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Paleogeography and paleoecology of the upper Miocene Zillingdorf lignite deposit (Austria)

A. Bechtel [a,*], D. Reischenbacher [a], R.F. Sachsenhofer [a], R. Gratzer [a], A. Lücke [b]

[a] *Department Angewandte Geowissenschaften und Geophysik, Montanuniversität Leoben, Peter-Tunner-Str. 5, A-8700 Leoben, Austria*
[b] *Institut für Chemie und Dynamik der Geosphäre V: Sedimentäre Systeme (ICG V), Forschungszentrum Jülich, D-52425 Jülich, Germany*

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Abstract

The Zillingdorf deposit formed during the late Miocene filling of Lake Pannon and contains Austria's largest lignite reserves. Two lignite seams are present and developed within frequently flooded, low-lying mires in near shore environments. High sulphur contents are due to the influence of the brackish water body of Lake Pannon. During peat accumulation a transgression forced the NW–SE trending shoreline northeastwards.

Differences in soluble organic matter (SOM) yield and hydrocarbon content of borehole samples and woody macrofossils are related to differences in the content and composition of free lipids of microbial origin and/or hydrocarbons derived from the biogeochemical degradation of plant tissue. Variations of pristane/phytane ratios are interpreted to reflect differences in the redox conditions of the mire. Peatification in an acidic and aerobic environment is further reflected by the predominance of aromatic over saturated hydrocarbons, the presence of an intense complex mixture in the GC traces due to biodegradation processes, high ratios for diasterenes relative to sterenes, and high concentration ratios of hopanes to hop-17(21)-ene of the respective samples. Gelification of plant tissue is governed by microbial activity, as indicated by the positive relationship between gelification index and hopanoids concentration. The composition of terpenoid biomarkers indicates the predominance of gymnosperms over angiosperms and increasing proportions of angiosperms in the peat-forming vegetation with decreasing depth in the upper seam. From the sesqui- and diterpenoids present in the lignite and fossil wood remnants, a predominant role of species of the Coniferales families Cupressaceae/Taxodiaceae are concluded. The preservation of plant tissue is governed by the presence/absence of decay-resistant gymnosperms.

A general influence of the floral assemblage on the isotopic composition of organic carbon of the lignite ($\delta^{13}C=-27.2$ to -24.6‰) is proposed. Decomposition of plant tissue and biogeochemical carbon cycling is assumed to further affect the $\delta^{13}C$ values of the lignite. Carbon isotope data of fossil wood remnants are consistent with their chemotaxonomical classification as gymnosperms ($\delta^{13}C$ between -22.5‰ and -24.9‰) and angiosperms ($\delta^{13}C$ between -25.5‰ and -26.6‰), respectively. The $\delta^{13}C$ data of the extracted cellulose reveal clear differences between fossil wood from gymnosperms (average $\delta^{13}C=-20.3$‰) and angiosperms (mean $\delta^{13}C=-22.9$‰). The higher isotopic difference of about 3.5‰ between cellulose and fossil wood, compared to that found in modern trees, is explained by the smaller effect of ^{13}C discrimination for cellulose when compared with wood during decomposition.

Keywords: Biomarker; Carbon isotopes; Coal petrography; Pannonian Basin; Upper Miocene

* Corresponding author. Tel.: +43 3842 402 6307; fax: +43 3842 402 6302.
E-mail address: Achim.Bechtel@mu-leoben.at (A. Bechtel).

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1. Introduction

Upper Miocene lignite deposits in the Pannonian Basin System formed in shallow lacustrine, delta plain and fluvial environments, which became increasingly widespread as Lake Pannon was filled during the late Miocene (e.g. Magyar et al., 1999). Economically most important are coal deposits in Hungary (Visonta-Bükkábrány), Yugoslavia (Kolubara, Kostolac) and Bosnia (Kreka; see Fig. 1 for position of deposits), which together account for about 5% of the world's lignite production. Upper Miocene lignite in the Vienna Basin, a northwestern subbasin of the Pannonian Basin System, supports limited underground mining (Hodonín, Gbely).

