbaceous plants. Most of all they were communities of wet and waterlogged habitats. There were probably some other types of plant communities, besides grass-sedge ones, where dwarf birch shrubberies, alder, willow and brown moss grew together with other plants of dry non-forest steppe-tundra sites (*Artemisia*, *Chenopodiaceae* and *Helianthemum*). Trees could by found, if any, sparsely in small assemblages or in the Wisłok River valley. Palynological data and results of radiocarbon dating suggest that sediments were deposited in cool climatic conditions during the older part of Pleniglacial of the Vistulian glaciation. Łukawiec yielded yet another radiocarbon date made on peat sampled by L. Starkel from the layer forming rapids in the Wisłok River bed, exposed on the right edge of the terrace (Starkel, 1980). It is difficult now to point the place from which the dated sample derived. The age of peat, as obtained in 1975 by M. Geyh and equal to 43.9±2.1 ky BP (Hv-6388), is indicative of the interstadial series (interpleniglacial) of the last glaciation (Gradowski and Nalepka, 1985; Starkel, 1980).

Czarna-Podbór

At the distance of some 0.5 km NNE of Łukawiec profile, at the border of Czarna-Podbór hamlet, there are several open sand pits. Sand pits are located on the terrace plain elevated about 8-9 m above the river bed and up to 1.5 km wide. It is bordered on the floodplain by a distinct edge of the old paleochannel up to 2 m high (**Figs 1** and **2A**). The terrace surface is slightly undulated with flat swellings and depressions not higher, or deeper, than 2 m. Dune ridges, 5-10 m high, occur at higher elevations and low levees occur in places closer to the edge of the terrace. To the west of the biggest sand pit the terrace is

