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Palynostratigraphy and vegetation changes during the early Middle Pleistocene, based on new studies of deposits from Ferdynandów (central eastern Poland)

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ABSTRACT. New palynological data from the Ferdynandów site are presented and interpreted against the background of the earlier division of this stratotype pollen sequence by Janczyk-Kopikowa (1975), with special attention to a comparison with the nearest profile of a complete Ferdynandovian succession in Łuków (Łuków Plain). The proposed division of the new pollen diagram from Ferdynandów – into two warm periods of interglacial rank separated by a succession typical of glacial periods – is based on the new division of the Ferdynandovian pollen sequence *s.l.*, applied for the first time by Mamakowa (1996) to the Podgórze B1 pollen profile close to Nowe Miasto on the Pilica river. The two warm units and the cold one between them in the new pollen diagram from the Ferdynandów site correspond to the climatostratigraphic units named Ferdynandovian 1 and 2. Together with the cooling/glaciation (Ferdynandovian 1/2) separating them, the whole Ferdynandovian sequence *s.l.* can be related to the early Middle Pleistocene Cromerian Complex (Cromerian II Westerhoven and Cromerian III Rosmalen) and Marine Isotope Stages (MIS) 13–15.

KEYWORDS: palynostratigraphy, climatostratigraphy, Ferdynandovian pollen succession, Ferdynandów, early Middle Pleistocene, MIS 13–15, central eastern Poland

INTRODUCTION

The pollen sequence from Ferdynandów (CE Poland), known since 1975 (Janczyk-Kopikowa 1975), is widely known, as it is among the most important and fullest sequences of early Middle Pleistocene vegetation in Europe (Turner 1996, Zagwijn 1996). The two latter authors stressed the need to search for complete interglacial sequences in fossil lakes of the lowlands of Eastern Europe, as the early Middle Pleistocene sequences in the stratotype areas (Netherlands, eastern England) are quite fragmentary and require reinterpretation. Investigations done for the Detailed Geological Map of Poland (1:50 000 scale) revealed the existence of numerous fossil lakes in central eastern Poland bearing deposits of three different interglacials: the Eemian, Holsteinian, and Ferdynandovian (Żarski et al. 2005).

Sites of the Ferdynandovian interglacial are very rarely found, especially those with two warm periods recorded in organogenic deposits. Thus, the presence of several sites of this age in central eastern Poland is of great interest. Their unique character has been stressed by researchers including Janczyk-Kopikowa et al. (1981), Janczyk-Kopikowa (1991), Turner (1996), Zagwijn (1996), and Lindner et al. (2001). A map published by Rzechowski (1996) showed 10 sites bearing pollen successions of this age in Poland, most of them located in the central eastern part of the country, and also the stratotype site in Ferdynandów, investigated by Janczyk-Kopikowa in 1975, who revised her view on the age of these deposits and in subsequent years correlated them with the Cromerian Complex of Western European stratigraphy (Janczyk-Kopikowa et al. 1981). In the 1990s, however, new pollen data on the Ferdynandovian succession made it necessary to reinterpret it with respect to both the stratigraphy and the climate changes recorded by the pollen diagrams.

In 1996, Mamakowa analysed the pollen of lacustrine deposits from the Podgórze B1 profile drilled near Nowe Miasta on the Pilica river (Fig. 1). She found a very interesting pollen succession which undoubtedly was of Ferdynandovian age but showed features of strong cooling separating two warm periods of interglacial rank. Mamakowa called it an unnamed "Glacial" (Mamakowa 1996). Subsequently, I applied Mamakowa's division to the Zdany pollen succession in interpreting the pollen diagram of a newly drilled profile of lacustrine deposits from there (Pidek 2000). I found great similarities between the Podgórze and Zdany pollen sequences, which resembled each other much more than the Zdany and Ferdynandów stratotype pollen sequences. The pollen succession from Zdany turned out to be extremely long, covering not only two warm periods with a cooling separating them but also two glacial periods preceding (Elsterian1 = Sanian1) and following (Elsterian2 = Sanian2) the Ferdynandovian pollen sequence. Mamakowa was of the opinion that the unnamed "Glacial" had not been detected in the stratotype profile from Ferdynandów due to low-resolution sampling. The NAP values during this cold period exceeded 44% in the Podgórze pollen diagram, which suggested the predominance of open landscapes of herbaceous vegetation (Mamakowa 2003), while the pollen data published by Janczyk-Kopikowa (1975) from Ferdynandów culminated at 28.6% and were interpreted as open boreal forest.

In 2004, work on the Łuków sheet of the Detailed Geological Map of Poland (Małek & Buczek 2006) enabled a new core to be taken very close to the site of the old profile in Łuków. The old profile has been known since 1969 (Rühle 1969). At the very beginning of Sobolewska's (1969) pollen analysis she suggested the profile's correlation with the Cromerian Complex. The new pollen diagram from Łuków (Łuków-3a profile; Pidek 2013, Pidek & Małek 2010) revealed a complete Ferdynandovian pollen succession very comparable with the Zdany one. Based on these two pollen datasets, a detailed climate reconstruction was published (Pidek & Poska 2013).

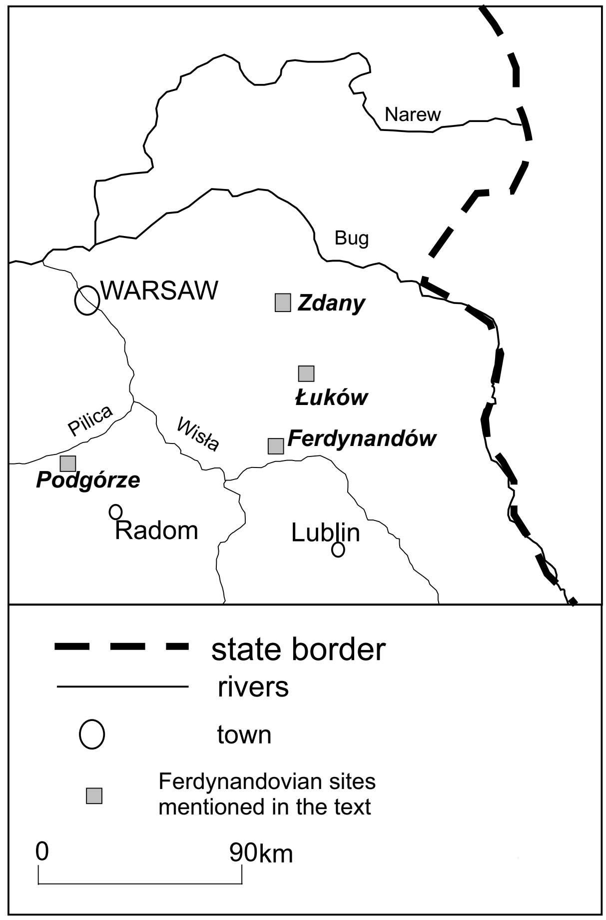

Fig. 1. Location of the Ferdynandów site and the three sites of the Ferdynandovian pollen succession mentioned in the text (Łuków, Zdany, Podgórze)

The same pattern of pollen assemblage zones occurred in all these pollen diagrams (Podgórze, Zdany, Łuków), which can be considered a complete Ferdynandovian sequence. The climate optima resemble each other, and the patterns of a cold period separating them bear the same features. These were two high culminations of NAP, with some pollen indicators of cold climate and steppe-tundra communities (*sensu* Granoszewski 2003). The two peaks of high NAP values were followed by high percentages of birch and pine pollen, reflecting the occurrence of open boreal forests. This pattern of vegetation development was characteristic for all stadial/interstadial oscillations in the Quaternary. In view of these findings and suggestions, a repeated drilling of the lacustrine fossil deposits in Ferdynandów would be expected to improve the resolution of pollen data and shed more light on the occurrence of steppe-tundra communities between the two warm units in the stratotype profile of Ferdynandów.

