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ANDRZEJ ŚRODOŃ

GLACIAL FLORA OF THE SAALIAN AGE FROM GÓRA KALWARIA NEAR WARSAW

Flora glacjalna wieku zlodowacenia Saalian z Góry Kalwarii koło Warszawy

ABSTRACT

Glacial flora remains were found at Góra Kalwaria in a 3·5 m thick layer of dusty sands, covered with boulder clay of the Warta substage. The organic macroscopic material was examined and 74 taxons of vascular plants determined, including 50 species, as well as 17 species and 2 genera of mosses. Some pollen spectra of the deposit are also given. In view of their contemporary distribution and infrequent occurrence in the fossil state, the following plant species are particularly noteworthy: *Chrysosplenium* cf. *tetrandrum, Hutchinsia* cf. *alpina, Papaver alpinum, Puccinellia sp., Ranunculus glacialis, R. hyperboreus, Rhodiola rosea, Silene furcata* and *Tragopogon* cf. *pratensis*. The paper includes a geographic analysis of the flora and attempts to reconstruct the picture of vegetation.

CONTENTS

INTRODUCTION

In the profile of a deep excavation connected with the construction of a new railway line, Dr. W. Karaszewski discovered (1952) a glacial flora abounding in organic macroscopic material. Geological research carried out in the vicinity of Góra Kalwaria has proved that this flora comes from the Saalian stage (Karaszewski 1952a, b; Sarnacka 1961, 1965). The age of this flora and its situation within the Central Polish Lowland induced the author to examine the material coming from this locality.

GEOLOGY

The Quaternary in the neighbourhood of Góra Kalwaria has well developed sediments of Saalian glaciation, in the form of boulder clay with an intercalated inter-moraine series (Fig. 1). This series is composed of two layers, plainly distinguishable. The lower one consists of compact banded clays, their thickness exceeding 30 m, which are stratified at the top and have been subjected to glaci-tectonic disturbances. A 2—6 m bed of microgranular sands, horizontally and diagonally stratified, containing glacial flora fossils borders on the clay layer (Karaszewski 1952a; Sarnacka 1965). The fact that the deposits are stratified proves that the basin was rhythmically supplied both with organic and inorganic material, and that probably this supply was regulated by the successive

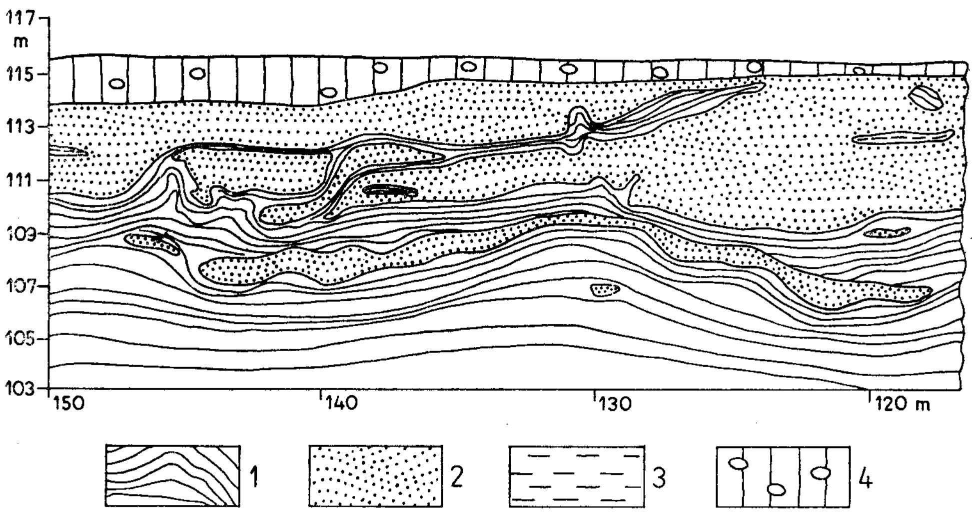

Fig. 1. Section showing the fragment of the northern wall at Góra Kalwaria (Sarnacka 1965)
1 — banded clays, 2 — limnoglacial sands, 3 — banded silts, 4 — till

Ryc. 1. Profil geologiczny fragmentu północnej ściany w Górze Kalwarii (Sarnacka 1965)
1 — iły wstęgowe, 2 — piaski zastoiskowe, 3 — mułki wstęgowe, 4 — glina zwałowa

seasons of the year. The gyttia and peat deposits representing the complete profile of the Eemian interglacial (Sobolewska 1961) found in the concave of the upper boulder clay (Sarnacka 1961) prove its relation to the Warta substage. Thus the glacial flora discussed below comes from the layer of microgranular sands, deposited during the period preceding the invasion of the Warta substage ice sheet in the neighbourhood of Góra Kalwaria (Fig. 1).

CHARACTERISTIC FEATURES OF THE PLANT-BEARING DEPOSITS

From the profile of the 3·5 m thick sandy layer, exposed in the north-facing wall of the excavation, Dr. W. Karaszewski had collected 14 samples — taken every 20—30 cm — for palaeobotanical research. The bottom horizons of the sand series were of special interest with distinct accumulation of organic macroscopic material. It was from these horizons, too, that the large extra samples were taken, which supplied the greatest part of botanical material for the investigations.

The analysis of these 14 samples has permitted the characterization of the deposit as follows. After drying they turn out to be compact microgranular dusty light-grey sands, with crystalline gravels and well rounded amber grains, rhythmically horizontally stratified with dark striae containing plant material. Macroscopic plant remains occur throughout the whole 3·5 m deposit, but their proportion decreases towards the layers situated in the profile top. In the higher situated samples these are, above all, single fruits of the *Betula*, *Potamogeton* and *Carex*, fragments of leaves of the *Salix*, *Betula* and *Dryas*, comparatively frequent moss remains, *Bryozoa* statoblasts and numerous well rounded pieces of wood. The deposit sample next to the boulder-clay bed contained fruit scales of *Betula nana*, fruit stones of *Potamogeton* sp. and pieces of wood.

Some samples derived from banded clays were also examined, without, however, revealing any macrofossils.

The plant species listed in Table 1 represent the results of research on material derived mostly from the bottom part of the sandy deposit. Beside the remnants of taxons included in Table 1, the deposit contains sclerotes of mushrooms (*Cenococcum*), *Bryozoa* statoblasts and *Daphnia* ephippia as well as snail and insect fauna abundant in some places. On the secondary bed there occur plant macrofossils recorded in the Tertiary (*Carpolithes rosenkjaeri* Hartz and *Decodon gibbosus* Reid — det. M. Łańcucka-Środoniowa) and megaspores of Jurassic plants (*Triletes turbanaeformis* Harris — det. T. Marcinkiewicz) as well as those of the Upper Carboniferous [*Tuberculacisporites* (*Triletes*) *mamillarius* (Bartlett 1928) Potonié & Kremp 1955, and *Zonalesporites* (*Triletes*) *brasserti* (Stach & Zerndt) Potonié & Kremp 1954 — det. J. Karczewska].

