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Pollen analysis of Malopolanian Interglacial deposits at Łowisko (Kolbuszowa Upland, southern Poland)

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ABSTRACT. At the northern margin of the Kolbuszowa Upland (southern Poland), a borehole was drilled north of Łowisko. In this borehole, the organic deposits covered with till of the South Polish (Sanian) Glaciation and resting on the fluvial deposits have been identified. setting of these deposits resembles that of Jasionka near Rzeszów. The pollen flora in the organic muds represents an interglacial. This period is correlated with the Malopolanian Interglacial. The organic muds are, first, overlain by silts containing organic detritus of a cold period and, then, by mud and till representing the South Polish (Sanian) Glaciation. The silts and clays are separated from the glacial deposits by a palaeosol the age of which is difficult to determine. A significant part of the profile comprises sediments which accumulated prior to the maximum advance of the ice-sheet, when tundra was present.

KEY WORDS: pollen analysis, South Polish Glaciation, interglacial, Quaternary, Sandomierz Basin, Kolbuszowa Upland

INTRODUCTION

Within the framework of the cartographic tasks for the Geological Map of Poland in the scale of 1:50 000 (the Sokołów Małopolski sheet) a borehole was drilled in the northern part of the Kolbuszowa Upland. The borehole was located north of Łowisko (Fig. 1) and north-west of the road around the cemetery and the old exposure for a planned railroad. In the core organic deposits were identified below layers of till and silts. The stratigraphy obtained in this borehole is very interesting as they might elucidate whether the organic deposits occurring in this region are of the Pliocene age or belong to the oldest part of the Quaternary epoch as it has been proposed. Therefore, detailed investigations of the core have been carried out.

The stratigraphy of the Quaternary deposits of the Kolbuszowa Upland are poorly known and have been referred to in a few specific publications only (Laskowska-Wysoczańska 1971, Buraczyński & Wojtanowicz 1967/68). The majority of the literature concerns the deposits known as the "Majdan series" or as "gravels from Majdan". Many ideas about both the genesis and age of these deposits have been put forward. The Majdan series used to be associated with the Witów series (Dżułyński et al. 1968). These are gravel-sandy deposits, characterized by a high lithologic variability, which occur both at the ground surface and at significant depths, that is evidenced by drillings. The deposits from the surroundings of Nowa Dęba (S.Z. Różycki personal communication), described by Laskowska-Wysoczańska (1971, 1987), belong to the thickest fluvial series of the older Quaternary. Here, the 82 m thick Quaternary deposits have been identified in the borehole located at 174 m a.s.l. In the lower part of the sequence a 5 m thick series of gravels with sand occurs that are considered to be older than the Majdan

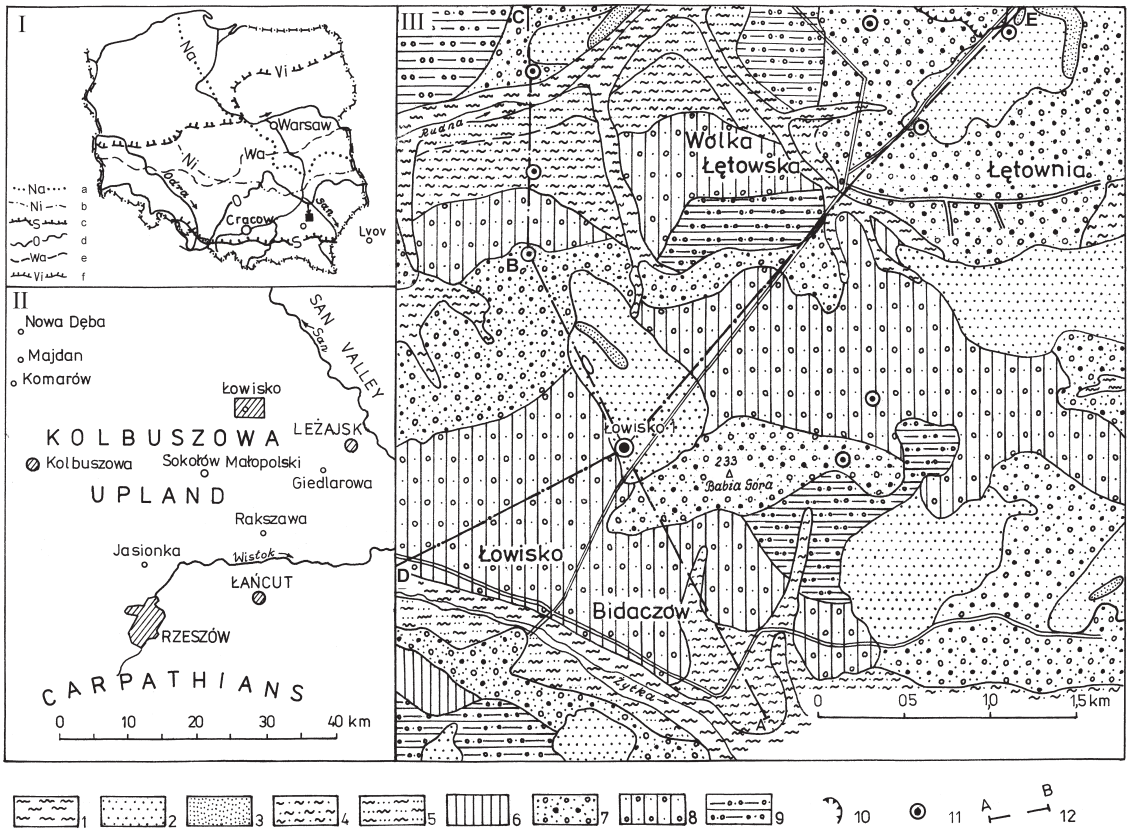

Fig. 1. Geologic map of the region of the Łowisko 1 borehole. **I** – sketch of the location of the study area with the extinsion of ice-sheets in Poland (after Mojski 1985, Lindner 1993). **a** – Narawian Glaciation (Na), **b** – Nidian Glaciation (Ni), **c** – Sanian Glaciation (S), **d** – Odrian Glaciation (O), **e** – Wartanian Glaciation (Wa), **f** – Vistulian Glaciation (Vi). **II** – location of the major Quaternary sites in the area of the Kolbuszowa Upland. **III** – Detailed geologic map. **1** – alluvial: sands and gravels, sands, silts, loams and clays, and alluvia of the valley floors, **2** – eolian sands, **3** – eolian sands in dunes, **4** – sands, silts and deluvial loams and deluvium on the floors of the small valleys, **5** – gravels, sands, silts and loams of the river terraces up to 3–7 m high, **6** – loams and silts on tills or on the Tertiary clays, **7** – gravels and fluvioglacial and glacial sands, **8** – till and gravels and glacial boulders, **9** – gravels, sands and glacial boulders on the Miocene clays or silts, **10** – gravel-pit, **11** – boreholes, **12** – transect lines

