

## Stratigraphy and paleoecology of the Late Pliocene and Early Pleistocene in the open-cast mine Hambach (Lower Rhine Basin)

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### Abstract

More than 400 samples for paleobotanical and sedimentological investigations were collected from Late Pliocene and earliest Pleistocene beds in the open-cast lignite mine Hambach. They were analysed to obtain information about the paleoecology and paleoclimate of this time interval. The sedimentation type changed from a high-energy meandering fluvial system to floodplain, swamp and oxbow lake sedimentation. The typical Tertiary floral elements decreased with the onset of increasingly cooler climatic conditions and disappeared at the beginning of the Pleistocene to be substituted by a impoverished and cold-adapted flora. These combined litho- and biostratigraphic investigations led to an improved and reproducible separation of Late Pliocene from Early Pleistocene deposits.

*Keywords:* Pliocene/Pleistocene boundary; Reuverian; Pretiglian; Germany; palynology; diaspores; palaeoecology; sedimentology

### Introduction

During the last few years, great progress has been achieved in collecting litho- and biostratigraphic data for the Miocene section of the Lower Rhine Basin to reconstruct its sedimentological dynamics (Schäfer et al., 1996, 1997; Ashraf & Mosbrugger, 1995; Huhn et al., 1997). However, our knowledge about the Pliocene and Pleistocene is comparably poor with respect to the integration of lithostratigraphy and biostratigraphy, at least in the German part of this region. Although Boenigk (1982) described distinctive changes in the petrography of the fluvial sediments during this period, we need an exact bio- and chronostratigraphic framework to understand the underlying processes in time and space.

Suitable sections for such an approach are available in the open-cast lignite mine Hambach which is locat-

ed in the centre of the Erft Block. Generally, a lithostratigraphic subdivision established by Schneider & Thiele (1965) and adopted by the 'Rheinbraun' company (RB) is used in the Lower Rhine Basin. However, no biostratigraphic data links this lithostratigraphy to chronostratigraphy, apart from a vertebrate fauna of Early Villanyian age in stratum 11 (RB; Reuver clay; Mörs et al., 1998). Therefore we started detailed paleobotanical studies including pollen and plant macrofossil analyses several years ago.

When dealing with Pliocene/Pleistocene deposits, the controversial discussion about the Pliocene/Pleistocene boundary (PPB) figures prominently. The current PPB was defined at Vrica, in southern Italy, at the top of the Olduvai normal event at 1.77 Ma, and it was adopted by the IUGS in 1984 (Tab. 1). There are strong biostratigraphic, magnetostratigraphic and climatostratigraphic arguments against a PPB located

at the top of the Olduvai event (Zagwijn, 1992; Suc et al., 1997; Partridge, 1997). As early as 1974, Zagwijn put forward evidence for the age of the earliest northern hemisphere glacial period (the Pretiglian in the Netherlands) post-dating at the Gauss-Matuyama boundary. Zagwijn (1992, 1998) is convinced that this climatic event, which can be correlated around the world (paleobotanical signal in Europe, oxygen isotope records from deep sea cores, onset of ice rafting in North Atlantic and loess formation in China), permits definition of the Quaternary relative to the Tertiary. There is a proposal by the INQUA Commission on Stratigraphy for lowering of the PPB to the vicinity of the Gauss/Matuyama paleomagnetic reversal within oxygen isotope Stage 104, approximately at 2.6 Ma (Partridge, 1997). This boundary has the advantage of facilitating global stratigraphic correlation in both marine and terrestrial sequences.

The problem of the PPB has not been solved yet. Nevertheless, for a clear correlation within the Lower Rhine Basin which extends from the Netherlands to Germany, we use the stratigraphic terminology of Zagwijn who locates the PPB at the transition between Reuverian and Pretiglian which is above the Gauss/Matuyama boundary between 2.5 and 2.6 Ma (Zagwijn, 1998).

## Lithology

The composite section at Hambach (Fig. 1) encompasses more than 50 m of sediments in five different sections in the open-cast mine. It starts with nearly 19 m of sand and gravel of the Kieseloolith Formation (50.0 m – 31.1 m, stratum 10 of terminology used by RB). The medium to coarse-grained, parallel- and cross-bedded, yellow-white sands were formed by a meandering fluvial system.