Here I present and interpret the preliminary results of the new pollen diagram from a new core taken at Ferdynandów in 2011 The results do not include the uppermost part of the profile (above the second interglacial), which is still under examination. The new pollen diagram from Ferdynandów is juxtaposed with the pollen succession from a neighbouring site of the same age in Łuków (Fig. 1).

The new pollen diagram from the stratotype site in Ferdynandów is presented here in preliminary form to show that, building upon Janczyk-Kopikowa's (1975) earlier findings, the cold unit between the two warm ones can be divided further on the basis of high-resolution sampling, allowing a more precise interpretation of its vegetation history in terms of local versus regional changes triggered by climate factors.

MATERIAL AND METHODS

The series of organogenic deposits in the new profile from Ferdynandów, subjected to pollen analysis, occur at 44.60–36.40 m depth. For this preliminary study 99 samples were analysed, taken at 2 cm intervals (in places with very high frequency of changes in pollen spectra) or 20 cm intervals (in places with similar features of pollen spectra). Thus the whole succession was studied. Samples were prepared by standard methods of pollen analysis (HCl, KOH, HF, Erdtman's acetolysis). The results are presented in a pollen percentage diagram (Fig. 2) plotted using POLPAL software (Nalepka & Walanus 2003). The data from the Łuków-3a profile are presented in the same form (Fig. 3). Calculations of pollen percentages are based on the sum of tree and shrub pollen (AP) and terrestrial herb and dwarf shrub pollen (NAP). Percentages of aquatic and reedswamp plant pollen, Pteridophyta and Bryophyta spores, and redeposited sporomorphs were calculated in relation to the AP+NAP+ examined taxon. The simplified pollen diagrams (Figs 2, 3) are divided into local pollen assemblage zones based on the criteria published by West (1970) and Janczyk-Kopikowa (1987). The main features of the pollen spectra in the new profile from Ferdynandów are given in Table 1.

RESULTS

The vegetation history of the surroundings of Ferdynandów derived from pollen data is described here in relation to the new division of the Ferdynandovian pollen sequence based on the Podgórze B1 pollen succession (Mamakowa 2003), subsequently named F1 and F2, representing two warm periods of interglacial rank, and F1/2, the cooling/glaciation separating them (acc. to Lindner et al. 2004, Winter 2006). The vegetation development in the new pollen diagram from Ferdynandów presents the same pattern as the one from the neighbouring Łuków-3a site (Pidek 2013). As these two pollen diagrams are directly comparable, the similarities and differences are stressed in comparing local pollen assemblage zones (L PAZs). Special attention is paid to the sequence of pollen zones separating the two warm units of interglacial rank. The pollen zones from the Ferdynandów and Łuków pollen diagrams are correlated in Table 2.

LATE GLACIAL OF THE SANIAN 1 (=ELSTERIAN 1) Fe-1 L PAZ

Fe-1 NAP-*Juniperus* L PAZ. The high percentage of herb pollen (NAP), the considerable values for *B. nana* t. and *Salix*, and the maximum of *Juniperus* are evidence of open landscape. The composition of the pollen spectra indicates different types of communities, among which the following are important: grass, sedge-moss, and shrub-tundra with a considerable share of dwarf birch and willow shrubs. Drier habitats probably were occupied by steppe-like communities with abundant *Artemisia* and Chenopodiaceae. *Juniperus* must have been numerous on less fertile sandy soils.

In spite of the predominance of open communities, high values of *Betula* undiff. (90% of which is *Betula alba* t. pollen) and the continuous curve of *Larix* give evidence of forest patches, probably with dominant *Betula pubescens* and abundant larch. The *Larix* pollen curve reaches a maximum of 3.6%. The values undoubtedly indicate its occurrence *in situ*, as larch pollen grains are large and not adapted for long transport. Pine may also have entered the composition of those forests but the low values for its pollen indicate that it may also have been transported from a longer distance.

The question of whether spruce and alder occurred at that time is open to interpretation. Studies of modern pollen deposition in Tauber traps in the Roztocze region (SE Poland), where *Picea abies* is present as a small admixture in the forests, have shown that spruce pollen grains, much heavier than those of pine, are not transported in huge quantities by air

Table 1. Description of local pollen assemblage zones of the Ferdynandów sequence

L PAZ code	Sample depth (m)	Main features of pollen spectra
Fe-1 NAP-*Juniperus*	Below 44.40 m	NAP predominates: Poaceae 13.5–18.5%, Cyperaceae 11.0–13.0%, *Artemisia* 5.5–9.0%, frequent Chenopodiaceae; pollen of *Betula nana* t. present; *Salix* pollen values between 3.0 and 5.0%; *Juniperus* percentages reach their maximum of 14.0%; *Pinus sylvestris* t. pollen values very low, range 8.0–20.5%; *Betula* undiff. pollen values 27.0–44.5%; *Larix* percentages very high, up to 3.6%; *Alnus* up to 9.5%; *Picea* up to 2.1%; single pollen grains of *Quercus* and *Ulmus*; frequent pre-Quaternary sporomorphs
Fe-2 *Betula*	44.20–44.30 m	*Betula* undiff. pollen values reach 51.5%; *Pinus sylvestris* t. increases to 38.0%; *Larix* increases to 1.0%; sporadic *Alnus*, *Quercus*, *Ulmus*, and *Fraxinus* pollen; frequent *Picea*, *Salix*, and *Juniperus* pollen; NAP percentages decrease distinctly
Fe-3 *Pinus-Betula-Quercus*	44.02–44.10 m	*Pinus sylvestris* t. pollen percentages increase to 55.0%, while *Betula* undiff., *Larix*, and *Piceae* percentages decrease; *Quercus* increases to 2.1%; more frequent pollen grains of *Ulmus*; *Alnus* values begin continuous pollen curve; *Salix* values low
Fe-4 *Quercus-Ulmus-Alnus-/Corylus/*	43.40–43.95 m	*Quercus* pollen values rise sharply to 30.5% at beginning of zone; clumps of *Quercus* pollen occur in sample from 43.40 m; in upper samples, oak values 18.5–27.0%; *Ulmus* values culminate first up to 19.0% and subsequently range from 9.0 to 14.5%; *Alnus* reaches 12.5%; in upper part of zone, *Corylus* rises sharply to 24.5%, falls to 3.5%, and rises again to 19.5%; *Fraxinus* and *Tilia* pollen frequent, up to ca 1.4% each; pine and birch pollen decrease to very low values; *Celtis* pollen appears and is more and more frequent; *Acer* pollen sporadic
Fe-5 *Corylus*	41.80–43.20 m	*Corylus* pollen pecentages rise rapidly and reach high maximum of 42.5%, then fall to 37%, and clumps of *Corylus* pollen occur in samples from 42.80 and 42.97 m; *Ulmus* values 12.0–20.5%; *Quercus* 11.0–18.0%; *Celtis* pollen still forms continuous percentage curve; in upper part of zone, *Alnus* pollen values rise to 21.5% and *Tilia* pollen reaches maximum at 4.13%; continuous pollen curves of *Abies* and *Taxus* begin; sporadic *Ligustrum*, *Vitis*, and *Viscum*; NAP values very low throughout zone Two subzones distinguished: older, *Ulmus-Quercus* (samples 42.40–43.20 m); younger, *Alnus-Abies-Taxus* (samples 41.80–42.32)
Fe-6 *Abies-Alnus-Quercus*	41.50–41.70 m	Considerable rise of *Abies* up to 23.0%, followed by distinct rise of *Picea* up to 13.0%; *Quercus* and *Alnus* rise to 21.0% each; *Ulmus* up to 6.5%; frequent pollen of *Fraxinus*, *Taxus*, *Acer*, and *Salix*; values of *Corylus* decrease to 7.0%; *Celtis* pollen not as frequent as in previous zone; sporadic *Carpinus* pollen grains
Fe-7 *Pinus-Betula*	40.30–41.40 m	*Pinus sylvestris* t. values rise extremely sharply, range 64.5–78.0%; *Betula* undiff. low, 12.0–24.0%; simultaneous fall in pollen percentages of all thermophilous trees (*Quercus*, *Fraxinus*, *Tilia*) and *Corylus*; *Picea* values fall but still significant, up to 5.1% in older part of zone; *Larix* pollen frequent; *Calluna* and other Ericaceae sporadic
Fe-8 *Betula-Larix*-NAP	39.82–40.20 m	Simultaneous rise of *Betula* undiff. and fall of *Pinus sylvestris* t.; *Larix* increases to 5.8%; high values of *Betula nana* t. and *Juniperus*, up to 6.5% in upper part of zone; NAP percentages increase, including Poaceae up to 6.3%, Cyperaceae up to 6.0%, *Artemisia* up to 4.6%, Chenopodiaceae up to 1.4%
Fe-9 *Picea-Pinus-Quercus*	39.55–39.70 m	Distinct increase of *Picea* up to 6.5%; *Quercus* up to 15.5%; *Ulmus* up to 4.1%; *Tilia* reaches 0.9% and *Fraxinus* reaches 0.6%; *Betula* undiff. increases to 36.5%; *B. nana* t., *Juniperus*, and NAP fall; *Artemisia* pollen percentages also decrease significantly
Fe-10 *Artemisia*-Poaceae-Cyperaceae	39.22–39.45 m	*Pinus sylvestris* t. values increase to 49.0%; *Picea* still high, up to 6.5%; NAP values increase, including Cyperaceae up to 6.0%, Poaceae up to 10.0%, *Artemisia* up to 12.5%, Chenopodiaceae 0.6%; frequent pollen of Ericaceae; increase of *Betula nana* t. up to 2.9%; distinct fall of pollen of all thermophilous trees in comparison to previous zone
Fe-11 *Betula-Pinus*	39.00–39.15 m	Pine pollen percentages increase to 54.5%; tree birch increases to 44.0%; still frequent *Larix* and *Picea* pollen; sporadic pollen of thermophilous trees; decrease in *Betula nana* t. and *Juniperus*; distinct fall in NAP values of NAP, including *Artemisia*, Poaceae, and Cyperaceae (less than 1% each)
Fe-12 *Pinus-Betula*-NAP	38.55–38.90 m	*Pinus sylvestris* t. falls distinctly; *Picea* pollen percentages still high; *Salix* reaches 4.0% and *Juniperus* reaches 8.5%; NAP values increase considerably again, including Cyperaceae up to 9.0%, Poaceae up to 11.5%, *Artemisia* up to 5.0% , Chenopodiaceae up to 1.1%; frequent pollen of Ericaceae Two subzones distinguished: older, *Pinus*; younger, *Juniperus-Salix*
Fe-13 *Betula-Artemisia*	38.30–38.50 m	NAP percentages high, including Poaceae 4.8–10.5%, Cyperaceae 2.2–8.0%, *Artemisia* up to 8.5%; Chenopodiaceae pollen frequent, up to 1.1%. *Betula* undiff. increases slightly to 51.0%; *Pinus sylvestris t.* falls to 33.0 %; single pollen grains of *Ulmus*, *Quercus*, *Picea*, and *Alnus*
Fe-14 *Pinus*	38.12–38.20 m	*Pinus sylvestris* t. 51.0–55.0%; *Betula* undiff. 26.0–33.5%; single pollen grains of *Picea* and *Alnus*; *Quercus* and *Ulmus* pollen curves begin; NAP values decrease, including Cyperaceae down to 2.5%, but still-high percentages of Poaceae (up to 6.5%) and *Artemisia* (up to 4.8%); *Salix*, *Juniperus*, and *Betula nana* t. pollen values fall

