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The mining of South African thick coal seams: rock mechanics and mining considerations

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THE MINING OF SOUTH AFRICAN THICK COAL SEAMS - ROCK MECHANICS AND MINING CONSIDERATIONS

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for the degree of Doctor of Philosophy.

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ABSTRACT

The thesis aims to provide a foundation on which to base decisions concerning the implementation of efficient underground mining methods for thick coal seams in South Africa. For the purposes of this work a thick coal seam is defined as 'any seam more than 4 m thick'. However, a number of multi-seam situations where the parting between seams is less than 4 m thick and the seams are at least 2 m thick, have also been included in this definition.

In terms of the above definition, it was calculated using reserve estimates of the 1975 Commission of Enquiry into the Coal Resources of the Republic of South Africa that thick coal seams constitute over 50 per cent of the country's coal reserve. Less than 20 per cent of this reserve can be extracted by utilizing present underground mining methods. Since coal supplies approximately 75 per cent of the country's energy requirement, the need for efficient thick seam mining methods in South Africa is obvious.

Until recently, the introduction of such methods was restricted by severe economic constraints, supported by the opinion that South Africa's coal reserves were virtually inexhaustible. Only limited research has been conducted previously which necessitated that extensive investigations be undertaken.

Thick seam mining methods which have become established in countries throughout the world are identified. They are classified in terms of two criteria, namely an extracted seam height and roof strata behaviour, which take the form of a 3 x 3 matrix. The geologic and economic characteristics and requirements of each of the methods are evaluated and tabulated with local geologic and economic conditions for later comparison.

Much of the information required concerning geologic conditions in the 12 coalfields which contain thick seam reserves was not available at the beginning of this study. Consequently, an extensive field investigation was undertaken to assess these conditions. It has been restricted to those coalfields where the economic potential for introducing thick seam mining methods exists. These coalfields are the Springs-Vischkuil-Witbank Coalfield, the Highveld Coalfield, the South Rand Coalfield and the Vereeniging-Sasolburg Coalfield.

Information pertaining to geologic conditions in thick seam regions in these coalfields is tabulated in a similar format to that pertaining to the geologic characteristics and requirements of established thick seam mining methods. Comparisons are made between these two sets of information to identify methods which are feasible technically in each of these regions. However, a number of practical problems are associated with implementing these methods. For example, the effect of a mining method on overlying mineable seams, available markets for coal and sources of stowing material. Those methods which are practical even in the light of such problems are identified and their economic viability is assessed. This assessment is based on comparisons between the economics of these methods and the economics of mining methods currently employed in moderately thick (2-4 m) seams in South Africa.

An examination of the practical problems highlighted the need to investigate two ancillary areas if this thesis is to achieve its aim. These are the use of power station ash as a stowing material and the influence of massive dolerite sills in the superincumbent strata on thick seam mining methods and operations. Research into power station ash has revealed that it has self-cementing properties when mixed with water. This feature is extremely advantageous when ashfill is incorporated into bord and pillar based mining methods. The lateral confinement provided by the ashfill to coal pillars

increases their strength and, depending on depth and seam thickness, enables an additional 5 to 30 per cent of thick seam reserves to be extracted.

Investigations have revealed that dolerite sills greater than 30 m thick can bridge over spans in excess of several hundred metres. A combination of strata control and economic considerations dictates that when mining methods which result in caving of the roof strata are employed, such sills should be induced to fail during the initial stages of mining. However, the panel widths typical of many thick seam mining methods are insufficient to induce failure. Consequently, massive dolerite sills significantly influence the potential of these methods. A possible solution to this problem is to induce failure of a sill by extracting an upper coal seam or coal horizon prior to the introduction of thick seam mining methods.

It is concluded that most established thick seam methods that achieve very high percentage extraction (>70 per cent) are not viable under present conditions because of their high capital cost, low rate of production and low productivity. With the exception of stope mining, viable thick seam mining methods tend to be based on methods used presently to extract local moderately thick (2-4 m) seams. The overall percentage extraction that could be achieved at present using those viable methods which maintain the integrity of the roof strata typically ranges from 30 to 50 per cent, while 40 to 70 per cent overall extraction could be achieved using methods which result in caving of the roof strata.

As such, research findings presented in this thesis provide the basis for at least doubling the overall percentage extraction in thick seams under present relatively restricted economic conditions. These findings can also be applied to increasing further the overall percentage extraction of thick seams as and when economic conditions improve.

I declare that this thesis is my own work and has not been submitted previously as a dissertation or thesis for any degree at any other University. The work for this thesis was undertaken while I was employed in the Research Organisation of the Chamber of Mines of South Africa.

J. Galvin

(James Maurice Galvin)

Dated this 7th day of October, 1981.

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LIST OF SYMBOLS AND NOTATION

A	area
B	bord width
C_o	uniaxial compressive strength
C_v	face convergence (m/m face advance)
C_vT	face convergence (mm/m face advance)
D	depth to a seam (or workings)
D_D	depth to the base of a dolerite sill
e	percentage areal extraction
E	modulus of elasticity (Young's modulus)
E_d	modulus of deformation
E_F	effective modulus of deformation of fill
E_l	modulus of deformation of a layer of fill
E_R	modulus of elasticity of surrounding strata
E_S	modulus of elasticity of seam
g	gravitational acceleration
h	pillar height (in-situ and model)
H	face height
k_F	fill stiffness
k_S	stiffness constant
k	strain magnification constant
K	material constant
l	length
l	convergence
L	load
m	analogue scaling factor
p	subsidence factor
PM	load bearing capacity of a longwall support

