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TECHNICAL MEMORANDUM NO. 8 OF 1975

THE PHYSICAL AND CHEMICAL PROPERTIES OF COAL WITH SPECIAL REFERENCE TO SOUTH AFRICAN COALS.

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By: B. Moodie

ABSTRACT

There are two variations in every coal seam namely type and rank. Type is determined by the plant material from which the coal was formed and rank is the degree of maturation or metamorphism.

Rank is the most important property of a coal and it influences virtually every other intrinsic coal property such as moisture, volatile matter, calorific value, carbon content, hydrogen content, absolute density, coking properties, reflectivity, etc.

The intrinsic coal properties are outlined, their relationship and variation discussed in terms of the variation in rank. The Seyler system of coal classification based on a number parameters is given and explained.

The type of plant material from which the coal was formed is reflected in the maceral composition of the coal seams and coalfields in terms of their vitrinite, exinite and inertinite content. These parameters are used to characterise the coalfields petrographically.

/1. INTRODUCTION ...

1. INTRODUCTION

There are two variations in every coal seam namely type and rank. Type is determined by the plant material from which the coal was formed and rank is the degree of maturation (also known as coalification) or metamorphism.

When broken down into its chemical elements, coal consists of carbon, hydrogen, nitrogen, sulphur and oxygen. Viewed from a somewhat different and perhaps more interesting angle, it is also correct to state that coal consists of water, mineral matter (ash), volatile matter and fixed carbon.

The determination of the basic elementary constituents of a coal and the proportions in which they occur, is generally referred to as an ultimate[*] analysis.

The determination of the moisture, ash, volatile matter and fixed carbon is referred to as a proximate[**] analysis and is the analysis usually made for practical purposes since it is much more readily made than the ultimate analysis and furnishes most of the data necessary for arriving at the quality of the coal.

The most important property of a coal when used for combustion purposes is the calorific value which is a measure of the coal's potential energy in the form of heat; it is normally determined at the same time as the proximate analysis.

/2. RANK .....

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[*] final

[**] immediate, first.

2. RANK

Rank is the most important property of a coal; it influences virtually all the other coal properties such as the carbon, hydrogen, volatile matter, moisture contents, calorific value, absolute density, coking properties, reflectivity, reactivity, solubility, etc.

During the second stage of coalification (also known as the metamorphic stage), pressure from the overburden, primary heat from the mantle, secondary heat generated by folding in the crust of the earth over long periods of time combine to reduce the volatile matter and moisture content of the coal thus causing an increase in carbon content. In this manner peat was converted into lignite thereafter into high, medium and low volatile bituminous coal followed by semi-anthracite and finally anthracite.

The degree of metamorphism or maturation in any stage of the coalification process is known as the rank of the coal. Rank can be expressed in terms of a number of parameters of which the carbon, volatile matter and moisture content are the most important.

The presently known coal deposits in South Africa are virtually all of the same geological age but rank differences are noticeable even for the seams of Middelburg-Witbank coalfield of the Transvaal where dolerites are virtually absent. In certain coal districts of Natal the rank differences are, without exception, due to the influence of dolerites.

/3. MOISTURE .....

3. MOISTURE IN COAL

All coals are porous substances notwithstanding the compression and compaction they have been subjected to during the coalification process.

The average pore diameters and the pore size distribution may change with rank but even mature coals have an internal surface area much in excess to the external area of even quite finely ground coal. These pores are accessible to molecules of the size of water molecules.

Water molecules are readily adsorbed on a coal surface and when the porous substance is placed in an environment where more or less water or water vapour is present,it will strive to obtain equilibrium. Water from the external and internal surface will be desorbed from the coal and lost to the environment or water molecules will be adsorbed by the coal.

Physically adsorbed moisture can be removed from the coal by either placing it in an atmosphere of lower relative humidity than that in which equilibrium was attained or by raising the temperature.

The rate of adsorption and desorption is dependent on the rate of diffusion to and from the coal and it is therefore understandable that the rate of losing water will depend on how rapidly desorbed molecules can be removed from the immediate vicinity of the coal. Thus, ventilation over and preferably through a bed of coal by air having a low relative humidity will increase the process of drying considerably.

In dealing with the moisture content of coal, great caution must be exercised because if one is not specific about the type of moisture that is being referred to, the concept of "moisture" can become very confusing.

/Theoretically .....

Theoretically, distinction can be drawn between
(a) physically adsorbed moisture excluding the actual condensation in pores or on the external surface and
(b) condensed water molecules which can range from the limit of physical adsorption to the dripping wet condition.

Coal seams that lie below the general water table of a coal-field are considered to be in an environment to be equivalent to an atmosphere of virtually 100% humidity and are believed to contain condensed molecules of water in the pores. This moisture held by the coal "in situ" is referred to as "bed moisture content" or "capacity moisture content". Bed moisture can be determined in a number of ways but the determinations are rather difficult.

Coal as mined can be considered as being in a capacity moisture condition. From the time the coal is mined until the time the washed product is prepared, extensive use is made of water and when the product leaves the washing plant it is actually dripping wet. This is not so serious in the coarser size grades, say from peas upwards but where fines are involved it can become critical as fine coal drains slowly. Coal containing moisture in excess of about 10% is difficult to handle by the producer and undesirable to the consumer and must receive special treatment before it can be efficiently utilized. This type of moisture is known as <u>free moisture</u> or <u>surface moisture</u>.

By drying the coal in the air the free moisture can be easily removed but air-drying does not remove all the physically adsorbed moisture in the micropores which can, as already stated, only be completely removed by heating the coal.

It is rather difficult to decide when a coal is properly air-dried as it depends on a number of

/factors .....

factors such as its top size, the relative humidity of the air surrounding the coal, the temperature of the air, etc. It is regarded to be completed when all traces of visible moisture have disappeared or more accurately, when the rate of loss in mass of a sample reaches a value of about 0,1% per hour.

For analytical purposes the moisture content is always determined on coal after it has been air-dried. Superficially dried coal is first crushed to -60 mesh B.S.S. and then air-dried before being analysed. The result obtained will then be the moisture content of air-dried coal or, it is also sometimes referred to as the inherent moisture content.

It must be understood that air-dried moisture content even on a laboratory sample is not an absolute but only a relative value. The value depends, apart from other physical and chemical characteristics, on ambient conditions in the laboratory such as relative humidity, temperature, ventilation. Changes in values can be considerable even in the course of a single day, particularly after a tropical storm and these will affect other determinations such as the calorific value, proximate analysis and the carbon and hydrogen contents.

To obviate mistakes and in order to obtain meaningful results, sophisticated coal laboratories work under constant temperature and humidity conditions and coal samples are placed in the laboratory for at least 24 hours to obtain equilibrium before being analysed.

In all subsequent discussions, moisture will mean, unless otherwise stated, the moisture of air-dried coal or the inherent moisture.

Generally speaking, the moisture content is a fairly reliable guide to the rank of the coal. High moisture indicates low rank coals; it reaches a minimum in the high rank coking coals and increases again towards the anthracites.

4. MINERAL MATTER IN COAL

The solid residue which remains after the combustion of the coal, normally called "ash", is partly due to mineral matter which found its way by devious routes into the peat beds during the formation of the coal. It may also be partly due to contamination during the mining process. During this process rock from the roof or the floor may be introduced into the coal by careless mining. It may also consist of shale or sandstone bands forming part of the coal seam.

