

NON-MARINE LAMELLIBRANCHS IN THE WESTPHALIAN C/D OF THE CAMPINE COALFIELD

by

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ABSTRACT

Non-marine lamellibranchs from the Westphalian C/D of the Campine coalfield are described for the first time. The Upper *similis-pulchra* and the *phillipsii* assemblage zones, established in the Pennines (U.K.) are recognized in the Westphalian C of the Campine as well. The transition between these assemblage zones nearly coincides with the Lower/Upper Westphalian C limit. No faunal break has been observed between Westphalian C and D. Nevertheless the faunal succession reflects major changes in facies rather than phylogenetic trends: *Naiadites*-dominated faunas characterizing the Upper *similis-pulchra* zone became preponderant at the eustatic sea level rise marking the base of the Westphalian C while the succeeding *phillipsii* zone reflects a return to more fresh water conditions with seasonal fluctuations as the result of a drier climate. The transition between these zones is diachronous in the Campine: *Naiadites* faunas which prefer a brackish water environment, persist in the western Campine coalfield where a series of marine-influenced bands occur in the Lower/Upper Westphalian C transition sequence.

RESUME

Les lamellibranches non-marins du Westphalien C/D de Campine sont décrits pour la première fois. Les zones d'assemblage *similis-pulchra* supérieur et *phillipsii* établies dans le Westphalien C britannique y ont été reconnues. La transition entre ces zones d'assemblage coïncide pratiquement avec la limite entre le Westphalien C inférieur et supérieur. Le Westphalien D de Campine ne se distingue pas de la séquence sous-jacente par la composition de ses faunes. Néanmoins, la succession faunique reflète des modifications majeures de faciès plutôt qu'une évolution phylogénétique. Des faunes dominées par *Naiadites* débutent avec la transgression marine de la base du Westphalien C, tandis que la faune à *phillipsii* reflète un changement climatique vers un environnement plus sec. La transition entre ces

zones est diachronique en Campine. *Naiadites*, qui est mieux adapté aux milieux saumâtres, persiste dans le bassin houiller occidental, où plusieurs horizons à influence marine s'intercalent dans la séquence de transition entre le Westphalien C inférieur et supérieur.

KEY WORDS

molluscs, Upper Carboniferous, Westphalian, Campine (Belgium), biozonation, biofacies.

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mollusques, Carbonifère supérieur, Westphalien, Campine (Belgique), biozonation, biofacies.

1. INTRODUCTION

Westphalian C/D sediments represent the terminal sequence of the Upper Carboniferous in the concealed coal mining basin of the Campine in Northeast Belgium. They form part of the paralic coalbearing deposits that once covered most of the northwest European lowlands. The total preserved thickness of these sediments attains ± 1425 m as deduced from seismic exploration and borehole evidence. They are truncated and unconformably overlain by Upper Permian (Zechstein) to Triassic (Buntsandstein) and/or Upper Cretaceous to Quaternary sediments.

The actual basin configuration is dominated by the Late Cimmeric uplift of the Brabant Massif to the south and the Late Cimmeric to Recent deepening of the Roermond Graben to the north. The most complete sedimentary succession containing the uppermost Westphalian C/D strata occurs near the edge of the Roermond Graben, close to the graben boundary faults with the greatest downthrow, suggesting that the actual graben already functioned as a regional depocenter during the Paleozoic (Fig. 1).

