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PETROGRAPHIC, PHYSICO-CHEMICAL, AND COAL FACIES STUDIES OF TEN MAJOR SEAMS OF THE SYDNEY COALFIELD OF NOVA SCOTIA

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Microscopic view of Sydney coal at 600x magnification.

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PETROGRAPHIC, PHYSICO-CHEMICAL, AND COAL FACIES STUDIES OF TEN MAJOR SEAMS OF THE SYDNEY COALFIELD OF NOVA SCOTIA

Abstract

Coal compositional data based on coal petrological analyses of ten major coal seams (0.9-4.3 m thick) in the Sydney coalfield have been presented. Projections are given for pyrite distribution, type of banding, coal strength, methane adsorption potential, and coal facies interpretations. Included also are detailed ash and sulphur analyses and coal rank data.

The occurrence and properties of thermal and metallurgical coal and the resultant coke are indicated. The updated calculations of coal resource estimates of the Sydney coalfield show the total "demonstrated resources" amount to 1133 million tonnes of which 66% is classed as thermal coal and 34% as metallurgical coal.

Résumé

Le présent bulletin synthétise les données dérivant d'analyses pétrologiques sur la composition de dix couches de charbon d'importance (d'une épaisseur de 0,9 à 4,3 mètres) faisant partie du champ houiller de Sydney. Les informations suivantes sont données pour chaque couche : la quantité de pyrite observée, le type de litage, la résistance du charbon, le potentiel d'adsorption du méthane et des interprétations des faciès houillers. Des données de classification du charbon (rang) et d'analyse de sa teneur en cendres et en soufre sont aussi incluses.

Les propriétés et la répartition régionale du charbon thermique, du charbon métallurgique et du coke dérivé font également l'objet d'une section. De nouveaux calculs des ressources en charbon du champ houiller de Sydney montrent que le total des «ressources prouvées» s'élève maintenant à 1 133 millions de tonnes métriques, dont une proportion de 66 % consiste en du charbon thermique et de 34 %, en du charbon métallurgique.

SUMMARY

The Sydney Basin is a paralic coalfield with minor marine incursions. Ten major seams, 0.9 to 4.3 m thick, are present in 2237 m of strata, which are of Westphalian C and D and Stephanian age. The coals are H.V. "A" and partially H.V. "B" bituminous, with vitrinite reflectance levels of V-7 to V-10. The rank increases from west to east, and downdip (or seaward).

Detailed petrographic data on ten column samples are illustrated in comprehensive diagrams. They show microlithotype and maceral composition, and projected information on pyrite distribution, coal banding, coal strength, coal bed methane evaluation, and proximate analyses data.

SOMMAIRE

Le bassin de Sydney est un champ houiller de type paralique comprenant de minces unités marines. Dix couches d'importance d'une épaisseur de 0,9 à 4,3 mètres sont présentes sur un total de 2 237 mètres de strates qui datent du Westphalien C et D et du Stéphanien. Les charbons sont du type bitumineux «A» très volatil et, partiellement, du type bitumineux «B» très volatil; ils ont des niveaux de réflectance de la vitrinite allant de V-7 à V-10. Le rang des charbons augmente d'ouest en est et vers l'aval-pendage (vers la mer).

Des données pétrographiques détaillées sont fournies pour dix échantillons (carottes de forage) sous la forme de diagrammes exhaustifs, lesquels figurent entre autres la composition des charbons (microlithotypes et macéraux), à partir de laquelle sont évalués les caractéristiques suivantes : la quantité de pyrite observée, le type de litage, la résistance du charbon, le potentiel d'adsorption du méthane; sont également représentées les données d'analyse immédiate.

All Sydney seams consist of predominantly bright coal with vitrite varying between 16 and 33%, clarite between 52 and 69%, fusite between 3 and 10%, and durite averaging only 7%.

The coal macerals show the following variations: vitrinite between 67 and 82%, with the telinite ranging between 22 and 44%, and collinite between 36 and 45%. Exinite averages 6% and inertinite 16%.

Pyrite and sulphur distributions show the highest content occurring in the lower seams (up to 6.2%) and the lowest content (0.8%) in the Harbour seam.

The methane adsorption potential is greatest in the upper five seams, which also have the lowest coal strength.

The coal facies diagrams show that the predominant environment of peat deposition was the forest moor in the telmatic zone. The average of all seams showed: forest terrestrial moor 26%; forest moor (telmatic) 50%; reed moor 22%; and open moor 2%.

The maceral facies diagram reveals that the Sydney seams originated in the lower delta plain with a freely meandering fluvial system.

The occurrence and properties of thermal and metallurgical coal and the resultant coke are indicated. Updated calculations of coal resource estimates of the Sydney coalfield are included also. The total "demonstrated resources" amount to 1133 million tonnes of which 66% is classed as thermal coal and 34% as metallurgical coal.

Toutes les couches de charbon du champ de Sydney sont surtout constituées de charbon brillant ayant les teneurs suivantes en microlithotypes : vitrite, de 16 à 33 %; clarite, de 52 à 69 %; fusite, de 3 à 10 %; durite, seulement 7 % en moyenne.

Quant aux teneurs en macéraux, elles montrent les variations suivantes : vitrinite, de 67 à 82 % (télinite, de 22 à 44 % et collinite, de 36 à 45 %); exinite, 6 % en moyenne; inertinite, 16 % en moyenne.

Pour ce qui est de la pyrite et du soufre, les teneurs les plus élevées apparaissent dans les couches les plus profondes (jusqu'à 6,2 %) et les plus faibles, dans la couche Harbour (0,8 %).

Le potentiel d'adsorption du méthane est maximum dans les cinq couches les plus hautes dans la stratigraphie, lesquelles ont aussi les charbons aux valeurs de résistance les plus faibles.

Les diagrammes des faciès houillers selon les microlithotypes montrent que l'environnement prédominant où la tourbe s'est accumulée était caractérisé par la présence de marécages forestiers de la zone telmatique. Une moyenne faite sur toutes les couches montre la distribution suivante : marécages forestiers terrestres, 26 %; marécages forestiers (zone telmatique) 50 %; marais tourbeux à roseaux, 22 %; marais ouverts, 2 %.

Les diagrammes des faciès houillers selon les macéraux révèlent que les couches du champ de Sydney se sont formées dans la partie basse d'une plaine deltaïque à réseau fluvial fortement sinueux.

Les propriétés et la répartition régionale du charbon thermique, du charbon métallurgique et du coke dérivé font également l'objet d'une section, tout comme de nouveaux calculs des ressources en charbon du champ houiller de Sydney. Selon ces calculs, le total des «ressources prouvées» s'élève maintenant à 1 133 millions de tonnes métriques, dont une proportion de 66 % consiste en du charbon thermique et de 34 %, en du charbon métallurgique.

INTRODUCTION

A detailed compilation of coal compositional data based on coal petrological analyses is presented in this report. Ten major coal seams were examined and a comprehensive diagram, showing the vertical succession of microlithotypes and macerals through each seam section, has been constructed. From these data information on pyrite distribution, type of banding, coal strength, methane adsorption potential, and coal facies interpretations are projected. Included also are detailed ash and sulphur analyses and coal rank data, as well as coal resource calculations.

The sampling and the microscopic analyses were carried out during the early 1950s at the Coal Division of the Geological Survey of Canada in Sydney, Nova Scotia. The release of these data and the revision of coal resource estimates for the Sydney Coalfield were the main objectives of this study.

GENERAL INFORMATION ON THE SYDNEY COAL BASIN

Location, age, and stratigraphy

The Sydney coal basin is situated in northeastern Nova Scotia on and offshore of Cape Breton Island (Fig.1). It consists of two parts: a small land area of about 520 km^2 and a region where mining is carried out below the sea. Both form part of a large Carboniferous basin that extends almost as far as Newfoundland, occupying some 36 300 km^2. It is referred to as the Sydney Basin. The structural style of the basin is relatively simple and, except for local folding, is essentially saucer shaped with the beds dipping towards the deeper and central parts of the basin.

The coal-bearing rocks belong to the Pictou (Morien) Group, which, on the basis of the megaflora and spore florule, has been assigned a Westphalian C and D, and Stephanian age (Bell, 1938; Barss and Hacquebard, 1967). The maximum

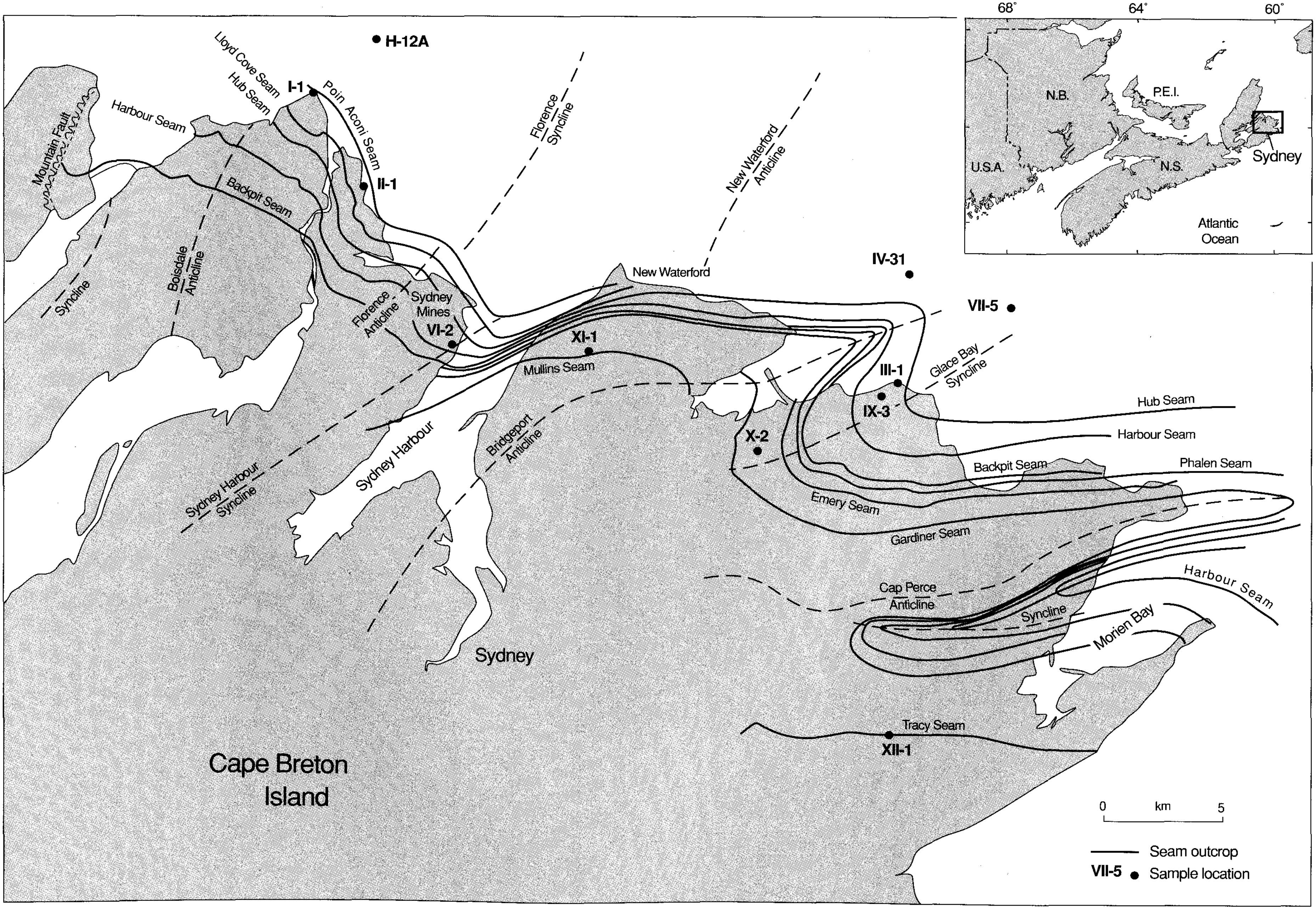

Figure 1. *Sydney coalfield, Nova Scotia, showing seam outcrops and locations of column samples.*

thickness of the Morien Group in the onshore portion is 1966 m, to which an additional 271 m, encountered in the offshore wells can be added, for a total thickness of 2237 m. The group has been divided into three formations, which from oldest to youngest are: 1) South Bar Formation; 2) Waddens Cove Formation; and 3) Sydney Mines Formation (Boehner and Giles, 1986). The last is the main coal-bearing formation and contains thirteen seams that are 0.9-4.3 m thick; twelve of which outcrop in the land area, and are named from the Point Aconi to the Tracy seam (Fig. 1 and see Fig. 3). All but one of these seams have been mined in the past, but at the present time submarine operations are carried out on only two seams.

General characteristics of coal composition and rank

The Sydney seams can be classed as humic coals in which the banded bright type predominates. In this type, clarain and vitrain bands alternate and form the principal megascopic constituents (Appendix A) (Diessel, 1965). However, seam intervals of intermediate and banded dull coal are present also, as well as thin layers of impure coal or carbargilite.

The coal rank is high volatile "B" to high volatile "A" bituminous in the onshore part of the coalfield, and increases from west to east. In the submarine part, where nearly all mining has taken place, the rank increases seaward with the depth of mining, reaching medium volatile bituminous between depths of 600 and 750 m (Hacquebard, 1993); Ro_{max} values range from 0.6 to 1.4%. All seams have low ash yields, which range from 3 to 9%. The sulphur content, however, is generally high and ranges from 0.8 to 6.2%. The sulphur occurs mainly as finely divided pyrite, predominantly in the roof and bench coal. The pyrite precipitation is probably related to sulphur-bearing solutions derived from gypsum deposits underlying the coal measures (Gibling et al., 1989). It is not caused by marine incursions, because substantial marine beds overlying the coal seams have not been identified.

Depositional environment and regional seam development

The Sydney coalfield forms part of a paralic basin of deposition in which terrestrial deposits are interbedded with marine sediments. The latter occur sporadically in the Sydney succession, which is thought to have originated in the lower delta plain of the basin. However, typical characteristics of paralic coals are clearly present, such as the occurrence of normal-banded autochthonous coals, the phenomenon of seam splitting and rejoining, the presence of fossil rivers, etc. (Hacquebard and Donaldson, 1969).

The regional seam developments are illustrated in Figure 2, which shows west to east cross-sections through five upper seams. The sections are based on actual seam measurements taken at numerous underground locations. The different patterns that are presented reveal the ever changing interaction between fluvial sedimentation and peat accumulation. This interaction also causes seam termination by the process of subdividing and eventual pinching out of individual coal benches.

Regionally, only the upper five seams are present over the entire width of the coalfield, namely the Point Aconi, Lloyd Cove, Hub, Harbour, and Backpit seams. The lower five seams, comprising the Phalen, Emery, Gardiner, Mullins, and Tracy seams, occur in the eastern part only. The western continuation of the upper seams is related to the transgressive nature of the upper zones of the Morien Group, which overstep the lowest zone to the west. The earliest coal formation started in the eastern part of the field (with the Tracy seam), and as time progressed the succeeding seams gradually extended to the west.

PETROGRAPHIC AND PHYSICO-CHEMICAL ANALYSES

Microscopic procedures

The petrographic study of the ten major seams of the Sydney coalfield was done on ten column samples with a total thickness of 18.6 m (Fig. 3). The samples were taken from seam outcrops, prospect adits, and underground mines, and collected at locations with optimum seam thickness, with least stone partings and undisturbed banded sequence. The "type" columns, therefore, are situated pretty well over the entire extent of the coalfield.

The microscopic examination was carried out between 1949 and 1953 with polished sections cut across the bedding plane, and measuring 6x8 cm. For the ten columns a total of 401 sections were prepared, and their microlithotype composition determined under reflected light at a magnification of x100. The sequence was then recorded at true scale in so-called coal logs, which are shown in simplified and reduced form on the left side of the diagrams (Fig. 4-1 to 4-10). The coal logs were subsequently subdivided into units of similar type coal, referred to as petrographic intervals. They were identified by the occurrence of distinct dull bands and bright coal units. The intervals reflect the changing conditions of peat formation during the life of the seam. In order to compare the conditions of peat formation among different seams, the Frequency of Petrographic Intervals (FPI) index has been introduced. It is obtained by dividing the number of intervals by the seam thickness in metres, which brings it to a uniform standard, regardless of the total seam thickness.

For each petrographic interval, the amount present of the respective microlithotypes has been determined and plotted (by volume) in the percentage diagrams (Hacquebard, 1951) (Fig. 4-1 to 4-10).

The maceral determinations were carried out on grain mounts representing the individual petrographic intervals. These were done at x150 magnification with an oil immersion objective on etched pellets (Hacquebard, 1960; Stanton and Moore, 1991), and are plotted also in percentage diagrams.