Mineral matter in coal can therefore be divided into two categories namely (1) inherent mineral matter and (2) extraneous mineral matter. The former, consisting mostly of clays is so intimately mixed with the coal substance that it cannot be removed by coal preparation techniques. The latter can be readily removed since a large portion of the material is free. In cases where dirt bands are strongly attached to the coal they can be liberated by crushing the coal finer.

Other types of extraneous mineral matter are pyrite, ankerite, calcite and dolomitic limestone. These are all secondary minerals deposited in the coal seam after its formation. Pyrite and ankerite can occur in very finely disseminated forms (sometimes only recognizable under the microscope) and from a coal preparation point of view they can be regarded as inherent mineral matter. Calcite normally occurs in cleats in the coal where it has been deposited by percolating water. A considerable amount of this material is usually liberated during the crushing of the coal. Dolomitic limestones are not very common in the South African coalfields but are regularly found in the Witbank No. 2 Seam where they occur in the form of lenticular bodies. When in a fairly pure form they can be eliminated during mining but when intimately mixed with carbonaceous material they are difficult to distinguish from coal.

/Mineral .....

Mineral matter in coal, like moisture, acts as a diluent and may have other adverse influences, such as the lowering of the ash fusion temperature, abrasion of boiler tubes or of grinding machinery for pulverized fuel, etc.

5. VOLATILE MATTER IN COAL

Volatile matter in coal can be defined as the material, other than moisture, which is driven off when coal is heated under standard conditions at 900°C. From the definition and from what has been said about moisture content in coal, it follows that the moisture content of the coal must be known and must have been determined at the same time as the volatile matter determination and that the moisture content must be deducted from the total loss in weight.

The volatile matter consists principally of tar, lighter oils, hydrocarbon gases, hydrogen, oxides of carbon and water as decomposition products of the coal substance. But since the determination is carried out at a temperature of 900°C in a closed atmosphere, minute volumes of methane absorbed in the coal pores, carbon dioxide mainly from the calcium carbonate and sulphur from the pyrite, are also given off.

The volatile matter decreases with increasing rank.

6. FIXED CARBON IN COAL

The fixed carbon is obtained by subtracting the sum of the moisture, ash and volatile matter expressed in percentages from 100. For obvious reasons the fixed carbon of a coal is always lower than its elementary carbon content.

/7. CALORIFIC .....

7. CALORIFIC VALUE OF COAL

The calorific value is one of the most important properties of a coal since it is a measure of the energy, in the form of heat, that can be obtained therefrom.

Calorific value can be defined as the amount of heat liberated by the complete combustion of a unit mass of coal under specified conditions. It can be expressed in terms of mega joules per kilogram, British thermal units per pound, calories per gram or pounds per pound.

The factors to convert one unit into the other are as follows:

1 MJ/kg = 430 Btu/lb = 239 kcal/kg = 0,443 lb/lb

Distinction is made between <u>gross</u> and <u>net</u> calorific value. (Sometimes referred to as real and industrial calorific value respectively.)

Gross calorific value refers to complete combustion and that the water vapour produced during combustion is completely condensed.

In large industrial appliances, combustion is not complete and the heat output is always, as the result of various losses, lower than the gross value. The useful heat is lower and the efficiency is expressed as heat usefully applied divided by the theoretical net heat in the coal, expressed as a percentage.

The net value is equal to the gross value minus the latent heat of the water (1055 Btu/lb) condensed from the products of combustion by cooling to 60°F. For the net value, all the hydrogen in the fuel has to be burnt to water. It is therefore necessary to know the percentage of hydrogen in the coal.

/The .....

The conversion of the gross to the net value can be done with the aid of the following formula:

$$N_v = G_v - (0{,}206\ H + 0{,}023\ M)\ MJ/kg$$

N_v = Net value, G_v = gross value, H = hydrogen content and M = moisture content of the coal.

The calorific value increases with increasing rank until the hydrogen has decreased to below 4%. It also decreases with increasing ash content and weathering.

8. RELATIVE DENSITY OF COAL

The relative density of coal is variable and depends largely on the amount of mineral matter present in the coal and its chemical character.

The relative density is also a function of the rank of the coal. It decreases steadily from the low rank bituminous coals to the medium rank bituminous coals. It thereafter remains fairly constant through the low volatile bituminous coals and starts increasing in the anthracites. In the meta-anthracites (anthracites having a very low volatile matter content in the order of about 3%) the relative density increases rapidly. Instances of low volatile anthracites containing about 10% ash and having a relative density of 1,65 are known.

Relative density is the departure point for the beneficiation of coal in the coal cleaning practice which is by no means straightforward in South Africa. A general impression of the complicated problem of coal cleaning can be gained from a study of the relationship of the ashes of the coals and their relative densities illustrated in Diagram 1.

/At .....

At the same relative densities the anthracites have lower ash contents than the bituminous coals. Generally, the lower the volatile matter content, the greater the departure from the bituminous coals. The bright coals tend to have higher ash contents than the normal bituminous coals.

9. SULPHUR IN COAL

Sulphur is of great economic importance since it reduces the quality of metallurgical coke, increases corrosion in boilers and pollutes the atmosphere in general.

South African coals are normally low in sulphur content; and is usually less than 1% in the coals of the Transvaal, and about 1,5% for the Natal coals although a few of the coals may exceed this figure.

It occurs in three forms namely sulphate, pyritic and organic sulphur. Sulphate sulphur is mainly derived from the sulphates of calcium and iron and occurs usually in very small quantities in unweathered coals. Pyritic sulphur, as the name indicates is derived from pyrite and marcasite. Organic sulphur is part of the coal substance and may have been derived from the plant material from which the coal was formed. It is determined by subtracting the sum of the pyritic and sulphate sulphur from the total sulphur determined in the coal.

10. COKING PROPERTIES

The coking properties of a coal are of great importance on account of the strategic role played by coke in the metallurgical industry all over the world.

A coking coal is distinguished from other coals by the fact when heated in an inert atmosphere it commences to soften at a certain temperature and with further application of heat it becomes plastic while gases are evolved that pass through the plastic mass imparting a

/cellular .....

cellular structure to it when solidification sets in. Thus three phases can be recognized in the process namely a solid, a plastic and again a solid phase.

The softening temperature and temperature range during the plastic phase may vary considerably from coal to coal and is an important property when blending is considered. By blending is usually understood the adding of another coal having poor coking properties to a good coking coal for certain technological reasons, for example, to minimise the expansion pressure of the coke in the oven or, more commonly, to conserve the reserves of good coking coals.

It is generally conceded that unless the plastic range of a blend coking coal coincides more or less with that of the straight coking coal, the carbonized product will hardly be of an acceptable quality.

There are a number of tests devised to determine the coking propensities of a coal. These vary from relatively simple tests such as the swelling and Roga indices to very sophisticated tests like those carried out on the dilatometer, plastometer and plastograph.

However, there are a number of prerequisites for a good coking coal and these can be summarized as follows:

1. The moisture content should be low and in the order of 1½-2%. The lower the moisture content the lower the porosity and the better the wetting characteristics.

2. The rank must be in the order of 85% carbon (dry ash-free) or slightly higher.

3. The coal must be mainly bright with a ratio of reactive to inert petrographic constituents of about 2:1 or higher. Some high rank coking

/coals .....

coals still give an acceptable product on carbonisation even when the ratio is somewhat lower but in medium rank coking coals or the so-called blend coking coals, the coking potential improves with an increasing ratio of reactive : inert components.