Between 38.2 m and 33.0 m, the energy level of this river system strongly increased. The river cut channels into the beds underneath and filled them with parallel- to cross-bedded, medium- to coarse-grained gravel. In this gravel, thin sandy layers with *Ophiomorpha* and carbonised logs can be observed.

After the sudden stop of the fluvial sedimentation at 31.1 m, it is replaced by a floodplain, swamp and oxbow sedimentation consisting of silt and fine-grained sands intercalated with thin clay layers. These beds are part of stratum 11 (Reuver clay of RB). The uppermost 2 m (26.4 m – 24.4 m) of these sediments, below a dark bed (middle part of stratum 11 of RB), are characterised by roots of trees, shrubs and herbs. The 1.40 m thick dark horizon is a brown coal seam located at 24.4 m – 23.0 m. Beds of silt and clay are intercalated. The sediments upwards to the next

brown coal seam (23.0 m – 21.5 m) are characterised by less calcareous silty and clayey beds, often with concretions. These beds are followed by a silty, fining upward section that shows many root traces at the top. According to Boenigk (1996), there is a remarkable change in the heavy mineral content in the upper part of stratum 11 (the transition between the so-called Kieseloolith Formation and Tegelen Formation; the latter is not the equivalent of the Tiglian in a chronostratigraphic sense, see Tab. 1).

The next lignite seam (18.8 m – 18.0 m) belongs to the upper part of stratum 11 of RB. Often it is divided into a lower and an upper coal-bearing layer intercalated by a less organic-rich silt. According to the interpretation of this section by RB, there is a hiatus between strata 11 and 13. This implies that stratum 12 (Pretiglian sands and gravel) is missing. This interpretation was not confirmed by our field observations (see below).

The next unit including the third significant coal seam (18.0 m – 11.0 m), is interpreted by RB as stratum 13 A, which is supposed to belong to the Tiglian complex. Silts of different grain size, which are more calcareous with some concretions in the lower part, represent a continuous sedimentation in an oxbow lake. A rich mollusc fauna and sometimes a thin coal seam were observed. Near the top of this sequence, below the lignite seam, a remarkable horizon with a conspicuous green-blue colour was observed. Because of its colour, this bed in combination with the following lignite layer can be used as a marker horizon in the mine.

The section above stratum 13 A (after RB) consists of sand, silt and clay layers and intercalated thin coal bands (11.0 m – 0.0 m). According to RB this sequence can be subdivided into several sub-strata of stratum 13 (13 B – 13 F ?) which probably belong to the Tiglian complex, too.

The entire sequence is unconformably overlain by the fluvial sediments of the 'Hauptterrasse' (strata 14 – 16 of RB). It consists of yellow-brown, medium to coarse gravels. These sediments can be correlated with parts of the Kedichem Formation and the Sterksel Formation of the Dutch lithostratigraphy (Boenigk, 1996).

## Biostratigraphy

Preliminary palynological investigations were carried out by Litt (1996) to improve the stratigraphic subdivision and to test the interpretation of RB that there is a hiatus between stratum 11 (of the Reuverian age) and stratum 13 (of the Tiglian age). Random samples were taken from thin intercalated lignite layers in stra-