Physical and chemical evaluations

For each petrographic interval the following physical and chemical properties were evaluated:

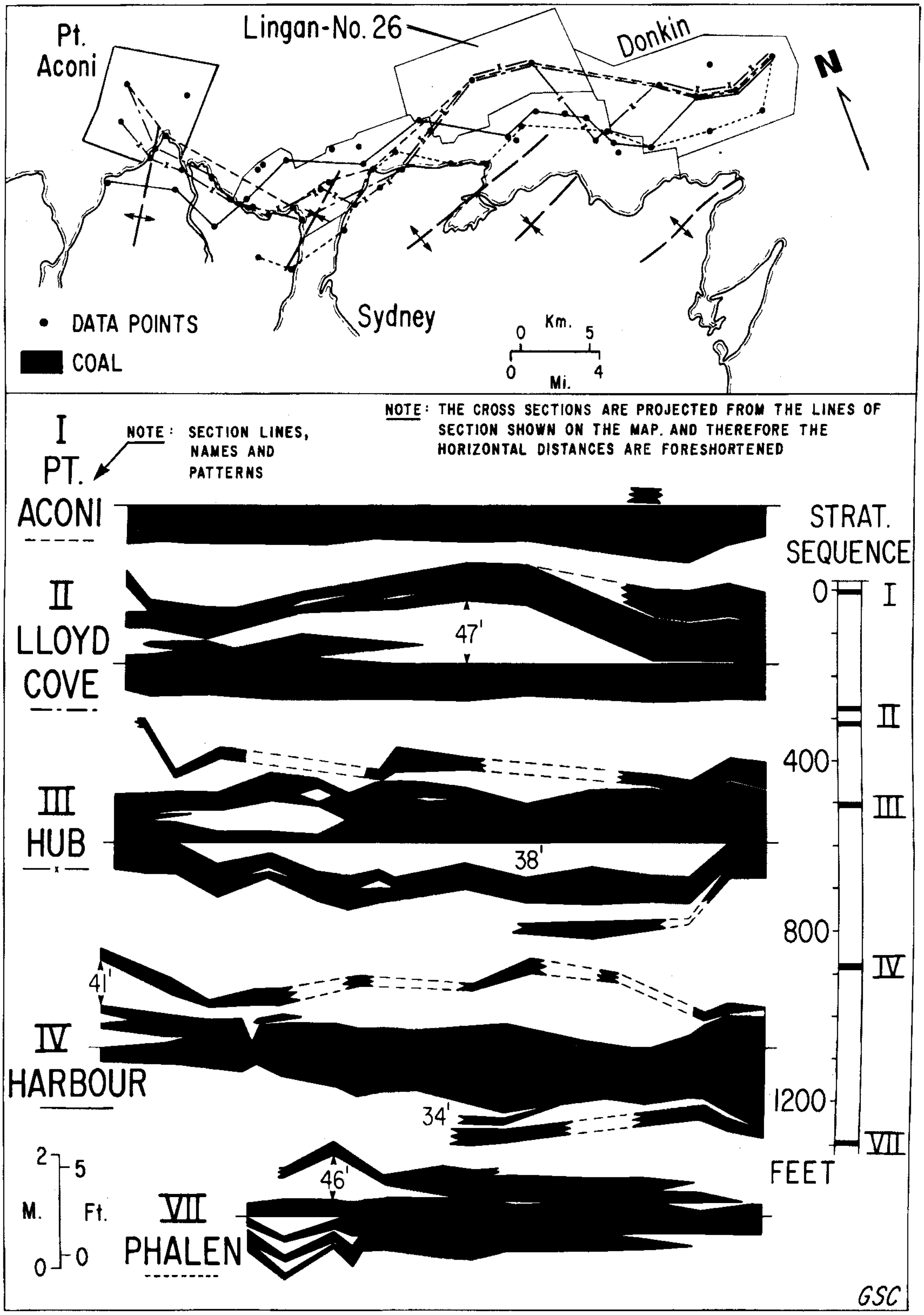

Figure 2. Cross-sections through five upper seams of the Sydney coalfield (after Hacquebard and Donaldson, 1969; updated).

Occurrence of pyrite

Visual distribution of pyrite is described in terms of low, medium, and high.

Banding of coal

The banding of the coal is described in terms of the vitrite plus fusite (V+F) index. This index is obtained by dividing the total thickness of vitrite plus fusite bands (in mm) by the total number of bands, which represents the average band thickness.

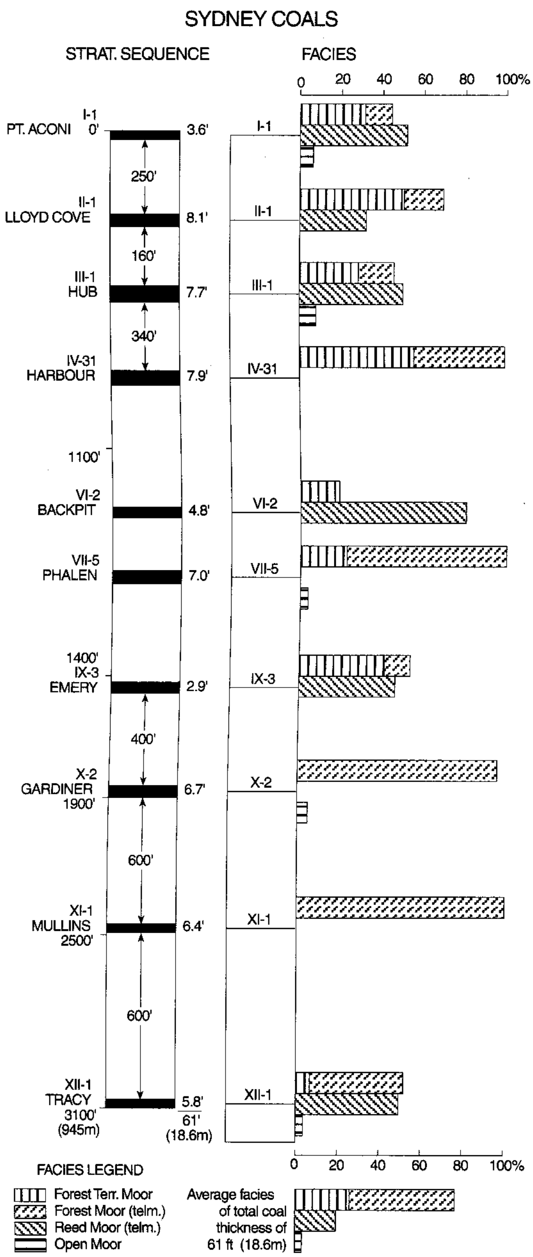

Figure 3. *Whole-seam facies variations of ten major coals of the Sydney coalfield based on microlithotype determinations (modified from Hacquebard, 1993).*

Coal strength

The coal strength is determined from the banding of the coal. Thin-banded coal with a V+F index below 1.9 mm is generally regarded as a strong, compact coal, whereas an index in excess of 2 mm signifies a weak and fractured coal.

Coal bed methane evaluation

The methane adsorption potential is deduced from the cleavage and the petrographic composition. High vitrite content and friable coal with a rank in excess of V-7 are considered favourable (Rightmire and Choate, 1986).

Proximate analyses data

The amounts of ash and sulphur for each interval are also indicated in the diagrams.

COAL FACIES INTERPRETATIONS

Microlithotype-based facies determinations

These determinations follow the procedure previously developed by Hacquebard and Donaldson (1969). By analogy with different vegetation zones present in peat bogs, four coal facies types are recognized, namely: forest terrestrial moor (FtM), forest moor (FM), reed moor (RM), and open moor (OM). The four diagnostic microlithotype combinations of the different facies types are: A: dull clarite; B: vitrite+fusite; C: bright clarite; and D: clarodurite+durite+impure coal. They are plotted at the vertices of a four-component, diamond-shaped diagram consisting of two equilateral triangles (Fig. 4-1 to 4-10). In the upper or bright coal triangle the petrographic composition has less than 20% dull coal components (D). In this case the amount of D is added to that of A. Likewise, the amount of B is added to C in the lower dull coal triangle, which has more than 20% dull coal.

The three classifying sectors of the upper triangle denote areas in which the corresponding end-member is present by more than one third of the total composition, and is always more than either of the other two. In the lower dull coal triangle the sector at the bottom denotes an area where end-member D exceeds 47% (=20%+ $^1/_3$ x 80%), and where D is more than either A or B+C. In the other two sectors, D is present by less than 47%, with A larger than B+C in the right-hand sector, and B+C larger than A in the left-hand sector. Each classifying sector is identified by its own pattern of shading.

The level of the groundwater plays a very important role in the type of vegetation and the mode of preservation of the plant debris. In relation to this level, Swedish investigators (Oswald, 1937) have introduced the following terminology: (1) terrestrial zone, above high water mark; (2) telmatic zone, between high and low water mark; (3) limnic zone, which designates the subaquatic region of deposition. In the terrestrial zone, where dry conditions prevail, the formation of vitrite+fusite is envisaged in a forested moor, which is designated as forest terrestrial moor. In the telmatic zone were formed the forest moor and reed moor facies of the upper bright coal triangle. The limnic zone is represented by the subaquatic deposits of the lowermost sector of the dull coal triangle, and the two remaining sectors of this triangle are considered as limno-telmatic deposits.

For each seam the type of facies of the different petrographic intervals (indicated by roman numerals) is shown in the facies diagram in Figures 4-1 to 4-10. In addition, the cumulative facies of the entire seam is plotted in a bar diagram. It reflects the vertical variations in facies development throughout the life of the seam, whereas the average facies (plotted as Av in the facies triangle) denotes the overall facies per entire seam unit. It does not show the presence of variable conditions within the seam.

Maceral-based facies determinations

Studies by Diessel (1982, 1986) and Calder et al. (1991) have shown that facies determinations can be done also from the refined maceral analysis, particularly in regard to the vitrinite constituents. The method, originally proposed by Diessel (1982), was later modified by Calder et al. (1991). Calder et al. (1991) emphasized the influence of the groundwater level and the type of vegetation. They used the terms groundwater influence index (GWI) and vegetation index (VI).

In this paper the breakdown of total vitrinite into structured vitrinite (cf. telinite), groundmass vitrinite (cf. collinite), and resinite (telo-collinite) has been achieved by the etching method (Hacquebard, 1960). The formulas of the Calder et al. (1991) method to determine the GWI and VI indices are:

$$\text{Groundwater Influence Index (GWI)} = \frac{\text{groundmass vitrinite} + \text{mineral matter}}{\text{structured vitrinite}}$$

$$\text{Vegetation Index (VI)} = \frac{\text{structured vitrinite} + \text{semifusinite} + \text{fusinite} + \text{resinite}}{\text{groundmass vitrinite} + \text{macrinite} + \text{sclerotinite} + \text{exinite}}$$

Effect of associated clastic sediments

The clastics below the seams reflect the depositional environment of the overlying peat deposit, be it in a delta plain, in abandoned river channels, or in overbank areas. But a relationship between seam thickness and lithology of the underlying clastics, as reported by Mastalerz and Wilks (1992) in the Polish coal basin, was not observed in the Sydney seams.

DETAILED ANALYSES OF TEN MAJOR COAL SEAMS

Point Aconi seam

Sample I-1, Figure 4-1, Appendix B-1 and C-1

Sample location

Shore section at Point Aconi
DEVCO coordinates (metric)
N 4,900; W 8,000

Seam section

Roof: grey shale with well preserved plant remains
Coal 109 cm (3.6 ft)
Pavement: fire clay with *Stigmaria* rootlets

Detailed petrography

This seam has eight petrographic intervals that consist of bright coal in all but interval VIII, which consists of impure coal. It lies at the top of the seam and is 6 cm thick. The bright coal has variable amounts of bright and dull clarite, which account for the recognition of the different intervals. Together they comprise 67% of the seam average composition. Only two thin durite bands are present. Fusite bands occur fairly abundantly, particularly in the upper half of the seam. A clean coal averaging only 6.6% ash but with 3.9% sulphur is present. The sulphur occurs in the form of finely disseminated pyrite, particularly in the roof and bench coal.

The maceral analyses show a high inertinite content in intervals V, VI, and VII. It occurs mainly in the dull clarite variety, and represents 21% of the seam average composition. Exinite is low and averages 5%, whereas total vitrinite averages 67%.

Physical data

The vitrite+fusite index shows that a thick and coarse-banded coal, with indices greater than 2.0 mm is present through most of the seam. The coal strength accordingly is weak and fractured, possessing many cleavage faces.

The methane potential therefore is considered good, although the rank of V-7 is rather marginal at the sample location. However, higher rank can be expected with an increase in overburden in the submarine area.

With a Frequency of Petrographic Intervals (FPI) index of 7.3, rapidly changing conditions of peat deposition likely occurred, although of moderate effect as only dull clarite rather than durite was formed.

Coal facies interpretations

The ternary microlithotype diagram indicates that the reed moor environment predominated, representing 51% in the "cumulative facies" calculation. The forest terrestrial and forest moor conditions occurred in 43%, and the groundwater level of the telmatic zone prevailed during all environments, except at the forest terrestrial moor position.

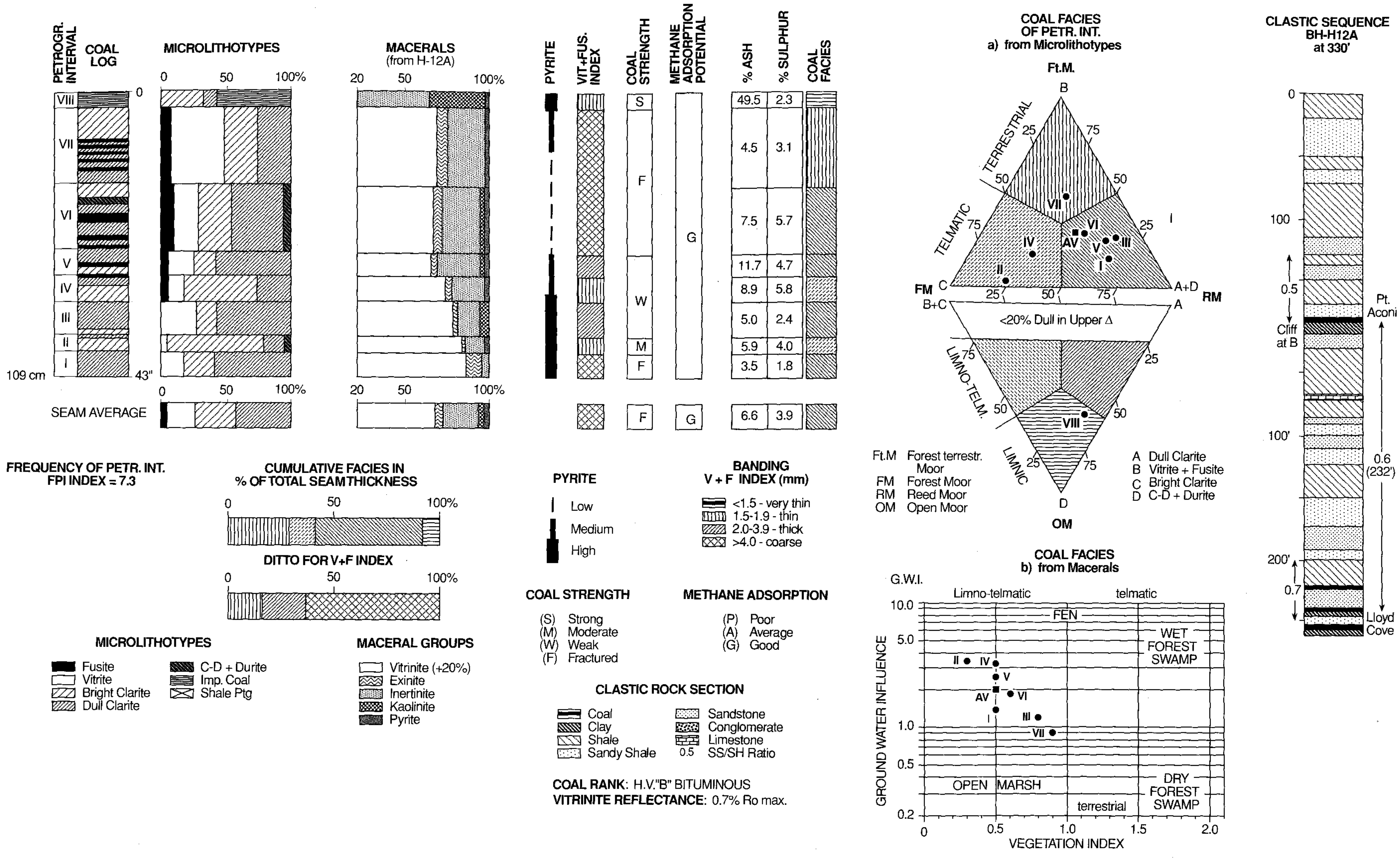

Figure 4-1. Petrological compilation: sample I-1, Point Aconi seam.

The maceral facies diagram shows that the peat formation took place under wet conditions in the limno-telmatic zone of the groundwater level. A deeper swamp is indicated by the maceral data than by the microlithotypes, but reed moor and marsh environments prevailed in both methods.

Lloyd Cove seam

Sample II-1, Figure 4-2, Appendix B-2 and C-2

Sample location

Borehole D-18 between 62 and 70 ft. (18.9 and 21.3 m); in Sydney Mines district
DEVCO coordinates (metric)
N 5,700; W 14,463

Seam section

Roof: grey sandy shale
Coal 163
grey shale 1.5
Coal 81.5
Total height <u>246</u> cm (8.1 ft)
Pavement: grey shale with poor plant remains

Detailed petrography

With a thickness of nearly 2.5 m, this is the thickest seam examined. It contains eleven petrographic intervals which consist of banded bright coal in the upper and lower part of the seam, and entirely bright coal in the central portion (intervals VI and VIII). The banded bright coal has several durite bands that are 0.3-1.5 cm thick. They cause the higher ash contents of 22.9, 20.4, and 21.3% in intervals XI, X, and V. Fusite bands that are 0.2-1.5 cm thick occur throughout the seam section but are more abundant in the upper and lower parts.

Bright and dull clarite are the dominant microlithotypes and together constitute 59% of the seam average composition. A relatively clean coal averaging 8.4% ash, with a very high sulphur content of 5.8% is present. The sulphur is almost entirely derived from finely disseminated pyrite, which occurs throughout the seam section, as is shown in the diagram.