4. The sulphur content must be on the low side.

5. The ash content must be moderate.

11. THE ULTIMATE ANALYSIS

Coal substance consists of the elements carbon, hydrogen, nitrogen, sulphur and oxygen.

Carbon and hydrogen are determined in a combustion furnace at the same time, while the nitrogen and organic sulphur are determined separately. Oxygen is found by difference.

The carbon content varies according to the rank of the coal. In South Africa, the variation is from 77% dry ash-free for the low rank coals of the Orange Free State to 92% for the anthracites of the Vryheid coalfield in Natal. It therefore increases with increasing rank.

The hydrogen content varies according to the type and rank of the coal. Bright coals always contain higher percentages of hydrogen than dull coals of equivalent rank. As the rank increases, the hydrogen decreases slowly to about 89% carbon (d.a.f.) and thereafter rapidly. The medium rank blend coking coals and the Ermelo bright coals have a hydrogen content of just over 5% and the anthracites of about 3½% on a dry ash-free basis.

The nitrogen content remains fairly constant. For the Transvaal and Orange Free State coals the variation

/is .....

is between 1,7 and 2,1% d.a.f. but for the Natal coals it is slightly higher and reaches a maximum of about 2,5% (d.a.f.) in some of the anthracites.

The organic sulphur content is generally very low and normally varies between 0,3% and 0,7% (d.a.f.) but it may increase to about 1,3% (d.a.f.) in the Klip River coalfield in Natal.

The oxygen content depends on the rank of the coal. Low rank coals are high in oxygen which decreases with increasing rank. The oxygen and carbon are therefore complementary. The low rank coals of the Orange Free State may contain as much as 17% oxygen (d.a.f.) while the highest rank coals namely the anthracites, contain about 3% (d.a.f.).

12. SOME DIFFERENCES IN CHEMICAL PROPERTIES BETWEEN BRIGHT AND DULL COALS

The chemical properties of the bright coals follow more or less the same trend as those of the Northern Hemisphere. However, for the higher rank coals, changes of slope, when other properties are plotted against carbon content, occur at lower carbon contents than for British coals. W.H.D. Savage found that South African coals are out of phase by about 1½ to 2% carbon in relation to moisture, swelling number, calorific value, volatile matter and hydrogen. He ascribes the differences to the effects of igneous intrusions on the coal, and is of the opinion that all South African coals that contain vitrinite with more than 85% carbon (d.a.f.) have been affected by dolerites.

The dull coals modify the picture considerably. They are higher in carbon and lower in volatile matter than the associated bright coals.
W.H.D. Savage found that selected bands of bright and dull coal from the same seam and taken at the

/same .....

same place may differ as much as 1% in hydrogen, 10% in volatile matter, 1000 Btu/lb in calorific value and possibly as much as 2% in carbon, expressed on a pure coal basis. The rank of the coal cannot therefore be expressed in terms of volatile matter content on a dry ash-free basis as in the case of European and American coals.

There is also a shift in the properties and the most obvious and striking difference is to be found in the coking properties. Throughout the whole range of rank no dull coals can be regarded as having true coking properties.

At equivalent carbon content the dull coals contain less volatile matter and the calorific value is also lower than that of the bright coal. At equivalent rank the hydrogen content of the dull coals is always lower than that of the bright coals.

In South African anthracites the dull coal is not very hard and this applies particularly to the so-called "burnt" coals i.e. coals badly affected by dolerite. In these instances the dull coal is sometimes very soft.

Dull coals weather more rapidly than the bright coals, particularly when the ash content is high.

13. THE CLASSIFICATION OF COAL

Since coals exhibit, by virtue of their different degrees of metamorphism or rank, different chemical properties, it is expedient to classify them in categories.

The most commonly used property is the change in ultimate and proximate analyses of the organic coal substance after the necessary corrections have been made for the amounts of inorganic matter associated with the coal.

/A .....

A number of principal changes associated with the increase in rank have already been mentioned in the text but for the sake of convenience these,and a few others,can be briefly summarized as follows:

In the process of maturation the following occur:

1. Increase in carbon (progressively and uniformly).
2. Decrease in hydrogen, gradually at first until the carbon content reaches 89% and then more rapidly.
3. Decrease in volatile matter.
4. Increase in calorific value until the hydrogen has decreased to below 4%.
5. Decrease in moisture content. It reaches a minimum in the coking coals and increases towards the anthracites.
6. Increase in absolute density in the higher rank coals.
7. Development of coking properties over a certain range and type.
8. Decrease in solubility in alkaline solutions.
9. Increase in depth of colour, lustre and reflectance.
10. Decrease in reactivity towards oxidising or hydrogenating agents.

There are a number of systems according to which coal can be classified the simplest being to the dry ash-free carbon or volatile matter content i.e. rank. Although illuminative, it has the disadvantage that only one parameter is involved.

Diagram 2 represents a visual survey of the positions occupied by most of the South African collieries if the rank of the coals mined by them is expressed on the basis of dry ash-free carbon content. Each

/vertical .....

