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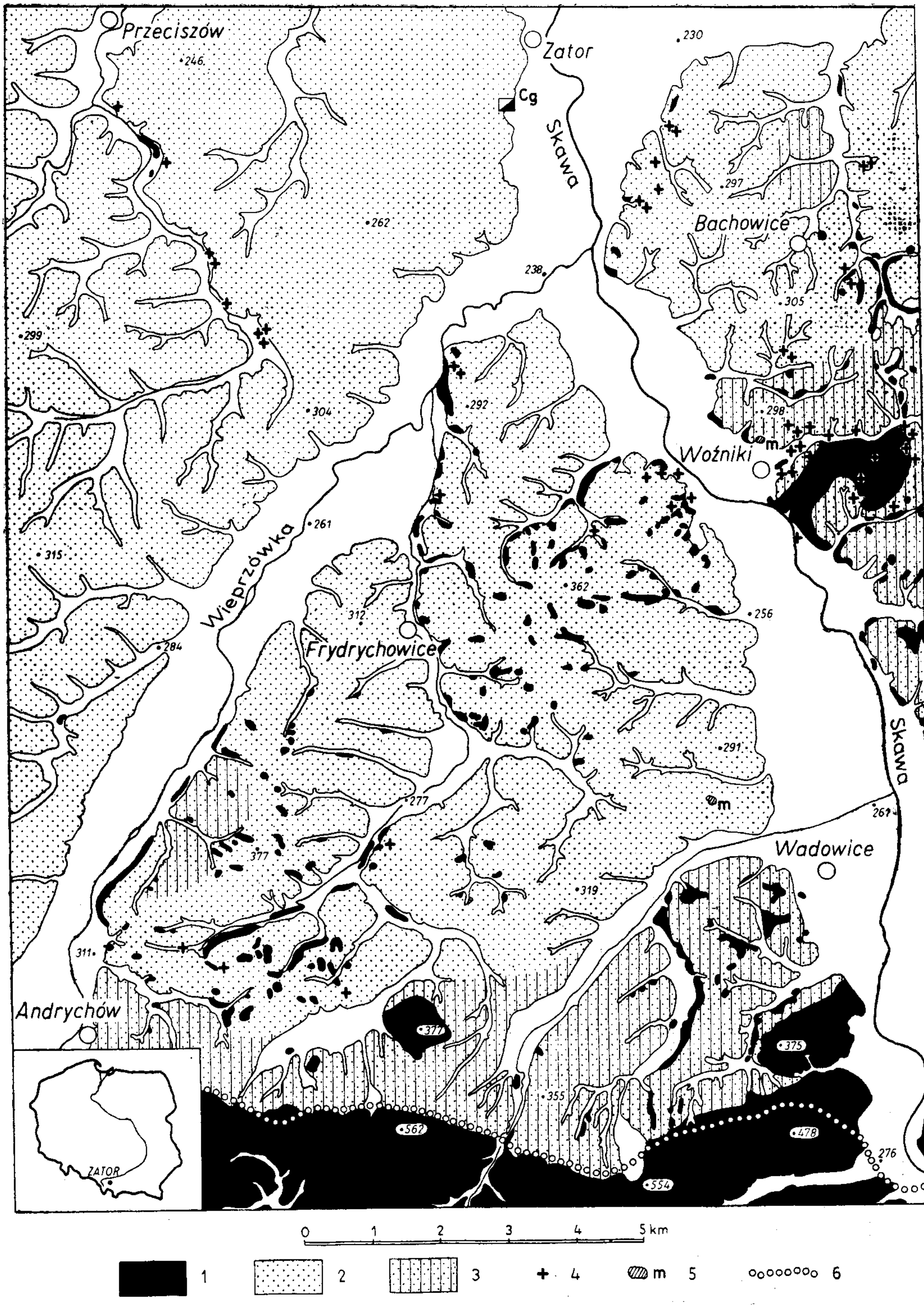
PLENIGLACIAL DEPOSITS OF THE LAST GLACIATION AT ZATOR (WEST OF KRAKÓW)

Pleniglacjalne osady z okresu ostatniego zlodowacenia w Zatorze

INTRODUCTION

The Quaternary sediments covering the foreland of the Beskid Mały (West Carpathians) are distinguished by a considerable thickness and variety. Shreds of moraines, rhythmites and solifluction sediments, peat, mud and thick gravel strata are covered here with loess-like clay (Klimaszewski 1948; Książkiewicz 1951). Glacial sediments with Scandinavian material mostly found on a secondary bed are connected with the presence in these parts of the Continental glacier (Cracovian), the short tongues of which penetrated into the Carpathian valleys (cf. fig. 1). Solifluction, mud, and peat contain remains of fossil plants and bones of Pleistocene mammals (Konior 1936, 1939; Stach 1956; Szafer 1956; Kowalski 1959; Sobolewska, Starkel, Środoń 1964). These various sediments are not yet sufficiently known. Several controversial observations and statements exist requiring examination and a cautious and critical analysis.

The fossil flora at Zator, discovered in 1953 by the second of the authors is situated at the brickyard that lies at a distance of about 1·5 km to the south of the town. This locality was often visited in the course of the last 10 years and it was investigated in detail as the exploitation advanced. The interest of the workmen in the brickyard was aroused and we are indebted to them, and especially to Mr A. Bercal, for the discovery of three mammoth teeth and a fragment of horn. Simultaneously, research was carried out in the nearer and further neighbourhood of Zator. The collected information seems to prove that the picture of the vegetation, climate, and sedimentation processes as deduced from the profile of Zator concerns considerable territory adjoining in these parts the Carpathians.


Przeciszów
246
Zator
230
Cg
Skawa
297
Bachowice
262
238
305
299
304
292
298
Woźniki
m
261
Wieprzówka
362
315
256
312
Frydrychowice
284
291
277
m
261
Skawa
Wadowice
377
319
311
Andrychów
377
375
355
562
478
276
554
ZATOR
0
1
2
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4
5 km
1
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6

GEOLOGY

The town of Zator (246 m above sea level) is situated on the northern border of an area which is covered towards the south with clays of various origin right up to the edge of the Carpathians. Among these clays, which cover almost entirely the older rocks, K s i ą ż k i e w i c z (1951) distinguished alluvial and deluvial clays and eolian loesses. We are interested here, in the first place, in the weathered deluvial clays and loess and loess-like clays differentiated by K s i ą ż k i e w i c z (l. c.) in his „Geological map, Wadowice sheet". The weathered deluvial clays cover the parts adjoining the Carpathian edge, while the loesses and loess-like clays are situated further towards the valley of the Wisła (Vistula) (cf. fig. 1).

The Lower and Middle Miocene occupies, according to Książkiewicz (1951), rather extensive areas in the northern part of the Wadowice sheet in the form of loamy sediments or of sediments with a prevalence of gravel and sand components. Traces of these, perhaps, sediments appear on the secondary bed in Quaternary layers. Among them are well-rounded lignites extracted from the boulder clay exploited in the brickyard of Frydrychowice (11 km to the south of Zator) and pollen grains of exotic plants found in the Zator profile (cf. fig. 5). Lignites, among which Dr. M. R e y m a n ó w n a identified the *Juniperoxylon* vel *Taxodiaceae,* are probably traces of the erosive action of the moving ice, while the pollen of exotic plants is perhaps connected with the process of blowing out of the open Miocene sediments during loess accumulation. Another possible source of these re-deposited pollen grains might be the boulder clays.

The loess structure can be observed in the outcrops appearing along the road leading from the market place of Zator to Wadowice. This road descends on leaving the town on an alluvial terrace and runs along a well developed loess terrace, with a relative height of about 10 m (Plate I). Layers of this terrace are exploited in the brickyard and their palaeobo-

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Fig. 1. Section (simplified) of the „Geological Map, Wadowice sheet" (M. Książkiewicz 1951)

1 — Flysch and Miocene; 2 — Loess and loess-like clays; 3 — Weathered clays; 4 — Erratics; 5 — Moraine; 6 — Limit of Cracovian Glaciation (acc. to Klimaszewski 1937).

Fig. 1. Wycinek (uproszczony) „Mapy geologicznej, arkusz Wadowice" (M. Książkiewicz 1951)

1 — flisz i miocen; 2 — less i gliny lessopodobne; 3 — gliny zwietrzelinowe; 4 — eratyki; 5 — morena; 6 — zasięg zlodowacenia Cracovian (wg Klimaszewskiego 1937)

tanic content became the main subject of investigation. The section of the northern wall of the brickyard was recorded as follows:

Depth in cm	Thickness in cm	Description of strata
000—060	60	soil;
060—330	270	yellowish-rust coloured loess-like, sandy clay with stains of grey clay;
330—370	40	greyish-white, sandy clay, stratified;
370—415	45	grey, sandy clay;
415—435	20	light-grey (whitish) sandy clay, stratified in waves;
435—545	110	sandy clay;
545—570	25	peaty mud with streaks of sandy grey clay;
570—590	20	light-brown, peaty mud, streaked;
590—615	25	greenish mud with insertions of peaty muds having streaks of sand in the bottom;
615—703	88	rusty green mud;
703—717	14	olive-grey mud with peat insertions;
717—732	15	brown peat, well decomposed with small pieces of wood;
732—750	18	brown, peaty mud, with a considerable amount of plant remains;
750—825	75	brown, peaty mud, with occasional flysch gravel;
825—840	15	bluish clay with fine flysch gravel;
840—855	15	bluish, coarse grained sand, passing into gravel;
855—		fluvial gravel, sandy, with a prevalence of flysch material, well rounded, with a diameter up to 10 cm; thickness not accurately known.

Geological boring carried out in different places surrounding the brickyard (borings executed in 1964 by „Hydrogeo") demonstrated that the thickness of the gravel stratum can be even 10 m. Rusty ferruginous concretions also appear in the entire profile. According to Książkiewicz (1951) the bottom of the terrace in question is composed „either of rather fine gravel or wholly of stratified greyish-blue and grey brick clays" (p. 255).

The exploitation of clay in the Zator brickyard is carried out down to the bottom of dark loams with small layers of peat which can be easily observed on the whole area of the yard. In an analogical stratigraphic position these loams appear in a well dug out in 1958 at the cross-roads, about 700 m to the north of the brickyard and at the bottom of the well in the Zator Market Place. In the first locality a stratum of fine bluish gravel with a prevalence of flysch material was found under the loam.

