9. GEOLOGICAL DEVELOPMENT AND ECONOMIC EVALUATION OF THE SYDNEY COAL BASIN, NOVA SCOTIA[1]

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Abstract

The Sydney Basin, which is almost entirely submarine, extends from northeastern Cape Breton Island almost as far as Newfoundland. It contains coal measures of Westphalian C, D and Stephanian ages, which have characteristics associated with paralic basins.

The structural style of the Sydney Basin is relatively simple and essentially saucer-shaped with the beds dipping towards the centre. A main feature is the (offshore) Boisdale Anticline, a pre-Westphalian high, which divides the western part of the Basin into the Ingonish and Glace Bay Subbasins.

The exploited part of the coalfield lies at the southern fringe of the Glace Bay Subbasin, which has its centre about 22 km from the coast. In the onshore area there are twelve mineable seams, whereas offshore there are only five. Four of these have been encountered in two oil exploration wells, drilled some 35 km seaward.

The centre of coal deposition in the nearshore area is located on the eastern side, where in the Donkin area four successive seams reach their greatest developments, with thicknesses of up to 4.3 m.

Cross-sections through five seams illustrate the development of coal and show the phenomenon of depositional splitting and rejoining. From detailed studies on two major seams it is apparent that the 'hinge lines' on succeeding terrigenous partings of the same seam run subparallel, while on partings of different seams they trend in different directions.

All coal is classed as high volatile 'A' bituminous, but there are significant changes within and beyond this category. These are related to the observation that the coalification is essentially postdeformational. This has resulted in an increase of rank with depth, as well as regionally from west to east within the same seam. Coke stability data indicate rank changes are economically favourable, because the coking characteristics of the coal improve with depth, and towards the east.

Total 'demonstrated' resources, present in ten seams, to a depth of 1220 m and/or 11 km from shore, amount to 1.6 x 10^9 t, when calculated on clean coal exclusive of partings and impure roof or bench coal. Of these in situ tonnages about 317 x 10^6 t may be suitable for metallurgical purposes, and 1.29 x 10^9 t can be classed as thermal coal. Some 82 per cent of the total estimate is contributed by four seams, namely the Phalen, Harbour, Hub and Lloyd Cove seams.

Introduction

Much new information has been gained on the extent and development of the Sydney coal basin from recent offshore exploration for oil, gas and coal. It is now realized that the detailed geology and the data acquired during some 200 years of mining relate only to a small region that lies on the fringe of an extensive offshore Carboniferous basin. Information on this basin is still limited, but interpretation of the new data in light of existing knowledge has considerably broadened the geological picture, as will be shown in this paper.

Location, Age and Stratigraphy

The Sydney coal basin is situated in northeastern Nova Scotia on and offshore Cape Breton Island (Fig. 9.1). It consists of two parts: a small land area of about 520 km^2 (200 square miles) 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 (14 000 square miles). It is referred to as the Sydney Basin and its extent was determined by King and MacLean (1976) using shipboard geophysical and acoustic methods.

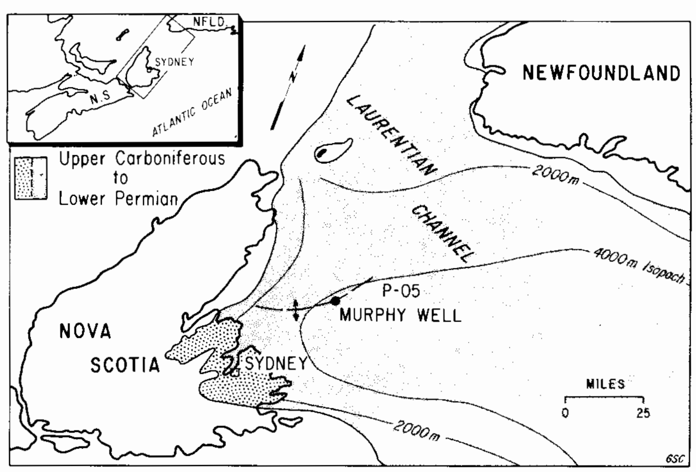

Figure 9.1. *Sydney coalfield and adjacent Carboniferous Basin (after King and MacLean, 1976).*

[1] Presented at the Ninth International Congress of Carboniferous Stratigraphy and Geology, Urbana, Illinois, May 22, 1979.

The coal-bearing rocks of the onshore part of the coal basin belong to the Morien Group, which, on the basis of the megaflora and spore florule, has been assigned a Westphalian C and D age (Bell, 1938; Hacquebard et al., 1960). The Group reaches its maximum thickness of around 1966 m (6450 feet) in the Glace Bay and Port Morien Districts, and has been subdivided into three biostratigraphic zones (A to C). These zones, which are based on plant and spore fossils (Barss and Hacquebard, 1967), are transgressive towards the northwest, where the younger zones overstep the older ones.

In the offshore part additional (post-Morien) coal measures are present. They comprise spore zone D which has an assemblage indicative of Stephanian age. This zone, which was first encountered in the uppermost seam of the shore section at Point Aconi, was intersected in several offshore wells where it ranged in thickness from 183-271 m (600-890 feet). It is followed by a sequence of red beds that may extend into the Permian (Fig. 9.2).

The coal-bearing sequence contains thirteen seams that are 0.9-4.3 m (3-14 feet) thick, nine of which occur in spore zones B and C, and three seams are present in zone D. All but the youngest three coals, of which two do not outcrop in the land area, have been mined in the past. The two most productive seams have been the Harbour and Phalen seams, which have been worked extensively in the submarine area adjacent to the coast.

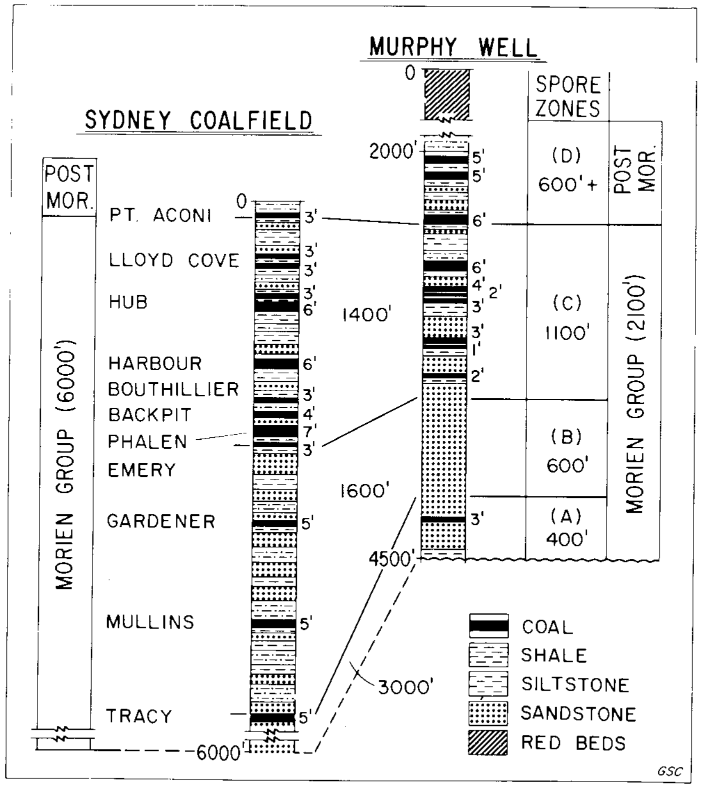

Figure 9.2. Coal bearing sequence of Sydney coalfield and correlation with Murphy et al. North Sydney P-05 well (after Hacquebard, 1979).

