CHARACTERISTICS OF AUSTRALIAN COKING COALS

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BHP-UTAH COAL

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1. INTRODUCTION

Australian coals range in age from Carboniferous to Tertiary, and commercial or potentially commercial deposits occur in a number of basins and in strata of Permian, Triassic, Jurassic, Cretaceous and Tertiary age; only isolated patches were formed in the Carboniferous period.

The major deposits of black coal are located in the eastern states of Queensland and New South Wales and are of Permian age and significant deposits also occur in Western Australia and South Australia. (Figure 1) A smaller deposit is operated in Tasmania.

The major deposits of brown coal are the Tertiary coals in Victoria and South Australia with major production in Victoria for domestic power generation.

The major production of black coal is from the Permian coals of the Bowen Basin in Queensland and the Sydney Basin in New South Wales and it is these coals, high quality coking and steaming coals, which form the major export market.

Proved reserves of black coal exceed 50,000 million tonnes and additional resources in place are many times this tonnage. Much of the reserves and resources is bituminous coal.

Saleable black coal production has increased substantially over recent years rising from 30 million tonnes in 1965 to over 136 million tonnes in 1986. Domestic consumption has increased to 44 million tonnes a year but the principal factor behind the increased production and the establishment of new mines has been the development of major export markets.

Coking coal reserves are very large at 20,000 million tonnes with present annual production rate of 55 million tonnes. Whilst the Australian steel industry has shown little growth during this period with consumption of coking coal presently at 6 million tonnes a year, the development of the open cut mines in Queensland for the export market has probably been the single most significant factor in world coking coal trade today.

Australian coking coals are of low to medium ash content, low sulphur content and with volatile matter of individual coals covering the complete range from 17 per cent (low volatile) to 37 per cent (high volatile). Both phosphorus content and alkali content are also medium to low. Carbonisation properties range from average medium swelling coals to low and medium volatile strongly coking coals of good plastic properties of fluidity and dilatation; also some good fluidity high volatile coals are produced.

Cokes produced from certain coals have excellent strength properties with low reactivity and high strength after reaction and such coals are considered equal or superior to all other coking coals and are used in major proportions in coke oven feed blends throughout the world.

2. COKING COAL PRODUCING REGIONS

The coking coal producing regions are the Sydney Basin in New South Wales and the Bowen Basin in Queensland.

(A) SYDNEY BASIN

The Sydney Basin (Figure 2) with on-shore area of 36,000 square km was for many years the major source of black coal in Australia. The coking coals range widely in rank and type from prime quality low medium volatile coking coals in the Southern Coalfield (Illawarra Coal Measures) to medium volatile coking coals in part of the South Western Coalfield and to high volatile "soft" coking coals over a wide area of the Northern Coalfield.

SOUTHERN COALFIELD

The Bulli seam (thickness up to 4 metres) and Wongawilli seam (thickness 9 to 11 metres with working of the bottom 3 to 4 metres) are the most important of the four commercial seams of the Southern Coalfield; the other two seams being the Balgownie and Tongarra seams which have greater variability in properties and have economic development only in more confined locations. Coal type expressed by maceral or microlithotype composition is a variable property of the Bulli seam and vitrinite content (mmf) ranges from 25 to 55 per cent. The vitrinite content of the Wongawilli seam is 70 to 80 per cent (mmf) and such vitrinite-rich coal can be blended with the vitrinite-deficient areas of the Bulli seam. Mining is by underground methods.

Extensive coal and coke testwork has been carried out by industry, government research centres and universities and where necessary blending of coal seams can be carried out to obtain the target 45 to 55

per cent vitrinite (mmf) to give the high coke strength, of stability 60-62, with an optimum range of rank for coke making of 1.20 to 1.40 expressed as mean maximum reflectance of the vitrinite.

