

Special issue paper

Subtropical relicts in the Pliocene flora of Brunssum (The Netherlands)

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Abstract

Macroscopical remains of the following genera in the Early Pliocene flora found near Brunssum (The Netherlands) are described: *Calamus*, *Hartia*, *Spiromatospermum*, *Symplocos*, *Toddalia*, *Trigonobalanus*, *Turpinia*. These genera have a subtropical character; their recent representatives occur in evergreen subtropical and tropical montane forests. Only two of them have been found in other Early Pliocene deposits in Europe, but all of them have been recorded in Miocene beds in this area. The relict character of part of the Brunssum flora is discussed in relation to palaeogeographic and climatic factors. Of special interest is a comparison with a living assemblage associated with *Trigonobalanus* in the Andean forest of Colombia (South America).

Introduction

In their monograph on the Pliocene floras of the border region between The Netherlands and Germany, Reid & Reid (1915) described fossil fruits and seeds found in a locality near Brunssum (province of Limburg, The Netherlands, Fig. 1). At that time, the composition of the fossil flora was considered to be so similar to that found near Reuver and Swalmen, about 40 kilometres further north, that they were thought to be of the same age, but later stratigraphical and pollen-analytical studies showed that the clay beds at the latter localities are of a different age (Zagwijn 1960). The material from Reuver and Swalmen came mainly from a single horizon within the Reuver Clay Member, which is of Reuverian and thus of Late Pliocene age. The material from Brunssum was found at several levels within another member, the Brunssum Clay of Early Pliocene (Brunssumian) age (Zagwijn 1960). In the paper cited, the Brunssum Clay was subdivided locally into six lithozones that

were numbered in descending order. Two of them are particularly rich in brown coal and humic clay (lithozones 2 and 4); the other zones are made up of clays that are less rich in organic components and that are sometimes more sandy as well. Also some new localities of fossil floras in the Brunssum Clay were mentioned. A flora found in a clay pit called Ora et Labora occurred in lithozone 2, and two other floras found in a pit called Bouwberg came from lithozones 4 and 5. The material mentioned by Reid (1915) as found in another pit in this area, probably came from the lower part of the Brunssum Clay too. In 1976 another fruit and seed flora was found in a pit a few kilometres further north, in the municipality of Schinveld (the Mol pit). This flora lay in a sand lense which was very rich in wood and other plant remains and was situated in the upper part of the Brunssum Clay (probably lithozone 2).

Most of the macroscopic remains from Brunssum await further description. Kirchheimer (1957) mentioned a fossil endocarp of *Symplocos*, now

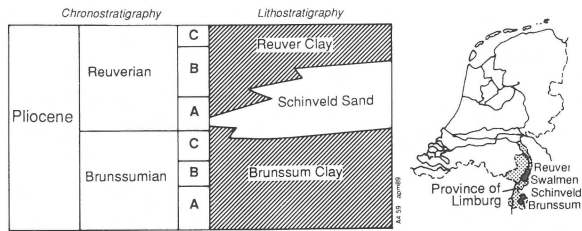


Fig. 1. Stratigraphy of the Pliocene in the southern Netherlands. Location of sites mentioned.

lost. Some specimens have been illustrated by Zagwijn (1959), and a specimen belonging to *Toddalia* has been described by Gregor (1979). The present paper deals with some finds of special interest, which are discussed in more detail because of their subtropical relationship and their late occurrence in this part of Europe.

Composition of the Brunssum flora

Although the floras from different sites in the Brunssum area differ from each other in composition due to palaeo-environmental factors, they are very similar in terms of phytogeographical relationships and will therefore be discussed as a whole. Most of the finds (except those from the Mol pit) have been made in heavy, very humic clay. Preservation is generally very good; they are not damaged by transport. No material obviously reworked from older beds was encountered. On these grounds, the presence of a number of species found in different places and hitherto almost unknown from Pliocene beds must be regarded as primary. These species have a subtropical or tropical montane affinity, and will be described below (7 species).

The greater part of the Brunssum flora, which now totals more than 90 named species, is phytogeographically related to South East Asia and North America (60% of the total). The remainder is European, Holarctic, or Cosmopolitan.

The following 75 genera from the Brunssum Clay have been determined so far:

Gymnosperms: *Abies*, *Picea*, *Pinus*, *Tsuga*, *Taxodium*, *Sequoia*, *Glyptostrobus*, *Cunninghamia*, and *Torreya*.