Structure of Sydney Basin

As the basin is almost entirely offshore, its structure could be determined only with the aid of shipboard geophysical methods, principally seismic reflection techniques. King and MacLean (1976) have pointed out that the structural style of the Sydney Basin is relatively simple and, except for local folding, essentially saucer-shaped with the beds dipping towards the deeper and central parts of the basin. Along its southern boundary, however, a marginal fold belt is present, which is manifested by folding and faulting in the land area of the Sydney coalfield (Fig. 9.3). Here the beds are flexed in open folds that trend easterly to northeasterly with prevailing dips on the flanking beds of 4-15°, reaching 30° in a few instances. This folding likely was initiated by warping during deposition, because in general the coal seams are a little thicker in the synclines than on the anticlines. Apart from two boundary faults with considerable vertical displacement, located at the western and southeastern corners of the land area, only minor thrust faulting has been observed in the coalfield. Therefore, the main structures are probably the result of variable subsidence due to sediment load enhanced by differential compaction of the coal measure strata.

The structure of the western part of the Sydney Basin has become much better known from extensive seismic reflection work, carried out for Murphy Oil Co. in 1972. A contour map was prepared from the seismic profiles on a phantom Horizon "J", which in the known part of the coalfield corresponds to the pavement of the Phalen seam. This map proved accurate during the 1977 and 1978 offshore drilling program, when the determined positions of the Phalen seam checked closely with those predicted by the map. Also the proposed correlation of the Murphy et al. P-05 well closely conformed with the predicted position. Therefore, considerable reliance can be placed on the seismic interpretation and a similar map with contours of the Harbour seam is presented as Figure 9.3. This map was derived from the Horizon "J" map by raising each contour 450 feet (137 m), which is equal to the average vertical distance between the Harbour and Phalen seams. The Harbour seam horizon was selected because it has better continuity than the Phalen seam and is the best producing coal seam with the largest reserves.

The main structural feature of the western part of the Sydney Basin is the Boisdale Anticline, which caused the formation of the Ingonish and Glace Bay subbasins (Fig. 9.3). The anticlinal structure is considered to be the continuation of the Boisdale Anticline of Bell and Goranson (1938) of Boularderie Island, which in turn is an extension of the pre-Carboniferous Boisdale Hills to the south and can be related to a pre-Morien high. This is revealed by the correlation of the section encountered in the Murphy et al. P-05 well with the sequence of the Sydney coalfield. Figure 9.2 shows a reduction in thickness of the individual spore zones in the Murphy et al. well as compared with the average thickness known from previous onshore geological studies. Zone A shows a thinning from 3000 to 400 feet (914-122 m), zone B from 1600 to 600 feet (488-183 m) and zone C from 1400 to 1100 feet (427-335 m) (Barss et al., 1979).

As the seismic interpretation shows a thrust fault on the south side of the (offshore) Boisdale Anticline, some lateral movement towards the southeast must have occurred. Similar faults are present on the south side of the Glace Bay Subbasin, but there the direction of movement was both to the southeast and to the southwest. The latter faults probably postdated the folding, whereas the former may have been contemporaneous with it.

The interpretation of the structure in the Morien Bay area (Fig. 9.4) was achieved by correlating the drilling results of borehole H-3 with those obtained from a shallow seismic survey, which was done with an acoustic transmitter (sparker) from a fishing boat. Drilling was carried out in Morien Bay with the expectation of intersecting the Harbour seam with sufficient cover to permit submarine mining. The 2.7 m (9 foot) thick seam was previously worked in a small land area, but could not be followed under the sea because of insufficient cover (it should be at least 55 m (180 feet) at the shoreline). Borehole H-3 was spotted in the projected seaward extension of the eastward plunging syncline and depths of -274 m (-900 feet) for the Harbour seam and -451 m (-1480 feet) for the Phalen seam were predicted (Fig. 9.4A). The drilling results were different than expected and the sequence encountered posed a correlation problem. Palynological studies showed that the top of spore zone B occurs near -305 m (-1000 feet) and therefore the coal at -198 m (-650 feet) correlates with the Phalen seam which is in spore zone C (Fig. 9.2; M.S. Barss, personal communication). Apparently the well started in the subsea outcrop of the Harbour seam and as a result no coal was obtained in the core.

A subsequent seismic survey (Howells, 1977) provided the data for the interpretation shown in Figure 9.4B. The structure can be explained by a thrust fault with movement towards the southeast. A similar thrust fault, but with much less lateral displacement, was reported by Haites (1951) in the workings of Dominion Nos. 6 and 20 Collieries in the Glace Bay area. This fault can be extended to meet the disturbed zone that was recorded by the seismic survey in the centre of Morien Bay. It caused a lateral displacement of the synclinal axis to the south and also reversed the plunge from east to west, as was recorded seismically. As a result the Harbour seam underlies only a very small area in Morien Bay, which is delineated by the assumed subsea outcrop shown in Figure 9.4B. This body of coal is too small and shallow for submarine mining and since borehole H-3 did not intersect any other coals of mineable thickness, the Morien Bay area can no longer be regarded as a potential future reserve.

Environment of Deposition and Development of Coal Seams

Although no marine horizons are known in the Sydney succession, the coalfield is genetically a paralic basin. Such basins normally occupied coastal lowland areas of regions that were tectonically stable. In such regions, normal-banded autochthonous coals accumulated in extensive peat bogs that were formed and buried where the vegetation grew.

The development of such bogs at the present time has been described by Fisk (1960). In that paper on recent Mississippi deltaic deposits he showed that vegetation and peat formation are related to the distribution and nature of the clastic sediments. An important factor in this relationship is the variation in relief due to differential compaction. The effect of compaction by itself can provide areas of subsidence and poor drainage necessary for the accumulation of thick peat deposits. According to Fisk, the most favourable areas are interdistributary troughs and levee-flank depressions along active and abandoned river channels. Such areas would be those underlain by fine clastic sediments. Similar observations can be made on the fossil peat bogs of the Sydney floodplain, as was revealed by detailed depositional studies of the coal seams.

Isopachs on the Harbour seam (Fig. 9.5) show a general thinning towards the west and eventual termination due to splitting. The optimum seam development occurs in the Glace Bay-Donkin area, although in part this is offset in the synclinal region by post Band I erosion or nondeposition.