SOUTH WESTERN COALFIELD

The Bulli seam in the South Western Coalfield is a medium volatile coking coal where quality variation is small and gradual. The seam has a vitrinite content (mmf) of 50 to 60 per cent with a mean maximum reflectance of approximately 1.0 per cent. Mining is by underground methods. Other coal seams are not considered sources of economic coal at the present time.

NORTHERN COALFIELD

The Northern Coalfield consists mainly of the Newcastle, Maitland, Cessnock and Singleton Coal Measures.

The Newcastle Measures contain the vitrinite rich seams which are the source of the high volatile coking coals; these seams are almost wholly concentrated in the Lambton Subgroup at the bottom of the sequence of 14 coal seams. The main coking coal seams worked are the Borehole, West Borehole, Dudley-Yard, Young Wallsend and Victoria Tunnel seams. Thicknesses of up to 7 metres occur with working thickness of 2 to 3 metres. These coals contain up to 80 per cent vitrinite (mmf) with a mean maximum reflectance of vitrinite in the range 0.80 to 0.90 per cent. Coal is mined by underground methods.

In the Singleton coal measures the quality of coking coals vary due to rank changes, with coal on the western and northern flanks being lower in rank. Coking coal seams at present worked include the Liddell, Arties and Pikes Gully in the lower half of the sequence and Mt. Arthur, Wambo and Whybrow in the upper half, with the major production coming from the Liddell Seam. Vitrinite percentage (mmf) is up to 80 per cent with mean maximum reflectance of vitrinite in the range 0.75 to 0.80 per cent. Coal is mined by both opencut and underground methods.

SUMMARY OF PROPERTIES OF PRODUCT COKING COALS

	RANK	VITRINITE		MF
LOCATION	Ro MAX %	% (mmf)	FSI	ddpm
Southern Coalfield	1.23 - 1.30	40 - 53	5 - 7	250 - 1000
South Western Coalfield	1.0 - 1.1	50 approx	5 - 7	1000 - 2000
Northern Coalfield	0.7 - 0.9	50 - 80	5 - 7	100 - 1500

(B) BOWEN BASIN

The Bowen Basin (Figure 3) covers an area of 75,000 square km of Permian marine and fresh water sediments in the hinterland of Central Queensland. The Permian coals vary progressively in rank from high volatile bituminous to anthracitic and the pattern of the changes provides clear evidence of the direct relationship of rank to the amount of superimposed structural deformation to which the coals have been subjected together with some contribution from depositional influences. In general rank decreases to the south and west of the Basin.

RANGAL - BARALABA MEASURES

The youngest interval of commercially important coal seams are those in the Rangal Coal Measures in the west and north west and the Baralaba Coal Measures in the south east. These coal measures are at the top of the Upper Permian Sequence. The major seam in the Rangal Measures is characteristically dull with a variable proportion of bright coal at the base and only in selected areas is there significant bright coal throughout the seam. Overall Rangal product coking coal has an FSI of 6 to 7.

The coal of the Baralaba Measures is more variable but with more vitrain content and FSI of product coal of 6 to 8.

Coal mined from these measures are both open cut and underground with the predominence of coal production from open cut operations.

FAIRHILL - GERMAN CREEK FORMATIONS/MORANBAH COAL MEASURES

Also in the Upper Permian sequence are the coalfields of the Fairhill and German Creek Formations and Moranbah Coal Measures, which have been recognised as one of the most important developments in world coking coal. The economic seams are contained within 300 metres of sediments which for the most part dip regularly to the east at between 3 and 5°. Only locally is there any significant structural disturbance and the coals extend virtually uninterupted for some 140 km along strike. In almost all cases the coal comes to between 20 to 40 metres of the surface. The seams are up to 10 metres thick with only a gradual rank increase from the northern part, mean maximum reflectance of vitrinite 1.10 per cent, to a higher rank, mean maximum reflectance of vitrinite 1.60 per cent, 140 km away.