series (Laskowska-Wysoczańska 1987). This gravel series with sandy interlayers is overlain by a 30 m thick series of laminated silt, and this in turn by a 17 m thick series of fluviatil gravels. Szajn (1991) also reports a sandy-gravel fluvial deposit without Scandinavian material in the profiles retrieved from the boreholes located in the vicinity of Nowa Dęba and at the northern marginal zone of the Kolbuszowa Upland.

Based on the lithologic composition Laskowska-Wysoczańska (1971, 1987) considers the gravels from the region of Huta Komorowska, Majdan and Komorów as old Pleistocene fluvial deposits. They predominantly contain rounded pebbles and cobbles of Carpathian sandstones, which build the culminations of the erosional outliers. The above interpretation has been questioned by Kwapisz and Szajn (1987) and by Szajn (1991) who are of the opinion that these are younger deposits containing single rounded pebbles of crystalline rocks of northern origin. A similar opinion was earlier expressed by Buraczyński and Wojtanowicz (1967/1968) and Wojtanowicz (1978) who also considered these deposits as originating from the retreat of the South Polish Glaciation which occurred during early Pleistocene. On the other hand, Tyczyńska (1978) is of the opinion that the gravels occurring in the region of Komorów are Sarmatian delta deposits of the Carpathian rivers. According to the study results currently known her findings are rather unlikely. Initially, Czarnocki and Kowalewski (1931) used to assign these deposits to the Sarmatian, but later they considered them to be of the Pleistocene age (Czarnocki & Kowalewski 1935). According to Tyczyńska (1978) the gravels from the region of Majdan and Huta Komorowska were associated with the expansion and retreat of the Cracovian ice-sheet.

South of the Kolbuszowa Upland pre-Pleistocene deposits have been described from the Subcarpathian Trough and its margins. The gravel profiles from the regions of Rakszawa and Brzoza Królewska (Laskowska-Wysoczańska 1971, 1987) belong to the best known. At the southern margin of the Kolbuszowa Upland, in Jasionka near Rzeszów, Laskowska-Wysoczańska (1967) has discovered the organic deposits which contain a flora of interstadial type (Laskowska-Wysoczańska 1967, 1987, Dąbrowski 1967). The sediments overlying the fluvial deposits and containing organic detritus, covered with silts and till correspond to an interglacistadial of the Cracovian Glaciation according to Laskowska-Wysoczańska (1971), but to the Malopolanian Interglacial according to Różycki (1978), while Lindner (1992) interpret them as the Ferdynandovian Interglacial.

In the region of Górno, north of Sokołów Małopolski, a series of boreholes have been drilled, based on the results from which Buraczyński and Wojtanowicz (1967/1968) have presented a general profile of the Quaternary deposits for this part of the Kolbuszowa Upland. These authors have distinguished the tripartite deposits of the South Polish Glaciation. At the base of this profile, the Miocene clays are covered with gravels which have to contain the rounded crystalline cobbles and which, in turn, are overlain by clays and sandy clays containing organic detritus locally. In the upper part of the profile these authors have distinguished tills and sand, and glacial gravels. Under the framework of the geologic-cartographic tasks, the borehole was drilled in Górno where the profile similar to that described by Buraczyński and Wojtanowicz (1967/1968) has been retrieved. At the bottom of this profile the gravel-sandy fluvial deposits contain sandstone pebbles of the Carpathian origin but no crystalline rocks of Scandinavian origin have been identified. Moreover, in the notes to the archive profiles there is no evidence about the occurrence of the material of the northern origin within the gravel layer. Therefore, it might be presumed that the fluvial deposits occurring at the bottom of the Quaternary profile are older than propsed by Buraczyński and Wojtanowicz (1967/1968).

This part of the Kolbuszowa Upland, located in the southern part of the Sandomierz Basin, is the area where the ice-sheet entered only once during the South Polish Glaciations. In the borehole drilled in Huta Komorowska located at the northern margin of the Kolbuszowa Upland two levels of till have been stated (Kwapisz & Szajn 1987, Szajn 1991). The lower level, dated at 595 ka by the TL (thermoluminescence) method, is related to the Sanian 1 Glaciation according to Pożaryski et al. (1994) and is correlated with the Ocinek profile near Sandomierz (Laskowska-Wysoczańska 1984, Lindner 1992) and with the glacial tills in Parchatka near Puławy (Pożaryski et al. 1994). Based on the above, it is hypothesised that the ice-sheet advanced to the northern margin of the Kolbuszowa Upland for the first time during the Sanian 1 Glaciation. The upper till bed has been assigned to the Sanian 2 Glaciation . At that time, the area was covered by the ice-sheet that spread into the Carpathians. This ice-sheet has left behind significant areas of tills, gravels, glacial and fluvioglacial sands. Despite these results, the stratigraphic position of the sediments occurring below the glacial deposits of the maximum extent of the ice-sheet of the South Polish (Sanianin) Glaciation (Mojski 1985, Lindner 1992), in Poland is still not clear.

GEOLOGY OF THE REGION NEAR ŁOWISKO PROFILE

The Kolbuszowa Upland is built up of the young Tertiary clays mainly covered with the deposits of the South Polish Glaciation which is also called the Sanian Glaciation (Różycki 1978). In the vicinity of Łowisko and north of it, glacial deposits predominate at the surface. These are tills containing sand and gravel as well as erratic boulders. The till beds vary in colour from dark to light grey, sometimes with yellow and reddish hue. These deposits mantle the hills and low ridges. In the region of Łętownia, tills inter-layered with sand and fluvioglacial gravel have been found (Fig. 2). The thickness of the till in the drillings vary from 3 to 8 metres. The tills reach their largest thickness between Łowisko and Bidaczów (Figs 1, 2).

