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Geology of the Niederlausitz Lignite District, Germany

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ABSTRACT

One of the largest brown coal producing districts in the world is the Miocene of Niederlausitz Lignite area in the southeastern part of Germany. Production is in a range of 320 million t/yr. The resources of the first (shallowest) Miocene seam have nearly been exhausted and it is now mainly the second seam which is being mined. A fourth is being explored. The third Miocene and the Oligocene seam, Calau, are unminable. All brown coal is mined in open pits. The rank of brown coal of the second Miocene seam ranges from fuel coal to coking coal. Its heat value (dry) from 22.2 to 23.5 MJ, its ash content (dry) from 6% to 13%, its moisture from 57% to 59%, and its seam thickness from 10 to 12 m. Due to the close relationship between swamp facies and the main coal quality parameters, the coal quality can be directly determined from the drill log.

The Oligocene and Miocene brown coal formation was synchronous with the alpine orogenesis and the seafloor spreading of the North Atlantic Ocean, which both caused north and east oriented migrations of the labile basement of central Europe. Periods of compression alternated with longer periods of isostatic subsidence and sedimentation. Additionally, the trends of thickness and facies of sediments were controlled by a block system in the basement of the brown coal district of Niederlausitz, uplifting, subsiding, collapsing, rotating or spreading.

The second Lower Miocene seam is situated at sea level in the north of the Niederlausitz area and rises to the south to + 150 to + 180 m above sea level, due to considerable widespread subsidence and uplifting since the Lower Miocene. Horizontal tectonic movements were caused by the collapse of asymmetric grabens with slight tendency to rotation. Regional shear movements led to block faulting followed by volcanism. Counter-clockwise rotation of the basement blocks is assumed, a hypothesis supported by recent tension measurements and seismic observations. Ice cover in the Pleistocene caused wide destruction zones, narrow and deep channels and intensively folded or imbricated seam structures. Some gravity-induced plastic structures were also formed.

INTRODUCTION

According to the electric power production per inhabitant, the former G.D.R. was, in 1985, in the third position in the world after the USA and

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Canada. Figure 1 shows the great increase of the total power production between 1960 and 1985. Of this power production, 70–80% was based on lignite, demonstrating the economic importance of lignite mining. Figure 1 shows the increase in the lignite output from 225.5×10^6 t in 1960 to 312.2×10^6 t in 1985. Lignite with an interstitial water content of 48–58% and a heat of combustion, Q_i^d from 22 to 24 MJ/kg is mined. Extensive amounts of overburden and water are moved for each ton of lignite produced (Fig. 1). The quality of the geological and geophysical information available, together with the large mining equipment used, make large-scale, successful mining possible.

The modest beginnings of lignite mining date as far back as the 14th century. The industrial application of soft lignite for heating began about 1870. Gasification experiments began in 1841, and low-temperature carbonization in 1846. The production of lignite briquettes began in this area in 1856. In the Senftenberg lignite quarter the first big boom began in 1871. In 1882, the

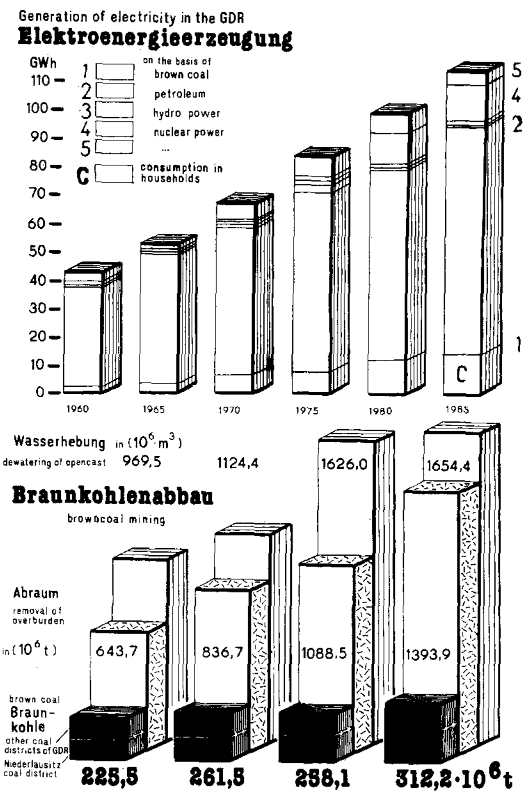


Fig. 1. Electrical generation from various energy sources in the former the former G.D.R. and relative amounts of brown coal mined in the Niederlausitz Lignite District compared to other coal districts in the former G.D.R. and amount of overburden removed.

first electric power station based on the use of lignite was built (Förster, 1968; Schanze, 1981; Hahmann, 1981; Pätz et al., 1986).

In this paper the Niederlausitz mining district is described as an example of some of the traditional lignite mining districts of southeastern Germany. Here, the mining industry began in the Senftenberg lignite quarter with the exploitation of the Number 1 Miocene seam horizon. The present mining wins lignite from the Number 2 Miocene seam (B Mf 2) in large open pits. The deeper Number 3 Miocene seam is mined on a local scale. The Number 4 seam at the base of the Miocene has been incompletely explored at present and is not economically exploitable. The Oligocene Calau seam is inexploitable (Fig. 5). At present, about 60% of the total lignite production from this region comes from the Niederlausitz lignite district.

REGIONAL AND GLOBAL GEOLOGICAL FRAMEWORK

In the Miocene, the middle and western European region had not yet been assembled into a rigid continental plate. At that time, the alpine mountains were moved to the region as nappe staples from the Tethyan geosyncline. The outer alpine mountains of middle Europe had great internal mobility. Partial blocks were separated by widening areas containing depressions, fault troughs and basaltic volcanism. In addition, there were both far-reaching and local depressions, elevation and tilting of blocks, as well as block displacements. In relatively short periods of time there were large floods and eluviation (Lotsch, 1968; Vinken et al., 1988). This mobility is characteristic of the "shelf crust" crustal type (Brause, 1979, 1990).

Important differences between the old platforms exist in the structure, heterogeneity and thickness of the lower crust. On the basis of stratigraphic interpretation, this is related to differences in their development during the Archean and Early Proterozoic. During the Middle Proterozoic, about Svecokarelidic time, metamorphism of sediments probably occurred in middle Europe, correlative to formations in Finland and Sweden. However, only relatively small thicknesses of older sediments, such as volcanics were affected. The assumed very old crystalline basement remained unstable and of small thickness, with a very heterogeneous distribution. It eventually broke into a basic mosaic of blocks. The Upper Proterozoic and Paleozoic development shows some degree of control by this old basic structural mosaic.

After the Hercynian, the middle European area remained in a relatively high state of mobility. In the late Mesozoic (Saxonian), germano-type block tectonics were still controlled by the oldest basement pattern. The late Mesozoic–Tertiary opening of the Atlantic Ocean brought about a discontinuous, horizontal dislocation of middle Europe from west to east on a scale of at least 2 cm/yr (Fig. 2). Times of rapid partial dislocation alternated with periods showing a slower rate of dislocation with less movement. In our opinion, the

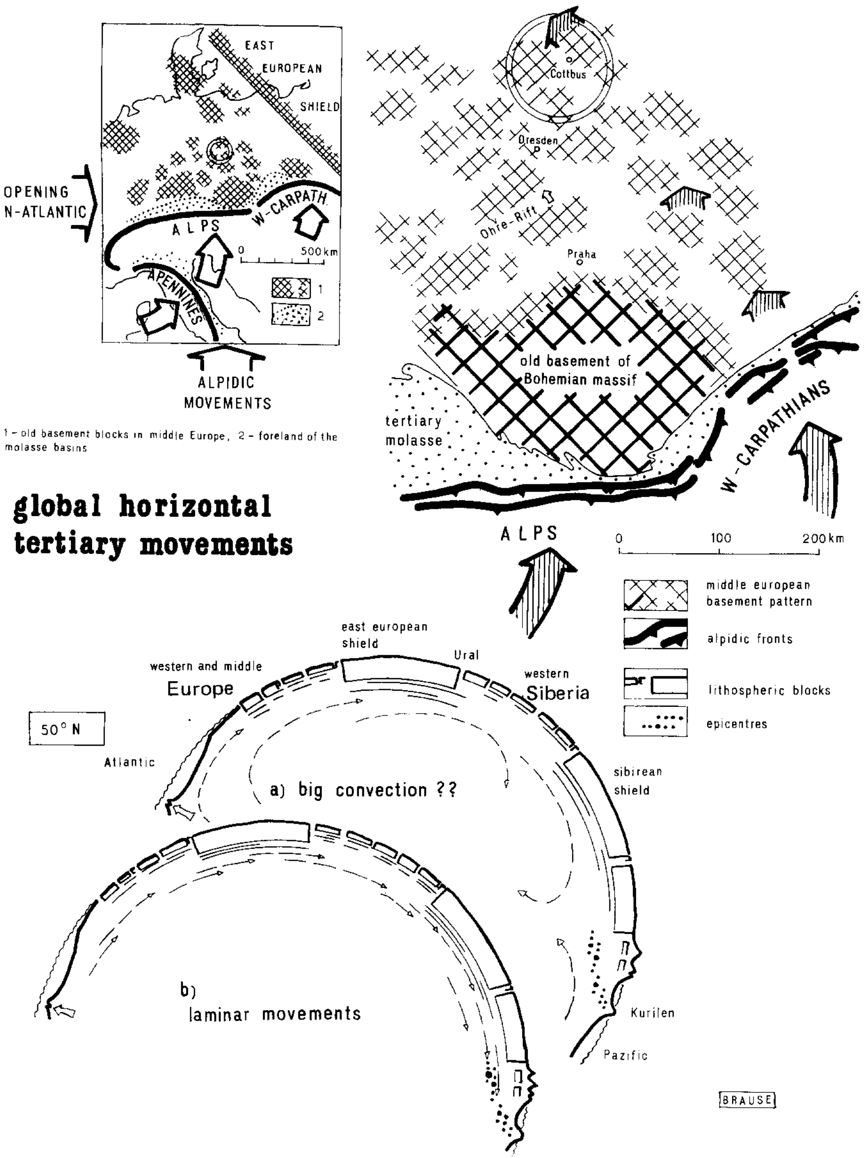


Fig. 2. Global tectonics and mid-European Tertiary horizontal movements.

conventional geodynamic model of plate tectonics, with major convections within an asthenosphere of great thickness is incorrect. On the contrary, we contend that the power transmission took place through laminar, sliding movements (Brause, 1980, 1990).

