

# Pollen analysis of a peaty mud sample from the Dunajec River alluvial fan (Sandomierz Basin, Poland) in the context of its morphological position, radiocarbon dating, and comparison with neighbouring sites

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**ABSTRACT.** The paper presents the results of pollen analysis and radiocarbon dating of a peaty mud sample from a gravel-sand outlier of the Vistulian alluvial fan of the Dunajec River. The study showed the occurrence of open birch-pine forests with sporadic larch and stone pine at the time of mud deposition. The vegetation, of park tundra type, was characterised by the development of shrubby and sedge-grass communities. The radiocarbon dating of  $39\,100 \pm 3\,000$  BP indicates that deposition occurred in the Middle Plenivistulian (Hengelo interstadial or older, colder climatic stadial). A comparison of the palynological analysis and radiocarbon dating with data from other sites suggests that both the alluvia of the north-western part of the Dunajec River fan and the alluvia of its southern part were formed during the Middle Plenivistulian.

**KEY WORDS:** pollen analysis, Dunajec alluvial fan, park tundra, Middle Pleniglacial, Sandomierz Basin

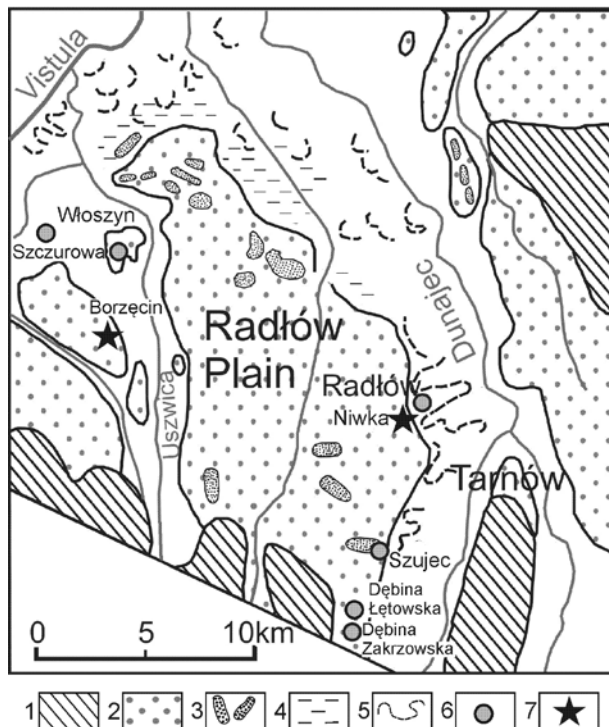
## INTRODUCTION

Between the Carpathian margin and the mouth of the Dunajec River, this river builds a Vistulian alluvial fan more than ten kilometres wide, whose broad western segment belongs to the Radłów Plain (Równina Radłowska). A sequence of gravel-sand sediments with peaty mud inserts, outcropped at the Włoszyn site west of the Uszwica River, was sampled and preliminary results of palynological analysis done by K. Mamakowa were published by Gębica (1995). The present paper reconstructs the environmental conditions on the basis of a complete pollen spectrum of the sample from the Włoszyn site, as well as a geomorphological analysis of this site and a comparison with other more complete pollen successions in the

Dunajec alluvial fan (Sokołowski 1995, Gębica 2004).

## GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

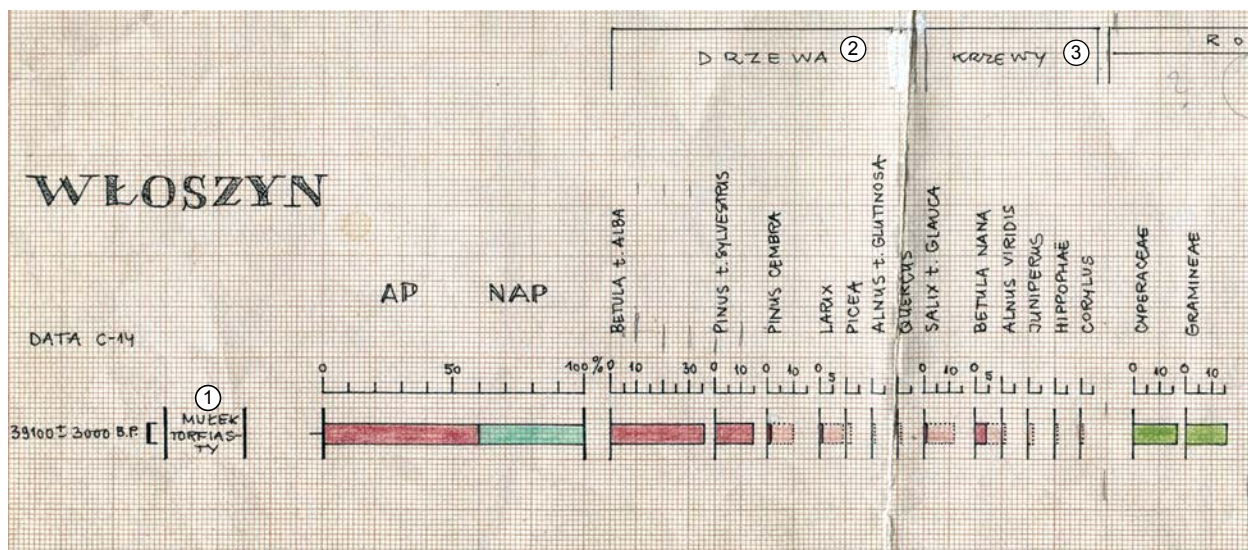
The study site (Włoszyn) is on the flood plain of the left bank of the Uszwica River, ca 1 km south-east of the centre of Włoszyn village (Fig. 1). The Uszwica River valley floor is formed of sand-gravel alluvia overlying Miocene clays at 5–8 m depth. The gravel alluvia build the western segment of the Vistulian alluvial fan of the Dunajec River, which is 8–12 m high. Its area, occupied by dunes, belongs to the Radłów Plain (Sokołowski 1981,



**Fig. 1.** Location of the Włoszyn site in the Dunajec River alluvial fan (after P. Gębica). 1 – Plateaus, 2 – Vistulian terraces and alluvial fans, 3 – aeolian sands and dunes, 4 – Late Vistulian depressions, 5 – Holocene floodplains with cut-off palaeomeanders, 6 – investigated sites: dots – dated by C-14 method, stars – dated by TL method

1995, Gębica 1995). The Radłów Plain is formed of Vistulian sediments overlying Miocene substrate dissected by palaeovalleys filled with a series of gravel-sand sediments 20 m thick. The lower alluvial series near Radłów was dated by the TL method at  $59 \pm 9$  ka BP (Lu-1215), and the upper series from  $39 \pm 6$  ka BP (Lu-1214) bottom to  $19 \pm 3$  ka BP (Lu-1216) top

(Sokołowski 1995). In the vicinity of Włoszyn the top of the alluvial fan is uneven, and several gravel-sand outliers are outcropped within the mud sediments. One of them, west of the current Uszwica riverbed, is ca 1 km long and 0.7–0.8 km wide, and reaches 183.3 m a.s.l. Its top surface stands 1–2 m above the Uszwica River floodplain and 8 m above the Dunajec riverbed. This outlier is surrounded by a floodplain built of overbank alluvial silts 2 m thick (Gębica 1995). Tree fragments found during the exploitation of several gravel pits situated within this outlier were identified as ash (*Fraxinus* sp.) by M. Krąpiec of AGH University of Science and Technology in Kraków. On the face of one of the gravel pits the following depositional sequence was exposed: 0.0–0.6 m – Holocene soil; 0.6–1.3 m – sand and gravel with a deformed silt layer several centimetres thick; 1.3–1.7 m – sand with gravel; and 1.7–2.1 m – olive-green clay and brown peaty mud with admixture of sand. Below the mud layer, down to 5 m depth, are fine and medium grained gravel, gravel with sand, and boulders of Scandinavian granitoids up to 0.5–0.6 m in diameter (these strata were exploited as raw material in the pit). Within the gravel alluvia are numerous granitoid and quartzite pebbles from the Tatra Mts. These pebbles are evidence of the existence of a Dunajec River outlet to the Vistula River between Uście Solne and Szczurowa and the accumulation of gravel-sand material west of the Uszwica River valley during the Vistulian (Sokołowski 1981, 1995).



