

PRODUCTIVITY GROWTH IN THE SOUTH AFRICAN
COAL MINING INDUSTRY : 1950 - 1980

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A thesis submitted to the Faculty of Commerce, University
of the Witwatersrand, Johannesburg, in fulfilment of the
requirements for the degree of Doctor of Philosophy.

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DECLARATION

I hereby declare that this thesis is my own unaided work and has not been previously submitted, in part or in whole, for a degree at any other University.

R. Jones

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30. 6. 1983

DATE

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This thesis would not have been possible without the willing co-operation received from many people directly and indirectly connected with the coal mining industry in South Africa. During the course of my research I have visited twenty six collieries, five ESCOM power stations, ISCOR, SASOL, and innumerable private firms including manufacturers of mining machinery. I have persistently bothered the personnel of the Economics Department of the Reserve Bank, Department of Mineral and Energy Affairs, Minerals Bureau, Chamber of Mines, Fuel Research Institute, and the different mining houses and marketing organisations with a wide range of queries and requests for statistics and information. I have attended seminars, participated in training sessions, and sat in on management meetings. I have talked to mine managers, miners, artisans, machine operators, engineers, geologists, training personnel and trade-union officials. At all times my brief has been to ask questions, listen, observe and learn. I mention no names in particular for that would be odious to those I omit. They have collectively moulded my knowledge. I thank them all.

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R.A.J.

ABSTRACT

This thesis was undertaken to measure productivity growth in the South African coal mining industry between 1950 and 1980. It arose out of a discussion between Professor A Spandau, former Head of the Department of Business Economics at the University of the Witwatersrand, Dr. Lawrence, Director of the Human Resources' Laboratory of the Chamber of Mines, and myself, in late 1978, during which it was noted that the industry had become progressively mechanised since the mid-1960's. However, the impact on productivity remained obscure, other than the observation that coal sales per man shift had grown progressively, and there was a need to relate increased coal production not only to a reduced labour force, but also to an enlarged capital stock and raw material consumption. This study sought to rectify this need.

This thesis is divided into three parts. Part I contains five chapters and consists of an analysis of the factors which are most crucial in affecting the level of productivity in the coal mining industry. Two broad forces were dichotomised - exogenous and endogenous. Exogenous forces are those which the industry regards as "given" in that it has no direct control over them and act as constraints within which policy matters must be formulated. These factors are natural and geological conditions (chapter 1) and economic conditions combined with political and sociological issues (chapter 2). Endogenous forces are those over which the industry does have control and the magnitudes of which are inherently determined by its own internal policies and decisions. These factors concern the organisation and management of the industry (chapter 3), technical issues (chapter 4), and the whole gamut of factors associated with the labour situation (chapter 5).

Such a discussion, in isolation, although instructive is inadequate as a productivity study in that it fails to provide quantifiable information. Some of the factors have undoubtedly had a positive productivity effect (such as favourable geological conditions), whilst others have worked in an adverse direction (such as the black-labour situation). The extent to which these forces had counteracted or reinforced each other in the aggregate could only be determined through a quantitative approach and the aim of Parts II and III was to provide this overall productivity measure.

Part II contains three chapters and consists of an analysis of the concept and measurement of productivity. The definition, significance, and theory of productivity change are dealt with in chapter 6, whilst chapters 7 and 8 examine the various methods of productivity measurement which have been devised and advanced by economists since the late 1940's. The emphasis throughout is laid on measuring total, as opposed to partial, factor productivity, that is, relating output changes to the growth of all tangible inputs combined as an aggregate. Chapter 7 examines the Ratio method (with emphasis primarily on the Kendrick approach), the Solow method, and the Production Function method utilising both the Cobb-Douglas and Constant-Elasticity-of-Substitution functions. All these approaches contain a set of common characteristics and deficiencies in their measurement of productivity which has led the writer to describe them as "unrefined". Studies which attempt to remove some or all of these traits are accordingly described as "refined", and these are the subject of chapter 8. A distinction is made between two approaches which have recently crystallised in the literature - measurement and explanation. The measurement approach concentrates on removing as many of the deficiencies, errors, and mis-specifications of the "unrefined" studies as possible, whilst retaining the objective of measuring productivity as a catch-all residual which remains behind as a "measure of our ignorance" after aggregate input growth has been purged from output change. On the other hand, the explanation approach emphasises the necessity of fully explaining the growth of output by decomposing it into all its component parts. In other words, the conceptual difference between the two approaches is that the former is content merely to measure, and leave unexplained, the residual, whilst the latter demands a full understanding of the component parts of the residual and their relative magnitude. It is made clear that this thesis is concerned only with the measurement approach.

Part III contains three chapters and attacks the problem of quantifying productivity growth in the coal mining industry. Chapter 9 is lengthy and includes two appendices. It is primarily devoted to data measurement - output, labour, capital, and raw materials - and it is made clear that these variables should be measured unadjusted for quality change. A full explanation is provided of the methodology employed in the measurement of each variable, but particular emphasis, and space, is devoted to the capital-input factor. It was the absence

of a readily-available and conceptually-acceptable capital-stock series for the coal mining industry which necessitated the writer embarking upon the time-consuming task of compiling the required series, and the achievement of this is recorded as a major contribution of the thesis. Chapter 10 tackles the problem of calculating total factor productivity in the industry by applying the data developed in chapter 9 to the principles and methods described in chapters 7 and 8. The Kendrick, Abramovitz-Domar, and Solow methods are employed, followed by an attempt utilising a Cobb-Douglas and CES production function. It became clear that no constant productivity trend was discernable throughout the study period. Rather, five distinct sub-periods of alternating positive and negative productivity growth were demarcated, and that overall there was little evidence that in terms of input foregone per unit of output produced coal was mined any more productively at the end of the study period than at the beginning.

This led the analysis in the direction of trying to account for the different sub-periods of productivity growth. It was discovered that the negative growth periods coincided with the introduction of new extraction technologies (learning periods) whilst positive growth was experienced several years after the introduction era (familiarity periods).

Decomposition of aggregate input into labour, capital and raw materials revealed a clear tendency for the annual average rate of increase of these variables to accelerate during learning periods and fall back during familiarity periods. These swings were particularly noticeable in the case of raw materials, further decomposition of which revealed that these oscillations were dominated by the movement of the spares and repairs series. The industry lost control of the growth of spares and repairs during learning periods only to regain that control once familiarity had been acquired. Emphasis is laid on three factors which explain these developments - personnel familiarity, local manufacture, and equipment design. Details of these factors for each of the five sub-periods are presented in chapter 11.

It is particularly noted that industry management failed to anticipate the adverse developments encountered during learning periods, and because of this lack of anticipation no co-ordinated policy programme was devised to deal with the problems subsequently occurring. In addition, reaction to these difficulties occurred on a

mine-to-mine basis, with learning being bedevilled by the setting of different criteria and the obtaining of varying results. This was compounded by the confidentiality of many trial results. The thesis recommends that management learn from their experiences of the past and anticipate rather than ignore the adverse developments of learning periods. Such realisation must then manifest itself in a policy programme designed to minimise the consequences. Secondly, provision must be made for the formal, co-ordinated pooling of knowledge at the industry level, and the efficient dissemination of this wisdom to concerned parties. It is recommended that the Coal Mining Laboratory of the Chamber of Mines extends its traditional areas of research to assume responsibility for this co-ordinating role.

TO MY PARENTS
MR. AND MRS. C. JONES

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PART I

FACTORS AFFECTING PRODUCTIVITY IN THE
SOUTH AFRICAN COAL MINING INDUSTRY

Introduction

Two major types of factors which affect productivity can be dichotomised. Firstly, there are those which the industry regards as "given" in the sense that they are imposed on it by outside forces and cannot be directly controlled by the industry. They can be regarded as constraints within which the industry's internal decision-making processes must be formulated. These forces can be called exogenous. Secondly, there are those which are capable of being controlled by the industry and are inherently determined by its own internal decisions. These forces can be called endogenous.

Exogenous forces form the content of Section A, and have been divided into two chapters: natural and geological factors (chapter 1), and economic and other extraneous factors (chapter 2). Endogenous forces form the content of Section B, and have been divided into three chapters: organisation and management (chapter 3), technical factors (chapter 4), and human factors (chapter 5).

SECTION A
EXOGENOUS FACTORS AFFECTING PRODUCTIVITY
CHAPTER ONE
NATURAL AND GEOLOGICAL FACTORS

Difficult mining conditions obviously have an adverse effect upon productivity and form a severe constraint within which the industry must operate. This chapter examines the nature of such forces facing the coal mining industry in South Africa.

The Origins and Geology of South African Coal Reserves

Coal is the end result of fossil vegetation deposited in shallow fresh water such as lakes and swamps, overlaid and compressed by layers of sediment. Coal was formed during several different periods of geological history. In the northern hemisphere the principal period was the Carboniferous epoch, whilst in the southern hemisphere coal was formed during the Permian epoch, some 150 million years later. The deposits of the two hemispheres differ in several respects: the nature of the coal, the type of vegetation it derived from, and the climatic and geographical conditions prevalent during development. The northern deposits appear to have been formed in a mild to tropical climate, and the southern deposits in an extremely cold climate. Because of the different vegetation the southern coalfields generally contain more ash in the form of additional mineral material deposited with the coal (1).

Immediately preceding the coal-formation era in the southern hemisphere there appears to have existed a large continuous continental mass, which included parts of India, South America, Australia, Antarctica, and Africa south of the equator, lying at, or below, sea level. This mass acquired a relatively level surface due to a cover of glacial tillite and as the land gradually rose and the sea receded there remained large level areas covered with lakes and swamps and fed with fresh water from higher regions. The resultant geological succession of sedimentary material is similar in all the, now separate, areas which comprised the continental mass. In Africa, this sedimentary sequence is called the Karroo system with the maximum vegetation and coal development occurring in the Middle Ecca Stage. Much later more over-lying coal was formed during the Beaufort Stage but this has now been almost entirely eroded away. The last phase in the Karroo system

was comprised of dolerite dyke intrusions and basalt outpourings on to a land surface now well above sea level.

Although the continental-mass platform on which coal deposits formed was enormous in extent, equally favourable conditions for such development were not found everywhere with resultant gaps being found in the pattern. Ecca coals occur in the Karroo system as far north as Lake Rukwa in Tanzania and as far south as Ladysmith in Natal, with intervening occurrences being limited to relatively small areas which have been preserved from erosion. By far the largest proportion of coal in Africa south of the Sahara is found in Zimbabwe and South Africa, although a great deal of the original coal-bearing sheet of Ecca sediments which covered the Transvaal and large areas of Natal and the Orange Free State has been eroded away leaving several separate coalfields of various sizes. Other than occasional faulting and dolerite intrusions there has been remarkably little structural disturbance of the beds since they were laid down, although the thickness and quality of the coals is variable, as is the number of seams. The largest proportion of South African coal comprises bituminous steam coal, with small percentages of coking - and blending - coking coal, and anthracite in Natal. These coals are defined as follows:

- Bituminous coal has a volatile-matter content on a dry ash-free basis of not less than 16,5 per cent.
- Coking coal is bituminous coal which softens on heating and is capable of providing coke of metallurgical grade when carbonised in a coke oven.
- Blend-coking coal is bituminous coal which has insufficient coking properties or is otherwise unsuitable (e.g. too high in volatile-matter content) to make a metallurgical coke when carbonised on its own, but is capable of yielding metallurgical coke when fortified with a lesser amount of a suitable coking coal before carbonisation.
- Anthracite is coal with a volatile-matter content on a dry ash-free basis of not more than 12,5 per cent. It has no coking properties (2).

In order to clarify these terms a brief examination of the characteristics and properties of coal will prove instructive.

Definition of Coal: Classification, Types and Properties

Coal can be defined as a combustible solid, originating from the accumulation, partial decomposition, and burial of vegetal organic matter in the geological past (3). Coal is not a homogeneous substance. There is a wide range in the composition, and in the physical and chemical properties, of different kinds of coal. Variations in coal quality and properties can occur not only between one seam and another, but within a single seam. However, despite the variety, all coal samples are composed essentially of the elements carbon, hydrogen, and oxygen, with smaller quantities of nitrogen and sulphur, plus varying amounts of absorbed moisture and inorganic mineral matter that remains as ash when the coal is burned (4). It is the different combinations of these elements that accounts for the non-homogeneity of coal. The composition of coal depends upon the different types and properties of vegetal matter from which it was formed, the degree of biochemical alteration of these ingredients, the depth of burial and temperature to which it was subjected during geological time, and the proportion and constituents of the ash.

A discussion of coal characteristics can be conveniently approached under three headings: type, rank, and properties (5).

Coal type is determined by variations in organic composition, that is, the dominating type of plant material from which it is derived. The organic composition of coal is usually described in terms of the principal maceral groups, i.e., exinite, vitrinite, and inertinite, the relative proportions of which are important in determining coal qualities and properties. Thus exinites are hydrogen-rich and relatively reactive, whereas inertinites are hydrogen-poor and relatively inert. Type can often be identified by coal lustre ranging from dull to bright, with intermediate stages or mixtures between bright and dull. Bright coals are rich in vitrinite and are usually of high quality with coking properties. They are higher in hydrogen, volatile matter, and calorific value, but lower in carbon, than dull coals. Truly dull coals never possess coking properties.

Coal rank is a measure of the degree of maturity or metamorphism that the coal has undergone. It is determined by the different temperatures to which coal has been subjected over geological time. Chemical composition is affected by rank which thus affects various coal

properties. Thus, for instance, with increasing rank volatile matter decreases whilst carbon content increases, giving two ways in which rank can be expressed, on the basis of either dry ash-free carbon or volatile-matter content of the coal. Rank is commonly described in terms of the following ascending series: peat - lignite (or brown coal) - sub bituminous - high, medium, and low bituminous - semi anthracite - anthracite - graphite.

There are many measurable properties commonly used for classifying, describing, evaluating, or physically separating different types or grades of coal. A reasonably exhaustive list would comprise: calorific value, fixed-carbon content, volatile-matter content, ash content, moisture content, ash-fusion temperature, sulphur content, free-swelling index, Roga index, optical properties (e.g. reflectance of vitrinite), specific gravity, elemental carbon, hydrogen and oxygen contents, and physical properties such as grindability, friability, abrasiveness, hardness, strength, and slacking (weathering) indices. The relative importance of these different properties depends upon the purpose for which the coal is to be used. Thus coal for coke manufacture for metallurgical uses should be of high grade and calorific value but with low ash and sulphur contents, which must swell to some extent and be moderately plastic, with a volatile content on a dry ash-free basis of between 21 and 30 per cent. For purposes of combustion, direct heating, and steam generation, important properties are the volatile, moisture, and ash contents, ash-fusion temperature, and grindability. For power stations and some processes of coal gasification, low-grade coals with high-ash contents are suitable, with specially-designed equipment (6).

Although coal can, for various purposes, be classified according to grade, chemical or petrographic composition, size grading, or other properties, the most commonly-used classification remains that based on rank.

Coal Quality in South Africa

There are wide variations in the quality and properties of South African coal both within and between different seams and coalfields. An exhaustive examination is neither necessary nor possible. The average quality of South African coal is rather poor, with the exception of the Witbank basin and Natal where coal quality is generally good. The poorest-quality coal is found in the Orange Free State, Northern

Transvaal, and South Rand and is only suitable for SASOL plants and power stations. The lowest-rank coals are found in the Orange Free State. They have a dry ash-free carbon content of 77 per cent, whilst the highest-rank coals are the anthracites found to the south east of Vryheid with a dry ash-free carbon content of 91,6 per cent. The ranks of all the other coals found in the country, including bituminous and coking coals, fall somewhere between these two limits. Most coal being mined at present is of high volatile bituminous rank or above. Bituminous coal in South Africa is classified into grades on the basis of calorific value. On an air-dry basis the calorific values of South African coals range from less than 21 MJ/kg to a maximum of about 32 MJ/kg.

Further discussion of the geology, properties, and quality of South African coal is undertaken in the following section which deals with the location and characteristics of the country's coalfields.

The Coalfields of South Africa

The coalfields of the Republic are demarcated and presented in figure 1.1. With the exception of the Molteno-Indwe field the nation's coal deposits occur in the northern and eastern parts of the country (Transvaal, eastern Orange Free State, and northern Natal) to the north and east of a line connecting Ladysmith and Bloemfontein. In the following discussion the least-exploited fields will be discussed first (7).

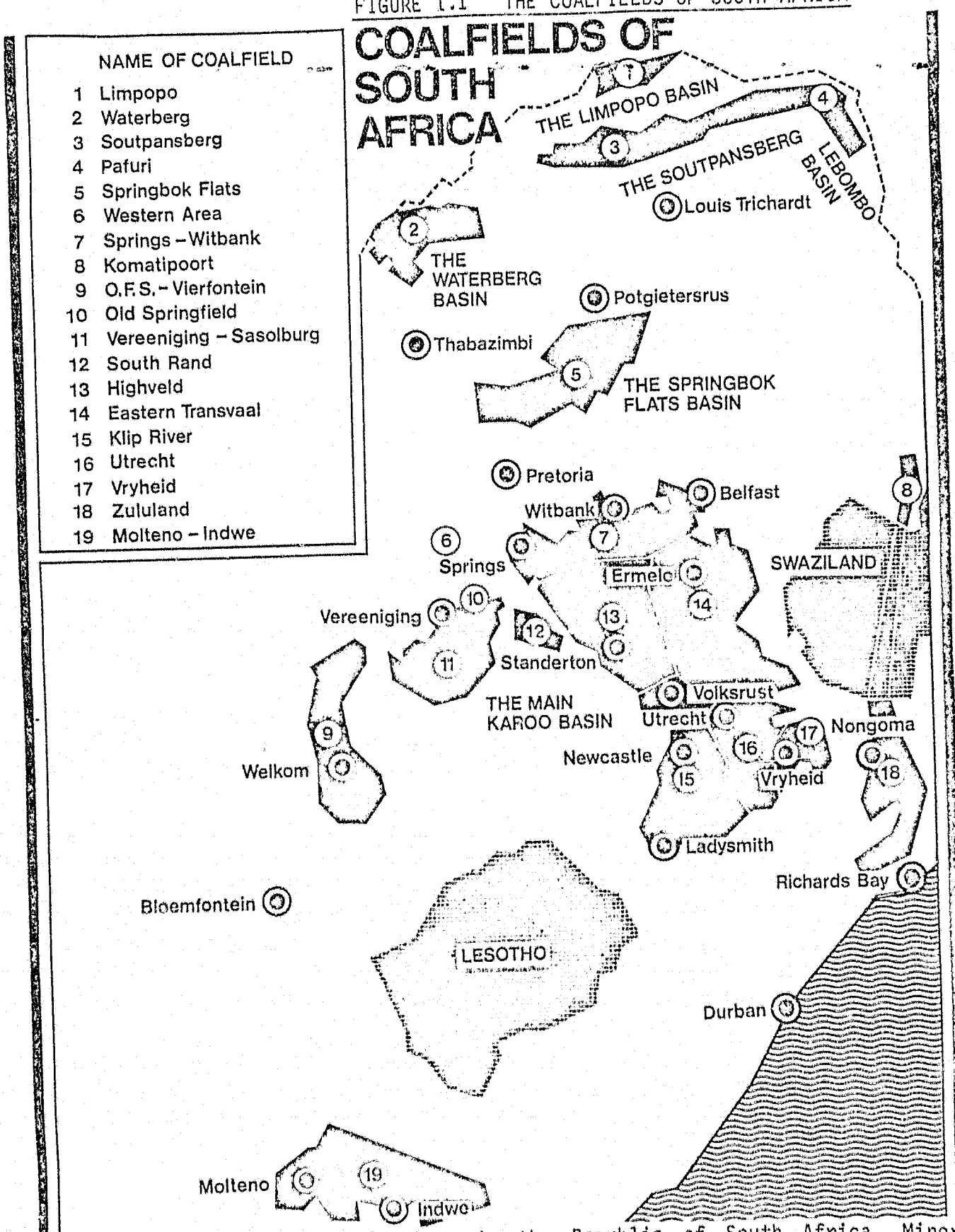
1. The Limpopo Coalfield. This field lies on the south bank of the Limpopo River to the west of Messina. Two seams are located close together at a depth of between 225 and 240 metres, and the field is approximately 20 kilometres in width.
2. The Waterberg Coalfield. This field covers an area of approximately 88 x 40 kilometres and is part of a larger field extending into Botswana. It is characterised by many thin seams most of which are extensively mixed with shale. Some of the coal has been classified as being of blend-coking quality. The western coals are shallow and amenable to open-cast mining as evidenced by the recent commissioning of the Grootegeluk colliery near Ellisras, but the eastern coals are mostly deeper than 160 metres and although there

is much coal of workable quality it poses formidable obstacles to economic extraction.

3. The Soutpansberg Coalfield. This field lies to the south of Messina and north of the Soutpansberg mountains, occupying flat country and striking out east and west. Deposits include bituminous and some coking coal. Several seams are encountered at depths in excess of 320 metres, having a height of between 0,3 and 4 metres, separated by shale.
4. The Pafuri Coalfield. This field is an eastwards extension of the Soutpansberg field, the two being intricately linked by a stretch of faulted Karroo rocks. It commences 20 kilometres west of Tshipise and strikes eastwards for another 40 kilometres past this locality, after which it has been subjected to post-Karroo movements causing a 90 degree change in strike turning it southwards for another 40 kilometres into the Kruger National Park. Coal of coking properties is available in two seams (the bottom one, thin, of a height of 0,5 metres; the top one, thicker, approximately 5,5 metres thick) separated by 2,5 metres of shale at a depth between 63 and 72 metres.
5. The Springbok Flats Coalfield. This field lies south, west, and east of Warmbaths comprising a large oval area of approximately 160 kilometres along a north-east line. Three seams of coal are located at a depth in excess of 340 metres. They are relatively thin and split by comparatively thick layers of shale. The coal is of poor quality but could be suitable for the production of liquid fuels and petrochemicals.

