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FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA.

ONDERWERP:
SUBJECT: THE MICROSCOPICAL EXAMINATION OF COAL IN REFLECTED LIGHT.

AFDELING:
DIVISION: CHEMISTRY.

NAAM VAN AMPTENAAR:
NAME OF OFFICER: B. MOODIE.

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

REPORT NO. 20 OF 1954.

THE MICROSCOPICAL EXAMINATION OF COAL IN REFLECTED LIGHT.

INTRODUCTION:

Chemists and physicists have for years surmised that coal originated from vegetable matter. Their presumption was proved to be correct only after specimens of coal were microscopically examined.

Although the microscope was first utilised in the coal industry exactly a hundred years ago, its practical application was delayed until the late twenties. Fundamental problems like the origin of coal in general and the origin and constitution of the various components in particular, occupied the minds of the numerous investigators.

The knowledge accumulated by coal petrographers during the years was only turned to profit after the second International Stratigraphical Congress at Heerlen in 1932.

The text of this report has been divided into four parts as follows:-

PART I.	-	A short history of the origin and development of coal petrography.
PART II.	-	A description of the various petrographical constituents occurring in S.A. coals, illustrated by photomicrographs.
PART III.	-	Practical applications of coal petrography.
PART IV.	-	Publications that have appeared since the beginning of 1950.

PART 1.

A SHORT HISTORY OF THE ORIGIN AND DEVELOPMENT OF COAL PETROGRAPHY.

Records show that the first microscopic observations were carried out on coal in the year 1830 by Lindley. The apparatus he used was crude and his work was mostly confined to the examination of fossilised leaves found in certain coals. However he recognised their botanical origin.

During the same year Henry Witham succeeded in making thin sections of coal and identified wood structures which he compared with wood derived from conifers.

Three years later Hutton examined British coals and concluded that the ordinary banded coals consisted of alternating layers of cannel coal and coking coal. He also observed that one of the major constituents in the cannel coals consisted of cell-like bodies and that they were absent in coking coals. Today it is known that these "cell-like bodies" are actually micro-spores.

In 1836 Goeppert incinerated certain coals and by inspecting the ashes under a microscope he recognised certain plant structures. Two years later Link recognised plant structures in coals previously boiled in oil. He was also the first to declare that coal originated from peat.

Other scientists notably Phillips (1842), Bailey (1846) and Eherenberg (1846) discovered certain structures in coal which left no doubt that coal was of botanical origin and it is interesting to note that the two schools comprising the auto-chthonists and allochthonists were formed during this period.

Briefly/.............

Briefly the first believed that coal was formed in situ from the primeval forests and the second, that the plant debris accumulated through drifting prior to burial. Even today, more than a hundred years later, the problem has not yet been solved.

In the course of the year 1854 the potential practical value of the microscopical examination of coal was realised for the first time when samples of torbanite from Torbane Hill (Scotland) were examined and compared with other coals as a result of lawsuit in which a decision had to be made whether torbanites (which we now know to be boghead coals) were to be taxed as ordinary coal or not. The expert opinion of no less than 78 geologists, chemists, engineers and microscopists was sought. Two members of the Microscopical Society of London were detailed to examine the torbanite microscopically. They came to the rather ironic conclusion that torbanite could not be regarded as a type of coal because they failed to recognise the greenish-yellow oil bearing bodies as being of plant origin.

However, men like Redfern, Balfour and Greville were not satisfied with these findings and Redfern in particular concluded a year later that torbanite is a cannel coal and that the greenish-yellow bodies were of plant origin. (His observations were only proved to be correct 69 years later by Thiessen and Zalesski who recognised these bodies to be the remains of algae).

During the following years geologists and botanists were mainly concerned with the origin of coal and its associated problems. Men like Schulze, Huxley and Dawson made invaluable contributions while other scientists continued with observations on cannel and boghead coals.

In 1887 Fayol described the macroscopic constituents which Stopes at a later date named vitrain, clarain, fusain and durain. Fayol also noted the coking properties of the vitrains

and/..........

and that the volatiles of some of the dull coals were higher than those of the bright coals.

Up to this stage the ideas and theories of the many individual workers in the various fields of coal petrography were rather confused and unco-ordinated. However a few years after the advent of the 20th. century Reinhard Thiessen was appointed to the staff of the Geological Survey Office of the U.S. Bureau of Mines. He was responsible for the establishment of a Fuel Research Station at Pittsburgh. There followed a systematic investigation in connection with the microscopy of coal which was soon followed by scientists in other countries.

The first task Thiessen set himself to do was to standardise his petrographical methods and nomenclature. In 1913 he published, in collaboration with D. White, a comprehensive work entitled "The Origin of Coal" in which he recorded for the first time all his microscopic observations.

He employed thin sections and in the microstructure of coal he identified three constituents which he named anthraxylon, attritus and fusinite. He explained that anthraxylon included the bright constituents of any coal whether they exhibit structure or not and that these constituents were derived from wood and bark. Anthraxylon is embedded in a spore-rich ground mass which he named attritus. Attritus again consists of vitrainous and opaque particles as well as spores, resins and cuticles. He realised the importance of the attritus and differentiated between:-

(a) Solid opaque matter

(b) Granular opaque matter

(c) Particles of fusain.

In 1923 Thiessen also discovered that spores could be utilised for the identification and correlation of certain coal seams.

During this period scientists in Europe made valuable contributions. Among the most notable investigators were Winter, Hickling, Potonié, Stach, Stopes, Seyler and Wheeler. The problem of the origin of coal was approached from the palaeo-botanical as well as from the geological angle.

The year 1927 brought an important change. The European school led by Winter, Seyler and Stach broke away from the tradition established by Thiessen and developed a totally different technique of microscopical examination. It was based on the current methods of ore-microscopists, namely the examination of highly polished surfaces in reflected light. This method may have certain disadvantages but the difficult and highly skilful technique of making thin sections was thus eliminated. Etching of the polished blocks enabled research workers to distinguish for the first time the micro-structures of high rank coals which remained opaque in thin sections on account of their high carbon content. This method has withstood the test of time very well and is today the accepted method in Britain and Germany.