In the southern part of this coalfield the upper seam splits into two to three metre sections and the rank decreases to a mean maximum reflectance of vitrinite of 0.95 per cent. In all cases the vitrinite percentage is 70 to 75 per cent and the FSI of coking coal product is generally 8-9.

Coal mined in this area is predominately by open cut methods although some underground operation has now commenced.

COLLINSVILLE MEASURES

The Lower Permian coals include the Collinsville Coal Measures in the north western part of the Basin and the Blair Athol Coal Measures in the western part of the Basin. Only the Bowen seam of the Collinsville Measures has coking properties with a product containing approximately 50 per cent vitrinite and an FSI of 6.

SUMMARY OF PROPERTIES OF PRODUCT COKING COALS

	RANK	VITRINITE		MF
COAL MEASURE	Ro MAX %	% (mmf)	FSI	ddpm
Rangal - Baralaba	0.95 - 1.25	60 - 70	6 - 8	150 - 2000
Fairhill - German Creek	0.95 - 1.60	65 - 78	8 - 9	30 - 7000
Moranbah				
Collinsville	1.10	50	6	2000

3. COKING COAL QUALITY

(A) DOMESTIC CONSUMPTION

The steelworks of Australia are located in New South Wales (Port Kembla Works and Newcastle Works) and in South Australia (Whyalla Works).

The New South Wales steelworks were designed to use coking coal from the immediate locality. Port Kembla Works are supplied with low medium and medium volatile coking coals from the Southern Coalfield whilst the Newcastle Works are supplied with high volatile coking coals from the Northern Coalfield (70 percent) supplemented with higher rank coals from the Southern Coalfield. The Whyalla Works are situated away from coking coal sources and now use a blend of low medium and medium volatile Southern Coalfield coal together with Queensland low volatile coking coal (25 per cent).

Typical coal blends are as in Table 1.

TABLE I - COAL BLENDS AT AUSTRALIAN STEELWORKS

		Port Kembla	Newcastle	Whyalla
Ash	(d.b) %	8.0	9.5	10.5
Volatile Matter	(d.b) %	22-23	30.0	22-24
Sulphur	(d.b) %	0.40	0.45	0.50
CSN		7-8	6-7	6-8
Maximum Fluidity	ddpm	200-600	300 (min)	500-1000
$\bar{R}o$ max	%	1.20-1.30	1.05	1.20-1.30

(B) EXPORTS

Coking coal is exported from the Southern, South Western and Northern Coalfields of the Sydney Basin in New South Wales and from the Bowen Basin in Queensland, the mines of the latter being developed for the export market.

SYDNEY BASIN

Export coking coals from the Southern Coalfields are characterised by low medium volatile matter, medium ash content, low sulphur content, medium FSI, medium dilatation, good fluidity and low vitrinite content.

Coals from the South Western Coalfields are characterised by medium volatile matter, medium ash content, low sulphur content, medium FSI, medium dilatation and fluidity and lowish vitrinite content.

Coal from the Northern Coalfields are characterised by high volatile matter, medium ash content, medium sulphur content, lowish FSI, generally lowish dilatation and fluidity. Vitrinite percentage is medium to high.

Typical properties of Sydney Basin export coking coals are listed, Table II.

BOWEN BASIN

Export coking coals from the Rangal-Baralaba Coal Measures are characterised by medium volatile matter, medium to low ash content, low sulphur content, medium FSI, generally lowish dilatation and fluidity although there are exceptions, and medium vitrinite content.

The coking coals from the Fairhill-German Creek Formations/Moranbah Coal Measures are generally considered the premium export coking coals of Australia. Individual coals range from low volatile to high volatile, with medium ash content, lowish sulphur content, good FSI, good fluidity and dilatation, medium to high vitriite content and low to medium phosphorus and alkalis. A significant feature of the low volatile coals is the low pressure generated during carbonisation, unlike most other low volatile coals. Cokes produced from certain coals have excellent strength properties with low reactivity and high strength after reaction.

