Correlations between petrographical properties, chemical structure and technological behaviour of Rhenish brown coal

E. A. Wolfrum

Rheinische Braunkohlenwerke AG
Stüttgenweg 2
5000 Köln 41

Federal Republic of Germany

1. Introduction

The Brown coal reserves in the Federal Republic of Germany amount to approx. 56 billion metric tons, 55 billion metric tons of which are in the Rhenish brown coal district located west of Cologne (Fig. 1). About 35 billion metric tons of that reserve are considered to be technologically and economically mineable today what, in terms of energetics, equals the overall oil reserves of Iran (1).

Rhenish brown coal is mined in five opencast mines (Fig. 2) with an average depth of about 280 m. Modern mining equipment having a daily capacity of some 240,000 m³ of brown coal and high-speed belt conveyor systems are used. About 119 million metric tons of brown coal were mined in 1981.

84.5 % of that output was used for power generation, 7.9 % for briquette production in 4 briquetting plants of the Rheinische Braunkohlenwerke and 4.2 % for powdered brown coal production in two grinding mills. A low portion, viz. 0.3 % was used in a Salem-Lurgi rotary hearth furnace to produce about 96,000 metric tons of fine coke in 1981. 2.7 % of the brown coal output was used for other purposes, inter alia in test plants for processes, like gasification and hydrogenation (Fig. 3).

Longt-term mining plans ensure that this source of energy will be available in sufficient quantities well beyond the turn of the millennium.

This calls for opening up the deep-seated seam horizons as it is being done for the first time with depths of 240 to 450 m at the Hambach mine which is now developed. Today's technology allows opencast mines with a maximum depth of 600 m to be operated.

Mining in greater depths leads to a change of the geotectonic conditions and hence a natural change in the brown coal quality characteristics.

This has varying and graduated effects on the individual refining processes (2).

The petrographical and chemical investigations presented in the following were carried out in order to describe the behaviour of the coal types characteristics of the Rhenish brown coal area during refining processes.

As an introduction, a short survey of the geological conditions of the Rhenish brown coal deposit is given.

2. Geological conditions in the Rhenish brown coal district

In geological terms, the deposit is part of the Lower Rhine Basin extending over about 2,500 km² which was formed by a subsidence in the Early Tertiary. Brown coal itself was formed about 15 to 20 million years ago in the Miocene; during millions of years it was repeatedly flooded with sea or river water and covered with sands, clays and gravels.

The geological profile from NE to SW across the southern part of the Lower Rhine Basin (Fig. 4) shows that the brown coal seams sank down to ever growing depths towards the southwest and then rose again from their deepest point below the Erft river towards the west. Tectonic events caused faults and fractures of several hundred meters.

Accounting these geological conditions, the opencast mines - following the seam - have to operate in ever growing depths.

Therefore selective mining for refining purposes is getting more and more expensive.

3. Structure and composition of Rhenish brown coal

Rhenish brown coal consists of a variety of lithotypes which are discernible in the coal seam already by brightness varations (Fig. 5).
Recent pollen analytical investigations proved that the bright and dark layers result mainly from changing conversion and decomposition conditions. The bog facies has only a limited influence.

The gradation from dark to bright layers reflects the degree of brown coal destruction (3.4).

Figures 6 to 8 show three different types of coal, viz. a bright unstratified coal, a medium-dark stratified coal and a dark heavily stratified coal. The high degree of decomposition of the lithotype represented in Figure 6 indicates an aerobic formation while the high-texture fibrous coal (Fig. 8) is an indicator of an anaerobic formation.

The discovered textures are above all gymnosperms represented by highly resistent coniferous woods which account for a quantity overproportionate to their share of the mainly anigospermous vegetation which formed brown coal.

Only a model can establish the complex, heterogeneous structure of brown coal.

Figure 9 shows a model that inter connects the various structural components, namely lignin, humic acid and aromatic structural elements. High content of functional groups causes high reactivity. Figure 10 shows how oxygen-containing functional groups are distributed in the Rhenish brown coal.

3.1 Macropetrographical characterization

Based on macropetrographical criterias 15 brown coal lithotypes were selected for the investigations described in the following; they represent more than 90 % of the main seam.

Figure 11 shows these 15 brown coal lithotypes arranged according to stratification an texture.

The coal can be subdiveded into 3 groups depending on the mode of stratification: unstratified, slightly stratified and heavily stratified.

The brightness tends to abate from unstratified to heavily stratified coals.

3.2 Micropetrographical characterization

Micropetrography evaluates the coal components ascertainable by microscopy. Figure 12 shows an extract of the results obtained from the combination analysis of the 15 brown coal lithotypes.*

Obviously the investigated brown coal lithotypes differ in micropetrographic respect.

*We thank H.W. Hagemann, PhD., member of the faculty of geology, geochemistry and oil and coal deposits of the Aachen technical university for having carried out the investigations.

Based on the qualitative assignment of the individual coal components, rhenish brown coal can be divided into four groups having similar petrographical properties which, correspond with the macropetrographical features (principle of classification: stratification and texture). This classification into 4 groups differs only negligibly from the macropetrographical division into three main groups.

The classification into four main groups results in the correlations shown in the following Figures. Figure 13 shows the liptinite content as a function of the group classifications 1 to 4. With rising group number, corresponding to stronger stratification and texture, the liptinite content declines. Figure 14 which shows the huminite as a function of the group numbers indicates that the huminite content rises with increasing stratification and texture.

These two correlations stand for a variety of functions of technological relevance between brown coal maceral groups.

3.3 Chemical and physical composition

Subsequent to the petrographical coal analysis, both a chemical and a chemo-physical investigation were carried out. Figure 15 shows the chemical and physical properties of the investigated brown coal lithotypes.

Rhenish brown coal has an average ash content of about 4 % (wf), a volatile matter of about 52 % (waf) and a lower heating value of 11.000 Btu/lb of coal (waf). The final analysis of the coal under waf conditions shows the following average composition:

69 % carbon, 5 % hydrogen, 1 % nitrogen and approx. 25 % oxygen; the sulphur content amounts to about 0.35 % (waf) about 50 to 70 % of which is bound to the ash during the combustion process since approx. half of the mineral components of Rhenish brown coal consist of basic alkali and alkaline earth compounds - primarily those of calcium.

The following investigations were aimed at revealing correlations between the chemical and chemo-physical coal data and the petrographical analysis that may help assess the coal quality prior to its use as a feedstock in various refining processes.

4. Correlations between petrographical structure, chemical composition and refining behaviour of Rhenish brown coal

The correlations between the chemical brown coal data, petrographical parameters and the refining behaviour are described in the following complex regression calculations therefore were carried out. Statistic calculation methods were applied as an objective criterion to prove such correlations.

To nearly all brown coal refining processes is applicable that

- the quality of the desired refinement products
- the refining cost
- the quality of the raw material

have a direct correlation. Hence, it is indispensible for any refining operation to know and assess the composition of the raw material and its behaviour during the refining process.

The usability of the results obtained from the raw material characterization in everyday practice depends on

- the spacing of drillings usuable for quality assessment
- the level of geological knowledge of the coal forming conditions
- a representative sampling in the opencast mine, taking into account the cutting geometry of the excavator (position of the excavator cuts to the deposit), the fast mining advance and the high mass flow involved.

4.1 Correlations between chemical and petrographical parameters

4.1.1 Heating value

Figure 16 shows that the heating value declines with increasing coal stratification. A comparison of the heating value of coal and its hydrogen content in Figure 17 indicates that according to expectation the heating value of the coal rises parallel to an increase in its hydrogen content. This again is due to the portion of hydrogen-rich minerals, such as liptinite, declining in the said order - a correlation clearly evident in Figure 18. The heating value of the coal obviously rises in proportion to its liptinite share. The oxygen-rich lignitic coal components, such as huminite, have the opposite effect on the heating value: Figure 19 shows that the heating value of the coal is down sharply with an increase in the portion of this maceral group.

4.1.2 Volatile content

The individual coal constituents contribute different shares to the volatile matter of the coals (5). With increased stratification, the volatile matter decreases, caused by the respective distribution of the various maceral groups. Figure 20 gives an example how the content of volatile matters and that of the hydrogen-rich liptinite maceral correlate. It is obvious that this constituent contributes a lot to the volatile matters.