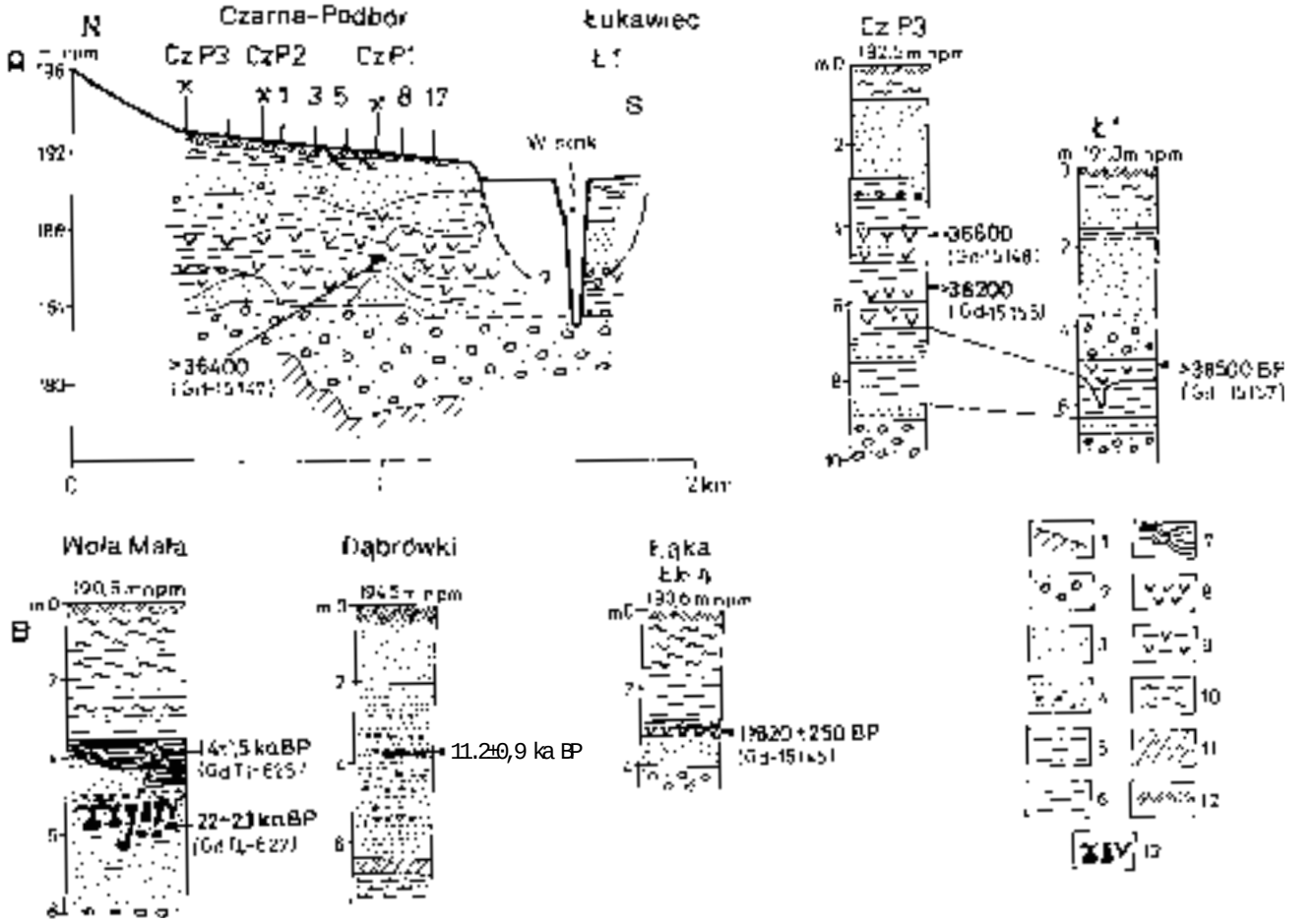

Fig. 2. *Radiocarbon dating results and the cross-section through the sandy terrace (8-10 m) in Czarna-Podbór and the right bank terrace (7 m) in Łukawiec site:*
1 – Miocene, 2 – sand with gravel, 3 – sands, 4 – stratified sands with fine gravels (eolian cover sands), 5 – sandy silts, 6 – muds and clays, 7 – stratified muds and sands disturbed by periglacial structures, 8 – peaty muds, 9 – organic silts, 10 – alluvial loams, 11 – fossil soil, 12 – Holocene soil 13 – involutions (drop soils) and frost wedges.

cut down by a valley of a small stream, the bottom of which is covered with flood muds. In the biggest sand pit belonging to Mr. Kazimierz Jeziorek from Medynia Łańcucka the layer of silt with organic matter was found at the depth of 5 m below the terrace surface. The structure of the terrace was documented by 23 archival drillings made on the sand pit area of 0.25 km^2. Sampling was made by three additional geological drillings using "Geomeres" derrick and samples for palynological and radiocarbon analyses were taken.

Four basic members of deposits have been recognised in the terrace structure (**Fig. 2A**). At the depth of 10-13 m a sandy gravel cover, 2-5 m thick, lies on Miocene clays. Above that there is a member of silty and sandy clays bedded with organic silts and peaty mud, 1.5 to 2 m thick, filling fossil depressions (paleochannels?) cut in the channel alluvia. The top of the terrace consists of dusty sands truncated by coarse sands with an admixture of gravel, 1-3 cm size, with a pavement in the bottom. The thickness of the upper members of the deposits is 3-4.5 m. Samples for dating have been taken from two selected drilling sites. A drilling core sample coming from an upper layer of peaty mud lying at the height of 4 m above the river bed in the Czarna-Podbór 3 profile, yielded an indefinite age >36.6 ka BP (Gd-15148), and the second sample of peaty mud from a layer lying 1 m below gave also an indefinite age >36.2 ky BP (Gd-15155). Another peaty mud sample taken from the Czarna-Podbór 1 drill core, 3.7-3.9 m above the Wisłok river bed was dated to >36.4 ka BP (Gd-15154). The age of the sampled deposits corresponds, probably, to the older part of the Middle Plenivistulian, similarly to the profile in Brzeźnica upon Wisłoka River (Mamakowa and Starkel, 1974; Mamakowa *et al*., 1997) or is much older.