PART II/.............

PART 11.

A DESCRIPTION OF THE VARIOUS PETROGRAPHICAL CONSTITUENTS OCCURRING IN SOUTH AFRICAN COALS ILLUSTRATED BY PHOTOMICROGRAPHS.

There are two different modes of variation in a coal seam. The first is known as rank and the second as type.

Rank is really a degree of metamorphism which a coal seam has undergone after deposition. Metamorphism can be regarded as the response in the coal seam to pronounced changes of temperature and pressure. Heat may be supplied by increase in depth (as in the case of most European coals) or by contiguous magmas such as thick dolerite sheets, so well known in certain coal provinces of the Union of South Africa. Pressure comes through the weight of superincumbent strata and volume expansion due to heating.

The effect of metamorphism is the devolatilisation of the coal with corresponding increase in fixed carbon content.

Type is determined by the kind of plant debris from which the coal has been formed and the type of reaction it has undergone. The banded nature of coals was caused by the combined effects of these influences.

Macroscopic examination of a coal seam will reveal one or more of the following types of bands. The most prominent type consists of brilliant black bands often minutely cleated and friable. It is known as vitrain. A second type clarain, is minutely striated giving a silky lustre. It is compact and has a smooth fracture. A third type durain is dull, tough and compact. The fracture is irregular. A fourth type is

known as/............

known as fusain and consists of dull porous and very friable material. By admixture, one type may gradually pass over into another.

The difference in these four types is to be found in the plant material that existed in the primeval coal swamps. Without going into details vitrain and fusain are regarded as having been formed from the same plant species (the Lycopods) under fairly dry climatic conditions. Durain was formed from the remains of the Equisetales which existed under wet conditions. Clarain consisting of alternating layers of vitrain and durain must have been formed during periods during which the climatic conditions continually changed from wet to dry.

These four coal types form the bulk of all the coal in the world. They have originated through the complicated process of humus formation, and are consequently classified as humic coals.

The remaining two coal types are differentiated from humic coals by their appearance and mode of origin.

The accepted theory is that they are products of putrefaction (which is defined as a process of decomposition in water with the complete exclusion of the air).

H. Potonié regarded this fluid organic slime (also known as sapropel) as having been formed in stagnant waters of lakes, sheltered bays and lagoons along the sea shore. Pollen grains play an important part in its formation. As the grains are blown about by the wind they settle on the waters and sink gradually to the bottom. There they intermingle with the remains of water-plants, plankton, algae and sometimes small crustaceans. With the increase in weight of the superincumbent sediments the water content is reduced, and what has formerly been a slimy mass, becomes solidified. Chemically it contains

more/..........

more hydrocarbon than humic coal on account of the numerous spores, waxes and pollen grains constituting it.

There are two types of sapropellic coals namely cannel and boghead coals. There is no clear demarcation between these two types and transgression of one into the other is a common occurrence.

The name cannel, is derived from "candle", this type of coal being easily ignited with a match. Its appearance is homogeneous and the lustre greasy. It is tough and has a sub-conchoidal fracture. The unusually high volatile matter content is due to the concentration of spores and pollen grains. Cannel coal is not common in South Africa and does not occur as an individual seam. It is occasionally found as a component of humic coal seams, notably of the No. 2 Seam of the Witbank coalfield. It generally changes imperceptibly into coal or shale in a lateral direction. (Refer photomicrograph No. 10).

Boghead coal in its purest form does not resemble ordinary coal. It is named after the locality in Scotland where it was first discovered. Later a very pure variety was discovered at Torbane Hill and has subsequently been known as torbanite. The impure variety is known as oil-shale. The outstanding feature of boghead coal is the concentration of algae-like bodies with a greenish-yellow appearance also known as kerogen, that occur in the ground mass. Torbanite has a dark brown colour and a lighter brown streak. The fracture is sub-conchoidal. The minute oil secreting bodies derived from the elaeophyton species are responsible for its high volatile matter content. (Refer photomicrograph No. 9).

Torbanite and oil-shale may occur in separate seams as in the districts of Wakkerstroom and Piet Retief in South-eastern Transvaal, or it may be interbedded with coal as in the No. 5 Seam of the Witbank district. The best known occurrence is at Mooifontein 287, Ermelo district where a band of some 20 inches forms the bottom portion of a coal seam.

These six coal types can be considered to be analogus to any rock type, say dolerite. The counterparts of the (rock forming) minerals are known as macerals. This is more clearly illustrated in the following table. (See table on following page).

It will be noted that there are in all seven macerals viz:-

1. Vitrinite.
2. Micrinite.
3. Fusinite.
4. Semi-fusinite.
5. Exinite.
6. Resinite.
7. Sclerotinite.

1. VITRINITE.

Vitrinite is the main constituent of vitrain and two varieties can be distinguished, namely telinite and collinite. Telinite shows a distinct woody structure and is generally regarded as being more abundant than collinite which shows no structure at all. Some authors contend that the structure of telinite can be seen without etching the coal in a mixture of H_2SO_4 and CrO_3 and that structures can sometimes be seen in collinite after severe etching. All attempts to recognise woody structures in S.A. vitrinites in reflected light has so far proved unsuccessful. This may be partially due to the paucity of vitrain of sufficient thickness to work on, or the present lack of technique.

In reflected light vitrinite shows a low relief and a low reflection of light. (Refer photomicrograph Nos. 6, 15 & 18).

Type.		Dolerite.	Humic coals.				Sapropellic coals.	
			Vitrain.	Clarain.	Durain.	Fusain.	Cannel.	Boghead.
Constitution.	Groundmass.	Labradorite. Augite.	Vitrinite.	Vitrinite.	Massive micrinite, semi-fusinite, sclerotinite, fine grained micrinite.	Semi-fusinite. fusinite.	Fine grained micrinite, vitrinite.	Fine grained micrinite, vitrinite.
	Inclusions.	Olivine.	Resinite.	Exinite. Resinite.	Exinite Resinite.	-	Exinite.	Algal bodies with some exinite.
	Accessories.	Orthoclase, quartz, titano-magnetite.	Semi-fusinite, micrinite, sclerotinite.	Semi-fusinite, fusinite, micrinite-flakes, Sclerotinite.	Fusinite, vitrinite.	-	Fusinite bands.	Fusinite bands.