Traditionally the above five fields have been regarded as of no economic importance. This can be ascribed to several factors of which the most important have been difficult mining conditions, low-quality coal, absence of rail facilities, shortage of water and other infrastructure, and unfavourable location with regard to markets. Recently, however, the increased price of coal and expanded demand from several sources have led to the commissioning of the Grootegeluk colliery at Ellisras in the Waterberg Coalfield,

FIGURE 1.1 THE COALFIELDS OF SOUTH AFRICA



Source : Coal Mines in the Republic of South Africa, Minerals Bureau, Department of Mineral and Energy Affairs, Directory No. 2/80, July 1980, page 26.

and serious discussion of exploiting coking coal in the Kruger National Park and on the Springbok Flats.

6. Western Area Coalfield. This field consists of isolated blocks of coal-bearing Karroo-System beds which have sunk into the prevailing dolomite formation north of the Far West Rand Goldfield. Three clearly-defined seams exist, each between 2 and 3 metres thick, separated by relatively thick shale barriers, at a depth of 36 to 50 metres.
8. The Komatipoort Coalfield. This field occurs where the narrow elongated strip of Karroo rocks which outcrop along the Lebombo Range widen sufficiently to contain some coal seams to the north of Swaziland. The seams continue south into Swaziland where they are commercially mined. Several seams exist ranging in thickness from one metre to 2,5 metres and at a depth of between 17 and 90 metres separated by mixed layers of shale, sandstone and dolerite.
18. The Zululan Province. This field is the southerly extension of the Komatipoort and Swaziland field with outcroppings of coal at Gollela, Nongoma, and Somkhele. In the western portion the seams are well developed but become thinner towards the east where they are anthracitic and poor in quality. Generally speaking the seams have been badly affected through faulting.
19. The Molteno-Indwe Coalfield. Coal occurs sporadically over an area of approximately 4 400 square kilometres in the north-east Cape, extending from west of Aliwal North through Molteno and Indwe. Production first began in 1864 and declined rapidly after 1900 and ceased altogether in 1948. The most attractive portion of the field, in the Indwe basin, was exhausted many years ago. The remaining coal is thin and discontinuous with numerous shale partings between the seams. Three main seams have been identified, but the coal is of poor quality with a low-volatile and high-ash content. Recoverable reserves are relatively small (75 million tonnes in situ, and perhaps 49 million tonnes are extractable), and the cost of mining the coal is high.

The nine coalfields discussed above are not systematically exploited at present and, hence, have been presented first. The

remaining ten will now be examined, and provide the primary producing area in South Africa.

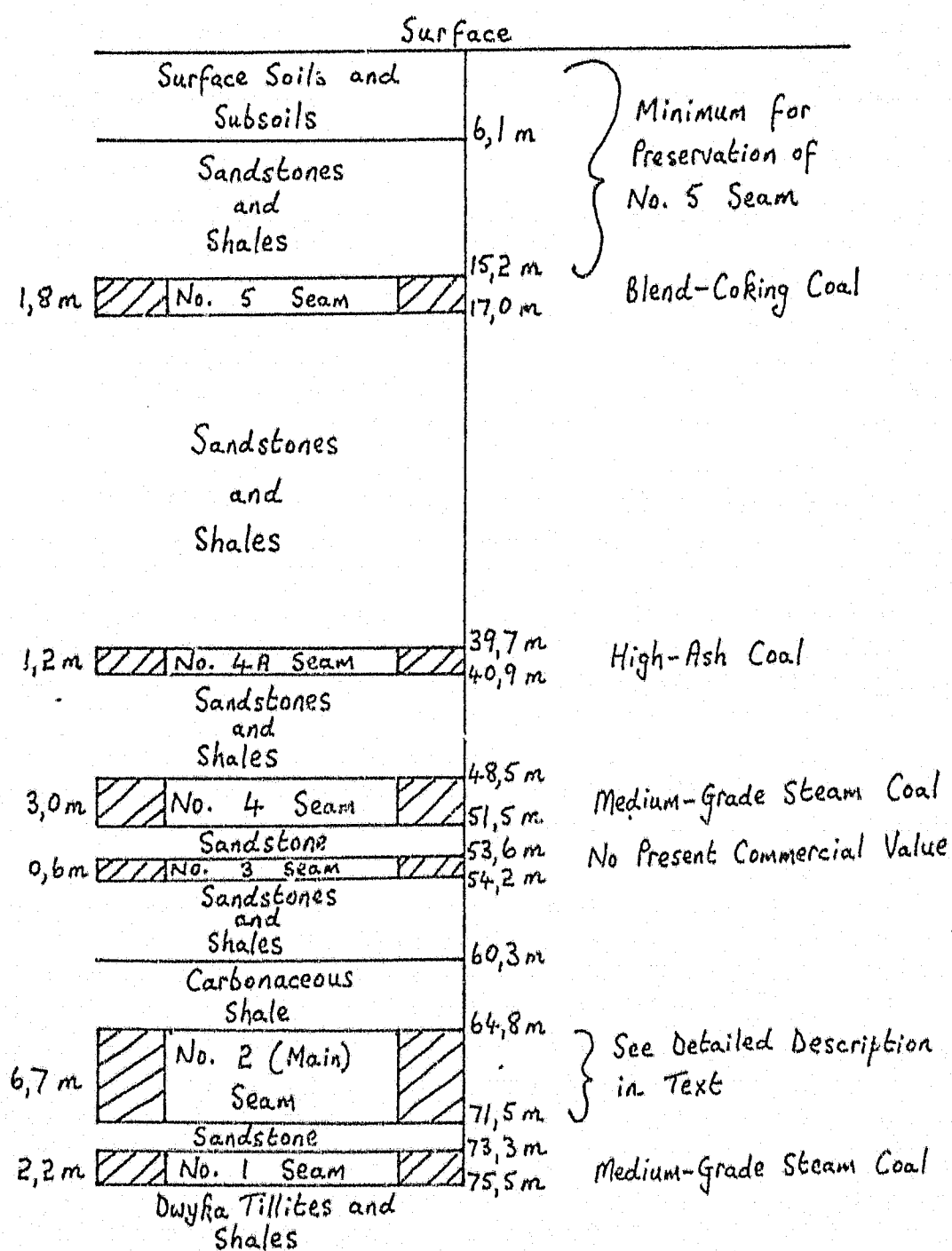
The main region of the Eccra formation commences to cover the basement rocks on the latitude Pretoria-Witbank-Belfast representing its approximate northern margin. The boundaries then extend south-west into the Orange Free State and south-east into Natal, with the Eccra stage ceasing to contain coal south of a line drawn approximately through Bloemfontein and Ladysmith. There is thus an enormous triangular area whose apex lies near Witbank, its western corner near Welkom, and its south-eastern extremity on the Ladysmith-Vryheid line, which should really be regarded as one coal province. However, the coal is not uniformly distributed nor is it of uniform quality. The character and number of seams varies from area to area, with seams being too thin to mine over large areas, and being entirely absent in others. Because of these discontinuities the region is arbitrarily divided up into a number of different coalfields according to the principal areas from which coal is extracted.

7. The Springs-Witbank Coalfield. The major producing area lies directly to the south of Witbank where coal seams are shallow, relatively thick, and virtually horizontal but with local undulations. The seams are also fairly regular in extent within the vicinity of individual collieries. Although dolerite dykes and sills do occur sporadically throughout the area, geological conditions are easy. Both roof and floor conditions tend to be good and as a result mining is comparatively straightforward. Even the deepest coal in this field is generally less than 90 metres below the surface allowing coal to be mined through inclined shafts.

For geological reasons the field is extended west to Springs and east to Belfast. In view of the fact that this is the oldest, most important, and best-developed field in South Africa an extended discussion is necessary.

Ideally, seven coal seams are present but with varying degrees of persistence, numbered from below as 1, 2, 3, 4 lower, 4 upper, 4A and 5. A typical strata section of the Witbank district is presented in figure 1.2.

FIGURE 1.2 TYPICAL STRATA SECTION, WITBANK DISTRICT



Source: Fraser, A.E., "Coal Mining in South Africa", Transactions of the Seventh Commonwealth Mining and Metallurgical Congress, Volume 2, 1961, page 894.

No. 1 seam is the deepest of the coal measures either resting on the tillite or separated from it by shale and sandstone bands. The seam is not always developed, occasionally being cut out by the rising of the lower rocks, and occasionally being unrecognizable from the No. 2 seam. It is not as regular as the No. 2 seam but nevertheless extends over a considerable area of country. It is best developed in the north of the field where it can exceed 3 metres in thickness but it gradually thins towards the south. The seam consists mainly of dull coal, although bright coal predominates in some places. The working of the seam produces a large percentage of round coal of a hard nature. It is extremely tough, and can withstand severe handling and transport. It is a clean coal and is easily mined fracturing readily into cubical blocks. It is a truly bituminous, non-coking coal, which ignites readily making a good steam and household coal.

No. 2 seam is the principal seam, which may follow directly above No. 1 seam or may be separated by several metres of sandstone. On account of its geological position it is the most extensive seam in the whole series. It is situated sufficiently above No. 1 seam to be unaffected by the irregularities of the lower rocks, but is sufficiently below the surface to have escaped the denudation of the upper seams. This seam is the most extensively worked in the whole field and is present throughout the areas of all the collieries. It varies between 4 metres and 8 metres in thickness but the coal is not of constant quality across its width. Two distinct portions, upper and lower, can be categorised. The upper portion is generally of dull coal carrying shale and sometimes sandstone bands making it of inferior quality. When mined it produces excessive fines and is high in ash and low in calorific value, but is nevertheless suitable for power station purposes. The lower portion is of higher quality and is suitable for household purposes. It is a bituminous coal with a low specific gravity which ignites readily and is low in sulphur. Due to its very hard nature it can withstand severe handling. The purest coal in the seam is contained in the lowermost metre resting on the sandstone floor. It generally consists of bright coal which, when washed at a low relative density, gives a blend-coking-coal fraction which can be successfully marketed.

No. 3 seam is an extremely thin vein of bright coal varying in thickness from a few centimetres to half a metre. It is often discontinuous, being entirely absent from many localities. Because of

its thinness and lack of general development it is of little commercial significance.

The three seams comprising No. 4 seam constitute a zone consisting predominantly of coal and carbonaceous shale with sandstone over a thickness of about 14 metres. The three seams occur either directly on top of one another or else separated by thin partings. They are situated some 14 to 20 metres above the main No. 2 seam and as a result have suffered from denudation. The seams are considerable in area but only on the ridges between the valleys are they found to any extent. 4A is intermittent and thin and is interlaced with bright and dull coal. It has a low calorific value and is very similar to the upper portion of No. 2 seam. The other two seams vary in thickness from 1,2 to 4,6 metres. Generally speaking, the coal in No. 4 seam is only suitable for power station purposes.

No. 5 seam is the top seam of the coal measures and as a result it has suffered extensively from denudation so that it tends to occur in small patches on the highest parts of the terrain. It has an average thickness of approximately 2 metres of very clean coal, and provides blend-coking quality.

Except for the No. 5 seam and the lower portion of the No. 2 seam the coal from this field is virtually devoid of coking properties and even where these exist it is only on a very poorly-developed basis. The remainder is bituminous, or steam coal; there is no anthracite. From a geological point of view the field is remarkably free from disturbances which could affect mining operations. There are no faults of any great magnitude with which to contend and the field is also free from dyke intrusions of a serious nature, although dykes of an igneous nature do occur towards the south. Other problems which are occasionally encountered are "washouts", floor rolls, and natural tunnels (8). Washouts are bodies of clay which are frequently experienced in the No. 2 seam towards the northern edge of the coalfield. Floor rolls are a frequent occurrence especially towards the south-east of the field where they are very regular. They can vary in size up to several metres and can make smooth mining progress troublesome wherever coal cutting is performed on the floor of the seam. Finally, natural underground tunnels are sometimes encountered which can also affect progress. They are usually a metre or two wide and filled with water.

13. The Highveld Coalfield. This field lies to the south of the Witbank field from which it is separated by a pre-Karoo east-west felsite ridge. Southwards the field extends beyond Standerton to near the Klip River. The Sasol II and III projects, located on this field at Secunda are supplied by the Bosjesspruit colliery.

The No. 1 seam is only seldom developed and is always very thin. The No. 2 seam is well developed in local basins at several localities, and has an average thickness throughout of nearly one metre though it does reach almost 5 metres in the north. The No. 3 seam is invariably in the form of an intermittent thin coal band. The No. 4 upper and lower seams have a widespread distribution with the lower seam being the main seam of the field ranging in thickness from 2 - 10 metres, with an average of 4 metres. It has no coking properties. The upper seam has an average thickness of only 0,7 metres but contains good-quality coal in places. The No. 4A seam is not always developed and is invariably a thin coal band. The uppermost No. 5 seam averages less than one metre thick and lies gradually deeper below the surface on a southwards progression.

14. The Eastern Transvaal Coalfield. This field is approximately 140 kilometres long and 55 kilometres wide, and extends from Carolina in the north southwards to Wakkerstroom on the Natal border. In the north the character of the coal and the conditions of deposition differ from the Witbank pattern. Extensive outcrops of coal occur along the northern and eastern boundaries along the escarpment, but the eastern escarpment cuts off the extension of the coal into the lowveld and Swaziland. The main producing area is in the Breyten-Ermelo region where three seams are encountered, but only one is generally mined, the others being thinner and of inferior quality as compared with the Witbank field. Mining is by horizontal, vertical, or inclined shafts down to the C, or lowest, seam which has an average width of about 2 metres. The coal is brighter than Witbank coal and furnishes more volatile matter.

The extension south-east of the main field of the Southern Transvaal leads into the Natal coalfields. Natal supplies some of South Africa's highest ranking coal. Both bituminous and coking seams occur but the abundance of dolerite sills and dykes has devolatilised the coal to anthracite in several areas, so that Natal

supplies the only important anthracite field in the country. However, coal reserves are limited because the fields have suffered considerably from erosion and the effect of igneous intrusions.

15. The Klip River Coalfield. This field includes the whole of the coal-bearing area from Volksrust to Ladysmith in the south. Coal occurs in comparatively thin seams 0,6 to 2,5 metres in thickness, averaging over one metre. Owing to the somewhat broken nature of the country the coal is sometimes found outcropping, but mining is chiefly by vertical or inclined shaft to depths in excess of 200 metres. Two seams, top and bottom, are well developed, and both are workable in one place or another and contain coal of good quality, both bituminous and metallurgical. However, igneous intrusions have spoiled much of the coal.
16. The Utrecht Coalfield. This field is situated in generally mountainous terrain. Six good-quality seams are present: Fritz, Moss, Main, Yard, Rider and Coke, but only the first four are well developed and seldom exceed 1,5 metres thick. However, the thickness of individual seams varies considerably due to local washouts and intercalations of sediment. Due to dolerite intrusions much of the coal is anthracitic and has even been converted into lean coal in places (having a volatile-matter content on a dry ash-free basis of 12,6 - 16,4 per cent). Occasionally the overlying dolerite exceeds 230 metres thick.
17. The Vryheid Coalfield. As in the rest of Natal the coal in this field has been extensively damaged by dolerite intrusions. These dolerites wander considerably with the result that patches of high-grade bituminous coal, straight coking coal, and anthracite are present. The coal-bearing area is relatively small and almost entirely confined to the isolated mountain masses which have been preserved from erosion by the hard dolerite rocks lying above the seams. There are six seams present: Fritz, Alfred, Gus, Dundas, Coking, and Targas, of which Alfred is split into two and Dundas into three. The seams are generally thin, but Alfred, Dundas, Gus and Coking are of mineable thickness in several places and average over one metre thick.

12. The South Rand Coalfield. This field lies between the Highveld and the Old Springfield coalfields in the triangle Heidelberg-Villiers-Deneysville. The seams are of great thickness and contain a high tonnage, although the area of the field is not large. Towards the eastern margin is situated the Grootvlei Basin (Springfield colliery) which supplies coal for power-station consumption. The upper seam in this colliery approaches 25 metres thick in places with a lower seam of between 3 - 5 metres thick, on average 17 metres below the upper. From north to south the coal zone gradually deepens with the lower seam approaching a depth of 200 metres below the surface in the southern section of the mine.

The coal succession stratigraphy very nearly duplicates that of the Vereeniging-Sasolburg field in the Orange Free State further to the west. A large proportion of the Orange Free State is coal-bearing but only towards the north and west do the coal measures outcrop. Over the rest of the Province the coal lies in excess of 300 metres below the surface. Commercial exploitation has been confined to the region around Vereeniging just south of the Vaal River.

11. The Vereeniging-Sasolburg Coalfield. This field is characterised by three thick, but low-grade, seams which are mined in the Cornelia, Coalbrook, and Sigma collieries. The last named is attached completely to SASOL I, whilst the output of the former two are used almost entirely for power-station generation, but with a small amount being sold for the Reef domestic market. In places the coal seams can reach 18 metres in thickness, but the coal is of low rank and high moisture, is inclined to weather, and its heating value is comparatively low. Mining is by inclined shafts to depths of 150 metres and nearer Vereeniging, where the coal is fairly shallow, open-cast mining is feasible. The presence of a dolerite sill up to 40 metres thick immediately above the coal seams places an abnormal strain on the roof requiring substantial supporting coal columns to be left behind to support the roof. It was the inadequacy of the supporting columns that caused the roof collapse at Coalbrook in 1960 with great loss of life.

10. The Old Springfield Coalfield. This field is relatively small, lying just north of Vereeniging and has supplied the Klip power station for many years. The coal zone has an average thickness of 50 metres. From the bottom, No. 1 seam is thin and poor. Nos. 2A and 2B seams are 15 metres and 5,5 metres thick respectively. No. 3 seam is 12 metres thick lying 17 metres above No. 2B. The coal is shallow, commencing on average 50 metres below the surface. Very large pillars have been left in situ and are amenable to open-cast mining.
9. The Orange Free State-Vierfontein Coalfield. The Vierfontein colliery adjoins this field to the north, which in total comprises many isolated blocks forming an extensive coal deposit. The coal lies mainly in two seams at an average depth of between 160 and 200 metres, providing reserves of steam coal, but the depth of the coal makes economic exploitation difficult. The bottom seam approaches 10 metres in thickness whilst the top seam is 4 metres.

Coal Producing Areas

The above discussion has indicated that there are three major coal-producing areas in South Africa: the Transvaal Highveld (Ermelo-Witbank), the northern Orange Free State (Vereeniging-Sasolburg), and northern Natal (Newcastle-Dundee-Vryheid). No coal has been mined in the Cape for 30 years, and previous to this was only exploited on a minor scale. Historically, the Transvaal has produced approximately 60 per cent of all coal mined in the country, with the remainder being shared roughly equally between the Orange Free State and Natal. In 1925 Natal's contribution was 36 per cent as opposed to the Orange Free State contribution of only 8 per cent. Since then, however, the situation has gradually changed. In 1979, the saleable coal production was split: Transvaal 73 per cent, Orange Free State 14 per cent, and Natal 13 per cent.

Productivity in Natal mines has been hampered by the difficult geological conditions already discussed, and the fact that most of the mines are small, nearing the end of their working lives, and using obsolete equipment. As a result they now tend to produce far smaller quantities than the Transvaal and Orange Free State collieries. The same geological impediments are, however, not present in the case of the

Transvaal and Orange Free State producing areas. Problems due to faults and dykes are of no concern. Washouts and underground tunnels provide only temporary troubles. Floor rolls and overlying dolerite sills can affect the condition of floors and roofs respectively but the magnitude of the former is not great and the latter can be compensated against. In general, both floor and roof conditions are good. The seams are sufficiently shallow to be worked either by open-cast or incline shaft, and they also tend to be thick, horizontal, and regular creating relatively uncomplicated mining conditions. Another favourable geological factor affecting productivity is the hardness of the coal. In general, hard coal is profitable because, when cut, it gives a higher proportion of large lumps of greater commercial value. Hard coal is better suited to mechanical processing in that large lumps are more easily cleaned by mechanical methods than small. When processed it gives less dust and sludge and hence is easier to clean so that fewer men should be required in the cleaning plant.

At the beginning of 1980, a total of 89 collieries (including five dump reclaimers) were listed by the Minerals Bureau (9) as either operating concerns or committed to start operations. Defunct mines that had ceased to mine coal were omitted, as well as some producers who may not have registered. However, the scale of operations of the latter category is very small and often discontinuous. Of the 89 collieries, 46 were in the Transvaal (producing 76,6 million sales tonnes in 1979), 5 in the Orange Free State (producing 14,5 million sales tonnes) and 38 in Natal (producing 14,1 million sales tonnes).

Transvaal output is, however, expected to expand enormously after 1980 to mine coal for SASOL II and III, ESCOM power stations, and the export trade, thus significantly increasing the Transvaal contribution to total sales tonnage.

Not surprisingly the scale of mining operations varies from one colliery to another. A breakdown of the 89 collieries according to sales tonnages produced in 1979 is given in table 1.1 for South Africa as a whole and for each Province separately.

TABLE 1.1 NUMBER OF COAL MINES ACCORDING TO SALES TONNAGES
IN 1979 (in 1000 tonnes)

Sales Tonnages	R.S.A.	TRANSVAAL	O.F.S.	NATAL
6000 and over	1	1	-	-
5000 under 6000	3	2	1	-
4000 under 5000	1	1	-	-
3000 under 4000	5	3	2	-
2000 under 3000	10	9	-	1
1000 under 2000	15	11	1	3
500 under 1000	6	1	-	5
100 under 500	24	7	-	17
50 under 100	5	1	-	4
under 50	<u>19</u>	<u>10</u>	<u>1</u>	<u>8</u>
TOTAL	<u>89</u>	<u>46</u>	<u>5</u>	<u>38</u>

Source: derived from Coal Mines in the Republic of South Africa, Minerals Bureau, op cit., pages 2-25.