Table 1
Tablica 1

List of plant macrofossils determined from the Góra Kalwaria bed

Abbreviations: fr, fruit; fst, fruit stone; s, seed; v, valve of silicula; c, calyx; l, leaf; g, glume; b, bulbil; per, perianth; m, megaspore; fqt, frequent; +, denotes a non-Polish taxon. In brackets are given the numbers of plant remains

Lista roślin oznaczonych na podstawie ich szczątków makroskopowych z Góry Kalwarii

Skróty: fr, owoc; fst, pestka; s, nasienie; v, łuszczynka; c, kielich; l, liść; g, plewka; b, bulwka; per, okwiat; m, megaspora; fqt, często; +, gatunek nie występuje we florze Polski. W nawiasach podane są liczby oznaczonych szczątków makroskopowych

Vascular plants:

Allium schoenoprasum L. — s (1)
Alnus viridis (Chaix) DC. — fr (1)
Alopecurus sp. — fr
Alyssum sp. — v (fqt)
Arabis alpina L. — s (3)
Arenaria ciliata L. — s (2)
Armeria maritima Willd. — c, s (22, 2)
Aster alpinus L. — fr (3)
Berteroa incana (L.) DC. — s (2)
Betula nana L. — fr, l (10, fqt)
Campanula sp. — s (1)
Carex sp. — fr (fqt)
Caryophyllaceae — s (5)
Cerastium alpinum L. — s (19)
C. lanatum Lam. — s (4)
Chenopodium album L. — s (1)
Chrysosplenium cf. *tetrandrum* (N. Lund) Th. Fries — s (3), +
Cruciferae — s (fqt)
Cyperaceae — fr (fqt)
Dianthus cf. *superbus* L. ssp. *speciosus* (Rchb.) Pawł. — s (2)
Draba cf. *aizoides* L. — s (19)
Dryas octopetala L. — l (1)
Empetrum cf. *nigrum* L. — fst (1)
Erysimum sp. — s (9)
Festuca rubra L. — fr
Festuca sp. — fr
Gramineae — fr, g (fqt)
Hedysarum hedysaroides (L.) Schinz & Thell. — l (3)
Heleocharis sp. — fr (1)
Helianthemum cf. *alpestre* (Jacq.) DC. — s, fr (2, 61)

Hutchinsia cf. *alpina* (L.) R. Br. — s (1)
Linum austriacum L. — s (5)
L. cf. *perenne* L. — s (5)
Menyanthes trifoliata L. — s (4)
Minuartia sp. — s (1)
Myriophyllum sp. — fr (1)
Oxyria digyna (L.) Hill. — fr (3)
Papaver alpinum L. — s (9)
Peucedanum cf. *palustre* (L.) Mnch. — fr (2)
Poa sp. — fr
Polygonum viviparum L. — b, 1 (21, 3)
Potamogeton filiformis Pers. — fst (5)
P. filiformis x *P. vaginatus* — fst (6)
P. pectinatus x *P. vaginatus* — fst (2)
Potamogeton sp. — fst (several)
Potentilla palustris (L.) Scop. — fr (2)
P. cf. *puberula* Krasan — fr (21)
Puccinellia sp. — fr, +
Ranunculus acris L. — fr (2)
R. flammula L. — fr (1)
R. glacialis L. — fr (4)
R. hyperboreus Rottb. — fr (11), +
R. sceleratus L. — fr (1)
Ranunculus sp. — fr (7)
Ranunculus (*Batrachium*) sp. — fr (24)
Rhodiola rosea L. — s (2)
Ribes sp. — s (1)
Rumex acetosa L. — fr, per (1)
Salix herbacea L. — 1 (fqt)
S. polaris Wahlenb. — 1 (fqt)
S. reticulata L. — 1 (2)
Sambucus sp. s (1)
Saxifraga aizoides L. — s (1)
S. oppositifolia L. — 1 (40)
Saxifraga sp. — 1
Selaginella selaginoides (L.) Lk. — m (3)
Silene acaulis L. — s (2)
S. furcata Rafin — s (2), +
Umbelliferae — fr (3)
Taraxacum sp. — fr (1)
Thalictrum alpinum L. — fr (14), +
Tragopogon cf. *pratensis* L. — fr (1)
Vaccinium myrtillus L. — s (1)
Viola sp. — s (12)

Mosses (det. B. Szafran, nomenclature after Dickson 1973)

Amblystegium juratzkanum Schimp.
A. varium (Hedw.) Lindb.
Bryum sp.
Calliergon giganteum (Schimp.) Kindb.
C. sarmentosum (Wahlb.) Kindb.

Table 1
Tablica 1

Mosses:

C. trifarium (Web. & Mohr.) Kindb.
Campylium stellatum (Hedw.) J. Lange & C. Jens.
Cratoneurum filicinum (Hedw.) Spruce
C. filicinum var. *curvicaule* (Jur.) Mönk.
Drepanocladus exannulatus (B., S. & G.) Warnst
D. exannulatus var. *rotae* Mönk.
D. revolvens (Sw.) Warnst.
D. sendtneri (Schimp.) Warnst.
Drepanocladus sp.
Fontinalis sp.
Hygrohypnum dilatatum (Wils.) Loeske
H. cf. *molle* (Hedw.) Loeske
Mniobryum carneum (L.) Limpr.
Scorpidium scorpioides (Hedw.) Limpr.
Tortula cf. *ruralis* (Hedw.) Gartn., Meyer & Scherb.

The occurrence of Tertiary plant macrofossils and sporomorphs (see Table 2) is easy to understand in view of the occurrence in the bed of Pliocene variegated clay and of detached blocks of Tertiary rocks frequent in the Quaternary of the area (Rühle 1967). Neither was it surprising to find Jurassic megaspores and numerous Mezozoic spores in the Góra Kalwaria deposit (see Table 2). Their occurrence is accounted for by the presence of ice transported blocks of the Jurassic in Saalian glaciation measures at Łuków (Jahn 1950) and Osiecko, barely 10 km to the east of Góra Kalwaria (Sarnacka 1965), as well as in the Quaternary deposits of Warsaw (Łuniewski & Świdziński 1929), Szczecin (Książkiewicz, Samsonowicz & Rühle 1965), and Vilno (Rydzewski 1926). On the other hand, the occurrence of Carboniferous megaspores seems enigmatic, and should be accounted for by geologic research.

MACROSCOPIC PLANT REMAINS

The samples collected from the excavation profile were submitted to laboratory treatment: first, water with an addition of soda was poured on them, then they were heated for a short time, and finally rinsed on strainers. All remains were kept in a mixture composed of equal parts of glycerine, water and alcohol with an addition of thymol.

A feature characteristic of the obtained material in the base samples is the abundance of both leaves (mostly willow and dwarf birch), and fruits and seeds. Thence it is likely that most plant remains, with the exception of water and (to some extent) of marsh-plants, reached the basin towards the end of the vegetation period, at a time when the Autumn gales carry large amounts of dry plant material from one spot to another. The amount reaching the basin was certainly diminishing as the edge of the transgradating ice sheet whose moraine covers the deposit under examination, shifted on. This explains the decreasing amount of macrofossils in the higher situated profile samples. The frequent occurrence of small rounded pieces of wood is of interest. Their shape recalls that of oval-shaped fruits or seeds. This rounding indicates that the material was either transported by water or worn by lapping movement in the shallow inshore zone of the basin.

POLLEN ANALYSES

The samples examined by the pollen-analysis method come from the lower horizons of the sandy layer, abounding in macroscopic plant remains. The results obtained are presented in Table 2. The upper part of it contains the names of families and genera represented in the tundra plant communities. It is interesting to note how numerous are the recorded pollen grains of *Alnus* and *Betula*, genera represented in the Góra Kalwaria flora by the macrofossils of *Alnus viridis* (1 fruit) and of *Betula nana* (many leaves, fruits, fruit scales and wood). The fact that the pollen of both these genera is so numerous can probably be attributed partly to its long-distance transport under woodless tundra conditions (Środoń 1960; Hyvärinen 1970). The large amount of the pollen of *Cruciferae*, *Cyperaceae* and *Gramineae*, which cannot be referred to the *Caryophyllaceae* family, widely represented in macroscopic flora is consistent with the research on macroscopic plant remains. The fairly large amount in the pollen spectra of *Compositae* (*Artemisia*) and *Chenopodiaceae*, and above all of *Gramineae* are the „steppe" elements in the composition of tundra communites from Góra Kalwaria.

The lower part of the Table contains the names of families and genera whose representatives do not belong to the tundra community. Their sporomorphs are derived either from the older (Pleistocene, Tertiary, Mezozoic) deposits, or from long distance transport (*Pinus* t. *silvestris*, and, perhaps, *Abies* and *Picea* as well).