Wola Mała

The site Wola Mała near Łańcut, on the right bank of a big southward bent meander of the Wisłok River, reveals an interesting sequence of sediments (**Figs 1** and **2B**). Below the overbank alluvial loams of Holocene age, sand and silt layers are exposed, part of it being disturbed. Holocene overbank deposits are represented by massive clays interbedded with silts of the total thickness of 3.5 m. A vertical profile exposes two sequences of deposits below the alluvial loams. The lowermost part of the profile, shows mixed sands with single gravels and silty sands with involutions (overbank deposits). The top of these sediments is cut and covered with another layer of cross-

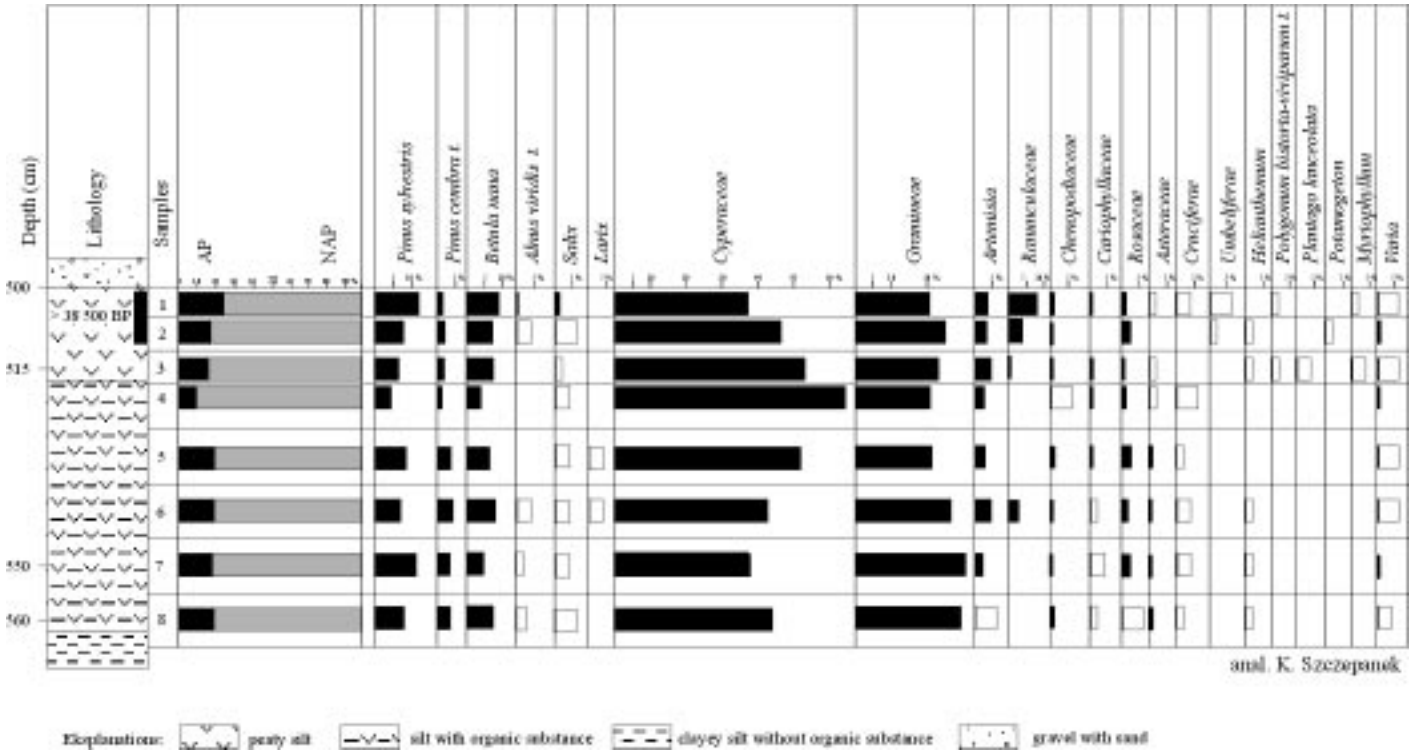

Fig. 3. *Pollen diagram from the Łukawiec-1 profile.*

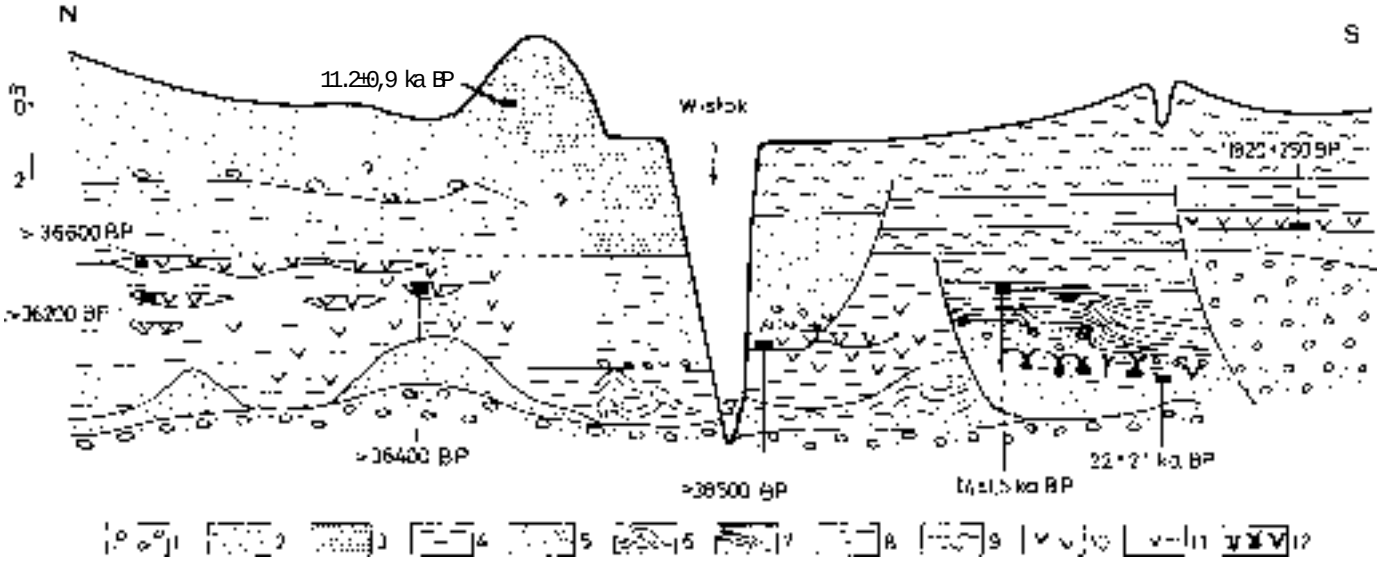

Fig. 4. *Schematic cross-section of the northern margin of the Wisłok River valley floor near Czarna and Łukawiec:*
1 – sands with gravels, 2 – fluvial sands, 3 – stratified fluvial sands with eolian cover sands in the top of the terrace, 4 – silty sands 5 – unstratified eolian sands, 6 – stratified sands and silts disturbed by involutions, 7 – laminated muds and sands, 8 – clays and muds, 9 – alluvial loams, 10 – peaty muds, 11 – organic silts, 12 – involutions and frost figures.

bedded sands with fine gravels and laminated silts (floodplain deposits). Layers of sands and silts in the top part are inclined and subjected to sliding.

Single sand wedge being up to 0.5 m long and truncated at the top, frost fissure and small faults caused probably by ground subsiding, were observed in the dusty sands. Abundant involutions, described as drop soils were found at the border between silts and sands. This type of structures usually develops as a result of differences in sediment density and processes of gravitational liquidation of plastic masses of water-saturated sediment and probably takes place during permafrost degradation (French, 1996; Eissmann, 1997). Two samples taken from this profile have been dated by the single aliquot optical dating (SAR OSL) method. The sample WM-1 taken from an undisturbed sands lying at the height of 2 m above the water level in the Wisłok River channel, and below the previously described involution structures, gave an age of 22.2±2.1 ka BP (GdTL-627). The second sample WM-2, taken from laminated silt lying directly below Holocene alluvial loams, 4 m above the river water level, was dated to 14.0±1.5 ka BP (GdTL-628). Thus, the dated alluvial series corresponds to the Upper Plenivistulian and it is younger than sediments described in Łukawiec and Czarna localities.