2. MICRINITE.

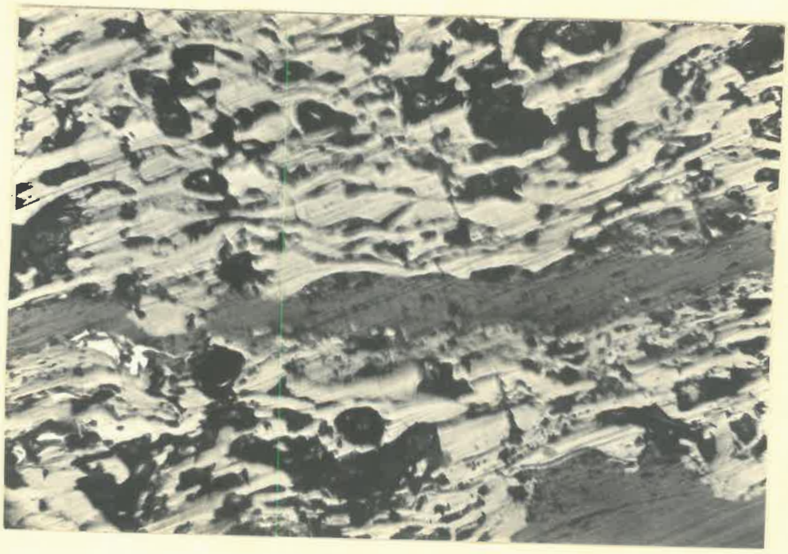
The term is applied to the opaque attritus devoid of any structure. It is one of the most important constituents of durain. Two different types can be distinguished viz.

(a) granular micrinite and

(b) massive micrinite.

(a) As the name implies, granular micrinite is composed of finely divided granules, angular shaped particles and splinters.

(b) Massive micrinite consists of opaque flakes very closely packed and giving a compact or massive appearance. Some authors are of the opinion that it may partially consist of finely disintegrated fusinite. This supposition is perhaps in part, based on the fact that its optical characteristics such as reflective power and high relief are similar to those of fusain.

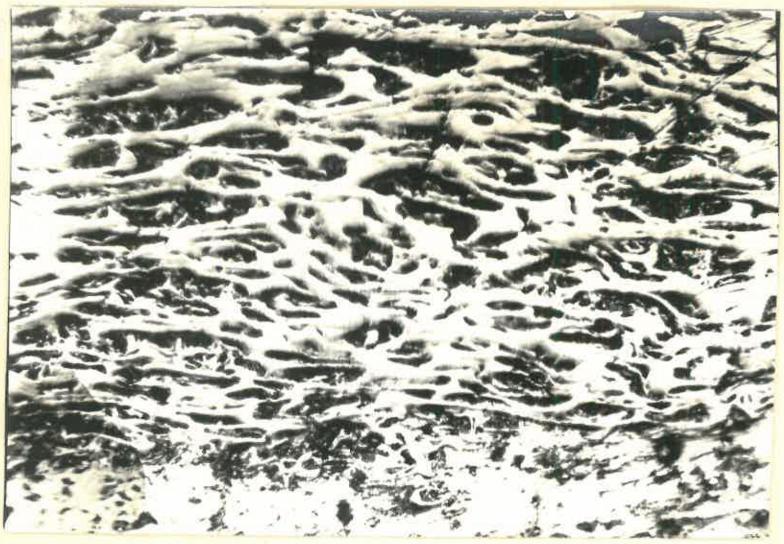


PHOTOMICROGRAPH NO. 1. Massive micrinite. Note band of vitrinite. Largo coal 250 x (oil).

3. FUSINITE/......

3. FUSINITE.

The opaque cell walls in fusain constitute the maceral fusinite. It is the major constituent in fusain and occurs as accessories in clarain and durain. Generally cell structures are very evident, its reflective power is very high (sometimes yellowish) and it shows a very high relief. The lumens of the cells are frequently occupied by mineral matter such as pyrites, calcite etc. Collapsing of the cell walls by pressure may give rise to "bogen"-structure. This type of fusinite must not be confused with the extremely soft variety generally known as "mother of charcoal" which is a fibrous tissue often occurring in thin wedge-like layers between vitrain bands. Such tissues are characterised by the absence of inorganic material inside the cell cavities.

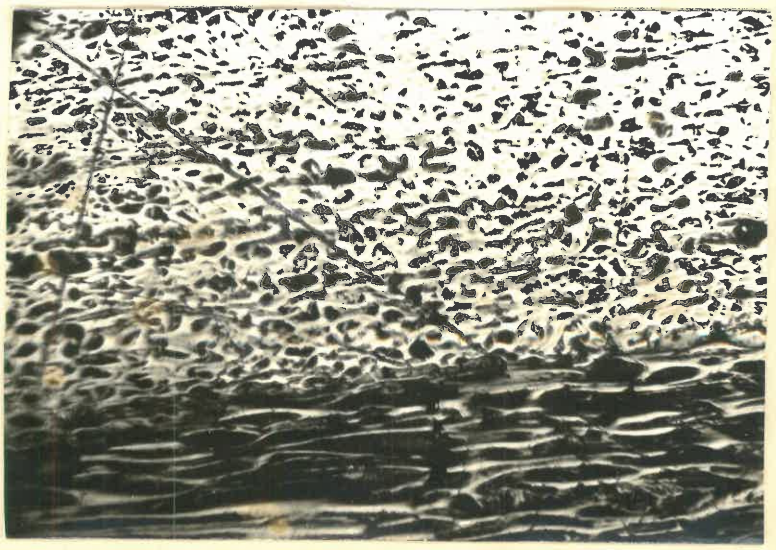


PHOTOMICROGRAPH NO. 2.

Fusinite showing cellular structure. Tete Coal P.E.A. 600 x (oil).

