CHAPTER 6

GEOLOGIC ASSESSMENT OF SOUTH AFRICAN THICK COAL SEAMS

6.1 Introduction

Having tabulated the geologic and economic characteristics and requirements of thick seam mining methods, the next logical step in identifying which of these methods are technically suitable for use in South African thick seam coalfields is to tabulate the geologic conditions associated with thick coal seams in each of these coalfields. However, there are 12 such coalfields which are distributed throughout a large portion of South Africa and which often contain three or more thick coal seams. Many of these coalfields are in excess of 1000 km^2 in area and coal mining operations have not been conducted in some of the coalfields. Thus, an assessment of geologic conditions in each of these coalfields is clearly impractical. Therefore, it is necessary initially to identify those coalfields, and specific regions within these coalfields, which offer the greatest potential for the introduction of thick seam mining methods. Geologic conditions within each of these specific regions can then be assessed in detail.

6.2 Potential Thick Seam Mining Coalfields

Reference to Table 2 reveals that seven South African coal-fields contain less than 250 million tonnes of thick seam reserve. In four of these coalfields coal mining operations have either never taken place or are defunct, whilst mining operations in the remaining three coalfields account for less than 20 per cent of South Africa's annual coal production. Furthermore, mining experiences to date in these coalfields have revealed that coal seams only satisfy the definition of a thick seam in isolated areas.

The remaining five thick seam coalfields each contain thick seam reserves in excess of almost 3 000 million tonnes. Mining operations in thick coal seams in four of these coalfields, namely, the Highveld Coalfield, the South Rand Coalfield, the Springs-Vischkuil-Witbank Coalfield and the Vereeniging-Sasolburg Coalfield, have been in progress for over 35 years. The four coalfields account for more than 75 per cent of the country's annual coal production. Ten thermal power stations and three liquefaction plants are located in these coalfields. As such, ancillary services for the coal mining industry are well established in the coalfields.

The fifth thick seam coalfield, namely, the Waterberg Coalfield is very remote to South Africa's major industries and services and no coal mining operations of any consequence have been developed in the coalfield. Economic considerations associated with the considerable depth of the seams, coal quality and remoteness restrict future mining operations in this coalfield.

It is apparent, therefore, that the greatest need and potential for increasing percentage extraction from thick coal seams exist in the Highveld Coalfield, the South Rand Coalfield, the Springs-Vischkuil-Witbank Coalfield and the Vereeniging-Sasolburg Coalfield. However, with the exception of the South Rand Coalfield, these coalfields are of considerable areal extent, the Highveld and Springs-Vischkuil-Witbank Coalfields both being in excess of 3 000 km^2 in area. Obviously, regions exhibiting the greatest potential for the introduction of thick seam mining methods within these coalfields must also be identified.

The identification can be based on a consideration of the regional geology of the coalfields which, in any case, is an important pre-requisite for assessing local geologic conditions in potential thick seam mining regions. Since it is most logical that, following an assessment of regional geologic conditions, local geologic conditions should be assessed, the approach adopted to assessing these local conditions needs to be discussed.

6.3 Approach to Assessing and Presenting Geologic Conditions

In all four coalfields, extensive mining operations have taken, or are taking place in regions which, on the basis of a consideration of regional geology, presented in following sections, have been identified to offer most potential for the implementation of thick seam mining methods. These operations provide an ideal opportunity to assess not only geologic conditions pertaining to thick seams in these regions, but also the influence of the conditions on past and present mining operations. Therefore, mines in each potential region were visited and detailed underground measurements and observations were made of parameters relating to the four previously identified (section 5.4.1) geologic zones of influence pertaining to a thick coal seam. In instances where mining operations were confined to a limited portion of a region or where additional information was required, measurements and observations were supplemented by borehole and survey information. Information was also collected concerning an additional zone of influence, namely, the surface geography.

To facilitate identification of potential thick seam mining methods, information has been tabulated in a similar format to that utilized to tabulate geologic conditions pertaining to thick seam mining methods, Chapter 5. However, access into thick seams and previous experiences in mining these seams has enabled many geologic parameters categorised as 'limitations' and 'considerations' to be recorded quantitatively and in much greater detail than as recorded in Chapter 5. This additional information is extremely valuable in assessing the potential influence of local geologic conditions on thick seam mining methods.

A number of novel classification systems were devised for quantitatively recording and assessing the significance of the additional information obtained as a result of past and present mining operations in thick seams in the regions of interest. These classification systems, along with an account of the approach adopted for measuring, observing and recording all the information obtained in the survey of geologic conditions in potential thick seam mining regions, are presented in Appendix V.

A set of master-tables of the format and classification systems devised to record geologic properties pertaining to a thick coal seam is reproduced in Tables 12 to 15. It can be appreciated that when conditions relating to up to five potential thick seam mining regions or sub-regions within a coalfield are tabulated, these tables become very large. Furthermore, since, in general, a set of tables has to be completed for each thick seam assessed and up to three such seams are present within each of the four coalfields under discussion, the number of tables also becomes large. Consequently, it is impractical to present these tables in the main text of the thesis. Therefore, the main text is restricted to identifying specific potential thick seam mining regions in each of the four relevant coalfields, and the tabulation of geologic conditions within each of these regions is presented in Appendix VI. On the basis of these tabulated properties it is possible to identify a number of geologically consistent sub-regions in some of the regions assessed. These are also noted in the main text.

6.4 Origin and General Geology of Coalfields

South African coal deposits form part of the Karoo System which covers a large portion of the country. This system is subdivided into four lithological units, namely, the Dwyka, Ecca, Beaufort, and Stormberg Series, and ranges in age from the Upper Carboniferous through the Permain and Triassic into the Lower Jurassic, Table 16.

TABLE 12 Master-table of geologic conditions and classification systems pertaining to the floor strata

i) Format

CATEGORY: Parameter / Region	CONSIDERATIONS: Depth Range (m)	Composition	Thickness (m)	C_o (MPa)	E (GPa)	ν	Friability	Smoothness of Seam Contact	Water Bearing Capacity	Deterioration upon Exposure to: Atmosphere	Water	Degree of Competence

ii) Classification Systems

Legend
SUPERFICIAL DEPOSITS
SHALE
COAL
SANDSTONE
GRIT
MUDSTONE
CONGLOMERATE
TILLITE
RE-WORKED TILLITE
DOLERITE
PRE-KAROO

Class	Description
0	Negligible
I	Slightly friable
II	Moderately friable
III	Friable
IV	Very friable

Class	Description
0	Smooth - well defined even parting plane
I	Slightly Uneven: Regular and frequent undulations ±100 mm
II	Moderately Uneven: Regular and frequent undulations ±200 mm
III	Uneven: Regular and frequent undulations ±300 mm
IV	Very Uneven: Regular and frequent undulations >300 mm

Class	Description
0	Negligible Inflow: No pumps in section
I	Occasional Inflow: requires infrequent pumping
II	Moderate Inflow: Requires periodic pumping
III	Large Inflow: Requires continuous pumping
IV	Extreme Inflow: Results in flooding of a panel in 1 to 3 days if no pumping

Class	Rate of Deterioration
0	Slow: 1 year
I	Mod. Quick: 1-12 months
II	Quick: 1-4 weeks
III	Rapid: 1-7 days
IV	Very Rapid: 24 hours

Rating	Potential Equipment Operation
0	Very Competent: All forms of heavy track equipment in wet environment
I	Competent: Light track equipment and all tyre equipment in wet environment
II	Moderately Competent: Light track equipment in dry environment. Tyre equipment in wet environment
III	Incompetent: No track equipment. Light tyre equipment in dry environment
IV	Very Incompetent: Only hand loading and endless rope or conveyor haulage

TABLE 13(A) Master-table of geologic conditions and classification systems pertaining to the coal strata

i) Format

CATEGORY			Parameter \ Region	
REQUIREMENTS			Depth Range (m)	
			Seam Thickness (m)	
			Variation in Local Thickness (m)	
			i) over 10 m	
			ii) over 1000 m	
	DIP		Regional (degrees)	
			Local Variation (degrees)	
			Compressive Strength, Co (MPa)	
			Elastic Modulus, E (GPa)	
			Poissons Ratio, ν	
			Quality Variation (MJ/kg)	
			Cleating	
			i) Density (No./m)	
			ii) Nature	
			Friability	
LIMITATIONS	SLIPS		Local density (No./10 m)	
			Regional zone spacing (kms)	
			Direction	
	FAULTS		No./10 km^2	
			Spacing (kms)	
		THROW	0,2-1 m	
			1-3 m	
			≥3 m	
	INTRUSIONS		No./10 km^2	
			Spacing (kms)	
			Width (m)	
			Width burnt coal (m)	
	STONE PARTINGS		Height above floor (m)	
			Composition	
		THICKNESS	< 0,3 m	
			0,3-0,7 m	
			0,7-1,5 m	
			1,5-4,0 m	
	STONE LENSES		Height above floor (m)	
			Composition	
			Thickness (m)	
			Pyrite Bands	
			Marker Bands	
CONSID-ERAT'NS			Gas Content	
			Proneness to Spontaneous Combustion	

ii) Classification Systems

Rating	Description
0	Visible only upon close and careful inspection
I	Closed Non-continuous
II	Closed Continuous
III	Open Non-continuous
IV	Open Continuous

Rating	Description
0	Negligible
I	Slightly friable
II	Moderately friable
III	Friable
IV	Very friable

Rating	Description
0	Negligible
I	Low
II	Medium
III	High
IV	Very High

Rating	Frequency of heatings
0	Negligible 1/10 years
I	Low 1/5 years
II	Moderately High 1/year
III	High 3-5/year
IV	Very High 5-10/year