Dąbrówki

On the left bank of the Wisłok River, in the village of Dąbrówki, there is a small, sandy hillock developed on a sandy plain. Its relative height is 3.5-4 metres and 13.5 meters above the Wisłok River bed (**Fig. 1**). To the north of this hillock, and slightly higher, there are dune ridges up to 20 meters high. Due to exploitation of sands, the western part of the hillock and the top part of the terrace plain have been exposed, enabling insight into the structure of both forms down to the depth of 7 m (**Fig. 2B**). The lower part of the terrace is built of sands, gravels and silts, while the upper one consists mainly horizontally laminated silty sands. The hillock consists mostly of somewhat coarser material, mainly fine- and medium-grained sands, alternately laminated with thin layers of coarse-grained sand and gravel up to 0.5 cm diameter. The lamination ceases towards the top of the hillock and sands become better sorted, with a Holocene soil developed in the top. The small size of the hillock and alternating layers of sand grains makes it similar to hillocks made of eolian cover sands found on the Polish Lowlands (Nowaczyk, 1976). Structures described above have been recorded in eolian sands of contemporaneously developing dunes (Fryberger *et al*., 1992) as well as in Pleistocene cover sands (Schwan, 1986; Goździk, 1998). The sample of sand taken from the bottom layer of the hillock, about 10 m above the Wisłok River level, has been dated by SAR OSL method to 11.2±0.9 ka BP (GdTL-626). This result points the Late Vistulian (Younger Dryas ?) when eolian processes intensified and sand was reworked by strong winds. These date correlates well with numerous eolian series of dune and cover sands dated in Poland (Nowaczyk, 1986).

Łąka

On the rendzina terrace, to the south of the present Wisłok River bed, several boreholes gave insight into the structure of the flat-bottomed depression surrounding the sandy patches of Pleistocene terrace near Łąka (**Figs 1** and **2B**). The structure of the wide depression consists of peat, lying on sands with silts, clays, and alluvial loams in the top. The radiocarbon dating of a sample from the Łąka-4 borehole (sample from the bottom of the peat layer at the depth 3.25-3.30 m) gave the result 11,820±250 BP (Gd-15146). This means that the infilling of the depression started in Alleröd, and peat, probably, covers a fragment of a Late Vistulian alluvial plain of a braiding river.

4. DISCUSSION OF ^{14}C DATING RESULTS

The measurements of ^{14}C concentration have been performed in the Gliwice Radiocarbon Laboratory by the gas proportional counting method (except for the Hv-6388 result which was obtained in the Hannover Radiocarbon Laboratory). Conventional radiocarbon age of each sample has been normalised to $\delta^{13}C = -25‰$, following the Stuiver and Polach's procedure (1977). One definite ^{14}C date (sample Łąka-4, Gd-15146) was calibrated using the Gliwice Calibration Program GdCALIB (Pazdur and Michczyńska, 1989) and the calibration curve of Stuiver *at al*. (1998). **Table 1** contains the results of radiocarbon dating as conventional radiocarbon ages (^{14}C Age, BP) and results of the calibration procedure in the form of the narrowest 68% confidence intervals (Cal. Age, BP).

The results of radiocarbon dating fell at or behind the limit of the applied method, except for Łąka-4 sample, which yielded a definite age. Considering the stratigraphical division of the Vistulian glaciation (Kozarski, 1991), radiocarbon dates obtained for Łukawiec and Czarna-Podbór profiles (older than 38.5 ka BP and older than 36.0 ka BP, respectively) mean that the respective organic sediments from the two sites were deposited during the older part of the Middle Plenivistulian (interpleniglacial). The probable candidate is the Hengelo interstadial (warm) period and an immediately earlier stadial period. Palynological data suggest that studied sediments were deposited under relatively stable conditions, during a period without significant climate fluctuations. The low percentage of tree pollen, reaching 25% at the best, together with the domination of open sets of herbaceous plants may be interpreted as a result of relatively stable climatic conditions of the colder period (stadial) immediately preceding the Hengelo interstadial. Numerous involutions and small frost wedges found at the contact between organic deposits and underlying layers developed under periglacial conditions are the other proofs supporting this hypothesis. It is also congruent with results of other studies of Middle Plenivistulian fluvial series in the southern part of Poland (Jersak and Sendobry, 1991; Superson, 1996) and in eastern part of Germany (Eissman, 1997; Mol, 1997).

