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Prehistoric and historic settlement recorded in a terrestrial pollen profile: Boreal to Subatlantic forest succession in a 60 cm thick sediment in Stanisławice (southern Poland)

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ABSTRACT. The palynological record from a small terrestrial profile in a forested sandy dune at the site Stanisławice covers the time from the Boreal to the Subatlantic chronozone. Fluctuations of the thermophilous deciduous tree pollen curves are correlated with the occurrences of anthropogenic indicators starting from the late Atlantic. The distinct impact of man's activity on the vegetation of the Niepołomice Forest till the recent times is described.

KEY WORDS: palynology, terrestrial profile, human impact, Holocene, southern Poland

INTRODUCTION

Studies on the vegetational history of the Niepołomice Forest, a relatively large forest complex extending east of Kraków, were undertaken several times without any conclusive results (Trela 1931, Szponder 1955). In the 1980s the present author, co-working with geomorphologists, began to study palaeobotanical materials, aiming at reconstructing the transformations of the natural environment of this area in the past.

A series of borings were made in old riverbeds and peat-bogs, and pollen analysis was carried out from 8 profiles. Pollen diagrams provided a picture of vegetation development from the Oldest Dryas to the Subatlantic chronozone (Nalepka 1994a,b, Nalepka & Wasylikowa 1998). The present publication deals with the influence of man's activity upon the vegetation of the southern part of the forest, reconstructed on the basis of pollen profile from the site of Stanisławice (Fig. 1).

STUDY AREA

The Niepołomice Forest (Puszcza Niepołomicka, Fig. 1) extends about 20 km east of

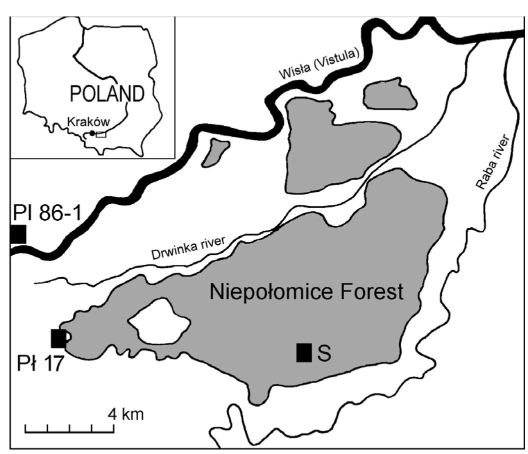

Fig. 1. Map of Niepołomice Forest showing the location of the sites at Stanisławice (S), Pleszów (Pl 86–1) and Podłęże (Pł 17)

Kraków in the northern foreland of the Carpathians. It is relatively slightly differentiated woodland complex, 10 846 ha in area (data from 1969, Suliński 1981), which the river Drwinka divides into the northern part occupying the floodplain of the Vistula (Wisła), with its numerous palaeochannels, and the southern part situated on the sandy alluvial fan of the river Raba.

In the main complex of the forest, lying to the south of the river Drwinka, prevail the association of mixed coniferous forest (*Pino-Quercetum*), mainly on gley and podzol soils, and the transitional communities to the lime-hornbeam forest (between *Pino-Quercetum* and *Tilio-Carpinetum*), on the brown earth soil. Bog coniferous forest (*Vaccinio uliginosi-Pinetum*) occurs in small areas, near the investigated site Stanisławice, whereas plantations of pine monocultures occupy a considerable space. There are very small areas of alder carrs (*Carici elongatae-Alnetum*) in both parts of the forest (Bednarz 1981, Ćwikowa & Lesiński 1981, Gruszczyk 1981). On the Vistulian floodplain in the northern part of the forest, mainly dominated by alluvial soils (Gruszczyk 1981), there are some abandoned channels at advanced stages of overgrowing, which still show natural phases of succession (Dubiel 1973). The abandoned channels and the meadows (Denisiuk 1976) are situated within more or less extensive forest complexes dominated by deciduous tree species (Dubiel 1995, Mitka 1998). Only a few tree stands have preserved their almost natural character. These are riverine woods (*Circaeo-Alnetum* and *Fraxino-Ulmetum campestris*), wet lime-hornbeam forests (*Tilio-Carpinetum stachyetosum*) and transitional communities between the riverine woods and alder carrs on the one hand and the wet lime-hornbeam forest on the other (Denisiuk et al. 1976, Ćwikowa & Lesiński 1981). Cultivated fields, meadows and rural housing predominate in higher situated places of the valley floor, in addition to woodlands (Denisiuk & Medwecka-Kornaś 1976).

The Niepołomice Forest lies in the region of a warm and moderately dry climate of the piedmont basins, in the subregion of the Sandomierz Basin (Niedźwiedź & Obrębska-Starklowa 1991). The climatic vegetation season is here the longest in Poland (Suliński 1981). The mean annual temperatures range between +8 – +8.5°C and the mean annual rainfall between 658–750 mm. The number of days with snow cover is 60 (Hess 1979).