TABLE 13(A) Master-table of geologic conditions and classification systems pertaining to the coal strata

i) Format

CATEGORY	Parameter		Region
REQUIREMENTS	Depth Range (m)		
	Seam Thickness (m)		
	Variation in Local Thickness (m)		
		i) over 10 m	
		ii) over 1000 m	
	DIP	Regional (degrees)	
		Local Variation (degrees)	
	Compressive Strength, Co (MPa)		
	Elastic Modulus, E (GPa)		
	Poissons Ratio, ν		
	Quality Variation (MJ/kg)		
	Cleating		
		i) Density (No./m)	
		ii) Nature	
	Friability		
LIMITATIONS	SLIPS	Local density (No./10 m)	
		Regional zone spacing (kms)	
		Direction	
	FAULTS	No./10 km^2	
		Spacing (kms)	
		THROW 0,2-1 m	
		THROW 1-3 m	
		THROW >3 m	
	INTRUSIONS	No./10 km^2	
		Spacing (kms)	
		Width (m)	
		Width burnt coal (m)	
	STONE PARTINGS	Height above floor (m)	
		Composition	
		THICKNESS < 0,3 m	
		THICKNESS 0,3-0,7 m	
		THICKNESS 0,7-1,5 m	
		THICKNESS 1,5-4,0 m	
	STONE LENSES	Height above floor (m)	
		Composition	
		Thickness (m)	
	Pyrite Bands		
	Marker Bands		
CONSIDERAT'NS	Gas Content		
	Proneness to Spontaneous Combustion		

ii) Classification Systems

Rating	Description
0	Visible only upon close and careful inspection
I	Closed Non-continuous
II	Closed Continuous
III	Open Non-continuous
IV	Open Continuous

Rating	Description
0	Negligible
I	Slightly friable
II	Moderately friable
III	Friable
IV	Very friable

Rating	Description
0	Negligible
I	Low
II	Medium
III	High
IV	Very High

Rating	Frequency of heatings
0	Negligible 1/10 years
I	Low 1/5 years
II	Moderately High 1/year
III	High 3-5/year
IV	Very High 5-10/year

TABLE 13(B) Master-table of geologic conditions and classification systems pertaining to the coal strata

(i) Format

CATEG.		Parameter \ Region		
MINING EXPERIENCES	Top-coal (>2m)	Thickness(m)		
		Support Density	Bords	
			Intersections	
		Roof Falls		
		Degree of Competence	Value	
			Rating	
	Bottom-coal	Thickness(m)		
		Deterioration Upon Exposure to:	Atmosphere	
			Water	
		Degree of Competence		
	Working Experiences			

(ii) Classification Systems

RATING		DENSITY	VALVE (B,C)
0		NONE TO IRREGULAR (SLIPS, INTRUSIONS)	φ
I	SYSTEMATIC	$>6 m^2$/BOLT	1
II		≤ 6 >3 m^2/BOLT	2
III		≤ 3 $>1,5$ m^2/BOLT	3
IV		$\leq 1,5 m^2$/BOLT PLUS ANY OTHER ADDITIONAL SUPPORT	4

RATING	POTENTIAL EQUIPMENT OPERATION
0	VERY COMPETENT ALL FORMS OF HEAVY TRACK EQUIPMENT IN WET ENVIRONMENT.
I	COMPETENT LIGHT TRACK EQUIPMENT AND ALL TYPE EQUIPMENT IN WET ENVIRONMENT.
II	MODERATELY COMPETENT LIGHT TRACK EQUIPMENT IN DRY ENVIRONMENT. TYRE EQUIPMENT IN WET ENVIRONMENT.
III	INCOMPETENT NO TRACK EQUIPMENT. LIGHT TYRE EQUIPMENT IN DRY ENVIRONMENT.
IV	VERY INCOMPETENT ONLY HAND LOADING AND ENDLESS ROPE OR CONVEYOR HAULAGE

RATING	RATE OF DETERIORATION
0	> 1 YEAR
I	1-12 MONTHS
II	1-4 WEEKS
III	1-7 DAYS
IV	< 24 HOURS

SUM of VALVES	RATING	DESCRIPTION	
<4	0	>6	TYPICALLY, STRATA WILL BRIDGE INDEFINITELY AN UNSUPPORTED SPAN (m) OF
4-<8	I	4-<6	
8-<12	II	3-<4	
12-<16	III	2-<3	
16-20	IV	<2	

RATING	FREQUENCY	VALVE (D)
0	≤ 1/PANEL	φ
I	2-3/PANEL	1
II	4-5/PANEL	2
III	6-10/PANEL	3
IV	>10/PANEL	4

TABLE 14 Master-table of geologic conditions and classification systems pertaining to the immediate roof strata

(i) Format

CATEGORY	CONSIDERATIONS									CALCULATION OF COMPETENCE					
Parameter / Region	Depth Range (m)	Composition	Thickness (m)	Co (MPa)	E (GPa)		Smoothness of Seam Contact	Water Bearing Capacity	Deterioration upon Exposure to Atmosphere	Support Procedures: Top-coal (<2m)(A)	Support Procedures: Bords (B)	Support Procedures: Intersections (C)	Effectiveness: Roof Falls (D)	Degree of Competence: Value	Degree of Competence: Rating

(ii) Classification Systems

LEGEND
SUPERFICIAL DEPOSITS
SHALE
COAL
SANDSTONE
GRIT
MUDSTONE
CONGLOMERATE
TILLITE
RE-WORKED TILLITE
DOLERITE
PRE-KAROO

RATING	DESCRIPTION
0	SMOOTH — WELL DEFINED EVEN PARTING PLANE
I	SLIGHTLY UNEVEN — FREQUENT UNDULATIONS ± 100 mm
II	MODERATELY UNEVEN — FREQUENT UNDULATIONS ± 200 mm
III	UNEVEN — FREQUENT UNDULATIONS ± 300 mm
IV	VERY UNEVEN — FREQUENT UNDULATIONS > 300 mm

RATING	DESCRIPTION
0	NEGLIGIBLE INFLOW — NO PUMPS IN SECTION
I	OCCASSIONAL INFLOW — REQUIRES INFREQUENT PUMPING
II	MODERATE INFLOW — REQUIRES PERIODIC PUMPING
III	LARGE INFLOW — REQUIRES CONTINUOUS PUMPING
IV	EXTREME INFLOW — RESULTS IN FLOODING OF A PANEL IN 1 TO 3 DAYS IF NO PUMPING

RATING	RATE OF DETERIORATION
0	> 1 YEAR
I	1-12 MONTHS
II	1-4 WEEKS
III	1-7 DAYS
IV	< 24 HOURS

PRESENCE	VALVE (A)
NO	ϕ
YES	4

RATING	DENSITY		VALVE (B,C)
0	NONE TO IRREGULAR (SLIPS, INTRUSIONS)		ϕ
I	SYSTEMATIC	> 6 m²/BOLT	1
II	SYSTEMATIC	< 6 m², > 3 m² / BOLT	2
III	SYSTEMATIC	≤ 3 m², > 1,5 m² / BOLT	3
IV	≤ 1,5 m²/BOLT PLUS ANY OTHER ADDITIONAL SUPPORT		4

RATING	FREQUENCY	VALVE (D)
0	≤ 1 / PANEL	ϕ
I	2-3 / PANEL	1
II	4-5 / PANEL	2
III	6-10 / PANEL	3
IV	> 10 / PANEL	4

SUM OF VALVES	RATING	DESCRIPTION: TYPICALLY STRATA WILL BRIDGE INDEFINITELY AN UNSUPPORTED SPAN (m) OF
< 4	0	> 6
4 - < 8	I	4 - < 6
8 - < 12	II	3 - < 4
12 - < 16	III	2 - < 3
16 - 20	IV	< 2

TABLE 15 Master-table of geologic conditions and classification systems pertaining to the upper roof strata

(i) Format

CATEGORY	CONSIDERATIONS															
Parameter	General Strata		Dominant Strata				Water Bearing Strata				Strength Properties					
	Composition	Thickness	Composition	Thickness	Depth	Significance	Composition	Depth	Capacity		Composition	Thickness	Depth	C_o	E	v
									Rating	Borehole						
Region		(m)		(m)	(m)			(m)		(l/hr)		(m)	(m)	(MPa)	(GPa)	

(ii) Classification Systems

Legend
SUPERFICIAL DEPOSITS
SHALE
COAL
SANDSTONE
GRIT
MUDSTONE
CONGLOMERATE
TILLITE
RE-WORKED TILLITE
DOLERITE
PRE-KAROO

Rating	Description
0	Negligible Inflow - no pumps in section
I	Occasional Inflow - requires infrequent pumping
II	Moderate Inflow - requires periodic pumping
III	Large Inflow - requires continuous pumping
IV	Extreme Inflow - results in flooding of a panel in 1 to 3 days if no pumping

TABLE 16 Geologic time scale.

Series	System	Age	Era
	TERTIARY TO QUATERNARY		CAINOZOIC
Upper Series	CRETACEOUS SYSTEM	[illegible]bian to Maastrichtian	MESOZOIC
Lower Series		Neocomian to Aptian	
Stormberg Series	KAROO SYSTEM	Triassic to Jurassic	
Beaufort Series			
Ecca Series		Upper Carboniferous to Upper Permian	PALAEOZOIC
Dwyka Series			
Witteberg Series	CAPE SYSTEM	Ordovician to Lower Carboniferous	
Bokkeveld Series			
Table Mountain Series			
	KLIPHEUWEL FORMATION	Cambrian	

The formation of the Karoo System was heralded by glacial action which tended to even out and level the pre-Karoo topography, stripping and eroding the higher areas, but also scouring out valleys whilst transporting debris. With the retreat of glaciers, this debris was deposited as a form of moraine and consolidated to form tillite, thereby constituting the lower stage of the Dwyka Series. Tillite, in turn, was overlain by carbonaceous shales which constitute the upper stage of the Dwyka Series.

The Ecca Series followed and this has been subdivided into three stages, namely, the lower, middle and upper stages. The coal measures of the Middle Ecca Stage constitute the major coal deposits of South Africa. Overlying strata have been extensively denuded over a large area of the country, with the result that the thick coal seams of the Highveld, South Rand, Springs-Vischkuil-Witbank and Vereeniging-Sasolburg Coalfields occur at a maximum depth of 250 m. Therefore, little is to be gained by tracing the stratigraphic column further, although it should be noted that the Stormberg Series had an indirect effect on the underlying strata. Contemporaneous hypabysal intrusions associated with this Series have resulted in dolerite sills and dykes being distributed extensively throughout the coalfields.

Owing to the progressive disappearance of the shales of the Lower Ecca and Upper Dwyka Stages in a north-westerly direction, coal seams in parts of the Transvaal and Orange Free State are found close to or resting on Dwyka tillite or pre-Karoo formations.

The coal measures of the four coalfields under review fall into this category. Consequently, the distribution and thickness of the lower seams in these coalfields have been influenced significantly by the pre-Karoo and Dwyka topography. Lower seams are usually found in elongated glacial basins generally trending in a north-south direction.