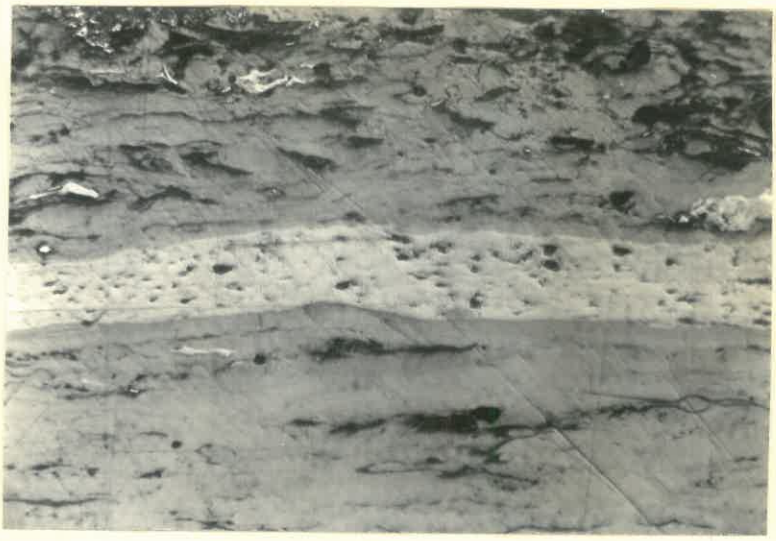
PHOTOMICROGRAPH NO. 3.

Fusinite, with partially collapsed cell walls. Tete Coal P.E.A. 250 x (oil).



4. SEMI-FUSINITE.

Semi-fusinite is intermediate between vitrinite and fusinite. It shows preserved cellular structure but differs from fusinite in so far as the cell cavities are filled with carbonised organic matter. Its reflective power is between that of vitrinite and fusinite. Owing to its transmigratory nature, it is sometimes difficult to distinguish this maceral from fusinite but it never exhibits the characteristic yellowish reflectance peculiar to some fusinites and the cells are seldom well developed. It occurs in durain and fusain as a major constituent and in vitrain and clarain as accessories.

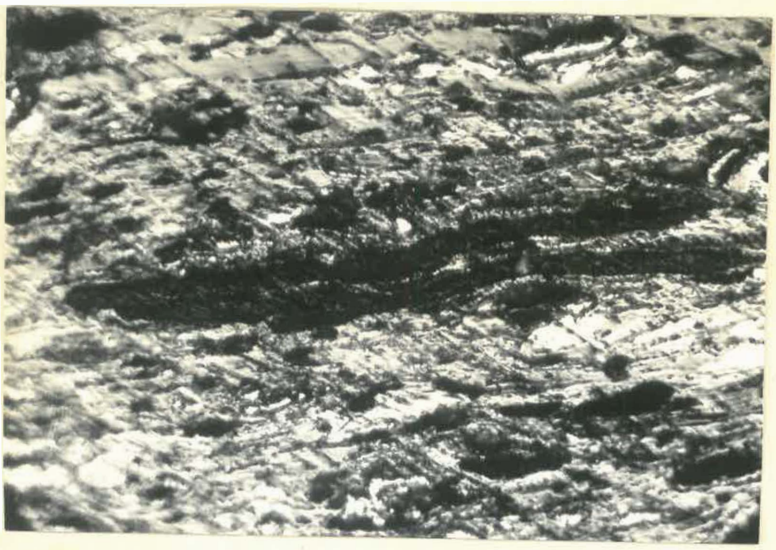


PHOTOMICROGRAPH NO. 4. A band of semi-fusinite separating vitrinite at bottom and claranious material in upper half. Waterberg coalfield. No. 6 Seam. 250 x (oil).

5. EXINITE/............

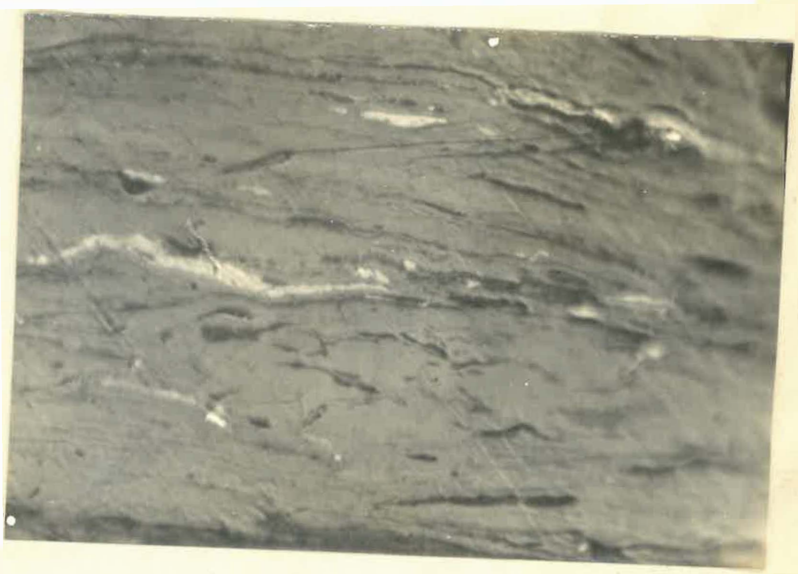
5. EXINITE.

This term denotes the concentrations of micro- and megaspores, cuticles, pollen grains etc. Exinite occurs in clarain and durain. As the rank of the coal increases, these bodies assume the reflective power of vitrinite and thus become invisible.



PHOTOMICROGRAPH NO. 5.

A megaspore (black) in durain. Koornfontein Coll. Witbank No. 2 Seam. 250 x (oil).