The north flank of the Brabant Massif containing the coal mining basin is thus characterized by a general northward dip of the basin. This structure has superseded the older (Asturic ?) deformation

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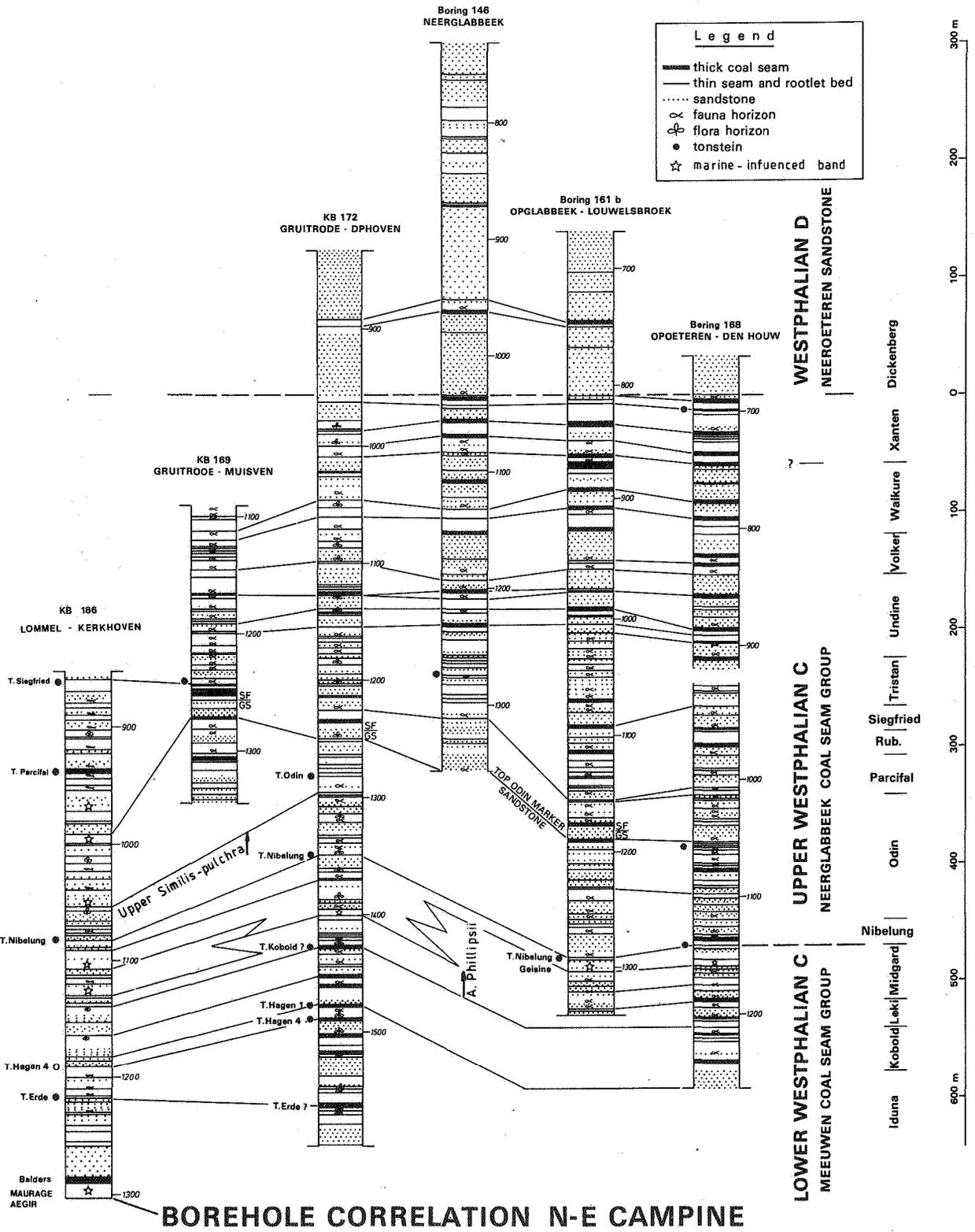


Figure 2.

Tonstein identification or the palynological zonation.

3. STRATIGRAPHY

The basic framework of the stratigraphical subdivision of the Westphalian in the northwest European paralic and limnic coal basins was established at the first International Carboniferous Congress held in Heerlen, 1927, when the Westphalian A/B and B/C boundaries were defined as corresponding to the Quaregnon (Catharina) and Petit Buisson (Maurage, Aegir) Marine Bands respectively. These marine bands, or at least the Petit Buisson Marine Band probably represent eustatic sea level rises and thus have chronostratigraphic value.