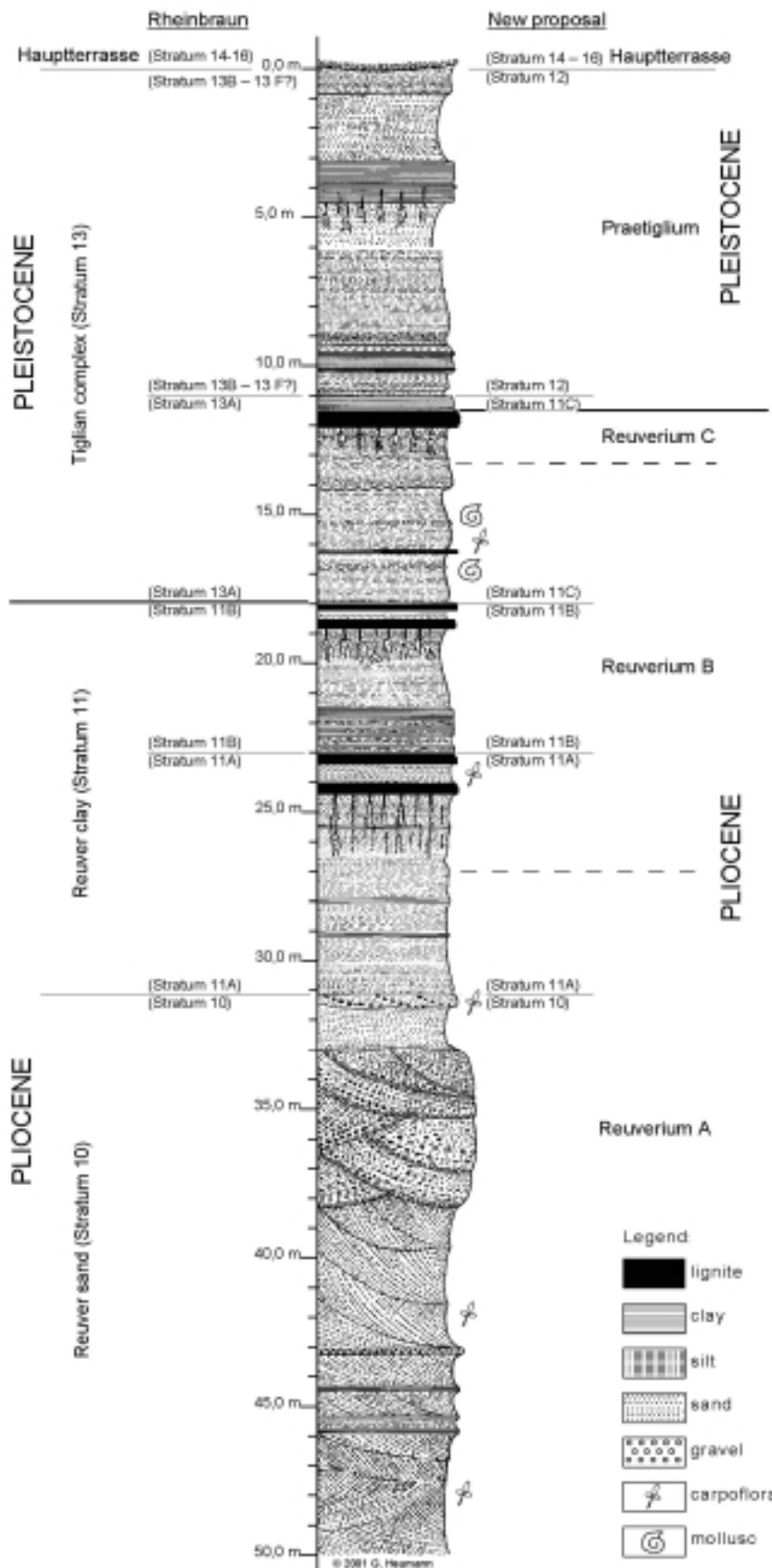


Fig. 1. Composite section of the Plio-/Pleistocene beds in the open-cast mine Hambach (based on field observations in 1998/1999).

tum 11. From the palynological perspective, there can be no doubt that these horizons correlate with the Reuverian (as indicated by the occurrence of *Sequoia*,

*Sciadopitys*, and *Nyssa*). A critical point was the biostratigraphic position of the significant lignite bed in stratum 13 A which can easily be used as a marker

Tab. 1. Stratigraphy of the Late Pliocene/Early Pleistocene in the Lower Rhine Basin.

<b>Lithostratigraphy</b> (in the Netherlands) (Boenigk, 1982, Tebbens et al., 1995, Huisman & Kiden, 1998)	<b>Biostratigraphy</b> <b>Palynology</b> (in the Netherlands) (Zagwijn, 1960, 1963)	<b>Pliocene/Pleistocene</b> <b>Boundary</b> (INQUA-Proposal)	<b>Pliocene/Pleistocene</b> <b>Boundary</b> (Vrica-Profil) (IUGS, 1984)	<b>Magneto-</b> <b>stratigraphy</b> (Shackelton et al., 1995)	<b>Time</b> (Ma)
Kedichem Formation	Eburonian		Pleistocene	<b>MATUYAMA</b>	1.7
					1.8
				Olduvai	1.9
	Tiglian				2.0
					2.1
Tegelen Formation					2.2
		Pleistocene	Pliocene		2.3
				<b>MATUYAMA</b>	2.4
	Praetiglian				2.5
					2.6
					2.7
	Reuverian C				2.8
Kieseloolite Formation	Reuverian B	Pliocene		<b>GAUSS</b>	2.9