Thus, these seams are comparatively limited in horizontal extent and abut against the pre-Karoo topography. Seam thickness is usually greatest in the deepest parts of the valleys and decreases towards the ridges. However, because of smoothing of the topography by sedimentation, younger seams are generally more widely spread. Over most of these areas the strata dip inwards at very low angles and, for all practical purposes, are virtually flat lying.

The shallow depth of burial of the seams has limited the metamorphic effects of temperature and pressure and so coal quality is generally poor, ranging from low to medium rank bituminous. Coal quality is reduced further by the high concentration of inert minerals, which result in the ash content of raw coal ranging from 13 per cent to in excess of 30 per cent. As such, only 2 per cent of South Africa's coal reserves can be classified by international standards as standard coal (calorific value $\geqslant$ 29,32 MJ/kg).

A more detailed assessment of geologic conditions in each of the four potential thick seam mining coalfields is most logically presented by discussing coalfields in the north to south sequence in which they occur; that is the Springs-Vischkuil-Witbank Coalfield first, followed by the Highveld, South Rand and Vereeniging-Sasolburg Coalfields, respectively.

6.5 Geology of the Springs-Vischkuil-Witbank Coalfield

6.5.1 Potential thick seam mining regions

The boundaries of the Springs-Vischkuil-Witbank Coalfield and the lease areas of all major producing and defunct collieries within the coalfield are shown in Fig. 18. It can be seen that no coal mining operations of any consequence have occurred in the south-west, or Springs-Vischkuil region of the coalfield, labelled 'A'. Coal deposits in this region are contained in many small

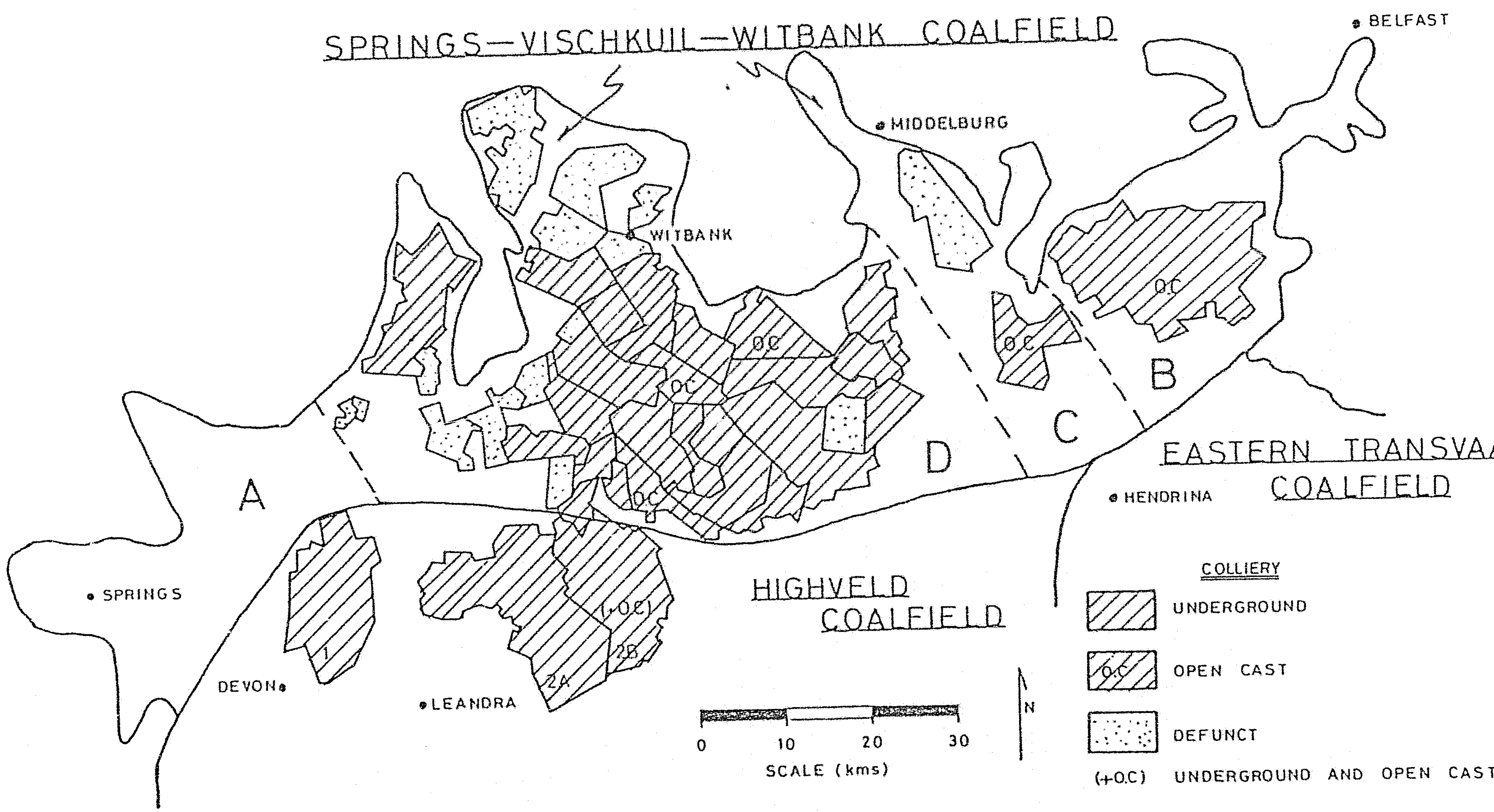

FIGURE 18 Boundaries of the Springs-Vischkuil-Witbank Coalfield.

glacial basins. The coal is generally of poor quality and, whilst it may be suitable for power generation, it is doubtful if adequate reserves exist for this purpose. Consequently, the potential for introducing thick seam mining methods in this region of the coalfield is minimal.

Located throughout the remainder of the coalfield, which is usually referred to as the Witbank Coalfield, are 24 producing collieries which account for over 70 per cent of South Africa's annual coal production. The identification of potential thick seam mining regions within this coalfield is only possible in the light of a more detailed knowledge of the geologic conditions which exist throughout the coalfield.

6.5.2 Regional geology of the Witbank Coalfield

A typical stratigraphic section in the Witbank Coalfield is shown in Fig. 19. The strata in which coal seams occur consists predominantly of fine, medium and coarse-grained sandstone with subordinate mudstone, shale, siltstone and carbonaceous shale. Usually, there are a total of seven distinct coal seams with varying degrees of persistence, numbered in order of decreasing depth, as No. 1, No. 2, No. 3, No. 4 Lower, No. 4 Upper, No. 4A and No. 5. Seams, Fig. 19. The coal zone has a stratigraphic thickness averaging about 70 m, and the depth to the No. 1 seam rarely exceeds 120 m. Generally, the coal is medium bituminous in rank, although minor variations do occur. The coal succession stratigraphy shows a marked similarity and consistency over the whole of the coalfield, and even correlates with the seams of the Highveld, South Rand, and Vereeniging-Sasolburg Coalfields.

The following points pertain to the coal seams of the Witbank Coalfield:

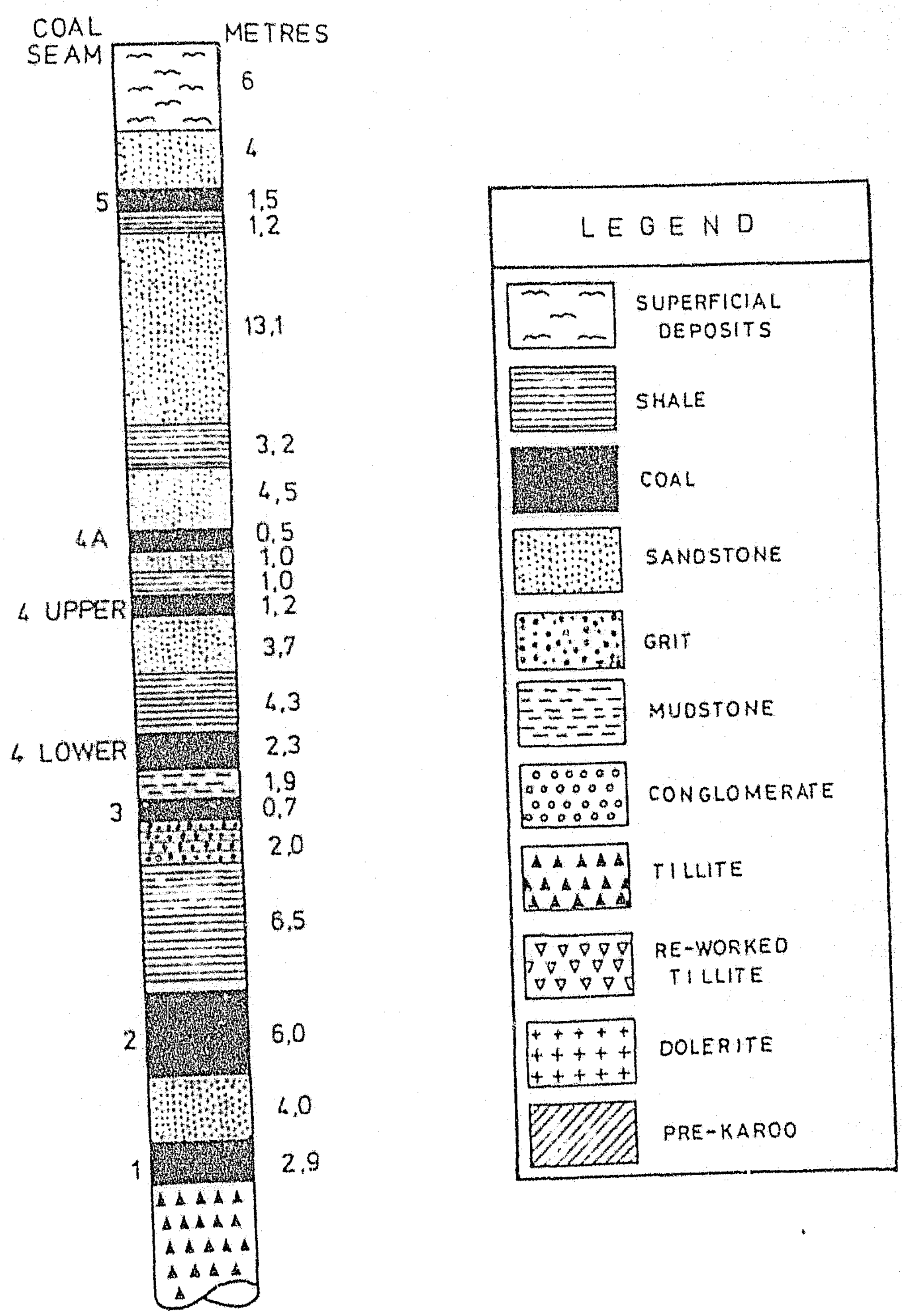

FIGURE 19 Typical stratigraphic section in the Witbank Coalfield.