Table 2
Tablica 2

Pollen spectra of samples derived from the bottom part of the microgranular sand layer, abounding in macroscopic remains of plants and molluscs in sample No 1. The analysis was carried out by Dr. J. Oszast
Spektra pyłkowe prób pochodzących ze spągowej części warstwy piasków drobnoziarnistych obfitujących w szczątki makroskopowe roślin i mięczaków (próba nr 1). Analizę wykonała dr J. Oszast

Taxon \ No. of sample	1	2	3	4
1	2	3	4	5
Alnus	6	7	14	47
Betula	34	95	14	8
Salix	7	7	2	6
Armeria	—	—	—	10
Artemisia	8	41	—	9
Caryophyllaceae	2	—	—	4
Centaurea	1	—	—	—
Chenopodiaceae	1	9	—	3
Compositae	2	1	—	4
Cruciferae	2	10	—	—
Cyperaceae	1	83	—	12
Ericaceae	3	3	5	8
Gramineae	2	74	3	674
Helianthemum	3	1	—	2
Labiatae	—	4	—	1
Lycopodium		—	1	—
Polygonum cf. *viviparum*	—	—	—	1
Polygonum	1	—	—	—
Polypodiaceae	4	—	4	3
Potentilla	5	—	—	—
Ranunculaceae	—	—	—	2
Rosaceae	2	1	1	7
Rubiaceae	1	3	—	3
Rumex	—	—	—	1
Selaginella	—	2	1	1
Thalictrum	2	3	—	34
Umbelliferae	1	—	—	1
Sphagnum	3	—	2	3
Pediastrum	1	—	—	—
Abies	—	—	2	4
Acer	—	—	1	2
Araliaceae	1	—	—	10
Carpinus	—	—	2	1
Carya	—	—	—	2
Castanea	—	—	1	—
Cornaceae-Araliaceae	—	—	—	1

1	2	3	4	5
Cornus	—	—	—	1
Cyrilla	1	—	—	—
Engelhardtia	1	—	1	—
Fagus	2	—	1	1
Gleicheniaceae	—	—	—	1
Hedera	—	—	2	—
Ilex	—	—	1	1
Juglans	—	—	—	1
Liquidambar	—	2	—	1
Nymphaea	—	—	1	—
Nyssa	—	4	2	7
Osmunda	—	—	1	5
Pinus t. *haploxylon*	—	1	4	3
Pinus t. *silvestris*	58	83	80	144
Picea	2	1	1	3
Pterocarya	4	2	3	—
Quercus	—	—	2	3
Sciadopitys	—	1	2	—
Sequoia	5	—	4	6
Taxodium	6	—	3	1
Tilia	—	—	—	1
Tsuga	—	—	2	1
Ulmus	5	1	—	3
Mesozoic spores	7	1	—	56
Hystrix	4	14	22	11

NOTES ON SOME OF THE PLANT MACROFOSSILS

Allium schoenoprasum L. — One seed (3·0 × 1·4 mm) with morphological structure consistent with comparative material and detailed description presented by Kulczyński (1932). In all probability this is the seed of *A. schoenoprasum* L. var. *sibiricum* (L.) Hartm., a plant of arctic-alpine distribution (Hultén 1962), which occurs in the upper montane and mountain-pine zones of the Sudets, Tatra, and East Carpathian Mts. Its fossil seeds have been recorded previously in glacial flora exposures in the Carpathian Foreland (Barycz, Walawa)[1] of the last glaciation.

Alnus viridis (Chaix) DC. (Fig. 3, *3*). One fruit (dimensions 1·9 × 1·2 mm) with vestiges of membranous (translucent) wings, sharply set apart from the edge of the nutlet. The *A. viridis* wood has previously been recorded in Saalian deposits at Krystynopol. At present it grows in an

[1] The localities of the glacial floras mentioned have been mapped in Fig. 2.

area extending to the mountains of Central Europe and the Balkan Peninsula, from the East Carpathians it reaches to the West Bieszczady in Poland, but does not occur in the Tatra or Sudetic Mts.

Arabis alpina L. — Seeds inversely egg-shaped, throughout the periphery narrowly winged (dimensions without the wings: 1·2 × 0·87, 1·52 × 1·2, 1·6 × 1·1 mm). An arctic-alpine species, widely distributed, in

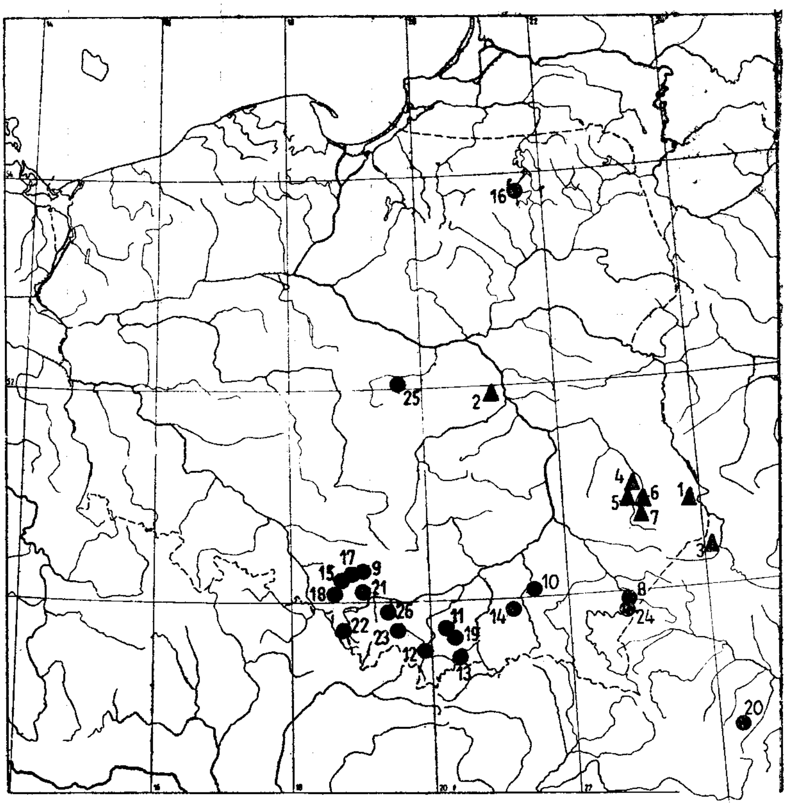

Fig. 2. Location of glacial flora stands referred to in the paper

Ryc. 2. Rozmieszczenie stanowisk flor glacjalnych wymienionych w tekście pracy
Saalian glaciation (black triangles) — **Zlodowacenie Saalian** (czarne trójkąty): 1. Czumów (Środoń 1955); 2. Góra Kalwaria; 3. Krystynopol (Szafer 1912); 4. Latyczów (Karczmarz 1971); 5. Tarnogóra (Środoń 1954); 6. Tarzymiechy (Środoń 1954); 7. Zamszany (Środoń 1954). — **Vistulian glaciation** (black circles) — **Zlodowacenie Vistulian** (czarne kółka): 8. Barycz (Kulczyński 1932); 9. Brzozowica (Stuchlik, unpubl.); 10. Dębica (Środoń 1965); 11. Dobra (Środoń 1968); 12. Grel (Koperowa 1962); 13. Krościenko nad Dunajcem (Klimaszewski et al., 1950); 14. Łęki Dolne (Klimaszewski, Szafer 1945); 15. Makoszowy (Kozłowska 1933); 16. Mikołajki (Ralska-Jasiewiczowa 1966); 17. Milowice (Kozłowska 1933); 18. Podlesie koło Żor (Środoń, unpubl.); 19. Sowliny (Środoń unpubl.); 20. Starunia (Szafer 1930); 21. Ściejowice (Dyakowska 1939); 22. Ustroń (Szczepanek 1965); 23. Wadowice (Sobolewska, Starkel, Środoń 1964); 24. Walawa (Kulczyński 1932); 25. Witów (Wasylikowa 1964); 26. Zator (Koperowa, Środoń 1965).