4.1.3 Hydrogen content

Figure 21 shows that also the hydrogen content is closely corresponding to the petrographical brown coal properties. Figure 22 shows the correlation between the hydrogen content and the Lipto-Humodetrite and/or the Humo-Telinite content of the investigated lithotypes. A higher amound of Lipto-Humodetrite leads to an increased hydrogen content. The content of the Humo-Telinite maceral, however, has a totally different effect: This component has a high portion of oxygen-rich molecular groups what causes the hydrogen content of the brown coal to drop.

4.2 Correlations between coal quality and refining behaviour

4.2.1 Briquetting and coking

There are many investigations and publications available on the briquetting behaviour of brown coals, both from the GDR and the Rhenish area (6 to 9).

In order to establish statistically usable data on the briquetting behaviour of Rhenish brown coals, the 15 brown coal lithotypes were briquetted under identical conditions with a laboratory press (water content, grain size distribution and mould pressure).

For assessing the briquettability of these coals, a number of briquetting parameters were correlated with the petrographical properties of the brown coal types. A statistic evaluation of these briquetting parameters and the micropetrographical composition of the coals reveal only a minimal degree of interdepence. Figure 23 clearly shows that the Humo-Telinite content stands for the height and volume expansion of the briquettes.

The briquetting expenditure is related to the Telo-Humocollite content. The definition factor (r^2) varies between 0.58 and 0.67, and is comparatively low. All the other correlations between the briquetting parameters (e.g. diametrical expansion) and the petrographical coal composition turned out to be rather insignificant so that they need not to be taken into consideration.

These investigations on correlations established between the raw material properties and briquettability of Rhenish brown coal led to the following results:

1. A macro- and micropetrographical analysis with a view to technological problems involved in the briquetting process allows at the most to judge the briquettability of Rhenish brown coal on the basis of trend data.

2. A correlation analysis of the chemo-physical parameters of Rhenish brown coal and its briquettability gives only trend data as well.

Therefore generaly an anticipated quality assessment of the briquettes is restricted to the following points:

1. Macropetrographical assessment of the coal seam and evaluation of the briquettability on the basis of values gained by experience.

2. Laboratory production of briquettes and determination of their pressure resistance.

3. Determination of the ash content as an essential factor for the assessment of brown coal briquettability. Ash contents exceeding 3 to 4 % result both in a reduction of the resistance to pressure and a high wear of the molds of the briquetting presses, and are not suited to be processed into briquettes.
   Gelled coals, unsuitable for briquetting purpose as well, are used as steam coal.

Coking

Numerous publications (10 to 12) have been made above all in the GDR on the required quality properties of brown coal and their influence on the quality characteristics of formed coke. Since the Rheinische Braunkohlenwerke AG does not consider formed coke production at present, raw material quality and coking behaviour are of interest only for the production of fine coke using the rotary hearth furnace principle (13, 14) (Fig. 24).

This technology is dependent only to a low extent on the specific raw material composition. The petrographical factors of the feedstock have an impact above all on grain size and grain size distribution. It is not the final coke strength that is crucial for this process but the grain spectrum caused by grain decomposition.

Correlations so far unkown may lie in the petrographical composition of brown coal (in connection with the mineral composition) and the reactivity of fine coke to oxygen. Therefore, an anticipated quality assessment of feed coals corresponds to that used for briquetting coal.

4.2.2 Gasification

Two gasification processes under development, namely gasification using oxygen (HTW) and hydrogasification, (HKV), helped to study the gasification behaviour of various brown coal lithotypes (15).

The reactivity of the residual char is the speed-controlling factor for brown coal hydrogasification (16). Laboratory-scale investigations on the gasification behaviour of various types of brown coal coke showed that the mode of pretreatment has a greater influence on the gasification process than the raw material properties. To give an example, helium flushing of the coke under gasification temmperature has a very favourable effect on gasification.

With one exception only, gasification rates close to 100 % were achieved.

Differences in gasifaction speeds are due to the heterogeneous pore structure and the inhomogeneous iron distribution in the coal matrix.

Irregularly localized iron groupings contained in cokes of the lithotypes 1 and 8 show a varying reactivity behaviour.

Cokes of the lithotypes 4, 5, 9, 11, 13 and 15 with similar gasification behaviours have a comparatively homogeneous distribution of all ash components (Fig. 25). No correlation was established between the maceral composition and the reactivity behaviour of the cokes (17).

As it was the case with the mentioned hydrogasification process, the results obtained with HTW gasification did not show any statistically significant correlations between the petrographical composition of the lithotypes and their gasification behaviour.

4.2.3 Liquefaction

To determine potential raw material impacts on brown coal hydroliquefaction, the 15 lithotypes were converted into liquid products using various techniques (18).

1. moderate indirect hydrogenation with tetralin as a hydrogen-transferring solvent

2. direct hydrogenation with hydrogen and different catalysts similar to operational conditions.

- Indirect hydrogenation with tetralin

Indirect hydrogenation using tetralin at a reaction temperature of 410 °C, a pressure of 400 bar and an overall reaction time of 2 h produced carbon conversion rates from 50 to 79 (%wt) and liquid product yields from 43 to 69 (%wt). Of the multitude of correlations established between the results of the hydrogenation tests and the micropetrographical composition of the coal types only a few examples are given.

Figure 26 shows the product yields of indirect brown coal hydrogenation with tetralin as a function of stratification and texture (lithotype number). It is obvious that with increasing stratification and texture, i.e. with rising lithotype number, the liquid product yield drops and the portion of hydrogenation residue increases. Regarding the fine structure of the coal the following correlations turn out:

Figure 27 represents the carbon conversion rate as a function of the liptinite and huminite maceral portions. It can be seen that an increase in the hydrogen-rich liptinite constituent improves carbon conversion while the oxygen-rich huminite reduces the carbon conversion rate. These trends also apply to the yield of liquid products. It should be pointed out again that it is only possible to give trend data. Quantitative assignments are impossible since the statistical certainty is insufficient.

- Direct hydrogenation with molecular hydrogen and catalyst

The influence of the raw material was expected to weaken using hydrogen and a catalyst under the conditions similar to those in the real hydroliquefaction process. An increase in the carbon conversion rate up to a maximum of 96 (%wt) shows that both brown coals with high or low carbon-to-hydrogen ratios achieve high product yields. Plain impacts of the raw material on the liquefaction results are no longer observed.

Resuming it can be said that the hydrogenation degree from indirect to direct hydrogenation rises parallel to an increase in carbon conversion. The result is that nearly all brown coal types mineable in the Rhenish area can be converted into liquid products with high yields. Hydrogenation process engineering, i.e. the optimization of the reaction conditions (temperature, pressure, residence time, catalyst type), is considered with priority over the raw material properties.

The investigations showed that in general practice no importance is attributed to a micropetrographical assessment of the coal types as a criterion for selecting specific brown coals from the Rhenish area. Tar content and/or low-temperature carbonization product yield and paraffin content suffice as parameters to assess the hydrogenatability of Rhenish brown coals. For exploratory drilling programmes, these parameters are determined separately. In general, brown coals from various areas that meet the quality parameters given in Figure 28 have satisfactory hydrogenation properties.

5. Summary

For the purpose of an assessement with a view to refining, the petrographical, chemical and physical properties of lithotypes of Rhenish brown coal were established and compared with one another.

The investigated coal typs cover more than 90 % of the coal types proved in the Rhenish deposit. A correlation of the results shows a describable, sometimes multidimension al dependancy.

A comparison of raw material properties and the results of the technical experiments quickly reveals the limits set to such an approach.

Out of all the refining processes subjected to investigation briquetting places the highest requirements on the raw material properties. The major part of the established parameters leads only to qualitative indications of the briquetting properties of the coals. Parameters of greater significance can hardly be utilized in pratice. What remains in the experience gained by coal technologists, is the determination of the classical coal properties and indications from laboratory briquetting.

For the gasification process no usuable quantitative relations were established between the petrographical coal properties and the gasification behaviour. It is possible without any material problems to convert nearly all the rhenish coal types into gaseous hydrocarbons or synthesis gas.

This statement applies without any restriction to coal liquefaction as well. Apart from a few comparatively rare coal types, all brown coals from the Rhenish area can be converted into liquid hydrocarbons with high product yields. Hence, hydrogenation process engineering, i.e. the optimization of the reaction conditions, has priority over the raw material properties.