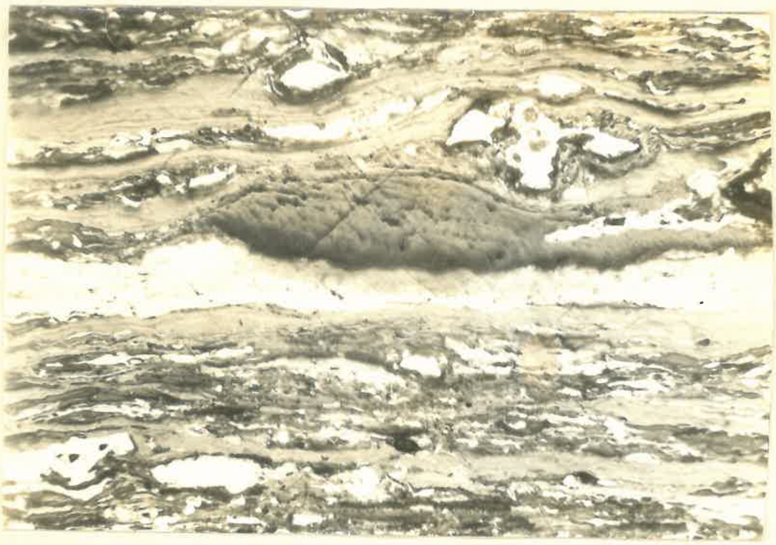


PHOTOMICROGRAPH NO. 6.

Microspores (black) in vitrinite. Note fine grained micrinite (nearly white). Tweefontein Coll. Witbank. No. 2 Seam. 600 x (oil).

6. RESINITE.

Resinite is the collective name for resins and waxes which have been secretion products of vegetable metabolism (In the case of resins the conductive organs have disappeared through decomposition). In reflected light they appear as irregular bodies of somewhat lower reflective power than vitrinite.



PHOTOMICROGRAPH NO. 7.

Resinite (very dark grey) in a groundmass of vitrinite (lighter grey) semi-fusinite band (off white) and micrinite (nearly white). Twee-fontein Coll. Witbank. No. 2 Seam. 250 x (oil).

7. SCLEROTINITE.

Sclerotinite is the name given to fungal matter in coal. It is represented in coal as sclerotia, fungal tissues or fragments of sclerotia. They are permanent forms, formed under quiet conditions. In dry periods many plasmodes were converted to sclerotic coats assuming stringy and circular forms. They can generally be recognised by their peculiar spherular forms resembling a higher organised plant, having irregular cell structure and a very high reflective power.

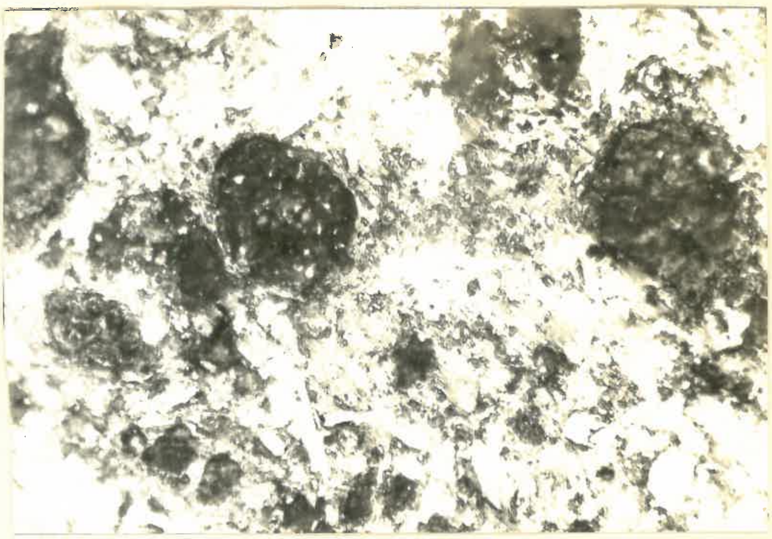
PHOTOMICROGRAPH NO. 8/....

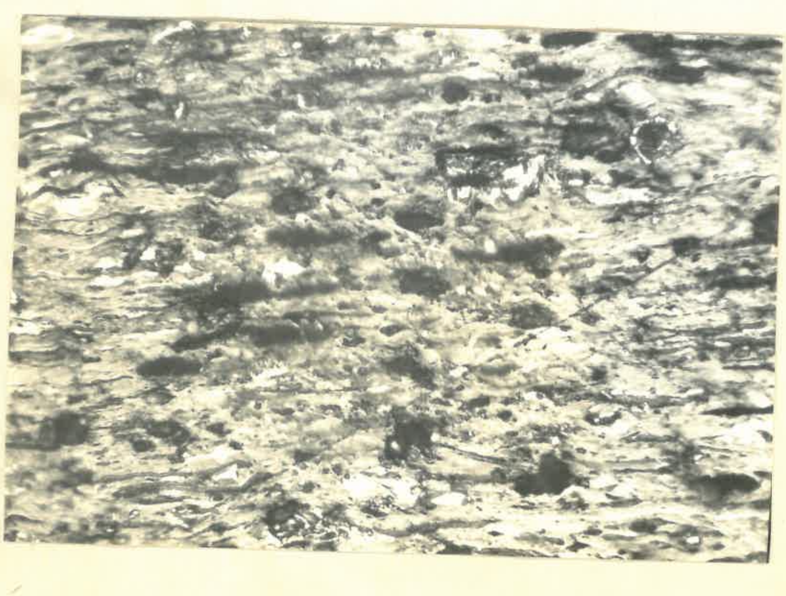
PHOTOMICROGRAPH NO. 8.

Sclerotinite in a durainous groundmass. Note vitrinite band at top. Largo Coll. Vereeniging. 250 x (oil).

PHOTOMICROGRAPH NO. 9.

Torbanite. Kerogen or oil secreting algal bodies of elaeophyton (black) in a durainous groundmass. Satmar Coll. at Mooifontein, Ermelo. 250 x (oil).





PHOTOMICROGRAPH NO. 10.

Cannel coal. Concentrations of microspores (elongated black bodies) in a groundmass consisting of vitrinite, micrinite and mineral matter (irregular rounded bodies). Koornfontein Coll. Witbank. No. 2 Seam. 250 x (oil).

High Rank Coals.

It has already been stated that high rank coals remain opaque in thin sections on account of their high carbon content. They can however, be examined in reflected light but identification is hampered by the increasingly higher reflective power of all the constituents. In anthracites it becomes so high that no distinction can be drawn between any of the components (Refer photomicrograph No. 11). To surmount this difficulty the specimens are examined with the nicols of the microscope crossed. In extreme cases the specimens may be etched either by flame or chromic acid prior to the examination under crossed nicols.