$\bar{q}_{max}$	maximum average pillar load
q_{mod}	modified cover load
R	pillar width:height ratio
S	minimum panel dimension required to induce failure of an overlying dolerite sill (analogues to failure span of a thin elastic plate)
S_{eff}	effective unsupported span of a dolerite sill
t	thickness of a plate
t_D	thickness of a dolerite sill
t_l	thickness of a layer of fill
t_p	thickness of parting between a seam and an overlying dolerite sill
t_{ps}	thickness of parting between adjacent seams
t_s	seam thickness
T	total fill thickness
V	pillar volume
w	pillar width
Δw	lateral pillar expansion
W	weight of strata
w_{min}	minimum interpanel pillar width
α	caving angle of strata
ε_H	lateral model pillar strain
ε_f	lateral fill strain
ε_p	lateral pillar strain
ε_v	vertical pillar strain
ν	Poisson's ratio
ρ	density
σ	stress
σ_A	lateral ash pressure
σ_F	fill reaction

p	vertical pillar stress
v	virgin stress
z	vertical stress
zm	maximum axial stress
3	confining pressure
	dimensionless factor

CHAPTER 1

THE STATUS OF COAL IN THE SOUTH AFRICAN ECONOMY

1.1 Introduction

During the last decade the realization that oil reserves are approaching depletion, combined with related oil price increases and the lack of significant progress in developing alternative sources of energy, has resulted in renewed interest in coal as an energy source. Consequently, plans for the expansion of coal production capacity are universal, with world production expected to double before the end of the century.

Viewing the South African coal mining industry against this background, a number of important differences are seen. In particular, the economics of coal mining and the utilization of coal in South Africa are significantly different to those associated with other semi-developed and developed countries. An appreciation of these rather unique factors is an essential prerequisite for conducting research into coal production in South Africa.

1.2 The Present Utilization of Coal

Coal is South Africa's primary source of energy, supplying approximately 75 per cent of the country's energy requirements. Approximately 95 per cent of South Africa's electricity is generated by means of coal-fired power stations. In 1980, almost 45 per cent of the annual saleable coal production of 115 million tonnes was employed in electricity generation.

A further 25 per cent of the annual coal production was exported. These exports were valued at 687 million rands, making coal the country's second largest earner of foreign exchange.

Coal liquefaction plants consumed over 11 per cent of the 1980 coal production. This utilization of coal not only supplements the country's liquid petroleum import needs, but is also a source of chemical feedstocks for many other industries.

Obviously, coal has contributed considerably to the economic development of South Africa. This contribution is significantly different to that of coal in other countries throughout the world. For example, in 1977 the world as a whole generated only 32 per cent of its energy requirements from coal (Peters and Schilling, 1978) whilst, generally, coal liquefaction plants elsewhere are still at an experimental stage. Furthermore, South Africa is currently the second largest exporter of steam coal (Granville and Murray, 1979) and the fourth largest exporter of black coal in the world.

1.3 The Development of the South African Coal Mining Industry

In order to evaluate the future role of coal in the South African economy it is necessary to review briefly those factors which have resulted in the present importance of coal.

South Africa's very large dependence on coal as a source of energy arose primarily because the pithead price of coal in this country has always been amongst the lowest of any semi-developed or developed country in the world. In 1974 the average pithead price of bituminous coal ranged from R2,350 to R2,580 per tonne, whilst in 1978 it ranged from

R7,535 to R7,760 per tonne. In comparison, the average production cost of coal produced in France in 1977 and in Britain in 1978 was of the order of R45,50 (Jamme, 1978) and R43,50 (Kerstan, 1979), respectively.

A combination of geologic and economic factors account for the low price of South African coal. Generally, coal deposits are extensive, thick, shallow, and flat dipping with good roof conditions, and are thus suited to the bord and pillar method of mining. Because this mining method leaves coal pillars to support the superincumbent strata, the cost of artificial support is minimal. In addition, these pillars prevent surface subsidence and so there is no need to purchase surface rights or to pay compensation for mining induced surface damage. This method of mining also offers great operational flexibility and, consequently, in conjunction with a cheap and plentiful labour supply, it was widely adopted and refined by early mining operations and resulted in very cheap coal.

The production of cheap coal meant that energy was also produced cheaply. The introduction of price control in 1950 ensured that the cheap energy policy was maintained in order to promote economic development. The policy was aimed particularly at ensuring the survival of the developing gold mining industry, an important source of foreign exchange but a very large consumer of energy which, today, is the backbone of the South African economy.

Unfortunately the method used to determine the controlled price of coal resulted in an artificially low coal price, and this had a very detrimental effect on the growth of the coal industry. The coal price was based on a sample of mines and determined to be that price which covered the cost of production and gave a return of 12,5 per cent on the depreciated capital value of the mines sampled. This meant that a smaller return on capital invested was calculated for a mine as it became older. However, the capital costs to

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The production of cheap coal meant that energy was also produced cheaply. The introduction of price control in 1950 ensured that the cheap energy policy was maintained in order to promote economic development. The policy was aimed particularly at ensuring the survival of the developing gold mining industry, an important source of foreign exchange but a very large consumer of energy which, today, is the backbone of the South African economy.