**Fig. 2.** Pollen spectrum of peaty mud from the Włoszyn site radiocarbon-dated to  $39100 \pm 3000$  BP (Gd-5704) (Mamakowa 1992) ①–⑤ – translation from Polish. 1 – peaty mud, 2 – trees, 3 – shrubs, 4 – herbaceous plants, 5 – aquatics and marshy plants,



## RESULTS OF PALYNOLOGICAL ANALYSIS

A sample for palynological analysis was taken from the peaty mud layer at 2.05–2.10 m depth in the sequence described above (Fig. 2). The sample was characterised by very high pollen frequency (553 AP grains/cm<sup>2</sup>, 364 NAP grains/cm<sup>2</sup>). Tree pollen constituted 60.3% of the pollen. In the pollen spectrum, tree-birch (*Betula t. alba*) pollen predominated at 35.9%, and pine (*Pinus t. sylvestris*) pollen formed 15.4%. The content of larch (*Larix* – 0.9%) and stone pine (*Pinus cembra* + *P. cf. cembra* – 2.4%) pollen was low. Among the shrub species only pollen of dwarf birch (*Betula nana*) and gray willow (*Salix t. glauca*) showed slightly higher concentrations (*Betula nana* + *B. cf. nana* – 3.7%, *Salix t. glauca* – 1.2%). Pollen of juniper, buckthorn and green alder (*Juniperus*, *Hippophaë* and *Alnus viridis*) occurred sporadically. Sedge and grass pollen predominated among the herbaceous plants (Cyperaceae – 16.7%, Gramineae – 15.7%). Content of mugwort pollen (*Artemisia* sp. – 1.9%) in the sample was relatively high. The diversity of herbaceous plants was relatively high but their pollen percentages were below 1%, or only single pollen grains were noted.

### RECONSTRUCTION OF VEGETATION

The pollen spectrum indicates that deposition of peaty mud took place when the area was covered by open birch-pine forests with

larch and sporadic stone pine. The vegetation has features of park tundra, with well developed shrub communities, with dwarf birch, willow and green alder (*Alnus viridis*) occupying marshy places. In the sedge-grass communities connected with these habitats the following species occurred: lesser clubmoss (*Selaginella selaginoides*), great burnet (*Sanguisorba officinalis*), valerian (*Valeriana officinalis*), marsh marigold (*Caltha* sp.), greater plantain (*Plantago maior*), bistort (*Polygonum bistorta/viviparum*), and others. The drier habitats were probably occupied by grass communities with mugwort (*Artemisia* sp.), rock-rose (*Helianthemum* sp.), anise (*Pimpinella* sp.), chamomile (*Anthemis* sp.), and others, as well as occasional juniper (*Juniperus* sp.) and buckthorn (*Hippophaë* sp.).

### RADIOCARBON DATING

The radiocarbon dating obtained from the peaty mud layer sampled at 2.05–2.10 m depth is 39 100 ± 3000 BP (Gd-5704, 46 600–41000 cal BP). This dating and its margin of error match the Hengelo interstadial (39 100–3000 = 36 100 BP) or the colder stadial preceding this interstadial (39 100 + 3000 = 42 100 BP) (Behre & Lade 1986). If the dating is underestimated owing to admixture of younger organic material from current tree roots penetrating the studied mud, the mud layer may have been deposited earlier than indicated by this radiocarbon dating. However, it was not deposited before the Vistulian glaciation.