Of the ten collieries producing over 3 million sales tonnes in 1979, seven were situated in the Transvaal, three in the Orange Free State, and none in Natal. In decreasing order of tonnage these ten collieries were: (i) Kriel colliery in the Transvaal (8,2 million tonnes: 4,1 million tonnes from open-cast and 4,1 million from mechanised bord and pillar); (ii) Optimum colliery in Transvaal (5,7 million tonnes: 3,8 million tonnes from open-cast and 1,9 from mechanised bord and pillar); (iii) Sigma colliery in the Orange Free State (5,5 million tonnes from mechanised bord and pillar and longwall); (iv) Arnot colliery in the Transvaal (5,5 million tonnes: 3,8 million tonnes from open-cast and 1,7 from mechanised bord and pillar); (v) Usutu colliery in the Transvaal (4,8 million tonnes from mechanised bord and pillar); (vi) Cornelia colliery in the Orange Free State (3,8 million tonnes from bord and pillar, mechanised and hand-got); (vii) Rietspruit colliery in the Transvaal (3,6 million tonnes from open-cast); (viii) Coalbrook colliery in the Orange Free State (3,5 million tonnes from mechanised bord and pillar and longwall); (ix) Springfield colliery in the Transvaal (3,4 million tonnes from mechanised bord and pillar); (x) Van Dyks Drift colliery in the Transvaal (3,2 million tonnes from mechanised bord and pillar).

In aggregate, these ten largest collieries produced 47,1 million sales tonnes in 1979, or 48 per cent of total South African production in that year.

Several collieries are reflected in the above table as only producing relatively small quantities of coal in 1979, but have been prepared for rapid expansion after 1980 and will significantly affect the results quoted above. These include:

- (i) Bosjesspruit colliery (planned output to reach 27 million metric tonnes per annum to supply SASOL II and III from mechanised bord and pillar and longwall);
- (ii) Matla colliery (planned output to reach 9,5 million metric tonnes per annum to supply Matla power station from mechanised bord and pillar and longwall);
- (iii) Duvha colliery (planned output to reach 10,2 million metric tonnes per annum to supply Duvha power station from open-cast);
- (iv) Rietspruit colliery (planned output to reach 5-8 million metric tonnes per annum to supply the export trade from open-cast);
- (v) Kleinkopje colliery (planned output to reach 4-6 million metric tonnes per annum to supply ISCOR, exports, and local sales from open-cast);
- (vi) Ermelo colliery (planned output to reach 3 million metric tonnes per annum to supply the export trade from mechanised bord and pillar);
- (vii) Grootegeeluk colliery (initial planned output to reach 4,3 million metric tonnes per annum: 1,8 million tonnes of coking coal for ISCOR, and 2,5 million tonnes of steam coal for the Matimba power station. Later expansion may reach 10-15 million tonnes).

All these collieries are situated in the Transvaal. In addition, several new collieries are planned to supply ESCOM power stations after 1984, discussion of which is reserved for chapter 2.

Natural Composition of the Coal

Not all the coal raised from underground is commercially marketable. Much of the raw coal which is extracted and hauled, known as "run-of-mine", has to be rejected for various reasons. Quite obviously, stones and shale and foreign objects, such as pieces of pit props and metal, have to be isolated and discarded. This means that the raw coal has to undergo a screening and cleaning process on the surface to rid it of impurities. For certain purposes, for instance, ESCOM power stations and SASOL plants, the only preparation required is simple screening of the coal to remove large unwanted objects, passing it under a magnet to eliminate pieces of metal, and crushing the coal to the size required by the consumer. Such users can utilise virtual "run-of-mine" coal, taking low-grade coal of a high-ash, low-calorific value, and duff (10).

However, for more-discerning markets such as household consumption and the export trade a higher-quality coal is required with high-calorific value and low-ash content. Coal has to be carefully sized, with the greater part of the impurities removed, and for these users coal must be subject to quite complicated preparation techniques, involving grading, screening, washing and separation of the ash to upgrade or "beneficiate" the coal. The processes can be very complex - with several phases of washing and screening, depending on the purposes for which the coal is to be used. Accordingly, depending upon the nature and demands of the final market, there will be a need to install complicated and extensive mechanical preparation plant above ground, requiring a fairly large labour force. Production costs are considerably increased, and both output per manshift and output per unit of input are reduced.

This need becomes more prevalent as mechanised cutting and loading of coal is progressively adopted underground in favour of hand loading. Mechanical loaders, continuous miners, and longwall systems are less selective than hand loading, placing greater responsibility for coal cleaning on the surface personnel and installations.

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Natural Composition of the Coal

Not all the coal raised from underground is commercially marketable. Much of the raw coal which is extracted and hauled, known as "run-of-mine", has to be rejected for various reasons. Quite obviously, stones and shale and foreign objects, such as pieces of pit props and metal, have to be isolated and discarded. This means that the raw coal has to undergo a screening and cleaning process on the surface to rid it of impurities. For certain purposes, for instance, ESCOM power stations and SASOL plants, the only preparation required is simple screening of the coal to remove large unwanted objects, passing it under a magnet to eliminate pieces of metal, and crushing the coal to the size required by the consumer. Such users can utilise virtual "run-of-mine" coal, taking low-grade coal of a high-ash, low-calorific value, and duff (10).

However, for more-discerning markets such as household consumption and the export trade a higher-quality coal is required with high-calorific value and low-ash content. Coal has to be carefully sized, with the greater part of the impurities removed, and for these users coal must be subject to quite complicated preparation techniques, involving grading, screening, washing and separation of the ash to upgrade or "beneficiate" the coal. The processes can be very complex - with several phases of washing and screening, depending on the purposes for which the coal is to be used. Accordingly, depending upon the nature and demands of the final market, there will be a need to install complicated and extensive mechanical preparation plant above ground, requiring a fairly large labour force. Production costs are considerably increased, and both output per manshift and output per unit of input are reduced.

This need becomes more prevalent as mechanised cutting and loading of coal is progressively adopted underground in favour of hand loading. Mechanical loaders, continuous miners, and longwall systems are less selective than hand loading, placing greater responsibility for coal cleaning on the surface personnel and installations.

As a colliery progresses through its development, it will find productivity levels varying according to the composition of the coal currently being worked (11). During some periods, for instance, it will be necessary to extract long stretches of, say, inferior coal with numerous dirt bands in order to reach higher-quality coal behind it. Naturally the dirt must be discarded and, depending on the market supplied, the colliery may be compelled to dump and burn large percentages of the inferior coal and duff. During this operation the amount of saleable coal will obviously drop although there has been no reduction in effort or efficiency. Hence, the natural composition of the coal and the type of market being supplied are crucial factors in determining the ratio of saleable to raw coal and, thus, the level of productivity.

Table 1.2 gives an indication of the amount of raw coal rejected in South African coal mining at five-yearly intervals since 1950.

TABLE 1.2 TOTAL TONNAGE MINED, SALEABLE PRODUCTION, AND PERCENTAGE WASTE: 1950-1980 (in millions of metric tonnes)

<u>YEAR</u>	<u>TONNES MINED</u>	<u>SALEABLE PRODUCTION</u>	<u>TONNES WASTE</u>	<u>PER CENT WASTE</u>
1950	28,1	26,1	2,0	7,1
1955	37,4	32,4	5,0	13,4
1960	42,8	38,3	4,5	10,5
1965	55,4	48,5	6,9	12,5
1970	62,9	54,6	8,3	13,2
1975	78,2	69,4	8,8	11,3
1980	<u>137,9</u>	<u>115,1</u>	<u>22,8</u>	<u>16,5</u>
	442,7	384,4	58,3	13,2

Source: derived from Department of Mines, Mining Statistics, Government Printer, Pretoria, published annually, table 12.

For the selected years used in the table the percentage of raw coal rejected has varied between 7,1 and 16,5 with an average of 13,2. The above figures include those collieries which supply their output exclusively to ESCOM power stations and hence can be expected to have a lower percentage of raw-coal rejection. The inclusion of these

collieries, therefore, biases downward the rejection rate when considering the collieries which produce for more-demanding markets, such as household consumption. Thus, during personal research at an Eastern Transvaal colliery which has traditionally produced for general local (non-power station) use the author discovered that since 1941 the rejection rate had varied between 10,5 and 26,0 per cent with an average of 17,4 per cent. In addition, the Chamber of Mines reports that the new Grootegeluk colliery has been geared to handle an even larger rejection rate. The coal measures in the area are characterised by thin, highly-interbanded seams in which the dirt bands exceed the amount of coal in a mining section (12). Since Grootegeluk is a highly-mechanised open-cast colliery, no selectivity is carried out in mining. Correspondingly, approximately 15 million tonnes of run-of-mine coal annually will be washed to provide 1,8 million tonnes of blend-coking coal for ISCOR and 3,5 million tonnes of middlings for ESCOM. In 1970 such an operation would have been uneconomic but is now possible through increased prices.

A feature of table 1.2 is the large increase in the rejection rate of run-of-mine coal between 1975 and 1980. Two reasons would seem to account for this feature, firstly, increased mechanisation in coal extraction, and secondly, the need to prepare high-quality coal for export (13). In 1978, 52 per cent of saleable coal had been cleaned, compared with 42 per cent in 1974. However, this figure is expected to decline to 40 per cent by the year 2000 due to the rapid growth of ESCOM.

Great concern is periodically expressed at the dumping and burning of large amounts of low-grade coal annually discarded from colliery washing plants because of the lack of a suitable market (14). Accordingly, schemes have been mooted to use such discards in a centralised ESCOM power station, oil-from-coal plant, or for gas production (15). By turning current waste into saleable production in this manner, productivity is correspondingly raised. MacGillivray (16), in addition to supporting such schemes, also suggests that industry should be encouraged to make greater use of lower-grade coal, that more use should be made of techniques like fluidised-bed combustion, and that the controlled price differential between different coal grades should be more realistic to encourage greater usage of low-grade coal. Such policies would discourage not only surface burning but the practice of

selective, wasteful mining whereby large amounts of low-grade coal are left behind in the ground. If collieries could be assured of a market for all coal grades they would practice less-wasteful, high-extraction methods to mine all the coal in a block. This higher output with less waste results in increased saleable production and enhanced productivity.

Other Natural and Geological Factors

Besides those characteristics which relate to the nature of the coal measures such as the depth, thickness, dip and regularity of the seams, the hardness of the coal, the nature of the floor and roof, and the composition of the raw coal, there are other factors present in coal mining which affect the level of productivity. These are of two kinds. Firstly, those which affect the "pleasantness" of the working environment such as humidity, temperature, dust, water, and general hygiene and safety measures. Secondly, those which affect the personal risk of the miners, such as fire-damp, carbon dioxide, dust, fire, and flooding.

A coal mine is not a congenial working environment. It is dirty, the work is physically exacting, and there are many attendant dangers. Nevertheless, in comparison with, say, Western European coal miners, MacGillivray considers that the South African equivalent is relatively fortunate enjoying physical mining conditions that are fairly good. In the former case he has had to contend with deep, thin, and irregular coal seams that make working conditions arduous and hazardous. However, the easy geological nature of South Africa's shallow, thick and horizontal coal seams has by-passed this problem by making mining relatively easy (17). In addition, the comprehensive regulations published under the Mines and Works Act, No. 27 of 1956 (18) have further reduced the magnitude of traditional dangers facing coal miners and improved their working environment.

Excessive humidity and high temperatures have not been a serious problem in South African coal mines due to the shallow depth and thick nature of the seams worked. This is particularly the case in the early stages of a mine's development when the close proximity of the main shaft to the workings provides adequate ventilation. However, as the workings advance away from the shaft both temperatures and humidity are bound to rise making conditions more uncomfortable.

Of more concern than temperature or humidity are the traditional dangers, facing coal miners anywhere in the world, caused through the presence of coal-dust and fumes and gases, such as carbon dioxide, harmful smoke, methane gas, diesel-engine emissions, and so on. The risks are twofold: inflammability and noxiousness. Explosions of coal-dust and methane gas are ever-present possibilities in coal mines. In addition, the continued inhalation of dust, fumes and gases can seriously impair the health of underground workers. Dust inhalation, in particular, can cause a debilitating lung disease, pneumoconiosis.

The traditional approach to combating such dangers has been through the provision of an adequate ventilation system both to provide sufficient air to maintain cool and pleasant working conditions, and to act as a dilutant for noxious and inflammable elements. The Regulations to the Mines and Works Act have customarily given a lead in this direction, and over the years have progressively been made more stringent. Even in the 1920's Graham was of the opinion that the ventilation of Witbank collieries was "very efficient" (19). During this decade all mines in the area, including the northern ones which had previously relied only on small ventilating shafts to provide air to the shallow seams, had installed fans of various types, having capacities ranging from 100 000 to 250 000 cubic feet of air per minute. Graham explained that downcast air was split into three or four main ventilating districts and then coursed around the various faces by means of brick stoppings and brattice cloth. Mines were laid out on the "panel system" with one intake and one or two returns. Panels were sealed off whenever an area had been exhausted. Half a century afterwards little fundamental change had been made to this basic method.

Thorp (20) explains that in planning the ventilation system of a colliery the required air volume must be determined at the outset. Once this has been decided then the correct size of shafts, airways, and facilities can be defined, as well as the siting of the main fans. Mines and Works Regulations have been framed to cover all these situations.

In general terms it is required that "the workings of every part of a mine where persons are required to travel or work shall be properly ventilated to maintain safe and healthy environmental conditions for the workmen . . ." (regulation 10.6.2), re-inforced by regulation 10.3.1, "where deficiency of oxygen is likely to develop, adequate ventilation

shall be provided . . ." In addition, in the presence of dust and noxious or inflammable fumes and gases in quantities likely to endanger the safety or health of workmen then not only is it required that "adequate ventilation shall be provided" (regulation 10.3.1) but also that "the ventilating air shall be such that it will dilute and render harmless any inflammable or noxious gases and dust in the ambient air" (regulation 10.6.2). All ventilating appliances must be operated and positioned so as to prevent a "dangerous accumulation" of inflammable gas or dust (regulation 10.6.3). All main fans must be situated on surface, be equipped with an automatic alarm to alert responsible persons in the event of a stoppage and be provided with two independent sources of power supply. The positioning of shafts and fans is determined initially by the current mine layout and ultimately by the future mining programme. With the rapid advance achieved by mechanised mining, working areas become remote from the main intake shafts in a relatively short time, necessitating the sinking of supplementary ventilation shafts and the provision of multi-fan installations in preference to the single-fan installation that predominated on the older mines.

Comprehensive regulations exist in relation to matters such as the stoppage of fans or ventilation currents, the positioning of fans, the nature and operation of ventilation doors, regulators, stoppings, and so on, but these are far too detailed to discuss.

The minimum quantity and velocity of air circulating in coal mines is strictly controlled in terms of regulations 10.8 to 10.8.6. The minimum volume of air, in cubic decimetres per second, to be provided to a ventilation district may not be less than 25 times the maximum metric tonnage mined per shift in that district. As a result the minimum air volume required for a district producing one thousand tonnes per shift would be 25 m³/s. Every coal mine must take measurements during the main working shift not less than once a month of the quantity of air circulating through the mine and each ventilating district and working section and the average velocity of the air current along working faces and roadways. A return of the average volume of air per minute downcast during the main working shift, and such other information relating to ventilation as may be required by the Government Mining Engineer, must be forwarded by each mine manager to the Inspector of Mines once every 3 months unless specially exempted. The Chamber of Mines reported in 1978

that the figures for the amount of air circulating in coal mines were "staggering" with 2,4 tonnes of fresh air circulating for each tonne of coal mined or 230 litres for each worker (21).

However, it was not until 1980 that the appointment of ventilation officers on coal mines was made a statutory requirement. Such appointees must report to the mine manager on,

- the ventilation in the mine, its quantity and distribution,
- the presence of noxious and inflammable gases,
- the presence of airborne dust concentrations (except where measurements are made by a body approved by the Government Mining Engineer),
- the effectiveness of the measures taken to prevent explosions of coal-dust or of inflammable gas.

However, adequate ventilation is not the only measure designed to deal with the problems of dust, smoke, fumes, and gases. Regulations laid down stipulating the maximum permissible quantities of gas and the general body of the air. These relate to carbon dioxide, carbon monoxide, oxides of nitrogen, hydrogen sulphide, inflammable gas, dust concentration, and diesel-engine exhaust emission. If permissible concentrations are exceeded then all persons must be withdrawn from the affected workings and only persons wearing effective breathing apparatus are permitted to enter such areas.

In order to combat the danger of noxious fumes underground, no internal-combustion engine, other than a diesel-engine, can be operated. Every diesel-engine used underground must be provided with means whereby the air entering the engine is cleaned, the exhaust gases are cooled and diluted before being expelled, and the emission of flames or sparks is prevented. At least once a month samples must be taken of the general body of the air while the engine is running, and at least once every 3 months of gas emitted from the exhaust when the engine is developing maximum power and also when the engine is idling. The percentage by volume of carbon monoxide or oxides of nitrogen present in each sample must be determined, and the operation of the engine discontinued if critical levels are exceeded as stipulated in regulation 10.25.5.

Dust suppression is particularly important in coal mines. Sampling for dust concentrations began in 1956. The Chamber of Mines is of the opinion that since the collieries were able to take advantage of the control system developed in gold mining they were controlling dust long before other coal-mining countries had resolved their problems (22). Dust measurement is important for control purposes. At intervals stipulated by the Government Mining Engineer, measurements must be made during the main working shift of the amount of dust in the air in representative working places in each section while drilling, cutting, breaking, loading or transfer of coal is taking place. Dust sampling and assessment has been carried out almost exclusively by the Collieries Environmental Control Service of the Chamber of Mines. Dust and Ventilation Laboratories are located in Witbank, Vereeniging, Evander and Dundee, the latter being operated by the Natal Coal Owners' Association until 1979. These laboratories have provided the following services for member collieries of the Chamber,

- take surveys of airborne dust,
- measure and survey underground ventilation conditions,
- arrange lectures on the use of scientific instruments and techniques used for measuring airborne dust and ventilation conditions,
- provide technical assistance to colliery employee prior to writing examinations for Government certificates of competency,
- take samples of the mine atmosphere in the working areas to determine nitrous fumes, carbon monoxide and dioxide concentrations.

The appointment of ventilation personnel to the mines has relieved the laboratories of most of their ventilation commitments and today their prime concern is all aspects of dust assessment and control.

Suppression of dust is invariably performed by means of water but dust filtration underground is carried out to a limited extent. Dust is particularly generated both during and after the cutting, blasting, and loading of coal, and at transference points during its conveyance. Measures aimed at dust allaying during such operations are dealt with in regulations 10.20 to 10.21.3 and measures aimed at preventing coal-dust explosions are dealt with in regulations 10.24 to 10.24.11. All coal cutting is performed "wet" by means of a water jet aimed alongside the cutting chain. After blasting, the general practice is to apply large

amounts of water onto the broken coal as soon as possible. Water continues to be applied onto the coal during loading whether this is performed mechanically or by hand (23). Dust suppression in collieries employing continuous miners which cut, gather, and load the coal in a simultaneous operation creates a special problem and this is currently the subject of research by the Department of Mines. Water sprays are also located at transfer points in the conveyance of the coal. No dust-suppression measure is complete, however, unless it is complemented by sound ventilation practice and an adequate circulated air volume in the workings. This is particularly relevant in recent years during which increased dust levels have been generated by increased production and mechanisation.

The loss of 425 lives in the 1972 Wankie Colliery disaster is evidence of the danger of a coal-dust explosion. Mining operations create dust which settles on the roof, floor, and sides of workings. Most South African coals have a volatile content putting this dust into the explosive range. The minimum concentration of dust in a cloud capable of propagating an explosion is 20-50 g/m³ of air. Almost invariably a coal-dust explosion is caused by a methane explosion. As little as 0,4m³ of methane is sufficient to initiate an explosion. A coal-dust explosion is often self-propagating as the shock wave preceding the advancing flame front raises additional dust into suspension. After an explosion toxic gases often form polluting the mine atmosphere and constituting as serious a hazard as the explosion itself.

The industry works according to the adage that "prevention is better than cure". Haulage roadways are frequently hosed down depending upon local conditions and walls, floors, and roofs are stone-dusted to minimize dust disturbance. In order to reduce the risk of coal-dust explosion before any area of a coal mine is isolated by stoppings, the floor, roof and sides of all roads therein must be systematically cleared of dust and freshly stone-dusted. The precautions taken to prevent explosions occurring may be categorised as follows (24),

- the reduction and suppression of coal-dust at the points it is made and the cleaning up of accumulations with minimum dispersal of dust into the air,
- avoiding conditions likely to cause an ignition,

- rendering coal-dust inexplusive,
- confining an explosion to the part of the workings in which it might occur.

Good housekeeping and good ventilation are the primary precautions in the first two categories, stone-dusting for the third and stone-dust barriers for the fourth. The quality of stone-dust is strictly laid down by Regulations. The old method of hand strewing has now largely been replaced by stone-dusting machines. The frequency of stone-dusting depends on the rate of coal-dust deposition. The installation of stone dust barriers to contain an explosion is optional on the manager's judgement. They are designed to collapse when a shock wave strikes, creating a cloud of stone-dust just before the flame arrives and so preventing further propagation of the explosion.

Comprehensive regulations are framed to protect coal miners from the effects of noxious or inflammable gases and fumes. All South African coal mines (with the exception of Vierfontein in 1980) were classified as "fiery" by the Department of Mines, implying that there is a "possibility" of a presence of methane gas. This gas, in combination with carbon dioxide and oxygen, creates "fire-damp", a dangerous inflammable element which may explode in the presence of a spark. In the Transvaal and Orange Free State coal mines fire-damp in detectable quantities is occasionally found in the ventilated areas and it also accumulates in worked-out sealed-off sections. In Natal its occurrence is more frequent due to a higher rate of gas emission. Nevertheless, European and American coalfields generally suffer from a far higher emission of methane gas than in South Africa, basically due to the shallow seams and bord and pillar mining method in this country.