No. 1 Seam

This seam is not always developed or may be unrecognisable when followed directly by the No. 2 Seam. It lies close to or on the Dwyka tillite and wedges out against pre-Karoo ridges. The seam is best developed in the northern part of the coalfield where it may be up to 3 m in thickness. It consists mainly of dull coal, having an average calorific value of 20 to 22 MJ/kg and, for this reason, is rarely mined.

No. 2 Seam

The No. 2 Seam is the most extensively mined seam in the coalfield. It either follows directly above the No. 1 Seam or may be separated from it by several metres of fine to coarse grained sandstone. In the central portion of the coalfield the seam thickness is usually in the range of 4 to 6 m and may occasionally reach 9 m in valleys. The seam thickness decreases to the west and is generally less than 4 m in region B, Fig. 18. Seam depth also decreases to the west and in regions B and C, Fig. 18, surface mining techniques are to be employed extensively to extract remaining reserves. Calorific value varies greatly throughout the seam thickness, with either the total seam thickness being mined for local power generation purposes, having an average calorific value of 22 to 24,5 MJ/kg, or the lower 3 to 5 m being mined for power generation purposes outside the coalfield or for export, having an average calorific value of 26 to 28 MJ/kg.

No. 3 Seam

This seam is separated from the No. 2 Seam by up to 13 m of carbonaceous shale, sandstone, siltstone and shale. The seam is rarely more than 0,5 m thick and is not developed at some localities.

No. 4 Lower, No. 4 Upper and No. 4A Seams

These seams constitute a zone consisting predominantly of coal and carbonaceous shale with subordinate sandstone over a thickness of about 14 m. In the western portion of the coalfield the 4 Lower and 4 Upper Seams tend to occur on top of each other and constitute a 4 to 7 m thick seam. In the south-east and eastern portion the seams are separated by partings of up to 9 m in thickness. In the latter portion, comprising regions 'B' and 'C', Fig. 18, the No. 4 Lower Seam is the best developed seam, ranging in thickness from 1,2 to 4,8 m, but typically less than 4 m, whilst the No. 4 Upper Seam is generally in the order of 1 to 2,8 m thick. The No. 4A Seam is intermittent and generally less than 0,1 m thick.

The No. 4 Seam (No. 4 Lower and/or No. 4 Upper) is mostly mined in the south-west and western portion of the coalfield where its calorific value typically ranges from 23 to 27 MJ/kg. The coal is either consumed unwashed by local power stations or washed to a higher calorific value and supplied to power utilities outside the coalfield.

No. 5 Seam

This seam has been extensively denuded and occurs intermittently throughout the coalfield. When present, it lies about 25 m above the No. 4A Seam and has an average thickness of just under 2 m. It is usually used as a blend coking coal, typically having a calorific value of 29 to 31 MJ/kg.

On the basis of the preceding discussion it is apparent that thick seam reserves may be contained in the No. 1 Seam (Category II reserves), the No. 2 Seam (Category I or II reserves) and the No. 4 Seam (Category I, II or III reserves) in the Witbank Coalfield. It is also apparent that the potential and need for the introduction of underground thick seam mining methods in regions B and C, Fig. 18, is limited. Therefore, a detailed survey and assessment of geologic conditions in the Witbank Coalfield can be restricted to region D, Fig. 18.

6.5.3 Local geology of region D

Currently, there are 23 producing collieries in region D of the Witbank Coalfield. The lease area of these collieries, together with that of defunct mines, accounts for over 70 per cent of the area of region D. A large proportion of the viable leases contain another 15 to 50 years of coal reserves at current percentage extraction rates. The remaining 30 per cent of the coal reserves are mostly contained in areas through which major rivers flowed at the time of coal formation. Consequently, in these areas seams frequently split and are non-continuous, extremely variable in thickness, and contain a high ash content. On this basis it is reasonable to assume that any advances in thick seam mining techniques in the foreseeable future will be implemented in, or adjacent to, current lease areas, if not in current operating collieries. Therefore, a survey of conditions in the present workings, supplemented by borehole information and the like, is considered to be a valid means of conducting a geologic assessment of region D.

Consequently, geologic conditions associated with 18 mining operations in thick seams in region D were assessed. Generally, these conditions were found to be remarkably consistent over large areas of the region, with the result that a number of geologically consistent sub-regions could be identified. The location of each of these sub-regions pertaining to each of the three thick seams, namely the No. 1, No. 2 and No. 4 Seams, is shown in Figs. 20(a) to 20(c). Geologic conditions

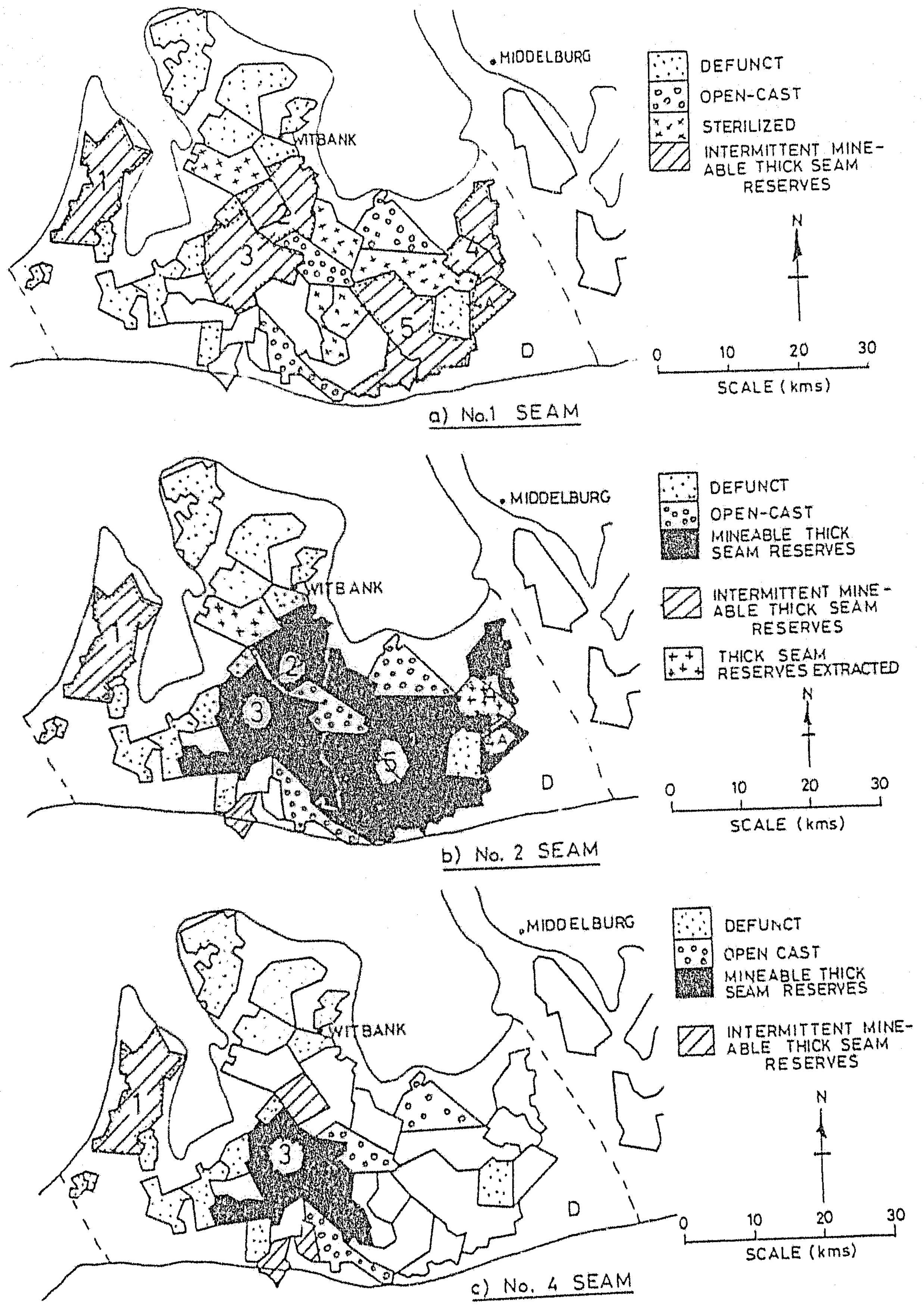

FIGURE 20 Location of geologically consistent sub-regions pertaining to thick seam reserves in region D, Witbank Coalfield.

pertaining to each of these seams in each sub-region are tabulated in Appendix VI.2 (Tables VI.5 to VI.17).

6.6 Geology of the Highveld Coalfield

6.6.1 Potential thick seam mining regions

A broad outline of the boundaries of the Highveld Coalfield has been shown in Fig. 2. The coalfield lies to the south of the Witbank Coalfield, the boundary between the two coalfields being defined by a pre-Karoo east-west felsite ridge. The coal succession stratigraphy is similar to that of the Witbank Coalfield, Fig. 19, although seams are developed to different degrees. In particular:

i) the No 1 Seam is only seldom developed and is always very thin;

ii) the No. 2 Seam has an average thickness of less than 1 m over most of the coalfield, but in the north attains a thickness of up to 9 m in local valleys;

iii) the No. 3 Seam occurs as intermittent thin coal bands;

iv) the No. 4 Seam has an average thickness of just under 4 m, but varies from 2 m in the south up to 10 m in the north;

v) the No. 5 Seam has only been denuded in isolated patches in the north;

vi) seam depth increases appreciably to the south.

On the basis of these coal occurrences, it is apparent that the greatest potential for introducing thick seam pertaining to each of these seams in each sub-region are tabulated in Appendix VI.2 (Tables VI.5 to VI.17).

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v) the No. 5 Seam has only been denuded in isolated patches in the north;

vi) seam depth increases appreciably to the south.