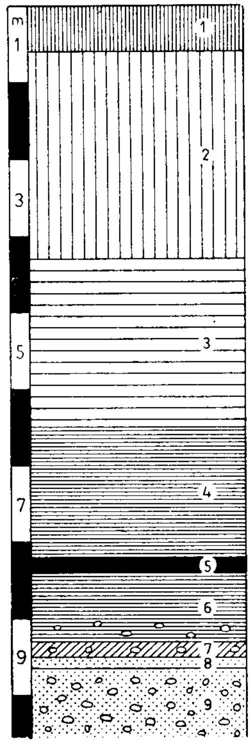

Fig. 2. Schematic profile of the Pleistocene terrace in the brickyard at Zator

1 — soil; 2 — loess-like clay, yellow, sandy; 3 — loess-like clay, light grey, sandy, stratified; 4 — peaty mud, disturbed by solifluction; 5 — peat disturbed by solifluction; 6 — peaty mud disturbed by solifluction with flysch gravel in the bottom and with bones of mammals; 7 — light grey clay with flysch gravel; 8 — coarse grained sand; 9 — fluvial gravel, sandy with a prevalence of flysch material

Fig. 2. Schematyczny profil terasy plejstoceńskiej w cegielni w Zatorze

1 — gleba, 2 — glina lessopodobna, żółta, piaszczysta, 3 — glina lessopodobna, jasno-popielata, piaszczysta, warstwowana, 4 — mułek torfowy, soliflukcyjnie zaburzony, 5 — torf soliflukcyjnie zaburzony, 6 — mułek torfowy ze żwirkami fliszowymi w spągu, soliflukcyjnie warstwowany z kośćmi ssaków, 7 — glina siwa ze żwirkami fliszowymi, 8. — piasek gruboziarnisty, 9 — żwir rzeczny, piaszczysty z przewagą skał fliszowych

At Bachowice (250 m above sea level), situated on the eastern side of the Skawa, at a distance of about 5 km to the south-east of Zator (cf. fig. 1) formations similar to those noted at Zator appear in the brickyard.

The description presented below is from the year 1954.

0·35 m soil;
1·60 m yellowish-grey loess-like clay;
3·80 m grey loess-like clay, with rusty stains;
0·20 m rusty loess-like clay, with ferruginous concretions;
0·10 m rusty-grey loess-like clay, stratified;
0·20 m bluish clay, with ferruginous concretions up to 15 cm in diameter, forming a distinct level;
0·65 m bluish clay with irregularly disposed thin layers of peaty mud containing fairly large amounts of plant remains;
0·40 m bluish unstratified clay.

According to information obtained from the workmen of the brickyard, a stratum of water-bearing gravel appears under the bluish clay, whose thickness has not been stated. Książkiewicz (1951) mentions this gravel hidden beneath the loess on the eastern side of the Skawa.

In the brickyard of Przeciszów (240 m above sea level) at a distance of about 5·5 km to the west of Zator (cf. fig. 1) the strata disposition is similar:

0·70 m soil;
3·40 m loess-like clay, with rusty stains, dividing into vertical lumps;
0·90 m light grey loess-like clay, with rusty stains;
0·08 m thin layer of very hard rusty clay;
1·50 m dark bluish clay with thin irregularly disposed layers of peaty mud with fairly large amounts of plant remains.

In the opinion of the workers of the brickyard these layers rest upon sands and gravel. In the stratum of clay containing bands of peaty mud, two mammoth teeth were found in 1963 (inform. of Prof. K. Kowalski).

When comparing the geological profiles of Zator, Bachowice, and Przeciszów, situated at a short distance from each other on the northern border of the loess cover, it can be easily observed that the strata of which these profiles are composed are similar and demonstrate an analogical rhythm of sedimentation. Sands, and, higher up, dark loams with thin layers of peat, covered by a thick stratum of loess clays, rest upon fluvial gravel in which flysch material prevails. The same sequence in similar sediments was also noted in other localities. This will be discussed in the chapter concerning the stratigraphy and age of the sediments (cf. p. 25). Peaty muds and loess-like clays appearing in the three already-mentioned profiles were developed in a periglacial climate under the influence of solifluctional and downwash processes (Plate II). This kind of genesis of the formations in question is also confirmed by the results of investigations carried out on the flora contained in peaty muds. Its composition indicates a land sedimentation in which small and shallow tundra lakes participated.

The name of peaty muds given to the stratum containing plant remains, with a simultaneous exclussion of river and lake accumulation, rises automatically the problem of the origin of these muds. An analysis of the composition percentage of heavy minerals, was carried out by Dr. M. Krysowska (Chair of Mineralogy and Petrography of the Jagellonian University) with the aim of elucidating this question. Four samples of material were studied, collected from the following strata of the profile:

sample „a" — sand (8·50—8·35 m)
sample „b" — peaty mud (7·45—7·20 m)
sample „c" — peaty mud (6·10—5·95 m)
sample „d" — loess-like clay (4·00—3·80 m)

Table 1

ANALYSIS OF THE COMPOSITION PERCENTAGE OF HEAVY MINERALS IN THE PROFILE FROM ZATOR

Tabela 1

Analiza składu procentowego minerałów ciężkich w profilu z Zatora

	Samples			
	a	b	c	d
Opaque minerals	47·0	40·0	32·0	37·0
garnet	13·0	4·0	10·0	7·0
zircon	20·0	20·0	33·0	31·0
tourmalin	12·0	16·0	9·0	6·0
epidote	2·0	3·0	5·0	4·0
rutile	2·0	9·0	2·0	6·0
staurolite	1·0	1·0	—	1·0
amphibole	3·0	7·0	9·0	8·0

The results of the analysis, as listed in Table 1 were defined by Dr. M. Krysowska in the following manner: „In the profile of loess strata, as well as in their substratum, assemblages of heavy minerals appear, though in different quantitative relations. The prevalence of zircon and the presence of very resistant minerals (garnet, zircon, tourmalin, rutile, staurolite) besides non-durable minerals (amphibole, epidote) are a characteristic feature of these associations. Heavy minerals from the substratum differ from the heavy minerals in loesses by a larger size of the grains. A lower content of amphibole and epidote in the substratum may be the result of weathering processes taking place in sediments under the influence of a periodical rise of the water level in ground waters. The uniformity of the qualitative composition of the assemblages of heavy minerals mentioned above suggests that these formations originate from the same source of detric material".

The last sentence concerning the analysis unequivocally expresses the opinion that the profile of Zator is composed of material with the same genesis. If, therefore, the stratum of loess-like clays contains eolian loess, it was also deposited during the sedimentation of peat muds situated below.

RADIOCARBON DATING OF WOOD FROM PEAT

A number of pieces of *Salix* wood were extracted from the layer of peat at a depth of 717—732 cm. They were sent to the Carbon-14 Dating Laboratory in Copenhagen where the age was evaluatęd as greater than 40 000 years B. P. (Tauber 1962, K-719).

Table 2

LIST OF MACROSCOPIC PLANT AND ANIMAL REMAINS

Abbreviations: c — calyx; w — wood; ep — ephippium; f — fruit; l — leaf; m — macrospore; o — oospore; s — seed; st — statoblast; v — valve of pod. Frequency of occurrence: +++ abundant; ++ frequent; + occasional

Tabela 2

Lista szczątków makroskopowych roślin i zwierząt

Skróty: c — kielich; w — drewno; ep — ephippium; f — owoc; l — liść; m — makrospora; o — oospora; s — nasienie; st — statoblast; v — klapa łuszczynki. Frekwencja: +++ — obficie; ++ — często; + — rzadko

Name of plant and animal remains Nazwy roślin i zwierząt	Type of remains Rodzaj szczątka	Depth in cm. Głębokość w cm									
		855—825	825—785	785—750	750—730	730—720	720—705	705—600	600—570	570—535	535—505
		Sample no. Numery prób									
		1—7	8—15	16—22	23—26	27—28	29—31	32—52	53—58	59—65	66—71
Alyssum sp.	v				1						
Armeria maritima	c				1						
Batrachium sp.	f	12	1	9	208	55					
Betula cf. *nana*	f				1						
Callitriche autumnalis	f				1						
Carex sp. div.	f	+	+	+	+++	++	++				
Cruciferae	s			15							
Gramineae	f	1		4	3						
Heleocharis palustris	f			2	11	1					

Hippuris vulgaris	f	1			1						
Myriophyllum sp.	f			1							
Potamogeton filiformis	f				81						
Potamogeton lucens	f				3	1	1				
Potamogeton sp.	f				6	2					
Potentilla sp.	f	1									
Ranunculus flammula	f	1				29		15	3		
Ranunculus sceleratus	f				12	2					
Salix herbacea	l				2						
Salix sp.	w				28						
Selaginella selaginoides	m		1								1
Sparganium minimum	f				1						
Stellaria media	s	1									
Viola sp.	s	1					2				
Calliergon Richardsoni	l				+++						
Drepanocladus revolvens	l				+++						
D. Sendtneri f. *aristinervis*	l				+++						
Mnium affine	l				+						
Characeae	o				2						
Bryozoa	st		1								
Daphnia	ep		2	11	35	2	122				
Insecta					+++	+++	+++	++	+	++	+

PALAEOBOTANY

MACROSCOPIC PLANT REMAINS

Fruits, seeds, leaves, pieces of wood etc. were found, in the first place, in the layer of peaty mud and in the peat itself. Ten samples of a volume of about 1 dcm^3 each were collected in the part of the profile under the loess and, besides this, a large amount of material from the peat stratum and the adjacent dark loam was investigated. The quantity of plant remains which could be determined was not great and their species composition was not much differentiated (Table 2). Plants attached to a distinctly wet environment prevailed. No remains of trees were found: as for shrubs, only small pieces of *Salix* wood (abundant in peat), leaves of *Salix herbacea* and one fruit of *Betula cf. nana* were collected (Fig. 3). Apart from plants from boggy habitats there is a marked lack of forms characteristic of larger sheets of water. Dry habitats elevated above the tundra

Table 3

QUANTITATIVE OCCURRENCE OF REBEDDED SPOROMORPHS

(Numerals outside brackets indicate No. of sample, those in brackets — quantity of sporomorphs in the sample)

Tabela 3

Bezwzględne ilości sporomorf na wtórnym złożu

(Liczby przed nawiasami oznaczają nr próby, w nawiasach — ilość sporomorf w próbie)

Abies	3(1); 7(1); 22(1); 23(1); 24(1); 26(1); 37(2); 38(2); 39(1); 40(1); 42(2); 43(2); 44(9); 45(3); 46(5); 47(3)
Sciadopitys	2(1); 20(1); 42(2); 43(3); 44(7); 45(1); 46(2)
Sequoia	38(1); 39(1); 42(1); 44(2); 46(1)
Taxodiaceae	2(4); 3(4); 4(1); 42(1); 45(1); 46(1)
Tsuga	2(1); 3(1); 17(1); 43(2); 44(2); 46(2); 47(3)
Araliaceae	41(1); 43(1); 46(1)
Carpinus	17(1); 28(1); 42(3); 44(2)
Carya	42(1); 43(3); 45(2)
Corylus	38(1); 40(1); 42(2); 43(4); 44(2); 45(1)
Fagus	23(1); 42(1); 43(1)
Ilex	37(1); 42(1); 43(1)
Juglandaceae	10(1); 44(1)
Myrica	40(1); 43(2); 45(1)
Myrtaceae	20(1); 41(1); 42(1); 46(1)
Pterocarya	42(5); 43(2); 44(6); 45(3); 46(3)
Symplocos	7(1); 8(2); 39(1)
Tilia	17(1); 39(1); 43(1); 45(2); 46(1); 47(1)
Ulmus	20(1); 40(1); 43(1)
Gleicheniaceae	44(1); 46(5); 47(1)
Sporae	2(3); 5(5); 4(1); 5(1); 6(3); 7(3); 13(2); 39(1); 46(11); 47(4)

are only represented by two plants — *Armeria maritima* and *Alyssum* sp. Remains of these plants, found only in single specimens, must have been carried by the wind from a relatively close neighbourhood.