The alpine orogenesis, caused by the approach of Africa and the narrowing

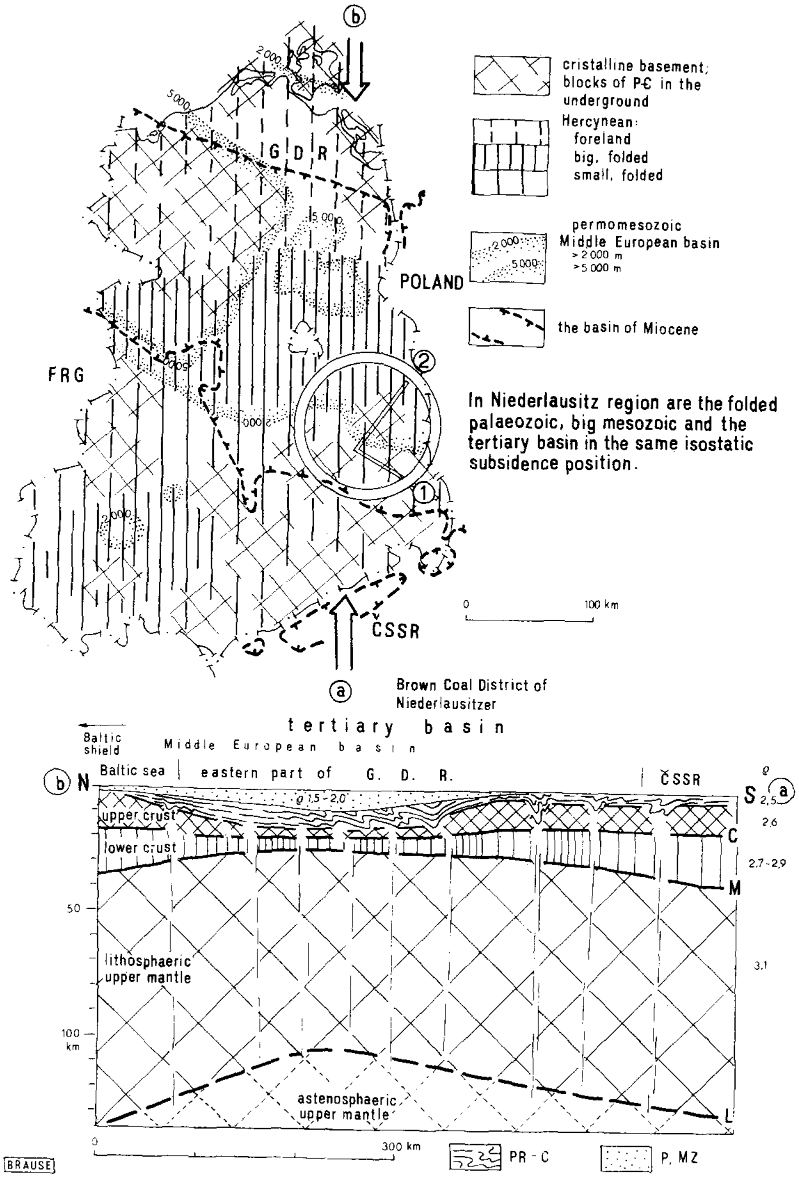
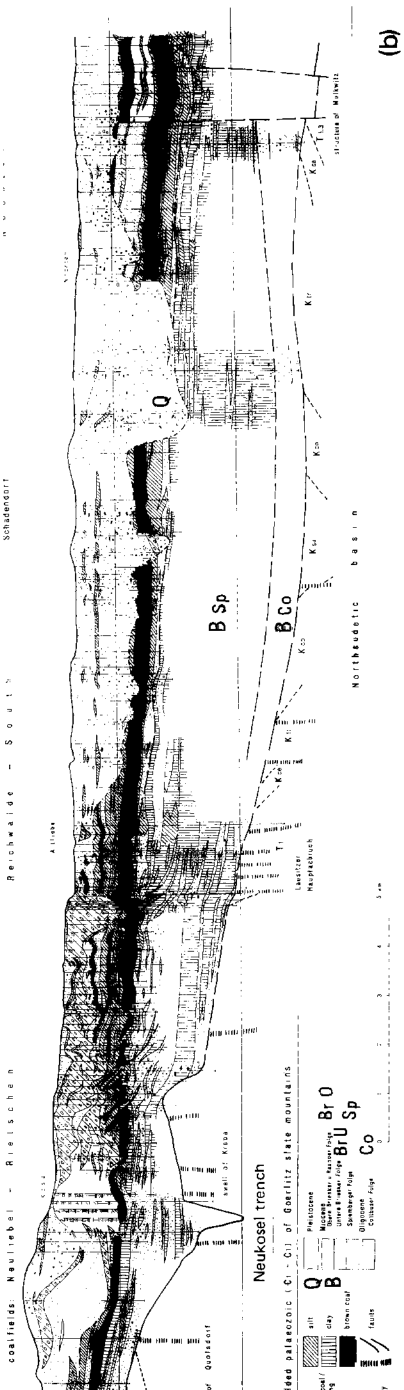


Fig. 3. Areal and cross-sectional sketches of the Niederlausitz region and surrounding area indicating relative tectonic activity of Precambrian basement and subsequent modifications of overlying strata in the Paleozoic, Mesozoic and Tertiary. PR-C=; P,MZ=.

of the Tethyan geosyncline, was also intermittent (Fig. 2). During the formation of the alpine mountains, times of strong compression alternated with times during which the compressive forces were relatively relaxed. As a result



(b)
SO
coalfields: Neuliebel - Rietschen - Reichwalde - South
Schadendorf
swell of Quolsdorf
swell of Kreba
Neukosel trench
folded palaeozoic (C1 - C1) of Goerlitz slate mountains
Q
B Sp
B Co
Lausitzer Hauptabbruch
Northsudetic basin
structure of Malkwitz
pebbles
pebbles of coal / coal-bearing
gravel
sand
boulder clay
silt
clay
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faults
Pleistocene
Miocene
Oligocene
Br O
BrU
Sp
Co

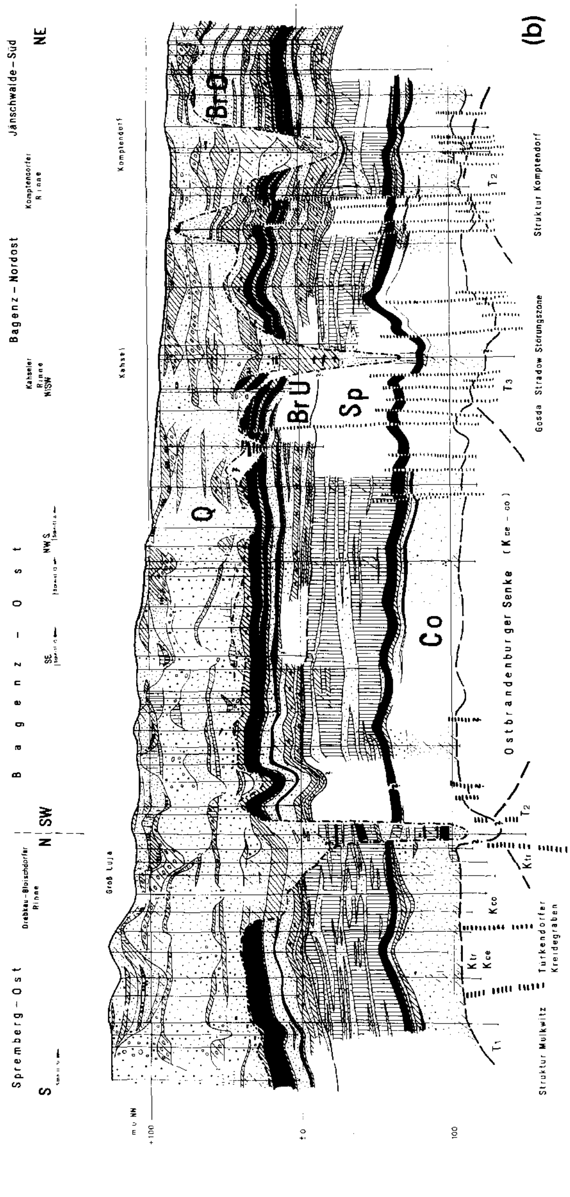


Fig. 4. Regional geological cross section of the Niederlausitz Lignite District. (a). (b).