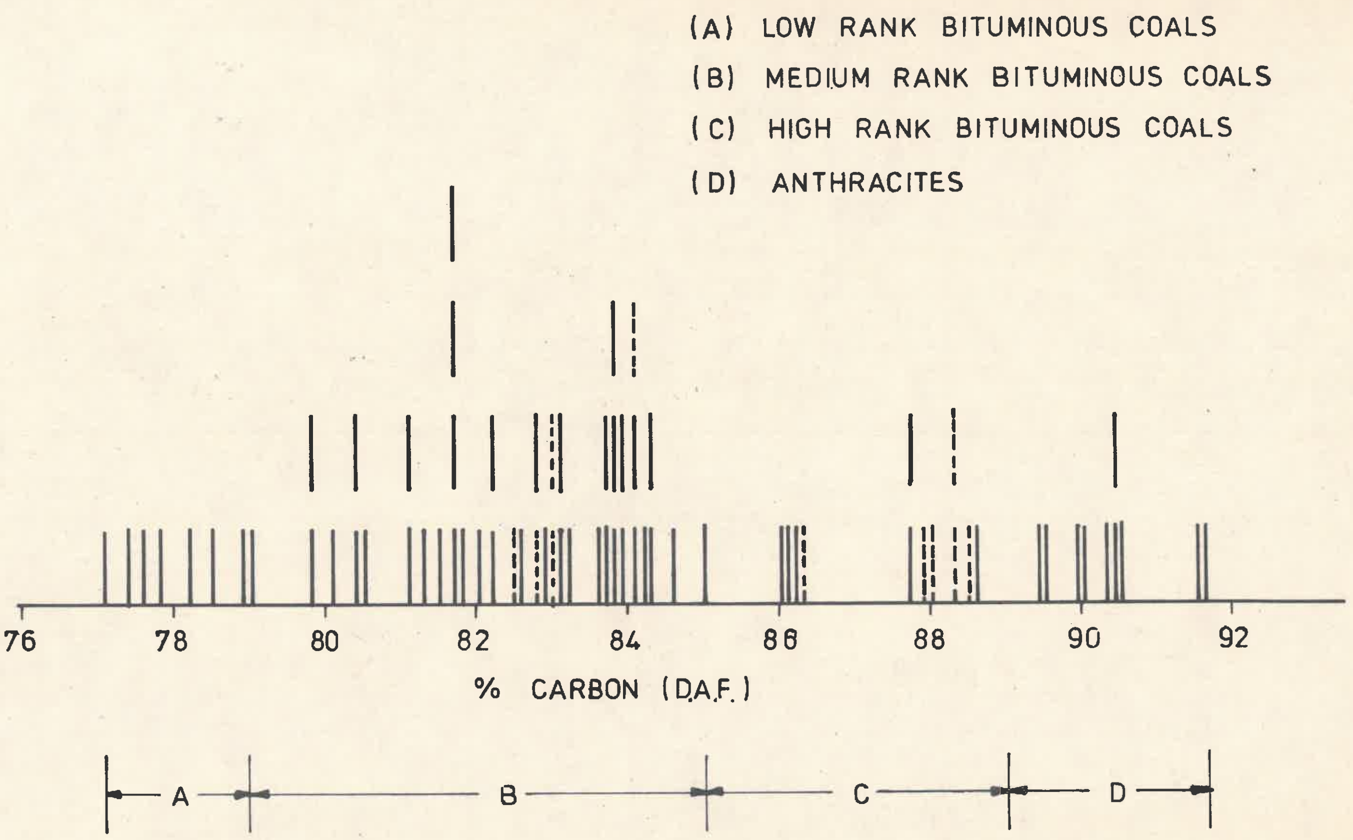


DIAGRAM 2

CONVENTIONAL CLASSIFICATION OF S.A. COALS ACCORDING TO RANK vertical line represents a colliery and is drawn in a position corresponding to the dry ash-free carbon content of the coal it produces. Where two or more collieries produce coal of similar rank the lines are drawn above each other. Collieries producing blend and straight coking coals are represented by broken lines.

It can be noted that the coals produced by the collieries fall roughly into four groups viz. A, B, C and D. Group A represents the low rank bituminous coals of the Orange Free State. Group B represents the medium rank bituminous coals and, with a few exceptions, are all mined in the Transvaal. Most of the coals (about 60%) mined in the Republic fall in this group. Group C represents the high rank bituminous coals of Natal and Group D represents the anthracite coals of the Vryheid district of Natal. It can further be noted that the coals are very poorly represented in the range 85 to 87,5% carbon (d.a.f.). Most of the coking coals produced in Europe and America fall in this range.

The most outstanding and historical system of classification was introduced by C.A. Seyler in the year 1900 and is based on the ultimate analysis using the carbon and hydrogen contents as his starting points. Since its introduction it has been modified many times.

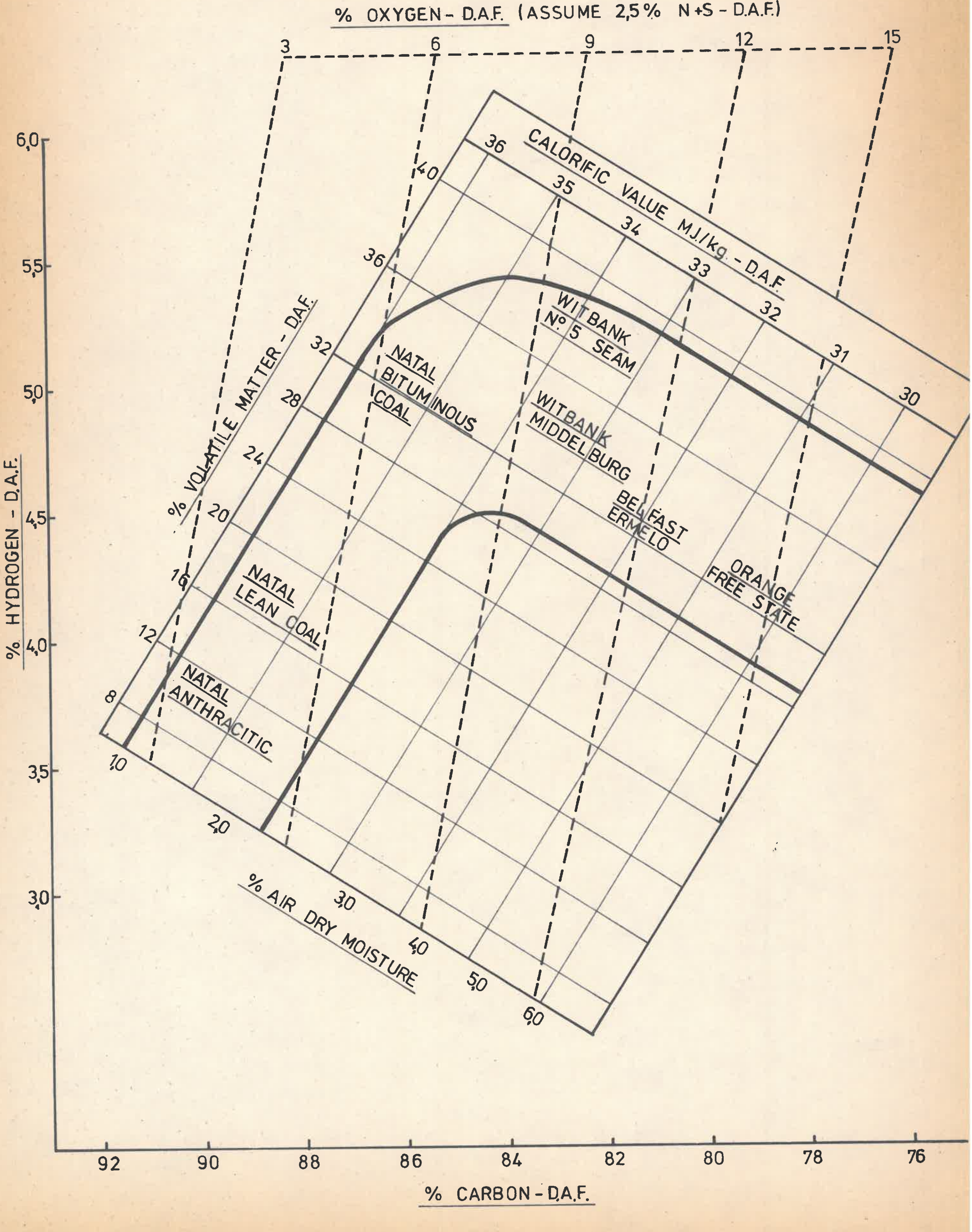
Diagram 3 illustrates a typical Seyler carbon-hydrogen chart as modified by M.C. van Vuuren of the Fuel Research Institute for its application to South African coals. Since the figure is very small a number of parameters have been omitted in order to avoid clustering.

The values used by Seyler are for a pure coal i.e. they have been calculated on a dry mineral matter free basis. This is a very sophisticated approach because

/allowances .....

DIAGRAM 3

THE SEYLER CARBON HYDROGEN CHART MODIFIED FOR SOUTH AFRICAN COALS



allowances must be made for mineral sulphur, sulphate sulphur, sulphur in ash, carbonates, chlorine contents, water of constitution, etc. These determinations entail a considerable amount of chemical work and are normally only carried out in fundamental research projects.

On the other hand, proximate analyses and calorific values on coal samples are carried out as a matter of routine and are always freely available. From these results the dry ash-free values can readily be calculated and usefully employed to compile a chart.

However, it must be realized that by using dry ash-free instead of dry mineral matter free values a number of minor errors are introduced. Thus the dry ash-free carbon on the chart includes the carbon from the carbonates i.e. calcite and siderite. Coals having high carbonate contents will give lower calorific values calculated from the carbon-hydrogen contents (from Seyler or du Long formulae) due to the lower content of combustible carbon.