The picture of the vegetation, reconstructed on the basis of determined macroscopic plant remains, would be a wet mossy tundra with a large participation of sedges and shrubby willows (*Salix herbacea*). The habitat of the determined aquatic plants (*Batrachium, Myriophyllum, Potamogeton, Sparganium minimum, Characeae*) was probably small and rather shallow tundra lakes (tarns). Their presence is also confirmed by the abundance of summer eggs (ephippium) of the *Daphnia* and the statoblasts of the *Bryozoa.*

Notes on some species

Alyssum sp. L. — A fragment of the valve of a pod with a characteristic anatomic structure originates from the peat stratum (cf. Środoń 1954, Table II, fig. 13). The Zator specimen is distinguished by a structure different from that of *Alyssum Arduini,* but it resembles that of *A. montanum.*

Armeria maritima (Mill.) Willd. — A calyx 4·5 mm long, with hairs distributed only on the ribs. In Poland, this species approaches the south-eastern limit of its geographical distribution (Pawłowski 1962, 1963).

Callitriche autumnalis L. em. Whlb. (Fig. 3). — At a level of 730—750 cm a broadly winged fruit 2·1 mm long (1·6 mm without the wing) was found. The trace of a connection with the remaining part of the fruit is narrow in the fossil specimen and this is a good feature for distinguishing this species from the *C. stagnalis* in question. Our other species have fruits

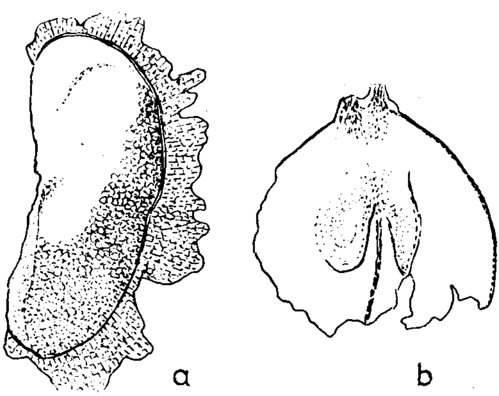

Fig. 3. a. *Callitriche autumnalis,* L. em. Whlb. fruit; b. *Betula* cf. *nana* L., fruit; × 24. Drawn by M. Łańcucka-Środoniowa

Fig. 3. a. *Callitriche autumnalis* L. em. Whlb. owoc; b. *Betula* cf. *nana* L. owoc; × 24. Rysowała M. Łańcucka-Środoniowa.

deprived of wings or are characterised by narrow ones (Pawłowski 1956, 1959). *Callitriche autumnalis* is a boreal species which in Scandinavia reaches 70° of northern latitude (Hultén 1950). This plant is rare in Poland and attains its southern limit in the northern part of the country, with insular stands in the district of Ostrów and near Częstochowa and Kraków (Pawłowski 1956, Fig. 5).

FOLLEN DIAGRAM[1]

Methodical remarks

All the samples, as well as those containing peat, were prepared for pollen analysis by the same method, in the following manner:

boiling with 40% HF for 5 to 8 minutes, washing with hot distilled water, pouring in of hot concentrated HCl (or heating), washing with hot distilled water (till neutralisation takes place), washing with CH_3COOH, acetolysis.

Unstained material was looked through in glycerine.

The pollen diagram (Fig. 5) has been divided into several parts. Part „A" illustrates the relation of the percentage participation of the pollen of trees (AP) to non-tree pollen (NAP), several curves for the pollen of trees derived from a shorter or longer transport distance and a curve of rebedded pollen. This part of the diagram is constructed on the basis of the sum of pollen grains from the following trees, shrubs and anemophilous herbs: *Pinus* t. *silvestris, P. cembra, Larix, Betula* t. *alba, Populus tremula, Juniperus, Ephedra distachya, Betula nana, Salix, Empetrum nigrum, Artemisia, Chenopodiaceae, Cyperaceae, Gramineae, Helianthemum, Plantago, Thalictrum.* The total amount of the pollen of trees is composed of the pollen grains of all the trees mentioned above, but the pollen grains of *Salix, Betula nana, Juniperus, Empetrum,* and *Ephedra* have been included in the sum of non-tree pollen (NAP). Part „B" contains the relation of the percentage of the pollen of shrubs (ShP) composed of: *Betula nana, Salix, Juniperus communis, Ephedra distachya,* and *Empetrum* to the non-tree pollen (NAP) mentioned in part „A". Part „C" presents curves for local plants, arranged in the succession of their appearance and domination in the profile. The percentage of insect pollinated plants, as well as of *Sphagnum* and *Pediastrum,* was calculated as the percentage from the basic sum of ShP + NAP. No spores of other mosses (except *Sphagnum*) were demonstrated in the diagram, although their appearance in the whole profile was abundant. To facilitate a reconstruction of the plant cover and in order to demonstrate the lack of forests in it, curves were drawn in part „D" representing the frequency of the tree pollen and the general frequency.

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[1] Chapter written by W. Koperowa.

R e b e d d e d p o l l e n a n d p o l l e n f r o m a l o n g - d i s t a n c e t r a n s p o r t

The rebedded pollen curve contains in the first place Tertiary forms (cf. Table 3). It also comprises species of trees common for the European Tertiary and Quaternary, whose pollen grains in the Zator deposit may also derive from a long-distance transport. Eolian transport of undoubtedly Tertiary pollen is the most probable in this case. This is proved by the increase in its share participation towards the upper part of the profile as the sediment becomes more and more loess-like and the plant cover less dense. Both moraines from the Cracovian glaciation and Tertiary sediments present around Zator in the bottom of Quaternary deposits could be the sources of Tertiary pollen. The pollen spectrum of the sample collected from a moraine exploited in the brickyard at Frydrychowice, (15 km to the south of Zator), is a proof of the first of these possibilities (Table 4).

Table 4

POLLEN SPECTRUM OF THE SAMPLE FROM THE MORAINE CLAY AT FRYDRYCHOWICE

Tabela 4

Spektrum pyłkowe próby gliny morenowej z Frydrychowic

Abies	1·3	*Caryophyllaceae*	0·1
Picea	0·3	*Chenopodiaceae*	0·1
Pinus t. *haploxylon*	0·4	*Cruciferae*	0·1
Pinus t. *silvestris*	28·6	*Cyperaceae*	6·7
Sequoia	0·7	*Epilobium*	0·1
Taxodiaceae	5·9	*Equisetum*	0·9
Tsuga	0·8	*Ericaceae*	0·1
Alnus	4·9	*Filipendula*	0·8
Betula t. *alba*	8·4	*Gramineae*	9·3
Buxaceae	0·1	*Helianthemum*	0·1
Carpinus	0·4	*Nymphaea*	0·1
Carya	2·1	*Papilionaceae*	0·3
Cyrillaceae	0·1	*Pirolaceae*	0·1
Fagus	0·8	*Potamogeton*	0·3
Ilex	0·3	*Ranunculaceae*	0·8
Juglandaceae	0·4	*Rosaceae*	0·1
Myrtaceae	0·6	*Sparganium*	0·1
Nyssa	2·7	*Thalictrum*	0·5
Pterocarya	1·7	*Typha angustifolia*	1·1
Quercus	0·6	*Umbelliferae*	0·2
Sorbus	0·2	*Gleicheniaceae*	1·4
Symplocos	0·4	*Mohria*	0·3
Tilia	0·4	*Osmunda*	0·2
Ulmus	0·6	*Polypodium*	0·3
		Polypodiaceae	3·1
Alisma	0·6	pre-Tertiary spores	1·4
Artemisia	0·6	*Varia*	4·8

The question what percentage of pollen grains in the curves for *Pinus* t. *silvestris*, *P. cembra*, *Betula alba*, *Alnus*, and *Picea excelsa* derives from moraine and what percentage derives from transport remains open.

Remarks on some plants

Betula sp. An attempt was made to separate *Betula nana* pollen from that of tree-birches on the basis of diagnostic criteria presented by Jentys-Szaferowa (1928), Terasmäe (1951) and Pragłowski (1962). In the diagram the curve for *Betula nana* pollen illustrates the results.

Table 5

SIZE-MEASUREMENTS OF FOSSIL-POLLEN GRAINS OF *BETULA* FROM ZATOR

Tabela 5

Wyniki pomiarów wielkości pyłku kopalnego *Betula* z Zatora

No of samples	Number of measurements	Mean in microns
19	100	21·38
21	100	22·96
27	100	21·29
30	100	21·03

Moreover, measurements of the *Betula* pollen in four levels of the investigated sediment were carried out (Table 5, fig. 4). Recent pollen grains of four species of birches were also measured for control purposes, by means of the method of maceration, as for fossil material.

Table 6

SIZE MEASUREMENTS OF RECENT POLLEN GRAINS OF SOME *BETULA* SPECIES

Tabela 6

Wyniki pomiarów wielkości pyłku współczesnego kilku gatunków *Betula*

Authors	Preparation method	Mean size in μ			
		B. verrucosa	*B. tortuosa*	*B. carpatica*	*B. nana*
Jentys--Szaferowa (1928)	boiling with KOH H_2SO_4 conc.	21·44 21·71			18·41 18·84
Eneroth (1951)	boiling with KOH (for 2 hours)	22·1	26·1		19·4
Salmi (1962)	acetolysis	27—28			23·0
Measurements made by the author	boiling with HF, heating with HCl, acetolysis	25·08	27·06	26.3	20·63