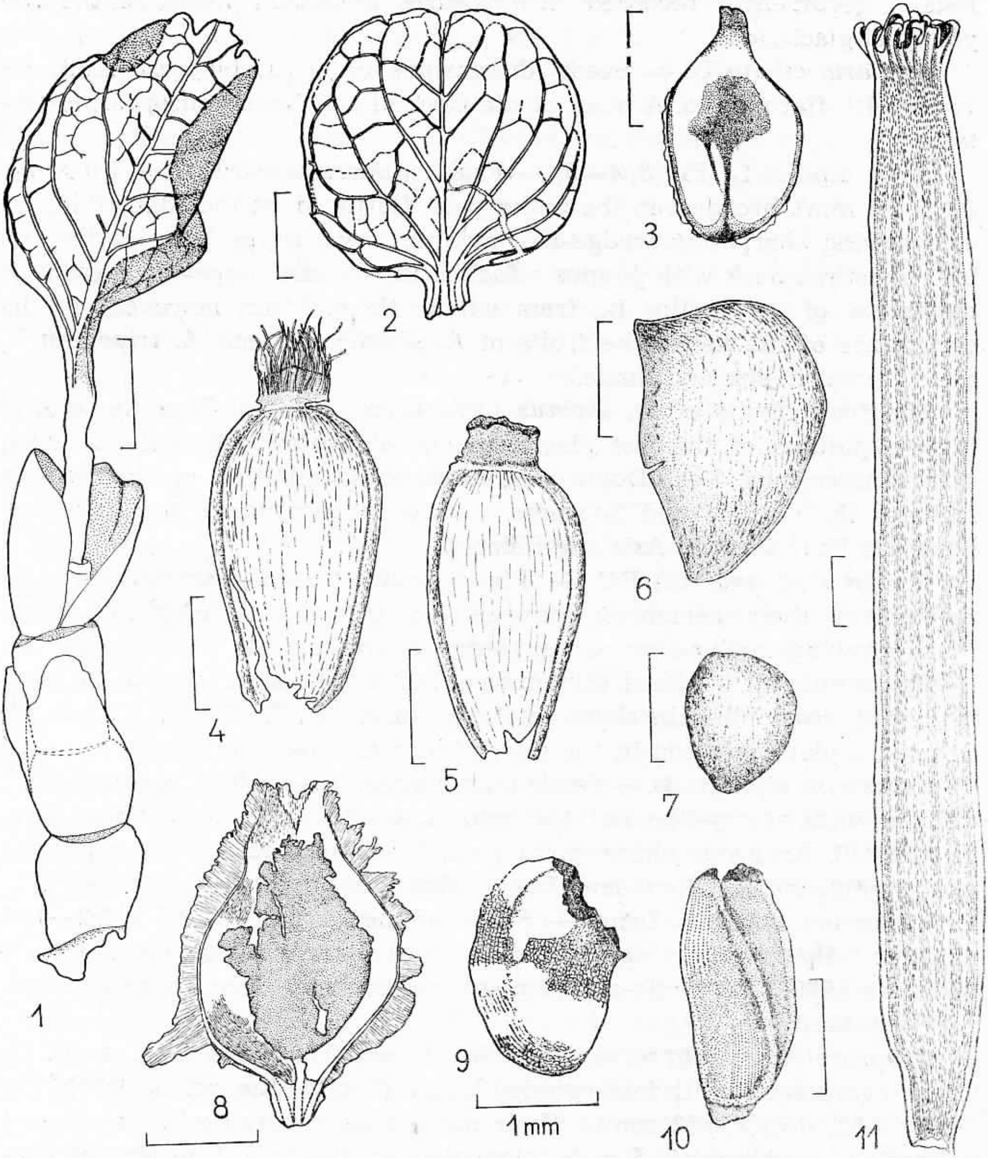

Fig. 3. 1-2 — *Salix polaris* Wahlenb., leaves; 3 — *Alnus viridis* (Chaix) DC., fruit; 4-5 — *Aster alpinus* L., fruits; 6 — *Ranunculus glacialis* L., fruit; 7 — *Ranunculus hyperboreus* Rottb., fruit; 8 — *Oxyria digyna* (L.) Hill, fruit; 9 — *Empetrum* cf. *nigrum* L., fruit stone; 10 — *Erysimum* sp., seed; 11 — *Tragopogon* cf. *pratensis* L., fruit

Ryc. 3. 1-2 — *Salix polaris* Wahlenb., liście; 3 — *Alnus viridis* (Chaix) DC., owoc; 4-5 — *Aster alpinus* L., owoce; 6 — *Ranunculus glacialis* L., owoc; 7 — *Ranunculus hyperboreus* Rottb., owoc; 8 — *Oxyria digyna* (L.) Hill, owoc; 9 — *Empetrum* cf. *nigrum* L., pestka; 10 — *Erysimum* sp., nasienie; 11 — *Tragopogon* cf. *pratensis* L., owoc

Poland recurrently recorded at exposures of glacial floras of the two youngest glaciations.

Arenaria ciliata L. — Seeds (dimensions 1·3 × 1·1, 1·0 × 0·8 mm), covered with flat papilla. A plant of the Central and North European mountains.

Aster alpinus L. (Fig. 3, *4—5*). — Fruits (dimensions: 3·0 × 1·4, 3·0 × 1·5, 2·2 × 1·1 mm), broadest in the upper part, flattened, at the edges thickened, growing sharper in wedge-like manner towards the base, at the top into a distinct neck with pappus remains. In size and shape they resemble the fruits of *A. amellus* L., from which they differ, however, in the occurrence of the neck. The fruits of *A. sibiricus* L. and *A. tripolium* L. are different in size and shape.

The fossil fruits of *A. alpinus* have been reported from the glacial flora exposures of the last glaciation age at Walawa, Krościenko upon the Dunajec, and Łęki Dolne. The present distribution of this species includes the Central and Southern European mountains, the Caucasus, Southern Ural, Central Asia and Siberia.

Berteroa incana (L.) DC. — Flat circular seeds, narrowly winged throughout their periphery (dimensions: 1·62 × 1·42, 1·4 × 1·32 mm). Plant growing in Eurasian areas, in dry sandy habitats.

Campanula sp. — Seed (dimensions 1·02 × 0·47 mm), elliptic, striated in length, resembling in shape and type of striae *C. abietina* Griseb. et Schenk, a plant growing in the Carpathians and Balkans.

Cerastium alpinum L. — Seeds (dimensions: 1·1—1·35 × 0·5—1·25 mm), circular with starry-like flat tubercle on epidermal surface (Wojterska 1969). An arctic-alpine plant recorded from glacial flora exposures at Tarzymiechy (Saalian) and Łęki Dolne (Vistulian).

Cerastium lanatum Lam. — Seeds (dimensions 1·35—1·7 × 1·2—1·35 mm), broadly inversely egg-shaped with semispherical tubercle (Wojterska 1969). An arctic-alpine plant, recorded at Dobra near Limanowa (Vistulian).

Chrysosplenium cf. *tetrandrum* (N. Lund) Th. Fries (Fig. 4, 2). — Three ovate seeds with fold running longitudinally (dimensions: 0·72 × 0·5, 0·85 × 0·52, 0·95 × 0·52 mm). Their surface is covered with a distinct network of isodiametrical cells, elongated on the fold. The size of contemporary seed of *Ch. tetrandrum* from Western Spitsbergen varies as follows: 0·7—0·8 × 0·45—0·6 mm.