According to the fifth International Carboniferous Congress in 1963, the Westphalian C/D boundary was defined as the basis of the *Neuropteris ovata* biozone. *N. ovata* is indeed very characteristic for Westphalian D megaflores associations in the limnic Saar basin. Unfortunately no typical examples of this species have been found in the Campine coalfield which belongs to the paralic realm. In the Campine forms showing affinities to *N. ovata* occur within a limited stratigraphical sequence, slightly preceding the *Torispora securis-Vestispora fenestrata* (SF) - *Thymospora obscura-T. thiessenii* (OT) zone limit of the miospore zonation, and the *Setosporites pseudotenuespinosus* (MGIII) - *Triletesporites tuberculatus* (MGIV) zone limit of the megaspore zonation (Paproth *et al.*, 1983). Furthermore these biozonation limits are recognized at short intervals (max. 50 m) below the base of the Neeroeteren Sandstone member of the Belgian Coal Measures. Since the Westphalian C/D boundary cannot be established according to its principal guide but can be approximated by other fossil groups of known lithostratigraphic position with reference to the base of the Neeroeteren Sandstone, this lithostratigraphical marker has been used for all local correlations (Fig. 2).

Lithological correlations based on geophysical well logs enable a comparison with the Munster basin (Rhine-Ruhr and Ibbenbüren coalfields)². The base of the Neeroeteren Sandstone (Campine) corresponds to the base of the Dickenberg Sandstone (Ibbenbüren). In the latter area the Westphalian C/D boundary has been established at the Dickenberg coal seam overlying the Dickenberg Sandstone. In comparison with the Campine the Westphalian C/D boundary has been shifted ± 100 m upwards. A possible explanation for this divergent stratigraphical interpretation is the scarcity of vegetal remains in the predominantly sandy sequence underlying the Dickenberg Sandstone. The Campine basin apparently presents more favourable lithofacies conditions for the definition of a biozonation when compared to the Munster basin. The same also applies for the non-marine

lamellibranchs in the Upper Westphalian C: the Campine basin also contains richer and better preserved faunas.

The Lower/Upper Westphalian C boundary is proposed at the Tonstein Nibelung, a volcanic ash marker bed with regional chronostratigraphic importance. This marker nearly coincides with the Top Marine Band of the Pennine Basin (Bless *et al.*, 1977) which may be represented by a marine-influenced *Geisina* (ostracode) Band in the Campine, corresponding to the Midgard faunal horizon in the Ruhr (Dusar *et al.*, 1986). The *Geisina* Band itself has no firm chronostratigraphical expression: it is best explained as the response to a temporary influx of brackish water conditions progressively drowning the coal swamps. This event is clearly diachronic when compared to the overlying Tonstein Nibelung. Furthermore the western Campine coalfield shows better developed and repetitive events of this nature indicating a closer connection to the salt water supply zone eventually coupled with less sediment influx.

A subdivision of the Westphalian C at the Tonstein Nibelung has several advantages: it divides the Westphalian C strata in two units similar in size and character to the subdivision of the Westphalian A and B. Tonstein Nibelung is closely succeeded by the *Punctatosporites granifer-Triquirites sculpitilis* (GS) - *Torispora securis-Vestispora fenestrata* (SF) zone limit of the miospore zonation. This limit has been recognized in all Campine boreholes which were carefully sampled: systematic sampling of mudstones and silty mudstones overlying coal seams provides the best guarantee for high resolution biozonation, allowing excellent correlation possibilities with the detailed lithological succession.