Table 1. *Description of the samples and their radiocarbon and luminescence ages. Calibrated age range (Gd-15146) has been determined at 68% confidence level using GdCALIB program.*

Sample name type of sediment	**Stratigraphy**	**Lab. No.**	**^{14}C Age** [BP] **Cal. Age** [BP]	**OSL Age** [BP]
Łukawiec-1 peaty mud	top layer of peaty mud, 2 m above channel water level	Gd-15157	> 38,500	
Łukawiec peaty mud	Peat from a bank forming a riverbed bar	Hv-6388	$43{,}900\ ^{+2100}_{-1650}$	
Czarna Podbór-3 peaty mud	top layer of peaty mud, 5 m above channel water level	Gd-15148	> 36,600	
Czarna Podbór-3 peaty mud	Layer lying 4 m above channel water level	Gd-15155	> 36,200	
Czarna Podbór-1 peaty mud	Layer lying 4 m above channel water level	Gd-15154	> 36,400	
Wola Mała WM-1 sand	Layer lying 2 m above channel water level	GdTL-627		22,200 ± 2100
Wola Mała WM-2 laminated mud	Layer lying 4 m above channel water level	GdTL-628		14,000 ± 1500
Dąbrówka sand	Layer lying 10 m above channel water level	GdTL-626		11,200 ± 900
Łąka-4/3.25-3.30 m peat	lower layer of peat	Gd-15146	11,820 ± 250 [14,050 ÷ 13,530]	

5. DISCUSSION OF RESULTS OF OSL DATING

Luminescence dating of three sediment samples has been made in the Luminescence Dating Unit of the Department of Radioisotopes, Institute of Physics, Silesian University of Technology, Gliwice, Poland. The OSL measurements have been done on coarse quartz extracts (125-200 μ) applying a single aliquot regenerative dose protocol (SAR) to obtain values of paleodoses absorbed by grains. The respective dose-rate values have been calculated from radioactivity of the sediment samples measured by means of high-resolution gamma spectrometry, making appropriate corrections for sediment water contents, etching of quartz grains in concentrated hydrofluoric acid, and taking into account the cosmic dose-rate.

OSL of quartz aliquots have been measured with Daybreak 1150 automated reader equipped with a green light source (halogen lamp based) and a beta source for "in-place" irradiations. Irradiations, preheating and OSL measurements were executed automatically in a one continuous run. A typical SAR measurement protocol was employed with the following parameters:

- aliquot mass: *ca* 3 mg;
- test dose: 1.9 Gy;
- preheat after test dose: 0 s at 160° C;
- regenerative doses: 9.6, 19.1, 38.3 Gy;
- Preheat after regenerative dose: 10 s at 220° C;
- OSL taken at 125° C during 1 s of green light (514±17 nm wavelength) excitation followed by 58 s long bleaching and then 1 s excitation for recording a background signal (a total of 60 s of green light exposure)

Equivalent dose (ED) values have been calculated by interpolation of the non-linear saturated exponential fit to the laboratory growth points. Results of the laboratory measurements and OSL dating are presented in **Tables 2** and **3**.

The single aliquot method is usually applied to a number of aliquots making it possible to investigate the distribution of luminescence ages of quartz grains within the sediment. In this case aliquots consisted of many individual grains so the interpretation of the distribution is less straightforward. Nevertheless, it was shown that only a few grains give actually rise to luminescence observed from an aliquot, so the distribution should have similar

Table 2. *Depth, water content, radioactivity and effective dose-rate for three samples.*