Coals having high ash contents have relatively lower dry ash-free carbon, hydrogen and nitrogen contents and again higher dry ash-free volatile matter contents due to effects of molecular water in the clay constituents of the ash.

However, the purpose of this chapter is not to discuss the differences between dry ash-free and dry mineral matter free values. Suffice to say that the modified chart is reasonably accurate and should allow the reader to estimate the hydrogen of any given coal to within 0,1% and that of the carbon to within 1%. On the other hand, the volatile matter content and the calorific value can be estimated from the ultimate analysis to within 1-2% and 0,5 MJ/kg respectively.

/In .....

In the modified chart an attempt has been made to indicate the typical positions occupied by the coals in the Country on the basis of the various parameters. It must, however, be understood that there are no clear demarcation lines in the properties of the coals from the various coalfields and these tend to overlap depending on the quality of the coals.

14. THE MACERAL COMPOSITION OF SOUTH AFRICAN COALS

The other variation in a coal seam, namely type, is determined by the type of plant material from which the coal originated. Thus type is reflected in the elementary coal components or the so-called macerals.

There are a considerable number of macerals and some of them are still in the process of being discovered.

From a technological point of view macerals can be divided into two main groups, namely the chemically reactive and the chemically inert macerals. The former have a lower carbon to hydrogen ratio than the latter.

The reactive macerals can be sub-divided into two groups viz. vitrinites and exinites (also known as sporinites). The vitrinites are represented by the vitrains and exinites by the clarains (when occurring visibly with the vitrains) of the older nomenclature introduced by Stopes. The inertinites (there are a number of them that can be clearly defined) are represented by the durains (black and grey) and fusain. At least 90% of the durains found in South Africa are of the grey variety which is appreciably less reactive than the black durain by virtue of the fact that it is composed of intimately mixed vitrinite and semi-fusinite and the latter of exinite and semi-fusinite. Semi-fusinite is the predominant

/component .....

component of the inert maceral group, with fusinite the most important of the minor components.

The system of three groups of macerals is conventional and a simplification which is very convenient since the macerals belonging to each group have very similar properties.

Mineral matter has no genetic relationship to macerals. It acts as a diluent and may have other adverse influences. Thus in the evaluation of a coal, the minerals must also be taken into account.

In this paper the terms "vitrinite","exinite", "inertinite" and "visible mineral matter" are used as collective terms for a number of macerals and minerals respectively.

For the technological assessment of a coal on a petrographical basis, the ratio of the reactive to inert macerals is important. Reactive macerals are the essential components of a coking coal.

In order to obtain a broad view of the maceral composition of the coal seams and the coalfields in the Republic, a petrographical survey was carried out on the products prepared by the collieries for the commercial market.

The products were all taken according to the standard prescribed methods to ensure that each sample was representative of that specific sized product and the mass of the samples varied from 230 kg for the large sized products to 30 kg for the smaller sizes. In all, 448 products prepared by 55 collieries were investigated.

The survey stretched over a number of years. Apart from being a fairly large undertaking it was necessary to space the samples fairly widely to compensate for several factors.

/Since .....

Since the coal in a seam may vary in quality and petrographic composition, it follows that coal mined by collieries applying mechanical mining methods may show greater variation because of the restricted areas mined, than those where hand loading is applied over large areas at the same time and where greater discrimination is practised by the hand loaders.

Many collieries also practise selective mining in order to satisfy the demand for a certain quality of coal. Sometimes collieries also resort to top-coaling,resulting in a poorer quality coal than their normal run-of-mine product.

The position is further complicated by the fact that some collieries mine two or more seams simultaneously and the coal is transported to a single stockpile from which the washing plant is fed. Thus a washed product may consist of a coal representing more than one seam in variable proportions as the result of underground stoppages as well as size segregation in the stockpile.

Considering these factors it is logical to expect that analyses for the same coal seam may vary and, on a smaller scale, that a variation can occur in the products prepared by a specific colliery.

14(a) The coals of the Witbank-Middelburg Coalfield in the Transvaal

Three coal seams, Nos. 5, 4 and 2 are being extensively mined in this field.

No. 5 Seam: Coal from seven collieries were analysed. Five major collieries produce blend coking coal for carbonization purposes while two smaller collieries produce coal for the general market.

/The .....

The results obtained on the products from each colliery was very consistent over a period of more than two years and in general the results were very similar for the seam.

The following are the mean calculated values for the Seam where mined:

Vitrinite %	67,0
Exinite %	7,3
Inertinite %	21,8
Visible Minerals %	3,9
Ratio of reactives:inerts	2,9:1

No. 4 Seam: The No. 4 Seam shows more variation in thickness and quality than any other seam in the Witbank coalfield. The Lower No. 4 Seam, where the parting is absent, is mined extensively in conjunction with the No. 2 Seam. The Seam is mined by ten different collieries in the Witbank area but only two of them mine it exclusively.

The results obtained on the various sized products for each colliery were very consistent although one colliery mined a coal slightly superior to that of the other.

The mean calculated values for the Seam where mined are as follows:

Vitrinite %	45,4
Exinite %	5,3
Inertinite %	42,1
Visible Minerals %	7,2
Ratio of reactive:inert constituents	1,0:1

The No. 4 Seam is composed of inferior coal with a low heating value and high ash content. The latter is reflected in the high percentage of mineral

/matter .....

matter, notwithstanding the fact that both collieries are equipped with mechanical cleaning plants.

It was also found that the No. 4 Seam contains more bright coal where mined, than what is generally believed.

No. 2 Seam: This is the principal working seam in the Witbank-Middelburg coalfield. It is generally about 6 m thick and consists of about 1 m of bright coal at the base followed by mixed mainly dull coal towards the top with occasional bright bands merging into the top coal. In some places a fairly thick bright coal band appears just below the roof.

At least twenty-two major collieries produce coal from this Seam. Of these, twelve produce coal from the No. 2 Seam exclusively. The other collieries produce coal from No. 2, No. 4 and/or No. 1 Seam.

The products produced by each colliery did not show much variation in petrographic composition but the values varied considerably from colliery to colliery. This is due to factors such as variation in the coal seam, the mining height employed and the geographical position of the colliery. Collieries operating on the margins of the coalfield produce coal of an inferior quality. A number of collieries do not wash their coal which also influences the results.

The mean calculated values of the Seam where mined are as follows:

	No. 2 Seam only	No. 2 Seam combined with No. 4/No. 1
Vitrinite %	37,3	39,8
Exinite %	4,3	4,1
Inertinite %	53,0	51,0
Visible Minerals % ..	5,4	5,1
Ratio $\frac{\text{Reactives}}{\text{Inerts}}$	0,7:1	0,8:1

The results are very similar except that the collieries mining No. 4 and/or No. 1 Seams produce a slightly superior product.

14(b) Ermelo Coalfield

Three major collieries in this field produce coal from Seams B, C, Lower C and Upper C. As the coals from the separate Seams are mixed prior to washing, it was impossible to obtain products from them separately.

The Ermelo coals are, by South African standards, essentially bright coals and the mean calculated values for these coals are as follows:

Vitrinite %	52,4
Exinite %	5,9
Inertinite %	37,0
Visible Minerals %	5,8
Ratio $\frac{\text{Reactives}}{\text{Inerts}}$	1,3:1

The values indicate that the Ermelo coals are, in terms of reactive:inert components, superior to the coals of the Witbank Nos. 2 and 4 Seams and are inferior only to the No. 5 Seam.