4. DEPOSITIONAL ENVIRONMENT

In the Campine region, the Westphalian C/D Coal Measures have been deposited in an upper delta plain environment, grading into a lower delta plain at the base of the sequence and into alluvial floodplain for the uppermost beds. Coal seams formed on the abandoned infill surfaces of interdistributary lakes and bays. Their present thickness does not exceed 3 m; their lateral extent is in the order of kilometers. Mineable coal seams occurring throughout the coalfield over differently subsiding zones are known only from the Westphalian A. Repeated episodes of peat formation in a cyclic pattern of sedimentation were produced by switching distributary channels and by compaction effects (Elliott, 1968). Coal seams normally rest on paleosols developed on interdistributary or overbank siltstones and mudstones; they are drowned and covered by

² Geophysical well log correlations for the Westphalian C/D were worked out with Dr. A. Schuster (Neuenhaus) and Dr. D. Schmitz (WBK, Bochum). Some examples of remarkable wide-ranging correlations will be published by these authors.

lagoonal mudstones or by crevasse splay/lagoonal delta/lake margin or overbank deposits. Channel fill sandstones may quickly succeed to any of these lithofacies and are predominant in the Neeroetcren Sandstone member.

As evidenced by the fossil assemblages, all these lithofacies were deposited in a fresh water to slightly brackish water environment, interrupted by short lived seawater incursions. At least in part these are related to eustatic sea level rises (Aegir Marine Band at the base of the Westphalian C). In the fresh water environments non-marine lamellibranchs occur in several lithofacies types.

The occurrence of non-marine lamellibranchs in different lithologies with associated sedimentary structures and their relation to lithofacies has been summarized by Guion & Fiddling (1988). They are most common in black carbonaceous mudstones, also often bituminous, which were deposited under suboxic conditions at lake floors. In such an environment they are often associated with fresh water ostracodes, spirorbis and fish remains. These beds which directly overlie the coal seams possess thicknesses limited to the order of centimeters.

Non-marine lamellibranchs become progressively scarcer in the overlying more silty lake-fill deposits (passive lake/bay margin, minor delta/distal crevasse splay). Near the base of this sequence *Guilielmites*-type ichnofossils are frequently found. Non-marine lamellibranchs also frequently occur in massive siltstones and silty mudstones, characteristic for overbank deposits with high sedimentation rates. Other fossils found in this environment though generally not at the same levels, are orientated plant remains (hackles), entrapped plant stems (mostly *Calamites*) at oblique angles or in-situ, pinnules and even complete fronds of fern-like plants. More sandy overbank deposits containing thinly interbedded sandstones normally do not yield mollusc shells but display vertical escape shafts up to 5 cm in length.

Diversified faunas of non-marine lamellibranchs dominated by forms more adapted to brackish water are found interbedded in marine or marine-influenced bands. The preservation of the molluscs is often best in the lake-fill beds which are less compacted than the carbonaceous mudstones and less prone to weathering and oxidation than the more permeable and shallow sandy beds.

Differences in adaptation to high salinities or to salinity and water level fluctuations were noted by Paproth (1978). Among the genera present in the Westphalian C/D, *Naiadites* and *Anthraconaia* (see Plate 2) are favouring more brackish water conditions, whereas *Anthraconauta* (see Plate 1) may be more resistant to climate-induced fluctuations: during the Upper Westphalian C and the Westphalian D the climate became gradually drier with marked seasonality in water supply. This is reflected by the strong reduction in size, numbers and variability (limited essentially to *Anthraconauta phillipsii*) of the fresh water faunas (Paproth, 1987).

5. STRATIGRAPHIC SIGNIFICANCE

Non-marine lamellibranchs have been successfully used for a biostratigraphic subdivision of the British Coal Measures (Dix & Trueman, 1937). The subdivision now in use follows the definitions of the assemblage zones by Trueman & Weir (1946), further refined by Calver (1955) who described sub-zones (Faunas) based on dominant lamellibranch associations.