North-east of Łowisko the till covered with sands and glacial gravels build the hills. Near Bidaczów the elongated hill is built of gravels. The latter rest on the glacial till (Fig. 2) as it has earlier been stated by Buraczyński and

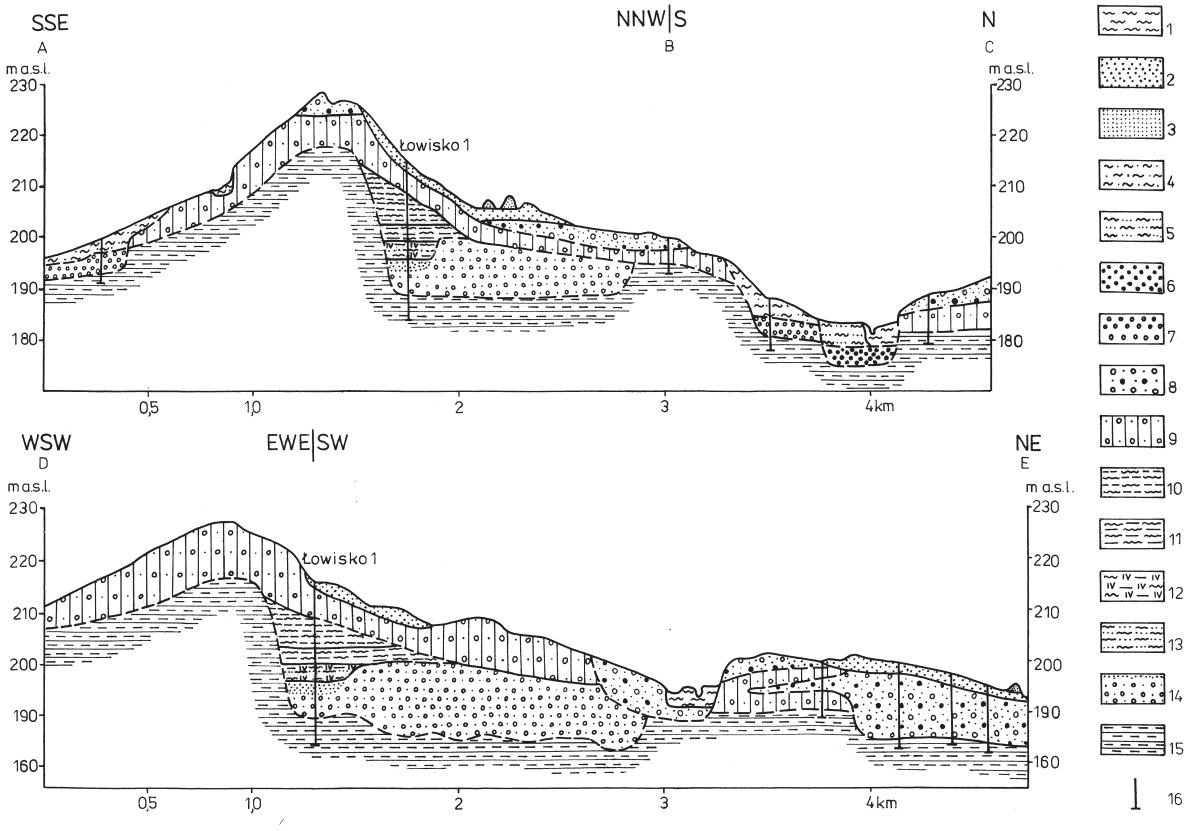

Fig. 2. Geologic profiles of the Łowisko 1 borehole: A → B → C – geological crossection SSE → NNW and S → N; D → E → geological crossection WSW → EWE and SW → NW; **1** – river alluvia (Holocene), **2** – eolian sands, **3** – eolian sands in dunes, **4** – clays, loams and deluvial sands, **5** – fluvial loams, sands and gravels (North Polish Glaciation), **6** – fluvial gravels and sands, **7** – fluvial gravels, sands and silts? (Middle Polish Glaciation), **8** – fluvioglacial gravels and sands, **9** – moraine loams, sands and gravels, **10** – silty clays and clayey silts, **11** – clayey silts, **12** – organic muds, **13** – clayey sands and sandy silts, **14** – fluvial sands or gravel and sands, **15** – clay and Miocene claystones, **16** – boreholes

Wojtanowicz (1967/1968) and Kwapisz and Szajn (1987). In other parts of the Kolbuszowa Upland gravel directly overlies the Tertiary clays. In the region of Łętownia there is a large gravel-pit (Fig. 1) where the thickness of sandy-gravel deposits reaches 18 m. These are fluvioglacial deposits of the age of the South Polish (Sanian) Glaciation. The residua of the glacial deposits present there occur mainly in the summit part of the ridges.

Deposits younger than the South Polish Glaciation, are represented by fluvial, deluvial and eolian sediments. The fluvial sediments are developed as sands with inserts of gravels, tills and clays that form the palaeoriver terraces of the Middle Polish Glaciation period (Fig. 2) as well as the terraces of the period of the Last Glaciation which are partially accreted by loamy deluvial-solifluction covers (Fig. 2). Relatively large surfaces are occupied by eolian sands out of which longitudinal and parabolic 3–5 m (8 m as the maximum) high dunes are built. South of the discussed terrain the dunes are much larger and higher, even up to tens of metres. In the dunes, 0.75–1.0 m below the surface there are palaeosols which have been stated in small sand-pits near Łętownia and Górna. Small dunes have also been observed on the fluvial deposits associated with the last cold stage (Vistulian Glaciation). The youngest Holocene alluvia are inserted into the deposits of the older stages. The alluvia mainly comprise clayey silts with intercalations of silty sands, sometimes with peat.