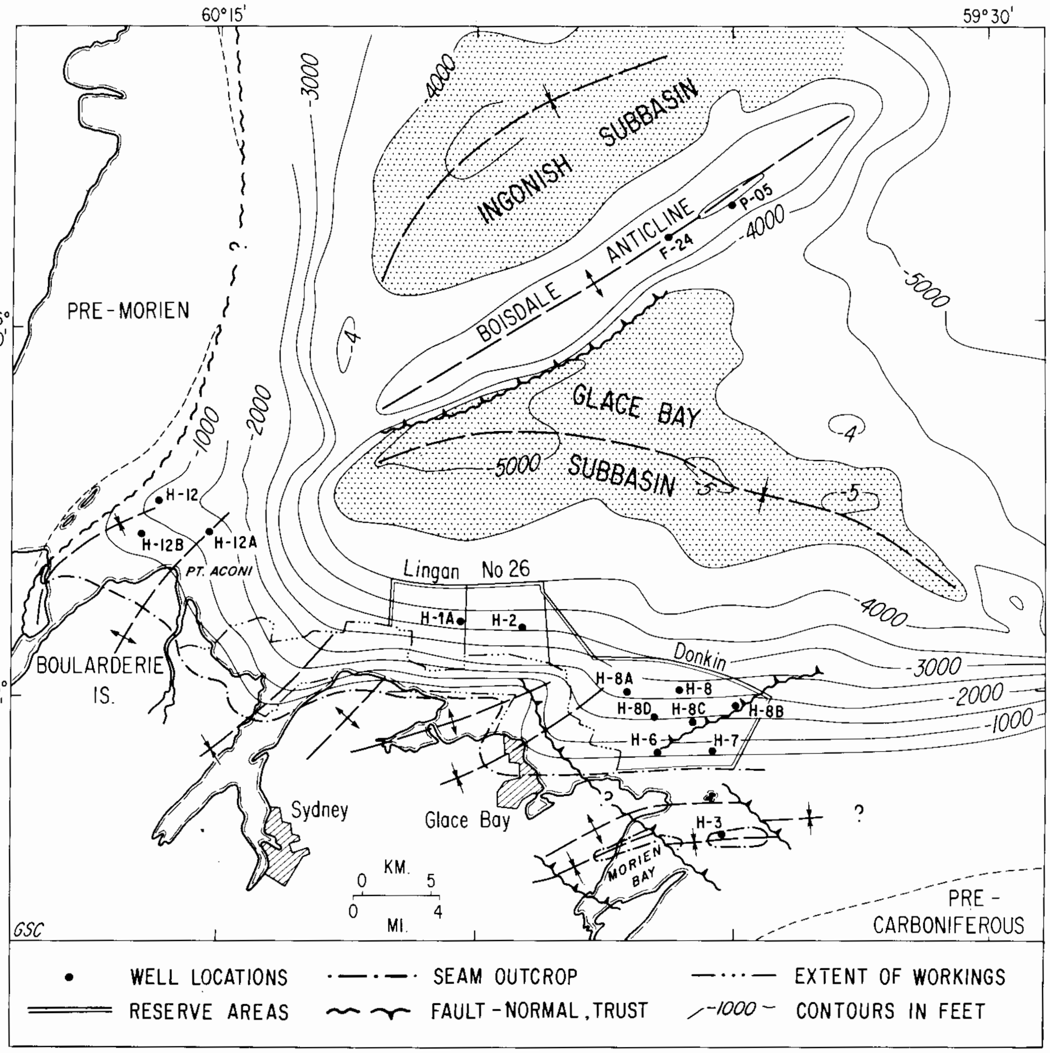

__Figure 9.3.__ Structural development of western part of Sydney Basin shown with Harbour seam contours.

The depositional pattern of the Harbour seam was controlled by the underlying sediments, as is shown in Figure 9.6. The borehole sections of Figure 9.6 reveal that the decrease in seam thickness is accompanied by an increase in the thickness of clastic rocks between the main seam and Lower

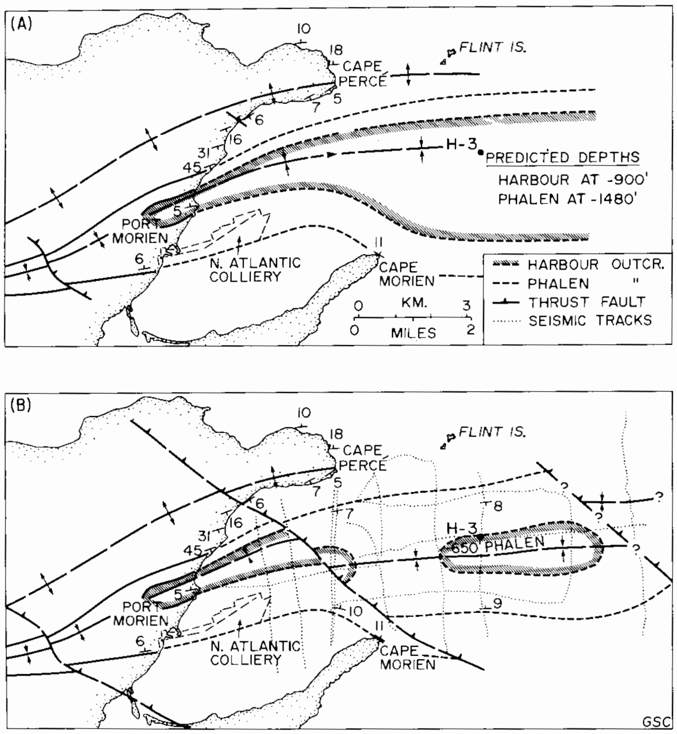

Figure 9.4. *Structural interpretation of Morien Bay District; A. Before drilling; B. After drilling of borehole H-3 and seismic survey.*

Bench coal. This phenomenon is related to the paleotopography that existed during the early stages of the Harbour peat accumulation. Higher ground was present in the western region due to the greater influx of clastic materials. Differential compaction, caused by differences in sedimentation, produced a localized basin in the Glace Bay-Donkin area. In this basin active peat accumulation started in the centre, while clastic sediments were still being laid down in the western part of the region. As time progressed the peat-forming vegetation migrated outward from the trough or subbasin, crossed the postulated levee and distributary channel of New Waterford, then went across the Sydney Mines interdistributary trough, and finally covered the 'Boularderie River' channel. It was only after this point was reached that peat growth occurred simultaneously over the entire areal extent of the Harbour bog.

The development of the other major seams of the Sydney coalfield is shown by the cross-sections in Figure 9.7. The many different patterns that are represented reveal the ever changing interaction between fluvial sedimentation and peat accumulation. Some of the seams, notably the Phalen and Hub seams, show the influence of a very active river by their pronounced splitting, rejoining, and digitation. Others like the Harbour and Point Aconi seams were much less affected. However, a common characteristic of all these autochthonous coal seams is their termination by the process of subdividing and the eventual "pinching out" of individual benches.

The vertical arrangements of the seam sections in Figure 9.7 show two significant depositional features, namely:

1. A general westward seam extension from older to younger seams, reaching maximum coverage of the coalfield from the Harbour seam upwards. This includes four seams below the Phalen seam that are not shown in Figure 9.7, but which all have their nucleus of coal deposition in the eastern part of the coalfield. The western seam extensions are related to the transgressive nature of the