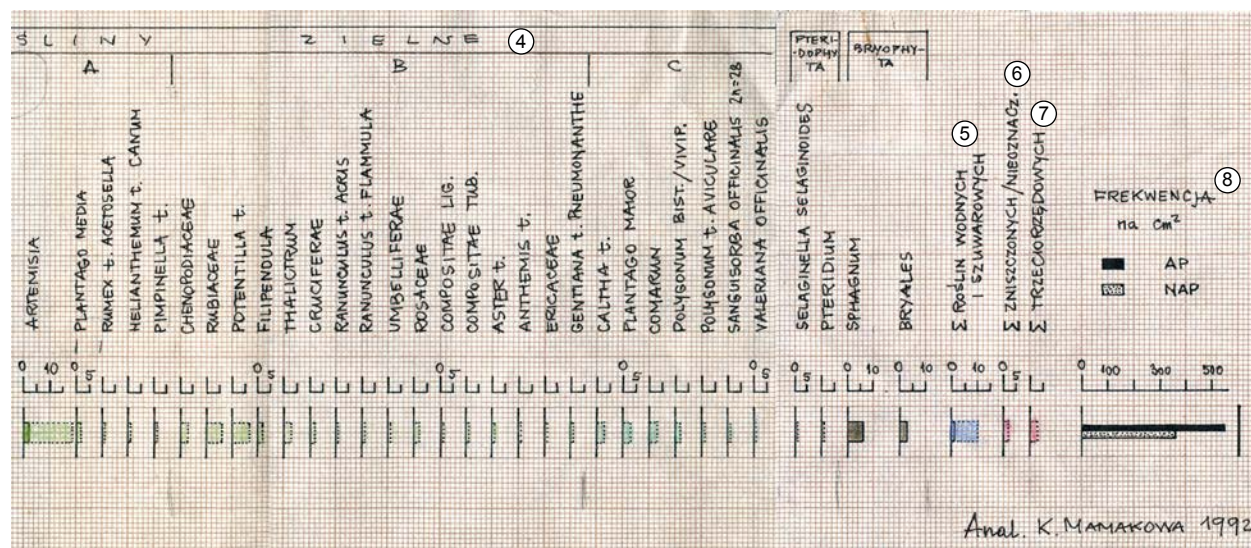


Fig. 2. Continued

6 – degraded/indeterminate pollen, 7 – Tertiary pollen, 8 – frequency/cm<sup>2</sup>

## COMPARISON WITH OTHER SITES

The geomorphological situation of the Włoszyn site and its pollen spectrum is similar to those of sites in the Dunajec River alluvial fan south of Łętowice village in the Dębina Zakrzowska gravel pit (Gębica 2004) (Fig. 1). A sequence of cut-off palaeomeander sediments on the face of this gravel pit was described. In plant detritus sampled from 3 m depth in this sequence, K. Szczepanek of the Institute of Botany, Jagiellonian University in Kraków, identified several dozen pollen grains of trees, mainly pine (*Pinus* sp.), stone pine (*Pinus cembra*), spruce (*Picea* sp.), and birch (*Betula* sp.). Among the herbaceous plants, sedges (Cyperaceae) predominated. Pollen of water-milfoil (*Myriophyllum* sp.) found in the latter sample indicates deposition in a shallow oxbow lake. The pollen spectrum also suggests the occurrence of coniferous and tree-birch clusters, as well as herbaceous plants in the area surrounding the site, thus communities of park tundra type. Radiocarbon dating of the sample's organic silt indicated that the sediment was older than 30 290 BP (Gd-18180), which generally confirmed the results of the palynological analysis and placed the deposition of the silt in the younger part of the Middle Plenivistulian (Gębica 2004).

At the Dębina Łętowska site, 0.5 km north of the Dębina Zakrzowska site, the organic clay filling the cut-off palaeomeander of the Dunajec River contained plant detritus in which only occasional pollen grains of pine (*Pinus* sp.) and birch (*Betula* sp.) were found. The radiocarbon dating of this organic clay sampled at 1.3 m depth gave a date of 27 650 ± 2250 BP (Gd-16165), which refers the deposition of the palaeochannel deposits to the Denekamp interstadial (Gębica 2004).

## CONCLUSIONS

The gravel-sand outliers with peaty mud inserts remaining on the left bank of the Usz-wica River mark the extensive west range of the Vistulian alluvial fan of the Dunajec River.

The results of palynological analysis indicate the occurrence of open birch-pine forests with sporadic larch and stone pine trees at the time of mud deposition. In the vegetation, of park tundra type, shrub (dwarf birch and willow) and sedge-grass communities were common. The radiocarbon dating (39 100 ± 3000 BP, Gd-5704) places the mud deposition in the Middle Plenivistulian (Hengelo interstadial or older cold climatic phase). A comparison of the results of this palynological analysis and radiocarbon dating with such data from neighbouring sites confirms that the alluvia of the north-western segment of the Dunajec River fan and the alluvia of its southern segment were deposited during the Middle Plenivistulian.

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