The maceral analyses confirm the abundance of bright and dull clarite with a high percentage of vitrinite, averaging 67%. Seam total inertinite content is 22%, but reaches 44% in interval VII where a durite band occurs. About half of the inertinite consists of fusinite splinters and the other half of macrinite and micrinite. Exinite averages 6%, which is about normal for the Sydney coals.

Physical data

The vitrite+fusite index shows that a thin-banded coal is present throughout, with an index of 1.5-1.9 mm. Based on the banding and the presence of dull microlithotypes (claro-durite, durite, and impure coal) and thickness of fusite bands, coal strength has been interpreted as follows: a generally weak coal is present, which is particularly fragile in the upper part (intervals VIII to XI) because of the numerous fusite bands.

The methane adsorption potential is considered good because of (1) the high content of vitrinite, (2) the fractured nature of the coal, and (3) the rank of V-7, although marginal, will increase downdip (seaward) with greater overburden.

With an FPI index of 4.4, the vertical variation in composition indicates significant changes in conditions of peat formation during the life of the seam.

Coal facies interpretations

The ternary diagram of the microlithotype combinations indicates that essentially forest terrestrial and forest moor facies (in the terrestrial and telmatic zones) are present, with a minor occurrence of the reed moor facies. This is shown also in the bar diagram of the cumulative facies where the forest terrestrial and forest moor environment together account for 68%. A generally dry forest moor is envisaged for the formation of this seam.

The maceral facies diagram shows more wet conditions, with a tendency to a forest moor environment.

Hub seam

Sample III-1, Figure 4-3, Appendix B-3 and C-3

Sample location

Shore section at Glace Bay in adit of Burned Mine
DEVCO coordinates (metric)
S 1,500; E 4,500

Seam section

Roof: dark grey shale
Coal 25
grey shale 2.5
Coal 7.5
grey shale 2.5
Coal 178.5
impure coal <u>18</u>
Total height 234 cm (7.7 ft)
Pavement: grey shale

Detailed petrography

This seam has five petrographic intervals which consist of banded coal and banded bright coal in the upper one third of the seam (intervals III-B and IV), and bright coal in the lower two thirds. Dull bands of durite and impure coal occur in intervals III-B and IV and are up to 1.5 cm thick. Two thin shale partings occur also in interval IV. Fusite bands are not abundant in this seam, and measure only 0.2-0.4 cm in thickness.

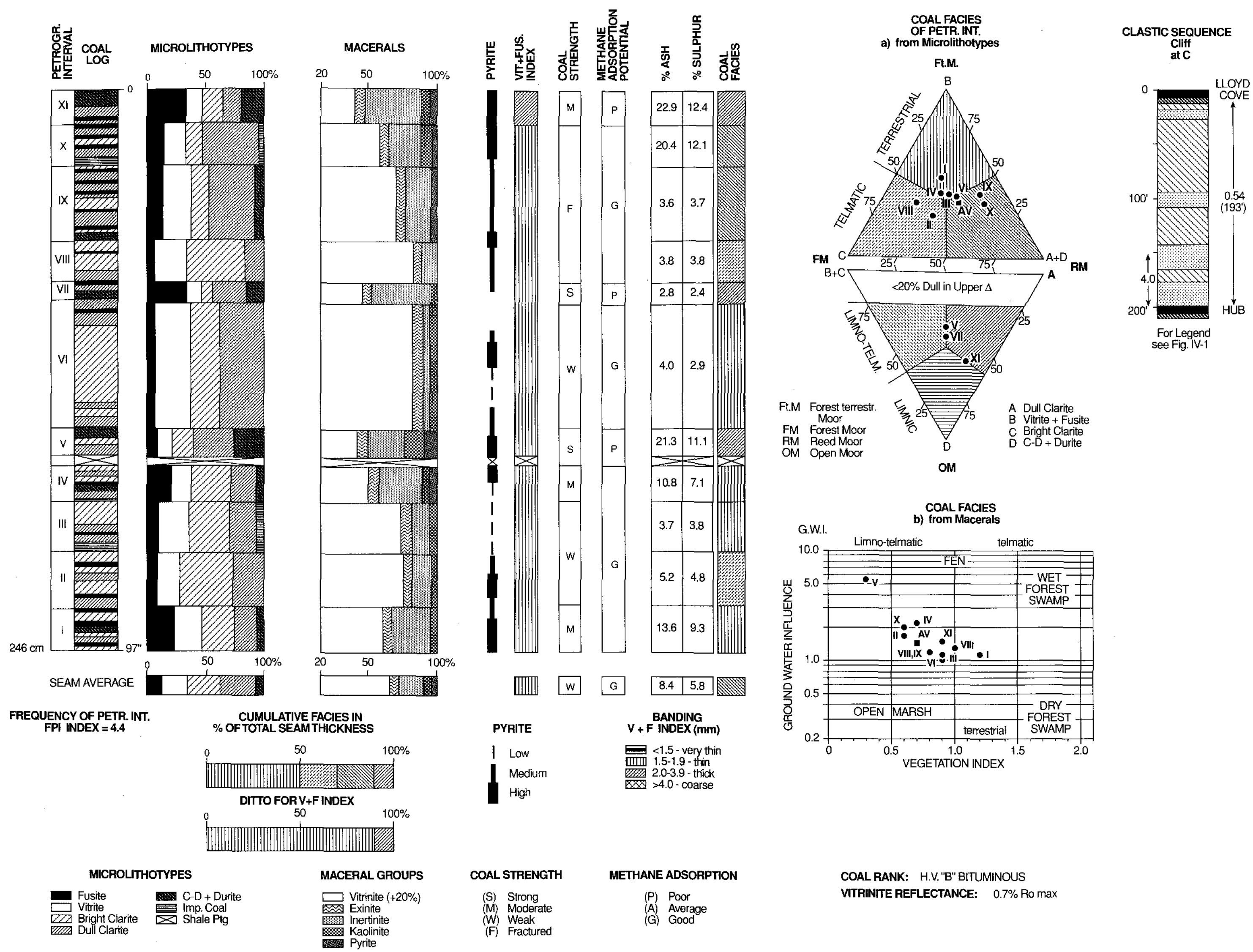

Figure 4-2. *Petrological compilation: sample II-1, Lloyd Cove seam.*

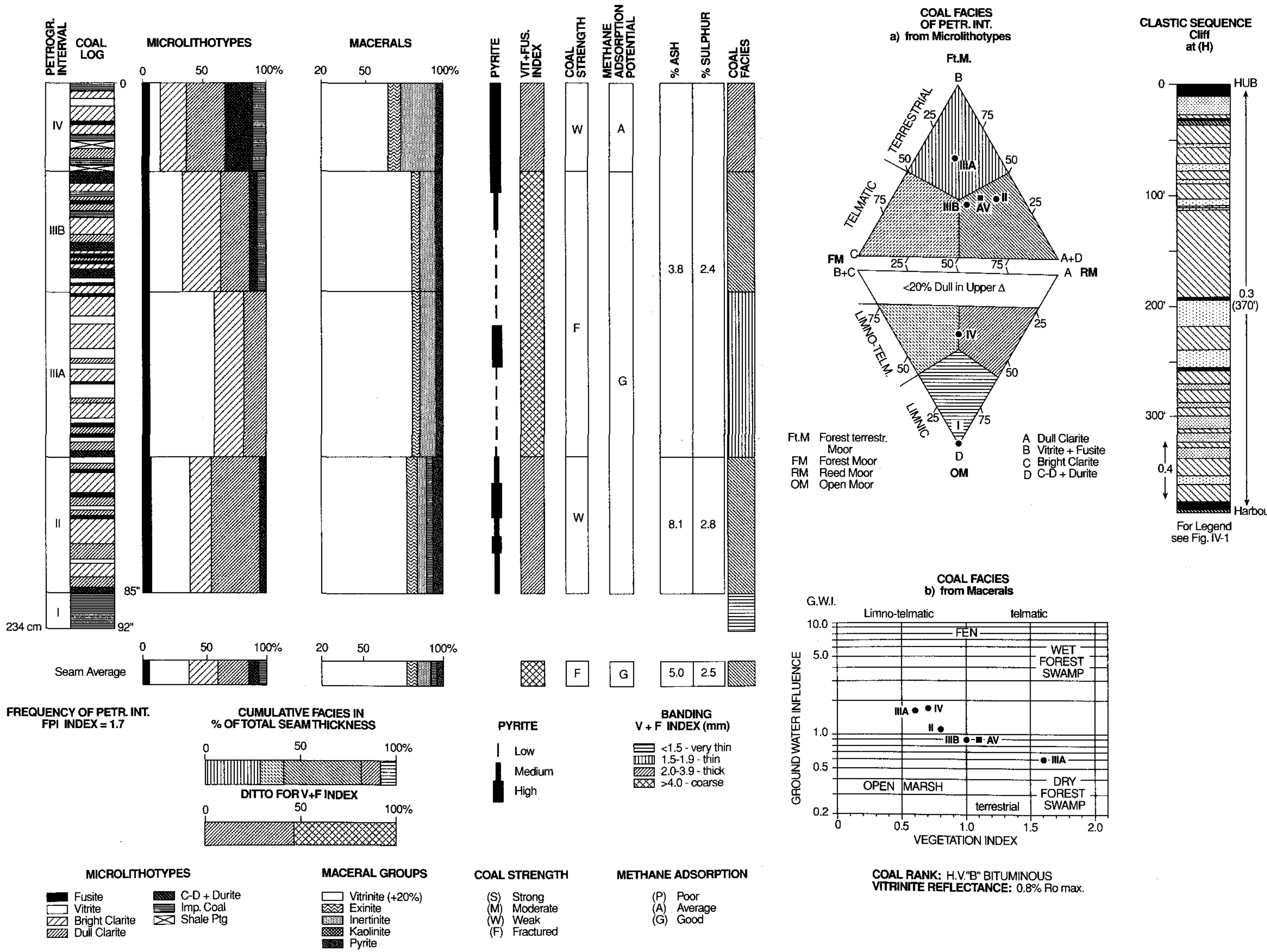

Figure 4-3. Petrological compilation: sample III-1, Hub seam.

Bright and dull clarite are the dominant microlithotypes and together constitute 52% of the seam average composition. A remarkably clean coal averaging 5% ash, with a sulphur content of 2.5% is represented. The sulphur is mainly derived from finely disseminated pyrite, which occurs more abundantly in the upper and lower parts of the seam.

The maceral analyses show that a very bright coal is present, having 77% total vitrinite, with only 13% inertinite and 5% exinite. Except for interval IV, which has 24% inertinite, the maceral distribution is remarkably uniform throughout the seam section.

Physical data

The vitrite+fusite index varies between 2 and >4 mm, showing that a thick- to coarse-banded coal is present. As a result, the coal strength may be considered weak and fractured. Cleavage is prominent, particularly in the coarse vitrite bands, several of which are up to 3 cm thick.

The methane adsorption potential of this coal is very good, because of the favourable rank of V-8 and its high vitrinite content of 77%, in addition to the fractured nature of the vitrite bands.

With an FPI index of 1.7, the vertical variation in composition shows remarkably constant conditions of peat formation during the life of this seam.

Coal facies interpretations

The microlithotype facies diagram of three lower intervals (II, III-A, and III-B) indicates reed moor and forest terrestrial moor conditions. The level of the groundwater in these moors was generally low, and reflects the terrestrial and terrestrial-telmatic-transition zones. This caused uniform peat formation without clastic contamination and resulted in the exceptionally low ash coal of only 3.8%.

The facies of interval IV showed a distinct rise in the groundwater level, indicating termination of the Hub seam peat bog by drowning.

The cumulative facies of the entire seam shows that together the forest terrestrial and reed moor facies account for 77%.

The maceral facies diagram also supports generally low water level and forest swamp conditions.

Harbour seam

Sample IV-31, Figure 4-4, Appendix B-4 and C-4

Sample location

Underground sample from Dominion No.26 Colliery at Glace Bay, collected in 1957
DEVCO coordinates (metric)
N 1,646; E 8,992

Seam section

Roof: dark grey shale with plant remains
Coal: 240 cm (7.9 ft)
Pavement: underclay

Detailed petrography

This has been the most extensively mined seam, with some 20 underground collieries present at different times over the entire extent of the Sydney coalfield. It has five petrographic intervals which consist of banded bright coal in the upper half of the seam and bright coal in the lower half. The banded bright coal has several durite bands that are 0.4-1.2 cm thick. Fusite bands occur locally, mainly in the upper part. They are 0.2-1.6 cm thick.

Bright and dull clarite are the main microlithotypes and together comprise 58% of the seam average composition. An exceptionally clean coal, averaging only 2.6% ash and 0.8% sulphur, is present. The sulphur occurs as finely divided pyrite at a few places only, notably in the roof coal and at interval III.

The maceral analyses confirm the presence of banded bright coal in intervals IV and V with a higher percentage of inertinite, which is 25 and 28% respectively. In the bright coal of intervals I and III it varies from 10 to 15%. The vitrinite content of this seam also supports the bright character of the coal. It averages 69%, and reaches 82% in interval I. Exinite content of this seam is higher than in any of the others, with an average of 11%. It reaches 21% in interval II, which has a 1.2 cm thick band of durite.

Physical data

The vitrite+fusite index shows that a thin-banded coal is present in the upper part of the seam (62 cm thick), whereas the remaining lower part (178 cm thick) is thick-banded. As a result only the upper part of this seam consists of a strong coal, whereas the remainder is weak and fractured. This is particularly noticeable in the vitrite layers, which are up to 2 cm thick.

The methane adsorption potential of the lower part of the seam (140 cm thick) is considered to be excellent because of (1) the fractured nature of the coal; (2) the high vitrinite content; and (3) the favourable rank of V-9.

With an FPI index of 2.1, the vertical variation in composition is only minor. Only in intervals IV and V was the peat deposition affected by more variable conditions.

Coal facies interpretations

The microlithotype facies diagram shows that the forest moor environment prevailed throughout the formation of the Harbour seam. The groundwater level varied from terrestrial (intervals I and III), to telmatic (intervals IV and V), to limno-telmatic (interval II). A dry forest occurred by 55% in the cumulative facies diagram, which is the highest figure recorded in the seams examined.

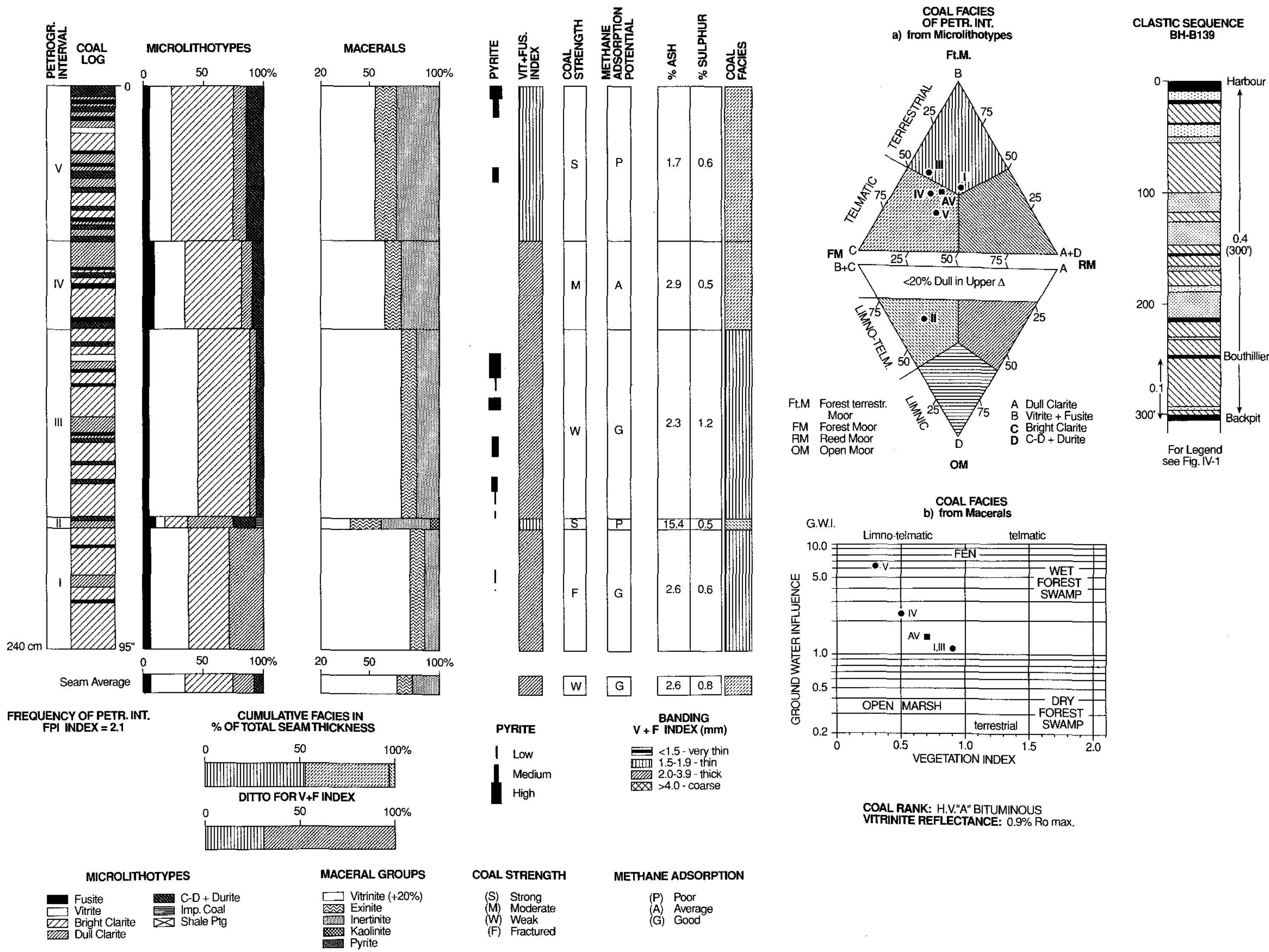

Figure 4-4. Petrological compilation: sample IV-31, Harbour seam.