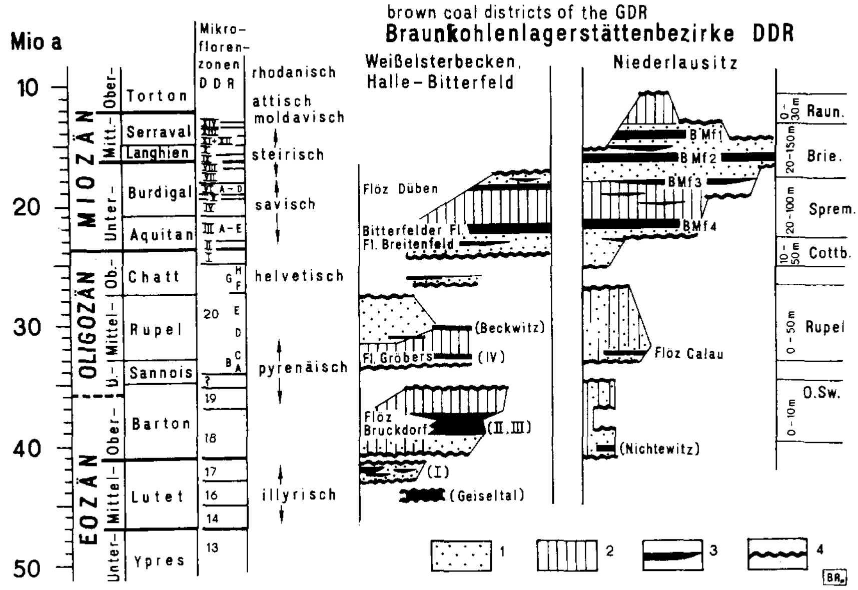


Fig. 5. Geological columns of the Tertiary of lignite districts of the former G.D.R. (Rauno, Brieske, Spremberg, Cottbus, Rupel and Upper Schönewalde sequences). *1* = sand; *2* = silt and clay; *3* = lignite; *4* = tectonic impulse and unconformities.

of alternating regional compression from the south and intervening periods of relative dilation, forces acted on the middle European crust from both principal directions during the Tertiary. N–S directed expansion joints and depressions were formed when the W–E vector of force predominated. W–E directed structures were created during dominance of the N orientated thrust.

The relatively large and stable old block of the central Bohemian massif lies to the south of this region. This means that the area of or study lay in the shadow of the thrust zone during the Tertiary. In the area of the southeastern Germany, thrust and transmission components of forces from the southeast were effective during the Tertiary, bypassing the rigid Bohemian massif to the east and seismic tension with this orientation still exists (Grünthal et al., 1985).

On a geotraverse, approximately along the meridian 14°E (Brause, 1979), it can be seen that the old crystalline basement of the lower and upper crust thins out in the middle part of southeast Germany (Fig. 3b). This section, with a thinner crust, sank isostatically during the Paleozoic and Mesozoic. In the Paleozoic we assume a relatively larger scale development with thick sequences of sediments. In the lower Permian, a zone of basic volcanism was situated here. The large, middle European depression developed from the upper Permian onwards in southeastern Germany. The main zone of subsidence during the Tertiary was also in this same region, showing that old isostatic tendencies continued during the Tertiary development of basins.

The Niederlausitz region is situated above the southern rim of the middle European depression. There the regional isostatic tendency is modified according to circumstances by the local block pattern in the basement. Figure 4 shows two parts of a regional section of the Niederlausitz Lignite District. The lignite layer B Mf 2 shows the regional, isostatic sinking of the basin from about + 120 m NN (above sea level) in the south to about + 10 m NN at the northern rim of the section. Lignite is mainly thicker in the deeper part of the basin (Fig. 4b). The thicker lignite layers of the No. 4 Miocene seam horizon are only in the deeper parts of the basin. The sandy sequence at the base of the Tertiary is the Cottbus sequence of the upper Oligocene (Fig. 5).

STRATIGRAPHY

A generalized stratigraphic classification for two important lignite areas in southeastern Germany is presented in Fig. 5 in two columnar sections. The upper part of section, "Niederlausitz", corresponds to the stratigraphic sequence of the regional section in Fig. 4 (Table 1). In the Weisselster basin and in the Halle-Bitterfeld area, Oligocene and Eocene beds and lignite seams appear on a large scale.

In the former G.D.R., classification into para-stratigraphical microfloral zones has reached a high level. Using these, a subdivision and classification into very short intervals of time is possible with an accuracy of about 0.2–1 Ma. The general classification of the Tethyan Tertiary and radiogeochronology are less accurate.

The correlation between the orthostratigraphic scale of the Tethyan and Atlantic Tertiary and the parastratigraphy of the middle European Tertiary is still full of gaps. The same is true for a more accurate dating of the kinematics of the alpine orogeny. In middle Europe, we are able to register more accurately the long-range chronology of the alpine tectonism during its intervals

TABLE 1

Stratigraphic sequence of the regional section illustrated in Fig. 4 (from the base upwards)

Rauno sequence	
Brieske sequence with the No. 1 and No. 2. Miocene seams	
	No. 3. Miocene seam
Spremberg sequence	No. 4. Miocene seam
Cottbus sequence	
Rupel sequence	
Upper Schönewalde sequence	

than within the alpine orogeny itself. Exact stratigraphic and geodynamic complex statements are not yet certain because of the doubtful correlation between the stratigraphic scales.

GEOPHYSICAL EXPLORATION

For the purpose of lignite exploration, various geophysical methods have been applied on a large scale. These include: regional gravimetry, special gravimetry, gravimetrical calculation of profiles, magnetics, regional seismology, different methods of close seismology and geoelectrical methods. For more than 30 yr tens of thousands of boreholes were geophysically measured using standardized viewpoints as part of a lignite exploration program. These data provide a rich source for computer processing.

Figure 6 shows some selected parts of geophysical logs illustrating various developments of the seam section B Mf 2. Very exact determinations were

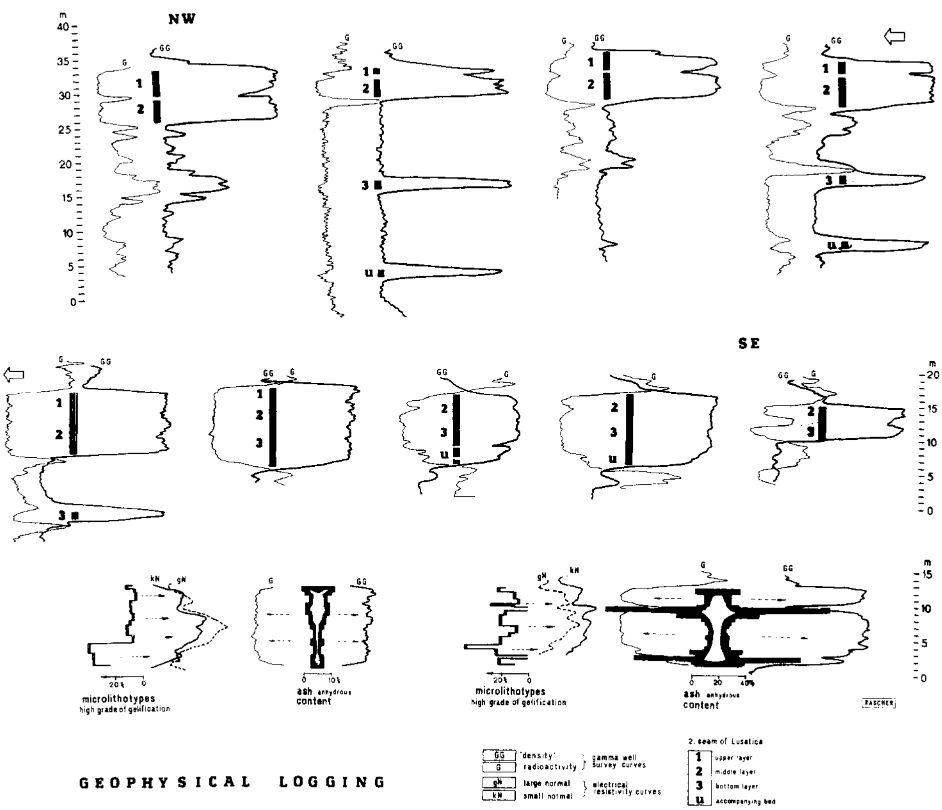


Fig. 6. Geophysical logs of bore holes showing coal and the relation between the geophysical and chemical–petrographical parameters of the coal seams.

possible by regional correlations with the help of these geophysical curves combined with bio- and lithostratigraphical investigations. In the lower line of Fig. 6, data on lignite quality derived from borehole measurements are given in brief. This data concerns both lignite geochemical data (e.g., ash content) and petrographical features (e.g., stage of lignite gelation).

BOG FACIES/LIGNITE QUALITY

The Tertiary succession of beds of the Niederlausitz lignite district reflects a series of transgressions and regressions. The largest distribution of the sea and of the sedimentary cover was attained during the Middle Miocene. Although there is no evident deep sea inundation, that is, by normally saline waters, brackish water inundated the area during short marine ingressions.

During the periods of regional compressive tension (see above) the tectonic basement mosaic was also pressed together. Regression resulted from the tendency of this tension to form a kind of vault. Single blocks were hardly able to respond during the compressive regime. The periods of regional dilatation imply the cessation of the vault tendency, a general transgression and the isostatic room to move single blocks (Seifert et al., 1989; Brause, 1990).

Further work needs to be done to substantiate the accuracy of the correlation of the dynamic processes within the alpine orogeny and the kinematics of the Atlantic opening. This imaginative model can only be considered as the beginning of a much deeper investigation. Using such geodynamic considerations we try to explain the interplay of the transgression and regression history.

