Cretaceous Research 30 (2009) 483–495

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

Conifers from the Santonian of Limburg, The Netherlands

Hylke F. Bosma [a,*], Johanna H.A. Van Konijnenburg-Van Cittert [a,b,c], Raymond W.J.M. Van der Ham [b], Henk W.J. Van Amerom [d], Christoph Hartkopf-Fröder [e]

[a] Nationaal Natuurhistorisch Museum Naturalis, P.O. Box 9517, 2300 RA Leiden, The Netherlands
[b] Nationaal Herbarium Nederland, Leiden branch, P.O. Box 9514, 2300 RA Leiden, The Netherlands
[c] Universiteit Utrecht, Budapestlaan 4, 3584 CD Utrecht, The Netherlands
[d] Jos Habetsstraat 30, 6419 CD Heerlen, The Netherlands
[e] Geologischer Dienst Nordrhein-Westfalen, Postfach 100763, 47707 Krefeld, Germany

ARTICLE INFO

Article history:
Received 31 January 2008
Accepted in revised form 18 September 2008
Available online 9 October 2008

Keywords:
Conifers
Santonian
Cretaceous
Limburg
The Netherlands

ABSTRACT

The Santonian conifers from Limburg (The Netherlands) described by Kräusel (1922 Mededeelingen van 's Rijks Geologischen Dienst, Serie A, 2, 40) have been revised and combined with those from a coeval flora from a nearby location. The diversity of the flora is increased; new species have been added and others have been reassigned to different genera. *Aachenia debeyi* is emended on the basis of cuticle data. Comparison with other, regional, Late Cretaceous floras shows a distinct change in species during this period. Compared to the coeval floras of the world, the Santonian flora from Limburg is intermediate between Central European and American floras.

1. Introduction

In 1922 Kräusel described a Santonian flora from a borehole drilled by the "Dienst der Rijksopsporing van Delfstoffen" near Swalmen (Limburg, The Netherlands, see Fig. 1). The flora consists mainly of conifer remains (~80%) and some angiosperms. Fungal remains are found on several of the conifer leaves.

Material from the same borehole, not described by Kräusel (1922), was found in the collections of the former Geological Suvery of The Netherlands. Undescribed Santonian material, collected in the 1950s near 'Grenspaal 7' (boundary post 7, on the border between Belgium and The Netherlands, near the village of Cottessen, see Fig. 1), was also retrieved. On discovery of this new material it was decided to re-examine the material described by Kräusel (1922) and combine the data from both localities.

The sediments encountered in the borehole near Swalmen originate from the Aachen Member of the Aachen Formation (Santonian) and the sediments from 'Grenspaal 7' originate from the Hergenrath Member of the Aachen Formation, which is also dated as Santonian (see Fig. 2) (Felder and Bosch, 2000; Niebuhr et al., 2007). In both localities the majority of the fossil remains are coniferous in origin and they comprise two of the same species in high abundance.

When Kräusel (1922) described the flora from Swalmen, the following conifer species were distinguished: *Araucaria crassifolia* Corda, *Elatocladus elegans* (Corda) Seward, *Moriconia cyclotoxon* Debey et Ettingshausen, *Sequoia reichenbachii* (Geinitz) Heer, *Sequoia* sp., conifer wood. All of these conifer species are revised and, where necessary, assigned to other genera or species. New taxa found both in the material from Swalmen and 'Grenspaal 7' are also described.

The Santonian flora of Limburg is compared with other Late Cretaceous (Campanian and Maastrichtian) floras of the same region as well as with coeval floras from different regions of the Northern Hemisphere, especially Western Europe and the United States.

2. Material and methods

The material from the borehole near Swalmen (51° 13′ 56″ N; 06° 02′ 17″ E) originates from an 1112.02 m deep core, which pierced the Pleistocene, Neogene, Paleogene, Cretaceous and Carboniferous. The Cretaceous is represented by 17 m and was originally described by the "Dienst der Rijksopsporing van Delfstoffen" (1918) as follows:

* Corresponding author.
E-mail address: bosma@naturalis.nl (H.F. Bosma).

0195-6671/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cretres.2008.09.007