The present water network is the effect of both natural conditions and human economic activity (Suliński 1981). Smólski (1981) dates the first land reclamation works to the 1820s. In the southern part there are numerous elevations of aeolian origin, formed in the Older or Younger Dryas, which underwent transformations in the Subboreal and deflations in the Subatlantic, just as in the whole territory of Poland (Izmaiłow 1975). Extensive wind-blown troughs without outlets are adjacent to the dunes on the northern and western sides.

The study site at Stanisławice (50°01'N, 20°19'E) lies in the southern part of the main complex of the forest, inside 267 forest section, which is under protection because of the fern *Osmunda regalis* presence. After Dubiel (1995) the whole 267 forest section is covered by degraded moist pine forest (*Vaccinio-uliginosi-Pinetum*) and mixed pine forest (*Pino-Quercetum*). The investigated profile lies on the NW slope of the dune, covered with peat-podzol soil, and overgrown by a degraded coniferous forest (*Pino-Quercetum*). *Pinus sylvestris*, *Quercus robur*, *Frangula alnus*, *Fagus sylvatica*, *Abies alba*, and *Sorbus aucuparia* build the tree cover, *Rubus plicatus* and *R. hirtus* are important among shrubs. *Vaccinium myrtillus*, *Trientalis europaea*, *Moehringia trinervia*, *Galeopsis bifida*, *Molinia arundinacea*, *Dryopteris spinulosa*, and *Luzula pilosa*, grow in the herb layer (Mitka pers. comm.). There are some small hollows in the ground, which are probably traces of fallen trees. To the N and NE of the dune there are transitional communities between *Carici elongatae-Alnetum* and *Pino-Quercetum*. The deflation depression adjacent to the dune on the northern side occupied by swamp pine forest (*Vaccinio uliginosi-Pinetum*) is partly dried by means of drain ditches (Dubiel 1995). In the temporary dried depression grows the fern *Osmunda regalis* (Baryła & Pietras 1982, Dubiel 1995). In the southern and south-eastern direction of the dune there is a fresh variant of *Pino-Quercetum*, and in the West a moist one.

ARCHAEOLOGICAL BACKGROUND

A lot of archaeological investigations were carried out along the Vistula river, east of Kraków. Many settlements from the Neolithic, Bronze Age, Roman Period and Middle Ages were discovered. The beginnings of the Neolithic settlement in the catchment-area of the Vistula are dated to about 6500 BP, when on the loess uplands small settlements were set up by the oldest central European farmers, representing the Linear Pottery Culture (Kruk 1992, Godłowska et al. 1987). From that time onwards settlement was maintained continuously in the loess areas and in the Vistula valley with variable intensity (Gluza 1971, 1984, Godłowska et al. 1987, Kruk 1980, 1983, Wasylikowa et al. 1995 and others). Along the Vistula valley, east of Kraków, eleven larger villages of the peoples of the Przeworsk culture (Pre-Roman and Roman Period) were situated (Dobrzańska 1998).

The area of the Niepołomice Forest itself has not been studied in detail in respect to archaeology. A very limited information is available about the Neolithic, Bronze Age and the older part of the Iron Age. A few oldest traces of settlement on the periphery of the forest are connected with the Linear Pottery Culture. A fairly large number of settlements from the Roman times have been recorded at the southern border of the Niepołomice Forest. In the middle of the 1^{st} millennium A.D. there was a temporary fall in the number of settlements, which was followed, starting from the $7^{th}/8^{th}$ centuries, by the recolonization (Köhler 1991). Historical documents show that the Niepołomice Forest was royal property, so it has been relatively well protected (Rokosz 1984). Up to the end of the 12^{th} century it formed a continuous, dense forest stand. Anthropogenic changes began in the 12^{th} century. Timber from Niepołomice Forest was used in the royal salt mines at Wieliczka and Bochnia, beginning from the middle of the 13^{th} century. The greatest changes in the forest environment occurred in the 19^{th} century, when extensive areas were cleared and planted with pine and a network of drainage ditches was dug. Starting in the 1950s industrial air pollution, and accompanying mass outbreaks of insects pests badly affected the health condition of the forest (Mitka 1998).

PREVIOUS POLLEN INVESTIGATION IN THE STUDY AREA

Stanisławice site is situated in the most western part of the Sandomierz Basin (type-region P-k, Ralska-Jasiewiczowa & Latałowa 1996), from which no pollen diagrams covering the whole Holocene period were available. It is the only site found so far which made it possible to reconstruct the almost entire Holocene history of vegetation of the Niepołomice Forest. The Late Glacial and/or early Holocene sections have been studied at Kraków-Rondo, Kraków-Piastowska (Mamakowa 1970), Błoto, Podłężówka, Pleszów 86-1, Branice, Drwinka and Grobla (Nalepka 1994a, b). Sediments at Pleszów I site contained a fragment of the Atlantic chronozone only (Wasylikowa et al. 1985). At the eastern part of the Sandomierz Basin a few sites are situated from which Late Glacial and Holocene profiles were elaborated palynologically by Mamakowa (1962).