The coking coals from the Collinsville Coal Measures are medium volatile, medium ash content, highish sulphur, medium FSI, medium dilatation and fluidity but with lowish vitrinite content.

Typical properties of Bowen Basin export coking coals are listed, Table III.

Australian coking coals with lower vitrinite contents do not conform to the coke prediction models from petrographic properties which were developed in the northern hemisphere and in almost all cases coke strength predicted underestimates the strength of the actual coke produced.

4. COAL MINING OPERATIONS

Individual coking coal mines are large both in size, up to 25 km long, and in production rate, up to 5 million tonnes a year of product coal. Coal seams vary in thickness up to 10 metres and are at depths from 20 metres.

In the Bowen Basin coal is mined principally by opencut methods although some relatively small underground mines have been in operation for some time. More recently more underground development has taken place.

The opencut operations involve the use of large draglines, bucket wheel excavators and scrapers and trucks for overburden removal. This overburden at present is of working thickness of 20 to 65 metres depending on the particular mine, and it is planned to develop opencut operations to at least 90 metres given suitable strip ratios. Large electric shovels and front end loaders are used for coal mining.

The underground mining methods use both the room and pillar and longwall systems with seam extraction up to 3 metres.

The mined coal is usually too high in ash content for direct utilisation and large complex coal preparation plants have been constructed to give products of high consistency. Some mines and preparation plants produce a single product, coking coal, whereas others are now multiple product operations producing coking coal, weak coking coal and thermal coal.

Quality control is of the highest standard and since the Permian Coal Measures are overlain by Tertiary sediments there is minimum weathering. The coal seams are generally thick and gently dipping within minimum rank changes over a particular mine. Tens of thousands of bore cores have been drilled for pre mine and mine studies where the coal properties can be evaluated before mining commences in order to ensure maximum consistency of product. This is followed by continuous quality

control during mining and preparation operations.

New railways linked to large new ports constructed at Gladstone, Mackay and Bowen ensure continuity of supply.

In the Sydney Basin coking coal is mined by underground methods in the Southern and South Western Coalfields and by underground and opencast methods in the Northern Coalfield. Large complex coal preparation plants have been built to give the desired products of high consistency. A number of mines produce multiple products of coking coal, weak coking coal and thermal coal. Quality control is equally rigorous to ensure product consistency.

New and expanded ports have been built at Port Kembla and Newcastle to serve the export markets.

5. WEAK COKING COAL

More recently new terminology has been introduced to describe coking coals with very inferior carbonisation properties, but which can be either high or low rank. These coals are called weak coking coals, sometimes known as semi-soft coking coals.

Such coals are produced generally in smaller tonnages and mostly as secondary products from coking coal operations. Most coking coal production regions in the Sydney Basin and the Bowen Basin produce such coals.

Weak coking coals are generally higher in ash content, slightly higher in sulphur content but considerably inferior in FSI, fluidity and dilatation properties and generally have a reduced vitrinite content when compared with normal coking coals.

Such weak coking coals are produced either by selective mining, selective preparation, or incorporating some partly oxidised coking coal in the open-cut operations, or by selective mining and selective preparation for the underground operations.

A table of some Australian weak coking coals is included, Table IV.

6. CONCLUSIONS

Australian coking coals cover a wide range of properties from low volatile to high volatile content. Many product coals are of excellent quality producing superior cokes and such coals are used as major blend components throughout the world. In 1986 product coking coal was 55 million tonnes of which 49 million tonnes were exported to the following diversified markets.