An evaluation of the possibilities and constraints of the non-marine lamellibranch biozonation with reference to the Belgian coalfields led to the following conclusions (Paproth *et al.*, 1983):

- the faunal succession established in the Pennines can be recognized in the other paralic coal basins of NW Europe as well; however the abundance and faunal diversity is decreasing from north and west to south and east. Faunas in the Campine basin are richer than those recorded from the Rhine-Ruhr coalfield but less developed than those from the Pennines (Paproth, 1962);

- faunas from the Belgian Coal Measures have been described in great detail by Pastiels (1951-1975) whose untimely death prevented the completion of his study: Belgian Westphalian C/D faunas have not been studied nor figured. These faunas then were not so readily available. The Borinage coal mines allowing access to the Westphalian C in the Borinage and Masse allochthonous massifs were all closing down whereas the exploration of the youngest deposits in the Campine had not yet started;

- taxonomic investigations and determinations to species level are of limited applicability because of the high morphological diversity, complicated by the generally poor state of preservation and the strong deformation of the shells, exerted by tectonic forces or by vertical pressure (compaction and dissolution);

- the occurrence of non-marine lamellibranch faunas is facies-dependent; they attain their greatest abundance and variability in the upper part of the Westphalian A and the lower part of the Westphalian B, also a section particularly rich in coal. Faunal breaks frequently coincide with marine bands, sometimes causing long-lasting changes in salinity of the interdistributary bays and lakes.

6. BIOZONATION

6.1. Lower Westphalian C

The lower part of the Westphalian C is assigned to the Upper *similis-pulchra* Assemblage Zone which is characterized by a *Naiadites-Anthraconaia* association, also in the Campine. *Anthraconauta phillipsii* appears in its upper part. The range of

this zone, as established in the Pennines, corresponds to the Lower Westphalian C (Calver, 1955). The lower limit coincides with the Mansfield (= Aegir, Petit Buisson, Maurage) Marine Band; the upper limit coincides with the Top Marine Band, nearly time-equivalent to the Tonstein Nibelung (Bless *et al.*, 1977).

The dominant form of the Westphalian B, *Anthracosia*, disappears below the base of the Westphalian C, and is replaced by the long-lasting form, better adapted to brackish water, *Naiadites*. In the Rhine-Ruhr basin the fauna is scarce and poorly preserved. *Naiadites* is the only form recognized so far in the lower Horstener Schichten (sequence between the Aegir Marine Band and the Hagen-1 Tonstein). Above the latter level, the fauna is less well defined (Paproth, 1962).

In the Campine basin, both *Naiadites* and *Anthraconaia* occur, the latter exclusively interbedded in marine-influenced horizons which normally pass into non-marine lamellibranch levels (Plate 2, 1-4). Sections which are richer in these horizons such as in borehole KB 186 (Fig. 2) invariably contain richer mollusc faunas as well. Forms showing clear affinities to both guide species *N. daviesi* and *N. elongatus* occur (Plate 1, 1; Plate 2, 5-8) (Dusar *et al.*, 1987b).

In the upper part of the Upper *similis-pulchra* Assemblage Zone, *Anthraconauta phillipsii* appears. Some boreholes in the Campine basin (KB 186, KB 172; see Dusar *et al.*, 1987b) contain a transitional fauna which however is considered as the lateral equivalent of the *phillipsii* Zone (cf. infra.). Because of their facies dependency, *Naiadites* and *Anthraconauta* always occur in separate beds.

6.2. Upper Westphalian C

The upper part of the Westphalian C is assigned to the *phillipsii* Zone, starting at the Top Marine Band in the Pennines. *Naiadites* is only known from the basis of this zone. Otherwise *Anthraconauta phillipsii* is the dominant form (Calver, 1955). The full palaeontological description of this species, including its transition to *A. tenuis* is provided by Weir (1960).

In the Campine, *A. phillipsii* is also the only form characterizing this zone (Pl. 1, 2-8). The richest faunas are generally found toward its base. At higher stratigraphic levels *A. phillipsii* becomes scarcer and reduced in size.