Unfortunately the method used to determine the controlled price of coal resulted in an artificially low coal price, and this had a very detrimental effect on the growth of the coal industry. The coal price was based on a sample of mines and determined to be that price which covered the cost of production and gave a return of 12,5 per cent on the depreciated capital value of the mines sampled. This meant that a smaller return on capital invested was calculated for a mine as it became older. However, the capital costs to

establish a new mine continued to increase. The coal price was too low to cover these increasing costs and so few new mines were established. Thus, the coal price continued to be based on the capital value of old mines with the result that the capital employed per annual tonne of production, after depreciation, was calculated to be less each time the coal price was reviewed. For example, Wassenaar (1977) reports that in 1957 this figure was calculated to be R3,30 whilst in 1976 it was calculated to be only R2,58. However, the capital cost of establishing a new mine in 1976 was in the order of R20 per annual tonne of production. Therefore, it is not surprising that, excluding collieries tied to the Electricity Supply Commission (Escom) power stations through cost escalation contracts, only two new collieries were established for domestic coal supply between 1954 and 1977. (Granville, 1979, personal communication).

Besides effectively preventing the expansion of the coal mining industry, the low coal price meant that the bord and pillar mining method was the only economically viable method for mining the large, low grade, coalfields in the Transvaal and Orange Free State, which account for over 85 per cent of the country's coal production. At shallow depth and moderate seam thickness this mining method is, even today, difficult to improve on for efficiency, cost effectiveness and percentage extraction. However, as the depth of mining and/or seam thickness increased, bord and pillar mining resulted in a rapid decrease in percentage extraction, Fig. 1. In addition, reserves in seams adjacent to bord and pillar workings were often sterilized due to adverse interaction consequent upon leaving pillars. Selective mining was also practiced extensively, with only the higher grade seams and horizons within seams being extracted to maximise revenue and to avoid additional washing costs. Thus, the overall percentage extraction which has been achieved on many collieries to date is as low as 20 per cent.

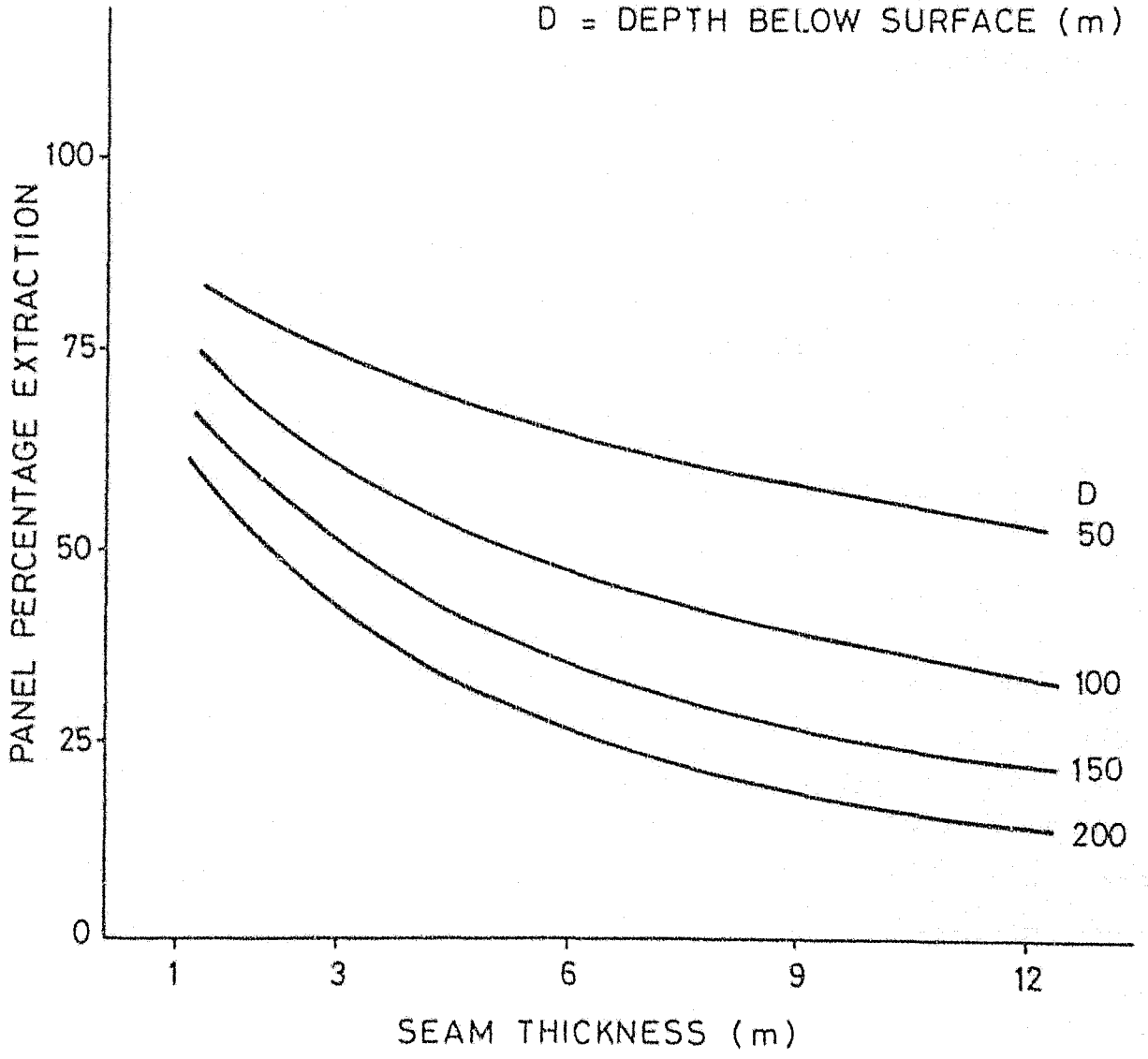


FIGURE 1 Influence of depth of mining and seam thickness on percentage extraction achieved by bord and pillar mining (based on Salamon Pillar Design Formula, Salamon (1966b)).