Since methane ignitions are invariably responsible for coal-dust explosions, its detection is a matter of utmost priority. Regulations recognise only a flame safety lamp for detecting inflammable gas. However, methanometers are often used to supplement but not replace flame safety lamps.

Additionally, in 1978 the Chamber of Mines acquired a mobile gas analysis laboratory (MOGAL), which is made available free of charge to all collieries which are members of the Chamber for the purpose of assessing gas concentrations in routine mine atmospheric samples particularly from sealed areas, return airways, or any location where

unusual circumstances arise. Regulations lay down strict procedures to be followed for inflammable gas detection as a matter of daily routine.

Most methane ignitions are due to carelessness. Blown-out shot holes are cited as the main cause of methane ignitions during blasting, followed by blasting in the presence of methane. Naked flames are also a common cause ranging from unscheduled opening and lighting of lamps to the use of unauthorised cutting equipment. Electrical faults have also been causes. In order to deal with the potential danger caused through the presence of methane gas all mining personnel must be in possession of a gas-testing certificate based on a syllabus approved by the Government Mining Engineer, and taught either at the Chamber of Mines' Collieries' Training College or in individual mines' training centres. Every ganger must test for gas before performing a blast. The action that must be taken in the event of inflammable gas being detected is strictly laid down, as previously explained. The use of permitted explosives only is allowed (25). All electrical machinery must be "fire-damp proofed". In addition, diesel-engined vehicles must be of a design and construction approved by the Government Mining Engineer and must be operated under such conditions and restrictions as he specifies in order to minimize the risk of igniting gas or coal-dust. However, Thorp emphasizes that no matter how elaborately the precautions against a methane ignition are set out in codes of practice or regulations, safety rests essentially in the hands of the individual and depends on training and a sense of responsibility. "The source of methane ignition lies generally at, or near, the working face and it is here that an irresponsible act in the presence of inflammable gas is most likely to give rise to disaster There is no room for complacency or any substitute for diligence when it comes to dealing with inflammable gases for the price that is paid for any such lapse is too high" (26).

The danger of fire is minimized if regulations relating to inflammable gas and coal-dust explosions are strictly observed. Precautions against fire are uppermost in the framing of regulations relating to the use of equipment underground. Thus, regulation 21.16 requires that "where there may be a risk of igniting gas, coal-dust, or other explosive material, only flameproof, explosion-proof, or intrinsically safe apparatus of a design and construction approved by the Government Mining Engineer shall be used". This includes electrical machinery and diesel engines (regulation 10.25.2) the operation of which

must be under such conditions and restrictions as he specifies (27). Fire precautions also predominate in the framing of regulations relating to blasting; the storage, handling, and detonation of explosives; the performance of welding, flame-cutting, and flame-heating; the carrying of any naked light or flame, burning torch, match, cigarette, paper or other burning material; and so on. Every mine must establish an organisation for fire prevention and control. The manager must provide and maintain suitable and adequate fire-fighting equipment and material, and enforce a code of practice approved by him for the organisation of fire prevention, fire-fighting and fire drill. He must appoint competent "scheduled persons" (i.e. non-black) to examine at least once a month all the fire-fighting equipment and material. A supply of water sufficient for the purpose of underground fire fighting must be provided and maintained for immediate use. Finally, the disposal, through burning, of all unmarketable and inferior coal debris and bituminous rock must be at such a distance from any shaft structure or building as to minimize the danger from fire. Coal seams must not be worked beneath any such accumulation of unburnt, burning or smouldering coal except with the permission of the Government Mining Engineer.

Underground water is present in South African coal mines but it is not a major problem and varies in magnitude from one colliery to another. In most mines it is possible to use local face-pumps to pump the water into local sumps from where more-powerful pumps deliver the water to main sumps and then to the surface. In shallower collieries the water can be pumped directly to the surface from the local sumps. Where seams outcrop on hillsides, as in some Natal collieries, it is possible to employ adit drainage (28). To combat the danger of flooding of underground workings several regulations are also in operation. Where a mine is situated in low-lying ground the collar of every shaft and other similar openings from the surface which connect with underground workings must be raised to afford efficient protection against flooding. Every mine must also be equipped with storm-water trenches and embankments to protect both surface and underground personnel and installations from flooding. It is the mine manager's responsibility to ensure that adequate watch is kept on all reasonably accessible sources of danger from flooding. These sources include all artificial constructions at his mine for conserving water or which may cause water to converge or accumulate. In the event of danger of

flooding from the surface the manager must ensure that all underground personnel are immediately withdrawn. Flooding need not necessarily always be from the surface. Underground flooding can occur if face advancement meets a waterbearing fissure. To combat this, boreholes are usually drilled in advance of all development headings.

The safety, in general, of miners working underground can be regarded as depending upon the combination of all the potentially dangerous factors discussed above. It is a truism to state that if miners work in dangerous, unsafe conditions then their morale, confidence, and job satisfaction are undermined and productivity is adversely affected. A more extensive discussion of safety and accidents is undertaken in chapter 5. At the present stage only safety in relation to natural and geological factors is examined. In table 1.3, statistics are presented relating to accidents caused by such factors for 5-yearly intervals since 1950.

For the years under review it can be seen that no accidents have been recorded in connection with underground fires or subsidence. In addition, rockbursts, heatstroke or exhaustion, and inundation by water or mud of underground workings are only isolated occurrences, mainly because of the shallow and thick nature of the seams traditionally worked. More danger, however, is prevalent from the presence of gas and fumes. Accidents caused both by gas explosions and in connection with explosives due to fumes have occurred on several occasions but the magnitude of such accidents has not been great. The number of deaths and injuries have been small. Of far greater importance, in terms of the magnitude of the statistics, are falls of ground - with several hundred separate accidents being recorded every year. The total killed and injured as a result of such accidents runs into several dozens and hundreds respectively. These figures have displayed a persistent downward trend over the study period which is hardly surprising in view of the undoubted advances which have been made in geological techniques and mining engineering. Knowledge has continued to increase in connection with the nature of stresses and strains in geological formations induced as a result of mining operations. Roof-support systems have become more technical and sophisticated. The strength of coal pillars necessary to support the roof in bord and pillar operations has been the subject of continual research since 1960. In that year a roof collapse at Coalbrook colliery caused great loss of life when the

TABLE 1.3 ACCIDENTS CAUSED BY NATURAL AND GEOLOGICAL FACTORS, 1950-1980

	FALL OF GROUND ROCK- BURSTS	OTHER FALLS	UNDERGROUND FIRES	INUNDATION BY WATER OR MUD	EXPLOSION OF GAS	SUBSIDENCE	HEAT- STROKE OR EXHAUSTION	EXPLOSIVES - DUE TO FUMES
NUMBER OF SEPARATE ACCIDENTS	1950	395	-	-	-	-	1	-
	1955	398	-	-	2	-	-	1
	1960	301	-	-	-	-	-	1
	1965	306	-	-	2	-	-	4
	1970	247	-	-	-	-	-	-
	1975	225	-	2	-	-	-	-
	1980	193	-	1	-	-	-	-
	1950	55	-	-	-	-	1	-
	1955	49	-	-	1	-	-	-
	1960	466	-	-	-	-	-	-
	1965	44	-	-	-	-	-	-
	1970	41	-	-	-	-	-	-
	1975	49	-	1	-	-	-	-
	1980	35	-	1	-	-	-	-
	1950	370	-	-	-	-	-	-
	1955	382	-	-	6	-	-	2
	1960	285	-	-	-	-	-	3
	1965	278	-	-	5	-	-	5
	1970	238	-	-	-	-	-	-
	1975	290	-	1	-	-	-	-
	1980	172	-	-	-	-	-	-

Source: derived from Department of Mines, Mining Statistics, op cit., various years, Table 13.

Note: Any injury included in the above statistics is, as prescribed by regulation, such as results in the injured person being disabled for at least 14 days.

supporting coal pillars proved inadequate and collapsed when a portion of the overlying dolerite sill slipped. As a result of these improvements such an accident should never occur again (29).

The Extent of Coal Reserves

To conclude this chapter on the natural and geological factors that affect productivity in coal mining a discussion of the extent of reserves is necessary. The reason for this is straightforward. When reserves are small and are calculated to be exhausted in a relatively short period of time, the emphasis tends to be on conservation and maximum extraction. As a result all seams are worked, including those which are deep, thin, dipping, and irregular, and these difficult working conditions obviously have an adverse effect upon productivity. However, when reserves are large (the word "infinite" is often used) it is possible to be far more selective in regard to the type of seams worked. The difficult seams can be avoided and operations concentrated on those seams which are regarded as easy, i.e. they are shallow, thick, and horizontal. Consequently, productivity under these conditions is enhanced. It is also possible to be far more wasteful in regard to the extraction of coal, for instance, large supporting pillars can be left in bord and pillar mining. This increases the safety of the working environment, with further favourable effects on productivity. In addition, other wasteful operations can be employed, for instance, the practice of working a deeper but thicker and more regular seam in favour of a shallower seam which is thinner and less regular. This often makes the latter seam unworkable at any point in the future, thus wasting the coal contained in it.

Studies of the extent of the coal reserves are made with one primary objective in mind, this being to stress that coal is a wasting asset, and reserves are not infinite and not renewable. Eventually it must be replaced by some other form of energy. The purpose is, therefore, not to establish whether there is enough coal for the future but how much time remains to develop some other replacement source of energy. It is designed to instil some measure of urgency into the situation. When large reserves of coal are indicated this urgency is dissipated. Coal-mining men are practical and are concerned with short-term results. They can afford to adopt wasteful, but more-productive, mining operations content to let the more-distant future take care of

itself, often to the dismay of the more long-sighted conservationists. This has generally been the case in South Africa. Except for a period of approximately ten years in the late 1960's and early 1970's, coal-mining men have operated in an atmosphere of "unlimited" reserves. They have been unencumbered by calls for conservation and consequently have been able to employ wasteful extraction techniques whilst avoiding mining the more-difficult seams. This approach has been conducive to maximum productivity.

Several studies of the extent of coal reserves in South Africa have been carried out and a review of the history of the debate will prove fruitful. Unfortunately, such inventory studies are notorious for the wide discrepancies between them. Indeed this is only to be expected due to the enormity of the task. In the case of South Africa this has been compounded by a failure to adopt universally-accepted terminology, practices, and definitions making comparisons between studies extremely difficult.

Prior to World War I no official attempt had been made to calculate South African coal reserves. Geological knowledge of coalfields was extremely limited and in any case the small annual extraction rate gave rise to no official concern over long-run adequacy. However, World War I provided an impetus to annual extraction rates and geological knowledge was enhanced following expanded drilling programmes. This led to the first attempt at a nation-wide survey of coal reserves by W.J. Wybergh of the Geological Survey, Department of Mines. This work was published in three volumes between 1921 and 1928 (30). Unfortunately, his study was not based on any actual geological surveying of coal-bearing areas, which led to a gross over-estimation of extractable coal. He estimated that the country's coal reserves amounted to 227 000 million short tons, distributed as follows: 152 000 million tons in the Orange Free State, 66 000 million tons in the Transvaal, and 9 000 million tons in Natal (plus an uncalculated amount in the Cape).

Thereafter it became fashionable to talk about the "inexhaustible" resources of coal in the country, described by the Petrick Commission (31) as a "facile misconception" arising from a failure to realise that coal tonnages in the ground are far different from the tonnages which can be extracted.

However, more-accurate figures for reserves were made possible after 1935 due to the increased number of personnel in the Geological Survey. It became possible to devote more geologists to extensive surveys of the more-important coal-bearing areas. The establishment of the Fuel Research Institute in 1931 also expanded existing knowledge of the physical and chemical properties of South African coal. In 1946 a Coal Commission was appointed by the Government which benefited from the survey work and the systematic collection of information on coal deposits by the Geological Survey and the Fuel Research Institute. This Commission reported, for the first time, on the extractable coal reserves in the country and arrived at an estimate of over 12 000 million short tons of extractable coal, situated mainly in the Witbank-Middelburg field (6 300 million tons) and the Vereeniging field (4 000 million tons) (32). This figure was very much lower than that estimated by Wybergh in 1928. However, it failed to arouse any "immediate consternation", according to the Petrick Report, because the Commission failed to display its tonnage estimate clearly in a summarised form. Rather, tonnages had to be deduced from "scattered references" in the Report (33). In addition, the Commission did not estimate any extractable coal for the Limpopo, Soutpansberg, Waterberg, Pafuri, Springbok Flats, Komatipoort, Orange Free State Goldfield, or Molteno-Indwe fields. A positive recommendation by the Commission was acted upon by the Government to establish a Coal Advisory Board to advise the Minister of Mines on matters relating to coal.

Improved geological surveys over these years led to further attempts to estimate the coal reserves of the country. In 1952, Venter (34) calculated a grand total of almost 75 000 million short tons, whilst in 1959 the "Mineral Resources of the Union of South Africa" (35) calculated a total of almost 80 000 million short tons. However, it was far from clear whether these figures referred to coal in situ or extractable coal (36). Indeed, they suffered from a notable lack of clear terminology. The 1969 Coal Advisory Board Report (37) considered the figures to refer to coal in situ and, hence, were directly comparable to Wybergh's 1928 estimate, representing only about one-third of his calculated total. However, if the figures related to extractable coal, the Petrick Report noted that both estimates compared reasonably well with the calculated figure of that Report of 81 000 million metric tonnes of mineable coal in situ (38). Both Venter and Mineral Resources

preferred to distinguish between proved reserves and probable reserves, in situ. Venter's total of 75 000 million short tons was comprised of 24 000 proved and 51 000 probable; whilst the Mineral Resources total of 80 000 million short tons was comprised of 41 000 proved and 39 000 probable. However, "proved" and "probable" were used without adequate definition of what was meant by these terms.

This confusion continued to perpetuate the notion of "inexhaustible" reserves, or, at least, failed to instil any urgent consternation. This complacency emerged in the writings of several authors. Thus Lategan (39) in 1961, revealed that there were some 25 000 million tons of "proved" coal reserves, i.e., reserves disclosed through extensive prospecting, in addition to some 50 000 million tons of "known" reserves, i.e. those which have not been prospected and studied to the same extent as the proved reserves. He estimated that at the then annual rate of consumption of 40 million tons the reserves were sufficient for nearly 2 000 years.

Subsequent to this date more accurate and comprehensive information on coal reserves continued to be obtained by the Geological Survey, the Fuel Research Institute, and private firms. It gradually became clear that in situ reserves did not give a clear picture of coal resources and their adequacy in terms of anticipated demands, and what was required was a more up-to-date assessment of extractable coal reserves. As a result, the Coal Advisory Board decided in 1967 to embark upon such a study, its final report being presented in 1969.

The Report immediately dispelled the "general air of optimism" which had hitherto prevailed concerning the country's coal reserves. It found that such terms as "coal reserves", "proved reserves" and "probable reserves" had often been used rather loosely in past studies, creating a confusion which resulted in false optimism. As a result this led the Report to distinguish closely between "reserves" (economically exploitable deposits of which the magnitudes are known within definite limits) and "resources" (denoting known occurrences of coal where the magnitude of the deposit and the economic exploitability are either not known or are such that exploitation is not warranted at present).

In an attempt to dispel further terminological confusion the Report also distinguished between in situ, extractable, and saleable reserves. Under the heading of in situ reserves the Board included the

total amount of coal which occurs in place and is suitable for various known uses, with the exception of coal in very thin seams (less than 3 feet), coal of very poor quality (ash content higher than 35 per cent), and coal deposits of which very little is known. In determining these in situ reserves, three difficulties are observed. Firstly, that of inadequate information obtained from actual mining, drill holes, geological mappings, and so on, to accurately calculate these reserves. Secondly, the physical variability of coal seams caused through folding, faulting, washouts, denudation, thickness variations, dolerite sills, and so on, has to be known to make accurate calculation possible. Thirdly, the variability of the coal quality (which can vary extensively even within small confines) has to be known.

Once in situ reserves have been calculated it must be remembered that not all this coal is extractable. Extractable reserves therefore, refer to that portion of in situ reserves which is technically and economically extractable under current conditions of price, demand and technology. In such calculations many variable factors are involved such as the mining method, maximum mining height, size of bords and pillars, effects of bad ground and closely-spaced seams, condition of the roof, depth of seams, mining legislation, demand for, price of, and quality of the coal, costs and availability of labour, technical know-how, the state of the economy, and so on. Changes in any of these factors can affect the level of extractable reserves.

Not all the coal which is extracted, however, is saleable. Losses are encountered due to the mining method employed and the washing out of shale, stones, etc. The percentage of the material lost through washing varies from one colliery to another and depends on the quality of the in situ deposits, the demands for various grades of coal, the specifications for coal required by various consumers, the prices of various grades of coal, and company policies.

It is clear, therefore, that only in situ reserves are fixed, whilst both extractable and saleable reserves depend upon economic, technological and policy factors. The Report also distinguished between "reserves of coal", "potential reserves of coal", and "other coal resources".

"Reserves of coal" referred to those in existing mines, or in explored areas where it was definitely known that the coal could be

total amount of coal which occurs in place and is suitable for various known uses, with the exception of coal in very thin seams (less than 3 feet), coal of very poor quality (ash content higher than 35 per cent), and coal deposits of which very little is known. In determining these in situ reserves, three difficulties are observed. Firstly, that of inadequate information obtained from actual mining, drill holes, geological mappings, and so on, to accurately calculate these reserves. Secondly, the physical variability of coal seams caused through folding, faulting, washouts, denudation, thickness variations, dolerite sills, and so on, has to be known to make accurate calculation possible. Thirdly, the variability of the coal quality (which can vary extensively even within small confines) has to be known.

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"Reserves of coal" referred to those in existing mines, or in explored areas where it was definitely known that the coal could be

economically extracted under current economic and technological conditions. "Potential reserves of coal" referred to areas where the necessary economic infrastructure was at present lacking, coal which could be recovered by improved mining methods or after the cessation of gold-mining operations in the area, additional coal which could be supplied to power stations or synthetic-oil plants, and other deposits which were usable but were not likely to be exploited in the immediate future for various reasons. "Other coal resources" referred to coal which because of poor quality, depth, or limited tonnage was not considered economically extractable.

The final calculated figures as presented in the Report were as follows: (in millions of short tons).

TABLE 1.4 EXTENT OF COAL RESERVES CALCULATED BY THE COAL
ADVISORY BOARD, 1969

	<u>IN SITU</u>	<u>EXTRACTABLE</u>	<u>SALEABLE</u>
RESERVES OF COAL	26 504	12 619	11 558
POTENTIAL RESERVES OF COAL	10 847	8 194	6 554
OTHER COAL RESOURCES	11 325	-	-

Source: South Africa's Coal Resources, Coal Advisory Board, Office of the Government Mining Engineer, Government Printer, Pretoria, February 1969, pages 15-16.

The Report ignored coal resources in the Springbok Flats, Lebombo field, Limpopo field, part of the Soutpansberg field, most of the Molteno field, some of the Orange Free State deposits, and the unexplored portion of the Waterberg field, because available information did not allow reliable calculations to be made.

The estimate of 20 813 million short tons of extractable coal exceeded the estimate of 12 000 million short tons calculated by the 1947 Commission. However, whereas the latter estimate failed to arouse any "immediate consternation" (for reasons already outlined), the former estimate (although greater) aroused considerable disquiet, mainly due to its comprehensive approach and clear definition of terminology. The Report stressed that the Republic's "usable" coal reserves were not

nearly as extensive as was commonly accepted, and one could discount previous estimates of a life of several thousand years. Most previous predictions had been "wildly optimistic", and were generally based on three erroneous assumptions. Firstly, the in situ coal reserves were not as extensive as commonly believed; secondly, they did not consider that a relatively large percentage of coal had to be left underground; and thirdly, it was not appreciated that demand for coal was growing at approximately 4 per cent per annum. The Report suggested that on the available evidence the country's coal reserves would be exhausted, or very seriously depleted, in between 40 and 100 years. Certainly the notion of "unlimited" coal reserves had to be dispelled.

This conclusion aroused immediate concern in official circles and led to the establishment in 1970 of a Commission of Inquiry (under the chairmanship of A.J. Petrick) with wide terms of reference to enquire fully into the coal resources of South Africa. The Petrick Commission presented its report in 1975. Working on the three assumptions that the minimum mining height for bituminous coal was 1,2 metres, the maximum ash content was 35 per cent and the maximum mining depth was 300 metres, the Report calculated that 89 401 million short tons of coal reserves were technically extractable, but that only 27 407 million short tons (or 31 per cent) were economically recoverable under conditions prevailing in 1975. This was almost 7 000 million short tons more than calculated by the 1969 Coal Advisory Board Report, but nevertheless added to the general air of pessimism engendered following the 1969 Report concerning the rebuttal of the notion of "unlimited" coal reserves. The Petrick Commission spent much time in debating how coal could be conserved in the future.

In 1977 the Franzsen Report (40) estimated that on the assumptions of (i) a gradual increase in production reaching 230 million short tons per annum by the year 2000; (ii) the ability of the industry to rationalise measures for optimum extraction and more than double its production capacity by 1992; and (iii) the exercise of strict control over the export of high-grade coals, reserves based on the Petrick Commission estimates would be sufficient to meet requirements until approximately the year 2026.