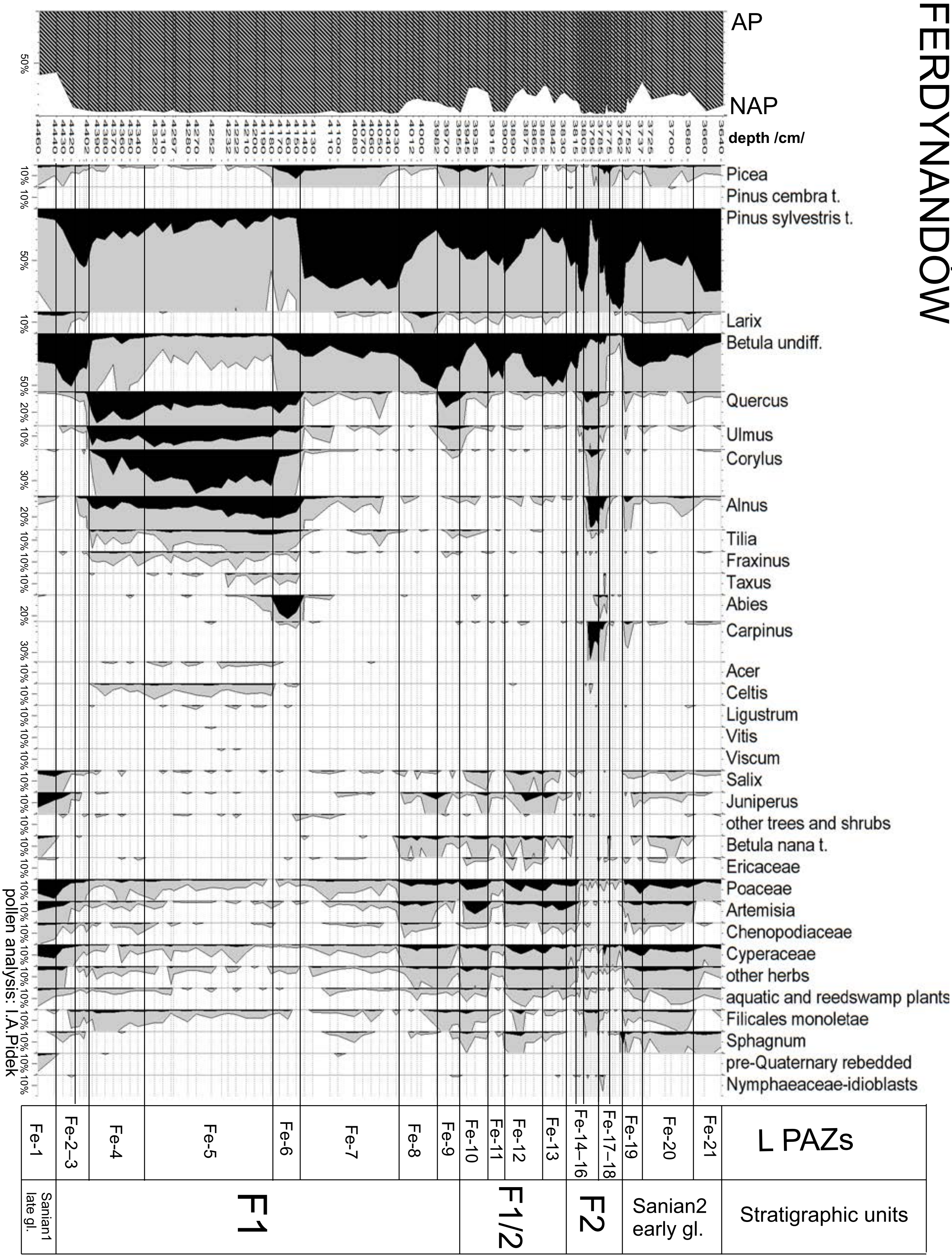

Fig. 2. Simplified pollen diagram of the new Ferdynandów profile

currents. The vast majority probably is deposited within 1 km of the source trees (Pidek et al. 2010). The spruce pollen percentages (0.3–0.6%) in modern pollen rain in the Roztocze region are lower than in the Fe-1 zone (up to 1.9%). On the basis of the old profile from Ferdynandów, Janczyk-Kopikowa (1975) discussed the question of spruce occurrence in communities of the late glacial previous to the Ferdynandovian interglacial. She suggested