14(c) The mean maceral composition of the Transvaal coal seams

The mean maceral composition of all the products from each seam, calculated on a visible mineral matter free basis, is as follows:

Seam(s)	Vitrinite %	Exinite %	Inertinite %	Ratio $\frac{\text{Reactives}}{\text{Inerts}}$
Witbank No.5	69,7	7,6	22,7	3,4:1
Witbank No.4	48,9	5,7	45,4	1,2:1
Witbank No.2	39,5	4,5	56,0	0,8:1
Ermelo	55,8	6,8	37,4	1,7:1

These results are plotted in Diagram 4.

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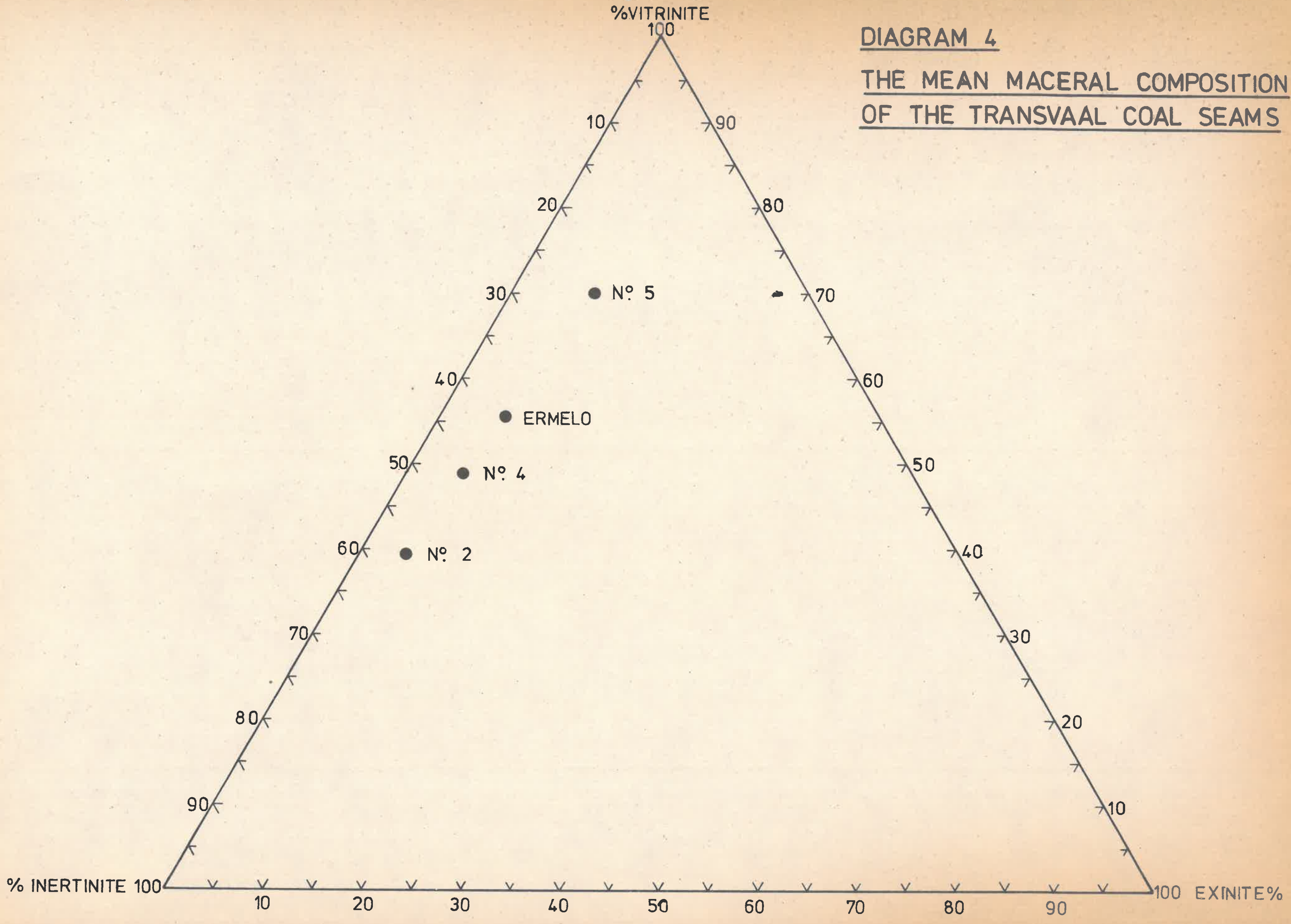
DIAGRAM 4

THE MEAN MACERAL COMPOSITION OF THE TRANSVAAL COAL SEAMS



The variation in petrographic composition of the products prepared by each colliery was rather small. At least 80% of the collieries produced coal of which the variation in the vitrinites and exinites was less than 8%. For the exinites and visible mineral matter the variation was 4% and even less.

It does not appear that the vitrinites follow any consistent pattern from the larger to the smaller coal sizes. The number of cases where the larger sized products contained more vitrinite than the smaller sizes and vice versa are more or less equal.

In two instances where the No.5 Seam coal was not washed the vitrinites concentrated in the fines.

There is also a very marked tendency that collieries adjoining each other, or collieries covering a certain area, tend to give comparable results.

14(d) The coals of the Orange Free State

There are five collieries in this field and they are responsible for about 25% of the Republic's total annual production from seven shafts. About 95% of the coal produced from this field is utilized for the generation of electricity and gasification.

There are three thick seams present. They are very similar in appearance and consist of dull low grade coal containing a considerable amount of visible mineral matter.

It was impossible to obtain separate samples from the three seams where mined but a comparison between the No. 2 (Middle) Seam and a combination of the three seams was possible. The results were practically identical.

/The .....

The greatest variation in maceral composition was between the products of the collieries situated in the western and eastern extremities of the coalfield. The variation in vitrinite content was about 8%, but the collieries in the Vereeniging-Sasolburg area produce coal of practically similar maceral composition.

The calculated mean maceral composition of the coals from this field is as follows:

Vitrinite %	26,3
Exinite %	3,4
Inertinite %	55,6
Visible Minerals %	14,7
Ratio $\frac{\text{Reactive}}{\text{Inert}}$ constituents ..	0,4:1

14(e) The coals of Natal

There are fifteen collieries producing bituminous coal from a variety of seams in this province. In a few cases samples could be obtained from individual seams otherwise the samples consisted of a mixture of the seams mined. The anthracites were not included in the survey.

In Natal the position is somewhat different to that in the Transvaal and Orange Free State where only relatively small differences in maceral composition exist in the products prepared by any single colliery. The coals from certain Natal collieries, particularly those producing coal for the general market, in addition to their main product, coking coal, show considerable variation in their maceral composition. Thus in order to arrive at values representative of the whole output of the colliery, it was necessary to calculate them on a weighted basis using the colliery's production figures for each size grade.

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The Natal Collieries can conveniently be divided into six areas and the coals belonging to each area have very similar properties.

The following are the mean calculated values obtained for each area:

Area	No. of Collieries	Vitrinite %	Exinite %	Inertinite %	Vis. Min. %	Ratio Reactives/Inerts
Northern Klip River	4	45,5	2,8	44,7	7,0	0,9:1
Central Klip River	3	62,5	1,7	31,1	4,7	1,8:1
Southern Klip River	1	35,1	1,0	56,3	7,2	0,6:1
Utrecht	3	36,7	4,1	54,4	4,8	0,7:1
Paulpietersburg	2	59,3	5,7	30,9	4,1	1,9:1
Vryheid	2	58,3	2,7	35,4	3,6	1,6:1

It can be noted from the table that the coals from those areas producing coking coal namely Central Klip River, Paulpietersburg and Vryheid have high ratios of reactive to inert constituents. These differences are illustrated in Diagram 5 where the mean maceral composition of the products are plotted on a visible mineral matter free basis.