During the Miocene, the four, regionally widespread, seams mark four extensive, if short-lived, inundations which resulted in extensive peat formation. Looked at more closely, it appears that single beds, representing partial sections of the B Mf 2, display rhythms of transgression and regression. The B Mf 2 consists of several partial cycles. Each partial cycle is controlled by extensive changes in water level. In some of the details of these cycles modifications due to synsedimentary movements of blocks are evident.

Figure 7 shows the beginning of the associations of plants of the coal moor and their dependency on the changing ground water level within a partial cycle. Such statements are possible because the plant remains of the B Mf 2 lignite have been clearly documented by during field studies (Schneider, 1984; Bönisch, 1986). On the basis of microscopically recognizable associations of plants, facies terms were developed. These facies are mappable by means of the palaeobotanical and petrographical characteristics. These facies reflect an increasing and then a decreasing ground water level. The regional development is locally modified by flowing waters (Bönisch and Grunert, 1985). Lateral facies transitions also arise, due to variations in the nutrient content

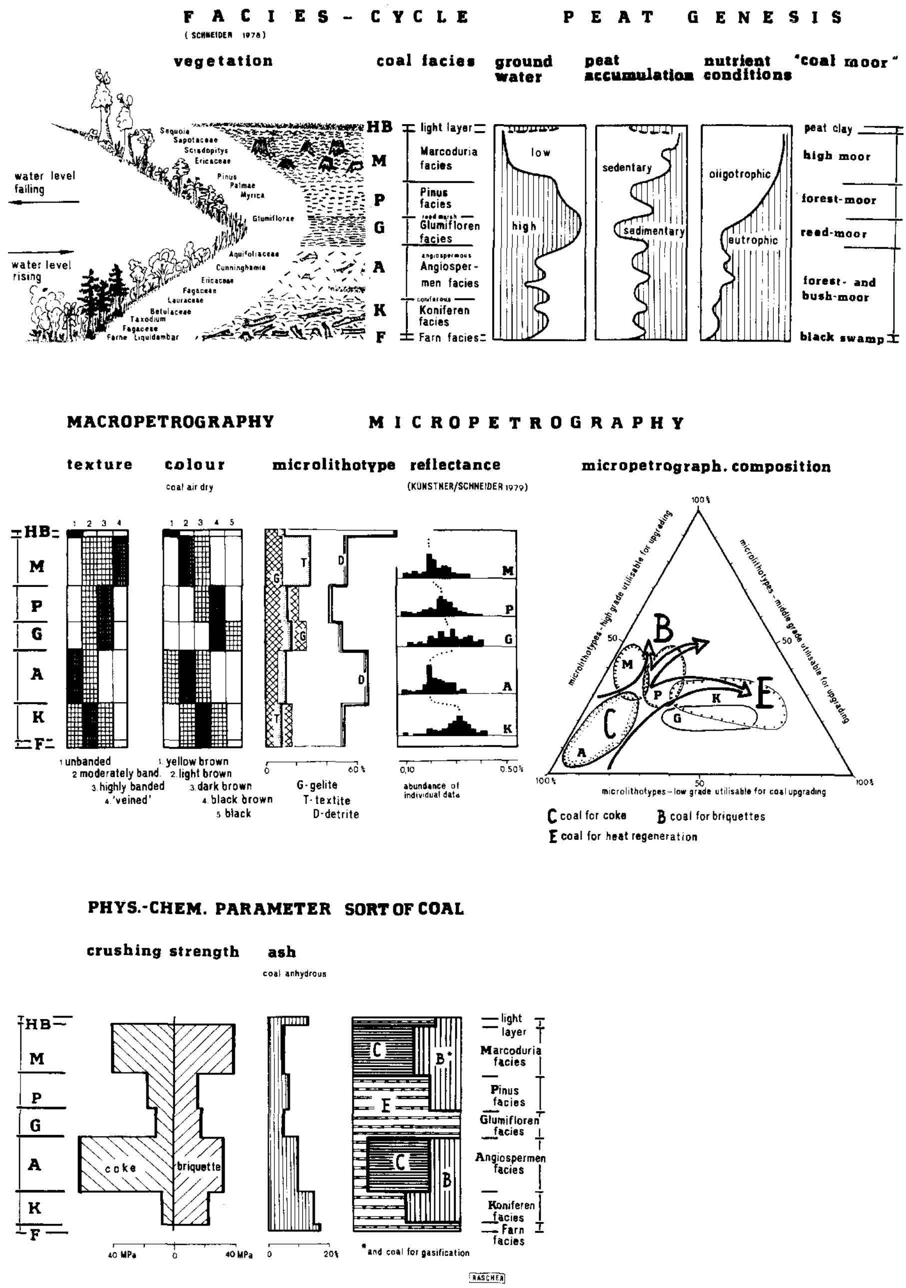


Fig. 7. Facies cycle of a single Miocene seam and parameters of the coal quality.

of waters. This is controlled by their proximity to the terrestrial or to the marine rim of the coal moor.

Differences within the lignite layer in macropetrographical (e.g., structure and colour) and micropetrographical (e.g., detrital, gelatinous and textite portion and reflectivity characteristics) are in accordance with the facies periods (*M*, *P*, *G*, *A*, *K*, *F*—see Table 2) of the coal moor. Further correlations consist in the physicochemical parameters of the lignite, such as the resistance to crushing of the briquettes and the ash content. Mapping of the facies types of the coal moor has enabled the quality of lignite and its use for briquetting, coking, gasification and direct application as fuel for power stations to be determined.

In addition to the successive vertical changes, there are horizontal differences within the coal moor. Depending on relative uplift or sinking of the basement blocks, the facies periods of the normal cycle are maintained for different lengths of time. A reed moor is dominant on strongly sinking blocks: a woody moor on rising ones. Figure 8a is a regionally generalized model with the most important facies periods of a cycle overemphasized. The sketch refers to the development of the lower bed B Mf 2.3 within a definite limited area. For that area, in Fig. 8b facies coefficients are summarized, giving data about the water level (moisture) during peat deposition. The highest values of this coefficient are in the area of the Drebkau block (II, Fig. 8a). Above the adjoining areas there are relatively dry moor areas (low coefficients). The lignite prevailing in such moors is well suited to being refined and used.

The ash content of the lower bed, B Mf 2.3, is indicated in Fig. 9a. The highest values of ash content are situated in the northern border area of the distribution of B Mf 2.3, hence in the transition area from moor to sea. The

TABLE 2

Plants, facies terms and relative rise or fall of water level in a normal sequence of occurrence of a facies cycle of Miocene peat development in Niederlausitz Brown Coal District, Germany

Code	Facies	Description	Water level
A normal sequence is arranged as follows (from the base):			
(*F*)	fern	eutrophic meadow wood	increasing
K	conifer	eutrophic woody moor	increasing
A	angiospermous	woody and shrubby moor	increasing
G	glumifloral	reed moor	increasing
P	pine	oligotrophic woody moor	decreasing
M	Marcoduria	relatively dry phase, high moor-like conditions	decreasing

Intercalations of "light band" (*HB*) = pure clastic sediments and muds.

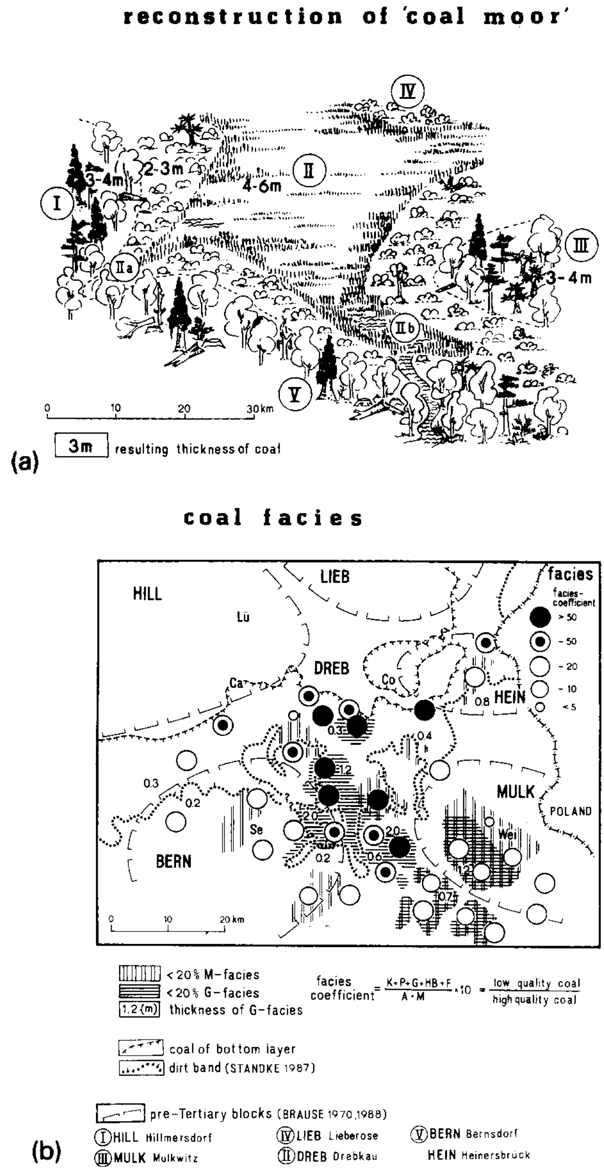


Fig. 8. (a) Sketch indicating different facies types in a coal moor. (b) Distribution of relative amounts of low-water level woody/shrubby and high moor types of lignite compared to lignites formed in high-water level moors (K–P–G–HB–F)/(A–M) (see Table 2).

transport of inorganic clastic material eroded from the southern swell areas was less important than the influence of sediment derived from the "coast".