This fact denotes that such mature coal is no longer isotropic but has become anisotropic or bi-refringent.

The trend of increasing rank of coal is towards the formation of graphite. This behaviour can be explained by the fact that the increase in rank is accompanied by the tendency of some of the carbon atoms to assume a definite orientation around which other carbon atoms start building a space lattice of the graphite type i.e. one where the carbon atoms are arranged in parallel layers with each layer forming interlocking hexagons.

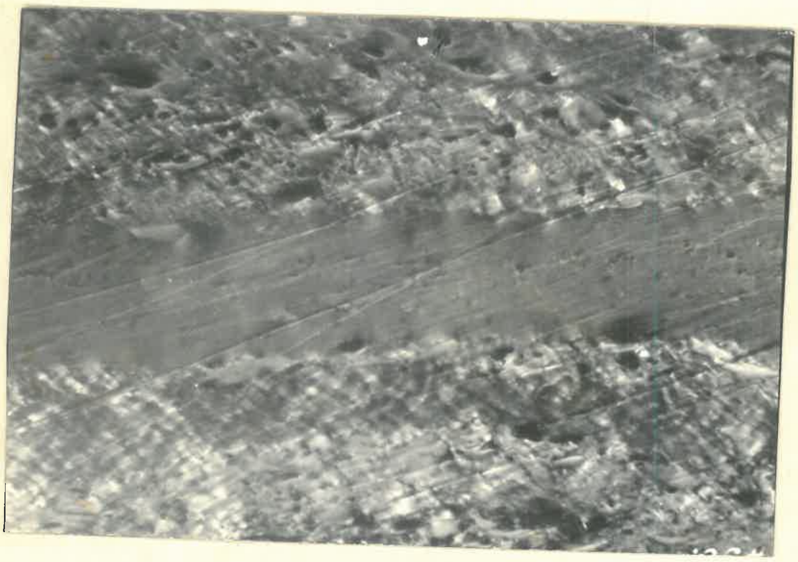
Graphite belongs to the hexagonal system, and is optically uni-axial. The bi-refringence which is directly proportional to the extent of coalification can thus be measured with the aid of a Berek compensator if the observations are carried out parallel to the bedding plane of the coal. The microscope enables us therefore to determine the rank of a coal without the help of a chemical analysis. However, it must be understood that this method can only be applied in cases

where/............

where the rank of the coal is sufficiently high for the coal to become bi-refringent and is no measure of its carbon content.

PHOTOMICROGRAPH NO. 11.

Anthracite: Due to the high reflectance of all the constituents, they can hardly be distinguished from another.
Alpha Anthracite Coll. Natal. 250 x (oil).



PHOTOMICROGRAPH NO. 12.

Anthracite: The same photomicrograph as No. 11 but with nicols crossed. A vitrinite band can clearly be seen in the durainous groundmass.
250 x (oil) + nicols.

Mineral Matter in Coal.

Coal invariably contains mineral matter which is responsible for the formation of an ash residue on combustion of the coal. A variable portion of this mineral matter is derived from the original entities and may be regarded as true inherent mineral matter of the coal.

The adventitious impurities may either have been introduced into the coal during the period of its biochemical change or during the subsequent maturing stage. The first is called syngenetic mineral matter and the second epigenetic mineral matter.

The most common minerals are the clay minerals in the form of shale and carbonaceous shale. Shale minerals are characteristic components of South African coals, especially the dull coals (grey durains), and are mainly responsible for their relatively high "inherent" ash content. High concentrations of these minerals result in shaly coals and carbonaceous shales which are so frequently found particularly in the upper portions of the thicker South African coal seams.

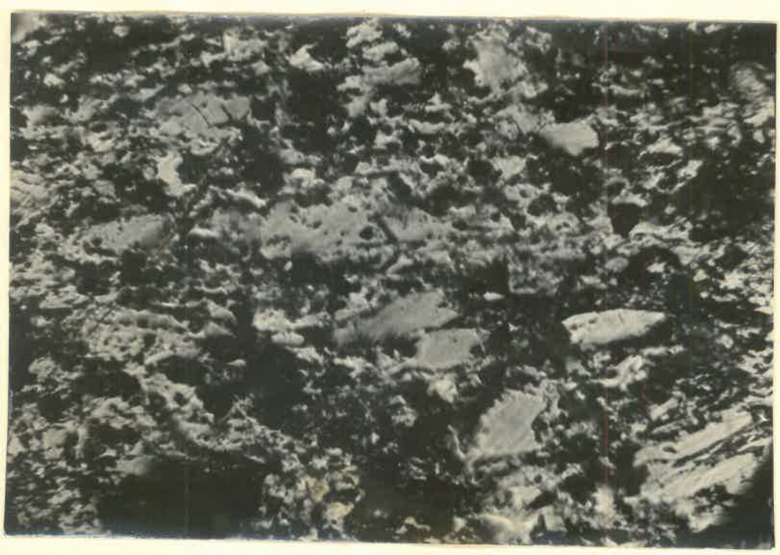
Pyrite, marcasite, ankerite, dolomite, calcite, siderite and quartz are all known to occur in South African coals. Some of these minerals may be present as syngenetic or epigenetic mineral matter. Thus pyrite and marcasite occurring as minute concretions are regarded as syngenetic but in the form of impregnations in fusinite or in fissures and cleats as epigenetic.

Siderite, calcite and ankerite may also either be syngenetic or epigenetic. If the concretions are of a radial structure they are regarded as having been formed during the period of the biochemical change of the coal, but if they occupy cleats and fissures it is clear that they are of a "secondary" nature or epigenetic.

Dolomite occurs only as syngenetic mineral matter.

(a) Carbonaceous shale.

In reflected light carbonaceous shale has a black groundmass containing splints of micrinite, fusinite, semi-fusinite and sometimes vitrinite. In cases where the clayey inclusions exceed 60 % by volume it is no longer regarded as carbonaceous shale but as ordinary shale.



PHOTOMICROGRAPH NO. 13.

Carbonaceous shale containing micrinite and semi-fusinite. Note the lack of orientation. Witbank No. 5 Seam. 250 x (oil).