The calculated mean variation for the products investigated was 13,8% for the vitrinites, 1,8% for the exinites, 13,7% for the inertinites and 4,6% for the visible minerals. Variations of less than 10% in the vitrinites and inertinites in the different products prepared by the same colliery were recorded for only three collieries.

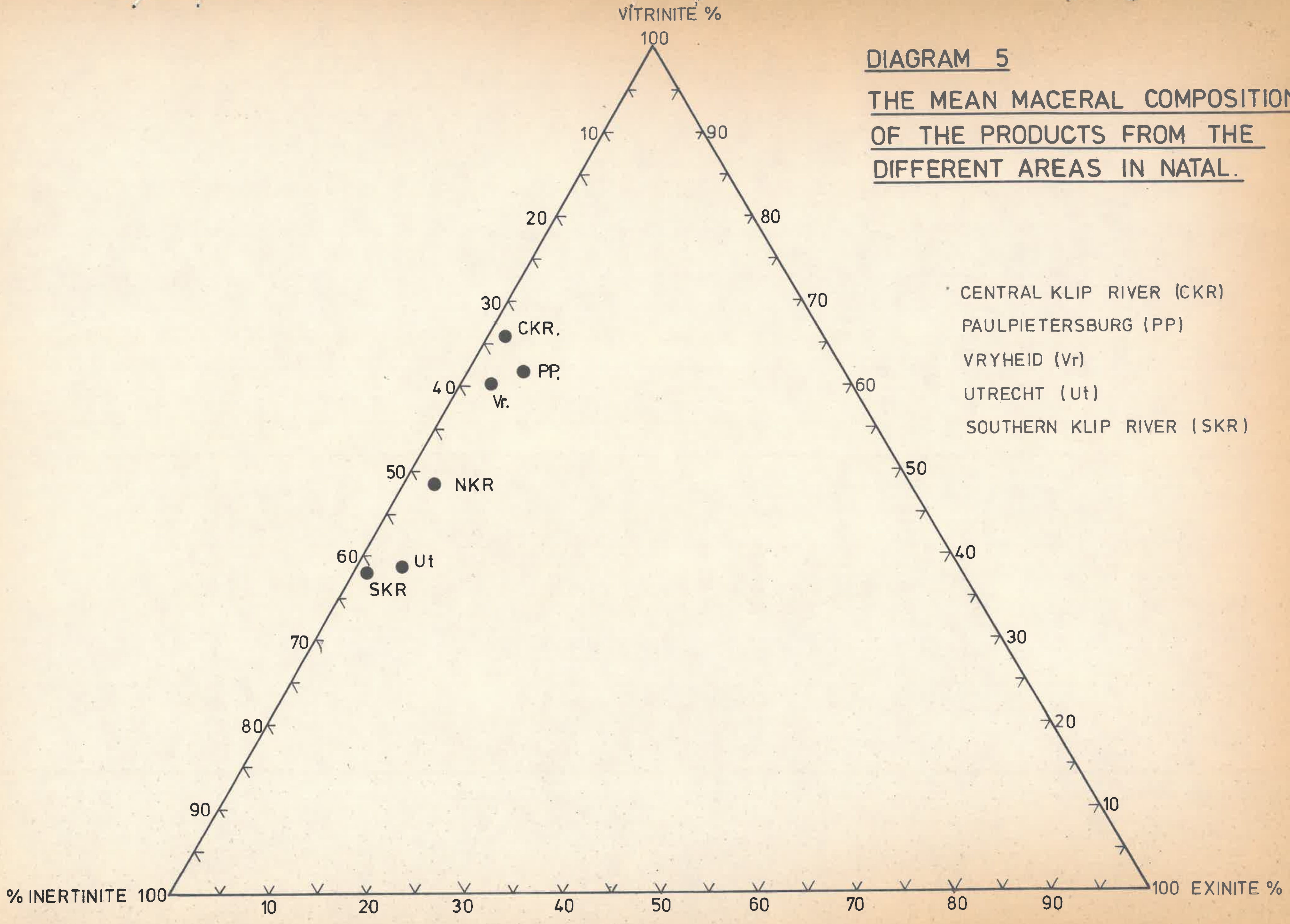
In contrast to the Transvaal coals where no clear pattern could be observed from the larger to the smaller size ranges, the vitrinites follow a consistent pattern

/by .....

DIAGRAM 5

THE MEAN MACERAL COMPOSITION OF THE PRODUCTS FROM THE DIFFERENT AREAS IN NATAL.

CENTRAL KLIP RIVER (CKR)
PAULPIETERSBURG (PP)
VRYHEID (Vr)
UTRECHT (Ut)
SOUTHERN KLIP RIVER (SKR)



by showing a steady increase in the decreasing coal sizes of most of the collieries.

14(f) The mean maceral composition of the coals produced in the Republic

In order to obtain a general picture of the petrographic composition of the coals produced in the three provinces the results obtained in the course of the survey were used to calculate the mean maceral composition of the coals for each province.

The values obtained cannot be regarded as being of an absolute nature particularly those concerning the Natal coals where a fairly large number of coal seams are involved and where considerable variations in the values of the products occur.

The results, calculated on a visible mineral matter free basis are, however, significant and can be summarized as follows:

Province	Vitrinite %	Exinite %	Inertinite %	Ratio $\frac{\text{Reactives}}{\text{Inerts}}$
Natal	52,7	2,9	44,4	1,3:1
Transvaal	45,1	6,9	48,0	1,1:1
O.F.S.	31,1	4,1	64,8	0,5:1