Table 7

Tabela 7

Quantitative occurrence of sporomorphs in the profile of Zator

Bezwzględne ilości sporomorf w profilu z Zatora

No Sample	Pinus t. haploxylon	Pinus t. silvestris	Betula t. alba	Populus tremula	Betula nana	Ephedra distachya	Juniperus communis	Salix	Picea	Alnus	Aconitum Delphinium	Allium	Armeria vulgaris	Artemisia	Batrachium	Campanulaceae
1.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
3.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	1
5.	23	25	4	-	2	-	-	1	-	-	-	-	-	1	2	-
6.	44	69	43	-	11	-	-	11	1	1	-	-	1	21	23	-
7.	38	32	44	-	11	-	-	14	1	-	-	-	2	25	11	-
8.	16	8	128	-	31	-	1	10	-	-	-	-	2	11	12	-
9.	25	53	82	-	14	-	1	27	-	-	-	1	3	13	24	1
10.	36	35	98	-	33	-	1	40	1	1	-	-	2	9	19	2
11.	21	42	166	-	31	-	-	22	-	1	-	-	-	21	42	-
12.	5	21	29	-	3	-	-	5	-	-	-	-	-	2	4	-
13.	32	92	113	3	25	-	1	13	-	-	-	1	1	14	33	1
14.	37	73	167	-	29	2	3	21	-	3	1	1	2	12	20	1
15.	43	190	190	1	51	-	2	33	5	2	-	-	1	30	13	2
16.	25	106	127	-	35	1	3	13	2	2	-	-	4	20	9	-
17.	46	167	133	3	62	2	-	11	-	1	3	-	-	37	7	-
18.	14	176	175	-	68	1	5	6	4	3	1	-	2	29	3	1
19.	25	137	210	3	61	1	-	19	2	2	-	1	1	18	5	-
20.	20	167	152	1	92	-	3	17	2	3	-	-	1	17	8	-
21.	26	200	212	1	70	-	2	13	1	2	-	-	-	20	6	-
22.	11	127	202	1	89	2	2	14	3	5	-	-	1	14	5	1
23.	23	131	135	-	143	1	1	15	1	1	1	1	-	18	4	-
24.	14	100	113	-	74	1	-	32	1	2	-	1	-	27	6	1
25.	12	44	85	-	9	-	-	16	-	1	-	1	-	33	-	-
26.	11	44	38	-	10	1	-	27	-	2	-	-	-	87	-	-
27.	8	96	66	1	66	-	-	10	1	4	1	-	-	22	1	1
28.	20	138	102	3	200	-	3	24	1	3	3	-	-	41	5	-
29.	5	70	129	-	133	-	-	32	-	2	1	-	-	24	2	1
30.	20	131	125	5	182	1	3	22	2	1	-	1	-	36	4	1
31.	7	114	97	3	116	-	1	10	1	2	-	-	-	24	6	2
32.	21	134	115	1	105	-	1	14	1	1	-	-	-	26	5	-
33.	10	107	120	3	154	-	1	15	2	4	1	-	-	28	4	-
34.	16	153	83	2	117	1	-	14	3	-	1	1	1	26	5	1
35.	20	128	83	3	154	-	3	30	3	1	1	-	1	30	3	-
36.	11	114	81	4	110	-	-	10	4	4	-	1	1	30	2	1
37.	13	100	27	2	19	-	-	3	3	2	1	-	-	35	4	-
38.	9	97	26	-	23	-	-	6	5	9	-	-	-	30	1	-
39.	16	90	20	-	58	-	-	3	3	10	-	-	-	25	2	-
40.	8	60	16	1	39	-	-	8	4	11	-	1	-	22	2	-
41.	10	91	24	-	20	-	-	7	3	9	-	1	-	16	5	-
42.	9	100	13	-	7	-	-	6	1	9	-	-	-	12	1	-
43.	17	161	53	-	11	-	-	13	5	14	-	-	-	13	-	-
44.	14	238	14	-	1	-	-	1	6	8	-	-	-	1	-	-
45.	4	47	6	-	1	-	-	-	3	2	-	-	-	2	-	-
46.	3	48	12	1	-	-	-	1	5	6	-	-	-	1	3	-
47.	3	35	4	-	-	-	-	-	2	3	-	-	-	-	2	-

No Sample	Caryophyllaceae	t. Dianthus	t. Gypsophila	Melandrium	Caryophyllaceae t. Minuartia	Chenopodiaceae	Compositae Liguliflorae	Compositae Tubiflorae	cf. Cirsium	Cruciferae	Cyperaceae	Empetrum nigrum	Epilobium	Filipendula	Gentiana	Geranium
1.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
3.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.	-	-	-	-	-	-	-	7	-	1	7	-	-	-	-	-
6.	-	-	-	-	-	-	-	53	-	2	38	-	-	-	4	2
7.	5	-	-	-	-	2	-	63	5	10	29	-	6	-	-	4
8.	6	-	-	-	-	4	-	28	-	11	23	-	1	-	-	1
9.	5	-	-	1	2	1	1	55	-	17	46	-	3	-	-	4
10.	7	-	-	-	1	6	4	21	-	29	140	-	1	-	1	3
11.	1	-	-	-	6	2	1	69	-	19	89	-	-	-	-	1
12.	4	-	-	-	-	1	-	5	-	5	21	-	-	-	-	-
13.	14	-	-	-	-	7	2	59	-	24	167	2	2	1	1	2
14.	9	-	-	-	5	6	2	50	-	29	109	-	2	2	-	2
15.	6	-	-	-	1	8	4	26	-	16	311	-	2	1	-	3
16.	7	-	-	-	-	4	2	31	-	10	139	1	1	1	-	-
17.	4	-	-	-	3	16	2	17	-	12	191	2	1	2	-	2
18.	2	3	-	-	-	3	1	15	-	8	94	-	1	-	4	-
19.	4	-	-	-	-	8	1	7	-	9	362	1	-	1	-	-
20.	1	1	-	-	1	15	-	23	-	9	291	-	-	4	3	-
21.	8	-	-	-	-	11	1	21	-	15	287	-	1	4	-	-
22.	-	-	-	-	5	6	-	3	-	18	421	-	-	3	4	-
23.	2	-	-	-	-	9	-	7	-	17	435	-	-	4	1	-
24.	-	2	-	-	1	6	1	5	-	15	294	1	-	1	3	-
25.	5	-	1	-	-	9	1	4	-	81	492	-	-	-	-	-
26.	2	-	-	-	-	21	-	2	-	89	786	-	-	1	-	-
27.	-	4	-	-	1	12	-	4	-	20	392	-	-	1	-	-
28.	5	-	1	-	1	8	3	10	-	18	289	1	-	-	-	-
29.	-	-	-	-	3	17	-	1	-	36	599	-	1	1	-	-
30.	4	-	-	-	-	5	2	16	-	16	244	1	1	-	-	-
31.	1	1	-	-	4	4	-	8	-	21	209	-	-	-	-	-
32.	3	-	8	1	5	7	1	10	-	14	264	-	-	-	1	-
33.	2	1	-	3	1	3	-	11	-	10	212	-	1	2	-	-
34.	8	-	-	2	3	4	-	9	2	13	244	-	1	1	-	-
35.	5	2	-	-	1	6	1	5	-	16	303	2	-	-	-	-
36.	7	1	-	-	2	9	1	2	1	25	262	1	1	4	-	-
37.	34	-	-	-	7	7	-	1	-	37	371	-	-	2	1	-
38.	1	-	3	1	1	17	-	4	-	31	390	-	-	1	1	-
39.	10	-	-	-	4	12	-	4	-	23	505	1	-	-	-	-
40.	4	-	-	1	1	12	-	3	-	28	506	1	-	5	-	-
41.	7	-	-	-	2	8	1	3	-	17	454	-	-	1	-	-
42.	9	-	-	2	-	3	-	-	-	9	967	-	-	-	-	-
43.	1	-	-	-	-	9	-	1	-	7	512	-	-	2	-	-
44.	7	-	-	-	1	-	-	-	-	1	156	-	-	-	-	-
45.	8	-	-	-	-	-	-	-	-	3	68	2	-	-	-	-
46.	315	-	5	-	6	-	-	1	-	5	214	-	-	-	-	-
47.	4	-	-	-	-	2	-	-	-	1	16	-	-	-	-	-

No Sample	Gramineae	Helianthemum	Koenigia islandica	Labiatae	Liliaceae	Myriophyllum	Oxyria digyna	Plantago media-maior	Polemonium	Polygonum bistorta	Polygonum viviparum	Potamogeton	Pyrolaceae	Ranunculaceae	Rosaceae t. Comarum	Rosaceae t. Geum
1.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.	4	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-
3.	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.	20	-	-	1	-	-	-	-	1	-	73	-	-	7	-	-
6.	225	8	-	2	-	-	2	1	15	-	275	-	-	4	-	-
7.	344	12	-	8	-	-	2	-	11	2	209	-	-	7	-	-
8.	615	1	-	10	-	-	-	-	3	4	20	-	-	19	1	1
9.	715	1	1	5	-	-	2	-	13	-	35	1	-	7	1	2
10.	1034	-	1	7	-	1	-	1	8	-	43	8	-	14	1	3
11.	704	-	-	6	-	1	-	1	8	-	85	4	-	10	1	3
12.	100	-	-	-	-	-	-	-	3	-	19	2	-	-	-	1
13.	822	-	1	10	-	1	-	1	6	1	108	1	-	20	-	1
14.	755	-	-	8	1	1	-	2	2	-	72	3	-	25	1	2
15.	582	2	-	2	-	1	-	3	5	1	31	9	-	17	-	-
16.	542	1	2	2	-	-	-	2	9	-	61	4	-	13	-	-
17.	303	-	-	1	-	-	-	3	3	-	23	-	-	13	-	-
18.	261	1	-	-	1	-	-	5	1	-	59	2	-	9	-	-
19.	391	8	2	-	1	1	-	-	1	2	12	5	-	9	1	-
20.	525	3	-	-	-	-	-	-	3	-	21	-	-	10	-	-
21.	311	7	1	-	-	1	-	-	1	-	18	5	-	10	2	-
22.	389	1	-	1	-	-	-	-	2	1	4	2	-	10	-	-
23.	250	2	1	-	1	1	-	-	1	-	5	5	-	22	5	-
24.	373	-	-	-	-	1	-	2	-	1	2	3	-	19	1	1
25.	480	1	-	-	-	-	-	-	-	-	-	2	-	24	-	1
26.	525	6	-	-	-	-	-	1	-	-	-	1	1	11	-	-
27.	332	1	-	-	1	-	-	1	2	-	1	2	1	9	-	-
28.	490	3	-	-	2	1	-	5	2	-	14	4	-	15	1	-
29.	510	2	-	2	-	-	-	-	1	-	3	1	-	36	-	-
30.	416	1	-	-	1	2	-	2	1	-	12	2	-	8	3	-
31.	378	3	-	1	-	-	-	1	1	-	8	5	-	11	1	-
32.	403	3	-	1	1	1	-	-	-	1	7	8	1	22	-	-
33.	462	3	-	2	-	-	-	1	2	-	5	1	-	23	1	-
34.	412	2	1	1	-	-	-	5	-	1	6	4	-	9	2	-
35.	454	3	-	-	-	-	-	-	2	-	9	6	-	29	1	-
36.	500	2	-	3	-	1	-	2	-	-	6	6	-	10	2	-
37.	416	6	-	-	-	-	-	1	1	1	2	3	-	7	-	-
38.	383	8	-	1	-	-	-	-	1	-	1	1	1	-	-	-
39.	535	4	-	-	-	-	-	3	-	-	-	2	-	9	-	-
40.	387	3	-	1	-	-	-	-	1	2	-	4	1	11	4	1
41.	350	3	-	-	-	-	-	1	1	-	1	3	-	3	1	-
42.	130	1	-	-	-	-	-	1	-	-	1	-	1	-	1	-
43.	271	-	-	-	-	-	-	-	-	-	-	7	-	3	1	-
44.	63	3	-	-	-	-	-	-	1	-	-	-	-	2	-	-
45.	42	1	-	-	-	-	-	3	-	-	-	-	-	-	-	-
46.	260	2	-	1	-	-	-	2	1	-	5	4	2	28	-	1
47.	15	1	-	-	-	1	-	-	-	-	1	-	-	1	-	-