The nearest reference site Wolbrom lies in the distance of over 30 km to the North-East, in the type region Silesia-Cracow Upland (P-h). For this area the regional pollen zones were described by Latałowa and Ralska-Jasiewiczowa (Latałowa & Nalepka 1987, Latałowa 1989, Ralska-Jasiewiczowa & Latałowa 1996). However, this zonation can not be used for age estimation of local pollen assemblage zones in the diagram from Stanisławice, because the two sites differ too much in their relief, geographical position, geomorphological features, climate and vegetation.

MATERIAL AND METHODS

The profile was taken from an exposure in a small depression situated on the north-western slope of the dune at Stanisławice, in section 267 of the Niepołomice Forest (Tab. 1). The material from the depth of 0.0–29.0 cm was collected as a monolith 30.0 × 30.0 × 30.0 cm in size and after its transportation to the laboratory, it was deep frozen. The material from the sandy layers, from a depth of 29.0–66.5 cm, was sampled directly in glass tubes. The method worked out for soil profiles was applied for this material (Aaby 1983, Nalepka 1999). Part of the material was dried to calculate dry density and ignited to determine the ignition residue. Another portion was subjected to the chemical treatment in the laboratory of the Danish Institute of Geology (DGU) in Copenhagen. After its vacuum freezing, a sample of ± 0.05 g of material was prepared for pollen analysis by Erdtman's acetolysis (Faegri et al. 1989), together with a known number

Table 1. Description of the profile Stanisławice (S) (depth measured from the field point at 1.5 cm below present surface level)

Depth (cm)	Lithology
0.0–1.0	Light brown, unconsolidated litter
1.0–4.0	Raw humus, weakly consolidated
4.0–5.0	Raw humus, dark brown, more decomposed
5.0–7.0	*Sphagnum* peat, light yellow, weakly decomposed
7.0–13.0 (10.0–sand)	Strongly decomposed peat, brown, fresh rootlets visible, streak of sand at a depth of 10.0 cm. From the depth 10.5–12.5 cm ^{14}C date 480 ± 60BP (Gd 6505)
13.0–29.0	Highly decomposed peat, black-brown, with the presence of sand increasing downwards. Most roots end in the upper part. From the depth 19.0–21.0 cm ^{14}C date 1870 ± 50 BP (Gd5973)
29.0–36.5	Sand, grey-brown, with humus matter, with black, thread-like traces of subfossil roots
36.5–51.0	Sand, grey-beige, with traces of old root. From the depth 46.0–51.0 cm ^{14}C date 2670 ± 60 BP (Gd 5833).
51.0–61.5	Sand, marbled, brown-rust, with single traces of old roots
61.5–66.5	Sand, rusty
from 66.5 cm	Sand, light beige

(2–5 tablets) of indicator spores of *Lycopodium* (Stockmarr 1971). Mineral components were removed by decantation and boiling in hydrofluoric acid. The material was mounted in silicone oil. The same preparations were used to count sporomorphs, charcoals (Tolonen 1986), hyphae fragments and to estimate the state of preservation of the sporomorph walls of *Alnus*, *Betula*, *Carpinus*, *Corylus*, *Tilia* and Filicales monoletae (Aaby 1983). The results of analyses of hyphae fragments and the state of preservation of sporomorph walls will be discussed in a separate paper.

The pollen sum of trees, shrubs and herbs, excluding aquatic and swamp plants and spores, was used as the basis for calculating the percentages. The concentration of sporomorphs was counted in three ways: in 1 g of dry matter, in 1 cm^3 and in 1 g of organic matter, but only the summary curve of concentration, calculated for 1 g of organic matter, is presented in the diagram. For counting parts of the spectra, drawing the diagrams, and providing numerical analysis (CONSLINK), the POLPAL computer programmes were employed (Nalepka & Walanus 1989, Ralska-Jasiewiczowa & Walanus 1989, Walanus & Nalepka 1999).

DEVELOPMENT OF VEGETATION

The vegetation history in the area of the present-day Niepołomice Forest and its surroundings was reconstructed on the basis of 8 pollen profiles (Nalepka 1994a, b). The general trends in vegetation development are shown in a simplified survey diagram (Fig. 2) which is compiled of three diagrams from the sites Pleszów, Podłęże and Stanisławice (Fig. 1).