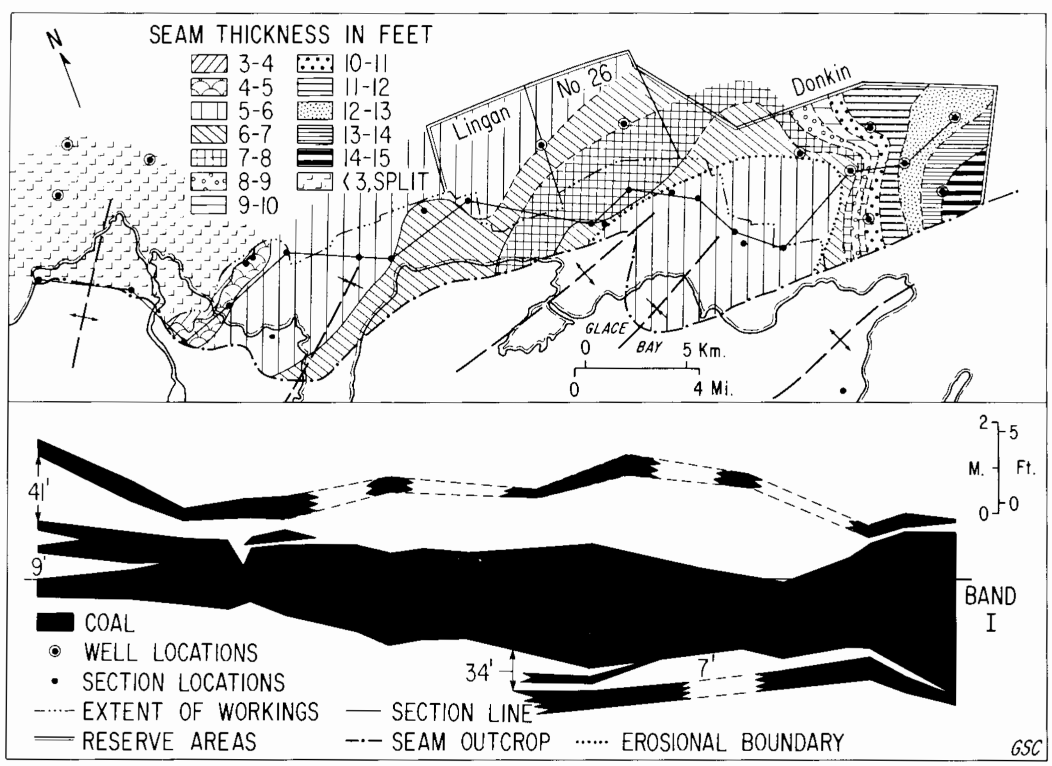

Figure 9.5. *Isopach map and cross-section of the Harbour seam, Sydney coalfield.*

upper biostratigraphic zones of the Morien Group (containing the younger coals), which overstep the lowest zone towards the west. The oldest coal deposition started where the basin was initiated in the eastern part of the coalfield, where below the Tracy seam some 914 m (3000 feet) of zone A sediments were laid down that are not present in the west.

2. The four uppermost seams, from Harbour to Point Aconi, all have their greatest development in the Donkin area. Here the different benches of the seams join together and form thicknesses of 3 m (10 feet) and more. The formation of this favourable area of coal accumulation was initiated during the deposition of the Harbour seam and its origin has been discussed with reference to Figure 9.5. The reason that the centre was maintained through four successive seams is probably the fact that the Donkin area was situated near the relatively steeply inclined northern limb of the Cap Percé Anticline.

Information concerning the presence of coal in the farther regions of the offshore Glace Bay Subbasin is available only from two oil exploration wells drilled on the Boisdale Anticline (North Sydney F-24 and P-05, Fig. 9.3). These wells intersected the known Sydney succession and as shown by the correlation of well P-05 (Fig. 9.2) contain the equivalents of the Harbour, Hub, Lloyd Cove and Point Aconi seams. In addition, there are two seams in spore zone D that do not occur in the land area. The thicknesses of these coals are uncertain because the formation-density logs were run at too great a speed for accurate measurements and only cuttings were provided. Nevertheless estimates of 0.9-1.8 m (3-6 feet) seem reasonable and are encouraging considering the fact that the coals occur on an anticline, where normally the seam thicknesses are reduced somewhat. Seam continuity through the Glace Bay Subbasin can be expected and an increase in thickness towards the centre is a fair assumption. However, the nature of the seam sections with regard to partings, and therefore their mineability, cannot be assessed without considerably more offshore drilling.

It would appear from the available information that a vast amount of coal may be present in the Glace Bay Subbasin and that, with the exception of the central area, a considerable part of this coal lies above the -1220 m (4000 feet) depth of mining limitation. Figure 9.3 shows that in the centre of the Subbasin the Harbour seam is projected to -1524 m (-5000 feet), which places the Point Aconi seam at -1250 m (-4100 feet), when using a 274 m (900 feet) stratigraphic separation. The coals between the Harbour and Point Aconi seams have progressively smaller areas in the centre that are below the -1219 m (-4000 feet) contour, with the younger coals all lying above it. The Glace Bay Subbasin occupies about 1300 km^2 (500 square miles) and a seam that is uniformly 1.2 m (4 feet) thick would contain 2.1 x 10^9 tonnes of coal. This illustrates the quantities of coal that could lie below the ocean floor within 56 km (35 miles) of the coastline.