Sample	**Depth** [cm]	**Water content** (assumed) [%]	**Activity [Bq/kg]**			**Dose rate** [Gy/ka]
			^{238}U	**^{232}Th**	**^{40}K**	
Wola Mała WM-1	600	12±3	5.18±0.86	3.76±0.29	249.2±4.3	0.99 ± 0.08
Wola Mała WM-2	400	12±3	18.12±1.48	15.10±0.58	420.9±7.4	1.93 ± 0.14
Dąbrówki D-1	400	12±3	5.38±0.77	3.32±0.26	182.1±4.1	0.90 ± 0.03

Table 3. *Equivalent dose (ED) and OSL age values obtained for the dated samples.*

Sample	**Number of aliquots**	**EDOSL** [Gy]	**OSL Age** [ka]
Wola Mała WM-1	10	22 ± 1	22.2 ± 2.2
Wola Mała WM-2	10	27 ± 2	14.0 ± 1.5
Dąbrówki D-1	40	10.1 ± 0.7	11.2 ± 0.9

features as the individual grain distribution but broader and with larger "background". **Figs 5** to **7** show the results for individual aliquots transformed in such a way that each point represents a single date. The abscissa of a point is inversely proportional to the dating error ΔT_i and its ordinate is proportional to the age value T_i less an arbitrary value (usually chosen to be an average of obtained ages) and inversely proportional to dating error. This transformation leads to that points representing same age lie on a straight line going through the point of origin (0, 0) and the larger the distance from the origin, the more accurate the date is. This type of plot helps better judgment of dominant features of the age distribution and its interpretation.

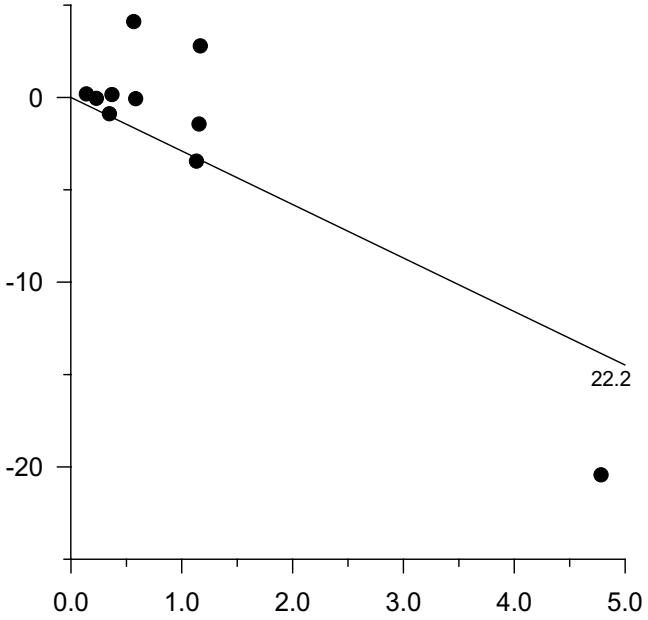

Fig. 5. *Results of the SAR method dating of the sample WM-1. The plot presenting single dates is constructed in such way that "equal age" points lie on the ray coming out of the point (0, 0). The distance along the horizontal axis is equal to* $\frac{1}{\Delta T_i}$ *while the distance along the vertical axis is* $\frac{T_i - \overline{T}}{\Delta T_i}$*. The ray shows an age of 22.2 ka.*

Samples WM-1 and WM-2 have relatively simple distributions meaning that deposition of the sediment took place after a moderately long exposure to light. The sample D-1, on the contrary, shows a quite complex distribution (being the reason why we decided to repeat dating for 40 aliquots). The most probable reason for this is that in the history of this sediment several episodes of reworking and re-deposition occurred. The OSL date stated for this sample cannot be interpreted as the age of the whole form. It is rather the last episode of more intense reworking. This site will be a subject of further investigations, including OSL dating of more samples with an aim to shed more light on the origin and age of the form.

6. CONCLUSIONS

Radiocarbon and luminescence dating (OSL) confirm complexity of alluvial series of deposits of Middle to Upper Plenivistulian age, occurring in the Subcarpathian pradolina section of the Wisłok River valley bottom between Łąka and Łańcut. A schematic section shows locations of dated alluvial series and their probable spatial extension along the bottom of the valley (**Fig. 4**). The distinguished Vistulian series of sediments occupies mainly the northern zone of the Wisłok River valley. The contemporary channel of the Wisłok River cuts into this series.