In the previous publications the results of palynological studies from Stanisławice were not discussed in detail. The present paper gives a more complete report of these investigations and concentrates the attention on past environmental changes in the southern sector of Niepołomice Forest (Fig. 3). When palaeobotanical studies at Stanisławice were started, it was expected that the results would produce a picture of the local history of plant communities, within a small radius from the examined profile, and going no further back than the Subatlantic, just as it happened in some of the forest soil profiles in Denmark (Andersen 1978, 1984, Aaby 1983). Meanwhile the diagram reflected the vegetation history from the Boreal to the Subatlantic (Mangerud et al. 1974, Ralska-Jasiewiczowa 1983, Ralska-Jasiewiczowa & Latałowa 1996) and showed distinct regional traits.

LOCAL POLLEN ASSEMBLAGE ZONES

Local pollen assemblage zones (LPAZ) were described on the basis of visual analysis of individual pollen curves supported by ConsLink analysis. The basis for zonal division of the diagram is presented in Table 2.

S-1, *Pinus–Ulmus–Filipendula* L PAZ. Pine forest with birch (Fig. 3) and *Ulmus* with a small admixture of *Corylus*, *Quercus*, and *Picea* dominated in the surroundings of the study site. The dune itself was probably grown over by an open pine wood. In open places the conditions were favourable for the development of herbs, including Poaceae, *Artemisia* as well as dwarf shrubs from Ericaceae, mainly *Calluna vulgaris*, and *Juniperus* scrub. *Salix* and many herbaceous plants, such as Cyperaceae, *Typha latifolia*, *Sparganium*, *Filipendula*,

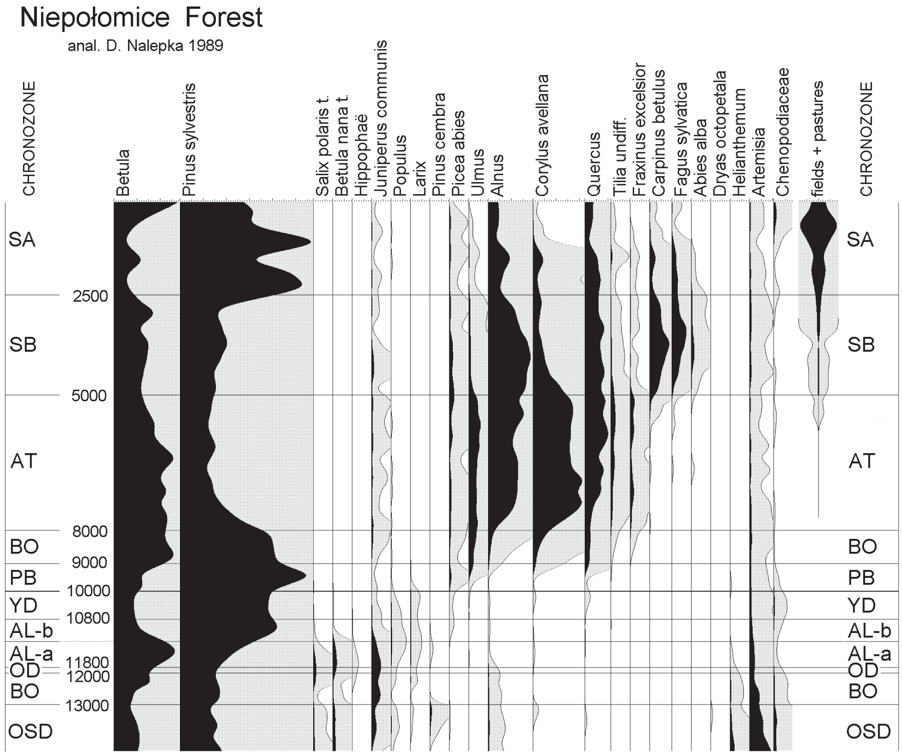

Fig. 2. Survey pollen diagram to show the general features of vegetation history in the Niepołomice Forest area. It is compiled of tree diagrams from the sites Pleszów, Podłęże and Stanisławice

Table 2. Stanisławice (S), summarized description of local pollen assemblage zones