On the basis of these coal occurrences, it is apparent that the greatest potential for introducing thick seam mining methods exists in the north of the coalfield, where widely distributed thick No. 4 Seam reserves and intermittent thick No. 2 Seam reserves occur.

6.6.2 Regional geology of the northern portion of the coalfield

A detailed outline of the northern boundary of the Highveld Coalfield and of the lease areas of the three collieries currently operating in the northern portion of the Coalfield is shown in Fig. 18. Lease area 1 lies in a north-south trending valley and, except close to the sides of this valley, both the No. 2 and No. 4 Seam exceed 4 m in thickness. In lease areas 2A and 2B, the No. 2 Seam was deposited on uneven topography, resulting in regional rolling of the floor and variations in seam thickness from 1 to 9 m. The No. 4 Seam was deposited on a more even surface with the result that floor rolling is only local and the seam thickness only varies from about 4,5 to 7,5 m.

The thickness of both the No. 2 and the No. 4 Seams decreases to less than 4 m to the east and to the south of the three lease areas. Limited available borehole information concerning the area to the south west of lease area 2A, between lease areas 1 and 2A, suggests that thick seam reserves are also contained in the No. 4 Seam and in patches in the No. 2 Seam within this area. It is apparent, therefore, that the potential for thick seam mining is greatest in Region A, Fig. 21, of the Highveld Coalfield.

6.6.3 Local geology of region A

Limited access to detailed borehole information concerning that area of region A which is not included in the lease area of existing collieries prevents an assessment of geologic conditions pertaining to the

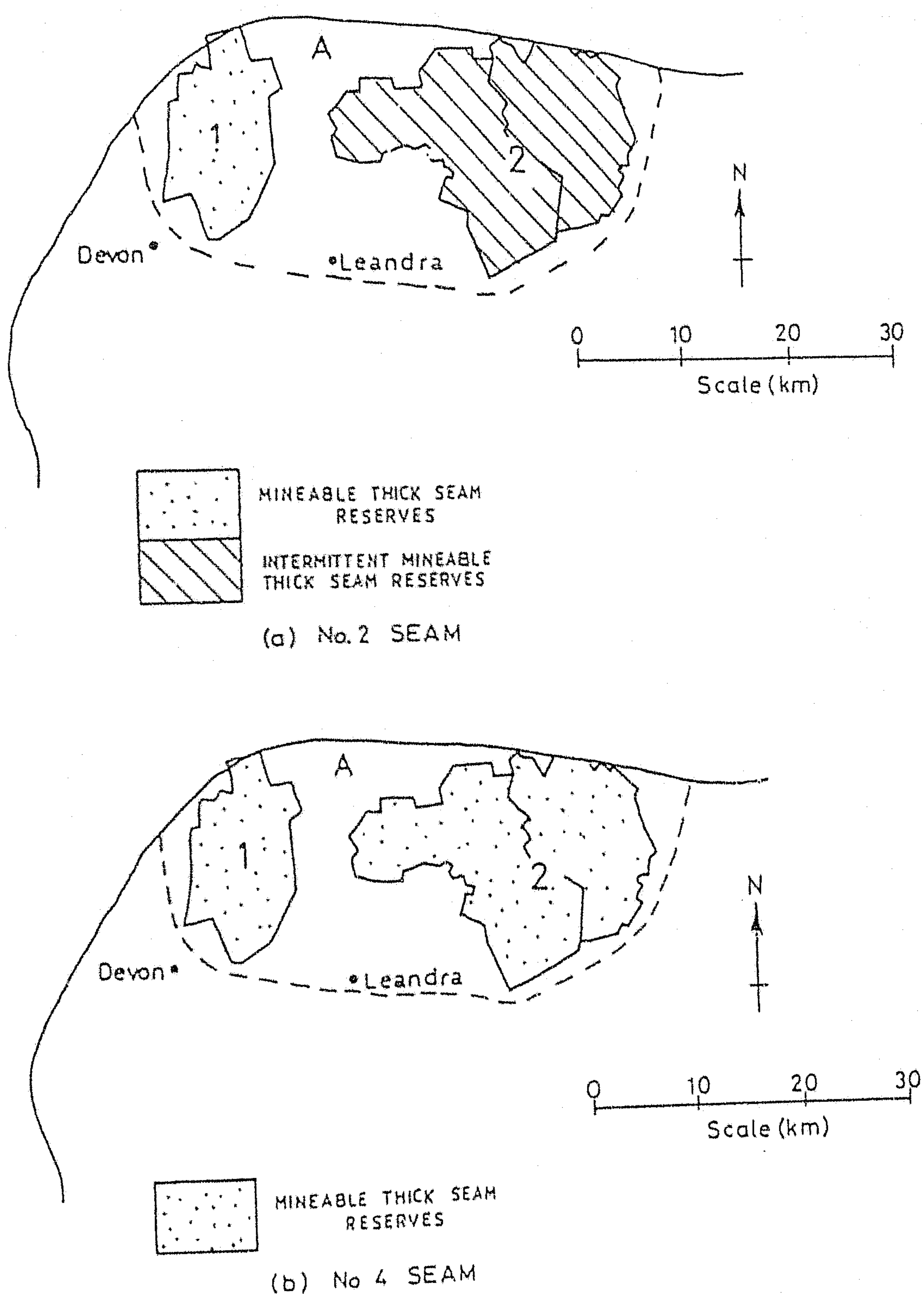


FIGURE 21 Location of geologically consistent sub-regions pertaining to thick seam reserves in region A, Highveld Coalfield.

thick coal seams in the area. Furthermore, a detailed underground assessment of geologic conditions in lease areas 2A and 2B is confined to small areas in the No. 4 Seam since mining operations have only been in progress for a few years in this one seam. However, underground measurements and observations have been supplemented with borehole and survey information and together this information indicates that geologic conditions throughout the two lease areas are very consistent. Consequently, two geologically consistent sub-regions, one corresponding to lease area 1 and the other to lease areas 2A and 2B, have been identified for both the No. 2 and the No. 4 Seam within region A, Fig. 21. Geologic conditions pertaining to these seams in each of the sub-regions are tabulated and discussed in Appendix VI.3 (Tables VI.18 to VI.25).

6.7 Geology of the South Rand Coalfield

6.7.1 Potential thick seam mining regions

An outline of the boundaries of the South Rand Coalfield is shown in Fig. 22. The coalfield lies in a pre-Karoo valley and is surrounded by low hills of the Witwatersrand System (Precambrian age) to the west, north and east. However, to the south, the coalfield extends to the Vaal River where it borders the Vereeniging-Sasolburg Coalfield. Thick seam reserves are contained in the Main Seam which may be up to 25 m thick in the central portion of the coalfield but which often splits into a number of coal horizons towards the perimeter of the coalfield. Generally, three such coal horizons are recognised, namely, in order of decreasing depth, the No. 1, No. 2 and No. 3 horizons. Each of these coal horizons can also exceed 4 m in thickness.

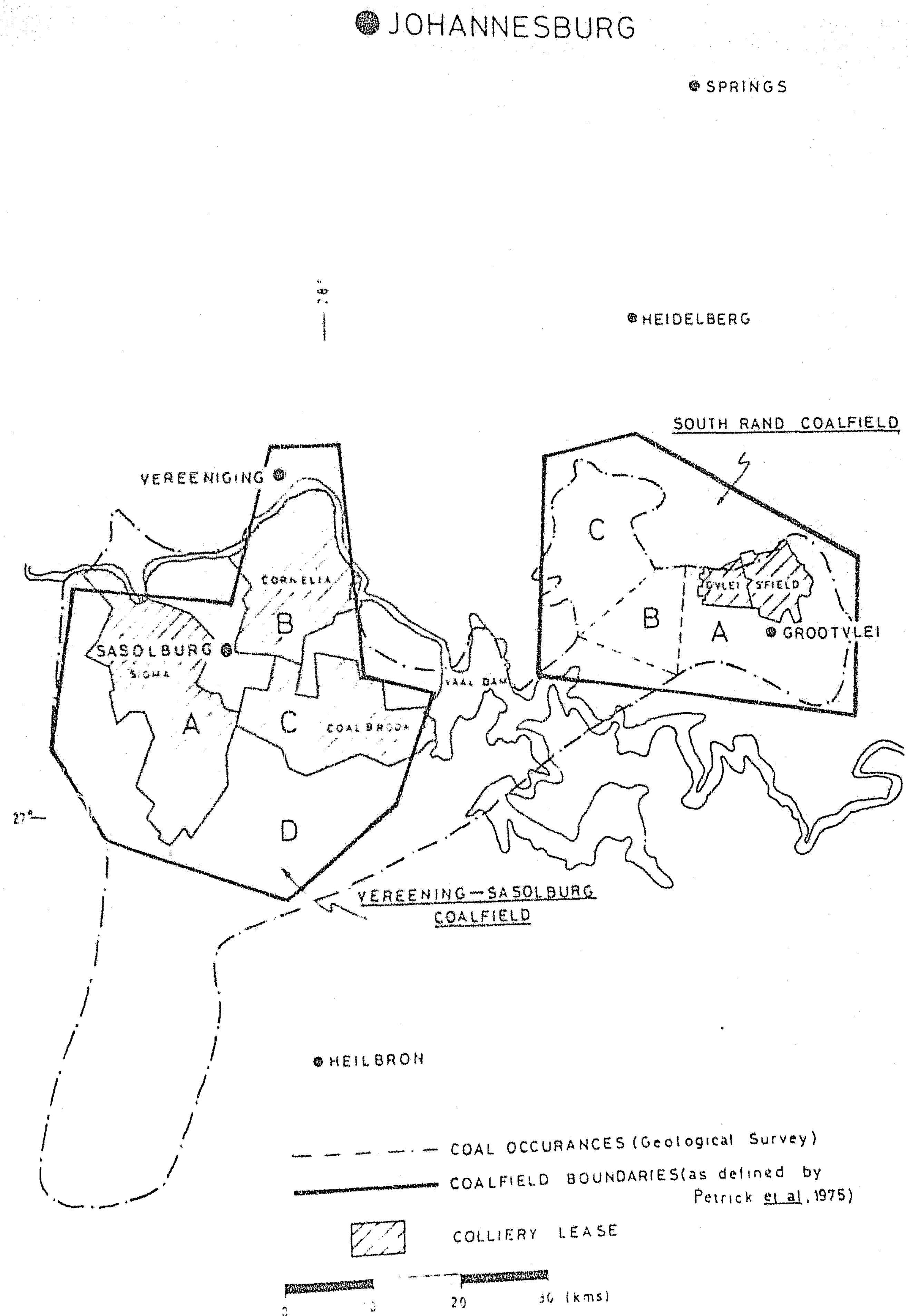


FIGURE 22 Outline of the South Rand and Vereeniging-Sasolburg Coalfields.