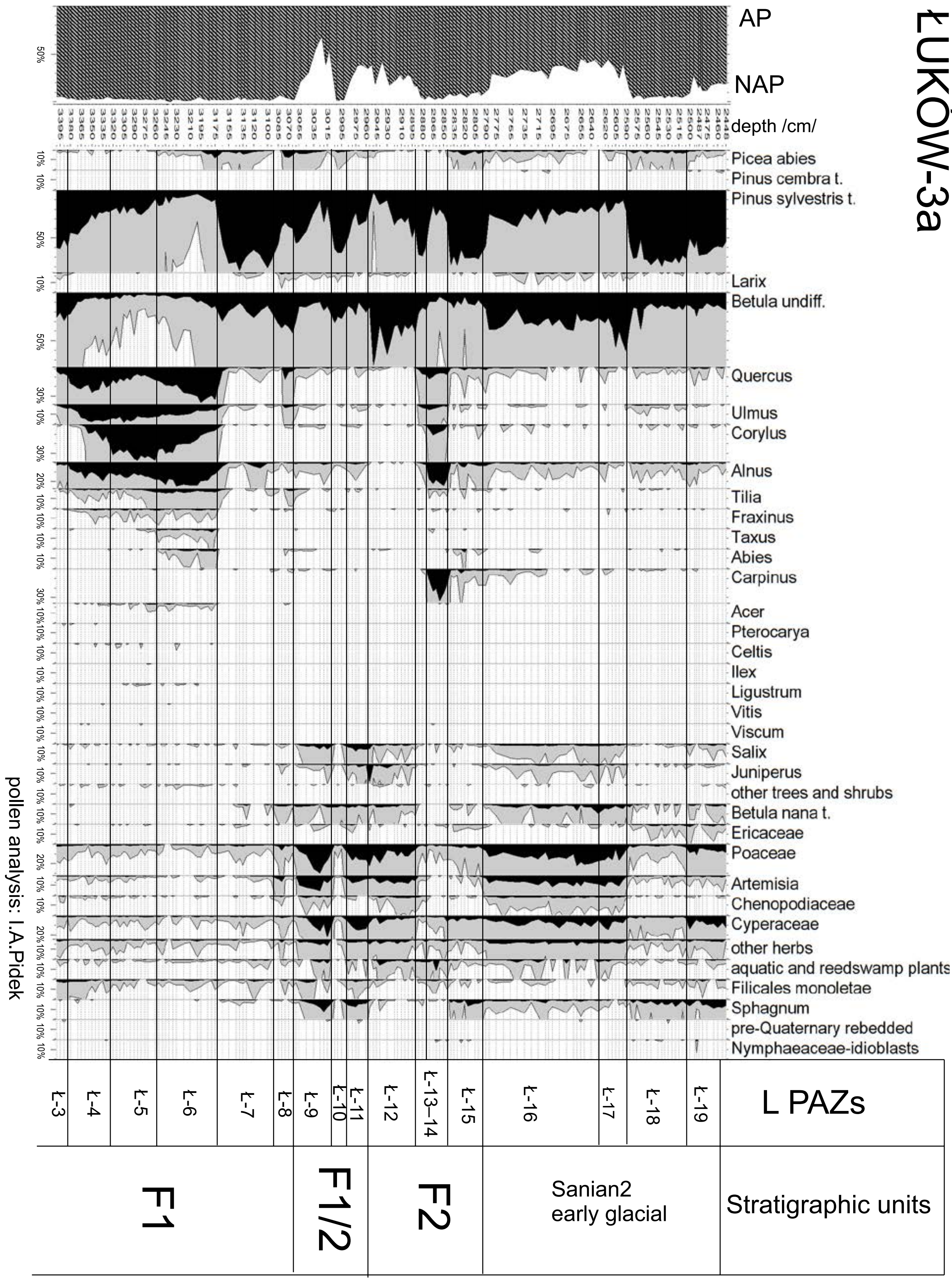

Fig. 3. Simplified pollen diagram of the Łuków-3a profile

that the plant community that occurred in the late glacial was similar to modern forest-tundra found in subarctic climatic conditions in the area between the White Sea and the Ural Mountains. The tree layer of this community consists of Siberian spruce (*Picea obovata*) and downy birch (*Betula pubescens*). Pine is absent from this community but herbaceous vegetation of open landscape is rich. An argument against the presence of *Picea* in the late glacial landscape of Ferdynandów is that its pollen curve is shaped like that of redeposited pre-Quaternary sporomorphs, so its pollen may also have been redeposited. The same argument can be invoked against the presence of alder. Its curve falls simultaneously with that of spruce and pre-Quaternary pollen, suggesting that the *Alnus* pollen probably was redeposited also. However, the occurrence of *Alnus* in river valleys cannot be ruled out completely. The zone has no analogue in the Łuków pollen diagram (Fig. 3), which starts with high values of *Betula* undiff. and *Pinus sylvestris* t.

Apparently the vegetation occurring during the late glacial/interglacial transition formed a mosaic of communities. It was forest-tundra, with patches of steppe vegetation in dry habitats. At this point the low values for spruce pollen and the lack of evidence that it represents *Picea obovata* prevent us from concluding that the vegetation was similar to the forest-tundra found today between the White Sea and Ural Mountains, as Janczyk-Kopikowa (1975) believed. Further work on the macrofossils from Ferdynandów may help solve this problem.

FERDYNANDÓW 1 INTERGLACIAL (Fe-2 – Fe-9 L PAZs)

Fe-2 *Betula* L PAZ. Numerous herb pollen and the still-frequent *Salix*, *Juniperus*, and *Artemisia* indicate the presence of different plant communities of open landscape in the cold climate of the late glacial/interglacial transition. Redeposited pre-Quaternary sporomorphs disappear in this zone, indicating stabilisation of the land. Birch and pine-birch forest types spread; those forests must have been thin, as evidenced by the considerable pollen percentages for Poaceae and Cyperaceae as well as heliophilous *Artemisia*. Probably larch and spruce formed a large admixture in these pine-birch forests.

Fe-3 *Pinus-Betula-Quercus* L PAZ. Communities of open landscape were replaced by pine forest, as indicated by a distinct decline of NAP and an increasing share of *Pinus sylvestris* t. pollen. *Quercus*, *Picea*, and *Larix* trees probably were scattered in those forests. The continuous curve of *Ulmus* up to 0.7% and an increase of *Quercus* pollen up to 2.1% suggest the encroachment of these trees in the wetter and more fertile habitats of river valleys. A similar type of riparian community seems to have started to develop around Łuków (Fig. 3) at the onset of the first interglacial (F1).

Floodplain woods probably resembling the modern *Ulmo-Quercetum* association known from Western Europe were described by Granoszewski (2003) at the beginning of the Eemian interglacial in the southern Podlasie region. He stressed the high affinity of *Quercus robur* for riparian habitats and was of the opinion that a high proportion of oak pollen should be associated mainly with wet fertile communities dominated by oak and elm. The start of the continuous pollen curve of *Alnus* and still-frequent *Salix* may testify to the presence of alder and willow patches in wet but poorer habitats.

Fe-4 *Quercus-Ulmus-Alnus-/Corylus/* L PAZ. Oak, elm, and alder were becoming more frequent. Sharply rising values of *Quercus* at the beginning of the zone, reaching up to 30.5% (Table 1, Fig. 2), indicate that oak not only spread in riverine communities but also probably participated in the development of mixed communities of various other types. Thermophilous oak woods most likely also started to form. *Tilia* and *Ulmus* apparently occurred as an admixture in these woods, and *Corylus* most likely formed the understorey. High values of *Ulmus* (up to 19.0%), the increasing values of *Alnus*, and the continuous curves of *Fraxinus* and *Celtis* pollen indicate that various types of riverine forests spread. The presence of *Celtis* is of special importance here as a climate indicator. Janczyk-Kopikowa (1975) related it to *Celtis australis* L., a species that occurs today in Southern Europe and North Africa, among other places. Its presence in the riverine communities around Łuków was also recorded, accompanied by high elm, oak, and alder pollen values (Fig. 3).