L PAZ	Name of L PAZ	Depth (cm)	Description of pollen spectra
S-1	*Pinus–Ulmus–Filipendula*	41.5–58.5	*Pinus* (max. 41%) dominates, *Betula* (max. 30%) relatively high; low, continuous curves of *Corylus* (0.1–6.3%), *Quercus* (0.9–4.4%), *Ulmus* (1.3–4.5%), *Filipendula*, and *Artemisia*. S 1/S 2 limit: *Pinus* and *Filipendula* decrease, *Alnus, Corylus, Fraxinus*, and *Tilia* increase
S-2	*Ulmus–Corylus–Tilia–Fraxinus*	21.0–41.5	The highest frequencies of *Corylus* (max. 23%), *Tilia* (max. 2.2%), *Fraxinus* (max. 2.4%), *Ulmus* (max. 6.1%), and *Quercus* (max. 11%); low frequency of *Pinus* (10–28%). *Carpinus, Fagus, Secale cereale*, and *Plantago lanceolata* appear in the younger part of the zone. S 2/S 3 limit: decrease of *Corylus, Ulmus, Fraxinus, Tilia*; increase of *Carpinus*, and *Fagus*
S-3	*Alnus–Carpinus–Fagus*	14.0–21.0	*Alnus* (max. 18%), *Carpinus* (max. 9.0%), *Fagus* (max. 6.7%), and *Calluna* (max. 23%) dominate. Low frequency of *Abies* (0.3–1.3%) and irregular occurrence of *Plantago lanceolata* and *Secale cereale*. S 3/S 4 limit: *Pinus, Plantago lanceolata*, and *Secale cereale* increase, *Alnus, Ulmus, Abies, Carpinus*, and *Fagus* decrease
S-4	*Pinus*	6.0–14.0	Among AP the highest values of *Pinus* (max. 71%). Relatively high frequency of *Secale cereale* (max. 2.5%). At the depth 8.0–10.0 cm strong fall of *Pinus* (min. 17%), *Secale cereale* (0.2–1.0%), and others anthropogenic indicators. Increase of *Calluna* (9.6–13%). S4/S 5 limit: AP decreases, fall of *Pinus*. Poaceae increase
S-5	Poaceae	1.0–6.0	*Pinus* decreases (min. 28%); the highest percentage of Poaceae (max. 25%) and anthropogenic indicators, especially *Secale cereale* (max. 3.4%) and *Plantago lanceolata* (max. 3.0%). In the upper spectra NAP and anthropogenic indicators decrease

Urtica, *Thalictrum*, and *Sphagnum* may have occurred close to the dune, in a waterlogged trough.

The vegetation reflected by this local pollen zone corresponds to the regional vegetation of the Boreal chronozone, and the ^{14}C date 2670 ± 60 BP (from the upper section of that zone) is evidently too young. The dated sample could have been contaminated with younger carbon due to humus percolating through sandy layer from above and younger roots visible in the profile.

S-2, *Ulmus–Corylus–Tilia–Fraxinus* L PAZ. Forests were subjected to transformations caused by the expansion of thermophilous deciduous trees. The maximum percentages of these trees in the diagram (Fig. 3) allow the supposition that the mixed deciduous forests with *Quercus*, *Tilia*, *Ulmus*, *Fraxinus*, and *Corylus* became dominant. At that time there were better conditions for the growth of hazel (maximum of *Corylus*), and hazel scrub spread in open places. Deciduous trees were ousting pine from more fertile biotopes (*Pinus* curve is the lowest), pushing it perhaps into poorer soils on the dune, but deciduous trees probably invaded the dune itself, too. Herbaceous light-demanding plant communities occupied only small spaces (low NAP curve). Such small open areas were formed in a natural way owing to fallen trees or fires. The heliophilous vegetation probably included communities with *Calluna vulgaris, Jasione, Gypsophila fastigiata*, *Spergula arvensis*, and *Anthericum*. *Lycopodium clavatum* could occupy open sites in dry pine forests (Pancer-Kotejowa et al. 1996) and could grow together with *Calluna* (Szafer & Zarzycki 1972). In the deflation trough thickets with *Salix* and *Betula* developed. *Alnus* started its expansion in moist habitats, forming alder carrs probably as early as that period. This vegetation type allows to correlate this zone with the Atlantic chronozone. More frequent appearance of *Pteridium aquilinum* in the upper section of the zone as well as the rise of charcoal curve may point to forest fire intensification. It probably was caused by people, as in the uppermost spectra of S-2 the first traces of agriculture appeared, namely pollen grains of *Plantago lanceolata*, *Rumex acetosella* t. and *Secale cereale.* In spite of the fact that agricultural activity started somewhere in the vicinity of the site, species composition of forest stands remained unchanged.

S-3, *Alnus–Carpinus–Fagus* L PAZ. The area occupied by thermophilous deciduous trees described in the previous section was replaced by hornbeam (*Carpinus*) and beech (*Fagus*) which appeared and the composition of forests has changed (decrease in the *Corylus, Ulmus, Tilia* and *Fraxinus* curves, and culmination of *Carpinus, Fagus* and *Abies* pollen curves). The abundant presence of *Carpinus* and *Fagus* pollen corresponds to the vegetation of the Subboreal chronozone. In the upper section of this zone reduction of wooded areas is indicated by the fall in pollen values of all trees. The processes of dune transformation dated to the Subboreal were described from the other forest sections (Izmaiłow 1975) and were explained there as the effect of forest clearance by means of fire. Similar processes probably took place on the dune in Stanisławice. This is documented in the diagram by the high concentration of charcoal and low but almost continuous curve of anthropogenic indicators. Thinning of the forest and the formation of new sandy habitats owing to the dune transformations made it possible for *Calluna* to expand (max. *Calluna*). Perhaps only oak did not retreat to the same degree as did the other tree species (almost unaltered course of the *Quercus* pollen curve), while pine still persisted probably only in poor habitats. In moist habitats, and in troughs alderwoods were dominant. Wet habitats are documented by the presence of *Ledum* and *Lycopodiella inundata*.