The maceral facies diagram shows a higher groundwater level, particularly during intervals IV and V, which are in the limno-telmatic zone.

Backpit seam

Sample VI-2, Figure 4-5, Appendix B-5 and C-5

Sample location

Underground sample from Greener Mine of Indian Cove Coal Co. at North Sydney, collected in 1950
DEVCO coordinates (metric)
S 1,573; W 10,616

Seam section

Roof: grey shale with plant remains

Coal	16
impure coal	1
Coal	36
impure coal	1
Coal	91
Total height	145 cm (4.8 ft)

Pavement: grey sandy shale

Detailed petrography

This seam has eight petrographic intervals which consist almost entirely of bright coal, but has a 17 cm thick interval of banded bright coal in the lower part (interval IV). The latter has a few thin bands of durite and impure coal. Fusite bands are common in the upper and lowermost part of the seam, where 1 and 2 cm thick layers were observed.

Dull clarite is the main constituent of this seam, reaching 46% in the seam total composition. A coal of average quality is present, with 5.9% ash and 1.9% sulphur. Sulphur content is particularly high (at 5.9%) in the bench coal (intervals I and II), and is caused by a high concentration of finely disseminated pyrite. A similar concentration occurs in the roof coal (interval VIII).

The maceral analyses show a relatively high percentage of inertinite, which averages 17%, but reaches 34 and 33% in the roof and bench coal. Fusinite and micrinite (of the dull clarite) are the main contributors to the inertinite maceral group. The average vitrinite content of 69% is lower than in most other seams, but still in accord with the bright coal classification. The average exinite content of 10% is surprisingly high. It is derived mainly from the durite bands present in intervals II to V, where exinite content ranges from 13 to 18%.

Physical data

From the vitrite+fusite indices it is apparent that this is a thin-banded coal. Only the roof and bench coals are thick banded, which is due to their high fusite content. The coal strength, based on the banding, accordingly lies between moderate and strong.

The methane adsorption potential of the Backpit seam is considered generally poor. The coal is too strong to produce fissures, and the rank of V-7 is on the low side.

With the high FPI index of 5.3 considerable vertical variation in peat deposition must have taken place during the life of the seam.

Coal facies interpretations

The microlithotype facies diagram shows that the reed moor environment in the telmatic zone existed during nearly the entire formation of the Backpit seam. In the cumulative facies bar it represents 75%. This is higher than in any of the other seams recorded.

The maceral facies diagram indicates even wetter peat deposition in the limno-telmatic zone, with intervals V and VII approaching open marsh conditions.

Phalen seam

Sample VII-5, Figure 4-6, Appendix B-6 and C-6

Sample location

Underground sample from Dominion No.2 Colliery at Glace Bay, collected in 1950
DEVCO coordinates (metric)
S 1,737; E 13,106

Seam section

Roof: grey shale
Coal: 213 cm (7 ft)
Pavement: dark grey shale

Detailed petrography

Next to the Harbour seam this seam has been the most extensively mined coal seam in the Sydney field. Since 1830, when the first production started, some 14 different mines have been in operation, but coal was extracted only in the eastern part of the field, it being too thin for mining at the western portion. The Phalen seam has six petrographic intervals, which consist of bright coal throughout, except for two durite-rich layers (intervals III and V) that are 8 cm and 5 cm thick, respectively. Fusite bands occur at more or less regular intervals throughout the seam section.

Bright clarite is the principal microlithotype and together with dull clarite comprises 59% of the seam average composition. A moderately clean coal, averaging 7.1% ash and 3.3% sulphur, is present. The sulphur occurs mainly as finely disseminated pyrite and as pyritic cell fillings in fusite. The high sulphur content of 6% of interval VI is due to a fusite "nodule" present in the proximate analysis sample, but not retained in the polished section. It therefore is not shown in the pyrite column of Figure 4-6.

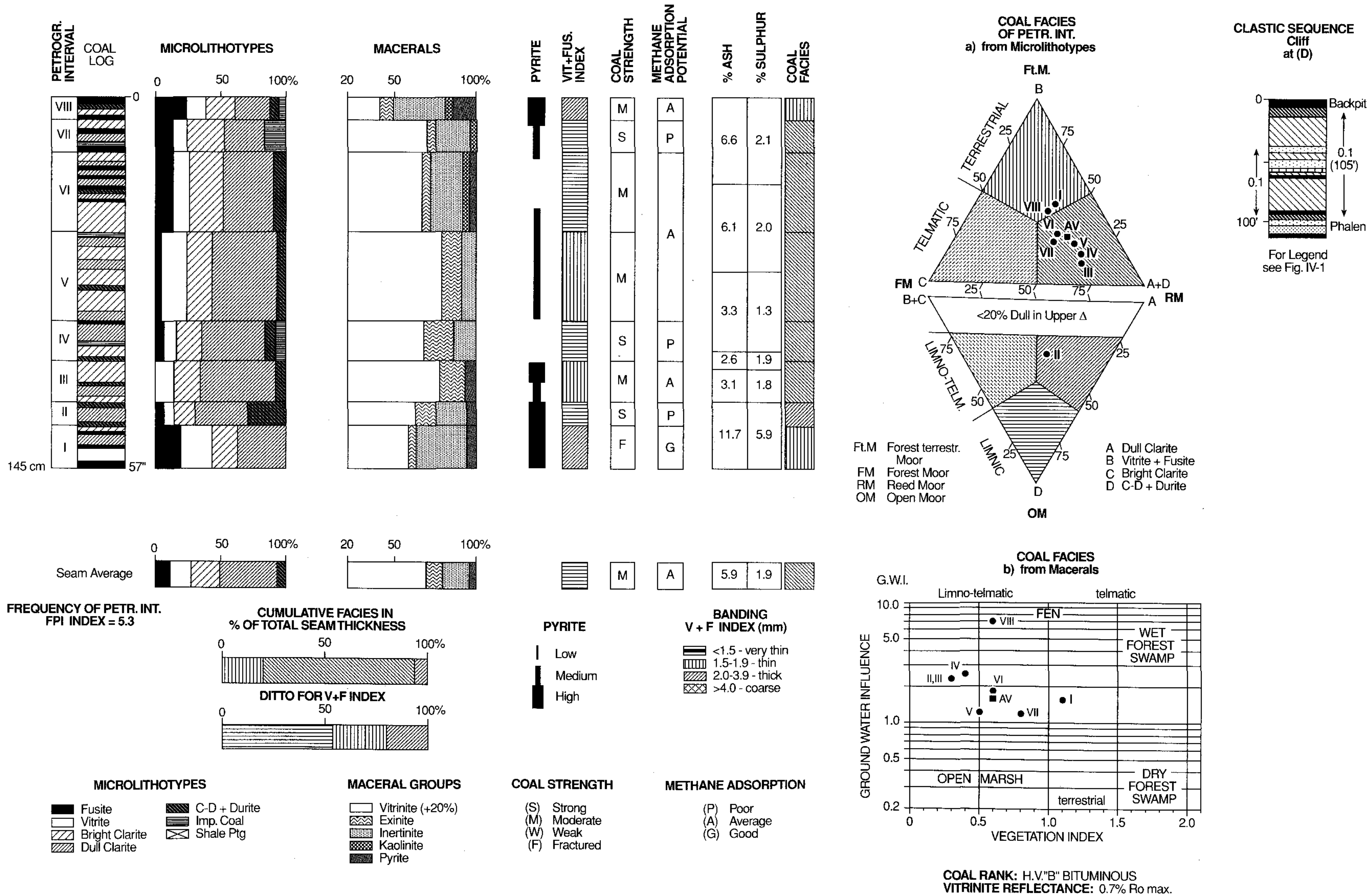

Figure 4-5. Petrological compilation: sample VI-2, Backpit seam.

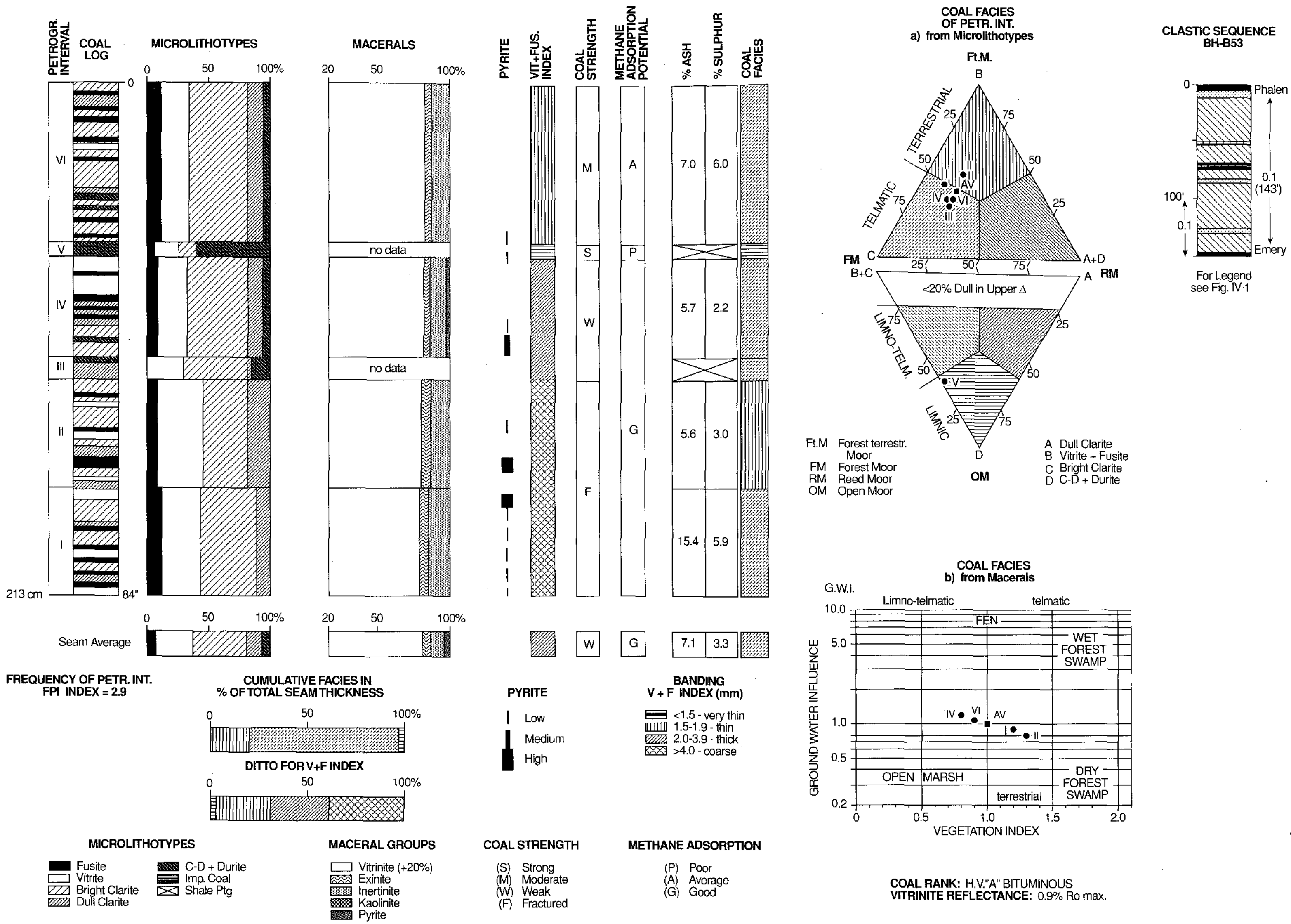

Figure 4-6. *Petrological compilation: sample VII-5, Phalen seam.*

The maceral analyses show remarkable constancy throughout the seam section. The average vitrinite content is 81%, which is amongst the highest of the Sydney seams. The average exinite content at 4% is remarkably low, as is the average inertinite content of 12%.

Physical data

The vitrite+fusite indices show that a thin-banded coal occurs in the upper one third of the seam (interval VI), whereas the remainder is thick and coarse banded. The corresponding coal strength is moderate in the upper part and weak and fractured in the lower part of the seam. The presence of many fusite bands also plays an important part in this.

The methane adsorption potential of the lower two thirds of the seam is considered excellent. It is 140 cm thick, with 81% vitrinite including many fractures and a favourable rank of V-9.

With an FPI index of 2.9 the vertical variation in composition is only minor. Only in intervals III and V was the composition affected by an abrupt change in depositional conditions, causing the formation of durite bands.

Coal facies interpretations

The microlithotype facies diagram shows that throughout the formation of the seam the forest moor environment prevailed. The groundwater level was essentially at the shallow side of the telmatic zone, bordering on the terrestrial level. In the cumulative facies diagram the amounts are: 22% forest terrestrial moor (Ft.M) and 76% forest moor in telmatic zone (FM-telmatic).

The maceral facies diagram also indicates peat deposition under generally dry forest swamp conditions.

Emery seam

Sample IX-3, Figure 4-7, Appendix B-7 and C-7

Sample location

Underground sample from Dominion No.11 Colliery at Glace Bay, collected in 1949
DEVCO coordinates (metric)
S 3,469; E 8,054

Seam section

Roof: grey, sandy shale

Coal	53
shale	2
Coal	34
Total height	89 cm (2.9 ft)

Pavement: soft grey shale with *Stigmaria*

Detailed petrography

This seam has been the thinnest coal mined in the Sydney field. It occurs only in the Glace Bay district and was extracted mainly within the land area. The seam is divided into six petrographic intervals, four of which consist of bright coal (I-A, II, III, and V) and two of banded bright coal (I and IV). Thin durite layers occur at different positions within the seam, and fusite bands are present in the upper part only.

Dull clarite is the main microlithotype and together with bright clarite comprises 55% of the seam average composition. A medium quality coal with 9.5% ash and 2.6% sulphur is present. Finely divided pyrite is the main contributor of sulphur and occurs mostly in the roof coal (intervals IV and V).

The maceral analyses conform with the microlithotype data showing higher inertinite percentages in the upper part of the seam, ranging from 10 to 20%. The average vitrinite content of 81% is amongst the highest figures recorded in the Sydney seams. Average exinite content of 6% compares with that found in the other coals. It reaches 8-9% in intervals I and II, which have several durite bands.

Physical data

From the vitrite+fusite index it is apparent that a thin-banded coal is present. Only the bench coal (I-A and I) is thick banded. The coal strength is variable through the section and is partly affected by the presence of durite bands. It ranges from weak to strong.

The methane adsorption potential of the Emery seam is considered to be about average. The coal is generally too strong to produce fissures, although the rank of V-8 is in the favourable range of coalification.

With the high FPI index of 6.7 considerable vertical variation in peat deposition must have taken place during the life of this seam.

Coal facies interpretations

The microlithotype facies diagram shows that most of the seam originated under reed moor conditions, but a forest moor environment occurred during the formation of the bench coal (intervals I-A and I). The position of the groundwater level was at the shallow end of the telmatic zone, and terrestrial during the start of the seam. In the cumulative facies diagram the amounts are: forest terrestrial 40%; forest moor in limno-telmatic zone 14%; reed moor in telmatic zone 46%.

The maceral facies diagram indicates a generally dry forest swamp environment, with interval IV pointing to the wet side.