A generalized picture of the areal distribution of various qualities of lignite of seam B Mf 2.3 is shown in Fig. 9b. The higher quality lignites are located

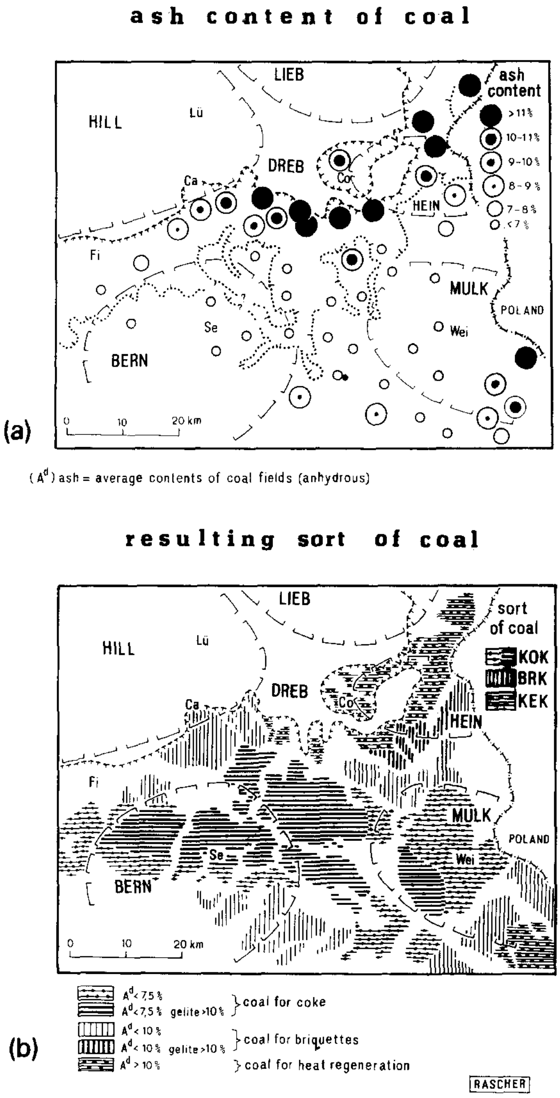


Fig. 9. (a) Areal distribution of ash in coal from the lower bed B Mf 2.3. (b) Areal distribution of coal in the lower bed, B Mf 2.3, best suited for coking (KOK), briquettes (BRK) or electric power generation (KEK).

at the southern rim of the Drebkau block. This was probably characterized by the greatest rate or amount of synsedimentary sinking during the development of the coal moor.

Facies profiles from various areas of the lignite extension of B Mf 2 in the Niederlausitz district are shown in Fig. 10. In the southeast the woody moor types predominate within the landward rim area of the lignite extension. In

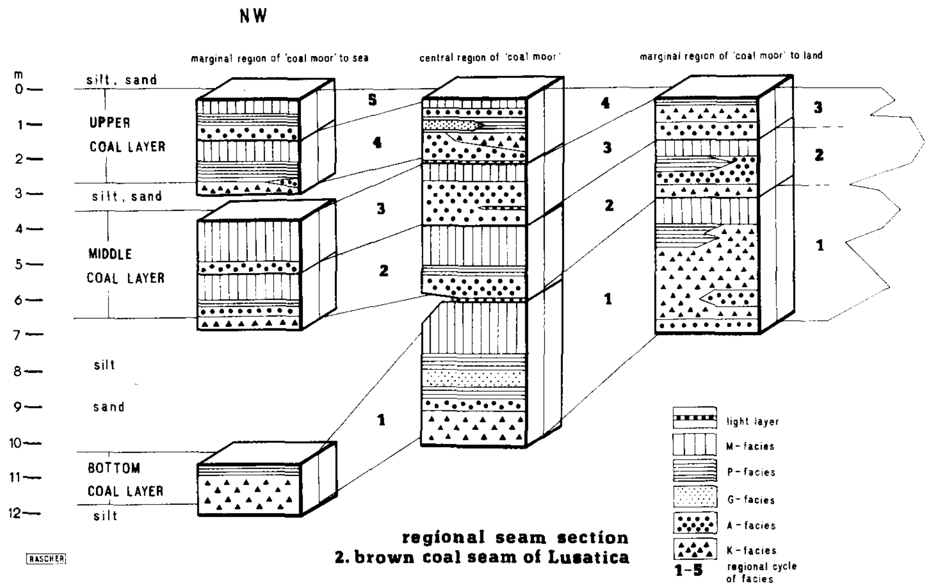


Fig. 10. Facies profiles of the lignite extension of B Mf 2 in the Niederlausitz district.

the central area the synsedimentary sinking was greater. This is evident from the changed coal moor facies, the greater general thickness, the occurrence of the No.4 facies cycle, the occurrence of completely developed cycles and the clearer boundaries between single cycles in the form of "light bands". The solid lignite is usable as fuel in power stations, for briquetting, coking and gasification.

Within area of the moor which borders on the sea, the general sinking was so great that the development of the coal moor was interrupted by two thick, sterile layers. The growth rate of the coal moor was not great enough for a continuous moor profile. The No. 5. facies cycle here developed in the area with the greatest sinking rate towards the end of the time of moor formation.

Within the southern and northern borders of the coal moor only lignite usable for energy production is present. It is possible to reconstruct the variations in the coal moor biotopes in time and space as sequence of types of changing landscape. In this way we get comprehensive data about the development of the lignite quality and also about the controlling factors, such as synsedimentary changes in the water level. Changes in the water level were probably of an eustatic nature only in some areas. An important factor here in controlling the water level was the extensive uplift and sinking of the country on a large scale in connection with the changing regional tensional conditions. However, in some areas of peat moors, water level was controlled locally by differential sinking, uplift or tilt of single basement blocks.

In addition to the field documentation of the moor facies types, extensive investigations were been conducted into the specification of the phytogenic material, for secondary alterations of plant material, microbotany and micropaleontology and for the determination of the technical parameters of the fuel (Süss, 1964; Süss and Sontag, 1966).

ENDOGENE–TECTONIC INFLUENCES ON PEAT FORMATION AND COAL DEFORMATION

There was generally a broad regional control of water levels during the formation of the peat moor. However, locally endogene–tectonic conditions also caused many aberrations in thickness, attitude and continuity. There were great synsedimentary block movements, as shown in part of the Nochten lignite field (Fig. 11). There were also some limited movements or tilt of blocks to the north.

The elevation of isolines of the lignite layer (used locally as base level) at the southern rim of the field is at +65/+70 m NN. The isolines show the slope of the surface northward, to the zone of NW–SE striking faults at below +40 m NN. The southern rim of the field has been lifted by about 30 m. Some block rotation is also identified. In the north, the tilted block is limited by the NW–SE striking zone of faults, similar to those represented in Fig. 11. The southern border is situated about 2 km south of the Lausitzer Hauptabbruch, which also strikes NW–SE (Fig. 12). The block is not normally tilted towards the northeast between its NW–SE border zones but it has been rotated a little anti-clockwise. At its northwestern corner, therefore, there are spreading tendencies (Fig. 11). Subsidence to below +10 m NN within the range of the NW–SE trending zone of faults have been caused by these dilations. Apparently, some subrosion had taken place or was additionally initiated.

Precision correlations have allowed use to determine that the tilt of blocks in the south of the Nochten field took place during the time of peat formation within the coal moor. The lower part of the already light, consolidated peat bed slid down, resulting in swells, or pockets, of lignite, fissures, small areas without lignite, dragged-in parts of underlying beds and other deformation phenomena (Hahmann, 1979; Brause and Hahmann, 1989). Within the upper part of the coal moor, that developed later, there was a compensation of the thickness over the irregularities of this disturbed, distorted lower (earlier) peat accumulation.

The NNW–SSE trending range of local depressions in the base level layer, B Mf 2, is placed at the western rim of the Nochten field like a string of pearls. The base level layer within the depression has sunk about 10–20 m compared with the surroundings. This depression zone belongs to a larger regional shear