It seems that both, the deterioration of climate and worsening edaphic conditions due to ever-increasing human activity caused the change of the mixed deciduous mesophilous forests to forests with *Carpinus* and *Fagus* (Iversen 1964, Tobolski 1976). ^{14}C date 1870±50 BP from the bottom section of that zone is too young, for reasons described with zone S-1.

S-4, *Pinus* L PAZ. In the time corresponding to this zone pine was the dominant forest tree (a rapid rise in the pollen values of *Pinus*). The remaining trees occurred in decreasing numbers, probably with the exception of oak. This zone corresponds to the Subatlantic chronozone and the ^{14}C date 480±60 BP obtained from the zone bottom is considered to be too young. It seems likely that pine – oak forest which began to develop in the southern part of the Niepołomice Forest may have given

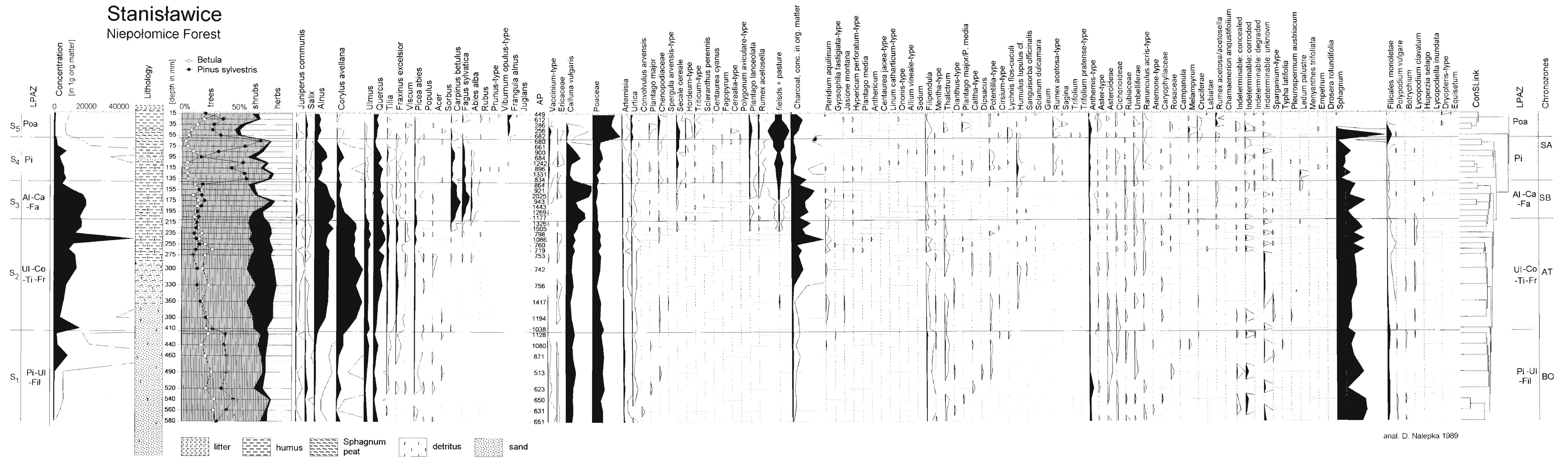

Fig. 3. Pollen diagram from Stanisławice. L PAZ – local pollen assemblage zone. Sum of anthropogenic indicators: fields (*Secale cerealee* + *Triticum* t. + *Hordeum* t. + Cerealia + *Fagopyrum* + *Centaurea cyanus*) + pasture plants (*Platago lanceolata* + *Rumex acetosella* t.)

rise to mixed coniferous forests resembling the present *Pino-Quercetum*, to the origin of which man has undoubtedly contributed. The increasing and continuous curve of anthropogenic indicators pollen and the decline of charcoal concentration suggest that the use of fire for forest clearance was given up or diminished. Open areas may have been partially utilised economically for pastures and cultivated fields. A short lasting fall of *Pinus* is distinctly marked in one spectrum at the depth 9.5 cm, above a thin sand layer. This event probably was a result of a stronger human activity, which caused the deforestation, and a new transformation of dunes. Similar processes were observed in the other parts of Niepołomice Forest (Izmaiłow 1975, 2001). The rise of *Calluna* pollen curve above that sandy layer indicates that heather colonized new places again. A second rise of *Pinus* curve is contemporaneous with the decrease of all trees, and the rise of *Vaccinium*, *Secale* and Filicales. Both maxima of pine pollen curve might be treated here as any answer to the anthropogenic pressure on sandy soils in the south part of Niepołomice Forest. The presence of *Drosera rotundifolia*, *Ledum* and *Vaccinium* t. pollen may suggest, that at the time corresponding to this zone a community similar to modern moist pine forest (*Vaccinio uliginosi – Pinetum*) might develop in the investigated area (Matuszkiewicz J.M. 2001, Matuszkiewicz W. 2001, Pancer-Kotejowa et al. 1996, Szafer & Zarzycki 1972).