Gardiner seam

Sample X-2, Figure 4-8, Appendix B-8 and C-8

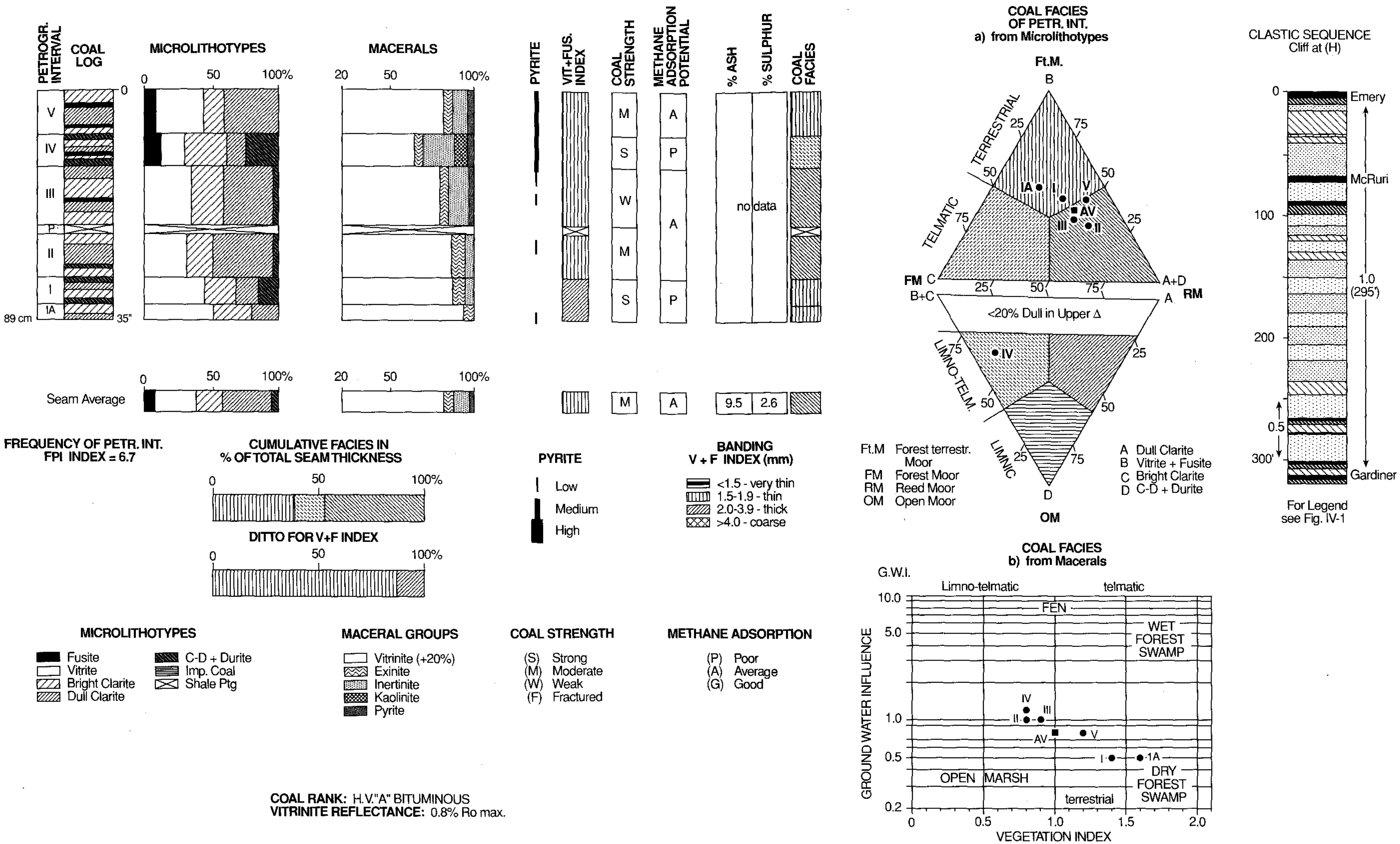

Figure 4-7. *Petrological compilation: sample IX-3, Emery seam.*

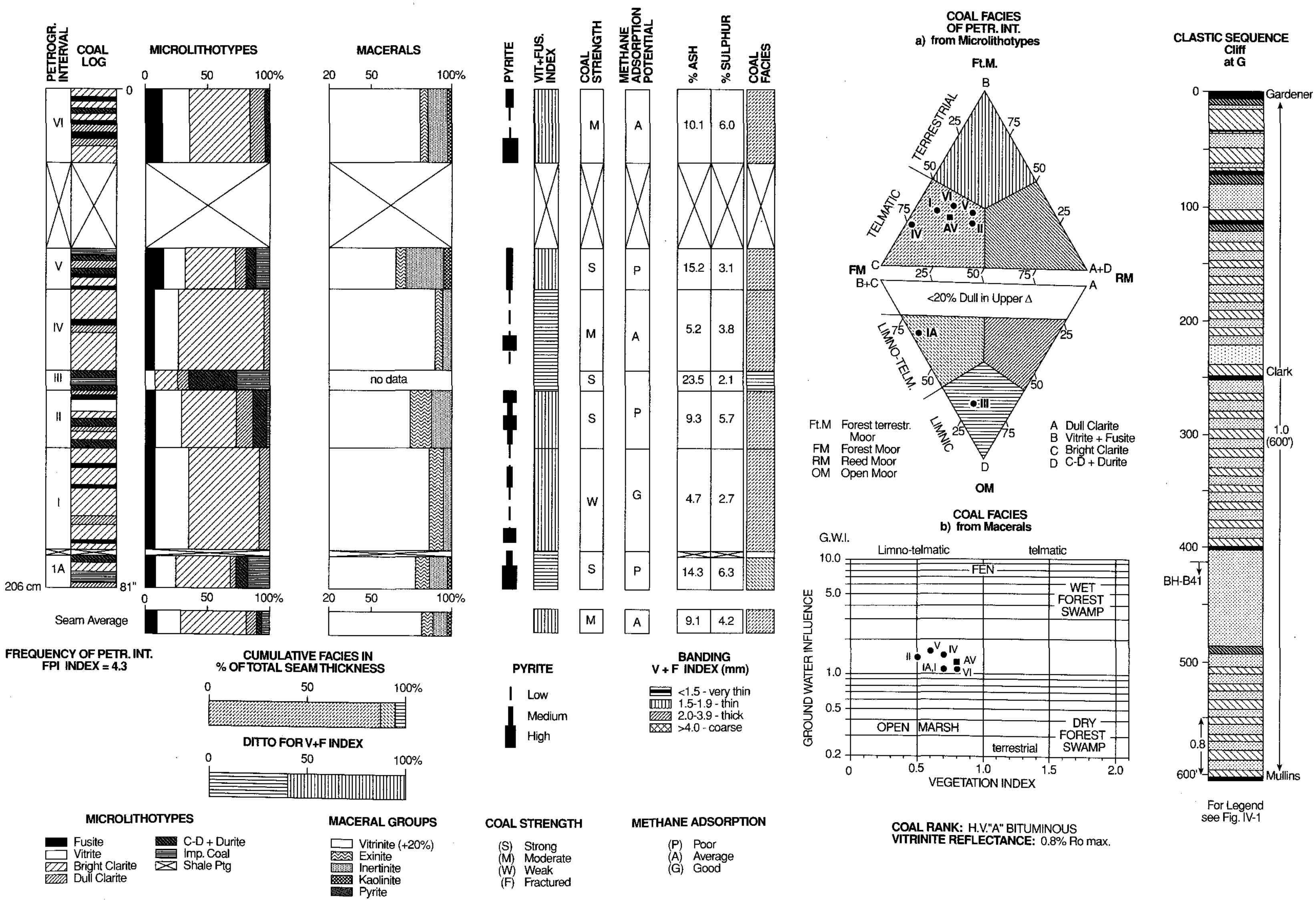

Figure 4-8. Petrological compilation: sample X-2, Gardiner seam.

Sample location

Underground sample from Dominion No.25 Colliery at Bridgeport area of Glace Bay district, collected in 1951
DEVCO coordinates (metric)
S 6,279; E 2,743

Seam section

Roof: grey shale	
Coal	30
sandy shale	35
Coal	124
shale	1
Coal	16
Total height	206 cm (6.8 ft)
Pavement: grey shale with *Stigmaria*	

Detailed petrography

The Gardiner seam is present only in the eastern part of the Sydney coalfield. It has been mined within the land area of the Glace Bay district. The seam has seven petrographic intervals and two shale partings. It consists of bright coal interbedded with three layers of banded bright coal (intervals I-A, II, V) and one layer of banded dull coal (interval III). Durite bands, up to 2 cm thick, occur at several places within the seam section, and fusite layers are encountered regularly.

The principal microlithotype is bright clarite and together with dull clarite comprises 62% of the seam average composition. A medium quality coal with 9.1% ash and 4.2% sulphur is present. Finely disseminated pyrite is the main contributor and occurs at many places in the seam section, particularly in the rider seam (interval VI).

The maceral analyses conform with the microlithotype data, showing higher inertinite percentages in the intervals with durite bands, namely I-A, II, V, and VI. The average vitrinite content of 79% is high in comparison with the other seams. The average exinite content is 7%, but reaches 15% in interval II because of the presence of two durite bands.

Physical data

The vitrite+fusite index indicates the presence of a thin- and very thin-banded coal. The coal strength lies between strong and weak, depending on the presence of fusite layers, and the occurrence of durite.

The methane adsorption potential of the Gardiner seam is considered to be about average. Although the vitrite content is high, it is too finely banded to produce fissures and cracks. The rank of V-8, however, is within the favourable coalification range.

With an FPI index of 4.3, the vertical variation in composition indicates significant changing conditions of peat formation during the life of the seam.

Coal facies interpretations

The microlithotype facies diagram shows that the forest moor environment strongly predominated during the formation of the seam. The cumulative facies diagram indicates that the forest moor facies represents 95%, of which 86% took place in the telmatic zone of the groundwater level.

The maceral facies diagram shows wetter and more open marsh conditions than the microlithotype interpretation.

Mullins seam

Sample XI-1, Figure 4-9, Appendix B-9 and C-9

Sample location

Prospect pit at Victoria Mines in New Waterford district, collected in 1950
DEVCO coordinates (metric)
S 1,768; W 5,822

Seam section

Roof: grey shale with plant remains

Coal	42
black shale	10
Coal	48
shale	1
Coal	75
shale	1
Coal	7
shale	1
Coal	5
clay	2
Coal	4
Total height	196 cm (6.4 ft)

Pavement: grey shale with *Stigmaria*

Detailed petrography

The Mullins seam is the only seam of the Sydney coalfield which still represents a largely virgin deposit. It is present only in the New Waterford district, except for one minor occurrence at North Sydney. Mining operations were carried out only in a small pit on the west side of Sydney Harbour, but none occurred in the New Waterford area.

The stratigraphic position of the Mullins and Gardiner seams in the Sydney sequence has not been definitely resolved. The Mullins seam is not precisely known in the Glace Bay district, and the Gardiner has been correlated with a thin coal in the New Waterford area only. Haites (1952) hinted that both seams could be the same. He thought that the fault intersecting the outcrop of the Mullins seam at its eastern end in the New Waterford district, could structurally explain the postulated correlation. The stratigraphic separation of 120-150 m when two seams are considered could then be explained by the displacement along the fault. A comparison of the petrographic profiles of both seams supports the assumed correlation.

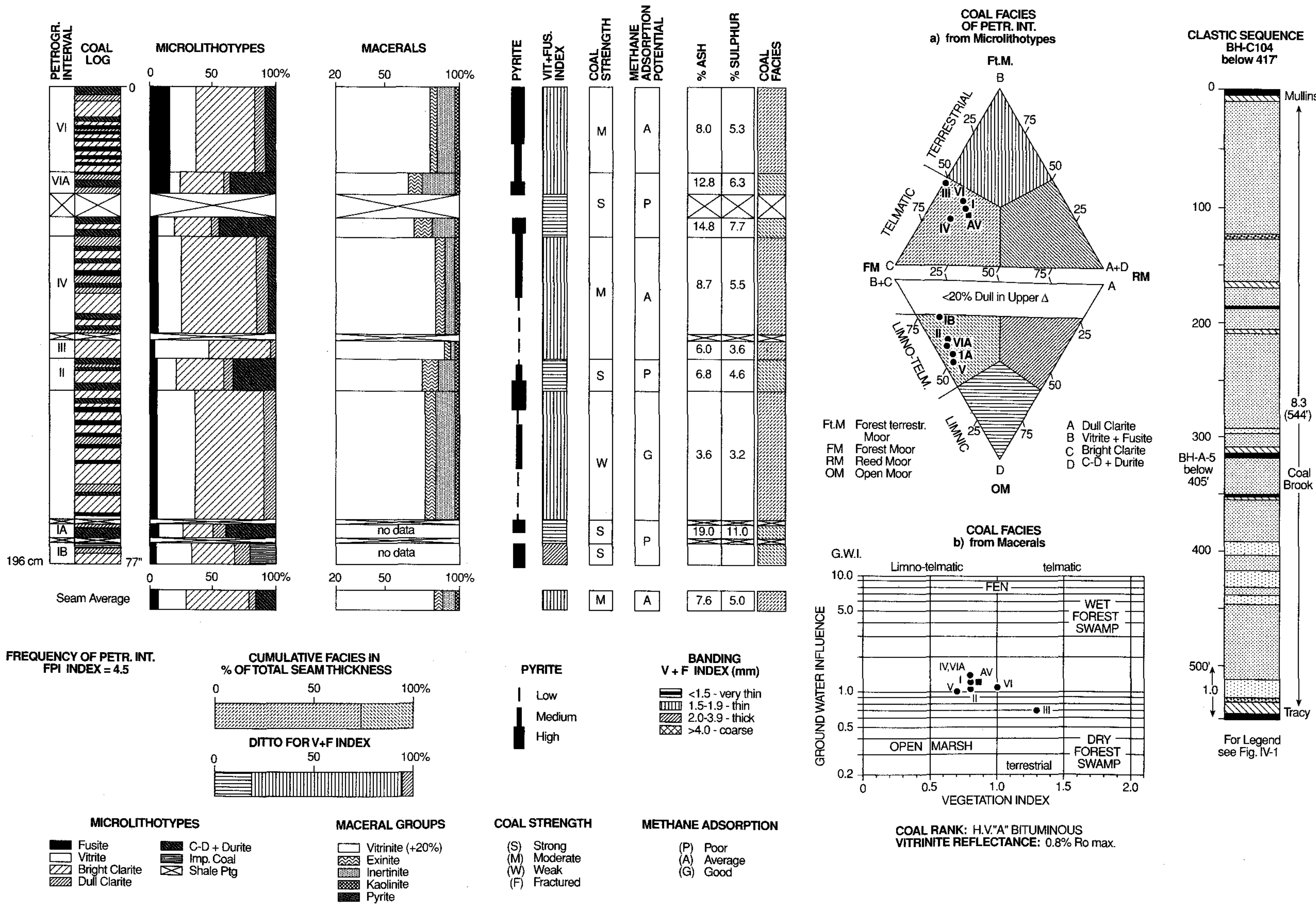

Figure 4-9. *Petrological compilation: sample XI-1, Mullins seam.*

The seam has nine petrographic intervals and four shale partings. It consists of bright coal interbedded with three layers of banded bright coal (intervals II, V, and VI-A). Durite bands, up to 3 cm thick, occur at several places within the seam section, and fusite layers are present regularly, particularly in the roof coal (interval VI).

The principal microlithotype is bright clarite and together with dull clarite comprises 60% of the seam average composition. An average quality coal with 7.6% ash and 5% sulphur is present. The very high sulphur content is due to finely disseminated pyrite, which occurs throughout the seam section, but mainly in the upper half.

The maceral determinations support the microlithotype data, showing higher inertinite percentages in the intervals with durite, namely in II, V, and VI-A. The average vitrinite content of 82% is high in comparison with the other seams. The average exinite content is 6%, but reaches 11% in interval V because of the presence of two durite bands.

Physical data

The vitrite+fusite index indicates the presence of a thin- and very thin-banded coal. The coal strength is between strong and weak, depending on the presence of fusite layers and the occurrence of durite.

The methane adsorption potential of the Mullins seam is considered about average. Although the vitrite content is high, it is too finely banded to produce fissures and cracks. The rank of V-8, however, is within the favourable coalification range.

With an FPI index of 4.5, the vertical variation in composition indicates significant changing conditions of peat formation during the life of the seam.

Coal facies interpretations

The microlithotype facies diagram shows that the forest moor environment prevailed during the formation of the seam. The cumulative facies diagram indicates that the forest moor facies represents 100%, of which 74% took place in the telmatic zone of the groundwater level.

The maceral facies diagram is very similar to the one of the Gardiner seam. It shows limno-telmatic conditions in an open marsh environment.

Tracy seam

Sample XII-1, Figure 4-10, Appendix B-10 and C-10

Sample location

Underground sample from Broughton Mine of the Bras d'Or Coal Co. in Port Morien district, collected in 1950
DEVCO coordinates (metric)
S 18,593; E 8,534

Seam section

Roof: grey shale	
Coal	9
shale	2
Coal	128
shale	3
Coal	6
clay	10
Coal	17
impure coal	3
Total height	178 cm (5.8 ft)
Pavement: grey shale with *Stigmaria*	

Detailed petrography

The Tracy seam is the lowest mineable seam known in the Sydney coalfield. It is present only in the Port Morien district of the southeastern part of the coalfield and comprises the largest known reserve within the land area. Several small underground operations have been active on the Tracy seam during the past.

The seam has nine petrographic intervals and three shale partings. It consists of alternating intervals of bright coal and banded bright coal. The latter has several durite bands that are up to 2 cm thick and fusite layers occur in the upper part of the seam. The main microlithotypes are bright clarite and dull clarite in about equal proportion, which together amount to 59% of the seam average composition. A medium quality coal with 9.5% ash and 6.2% sulphur is present. The very high sulphur content is due to finely disseminated pyrite, which occurs throughout the seam section, particularly in the roof and bench coal (intervals IX and II).

The maceral analyses correspond to the microlithotype composition. Higher inertinite percentages (up to 30%) occur in the intervals with durite and dull clarite, namely in VI, VII, VIII, and IX. The average vitrinite content of 76% is fairly high compared to the other seams. Exinite content averages only 4%, which is less than in the other seams.