Fe-5 *Corylus* L PAZ. Fertile riverine forests dominated the landscape around Ferdynandów at that time. Various elm species, ash, oak, maple, lime, and alder may have been components of the tree layer. Still-frequent *Celtis* pollen grains suggest that this tree occurred in riverine communities as well. Boreal elements (*Larix*, *Picea Betula*, *Pinus*) decreased considerably at that time, and open areas were reduced to a minimum. In these forests other thermophilous elements (*Ligustrum*, *Vitis*, *Viscum*) also occurred. The development of *Corylus* communities in more open places is the most characteristic feature of this zone. The maximum of hazel pollen in the Ferdynandów diagram (42.5%) is higher than in the Łuków diagram (36.5%; Fig. 3). *Corylus* may have partly replaced heliophilous birch on more fertile soils rich in calcium carbonates, and may have formed its own thermophilous thickets. In earlier work (Pidek 2013) I stated that the pattern of encroachment of elm, oak, and ash before a distinct expansion of hazel at the beginning of the F1 interglacial is similar to what Mamakowa (1989) and Granoszewski (2003) described and interpreted for the beginning of the Eemian pollen succession. Moreover, *Corylus* expanded before the maximum of *Tilia* in both of these interglacials. The latter maximum is observed in the upper part of the zone, together with the start of continuous pollen curves of *Abies* and *Taxus* and an increase in *Alnus* pollen values. All these changes mark the spread of wet forest communities, in which alder probably played a dominant role, with yew and fir occurring as admixtures.

Fe-6 *Abies-Alnus-Quercus* L PAZ. A sharp rise in the pollen values of *Abies* to the maximum of 23%, along with a rise in *Picea* percentages to 13%, are evidence of increasing shares of fir and spruce in forest communities. *Taxus* also may have been an important component of these forests. The increasing proportion of *Picea* in forest communities indicates hydrological changes caused by increased precipitation, also suggested by still-high *Alnus* percentages. Spruce may have expanded further into riverine forests and also into spreading alder forests. The *Quercus* percentages increase and single *Carpinus* pollen grains occur in this zone, possibly signalling the appearance of hornbeam in oak-dominated forests in drier and rather fertile habitats. They seem to have replaced hazel thickets, as evidenced by falling percentages of *Corylus* in the pollen spectra. *Tilia* was an important component there. These features are well visible in the Łuków pollen diagram (Fig. 3), while in the Ferdynandów pollen diagram the high maximum of *Abies* pollen is much more pronounced. This undoubtedly testifies to the presence of fir woods closer to lake shores. Such a conclusion is supported by pollen monitoring studies in Roztocze, where fir forms tree stands. The results of that monitoring confirmed that *Abies* pollen is not transported in large quantities over long distances. Most of the pollen grains are deposited within 500 m of the sampling point (Poska & Pidek 2010, Pidek et al. 2013). The fir maximum in the new diagram from Ferdynandów is higher than the 15% given by Janczyk-Kopikowa in 1975. The very low share of NAP throughout the zone testifies to the occupation of all the suitable habitats by forest communities.

Fe-7 *Pinus-Betula* L PAZ. A very sharp increase of pine pollen values and a simultaneous fall in the values for all thermophilous trees indicate the withdrawal of oak, lime, ash, and hazel. Pine-dominated communities encroached all possible habitats. Spruce was still present in wetter places. It apparently replaced alder, as the *Alnus* percentages in the pollen diagram drop and disappear towards the upper part of the zone. Spruce probably also partly replaced fir and yew in more fertile habitats. *Larix* appeared again in the upper part of the zone and probably formed an admixture in pine forests together with birch.

Fe-8 *Betula-Larix*-NAP L PAZ. The simultaneous rise of *Betula* undiff. pollen values, the *Larix* maximum, and the fall in *Pinus sylvestris* t. percentages signal the reconstruction of forests in which the role of birch and larch became greater. It is likely that *Betula pubescens* encroached on wet places. Open herbaceous communities markedly expanded, as indicated by the increase in Poaceae, *Artemisia*, Chenopodiaceae, and Cyperaceae, together with higher percentages of *Betula nana* t. and *Juniperus*. Open forest-steppe communities with larch, scattered birch, and juniper may have formed in drier habitats, while wetter ones may have been occupied by *Betula nana* and Cyperaceae.

Fe-9 *Picea-Pinus-Quercus* L PAZ. The high values of *Quercus* and a distinct increase of *Pinus sylvestris* t., *Ulmus*, and *Picea* are not yet fully interpreted in terms of vegetation development and climate changes. In the pollen diagram from Łuków (Fig. 3) the increase of thermophilous elements is preliminarily interpreted as redeposition of reworked material of older deposits (probably from the Ł-6 L PAZ). The great resemblance of the composition of pollen spectra to that of the upper part of the Ł-6 (Fig. 3) is stressed. A small admixture of silt in the sediments from the Łuków-3a profile suggested the possibility of activation of solifluction processes promoted by an increase of water level (Pidek 2013). On the other hand, the repeated occurrence of higher values for oak and elm and some other thermophilous trees in the present diagram from Ferdynandów and the one from Zdany (Zd-8 L PAZ, cf. Pidek 2003) tends to support the *in situ* occurrence of these trees. This alternative hypothesis of the re-advance of several thermophilous trees needs to be verified by comparative studies of plant macroremains and sediment composition. If oak, elm, and some other thermophilous trees did not withdraw far they could have persisted in small populations in warmer and more humid conditions somewhere south of the region. Traces of this putative re-advance are also seen in the profile from Podgórze (Mamakowa 2003).

FERDYNANDÓW 1/2 COOLING/GLACIATION
(Fe-10 – Fe-12 L PAZs)

Fe-10 *Artemisia*-Poaceae-Cyperaceae L PAZ. NAP predominates in the older part of the zone. In the younger part, higher values of *Betula* undiff. and *Juniperus* pollen were recorded. The maximum percentages of *Artemisia*, Poaceaea, and frequent Chenopodiaceae pollen evidence a dramatic change of plant communities. Forests were replaced by open communities. Wetlands were occupied by sedge-moss mires, as seen in the rise of Cyperaceae pollen values and the rising percentages of moss spores, including *Sphagnum*. Dwarf birch and willow shrubs expanded and formed vegetation patches of shrubby tundra type. Spruce may have survived in waterlogged places. The presence of more thermophilous taxa (pollen of *Quercus*, *Tilia*, *Ulmus*, *Carpinus*, *Corylus*) is doubtful, although their sporadic grains still occur in this zone. The development of open communities typical of subarctic climate marks the first stadial of the F1/2 cooling/glaciation between the two interglacials in the Ferdynandovian pollen succession. The pattern of the stadial/interstadial oscillations is consistent with the Łuków pollen data (Fig. 3).

Fe-11 *Betula-Pinus* L PAZ. A new expansion of birch and pine-birch boreal forests is reflected in the changed composition of the pollen spectra, in which NAP distinctly decreases and tree birch and pine pollen become more abundant. Spruce and larch apparently formed a small admixture in these communities. The zone reflects an interstadial oscillation during which boreal forest replaced open communities almost entirely. The sedge-moss community close to the lake in Ferdynandów probably was reduced, as reflected in the low Cyperaceae pollen values. However, the pollen percentages for *Betula nana* t. (up to 3.2%) indicate survival of the dwarf birch community.

