ON THE DEVELOPMENT AND PETROGRAPHY OF THE PHALEN SEAM IN THE LINGAN COLLIERY AND ADJACENT AREAS OF THE SYDNEY COALFIELD, NOVA SCOTIA

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Contract No.: 23420-88-C503/01-OSC
(Title: Coal Geology Investigations in Atlantic Canada)
February 1989

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ABSTRACT

Detailed petrographic studies of seven core-hole sections comprising of 88 increment samples (of about 15 cm each) gave the following results:

1. The best developed part of the Phalen seam with a thickness of 2.1 to 2.4 m occurs in the Lingan-No.26 area. To the northwest and to the east (at Donkin) the seam deteriorates through splitting and is no longer considered mineable.
2. A brigth-banded coal with a very high content of reactive macerals (averaging 87%) and more or less uniform composition between roof and pavement is represented. Only fusinite and pyrite vary appreciably; durite bands are scarce and insignificant.
3. Pyrite, as determined microscopically, is concentrated in the roof and bench coal, where in one section it reached 11% (by volume). In the seam-average it varies from 0.7 to 3.6%, while the sulphur ranged from 1.8 to 3.8%. More than 50% of the total sulphur is derived from the pyrite, and pyrite removal through washing can produce a coal with no less than 1% sulphur (as residual S, present mostly in the form of organic S).
4. Good correlations exist between the five petrographic intervals of the percentage diagrams and permit interpretations of variations in seam thickness.
5. Rank increases with the depth of mining (seaward). A H.V. "A" bituminous coal occurs to a depth of -600 m, beyond which a M.V. bituminous coal is present.
6. Coke stability factors calculated from maceral and Ro determinations also increase with depth. They range from 25 near the surface to 63 at a depth of -1077 m. Beyond -600 m a premium M.V. metallurgical coal will become available (after sulphur reduction through washing).

INTRODUCTION

In the past the Phalen seam constituted the major producer of the Sydney coalfield. From 1830 when mining of this seam commenced in the Bridgeport colliery to 1955 when it terminated in 1B colliery, some fourteen different mines were in operation at one time or another, and about 150 million tons were extracted.

Renewed production of the Phalen seam started in 1987 in the Lingan area, where some 191 million tons of "demonstrated" coal resources are still available in this seam (Hacquebard, 1983) (See map of Figure 4).

In the Lingan area mining has been in progress since 1970 on the Harbour seam, which overlies the Phalen by about 140 m. From the submarine workings of the Harbour seam, the Phalen seam has been surveyed and sampled by underground drilling. The samples from five underground core-holes were made available for this study, as well as those obtained from three wells put down from a drillship in 1978 and one from the land surface. All samples, except those derived from the drillship, were collected by the Geology Department of DEVCO.

SEAM DEVELOPMENT

Only in the central and eastern parts of the Sydney coalfield does the Phalen seam reach a mineable thickness, which varies from 1m to nearly 3 m. In the western and most easterly portion (at Donkin) the seam is split in several benches, which individually are too thin to be mineable.

Seam splitting is a common feature of the (paralic) coals of the Sydney basin 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 afterward 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, which vary considerably between the different seams, as is shown in Figure 1. In the underground workings the approach of these areas can be predicted from coal