The pessimism generated by these 1969 and 1975 Reports has, however, not gone unchallenged. Dutkiewicz and Bennett (41) noted how estimates of extractable reserves had increased steadily from 12 000

million short tons in 1947, to almost 21 000 million in 1969, to over 27 000 million in 1975. This was due to new coal discoveries or better knowledge of known coalfields and an increase in geological knowledge of the country. These trends could be expected to continue and nobody could deny the possibility of future upward re-estimates of reserves. (The Petrick Commission, however, considered the chances of finding substantial additional in situ coal resources to be "remote" (42)). They also called into doubt two crucial assumptions of the Petrick Commission in regard to the calculation of technically-extractable reserves. Developments in fluidised-bed boilers in the future would result in the ability to utilise coal with greater than 35 per cent ash; whilst it was not inconceivable that mining techniques in 20 or 30 years time would allow thinner seams to be recovered. Burnton (43) also noted that if depths down to 400 metres were permitted in the calculations, technically-extractable reserves would increase by another 11 000 million short tons to over 100 000 million short tons. The price of coal was another crucial variable. Using 1978 technology and "higher prices" (not specified) Burnton estimated over 60 per cent of the in situ reserves, or 60 000 million short tons, as being economically recoverable. Dutkiewicz and Bennett also noted that the Commission assumed coal is extractable by underground mining, but substantial improvements could be made if open-cast mining was adopted on a large scale, and mining techniques improved with a resultant improvement in extraction ratios.

There were thus several reasons for believing that the Commission's estimates of technically - and economically - extractable reserves represented the lower limit of the country's reserves. An optimistic appraisal of the studies of Burnton and Dutkiewicz and Bennett would (again) place a life of several centuries on coal reserves. These arguments found particular acceptance in Government circles. In September 1981, the Minister of Mineral and Energy Affairs announced in Parliament that in view of increased prices, intensive prospecting, and more-sophisticated mining methods, the State Geological Survey, after in-depth investigations in co-operation with the coal mining industry, found it necessary to update the 1975 Petrick Commission findings. Accordingly, in situ reserves were estimated 36 per cent higher at 121 000 million short tons and recoverable reserves over 100 per cent higher at 56 000 million short tons (44). These figures were considered

to be conservative by the Minister since coalfields about which incomplete information was available had not been included. There was reason to expect that with continued prospecting, price movements, and improved mining methods, estimated reserves would increase further in future.

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CHAPTER TWO ECONOMIC AND OTHER EXTRANEIOUS FACTORS

This chapter deals with economic, political, technological, social, and other factors which have influenced the levels of production and productivity in the coal mining industry. In essence these factors are similar to the natural and geological ones discussed in chapter 1 in that, although they crucially affect productivity levels, they are basically extraneous, that is, they arise from outside sources and cannot be directly controlled by any internal actions of the industry.

Coal Price

In comparison with overseas producing countries, South Africa has traditionally enjoyed lower mining costs and selling prices. This is due to a combination of favourable factors. The local black labour force has been cheap, non-unionised, docile, readily available, easily trained, and relatively efficient. This is coupled with easy geological conditions in the form of comparatively thick horizontal seams at shallow depth, relatively free from geological disturbance, and with stable roof conditions.

The average pithead price of coal in the Transvaal in 1946 was approximately 61 cents per short ton, having increased by about only 10 cents since 1930. The comparative figures for the Orange Free State were 65 cents and 9 cents. In Natal, however, better-quality coal has traditionally been mined from more-difficult geological conditions making the comparative figures 94 cents and 36 cents (1).

Since 1951 the selling price of coal on the inland competitive market has been controlled by the Price Controller, initially in terms of Regulation 3 of War Measure No. 49 of 1946, and latterly in terms of section 4 of the Price Control Act of 1964. Price increases have been granted on a conservative basis during this period in accordance with increases in working costs. Natal coal has been priced at levels in excess of Transvaal and Orange Free State coal in order to compensate for more-difficult mining conditions and higher working costs.

Two different methods of categorising coal in the Transvaal and Orange Free State for the purpose of price control have been employed since 1951. Until 1972, duff coal was separated from all other coal and

distinctions were made on the basis of calorific values either exceeding, or not exceeding, the value of 12. Since 1972, however, coal has been graded from A to D in quality on the basis of a calorific value on an air-dry basis measured in MJ/kg. The different maximum-price fixings which have been imposed since September 1951 are presented in table 2.1. Of particular interest is the observation that price increases have been far more generous in the period since February 1972 than they were in the period prior to this date. The respective increases are shown in table 2.2. Natal coal does not lend itself to a generalised grading system and prices are normally determined on a colliery to colliery basis.

Wholesale agents are only permitted to add a controlled amount onto the pithead price of a tonne of each coal grade (16 cents per tonne in 1981). At the retail level, selling prices are individually determined for each dealer. The pithead and wholesale-agent prices are added to costs associated with transport and delivery distances, and tonnage handled, as well as stockpiling and administration costs. A desired profit is allowed, and the final selling price is approved by the Price Controller. Accordingly the retail price of coal varies from place to place in the country.

It should be noted, however, that the controlled price has applied only to coal sold on the open inland competitive market. This has, of course, excluded export prices, for which substantially higher prices have prevailed and have resulted in greater profitability for export-orientated collieries as opposed to collieries supplying the local market. For example, during 1979 a typical f.o.b. price for steam coal was between \$20 and \$23 a tonne. However, by August 1980, the prevailing price for new business had increased to between \$35 and \$38 a tonne (2). On the other hand, the controlled maximum price is invariably undercut for large tonnages governed by long-term "cost plus profit" contracts with larger customers, such as ESCOM, which has traditionally paid considerably less than the controlled price to meet the needs of its various power stations. This is because in the case of captive collieries there are virtually no transport, beneficiation, or marketing costs involved, unlike, for example, coal destined for export. ESCOM utilises coal of a calorific value (in MJ/kg) in the range approximately 21-24 (Grade D) and this coal quality has progressively fallen in recent years. In 1979 ESCOM paid an average

TRANSVAAL AND OFS COLLIERIES
(but excluding Spitzkop colliery
from September 1974)

TABLE 2.1 MAXIMUM PRODUCER SELLING PRICE:
IN CENTS PER METRIC TONNE

Type of Coal	Sep 1951*	Jun 1952+	Mar 1955+	Nov 1955	Dec 1955	Oct 1958	May 1959	Sep 1959	Jan 1962	Apr 1965	Nov 1965	Oct 1968
Duff coal: of a calorific value - (i) not exceeding 12	55	64,5	69	96,5	101	114,5	110	106	117	133,5	139	161
(ii) exceeding 12	55	64,5	69	102	106,5	120	115,5	111,5	122,5	139	144,5	166,5

All other coal (excluding Smithy
coal and anthracite) : of a
calorific value -
(i) not exceeding 12

88	97,5	102	120	125	139	134	129,5	140,5	157	162,5	184,5
88	102	106,5	125	129,5	143,5	139	134	145,5	162	167,5	189,5

(ii) exceeding 12

* no distinction made between different grades of duff coal and other coal.
+ no distinction made between different grades of duff coal.

Type of Coal
(excluding Smithy coal, anthra-
cite, gas coal, and coal used
in metallurgical and chemical
processes)

Coal of a calorific value on an
air-dry basis of -
(i) less than 25,5 MJ/kg Grade D

(ii) 25,5 but less than
26,5 MJ/kg Grade C

(iii) 26,5 but less than
27,5 MJ/kg Grade B

(iv) 27,5 MJ/kg and above Grade A
(27,5-28,5 as from
September 1974)

	Feb 1972	Jun 1973	Sep 1974	May 1975	Jul 1976	Jan 1978	Feb 1979	Feb 1980
198,5	235,5	326,5	441,5	667,5	753,5	817,5	904	
206	243	334	449	675	761	846	940	
213,5	250,5	341,5	456,5	682,5	768,5	874,5	976	
221	258	349	464	690	776	903	1 012	

Source : Government Gazettes

TABLE 2.2 AVERAGE ANNUAL COAL PRICE INCREASES BEFORE AND SINCE
FEBRUARY 1972

<u>Average Annual Percentage Rate of</u> <u>Price Increase over the period</u> <u>Sept 1951 to Feb 1972</u>	
<u>Type of Coal</u>	
Duff coal: of a calorific value -	
(i) not exceeding 12	5,4
(ii) exceeding 12	5,5
All other coal (excluding Smithy coal and anthracite): of a calorific value -	
(i) not exceeding 12	3,7
(ii) exceeding 12	3,8

Average Annual Percentage Rate
of Price Increase over the
period Feb 1972 to Feb 1980

Type of Coal

(excluding Smithy coal,
anthracite, gas coal, and
coal used in metallurgical
and chemical processes)

GRADE D	
GRADE C	All 20,9
GRADE B	
GRADE A	

Source: calculated from Government Gazettes

price of less than R7 a tonne (3), and has for a long time been accused of obtaining its coal too cheaply. However, Dutkiewicz and Bennett point out that it is only since 1970 that ESCOM prices have fallen below Grade D prices. Over the period 1950-70 ESCOM was paying a higher price than the controlled D-grade coal (4).

The controlled price of coal has always been a contentious issue with producing collieries. The official justification of the system is to prevent excessive price inflation. Coal is a basic commodity in South Africa and escalations in its price have significant ripple effects throughout the economy. A free-market price, therefore, based on supply and demand would be instrumental in increasing more severely the overall costs of production throughout South African industry. The Republic is nearly 80 per cent dependent on coal for all energy sources and to leave its price to the vagaries of the market could prove extremely disruptive. Price control, it is claimed, allows for an orderly market (5). Two other advantages are frequently cited. Firstly, the Chamber of Mines has claimed that price control on coal and the cheap-energy policy has had the "positive effect of promoting economic development" (6). Secondly, this control has forced collieries to adopt mining and preparation policies designed to reduce costs to the minimum and emphasise efficiency in input utilisation. *Ceteris paribus*, this should have a favourable productivity effect from the input side. Even small cost escalations in a situation of static or slowly increasing revenue can have significant detrimental effects upon viability.

Unfortunately the periodic price rises which have been granted have traditionally lagged behind cost increases and merely compensated producers to allow them to catch up on their costs. As a result, producers have had to keep running to remain in the same place (7). Whilst it may be argued that this has instilled a sense of responsibility into producers concerning cost reduction, and efficiency and productivity growth, it has simultaneously hindered productivity from a different angle, that of capital substitution and capital growth. Ruling prices have never justified modernisation of plant at collieries serving the domestic market. The industry has traditionally found itself unable to entice capital to finance further exploration and development of new collieries. Many collieries continued to employ hand-got methods of extraction well into the 1970's because they could

not afford to switch their operations to the more-productive methods involving mechanical extraction. In a situation of static or declining profits many collieries found it impossible to plough back adequate funds to provide for future capital expenditure. They were unable to set aside the very considerable sums necessary to modernise and mechanise their collieries in order to expand their operation. As a result they tended to continue with old-fashioned hand-got methods many years after it was technically possible to replace them with more-efficient mechanical-extraction methods. There was also little encouragement to open new collieries as the profits earned by the industry were low in relation to the large capital sums required to equip a new colliery and bring it to the producing stage. Many collieries have mechanised their operations only in the latter half of the 1970's as a result of greater profitability stemming from more substantial annual rises in the controlled price of coal. However, other factors have also facilitated mechanisation (such as demand increases and labour problems). These are examined later in this thesis.

Basically, the problem arose from the nature of the price-determining formula which was related to the cost of coal produced and the return on capital invested, which the State now concedes "did not provide sufficient incentives for the expansion of production" (8). Profit margins were so small that expansion could not be financed from profits and outside capital could not be attracted. In 1976, Government accepted a new formula for coal pricing aimed at encouraging capital investment in coal. A formula whereby the coal price would be reviewed annually was agreed upon between the Government and the coal producers. More details are provided later in this chapter.

An additional problem of price control has arisen not only from the magnitude of the selling price but the size of the differential between the different grades of coal, which has traditionally been so small that industrial users are not encouraged to buy anything but the best. The pithead differential is even further eroded in percentage terms when railage costs are added, particularly coal sold in the Cape. This has caused price-induced distortions in demand with extremely high levels of demand for A-grade consumption to the detriment of the lower grades. Accordingly, collieries have either burned lower-grade coal on the surface, or else practiced selective mining by leaving such coal

underground, thus exacerbating low extraction rates. Only at great expense could this be extracted later, for instance, in the Witbank area where fairly large reserves of low-grade coal have been left in seams either overlying or underlying the main seam being mined. Wider price differentials could have eliminated this problem by curbing grade-A demand and diverting it to low grades, thus creating the necessary market.

Despite the more-generous pricing policy in recent years which has enhanced the viability of coal producers, the conceptual argument still remains of whether coal prices should be left completely to the free market (9). Many analysts point out that the export market is subsidising the inland market. A free-market price of domestic coal would undoubtedly be higher allowing such collieries to cover exploration and development costs, the amortisation of capital costs and still give a fair and reasonable return to the investor (10). In addition, price differentials would adjust to encourage larger demand for lower-grade coal. In 1981 the Competition Board commenced an investigation into all aspects of this problem. Despite the fact that it is now realised that price control has stifled the industry's development, it is believed that the Board will not recommend its abolition, since "the customer likes the annual review and controlled increases" (11).

Further discussion of the effects of the controlled coal price on the industry is undertaken in the following section on coal production.

Influences on Coal Production

The many and varied influences on the production of coal are best dealt with chronologically in order to emphasise how the conditions under which the industry has operated have changed over the years. Discussion will be made according to the major periods of expansion.

Early Coal Mining: before 1920

It is believed that coal was used several centuries ago by Zulus in Natal who utilised surface outcroppings near Nongoma and Somkhele to replace charcoal for smelting in the making of agricultural implements and weapons. The first recorded discovery of coal by Europeans was in 1699 in the Fransch Hoek valley in the Cape and coal was also used by

the Voortrekkers who extracted it at Breyten in the Transvaal soon after 1850.

The first recognised colliery however, did not open until 1864 at Molteno in the Eastern Cape, followed in 1877 by another near Indwe. These formed part of the Molteno-Indwe field, exploited to supply coal to Cape Town, but due to the poor quality of the coal and the transportation difficulties involved between the field and Cape Town, it never proved a commercial success. The collieries were, however, given a new lease of life through the discovery of diamonds at Kimberley which enabled the development of large-scale mining operations. By 1885 almost 15 000 metric tonnes of coal had been extracted and transported to Kimberley. Annual output reached a peak of 183 500 tonnes per annum between 1896 and 1906, but with the discovery and exploitation of better-quality coal in the Transvaal and Natal, production gradually declined to 7 500 tonnes in 1917 and ceased entirely in 1948. The total quantity of coal extracted from this field amounted to approximately 4 million tonnes.

Coal had been discovered in Natal as early as 1840 but apart from intermittent demand by ships calling at Durban for bunkers, little effort was made to commercially exploit the deposits until the country's industrial base was expanded following the Kimberley diamond discoveries in 1867 and the Witwatersrand gold discoveries in 1886.

Coal was discovered near Vereeniging, in the Northern Orange Free State, during the 1870's. This field first began production around 1885 with the intention of supplying coal to Kimberley and the original idea was to transport the coal by means of steel barges floated down the Vaal River, but this was found to be impractical after the river had been adequately surveyed. However, it was not until after the discovery of gold on the Witwatersrand that these deposits were significantly exploited on a commercial scale.

Coal was also discovered at Witbank during the 1870's but, again, significant commercial exploitation was not undertaken until after the gold discoveries. In 1887 coal deposits were found on the East Rand as a result of gold-mining activities in the area, stretching from the present-day towns of Boksburg to Springs and beyond, and a steam railway was constructed and opened in 1890 to transport coal to the gold mines from these collieries. This area remained the principal source of

supply to the Witwatersrand until 1895 when the Pretoria-Delagoa Bay railway reached Witbank. Subsequently, the better quality of the Witbank coal gave it an ascendancy over that from the East Rand, despite the latter's cheaper railway rates.

The region of the Southern Transvaal became a major industrial and residential growth area, and acted as a magnet for the large-scale importation of overseas capital and labour. It attracted secondary manufacturing industry and the establishment of a surrounding agriculture industry. Major road and railway transport networks began to radiate out towards the coast. The industrial and domestic demand for power, both steam and electrical, multiplied manyfold and coal provided the means to meet this demand. The number of collieries mushroomed in the Witbank area and Northern Natal to meet an ever-expanding range of uses from domestic usage to electricity generation, to steam locomotives and ship's bunkers. By 1920, coal production from the Transvaal and Natal had reached 11 million short tons.

Coal Production since 1920

Figures for total coal sales are presented in table 2.3 on an annual basis from 1920 to 1980.

Total sales have increased steadily over this period from 10,4 to 111,3 million metric tonnes, representing an average annual rate of growth of 4,1 per cent. However, the growth rate has been far from regular due to vagaries of the national economy and the special circumstances affecting particularly the coal mining industry. Five distinct eras can be isolated giving rise to radically differing average rates of growth. These are identified, measured, and discussed below.

TABLE 2.4 GROWTH OF COAL SALES

<u>PERIOD</u>	<u>AVERAGE ANNUAL PERCENTAGE RATE OF SALES GROWTH</u>
1920 - 1933	NIL
1933 - 1942	7,4
1942 - 1954	2,8
1954 - 1972	4,0
1972 - 1980	8,7
<u>OVERALL 1920 - 1980</u>	<u>4,1</u>

TABLE 2.3

COAL SALES: (IN MILLIONS OF METRIC TONNES)

<u>YEAR</u>	<u>SALES</u>	<u>YEAR</u>	<u>SALES</u>
1920	10,4	1950	25,7
1921	10,3	1951	25,8
1922	8,8	1952	27,1
1923	10,8	1953	27,6
1924	11,3	1954	27,9
1925	11,8	1955	30,1
1926	12,5	1956	32,2
1927	12,1	1957	33,7
1928	12,2	1958	36,2
1929	12,6	1959	35,6
1930	11,9	1960	38,1
1931	10,6	1961	40,5
1932	9,7	1962	41,0
1933	10,5	1963	41,9
1934	11,9	1964	44,1
1935	13,3	1965	47,6
1936	14,5	1966	46,9
1937	15,2	1967	48,3
1938	15,9	1968	50,6
1939	16,5	1969	51,2
1940	17,2	1970	53,1
1941	18,3	1971	57,0
1942	20,0	1972	57,0
1943	20,2	1973	61,5
1944	22,6	1974	64,6
1945	23,1	1975	69,1
1946	23,3	1976	75,7
1947	23,1	1977	85,0
1948	23,6	1978	85,7
1949	24,4	1979	98,2
		1980	111,3

Source: Minerals Bureau, Coal Mines in the Republic of South Africa,
 Department of Mineral and Energy Affairs, Directory No. 2/80, July 1980,
 Page 58.

(i) The period 1920 - 1933. This era of zero growth is actually composed of two distinct sub-periods: firstly, a slow but steady rise in sales throughout the 1920's reaching a peak in 1929 of 12,6 million tonnes, and secondly, a sharp severe depression of 3 years duration reaching a trough of 9,7 million tonnes in 1932. Although the recovery began in 1933, sales in that year were approximately the same as 1920.

The whole period was one of frustration for the coal mining industry. Exogenous factors, beyond the control of the industry had serious repercussions. Despite the relentless increase in working costs, the price realised tended to remain stable, and actually dropped in several years, having an adverse effect upon profitability. The difficulty was not in producing coal but in selling it, since internal demand was affected by the generally depressed condition of local industries throughout the 1920's. In view of the practically stationary nature of internal trade the industry could only look to any material increase in tonnage through an improved demand for shipment coal. Approximately 20 per cent of all Transvaal coal was taken for the export and bunker trade in 1920. Unfortunately, extraneous factors continued to hamper the development of this potentially lucrative trade, and the industry was particularly scathing of the policy attitudes adopted by the South African Railways. Two points of contention were obvious. Firstly, the Railways were unable to cope with the traffic, so that proper advantage could never be taken of this demand. Secondly, in 1920 the Railways raised the railage rates on shipping coal despite strong protests from the industry that such a policy, if persisted in, "could only end disastrously and would eventually result in killing the trade" (12). With the high railway rates the collieries found it extremely difficult to compete even in their traditional areas.

The small steady growth of production throughout the 1920's was, therefore, a remarkable achievement in view of the stationary internal demand caused by general depression and the exogenous and unfavourable factors affecting the export and bunker trade. The world-wide depression ushered in by the 1929 Wall Street Crash affected the coal industry severely for the next three years. Not only was the internal depression exacerbated, but the export trade was critically affected by another exogenous policy decision, namely South Africa's dogged refusal to depart from the Gold Standard. Britain made that decision in September 1931, but the continued maintenance of the system in South

Africa meant that, except for the fulfilment of contracts already existing in September 1931, the coal-export trade entirely ceased after that date. However, at the close of 1932, with the departure of the Union from the Gold Standard, the prospects for the industry were materially improved and this was reflected in a substantial increase in the export and bunker trade in 1933.

(ii) The period 1933 - 1942. Almost immediately after the decision to go off the Gold Standard the economic situation within South Africa began to improve. This was enhanced by the political decisions to form a coalition and then a Fusion Government in 1933 and 1934 respectively and thus to rid party warfare temporarily from the South African political scene. The price of gold rose substantially, giving a new lease of life to the marginal mines, and this increased prosperity of the gold mining industry had ripple repercussions throughout the economy. Higher profits and industrial confidence resulted in larger investment expenditure, capital was attracted from overseas, and employment rose. Manufacturing industry moved forward rapidly in this more-favourable economic climate and the first Iron and Steel Corporation (ISCOR) plant came into production in Pretoria.

The coal mining industry benefited greatly from this revival in internal demand. Although the price of coal changed only marginally during this period, the increased prosperity of the country resulted in an average annual percentage growth in sales on a compound basis of 10 per cent, the bulk of it being sold within the country. Demand came from all sources - industrial concerns, power companies, railways and mines, domestic consumption, and the export and bunker trade. The inability of the Railways to meet the demands for the transport of coal was again the subject of complaint from the industry, although the reasons were probably now more justifiable in view of the large increases in sales. For instance, during 1937 this inability was responsible for a fall in overseas trade and necessitated for a time the complete cancellation of coal supplies for bunkering and export. For more than half of the year, coal producers had to decline orders which they were in a position to supply had railway facilities been available.