Under the given conditions of the Rhenish brown coal deposit, an opencast mining operation, a high output and the large feed quantities required for future refining plants brown coal petrography is one out of many tesseraes for quality assessement.

The development of appropriate modes of determining the quality characteristics of raw brown coal is a task indispensable for the future.

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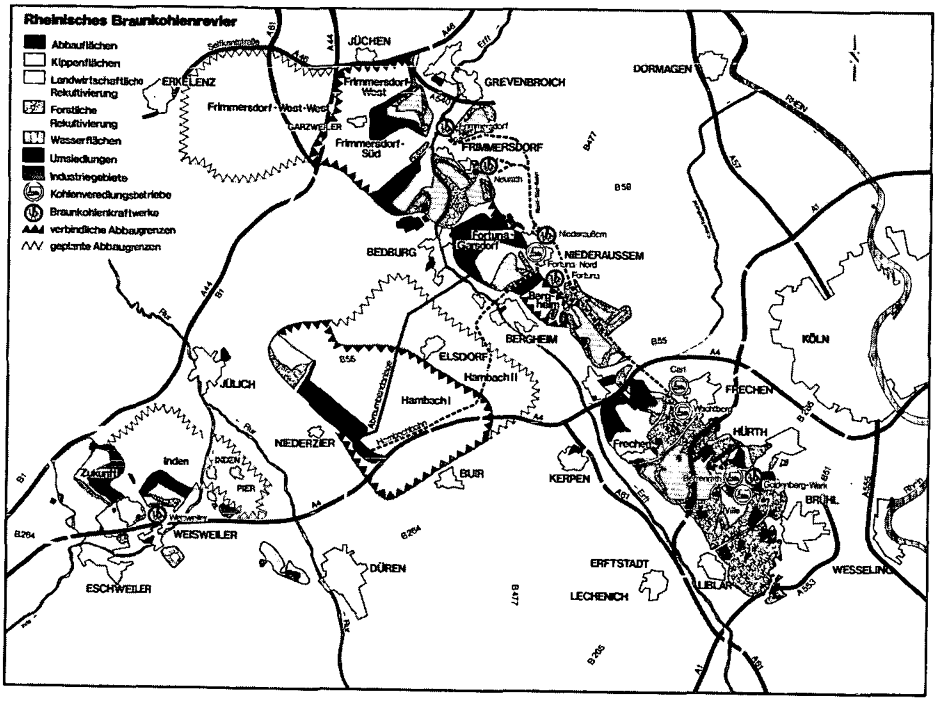
Fig. 1 Rhenish Brown Coal District



Rhenish brown coal district

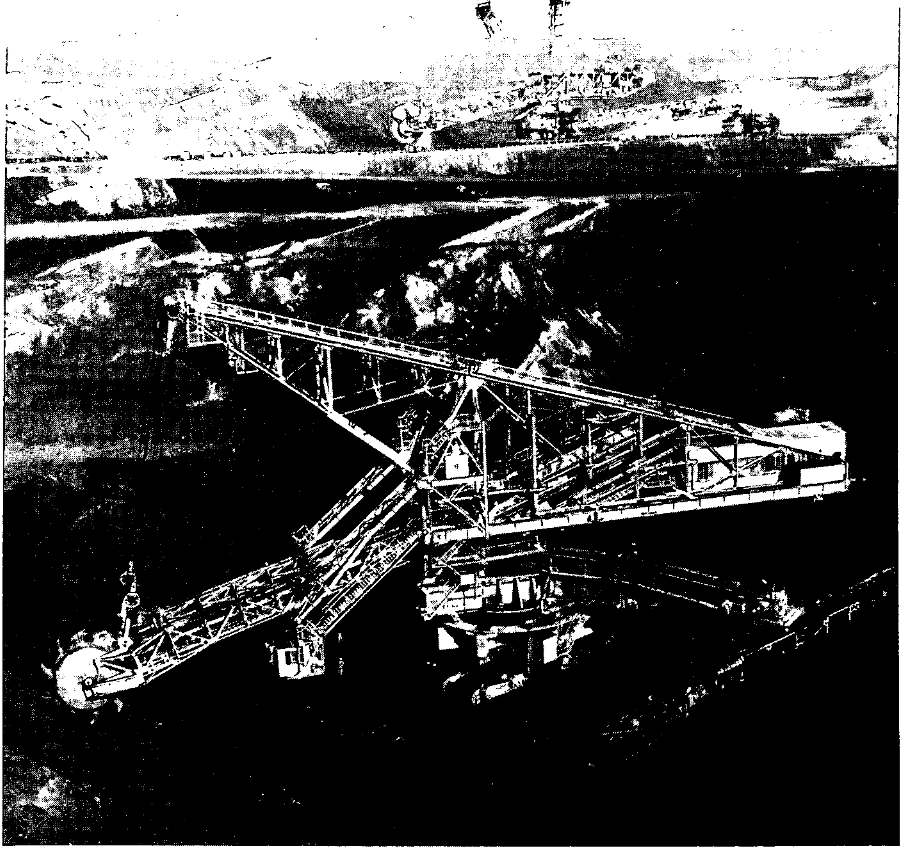
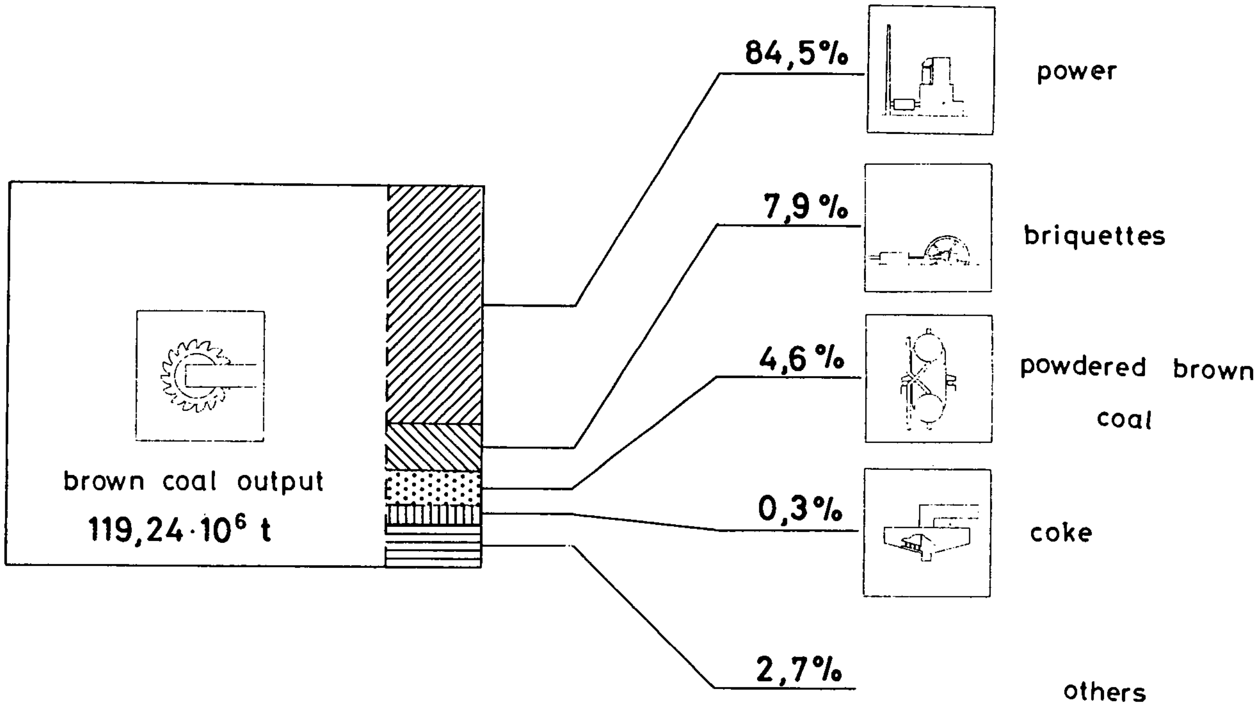