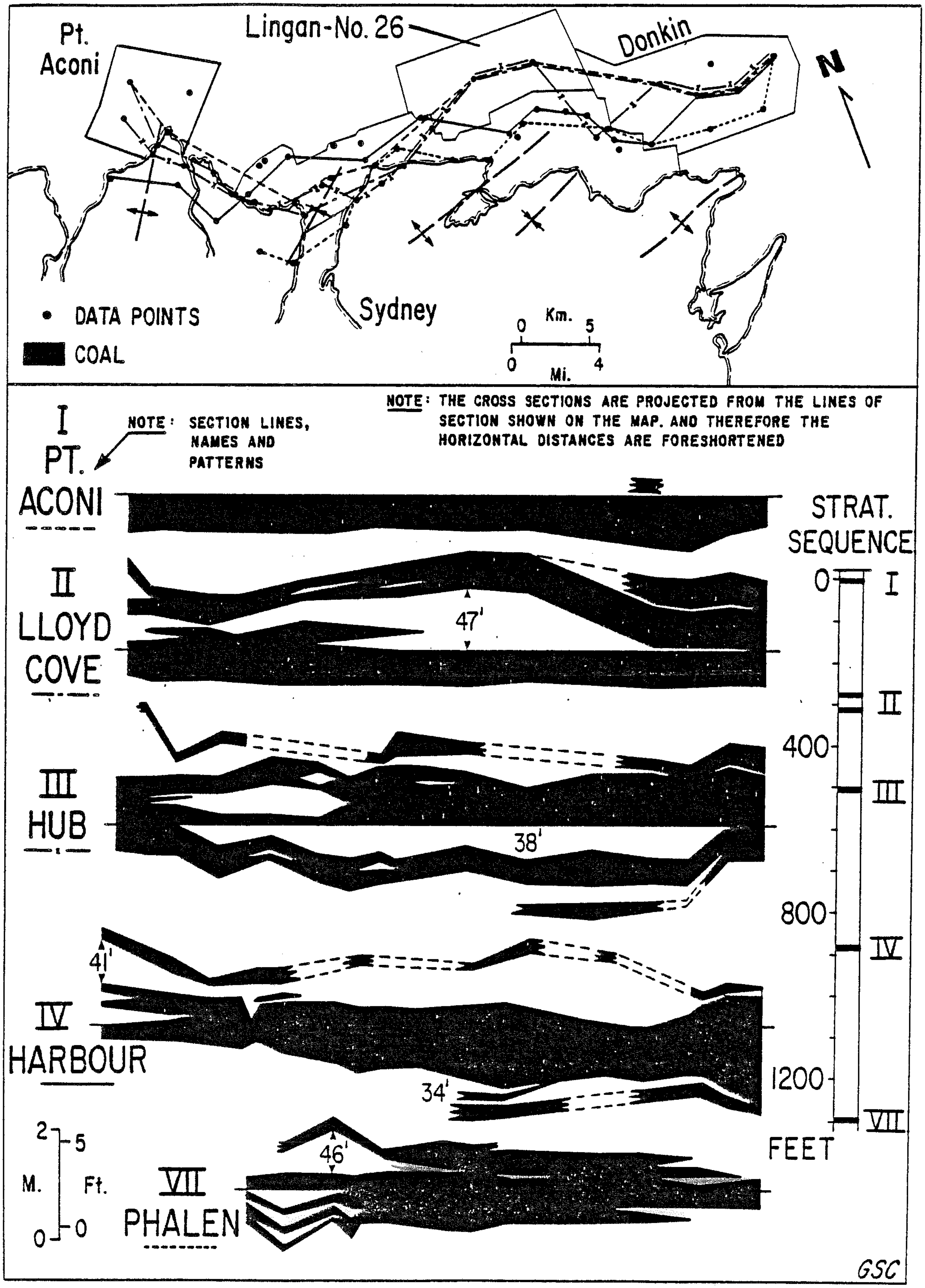

Figure 1. Cross-sections through five upper seams of the Sydney coalfield. (after Hacquebard, 1983)

facies studies. Such studies are based on nu/merous seam section measurements, and the one carried out for the Harbour and Phalen seams is illustrated in Figure 2.

The pillars shown in the three-dimensional diagrams represent seam sections that were obtained from 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 thick and has four partings. 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.

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 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 thick. The "Phalen River" responsible for partings "b" and "d" in this part of the field occurs west and north of the study area (as revealed by borehole H-2) and then turns east to affect the Donkin area. This can be seen from the cross-section of the Phalen seam in Figure 1.

From the foregoing it is clear that the Lingan-No. 26 reserve area occupies the best developed portion of the Phalen seam in the Sydney coalfield.

SAMPLING AND PETROGRAPHIC PROCEDURE

Based on megascopic logs measured by the staff of the Geology Department of DEVCO, conventional cores of seven drill hole samples were collected in narrow increment samples, that varied in thickness from 3 cm to 26 cm. A total of 88