Fe-12 *Pinus-Betula*-NAP L PAZ. A new, distinct opening of the landscape probably resulted from successive climate cooling, reflected in increased NAP values. Boreal pine-birch forest seems to have retreated from many habitats and become less dense. Spruce trees and perhaps also larch probably persisted as admixtures. A forest–steppe community with birch and larch and with abundant *Artemisia* and *Juniperus* presumably occupied drier habitats. Wet communities were widespread, reflected in the maximum of *Salix* pollen values and frequent *Betula nana* t. pollen. Numerous *Sphagnum* spores and Cyperaceae pollen indicate a new expansion of tundra communities. Solifluction processes appear to have become active again, as indicated by the silt admixture in the deposits and the presence of single pollen grains of thermophilous taxa.

Fe-13 *Betula-Artemisia* L PAZ. Pioneer birch boreal forest re-expanded but open habitats persisted. Pine, larch and spruce were also components of these forests. Single pollen grains of *Ulmus* and *Quercus* occur regularly, suggesting redeposition. Shrubs are represented by *Salix* and *Juniperus*, but towards the upper part of the zone their pollen values decrease significantly. Still-high NAP values, including abundant *Artemisia*, Poaceae, and Chenopodiaceae pollen, indicate that the forests were rather open. Herb communities were differentiated, as shown by numerous pollen of different taxa connected with both wet and dry communities. *Betula nana* tundra may have survived in some places.

FERDYNANDÓW 2 INTERGLACIAL
(Fe-14 – Fe-18 L PAZs)

Fe-14 *Pinus* L PAZ. The expansion of pine woods followed the open pine-birch boreal forests of the previous zone, marking the beginning of the new interglacial period. *Pinus* probably occupied all the available habitats, as can be inferred from the falling percentages of all trees, including tree birches, and most of the herbs. The presence of Nymphaeaeceae idioblasts and the simultaneous disappearance of *Sphagnum* spores indicate a rise of the lake water level and reduction of the mire area.

Fe-15 *Pinus-Ulmus-Quercus* L PAZ. A distinct increase of the percentages of many thermophilous taxa indicates the simultaneous formation of different types of deciduous forests. These were probably elm-dominated riverine communities with admixture of oak. A new rapid expansion of alder is seen in the rising values of the *Alnus* pollen curve. Alder trees may have occurred as an admixture in elm-dominated riverine forests and possibly formed its own communities. *Pinus sylvestris* t. domination of the pollen spectra reflects the presence of widespread pine forests, in which oak trees probably began to appear. At the same time, boreal shrubby communities dominated by willow, juniper, and dwarf birch withdrew completely. The presence of Nymphaeaeceae idioblasts indicates warm, eutrophic water in the lake (Podbielkowski & Tomaszewicz 1996).

The same pattern of forest expansion throughout the F2 interglacial is observed in the pollen diagram from Łuków.

Fe-16 *Carpinus-Alnus-Corylus* L PAZ. The zone represents the climate optimum of the second interglacial (F2) and is fully comparable to the Ł-14 zone (Fig. 3). A sharp rise of the *Carpinus* pollen percentages indicates the encroachment of hornbeam into the forests and rapid occupation of more fertile soils together with oak, lime and an admixture of ash and elm. *Celtis* may also have occurred in these forests. The role of oak in mixed pine forests increased as well, as indicated by the rise of *Quercus* pollen values up to 10.5% in this zone. The advance of hazel was again significant. Pine-oak forests may have transformed to deciduous oak-hornbeam forest, possibly of the modern *Querco-Carpinetum* type. The rapid rise of *Carpinus* pollen values in Ferdynandów (up to 36.5%) and in Łuków (up to 33.5%) are evidence of an extremely dynamic expansion of hornbeam. Based on the modern pollen data from Roztocze it can be assumed that values exceeding 30% in the fossil pollen spectra from both diagrams indicate the dominant role of hornbeam in the formation of dry-land forests. *Tilia* occurred frequently in communities occupying more fertile soils, as indicated by the continuous curve of its pollen. A distinct rise of *Alnus* pollen values indicates that alder forests played a very important role in wetlands throughout the zone.

Fe-17 *Pinus-Picea* L PAZ. The continuous curve of *Picea*, rising at the beginning of the zone, indicates that spruce entered wet forest communities. The high percentages of *Pinus* again reflect transformation of the forest communities as a result of climate change. Pine probably occupied drier habitats previously overgrown with hornbeam and oak, as suggested by a dramatic fall in *Carpinus* and also *Quercus* pollen values. The decline of thermophilous elements is accompanied by an increase of *Abies* percentages to 2.3%, followed by high *Picea* values. *Abies* pollen values, similar to modern values from Roztocze, suggest that fir constituted an important admixture in the spruce-fir communities. *Taxus* may have occurred sporadically in these forests. In the old pollen diagram from Ferdynandów (Janczyk-Kopikowa 1975), *Abies* pollen is extremely sporadic in the corresponding zone, but the same pattern of fir encroachment in the Ł-15 L PAZ and in the new Ferdynandów diagram (Figs 2, 3) suggests that *Abies* probably took over habitats previously occupied by oak-hornbeam communities and then may have been replaced by spruce. In the younger part of the zone, forest with *Abies* and *Taxus* withdrew, perhaps in response to drier and cooler climate.

The new occurrence of *Betula nana* at that time is worth stressing; it occurs in the pollen diagrams from Ferdynandów and Łuków simultaneously (Figs 2, 3), possibly marking a new mire expansion.

Fe-18 *Pinus* L PAZ. The re-advance of pine woods is typical for the close of the interglacial succession. The *Pinus sylvestris* t. pollen values reach their maximum in this zone (up to 97%), which testifies to the occupation of all available habitats by different types of pine communities.

SANIAN 2 (= ELSTERIAN 2) EARLY GLACIAL (Fe-19 – Fe-21 L PAZs)

Fe-19 *Betula*-Poaceae-Cyperaceae L PAZ. A sharp increase of NAP values, especially those of Poaceae and Cyperaceae, simultaneously with higher values of *Betula* undiff. and a distinct decline of *Pinus sylvestris* t., indicates more open forest cover in which tree birch began to gain dominance and herbaceous communities expanded anew. More frequent *Sphagnum* spores in both the Ferdynandów and Łuków pollen diagrams suggest the start of new mire development. The zone marks the first stadial of the Sanian 2 glaciation and presents a pattern of vegetation changes similar to that recorded in the Ł-16 L PAZ. Larch again starts to play a more important role in the forests, as its pollen percentages rise to 0.9%. The share of *Salix* increases considerably, together with dwarf birch, which suggests that more areas were occupied by shrubby tundra. Pollen of thermophilous taxa may be attributed to redeposition, as indicated by the pre-Quaternary sporomorphs. The landscape must have been quite open, as evidenced by frequent juniper and Ericaceae.

Fe-20 *Pinus*-NAP L PAZ. Some increase of the *Pinus sylvestris* t. pollen values indicates that pioneer pine-birch patches were more frequent again. Larch and spruce probably were an admixture. The similar pattern of the alder pollen curve in the Łuków diagram makes the presence of *Alnus incana* plausible. It may have been sparsely distributed in wetter places together with spruce. Birch forest did not invade all areas of tundra and steppe-like communities. High NAP values and an admixture of silt in the deposit suggest that pollen of thermophilous taxa was rebedded.

Fe-21 *Pinus* L PAZ. Pine-birch woodland was replaced by pine forests, perhaps with an admixture of spruce and larch. Much lower NAP values indicate that herbaceous communities were replaced by pine forests in most habitats.

DISCUSSION

The new pollen diagram from Ferdynandów exhibits features of a bimodal sequence encompassing two interglacial successions, and is closely correlated with the succession from the nearest site (Fig. 4) of the same age in Łuków (ca 30 km to the north). I applied the new division of the Ferdynandovian pollen succession proposed by Mamakowa (2003) to the new diagram from Ferdynandów. This enabled it to be more widely correlated with the Cromerian complex of Western European stratigraphy and with Marine Isotope Stages 13–15 (Tab. 2).