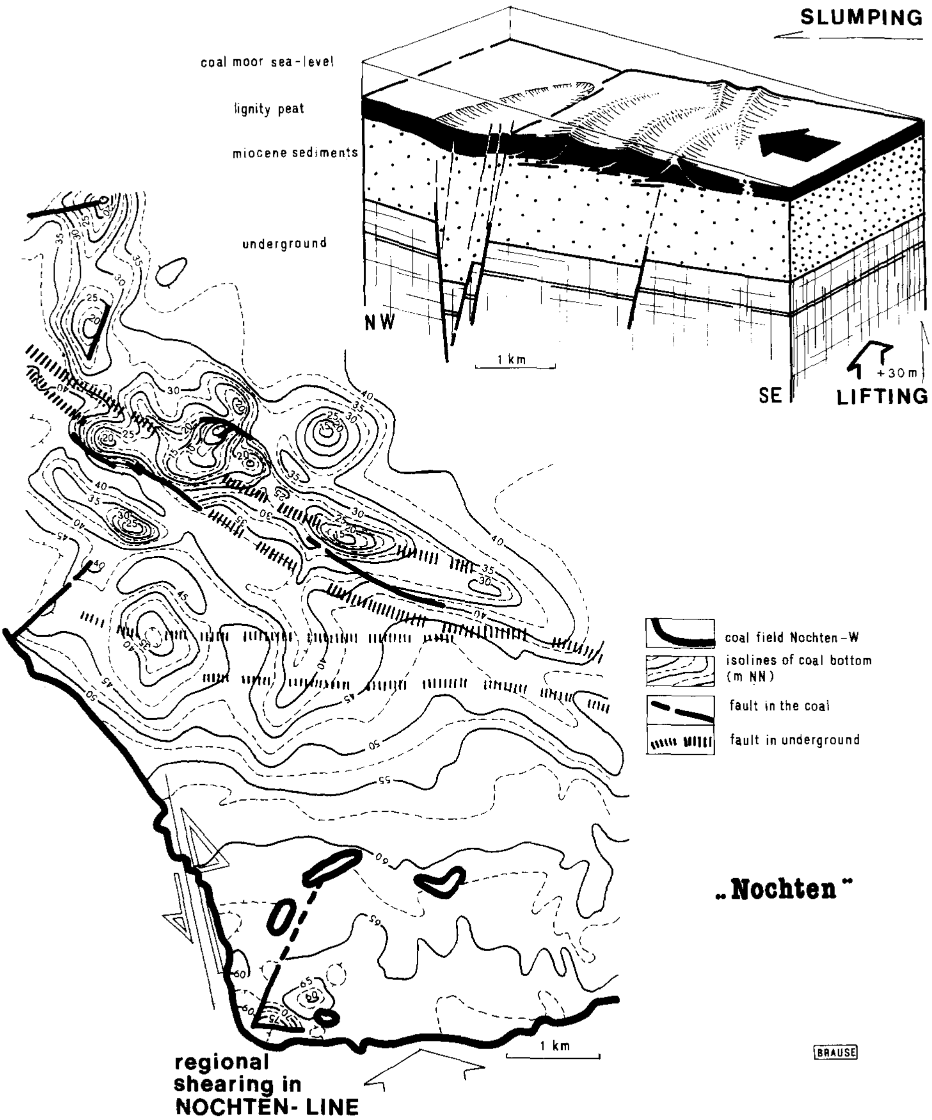


Fig. 11. Part of the Nochten lignite field showing faults in coal and deeper faults and differential block movement.

zone (Fig. 12) of the "Nochten line". The depression zone, modified by shearing and widening, is probably subrosionally modified.

There has been extensive adjustments in elevation, as illustrated above, in the area of the Niederlausitz lignite district which overlies the southern rim of the middle European basin. The regional subsidence has extensive isostatic causes. However, the development of the coal moor is generally and mainly

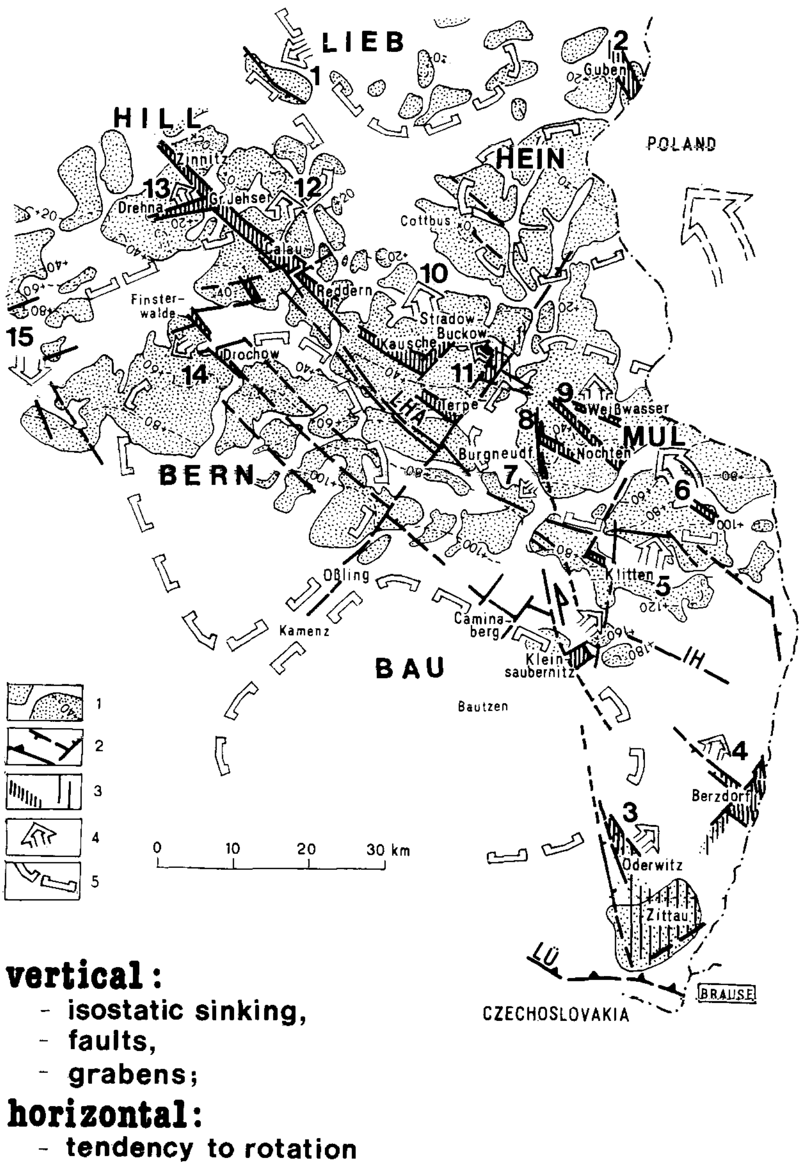
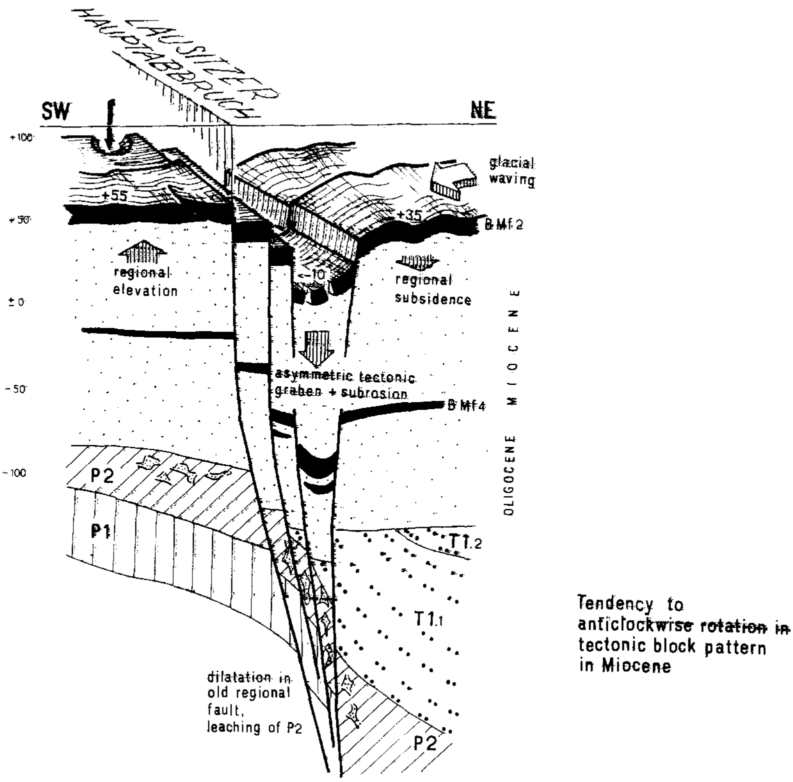


Fig. 12. Secondary block movements following coal accumulation in the Calau area.

controlled by extensive synsedimentary subsidence that led to the present elevational differences in the lignite layer levels (Figs. 4 and 12). This is shown in the detail of Fig. 12, where the base level is the lignite layer, B Mf 2: it is more than +100 m NN at the southern border of the Niederlausitz district;



..Calau..

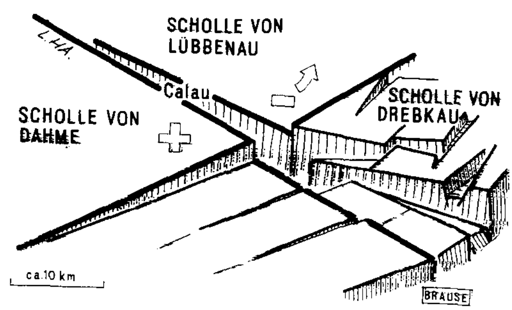


Fig. 13. The Niederlausitz lignite district. Coal fields and tectonics. *1* = lignite fields, depth of the coal basis B Mf 2; *2* = faults: *LHA* = Lausitzer hauptbruch, *IH* = Innerlausitzer Hauptverwerfung, *LÜ* = Lausitzer Überschiebung; *3* = grabens; *4* = direction of movements in the Miocene; *5* = basement block pattern: *LIE* = partial block of Lieberose, *HILL* = partial block of Hillmersdorf, *HEIN* = partial block of Heinersbrück, *BERN* = partial block of Bernsdorf, *MUL* = partial block of Mulkwitz, *BAU* = partial block of Bautzen.

in the southeast it is more than +180 m NN; in the northeast of Fig. 12 the base level layer is placed below ±0 to −20 m NN.

In addition to the regional tendency, there were local adjustments in the elevation of single blocks during the lignite formation. Further adjustments took place after the lignite formation. This is demonstrated in the sketches of the Calau area (Fig. 13). The Dahme block, south of the Lausitzer Hauptabbruch, was uplifted about 20 m compared with the Lübbenau block. At such secondary adjustments of elevation, which developed within the Cenozoic sediments, some real fractures developed while some adjustments were only flexures.