The outbreak of war in 1939 had an adverse effect upon the supply of white manpower to the industry as many men left on war duty. This caused considerable problems especially as the international situation

resulted in an increased demand for coal. Owing to the war, the importance of the coal industry in relation to the national economy was enhanced and the industry was called upon not only to maintain production but to increase it. Production was given a boost both by South Africa's contribution to the war effort and also by the increased internal demand caused as a result of the general curtailment of imports which stimulated local manufacture. This was particularly noticeable in the iron, steel, and engineering sectors.

(iii) The period 1942 - 1954. Coal sales continued to increase throughout this period but at the lower average rate of 2,8 per cent per annum. The general economy was marked by the growth of the local manufacture of consumer goods which commenced during the war and continued afterwards. Rapid industrial expansion was a feature throughout the post-war period fired by pent-up demand and the influx of large numbers of European immigrants. Growth was particularly rapid in the metal, engineering, textile, and chemical industries. A second ISCOR plant was opened in 1941 at Vanderbijlpark. Goldfields were discovered in the Orange Free State during the war and were exploited soon afterwards. Together with extensions to both the east and west Witwatersrand, and greater-depth mining, these led to major developments in the gold mining industry.

This continuing expansion in domestic manufacturing and mining bode well for the coal mining industry which enjoyed a period of confidence and a number of new collieries were opened up after the war. However, optimism was engendered not only by strong internal demand but external demand as well. The destruction of plant and equipment in the principal coalfields of Europe led to demands on the Union to supply a very wide area. Production and sales were, however, hampered throughout the period by the inefficiency of transport facilities. Although the Railways Administration made strenuous efforts to meet the increasing export and internal demands there was a perpetual shortage of railway rolling stock. Continual discussions took place between the collieries and the South African Railways with a view to making better use of the available rolling stock for the transport of coal, but all sectors suffered from intermittent coal shortages, due to an inability to receive adequate supplies. By the end of 1954 the rate of increase of coal sales had levelled off due to a critical shortage of coal trucks.

In contrast to the period 1920 - 1933 when the major difficulty was not to produce coal but to sell it, the problem had now been reversed to one of being unable to transport it fast enough.

(iv) The period 1954 - 1972. During this period the expansion of the coal mining industry continued but at the slightly higher average rate of 4 per cent per annum. The whole period was marked by conservative increases in the controlled price of bituminous coal sold on the inland competitive market which did not allow producers to adequately cover increases in their working costs nor to plough back sufficient funds for capital expansion. Together with a continuing shortage of an adequate supply of railway rolling stock to transport the coal, these two factors exercised a restraining influence on the growth of the coal industry, despite the existence of a permanently expanding and diversifying economy.

The increase in coal production until the early 1960's was part of the general pattern of development and expansion of the industry to keep pace with the general industrial advancement of the country. It was even possible to secure some export sales in 1961, but, as usual in times of expansion, problems were experienced with rail transport.

"A constant problem of the coal industry since the war has been either an insufficient or an erratic supply of rail transport. The strenuous efforts made by the South African Railways are now bearing fruit and for the first time for many years railway trucks have been in relatively-free supply. It is essential that the tempo of railway development be maintained if prospects of building up exports are not again to be hampered by inadequate rail facilities" (13).

However, during several years in the 1960's many collieries operated well below capacity as a result of a lack of orders. Some collieries closed down in the face of practically stationary internal demand. Production increases were due mainly to the development of "tied" collieries supplying ESCOM power stations. Working costs, however, continued to increase. Rises in the controlled price of coal

were hard won because of the effects on the rest of the economy, and lagged well behind increases in working costs so that it was only where output could be expanded that profitability could be maintained. The effect of rising costs was, therefore, particularly severe on those producers that were unable to expand their trade. The benefits of price increases were nullified soon after they had been introduced and in a situation where the competitive demand for coal refused to revive, this precluded the industry from earning even the controlled profit margin on capital. The industry was, therefore, caught between an inflation of working costs, a controlled price for its product, and a lack of demand, which severely affected colliery earnings, and reduced its profitability and attractiveness for investors.

"The effects of price control on the industry and the undue delays in reviewing prices remain the cause of grave concern. Price rises ... (are) ... to a considerable extent eroded before they are implemented. The rate of escalation of working and capital costs is such that producers are having difficulty in maintaining their production capacity for the future and in paying a fair return to their shareholders. The industry's burdens are further increased by the need to raise salaries and wages. Additional costs have to be met in the context of a fixed price for coal adjusted in arrears. It is imperative that the present pricing arrangements be revised so as to restore the viability of the coal industry" (14).

This same plea was made time and time again throughout this period as working costs increased and reduced the industry's competitiveness. Not only did several collieries close down, but at others production was rationalised in order to obtain the benefit of lower unit working costs by concentrating operations at mines with idle capacity. By 1969, 50 per cent of South African coal was burnt in power stations and it was a cause of some concern that demand increases were coming only from this source. Undoubtedly, the introduction of the ESCOM captive-colliery policy began a new era for coal mining and prospecting in South Africa, and as the demand for electric power accelerated companies vied with one

another for ESCOM contracts. Other internal competitive trade was static or declining. The demand from the railways continued to fall due to the change over to diesel-electric locomotives.

However, contributions from ISCOR and SASOL (the South African Coal, Gas, and Oil Corporation) should not be overlooked. A third ISCOR plant was announced in 1969 at Newcastle only a year after the private-enterprise Highveld steel works. This increased steel production had a profound influence on the production and search for coking coal. The SASOL plant at Sasolburg was commissioned in 1955 to produce petroleum products from coal, also giving rise to a surrounding industry based on coal by-products.

With the period of building up of new collieries tied to ESCOM many of the older collieries were operating considerably below capacity and in view of these factors the industry began urgently seeking export contracts. A country with considerable potential in this direction was Japan and efforts were rewarded in 1970 with the signing of a contract with Japan by the Transvaal Coal Owners' Association (TCOA) to supply that country with 27 million tonnes of coal over the period 1972-86. This event coincided with a world-wide resurgence in the demand for coal and emphasised the need for new rail and harbour facilities. Planning commenced on a railway link between Witbank and Richards Bay together with coal handling and loading facilities at that port. At the close of this period, therefore, there was more confidence in the future of the coal mining industry than there had been for over a decade, clouded only by the familiar drawback of rising working costs and a controlled coal price.

(v) The period 1972 - 1980. This period has been the most successful in the history of the coal mining industry. It has undergone an unprecedented boom, advancing at the average annual rate of 8,7 per cent. This has ushered in a period of immense optimism, and re-created strong confidence in the long-term viability of the industry. A combination of several factors has been responsible for this.

The major factor has been the increase in the demand for coal which has come from various sources. ESCOM and ISCOR have continued to expand. ESCOM has commissioned several large, new power stations in the Eastern Transvaal Witbank district (supplied by captive collieries) in order to keep pace with the continually increasing demand for

electricity. The steel industry in 1979 used more than 6 million tonnes of coal, mostly in the form of blast-furnace coke, and a large new open-cast colliery has been commissioned to produce blend coking coal at Ellisras in the North-Western Transvaal.

However, the most significant development affecting the demand for coal during this period was the energy crisis following on from the Arab-Israeli War. Uncertainty over oil supplies sharpened the world's awareness of the importance of coal as an energy source, and this increased both domestic and overseas demand for South African coal. In addition, the possibility of sanctions against South Africa, especially an oil boycott, in protest against this country's apartheid policy, gave added urgency to the move towards increasing the country's self-sufficiency in this respect. A second SASOL plant was commissioned at Secunda, later to be expanded on the same site to SASOL III. This is being supplied with coal from what will eventually become the world's largest coal mine, Bosjesspruit. On the export side, the Richards Bay Harbour was opened for coal exports in April 1976 which allowed South Africa to take full advantage of this demand. Coal exports increased from 2,7 million tonnes in 1975, to 29,2 million tonnes in 1980. The ability of the industry to gear up to the challenge of the burgeoning export market has been the main feature of the coal mining industry since 1976.

Further discussion of this increased demand for coal from ISCOR, SASOL, and the export trade is undertaken in the later section on the sources of demand.

The dramatic expansion of the industry during this period has been facilitated by the opening of several new large collieries and the expansion of existing ones. Mechanised mining techniques have now largely replaced hand-got methods and the introduction of labour-saving open-cast and longwall methods has been most marked. These developments have been made possible by an enlightened policy towards coal pricing which became evident particularly after 1975. Prior to this complaints were still very evident from the industry, especially in 1973 and 1974. In a situation of revived demand following the energy crisis, working costs continued to rise hampering profitability, and production facilities could not be geared up to meet the demand. The pricing policy was particularly restrictive in inhibiting the development of new collieries because the formula was based on a depreciated historical

capital investment in coal mines, most of which were established 20 or more years before. When the profit allowance calculated on this small capital base was compared with the enormous sums required to establish new production facilities it was not surprising that further investment was considered uneconomic. In addition, the formula made no allowance for either the cost or the market value of the coal resource itself, profit being calculated purely on the assets required to work the deposit. The whole atmosphere in the industry, therefore, was one of survival rather than to expand or attempt maximum extraction of reserves. This was an anomalous situation bearing in mind the country's dependence on coal-based energy and the length of time required to establish new production facilities to gear up to meet demand. It was obvious that a fundamental re-assessment of the price-control philosophy was a matter of urgency.

This re-assessment came following the Report of the Petrick Commission in 1975 which recommended a review of the price-control system and a substantial increase in price with a view to expanding production capacity and the introduction of mining and conservation practices which would extend the life of the country's reserves. A substantial price rise was forthcoming in 1974 although it fell far short of the price required to justify the establishment of new collieries. The main shortcoming was that the pricing policy still did not ensure an adequate return on the replacement value of coal mining asset.

"In addition to requiring a proper financial basis to justify the establishment of new collieries, the industry also faces the need to finance capital expenditure for the expansion of existing collieries to meet the growing inland and export demand, to make better use of labour by the mechanisation of its mining operations, to improve the standard of accommodation for its workers, and to improve as far as possible the present recovery of coal from reserves by adopting the far more capital-intensive longwall and open-cast mining methods ... it may not be easy for the Government to grasp the nettle and depart radically from the low-price policy of the

past, but the reward will be a modern thriving coal industry" (15).

However, in 1975 the Government, apparently, did "grasp the nettle" and accepted that the formula for coal pricing should be modified in an effort to encourage coal producers to install new capacity at existing mines. This agreement required coal producers to undertake that they would maintain and expand their productive capacity in order to cater for the full requirements of the internal market until the early 1980's. To be able to meet this requirement a programme of capital expenditure was immediately embarked upon involving expenditure on new coal mines and extensions to existing mines which has been responsible for the remarkable increase in coal production over this period.

Nevertheless, in view of the fact that coal is likely to provide an important part of the answer to world energy problems, the existence of price control in any form acts as an inhibiting factor in the orderly development of the industry and it is considered imperative by the coal producers that the authorities move towards the removal of the restriction as soon as possible (16).

Sources of Demand

Seven general areas of sectoral demand for coal are identified in the accompanying table 2.5 as being: exports, the Railways, power, mining, industry, carbonisation, and household use. For each source, the total metric tonnage consumed as well as the percentage this represented of the total consumption of coal, is presented for five-yearly intervals over the period 1952 to 1980. A more-detailed discussion of each of these sources can now be undertaken.

(i) Railways. Between 1910 and 1942 the South African Railways annually consumed between 20 and 25 per cent of the country's total coal sales. Even during the 1950's this percentage was still as high as 18-19 per cent. The greatest volume of coal consumed by the Railways was in 1958 when a total of 6,9 million metric tonnes of coal were used. Since then, however, the demand for coal has declined rapidly both in terms of absolute tonnage and as a percentage of the total consumption. By 1980, absolute tonnage had declined to 1,96 million tonnes representing only 1,7 per cent of total consumption. This diminishing use of coal is

attributable to the gradual replacement of steam locomotives by electric and diesel locomotives. Consumption is expected to fall to 1,1 million tonnes by 1985.

(ii) Mining. Consumption of coal by the mining industry has shown a steady decline from over 35 per cent in 1910 (at which time it was the largest single consumer of coal) to 0,8 per cent in 1980. In terms of absolute tonnage, however, the decline has not been as startling - the decrease in the percentage contribution being due to the faster growth of other sectors. The discovery of gold on the Witwatersrand and coal in the Witbank and Springs areas at approximately the same time was fortuitous, for growth in the gold mining industry was facilitated at a pace which would not have been possible in the absence of a close-proximity coalfield. The rapid opening of gold mines led, in turn, to the commissioning of new coal mines so that in the early days the development of both gold and coal mining was closely linked. The gold mining industry at first obtained its power requirements from coal converted into steam. However, this gradually gave way to electric power. There was a tendency to consume less and less coal as the old mines on the Central Rand were replaced by new electrified mines on the Far West and East Rands, and in the Orange Free State.

As far as the utilisation of coal is concerned, therefore, the mining industry has gone the same way as the Railways, as steam power has gradually been replaced by electric power. The aggregate demand for coal has not diminished - there has simply been a change in its utilisation. The change from coal-burning to electric locomotives, and from steam-powered mines to electric ones, simply means that ESCOM has taken over as the major consumer of coal. Coal previously consumed directly to produce steam by the Railways and the mining industry is now being burnt in power stations and supplied to them in the form of electric current. The Railways and the mines have, therefore, changed from direct coal consumers to indirect consumers.

(iii) Households. This source of demand has shown a very slow rising trend in terms of absolute tonnage, but has declined rapidly as a percentage of the total due to the faster growth of other sectors. Coal is consumed for domestic use in coal stoves and heaters, and for generating heat in hospitals, hotels, institutions, etc. However, coal

TABLE 2.5 CONSUMPTION OF COAL ACCORDING TO MAIN SECTORS: IN MILLIONS OF METRIC TONNES

YEAR	EXPORT Tonnes Total	% of Total	SAR Tonnes Total	% of Total	POWER Tonnes Total	% of Total	MINING Tonnes Total	% of Total	INDUSTRY Tonnes Total	% of Total	CARBONISATION Tonnes Total	% of Total	HOUSEHOLD Tonnes Total	% of Total	TOTAL
1952	0,62	2,2	5,78	20,9	10,65	38,6	1,4	5,3	3,87	14,0	2,25	8,1	2,99	10,8	27,62
1957	0,25	0,7	6,50	19,5	14,43	43,2	1,39	4,2	5,48	16,4	2,55	7,6	2,78	8,3	33,38
1962	1,22	3,0	6,18	15,4	18,90	47,0	1,22	3,0	6,46	16,1	3,54	8,8	2,71	6,7	40,23
1967	0,65	1,3	5,60	11,4	25,00	51,0	1,28	2,6	8,08	16,5	4,81	9,8	3,61	7,4	49,03
1972	1,37	2,4	4,34	7,5	32,76	56,6	1,33	2,3	9,09	15,7	5,25	9,1	3,77	6,5	57,92
1977	12,13	14,3	2,60	3,1	46,74	55,1	1,19	1,4	10,60	12,5	8,07	9,5	3,54	4,2	84,87
1980	28,44	24,1	1,96	1,7	58,85	50,1	0,91	0,8	16,13	13,7	7,53	6,4	3,75	3,2	117,57

Source: Fuel Research Institute, Pretoria: as published in Department of Mines, Mineral Resources of the Republic of South Africa, Geological Survey, 1976, page 323; and Chamber of Mines, Annual Report, 1980, page 84.

Note: Consumption of coal by SASOL is divided between "power" and "industry".

is subject to keen competition from other cleaner and more-convenient forms of energy such as electricity, kerosene, gas, and so on, which have displayed more-rapid growth rates. Legislation was enacted in 1965 to combat air pollution which threatened to have a serious effect on this source of demand but this appears to have been largely combated through the use of smokeless fuels and smoke-free coal burners, together with more-active research and aggressive promotional activities on the part of the coal industry and the availability of technical services. The future electrification of black townships, such as Soweto, is also bound to have an adverse effect on the direct household consumption of coal, turning households (like the Railways and mining) into indirect coal consumers via ESCOM.

(iv) Export. Some discussion of the export trade, particularly the problems besetting it, was undertaken in the earlier section on coal production, but this can be extended at this stage. As long ago as 1907 the Natal collieries were able to export over 50 000 tonnes of coal to such diverse destinations as Bombay, Madagascar, Mauritius, Singapore, and Buenos Aires. In 1910, coal for export and bunker accounted for over 20 per cent of total sales. However, since then the trade has been a fluctuating one for reasons outlined earlier, accounting for approximately 15 per cent of total sales in the mid-1930's and receiving a war boost during the early 1940's. Demand for bunker coal began to drop off due to the increased use of oil-driven vessels. By 1947 the total trade fell to 3 million tonnes representing about 13 per cent of total sales. This declined further to 1,2 per cent in 1958 and 0,7 per cent in 1967. This insignificant contribution can be ascribed to several factors:

- South African average run-of-mine coal is not of the same quality as European and North American coal,
- railway and harbour transport systems were incapable of dealing with the bulk demands of the export trade,
- chronic shortage of railway trucks especially when coal was diverted to the inland market during boom periods,
- high railage rates on shipment coal,
- large distance from potential markets and high sea freight rates,

- exports badly affected by political considerations, especially to the Far East.

However, export fortunes began to change rapidly in the early 1970's. The TCOA - Japanese contract instilled new confidence into the coal mining industry and this was re-inforced almost immediately through an increased world-wide demand for coal and the energy crisis after 1973. The figures in table 2.6 show that South Africa was only a minor exporter of coal in 1975, but this was followed by rapid expansion thereafter.

TABLE 2.6 COAL EXPORTS: 1975-1980

	<u>VOLUME</u>		<u>VALUE (FOB)</u>		<u>AVERAGE PRICE</u>	
	<u>M tonnes</u>	<u>% increase</u>	<u>RM</u>	<u>% increase</u>	<u>R</u>	<u>% increase</u>
1975	2,7	17,4	34,4	59,3	12,70	35,1
1976	6,0	122,2	103,4	200,6	17,20	35,4
1977	12,7	111,7	248,6	140,4	19,60	14,0
1978	15,3	20,5	325,1	30,8	21,20	8,2
1979	23,4	52,9	509,1	56,6	21,80	2,8
1980	29,2	24,8	688,1	35,2	23,60	8,3

Source: Department of Mines, Mining Statistics, published annually, Government Printer, Pretoria, table 12.

The majority of the coal exported comprises low- and medium-grade steam coal sold to various markets, with the remainder being made up by anthracite and low-ash blend-coking coal.

By 1979, therefore, coal exports accounted for almost 24 per cent of the total coal sales (as compared with 3,9 per cent in 1975) and in terms of revenue in that year coal was the country's fourth largest foreign-exchange-earning mineral after gold, platinum, and diamonds.

This growth has been facilitated by the development of an extensive transport and shipping infrastructure commenced in 1972. Under a Stage I programme designed to handle 12 million tonnes per annum, a new Witbank to Richards Bay railway line was completed, and in April 1976 the Richards Bay Harbour was opened for coal exports. Both railway and harbour facilities were subsequently upgraded under a Stage II expansion

programme to reach 20 million export tonnes by 1979, although this figure was actually exceeded by 3,4 million tonnes. In 1978 the Government gave permission for exports to be increased to 44 million tonnes per annum (40 million tonnes of bituminous coal and 4 million tonnes of anthracite), and a Stage III railway and harbour expansion programme was commenced to reach this objective by 1986 at the latest. The implementation of Stage III of the expansion programme envisages that by 1983 the Richards Bay Harbour, loading facilities and railway line will have the capacity to handle over 31 million tonnes annually increasing finally to 44 million tonnes by 1986. In order to meet this target it has been estimated that the Railways will have to spend approximately R200 million in 1978 prices on rolling stock, R65 million on railway line and civil-engineering work, and R10 million on a third quay at Richards Bay. It is planned to double the length of trains from 80 to 160 trucks. In addition, expansion to the coal terminal at Richards Bay (80 per cent owned by members of the TCOA, 10 per cent by members of APA, and 10 per cent by members of NAC) will cost about R100 million (17). These costs are, however, subject to constant revision, and in late 1980 the Richards Bay expansion alone was estimated to have increased to R230 million at ruling prices (18).

As a result of the revision of South Africa's coal reserves in 1980 which doubled extracable reserves to 51 000 million tonnes, the Government announced in 1981 that the coal-export quota was to be raised to 80 million tonnes per annum. This would be reached in two phases: 60-65 million tonnes by 1990 and 80 million tonnes soon after the turn of the century. This decision now allows the coal producers and the Railways the necessary long-term planning required for efficient operation.

The large expansion of the export trade has come about mainly as a result of political factors. Events in Iran during 1979 and the subsequent uncertainty surrounding the price and supply of oil as well as the political instability of the major oil-producing nations have prompted a far greater and more-rapid substitution of coal for oil than occurred after the 1973 oil crisis (19). Several countries have committed themselves both to convert oil-fired power stations to coal and to install new coal-burning capacity. Events in Poland in 1981 (the world's largest coal exporter at the time), opened up further markets for South African exports.

The largest demand for South African coal during the late 1970's came from Western Europe (especially France, Denmark, Italy, Belgium, and West Germany) which took 70 per cent of coal exports. The Far East (Japan, Korea, and Taiwan) accounted for 20-25 per cent, with the remainder going to the Middle East (Israel) and the southern United States. South Africa was the first country to meaningfully gear up production and infrastructure capacity to meet the expanded world demand for coal and by 1979 had moved into the position of the world's second-largest exporter of steam coal behind Poland. It was expected that with the expansion of exports to 44 million tonnes in 1986, combined with the continuing political and economic problems in Poland, this country would occupy top position by that year. However, over the period 1979-82 both the United States and Australia displayed an increased ability to ship export coal, despite several initial problems, and are expected to remain ahead of South Africa in terms of export tonnage, with Poland an unknown factor.