S-5, Poaceae L PAZ. Changes in the forest composition consisted in the decrease of pine and most of the deciduous trees, the appearance of *Frangula alnus* and the expansion of *Betula*. In the sediment of the lower part of the zone the increased moisture is indicated by the development of *Sphagnum* peat. This humid episode was stopped probably by the drainage conducted in the Niepołomice Forest in the historical time that caused a partial drying of soils in its southern part and led to the transformation and final destruction of the forest cover (Suliński 1981, Smólski 1965, 1981).

Plant cover at the time described in Poaceae local zone resembled the present day open mixed forest with *Pinus*, *Frangula* and *Quercus*, with more of *Betula* and *Alnus* in the waterlogged depression close to the dune. Vegetation must have been effected by the intensified agricultural activity carried out close to the investigation area (culmination of anthropogenic indicators in the lower portion of the zone).

HUMAN IMPACT ON VEGETATION IN THE VICINITY OF STANISŁAWICE SITE

The first traces of human presence in the region appeared in the middle part of pollen zone S-2. The use of fire for forest clearance was marked in the diagram (at 30.0 cm) by the beginning of a high charcoal particle concentration curve, which showed a few peaks in the upper zone section. Vegetation changes caused by this activity were probably short-lived and each deforestation was followed by a regeneration of forest to its initial state.

The high charcoal curve is direct evidence of fires (Clark 1988, Patterson et al. 1987, Wasylikowa 1990). Minor fluctuations of pollen curves of most of deciduous trees as well as changes in the curves of *Juniperus*, *Artemisia*, *Urtica*, *Pteridium aquilinum*, and corroded sporomorphs were indirect indicators of the presence of man (Behre 1981, Gaillard & Berglund 1988, Vorren 1986, Wasylikowa 1986). These indistinct fluctuations were probably caused by clearing of natural tree stands by felling and burning in order to acquire place for settlements fields. The presence of man may have caused soil enrichment in nitrogen creating thus favourable conditions for the expansion of *Urtica*. No pollen of cultivated plants was found in these layers. We might suppose, that either trees were cut mainly for timber or that the land cultivation was taking place far from the site.

At the still lower level of this zone (36.0 cm) one pollen grain of *Spergula arvensis* was found. In Poland, *Spergula arvensis* is counted among the archaeophytes growing in the segetal communities (Zając 1979, 1984). Its pollen is rarely present in the diagrams and usually as single grains only, occurring in levels in which cereal pollen is also recorded. Therefore so early presence of *Spergula* pollen at Stanisławice might seem rather enigmatic. Similarly, however, the single *Spergula* cf. *arvensis* pollen grain was noted in Darżlubie Forest (North Poland), in the level correlated with the early Neolithic, before the first appearance of cultivated plants pollen (Latałowa 1982). It seems thus, that its occurrence at Stanisławice could be interpreted, like in Darżlubie Forest, as an indication that the Neolithic farmers were already present somewhere in the study region.

The first indicators of pastures (*Plantago lanceolata, Rumex acetosella)* and cereal fields *(Secale cereale)* appeared in the uppermost part of zone S-2. The occurrence of rye in the Kraków region was confirmed by the finding of caryopses from the late Neolithic Radial Pottery Culture site at Zesławice (Giżbert 1960). At that time, however, rye was probably growing as a weed in wheat and barley fields (Behre 1992). These pollen spectra might correspond to the Neolithic time and reflect farming activities carried out at considerable distance from Stanisławice. The settlements belonging to the Danubian Cultures were discovered about 7 km south-east of the study site, on the left bank of the Raba river (Köhler 1991). Another centre of the Neolithic settlement developed on the loess terrace of the Vistula, about 20 km north-west of Stanisławice (Godłowska et al. 1987, Kruk 1980, 1983). In the pollen diagram from Pleszów I (Wasylikowa et al. 1985), the cereal cultivation and animal grazing were reflected in layers corresponding to the Linear Pottery and Lengyel Culture periods. In view of the fact that radiocarbon dates from Stanisławice are not reliable, the assignment of the changes discussed above to a definite culture is not possible. The question whether forest disturbance recorded in this zone below the first appearance of *Secale* and *Plantago lanceolata* pollen could be caused by the Mesolithic hunter – gatherers is discussed below. So far, however, no archaeological evidence has been found of the presence of Mesolithic tribes in Niepołomice Forest. The lack of pollen of agricultural indicators might be caused by the great distance to the nearest cultivated fields. Since some very cautious correlations can be made with the archaeological data from the early Neolithic, it seems more probable that the diagram reflects early Neolithic farming.