No Sample	Rubiaceae	Saxifraga	Saxifraga stellaris	Thalictrum	Umbelliferae	Valeriana officinalis	Veratrum	Botrychium	Equisetum	Polypodiaceae	Selaginella selaginoides	Varia	Sphagnum	Pediastrum
1.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.	-	3	-	-	-	-	-	-	1	1	-	1	-	-
6.	-	3	-	1	-	-	-	-	14	-	-	6	-	-
7.	-	3	2	-	-	1	-	3	43	-	-	8	1	-
8.	-	17	1	4	-	-	2	-	9	1	-	8	-	-
9.	-	12	-	8	-	1	1	3	13	-	-	7	5	-
10.	3	21	2	12	1	3	1	2	7	2	-	10	4	6
11.	1	17	-	4	4	1	2	2	17	1	-	3	2	1
12.	-	1	-	-	-	-	-	-	-	-	-	-	-	-
13.	2	14	-	6	3	2	-	5	20	3	-	9	7	-
14.	6	15	-	8	2	1	3	9	22	-	-	8	3	3
15.	3	7	-	15	4	1	-	10	18	2	2	7	32	29
16.	3	13	-	11	2	4	-	6	12	1	-	9	14	6
17.	1	5	1	14	2	3	-	5	12	-	2	7	26	7
18.	-	-	-	6	3	-	-	9	12	1	-	3	41	10
19.	3	2	1	17	2	-	-	3	15	2	1	7	35	18
20.	-	-	-	6	1	-	-	2	12	2	-	3	42	3
21.	1	2	-	9	5	1	-	4	18	-	-	6	35	2
22.	2	2	-	11	1	1	-	1	12	2	-	5	19	19
23.	1	1	-	17	2	-	-	-	19	-	-	5	22	40
24.	1	1	-	7	1	-	-	-	8	1	-	2	9	35
25.	-	1	-	20	4	-	-	-	4	-	1	6	-	-
26.	2	1	-	27	-	-	4	-	34	-	-	13	-	-
27.	-	3	-	10	1	-	-	2	10	1	1	4	4	3
28.	1	3	-	16	3	-	-	-	20	1	1	5	12	1
29.	4	2	-	13	2	-	-	-	6	1	-	5	3	2
30.	1	7	1	10	2	-	-	2	16	-	1	8	6	1
31.	3	2	-	10	1	1	-	-	16	-	-	4	6	6
32.	-	3	-	18	1	1	-	-	13	-	--	7	9	23
33.	1	2	-	14	2	1	-	-	11	-	-	7	5	23
34.	1	1	-	12	1	1	-	1	13	-	-	6	13	45
35.	-	1	-	17	2	-	1	-	18	-	-	3	12	43
36.	1	1	-	23	-	-	1	-	32	-	-	4	5	40
37.	1	2	-	12	2	-	-	-	10	-	-	4	3	1
38.	3	2	-	9	1	-	-	1	14	3	-	4	-	11
39.	-	3	-	20	2	-	-	1	21	2	-	9	4	21
40.	-	2	-	13	-	-	-	2	12	2	2	-	2	20
41.	-	-	-	11	-	-	1	-	20	1	-	7	6	28
42.	1	-	-	6	-	-	-	1	4	3	-	7	2	12
43.	2	-	-	3	1	-	-	7	5	6	-	12	9	12
44.	-	-	-	1	-	-	-	4	20	17	-	11	1	17
45.	-	-	-	5	-	-	-	2	2	7	-	2	1	-
46.	-	-	-	-	-	-	-	13	7	72	-	12	5	9
47.	-	-	-	-	-	-	-	1	-	10	-	5	-	-

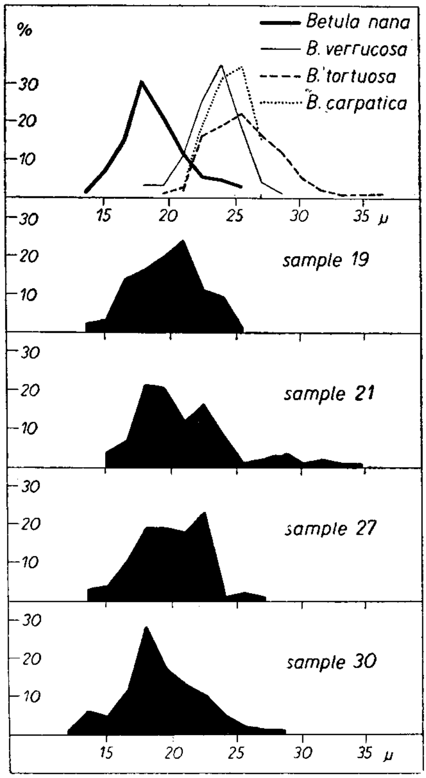

Fig. 4. Size-frequency distribution in recent and fossil *Betula* pollen
Fig. 4. Wyniki pomiarów wielkości pyłku współczesnego i kopalnego brzozy

The conclusion may be drawn from the variability curves and from mean values calculated for fossil material that both grains belonging to *Betula nana* and those of *Betula* t. *alba* are present in the Zator sediment, while the highest percentage of tree-birch pollen falls to sample 21. Although the variability curves differ from those based on morphological features, they confirm the fact of the simultaneous presence of the two types of birch. If we take into consideration the possibility of the appearance of *Betula humilis* pollen, which does not differ in size from the pollen grains of *Betula* t. *alba,* as well as the frequency curve for tree pollen and the limited possibility of spreading of the pollen of tree-birches which is only capable in 5 per cent of cases of covering a distance of more than 400 m and falls most abundantly in the direct neighbourhood of the mother trees (S a l m i 1962) — we must admit that in the pollen rain in the investigated area the pollen of *Betula nana* prevailed.

Pinus sp. Two types of *Pinus* pollen were distinguished — that of *Pinus* t. *silvestris* and of *Pinus* t. *haploxylon,* corresponding in our case to *P. cembra.* This second type, with the exception of two grains characteristic for the Tertiary, was absent in the spectrum of boulder clay and derives, therefore, from transport. In the diagram from Zator the *Pinus* t. *silvestris* curve fluctuates between 10 and 20 per cent, rarely falling below 10 per cent. Stomata of *Pinus* were found on two levels, but the whole participation of pollen of this tree derives most probably from not very distant localities in the Carpathians.

Polystichum lonchitis (L.) Roth. In two samples (13 and 22) spores with shreds of preserved exosporium were found. *Polystichum lonchitis* is an arctic-alpine circumpolar species, with its main centres of distribution in Scandinavian and in central and southern European mountains. In Poland, besides not very numerous stands in the Sudetic Mountains, it is widespread in the Carpathians and in the Tatra Mountains where it reaches an altitude of 2040 m (Pawłowski 1956). In the Tatras it is found in rocky places, in the upper forest belt (*Piceetum tatricum*) and in the belt of dwarf mountain pine (Pawłowski l. c.). In the Arctic it chooses quiet and sheltered places with a southern exposure (Arwidsson 1943; Polunin 1959).

Lycopodium annotinum L. A sub-arctic, boreal-alpine species. Seldom found in Poland on lowlands, frequent in the Carpathians where it is a species characteristic for the *Piceetum tatricum* (Pawłowski 1956). It also occupies poor and peaty soils, and in the Subarctic settles on heaths together with shrubby willows (Benum 1958).

Lycopodium selago L. An arctic-boreal and circumpolar species. Seldom found in Polish lowland, common in the Carpathians, and in the Tatras up to 2580 m. It most frequently chooses habitats in high mountain meadows, damp gravels, and grassy slopes near late lying patches of snow (Pawłowski l. c.).

Selaginella selaginoides (L.) Lk. An arctic-alpine and circumpolar species, with numerous fossil localities in Poland (Środoń 1961) and in central Europe (Tralau 1961). In Poland *Selaginella selaginoides* grows frequently in the Sudetic Mountains, in the Carpathians, and in the Tatras, where it reaches an altitude of 2154 m (Pawłowski 1956). It settles on damp, sandy and loamy, rocky soils, mostly calcareous. In Arctic regions it grows on damp meadows, along the borders of peat bogs, lakes and rivers, together with shrubby willows and on dry and stony slopes watered by frequent rainfall (Benum 1958; Polunin 1959).

Polygonum viviparum L. A plant with an arctic-alpine and circumpolar distribution, abundant in the Zator profile. In Poland, it grows in the Tatras and the West Carpathians and it has been found recently in the Gorce (Kornaś 1963) and in the Bieszczady Mountains (Jasiewicz, Zarzycki 1960). It grows most frequently above the timber line, up to an altitude of 2490 m (Pawłowski 1956). The species is indifferent to the origin and acidity of the soil, but avoids extremely dry or very damp localities near late lying snow patches. It is one of the first plants to occupy new terrains from which glaciers have retreated

(P a l m e r, M i l l e r 1961). It is the first to enter on solifluction soils and newly formed polygons which it occupies rapidly and fixes owing to its ability of apomictic reproduction which permits the building of extensive colonies in a short time (W i l l i n g s 1959; B l i s s 1962).

Oxyria digyna (L.) Hill. An arctic and alpine, circumpolar species. As common as the *Polygonum viviparum* in the Arctic, where it reaches 83°39' (S ø r e n s e n 1933). It grows in the Western Carpathians and the Tatras, up to an altitude of 2540 m (P a w ł o w s k i 1956). It occupies stands on damp and stony soil, in the neighbourhood of snow patches lying around lakes, along rivers and streams, often on an unstable substratum subjected to erosion (C h u r c h i l l, H a n s o n 1958).

Sanguisorba officinalis L. Only two pollen grains of this plant were found. It has a partly circumpolar distribution. It grows in Poland both on lowlands and mountains. It is seen in the Tatras on grassy damp slopes reaching a height of 1000 m (P a w ł o w s k i 1956). It settles on the tundra only in damp habitats (P o l u n i n 1959; S c h a e f e r, F r e n z e l 1959). The investigations of N o r d b o r g (1963) demonstrated that *Sanguisorba officinalis* appears in Sweden in two cytoforms, tetra- and octoploidal. This author supposes that the octoploidal forms are limited in their distribution to the eastern and the tetraploidal ones to the western parts of Europe. They can be distinguished by different ecological requirements and by the size of the pollen. The tetraploid has grains with a dimension of 23 μ to 26 μ (25 μ on the average) and the octoploid of 28 μ to 31 μ (average 30 μ). The tetraploidal form grows on heaths with a calcareous substratum and with a thin, often dried, layer of soil, together with *Linum catharticum, Centaurea jacea,* and others. Octoploids are characterised by a greater requirement of light and they settle mostly in uniformly damp localities, not necessarily calceous, together with *Filipendula ulmaria, Polygonum viviparum,* and others. In the Zator material no pollen measurements of this species were carried out but, judging from the ecological requirements of both differentiated forms, as stated by N o r d b o r g, it may be assumed that the octoploidal form appeared here.

Saxifraga stellaris L. This arctic-alpine and amphiatlantic form, appearing in the mountains of central and southern Europe, does not grow in the Northern Carpathians nor in the Tatras at present. The localities nearest to Poland are in the Eastern Carpathians. *Saxifraga stellaris* occupies damp stands (near the sources) and is apt to grow where the snow lies late and on meso- and oligotrophic peat bogs.

C h a r a c t e r i s t i c s o f v e g e t a t i o n

Taking into consideration the course of curves for pollen and its frequency, the Zator diagram can be divided into three zones. The first zone, up to sample 8, comprises the first pioneer phase of vegetation settlement. The second zone, to sample 42, represents the phase of optimal development of the vegetation cover. The third zone is a phase of advancing destruction and of the burying of the vegetative cover with loess-like clays.