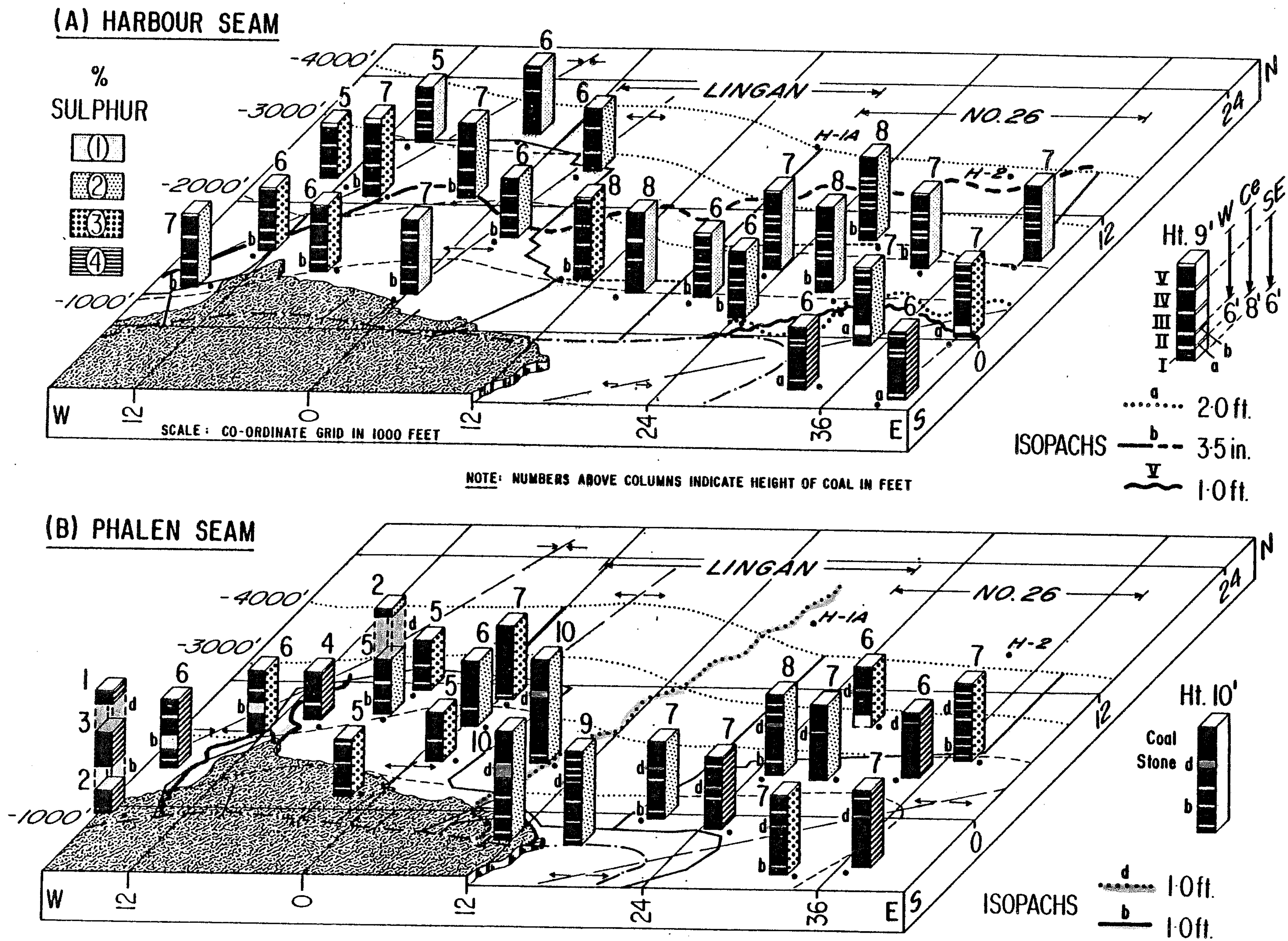

Figure 2 *Development of the Harbour and Phalen seams in central part of the Sydney coalfield.*
(after Hacquebard, 1983)

samples were made available for study.

Megascopically the Phalen seam may be classed as a very bright banded coal of fairly uniform composition between roof and pavement. Thin fusain bands occur throughout the section and form an important ingredient; durain bands are scarce and occur only occasionally in the upper part of the seam. Stone partings "b" and "d" (of Figure 2) have been observed in all seven cores examined. The roof and bench coal contain pyrite lenses that are occasionally several centimeters in thickness.

The petrographic examination of the narow increment samples was carried out under reflected light on lucite-bonded grainmounts at 500x and 160x magnification. An oil immersion objective was used for the maceral analysis and a dry objective for the mineral matter determinations. The latter included kaolinite (shale), quartz and pyrite. The composition was recorded quantitatively by means of the point-count method, which gives the results in percent by volume. The results were then plotted for each increment in a percentage diagram, an example of which is shown for core-hole sample B-162 (No. 4) in Figure 3. The narrow increment plots were later combined into larger units, referred to as petrographic intervals (Figure 4). In addition, separate pyrite and sulphur distribution diagrams were plotted of the same intervals (Figure 5).