Angiosperms: *Acer*, *Actinidia*, *Aesculus*, *Alnus*, *Anonaceae* gen., *Berchemia*, *Brasenia*, *Bucklandia*, *Calamus*, *Camellia*, *Carex*, *Carpinus*, *Carya*, *Cladium*, *Cornus*, *Corylopsis*, *Corylus*, *Cyclocarya*, *Decodon*, *Diospyros*, *Dulichium*, *Epipremnum*, *Eucommia*, *Euryale*, *Fagus*, *Fothergilla*, *Hancea*, *Hartia*, *Ilex*, *Jasminum*, *Lauraceae* gen., *Liquidambar*, *Liriodendron*, *Magnolia*, *Meliodendron*, *Meliosma*, *Najas*, *Nuphar*, *Nyssa*, *Orixa*, *Ostrya*, *Potamogeton*, *Proserpinaca*, *Prunus*, *Pterocarya*, *Pyracanthus*, *Pyrus*, *Quercus*, *Ranunculus*, *Rhus*, *Sambucus*, *Schizandra*, *Scirpus*, *Sparganium*, *Spirematospermum*, *Staphylea*, *Stuartia*, *Styrax*, *Symplocos*, *Thalictrum*, *Toddalia*, *Torreya*, *Trapa*, *Trigonobalanus*, *Vitis*, and *Zelkova*.

From the adjoining Lower Rhine region of Germany, Van der Burgh (1978, 1983) has described an equally rich flora found at several sites in beds of the same age as the Brunssum Clay. He named 103 species belonging to 71 genera, and gave a detailed evaluation of the habitats represented in these floras.

Descriptions

Calamus daemonorops (Unger) Chandler (Palmae). – Plate I.1.

Loc.: Bouwberg pit (Brunssum)

Age: Brunssumian (A)

Spines, pointed, often broken, with a flattened base, sometimes two adherent. Originally 3–7 mm long, 12 specimens. These fossils have been attributed to the palaeotropical lianaceous genus *Calamus* by Chandler (1957). *Calamus* is an element of evergreen forests in the paratropical zone and of tropical rainforest in South East Asia. It has been found in several floras of Miocene age in Europe (Mai 1964, Gregor 1978).

Hartia quinqueangularis (Menzel) Mai
(Theaceae). – Plate I.2.

Loc.: Bouwberg pit

Age: Brunssumian (A)

An immature capsule showing partial dehiscence, traces of an apical point, calyx damaged, with short sepals. Dimensions: 6.7×4 mm. The specimen conforms to *Aquilaria germanica* (Menzel 1913), which according to Mai (1975) is an immature fruit of *Hartia* (Theaceae). At present, *Hartia* is an evergreen element of southern China and Indochina, occurring in evergreen forest of the Laurel type.

Spirematospermum wetzleri (Heer) Chandler
(Zingiberaceae). – Plate I.3.

Loc.: Bouwberg pit

Age: Brunssumian (A)

Five specimens of this characteristic seed, showing a basal depression, a slightly twisted shape, and a finely striated spiral ornamentation. These seeds are 5.8–8.5 mm long and 3.1–4.2 mm in diameter. Another specimen is illustrated in Zagwijn (1959, Plate 1, Fig. 4). Chandler (1925) was the first to prove that this fossil, which is common in Miocene and older assemblages of the Tertiary, belongs to an extinct genus of the Zingiberaceae.

Symplocos lignitarum (Quenstedt) Kirchheimer
(Symplocaceae) – Plate I.4.

Loc.: Ora et Labora pit

Age: Brunssumian (C)

Endocarp, elongated, 4.9 mm long, 2.5 mm wide, flattened, trilocular, with 4 to 5 flattened ridges on each side and a small apical hollow. The specimen has also been illustrated in Zagwijn (1959, Plate 1, Fig. 7). It is very similar to finds from many other sites, mostly of Miocene age. A Pliocene age has been assigned to those in the Lower Rhine area described by Van der Burgh (1978, 1983) from beds of an age similar to that of the Brunssum Clay. Other *Symplocos* species too are present in these beds as well as in Pliocene deposits of the Wetterau region (Federal Republic of Germany – Mai 1973).