On the basis of a consideration of thick seam mining requirements, the coalfield can be divided into three distinct geologic regions, namely A, B and C, Fig. 22. The following points pertain to each of these regions.

Region A

In the north and west of this region the Main Seam may be up to 25 m thick, often in the form of continuous coal over the whole thickness. The average calorific value of the seam is in the range of 20 to 22 MJ/kg. In the east and south the seam splits into three horizons, with the calorific value of the No. 1 horizon increasing to about 27 MJ/kg. The No. 1 and No. 2 horizons progressively thin out eastwards whilst the No. 3 horizon maintains a thickness of about 4 m. All three horizons progressively thin out in a southerly direction. The depth of the coal zone gradually increases from 180 m in the west to 220 m in the east and south. To the north and east the coal zone sub-outcrops against strata of the Witwatersrand System whilst to the south it lies directly on Dwyka tillite.

Region B

Coal horizons become progressively deeper and thinner in a south-westerly direction in this region. Usually, horizons lie at a depth exceeding 220 m and are less than 1 m thick. Consequently, this region is of no economic significance.

Region C

In the south-eastern portion of this region, the Main Seam occurs as three coal horizons. The upper, or No. 3, horizon deteriorates into a carbonaceous shale in a north-westerly direction whilst the middle and lower, or No. 2 and No. 1 horizons form an 18 m thick coal zone. The No. 2 horizon may be up to 5 m thick and the No. 1 coal horizon up to 11 m thick, with sandstone separating the two horizons. The coal zone lies just above Dwyka tillite at a depth of around 180 m although in the far north-western portion of the region it outcrops against strata of the Witwatersrand System.

Generally, coal within this region has a high moisture content which adversely affects its calorific value. Thus, no mining operations of any significance have been undertaken in this region nor, as far as can be ascertained, are likely to be undertaken in the foreseeable future.

Consequently, region A offers the greatest potential for the introduction of thick seam mining methods into the South Rand Coalfield in the foreseeable future.

6.7.2 Geology of region A

An outline of the mineable coal reserves within region A is shown in Fig. 23. This region has been divided into three sub-regions, namely A_1, A_{2S} and A_{2N}. Although region A_1 has been extensively mined, less than 8 per cent volumetric extraction has been achieved from mine workings. Extraction of the remaining reserve, contained mainly in lower grade unmined horizons above and/or below mine workings, is a specialized problem which does not fall into the context of this thesis.

Sub-regions A_{2S} and A_{2N} are referred to as the Western Prospect Area by the mining company which owns the mineral rights to all of region A. During the last four years the geology of the sub-regions has been investigated extensively with the view to establishing a new colliery. These investigations have revealed that the quality of coal in sub-region A_{2S} is not suitable for consumption in the foreseeable future by the sole market

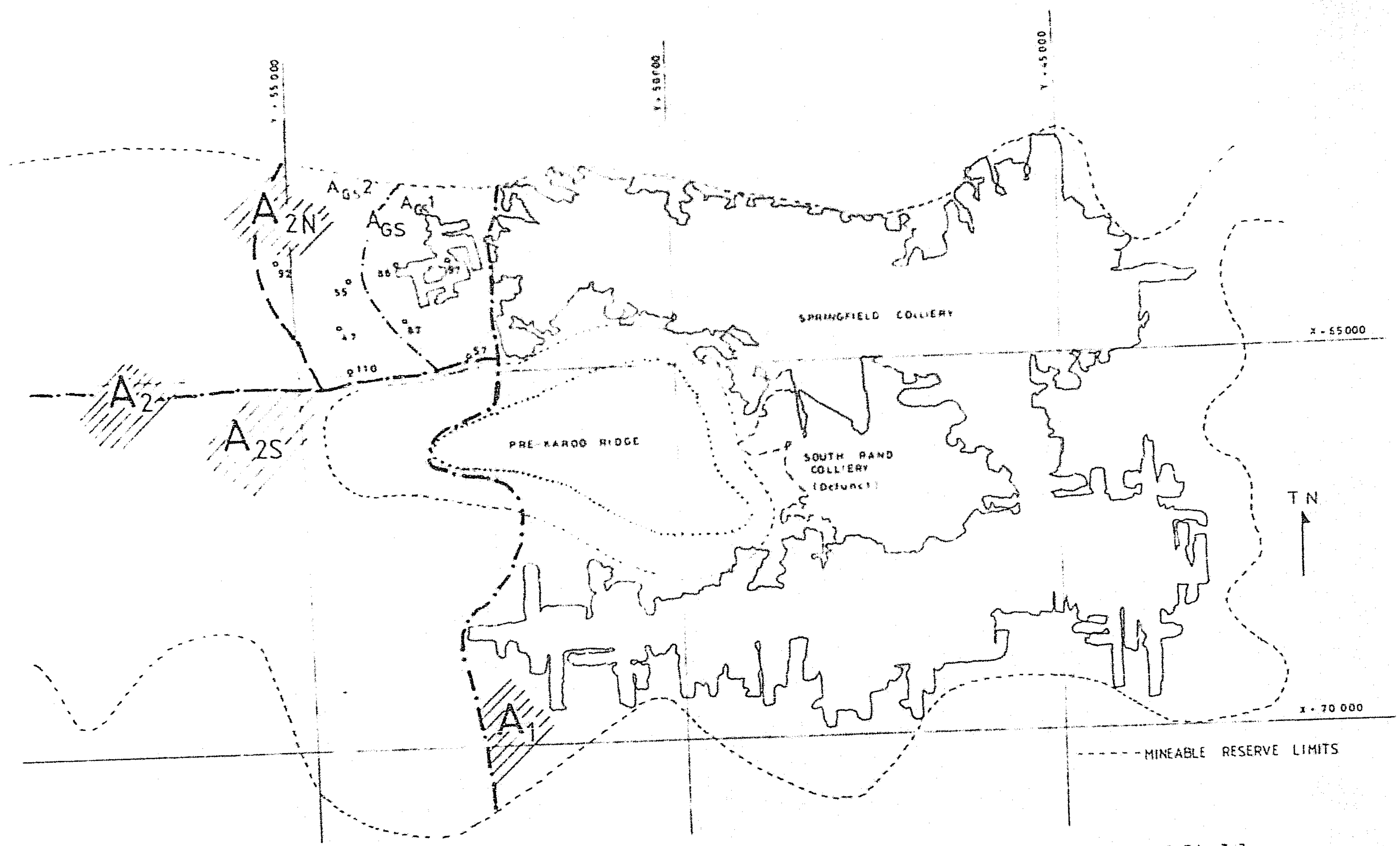


FIGURE 23 An outline of sub-regions, areas and sub-areas in region A, South Rand Coalfield.

for the coal, namely a thermal power station in close proximity to the sub-region. Consequently, the potential for thick seam mining in the future is confined to sub-region A_{2N}.

Preliminary mining operations in sub-region A_{2N} have, in fact, commenced. A number of shaft complexes referred to as the 'Grootvlei Shaft Section' (of Springfield Collieries) have been established in the west of the sub-region, adjacent to, but independent of, existing mine workings, Fig. 23. During the next five to ten years these shafts are intended to service thick seam mining operations in that area of sub-region A_{2N} labelled 'A_{GS}'. However, although primary developments are being established throughout this area, no decision has yet been taken as to what thick seam mining methods are to be utilized in this sub-region. Clearly, there is an urgent need to assess the potential of established thick seam mining methods under the conditions existing in area A_{GS}.

6.7.3 Local geology of area A_{GS}

Seam thickness and the number of seam horizons vary throughout area A_{GS}. This variation in an east-west direction is illustrated in Fig. 24, borehole positions having been shown in Fig. 23. It can be seen that at about 1,0 km to the west of Grootvlei Shaft the Main Seam splits into a number of coal horizons. To the south of Grootvlei Shaft the Main Seam also splits into a number of coal horizons. The approximate outline of that sub-area, $A_{GS}1$, where the Main Seam is a single composite seam is shown in Fig. 23. Geologic conditions pertaining to this area can be assessed in primary development workings associated with Grootvlei Shaft Section and in old West Shaft Section workings of Springfield Colliery immediately adjacent to the Grootvlei Shaft Section. Throughout the remaining