The four bottom samples from the stratum resting upon sand and gravel contain insignificant amounts of pollen (frequency of 0·9 cm^2) with an admixture of rebedded Tertiary pollen. The sediment from which these samples derive was probably formed in the first stage of river accumulation which coincided with change from a cool climate to a drier one with some arctic features. The new climatic conditions provoked intensive solifluction. On newly formed soils, soaked with water and displaced by solifluction, plants of the pioneer type appeared in the first place, among which *Polygonum viviparum*, *Oxyria digyna*, *Saxifraga stellaris*, and others played at first a considerable role. This vegetation also contained species of the *Saxifraga*, *Equisetum*, and *Salix* genera and plants belonging to the families of *Ranunculaceae*, *Caryophyllaceae*, *Compositae Tubiflorae*, *Cyperaceae*, and *Gramineae*.

Besides plants typical of a wet tundra we have in the pollen diagram species requiring higher temperatures of the air and dry, well drained mineral soils. They could grow on slopes of the Carpathians not very distant from Zator, and especially on the flysch rocks left in the sub-Carpathian region (cf. fig. 1). *Armeria vulgaris*, *Artemisia*, *Helianthemum*, *Geranium*, *Veratrum album*, and the *Chenopodiaceae* belong to this type of plant. At present the above-mentioned taxons are a rarity in the western Arctic, or they are entirely absent (*Helianthemum*), but they are widespread in the arctic regions of eastern Europe and of Asiatic Russia (Hultén 1937; Polunin 1959; Schaefer, Frenzel 1959).

The vegetation cover in these initial stages of development was still loose, only becoming dense later on (samples 8 to 42), when peat loams and peat were formed. This second phase is characterised by a lack of any great successive changes, undoubtedly obliterated in a great measure by processes of solifluction. During this optimal period the vegetation cover was more differentiated. In the depressions of the terrain shallow and small tundra lakes (tarns) were formed. Remains of fairly numerous aquatic and bog plants, such as the *Characeae*, *Alisma plantago-aquatica*, *Batrachium* sp., *Callitriche autumnalis*, *Heleocharis palustris*, *Hippuris vulgaris*, *Myriophyllum* sp., *Potamogeton filiformis* and *P. lucens*, *Ranunculus flammula* and *R. sceleratus*, *Sparganium minimum*, and probably others, are a proof of their existence. The tarns were surrounded by moss-grown areas on which the following mosses grew: *Calliergon Richardsoni*, *Drepanocladus revolvens*, *D. Sendtneri* f. *aristinervis*, and *Sphagnum* sp. Among higher plants *Cyperaceae* and *Gramineae* were common here. On moss-bogs at Zator *Koenigia islandica* grew, far beyond its present area (Koperowa 1962). On better drained soils *Polygonum bi-*

storta, Heleocharis palustris, Allium sp., *Thalictrum* sp., *Geum* sp., *Sanguisorba officinalis,* and others settled. Willows, mostly *S. herbacea,* and *Betula nana* could also find here convenient habitats. On especially favourable and well drained soils *Juniperus* sp. grew and in its neighbourhood plants of „steppe" character, among which appeared *Alyssum* sp., *Linum* sp., *Centaurea cyanus,* and perhaps also *Ephedra distachya,* which in those times may have begun its migration from the east which ended here in the Late-glacial period. Extensive moss-bogs and in them small tundra lakes with abundant aquatic and marsh vegetation, and small elevations with the habitats of plants rather exacting as to soil and temperature — these are the principal elements of the landscape of the sub-Carpathian tundra in the period preceding the drier part of the Pleniglacial, characterised by an intensive accumulation of loess-like clays.

Among the macroscopic material of plants extracted from the sediment at Zator no remains of trees were found. In the pollen diagram the relation AP/NAP indicates distinctly open areas without even patches of forest. However, in the diagram pollen grains of *Pinus* t. *silvestris, P. cembra, Larix* sp., *Picea* sp., *Betula* t. *alba, Alnus* sp., and *Populus* cf. *tremula* are present, even in fairly large quantities. It cannot be excluded (as mentioned previously) that the pollen grains of these trees are partly rebedded, especially in the upper parts of the profile where the share of exotic pollen is quite considerable. In the main, however, the pollen of the trees in question probably came from not very distant localities in the lower parts of the Carpathians. In sheltered valleys and on slopes exposed to the south small patches of forest may have grown at that time. This interpretation is supported by the results of investigations carried out at Wadowice which is situated 15 km to the south right on the Carpathian edge (Sobolewska, Starkel, Środoń 1964). In this locality, in the Brørup interstadial sediment which, as we know, preceded the period studied at Zator, grew profuselly all the previously mentioned trees.

The upper part of the pollen diagram is considerably disturbed. Rebedded pollen and that from long distant transport frequently prevails in the spectra, deforming their composition and preventing a correct interpretation.

Climate

The lower part of the profile containing peat loams was considered as belonging to Pleniglacial A, bordering, as we know, with the Brørup Interstadial. Assuming that the stratigraphic position of these loams is correct, the question arises of how long was the period from the decline of the Interstadial to the moment when the Pleniglacial loams began to deposit. If the composition of the forest vegetation of the Brørup Interstadial, investigated at the Wadowice locality, and the picture of the

Zator tundra with no forest at all are considered, the conclusion is that this interval must have been rather long.

Parallelisation of the climatic conditions during the accumulation of sediments in Zator with the present climatic regime of tundra areas meets with difficulties resulting from a different rhythm of day and night, a dissimilar insolation, and the direct vicinity of the great oceans.

On the basis of the list of plants presented, only general conclusions can be drawn as to the climate of that period. The presence of *Polystichum lonchitis* and *Lycopodium annotinum,* plants characteristic now of the Carpathian association of *Piceetum tatricum* (Pawłowski 1956), seems to indicate that the climate of Pleniglacial A was not very severe and rather wet. It is possible that both these species in the composition of the Zator tundra are remains of the spruce forests which existed here during the Brørup Interstadial. Some other plants found in Zator, i. e. *Alisma plantago-aquatica, Filipendula ulmaria, Frangula alnus, Pleurospermum austriacum,* and *Sanguisorba officinalis* have also high thermal requirements. It might be that a certain improvement in the climate occurred during the sedimentation of the layer of peat. This was manifested in the stopping of solifluction-processes and greater production of the organic mass. Above the peat layer the participation of loess increased in the profile and the climate became successively drier with arctic and continental features. Finally the thick layer of loess-like clays covered the loams containing tundra vegetation.

REMAINS OF MAMMALS

Three mammoth teeth (two tusks and one molar) were derived from a peat loam stratum present at a depth of 703—825 cm, as well as a small fragment of bone about which Mr. U. Møhl, custodian in Copenhagen, writes.

The molar tooth was determined by Dr. H. Kubiak (Institute of Systematic Zoology of the Polish Academy of Sciences in Kraków) as belonging to the *Mammonteus primigenius* (Blumenbach). The description given by Kubiak is as follows: "M^3 (third molar) strongly abrased. The teeth laminae very dense, which indicates an undoubted appurtenance to this species. The density of the laminae, 9•5 for 10 cm, is typical for a mammoth. The thickness of the enamel is 2·2 mm".

Both the mammoth tusks found in Zator have the ends broken off. Their length, measured along the external arc, and the maximum diameters are as follows: I — 76 cm × 9·5 cm; II — 67 cm × 9·5 cm.

The bone fragment from Zator was described by Dr. U. Møhl (Kvartaerzoologisk Lab. Zoo. Museum, København, Denmark):

"At the excavation at Zator — in the layer of the tundra vegetation which, according to Tauber (1962) is older than 40 000 years B. P. — a fragmented piece of bone was found, which is not easily identified (Pl. III f, g).

This bone fragment has a length of 13·5 cm; it has been broken off at both ends and is slightly conical lengthways, the greatest diameter being 27 mm. In cross-section the one long side appears practically level while the opposite side is curved. It is obvious that the whole interior of the bone fragment consists of spongy tissue while the surface shows a marked pattern of cracks caused, no doubt, by the drying-up process; there is also on one side a deep crack, cutting almost through. The surface is thus rather damaged while the form and the interior structure seem intact.

These facts combine to suggest two possibilities: either that the piece is a fragment from an antler or a piece of one of the front ribs of a large mammal, such as a deer or an ox or an even bigger animal.

It can be said that neither the form nor the surface of the fragment give a certain clue to a distinction between the above mentioned possibilities. A cross-section at one end of the piece from Zator was therefore made and, for comparison, I made cross-sections of different antlers, chiefly of reindeer *(Rangifer tarandus),* but also of fallow deer *(Dama dama)*, elk (*Alces alces*) and red deer (*Cervus elaphus*). Likewise cross-sections were made from ribs of the domestic ox *(Bos t. domest.),* the aurochs *(Bos primigenius)* as well as of the horse *(Equus caballus),* and the red deer *(Cervus elaphus).* Some of these cross-sections are shown in Pl. III.

Generally it is characteristic in cross-sections of antlers that the inner spongy tissue and the size of its pores have a more even transition into the hard layer and that the spongy tissue is built up of smaller, but more circular pores (Pl. III b). In the cross-sections of the ribs these cavities are larger, more elongated, and unevenly formed, the transition to the outer hard wall is more abrupt, without graduation in the size of the pores. Stray pores can, however, be found here and there in the outer layer, as in Pl. III c.

In view of these characteristics the fragment from Zator seems to be somewhere in between. The pores are larger and more unevenly formed than in the cross-section of the antler (Pl. III b), but considerably smaller than in the ribs. In the transition between the spongy tissue and the outer hard wall there seems to be a greater resemblance to a rib. The thickness of the wall of a rib increases somewhat with the age of the animal, and in some cases more or less circular growth-rings in the outer hard wall can be observed. In antlers — having only one short period of growth, with subsequent yearly shedding of the antlers — such growth-rings are never found. The fragment from Zator shows none.

There can thus be shown both pros & cons, and the cross-sections and samples at hand do not give sufficient evidence for a certain determination.

The fragment from Zator is presumed to belong to the above-mentioned tundra period, and it would be most natural to consider it a piece of a reindeer antler. The form seems to correspond very well with this, and it is very prevalent in this species but very difficult to find in antlers of other species of deer. However, as mentioned above, the cross-section does not give a certain determination in this direction.

Should the fragment be of a rib, there would be more alternatives and it would be more difficult to determine. Animals like steppe bison (*Bison priscus*), musk-ox (*Ovibos moschatus*), wild horse (*Equus caballus ferus*), and other large mammals belonging to the fauna of the tundra might then come into consideration. Teeth of mammoth (*Mammuthus primigenius*) were also found in these layers".

The remains of large mammals were many times noted in Pleistocene sediments in localities situated in the vicinity of Zator. They were found in the brickyards of Bachowice and Przeciszów, where the exploited sediments are of the same age as those in Zator. In the brickyard of Dziedzice, situated 35 km to the SW of Zator, Konior (1936) discovered bones of a horse (*Equus caballus*) and of a mammoth (*Mammonteus primigenius*). These bones were in a 2 m thick layer of loams with remains of tundra vegetation covered by a loess-like stratum 3 m thick. Konior (l. c.) considered that the loams with bones of mammals originated during the Saalian Glaciation. This opinion was based on the erroneous supposition that the flysch gravels and the Scandinavian material situated in the bottom of the profile are of the Cracovian (— Elsterian) Glaciation which, as is generally known, reaches the Carpathians. The character of the sediments in Dziedzice and their succession is so strikingly similar to the profile in Zator that the rating of the formations present in the two brickyards as belonging to the same Pleistocene period does not provoke any doubts (Środoń 1952 p. 60).