horizon. A characteristic feature in the pollen diagram from this bed is the high amount of *Osmunda* (Fig. 2). The predominance of *Pinus* and *Alnus* is notable whereas thermophilous woody plants are very rare. The stratigraphic correlation of the beds within the Tiglian complex is difficult, because the time span of the deposition of the lignite seems to be quite short (without a characteristic succession). If this seam belongs to the Tiglian, then the interpretation of RB is insofar correct as this horizon is part of 13 A and confirms that there is really a hiatus between strata 11 and 13. An alternative interpretation would be that the lignite is of latest Reuverian age. In this case, the bed would have to be included in stratum 11 (Reuver clay) and there would be no hiatus.

To address this question, more detailed field investigations were undertaken to find longer sections covering the climatic fluctuations of the Late Pliocene and Early Pleistocene.

More than 400 samples were collected from the entire section described above for palaeobotanical analyses (pollen and plant macrofossils). Stratum 10 is characterised by a rich and a very diverse macroflora. Cones of different conifers (*Pinus timleri*, *Picea*

*latisquamosa*), as well as fruits and seeds of angiosperms (*Liquidambar europaea*, *Magnolia cor*, *Juglans bergomensis*, *Carya ventricosa*, *Pterocarya limburgense*, *Carpinus betulus*, *Fagus decurrens*, *Quercus robur*, *Vitis sylvestris*, and others) were collected from this sand. These remains represent a warm temperate climate, typical for the Late Pliocene (Reuverian A after Zagwijn, 1960, 1963). In this respect, our paleobotanical investigations confirm the stratigraphic correlation of stratum 10 by RB.

The preliminary results of the palynological analyses of more than 270 samples are summarised in Fig. 3. More than 130 taxa were identified, but only a simplified diagram is presented here. The flora of the lowermost coal seam of stratum 11 consists mainly of *Pinus*, *Alnus*, and Cupressaceae, with a lower content of typical Tertiary elements such as *Nyssa*, *Pterocarya*, *Sequoia*, *Sciadopitys*, and *Taxodium*. The sum of herbs including Gramineae, Cyperaceae, and Ericaceae reaches values of up to 10 to 15 %. From the biostratigraphic point of view, it can be confirmed that this horizon belongs to the Reuverian B (*sensu* Zagwijn, 1960, 1963).