STRATIGAPHY IN THE ŁOWISKO 1 BOREHOLE

In the study area the research borehole Łowisko 1 has been drilled at the altitude of 215 m a.s.l. This borehole is located north of Łowisko village, on the gently inclined slope of a low, flat ridge whose culmination – Babia Góra – is at the altitude of 233.1 m a.s.l. The location of the borehole has been preceded by

the electrical resistivity studies (Lisik 1989). According to the resistivity profiles, the Quaternary deposits of an increased thickness, even up to 30–34 m, might have been expected in this region. Unfortunately, the results of the drillings have not confirmed such large thickness of the Quaternary. The lower part of the profile has been studied in details (Fig. 3). The stratigraphy of the Łowisko borehole is as follows (Figs 3–5):

0.00–0.75 m	fine sands, eolian
0.75–6.00	mtill- loam grey with singular crystalline pebbles and nests of sand; green, ashen and brownish sandy and clayey loams with reddish intercalations, and strongly weathered gravel at the bottom – glacial till
6.00–9.00	mgrey-green and ashen clayey silt and silty clay with iron concretions (up to 3 mm in diameter) at the bottom
9.00–10.50	msilt clayey and clay, ashen-green in colour, with iron concretions
10.50–12.00	msilt clayey ashen-grey and clay with clear laminations
12.00–12.50	msilt grey with black strips (palaeosol?)
12.50–14.50	msilt clayey grey and silty clays
14.50–17.65	mclayey silts grey with brownish strips and clayey silt with brownish mud intercalations; at the base – sandy silts and singular sand laminae
17.65–18.50	msandy silt ashen-green with laminae and layers of clayey sand, brownish at the base
18.50–19.50	clayey silt grey inter-laminated with black organic mud
19.50–20.20	sandy silts changing into clayey sands
20.20–20.50	silt grey changing into fine sands
20.50–26.00	sand and sandy gravel, rounded, comprising rounded sandstone, quartz and chert pebbles
26.00–36.00	mclaystones (Miocene) dark ashen

In the drilling profile three main sections can be distinguished. The upper section to the depth of 6 m consists of till associated with the

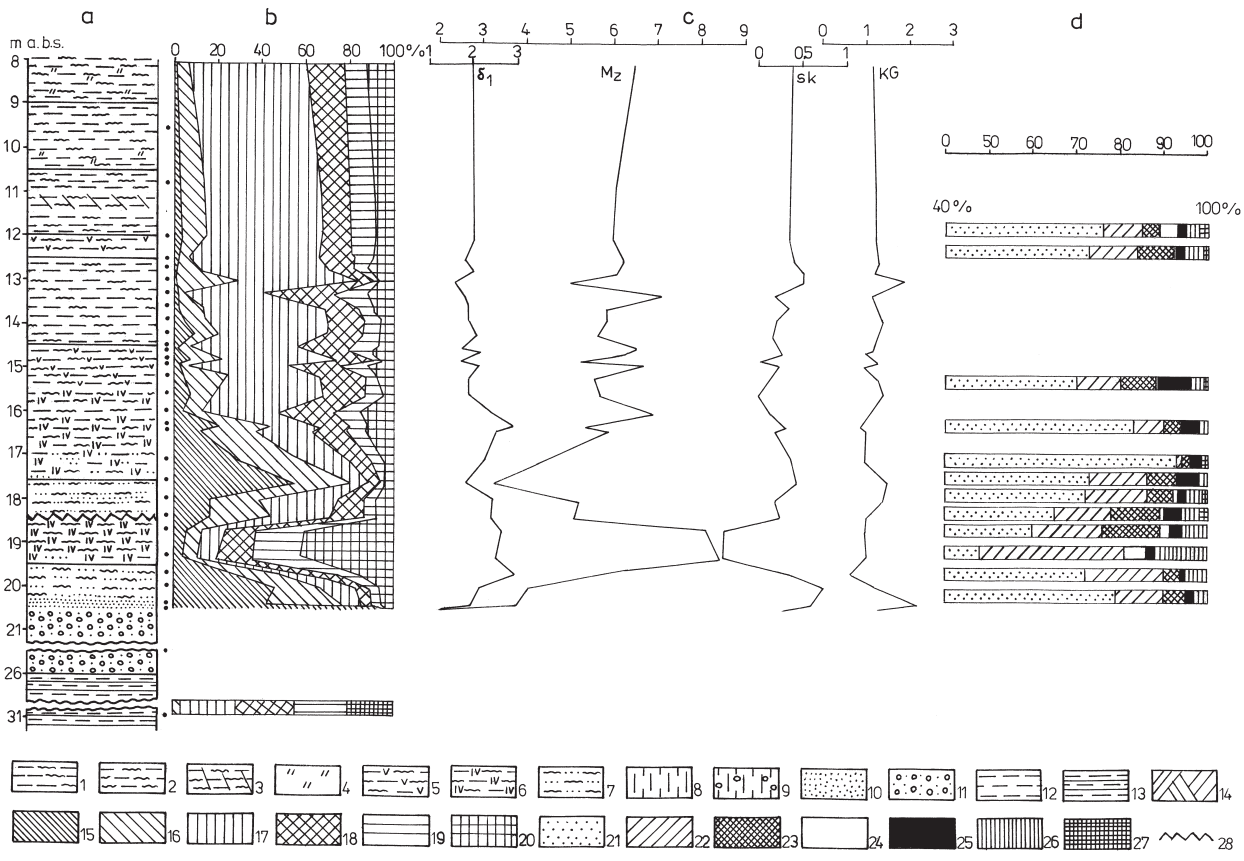

Fig. 3. Profile of the lower fragment of the Łowisko 1 borehole. **a** – lithology: **1** – silty clays, **2** – clayey silts, **3** – clayey silts and clays with horizontal lamination, **4** – reddish and irony levels, **5** – brownish silts with organic detritus, **6** – organic muds, **7** – sandy silts, **8** – clayey loams, **9** – clayey loams with gravels (tills), **10** – sands, **11** – sands and gravels, **12** – clays, **13** – clay-slate, **14** – soil. **b** – grain size composition (grain diameters in mm): **15** – >0.1, **16** – 0.1–0.05, **17** – 0.05–0.01, **18** – 0.01–0.005, **19** – 0.005–0.001; **20** – <0.001. **c** – variability of grain size coefficients in the vertical profile according to R.L. Folk and W.C. Ward's formulae: **Mz** – mean grain size; δ_1 – standard deviation; **Sk** – graphic skewness; **KG** – graphic kurtosis. **d** – heavy minerals (identification according to B. Kopciowska): **21** – garnet, **22** – zircon, **23** – tourmaline, **24** – rutile, **25** – staurolite, **26** – epidote + chlorite, **27** – amphibole. **28** – erosional surfaces

maximum extent of the Scandinavian ice-sheet which advanced into the Carpathians during the South Polish Glaciation called Sanian (Różycki 1978) or Sanian 2 (Lindner 1992, Mojski 1985, 1993). The middle section comprises the silts whilst the lower one – organic muds and fluvial sediments which do not contain the Scandinavian material.