The first appearance of *A. phillipsii*, which cannot necessarily be used as a definition of the base of this zone, is diachronous. This can be deduced from detailed lithological correlation lines between adjoining boreholes (Fig. 2). In the western and central part of the coalfield, *A. phillipsii* appears only in the Odin coal seam group, well above Tonstein Nibelung, at the base of a transitional zone still containing *Naiadites* as well. In the eastern part of the coalfield (KB 161, 168; Dusar *et al.*, 1986), *A. phillipsii* already appears for the first time at the *Geisina* Band, underlying Tonstein

Nibelung. No *Naiadites* forms are known at higher stratigraphic levels.

It is assumed that the first appearance of *A. phillipsii* in the Campine does not precede the first appearance in the Pennines where the fauna is much richer. Because of its divagating nature the *Geisina* Band may not present real time equivalence to any particular marine band in the Pennines, e.g. the Shafton or the Top Marine Bands. More important is the persisting occurrence of the *Naiadites-Anthraconaia* association in the western Campine which is more open to marine influences at the same levels. The biozonation limits recorded from the western Campine (KB 172, 186) are certainly delayed in time when compared to the Pennine region.

The *Paleostheria* forms mentioned from the Upper Westphalian C in the northeastern Campine (Delmer, 1958; Paproth *et al.*, 1983) are poorly preserved. They probably represent juvenile forms of *A. phillipsii* (Dusar *et al.*, 1986). Noteworthy is the observation of a *Palaeonodonta* form (det. E. Paproth), more typical for the Westphalian D of the limnic Saar basin (Paproth, 1966) at level 1082.20 m in borehole 146 (Fig. 2; Dusar & Houlliberghs, 1981).

6.3. Westphalian D

In the Pennines the Westphalian D is assigned to the *tenuis* Zone. This zone is characterized by the joint occurrence of *A. phillipsii* and *A. tenuis* (Calver, 1955). In the Campine basin this limit is poorly defined. Non marine lamellibranchs become rare and are poorly preserved in high energy environments with unsteady water levels. Diminutive forms of *A. phillipsii* persist, sometimes displaying a morphological resemblance to the more elongated *A. tenuis* (Dusar *et al.*, 1987a). Typical *A. tenuis* have not been recorded however. Apparently the climatic evolution of the northwest European paralic basin evolved towards less favourable conditions for molluscs. Long dry seasons with temporary floods prevailed in a depositional environment shifting from upper delta plain to alluvial floodplain in which the first redbeds appear (Paproth, 1987). The remaining fauna still provides good biofacies indications.

7. CONCLUSIONS

Westphalian C/D deposits in the Campine coalfield form part of the extensive paralic Coal Measures of northwestern Europe. In the concealed Campine basin Westphalian C/D strata are subcropping to the north and northeast of the coalfield close to the margin of the Roermond Graben which could correspond to a local depocenter. Outside this area, Upper Westphalian strata have been removed by successive phases of erosion. The total preserved thickness of the Westphalian C/D attains 1425 m.

The stratigraphic subdivision of the Westphalian C/D is based on limits of different nature. A ma-

rine horizon probably related to an eustatic sea level rise marks the base of the Westphalian C (Mansfield = Aegir = Petit Buisson = Maurage Marine Band). The Lower/Upper Westphalian C limit is based on a volcanic ash marker, Tonstein Nibelung, which is almost time-equivalent to the Top Marine Band in the Pennine Basin and slightly precedes the GS/SF miospore subzone limit. The Westphalian C/D limit is based on the first appearance of *N. ovata*, a plant restricted to limnic basins. This limit is approximated by megaspore and miospore zone limits and precedes the onset of the Neeroeteren Sandstones. Detailed lithological correlations relying on geophysical well logs and on faunal bands serve as the basis for local stratigraphic interpretation.

Coal deposits in rather thin laterally extensive seams result from repeated episodes of peat formation in a cyclic pattern of sedimentation. Non-marine lamellibranchs are representative fossils from interdistributary bay/lake sediments covering the coal seams. The faunal succession has been developed in a biozonation based on assemblage zones and first described from the Pennine coalfields. This succession (including the Westphalian C/D interval) is also recognized in the Campine which occupies an intermediate position between the fossil-rich Pennines and the impoverished Rhine-Ruhr coalfield.

