International Journal of Coal Geology 159 (2016) 57–70

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

An early Eocene *Sphagnum* bog at Schöningen, northern Germany

Walter Riegel [a,b], Volker Wilde [a,*]

[a] Senckenberg Forschungsinstitut und Naturmuseum Frankfurt am Main, Senckenberganlage 25, 60325 Frankfurt am Main, Germany
[b] Georg-August-Universität Göttingen, Geowissenschaftliches Zentrum, Geobiologie, Goldschmidtstr. 3, 37077 Göttingen, Germany

ARTICLE INFO

Article history:
Received 10 December 2015
Received in revised form 21 March 2016
Accepted 24 March 2016
Available online 8 April 2016

Keywords:
Lignite
Palynology
Ombrogenous peat
Restionad bog
Palaeoclimate
Palaeoecology

ABSTRACT

A thin local seam in the early Eocene lignite succession of the opencast mine Schöningen-Südfeld (Lower Saxony, northern Germany) revealed pollen and spore assemblages of low diversity. They are characterized by an abundance of *Sphagnum*-type spores, especially *Tripunctisporis*, and fern and lycopod spores together with the common occurrence of pollen of Ericaceae, Restionaceae and Droseraceae. Well-preserved fragments of *Sphagnum* leaves are common and loricae of *Habrotrocha*-like bdelloid rotifers have been recorded occasionally. We reconstruct an ombrogenous domed peat bog maintained by prolific growth of *Sphagnum* in association with a rich fern cover, oligotrophic and acidophilic plants as well as insectivorous plants indicating severe nutrient deficiency. This resembles in many respects an Eocene equivalent of a Quaternary high latitude *Sphagnum* bog. In view of the significant amount of Restionaceae pollen, however, it appears more similar to Southern Hemisphere restionad bogs. The total lack of a waterlogged layer in the highly permeable substrate strongly argues in favour of a purely rain-fed ombrogenous peat bog. The required high precipitation in combination with frequent wildfires as evidenced by the abundance of charcoal, however, suggests a highly stressed hydrological cycle under an alternating wet/dry climate close to the alleged Early Eocene Climatic Optimum (EECO).

1. Introduction

Peat mosses of the genus *Sphagnum* are outstanding in their ability to store water (up to 20–30 times their dry weight; Yoshikawa et al., 2004) and in generating an acid environment (between pH 3 and 5; Naucke, 1980) within themselves and in their surroundings thus literally creating their own environment (Gerken, 1983). Today the genus *Sphagnum* comprises ca. 300 species and has an almost worldwide distribution (Michaelis, 2011), but especially dominates in high-latitude peat mires of the Northern Hemisphere. The species are widely considered to be preadapted to oligotrophic habitats and attained their present significance and distribution in response to the late Neogene climatic deterioration and to the repeated glacial advance and retreat during the Pleistocene (Greb et al., 2006; Shaw et al., 2010b). However, according to molecular data sphagnoid mosses have a long phylogenetic history indicating that the lineage separated early from the other bryophyte classes (Shaw and Renzaglia, 2004; Shaw et al., 2010a). This is well supported by leaf remains of so-called Protosphagnales ranging back into the Lower Carboniferous (Hübers and Kerp, 2012; Hübers et al., 2013). They are especially known from the Permian of Russia (e.g., Neuburg, 1958, 1960; Ignatov, 1990) and characterized by a midrib, which is missing in leaves of modern *Sphagnum*.