RESULTS OF POLLEN ANALYSIS

The samples for pollen analysis have been taken from this profile from the depth of 14.20–19.50 m at intervals from 20 to 50 cm. The sampled material was primarily macerated by KOH, and then treated with hydrofluoric acid at high temperature, and finally it was subjected to acetolysis by the modified Erdtman's method (Erdtman 1943, 1960). Two microscope slides have been made for each sample analysed. The number of specimens differed from 40 to 377 sporomorphs/cm^2. The pollen spectra have been counted from one slide, but if the number of specimens was low – two slides were analysed. Based on the pollen spectra the pollen diagram has been plotted using the PolPal computer programme (Walanus & Nalepka 1999). The values for the separate taxa have been calculated on a basic sum consisting of all terrestial taxa (AP + NAP). The frequencies of water plants and cryptogamous taxa have been calculated on a basic sum consisting of all terrestial taxa (AP + NAP).

The pollen diagram of the Łowisko 1 profile (Fig. 4) is relatively rich and comprises 70 identified taxa out of which 23 are trees and shrubs (AP), and 47 herbaceous plants (NAP). The majority of the taxa occurs in low number and, in principle, they may not be considered when characterizing the vegetation and determining the age of the studied profile. Taking into account the sporomorphs occurring in satisfactory quantities, five local pollen zones (L PAZ) can be distinguished in the Łowisko 1 pollen diagram.

Łow-1 *Alnus-Quercus-Tilia*-Polypodiaceae L PAZ

This PAZ comprises the two lowermost samples taken at the depths of 19.50–19.20 m. The pollen spectra show a decline in thermophilous trees *Tilia, Quercus, Ulmus* and a maximum of *Alnus* pollen (over 60%). A local decline in pine, spruce and fir can also be noticed. Out of the herbaceous plants, spores of Polypodiaceae s.l. reachs a maximum (up to 127.9%). That is the only level in the profile where spores of *Azolla* occurs (to 2%). The upper boundary of this PAZ is determined by a marked decline in *Alnus* (almost to zero per cent) and in thermophilous species (*Quercus, Tilia, Ulmus*), a significant decrease in Polypodiaceae and an increase in pollen of herbaceous plants, especially of Cyperaceae and Poaceae.

PAZ Łow-1 undoubtedly represents a forest period with alder wood in wet habitats, mixed deciduous forest of oak-linden with hornbeam, elm and birch on the fertile soils, and with an admixture of coniferous trees growing on sandy soils. A significant role was played by ferns which formed either a forest ground layer or communities at the forest margins. Among the other herbaceous species, only Cyperaceae and Poaceae played a more significant role.

Łow-2 *Alnus-Pediastrum* L PAZ

This PAZ comprises samples 18–16 taken at the depths of 19.00–18.50 m. After the marked decline at the beginning of this PAZ the proportion of *Alnus* increases to about 50%, reaching its second maximum (Fig. 4). Other tree species are present only in low values. The proportion of *Betula* increases insignificantly, and in this PAZ *Larix* reaches a maximum of ca. 5%. Considering the herbaceous plants, the values of Cyperaceae and Poaceae increase, and pollen of the aquatic plants e.g. *Sagittaria, Alisma* and *Pediastrum* colonies are represented with ca. 25%. This PAZ ends with a 0.9 m thick gap in sedimentation of organic deposits, but sands and silts occur in the profile.

The composition of the pollen flora in Łow-2 PAZ suggests a forest period. The amount of thermophilous species declined to a minimum, excluding alder which role was again significant and the importance of birch in the forest composition increased. The rizing amount of water plants, and the green algae *Pediastrum* is particularly worth to notice. That evidences the appearance of ponds with algal blooms and reed-swamps at the banks.

Łow-3 *Pinus*-Cyperaceae L PAZ

This PAZ comprises samples 15–13 taken at the depths of 17.60–17.40 m. In the pollen