The cheap price of coal, and its widespread distribution, also resulted in much wasteful usage of coal-derived energy, and led to the view that the Republic's coal reserves were inexhaustible. Therefore, it was not surprising that the Coal Advisory Board's 1969 report (van Rensburg et al, 1969) created much concern when it concluded that the amount of extractable bituminous coal under the then prevailing technological and economic conditions was 12 619 million tonnes, which was very much smaller than originally thought, and indeed not inexhaustible. The concern expressed in the report at the low percentage extraction of coal at most collieries, and the urgent need to conserve coal, led to the appointment in 1970 of the Commission of Enquiry into the Coal Resources of the Republic of South Africa, better known as the Petrick Commission (Petrick et al, 1975).

This Commission conducted a comprehensive computer based analysis of the coal resources of the country based on 1972/73 borehole information, and concluded that, under prevailing or slightly improved economic and technologic conditions, 24 915 million tonnes of the 81 274 million tonnes of in-situ mineable bituminous coal were extractable. That is, only 31 per cent of in-situ coal reserves were economically and technologically recoverable at the time. Concern was also expressed at the 'shockingly low' volumetric extraction (in some extreme cases amounting to less than 10 per cent) that was being achieved in most South African collieries. It was concluded that reserves were exhaustible, and that as a result of the 1973 oil crisis, domestic demand for coal would be considerably greater than was previously estimated.

The Commission also concluded that the low price obtained for coal was the principal reason for the very low percentage extraction. Whilst proven technology existed for achieving high percentage extraction, such mining systems required heavy capital expenditure for up to two or three years prior to production. However, capital was scarce and could only be

obtained at high interest rates. Since return on investment was delayed and poor, due to low coal prices, these ventures were not economically viable. Consequently, the Commission recommended that the whole system of price control for the mining industry be revised, that the price of coal be substantially increased in order to allow much needed expansion in coal mining productive capacity, that steps be taken to enable coal mining companies to obtain the surface rights to coal-bearing land at reasonable prices, (to encourage high percentage extraction), and that all possible steps be taken to eliminate the wastage of coal.

Many of the Commission's recommendations were implemented. The method of determining coal prices was revised and prices have been increased by over 300 per cent during the last five years. Grade A coal (28,5 MJ/kg) now sells for R11,415 per tonne and Grade D coal (25,5 MJ/kg) sells for R10,200 per tonne. Whilst the immediate effect of higher coal prices has been an increase in output from established collieries, these prices have also enabled some collieries to give consideration to employing alternative mining methods to bord and pillar mining in order to increase percentage extraction.

In particular, pillar extraction and longwall mining are beginning to be utilized in moderately thick (2-4 m), low grade coal seams. Caving of the superincumbent strata can be tolerated because the higher coal price permits mining companies to either purchase surface rights or at least compensate for surface damage. The higher coal price offsets the additional cost of artificial support associated with pillar extraction and has permitted the introduction of continuous miners on a limited basis. The rapid rate of pillar extraction achieved by these machines minimises strata control problems, thereby significantly increasing the success and productivity of such operations.

A total of five longwall installations have been commissioned in moderately thick low grade coal seams since 1975. Two of

these installations are located in long established collieries where a combination of weak roof, moderate seam thickness and depth make bord and pillar mining an uneconomic proposition because of low production, low labour productivity and high working costs. Cloete and Halgreen (1981) report that in terms of cost per tonne of coal extracted these longwall mining operations are currently not as economically viable as bord and pillar mining, primarily because inflated engineering costs have negated savings in labour and mining costs.

However, the authors also note that a value should be assigned to the additional percentage extraction obtained from longwall mining since, in the long-term, this additional coal would have to be obtained from alternative sources. This aspect together with savings accruing from a reduced areal extent of workings is of most importance when a colliery is the sole supplier to a large utility, such as a power station or liquefaction plant, for the life of the utility. Recent developments highlight these considerations. Despite uncertainties concerning the present economic viability of longwall mining a further five, and possibly nine, longwall installations will be commissioned within the next five years at two collieries which, combined, are required to produce over 37 million tonnes of coal per annum for at least the next 40 years to supply fixed local markets.

It is apparent that the economics of South African coal mining have improved significantly since the publication of the Petrick Commission Report in 1975. However, whilst established colliery operators may benefit as a result, the improved economic situation is of little benefit in developing the South African coal industry unless markets exist in the future for the increased coal production. Therefore, the future role of coal in the South African economy needs to be evaluated before any research into improving local coal production can be justified.

1.4 The Future Utilization of Coal

Despite widespread exploration for over 10 years, no commercial quantities of petroleum and natural gas have been discovered in South Africa. In the interim the country's oil imports continue to be susceptible to increasing prices, sanctions and embargoes, and the rapid and ultimate exhaustion of world crude oil reserves. Without the development of breeder technology, South Africa's nuclear reserves are also an inadequate energy source (Anon, 1979). In addition, the development of nuclear energy sources is threatened by fears of the long-term pollution hazards of nuclear power. Solar and other alternative sources of energy are still in the early stages of development. Obviously, coal must continue to remain South Africa's primary source of energy.

Further considerations indicate that the utilization of coal for the economic development of South Africa will increase dramatically between now and the end of the century. Escom expect an average growth rate of 8 per cent up to 1985, and 6,5 per cent thereafter (Snow et al, 1980). This corresponds to a doubling of Escom's coal requirements during the next decade to almost 95 million tonnes per annum. Two new government controlled coal liquefaction plants, Sasol 2 and Sasol 3, are currently under construction. By 1985 these two plants will consume 27 million tonnes of coal per annum to supply approximately 60 per cent of South Africa's liquid fuel needs (Spira, 1981). Plans for an additional liquefaction plant to be financed by industry have been announced, while advanced planning for Sasol 4 is already taking place (Spira, 1981). Coal exports are expected to increase by 15 million tonnes to 44 million tonnes during the next five years, and perhaps to 55 million tonnes by the year 2000 (Granville and Murray, 1979). In the longer term, De Klerk (1981), reports that projections show a possible increase in domestic consumption by the year 2020 to 740 million tonnes a

year. Compared to present domestic consumption, this is almost an eightfold increase. Consequently, a considerable potential exists for the expansion of the South African coal mining industry, especially during the next decade.