The thick series of InterpleniVistulian sediments forming a sandy terrace, 8-10 m high, has been dated to be older

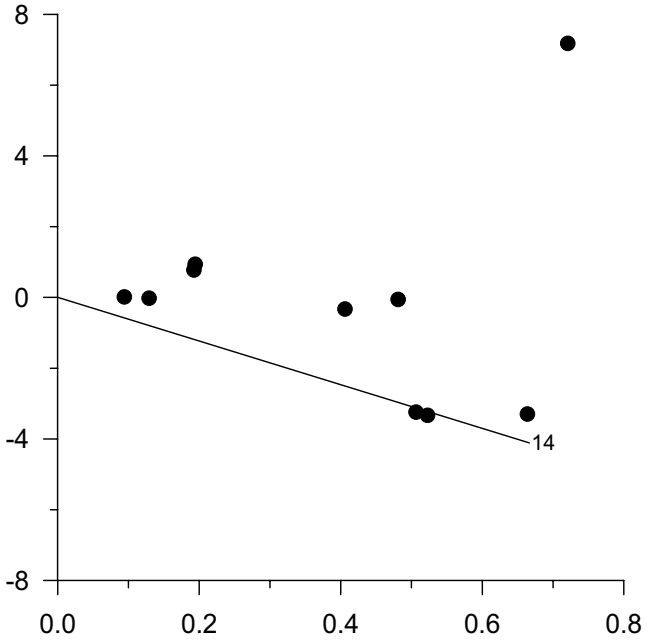

Fig. 6. *Results of the SAR method dating of the sample WM-2. The ray shows an age of 14 ka.*

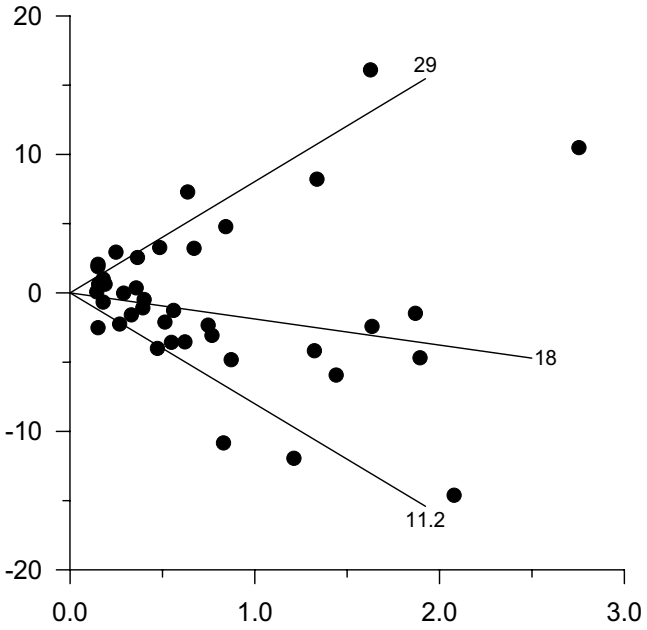

Fig. 7. *Results of the SAR method dating of the sample D-1. The three rays show ages of 11.2 ka, 18 ka and 29 ka.*

than 36 ka BP. The oldest links of this series occurring in the floor of the 7 m terrace have been dated to be older than 38 ka BP. The problem that needs further research are the genesis and age of the sandy formations covering the InterpleniVistulian series. Undoubtedly, a part of the uppermost formations of the sandy terrace is of eolian origin; besides dunes, low hillocks are found, that are built of eolian cover sands. A single OSL date obtained for these sands points to the end of the Late Vistulian.

The alluvial series, built of sediments dated back to 22-14 ka BP is covered with Holocene alluvial loams. Further to the south of the contemporary Wisłok River bed fragments of the Late Vistulian alluvial plain are found side by side with younger alluvial fills of fluvial sediments connected with abandoned paleochannel system of the Wisłok River. This feature may be related to migration of the river bed towards the left edge of the valley bottom.

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