The seeds of *Ch. alpinum* Schur and *Ch. oppositifolium* L. are smaller (compare Pawłowska 1947) and have no distinct network of cells on the surface. In this respect the seeds of *Ch. alternifolium* are similar to the fossil seeds from Góra Kalwaria, but smaller. For this species Katz et al. (1965) gives the dimensions 0·5—0·7 × 0·4 mm, and Pawłowski (1965) ca. 0·6 mm. *Ch. tetrandrum* is a plant of the arctic tundra, reaching up to North Scandinavia (Hultén 1950).

Cruciferae. — The fossil material belonging to this family consists of considerable number of seeds (ca. 150 specimens) and of equally frequent silicula valves. Only a small portion of the material could be determined and even when this was done, it was not always with full certainty. The pollen grains of *Cruciferae* are among the more abundant in the pollen spectra of the Góra Kalwaria deposit.

Dianthus cf. *superbus* ssp. *speciosus* (Rchb.) Pawł. — Two elliptic seeds (dimensions 2·4 × 1·55, 1·7 × 0·95 mm), with epidermal cells whose lay-out and size correspond to the cells in contemporary seeds. Plant of the higher mountain ranges of Central Europe recorded from the glacial flora exposures of the last glaciation at Dobra, Walawa, and Barycz.

Draba cf. *aizoides* L. — Seeds ovate or ovately elongated, the latter usually larger, with a fairly distinct network of cells disposed in longitudinal bands. Dimensions: 1·45—2·12 × 1·00—1·32 mm. Plant of alpine growth, occurring in the mountains of Central and Southern Europe, and in Great Britain.

Erysimum sp. (Fig. 3, *10*). — Seeds longitudinally ovate (dimensions: 2·0—2·2 × 0·9—1·1 mm), with a well preserved wing-shaped outgrowth at the top. The size and shape of the fossil material recalls the seeds of species from the Tatra Mts. [*E. wahlenbergii* (Asch. & Engl.) Borb., *E. witmannii* Zaw.] and from the Pieniny Mts. [*E. pieninicum* (Zapał.) Pawł.]. In their surface sculpture (finely striated), the fossil seeds resemble most *E. witmannii* Zaw.

Gramineae. — The caryopses (170 specimens) and glume of *Gramineae* are among the plant remains occurring most frequently in the fossil flora from Góra Kalwaria. Using K ö r b e r - G r o h n e's paper (1964) as a basis, the following taxons have been distinguished: *Alopecurus* sp., *Festuca rubra* L., *Festuca* sp., *Poa* sp. and *Puccinellia* sp.

Hedysarum hedysaroides (L.) Schinz & Thell. (= *H. obscurum* L.). — Three leaves partly destroyed, with short petioles, and distinct side veins, running parallel at an angle of 45°. The contemporary leaves are densely covered with small oil-substance reservoirs, brown-coloured in the older leaves. These reservoirs are clearly discernible on the fossil leaves — in the form of black dots. Plant occurring in the mountains of Central and Southern Europe, in the arctic part of the USSR and in the Ural Mts. Species derived from the glacial floras of the last (Walawa, Łęki Dolne) and penultimate (Tarzymiechy) glaciation.

Helianthemum cf. *alpestre* (Jacq.) DC. (Fig. 4, *6*). — Two ovate seeds, deltoid, growing sharper at the top with a broad base distinctly set apart. Smooth surface of seeds, finely spotted, dimensions: 1·65 × 1·3, 1·15 × 0·87 mm (compare W o j c i e c h o w s k a 1969). Apart from these, the deposit yielded capsule valves of this genus, 61 specimens in all (compare K u l c z y ń s k i 1932). The species grows in the mountains of Central and Southern Europe. In fossil state recorded in floras of Saalian (Tarzymiechy, Latyczów), and Vistulian age (Barycz, Walawa, Krościenko upon the Dunajec, Łęki Dolne).

Hutchinsia cf. *alpina* (L.) R. Br. (Fig. 4, 5). — Seed longitudinally ovate (dimensions: 1·9 × 1·0 mm), rounded at its base, widest above the middle of its length, covered with a network of large and distinctly delineated cells arranged in longitudinal bands. Plant growing in the alpine zone of the Central and Southern European mountains.

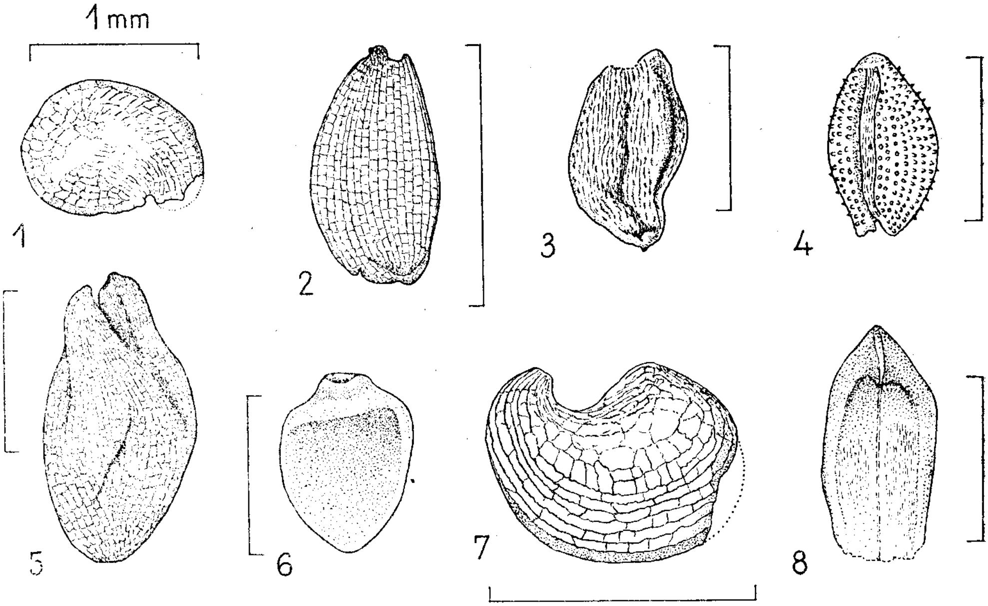

Fig. 4. 1 — *Minuartia* sp., seed; 2 — *Chrysosplenium* cf. *tetrandrum* (N. Lund) Th. Fries, seed; 3 — *Rhodiola rosea* L., seed; 4 — *Saxifraga aizoides* L., seed; 5 — *Hutchinsia* cf. *alpina* (L.) R. Br., seed; 6 — *Helianthemum* cf. *alpestre* (Jacq.) DC., seed; 7 — *Papaver alpinum* L., seed; 8 — *Armeria maritima* Willd., seed

Ryc. 4. 1 — *Minuartia* sp., nasienie; 2 — *Chrysosplenium* cf. *tetrandrum* (N. Lund) Th. Fries, nasienie; 3 — *Rhodiola rosea* L., nasienie; 4 — *Saxifraga aizoides* L., nasienie: 5 — *Hutchinsia* cf. *alpina* (L.) R. Br., nasienie; 6 — *Helianthemum* cf. *alpestre* (Jacq.) DC., nasienie; 7 — *Papaver alpinum* L., nasienie; 8 — *Armeria maritima* Willd., nasienie

Linum austriacum L. — Five seeds of which 4 whole and one damaged (dimensions: 3·2—3·5 × 1·8—1·9 mm). For contemporary grains Helbaek (1959) gives the length 3·11—3·76 mm. The surface of fossil seeds has distinct wrinkles, which assume the form of continuous lines running parallel to the edge, which is the characteristic of contemporary seeds of this species. The wrinkling of seeds is also manifest in *L. perenne* L., but not with the same distinctness. The species grows in Central and Southern Europe, through Southern Podolia it reaches up to the regions of Lvov and Przemyśl, where it grows on sunny slopes and steppe-like meadows (Pawłowska 1972).