Fig.2 Excavator

Fig. 3



raw brown coal output and use

Rheinbraun 1981

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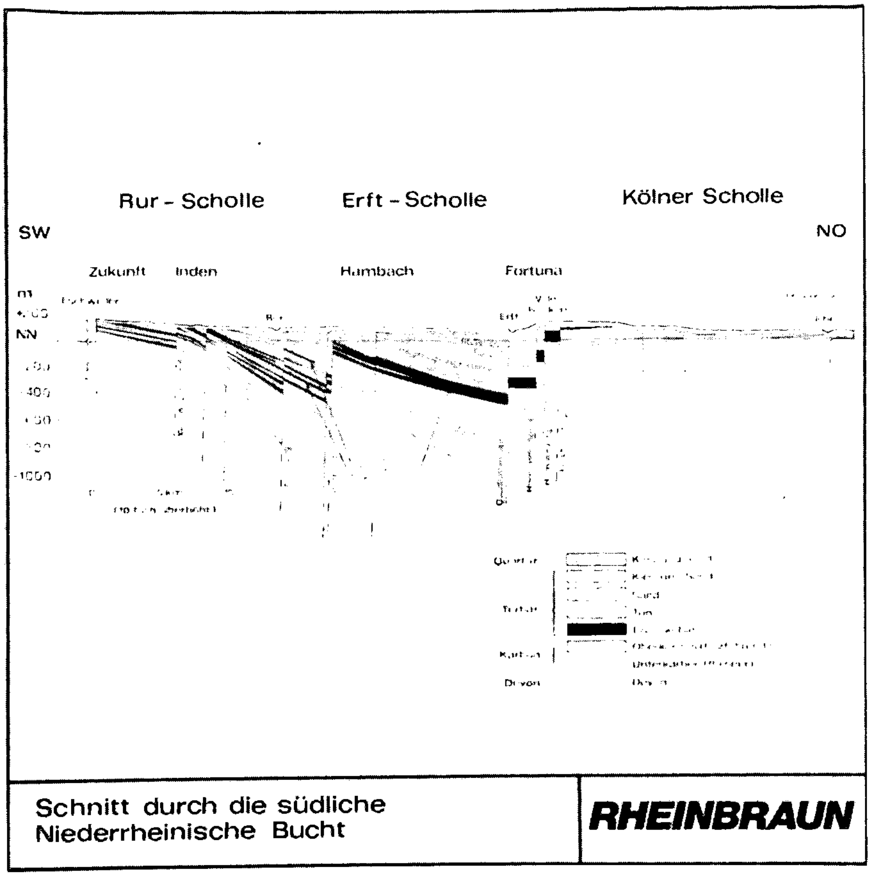