The present study deals with the Zillingdorf lignite deposit located in the southern Vienna Basin (Fig. 1). Lignite mining stopped at Zillingdorf in 1953 (Weber and Weiss, 1983). However, an exploration campaign in the 1980s established lignite reserves in the order of 50 Mt (Sommer et al., 1983), constituting the largest lignite reserves in Austria. The lignite-bearing sequence comprises a lower coal zone with an up to 13-m-thick main seam and an upper coal zone with an up to 10-m-thick upper seam. The moisture content of the lignite is about 45% on an ash-free basis. Ash yield (10–30%, as received) and sulphur contents (2.9%) are generally high. The ash contains a remarkably high uranium content (77–100 g/t; Broda et al., 1956).

In the present paper, geological, petrographical and geochemical data of the Zillingdorf lignite are used to reconstruct the paleomorphology and paleoecology of the mire. The aim of the present study is to evaluate the differences in petrography and in molecular and isotopic composition of organic matter with respect to their relations to sedimentary facies variations and changes in the floral assemblage during peat accumulation. The influences of variations of organic matter type and of the extent of microbial degradation on the carbon isotopic composition of the lignite are evaluated by combined stable isotope and organic geochemical analyses. Whole-fossil and cellulose $\delta^{13}C$ values of wood remnants are included in this study.

2. Geological setting

The Zillingdorf lignite deposit is located at the eastern margin of the southern Vienna Basin (Fig. 1). The SSW–NNE-trending Vienna Basin, a classical rhombohedral pull-apart basin, is about 200 km long and 50 km wide (Royden, 1985; Wessely, 1988). The basin subsided along sinistral strike–slip faults between the Alps and the Carpathians, as a consequence of large-scale extension and lateral tectonic extrusion (Ratschbacher et al., 1991).

Marine environments dominated in the Vienna Basin during early and middle Miocene times, but were gradually replaced by terrestrial–fluvial sedimentation during the late Miocene (Pannonian) filling of Lake Pannon, which is a large, long-lived brackish water body stretching across the Pannonian Basin system (Magyar et al., 1999; Harzhauser et al., 2004).

In terms of sequence stratigraphy, the Lower and Middle Pannonian (11.5–10.0 Ma) represent a single 3rd-order cycle. Large delta plains filled the Vienna Basin during the Middle Pannonian highstand systems tract resulting in floodplain conditions and isolated lakes at the Middle/Upper Pannonian boundary (~10 Ma; Harzhauser et al., 2004). The Upper Pannonian deposits are characterised by a basal part with widespread lignite seams and a sandy–shaly–marly upper part.

The term Lower Neufeld beds was proposed for the lignite-bearing sediments in the study area (Brix, 1988), but should be replaced by Čary Formation (see Harzhauser et al., 2004 for a discussion). The lignite-bearing sequence is underlain by marls and is comprised of two seams. The upper seam is restricted to the northern and eastern part of the study area. The two seams are separated by a 10- to 20-m-thick sequence comprising sand, silt, clay and marl. Both seams comprise frequent shaly and sandy seam splits. The coal horizon is overlain by marl, shale and silt with intercalations of sand, gravel, rare lignitic layers, and sporadic freshwater limestones.

The Zillingdorf lignite deposit is represented towards the east and south by the outcrop of the coal horizon near Pötsching and Zillingdorf–Bergwerk (Fig. 2a). There, lignite was exploited mainly by open-pit methods until 1953. The western boundary of the Zillingdorf lignite deposit is formed by the Pottendorf Fault, which separates the upper Miocene lignite-bearing strata from thick Quaternary deposits of the Mitterndorf Trough. No economic coal was drilled west of this fault in a 590-m deep borehole (Petraschack, 1926/29). A structural map of the base of the main seam (Fig. 2b) shows that near Pötsching and Zillingdorf–Bergwerk the sediments are displaced by faults with an en echelon arrangement. These faults form part of the marginal fault system of the Vienna Basin.