Linum cf. *perenne* L. — Five seeds, of which 3 whole (dimensions: 3·7—4·0 × 2·1—2·5 mm). The character of the Góra Kalwaria flora and the seed dimensions as cited above permit their inclusion in *L. perenne*, a species differentiated into several subspecies (comp. Flora Europaea), occurring in the mountains of Central, Southern, and Eastern Europe and in the Eurasian steppes (subsp. *perenne*). One cannot exclude altogether *L. nervosum* Waldst et Kit., a species growing on the steppes of South-East Europe, with seeds from 4·2 to 4·8 mm in length.

Fossil seeds determined as *L. extraaxillare* Kit. [= *L. perenne* L. subsp. *extraaxillare* (Kit.) Nymyn] have been reported from the exposures of glacial flora of Saalian (Tarzymiechy, Latyczów) and Vistulian (Barycz, Łęki Dolne, Krościenko upon the Dunajec) ages. Seeds from these exposures are generally larger than those from Góra Kalwaria. Their length at Tarzymiechy and Latyczów amounts to 4·0—4·7 mm, and at Barycz and Krościenko to 4·8—5·4 mm. For contemporary seeds of *L. perenne* subsp. *extraaxillare* in the Tatra Mts. Pawłowski (1965) gives the length of 4·0—4·5 mm.

Minuartia sp. (Fig. 4, *1*). — One damaged seed, in size (1·1 × 0·8 mm), shape and indistinct network of wrinkles on the surface resembling *M. sedoides* (L.) Hiern., a species growing in the mountains of Central Europe and Scotland. The grains of *M. verna* (L.) Hiern. have been reported at Dobra (Vistulian).

Oxyria digyna (L.) Hill. (Fig. 3, *8*). — Three easily designated fruits of a plant of arctic-alpine distribution. The *O. digyna* fruits have been reported from exposures of glacial flora of Saalian age (Tarzymiechy, Tarnogóra), whereas pollen grains were found in the flora of Zator (Vistulian).

Papaver alpinum L. (Fig. 4, 7). — Kidney-shaped seeds (dimensions: 0·87—1·0 × 0·7—0·87 mm), covered with a network of concentrically arranged meshes of rectangular shape, markedly elongated closer to the periphery of the seed.

This species comprises a number of taxons of lower range, growing in the Arctic and European mountain ranges.

Peucedanum cf. palustre (L.) Mnch. — Two broadly elliptic fruits with three blunt back ribs and lateral wings, 0·4 mm wide. Fruit dimensions: 3·6 × 2·6, 3·5 × 2·6 mm. Species of Eurasian growth, common in lowland and lower mountain zones.

Material derived from Góra Kalwaria contains in addition three damaged fruits belonging to the *Umbelliferae* family.

Potentilla cf. *puberula* Krasan. — A fair number of fruits of smooth (or very slightly wrinkled) surface, covered with a network of well discernible cells. Dimensions: 1·45—1·6 × 1·0—1·17 mm. The species grows in the Carpathians and other mountains of Central Europe.

Ranunculus acris L. — Two achenes (dimensions 3·5 × 2·6, 2·45 × 1·5 mm), broadly ovate with flattened edge. The surface of achenes covered with pits. The species grows on European and Siberian areas, reported from the Vistulian floras (Barycz, Łęki Dolne, Walawa).

Ranunculus flammula L. — One half of an achene (1·37 × 1·1 mm), its surface covered with a network of isodiametric pits. Species widely distributed in Europe, reported from several interstadial flora exposures of Vistulian glaciation (Dobra, Ściejowice, Ustroń, Witów, Zator).

Ranunculus glacialis L. (Fig. 3, *6*). — Four thin-walled halves of achene, ovately-convex (dimensions: 2·45 × 2·0, 2·4 × 1·6, 2·0 × 1·65 mm), with wing-like flattened edge. Outside surface of achene delicately striated. Species of arctic-alpine occurrence, growing in the highest Tatra zones.

Ranunculus hyperboreus Rottb. (Fig. 3, *7*). — Numerous achenes (dimensions: 0·95—1·65 × 0·87—1·2 mm), thickwalled, roundish, convex on both sides, finely dotted on the surface. Plant of circumboreal growth, occurring on the area of arctic and subarctic Europe (Scandinavian mountains). For Polish territory, attested so far (*R.* cf. *hyperboreus*, 1 achene) from an exposure at Mikołajki as found in late glacial deposits preceding the Allerød.

Ranunculus sceleratus L. — One half of achene (dimensions: 1·0 × 0·8 mm) with a bald spot devoid of parenchyma cells, upon which clearly discernible are elongated cells, arranged on lines parallel to the longer axis. A common species, widely distributed, many times noted in Polish Pleistocene floras of different ages.

Ranunculus (*Batrachium*) sp. — Numerous achenes representing at least two species.

Rhodiola rosea L. (Fig. 4, *3*). — Two seeds longitudinally ribbed and winged (dimensions: 1·27 × 0·7, 1·25 × 0·6 mm). An arctic-alpine plant, occurring in the Carpathians, Tatra and Sudetic Mts.

Ribes sp. — One oval-shaped seed (2·2 × 1·9 mm) without any peculiar morphological features enabling the definition of the species, with the characteristic network sculpture on the surface. Similar seed dimensions are displayed by *R. petraeum* Wulfen, *R. alpinum* L. and *R. uvacrispa* L.

Salix herbacea L. and *S. polaris* Wahlenb. (Fig. 3, *1*—*2*). — Numerous leaves of these two species, the majority devoid of any dentation of the leaf margins, feature characteristic of *S. polaris*. The material also contains large numbers of buds and budscales of *Salix* sp.

S. herbacea is an arctic-alpine species, while *S. polaris* grows in the Arctic extending to North Scandinavia. The leaves of both these species, in particular those of *S. herbacea* have been repeatedly found in Polish glacial floras.

Sambucus sp. — Half of a seed, resembling in size (2·7 × 1·55 mm) and shape *S. racemosa* L.

Saxifraga aizoides L. (Fig. 4, *4*). — One seed (dimensions: 1·2 × 0·65 mm) with conspicuous warts over the whole surface. The leaves of this plant have been reported from deposits of Saalian (Latyczów) and Vistulian (Krościenko upon the Dunajec) glaciations. Arctic (circumpolar) — alpine species, growing in the Tatra and East Carpathian Mts.

Saxifraga oppositifolia L. — Nearly 40 small leaves distinguished by their characteristic nervure. Species recorded in glacial floras of Saalian (Czumów, Latyczów, Tarzymiechy) and Vistulian (Dębica, Krościenko, Łęki Dolne, Milowice, Podlesie near Żory, Wadowice). Plant of arctic-(circumboreal)-alpine occurrence, growing in the Sudetic, Tatra and East Carpathian Mts.

Silene acaulis L. — Two characteristic seeds (1·5 × 1·35, 0·8 × 0·7 mm), whose determination is beyond doubt. Arctic-alpine species, reported in glacial flora at Tarzymiechy (Saalian).

Silene furcata Rafin. — Two seeds described and illustrated in a previous publication (Środoń 1973). Species of circumboreal growth, with habitats in North Scandinavia and arctic Asia.

Thalictrum alpinum L. — 14 fruits of this species were extracted from the deposit. Now an arctic-alpine plant, does not grow in the Tatra Mts. or in the Polish part of the Carpathians, but only in the East Carpathians, the Alps and the Pyrenees. The fossil fruits of this plant were recurrently reported in habitats of Vistulian age, situated in the Polish Carpathians and in their foreland (Barycz, Brzozowica, Dobra, Grel, Łęki Dolne, Makoszowy, Milowice, Sowliny, Starunia, Wadowice, Walawa, Ustroń), as well as in the habitats in the lowland in the Bug and Wieprz valleys, of Saalian age (Czumów, Latyczów, Tarnogóra, Tarzymiechy, Zamszany).