Troughs originated within the Niederlausitz lignite district at numerous larger or smaller faults activated by basement movements. The No. 2 lignite accumulation sank into these depressions between blocks (Figs. 12 and 13). Figure 12 shows the distribution of these troughs and in Fig. 13, an individual example is shown. These fault troughs often show asymmetric extension. In Fig. 12 plausible directions of widening were arbitrarily assigned to the troughs, in accordance with a complicated anti-clockwise rotation in the sense of Fig. 2. Further adjustments were caused by halokinesis (salt tectonics at depth) and subrosion.

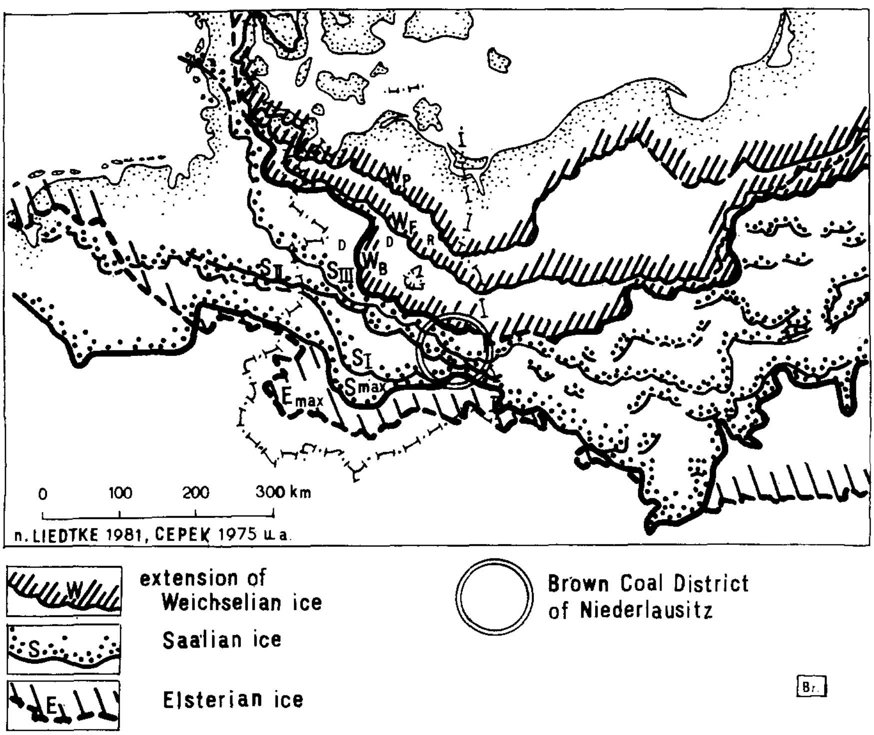


Fig. 14. End moraines of the Elster, Saale and Weichsel glaciations in the Niederlausitz lignite district.

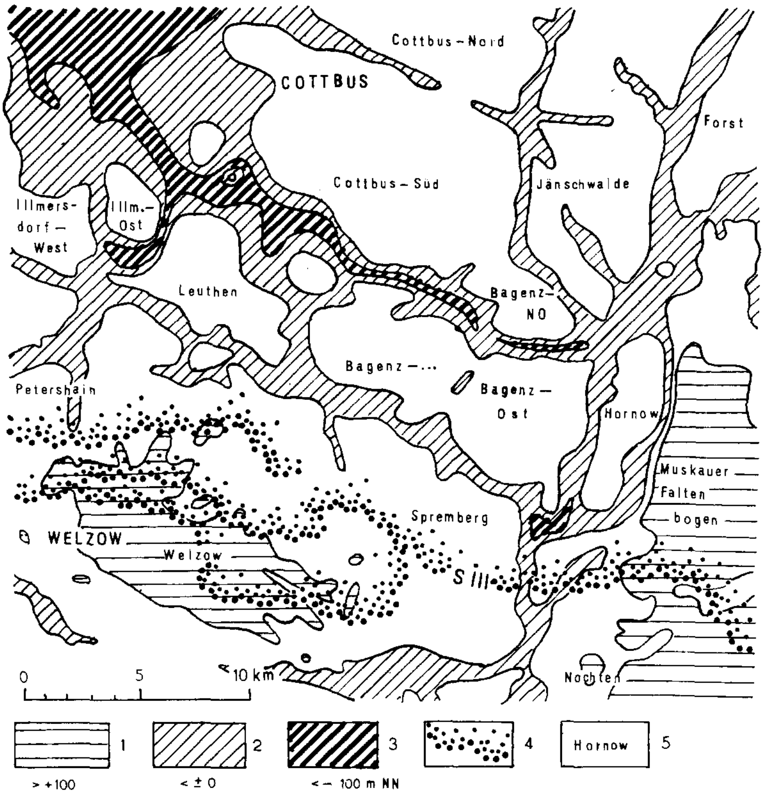


Fig. 15. Pleistocene channels in the northern part of the Niederlausitz lignite district, after Kupetz et al. (1989). *1–3*=depth of Pleistocene basins; *4*=terminal moraine of Saalian ice; *5*=lignite fields.

GLACIOGENIC PLEISTOCENE DISLOCATIONS

The lignite area of the Niederlausitz lignite district has been greatly influenced by three extended Pleistocene glaciations (Fig. 14). End moraines of the Elster, Saale and Weichsel glaciations, together with several intermediate steps (recessional (?) moraines) lie within the lignite area. Many dislocations originated as a result of forces exerted by ice movements or other attendant processes of glaciation. As a rule, the lignite fields here are not separated by natural borders. Locally, some coal fields have been cut or interrupted by Pleistocene channels (Fig. 15). Channels of various priority can be distinguished according to magnitude and depth (Nowel, 1984; Kupetz et al., 1989).

Pre-Elsterian valley erosion may explain the later stoping of the valleys by ground moraines of the Elsterian ice (Fig. 16). The depth of the valleys, as much as 200 m NN deep, is problematic. On the basis of our present-day

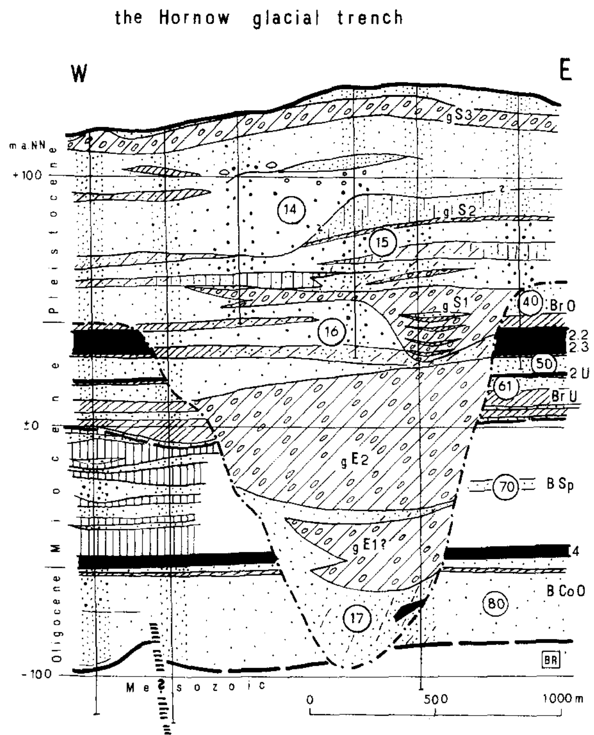


Fig. 16. The Hornow glacial trench: a pre-Elsterian valley eroded below the Upper Briesker and No. 4 coals, in the Niederlausitz lignite area.

knowledge there is no apparent drain for such valleys. The excavation may have been enlarged by ice or by movement in dead ice bodies.

Hydromechanical and subcrystic deepening and vertical effects below a network of fissures under the ice could have resulted in considerable destruction, caused by forcing down water, freezing and compression. Eissmann (1975) has described cases of this geologic process. The effects of subcrystic, compressed water under old, cut valleys are not very well understood. At present, the hydromechanic and hydrodynamic questions cannot be answered adequately. Some mechanical interpretations of the rupture and fissure formation by a different crystic burden imply a subsequent hydromechanic or glaciomechanic shaping or modification of the ruptures to the present channel forms.

Due to the important economic interests, it will be necessary to study the genetic problems of the channels in future. There is a relationship between the tectonic fracture pattern of the basement and the surface patterns of trenches and dislocations which appear in the coal.