PHOTOMICROGRAPH NO. 14.

Carbonaceous shale containing a vitrinite band, semi-fusinite, micrinite, mineral inclusions and a clay band (bottom portion). This is probably a pseudo-cannel coal according to European standards. Witbank No. 5 Seam. 250 x (oil).

(b) Pyrite and Marcasite.

These may occur either as very finely dispersed concretions throughout a coal or as large nodules. In reflected light they appear brass yellow. Pyrite is isotropic and marcasite anisotropic. The latter can therefore easily be distinguished under crossed nicols from the former.

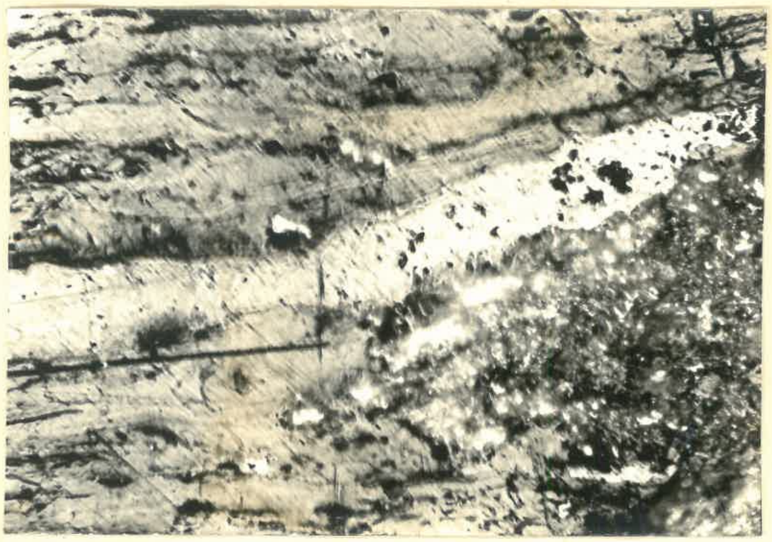
PHOTOMICROGRAPH NO. 15.

Vitrain cont. concretions of pyrite. At the left is a grain of quartz. No. 3 Seam. Witbank Coalfield. 250 x (oil).

(c) Siderite.

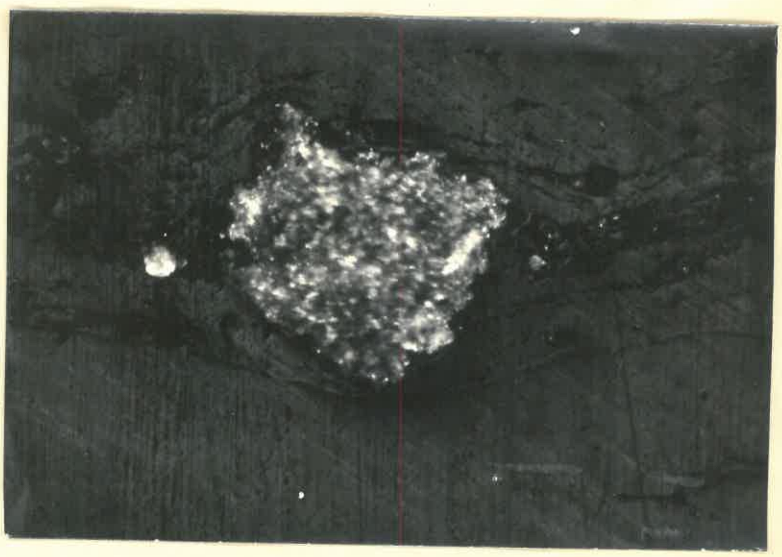
The occurrence of siderite in South African coals is fairly common especially in certain seams of the Waterberg coalfield where it appears as brown nodules in the coal. When using an oil immersion objective its colour is distinctly brown. By using polarised light it can be shown that this substance is strongly anisotropic. Occasionally, the occurrence of an indistinct interference cross can be observed.

PHOTOMICROGRAPH/......



PHOTOMICROGRAPH NO. 16.

Siderite (lower right hand quadrant) in a groundmass of vitrinite. Note band of semi-fusinite.
Waterberg Coalfield.
Seam No. 6. 250 x (Oil).



PHOTOMICROGRAPH NO. 17.

Siderite in Ngotshe Coal.
Zululand 160 x + nicols.

(d) Calcite.

Calcite frequently occurs as an epigenetic mineral and is found in minute cleats and cracks. With a dry objective it appears grey but with a objective immersed in oil it is somewhat darker. Sometimes calcite exhibits a distinct yellowish tone due to contamination by iron. It is very strongly anisotropic.

PHOTOMICROGRAPH NO. 18/....

PHOTOMICROGRAPH NO. 18.

Calcite occupying a cleat in vitrinite.
Largo Coll. Springs.
250 x (oil).

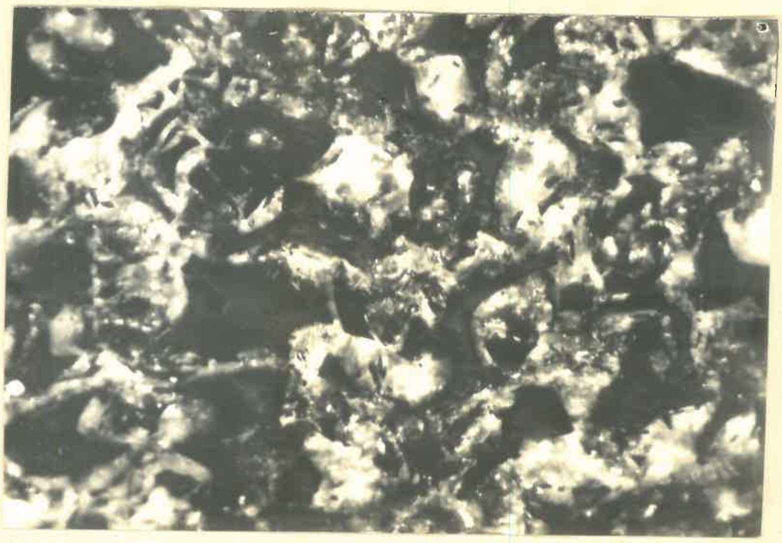
(e) Dolomite and dolomitic limestone.