1.5 Basic Means of Increasing Production

The two basic means of increasing overall production to meet the expected future demand for coal are by increasing production from established collieries and by establishing new collieries. Within these collieries production may be increased by:

i) Utilizing bord and pillar mining methods and increasing the number of working sections. Whilst, in the light of the Petrick Commission findings, such a solution is to be avoided, especially at depth, it is often the only practical solution in established collieries.

ii) Increasing the percentage areal extraction of a seam. As previously noted, high percentage areal extraction techniques, particularly pillar extraction and longwall mining, are being utilized increasingly more often in South Africa.

iii) Increasing the percentage volumetric extraction of a seam by increasing the extracted seam height. In the past, practical considerations have limited the mining height in bord and pillar workings to, typically, 6 m. Local economic and technologic considerations have usually limited high percentage areal extraction techniques to a maximum mining height of 3 m. Low coal prices have also tended to restrict mining operations to the high quality zones within seams.

In the light of numerous experiences with measures (i) and (ii), both local and overseas, it is not surprising that

these two measures have been utilized almost exclusively to increase local production during the last five years. However, in view of the considerable improvement in the economic viability of the South African coal mining industry during the last five years, and of the fact that many high percentage volumetric extraction mining methods are extensions of high percentage areal extraction mining methods, it is logical to presume that the potential may also exist for increasing production through increasing the extracted seam height. Obviously, the feasibility of this approach is dependent on the magnitude and distribution of the additional coal reserves which could be extracted if such mining methods were employed.

1.6 Conclusions

The continuing economic development of South Africa is dependent upon an increase in local coal production. Since the publication of the Petrick Commission Report in 1975 the economic viability of the local coal industry has improved significantly and should continue to do so. Consequently, consideration can now be given to employing alternative mining methods to bord and pillar mining, primarily to increase percentage extraction. In this regard, the magnitude and distribution of coal reserves contained in seams exceeding a thickness such that, in general, the full seam thickness cannot be extracted utilizing conventional mining techniques, warrants calculation in order to evaluate the need to introduce thick seam mining methods.

CHAPTER 2

THE CALCULATION OF SOUTH AFRICAN THICK COAL SEAM RESERVES

2.1 Introduction

Seams exceeding a thickness such that the full seam thickness cannot be extracted utilizing conventional mining techniques, usually because of productivity and/or practical considerations, are commonly referred to as 'thick' seams. A popular definition of a thick seam based on productivity considerations is that proposed by Cochrane (1972), which states that a thick seam is 'a seam which falls beyond the seam range in which maximum face productivity can be obtained using existing mining systems'. But, since mining systems are selected on the basis of local geologic, economic and technologic considerations, such a seam thickness can vary considerably from location to location. For example, in hand-got bord and pillar mining operations in India, productivity only reduces significantly when the mining height exceeds about 5 m. However, the productivity associated with mechanised longwall mining operations in West Germany decreases markedly with increasing mining height above 2,5 m.

Thick seam definitions developed on the basis of practical considerations are usually based on the maximum mining height of existing mining methods. Again, no universally unique definition exists. For example, if bord and pillar mining utilizing continuous miners with a maximum vertical reach of 3,5 m is the standard mining method at a given location, a thick seam could be defined as a seam exceeding 3,5 m in thickness. On the other hand, if conventional drilling, blasting and mechanised loading is conducted under the same conditions, only seams in excess of 4,5 m may be considered

as thick. Bottrill et al (1977) report that in the United Kingdom, where the average working section of the 704 major longwall faces in National Coal Board (N.C.B.) mines in 1975 was 1,42 m, thick seams are generally regarded as those which exceed 1,83 m.

It is apparent that there is no universally acceptable, unique value of seam thickness, above which a seam may be classified as a 'thick' seam. In fact, the definition of a thick seam could vary within an individual coalfield. Clearly, assumptions must be made in order to calculate the magnitude and distribution of South African thick seam reserves. A review of worldwide underground mining technology provides a simple basis on which to develop a definition of a South African thick coal seam. Such an approach is considered valid since, in view of the significant improvement in the economics of South African coal mining during the last five years, many overseas mining methods could find application in South Africa.

2.2 The Definition of a South African Thick Coal Seam

A review of worldwide underground mining technology reveals that there is no universally feasible method for mining seams more than 4 m thick in a single operation. Mechanised bord and pillar mining is generally limited to a mining height of 4 m in a single operation. Longwall mining operates well to a mining height of 3 m, but above this height problems become more serious and frequent, with the result that again mining height is generally limited to a maximum of 4 m. Mining methods such as hydraulic mining and longwall mining with sublevel caving, which are capable of mining to heights exceeding 10 m in a single operation, are not universally feasible because of the special geologic requirements of these methods.

On this basis, a South African coal seam has been defined, basically, as 'any coal seam more than 4 m thick'. However, there are also many situations where a number of coal seams occur in close proximity to each other, resulting in interaction between these seams during mining. If the parting thickness between these seams is small, and the seams are moderately thick, such multi-seam situations may be considered as constituting thick seams which contain stone bands. Therefore, additional criteria to the minimum seam thickness should be defined to take into account these special multi-seam situations.