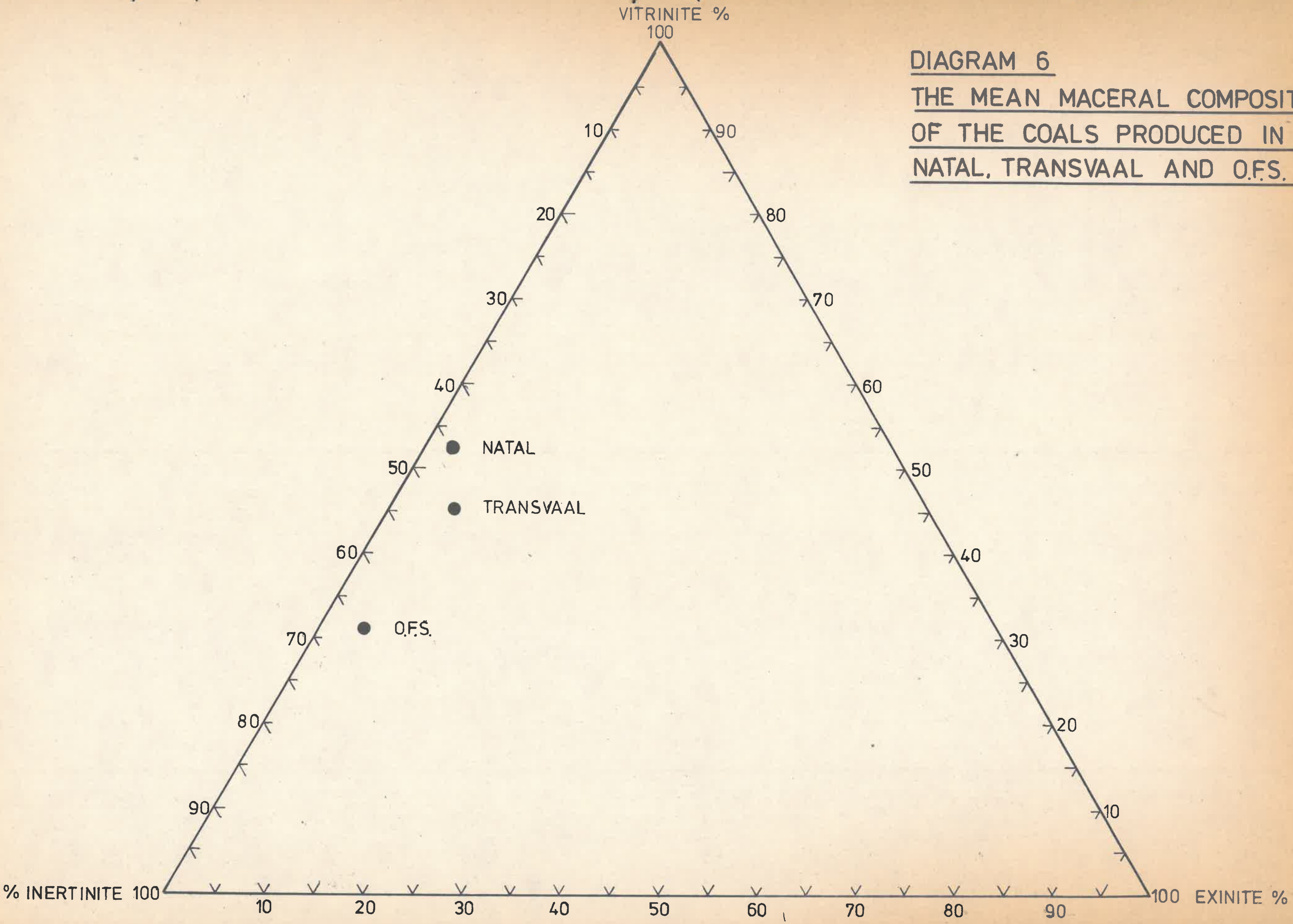
Judging by the vitrinite contents it is apparent that the Natal coals are brighter than those of the Transvaal and that the coals of the Orange Free State are very dull. These results are plotted in Diagram 6.

On the other hand, the exinite content of the Natal coals is surprisingly low. The individual results obtained on the products prepared by the Transvaal collieries show that 50% of them contained 5% or more exinite (with a maximum of 9%) in comparison with

/only .....

DIAGRAM 6

THE MEAN MACERAL COMPOSITION OF THE COALS PRODUCED IN NATAL, TRANSVAAL AND O.F.S.



only 15% of the Natal products. The high exinite content in the Transvaal coals is mostly due to the Witbank No. 5 Seam blend coking coals and the Ermelo coals.

While the Natal coals appear in general to be brighter than those from the Transvaal due to higher percentages of vitrinite, the vitrinites in the coals from the latter province are augmented by the exinites to such an extent that the relative ratios of reactive:inert components are very similar. The Natal coals are therefore petrographically speaking only slightly more reactive than the Transvaal coals. On the same basis the Orange Free State coals can be regarded as being very inert.

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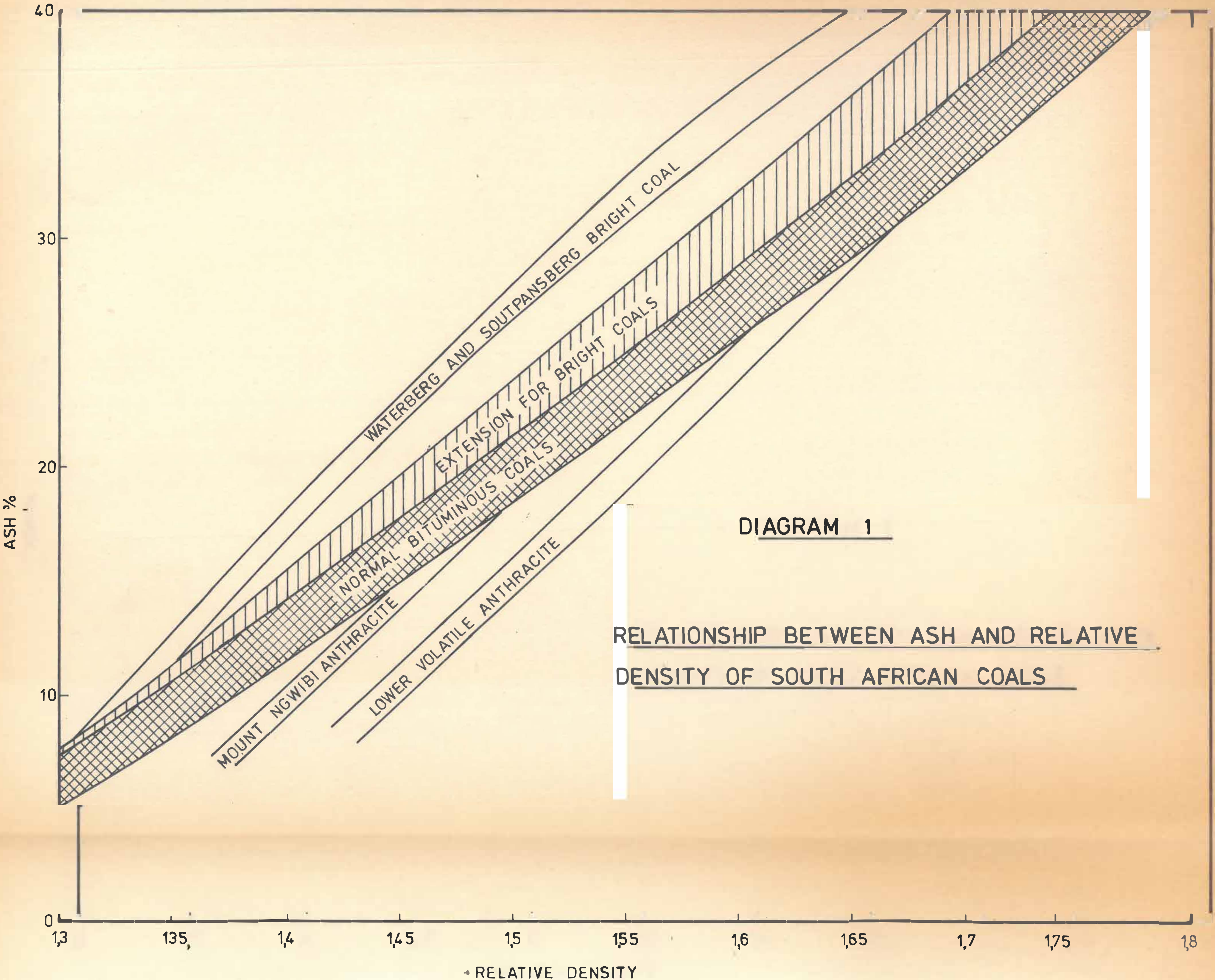

DIAGRAM 1

RELATIONSHIP BETWEEN ASH AND RELATIVE DENSITY OF SOUTH AFRICAN COALS