Fig.4 Geological profile

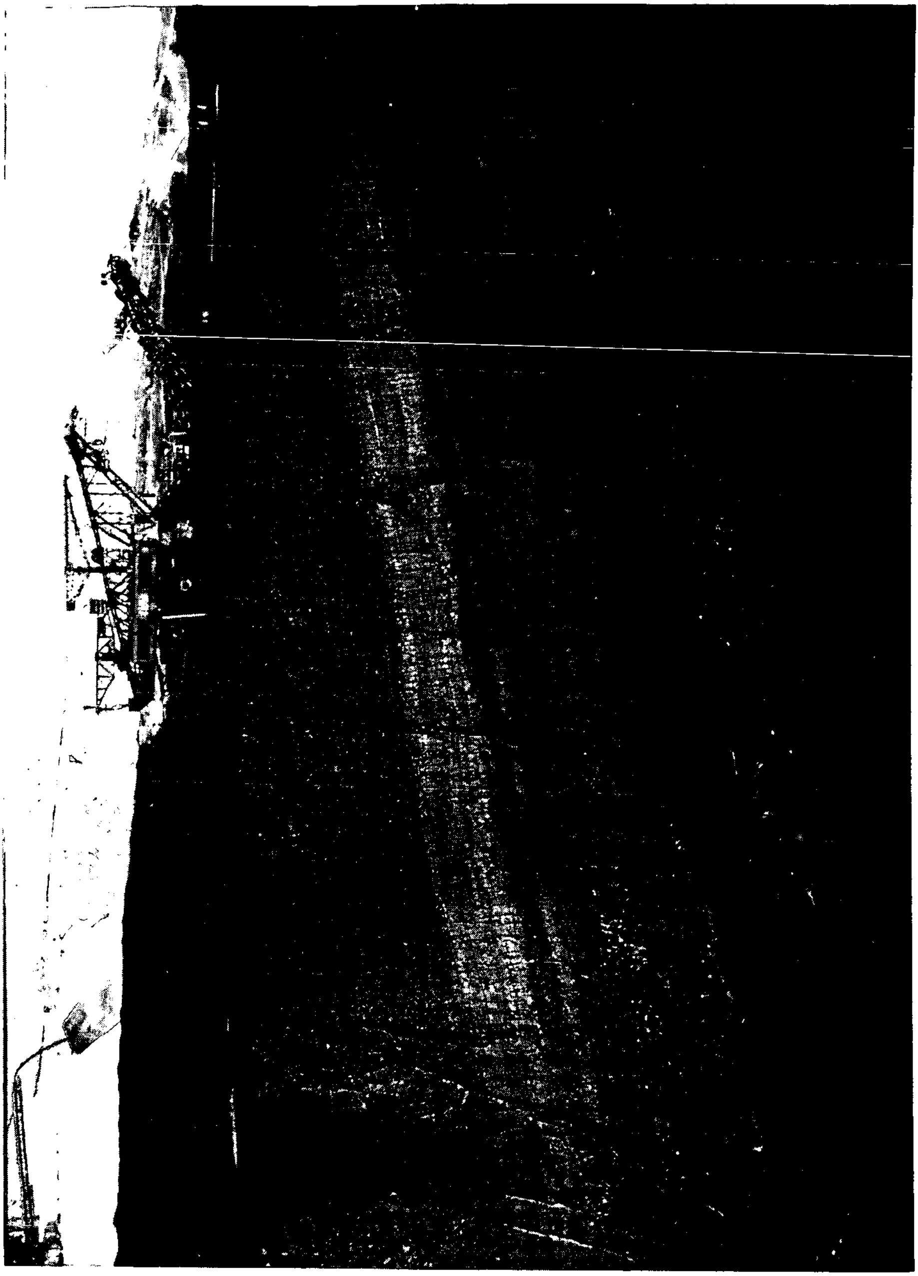


Fig.5 Brown coal seam

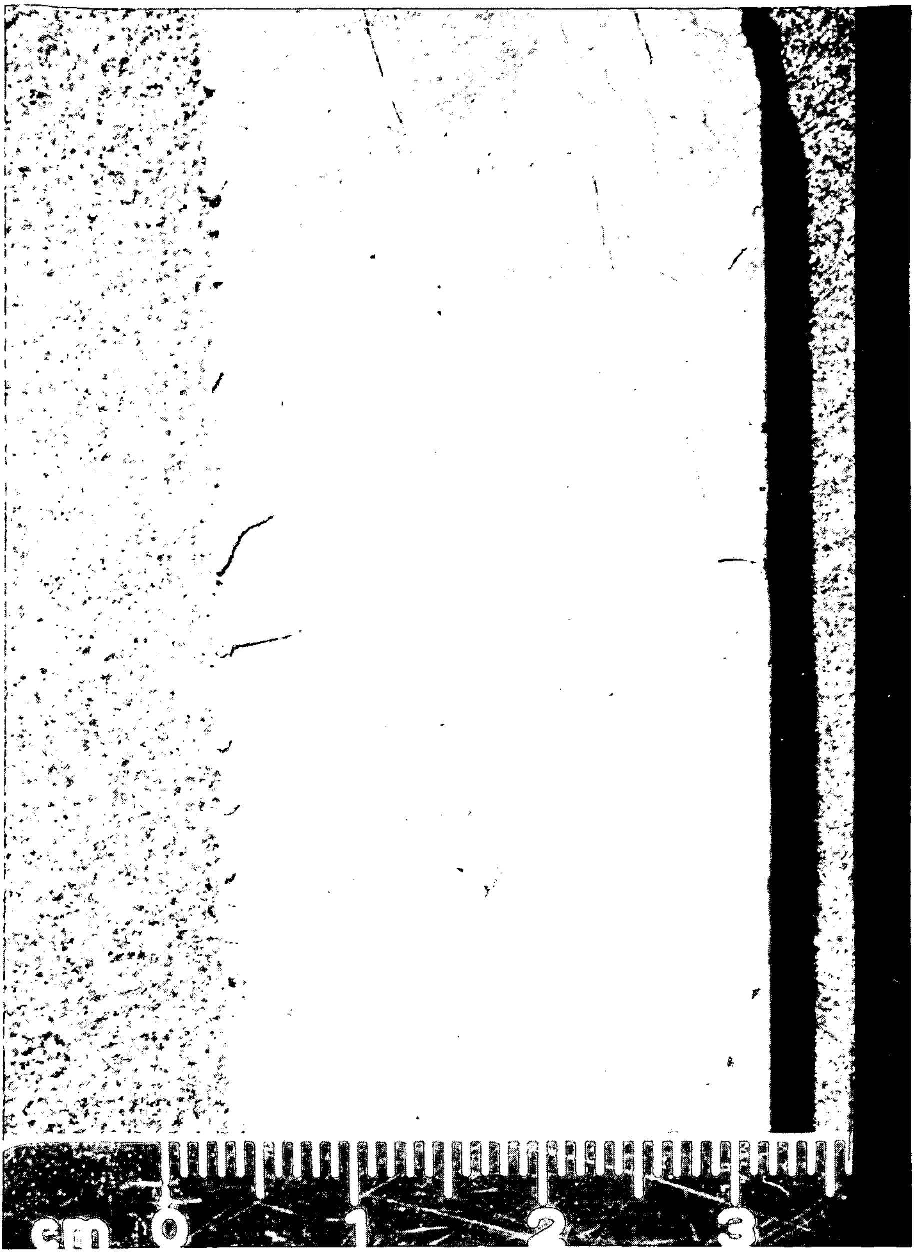


Fig. 6 Lithotype 1

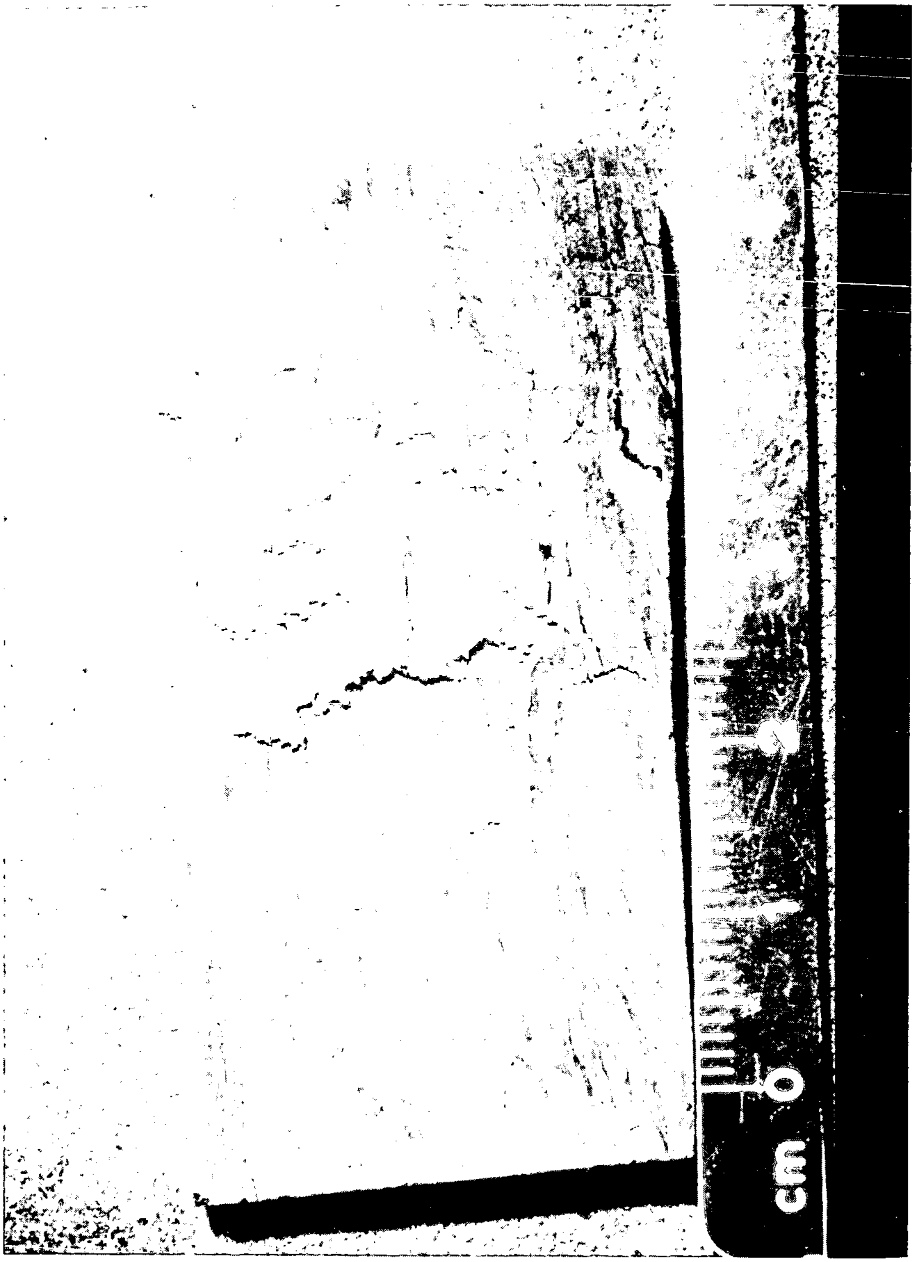
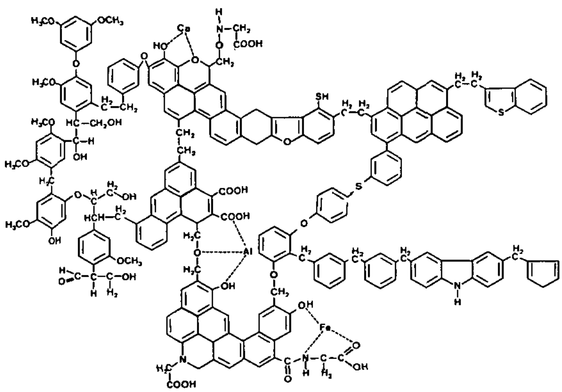


Fig. 7 Lithotype 9

Fig. 8 Lithotyp 15

Fig. 9



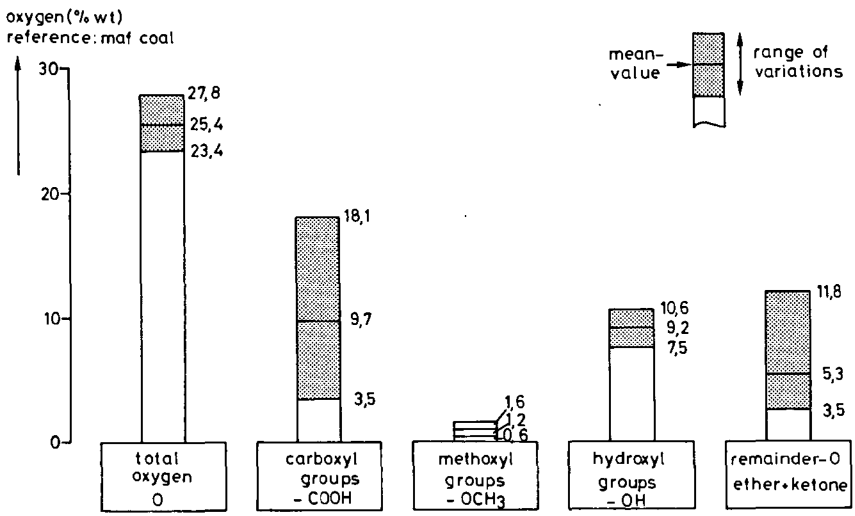
element	Rhenish brown coal (maf)
C	68,7
H	5,05
O	25,0
N	1,0
S (org.)	0,25

typical composition

lignin humic acids structural aromatic elements

Schematic composition of the brown coal structure elementary analysis

Fig. 10



Distribution of the oxygen-containing functional groups in Rhenish brown coal

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Fig. 11

percentage of a seam section	sample no.	structure matrix / texture	brightness and coluor	gelification rate accessory intercalations
4,2 %	1	unstratified coal	bright	xylite-and mineral-free, matrix
3,9 %	2	unstratified coal	dark	granular gelification nests, xylite
5,5 %	3	unstratified coal	medium-bright	xylite-containing
15,0 %	4	unstratified coal	medium-bright	slightly textured and xylite
12,8 %	5	unstratified coal	medium-dark	slightly textured,xylite,surface gel
7,8 %	6	unstratified coal	medium-bright	slightly textured,xylite-free
5,8 %	7	unstratified coal	dark	slightly textured,xylite,gel,fusite
18,5 %	8	slightly stratified coal	medium-bright	textured,xylite and resinous substance
9,2 %	9	slightly stratified coal	medium-dark	textured,xylite and bright texture
3,0 %	10	slightly stratified coal	dark	xylite and gelled,textured
5,7 %	11	slightly stratified coal	dark	textured,xylite and fusite nests
1,9 %	12	heavily stratified coal	medium-bright	heavily textured,bright texture,resinous sub.
2,5 %	13	heavily stratified coal	dark	heavily textured,xylite and fusite nests
2,2 %	14	heavily stratified coal	dark	heavily textured,xylite,gelled
2,0 %	15	fibrous coal	dark (black)	heavily textured,fusite texture