The next coal seam (at the top of stratum 11) is



# HAMBACH

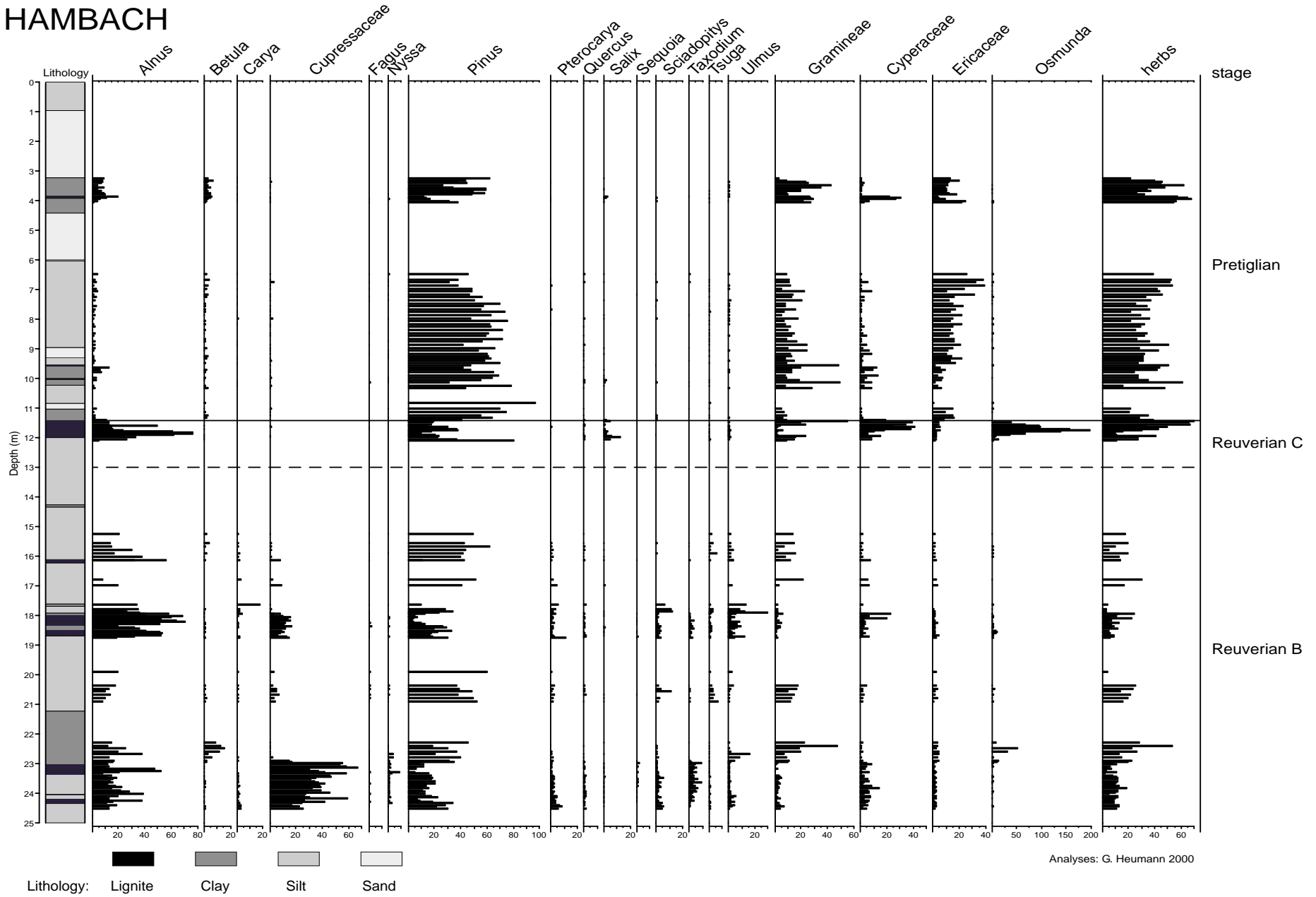


Fig. 3. Simplified pollen diagram from the Plio-/Pleistocene beds in the open-cast mine Hambach (see Fig. 1).

scarce Cupressaceae and *Nyssa*. There is no indication of *Pterocarya*, *Sequoia*, *Sciadopitys*, and *Taxodium*. The huge quantity of Gramineae, Ericaceae, and *Osmunda* is a characteristic feature of this bed (see also Fig. 3). The herb values increase from 30% up to 70%. We correlate this horizon with the end of the Reuverian (Reuverian C) because no paleobotanical and no lithological hiatus can be observed between the second coal seam in stratum 11 and this one.

The vegetation development from the lowermost lignite seam upwards clearly shows a decrease of thermophilous elements reflecting the gradual cooling at the end of the Pliocene. Therefore, the third coal seam does not belong to the Tiglian (stratum 13) as previously interpreted by RB. It should be included into the stratum 11.

The following samples (between 11.0 m – 0.0 m of the section) show a very pauperised flora which is characterised by decreased values of *Alnus* and *Pinus* and the absence of thermophilous elements, whereas Gramineae and Ericaceae have increased. The herb values reach 70%. This feature indicates cold climatic conditions which are typical for the Pretiglian (after Zagwijn, 1960).

Therefore we suggest that this unit (11.0–0.0 m) is equivalent to stratum 12. In contrast to previous interpretations, the palynological results clearly show the presence of deposits with a Pretiglian age. As a consequence, the PPB (*sensu* INQUA proposal) should be drawn at the top of the uppermost significant lignite seam of Reuverian C age.

## Conclusions

1. Lithological data alone, as applied in previous studies cannot solve the stratigraphic problems in the open-cast mine Hambach and adjacent regions of the Lower Rhine Basin.
2. Combined litho- and biostratigraphic investigations in this open pit led to an improved subdivision of Upper Pliocene and Lower Pleistocene deposits.
3. There is strong biostratigraphic evidence to modify the stratigraphic scheme currently used by the Rheinbraun Company.
4. The Pliocene/Pleistocene boundary at the Reuverian/Pretiglian transition is clearly reproducible in Hambach and can be used as a 'golden spike' for correlations in the Lower Rhine Basin.

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