Quaternary scientists debate whether the interglacial successions within the Ferdynandovian ("lower and upper optimum" acc. to Janczyk-Kopikowa 1975) should be correlated with Cromerian II and III (Zagwijn 1996, Rylova & Savchenko 2005) or with Cromerian III and IV (Lindner et al. 2004). Sometimes they are treated as one unit, Ferdynandovian, without further division (Ber et al. 2007).

The pollen successions from Ferdynandów are complete and cover MIS 13–15. In all three sequences of central eastern Poland (Zdany, Łuków, Ferdynandów) some features of the pollen spectra at the beginning of the F1 interglacial indicate high oceanicity of the climate. It is seen in the rapid spread of riverine communities, followed by hazel expansion and

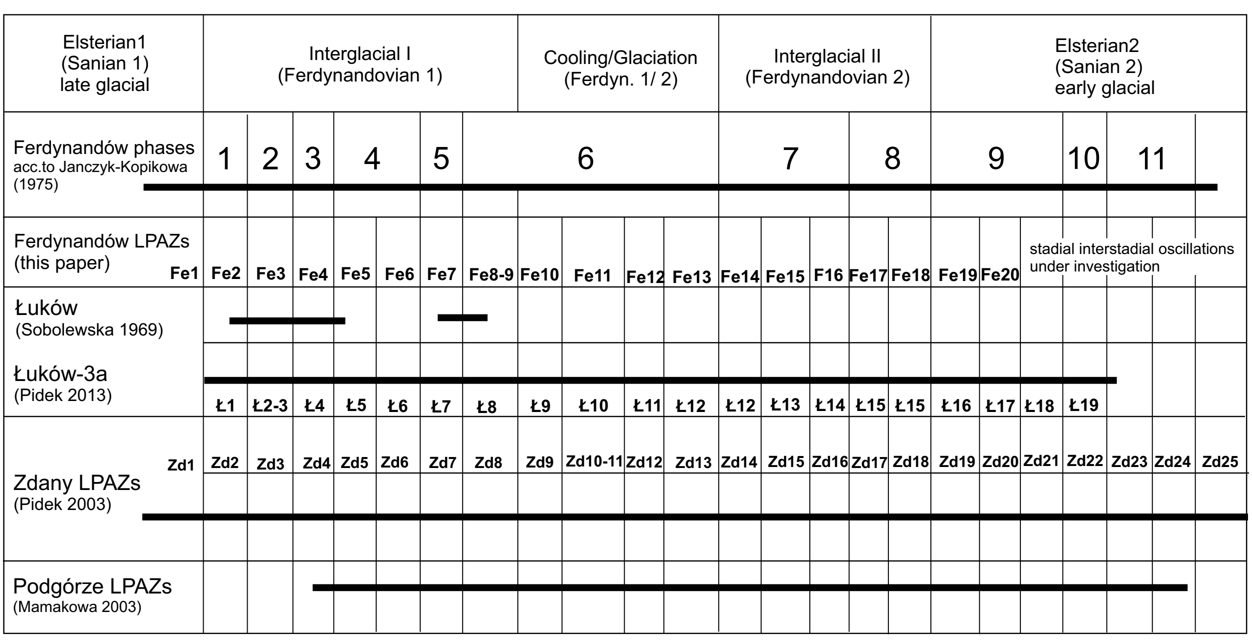

Fig. 4. Correlation of palyno- and climatostratigraphic divisions of pollen successions: Ferdynandów phases in the old profile from Ferdynandów (Janczyk-Kopikowa 1975), and L PAZs from the new profile from Ferdynandów (this paper) are presented versus the L PAZs from the profile from Zdany (Pidek 2003), the new Łuków-3a profile (Pidek 2013), the old profile from Łuków (Sobolewska 1969), and the profile from Podgórze (Mamakowa 2003)

Table 2. Correlation of the local pollen assemblage zones (L PAZs) in the diagram from Ferdynandów (this paper) and Łuków-3a (Pidek 2013), against the background of the new division of the Ferdynandovian pollen sequence *s.l.* by Mamakowa (2003) and Ferdynandovian phases acc. to Janczyk-Kopikowa (1975; Janczyk-Kopikowa et al. 1981), in relation to the stratigraphic units acc. to Lindner et al. (2004), Zagwijn (1996) and Rylova, Savchenko (2005)

Correlation with West Europe climatostratigraphic units (acc.to Lindner et al. 2004)	Correlation of Ferdynandów pollen diagram (this paper) with East Europe stratigraphy (acc. to Zagwijn, 1996; Rylova & Savchenko, 2005)	Marine Isotope Stages (MIS) (acc. to Lindner et al. 2004)	Climatostratigraphic division acc. to Lindner et al. (2004) and Winter (2006)	New division of the Ferdynandovian pollen sequence (acc. to Mamakowa 2003)	Ferdynandovian phases (acc. to Janczyk-Kopikowa 1975)	Division of Ferdynandovian pollen sequence (acc. to Janczyk-Kopikowa et al. 1981)	Łuków – 3a (Pidek 2013)	Ferdynandów (this paper)
Elsterian 2		**12**	Sanian 2 Glaciation (Elsterian 2)	Sanian 2 early glacial	10–11	Sanian 2 early glacial	Ł-17 – Ł-19	**From Fe-20 upwards**
					9		Ł-16	**Fe-19**
Cromerian Interglacial IV	**Cromerian III (Rosmalen)**	**13**	Ferdynandovian 2 Interglacial	Interglacial 2 (upper)	8	Upper climatic optimum	Ł-15	**Fe-17-Fe-18**
					7		Ł-14	**Fe-16**
							Ł-13 Ł-12 younger part	**Fe-15** **Fe-14**
					6	Cooling	Ł-12 older part	**Fe-13**
Cromerian Glacial C		**14**	Ferdynandovian 1/2 Cooling/ Glaciation	Glaciation			Ł-11	**Fe-12**
							Ł-10	**Fe-11**
Cromerian complex Interglacial III	**Cromerian II (Westerhoven)**	**15**	Ferdynandovian 1 Interglacial	Interglacial 1 (lower)			Ł-9	**Fe-10**
					5	Lower climatic optimum	Ł-8 younger part	**Fe-9**
							Ł-8 older part	**Fe-8**
							Ł-7	**Fe-7**
					4		Ł-6	**Fe-6**
					3		Ł-5 Ł-4	**Fe-5** **Fe-4**
					2		Ł-2-3	**Fe-3**
					1		Ł-1	**Fe-2**
Cromerian Glacial B (Elsterian 1)		**16**	Sanian 1 Glaciation (Elsterian 1)	Sanian 1 Late glacial				**Fe-1**

the spread of lime. Several indicators of warm and wet climate are also present. In interpreting the climate changes inferred from pollen data in the new profile from Łuków, I found numerous similarities with the Eemian succession in the Podlasie region of eastern Poland (see Pidek 2013). The high-resolution pollen data of the Eemian interglacial investigated by Granoszewski (2003) and Kupryjanowicz (2008) present the same pattern of elm, oak, and ash expansion followed by the spread of hazel communities. The development of these forests was conditioned by the enhanced maritime features of the climate at the start of the F1 interglacial. These climate interpretations are also supported by application of the modern pollen analogue approach to the Łuków and Zdany pollen data (Pidek & Poska 2013).

The present investigation focused on a cold period between two warm units of interglacial rank. The method of sampling the newly cored organogenic deposits from Ferdynandów yielded high-resolution pollen data, especially for the part of the deposits covering the period of distinct cooling. The F1/2 cooling/glaciation marks a period of strong continental features, which may have stopped further expansion of thermophilous forests. The plant indicator and modern pollen analogue approaches produce highly similar results when applied to this period (Pidek & Poska 2013). It shows typical features of the stadial/interstadial oscillations recorded in many cold units of the Quaternary. Climatostratigraphically the 1/2 interval undoubtedly reflects glacial conditions, but this point of view has not been fully accepted by geologists due to the absence of a correlatable glacial till deposit. The same stadial/interstadial oscillations are observed in profiles of the same age at sites east of Poland in Belarus. These oscillations occur between an older interglacial corresponding to the F1, called Belovezhian, and a younger one corresponding to the F2, called Mogilevian (Rylova & Savchenko 2005).