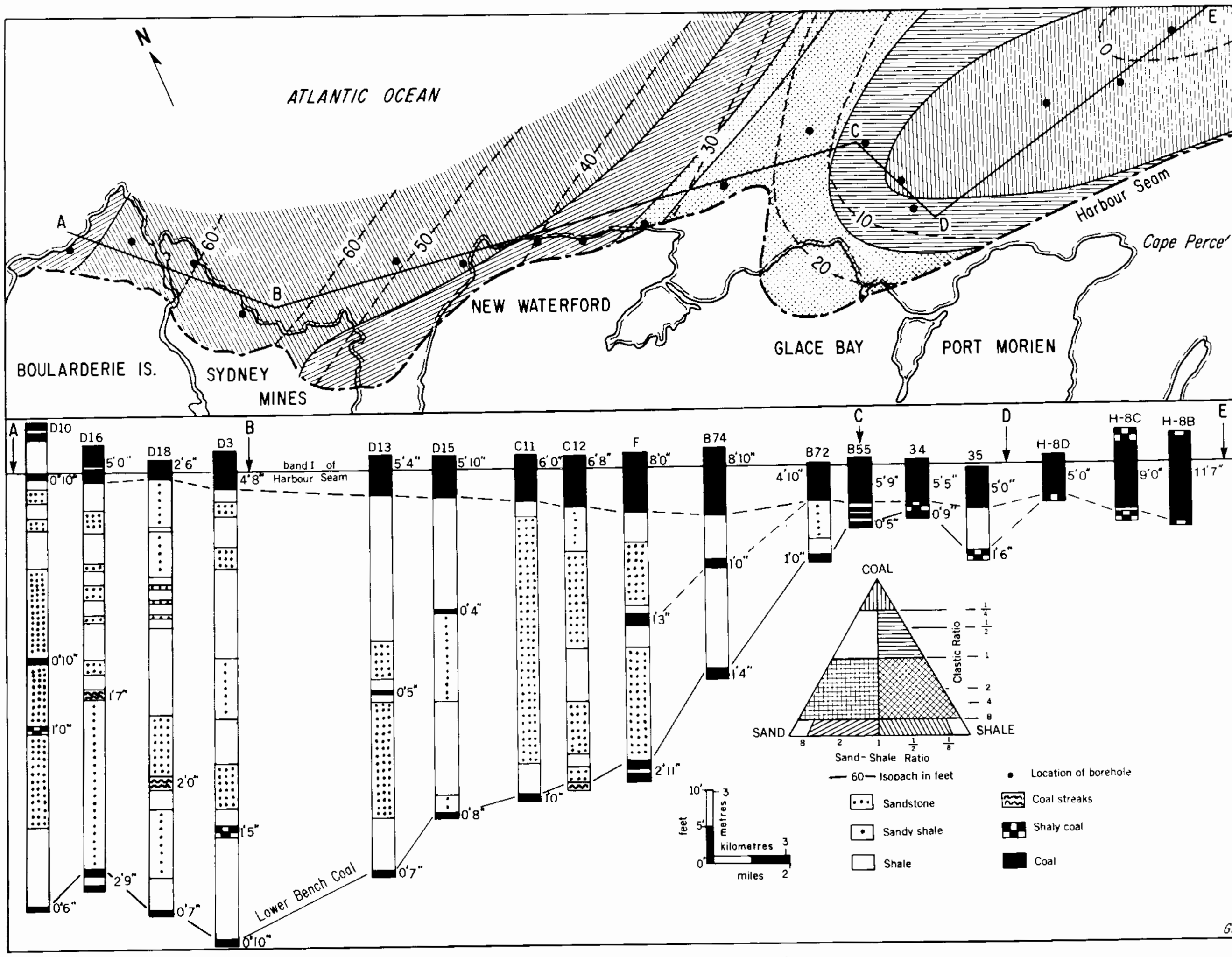

Figure 9.6. Lithofacies map and sections of interval between Harbour seam (Band I) and Lower Bench coal (after Hacquebard and Donaldson, 1969; updated).

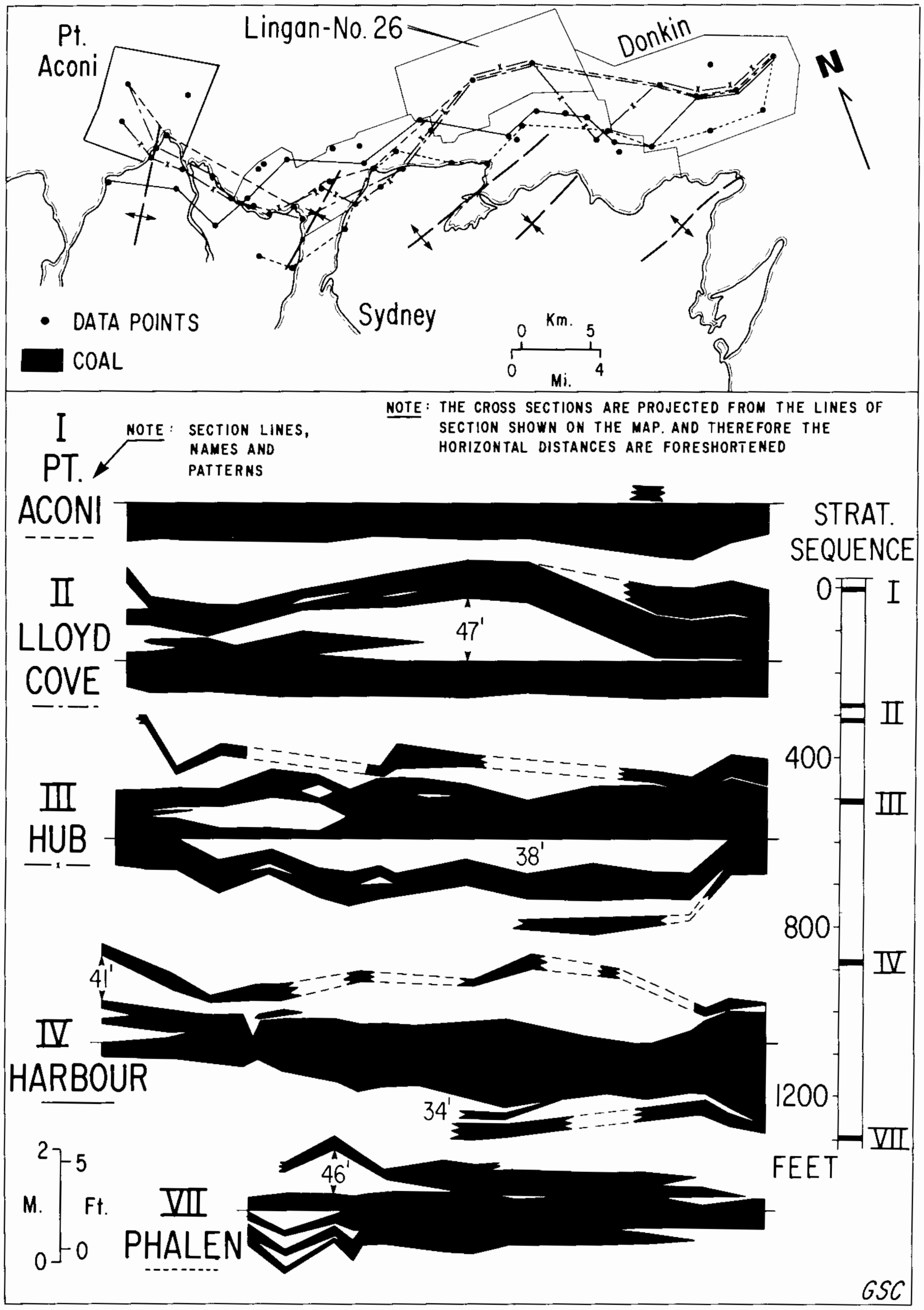

Figure 9.7. Cross-sections through five upper seams of the Sydney coalfield (after Hacquebard and Donaldson, 1969; updated).

Splitting of Seams

In the Sydney coalfield seam splitting is the principle reason for seam deterioration. Therefore, it is important to find the underlying cause of this phenomenon and if possible to predict its extent in the submarine area ahead of the present workings.

Seam splitting is a common feature of all coals deposited in paralic basins, and is the result of the interaction between fluvial sedimentation and peat deposition. Streams meandering through extensive lowland areas deposited sand, silt and clay on top of the peat, which afterwards continued to accumulate. After burial and compaction, these terrigenous deposits formed the stone partings within the coal. Sometimes renewed peat formation was limited, or entirely absent, leading to seam termination. It is of critical importance to determine the main river channel and its general course in order to outline the areas of seam splitting. Figure 9.8 shows how this can be determined with a detailed facies study of the Phalen and Harbour seams.

The pillars shown in the three-dimensional diagrams represent seam secitons that were measured in previously worked areas. They show the position of stone partings and splint bands. In the Phalen seam the optimum section is 2.7-3 m (8.8-10.0 feet) thick and has four partings