Two such criteria are the seam thickness, t_s, of each coal seam constituting a multi-seam situation, and the parting thickness, t_{ps}, between each of these seams. Obviously, the larger the value of t_s, and the smaller the value of t_{ps}, the closer a multi-seam situation approximates to that of a single thick seam. Thus, by specifying a lower limit for t_s, and an upper limit for t_{ps}, certain multi-seam situations may be classified as thick seams.

A limit of 2 m was selected as the minimum seam thickness after briefly reviewing thick seam mining methods used overseas. This review showed that in most instances each of these methods was sufficiently flexible to be able to operate down to a mining height of 2 m. In fact, this was often a stipulation in tenders for the supply of thick seam mining equipment to ensure that the equipment could be utilized in moderately thick seams (2-4 m) should thick seam mining operations prove unsuccessful.

The selection of a maximum parting thickness is complex because both the mining method employed and the quality of the parting determine the degree of interaction between adjacent seams. Under typical South African conditions, interaction between adjacent bord and pillar workings is minimal once the parting thickness exceeds 15 m. In the case of longwall mining, if panels are extracted in descending

order and the parting is competent, interaction is usually minimal once the parting thickness exceeds two to four times the mining height (Wagner, 1979, personal communication). However, a parting thickness of only 1 m may prohibit the use of hydraulic mining. Obviously, it is not possible to define a unique parting thickness based on mining considerations alone.

An insight into the solution of this problem was obtained by investigating the actual stratigraphy of the various South African coalfields. The geographic location of these coalfields is shown in Fig. 2. An analysis of numerous borehole logs reveals that adjacent seams which are thicker than 2 m tend to have partings of either less than 4 m or greater than 10 m, with partings of less than 2 m being very common. Therefore a limit of 4 m was selected as the maximum parting thickness.

The basic definition of a South African thick coal seam as 'any seam more than 4 m thick' has, therefore, now been extended to include certain multi-seam situations which, because of moderate seam thickness and small parting thickness, approximate to a single thick seam. Based on this extended definition, four categories of thick seam reserves can be identified. Reserves in three of these categories, namely categories I, II and III, are mineable by underground methods, whilst reserves in the remaining category, category IV, are mineable by surface methods. Unlike category I, II and III reserves, category IV reserves are not mutually exclusive. That is, category IV reserves may also constitute either category I, II or III reserves. Each of the four thick seam reserve categories is defined and illustrated in Table 1.

Numerous absurd coal seam configurations may be deduced from the definitions of category I, II and III reserves. However, since local borehole information was used when considering the definition of a South African thick coal seam, it is not

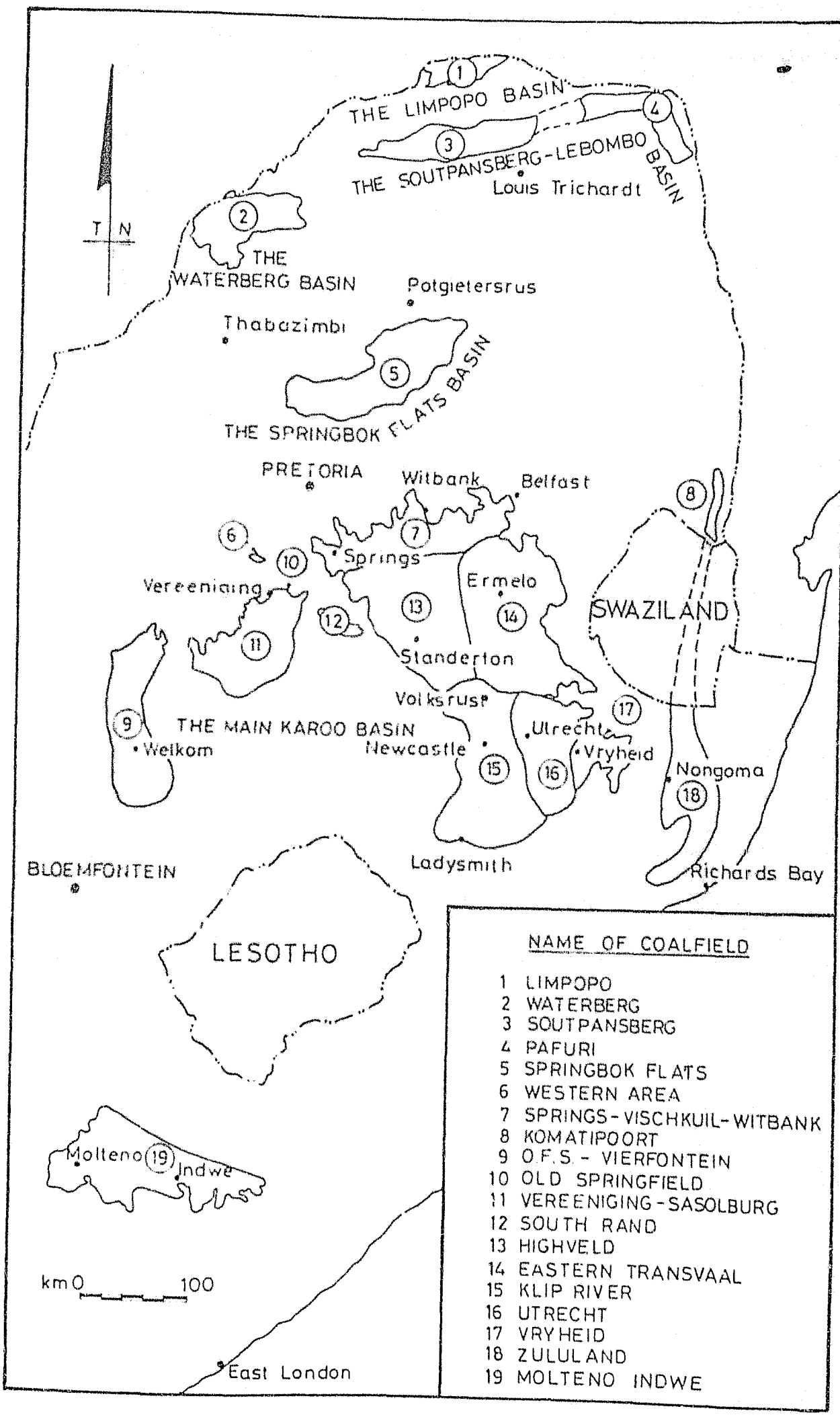


FIGURE 2 Geographic location of South African coalfields.