However the transition between successive assemblage zones reflects large-scale facies changes rather than a phylogenetic evolution. The marine incursion at the base of the Westphalian C marks the onset of a *Naiadites-Anthraconaia* association, characterizing the Upper *similis-pulchra* Zone but also more adapted to brackish water conditions. The transition to the *Anthraconauta phillipsii* fauna, characterizing the *phillipsii* Zone, nearly coincides with the Lower/Upper Westphalian C limit. Detailed correlations indicate its diachronous nature: marine-influenced bands in the western Campine coalfield remain colonized by the typical Lower Westphalian C assemblage while *A. phillipsii* makes its first appearance in the eastern Campine coalfield. Different subsidence regimes seem to be the controlling factor for this lateral biofacies variation.

The upper part of the Westphalian C/D sequence is characterized by the transition from an upper delta plain to an alluvial floodplain environment in a changing climate with marked seasonality. Non-marine lamellibranch faunas are impoverished and mostly restricted to one species, *A. phillipsii*. Under these circumstances no faunal change was observed at the Westphalian C/D transition.

It is demonstrated that non-marine lamellibranchs can be used for a biostratigraphic zonation at an interregional basin scale. However they are as valuable as facies indicators. This was already eloquently propagated by Eva Paproth (1978) who elevated these neglected fossils to a higher status as "Spiegel der Fazies Entwicklung".

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PLATE 1

cf. *Naiadites*

1. KB 186, 1049.40 m (6 X)

Anthraconauta phillipsii

2. KB 186, 1018.78 m (6 X)
3. KB 186, 942.47 m (2.5 X)
4. KB 186, 933.81 m (6 X)
5. KB 186, 934.51 m (2.5 X)
6. KB 186, 933.81 m (3 X)
7. KB 186, 933.91 m (6 X)
8. KB 186, 878.98 m (12 X)

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PLATE 1

cf. *Naiadites*

1. KB 186, 1049.40 m (6 X)

Anthraconauta phillipsii

2. KB 186, 1018.78 m (6 X)
3. KB 186, 942.47 m (2.5 X)
4. KB 186, 933.81 m (6 X)
5. KB 186, 934.51 m (2.5 X)
6. KB 186, 933.81 m (3 X)
7. KB 186, 933.91 m (6 X)
8. KB 186, 878.98 m (12 X)