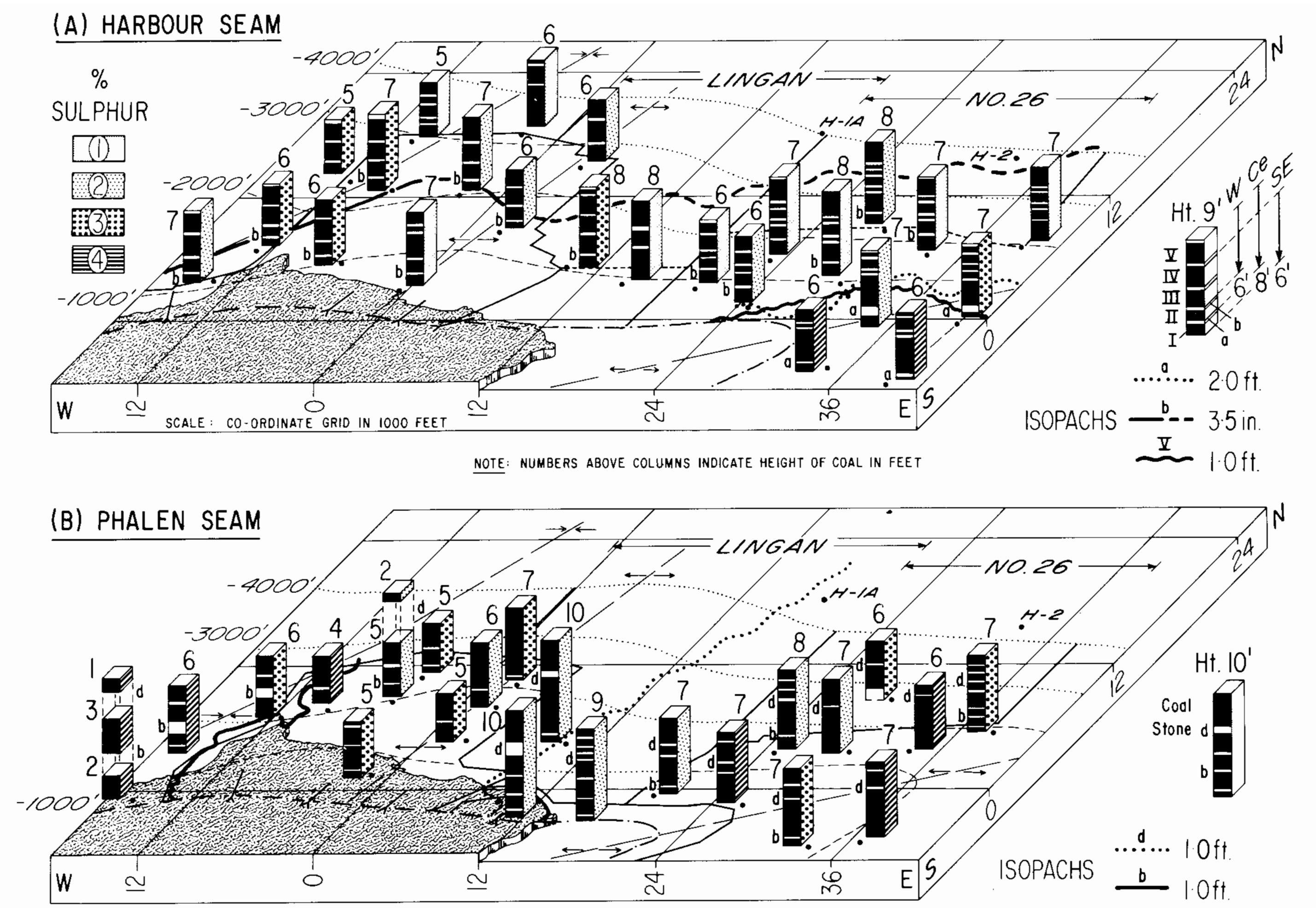

Figure 9.8. Development of the Harbour and Phalen seams in central part of the Sydney coalfield.

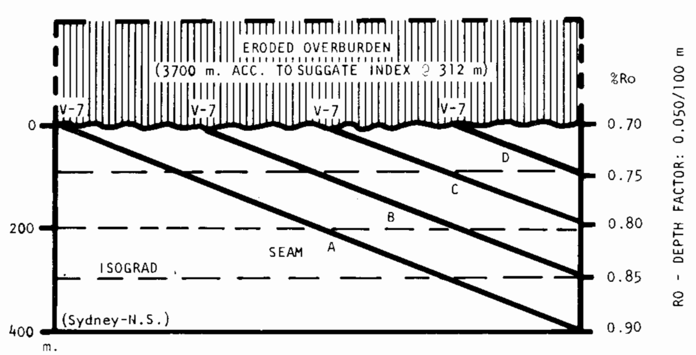

Figure 9.9. *Diagnostic features of postdeformational coalification (after Hacquebard, 1975).*

(Fig. 9.8B). Correlation of these partings shows that those marked 'b' and 'd' thicken on the west side of the Lingan area to such an extent that the individual benches of coal can no longer be mined. In the case of parting 'b' this caused the termination of mining entirely; in relation to parting 'd' it reduced the height of coal by 0.6-0.9 m (2-3 feet). For each parting a 'hinge line' has been constructed. This line is an isopach on the critical thickness of the parting, beyond which the entire seam can no longer be mined as one unit. It should be noted that the 'hinge lines' on partings 'b' and 'd' are subparallel and trend in a northerly direction. It was concluded from this that parting 'd' would only affect the western part of the Lingan Reserve, and that heights of coal of between 2.1 and 2.4 m (7 and 8 feet) can be expected to the east. This interpretation was confirmed by the offshore drilling carried out in 1977, where borehole H-1A found the equivalent of parting 'd' to be 25 cm (10 inches) thick. The 'Phalen River', responsible for partings 'b' and 'd' in this part of the field, occurs west of the study area but swings to the east in the Donkin area. This can be seen from the cross-section of the Phalen seam in Figure 9.7.

The development of the Harbour seam in the same study area is shown in Figure 9.8A. The optimum seam development is 2.7 m (9 feet) thick and consists of five benches separated by four stone partings or splint bands. The optimum thickness, however, is not present at any one locality because different parts of the seam section occur in different collieries. Collieries to the west possess benches III to V, those in the centre contain benches II to V and those in the southeast (in Glace Bay district) have benches I to IV. This variation in the thickness of the Harbour seam has been mentioned previously when discussing Figures 9.6 and 9.7. The 'hinge lines' on partings 'a' and 'b' are subparallel, as was the case in the Phalen seam, but they trend from west to east. As a result, less favourable conditions can be expected in the Lingan and No. 26 reserve areas with regard to parting 'b' of the Harbour seam, than with regard to parting 'd' of the Phalen seam. In the northern and deepest part of the reserve area only benches III to V, with a thickness of 1.8 m (6 feet) or less can be expected. This prognosis was substantiated with borehole H-1A, which intersected the Harbour seam with a thickness of 1.77 m (5.8 feet).

As a result of this comparative study it can be stated that, within specific areas of the coalfield, 'hinge lines' plotted on succeeding partings within the same coal seam run subparallel, whereas on partings of different seams they trend in different directions. This observation permits predictions on seam development ahead of existing workings, because it can indicate the approximate location of the river channels that are responsible for deterioration by seam splitting.

Coalification and Variations in Rank

In Carboniferous coals of Eastern Canada the coalification is predominantly postdeformational. Hacquebard and Donaldson (1970) showed that the rank of coal increases with the present depth below the surface but does not alter in surface exposures in relation to stratigraphic occurrence.

Figure 9.9 shows the results of a study of four coals (A to D) in the Sydney coalfield. At the surface these coals have the same Ro rank, namely V-7, notwithstanding a total stratigraphic separation of some 300 m (985 feet). However in boreholes the rank increases with depth from 0.75 to 0.80, 0.85 and 0.90 per cent Ro, respectively (or from V-7 to V-9). In underground mines the rank of individual seams increases with the depth of mining. The isograds, therefore, run horizontally and are not parallel to the seams as is the case in predeformational coalification. This means that the coal obtained its present rank from the maximum overburden that existed after deformation. In the example shown the eroded overburden was calculated at 3700 m (12 140 feet), using the method employed by Suggate (1959).