Toddalia rhenana Gregor (Rutaceae) –
Plate I.5a–c

Loc.: Bouwberg pit

Age: Brunssumian (A)

One complete seed (5.4 mm long, 3.1 mm high, 2.1 mm wide) and a fragmentary specimen closely resemble the reniform, elongated, shiny seeds with a triangular hilum and prominent raphe described from several sites and originally attributed to Leguminosae under the name *Cytisus latisiliquata* Ludwig or *Martyia naviculaeformis* E.M. Reid. One fossil from Brunssum was illustrated under these names by Zagwijn (1959). Gregor (1979), who showed that all these finds belong to *Toddalia* but to different species, considered the specimen from Brunssum to be a separate variation (*T. rhenana* var. major). The present author hesitates to follow him in this respect, because the number of specimens is too small to permit statistical analysis. This species has been described from Miocene beds and from the Pliocene Red Clay at Fortuna Garsdorf (Lower Rhine area, Federal Republic of Germany, Van der Burgh 1983). The latter deposit has the same age as the Brunssum Clay.

Trigonobalanus exacantha Mai (Fagaceae) –
Plate I.6ab

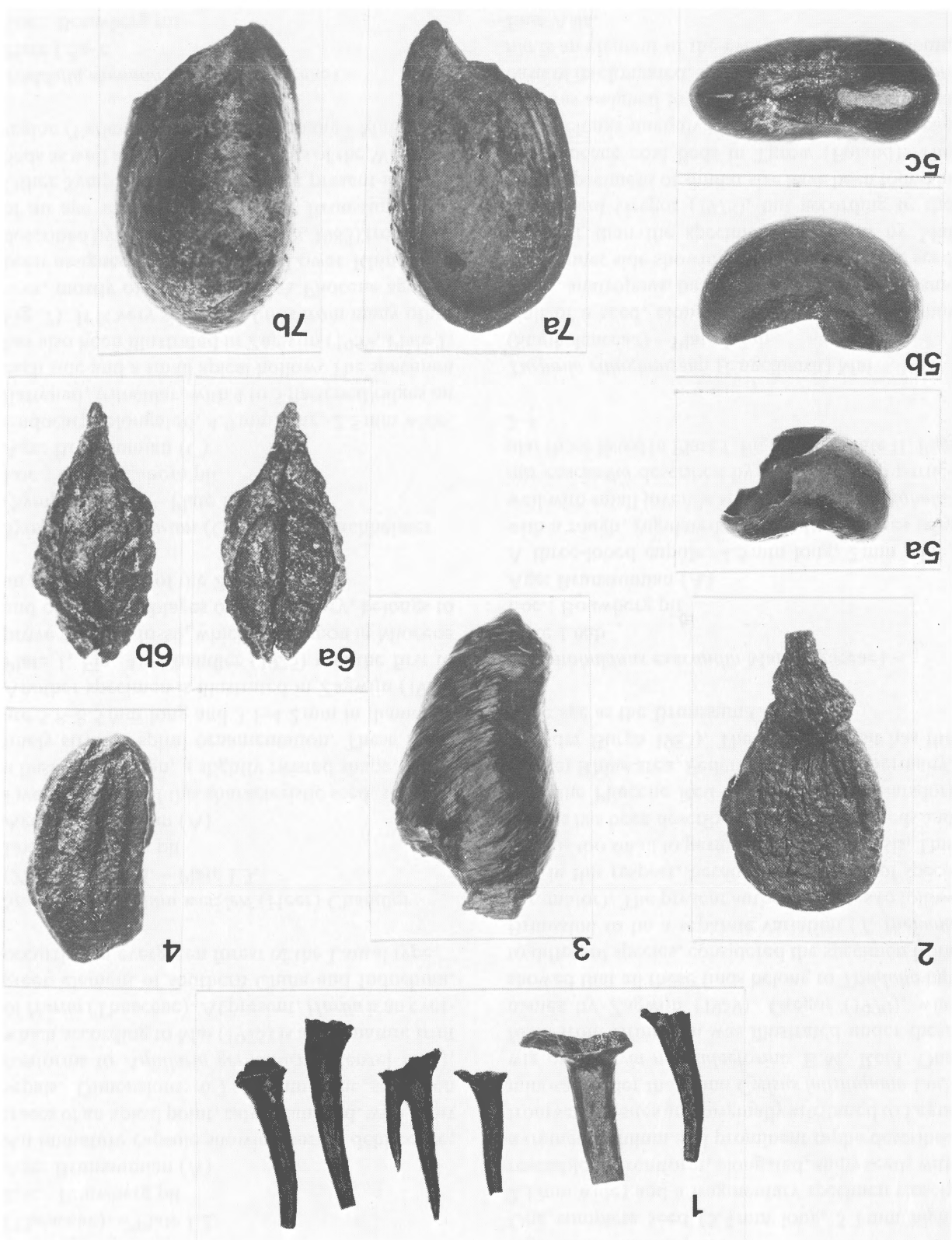
Loc.: Bouwberg pit

Age: Brunssumian (A)

A three-lobed cupule, 4.5 mm long, 2 mm wide, with a rough, rugulated surface. It compares very well with small juvenile specimens of *Trigonobalanus exacantha* described by Mai (1970), in particular those listed in Plate I, Fig. 25 and Plate II, Figs 2–4.

Turpinia ettinghausenii (Engelhardt) Mai
(Staphyleaceae) – Plate I.7ab

Half of a seed, elongated (8.7 mm long, 5.3 mm wide), anatropous, base oblique, hilum large, damaged, inner side showing raphe channel. The seed is larger than the specimens described by Mai (1964) and Gregor (1978), but according to the latter, specimens of similar size have been found in the Miocene coal beds in Turow (Poland). The seed belongs unequivocally to the Staphyleaceae and was assigned to *Turpinia* by Mai (l.c.) on the basis of its elongated, slightly angular shape. *Turpinia* is an element of the evergreen forest of South East Asia.



Remarks on *Trigonobalanus*

Of special interest among the finds is the occurrence of *Trigonobalanus*. This genus of Fagaceae, characterized by a lobate cupule (3 or 5 lobes, not 4 as in *Fagus* and *Nothofagus*) and trigonous achenes, was found for the first time alive as late as 1962 during an expedition in the mountains of North Borneo and another species was recognized among older herbarium material (Forman 1964). *Trigonobalanus* is a primitive genus. At present it is found in tropical montane forests.