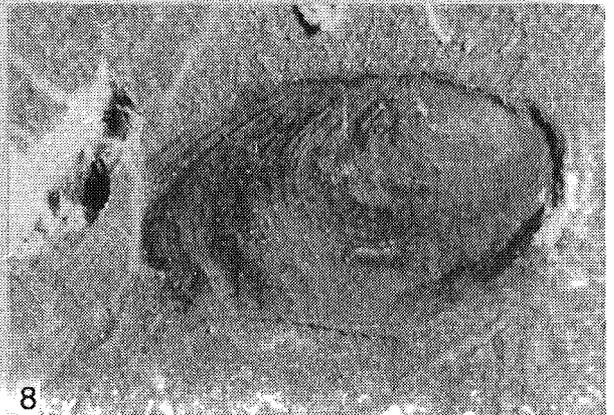
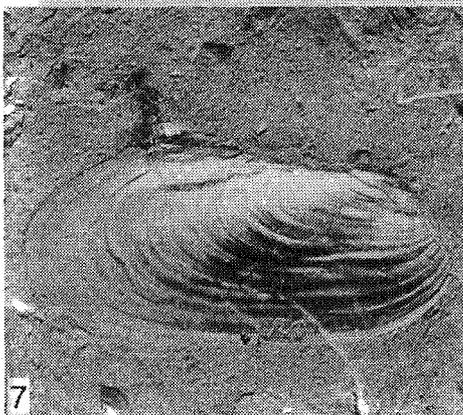
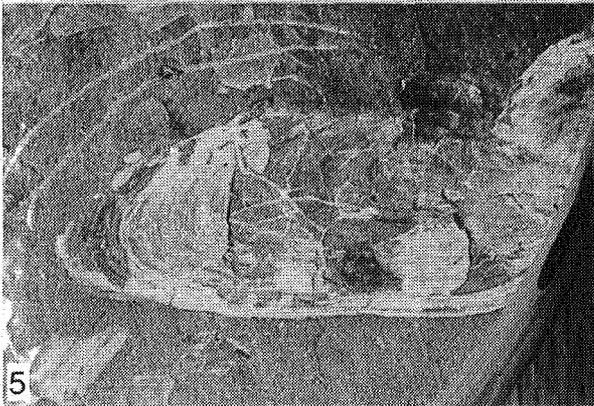
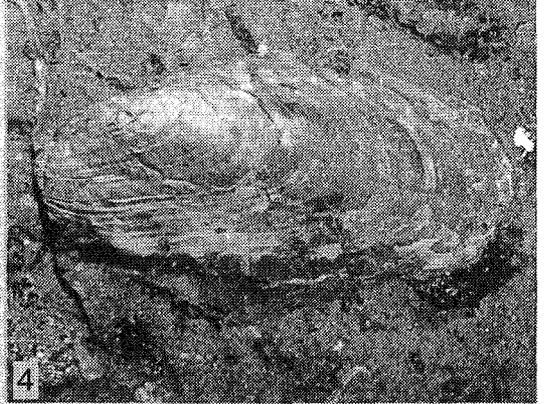
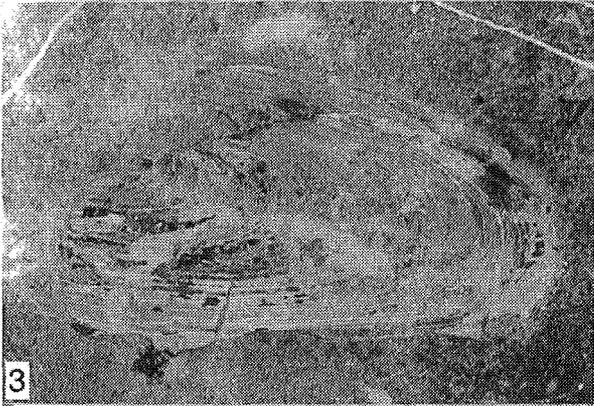
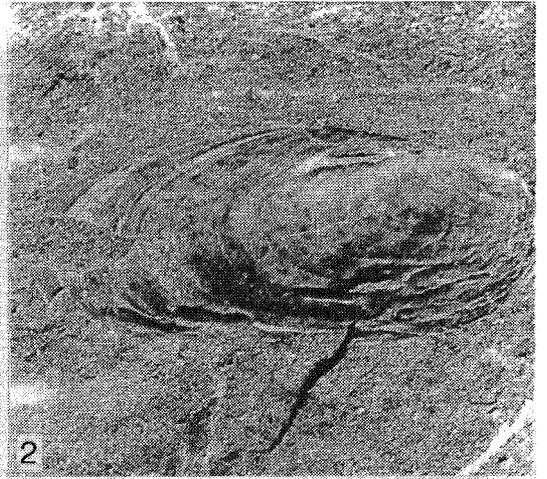


PLATE 2

Anthraconaia sp.

1. KB 186, 1298.65 m (2 X)
2. KB 186, 1294.55 m (3 X)
3. KB 186, 1298.65 m (3 X)
4. KB 186, 1049.80 m (6 X)

Naiadites sp.

5. KB 186, 1049.60 m (6 X)
6. KB 186, 1049.60 m (12 X)

Naiadites with *Spirorbis*

7. KB 186, 1053.00 m (3 X)
8. KB 186, 1050.30 m (5 X)