However, in spite of the importance and widespread occurrence of peat mosses today (e.g., Clymo and Hayward, 1982; Greb et al., 2006) and the resistance of their leaves to decay (Kroken et al., 1996) leaf remains of sphagnoid mosses have rarely been described from the fossil record and are extremely rare in the Mesozoic. *Sphagnophyllites* (Pant and Basu, 1978) was described as representing sphagnoid leaves from the Triassic of India. The earliest leaf that was assigned to the genus *Sphagnum* itself has been figured from the Lower Jurassic of Germany (Reissinger, 1950). Another leaf fragment most probably also belonging to the genus was recovered from Upper Cretaceous coals of Greenland (Arnold, 1932), and "*Sphagnum* 'leaf' tissue" was mentioned from the Upper Cretaceous of Wyoming (Wilson and Webster, 1946). For the Cenozoic, Boulter (1994, Fig. 11.9.8) figured a *Sphagnum* leaf which was recovered together with "*Stereisporites*" and fern remains from Paleocene marine clastic sequences of the Forties Field, North Sea, to where they are supposed to have been transported from coastal mires by surface drift or turbidity currents. The only other Paleogene remains of *Sphagnum* leaves figured are from the Baltic Amber (Frahm, 2009). Furthermore, *Sphagnum* leaf remains were mentioned for the Paleogene of the Canadian Arctic (Kuc, 1973a). Leaf remains from Miocene and Pliocene coals or peat of Germany, China and the Canadian Arctic (Kuc, 1973b; Lu and Zhang, 1989; Ovenden, 1993; Schneider, 2012) bridge the gap to the Quaternary record. In contrast to the few remains of leaves a diversity of *Sphagnum*-type spores has been recorded from the Triassic upwards (Krutzsch, 1963; Döring et al., 1966; Schulz, 1970).

Sphagnum peat today is an important sink for organic carbon especially in humid areas of the Northern Hemisphere (e.g., Clymo and

* Corresponding author.
E-mail addresses: wriegel@gwdg.de (W. Riegel), Volker.Wilde@senckenberg.de (V. Wilde).

http://dx.doi.org/10.1016/j.coal.2016.03.021
0166-5162/

Hayward, 1982), but *Sphagnum* has rarely been identified as a peat/coal-forming element before the Quarternary. A *Sphagnum* coal has been described as a “new genetic type of coal” from the Pliocene of China (Lu and Zhang, 1989), and *Sphagnum* peat of a similar age has been recovered from Ellesmere Island (Canadian Arctic; Ovenden, 1993). Based on the occurrence of spores *Sphagnum* was suggested as an element of the coal-forming vegetation in the Miocene of Germany (Thomson, 1952; Minnigerode and Klein-Reesink, 1984). This has recently been confirmed by some leaf remains from the Miocene of Lusatia, Germany (Schneider, 2012). *Sphagnum*-type spores have frequently been observed in the Paleogene of North America and the Arctic and sometimes also been used to suggest peat mosses as common elements of a swamp vegetation (e.g., Sweet and Cameron, 1991; Nichols, 1995; Daly et al., 2011).

This paper presents an early Eocene record of *Sphagnum* leaves together with a great number of *Sphagnum*-type spores. They occur together with pollen and spores of other putative peat-swamp elements in a locally developed lignite at Schöningen, northern Germany (Riegel et al., 2012). This is regarded as strong evidence for a *Sphagnum* peat origin of the respective lignite.

2. Geological situation

Migration of Upper Permian (Zechstein) salt in the subsurface of northern Germany resulted in the formation of numerous salt domes and ridges rising along ancient structural sutures (Baldschuhn et al., 1996). One of them is the prominent NW–SE trending Helmstedt–Stassfurt salt wall which is accompanied by two parallel rim synclines. In the Helmstedt–Schöningen mining district they accommodated up to more than 400 m of alternating terrestrial and marine sediments of late Paleocene to early Oligocene age including several lignite seams of economic importance (Look, 1984; Riegel et al., 2012).