Tragopogon cf. *pratensis* L. (Fig. 3, *11*). — One fruit, 17 mm long, distinctly narrowing, broken at the end, smooth on the surface, with faintly discernible ribs. Most similar to the often smooth-surfaced fruits of *T. pratensis* L. subsp. *orientalis* (L.) Čelak. Plant of Euro-Siberian growth, in the north reaching to central Scandinavia.

DESCRIPTION OF VEGETATION

Within the composition of the flora preserved in the deposit from Góra Kalwaria, there are representatives of different plant-communities, from aquatic, through peat-bog and peat communities, to those growing in elevated dry habitats.

In the lake, whose stratified bottom deposits contain the remains of the whole flora here discussed, there were plants characteristic of moderately deep (not-too-deep) open waters, of the genera: *Batrachium, Myriophyllum, Potamogeton* and *Fontinalis*. The peaty habitats bordering on the lake were occupied by scrubs of *Betula nana*, abundant *Cyperaceae* with probably a fair amount of *Gramineae* and *Saxifragaceae*, and genera such as: *Chrysosplenium* cf. *tetrandrum*, *Empetrum* cf. *nigrum*, *Menyanthes trifoliata*, *Potentilla palustris*, *Ranunculus flammula*, *R. hyperboreus*, *R. sceleratus*, *Selaginella selaginoides*, *Vaccinium myrtillus*, and probably others as well. These communities were accompanied by mosses characteristic for the wet soil: *Drepanocladus exannulatus*, *Calliergon giganteum*, *Scorpidium scorpioides*.

Along the streams discharging into the lake, there might have occurred scrubs of *Alnus viridis* with an addition of *Sambucus* sp. and *Ribes* sp., while the elevated dry areas with a varied relief were compactly covered with differentiated tundra communities. Within their composition were spots of dwarf willow species (*Salix polaris*, *S. herbacea*, *S. reticulata*) and *Dryas octopetala* as well as extensive meadows with a large proportion of species belonging to the families of *Caryophyllaceae*, *Cruciferae* and *Saxifragaceae*. The representatives of steppe vegetation, belonging to the families of *Compositae* (*Artemisia*, *Tragopogon*), *Chenopodiaceae*, and *Gramineae* are a fairly important element in these communities. Their proportion was not prominent, which seems to be a trait characteristic of tundra communities in areas situated not far from the edge of an oscillating ice sheet. The climatic conditions at that time, though severe, were not arctic, permitting the development of a fairly compact vegetation cover.

A number of plants at Góra Kalwaria are today calciphilous species, a feature which has been recurrently emphasized in *Dryas*-flora descriptions. This is probably related — to some extent, at least — to the occurrence of loess in soils formed in the periglacial zone. Another significant fact in the pollen spectra from Góra Kalwaria is the absence of pollen of *Ephedra* and *Hippophaë*, two shrubs which have been quite often recorded in the deposits of the last two glaciations.

The flora from Góra Kalwaria is fairly differentiated as regards the contemporary geographic distribution of its respective components. With greater or lesser accuracy 50 species of vascular plants have been denoted, plants classifiable as belonging to four easily distinguishable groups, each of them representing different geographic elements.

The first group consist of plants of arctic-alpine growth, usually occurring in great abundance in floras of this type (17 species). The second, less numerous group is composed of the plants of Central and Southern European mountains (10 species). The third group is of special interest and contains specimens infrequently recorded in glacial floras so far. It comprises plants of the subarctic and arctic areas, which do not occur in Central Europe, but have their habitats in Scandinavia (4 species). The fourth group includes plants of the extensive Eurasian zone, with a fairly marked proportion of boreal element (19 species).

The geographic analysis of the flora composition at Góra Kalwaria does not leave any doubt about the scale of its connections with the vegetation of the Eurasian zone and with the Central and South European mountain vegetation. Another proof is the growing number — as revealed by consecutive research works — of plants whose occurrence is now confined to the subarctic and arctic areas, which have fossil localities of the Saalian or Vistulian glaciation ages, extending far southwards, such species as *Chrysosplenium* cf. *tetrandrum, Koenigia islandica, Polemonium boreale, Ranunculus hyperboreus, Salix polaris, Silene furcata* and *S. wahlbergella* (Koperowa 1962; Tralau 1963; Danielsen 1970; Środoń 1973, 1974).

Palaeobotanic data corroborate the predominance of these compounds in glacial floras of the Middle and Late Pleistocene, i.e., for a period which followed glaciations of the maximum range. It may be supposed that in the Early Pleistocene the composition of periglacial tundra differed in the participation of plants whose centre of development was then on the subarctic and arctic area. This supposition, however, seems to be at variance with the results of systematic-geographical analysis. This analysis has shown that in the mountains of Central Europe the number of plants to which an arctic origin may be attributed with a certain degree of likelihood (*Dryas octopetala, Salix herbacea*), is insignificantly small (Diels 1910; Pawłowski 1929; Pawłowska 1972).

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Institute of Botany of the Polish Academy of Sciences in Kraków
Department of Palaeobotany

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STRESZCZENIE

FLORA GLACJALNA WIEKU ZLODOWACENIA SAALIAN Z GÓRY KALWARII KOŁO WARSZAWY

Geologia, stratygrafia i charakterystyka osadu

Florę glacjalną w Górze Kalwarii odkrył dr W. Karaszewski w następującej pozycji stratygraficznej (ryc. 1): pod podkładem gliny morenowej stadiału Warty, datowanej nadległym osadem z interglacjału eemskiego (Sarnacka 1961; Sobolewska 1961), występuje 2,6 m warstwa piasków drobnoziarnistych (pylastych) podścielonych miąższą serią iłów wstęgowych glacitektonicznie zaburzonych (Karaszewski 1952 a, b; Sarnacka 1965). Flora kopalna bogata w różnorodne szczątki makroskopowe pochodzi z warstwy piaszczystej, a zwłaszcza z jej dolnej części.

Cechą charakterystyczną uzyskanego materiału jest równoczesna w próbach obfitość zarówno liści (głównie wierzb i brzozy karłowatej), jak owoców i nasion. Jest przeto prawdopodobne, że większość szczątków roślin, z wyjątkiem wodnych a częściowo i bagiennych, dostawała się do zbiornika pod koniec okresu wegetacyjnego, kiedy to jesienne wichury przenoszą na tundrze z miejsca na miejsce ogromne ilości suchego materiału roślinnego. Jego dostawa do zbiornika zapewne malała w miarę przesuwania się krawędzi transgredującego lądolodu, którego morena przykrywa badany osad. Tym prawdopodobnie tłumaczyć można zmniejszający się udział makrofosiliów w wyżej położonych próbach profilu. Zwraca poza tym uwagę często występujące obtoczenie drobnych drewien, kształtem upodobnionych do owalnych owoców lub nasion. Obtoczenie to dowodzi transportu wodnego, względnie obróbki materiału pod wpływem falowania w płytkiej strefie przybrzeżnej zbiornika.

Obok szczątków makroskopowych reprezentujących roślinność tundry glacjalnej, w osadzie występują na wtórnym złożu szczątki roślin trzeciorzędowych (*Carpolithes rosenkjaeri* Hartz i *Decodon gibbosus* Reid) oraz megaspory roślin jurajskich (*Triletes turbanaeformis* Harris) i górnokarbońskich [*Tuberculatisporites* (*Triletes*) *mamillarius* (Bartlett 1928) Potonié & Kremp 1955 i *Zonalesporites* (*Triletes*) *brasserti* (Stach & Zerndt) Potonié & Kremp 1954]. Stwierdzono również dość liczne ziarna obtoczonego bursztynu.