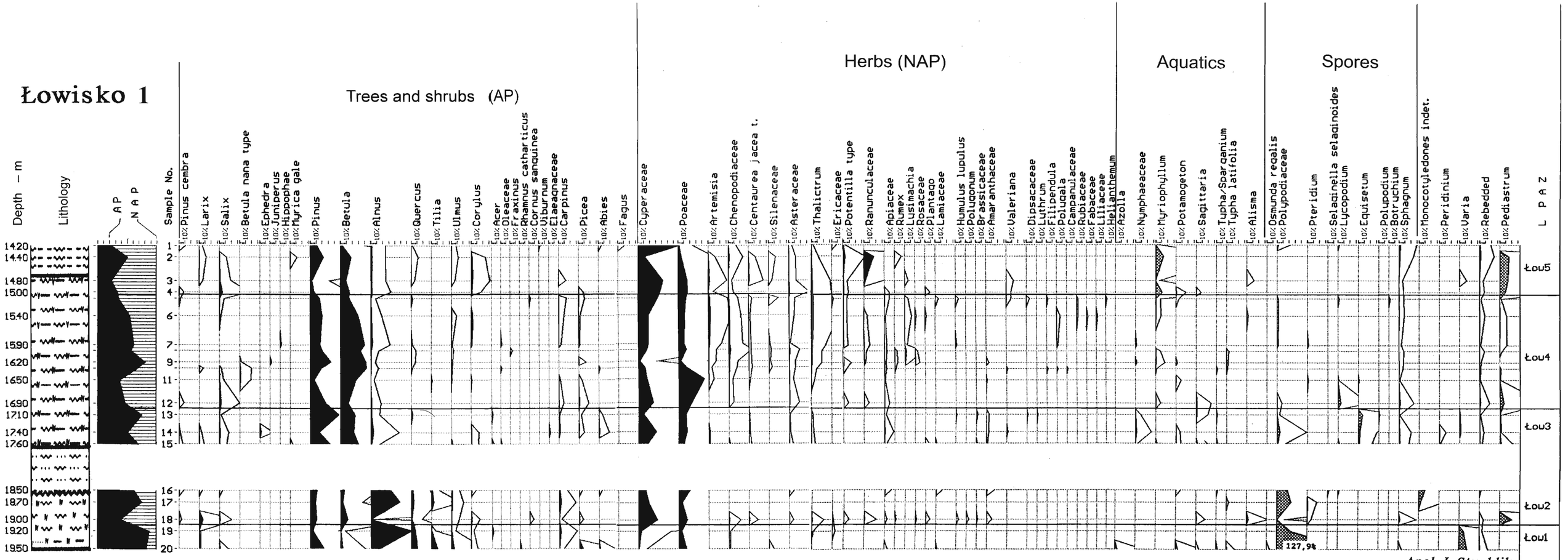

Fig. 4. Pollen diagram of the Łowisko 1 profile. Explantions as in Fig. 3.

spectra maximum values are reached by *Pinus* (40%), Cyperaceae (80%) and Poaceae (40%). Other herbaceous plants occur only sporadically, and among the deciduous trees birch pollen reaches 20%. Pollen of the thermophilous tree species occurred only in traces or was absent.

The upper boundary of the zone is determined by a significant decline in pine, a slight decline in birch and a pronounced decrease in Cyperaceae in the pollen spectra. Pollen of Amaranthaceae, Brassicaceae and *Abies* among the trees disappear as well as spores of *Equisetum*. In PAZ Łow-3 the boreal forests comprising pine and birch dominated while the communities of herbaceous plants probably did not play any significant role in the vegetation surrounding the basin.

Łow-4 *Betula*-Poaceae L PAZ

This PAZ comprises samples 12–5 taken at the depths of 16.90–15.10 m. The zone begins with an increase of birch, grasses (Poaceae) and (Cyperaceae), small emounts of spores of *Lycopodium* (up to 5%) and other herbaceous plants Chenopodiaceae, *Potentilla* and Ranunculaceae, as well as *Myriophyllum*, *Sagittaria* and *Pediastrum* (to 6,5%). The maximum in the entire profile has been reached by Poaceae (to 40%) in the lower part of this PAZ, *Betula* (over 42%) and *Betula nana* type (about 1%) in the middle part of this zone. Moreover, the frequencies of herbaceous plants, out of which Chenopodiaceae, *Thalictrum*, *Lysimachia* and *Humulus* reach their maxima in this PAZ. The upper boundary is delimited by the decline in all tree pollen with a simultaneous increase in herbaceous plants. That was the period of predominance of open boreal forest and open communities of herbaceous plants and bushes of a shrub-heath tundra.

Łow-5 NAP-*Pediastrum* L PAZ

This PAZ comprises samples 4–1 taken at the depths 15.00–14.20 m. The lower zone boundary is delimited by an increase and the maximum in the pollen spectrum reached by *Salix*, Asteraceae, *Artemisia* and mainly by the water plants *Myriophyllum*, *Alisma*, *Potamogeton* and the green algae *Pediastrum*. This zone is spectacular because of the significant dominance of the spormorphs of herbaceous plants (NAP) over the trees (AP). This zone reflects an environment without forest or with certain areas occupied by tiny pine wood and loose willow-birch thickets. The traces of the pollen of other trees found in the spectra originate from a long-distance transport.

AGE OF THE EXAMINED PROFILE

The precise determination of the age of the palynologically examined section of the sequence is very difficult, as the pollen diagram represents a considerable part of the profile with the pollen spectra characteristic of cold glacial and periglacial periods. At the bottom of the profile the zones Łow-1 and Łow-2 represent the decline of the warm period of the interglacial character. In this part of the profile, in the samples from the bottom only, *Quercus*, *Tilia*, *Ulmus* and, first of all, *Alnus* reached their highest values in the pollen spectra in the entire profile. By the decline of this period the climate was still so temperate that the important role was played by the mixed forests with the high amounts of linden, oak and elm and alder on the moist and swampy terrain. Later, the amount of these taxa decreases consequently to the minimum values or they disappear completely. The decline in the curves of all the trees to the minimum values, especially in the case of the thermophilous trees, confirms the interglacial nature of the vegetation of the lower section of the Łowisko-1 profile.

The disputable problem is to which interglacial the lower fragment of the Łowisko 1 profile can be related. Its stratigraphic position is clear (see Tab. 1).

The deposits of this lower part are below the glacial tills of the Sanian Glaciation. However, comparison of this fragment of the Łowisko 1 profile with other profiles palynologically examined and falling into the same time interval, does not provide a sure answer as to the question which interglacial it is?

When comparing the pollen spectra of the lower fragment of the Łowisko 1 profile with the profile of Kijewice assigned to the Podlasian Interglacial by Lindner (1992) and correlated with Dutch Cromer I, some common features can be indicated. In both the profiles the *Quercus-Ulmus* level occurs, but linden is absent in Kijewice. On the other hand, in Łowisko the per cent of *Tilia* in the pollen spectra is high – up to 10%. Moreover, in the Kijowice profile the amount of the re-deposited Tertiary material is high while in Łowisko the Tertiary

Table 1. Stratigraphical correlation of interglacial and glacial units in Europe and Poland (after Lindner 1992, emended)