The expansion of hornbeam, the most characteristic feature of the second interglacial (F2), seem to be very rapid in all of the successions mentioned here – Ferdynandów, Łuków, and Zdany. It was preceded by the spread of oak, elm, and alder communities. The very rapid course of hornbeam expansion might be due to changes towards more continental climate in the F2 than in the F1 interglacial, which was suggested in analyses using the modern pollen analogues approach (Pidek & Poska 2013). On the other hand, regular pollen grains of *Carpinus* occur as early as the youngest part of the F1 (Fe-6 L PAZ), and in the subsequent pollen zones hornbeam appears from time to time as single pollen grains. These findings may indicate proximity to refugial areas in which this thermophilous tree survived.

This study of new pollen data from Ferdynandów provides evidence that the pattern of climate-driven vegetation development during the MIS 13–15 is highly consistent and highly repeatable over vast areas of the North European Lowlands. Further studies of plant macrofossils from this interesting core may be prove decisive in determining the *in situ* occurrence of some interesting taxa, including exotic genera alien to the contemporary Polish flora such as *Celtis*, whose pollen values form a continuous curve in both the old and the new diagrams from Ferdynandów. Another problem to be solved is whether oak-elm riverine communities occurred at the close of the first interglacial (F1), which seems indicated by the distinct increase of *Quercus* and *Ulmus* pollen percentages.

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REFERENCES

BER A., LINDNER L. & MARKS L. 2007. Propozycja podziału stratygraficznego czwartorzędu Polski. Prz. Geol., 55(2): 115–118.

GRANOSZEWSKI W. 2003. Late Pleistocene vegetation history and climatic changes at Horoszki Duże, Eastern Poland: a palaeobotanical study. Acta Palaeobot., Suppl. 4: 3–95.

JANCZYK-KOPIKOWA Z. 1975. Flora of the Mazovian Interglacial at Ferdynandów. Biul. Inst. Geol., 290: 5–94.

JANCZYK-KOPIKOWA Z. 1987. Remarks on palynostratigraphy of the Quaternary. Kwart. Geol., 31(1): 155–162.

JANCZYK-KOPIKOWA Z. 1991. The Ferdynandów Interglacial in Poland. Kwart. Geol., 35(1): 71–80.

JANCZYK-KOPIKOWA Z., MOJSKI J.E. & RZECHOWSKI J. 1981. Position of the Ferdynandów

Interglacial, Middle Poland, in the Quaternary Stratigraphy of the European Plain. Biul. Inst. Geol., 335: 65–79.

KUPRYJANOWICZ M. 2008. Vegetation and climate of the Eemian and Early Vistulian Lakeland in northern Podlasie. Acta Palaeobot., 48(1): 3–130.

LINDNER L., MARCINIAK B., SANKO A.F. & KHURSEVICH G.K. 2001. The age of the oldest Scandinavian glaciations in mid-eastern Poland and southwestern Belarus. Geol. Quart., 45(4): 373–386.

LINDNER L., GOZHIK P., MARCINIAK B., MARKS L. & YELOVICHEVA Y. 2004. Main climatic changes in the Quaternary of Poland, Belarus and Ukraine. Geol. Quart., 48(2): 97–114.

MAŁEK M. & BUCZEK K. 2006. Szczegółowa mapa geologiczna Polski w skali 1:50 000 arkusz Łuków (602) (wraz z objaśnieniami). Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.

MAMAKOWA K. 1996. Nowe dane palinologiczne z profilu Podgórze, ark. Białobrzegi SMGP 1:50 000. Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.

MAMAKOWA K. 1989. Late Middle Polish Glaciation, Eemian and Early Vistulian vegetation at Imbramowice near Wrocław and the pollen stratigraphy of this part of the Pleistocene in Poland. Acta Palaeobot., 29(1): 11–176.

MAMAKOWA K. 2003. Plejstocen: 235–266. In: Dybova-Jachowicz S. & Sadowska A. (eds), Palinologia, Instytut Botaniki im. W. Szafera PAN, Kraków.

NALEPKA D. & WALANUS A. 2003. Data processing in pollen analysis. Acta Palaeobot., 43: 125–134.

PIDEK I.A. 2000. Palynostratigraphic interpretation of the cold unit between two warm ones in the Ferdynandovian succession from Zdany (eastern Poland). Prz. Geol., 48(11): 1035–1038.

PIDEK I.A. 2003. Mesopleistocene vegetation history in the northern foreland of the Lublin Upland based on palaeobotanical studies of Zdany and Brus sites. Wyd. UMCS, Lublin.

PIDEK I.A. 2013. Pollen-based vegetation and climate reconstruction of the Ferdynandovian sequence from Łuków (E Poland). Acta Palaeobot. 53(1): 115–138.

PIDEK I.A. & MAŁEK M. 2010. A bi-partite Ferdynandovian succession from Łuków, Eastern Poland: a new palynostratigraphic approach. Geol. Quart., 54(1): 69–85.

PIDEK I.A. & POSKA A. 2013. Pollen-based quantitative climate reconstructions from the Middle Pleistocene sequences at Łuków and Zdany (E Poland): species and modern pollen analogues based approach. Rev. Palaeobot. Palynol., 192: 65–78.

PIDEK I.A., PIOTROWSKA K. & KASPRZYK I. 2010. Pollen-vegetation relationships for pine and spruce in southeast Poland on the basis of volumetric and Tauber trap records. Grana, 49(3): 215–226.

POSKA A. & PIDEK I.A. 2010. Pollen dispersal and deposition characteristics of *Abies alba*, *Fagus sylvatica* and *Pinus sylvestris*, Roztocze region (SE Poland). Veget. Hist. Archaeobot., 19(1): 91–101.

PODBIELKOWSKI Z. & TOMASZEWICZ H. 1996. Zarys hydrobotaniki (Outline of hydrobotany). Wydawnictwo Naukowe, PWN, Warszawa.

RYLOVA T. & SAVCHENKO I. 2005. Reconstruction of palaeotemperatures of Pleistocene interglacial intervals of Belarus from palynological evidences. Pol. Geol. Inst. Special Papers, 16: 83–93.

RZECHOWSKI J. 1996. The Ferdynandowian Interglacial and its stratigraphical position in the Middle Pleistocene of Europe: 279–293. In: Turner Ch. (ed.), The early Middle Pleistocene in Europe. Balkema, Rotterdam.

RÜHLE E. 1969. Profil osadów czwartorzędowych w Łukowie na Podlasiu (summary: The section of Quaternary deposits at Łuków in Podlasie). Biul. Inst. Geol., 220: 81–103.

SOBOLEWSKA M. 1969. Osady interglacjalne w Łukowie na Podlasiu w świetle analizy pyłkowej (summary: Interglacial deposits at Łuków in Podlasie in the light of pollen analysis). Biul. Inst. Geol., 220: 105–114.

TURNER CH. 1996. A brief survey of the early Middle Pleistocene in Europe: 295–317. In: Turner Ch. (ed.), The early Middle Pleistocene in Europe. Balkema, Rotterdam.

WEST R.G. 1970. Pollen zones in the Pleistocene of Great Britain and their correlation. New Phytologist, 69: 1179–1183.

WINTER H. 2006. Problem of Pleistocene interglacials and glaciations – general remarks. Prz. Geol., 54(2): 142–144.

ZAGWIJN W.H. 1996. The Cromerian Complex Stage of the Netherlands and correlation with other areas in Europe: 145–172. In: Turner Ch. (ed.), The early Middle Pleistocene in Europe. Balkema, Rotterdam.

ŻARSKI M., NITA M. & WINTER H. 2005. New interglacial sites in the region of the Wilga and Okrzejka river valleys at the Żelechów Upland (SE Poland). Prz. Geol., 53(2): 137–144.