Soon after the first recent finds were reported, it was recognized that *Trigonobalanus* also occurs in a fossilized state. In Europe, Mai (1970) reported several species from many localities. He described three species from the Early Tertiary (possible belonging to a single species) and a fourth species from the Miocene, i.e., *Trigonobalanus exacantha* Mai. Mai (l.c.) made an elaborate evaluation of the recent and fossil habitats of *Trigonobalanus*. His main conclusion was that during the Tertiary in Europe this genus was an inhabitant of the Lauraceae evergreen forest type on fertile upland soils. It may have transgressed into lower areas, such as the river flood-plain forest, but was absent in oligotrophic, peaty habitats.

In 1979, Lozano et al. reported the unexpected find of another recent species in the Subandean cloud forest of northeast Colombia (South America). This meant that *Trigonobalanus* is another example of a genus with a disjunct Amphi-Pacific distribution. In a later publication the same authors (Hernandez-Camacho et al. 1980) considered *Trigonobalanus* to be an immigrant which had arrived

from the north via Central America and survived in very humid habitats of climatic equability. Melville (1982) disagreed with this view and suggested that this primitive genus had originated in a western part of the Gondwana Continent and that the present disruption could be explained by continental drift.

However, Van der Hammen & Cleef (1983) pointed out that in the Andean forest *Trigonobalanus* is associated with a number of genera with a similar tropical Amphi-Pacific distribution, which means that at present these genera occur in both the Malayan region and the tropical montane zones of America. It therefore seems that in all likelihood this group of plants immigrated into South America from the north after the emergence of the Panama land connection, which came into existence less than 5 million years ago. At first this connection was intermittent, permitting only the migration of tropical lowland species, but later, when uplift gave rise to the mountain ranges, elements belonging to higher altitudinal zones could migrate, and eventually even temperate and cold elements arrived from the north to populate the high mountains of South America.