The lignite mine Schöningen Südfeld which will finally be closed in October 2016 still exposes a c. 150 m thick section of the Schöningen Formation, which probably starts in the uppermost Paleocene and covers the entire early Eocene (Riegel et al., 2012). The Schöningen Formation at Schöningen includes nine almost continuous lignite seams (Fig. 1), which are separated by siliciclastic interbeds showing marine influence to varying degrees. Several minor seams, with thicknesses of less than 20 cm, have a lateral extent of up to few hundred metres, but cannot be traced across the entire open cast mine. They have been recognized during various stages of our study and are therefore not included in the numbered series of seams (Riegel et al., 2012). One of them, the object of the present study, has been designated as the “Sphagnum Seam” once the common occurrence of *Sphagnum* leaves and spores became clear. It is situated within the nearly 20 m thick Interbed 4, about 7 m above Seam 3, for which an early Eocene (Ypresian) age can be assumed as discussed by Riegel et al. (2012) on the basis of palynological evidence (pollen, spores and dinoflagellate cysts; Pflug,

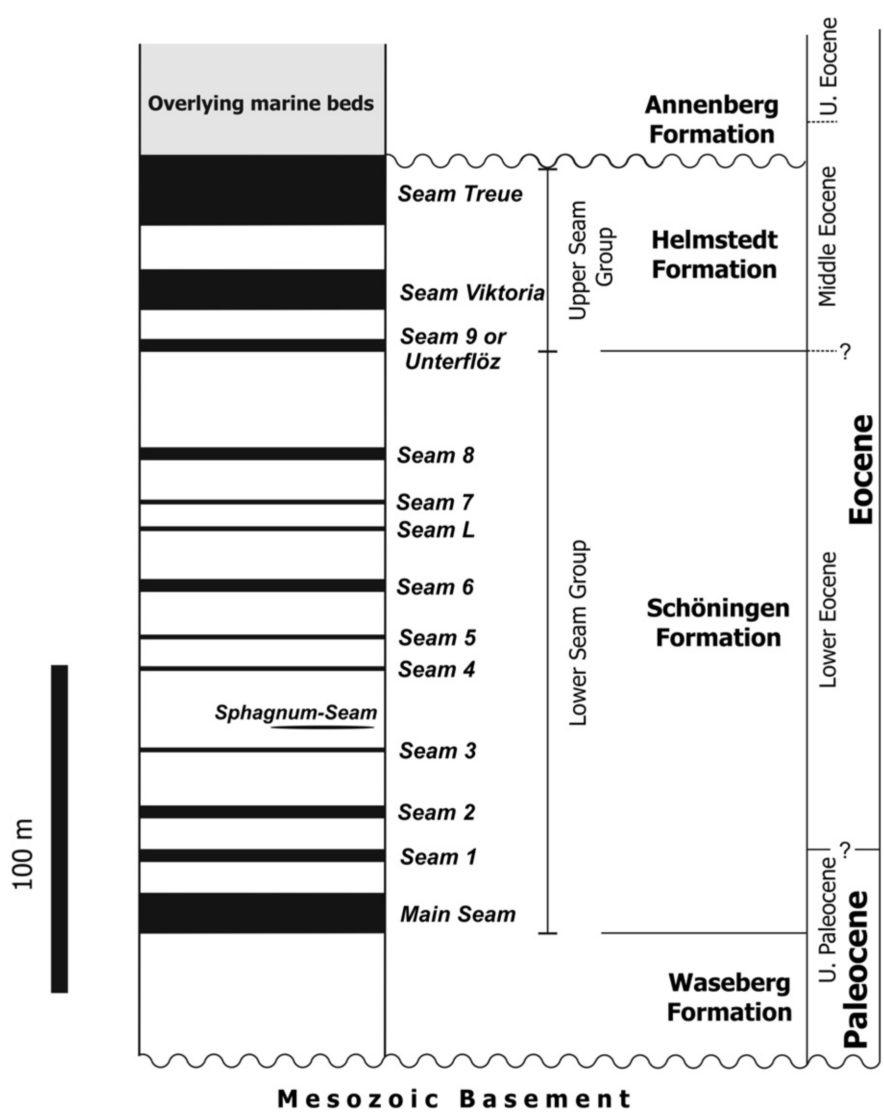

Fig. 1. Generalized section of the Paleogene succession at Schöningen showing the stratigraphic position of the Sphagnum Seam (modified from Riegel et al., 2012).