The enormous tonnages involved in this export programme have attracted the giant oil companies onto the coal-mining scene for the first time in South Africa. Shell Oil and TC Lands (a member of the Barlow-Rand group) are involved in a 50-50 venture in developing the Rietspruit open-cast mine, with Rand Mines being responsible for the mining and Shell for the marketing. Similarly, BP and Total are co-operating in the development of the Ermelo mine with General Mining, under the same arrangement of the oil companies handling the marketing and General Mining the actual mining operations. The other large new export colliery at Kleinkopje is, in fact, owned by Amcoal which is the coal division of the Anglo-American Corporation but Shell is collaborating in the marketing.

Export quotas for Stage I of the export programme up to 12 million tonnes were allocated between TCOA, NAC, and APA, but for Stage II (up to 20 million tonnes) and Stage III (up to 44 million tonnes) export allocations were made on the basis of particular parties' contributions to the overall provision of energy in South Africa. Hence the oil companies received the bulk of these later allocations. Stage I was allocated 9,6 million tonnes to TCOA, 1,2 million tonnes to NAC, and 1,2 million tonnes to APA. The 8-million-tonne step-up during Stage II was allocated 3 million tonnes to Rietspruit, 3 million tonnes to Ermelo, and 2 million tonnes to Kleinkopje. The Stage III allocation is presented in table 2.7 below.

TABLE 2.7 1986 RICHARDS BAY COAL EXPORTS
 (Million tonnes per annum)

TCOA	10,0
NAC	2,0
APA	2,5
Anglo American	6,0
General Mining	6,0
Rand Mines	2,5
Shell	5,5
BP	5,5
Total	2,5
Kwa Ngoma	1,5
	44,0

Source: Standard Bank Review, May 1980, page 4.

A noticeable omission from this list is that of JCI, but its collieries do benefit from the TCOA allocation. At the time of writing, no Stage IV allocations had been announced.

The increasing exports of coal have occasioned controversy in that this is occurring at a time when the world is facing a critical energy situation. The argument is that in the wake of the Iran crisis and in the face of politically-inspired sanctions against South Africa this country should not be exporting the one energy source we do possess. The subject is a contentious one with a high emotional content, and the belief is expressed that the conservation of resources for the future is an overriding end in itself. Burnton (20) summarises the argument as:

- why export our best coal when the resources are stated to be limited (as in the Petrick Commission Report)?
- we are selling our birthright for a mess of pottage,
- our coal resources form part of a capital resource which belongs to our children as well as to us. We should conserve our precious energy resources instead of shipping them to foreigners.

There are several replies to these arguments:

- coal exports make economic sense from two standpoints, revenue and employment. Export prices greatly exceed inland prices without which the viability of the coal industry would be in doubt. South Africa must earn the foreign currency it needs to pay for imported capital goods which will generate its future energy and, indeed, for the increasing oil-import bill. There is currently no additional prospect of any other export industry able to earn foreign exchange on the scale that coal can. In addition, the production of 44 million tonnes of coal creates job opportunities for about 15 000 people at the collieries alone, as well as about the same amount in the supply and infrastructure industries. In a time of high unemployment creating political tension this is a positive move (21). It is the greater profitability of export coal which has primarily been responsible for the modernisation of the industry in the form of wide-scale mechanisation, research, training, and improvements to working and living conditions of its employees.
- subsequent criticism of the Petrick Report now puts our coal reserves much higher than its conservative estimates. Extracable reserves of over 50 billion tonnes would take well over 1 000 years to exhaust if we exported all our coal at the Stage III rate. Put in another way, after over 100 years of supply only 10 per cent of our coal would have been exploited. "There may be those who are concerned about the situation in over 1 000 years time, but most of us have got more immediate worries" (22).
- coal is going to "take off" as an energy source in the next 10-20 years while nuclear and other technologies are being perfected. In perhaps 30 years time the demand for coal will then level off. We should, therefore, make optimum use and extract maximum economic benefit from our coal resources whilst we can, for in 30 years time we may have the coal but nobody to export to (23). "The primary role of coal is one of bridging the energy gap between the present oil-dominated age and the

energy technology of the future. Coal's real importance is, thus, historically speaking, shortlived" (24).

and does not necessarily deplete our coal-reserve base. On the contrary, the higher earnings from export sales, by encouraging the employment of high-extraction production methods, have increased the extracable-reserve base.

is a problem for the free world. The fact that South Africa can become a reliable supplier of what it has to offer will strengthen our strategic position, and also help to justify our claim on oil supplies from other countries. Isolation from international trade would be a sure path to national isolation (25).

The coal export controversy has been extensively debated in recent years. A searching examination of the issues involved are presented by (26) and Banks (27).

Carbonisation. Carbonisation is the process involved in the production of coke and gas through the heating of coal. This type of coal utilisation has grown steadily but not spectacularly, from virtually nothing in 1915 to approximately 10 per cent of total sales in 1927. The tonnage involved in that year was 4,8 million tonnes. By the late 1920's this had grown to 7-8 million tonnes, but as a percentage of total sales it had dropped to 6,4 per cent due to the rapid growth of other sectors.

The growth of coal carbonisation reflects the expansion of the country's metallurgical industries. It has been particularly marked since the early 1930's when ISCOR began producing but privately-owned steel mills have also played their part in the expansion.

The iron and steel industry does not utilise ordinary bituminous coal, but rather coke, which is an upgraded, high-carbon form of coal. Coke is used very largely in the smelting of iron ore, although it is also used by foundries and for other metallurgical uses. In its major applications coke is used both as a source of heat and as a reducing agent. In the blast furnace, besides these functions, it also serves to keep the burden open, so that the blast can be maintained.

Metallurgical coke is prepared directly from straight coking coal. Coking coal softens to a plastic mass on heating, swells, decomposition occurs and re-solidifies while gas is still being evolved. This plasticity or fluidity is the most important characteristic of coking coal, and coals which do not exhibit this property do not yield coke on heating (28). However, if straight coking coal is not available in sufficient quantities, metallurgical coke can alternatively be prepared from what is called "blend coking coal" as long as a certain proportion of relatively strong coking coal is added to the process. This type of coal is less plastic, of a lower rank, and contains more volatile matter. South African coking coal samples are classed as being of first-grade quality compared with the coking coals found in several other countries. Coke producers, therefore, are obliged to use medium to below-medium-quality coals in blends for the manufacture of metallurgical coke. In addition, the country's reserves of coking coal are small relative to the demand and the importance of conservation have to be upheld. For these reasons straight coking coals have traditionally been mixed with blend coking coals in the ratio of about 40:60.

Much concern has traditionally been expressed about the adequacy of South Africa's coking-coal reserves. Coal with reasonably well-developed coking properties is restricted to Natal, Witbank, and the Waterberg, and Soutpansberg-Pafuri coalfields. Straight coking coal occurs in some of the collieries in the Vryheid coalfield, and in the Durban Navigation Colliery area (Klip River) and to a lesser extent in a few other coal-mining areas in the Klip River coalfield. There are also reserves of straight coking coal in the Waterberg and Soutpansberg-Pafuri field. Blend coking coal also occurs in the Waterberg field and in the No. 2 and 5 seams of the Witbank field.

ISCOR has traditionally drawn its straight coking coal from its own colliery at Durban Navigation (production of 1,5 million tonnes in 1979), but to supplement its requirements it has been obliged to purchase straight-and blend-coking coal from the limited number of other collieries which are able to produce these grades. It has also commissioned a second mine, (Grootegeeluk) at Ellisras in the Waterberg field, to extract blend coking coal by open-cast. This colliery will also produce bituminous coal for general sale and will come into production in the early 1980's.

The production of gas and by-products can also be mentioned at this stage. Every tonne of coal carbonised yields approximately 283 m³ of gas with a calorific value of about 5000 Kcal/m³. During the purification of the gas various by-products can be recovered such as tar, pitch, naphtha, benzole, crude phenol, and ammonia, amongst others. In 1978, approximately 91 000 tonnes of coke-oven by-products worth R3,5 million were sold by ISCOR (29).

As regards the future, ISCOR has calculated that its coking-coal requirements will increase to 11,4 million tonnes in 1990 (30). Although the iron and steel industry is the major consumer of coke in the Republic, smaller quantities are used in the explosives industry, for the manufacture of carbides, and for general use. Other important consumers of coking coal are the African Metals Corporation and the Highveld Steel and Vanadium Corporation. The copper industry also uses fairly-large amounts of coal in the production of anode copper. Although it does not require coking coal it does, nevertheless, demand a high-grade coal. All these sources will face marked increases in the demand for coking coal and other coal for metallurgical purposes, and the Coal Advisory Board Report (31) estimated the demand could reach 20 million tonnes by the year 2000.

Discussion would not be complete without mention of the process of carbonisation to produce town gas for heating and individual purposes. There are five municipal or private concerns in Johannesburg, Cape Town, Port Elizabeth, Springs, and Grahamstown, which produce gas from coal. The coal used is not necessarily coking coal, but when it is used coke can be produced as a by-product and is often sold locally to domestic users. The amount of coal consumed by this process is, however, insignificant and is not expected to grow. SASOL also produces gas which is sold through GASCOR but this is examined later.

(vi) Industry. Industry is an important consumer of coal. There was rapid expansion up to the mid-1960's, and although expansion has continued since then in terms of absolute tonnage, the percentage it comprises of total sales has declined. Between 1967 and 1980 this percentage fell from 16,5 to 13,7 (having fallen as low as 12,5 in 1977), although tonnage consumed roughly doubled from 8,1 to 16,1 million tonnes.

These figures, of course, depend crucially on the classification of "industry". Strictly speaking they should include both ISCOR and SASOL since both are industrial-type operations. However, the Fuel Research Institute treats ISCOR separately under the classification of "carbonisation" and SASOL's coal consumption is split roughly 50-50 between "power" and "industry" since a considerable amount of coal is used directly in SASOL's power plant. For these reasons the figures for "industry" have risen less rapidly than would have been expected.

Generally speaking, the industrial use of coal can be divided into two categories: (a) direct combustion for heating and steam raising, for example, in the manufacture of cement, glass, and ceramics and refractories, and (b) coal conversion into other substances, for example, gasification, liquefaction, and the manufacture of plastics, chemicals, fertilisers, and explosives.

A CSIR investigation in 1963 revealed that under the FRI classification, the main industrial consumers of coal were the chemical industry (including SASOL), cement factories, brickmaking concerns, and engineering factories, with smaller quantities being used by fisheries and fish canneries, wine industry, textile industry, glass manufacturers, lime works, and the sugar industry (32). Since then, new business has come from a wide range of industries including paper, motor, brewing, and food industries (33).

Manufacturing industry expanded enormously during the 15 years after the Second World War becoming the major growth sector in the economy. This was not reflected to the same extent in the demand for coal as a fuel, however, due to increasing competition from fuel oil and electricity. Coal-burning power units have slowly been replaced by these cleaner and more-convenient forms of energy. However, since coal is the major fuel used in the generation of electricity, the switch from coal-burning units to electricity, as in the case of the Railways and the mining industry, has simply meant a change in the manner of coal utilisation, from direct to indirect consumers.

The SASOL I plant at Sasolburg was commissioned in the early 1950's to produce petrol from coal. It is tied to its captive colliery at Sigma mine which in 1979 produced 5,5 million tonnes of coal. Approximately 50-60 per cent is used for gasification, the rest is used for steam and electricity generation. In the mid-1960's SASOL embarked

on a R100-million expansion programme which concentrated on producing intermediate products for the secondary chemical industries. These products in turn allow a series of local factories to process new items ranging from paints to fertilisers. SASOL supplies approximately 600 South African industrial companies with raw materials and in 1978 exported chemicals to 33 countries. All this is apart from the oil and gas it produces as its primary function. The oil-from-coal plant produces both the lighter hydrocarbons such as liquid petroleum gas, petrol, and diesel oil, and the medium to heavy hydrocarbons such as naphtha upwards to waxes. During the chemical processes a surplus of methane gas is produced, which has proved to be more economical to sell as a fuel than to convert to other products. SASOL (through its subsidiary GASCOR) now supplies the Witwatersrand area with this gas. It has proved to be suitable for use in metallurgical works, potteries, and canning factories, and in certain engineering industries.

By 1985, SASOL II and III will be in full production at Secunda. The Bosjesspruit colliery has been developed to supply the Secunda plant and it will gradually build up to a maximum production of 27 million tonnes making it South Africa's (and possibly the world's) largest coal mine.

Coal has numerous uses as a chemical feedstock. It is the basic raw material for a wide range of products. Generally speaking, anything that can be made from oil can also be made from coal - it is merely a question of economic viability. Much of the chemical industry's impressive progress is attributable to coal, whether independently processed or turned into feedstocks by SASOL. The chemical industry has grown consistently at twice the rate of the overall economy. It contributes more than 5 per cent of the Gross National Product and employs 100 000 people. By 1980, 30 per cent of the industry's feedstocks were met from coal, a figure which had increased steadily since the oil crisis of 1973, and which is expected to reach 50 per cent by the mid-1980's.

"Aspirin, benzole, creosote, dyes, explosives, floor-covering ... one can run through the alphabet several times to try to keep pace with the ever-growing wealth of products from coal chemicals. Coal's by-products are sat on, eaten, looked at, read and used in a thousand different ways" (34). Much of the technology is not new; it has merely been re-discovered. Coal-based chemistry reached a high state of

development during Hitler's Germany, but with the advent of cheap oil, research was largely neglected until the 1970's. South Africa was one of the few countries which persevered with coal technology throughout the 1950's and 1960's, and is today a recognised world innovator.

In 1932, the African Explosives and Chemical Industries (AECI) opened a small plant at Modderfontein, using coke as the basic raw material to produce ammonia. Ammonia is used as a feedstock for fertilisers and explosives. Initially the plant produced 12 tonnes of ammonia per day, which by 1980 had expanded to 1000 tonnes per day, consuming 3000 tonnes of coal in the process, making it the largest coal-based ammonia plant in the world. It is also the world's only coal-based methanol producer. AECI has produced methanol alongside ammonia in small quantities since the early 1960's, and in 1980 produced 60 000 litres per day. Apart from its potential as an alternate fuel methanol has an important application in the production of formaldehyde which is used to make synthetic resins for the furniture industry. Other products derived from methanol are used in the manufacture of rubber - vulcanisation materials, plasticisers, perspex, local anaesthetic, insect repellants and fumigants.

In 1978, AECI and Sentrachem joined forces in the establishment of the Coalplex complex at Sasolburg, to produce polyvinyl chloride (PVC) via the "coal route" instead of from petrochemicals. PVC is a versatile plastic which is used to manufacture a range of products, including piping, insulation, footwear, clear-plastic bottles, vinyl-coated fabrics, luggage, car upholstery, and many other domestic items.

It is not possible in this thesis to go into any further detail regarding the type of technology used, the nature of the chemical processes employed, or the range of chemical products and industrial and consumer products produced by the chemical industry using coal as a basic raw material. Full details are provided in the articles cited in the references (35).

(vii) Power. Electricity is raised from coal in South Africa by several large industries (such as SASOL) for their own requirements, by local authorities, and by numerous local power plants, but by far the most important generator of electricity from coal is the Electricity Supply Commission (ESCOM). The amount of coal consumed for power purposes has increased from 10,7 million tonnes in 1952 to 58,9 million

tonnes in 1980, rising as a percentage of total sales from 38,6 to 50,1, although this has declined from 56,6 per cent achieved in 1972 basically because of the increasing proportion being claimed by the export trade. The magnitude of these figures is made the more remarkable when compared with a total of 2,9 million tonnes of coal consumed for electricity generation in 1934 (24 per cent of total sales) rising to only 6,4 million tonnes in 1946 (28 per cent of total sales).

According to the FRI division, 50 per cent of the coal consumed annually by SASOL is used for steam and power generation, and is categorised under "power". This total (in millions of tonnes) has increased from nil in 1954 to 1,4 in 1962, 2,0 in 1972 and 3,7 in 1979. Also categorised under "power" is electricity generated by municipal power stations, mainly in Johannesburg, Pretoria, Cape Town, Port Elizabeth and Bloemfontein. Coal consumption from this source grew from 1,5 million tonnes in 1950, to 3,0 in 1965, and reached 4,8 in 1973. Since then the total has stabilised at approximately 4,5 million tonnes and future expansion is not envisaged due to the policy of ESCOM. The remainder of the coal tonnage categorised under "power" is accounted for by ESCOM which is the country's largest single coal consumer, burning 43,3 million tonnes in 1979, or 44 per cent of total sales (57,7 per cent of domestic sales). These figures have increased from 7,0 million tonnes in 1950 (27,5 per cent of total sales), and 18,4 million tonnes in 1965 (35,9 per cent of total sales). The growth of ESCOM has come about not only because of the switch to direct electricity consumption from several sources (mining, railways, industries, households), but because of the natural growth of the economy, particularly since the Second World War, and the extension of the ESCOM network into rural areas and regions distant from the Eastern Transvaal coalfields.

A good deal of the coal consumed in ESCOM power stations is of comparatively low grade and the coal is consumed direct from the mine with no preparation beyond crushing, screening, and grinding. ESCOM's philosophy is that it is cheaper to transmit electricity around the country than to rail coal, so its policy is to locate stations on the coalfields which supply them. The stations are thus designed to suit the coal, rather than the other way round, as is common elsewhere in the world (36). Each power station receives its supply of coal direct from a "captive" or "tied" colliery. These collieries are not owned by

ESCOM. Rather the coal is mined by private enterprise (basically Anglo American, General Mining, and Rand Mines). These power stations, together with their tied colliery, are as follows (as at mid-1980): Vaal/Klip (Cornelia), Arnot (Arnot), Kriel (Kriel), Matla (Matla), Duvha (Duvha), Wilge (New Largo), Grootvlei (Springfield), Vierfontein (Vierfontein), Komati (Blinkpan), Hendrina (Optimum), Camden (Usutu), Ingagane (Natal Navigation), and Taaibos/Highveld (Coalbrook). Other power stations at Colenso, Congella, Umgeni, Hex River, West Bank, Witbank, and Salt River are served mainly by the coal-selling organisations.

The pithead power stations supply the base load for ESCOM's national high-voltage grid which interconnects all the major load centres and power stations. The power stations established in the coastal areas before interconnection was effected have been relegated to peak-load and emergency duty and better-quality coal is railed to these stations. Specially-designed boilers enable ESCOM to use practically "run-of-mine" coal - even low-grade coal - and this saves extensively on preparation costs provided that a sufficiently large block of coal is available of consistent quality. This is best assured by drawing coal from only one colliery and explains the trend towards pithead power stations. In addition, it simplifies the administration. Together with favourable low-price contracts negotiated on a long-term basis and the saving of transport costs these factors help to keep fuel costs reasonably low. The policy of situating the power station at a captive colliery also has the added advantage of providing the greater security of an uninterrupted supply of fuel - a matter of growing importance as larger generating units are installed.

The Future of Coal

The demand for coal in the future will depend upon the development of technological, economic, social, and political changes both domestically and overseas. It has already been noted that the Railways, the mining industry, and households have now become insignificant direct users of coal. This trend is certain to continue in the future as their indirect utilisation of coal in the form of electricity continues to expand. As regards the future of coal, therefore, emphasis can be placed solely on the four sectors of export, power, industry, and carbonisation.

The export market is particularly susceptible to political developments. Although contracts have been signed assuring South Africa of large export tonnages to the end of the 1980's, the course of developments beyond this is unknown. Greater political stability in Middle-East oil-producing countries together with less-dramatic escalations in the oil price and greater assurance of more-regular oil supplies to the Western nations would result in a decline in the demand for coal. However, the designs of Russian expansionism would seem to indicate that this is a remote possibility. Together with the fact that many countries have already made decisions on the substituting of coal-fired for oil-fired power stations having lives of 30 years and more, there would appear to be a healthy overseas market for coal well beyond 1990. However, several countries, notably France and Denmark, have been subject to political pressure to halt coal imports from South Africa as part of the overseas anti-apartheid policy. The course of these developments is difficult to chart. Certainly economic demands usually override political expediency. It has been observed in the past that liberal changes in South Africa are usually accompanied by a lessening of international pressure and hence the possibility of the success of these protests may be diminished as South Africa continues to make social, economic, and political reforms. Finally, coal exports will be bound to diminish as nuclear energy is perfected and commercialised, but this appears to be a development which will only assume prominence towards the year 2000.

Almost all studies point to a substantial shift over the period 1978-2000 to coal-based energy sources at the expense of oil producers. Coal is anticipated to account for 44 per cent of total world energy consumption as compared with 26 per cent in 1978. Oil is expected to fall to 26 per cent from 50 per cent, whilst nuclear power will rise to 14 per cent from 4 per cent. Hydro-electric power and gas make up the remainder of energy consumption (37). The World Coal Study (WOCOL) anticipates that in order to meet this swing, coal exports could surpass 700 million tonnes per annum by the year 2000 (38). South Africa will be the world's third-largest exporter behind the United States and Australia with a total of 80 million tonnes. The United States and Canada should collectively be exporting in excess of 200 million tonnes, Australia 100 million tonnes, and the EEC and COMECON countries around 75 million tonnes.

As far as the future of coal in the carbonisation process is concerned, it has already been noted that the iron and steel industry is set for major expansion during the next decade. Demand has traditionally been for coking coal. However, future demand for coking coal will depend not only on natural expansionary forces in the economy, but upon the nature of technological and competitive economic changes which could make possible the use of non-coking coal as a substitute. This involves the production of artificial coke. Any carbon which is sufficiently free from deleterious impurities, is strong, and of the correct reactivity can serve as an alternative to coke. One alternative is a carbonised briquette, or "form coke", that can be made from non-coking coal with a pitch binder, which is pressed and given a suitable heat treatment. This is an expensive process but could become competitive in the face of severe shortages and cost escalation of coking coal. The whole aim is to utilise non-coking coals for the manufacture of metallurgical coke suitable for a blast furnace. ISCOR has shown strong interest in this process and has commissioned two coal-briquetting plants at Vanderbijlpark and Newcastle costing R63 million in 1981 prices with the objective of briquetting some 40 per cent of its coking coal (39). When the plants come on stream in late 1982 they will convert low-grade metallurgical coal into coke briquettes at the rate of almost 9000 tonnes per day (40).