Japan	27.0 million tonnes
Other Asia	8.9 million tonnes
European Region	11.8 million tonnes
The Americas	1.0 million tonnes

REFERENCES

1. AUSTRALIAN BLACK COAL SYMPOSIUM - Editor A.C. Cook
Australasian Institute of Mining and Metallurgy, 1975

2. ECONOMIC GEOLOGY OF AUSTRALIAN AND PAPUA NEW GUINEA. PART 2, COAL
Australasian Institute of Mining and Metallurgy, 1975

3. AUSTRALIA'S COKING COAL RESOURCES - K.W. Bateman
International Iron and Steel Institute Meeting, Australia 1982

4. COAL MARKETING MANUAL 1986
Published by Australian Coal Report

FIGURE 1 - AUSTRALIAN COAL RESOURCES

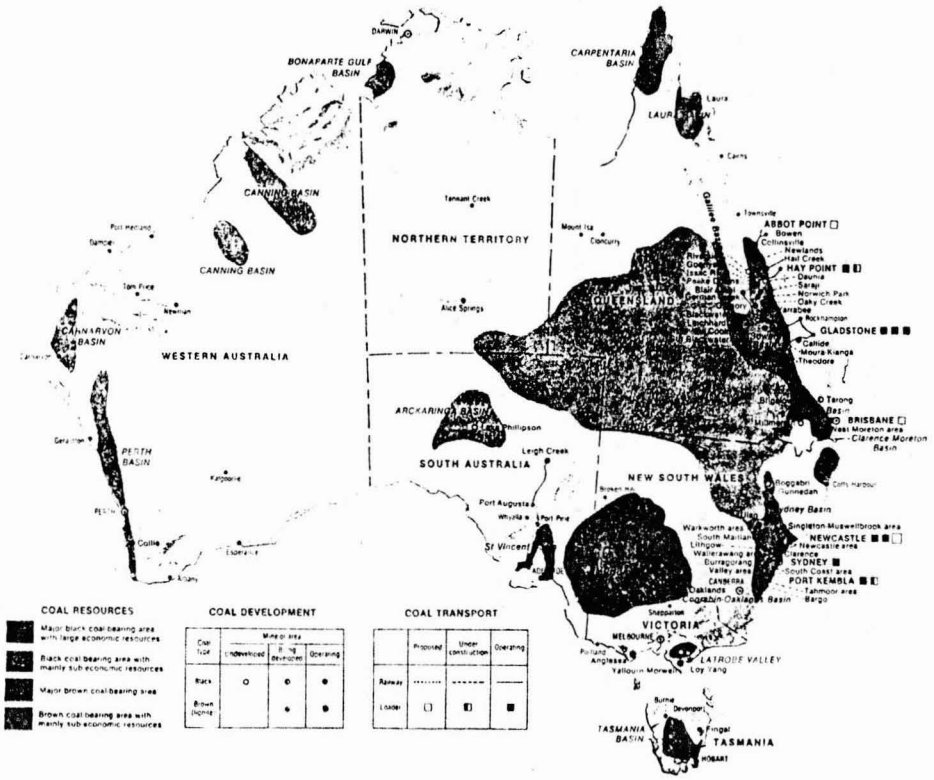

FIGURE 2 - SYDNEY BASIN

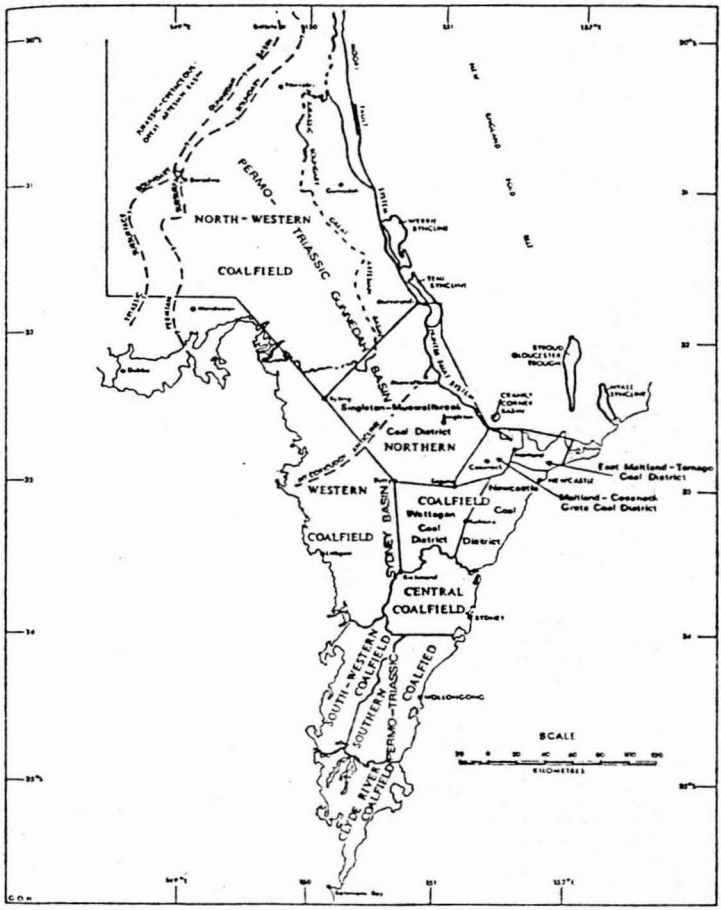

FIGURE 3 - BOWEN BASIN

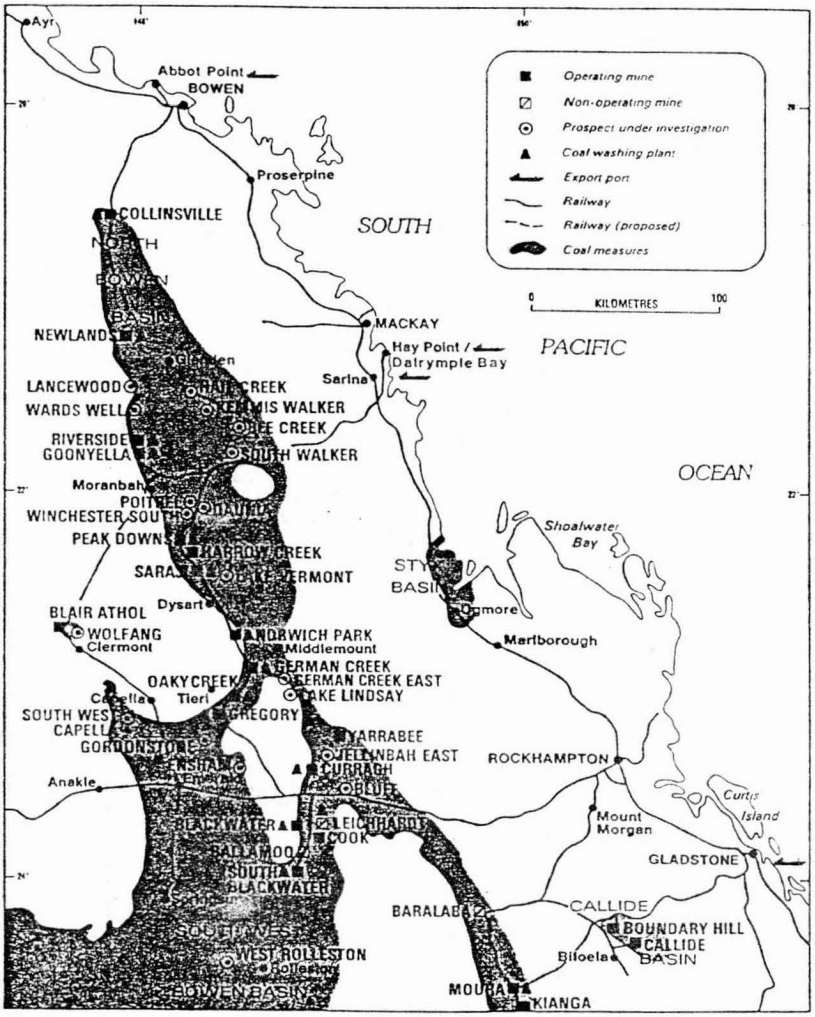

TABLE II - SYDNEY BASIN COKING COALS