It is conspicuously noticeable that from the 17 genera of Malayan-American distribution which occur in the Andean forest (Van der Hammen & Cleef, l.c.) as many as five are represented in the Brunssum flora (*Meliosma*, *Styrax*, *Symplocos*, *Trigonobalanus*, and *Turpinia*), although even more are known to occur in the older Tertiary of Europe. It seems that this group of plants, which now have a disjunct tropical Amphi-Pacific distribution, originally had a wider range extending as

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Plate I

- I.1. *Calamus daemonorops* (spines). Enlargment: $\times 6$. Location: Bouwberg pit, Brunssum.
- I.2. *Hartia quinqueangularis* (immature fruit). Enlargment: $\times 7$. Location: Bouwberg pit, Brunssum.
- I.3. *Spirematospermum wetzleri* (seed). Enlargment: $\times 8$. Location: Bouwberg pit, Brunssum.
- I.4. *Symplocos lignitarum* (endocarp). Enlargment: $\times 8$. Location: Ora et Labora pit, Brunssum.
- I.5a, b, c *Toddalia rhenana* (seeds). Enlargment: $\times 7$. Location: Bouwberg pit, Brunssum. a: fragment of seed, b, c: lateral and ventral views of complete seed, respectively.
- I.6a, b *Trigonobalanus exantha* (juvenile cupule). Enlargment: $\times 10$. Location: Bouwberg pit, Brunssum. Two sides of the same specimen.
- I.7a, b *Turpinia ettinghausenii* (half of seed) Enlargment: $\times 6$. Location: Moll pit, Schinveld. a: inner side, b: outer side.

The original specimens are kept in the collection of the Department of Palaeobotany of the Geological Survey of the Netherlands. Photographs by J. van Delft.

far as western Europe. Being adapted to a similar climate and environment, they could migrate as a group. During this process changes took place at the species level but the generic character remained unchanged. This probably means that in the Late Tertiary these plants were adapted to conditions similar to those prevailing today: habitats characterized by fertile soils and a warm to warm-temperate moist climate showing moderate seasonal effects.

Concluding remarks

During the Early Pliocene (Brunssumian) several plants occurred in the Brunssum area that have not been found later than the Miocene elsewhere in Europe (*Calamus daemonorops*, *Hartia quinqueangularis*, *Spirematospermum wetzleri*, *Trigonobalanus exacantha*, and *Turpinia ettinghausenii*). All of these have subtropical affinities. Two more species with a similar climatic preference (*Symplocos lignitarum*, *Toddalia rhenana*) have been found in the Early Pliocene of the nearby Lower Rhine region of Germany (Van der Burgh 1978, 1983) but are not reported from other Pliocene sites.

The Brunssum Clay Member was deposited in the upper deltaic part of a coastal plain formed by the outflow of a river system, a precursor of the present river Rhine (Zagwijn 1989, Fig. 10). In the adjoining area, as pointed out by Van der Burgh (1983), the fossil floras indicate various environments, i.e., upland forest and marshy forest; curiously enough, the floodplain forest is underrepresented. Nevertheless, the general picture of a lowland river bordered by marshy interfluvial areas is consistent with the palaeogeographical reconstruction.

The pollen-analytical data pertaining to the Brunssum Clay (Zagwijn 1960) show that there were large bog areas in which *Sequoia* dominated and *Taxodium* and *Nyssa* swamps were present locally. A large proportion of the fossil fruits and seeds found in the Brunssum Clay proper probably came from other environments, in particular river flood plains and uplands, and were transported

over some distance. This distance was perhaps relatively short, because the Brunssum site is at the southern limit of the palaeo-delta, which means that tributaries from southern upland regions could have brought this material.

Both the pollen-analytical and the other palaeobotanical data indicate that the climate was warm and moist during the early and late parts of the Brunssumian Stage (Brunssumian A and C). Mean summer temperatures may have been around 20 to 22 degrees Celsius, and mean temperatures during the coldest winter month were certainly much higher than at present; frosts did not occur, as suggested by, for instance, the presence of the palm *Calamus*. However, the presence of a large group of deciduous trees indicates substantial seasonal temperature variations. Furthermore, the widespread formation of peat indicates that the climate was moist and oceanic.

The foregoing palaeogeographic and palaeoclimatic data for this part of western Europe so close to the sea may help explain why so many species restricted to the Miocene elsewhere in Europe could live there during the Early Pliocene. These coastal lowlands can be seen as a refuge area where a group of plants of subtropical character survived and found climatic conditions which had prevailed over large parts of Europe during most of the Miocene. They were not found there in the Pliocene, however, when the climate was either too cold or too dry.

Acknowledgement

This paper is dedicated to Thomas van der Hammen on the occasion of his 65th birthday.

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