Macropetrographical classification of 15 brown coal lithotypes from the Rhenish area

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Fig. 12

maceral, maceral subgroup, lithotype	group no.	1	2	3	4
	lith. no.	1,2	7,3,4,6	5,10,8	14,15,11 13,9,12
Liptinite	% vol.	26 - 28	20 - 26	6 - 11	3 - 12
Humo-Detrinite	% vol.	56 - 59	54 - 58	31 - 43	12 - 31
Humo-Telinite	% vol.	3 - 5	10 - 17	26 - 33	34 - 50
Humo-Collinite	% vol.	6 - 7	3 - 8	19 - 26	17 - 31
Huminite	% vol.	67 - 69	72 - 79	87 - 92	80 - 90
Inertinite	% vol.	5	1 - 3	1 - 4	2 - 17
Lipto-Humodetrite	% vol.	79 - 80	56 - 67	3 - 17	-
Telo-Humodetrite	% vol.	3	21 - 30	8 - 15	10 - 30
Telo-Humocollite	% vol.	-	-	9 - 15	3 - 17
Detro-Humocollite	% vol.	-	-	3 - 7	3
Gelo-Humotellite	% vol.	3	3	10 - 12	10 - 39

Micropetrographical classification of 15 lithotypes into 4 groups

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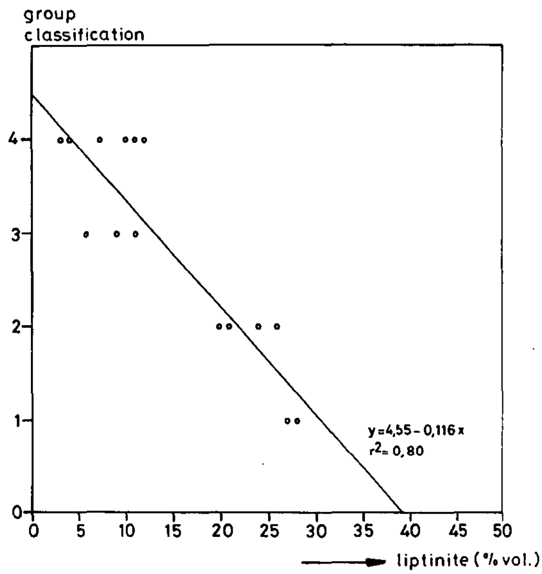
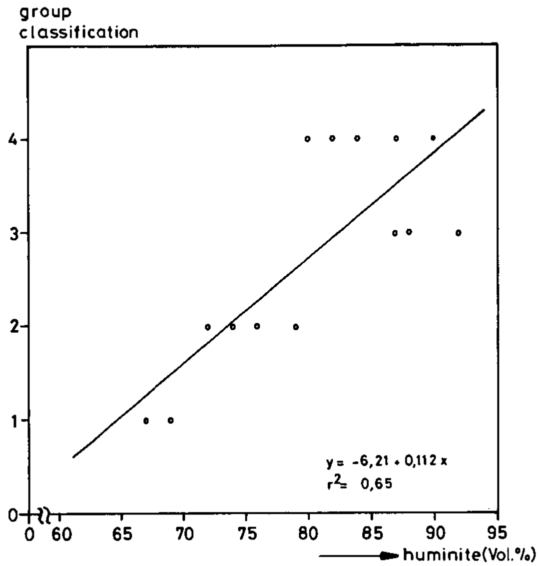
Fig. 13



Liptinite content as a function of micropetrographical classification	RHEINBRAUN

Fig. 14



Huminite content as a function of micropetrographical classification	**RHEINBRAUN**

Fig. 15

lithotype no.			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Short analysis																	
- brown coal (raw)	an *	% wf	52,2	60,4	60,1	55,6	52,0	56,6	54,0	60,0	53,4	55,1	54,0	59,7	60,8	58,6	49,0
- ash content	mf	% wf	6,53	2,44	2,78	3,86	3,90	4,42	3,55	4,27	3,04	3,52	3,73	2,73	3,56	3,36	3,92
- volatiles	maf	% wf	59,68	55,25	55,11	54,70	52,42	52,09	51,91	52,98	49,65	49,76	48,36	53,72	51,74	51,77	48,79
- C-fix	maf	% wf	40,32	44,75	44,89	45,30	47,58	47,2'	48,09	47,02	50,35	50,24	51,64	46,28	48,26	48,23	51,21
- heating value	maf	MJ/kg	27,99	25,67	25,89	26,69	25,85	25,97	26,30	26,27	25,55	26,43	25,31	24,96	25,43	25,36	24,99
Elementary analysis																	
- carbon	maf	% wf	69,6	67,5	67,8	68,9	68,2	69,3	69,6	65,7	68,5	68,4	68,9	67,4	66,3	67,4	69,5
- hydrogen	maf	% wf	5,89	5,60	5,24	5,56	5,19	5,21	5,25	4,71	5,10	4,92	4,69	4,91	4,79	4,66	4,51
Extraction analysis																	
- bitumen content	maf	% wf	12,87	12,25	10,96	12,04	8,79	7,43	8,96	7,29	7,10	6,40	9,18	7,20	9,65	5,11	7,31
- paraffin content	maf	% wf	10,19	9,46	9,00	10,00	4,93	6,53	7,48	6,00	5,77	3,93	5,90	5,93	8,20	4,19	3,18

* as received

Chemo-physical characterization of the brown coal lithotypes subjected to investigation

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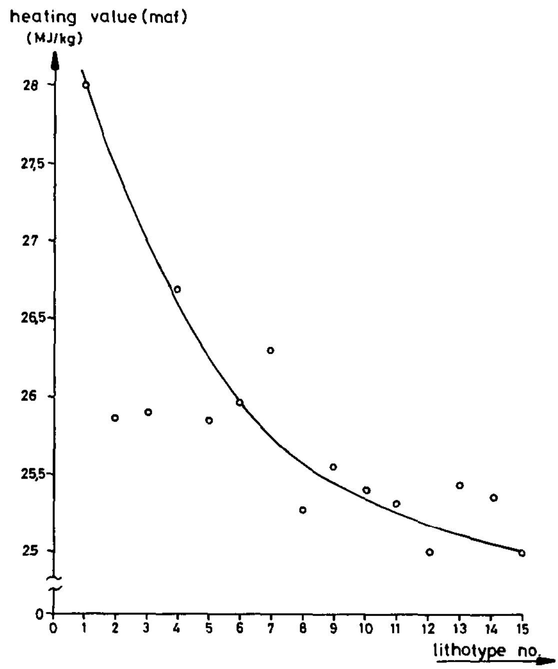
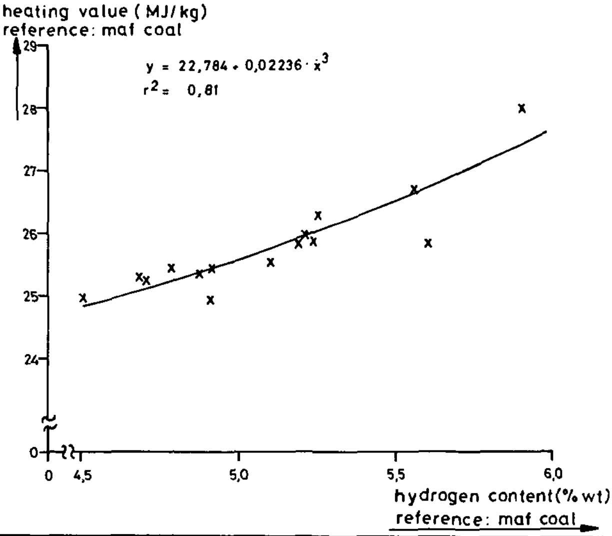
Fig. 16