The Sydney coal is classed as high volatile 'A' bituminous but within and even beyond this broad category there are significant changes. These variations can be judged most accurately by vitrinite reflectance measurements which can be closely related to the content of volatile matter, the commonly used rank parameter. Within the high volatile 'A' class the reflectance ranges from 0.8 to 1.1 per cent Ro, or from V-8 to V-10. Medium volatile coal shows variations of V-11 to V-14 (M. Teichmüller in Stach et al., 1975, p. 42).

Previous studies by Hacquebard and Donaldson (1970) showed an increase in rank of the Harbour seam in Dominion Nos. 14 and 12 Collieries of V-8 to V-10 over a depth of 610 m (2000 feet). Comparable increases have been recorded recently on samples obtained from the 1977 and 1978 offshore coal drilling program. An increase was noted from 0.90 per cent Ro in workings of the Lingan mine at a depth of -350 m (-1150 feet) to 1.11 per cent Ro at -914 m (-3000 feet) in borehole H-1A. In the Donkin area the Harbour seam showed variations from 0.91 per cent Ro at -227 m (-744 feet) to 1.13 per cent Ro at -707 m (2321 feet).

In addition to these vertical changes in rank there also exists a regional increase from west to east, although it is less pronounced. The Harbour seam shows a change of two V-types over the width of the coalfield, namely from V-7 on Boularderie Island to V-9 at Donkin. This change occurs in coal that lies at about the same depth below the surface. It is also apparent by comparing readings obtained in the offshore area at greater depth. The Harbour seam intersected at -914 m (-3000 feet) in borehole H-1A at Lingan has a rank of 1.11 per cent Ro, whereas at -707 m (2321 feet) in borehole H-8 at Donkin it reached a rank of 1.13 per cent Ro. This means that it requires 207 m (679 feet) less depth of mining at Donkin than at Lingan to encounter coal of the same rank.

This double effect on rank changes, vertically and regionally, is illustrated in Figure 9.10. This rank map is based on a limited number of data and therefore only gives a general outline. It is noteworthy that the areas of equal rank cross the structure contours, which is further evidence for postdeformational coalification. As was mentioned previously, such coalification is caused by the maximum amount of overburden that existed after the deformation. The observed regional increase in rank, therefore, indicates that there existed less depth of burial in the western than in

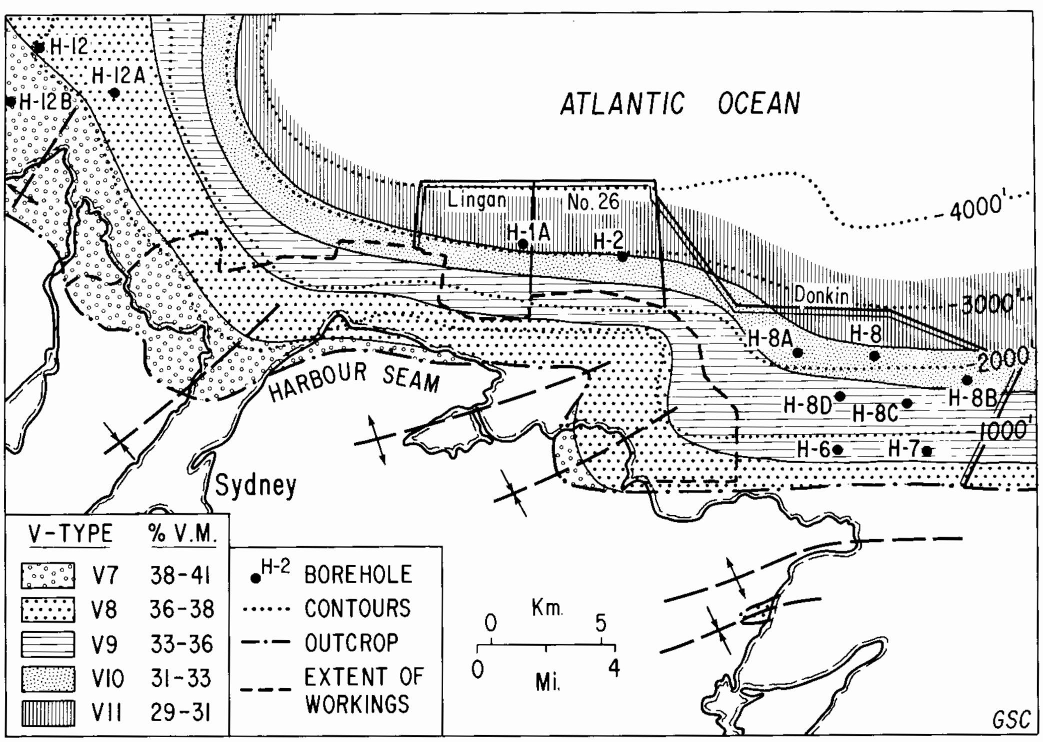

Figure 9.10. *General outline of rank variations in Sydney coalfield, illustrated with areas of equal vitrinite reflectance in Harbour seam.*

the eastern part of the coalfield. Calculations according to the method of Suggate (1959) gave 3700 m (12 140 feet) of eroded overburden in the Boularderie Island region (Fig. 9.9) as compared to 4200 m (13 776 feet) at Donkin (for locations see Fig. 9.3). This calculation is in agreement with the previously mentioned transgressive nature of the Morien Group, resulting in a regional thickening of the different spore zones from west to east.

Coal Resource Estimates

Since Dowling (1915) first published an estimate of the coal resources of the Sydney field, revisions have been made by MacKay (1947), Latour (1960), and Hacquebard (1976, 1979). The revisions were necessary as new data became available from borehole records and underground workings and because of changes in the resource parameters made in recent years.

The most significant change in the resource evaluations of the Sydney coalfield resulted from 13 wells drilled with a drillship in the offshore area during 1977 and 1978. This program provided much needed information on the submarine extension of existing workings and on those areas where seam continuity could not readily be predicted from onshore observations.

The new coal resource estimates here presented follow the format and parameters used by the Coal Division of the Cape Breton Development Corporation in their 1978 calculations. However, the author's figures (Table 9.1) are considerably lower because the heights of coal used in the calculations refer to 'clean' coal devoid of partings and impure roof or bench coal (with 15-50 per cent ash), whereas the Devco data were based on the entire opening between roof and pavement. In addition, not the seam outcrop but the -500 foot (152 m) contour was regarded as the upper boundary for resource estimates in the submarine areas.

The common parameters used in both calculations are as follows: (a) a 2.4 km (1.5 mile) influence radius of data points for coal included in the category of 'demonstrated' resources; (b) a maximum depth of mining of 1220 m (4000 feet) and/or a distance of 11 km (7 miles) from shore; (c) a minimum seam thickness of 1.2 m (4 feet) in the submarine areas.