The skull and the vertebrae of the rhinoceros (*Coleodonta antiquitatis*) are known from the profile of Wadowice situated 15 km to the south of Zator (Stach 1956). These bones were found in a thick solifluction stratum covering a layer of forest peat dating from the Brørup Interstadial (Sobolewska, Starkel, Środoń 1964).

The information concerning the remains of large Pleistocene mammals found in the investigated area in pleniglacial sediments prove that animals such as the mammoth, the rhinoceros, the horse, and probably also the reindeer played an important part in the composition of the fauna of that period which fed on the vegetation of the tundra extending in a broad belt along the Carpathian Mountains. The fossil flora of Zator presents a good picture of this vegetation.

The bones of mammals are usually found in muddy clays with peat below the main loess stratum. This disposition of the strata was caused by a change in the climate which became drier and more continental, favouring an intensive accumulation of loess which covered with a thick layer the highland of southern Poland and the Carpathians, causing alterations in the character and composition of the vegetation existing until then. On a wet and rich tundra appeared associations with a participation greater than before of steppe plants, which were, perhaps, less suitable for feeding numerous animals. More favourable conditions from this point of view probably existed at the same time higher up and in the interior of the Carpathians. It is possible that the enormous and heavy mammoths began only then to reach in greater numbers the interior of the adjacent mountains. In the interior of the northern Carpathians their remains are known from several localities of the Nowy Targ Basin situated at the foot of the Tatras at an altitude of about 600 m above sea level (Niezabitowski 1912; Kulczycki and Halicki 1950) and from Przenosza near Skrzydlna (470 m above sea level) where the molar of a mammoth was found in a gravel terrace. (The specimen is now in the collection of the Zoological Museum of the Polish Academy of Sciences in Cracow).

The fossil localities of reindeer (*Rangifer tarandus*) in the northern Carpathians probably of the Last Glaciation age, were found in Nowy Sącz at a height of about 290 m above sea level (Niezabitowski 1914) and in the brickyard of Myślenice (300 m above sea level) (Środoń unpublished).

The problem raised here of the influence of the forming loess cover on the tundra vegetation and on the qualitative and numerical composition of the fauna deserves a separate study considered in all its aspects.

THE AGE OF THE FLORA

Taking into consideration the stratigraphic scheme worked out by Klimaszewski (1949) for the Quaternary of the West Carpathians, the loess terrace of Zator should be considered as a counterpart of the Saalian glaciation. This estimate was accepted by Książkiewicz (1951) with the reservation that he himself had no stratigraphic proofs concerning it. Geological and palaeobotanical investigations carried out later in many parts of the Carpathians proved that the terrace covered with loess with a height corresponding to that of Zator is younger and should be connected with the period of Vistulian Glaciation (Środoń 1952; Jahn 1957; Starkel 1957).

For determining the age of the flora from Zator in the period of the Last Glaciation, the results of investigations on the flora from localities in the area of the upper Wisła (Vistula) and Odra, having a similar stratigraphic position as that of Zator, are of importance. Szczepanek (1964) considered that the flora of Ustroń on the Wisła, contained in formations of which the so-called „Ustroń cone" is composed, as probably derived from the Pleniglacial „A" of the Last Glaciation. This estimate is in accordance with the results of geological investigations (Stupnicka 1962). Profile T3 of Český Těšin (15 km to the west of Ustroń) is more complete as the decline of the Brørup Interstadial is shown here as well as the Pleniglacial series (Kneblová-Vodičková 1962, 1963). In the locality of Racibórz—Ocice, in the valley of the upper Odra, a profile containing protohistorical relics is known in which under a stratum of younger loess, 5 m thick, a layer of fossil soil with pine (*Pinus*) charcoal is situated, resting upon a terrace of sand and gravel (Czeppe, Kozłowski, Krysowska 1963). These authors consider the stratum of fossil soil as belonging to Amersfoort and Brørup Interstadials. The most complete series of the Vistulian Glaciation formations is represented in the investigated area in the profile of Wadowice (Sobolewska, Starkel, Środoń 1964).

With the aid of the Danish-Dutch stratigraphic scheme for the Last Glaciation (Andersen, de Vries, Zagwijn 1960) and on the basis of the results obtained in the above mentioned works, the present authors consider that the formations situated above the gravels in the profile of Zator belong to the Pleniglacial part of the Vistulian Glaciation. The bottom loams containing flora, whose absolute age has been estimated as exceeding 40 000 years (Tauber 1962), belong to the cold and wet Pleniglacial „A" above which loess-like clays, lacking humus remains, originated during the cold but dry Pleniglacial „B".

The age of fluvial gravels, lining all the profiles mentioned above, is a problem raising many doubts. In these gravels flysch material dominates, while the participation of Scandinavian rocks is relatively small (Ustroń on the Wisła (Vistula), Český Těšin, Racibórz-Ocice). The gravels are usually not large, containing sand, and many metres thick. The gravel appearing in the profiles of Zator and Wadowice has not been investigated till now as to their content of erratic material. It is unlikely that they should contain no erratic material as we find it in contemporaneous gravels of the Carpathian tributains of the upper Vistula.

In 1956 B. Halicki expressed an opinion, which the authors consider correct, that „the main intensification of fluvial accumulation in the Carpathians took place at the decline of the interglacial and not during the glacial itself" (p. 5). The age of gravels in the profiles of Brzeziny (Birkenmajer, Środoń 1960) and of Wadowice (Sobolewska, Starkel, Środoń 1964), where they line forest peats of the Brørup Interstadial period, were evaluated similarly. In the same stratigraphic position, that is on the border of the Eemian Interglacial and the Vistulian Glaciation, we place also the Zator gravels. To the opinion of Halicki (1956) it may be added that the period comprising the long-lasting decline of the Eem Interglacial and the early Vistulian till the decline of the Brørup Interstadial lasted for more than 20·000 years (Andersen, de Vries, Zagwijn 1960) and was characterised by a cold and damp climate. Therefore there were suitable conditions and a sufficiently long period of time, longer than the entire Holocene and the Late-Glacial, for the sedimentation of a thick gravel stratum to take place.

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STRESZCZENIE

PLENIGLACJALNE OSADY Z OKRESU OSTATNIEGO ZLODOWACENIA W ZATORZE

Rozprawa zawiera studium paleobotaniczne nad florą kopalną odkrytą w spągu młodoplejstoceńskiej terasy lessowej na terenie cegielni w Zatorze (por. fig. 1, tablica I i II). Terasa zbudowana jest — idąc od stropu — z glin lessopodobnych, mułków torfowych z warstwą torfu, glin niebieskawych, piasku i żwiru rzecznego z przewagą materiału fliszowego (por. fig. 2). Były również badane osady tej samej terasy w cegielniach w Bachowicach i w Przeciszowie, położonych w niedalekim od Zatora sąsiedztwie (por. fig. 1). Stwierdzono, że osady występujące w trzech wymienionych cegielniach są podobne i wykazują analogiczne następstwo. Stwierdzono dalej, że zarówno mułki torfowe, jak i gliny lessopodobne kształtowały się pod wpływem procesów soliflukcyjnych, dających się bez trudu prześledzić w postaci nierównomiernego warstwowania o charakterze stokowym (tablica II). Tabela 1 (str. 9) zawiera wyniki analizy składu

procentowego minerałów ciężkich w czterech próbach pochodzących ze spągowego piasku (a), mułku torfowego (b, c) i gliny lessopodobnej (d). Zdaniem dr M. Krysowskiej, która wykonała te analizy, jednostajność składu jakościowego przytoczonych zespołów minerałów ciężkich, przemawia za pochodzeniem zbadanych utworów z jednego źródła detrycznego. Jeśli więc warstwa glin lessopodobnych zawiera eoliczny less, to był on również składany w czasie sedymentacji leżących poniżej mułków torfowych.

Warstwa torfu była datowana w Kopenhadze przez inż. H. Taubera i jej wiek został oceniony jako starszy od 40 000 lat.

Z mułków torfowych oraz z torfu wydobyto dość liczne makroskopowe szczątki roślin, zestawione na tabeli 2. Pojawiają się wśród nich gatunki związane przede wszystkim ze środowiskiem podmokłym. Nie znaleziono makroskopowych szczątków drzew.

Wyniki badań metodą analizy pyłkowej zestawione są przy pomocy diagramu (fig. 5) oraz tabeli 7, zawierającej bezwzględne ilości stwierdzonych sporomorf. Podane są również bliższe informacje o paru bardziej interesujących roślinach. Na uwagę zasługuje wyróżnienie pyłku *Betula nana* na podstawie analizy biometrycznej (por. tabele 5 i 6) oraz odkrycie pyłku *Saxifraga stellaris* L., rośliny o rozmieszczeniu arktyczno-górskim, nie rosnącej w granicach Polski.

Diagram pyłkowy oraz rośliny oznaczone na podstawie szczątków makroskopowych składają się na obraz bezleśnej tundry podmokłej z niewielkimi wśród mszarników jeziorkami. Na glebach suchszych i zasobniejszych oraz na ostańcach fliszowych (por. fig. 1) rosły gatunki roślin o wyższych wymaganiach siedliska i klimatu. Wysunięte jest poza tym przypuszczenie wynikające z analizy diagramu pyłkowego, że w zacisznych dolinach niedalekich Karpat mogły w tym czasie róść płaty lasów szpilkowych z brzozą, osiką i olszą. W ogólnym obrazie roślinności badanego stanowiska wyróżniono trzy fazy rozwoju: pionierską na opuszczonym przez rzekę terenie, zwartego pokrycia roślinnością (warstwa torfu) i fazę zasypywania roślinności glinami lessopodobnymi.

Podane są sugestie co do jakości klimatu zbadanego odcinka plejstocenu. W pierwszej, starszej części profilu obejmującej mułki torfowe, klimat prawdopodobnie nie był zbyt surowy i raczej wilgotny. Wskazuje na to obecność roślin takich jak *Polystichum lonchitis* i *Lycopodium annotinum*, które są charakterystyczne dla karpackiego zespołu *Piceetum tatricum*. Nie jest wykluczone, że oba wymienione gatunki mogą być pozostałością po zwartych lasach świerkowych, jakie tu panowały w interstadiale Brørup. Inne rośliny o dość znacznych wymaganiach termicznych to: *Alisma plantago-aquatica, Filipendula ulmaria, Frangula alnus, Pleurospermum austriacum* i *Sanguisorba officinalis*. W drugiej, młodszej części profilu klimat stawał się coraz to suchszy o cechach arktyczno-kontynentalnych, sprzyjający akumulacji lessu, który w postaci glin lessopodobnych okrywa mułki ze szczątkami tundry w Zatorze.

W mułkach torfowych znaleziono dwa ciosy i jeden ząb trzonowy mamuta oraz ułamek kości przypominającej fragment rogu renifera (por. tablicę III). O kości tej pisze osobno duński specjalista U. M ø h l z Kopenhagi (por. str. 22). Podane są informacje i o innych szczątkach wielkich ssaków plejstoceńskich znalezionych na tym obszarze w utworach z czasów ostatniego zlodowacenia zazwyczaj poniżej głównego pokładu glin lessopochodnych. Zwrócona jest uwaga na zagadnienie wpływu formującej się pokrywy lessowej na roślinność tundry oraz na skład gatunkowy i liczebny fauny.