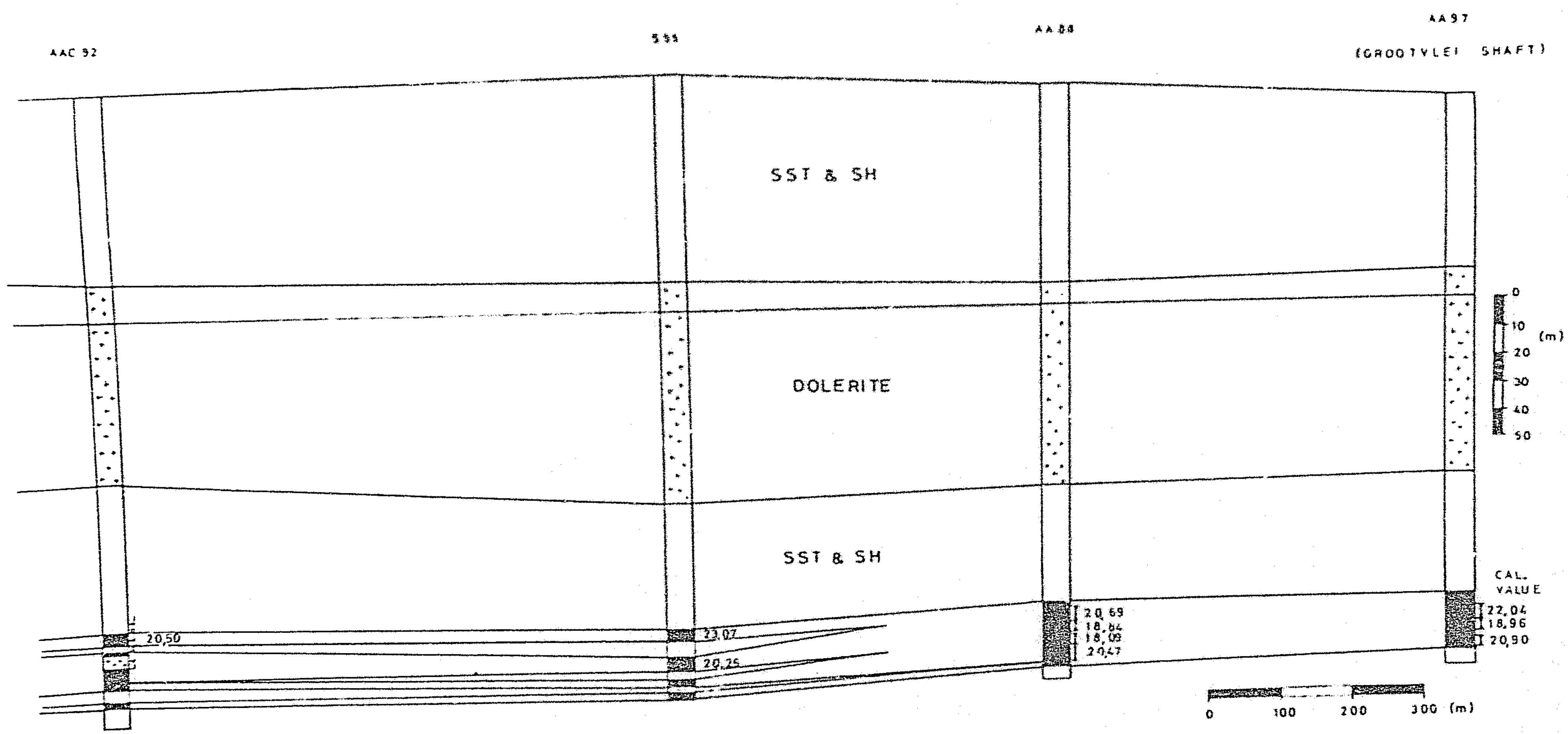


FIGURE 24 East-west geologic cross-section through area A_{GS}, South Rand Coalfield.

portion of area A_{GS}, that is, in sub-area $A_{GS}2$, an assessment of geologic conditions can only be based on borehole information. A tabulation and discussion of these conditions is presented in Appendix VI.4 (Tables VI.26 to VI.29).

6.8 Geology of the Vereeniging-Sasolburg Coalfield

6.8.1 Potential thick seam mining regions

An outline of the boundaries of the Vereeniging-Sasolburg Coalfield is shown in Fig. 22. Within this coalfield coal deposits are generally thick ($\geq$4 m), similar in character and rank, and lie close to the Dwyka tillite in rather deep glacially scoured valleys or basins. Three major basins can be identified, namely the Sigma, Cornelia and Coalbrook basins. These three basins correspond to the lease regions A, B and C, respectively in the Vereeniging-Sasolburg Coalfield, Fig. 22. The limited information available indicates that coal deposits in region D are also contained in basins but these deposits are too deep for bord and pillar mining. Restricted access to detailed information concerning this region prevents a more detailed assessment of geologic conditions in the region.

Extensive mining operations accounting for an annual production of about 13 million tonnes have been taking place for many years in thick seams in regions A, B and C. This entire production is consumed locally by four power stations and one liquefaction plant. Production from region B will be increased in the next five years to supply a fifth local power station. Meanwhile mechanised longwall mining operations have been introduced in regions A and C during the last five years to extract thick seams to a height of 3 m. Furthermore, there is speculation (Spira, 1981) that an additional liquefaction plant to be supplied with coal from region A will be established in the near future. Therefore, it is obvious that a considerable potential for introducing thick seam mining methods exists in regions A, B and C, forthwith referred to as the Sigma, Cornelia and Coalbrook basins, respectively.

6.8.2 Regional geology of the Sigma, Cornelia and Coalbrook basins

The coal zone within each of these basins is up to 40 m thick and contains three principal seams, namely, in order of decreasing depth, the No. 1, No. 2 and No. 3 Seam, Fig. 25. In all three basins the No. 2 Seam is split into the No. 2A Seam and the No. 2B Seam by a mudstone or shale parting.

6.8.2.1 Sigma basin, region A

The Sigma basin is a broad valley, about 9,5 km wide which trends north-south for almost 39 km. A number of secondary valleys trending parallel to the long axis of this valley are contained within the valley. Although the palaeotopraphy was partially smoothed by the deposition of tillite, coal seams were still deposited on an undulating surface.

A typical geologic cross-section across a 3 km width of the basin is shown in Fig. 26. The following points pertain to each of the coal seams, and are summarised in Fig. 27(a):

i) No. 1 Seam

This seam was only formed within secondary channels and valleys in the basin and varies in thickness up to 5 m. It is a low grade, dull coal having an average ash content of 30 per cent. Seam quality and thickness decrease towards the edges of

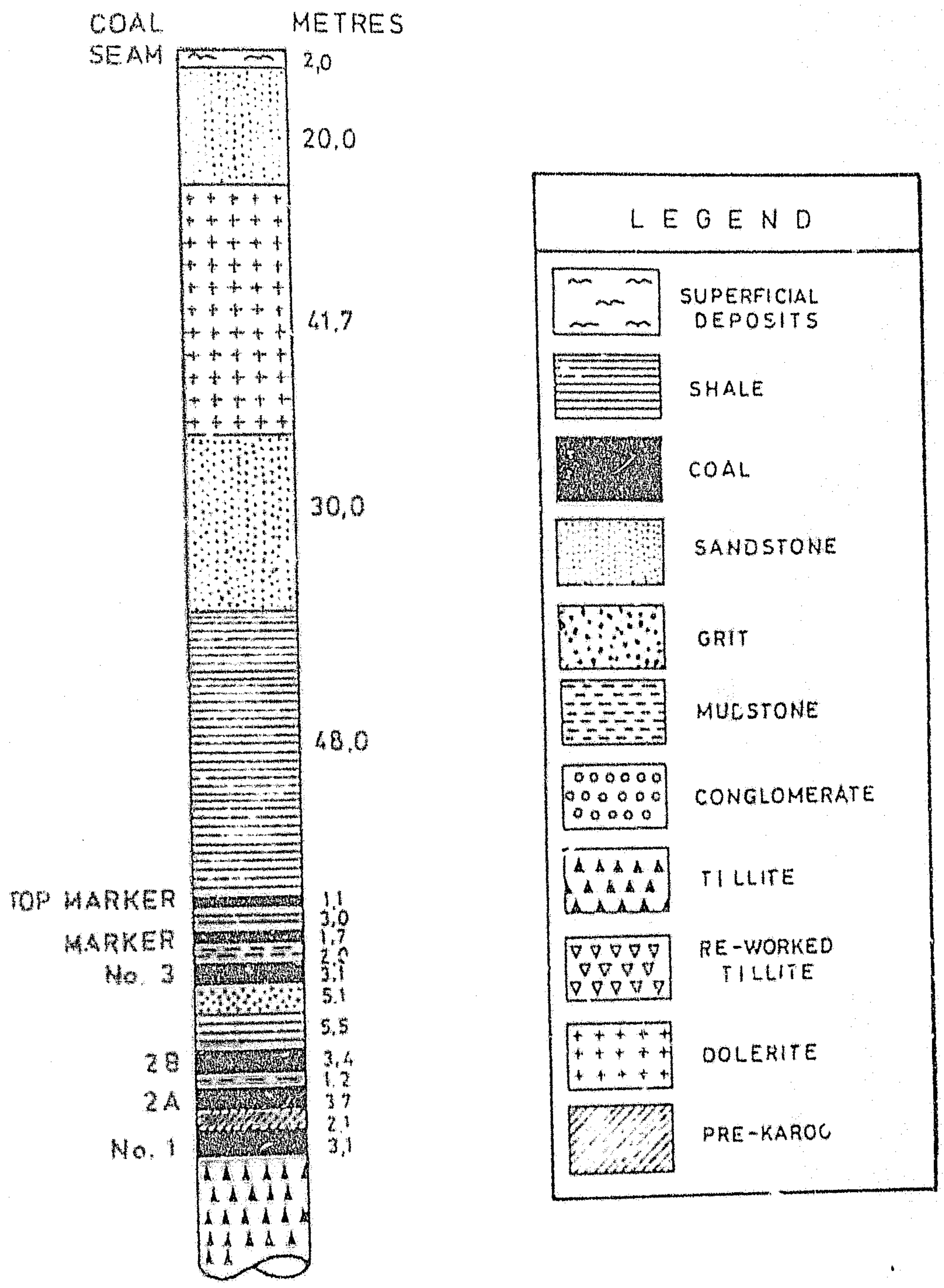


FIGURE [illegible] Generalized stratigraphic section in the Vereeniging-Sasolburg Coalfield.