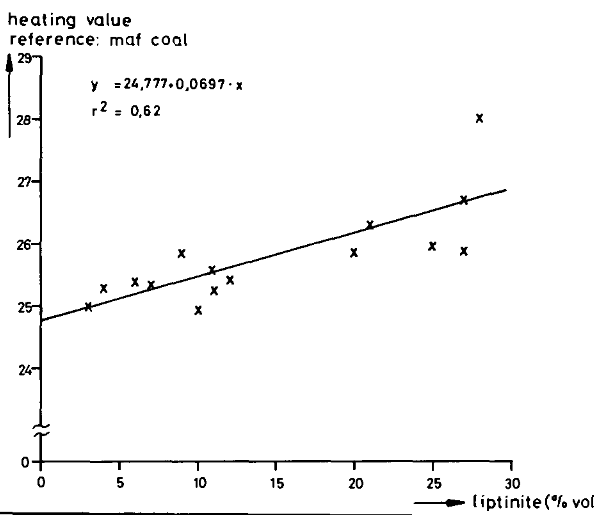
Heating value of the brown coal lithotypes as a function of macropetrographical classification	RHEINBRAUN

Fig. 17



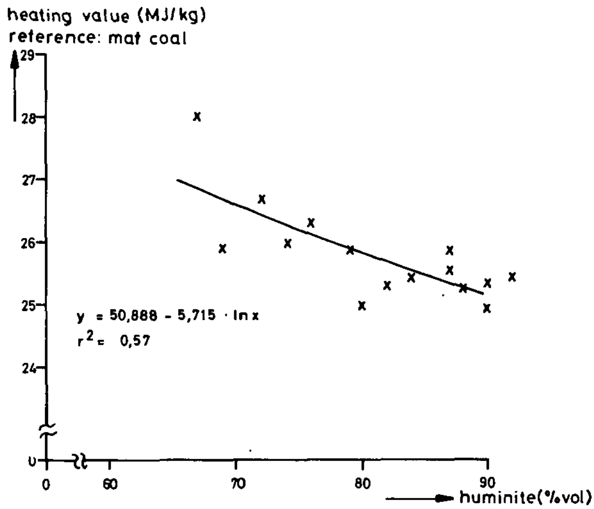
Correlation between the heating values and hydrogen contents of the 15 lithotypes investigated	**RHEINBRAUN**

Fig. 18



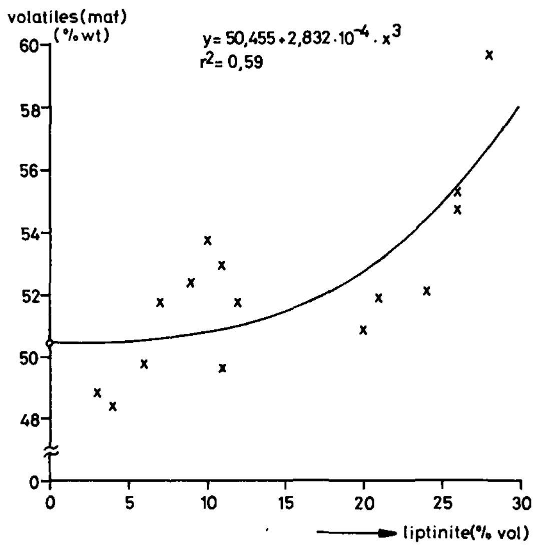
Heating value as a function of the liptinite content of the 15 lithotypes investigated	***RHEINBRAUN***

Fig. 19



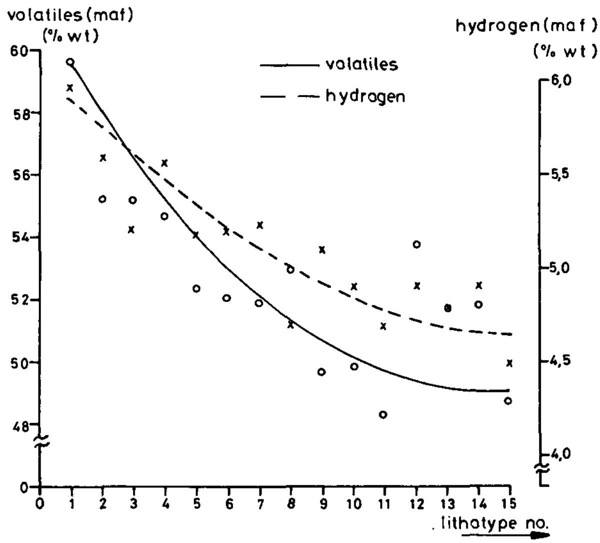
Correlation between heating values and huminite contents of the 15 lithotypes investigated	**RHEINBRAUN**

Fig. 20



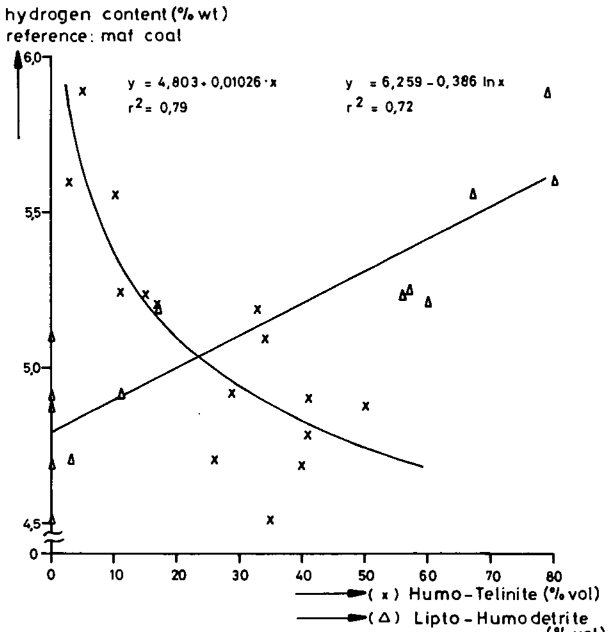
Volatile portion as a function of the liptinite content	**RHEINBRAUN**

Fig. 21



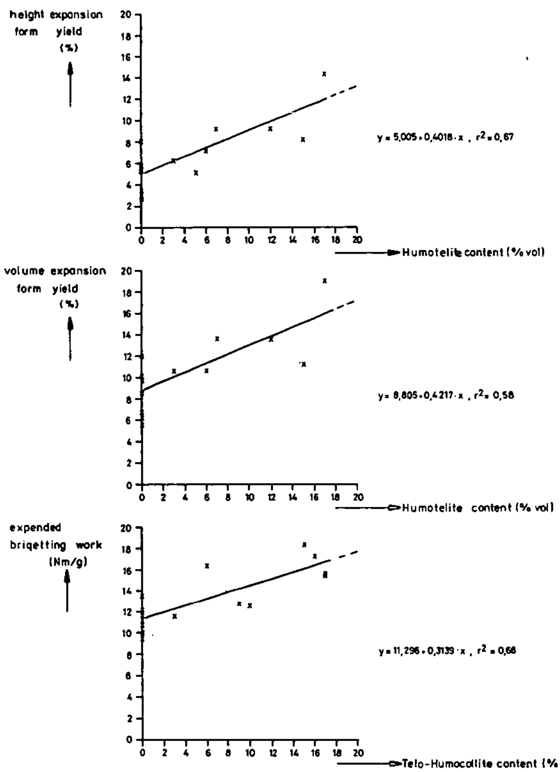
Correlation between volatile matters, hydrogen contents of the lithotypes and the macro-petrographical classification	RHEINBRAUN

Fig . 22



Correlation between hydrogen and Humo-Telinite and Lipto-Humodetrite portions	**RHEINBRAUN**

Fig. 23



Correlation between the contents of various microlithotypes and for subgroups and various briquetting results