A peculiar component of the Tracy seam is the presence of so-called "squat-bulky" spores. They vary in size from 180 to 240 μm, and stand out in polished sections by a very pronounced relief. Under reflected light they appear grey and in general are similar to spores (Hacquebard, 1952). Upon maceration, the squat-bulky spores were identified as pollen of

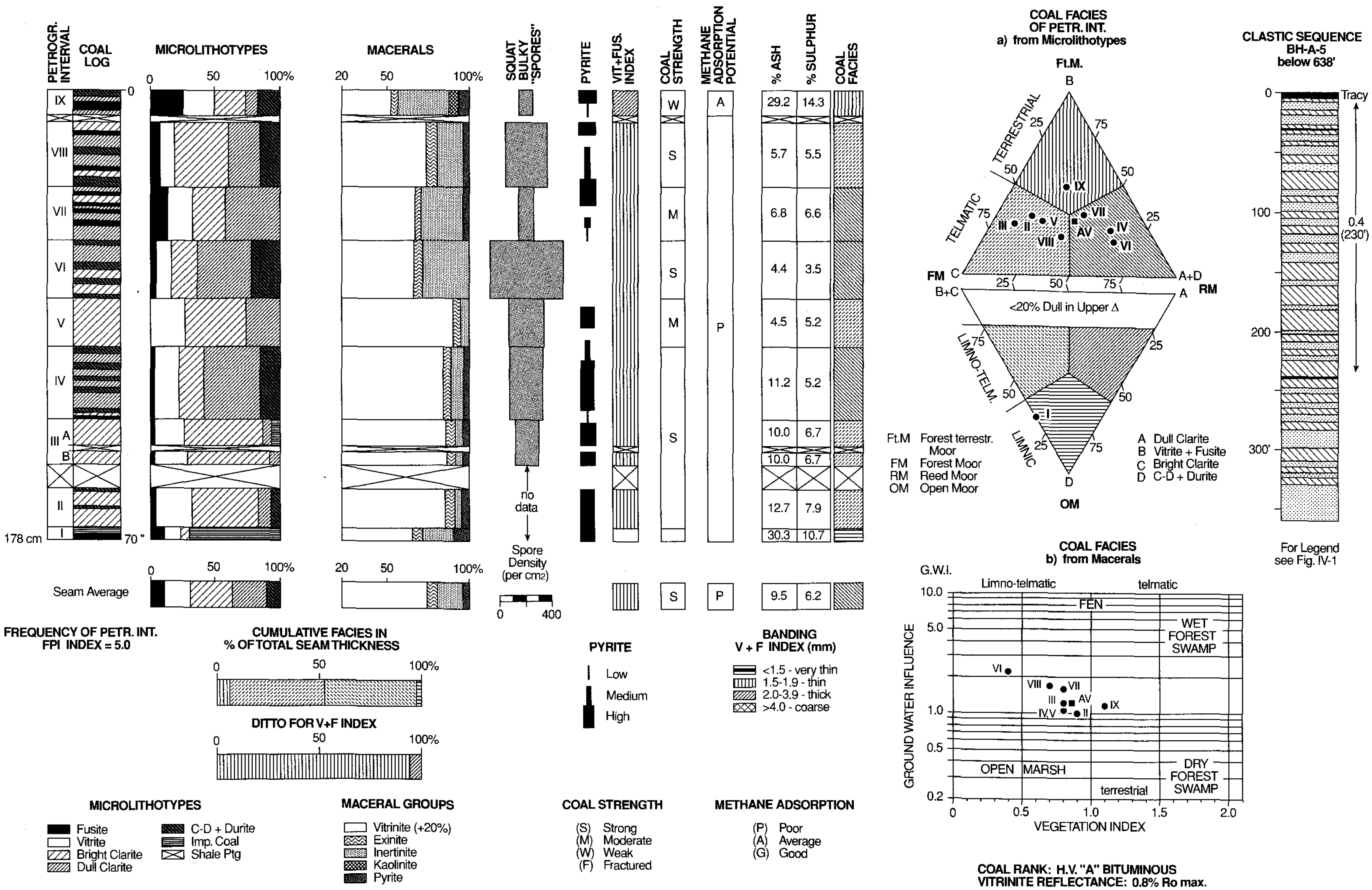

Figure 4-10. *Petrological compilation: sample XII-1, Tracy seam.*

Whittleseyinae. They occur in great numbers and variable densities throughout the seam section, reaching a high of $627/cm^2$ in one particular durite band. The Tracy seam is unique in this respect because the other seams of the Sydney field possess these spores only sporadically and never in large numbers, i.e. the Mullins seam. The squat-bulky spores provided a method to identify the Tracy seam, even from small random blocks of coal, and were used to trace the seam west of the known outcrop (Hacquebard, 1952).

Physical data

The vitrite+fusite index indicates the presence of a thin-banded coal through nearly the entire section. The coal strength varies from strong to moderate, depending on the presence of fusite layers and the occurrence of durite and dull clarite.

The methane adsorption potential of the Tracy seam is considered poor. The strong nature of the coal did not promote the development of cleats and fissures. The rank of V-8, however, is within the favourable coalification range.

With an FPI index of 5.0, the vertical variation in composition indicates significant changing conditions of peat formation during the life of the seam.

Coal facies interpretations

The microlithotype facies diagram shows that the forest and reed moor facies prevailed during the formation of the seam. The cumulative facies diagram indicates that both environments existed for about equal time, namely by 46% and 47%, and both in the telmatic zone of the groundwater level.

The maceral facies diagram generally shows wetter conditions and a more open marsh environment.

COMPARISON OF SEAM COMPOSITIONAL DATA

1. Of the ten seams examined the thickest is the Lloyd Cove seam (246 cm) and the thinnest is the Emery seam (89 cm). The average seam thickness is 184 cm.
2. The petrographic subdivisions, as expressed in the FPI indices, show a variation between 7.3 in the Point Aconi seam and 1.7 in the Hub seam. The most stable seam during peat deposition therefore, was the Hub seam and the most variable seam the Point Aconi. Other variable seams with high FPI values are the Emery (6.7), Backpit (5.3), and Tracy (5.0).
3. In terms of microlithotype composition, all seams of the Sydney field are very bright, with vitrite contents between 16% (Backpit seam) and 33% (Hub seam). The bright+dull clarite varies from 69% (Point Aconi seam) to 52% (Hub seam). Durite+clarodurite is low in all seams; it averages 7%. Fusite is more variable, ranging from 3% (Hub seam) to 10% (Lloyd Cove and Backpit seams).
4. The maceral composition confirms the bright nature of the seams. The vitrinite content varies between 67% (LLoyd Cove seam) and 82% (Mullins seam). Of the vitrinite, the structured variety (cf. telinite) lies between 22% (Point Aconi seam) and 44% (Emery seam), whereas groundmass vitrinite (cf. collinite) varies between 36% (Hub seam) and 45% (Point Aconi seam). Exinite averages 6%, with highest figures occurring in the Harbour (11%) and Backpit seams (10%). The inertinite content averages 16%, with 22% in the Point Aconi and Lloyd Cove seams and 20 and 18% in the Harbour and Tracy seams.
5. In many of the seams the brightest coal (highest in vitrite and vitrinite) occurs in the lower part of the section with the dullest coal near the top (highest in durite and inertinite). This confirms the development of a raised bog during the terminal stage of peat deposition (McCabe, 1984). Very similar variations in seam sections have been reported by Mastalerz and Wilks (1992) in coals from the Polish Intrasudetic Basin.
6. The distribution of pyrite through each seam can be observed in the ten seam diagrams of Figures 4-1 to 4-10. In most seams it is highest near the roof and near the floor. The least pyrite contamination occurs in the Harbour, Phalen, and Emery seams, and the highest and most widely distributed pyrite is present in the Lloyd Cove, Backpit, Gardiner, Mullins, and Tracy seams. The last seam, in particular, is highly contaminated with finely disseminated pyrite particles.
7. The banding of the coal, as expressed in the vitrite+fusite indices showed the following variations between the different seams (Fig. 4-1 to 4-10). The Point Aconi, Hub, Harbour, and Phalen seams (lower third only) are thick and coarse banded. The bands are 2 mm to more than 4 mm thick. All the other six seams are thin banded (1.5 to 1.9 mm).
8. The coal strength, which is related to the banding and the presence of fusite and durite, varies accordingly. The upper four coals are weak and fractured, and the lower six seams are strong or have a moderate strength.
9. Methane adsorption potential is affected by coal rank, coal strength, and vitrite content (Close, 1992; Creedy, 1988; Paterson et al., 1993; Rightmire and Choate, 1986). The methane adsorption varies from good to poor. It is considered good in the upper five seams (from Point Aconi to Phalen seam), and average in the lower coals. The greatest potential is in the Harbour and Phalen columns, both of which have a rank of V-9 (near medium volatile bituminous coal). The least methane will likely occur in the Tracy seam.

10. The ash and sulphur contents of the Sydney seams vary between 2.6% (Harbour seam) and 9.5% (Emery seam) for ash, and 0.8% (Harbour seam) and 6.2% (Tracy seam) for sulphur.

11. The coal facies interpretations based on the microlithotypes between the Sydney seams are illustrated in Figure 3. Cumulative whole-seam facies, as a per cent of total seam thickness, has been plotted. Some distinct differences can be noted between the various seams. However, the predominant environment of peat deposition was the forest moor in the telmatic zone. In the average calculation of all seams (with a total thickness of 19.5 m), the following facies distribution was obtained: Ft. M 26%, FM(telm.) 50%, RM 22%, and OM 2%.

    Considered by individual seams, the following can be noted. The forest terrestrial moor facies reached its highest proportion in the Harbour and Lloyd Cove seams (55% and 50%); the forest moor facies peaked in the Mullins, Gardiner, and Phalen seams, at respectively 100%, 95%, and 76%. The reed moor facies was highest in the Backpit seam at 81%. The Point Aconi seam with the reed moor facies at 51% also stands out.

12. Interpretation of the sedimentary environment is based on coal maceral data. In Figure 5 the Tissue Preservation Index-Gelification Index (TPI-GI) facies diagram of Diessel (1986) shows the depositional areas of west Australian coals. When the maceral compositions of the main Sydney seams are plotted in this diagram, they reveal the following. The Sydney seams originated in the lower delta plain with a freely meandering fluvial system. This is supported by Gibling and Bird's (1994) study of the cyclothem development in the Sydney Basin, where they placed the coal deposition in broad coastal mires. Sporadically these mires were inundated by the sea as deduced from the presence of foraminifera (Wightman et al., 1993). A paralic coal basin was deduced by Hacquebard and Donaldson (1969) from the development of the different coal seams.

13. The clastic sequences above and below the seams have been plotted on the extreme right side of the diagrams (Fig. 4-1 to 4-10). A correlation between the thickness of sandstone present below the coal and the total seam thickness was mentioned by Mastalerz and Wilks (1992). No such relationship was found with any of the ten seams reported here.

    The lithology between the seams and that occurring in the roof strata (to about 12-15 m above the coal) is shown in the columns by the sand/shale ratios. They vary considerably, indicating the presence of mainly shale, equal shale and sandstone, or predominantly sandstone. The roof strata of the Hub seam, with a ratio of 4.0 is almost entirely sandstone, whereas strata above the Backpit, Phalen, and Emery seams consist of shale. The variation in clastic rocks between the seams shows that almost the entire succession is sandstone between the Mullins and Tracy seam, but shale dominates between the Backpit, Phalen, and Emery seams.

INFORMATION ON THE OCCURRENCE OF THERMAL AND METALLURGICAL COAL IN THE SYDNEY FIELD

Regional distribution and coal composition

The Sydney field produces both thermal and metallurgical coal, which occur in different parts of the field.

Thermal coal has a rank of V-7 (38% volatile matter) and a sulphur content above 3.5%. All coals of the Sydney field have a rank of high volatile "A" or high volatile "B" bituminous, and coals with a reflectance below V-7 are not present. However, there is a progressive increase in rank in the high volatile bituminous coal from east to west, and downdip (or seaward from the coast). Because of these changes, exclusively thermal coal occurs only in the western part of the coalfield. At present it is mined in the Prince Colliery at Point Aconi (see Fig. 8).

Metallurgical coal should have a rank of V-8 (35% volatile matter) or higher, and the raw coal should contain less than 3.5% sulphur. Such a coal can be cleaned economically in modern washplants to 1.0% sulphur required for metallurgical coke. An ash limitation is not considered necessary, because the ash content of all Sydney coals is low, being normally less than 10%. Because of the rank variations previously mentioned, metallurgical coal is not present in the

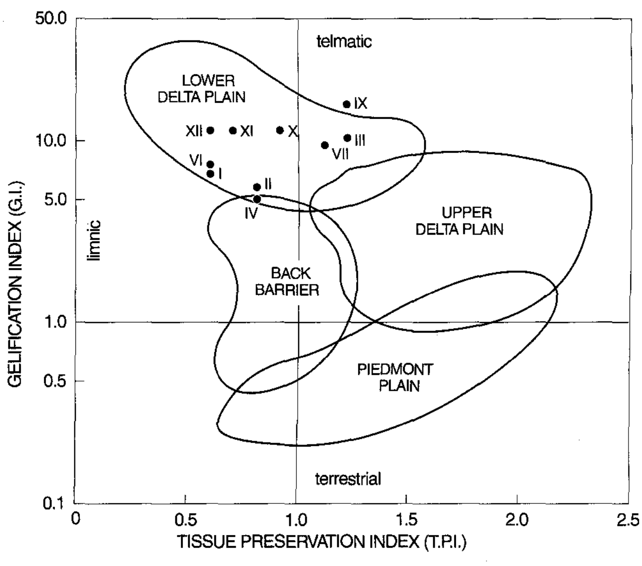

Figure 5. Depositional environments deduced from Diessel's (1986) TPI-GI diagram, showing whole-seam facies positions of ten major coals of the Sydney coalfield. For seam index, see Figure 3.

western part of the coalfield. It has been mined in the New Waterford and Glace Bay submarine collieries, on both the Harbour and Phalen seams. It occurs also in the Harbour seam in the Donkin reserve area (see Fig. 8).

Determination of coke properties

Coke is made by heating (not burning) coal in coke ovens, and is used in the steel industry. During the heating process volatiles and valuable chemical products (ammonia, etc.) are released and what remains is almost pure carbon, in the form of coke. For metallurgical coke specific standards have to be met. The most important of these is coke strength, which is expressed by the coke stability factor (CSF) and is obtained from the tumbler test.

Studies carried out in the 1960s by Shapiro et al. (1961) have shown that the coke stability factor can be predicted from the maceral composition and variation in rank as determined by vitrinite reflectance (Fig. 6). For maximum coke

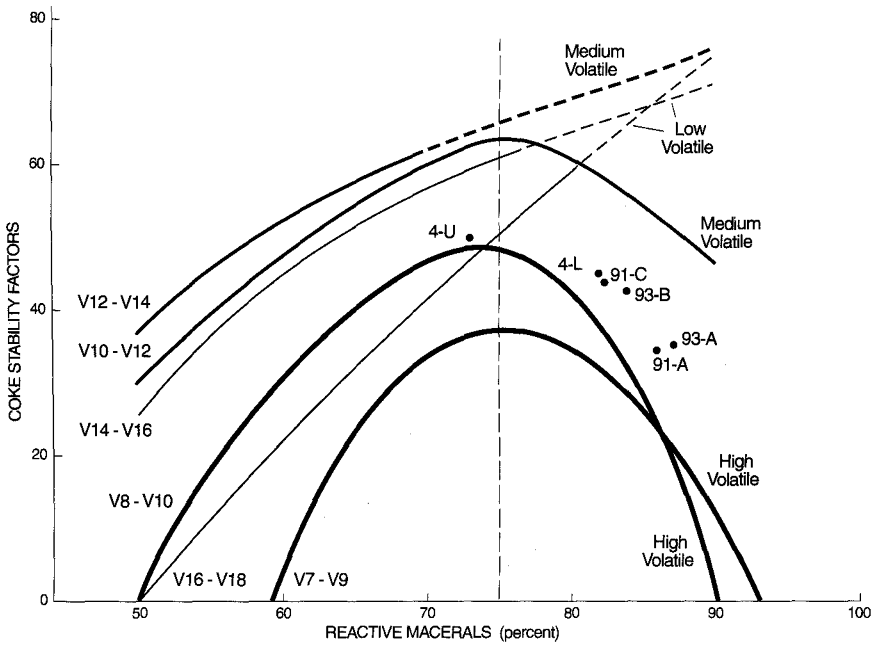

Figure 6.

Relationship of petrographic composition and rank to coke stability, with Phalen seam coal positions (after Cameron, 1975). V7 to V18 refer to increments of vitrimite reflectance in terms of % max. Ro.

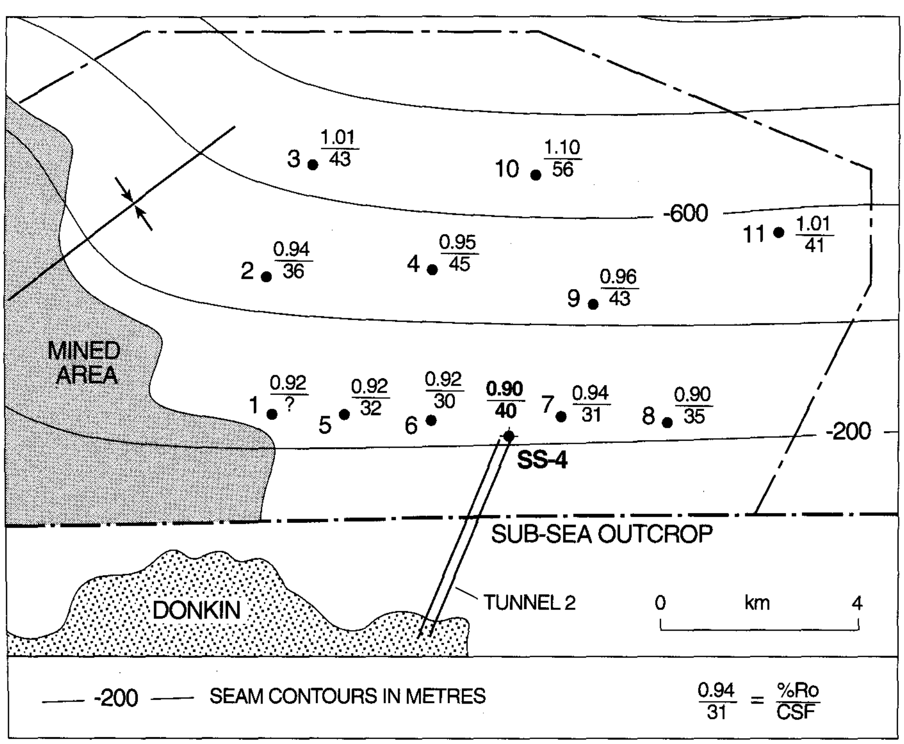

Figure 7.