Some of the terminal moraines of the several glacial advances (Fig. 14)

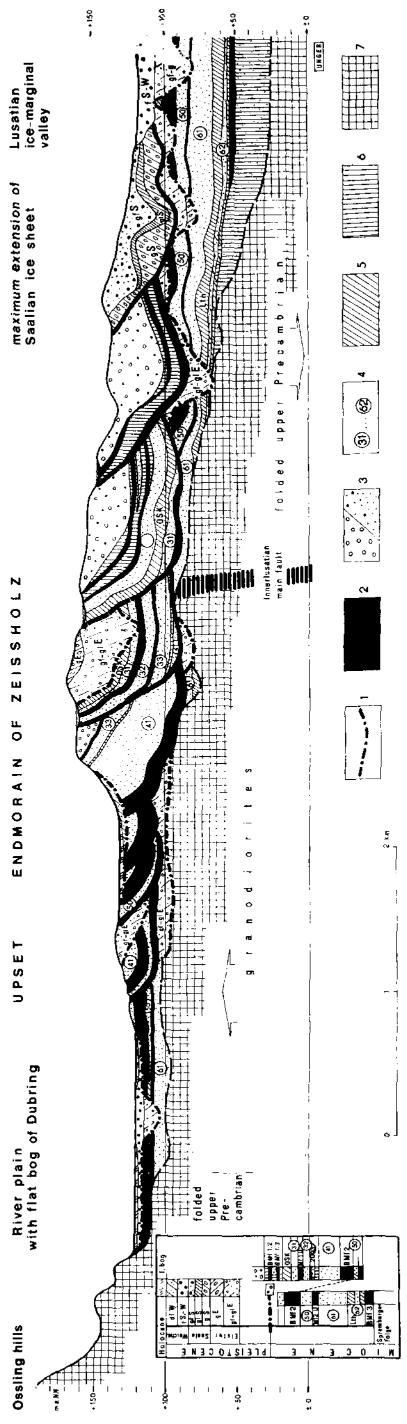


Fig. 17. Cross section of upset terminal moraine of Zeissholz (after K. Unger).

have been deformed in this region. At some terminal moraines there are large, ice-pushed, dislocated pile-ups of Pleistocene and Tertiary blocks. Figure 17 shows the well-studied upset terminal moraine of Zeissholz (Hübner and Unger, 1989). It is situated on a regional tectonic fault. The altitude of B Mf 2 is above 90 m NN north of the fault and more than 110 m NN south of the Innerlausitzer Hauptverwerfung, within the area shown in Fig. 17. Within the compressed area, considerable dislocations of the lignite-bearing Tertiary and Pleistocene layers occur. There are also broad zones of overturned folds in the lignite field covering an area of 1.5 km within the field Spreetal-NE. These were caused by a barrier compression in front of the main Lausitzer Hauptabbruch fault. It is not possible to treat all the many glaciogenic dislocations here. Many impressive photos and details are available in the extensive literature (Nowel, 1981–1984; Kupetz et al., 1989).

SUMMARY

The Niederlausitz lignite region is one of the main sources of lignite for electric power generation, coking, gasification and briquetting, in the former German Democratic Republic. Over 320 M t/yr were produced by the late 1980s for coking, briquetting, heating and electric power generation. This Tertiary basin was formed as a continuation of the sinking of the middle European basin (during the Permian and Mesozoic). It developed synchronously with the opening of the Atlantic Ocean and the alpine orogeny. Its transgression history was controlled by regional geotectonics. Regional and local tectonic factors controlled the peat facies.

Four coals of Miocene age and one of Oligocene are found over extensive areas in this region. The youngest seam, B Mf 1, has been generally depleted by mining and seam B Mf 2 is now the main lignite source and is won by open pit mining operations. B Mf 3 is less continuous and not a significant resource. B Mf 4, at the base of the Miocene, is extensive and has been explored with thousands of boreholes but it is not considered to be of economic potential at present. The Calau seam, of early Oligocene age, is also too deep to consider at this time.

The lateral continuity of these brown coals is extensively interrupted by block faulting and extensive post-depositional valleys, mostly filled with Pleistocene alluvial and moraine sediments. These channels divide the lignite district into several fields. The block faulting was mainly controlled by basement faults, which propagated to the surface during and following deposition of the peat beds. The faulting caused some penecontemporaneous dislocations as the peat accumulated. Later uplift, subsidence, spreading and rotation of blocks resulted in distortion, regional shearing, ruptures and fault troughs. Imbricate folding, lens-like thickening or absences (voids by displacement) in the brown coal were also post-depositionally induced by sub-

rosion, halokinesis and glaciogenic stress. Post-depositional regional dip to the north resulted from regional subsidence towards the north and uplift towards the alpine tectonic belt to the south.

Seams of brown coal consist of several cycles of alternate moor and swamp facies as a result of rising and lowering water levels (mostly controlled by sea levels). These facies can be differentiated both in mine exposures and in exploratory cores by the species of plants that contributed to the formation of each layer of peat. The successional communities identified to have formed the peat range from back swamp through forest bush moor, to reed moor, to forest moor, to high moor. Each of these types of peat is shown to have formed different qualities of coal (in their ash and sulphur contents and texture) and to have a different economic use (for coke, briquettes or heat generation). This means that, during exploration by boreholes, the relative amounts of coal for different economic use may be determined.

Valuable information on the geological history of the Niederlausitz region has been obtained during the exploration and development of these lignite deposits, particularly concerning the late Tertiary tectonic activity, regional tilting and erosional and deformational forces of glaciation or accompanying glacial erosion.

REFERENCES

Bönisch, R., 1986. Zur regionalen Auswertung fazieller Untersuchungen des No. 2. Lausitzer Flözes. WTI, 27 (3): 52–61.

Bönisch, R. and Grunert, K., 1985. Verschluffung und Aufspaltung der No. 2. Bank des No. 2. Lausitzer Flözes im Gebiet Lübbenau–Cottbus–Forst. Z. Angew. Geol., 31 (2): 33–39.

Brause, H., 1979a. Schelfkruste und Drift, konsequente Fortsetzung der v. Bubnoff'schen Aussagen. Z. Geol. Wiss., 7 (2): 183–191.

Brause, H., 1979b. Probleme des Krustenbaues und der geotektonischen Entwicklung auf der Geotraverse Baltikum, DDR, Cesky massif. Schriftenr. Geol. Wiss., 15: 5–36.

Brause, H., 1980. Differentialmobilismus. Z. Geol. Wiss., 8 (4): 405–414.

Brause, H., 1990. Beiträge zur Geodynamik des Saxothuringikums. Dissertation B, Karl Marx Univ., Leipzig.

Brause, H. and Hahmann, H.-G., 1989. Kipp- Gleit- Tektonik Typ Nochten. Geoprofil, 1: 63–64.

Eissmann, L., 1975. Das Quartär der Leipziger Tieflandsbucht und angrenzender Gebiete um Saale und Elbe. Modell einer Landschaftsentwicklung am Rande der europäischen Kontinentalvereisung. Schriftenr. Geol. Wiss., 2.

Förster, F., 1968. Senftenberger Revier 1890–1914. Zur Geschichte der Niederlausitzer Braunkohlenindustrie. Dtsch. Akad. Wiss. Berlin, Schriftenr. Inst. Sorbische Volksforschung in Bautzen, 37: 1–328.

Grünthal, G., Bankwitz, P., et al., 1985. Preliminary results about regional seismotectonic studies in Central Europe. Gerlands Beitr. Geophys., 94 (4–6): 290–293.

Hahmann, H.-G., 1979. Die endogen-tektonischen Überschiebungen im No. 2. Lausitzer Flöz des Tagebaues Nochten-West. Z. Geol. Wiss., 7 (2): 293–297.

Hahmann, H.-G., 1981. Zur Gewinnungstechnologie im ehemaligen Alaunbergwerk zu Muskau. Abh. Ber. Naturkundemus. Görlitz, 54 (2): 1–9.

Hübner, F. and Unger, K.P., 1989. Die Zeissholzer Stapelendmoräne. Beispiel einer extrem glazigen geprägten Braunkohlenlagerstätten. Freiberg. Forschungsh. C, 434: 89–100.

Kupetz, M., Schubert, G., Seifert, A. and Wolf, L., 1989. Quartärbasis, pleistozäne Rinnen und Beispiele glazitektonischer Lagerungsstörungen im Niederlausitzer Braunkohlengebiet. Geoprofil, 1: 2–17.

Lotsch, D., 1968. Tertiär. Tertiäre (postlaramische) Tektonik. In: Grundriss der Geologie der Deutschen Demokratischen Republik. Akademie Verlag, Berlin, Vol. 1, pp. 356–384.

Nowel, W., 1981. Die geologische Entwicklung des Bezirkes Cottbus. Kapitel Tertiär und Quartär. Nat. Landschaft Bezirk Cottbus, 3: 3–38.

Nowel, W., 1982. Die geologische Entwicklung des Bezirkes Cottbus. Kapitel Tertiär und Quartär. Natur und Landschaft Bezirk Cottbus, 4: 3–38.

Nowel, W., 1983. Die geologische Entwicklung des Bezirkes Cottbus. Kapitel Tertiär und Quartär. Natur und Landschaft Bezirk Cottbus, 5: 3–26.

Nowel, W., 1984. Die geologische Entwicklung des Bezirkes Cottbus. Kapitel Tertiär und Quartär. Natur und Landschaft Bezirk Cottbus, 6: 3–33.

Pätz, H., Rascher, J. and Seifert, A., 1986. Kohle, ein Kapitel aus dem Tagebuch der Erde. Teubner, Leipzig, 150pp.

Schanze, W., 1981. Zur Geschichte des ehemaligen Alaunbergwerkes zu Muskau. Abh. Ber. Naturkundemus. Görlitz, 54 (2): 10–13.

Schneider, W., 1984. Angewandte Paläobotanik und Braunkohlenpetrologie, pflanzliche Gewebe als Gefügebildner in der Braunkohle. Freib. Forschungsh. C, 381: 14–19.

Seifert, A., Alexowsky, W., Brause, H., Geissler, E. and Suhr, P., 1989. Zu endogen-tektonischen Lagerungsstörungen im Niederlausitzer Braunkohlenlagerstättenbezirk. Freib. Forschungsh. C, 434: 8–25.

Süss, M., 1964. Petrologische und technologische Untersuchungen am No. 2 und No. 4. Niederlausitzer Flözhorizont. Freib. Forschungsh. C, 185: 1–132.

Süss, M. and Sonntag, E., 1966. Ein Beitrag zur petrographischen Nomenklatur und Systematik von Weichbraunkohlen. Bergbautechnik, 16 (4): 186–190.

Vinken, R. (Editor), 1988. The Northwest European Tertiary Basin. Geol. Jahrb., Hannover, Vol. A.