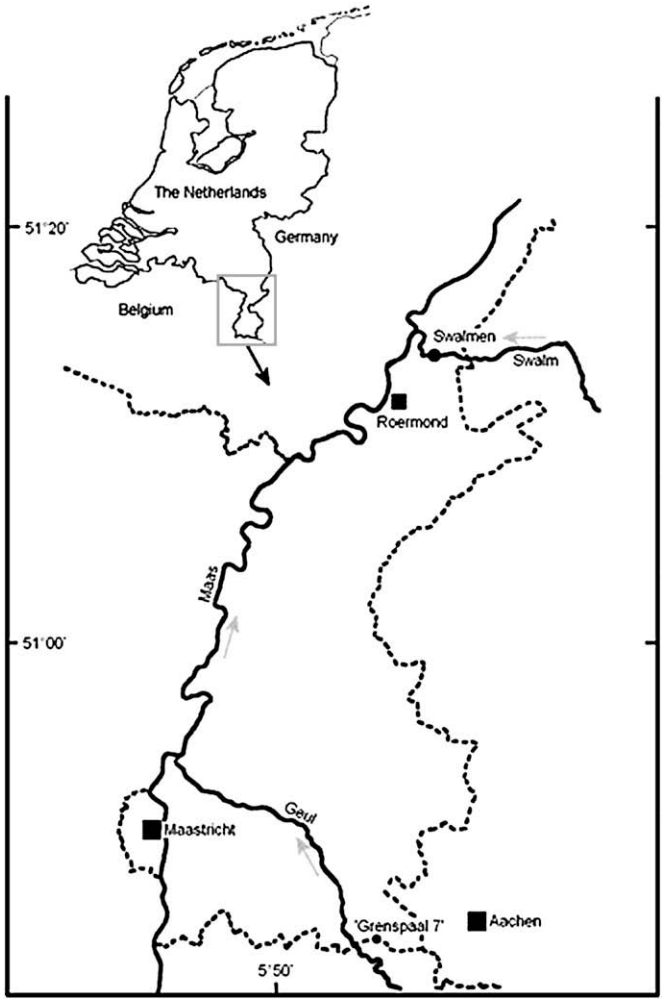

Fig. 1. Map of Limburg, The Netherlands, showing both Santonian localities.

642–646 m: grey, marly, fine-grained sandstone with wood remains
646–653 m: no core preserved
653–659 m: dark to light grey clay with plant remains

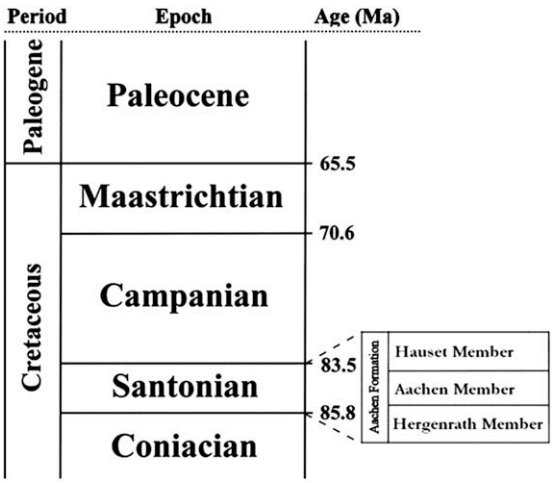

Fig. 2. Stratigraphical column of the Late Cretaceous.

Kräusel (1922) examined the lower 6 m of the Cretaceous profile. He distinguished six different "zones" starting at the base of the section:

1. Sandy clay with a few plant remains and frequent lignite splinters
2. Zone of the root bed
3. Zone of *Elatocladus* (*Cunninghamites*) *elegans* (Corda) Seward with *Sequoia reichenbachii* (Geinitz) Heer
4. Zone with *Moriconia cyclotoxon* Debey et Ettingshausen and *Myrica pseudo-quercifolia* Kräusel
5. Zone with dicotyledons with narrow leaves (*Salix*?, *Myrica*)
6. Zone with remains of large dicot leaves

All plant fossils are compressions, commonly with cuticles. The conifer material is derived from zones 3 and 4 exclusively. All Kräusel's (1922) figured conifer material has been retrieved, but his original cuticle preparations seem to have been lost.

The material from 'Grenspaal 7' (50° 45′ 38″ N; 05° 57′ 22″ E) originated from an exposure, in the bank of the small stream 'Grensbeek' near Cottessen. Here the Cretaceous sediments span 1.20 m and have been described by W. Felder (1956, unpublished internal report) as follows:

65–120 cm: Soft bank, sometimes with fossils. At the base mainly echinoids. At one horizon multiple fragments of fossilized wood
50–65 cm: First hard bank with few fossil remains, mostly fragmented
20–50 cm: Second hard bank with numerous fossils, especially right above the horizon beneath
20 cm: Horizon with numerous fossil remains
0–20 cm: Lower hard bank with few fossils. Sometimes clusters of highly fragmented fossils
Soft base without any fossil remains

All plant fossils are compressions, commonly with cuticles. The fossil plant material is derived from the lower 65 cm of the exposure.

Both Meessen (1980, unpublished internal report) and the palynomorphical data of one of the authors (CH-F) indicate the same age for both localities.

The specimens have been studied with the aid of a dissecting microscope and, where possible, cuticle preparations were made. For this purpose, small pieces of the coalified leaf material were macerated in Schulze's reagent ($KClO_3$ and 30% HNO_3) and neutralized with 5% ammonia. The cuticles were then separated into upper and lower cuticle with the aid of needles, mounted in glycerine jelly and sealed with paraplast.

All studied material is stored at the Nationaal Natuurhistorisch Museum Naturalis and numbered with a prefix JMS.

For the selected synonomy, the data for the basionyms and references and/or data important for identification have been used. In the comparison with different Late Cretaceous localities in North America and Europe only material which is identified beyond generic level has been used, except for *Pagiophyllum*-species.

3. Systematic palaeontology

Order Coniferales
Family ?Araucariaceae Henkel and Hochtstetter 1865
Morphogenus *Brachyphyllum* Brongniart 1828
Brachyphyllum crassifolium (Corda) comb. nov.
Figs. 3G, 4A, B