Reflectance and coke stability factors (CSF). Harbour seam, Donkin Reserve area (after Hacquebard and Avery, 1988).

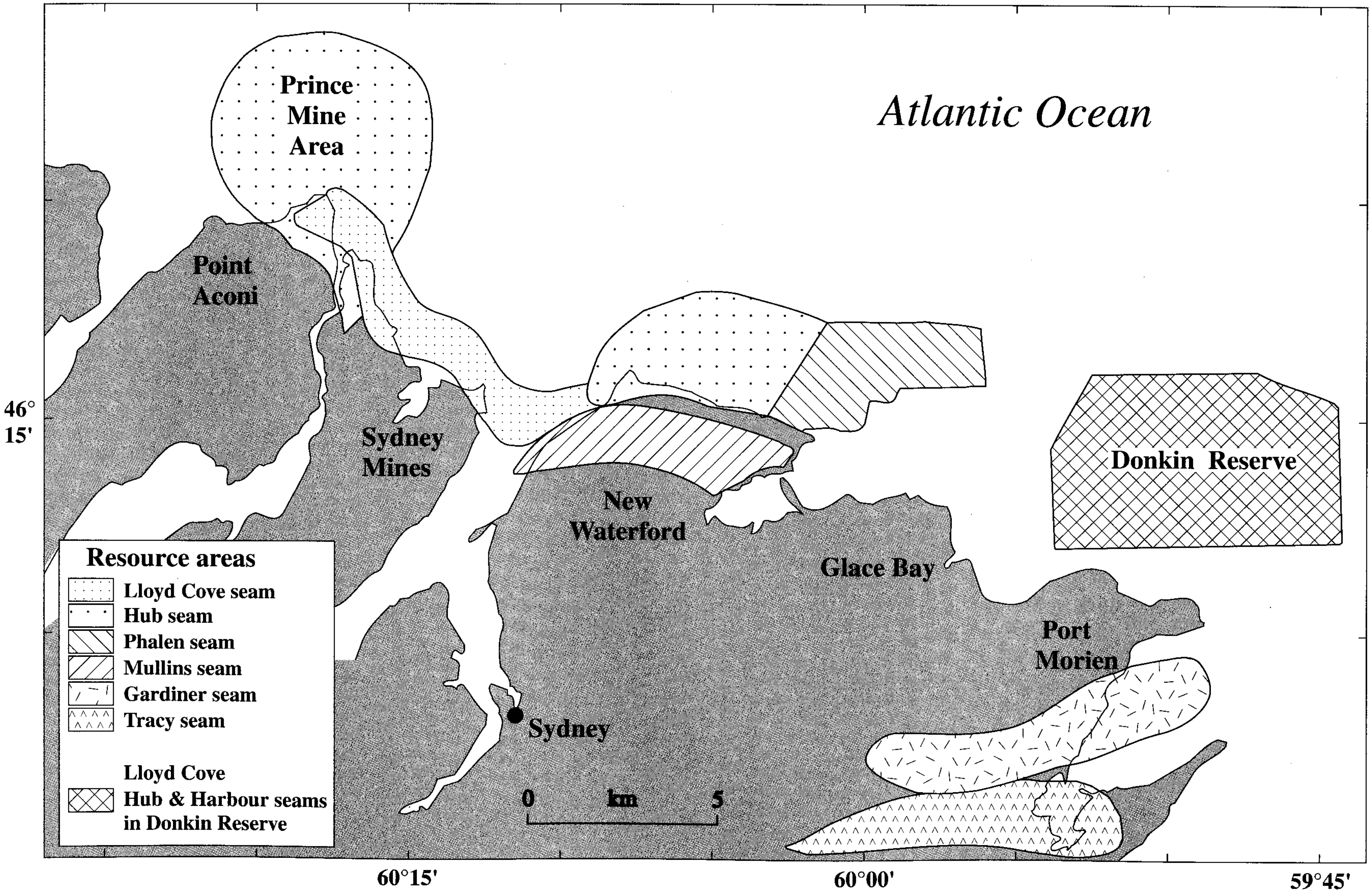

Figure 8. *Sydney coalfield showing resource areas of major coal seams.*

stability at a given rank of coal a critical ratio of reactive macerals (vitrinite+exinite+½ semifusinite) to inert macerals is required.

In the Harbour seam, this ratio has an excess of reactive components, resulting in below optimum strength factors. The coal is too "bright" and improvements in coke stability factor values can likely be obtained by additions of inert-rich constituents, such as fusite and durite i. This is born out by sample SS-4, which in comparison with 5, 6, 7, and 8 (Fig. 7) has a surprisingly high coke stability factor value of 40, notwithstanding the fact that all samples are of about equal rank, namely ± 0.92% Ro. The higher stability factor in SS-4 can be explained by a greater amount of inert macerals, which in the seam average is 12%, as against 5-8% in the other samples.

The favourable effect of an increase in rank on coke strength is clearly revealed in Figure 6. With a greater depth below the surface, the reflectance increases and is accompanied by higher stability factors. For example, sample 6 (Fig. 7) at a depth of 237 m has an Ro of 0.92% and a coke stability factor of 30, whereas sample 10 at a depth of 706 m has an Ro of 1.10% and a coke stability factor of 56.

From the above, it is apparent that with an increase in the depth of mining (farther offshore), a better metallurgical coking coal will become available. Below 700 m blending with imported medium volatile coal will no longer be necessary, because the commercially acceptable coke stability factor of 56 has been reached (in sample 10) (Hacquebard and Avery, 1988).

1996 REVISION OF COAL RESOURCE CALCULATIONS OF THE SYDNEY FIELD

This revision of coal resource estimates is included because of changes that have occurred since the last calculations were made (Hacquebard, 1976, 1978). Problems encountered with mining the Harbour seam at the Lingan and No. 26 collieries have caused the closure of these operations. As a result, access to the previously defined resource areas is no longer possible.

The coal resource definitions and parameters used in the Sydney field are as follows:

Coal resource estimates relate to coal in the ground, which in submarine areas should not be less than 1.20 m thick. Of these resources only a portion is considered recoverable, namely about 45% for room and pillar extraction and 67% in long-wall mining.

Three categories of coal resources are used in relation to the availability and density of data points.

1. Measured Resources: based on control points about ½ mile (0.8 km) apart. They are judged to be accurate within 20% of the true tonnage. The term proven resources also is used for this category.
2. Indicated Resources: based on control points about 1 mile (1.6 km) apart, but they may be as much as 1½ miles (2.4 km) apart for beds of known continuity.
3. Inferred Resources: based on control points (boreholes, outcrop, old workings) are in general more than 2 miles (3.2 km) apart.
4. Demonstrated Resources: a collective term describing measured plus indicated resources.

Appendix D presents the 1996 update of the remaining mineable coal resources of the Sydney field. It lists the calculated tonnages (in metric tonnes) of seven seams and Figure 8 shows the locations of the respective resource areas. Of the other three seams no more mineable resources are considered to be present.

Of the grand total of 1133 million tonnes, 750 million metric tonnes or 66% is classed as thermal coal, and 383 million metric tonnes as metallurgical coal. However, the latter can be used for thermal purposes also, but the former is not suitable for metallurgical use.

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Appendix A

Lithotype nomenclature (modified after Diessel, 1965).

Lithotypes (after Stopes, 1919)	Microlithotypes	Megascopic divisions (after Diesel, 1965)	Description
vitrain	vitrite	bright coal	subvitreous to virtreous lustre, conchoidal fracture, less than 10% dull coal laminae
	bright clarite	banded bright coal	predominantly bright coal with 10 to 40% dull coal laminae
clarain	dull clarite	banded coal	bright and dull coal interlaminated in approximately equal proportions
	clarodurite	banded dull coal	dull coal with 10 to 40% bright coal laminae
durain	durite carbargilite	dull coal	matt lustre, uneven fracture, less than 10% bright coal laminae
fusain	fusite	fibrous coal	satin lustre, very friable

Appendix B

Microlithotype data and coal facies designations of the ten coal seams.

Table B-1. Microlithotype data and coal facies designations of the Point Aconi seam.

	Column No. I-1 and H-12A. Pt. Aconi seam											
	Petrographic Interval		I	II	III	IV	V	VI	VII	VIII	Seam Average	Microlith. comb. for facies triangle
	Thickness	inch	3.5	2.5	5	4	3.5	10	12	2.5	43	
		cm	9	6	13	10	9	25	31	6	109	
Volume %	Fusite		–	–	–	6	7	11	9	–	6	B
	Vitrite		17	5	28	12	20	19	41	–	25	
	Bright Clarite		20	73	13	54	16	26	23	33	27	C
	Dull Clarite		63	17	59	28	57	40	27	11	42	A
	Clarodurite+ Durite		–	5	–	–	–	4	–	–	–	D
	Carbargilite		–	–	–	–	–	–	–	56	–	
	Facies designation		RM (tel.)	FM (tel.)	RM (tel.)	FM (tel.)	RM (tel.)	RM (tel.)	Ft.M	OM	RM (tel.)	
	Total facies in % of seam thickness		Ft.M = 30%, FM (tel.) = 13%, RM (tel.) = 51%, OM = 6%									

Table B-2. Microlithotype data and coal facies designations of the Lloyd Cove seam.

Column No. II-1. Lloyd Cove seam														
Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**Seam Average**	**Microlith. comb. for facies triangle**
Thickness	inch	8.5	8.9	8.5	6.6	5.4	22.5	3.5	7	12.8	6.8	5.5	96	
	cm	21	23	21	17	14	57	9	18	32	17	14	243	
Volume %	Fusite	23	8	10	20	6	5	34	6	12	14	32	10	B
	Vitrite	24	18	26	11	31	31	14	28	25	18	14	25	
	Bright Clarite	30	46	32	33	15	27	9	50	15	15	19	28	C
	Dull Clarite	20	28	26	24	34	37	31	16	45	50	14	31	A
	Clarodurite+ Durite	3	–	–	5	31	–	12	–	3	–	20	6	D
	Carbargilite	–	–	6	–	3	–	–	–	–	3	–	–	
Facies designation		Ft.M	FM (tel.)	Ft.M	Ft.M	RM (1.tel.)	Ft.M	RM (1.tel.)	FM (tel.)	RM (tel.)	RM (tel.)	RM (tel.)	RM (tel.)	
Total facies in % of seam thickness		Ft.M = 50%, FM (tel.) = 18%, RM (tel.) = 20%, RM (1.tel.) = 12%												

Table B-3. Microlithotype data and coal facies designations of the Hub seam.

Column No. III-1. Hub seam								
Petrographic Interval		**I**	**II**	**IIIA**	**IIIB**	**IV**	**Seam Average**	**Microlith. comb. for facies triangle**
Thickness	inch	6.3	23.5	27	20.4	14.8	92	
	cm	16	60	68	52	38	234	
Volume %	Fusite	–	4	3	3	3	3	B
	Vitrite	–	31	54	28	9	33	
	Bright Clarite	–	15	24	31	22	22	C
	Dull Clarite	–	46	19	25	32	30	A
	Clarodurite+ Durite	–	4	–	8	21	9	D
	Carbargilite	100	–	–	5	13	3	
Facies designation		OM	RM (tel.)	Ft.M	RM (tel.)	FM (1.tel.)	RM (tel.)	
Total facies in % of seam thickness		Ft.M = 29%, RM (tel.) = 48%, FM (1.tel.) = 16%, OM = 7%						

Table B-4. Microlithotype data and coal facies designations of the Harbour seam.

Column No. IV-31. Harbour seam									
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	21	2	31.5	14.5	26	95	
		cm	53	5	80	37	66	241	
Volume %	Fusite		4	10	2	10	5	5	B
	Vitrite		32	8	43	25	19	31	
	Bright Clarite		32	34	44	47	50	40	C
	Dull Clarite		32	18	9	9	14	18	A
	Clarodurite+ Durite		–	23	2	9	12	6	D
	Cabargilite		–	7	–	–	–	–	
	Facies designation		Ft.M	FM (1.tel.)	Ft.M	FM (tel.)	FM (tel.)	FM (tel.)	
	Total facies in % of seam thickness		Ft.M = 55%, FM (tel.) = 43%, FM (1.tel.) = 2%						

Table B-5. Microlithotype data and coal facies designations of the Backpit seam.

Column No. VI-2. Backpit seam												
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	7	3.4	6.3	6.6	13.3	14.2	2.8	3.8	57.4	
		cm	18	8	16	17	34	36	7	10	146	
Volume %	Fusite		20	4	–	6	2	13	14	26	10	B
	Vitrite		23	11	14	11	22	14	11	14	16	
	Bright Clarite		18	15	21	20	20	26	28	23	22	C
	Dull Clarite		39	42	60	49	52	42	34	26	46	A
	Clarodurite+ Durite		–	28	5	10	4	5	–	5	6	D
	Carbargilite		–	–	–	4	–	–	13	6	–	
	Facies designation		Ft.M	RM (1.tel.)	RM (tel.)	RM (tel.)	RM (tel.)	RM (tel.)	RM (tel.)	Ft.M		
	Total facies in % of seam thickness		Ft.M = 19%, RM (tel.) = 75%, RM (1.tel.) = 6%									

Table B-6. Microlithotype data and coal facies designations of the Phalen seam.

Column No. VII-5. Phalen seam										
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	17.8	18.4	3.2	16.5	2.2	26.2	84.3	
		cm	45	47	8	41	5	67	213	
Volume %	Fusite		11	9	–	8	5	9	8	B
Volume %	Vitrite		31	38	30	25	20	24	29	
Volume %	Bright Clarite		46	35	50	50	14	48	44	C
Volume %	Dull Clarite		12	18	5	15	–	16	15	A
Volume %	Clarodurite + Durite		–	–	15	2	61	3	4	D
Volume %	Carbargilite		–	–	–		–	–	–	
	Facies designation		FM (tel.)	Ft.M	FM (tel.)	FM (tel.)	OM	FM (tel.)	FM (tel.)	
	Total facies in % of seam thickness		Ft.M = 22%, FM (tel.) = 76%, OM = 2%							

Table B-7. Microlithotype data and coal facies designations of the Emery seam.

Column No. IX-3. Emery seam										
	Petrographic Interval		**IA**	**I**	**II**	**III**	**IV**	**V**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	2.6	4.1	6.4	9.4	4.6	6.9	34	
		cm	7	10	17	24	12	18	88	
Volume %	Fusite		–	–	–	7	10	6	5	B
Volume %	Vitrite		50	44	30	27	20	37	32	
Volume %	Bright Clarite		30	23	18	22	30	13	21	C
Volume %	Dull Clarite		20	17	47	40	12	44	34	A
Volume %	Clarodurite + Durite		–	16	5	4	28	–	8	D
Volume %	Carbargilite		–	–	–	–	–	–	–	
	Facies designation		Ft.M	Ft.M	RM (tel.)	RM (tel.)	FM (1.tel.)	Ft.M	FM (tel.)	
	Total facies in % of seam thickness		Ft.M = 40%, FM (1.tel.) = 14%, RM (tel.) = 46%							

Table B-8. Microlithotype data and coal facies designations of the Gardiner seam.

	Column No. X-2. Gardiner seam										
	Petrographic Interval		**IA**	**I**	**II**	**III**	**IV**	**V**	**VI**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	6.2	16.9	9.2	3.2	13.2	6.4	11.7	66.9	
		cm	16	43	24	8	33	16	30	170	
Volume %	Fusite		5	5	4	–	3	13	13	7	B
	Vitrite		18	27	22	5	20	17	22	22	
	Bright Clarite		44	57	43	16	73	40	47	52	C
	Dull Clarite		5	10	15	12	4	8	15	10	A
	Clarodurite + Durite		10	1	16	37	–	8	3	4	D
	Carbargilite		18	–	–	30	–	14	–	5	
	Facies designation		FM (1.tel.)	FM (tel.)	FM (tel.)	OM	FM (tel.)	FM (tel.)	FM (1.tel.)	FM (tel.)	
	Total facies in % of seam thickness		FM (tel.) = 86%, FM (1.tel.) = 9%, OM = 5%								

Table B-9. Microlithotype data and coal facies designations of the Mullins seam.

	Column No. XI-1. Mullins seam												
	Petrographic Interval		**IB**	**IA**	**I**	**II**	**III**	**IV**	**V**	**VIA**	**VI**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	4.5	2.7	20.8	5.3	3.1	16	3.1	3.3	13.3	72	
		cm	11	7	53	14	8	40	8	8	34	183	
Volume %	Fusite		3	6	3	6	3	6	6	14	15	8	B
	Vitrite		29	20	31	15	44	20	14	7	22	22	
	Bright Clarite		36	25	50	37	53	60	30	35	48	50	C
	Dull Clarite		12	9	10	10	–	10	6	9	9	10	A
	Clarodurite + Durite		–	40	6	32	–	4	44	35	6	10	D
	Carbargilite		20	–	–	–	–	–	–	–	–	–	
	Facies designation		FM (1.tel.)	FM (1.tel.)	FM (tel.)	FM (1.tel.)	FM (tel.)	FM (tel.)	FM (1.tel.)	FM (1.tel.)	FM (tel.)	FM (tel.)	
	Total facies in % of seam thickness		FM (tel.) = 74%, FM (1.tel.) = 26%										

Table B-10. Microlithotype data and coal facies designations of the Tracy seam.