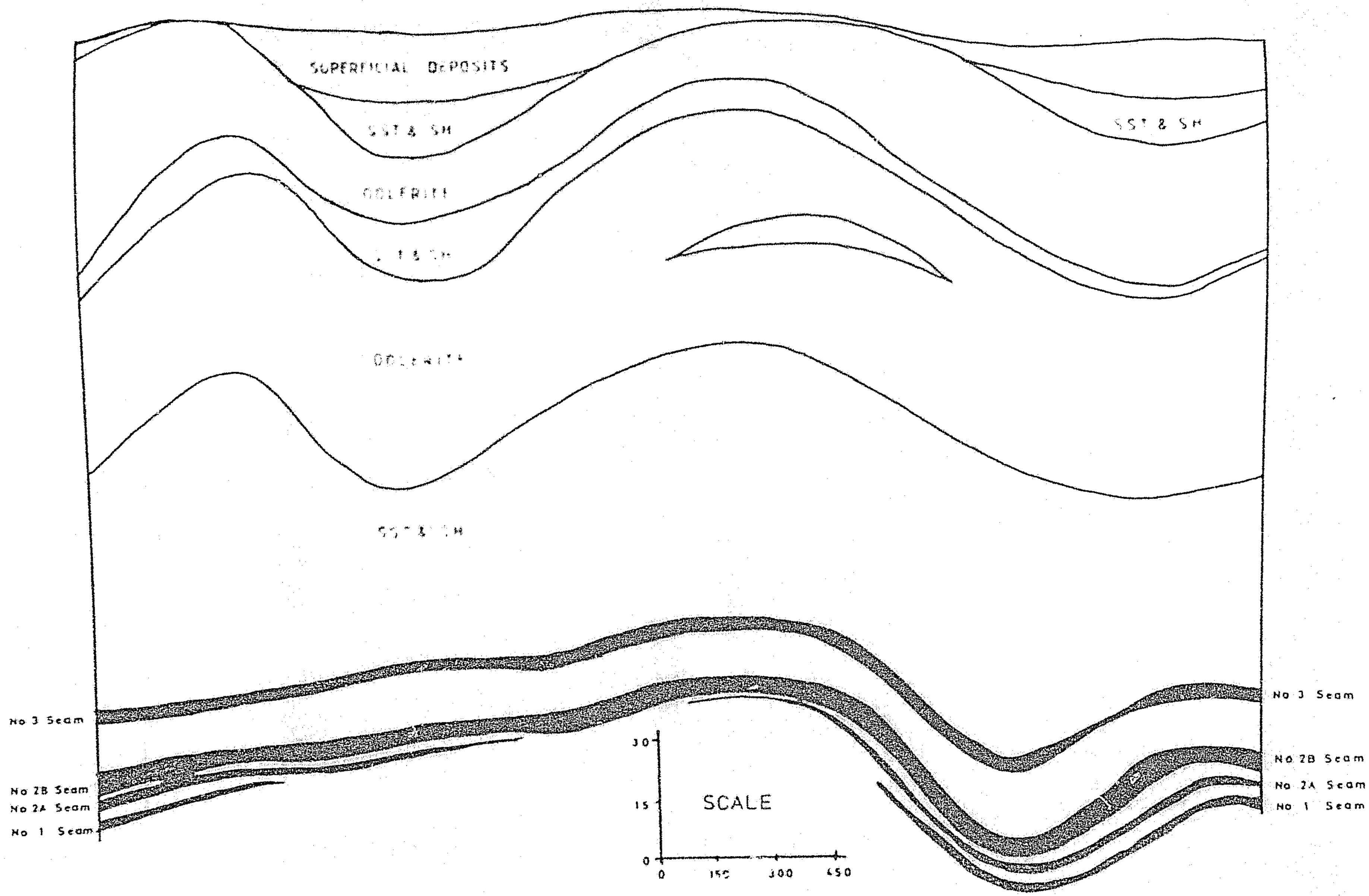


FIGURE 26 Geologic cross-section across a portion of the Sigma basin.

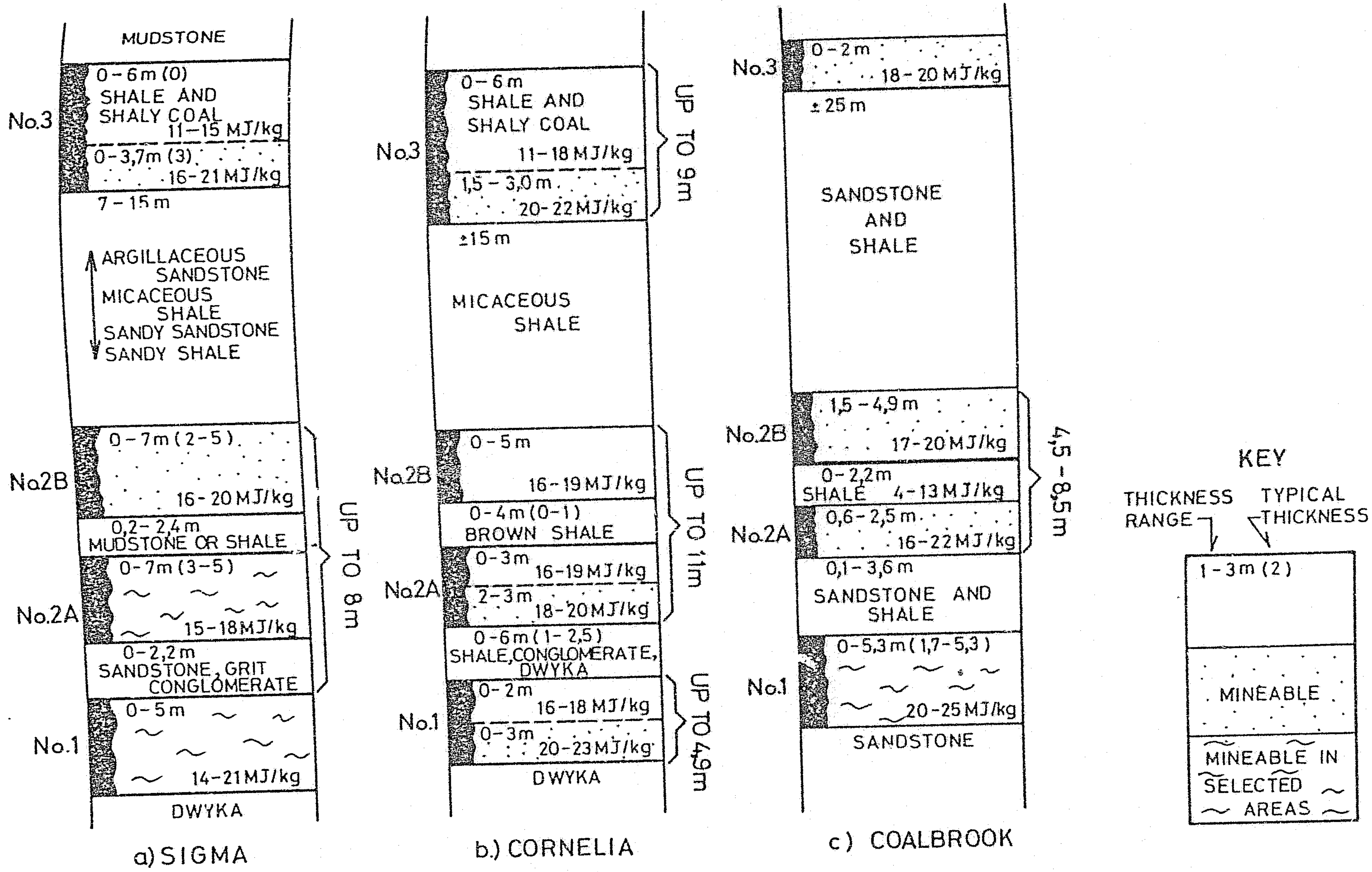
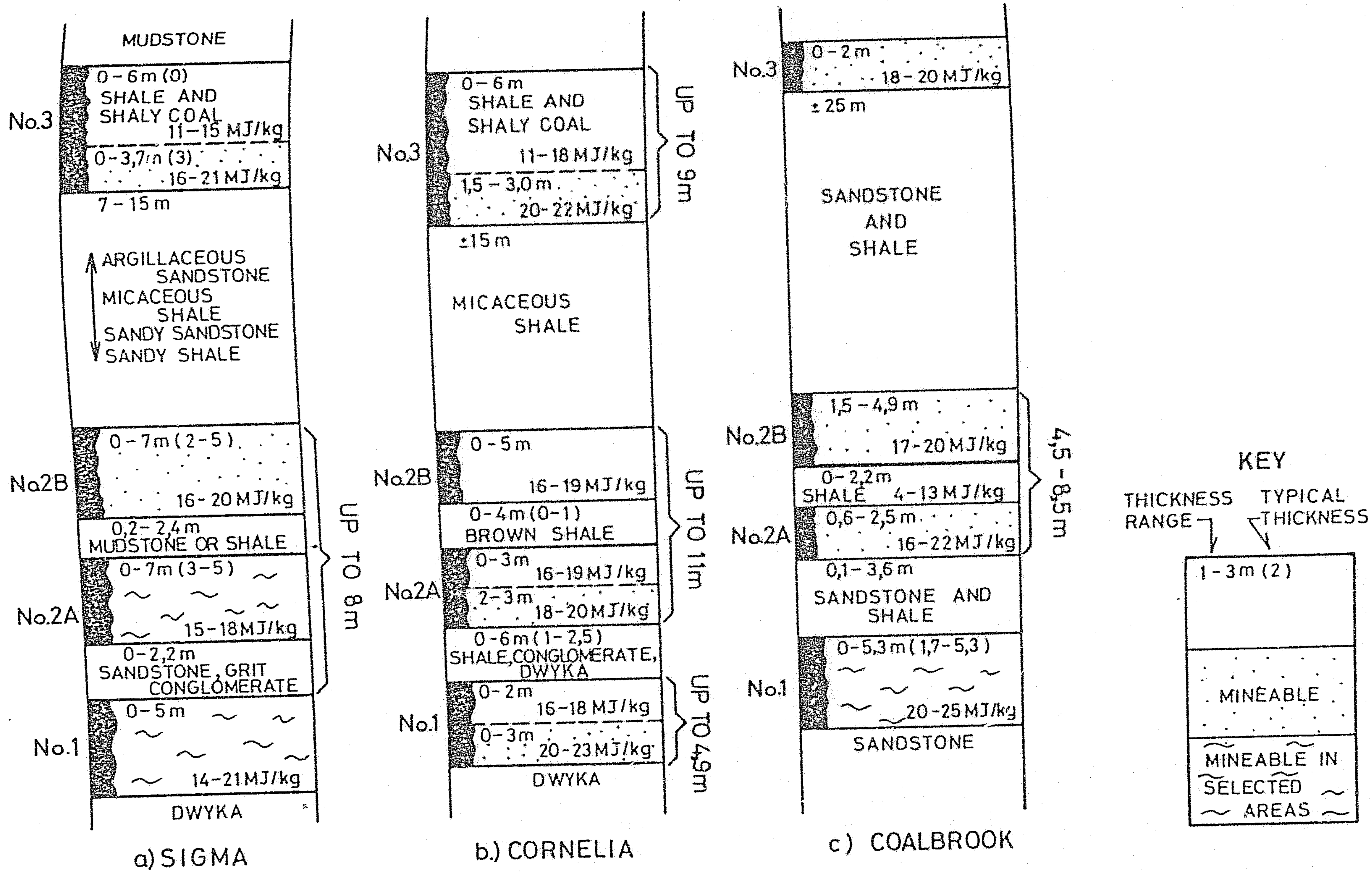


FIGURE 27 Summary of coal successi:n and mineable coal horizons in the Sigma, Cornelia and Coalbrook basins.



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