Pollen indicators of agriculture are better represented in zone S-3. During the time corresponding to this zone human activity, which continued in the surroundings of the site, may have resulted in the formation of a more open forest structure by felling and burning trees. The forests regenerated due to low level of exploitation but their species composition was changed because *Carpinus* and *Fagus* became new important forest components. The presence of cereals and pasture plants reflects the enlargement of cultivated areas. In this zone a negative correlation can be seen between the course of the hornbeam curve and the occurrence of plants indicating farming. First *Carpinus* curve shows a maximum synchronous with the minimum of anthropogenic indicator curve (*Secale*, *Plantago lanceolata*, *Urtica*), and then it decreases while the curve of field and pasture plants rises. This may mean that hornbeam invaded abandoned fields (Ralska-Jasiewiczowa 1964). S-3 zone probably corresponds to the decline of the Neolithic. It is known from archaeological sources that at that time the study area was poorly populated, and the small proportion of anthropogenic indicators in the pollen diagram corroborates this opinion. The ^{14}C date 1870 ± 50 BP from the bottom of S-3 zone would suggest the correlation of this section with the Roman period. However, this date must be too young because the spread of *Carpinus*, *Fagus* and *Abies* in several sites is well dated to the beginning of the Subboreal chronozone, about 45000 years ago.

Pollen zone S-4 reflects a more intensified farming. Among the anthropogenic indicators, which already form continuous curves, *Secale cereale* is dominant, indicating that rye was already grown. *Centaurea cyanus* grew in cornfields, *Fagopyrum* probably appeared as a weed among cultivated plants. The decrease of charcoal concentration suggests that the fire clearance of woodlands was given up or diminished (Kaczanowski & Kozłowski 1998). Deciduous trees with the exception of oak occurred in low and fluctuating numbers, probably in consequence of man's interference in the natural environment having varying intensity, which is evidenced by the fluctuations in the proportion of pollen of anthropogenic indicators. A fall of *Pinus* in the middle part of the zone was probably caused by man who destroyed pine forest on the dune. It resulted in dune transformation and opened new sites for *Calluna vulgaris* colonization.

The start of the predominance of *Secale cereale* among the cereals and the reduction of the use of fire in deforestation make very likely the correlation of this section of the profile with the Roman period. The ^{14}C date 480 ± 60 BP, which does not fit to this age estimation, indicates the contamination with younger carbon. It must be admitted, however, that the appearance of *Fagopyrum* pollen in several samples from this zone creates certain difficulties as far as the age estimation of this zone is concerned. It could not be excluded a hiatus in the sediment at 140 mm (the turn of S-3/S-4 local zones), marked by sharp increase of *Pinus* pollen grains, decrease of almost all pollen trees. To accept this explanation, the S-4 local zone could be correlated with the Middle Ages. Scattered *Fagopyrum* sp. pollen grains were recorded in several other pollen diagrams from the older part of the Subatlantic (Mamakowa 1962), corresponding to the Pre-Roman Iron Age, and were interpreted as coming from plants growing as weeds. Only continuous curves formed in the early Middle Ages sections of diagrams indicated the spread of *F. esculentum* cultivation. The history of *Fagopyrum* is not cleared up, as yet, macrofossils indicate that *F. esculentum* was known to the Scythian tribes in the Ukraine as early as about 2500 BP, in central Europe it appeared not earlier that the VII and VIII cent. AD and in western Europe not earlier then X cent. AD (Swederski 1926, Badura 1999, Wasylikowa et al. 1991). In view of these data the occurrence of *Fagopyrum* pollen at Stanisławice zone S-4 was not treated as an indicator of the age of this zone.

During the time of pollen zone S-5 agricultural activity intensified in the investigation area. Herbaceous plants including grasses, cereals (*Secale cereale*, *Hordeum* t., and *Triticum* t.) and other anthropogenic indicators became more significant. This zone may cover the historical period, perhaps the last few hundreds years.

CONCLUSIONS

The pollen diagram from only 60 cm thick terrestrial deposits on the dune in Stanisławice illustrates the history of vegetation of the Niepołomice Forest from the Boreal chronozone until the recent time. The oldest traces of human impact on natural environment are visible in the late Atlantic and are correlated with early Neolithic settlement.

The charcoal concentration curve gives evidence of the great role of fire in forest clearances in the Neolithic and in historical times and its decrease during the Roman Age.

The analysis has shown the usefulness that type of material as a source of valuable information about the history of vegetation in the Holocene and human impact upon local environment.

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