Analiza makroskopowa

Na podstawie szczątków makroskopowych oznaczono 74 taksony roślin naczyniowych (w tym 50 gatunków), a także 17 gatunków i 2 rodzaje mchów (tab. 1). Ze względu na współczesne rozmieszczenie i rzadkość występowania w stanie kopalnym, na szczególną uwagę zasługują następujące rośliny: *Chrysosplenium* cf. *tetrandrum, Hutchinsia* cf. *alpina, Papaver alpinum, Puccinellia* sp., *Ranunculus glacialis, R. hyperboreus, Rhodiola rosea, Silene furcata* i *Tragopogon* cf. *pratensis.*

Wyniki analizy pyłkowej

Metodą analizy pyłkowej zbadano cztery próby osadu obfitującego w szczątki makroskopowe roślin (tab. 2). Górna część tabeli zawiera nazwy rodzin i rodzajów, których przedstawiciele wchodzili w skład zbiorowisk roślinnych tundry. Zwraca uwagę wysoki udział ziarn pyłku *Alnus* i *Betula,* rodzajów reprezentowanych przez szczątki makroskopowe *Alnus viridis* (1 owoc) i *Betula nana* (liczne liście, owoce, łuski owocowe i drewno). Tak znaczny udział pyłku obu tych rodzajów prawdopodobnie wiąże się częściowo z ich dalekim transportem w warunkach bezleśnej tundry. W zgodzie z wynikami badań nad szczątkami makroskopowymi roślin pozostają duże ilości pyłku *Cruciferae, Cyperaceae* i *Gramineae*, czego nie można powiedzieć o rodzinie *Caryophyllaceae*, reprezentowanej obficie we florze makroskopowej. Dość znaczny w spektrach udział *Compositae* (*Artemisia*) i *Chenopodiaceae*, a zwłaszcza *Gramineae*, to „stepowe" elementy w składzie zbiorowisk tundry z Góry Kalwarii.

W dolnej, oddzielonej części tabeli podane są nazwy rodzin i rodzajów, których przedstawiciele nie należą do składu tundry. Ich sporómorfy pochodzą bądź to z osadów starszych wiekiem (interglacjalnych, trzeciorzędowych, mezozoicznych), bądź też z dalekiego transportu (*Pinus* t. *silvestris*, a być może również *Abies* i *Picea*).

Obraz roślinności

W składzie flory zachowanej w osadzie z Góry Kalwarii reprezentowani są przedstawiciele różnych zbiorowisk roślinnych od wodnych poczynając, poprzez bagienne i torfowiskowe do zajmujących siedliska wyniesione i suche.

W jeziorze, którego warstwowy osad denny zawiera szczątki całej omawianej flory, występowały charakterystyczne dla niezbyt głębokich wód otwartych rośliny z rodzajów: *Batrachium, Myriophyllum, Potamogeton* i *Fontinalis*. Przyległe do jeziora siedliska zatorfione zajmowały zarośla *Betula nana*, obfite *Cyperaceae* z dość znacznym zapewne udziałem *Gramineae* oraz takie gatunki, jak: *Chrysosplenium* cf. *tetrandrum, Empetrum* cf. *nigrum, Menyanthes trifoliata, Potentilla palustris, Ranunculus flammula, R. hyperboreus, R. sceleratus, Selaginella selaginoides, Vaccinium myrtillus*, a zapewne i inne. Zbiorowiskom tym towarzyszyły mchy przywiązane do miejsc podmokłych: *Drepanocladus exannulatus, Calliergon giganteum, Scorpidium scorpioides*.

Wzdłuż potoków spływających do jeziora mogły występować zarośla *Alnus viridis* z domieszką *Sambucus* sp. i *Ribes* sp., natomiast tereny wyniesione, suche, o urozmaiconym reliefie pokryte były przez wielogatunkowe zbiorowiska tundry. W jej skład wchodziły płaty wierzb karłowatych (*Salix polaris, S. herbacea, S. reticulata*) i *Dryas octopetala* oraz rozległe łąki, odznaczające się obfitym udziałem gatunków z rodzin: *Caryophyllaceae, Cruciferae* i *Saxifragaceae*. Dość znaczną rolę w tych zbiorowiskach pełnili przedstawiciele roślinności stepowej z rodzin *Compositae* (*Artemisia, Tragopogon*), *Chenopodiaceae* i *Gramineae*. Ich udział nie był jednak wysoki, co, jak się wydaje, jest cechą charakterystyczną dla zbiorowisk tundry na terenach położnych w niedalekim sąsiedztwie brzegu oscylującego lądolodu. Panował tu wówczas klimat surowy, ale nie arktyczny, umożliwiający rozwój dość zwartej pokrywy roślinnej.

Szereg roślin z Góry Kalwarii to gatunki dziś wyraźnie wapieniolubne, cecha podnoszona wielokrotnie w opisach flor dryasowych. Pozostaje to prawdopodobnie w częściwym przynajmniej związku z występowaniem lessu w glebach formowanych w strefie peryglacjalnej. W spektrach pyłkowych z Góry Kalwarii znamienny jest poza tym brak pyłku *Ephedra* i *Hippophaë,* krzewów notowanych dość często w osadach glacjalnych obu ostatnich zlodowaceń.

Flora z Góry Kalwarii odznacza się dużym zróżnicowaniem pod względem współczesnego rozmieszczenia geograficznego jej poszczególnych składników. Z mniejszą lub większą dokładnością oznaczono 50 gatunków roślin naczyniowych, które zaliczyć można do czterech wyraźnie rysujących się grup, reprezentujących różne elementy geograficzne.

Pierwsza grupa to rośliny o rozmieszczeniu arktyczno-alpejskim, obficie zazwyczaj występujące we florach tego typu (17 gatunków). Do mniej licznej grupy drugiej należą rośliny gór Europy środkowej i południowej (10 gatunków). Szczególnie interesująca jest grupa trzecia, słabo dotychczas rozpoznana we florach glacjalnych, obejmująca rośliny obszaru subarktycznego i arktycznego, nie występujące w Europie środkowej, ale ze stanowiskami w Skandynawii (4 gatunki). Do grupy czwartej włączono rośliny rozległej strefy euroazjatyckiej z dość znacznym udziałem elementu borealnego (19 gatunków).

Analiza roślin wchodzących w skład flory z Góry Kalwarii nie pozostawia wątpliwości co do jej związków z roślinnością strefy euroazjatyckiej oraz gór Europy środkowej i południowej. Świadczy o tym również rosnąca w miarę postępujących badań liczba roślin ograniczonych w swym występowaniu do obszarów subarktycznych i arktycznych, posiadających daleko na południu stanowiska kopalne wieku zlodowacenia Saalian albo Vistulian, takich jak *Chrysosplenium* cf. *tetrandrum, Koenigia islandica, Polemonium boreale, Ranunculus hyperboreus, Salix polaris, Silene furcata* i *S. wahlbergella* (K o p e r o w a 1962; T r a l a u 1963; D a n i e l s e n 1970; Ś r o d o ń 1973, 1974).

Dokumentacja paleobotaniczna potwierdza dominowanie tych związków we florach glacjalnych środkowego i późnego plejstocenu, tj. w okresach po zlodowaceniach o maksymalnym zasięgu. Można by sądzić, że we wczesnym plejstocenie w skład bliżej nam nieznanej europejskiej tundry peryglacjalnej mogły wchodzić rośliny, których centrum rozwoju znajdowało się na obszarze subarktycznym i arktycznym. Przypuszczeniu temu zdają się jednak przeczyć wyniki analizy systematyczno-geograficznej, która wykazała, że w górach Europy środkowej liczba roślin o pochodzeniu arktycznym jest znikomo mała (D i e l s 1910; P a w ł o w s k i 1929; P a w ł o w s k a 1972).

Instytut Botaniki Polskiej Akademii Nauk w Krakowie
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