Column No. XII-1. Tracy seam													
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Seam Average**	**Microlith. comb. for facies triangle**
	Thickness	inch	1.1	6.7	6.2	12.1	7.5	9.3	9.3	9.5	3.6	65.3	
		cm	3	17	16	31	19	24	24	24	9	167	
Volume %	Fusite		11	4	4	2	1	5	14	9	28	9	B
	Vitrite		14	29	24	23	29	14	20	12	21	21	
	Bright Clarite		7	51	62	19	47	20	26	42	27	32	C
	Dull Clarite		–	11	4	44	23	41	40	25	9	27	A
	Clarodurite + Durite		–	5	–	12	–	20	–	12	15	11	D
	Carbargilite		68	–	6	–	–	–	–	–	–	–	
	Facies designation		OM	FM (tel.)	FM (tel.)	FM (tel.)	FM (tel.)	FM (1.tel.)	FM (tel.)	FM (tel.)	Ft.M	FM (tel.)	
	Total facies in % of seam thickness		Ft.M = 5%, FM (tel.) = 79%, FM (1.tel.) = 14%, OM = 2%										

Appendix C

Maceral, proximate analyses, and coal facies data of the ten coal seams.

Table C-1. Maceral, proximate analyses, and coal facies data of the Point Aconi seam.

Column No. I-1 Pt. Aconi seam											
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Seam Total**
	Thickness	inch	3.5	2.5	5	4	3.5	10	12	2.5	43
		cm	9	6	13	10	9	25	31	6	109
Volume %	Vitrinite	Total	86	83	78	75	64	66	68	CARBARGILITE	69
		Structured	34	18	35	18	18	23	35		24
		Groundmass	52	65	43	57	46	43	33		45
	Exinite		10	3	2	3	4	5	5		5
	Inertinite	Total	4	11	17	20	27	24	25		22
		Fusinite	1	2	4	10	4	4	5		5
		Semifusinite	–	1	3	4	8	7	6		6
		Macrinite + Micrinite	3	8	10	6	15	13	14		11
	Kaolinite		–	1	1	–	1	4	1		3
	Pyrite		–	2	1	1	2	1	1		1
By Weight	% Ash		3.5	5.9	5.0	8.9	11.7	7.5	4.5	49.5	6.6
	% Sulphur		1.8	4.0	2.4	5.8	4.7	5.7	3.1	2.3	3.9
Facies factors	Groundwater Influence (G.W.I.)		1.5	3.6	1.2	3.2	2.6	1.9	0.9	–	2.0
	Vegetation Index (V.I.)		0.5	0.3	0.8	0.5	0.5	0.6	0.9	–	0.5

Table C-2. Maceral, proximate analyses, and coal facies data of the Lloyd Cove seam.

Column No. II-1. Lloyd Cove seam														
	Petrographic Interval		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Seam Total
	Thickness	inch	8.5	8.9	8.5	6.6	5.4	22.5	3.5	7	12.8	6.8	5.5	96
		cm	21	23	21	17	14	57	9	18	32	17	14	243
Volume %	Vitrinite	Total	63	77	76	55	47	82	49	84	72	62	43	67
		Structured	29	28	36	17	7	41	21	39	33	21	17	27
		Groundmass	34	49	40	38	40	41	28	45	39	41	26	40
	Exinite		5	6	6	7	7	8	4	5	5	4	5	6
	Inertinite	Total	25	10	14	30	25	8	44	10	21	22	39	22
		Fusinite	21	7	8	20	10	5	23	4	9	11	21	10
		Semifusinite	1	1	2	–	1	–	9	2	3	1	3	3
		Macrinite + Micrinite	3	2	4	10	14	3	12	4	9	10	15	9
	Kaolinite		5	5	4	5	14	1	3	–	–	8	3	3
	Pyrite		2	2	–	3	7	1	–	1	2	4	10	2
By Weight	% Ash		13.6	5.2	3.7	10.8	21.3	4.0	2.8	3.8	3.6	20.4	22.9	8.4
	% Sulphur		9.3	4.8	3.8	7.1	11.1	2.9	2.4	3.8	3.7	12.1	12.4	5.8
Facies factors	Groundwater Influence (G.W.I.)		1.2	1.8	1.1	2.2	5.7	1.0	1.3	1.2	1.2	2.0	1.5	1.5
	Vegetation Index (V.I.)		1.2	0.6	0.9	0.7	0.3	0.9	1.0	0.8	0.8	0.6	0.9	0.7

Table C-3. Maceral, proximate analyses, and coal facies data of the Hub seam.

	Column No. III-1 Hub seam							
	Petrographic Interval		I	II	IIIA	IIIB	IV	Seam Total
	Thickness	inch	6.2	23.5	27	20.4	14.8	92
		cm	16	60	68	52	38	234
Volume %	Vitrinite	Total	NO DATA	77	80	80	63	77
		Structured		37	51	42	23	41
		Groundmass		40	29	38	40	36
	Exinite			6	5	5	9	5
	Inertinite	Total		6	13	13	24	13
		Fusinite		2	5	3	7	4
		Semifusinite		1	4	3	8	4
		Macrinite + Micrinite		3	4	7	9	5
	Kaolinite			3	–	–	–	2
	Pyrite			8	2	2	4	3
By weight	% Ash			8.1	3.8			5
	% Sulphur			2.8	2.4			2.5
Facies factors	Groundwater Influence (G.W.I.)			1.1	1.6	0.9	1.7	0.9
	Vegetation Index (V.I.)			0.8	0.6	1.0	0.7	1.1

Table C-4. Maceral, proximate analyses, and coal facies data of the Harbour seam.

Column No. IV-31. Harbour seam								
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**Seam Total**
	Thickness	inch	21	2	31.5	14.5	26	95
		cm	53	5	80	37	66	241
Volume %	Vitrinite	Total	82	39	75	63	57	69
		Structured	39	5	36	18	8	26
		Groundmass	43	34	39	42	49	43
	Exinite		7	21	9	11	15	11
	Inertinite	Total	10	34	15	25	28	20
		Fusinite	7	22	7	13	11	11
		Semifusinite	1	4	4	3	5	3
		Macrinite + Micrinite	2	8	4	9	12	6
	Kaolinite		–	6	–	–	–	–
	Pyrite		1	–	1	1	–	–
By Weight	% Ash		2.6	15.4	2.3	2.9	1.7	2.6
	% Sulphur		0.6	0.5	1.2	0.5	0.6	0.8
Facies factors	Groundwater Influence (G.W.I.)		1.1	17	1.1	2.3	6.1	1.6
	Vegetation Index (V.I.)		0.9	0.5	0.9	0.5	0.3	0.7

Table C-5. Maceral, proximate analyses, and coal facies data of the Backpit seam.

	Column No. VI-2. Backpit seam										
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Seam Total**
	Thickness	inch	7	3.4	6.3	6.6	13.3	14.2	2.8	3.8	57.4
		cm	18	8	16	17	34	36	7	10	146
Volume %	Vitrinite	Total	60	63	78	68	79	67	71	40	69
		Structured	23	19	24	20	33	23	28	5	24
		Groundmass	37	44	54	48	46	44	43	35	45
	Exinite		3	13	16	18	13	4	5	8	10
	Inertinite	Total	34	20	1	12	8	21	21	33	17
		Fusinite	28	4	–	5	2	11	10	25	9
		Semifusinite	–	–	–	1	–	2	4	1	1
		Macrinite + Micrinite	6	16	1	6	6	8	7	7	7
	Kaolinite		–	–	1	1	–	4	–	3	1
	Pyrite		3	4	4	1	–	4	3	16	3
By Weight	% Ash		11.7		2.9	3.3	6.1		6.6		5.9
	% Sulphur		5.9		2.1	1.3	2.0		2.1		1.9
Facies factors	Groundwater Influence (G.W.I.)		1.6	2.3	2.3	2.4	1.4	1.9	1.5	7.0	1.9
	Vegetation Index (V.I.)		1.1	0.3	0.3	0.4	0.5	0.6	0.8	0.6	0.6

Table C-6. Maceral, proximate analyses, and coal facies data of the Phalen seam.

<table>
<tr><th colspan="10">Column No. VII-5 and C-125 Phalen seam</th></tr>
<tr><th></th><th colspan="2">Petrographic Interval</th><th>I</th><th>II</th><th>III</th><th>IV</th><th>V</th><th>VI</th><th>Seam Total</th></tr>
<tr><td></td><td rowspan="2">Thickness</td><td>inch</td><td>17.8</td><td>18.4</td><td>3.2</td><td>16.5</td><td>2.2</td><td>26.2</td><td>84.3</td></tr>
<tr><td></td><td>cm</td><td>45</td><td>47</td><td>8</td><td>41</td><td>5</td><td>67</td><td>213</td></tr>
<tr><td rowspan="11">Volume %</td><td rowspan="3">Vitrinite</td><td>Total</td><td>82</td><td>82</td><td>(C-125)</td><td>81</td><td>(C-125)</td><td>83</td><td>81</td></tr>
<tr><td>Structured</td><td>43</td><td>46</td><td rowspan="8">P A R T I N G</td><td>36</td><td rowspan="8">P A R T I N G</td><td>38</td><td>40</td></tr>
<tr><td>Groundmass</td><td>39</td><td>36</td><td>45</td><td>45</td><td>41</td></tr>
<tr><td colspan="2">Exinite</td><td>5</td><td>5</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td rowspan="4">Inertinite</td><td>Total</td><td>12</td><td>12</td><td>11</td><td>12</td><td>12</td></tr>
<tr><td>Fusinite</td><td>10</td><td>9</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>Semifusinite</td><td>1</td><td>–</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>Macrinite +Micrinite</td><td>1</td><td>3</td><td>4</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Kaolinite</td><td>–</td><td>–</td><td>2</td><td>–</td><td>1</td></tr>
<tr><td colspan="2">Pyrite</td><td>1</td><td>1</td><td></td><td>2</td><td></td><td>1</td><td>2</td></tr>
<tr><td rowspan="2">By Weight</td><td colspan="2">% Ash</td><td>15.4</td><td>5.6</td><td></td><td>5.7</td><td></td><td>7.0</td><td>7.1</td></tr>
<tr><td colspan="2">% Sulphur</td><td>5.9</td><td>3.0</td><td></td><td>2.2</td><td></td><td>6.0</td><td>3.3</td></tr>
<tr><td rowspan="2">Facies factors</td><td colspan="2">Groundwater Influence (G.W.I.)</td><td>0.9</td><td>0.8</td><td></td><td>1.3</td><td></td><td>1.2</td><td>1.0</td></tr>
<tr><td colspan="2">Vegetation Index (V.I.)</td><td>1.2</td><td>1.3</td><td></td><td>0.8</td><td></td><td>0.6</td><td>0.1</td></tr>
</table>

Table C-7. Maceral, proximate analyses, and coal facies data of the Emery seam.

	Column No. IX-3 Emery seam									
	Petrographic Interval		IA	I	II	III	IV	V	Seam Total
	Thickness	inch	2.6	4.1	6.4	9.4	4.6	6.9	35
		cm	7	10	17	24	12	18	88
Volume %	Vitrinite	Total	94	87	86	80	64	81	81
		Structured	61	57	44	40	29	46	44
		Groundmass	33	30	42	40	35	35	37
	Exinite		4	8	9	5	4	6	6
	Inertinite	Total	–	4	3	12	20	10	10
		Fusinite	–	–	–	3	7	4	4
		Semifusinite	–	–	–	4	3	2	1
		Macrinite +Micrinite	–	4	3	5	10	4	5
	Kaolinite		1	–	1	1	10	–	–
	Pyrite		1	1	1	2	2	3	3
By Weight	% Ash		NO DATA						9.5
	% Sulphur		NO DATA						2.6
Facies factors	Groundwater Influence (G.W.I.)		0.5	0.5	1.0	1.0	1.2	0.8	0.8
	Vegetation Index (V.I.)		1.6	1.4	0.8	0.9	0.8	1.2	1.0

Table C-8. Maceral, proximate analyses, and coal facies data of the Gardiner seam.

			IA	I	II	III	IV	V	VI	Seam Total
	Column No. X-2 Gardiner seam									
	Petrographic Interval		**IA**	**I**	**II**	**III**	**IV**	**V**	**VI**	**Seam Total**
	Thickness	inch	6.2	16.9	9.2	3.2	13.2	6.4	11.7	66.9
	Thickness	cm	16	43	24	8	33	16	30	170
Volume %	Vitrinite	Total	75	83	71	NO DATA	89	63	80	79
Volume %	Vitrinite	Structured	34	37	28		35	24	37	35
Volume %	Vitrinite	Groundmass	41	46	43		54	39	43	44
Volume %	Exinite		11	9	15		3	7	4	7
Volume %	Inertinite	Total	12	8	14		8	25	15	12
Volume %	Inertinite	Fusinite	5	–	5		5	12	8	6
Volume %	Inertinite	Semifusinite	–	2	–		1	1	2	1
Volume %	Inertinite	Macrinite +Micrinite	7	6	9		2	12	5	5
Volume %	Kaolinite		–	–	–		–	5	–	1
Volume %	Pyrite		2	–	–		–	–	1	1
By Weight	% Ash		14.3	4.7	9.3	23.5	5.2	15.2	10.1	9.1
By Weight	% Sulphur		6.3	2.7	5.7	2.1	3.8	3.1	6.0	4.2
Facies factors	Groundwater Influence (G.W.I.)		1.2	1.2	1.5	–	1.5	1.6	1.2	1.3
Facies factors	Vegetation Index (V.I.)		0.7	0.7	0.5	–	0.7	0.6	0.8	0.8

Table C-9. Maceral, proximate analyses, and coal facies data of the Mullins seam.

	Column No. XI-1 Mullins seam											
	Petrographic Interval		IB	IA	I	II	III	IV	V	VIA	VI	Seam Total
	Thickness	inch	4.5	2.7	20.8	5.3	3.1	16	3.1	3.3	13.3	72
	Thickness	cm	11	7	53	14	8	40	8	8	34	183
Volume %	Vitrinite	Total	NO DATA	NO DATA	84	76	91	85	71	67	82	82
Volume %	Vitrinite	Structured			38	36	54	36	35	28	39	38
Volume %	Vitrinite	Groundmass			46	40	37	49	36	39	43	44
Volume %	Exinite				6	11	4	5	11	9	4	6
Volume %	Inertinite	Total			9	11	3	8	15	22	12	10
Volume %	Inertinite	Fusinite			5	6	2	6	6	12	10	7
Volume %	Inertinite	Semifusinite			1	–	–	–	–	2	–	–
Volume %	Inertinite	Macrinite +Micrinite			3	5	1	2	9	8	2	3
Volume %	Kaolinite				–	–	–	–	–	–	–	–
Volume %	Pyrite				1	2	2	2	3	2	2	2
By Weight	% Ash			19.0	3.6	6.8	6.0	8.7	14.8	12.8	8.0	7.6
By Weight	% Sulphur			11.0	3.2	4.6	3.6	5.5	7.7	6.3	5.3	5.0
Facies factors	Groundwater Influence (G.W.I.)		–	–	1.2	1.1	0.7	1.4	1.0	1.4	1.1	1.2
Facies factors	Vegetation Index (V.I.)		–	–	0.8	0.8	1.3	0.8	0.7	0.8	1.0	0.8

Table C-10. Maceral, proximate analyses, and coal facies data of the Tracy seam.

	Column No. XII-1 Tracy seam											
	Petrographic Interval		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Seam Total**
	Thickness	inch	1.1	6.7	6.2	12.1	7.5	9.3	9.3	9.5	3.6	65.3
		cm	3	17	16	31	19	24	24	24	9	167
Volume %	Vitrinite	Total	NO DATA	87	87	83	91	66	67	74	51	76
		Structured		43	40	40	44	22	25	27	23	35
		Groundmass		44	47	43	47	44	42	47	28	41
	Exinite			5	5	4	2	5	2	4	4	4
	Inertinite	Total		5	5	11	6	28	29	20	33	18
		Fusinite		2	2	2	–	5	15	12	23	6
		Semifusinite		1	–	–	1	3	2	–	–	1
		Macrinite +Micrinite		2	3	9	5	20	12	8	10	11
	Kaolinite			–	–	–	–	–	–	–	4	–
	Pyrite			3	3	2	1	1	2	2	8	2
By Weight	% Ash			12.7	10.0	11.2	4.5	4.4	6.8	5.7	29.2	9.5
	% Sulphur			7.9	6.7	5.2	5.2	3.5	6.6	5.5	14.3	6.2
Facies factors	Groundwater Influence (G.W.I.)			1.0	1.2	1.1	1.1	2.0	1.6	1.7	1.2	1.2
	Vegetation Index (V.I.)			0.9	0.8	0.8	0.8	0.4	0.8	0.7	1.1	0.8

Appendix D

1996 Revision of coal resource estimates of the Sydney coalfield.

Seam	District	Resource area (in km²)	Average thickness (in m)	Demonstrated Resources in million tonnes
Lloyd Cove	Prince Mine and Sydney Mines area	30.7	2.4	56
	Donkin	48.9	2.0	157
Hub	Prince Mine	74.8	2.1	214
	New Waterford	33.3	1.8	71
	Donkin	53.9	1.8	150
Harbour	Donkin	100	2.8	254
Phalen	Lingan – No. 26 Colliery	36	2.5	129
Gardiner	Port Morien	19	1.2	30
Mullins	New Waterford	11	1.3	39
Tracy	Port Morien	21	1.4	33
	Total: Thermal coal: 750 m.t. (=66%), Metallurgical coal: 383 m.t. (34%) Grand Total: 1133 m.t.			