Palynological studies of Holsteinian lake sediments from the Podlasie region, eastern Poland, reveal a relatively abundant occurrence of *Parrotia persica* pollen (Hamamelidaceae). This species, unknown in the late stage of Pleistocene in Poland, was noted in the climatic optimum. This is a new floristic element, which permits a more precise identification of climate changes and which may also be potentially useful as a stratigraphical tool in age determination to separate different interglacial. The similarity to other pollen types of Hamamelidaceae is discussed, and a provisional description for pollen identification of some related taxa provided.

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(Manuscript received 6 May 2002; accepted 30 May 2003)
RESULTS

Modern Parrotia pollen

Grains spherical or oblate, tricolpate, very rarely tetracolpate or porate. Colpus short to rather long and very broad, often irregularly shaped and disrupted in its central part. Colpus membrane covered with large granules, increasing towards the edges of ectoaperture (Fig. 2 B). Reticulum with two-size gradation of meshes-large lumina and small perforations. Large lumina, variable in shape, size from 1.5 to 2.3 μm in one examined grain and between individual pollen grains. Pollen with generally smaller meshes are seldom noted in the reference slide. A reticulum with very small meshes (Fig. 2 A, B) is also noted. The size of lumina decreases slightly in the polar area. Margo present but not clearly defined. Muri narrow, with small scabrae visible only on SEM images. Polar axis varies from 28 to 40 μm.

Fossil Parrotia – type pollen

Grains most often tricolpate (Fig. 3 E–G & H–J), rarely tetracolpate (Fig. 3 K, M) or sometimes pantoporate with more or less clearly defined pores. Semitectum with coarse or finely reticulate sculpture, rarely microreticulate (Fig. 3 A, B); sometimes irregularly perforate – microreticulate. In a few noted specimens it represents some kind of frustulate type (Fig. 3 C). A typical feature clearly visible in grains with coarse reticulum (Fig. 3 A, E, F) is two-size gradation of lumina – very small ones often in clusters (1–4) among larger lumina irregular in shape – rounded or angular. Typically, the size of lumina is only slightly reduced in the polar area in comparison with the mesocolpium. In the mesocolpium, the reduction in reticulum size is seen in a narrow belt around the colpi (building a not clearly defined margo) where the size of lumina is similar to that of small meshes of the mesocolpial area. Muri of reticulum exhibit minute granules. Apertures (hard to observe because of the delicate nature of the pollen) – rather short and broad colpi or rarely pori. Colpus membranes, often disrupted, are covered by large granules varied in size, isolated or arranged in large irregular, elongated and twisted structures (Fig. 3 G, O, R). The size range of fossil grains is difficult to measure because the pollen was often disturbed with disrupted pores. Polar axes vary in length from 35 to 40 μm.

The fossil pollen described above undoubtedly matches those of some taxa of the family Hamamelidaceae, especially Parrotia persica. The commonly observed features include a very characteristic definition of colpi covered with coarse granules, reticulum with two-size gradation of lumina and muri with supratectal scabrae. In our opinion, the fossil pollen represents Parrotia persica. A somewhat similar sculpture can be observed in Fortunearia sinensis and Sinowilsonia henryi.

Modern pollen of Hamamelidaceae has been studied in detail by many researchers (Chang 1964, Lee 1969, Bogle & Philbrick 1980, Zhang 2001). A close resemblance between Parrotia and other members of the family has been recorded. For example, Bogle & Philbrick (1980) suggested features of the reticulum of Parrotia resembled that of Fortunearia rather than Sinowilsonia. In typical specimens, the latter genus shows narrow muri without minute scabrae on the surface. Chang (1964) also cited some similarities between these three genera.

In our opinion, the character of the reticulum with smaller meshes is less typical in the fossil grains (Figs 3 B, F, G & R). The membrane features illustrated in this paper also has much common with that of Sycopsis Oliver (e.g. S. sinensis Oliver) and Distylium Sieb. et Zucc. (e.g. D. racemosum Sieb. et Zucc.) as can be seen in the high resolution SEM micrographs of Bogle & Philbrick (1980; Figs 27, 29) or in LM micrographs of Chang (1964; Fig. 14. 4–9).

Some of these types have ectoapertures developed as illdefined more or less rounded pori, and are similar to specimens in our fossil material. Identification of such fossil grains (rarely noted in the examined interglacial sections) may be less reliable.

The pollen differences in the exine building of Parrotia persica (Fig. 2 A–C), Fortunearia sinensis (Fig. 2 G–I) and Sinowilsonia henryi (Fig 2 D–F) are presented in Table I. They are based on LM and SEM observations of the margo, the presence of supratectal elements, the variation of size of lumina in mesocolpia and in the polar area as well as the character of the membrane cover.

In the pollen diagram from the Kaliłów site (Fig. 4), single grains of Parrotia - type were recorded as early as at the end of a short Pinus and Betula culmination in assemblages of Pinus - Larix L. P.A.Z. (Bińka & Nitychoruk 1996). They were also recorded at the very beginning.
of this subzone at Woskrzenice (Bińka & Nitychoruk 1995), however, its maximum abundance falls in the *Carpinus - Abies* L. P.A.Z. At the end of the interglacial thermal optimum, pollen of *Parrotia* type gradually decreases.