Dolomite is more often associated with fusinite than with any of the other macerals. A variety, which is actually a dolomitic limestone has been found in most of the coal seams in the Union. It appears as lenticular bodies on certain horizons in a seam and these bodies transgress from practically pure rock into coal. It cannot be successfully handpicked and pieces of coal containing as much as 50 % of dolomitic limestone by volume adhere tenaciously to the coal. The material therefore constitutes a washing problem. Dolomitic limestone has a very deleterious effect on the ash fusion temperature of the coal.

Under a dry objective it appears grey but is somewhat darker than calcite when an oil immersion objective is employed. It is distinctly anisotropic.

PHOTOMICROGRAPH NO. 19.

Dolomitic limestone occurring in fusinite. Note the fragments of thick cell walls (nearly white).
Phoenix Coll. Witbank.
No. 2 Seam. 250 x (oil).



PHOTOMICROGRAPH NO. 20.

Exactly the same photograph as No. 19 but with nicols crossed. Only the dolomitic limestone is visible (white and off-white) 250 x + nicols.

(f) Quartz.

Quartz is not a very common inclusion in our coals. It is generally associated with vitrinite where it appears as minute bodies giving rise to deep ambient shadows, (see photomicrograph No. 15).

PART III/.................

PART III.

PRACTICAL APPLICATIONS OF COAL MICROSCOPY.

There has not yet been any attempt in South Africa to apply the microscopical examination of coal for industrial purposes. In overseas countries full use of the microscope is being made especially in the fields of mining, coal preparation and the coking industries.

The basis of the application is a petrographical survey of the coal seams to be utilised. The first work is carried out on borehole samples. The results thus obtained serve as a measure of what to expect even before a mine goes into operation. Later on, after development of the mine the information obtained during the prospecting operations is augmented by systematic surveys of the coal faces.

For this purpose a solid pillar sample is cut out of the coal face and every 5 cm. is then subjected to microscopical examination. Intervals of more or less than 5 cm. may also be taken, but as it is generally accepted that 5 cm. of coal resulted from 1 metre of vegetation, this thickness is mostly employed. In order to eliminate this tedious and delicate work and to prevent damage that may result during handling, cutting and polishing of the coal specimens, an alternative method can be employed. This consists of sampling every 5 cm. of the coal face with a small pick and crushing the coal-chips in stages to approximately 0.5 mm. A small representative sample of 3 to 4 grams is then cut out, thoroughly mixed with twice the amount of leucite powder and compressed into a block. After polishing, the block is examined under a microscope fitted with an integrating stage. The constituents are then planimetrically analysed. By a simple calculation the results may then be

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expressed as weight percentages. The amounts of the various coal types are thus known over every 5 cm. of the seam and a seam profile can be compiled. The remarkable fact is that such a seam profile remains constant within certain limits over wide areas of any specific seam. Such a characteristic can thus be used for the correlation of coal seams in very disturbed mining districts.

The most important aspect of such a petrographic survey is that it serves as a permanent record with which other results can later be collated. It also follows that such petrographical surveys can be most helpful in cases where selective mining has to be carried out.

Other applications are in mine ventilation problems and the prevention of underground fires. It has been established that underground fires may occur only in certain sections of a mine while other sections may be entirely free from fire hazards.

The coal microscope is also widely used in connection with research into the causes of pneumokoniosis amongst miners.

In coal preparation problems the microstructure of the various coal constituents plays an important part. Each constituent behaves differently during mechanical handling. For example durain is relatively independent of its microstructure as far as its resistance to breakage is concerned. On the other hand the breakage of vitrain, fusain and clarain occurring in the same seam as the durain is to a very large extent dependent on their microstructure.

Mineral inclusions also play a very important part in a coal's resistive properties. Syngenetic minerals such as finely disseminated pyrite and dolomite occupying cellular spaces in fusains, may make these extremely resistive. Finely distributed shale particles may cause vitrains and clarains either

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to become more, or less resistive. Epigenetic minerals i.e. minerals occurring in cleats and cracks generally have a deletrious influence on a coal's resistance to breakage during handling.

In the coking industry the microscope can be utilised for various purposes. Qualitative and quantitative determinations of texture, porosity and microstructure can be carried out. The collation of these results with those prior to carbonisation may not only lead to a better quality of coke but also a coke more suitable for specific purposes. In Germany today one of the widest uses of the microscope is for blending purposes and the consequent conservation of coking coal reserves.

It is not the purpose of this report to go into details regarding the practical applications because at such an early stage it is impossible to predict to what extent the microscope could be successfully utilised to solve the numerous problems associated with South African mining and various other industries.

The fact that South African coals differ in some respects from those in Europe is well known. For example, in South Africa dull coals are always regarded as inferior to bright coals whereas in Europe the opposite is often true. In the Northern Hemisphere it is generally conceded that the coal seams were formed under autochthonous conditions. In how far their current methods are applicable in our country where an abundance of evidence points to an allochthonous origin has yet to be carefully studied.

One should however not be discouraged by these differences. It is a significant fact that only a short time after the inception of the microscopical study of coal at the Fuel Research Institute, all the components occurring in the European coals have been discovered and identified in our own coals. In this simple discovery lies perhaps the biggest promise and encouragement for more intensive basic research work that may have a profound influence on the coal industry in South Africa.

PART IV.

PUBLICATIONS THAT HAVE APPEARED SINCE THE BEGINNING OF 1950.

The final part of this report contains lists of publications that have appeared on coal petrology since the beginning of 1950.

A perusal of the lists will make it clear that scientists representing many nations have made substantial contributions. Those from Germany, U.S.A. and Britain are in the majority.

There are contributions that deal with practically every aspect of solid fuel technology. Diverse subjects such as the classification of coal to the manufacture of better metallurgical coke are discussed. Some contributions may be regarded as highly academic while others are of a very practical nature.

The number of contributions illustrates the rapid progress of coal petrography and can also be regarded as a measure of the importance attached to the subject.

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PRETORIA.

20th October, 1954.

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