WEST EUROPE		ALPS	POLAND
Weichselian		Würm	Vistulian Glaciation
Eemian		R/W Interglacial	Eemian Interglacial
Saalian	Warthian	Riss II	Wartanian Glaciation
	Rügenian	Riss I/II	Lublinian Interglacial
	Drenthian	Riss I	Odranian Glaciation
Holsteinian		M/R Interglacial	Masovian Interglacial
Elsterian		Mindel III	Wilga (Sanian II) Galciation
		Mindel II/III	Ferdynandovian Interglacial
		Mindel II	Sanian (Sanian I) Glaciation
Cromerian Complex		Mindel I/II Interglacial	**Malopolanian** Interglacial (Łowisko 1)
		Mindel I	Nidanian Glaciation
		Günz/Mindel	Podlasian Interglacial
		Günz	Narevian Glaciation

sporomorphs occur only sporadically. Therefore, the lower section of the Łowisko 1 profile cannot be correlated with the Podlasian Interglacial. A correlation of the Łowisko 1 with the Ferdynandovian Interglacial is not possible. Although by the decline of the so called "lower climatic optimum" of the Ferdynandovian Interglacial, the *Alnus-Quercus-Ulmus* zone similar to that of Łowisko is distinguished, but it is without linden. Moreover, *Fraximus* and *Taxus*, and mainly *Abies*, which forms a separate level, occur in this part of the Ferdynandovian Interglacial. These species are absent or present only in traces in the Łowisko profile. The absence of the clearly marked *Abies* level would coincide with accumulation of sands and silts at the depth of 17.60–18.50 in the Łowisko profile and, thus, this fragment might be assumed the termination of the first climatic optimum of the Ferdynandovian Interglacial. Another approach might be the comparison of the discussed fragment of the Łowisko profile with the Przasnysz Interglacial, in which the high values in the pollen spectra are reached by *Quercus, Abies, Alnus, Carpinus* and *Pterocarya*, while *Tilia* occurs only in the trace amounts. Such pollen sequence is absent in the Łowisko profile. The geologic set-up as well as the palynological spectra show the closest similarity of the Łowisko profile to the Jasionka profile where the *Tilia* pollen occurs only in a small amount in the *Quercus-Ulmus-Picea* zone, and the small values of *Alnus* increase just in the next *Quercus-Alnus* and *Alnus-Picea* zones. These differences can be attributed to local habitat conditions. Summarising, it can be stated that despite certain differences the lower part of the Łowisko profile represents probably the decline of the climactic optimum of the Malopolanian Interglacial.

STRATIGRAPHIC POSITION OF THE DEPOSITS OF THE ŁOWISKO 1 PROFILE

The 6.5 m thick, fluvial gravel-sandy deposits which rest on the Miocene clays at the depth of 26.00–20.50 m and fill up the palaeochannel, are the oldest Quaternary deposits in the profile of the Łowisko drilling (Fig. 5). These deposits comprise fluvial gravels of 2–8 cm in diameters and various-grained sands. In the gravel material rounded pebbles of Carpathian origin predominate. The grains of white quartz and cherts, likely originating from erosion of the menillite beds in the Carpathians, occur here as well. In the sample taken from the top of this fragment of the profile very resistant and resistant heavy minerals (garnet, zircon, tourmaline and others) have been found (Fig. 3). Based on the petrographic composition it is evident that these are the sediments of the rivers draining the Carpathians and which were deposited prior to the advance of the Scandinavian ice-sheet. Because of the interlocking with the solifluction covers the gravel series known up-

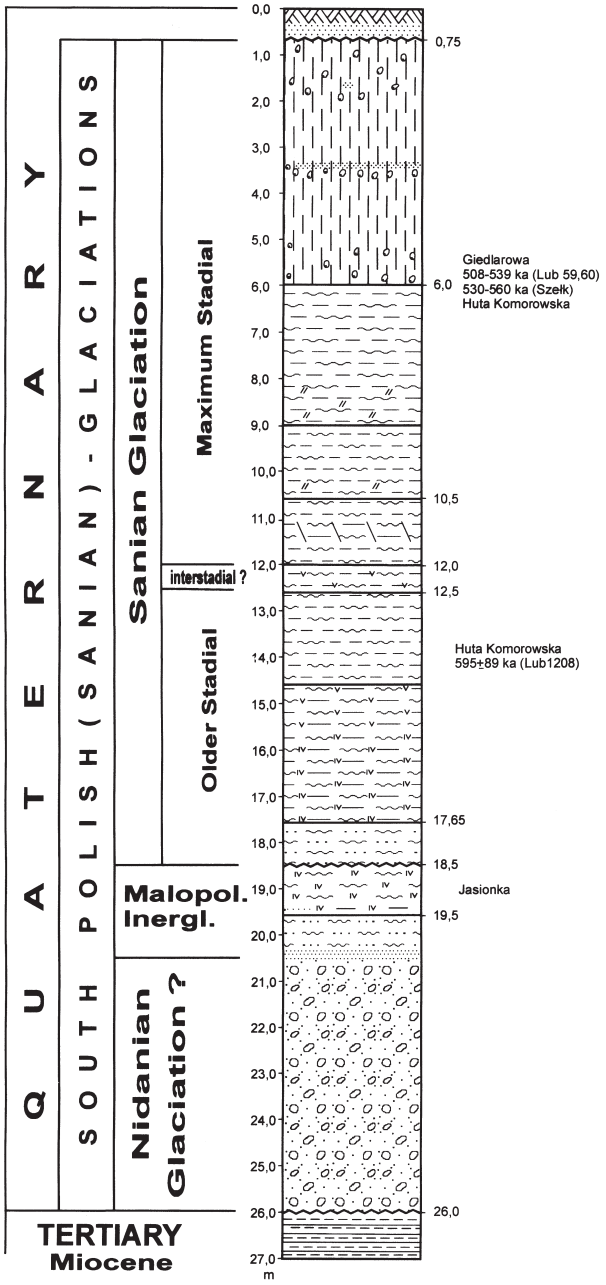

Fig. 5. Stratigraphic profile of the Łowisko 1 borehole. Explanations as in Fig. 3

to-date and occurring in the Carpathians and at their outskirts were assumed to have been deposited during the cold stages (Starkel 1971, 1984). Accepting this assumption, the accumulation of the gravel-sandy series can be related to the Nidanian Glaciation. However, it may not be excluded that these sediments can be older and were deposited after erosional dissection of the Miocene deposits and formation of the paleovalley during the earlier periods.