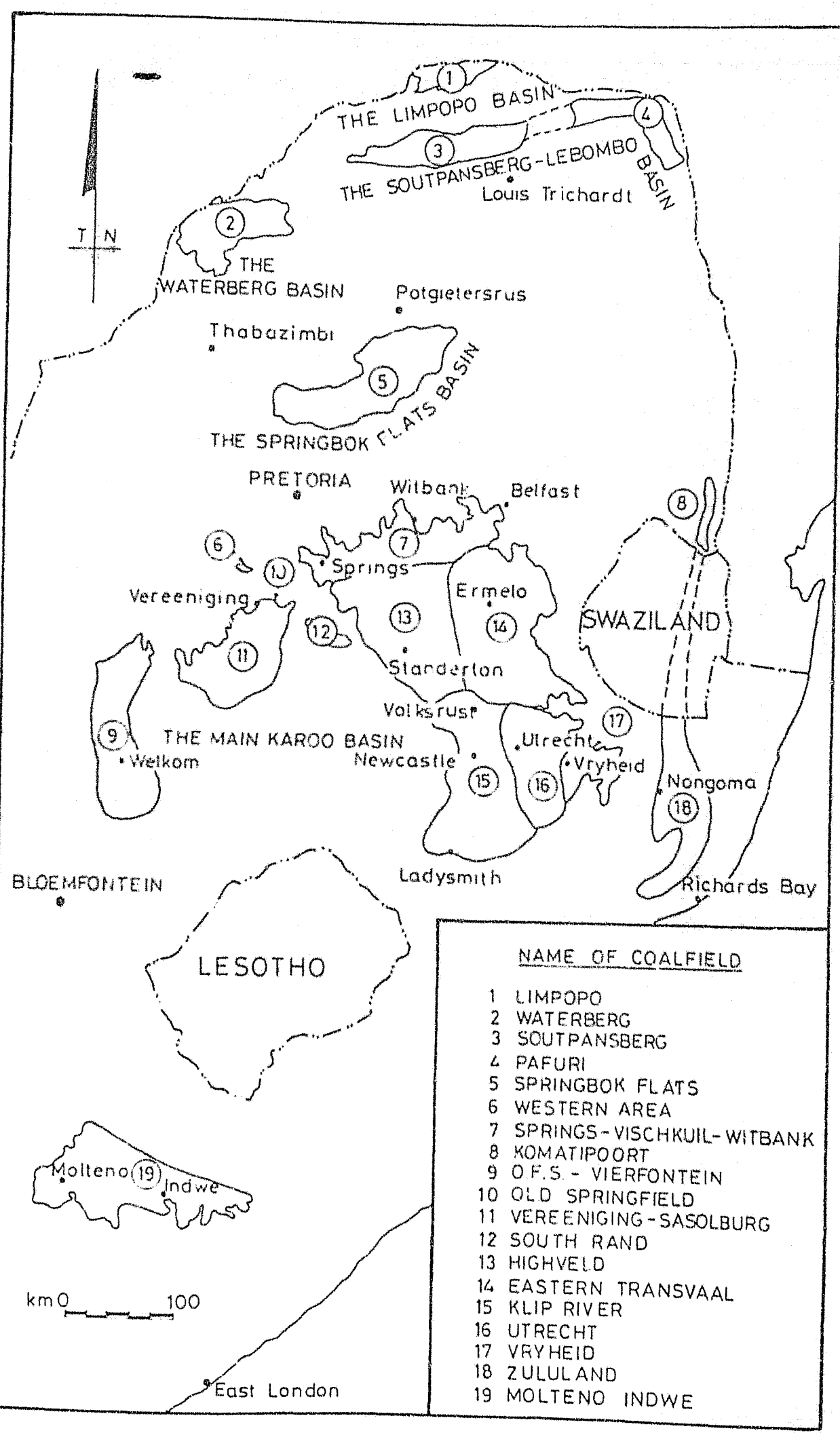


FIGURE 2 Geographic location of South African coalfields.

TABLE 1 Definition and illustration of South African thick coal seam reserves.