COAL BRAND	TOTAL MOISTURE %	PROXIMATE ANALYSIS (A.D BASIS)			TOTAL SULPHUR (A.D) %	PHOSPHORUS (A.D) %	LABORATORY CARBONISATION TESTS			PETROGRAPHIC SUMMARY			ALKALIS IN ASH		CORE REACTIVITY (N.S.C.)	
		MOISTURE %	ASH %	VOLATILE MATTER %			FSI	MAX FLUIDITY DDPM	TOTAL DILATATION %	VITRINITE %	EXINITE %	$\bar{R}$O MAX %	Na_2O %	K_2O %	CRI	CSR
COALCLIFF	7.0	1.0	9.8	21.5	0.38	0.06	5-7	>250	35-75	49	0.5	1.30	0.29	0.71	-	-
WESTCLIFF	7.0	1.0	9.8	21.5	0.38	0.07	5-7	>500	50-80	49	0.5	1.29	0.29	0.71	25.5	66.1
SOUTH BULLI	7.0	1.0	9.5	21.4	0.40	0.03	5-7	1000	34	39	-	1.23	0.42	1.80	22.0	68.3
ILLAWARRA	9.0	1.0	10.0	22.0	0.35	0.04	6-7	500	68	51	0	1.27	0.3	1.0	22.0	69.0
TAHMOOR	7.0	1.2	8.5	27.5	0.40	0.05	6	2000	56	47	0	1.10	0.17	0.80	28.1	57.1
WOLLONDILLY	7.0	1.5	7.9	27.5	0.40	0.06	5	1000	7	47	3	1.01	0.15	0.77	33.4	51.5