In the Sandomierz Upland four series of alluvia older than the South Polish Glaciation can be distinguished (Starkel 1994). They have been stated in two following belts: in the northern one – from Witów to Majdan and in the southern one – along the Subcarpathian Trough. South of the discussed region, in the Subcarpathian Trough in the vicinity of Rzeszów, the lowest series of the alluvia occurs at 190–200 m a.s.l., i.e. at the elevation of the socle in the region of Łowisko. This series was correlated with the Cromer Interglacial by Starkel (1994). The upper series, lying at the elevation of 210–215 m a.s.l., used to be related to the Günz Glaciation (Laskowska-Wysoczańska 1971), it seems that the fluvial gravel-sandy series in Łowisko can correspond to this level. However, this problem requires further investigations.

The fluvial gravel series are overlain by the fine sands changing into sandy silts, and then into organic muds which contain pollen of a pollen forest flora. The accumulation of sands and organic muds took place in the warm period corresponding to the interglacial (Figs 4, 5). Most likely, the accumulation of these deposits took place in a palaeochannel. The absence of the Tertiary spormorphs and the exclusive presence of the Quaternary elements in the pollen spectra, indicates the coverage of the closest vicinity with the Quaternary deposits. The older deposits were not eroded in this period, as in such a case, the elements of the older periods would have been preserved in the spectra as it is observed in numerous profiles palaeobotanically examined. This relatively thin fragment of the profile (20.00–18.50 m) is erosionally cut off. That is evidenced by the layer of sandy silts and clayey sands occurring at the top of this level. According to the pollen analysis (Fig. 4) it is apparent that the accumulation took place during the later part of the interglacial. Undoubtedly, this part of the interglacial is older than the South Polish (Sanian) Glaciation. The comparison of the pollen spectra are not in accordance with the Ferdnynandovian Interglacial as well as the Podlasian Interglacial. The position of the organic deposits occurring in the discussed profile is closest to the Jasionka profile near Rzeszów. The differences in the pollen succession of Jasionka and Łowisko can be explained by the local conditions. Różycki (1978) has associated the Jasionka profile with the Malopolanian Interglacial, while Lindner (1992) referred it to the Ferdynandovian Inter-

glacial. Within the approach presented by the authors of this paper, the discussed interglacial is older than the Sanian Glaciation and differs from the Ferdynandovian Interglacial, thus following Różycki (1978.) it is suggested to correlate it tentatively with the Malopolanian Interglacial (Fig. 5).

The stratigraphic gap at 18.5 m depth, occurring at the top of the deposits, corresponding to the Malopolanian Interglacial, as well as the magnitude of cutting of the interglacial sediments are difficult to retrieve. The change in lithology from the depth of 18.5 m upward, where clayey sands and the series of brownish and yellow laminated sandy silts occur (Fig. 3), is most likely related to the river action during the floods and cutting of the sediments that have been deposited earlier at the interglacial-glacial boundary. Upward, the sediments change into brownish silts intercalated with ashen silts. From the depth of 17.65 m upward, the grain size gradually decreases (Figs 3,5), and this deposit can be called clayey alluvial loams ("madas"). The brownish intercalations in the profile are rarer and rarer. These deposits indicate sedimentation under cool and cold climate (zones Łow-3 – Łow-5) and can be related to the initial phase of the Sanian Glaciation. The accumulation took place on the valley floor, when climatic conditions were gradually worsening and the vegetation was changing from the boreal forests (Fig. 4), through the shrub and heath tundra to the tree- and shrub-less areas (zone Łow-5). In the upper fragment of the profile the accumulation on the valley floor took place under permafrost conditions and shallow water bodies present that is documented in the spectra by the increase in the proportion of water plants (*Myriophyllum*, *Alisma*, *Potomageton* and *Pediastrum*) and changes in colour (reddish spots, traces of gleying). In the upper part of this section, the silts which do not contain organic detritus are present. Here, the accumulation of sediments can be attributed to the changes in hydro-climatic conditions and to a rise in the base level due to the presence of the ice-sheet. The proximity of the ice-sheet can be evidenced from the presence of amphiboles in the spectra of the heavy minerals (Fig. 3).

The black strips visible within the ashen clayey silts at the depth 12.00–12.50 m from the surface are most likely the level of a poorly developed palaeosol. That would point to a gap in the accumulation and to the formation of a soil horizon.

The overlying series of silts of the thickness of 6 m (depth 6.00–12.00 m) is relatively poorly differentiated; only the changes in the sediment colour to reddish-irony (Fig. 5) show up here. This mud series was deposited under cold climate conditions in the period directly preceding the advance of the ice-sheet on to the Kolbuszowa Upland. In the lower part of this fragment the 0.5 m thick layer with vertical lamination of the varve type (dark and light grey laminae) is found. These laminae point to the proximity of the front of the ice-sheet. This fragment of the profile resembles best the profile of Hucisko described by Wojtanowicz (1997). The upper series of the clayey silts is overlain by the glacial tills which are related to the maximum extent of the Scandinavian ice-sheet. The profile as the whole is covered with the eolian sands.

CONCLUSIONS

The Łowisko 1 profile is the second site in the Sandomierz Basin, after the Jasionka profile near Rzeszów, that documents the find of sediments representing an interglacial older than the maximum extent of the Scandinavian Glaciation in the area of Poland during the South Polish Glaciations. The results of pollen analysis indicates that the organic silts have been deposited on gravels and fluvial sands under temperate climatic conditions, where the significant role in the landscape was played by the mixed forests with the large percentage of linden, oak, elm and alder. The comparison of the pollen spectra in the lower part of the profile with other profiles does not allow for the correlation to the Podlasian and Ferdynandovian Interglacials. The stratigraphic position of the Łowisko profile is clear as its deposits lie under the glacial tills of the Sanian Glaciation. Thus, it has been assumed that with respect to palynological data this interglacial is different from the Ferdynandovian Interglacial, and the name "Malopolanian Interglacial" has been accepted for it after Różycki (1978). The organic deposit are not easily available and maybe new findings of the organic deposits in similar settings allow for a more precise determination of the position of this interglacial, especially as the recent

studies suggest a different position of the Ferdynandovian Interglacial in this region (Granoszewski 1999).

The absence of amphiboles in the spectra of the heavy minerals in the lower fragment of the profile, and their presence in the upper fragment clearly divides the discussed sediments into the pre-glacial ones and the series associated with the presence and stagnation of the Scandinavian ice-sheet.

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