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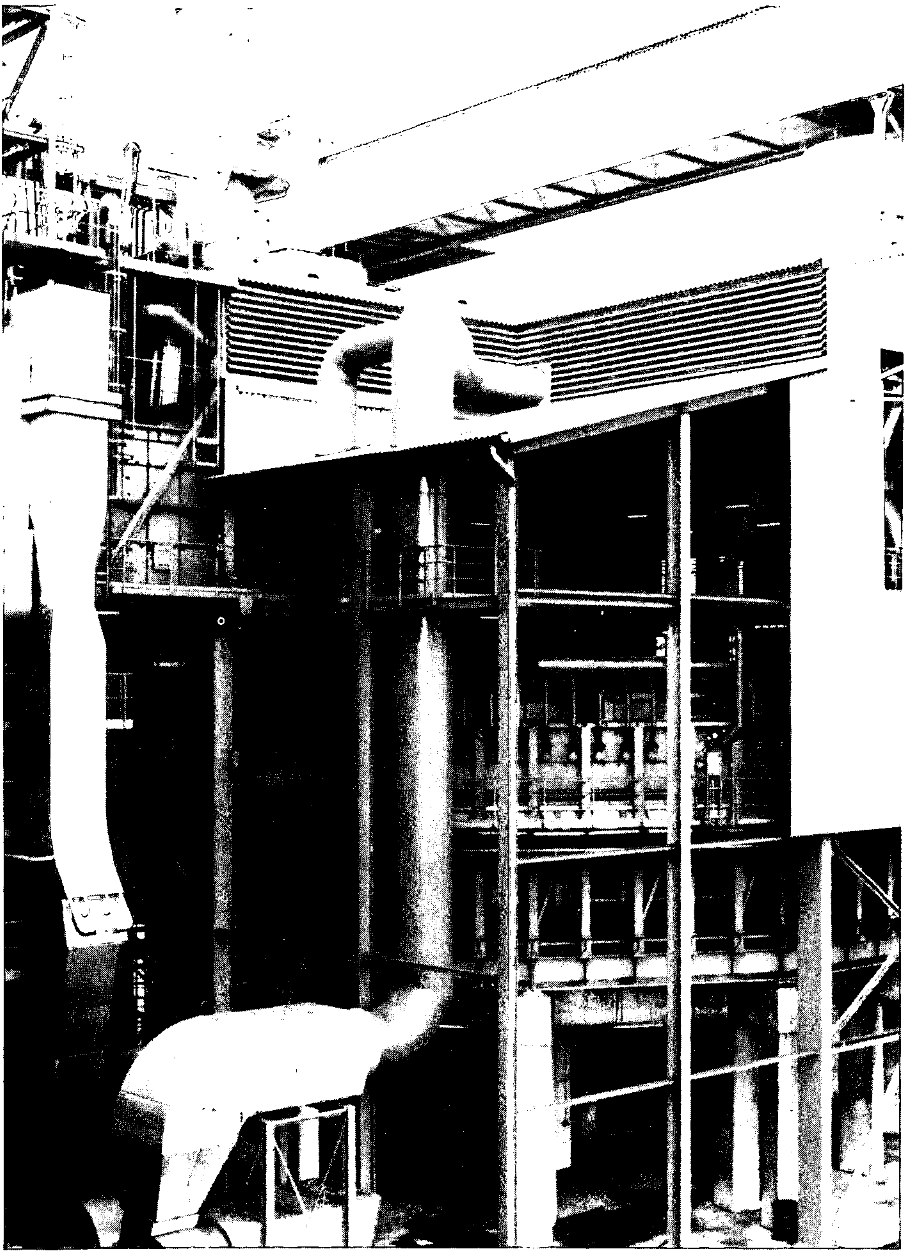


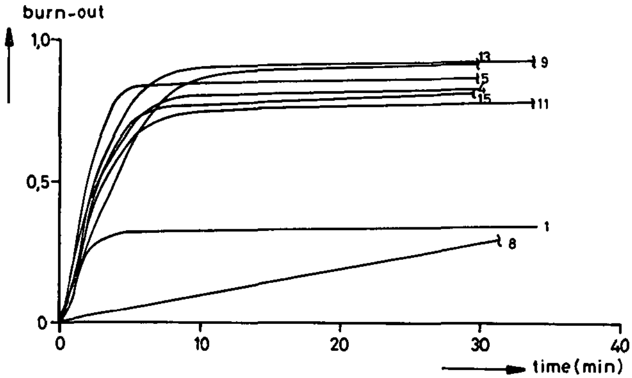
Fig. 24 rotary hearth furnace

Fig. 25

40 atm H_2 bei 900°C

Vorbehandlung: 1/2 h im Heliumstrom von 1 atm bei 900°C

lith. no.	burn-out	time (min)
9	93,3	72
13	92,5	80
5	88,3	120
4	82,1	30
15	82,4	46
11	87	240
1	34,1	34
8	100	390



Conversion as a function of time with hydrogasification of brown coal cokes

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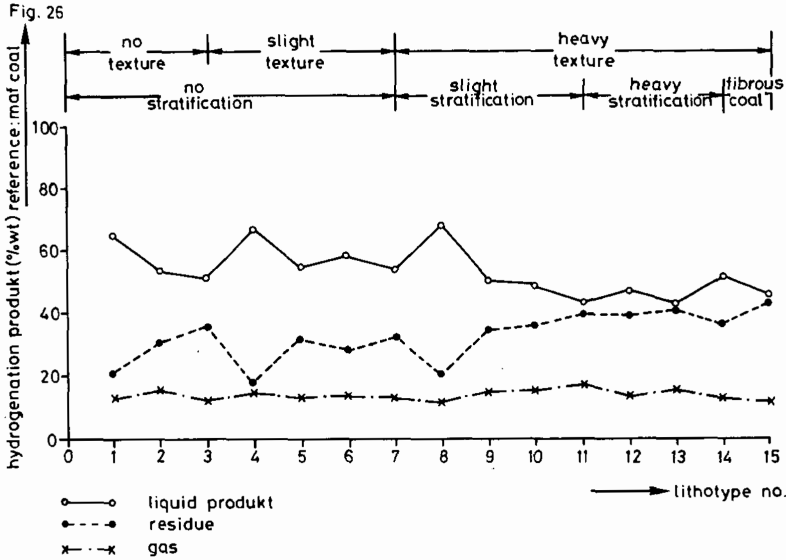
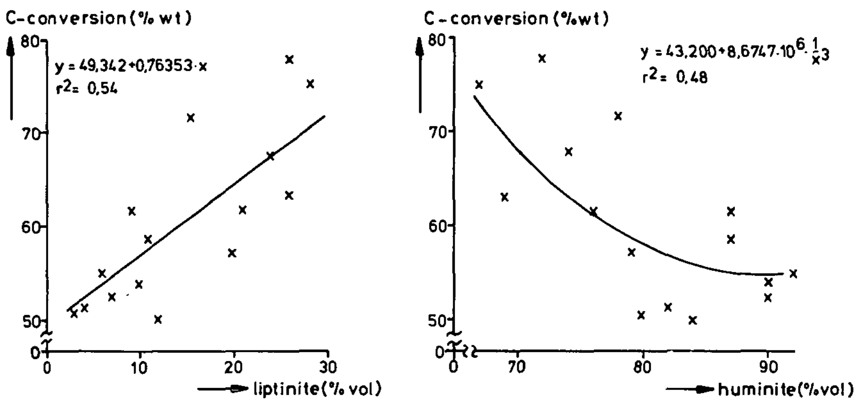
Fig. 26



Produkt yields achieved through indirect hydrogenation with tetralin as a function of stratification and texture (lith. no.)	RHEINBRAUN

Fig. 27



Carbon conversion achieved through indirect hydrogenation with tetralin as a function of the liptinite and huminite contents	**RHEINBRAUN**

Fig. 28

1. Petrographical properties

Liptinite content	>20 % vol
Lipto - Humodetrite content	>50 % vol
Humo - Detrinite content	>50 % vol
Inertinite content	< 3 % vol
Gelo - Humotelite content	< 6 % vol
Reflectance value	> 7 % vol

2. Chemical properties

Tar content	>11 % wt	(mf)
Paraffin content	> 7 % wt	(maf)
Hydrogen content	>5,3% wt	(mf)
C/H ratio	< 1,1	
Volatiles	>53 % wt	(maf)
Carbonization water	< 8,7% wt	(mf)

Under the conditions stated above, the 5th and 6th seam of the Fortuna - Garsdorf mine contain approx. 78 %wt of good hydrogenation coals

Petrographical and chemical properties of good hydrogenation coals	RHEINBRAUN