MACQUARIE	8.0	2.5	7.5	34.5	0.45	0.05	6-7	>1000	110	78	8	0.90	0.7	1.0	42.0	37.0
LEMINGTON	8.0	2.5	7.5	34.9	0.40	0.015	5.5	300	25	64	4	0.77	0.48	1.16	44.0	35.5
HUNTER VALLEY	8.0	3.0	7.0	35.0	0.50	0.01	5	100	20	70	2	0.71	0.5	1.1	42.3	36.2
MOUNT THORLEY	9.0	2.5	8.5	34.0	0.55	0.006	5	100	35	75	2	0.78	0.50	0.59	-	-
WARKWORTH	8.0	2.5	7.0	36.0	0.50	0.01	5-7	-	-	-	-	-	-	-	38.2	39.7
LIDDELL	7.0	2.5	8.5	36.0	0.60	0.07	5-6	1000	90	78	4	0.74	1.0	0.8	42.2	33.5
RATHLUBA	7.0	2.3	8.0	36.0	0.73	0.022	5.5	400	47	73	4	0.81	0.37	1.21	38.9	40.8
WEST WALLSEND	9.0	2.5	9.0	36.5	0.60	0.08	5	350	40	78	2	0.80	0.6	0.7	-	-
NEWDELL	7.0	3.2	8.5	37.5	0.60	0.04	5.5	220	56	72	8	0.70	0.33	0.70	49.2	31.1
DAIYON	8.0	2.5	7.5	37.5	0.70	0.04	5-6	>1000	61	60	10	0.75	1.0	1.3	42.6	35.6