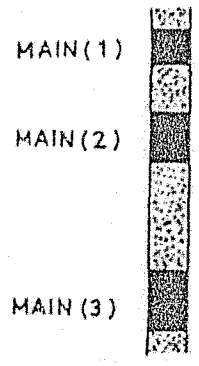
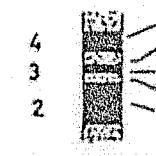
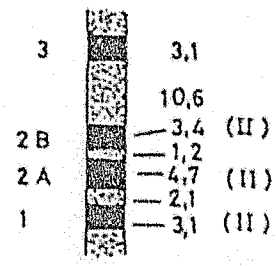
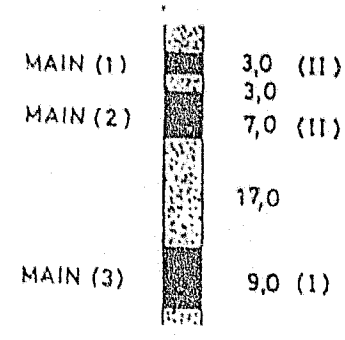
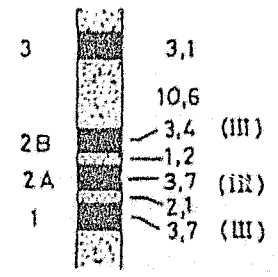
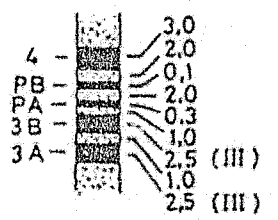
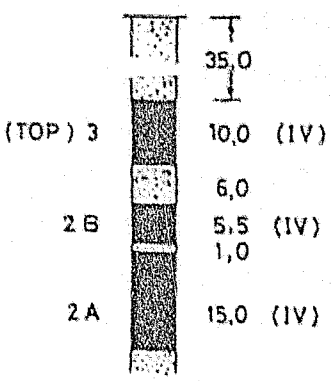
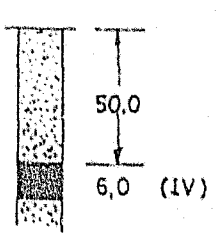
	Category	DEFINITION	TYPICAL EXAMPLE
Extractable by Underground Mining	I	Reserves are contained within a single thick seam; that is, reserves are contained in a coal seam which is more than 4 m thick and which does not occur within 4 m of any seam that is more than 2 m thick.	 SOUTH RAND COALFIELD  SPRINGS-VISCHKUIL-WITBANK COALFIELD
	II	Reserves are contained within a group of coal seams, one of which is more than 4 m thick; that is, reserves are contained in a group of coal seams where at least one seam is more than 4 m thick, and all other seams considered as reserves are more than 2 m thick with no parting between seams being greater than 4 m.	 VEREENIGING-SASOLBURG COALFIELD  SOUTH RAND COALFIELD

TABLE 1 (cont.)

	Category	DEFINITION	TYPICAL EXAMPLE
Extractable by Underground Mining	III	Reserves are contained within a group of coal seams, none of which are more than 4 m thick; that is, reserves are contained in a group of coal seams where each seam which is considered as reserve is between 2 and 4 m thick, with no parting between seams being greater than 4 m.	 VEREENIGING-SASOLBURG COALFIELD  SOUTPANSBERG COALFIELD
Extractable by Surface Mining	IV	Reserves are contained within a coal seam which is more than 4 m thick and less than 60 m below surface, and which has a stripping ratio by volume of less than 10:1.	 OLD SPRINGFIELD COALFIELD  SPRINGS-VISCHKUIL-WITBANK COALFIELD

surprising that these definitions correspond well with the stratigraphic sequence of the various South African coalfields, Table 1.

2.3 The Calculation of South African Thick Coal Seam Reserves

The calculation of South Africa's mineable and extractable coal reserves by Petrick et al.(1975) was facilitated by the establishment of a computerised data base containing basic information relating to all borehole intersections of coal in the country. Utilization of this data base is an obvious means of calculating thick coal seam reserves. Specifications relating to the quality of thick seam reserves to be evaluated have been set to those values adopted by Petrick et al.(1975), Table I.1, Appendix I. This approach has been adopted to facilitate comparisons between the two reserve estimates.

Experience with high percentage extraction mining systems in South Africa during the last 15 years has highlighted the significant influence of overlying massive dolerite sills on mining operations. When such sills are in excess of 30 m in thickness they can have an over-riding influence on the selection of a mining method, mine design, mine operating procedures and the economic viability of mining operations. Therefore, it is considered astute to utilize the data base to establish that portion and location of thick seam reserves overlaid by massive dolerite sills.

A breakdown of South African mineable thick seam reserves into reserve category (I, II, III or IV) and coalfield is presented in Table 2. The subscript 'd' denotes those reserves overlain by one or more dolerite sills in excess of 30 m thick. Thick seam reserves mineable by underground methods were calculated to be 43 657 million tonnes, whilst 6 395 million tonnes were calculated to be mineable by

TABLE 2 Summary of South African mineable thick coal seam reserves according to coalfield and reserve category.

(million tonnes)

Coal-field \ Category	I	I_d	II	II_d	III	III_d	Total under-ground	IV
ETVL	233						233	83
HVSC	10 304		1 971				12 275	1 301
KLRV		95					95	20
KOPT								
LIMP								
MIND								
OFSV					28	31	59	
OSPF	48						48	48
PFRI								
SOBG					49	22	71	
SORD	206	1 391	989	337			2 923	
SPFL								
SPVW	10 009		90		301		10 400	4 067
UTCT								
VESA	1 622	785	687	516	181	100	3 891	158
VRHD								
WEAR	65						65	
WTBG	8 123		5 043		297		13 463	718
ZULU			103	31			134	
TOTAL	30 610	2 271	8 883	884	856	153	43 657	6 395

ETVL - Eastern Transvaal
HVSC - Highveld
KLRV - Klip River
KOPT - Komatipoort
LIMP - Limpopo
MIND - Molteno-Indwe
OFSV - O.F.S. Vierfontein
OSPF - Old Springfield
PFRI - Pafuri
SOBG - Soutpansberg
SORD - South Rand
SPFL - Springbok Flats
SPVW - Springs-Vischkuil-Witbank
UTCT - Utrecht
VESA - Vereeniging-Sasolburg
VRHD - Vryheid
WEAR - Western Area
WTBG - Waterberg
ZULU - Zululand

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