It is also realised that in the final issue, it is not necessary to use a blast furnace to produce iron. Direct reduction of iron ore is a distinct possibility. Horizontal furnaces fed with ore, fine coal, and fluxes, if necessary, can reduce iron ore to metal, and electric furnaces fed with ore and a suitable reductant - which could be char or anthracite - can also produce iron. A combination of these processes can also be used, as at the Witbank plant of the Highveld Steel and Vanadium Company. ISCOR has also displayed interest in this process and after extensive tests has decided to install what is believed will be the world's largest kiln direct-reduction plant at Vanderbijlpark. The cost, in 1981 prices, is calculated at R121 million and operations are scheduled for late 1984.

However, as far as the overall demand for coal is concerned, the use of form coke and direct-reduction methods represent changes in detail rather than in substance. Whatever the nature of technological and economic changes affecting the demand for coking coal, some form of

coal will continue to be used in very large amounts by the iron and steel industry.

The future industrial usage of coal can be examined under two headings: as fuel and as a chemical raw material. Fuel utilisation is expected to hold steady or even increase in the short to medium term, as a continuation of the effects of the oil crisis. The TCOA is of the opinion that at the present time "industrialists choose coal first as a means of providing energy" (41) and until at least 1985 the organisation expects an increased demand for large nuts used in producer gas plants and for "smalls" used in steam-raising boiler plant. In the long term, fuel utilisation depends upon technological, economic and political factors, but is generally expected to decline even though economic expansion until the end of the century is expected. Industry will increasingly replace its coal-burning units with electricity and other cleaner and more-convenient forms of energy thus becoming another major indirect coal consumer.

However, the utilisation of coal by the chemical industry as a basic raw material is another matter. Of particular significance are the massive expansions under way both by SASOL (petrol from coal) and AECI and other producers (methanol from coal). By 1985 the SASOL I, II, and III plants will be consuming in excess of 32 million tonnes of coal annually from the captive Sigma and Bosjesspruit collieries, and will be supplying an estimated 47 per cent of South Africa's petrol and diesel requirements as well as a host of chemical feedstocks especially ethylene. A SASOL IV plant is already an economic proposition and seems likely to be built after 1985, and, depending upon the threat of an international oil boycott, SASOL V may be under construction by 1990 (42). The Minerals Bureau has estimated that SASOL's demand for coal will rise to 39 million tonnes per annum by 1990, reaching 56 million tonnes per annum by the year 2000 (43).

Several producer consortiums have expressed interest in methanol-from-coal schemes. The most advanced is a venture by AECI, Amcoal, and Shell announced in 1980 to construct a plant in the Eastern Transvaal at a cost of R650 million to produce 1000 million litres of methanol annually (44). A second venture by Anglovaal, Middle Wits, Anglo Alpha, and Caltex, was still in the research and development stage in 1981. A third consortium of Gencor and Sentrachem is also well advanced in planning a coal-liquefaction project to be based on the Springbok

Flats. The attraction of methanol lies in its use as a substitute for diesel. The demand for diesel, compared with that for petrol, has been steadily rising mainly because of greater use of agricultural machinery and road transport. A traditional imbalance has existed in South Africa between the demand for petrol and diesel, to such an extent that excess petrol has been exported whilst excess crude-oil supplies had to be imported to meet the demand for diesel (45). Accordingly, the country has been politically vulnerable in the diesel-fuel area. However, methanol mixed with an additive already developed by AECI produces a fuel suitable for use in diesel-powered vehicles, without the need for engine modification (46).

These synthetic-fuel projects have been given greater urgency by the world energy crisis and also the possibility of politically-inspired trade (especially oil) boycotts and sanctions against South Africa. However, they could be adversely affected by developments already discussed namely greater Middle-East political stability and faster domestic change in South Africa. In addition, the discovery of large reserves of economically-exploitable natural gas and oil within South Africa would also reduce the urgency of these "fuel-from-coal" projects.

However, apart from its potential as a fuel, methanol acts as a promising starting point for chemical feedstocks. It could make possible the replacement of oil-based naphtha as a feedstock, and start a whole new chemical era (47). Chemicals derived from naphtha include ethylene, propylene, benzene, toluene, and xylene, which are used to produce a wide range of essential raw materials for the plastics and synthetic-fibre industries. However, such chemicals can be produced by passing methanol over a zeolite catalyst, already developed in the United States by the Mobil corporation (48).

Finally, the future of coal as a generator of electricity appears assured for several decades. ESCOM utilised 46,8 million tonnes of coal in 1980 and 53,0 million tonnes in 1981. By 1985, both the Duvha and Matla power stations will have reached full capacity, burning between 9-10 million tonnes of coal each, annually. By this time, ESCOM's consumption will have reached 66 million tonnes annually.

ESCOM's expansion programme over the period 1980-90 will double generating capacity to approximately 40 000 MW, which will probably be doubled again before the year 2000. To feed this capacity, coal

consumption, according to the latest estimates, will have reached 98 million tonnes by 1990 (49), 160 million tonnes by 2000, and 510 million tonnes by 2020 (50). Figures beyond 1990, however, become increasingly speculative. In addition to Matla and Duvha, the 1980's expansion programme incorporates six new coal-fired power stations due for commissioning between 1985-90. The four most advanced, in terms of planning, together with their captive collieries, are: Tutuka (New Bemark), Lethabo (New Vaal), Matimba (Grootegeeluk) and Khutala (Khutala). They are to be located, respectively, near Standerton in the Northern Transvaal, near Vereeniging in the Northern Orange Free State, near Ellisras in the Northern Transvaal, and near Kendal in the Eastern Transvaal. Two further stations, initially called D and E, but now alternatively named Majuba and Lekwe, complete the programme (51). The total cost of the programme is estimated at R14 000 million, in

addition to these developments, there is no indication that coal consumption for electricity generation will decline before the year 2000. Since most power stations have a 30-40 year life, and coal-fired stations will still be commissioned throughout the 1980's, it is therefore obvious that large amounts of coal will continue to be required for electricity generation well beyond the year 2000. An increasing percentage of electricity will gradually be provided by hydro-electric power and nuclear power but the course of these developments is difficult to foresee. In 1969 the Coal Advisory Board estimated that by the year 2000, hydro-electric power would account for 5 per cent of electricity generation, nuclear power 35 per cent, and coal-fired stations 60 per cent. This, however, was based on the assumption that after 1980, 50 per cent of all new plants would be nuclear-power stations. This is now realised to be over-optimistic. In 1976, the Department of Mines (53) made the more-conservative estimate of a nuclear contribution between 10-15 per cent by 2000. The Koeberg nuclear power station, scheduled for fuel loading in March 1982, but has experienced several delays, and according to some sources a second nuclear-power station will not be considered for commissioning during the 1980's (54). Other attributing future growth in power demand to three factors: further industrialisation, the electrification of black townships, and the swing from oil-based energy sources to electricity (55). Obviously many political and economic issues are

involved in the last factor including the price of oil, Middle-East stability, and politically-inspired boycotts. It is also clear that substantial gas or oil discovery in South Africa by SOEKOP would have significant impact on the energy situation.

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SECTION B
ENDOGENOUS FACTORS AFFECTING PRODUCTIVITY
CHAPTER THREE
ORGANISATION AND MANAGEMENT

The structure of an industry can have a significant influence on its productivity. Its organisation and management determine how it is run and are responsible for the type and quality of policy decisions made. There are three general systems of organisation which are employed world-wide in the coal mining industry, namely complete State ownership, various types of nationalisation (sometimes combined with a limited amount of private enterprise), and complete private enterprise (1). The industry has become a nationalised concern in many countries, particularly since the end of the Second World War, creating a large-scale industrial and administrative undertaking, which has brought with it complicated management problems and the inevitable stifling bureaucracy and lack of enterprise so evident in such concerns. However, even where the industry is mainly in private hands a strong central organisation is still required to give direction and formulate co-ordinated policy planning, and, in addition, the influence of the State can never be completely eradicated from all the industry's various activities. This is the case in South Africa. The ownership and exploitation of the coal has been left in the hands of private enterprise, co-ordinated by a central body (the Chamber of Mines) within the framework of Government planning and policy.

The Impact of the State

The Government's central role is to ensure the optimum utilisation of all resources (including coal) in an orderly and efficient manner, in the national interest. It must ensure the continuing availability of mineral supplies (again, including coal) mainly for the country's own use but also for world consumption. By promoting and maintaining political stability and economic development, the State creates conditions which provide a framework within which private enterprise can operate in order to develop and exploit the resources of the country. Government influence on the industry has traditionally been felt through the Department of Mines, but other Ministries have also exerted some influence (for instance, Manpower Utilisation, Commerce and Industries).

There are four Acts of Parliament which directly impinge upon various activities of the coal mining industry:

- (i) the Mines and Works Act, No. 27 of 1956, which creates the post of the Government Mining Engineer and which tightly regulates the working conditions, and the safety, health, and welfare of employees in the industry,
- (ii) the Price Control Act, No. 25 of 1964, which regulates the internal selling price of coal in the Republic,
- (iii) the Fuel Research Institute and Coal Act, No. 35 of 1963, which establishes the Fuel Research Institute and regulates the export of coal,
- (iv) the Mining Rights Act, No. 20 of 1967, which regulates the ownership of mining rights and mining title, and the mining of coking coal.

The Minister of Mineral and Energy Affairs, Mr. F.W. de Klerk, claimed in May 1982 that the State's "enlightened mining and mineral legislation" had "assisted in the flowering of an indigenous mining industry". He stated that as a matter of State policy, "the Government has always propagated liberal mining policies which recognise the benefits of the free-enterprise system and the need for a fair return on investment" (2). Thus legislation encompassed aspects like security of title and guaranteed mining rights to successful prospectors, realistic lease conditions related to economic viability, as well as accommodating fiscal arrangements. However, true to the principles of the free-market system, the Government's intention was not to infringe on the terrain of the regular financing institutions by providing financing to mining operators, except in the form of temporary assistance under exceptional socio-economic conditions.

As part of the organisational rationalisation of the Public Service the energy functions of several separate Departments were consolidated under the umbrella of the Department of Mines in 1980 which was re-named the Department of Mineral and Energy Affairs. "For the first time in the history of the public administrative system in South Africa all energy-related functions are not only housed in one and the same department, but are housed in a department which is responsible for both

the mineral and the energy policy of the country. Since coal is South Africa's most important source of energy, the combination of the minerals and energy functions is of great importance for effective determination of policy by the Government on a co-ordinated basis" (3).

Accordingly, the Department of Mineral and Energy Affairs, through its Energy Branch, is the executive Government agency charged with the formulation and execution of a national energy policy. The functions of the Energy Branch, as summarized by the Commission for Administration, are,

- determine present and future energy demands,
- determine energy sources and potential sources of energy,
- arrange for the satisfaction of the country's energy requirements,
- initiate energy conservation measures.

The State's energy policy is directed towards attaining the highest degree of energy self-sufficiency for the country within the framework of balanced strategic and economic priorities. South Africa's energy strategy, therefore, as it relates to coal, embodies various interrelated elements aimed at ensuring the following,

- an uninterrupted energy supply at reasonable cost, from both domestic and foreign sources,
- optimal extraction of coal to provide for adequate future supplies,
- exports of reasonable quantities of energy carriers, notably coal and uranium, to enhance foreign-exchange earnings,
- the active pursuit of energy conservation in all sectors,
- research and development on a level commensurate with the various policy objectives and priorities,
- continued further development of the local synthetic-fuels industry, preferably by the private sector,
- appropriate long-term energy-policy planning to provide for, in particular, orderly and timely phasing in of alternative energy sources.

It is stressed, however, that even though the State has assumed important responsibilities and executive powers relating to energy management, acquisition, and distribution, the private sector is

essentially responsible for the exploitation of the country's energy resources and for the distribution and sale of energy commodities, necessitating close consultation on matters of common concern between the two sectors (4).

In order to carry out its tasks and efficiently discharge its "umbrella" function the State operates through the medium of specially-constituted positions and organisations.

Of particular importance is the Minerals Bureau, established in 1975, with the task of advising Government on the formulation of an appropriate and feasible mineral policy. The ultimate objective is a "total mineral strategy", so that the Bureau's activities are geared towards identifying appropriate mineral-policy priorities on which policy decisions can be based. The Bureau's advice to Government is based upon mineral-economic studies of a multi-disciplinary nature in order to acquire in-depth knowledge of the world mineral industry. One of its major tasks concerns the collection and analysis of all kinds of data and information related to the minerals industry. In this way the Bureau provides a "minerals-intelligence" service to Government. This is concerned not only with economic and technological factors, but also political and strategic relationships. This creates a complex web which makes the forecasting of developments in the mineral field a difficult task. Nevertheless, the development of a framework which can be used to predict future mineral-related problems and to assess existing and alternative policies so as to overcome these problems, is a continuing process within the Bureau.

One of the tasks of the Minerals Fuels and Energy Division of the Bureau is concerned with technical and mineral-economic developments affecting the supply of and demand for coal, for instance, reserves, mining, processing, conversion, distribution, use, exports, and so on. These factors are assessed and trends are identified that could affect the development of national coal and energy policies. (Since 1980 this Division has been designed to complement and work in close liaison with the Energy Branch of the Department of Mineral and Energy Affairs). A significant objective of the Bureau is to develop a computerised national coal-data base and information system, capable of supporting mineral-and energy-policy analysis and implementation. Such information includes: borehole data and national resources and reserves; coal-mine locations; mine-by-mine data on mining methods, output, sales, labour

statistics, marketing, environmental factors, etc; coal-supply and demand analyses and forecasts; coal preparation and beneficiation; internal transport requirements and infrastructure; coal utilisation; coal quality; coal conversion; and coal economics, such as financial data, prices, and macro-economic data.

In the collection and analysis of information the Bureau acts in close co-operation with both the Geological Survey and the Fuel Research Institute, which, in themselves, provide a significant service to Government. The major task of the Geological Survey is the geological and geophysical mapping of the Republic. It also indulges in data collection, research on gathered data, and the prompt release of information in order to stimulate dynamic exploration by the mining industry. With regard to coal it is mainly engaged in the drilling of boreholes in order to discover information on the structure and stratigraphic correlation of coal seams, and the resource and reserve figures of coal-bearing areas.

The Fuel Research Institute is a statutory, corporate body, originally established in 1930 but now constituted in terms of the Fuel Research Institute and Coal Act of 1963. The statutory objects of the Institute are to study and investigate the fuel resources of the Republic and to undertake scientific and technical research on all matters relating to fuels in general or fuel by-products. It also tests, analyses, and grades coal and coal products. From time to time it publishes details of the grades of coal available in the country. In similar manner, the work of other statutory bodies such as the National Institute of Metallurgy and the Council for Scientific and Industrial Research occasionally conducts research into activities related to coal and coal mining.

In terms of section 2 of the 1956 Mines and Works Act, supervision over all mines, works, and machinery is exercised by the Government Mining Engineer, and, subject to his directions, by the Deputy and Assistant Government Mining Engineer, inspectors of mines, inspectors of machinery, and other officers appointed for the purpose under the 1967 Mining Rights Act. He is ultimately responsible for the enforcement of the provisions of the Mines and Works Act and its Regulations as they relate to safety, health, welfare, and working conditions (5). He monitors, and publishes in the form of an annual report, such developments as labour trends, wages, accidents and their classification

(including fires, explosions, and roof falls), mine air, airborne dust, and gases. He also chairs the Mine Safety Committee, a statutory body, which offers advice on the supervision to be exercised over mines in relation to practices likely to affect the safety or health of mining employees.

The Government Mining Engineer also acts as chairman of two other Government-inspired organisations - the Coal Advisory Board and the Coal Mining Research Controlling Council (6). The former was constituted in 1950 to advise the Minister of Mines on all matters relating to coal, especially coking coal. Its members represent other interested organisations such as the Geological Survey, Fuel Research Institute, and the coal-marketing concerns. The latter exercises a directing and co-ordinating function in specific avenues of research in regard to coal-mining matters. Its primary aim is to foster optimum coal exploitation subject to the maintenance of adequate safety standards.

From the nature of the above discussion it can be seen that the State does not directly concern itself in the mining, preparation, and marketing of coal. However, there has been speculation in the past concerning the possible establishment of a national coal board to control and restrict coal sales in the face of the uncertainty over the long-term adequacy of coal reserves (7). Such speculation has not been realised. The idea did not find favour within the industry. Richard Bird, the Managing Director of the Transvaal Coal Owners' Association, reacted in typical fashion: "I do not know of any case where the nationalisation of an industry has been an accepted improvement" (8). However, at the end of June 1980, the Minister of Mineral and Energy Affairs announced the formation of a Minerals' Policy Committee which will be concerned with the optimal utilisation of the Republic's minerals (9). This has been prompted by the complexity of the mining industry and the desire for a "sensible future development of the mining industry". The Committee will be chaired by the Minister of Mineral and Energy Affairs and its members include representatives from private enterprise and Government bodies.

It will be specifically concerned with the development and marketing of minerals, technological developments, co-ordination of exploration, problems of infrastructure such as railway services, pricing policies and beneficiation. Despite the private-sector representation on the Committee and the fact that all decisions will be

made in a spirit of consultation between the Government and the private sector, nevertheless the wide-ranging brief of the Committee, covering the broad spectrum of mining activities and problems, and the importance of this brief, must ultimately represent some degree of government intrusion into the activities of private enterprise.

The Impact of Private Enterprise

The independence of the coal mining industry from State intervention in the mining, preparation, and marketing of coal has largely been facilitated through the existence of strong, stable, and efficient private organisations in these areas. The industry has largely been self-regulating. It has been left free to set its own production and quality standards, to develop new markets and consolidate existing ones, to establish organisations for promoting markets, and to apportion sales among producers. It has also been allowed freedom in the conduct of research, the choice of mining methods, and the purchase of raw material; and equipment.

(a) Mining of Coal:

The structure of the industry is basically one in which groups of mines are administered by mining finance houses which are ultimately responsible for policy decisions regarding the exploitation of coal. Through separate divisions these finance houses provide a range of specialist services to individual mines and groups of mines. The main interest of the mining houses is in gold, and coal has tended to occupy only a subservient role. Historically, the major coal-producing areas came directly under the ownership and control of the gold-mining houses to meet the demand for power required to carry out hard-rock mining and milling. This soon led to the acquisition and development of known coalfields by the mining houses.

Large-scale gold mining towards the end of the last century could not have developed without a high degree of skilled organisation and control, and the provision of large sums of risk capital. Without this, profitable exploitation of deep and mainly low-grade reefs would not have been possible. Correspondingly, there evolved at an early stage a system of collective organisation in the mining industry known as the "Group System" which developed around finance corporations, each of

which administered a group of mining and other companies. The entity is referred to as a "group" which takes the name of the controlling or parent corporation. Each company within each group is a separate entity with its own shareholders and board of directors. However, the finance corporation provides the companies collectively with a wide range of services at a lower cost than the mines could otherwise obtain them, such as accounting, secretarial, buying, and technical, the latter including consulting engineering, geological and surveying, research, and so on. It is also able to provide risk capital far beyond the resources of the individual companies (10).

The pooling of resources, skills, ideas, and knowledge within each group has enabled the rapid accumulation of mining expertise and techniques. The development of highly-skilled manpower and the incorporation of technical advances on a group basis has also facilitated growth and productivity in the industry. In addition, the accumulation of skills and capital within the group system has enabled the finance corporations to effectively diversify into other industrial undertakings especially in mineral processing and manufacturing industry. Some of the groups have also extended their activities onto an international level (11).

Of the 89 collieries and coal producers operating in 1979, a total of 37 were administered by small independent companies, and contributed an insignificant amount to the country's total coal output. The remaining 52 were grouped either under a mining finance house or were administered by ISCOR or SASOL. Table 3.1 below reveals that total coal sales tend to be dominated by two finance houses - Anglo American and General Mining - which in 1979 produced over 63 per cent of total sales from 29 collieries. This figure rises to 76 per cent when the 11 collieries administered by Rand Mines are added.

TABLE 3.1 1979 SALES PRODUCTION: ACCORDING TO CONTROLLING CONCERN AND PROVINCE

CONTROLLING CONCERN	R.S.A.		TRANSVAAL		O.F.S.		NATAL	
	NO. OF MINES	MILLION TONNES %	NO. OF MINES	MILLION TONNES	NO. OF MINES	MILLION TONNES	NO. OF MINES	MILLION TONNES
ANGLO AMERICAN	17	36,2 34,5	10	28,4	3	5,5	4	2,3
GENERAL MINING	12	30,3 28,8	8	23,4	1	3,5	3	3,4
RAND MINES	11	12,8 12,2	7	11,0	-	-	4	1,8
JCI	3	3,9 3,7	3	3,9	-	-	-	-
LONRHO	4	4,0 3,8	2	3,5	-	-	2	0,5
GOLDFIELDS	1	2,5 2,4	1	2,5	-	-	-	-
ISCOR	2	1,5 1,4	1	0,0	-	-	1	1,5
SASOL	2	7,3 6,9	1	1,8	1	5,5	-	-
OTHER PRODUCERS	37	6,7 6,3	13	2,1	-	-	24	4,6
TOTAL	89	105,2 100	46	76,6	5	14,5	38	14,1

Source: derived from Minerals Bureau, Coal Mines in the Republic of South Africa, Department of Mineral and Energy Affairs, Directory No. 2/80, July 1980, pages 2-25.

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