TABLE III - BOWEN BASIN COKING COALS

COAL BRAND	TOTAL MOISTURE %	PROXIMATE ANALYSIS (A.D BASIS)			TOTAL SULPHUR (A.D) %	PHOSPHORUS (A.D) %	LABORATORY CARBONISATION TESTS			PETROGRAPHIC SUMMARY			ALKALIS IN ASH		COKE REACTIVITY (N.S.C.)	
		MOISTURE %	ASH %	VOLATILE MATTER %			FSI	MAX FLUIDITY DDPM	TOTAL DILATATION %	VITRINITE %	EXINITE %	$\bar{R}$O MAX %	Na2O %	K2O %	CRI	CSR
CURRAGH	8.0	1.5	7.0	22.0	0.52	0.03	7	>100	25-75	55-70	0	1.24	0.10	0.96	34.5	58.4
BLACKWATER	8.0	2.0	7.8	27.0	0.50	0.04	6	150	25	58	2	1.05	0.29	1.64	44.1	36.8
COOK	9.0	1.4	7.0	27.5	0.38	0.05	7-8	>2000	100-130	60	2	1.08	0.5	0.9	43.9	35.4
SOUTH BLACKWATER	8.0	2.0	5.5	28.4	0.45	0.05	7	500	30	58	2	1.08	0.22	1.05	36.8	48.0
MOURA	8.0	2.0	8.0	28.0	0.45	0.02	8	1000	130	60-65	3	1.05	0.5	3.0	35.0	52.0
NORWICH PARK	8.0	0.9	9.5	17.2	0.65	0.03	8-9	35	60	74	0	1.60	0.43	0.96	17.2	72.8
SARAJI	8.0	1.0	9.3	19.5	0.55	0.03	8-9	150	94	71	0	1.50	0.51	1.00	17.3	73.3
PEAK DOWNS	8.0	1.0	9.3	21.0	0.55	0.03	8-9	300	105	71	0	1.40	0.36	1.19	16.7	74.2
GERMAN CREEK	8.0	1.2	8.5	21.0	0.70	0.05	8-9	700	154	73	0	1.40	0.4	1.0	21.6	64.1
RIVERSIDE	8.0	1.4	9.8	23.9	0.57	0.006	7.5	800	120	58	2	1.17	0.5	0.8	23.0	67.6
GOONYELLA	8.0	1.0	8.0	25.5	0.50	0.03	8	1750	166	63	1	1.12	0.32	0.79	22.6	67.7
OAKY CREEK	8.0	1.2	8.0	29.5	0.80	0.05	8-9	>5000	235	76	0	1.07	0.48	0.63	30.5	55.4
GREGORY	8.0	2.0	8.0	32.0	0.65	0.03	8-9	3000	127	74	3	0.95	0.30	0.76	30.6	53.6
COLLINSVILLE	8.0	1.5	9.0	26.0	0.95	0.02	6	2000	118	49	3	1.09	0.14	0.55	28.9	51.4

TABLE IV - WEAK COKING COALS

COAL BRAND	TOTAL MOISTURE %	PROXIMATE ANALYSIS (A.D.) MOISTURE %	ASH %	VOLATILE MATTER %	TOTAL SULPHUR %
HOSKISSON	8.0	2.5	9.5	34.0	0.6
PEKO	8.0	2.5	9.5	36-38	0.9
BAYSWATER	8.0	3.0	8.5	34.0	0.8
WARKWORTH	8.0	2.5	9.0	34.8	0.5
LITHGOW	8.0	2.5	10.0	31-33	0.65
HUNTER VALLEY	8.0	3.0	9.5	34.0	0.6
WAMBO	9.0	3.0	9.0	35.0	0.6
BIG BEN	8.0	2.5	9.5	35.0	0.6
HOWICK	8.0	3.0	9.5	35.5	0.7
BLACKWATER	8.0	2.0	9.5	27.0	0.5
CURRAGH	8.0	1.5	8.0	19-21	0.6
K-COAL	8.0	2.0	8.5	30.0	0.6
W-COAL	8.0	2.0	9.5	26.0	0.6
NORWICH PARK	8.0	1.0	11.0	17.0	0.65
OAKY CREEK	8.0	1.2	10.5	30.0	0.85
GREGORY	8.0	2.0	9.7	31.0	0.7

FSI IS TYPICALLY 2 TO 3 BUT WITH SOME EXCEPTIONS.