Table 9.1

Sydney Coalfield – 'Demonstrated' Coal Resources
(In Million Tons)

Seam		Areas			Totals	
		Donkin	Lingan 26	Other	Short Tons	Tonnes (metric)
Pt. Aconi		96	-	-	96	87
Lloyd Cove		268	-	61	329	298
Hub		195	47	140	382	347
Harbour		352	180	-	532	483
Backpit		-	-	30	30	27
Phalen		-	210	-	210	190
Emery		-	-	14	14	13
Gardener		-	-	34	34	31
Mullins		-	-	100	100	91
Tracy		-	-	40	40	36
TOTALS	Short Tons	911	437	419	1767	-
	Tonnes (metric)	827	396	380	-	1603

Table 9.1 shows that after nearly 200 years of mining about 1603 x 10^6 t of 'demonstrated' coal resources remain in the (nearshore part of) Sydney coalfield. Some ten seams contribute to the grand total, but large amounts are present in only four seams, namely in the Phalen, Harbour, Hub and Lloyd Cove seams. Of these, the Harbour seam is the most important. It possesses the largest resources, amounting to 483 x 10^6 t, and has the lowest sulphur content of all the seams in the Sydney field (varying from 1-3 per cent). Parts of this seam and probably the Phalen seam as well have a good potential for metallurgical coal. The other resources, being too high in sulphur content (in excess of 3 per cent), are classed as thermal coal and after cleaning are excellent for electric power generation because of their high heating value (ranging from 7389-7778 Kcal/kg, on raw coal).

The table also reveals the significance of the Donkin area, which possesses 827 x 10^6 t in four seams. This large reserve became known entirely from the 1977-1978 offshore coal drilling program, because its potential could not be predicted from existing geological information.

Availability of Coking Coal

For the production of metallurgical coke it is necessary to have suitable coking coals available. Such coals have to be of a particular quality and grade and should possess specific properties in order to produce coke that meets the requirements of the steel industry. Foremost of these are good coking and coal blending properties, resulting in strong, non-expanding cokes with high stability factors, and coals possessing a low sulphur content. These factors are controlled by the rank and petrographic composition of the coal.

The coal presently mined in the Sydney coalfield is a high volatile 'A' bituminous coal and because of its high fluidity, has excellent blending characteristics. It is therefore valuable for the export market as metallurgical coal when the sulphur content is low.

To obtain coke of a strength required by the Sydney Steel Plant, it is necessary to add 25 per cent low volatile bituminous coal to the coal mined locally. This L.V. coal is imported from the United States as it is not available from the Sydney field at the present time. With an increase in rank of the domestic coal, less L.V. coal is needed for blending, and for medium volatile bituminous coal blending can be dispensed with altogether. Figure 9.10 shows that M.V. coal (V-11 to V-14) occurs below the -3000 foot (-914 m) contour in the Lingan-No. 26 area and below -2300 foot (-701 m) in the Donkin area. This is economically very favourable, because as mining proceeds to greater depths better metallurgical coal from a rank point of view will be produced, and less L.V. coal will need to be imported for blending purposes.

Figure 9.11 illustrates how the petrographic composition, in combination with the rank of coal, is of critical importance to the strength of the resultant coke. The rank curves of the H.V. and M.V. coals in the reflectance ranges of V-7 to V-12 (three curves) peak at about 75 per cent reactive macerals (consisting of vitrinite plus exinite plus part of semifusinite). The respective optimum stability factors that can be attained are 37, 48 and 62. It can be seen that the coke stability factors decline rapidly with lower and with higher amounts of reactive macerals.

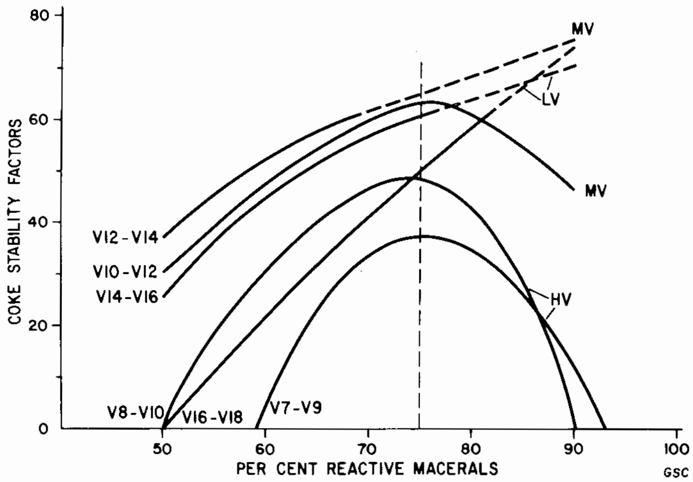

***Figure 9.11.** Relationship of petrographic composition and rank to coke stability (after Cameron, 1975).*

The metallurgical coal presently produced at Sydney is from the Harbour seam in the Lingan and No. 26 Collieries. It has a rank of V-7 to V-9, averages about 80 per cent reactive macerals, and without blending with L.V. coal would yield a coke with a stability factor of 33 to 39.

Detailed petrographic and rank determinations have been made on the offshore samples to appraise the coking qualities of the Harbour seam in the reserve areas of Lingan-No. 26 and Donkin. The results show that petrographically the seam is rather stable when considered in its overall composition. The reactive components vary between 81 to 87 per cent, indicating that a change in rank is the prime factor affecting the alteration in coke stability. The latter shows a marked improvement with depth, namely from 33 in borehole H-6 at -238 m (-780 feet), to 54 in borehole H-8 at -707 m (2321 feet). As a coke stability of 55 is acceptable in a commercial operation, these results indicate that for the deeper Harbour coal samples only the addition of a small amount of L.V. coal would be necessary to achieve the desired coke strength.

From the point of view of rank and coke stability, the prospects of the Harbour seam being of metallurgical quality in the offshore reserve areas are excellent. The critical factor that remains to be considered is the sulphur content. In the Sydney coals the amount of sulphur varies considerably, both vertically through the seam section and regionally between sections. Changes of 1 to 4 per cent per seam total, sometimes 5 per cent, have been observed in the worked areas. This can be seen from the pillars in Figure 9.8 for the Harbour and Phalen seams. In general it can be stated that the highest amount of sulphur occurs in areas that are affected by seam splitting. The Phalen seam, which splits on both the eastern and western side of the coalfield, shows this relationship in Figure 9.8B.

Metallurgical coal should have less than 1 per cent sulphur, which in raw coal occurs only rarely in the Sydney coalfield. However, with the new coal cleaning facilities recently installed, it is now possible to reduce raw coal with 2 to 2.5 per cent sulphur to metallurgical standards. This means that the Harbour seam in the Lingan-No. 26 and (eastern part of) Donkin reserve areas very likely has a sulphur content that can be reduced to acceptable standards for the production of metallurgical coke. Resource calculations of these areas show 169 x 10^6 t of recoverable coal, possessing 2 per cent sulphur or less.

The sulphur content of the other seams in the reserve areas is considered too high for metallurgical use, with the possible exception of the Phalen seam in the Lingan-No. 26 area. It has 2.5 to 2.9 per cent sulphur in some locations and 1.5 to 1.7 per cent in others. In borehole H-1A the Phalen has reached the rank of M.V. bituminous coal; it has a vitrinite reflectance of 1.24 per cent and a calculated coke stability factor of 62. The resources of the Phalen seam in the 'high coal' area of the Lingan-No. 26 reserve that may possess 2 per cent sulphur or less are estimated at 36 x 10^6 t of recoverable coal.

From the preceding it is concluded that on the basis of our present knowledge, there may be as much as 212 x 10^6 t of recoverable coal resources of metallurgical quality available in the Sydney coalfield.

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