Próba oceny wieku flory z Zatora podana jest na tle wyników dotychczasowych badań nad stratygrafią utworów czwartorzędowych na obszarze górnej Wisły i Odry. Jako podstawę przyjęto duńsko-holenderski schemat stratygraficzny ostatniego zlodowacenia, opracowany przez A n d e r s e n a, d e V r i e s a i Z a g w i j n a (1960). Wszystkie utwory leżące w profilu z Zatora powyżej żwirów zaliczono do pleniglacjału. Spągowe mułki torfowe, ocenione jako starsze od 40 000 lat, zostały zaliczone do chłodnego i wilgotnego pleniglacjału A, powyżej zaś występujące gliny lessopodobne, pozbawione resztek humusowych, włączono do zimnego i suchego pleniglacjału B.

Końcowe ustępy zawierają wypowiedź dotyczącą wieku żwirów rzecznych podścielających utwory pleniglacjalne. Przyjęto, że akumulacja tych żwirów dokonała się na pograniczu interglacjału eemskiego i ostatniego zlodowacenia. Trwający ponad 20 000 lat schyłek interglacjału i wczesny Vistulian aż po schyłek interstadiału Brørup charakteryzował klimat chłodny i wilgotny. Istniały więc odpowiednie warunki i dostatecznie długi okres czasu, dłuższy od trwania całego holocenu wraz z późnym glacjałem, aby mogła się dokonać akumulacja nawet bardzo grubej warstwy żwirów.

Plate I

Northern part of the brickyard; to the left under an oak, now non-existent, the profile described in the work is situated

Tablica I

Część północna terenu cegielni; na lewo pod nie istniejącym już dębem, znajduje się opisany w pracy profil

Phot. by *S. Łuczko*
Fot. *S. Łuczko*

Plate II

Peaty muds disturbed by solifluction

Tablica II

Mułki torfowe soliflukcyjnie zaburzone

Phot. by *S. Łuczko*
Fot. *S. Łuczko*

Plate III

Part of cross-section of:

a The fragment from Zator;

b. *Rangifer tarandus*, antler;

c. *Bos* t. *domest.*, rib;

d. *Bos primigenius* rib;

e. *Bos* t. *domest.*, rib (young specimen);

f, g. The fragmented piece of bone from Zator.

Size: a—e 1 : 4; f, g 1 : 1

Tablica III

Przekroje poprzeczne:

a. fragment kości z Zatora;

b. *Rangifer tarandus*, róg;

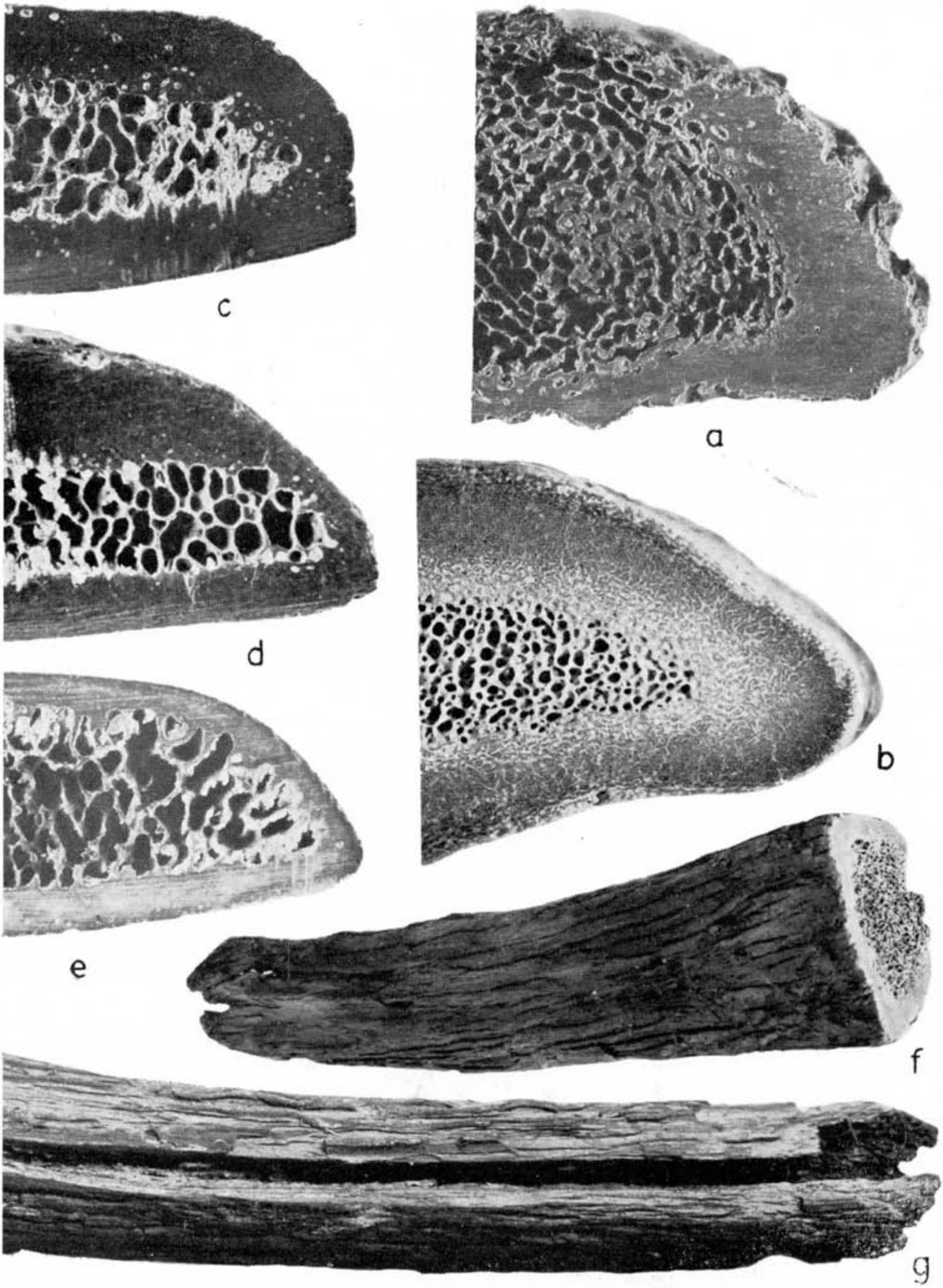
c. *Bos* t. *domest.*, żebro;

d. *Bos primigenius*, żebro;

e. *Bos* t. *domest.*, żebro (młody okaz);

f, g. ułamek kości z Zatora.

Powiększenia: a—e 1 : 4; f, g 1 : 1



Phot. by *U. Møhl* (a—e) and *S. Łuczko* (f, g)
Fot. *U. Møhl* (a—e) i *S. Łuczko* (f, g)

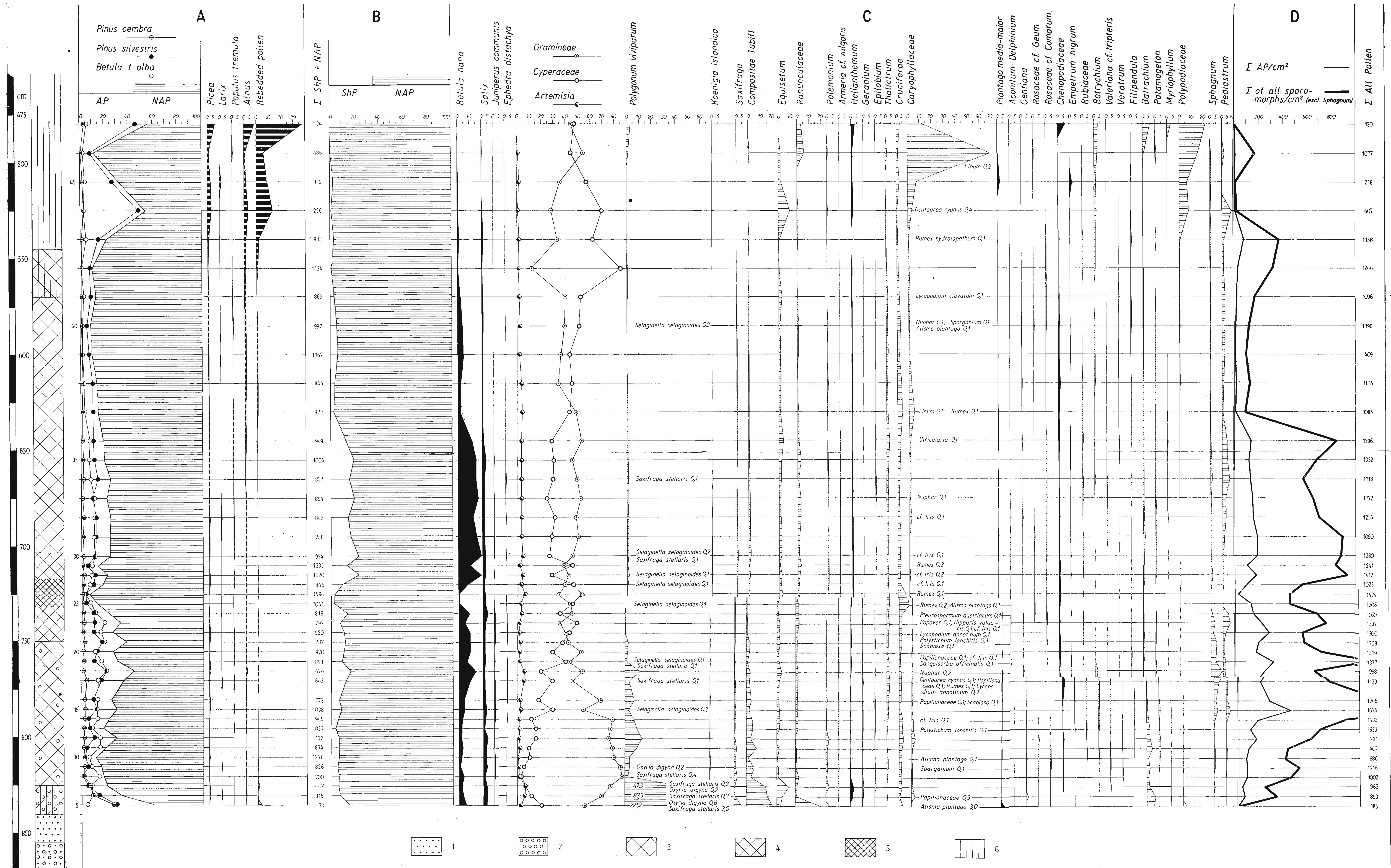


Fig. 5. Pollen diagram of the deposits from Zator. 1 — sand, 2 — fluvial gravel, 3 and 4 — peaty mud, 5 — peat, 6 — loess-like clay.
Fig. 5. Diagram pyłkowy osadów z Zatora. 1 — piasek, 2 — żwir rzeczny, 3 i 4 — mułek torfowy, 5 — torf, 6 — glina lessopodobna