**DISCUSSION**

The striking feature of the fossil grains is the irregular and variable structure of the semitectum. The semitectum varies from typical clear reticulum through to those with irregular lumina, (sometimes with the shape of meshes hardly defined), to a frustillate pollen type. Despite this variation they represent the same species; however, Bogle & Philbrick (1980) in their description of modern *Parrotia* pollen did not mention such variation of the reticulum. The same comment holds for the description of pollen of ironwood reported by Chang (1964) who documented a typical coarse reticulum only, with large lumina up to 2.88 µm in diameter.

In our reference material as well as in the fossil material, pollen have a somewhat finer reticulum (Figs 3 F–L, 2 A, C) than those illustrated by Bogle & Philbrick (1980) and Chang (1964). Grains from the Holsteinian resemble

Fig. 2. SEM micrographs of modern pollen. A–C. *Parrotia persica*: (A) Oblique polar view, atypical pollen grains with small meshes of reticulum; (B) Colpus area, membrane cover with large granules and narrow belt of tectum perforated; (C) Typical size of lumina on mesocolpium, muri covered with small granules. D–F. *Sinowilsonia henryi* modern pollen: (D) Reticulum with broad muri and small meshes passes into tectum perforated in polar area; (E) Colpus area; (F) Muri of reticulum without granules. G–I. *Fortunearia sinensis* modern pollen: (G) pollen with coarse reticulum; (H) Colpus area with small granular membrane and clear perforate belts around; (I) Reticulum with small bumps in lumina and muri covered with granules. Scale bars – 10 µm (A, D, G); 5 µm (B, H); 2 mm (C, E, F & I).
ironwood pollen from the Lower Pleistocene illustrated by Julia & Suc (1980). Lee (1969; quoted by Bogle & Philbrick 1980) reports variations in ectoaperture number (also observed in our modern material) in Parrotia, which may be syncolpate, dicolpate or tetracolpate. As it was described above, porate pollen was also recorded in the fossil and modern material.

Variations in the semitectum of the same species occur in other genera of the family Hamamelidaceae. Bogle & Philbrick (1980) noted that the foveolate and scrobiculate sculpturing occurs rarely in Sinowilsonia henryi modern pollen. Variation in mesh size can also be seen in modern Fortunearia pollen taken from bisexual and male flowers (cf. SEM micrographs in Zhang 2001; Figs 1 – 9).

In our reference material we also found Sinowilsonia pollen with an aberrant reticulate sculpture (Fig. 2 D – F) however, differently formed from that illustrated by Bogle & Philbrick (1980; Fig. 22 B – C).

There are only a few exotic plant taxa, known from the Holsteinian and the Eemian interglacial in Poland, that have potential diagnostic importance for age determination. Most taxa (i.e. Buxus sempervirens L., Syringa, Viburnum lantana L., Rhus cotinus L., Olea, Tilia tomentosa Moench, Osmunda cinnamomea L., Ilex aquifolium L., Cornus mas L. and Vitis sylvestris C.C. Gmelin) are noted in both interglacials with variable frequency. The last three taxa mentioned above have a western or southern distribution pattern in Europe (outside Poland), and they occur in the investigated area in the Holocene. The Holsteinian interglacial is distinguishable from Caucasus. Parrotia had greater potential for migration already during the continental Pinus-Larix L.P.A.Z., but shady communities with Taxus and Picea probably retarded its spread despite its high range of tolerance in this respect. The fact that it may take about 25 years to produce flowers and fruits (Łukasiewicz 1985) is also important as a limiting factor for an interglacial migration of ironwood. The interglacial migration rate of Parrotia (similar to Pterocarya) was slow possibly due to the presence of a migration lag and a large distance from glacial refuges.

Table I. Differential characters of the Parrotia persica, Fortunearia sinensis and Sinowilsonia henryi pollen (modern material).

<table>
<thead>
<tr>
<th>Exine features</th>
<th>Parrotia persica</th>
<th>Fortunearia sinensis</th>
<th>Sinowilsonia henryi</th>
</tr>
</thead>
<tbody>
<tr>
<td>membrane cover</td>
<td>coarse granules</td>
<td>fine granules</td>
<td>fine granules</td>
</tr>
<tr>
<td>margo</td>
<td>narrow microret. belt</td>
<td>broad belt (microret. or perforate)</td>
<td>more or less solid margo (sometimes with perforations) esp. near the ends of colpi, in the border with mesocolpium area not clearly defined, in grains with aberrant sculpture feature less visible</td>
</tr>
<tr>
<td>sexine 3</td>
<td>scabrae (SEM)</td>
<td>scabrae (SEM)</td>
<td>lack of scabrae</td>
</tr>
<tr>
<td>bottom of lumina</td>
<td>with rare small bumps</td>
<td>with small bumps</td>
<td>smooth</td>
</tr>
<tr>
<td>size of reticulum in mesocolpium and polar area</td>
<td>almost the same size</td>
<td>almost the same size</td>
<td>smaller than in mesocolpium</td>
</tr>
</tbody>
</table>


Grana 42 (2003)
Fig. 4. Simplified pollen diagram of Holsteinian sediments at Kalilów with the curve of Parrotia typed in capitals (after Bińka & Nitychoruk 1996).
These facts suggest that *Parrotia* may be a new important palaeofloristic component of interglacial communities of Poland, both as climatic indicator and useful stratigraphical tool in age determination.

**ACKNOWLEDGEMENT**

This research was supported by a grant from the Polish State Committee for Scientific Research (6 PO4C3921).

**REFERENCES**


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