PETROGRAPHIC STUDY

1. Maceral Composition

The percentage diagrams in Figure 4 show the vertical and lateral variations in maceral composition of the Phalen seam in petrographic intervals of similar types of coal. The correlation of these diagrams permit explanations of the variations in seam thickness.

In its maximum development, where the seam is nearly 3 m thick, there are six intervals, as in section 3. The upper three intervals (IV, V and VI) represent the coal

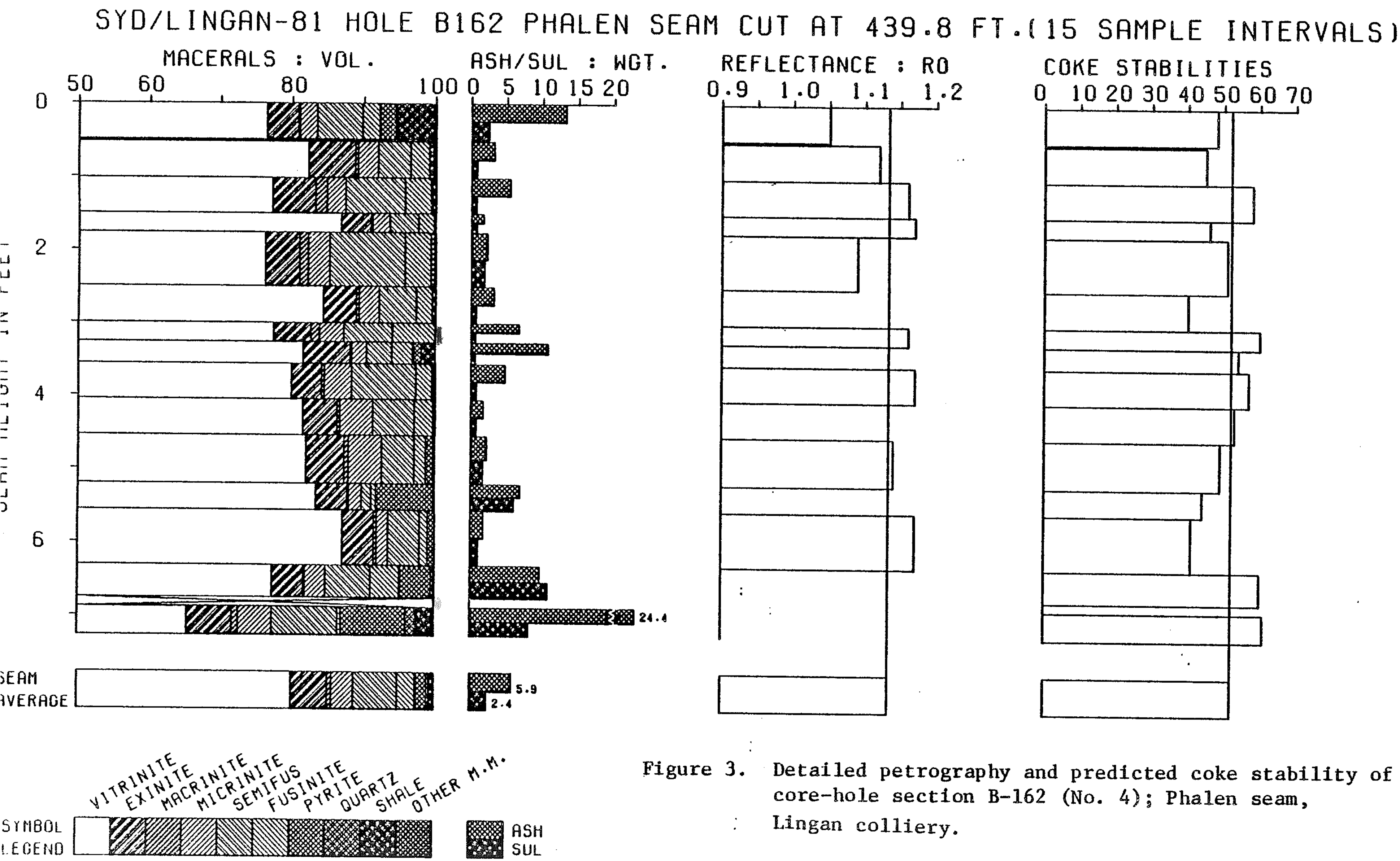

Figure 3. Detailed petrography and predicted coke stability of core-hole section B-162 (No. 4); Phalen seam, Lingan colliery.

above parting "d", of which the hinge line is shown in the map of Figure 4. West of this line the seam is split and only the coal below parting "d", represented by intervals I and II is mineable. It varies in thickness from 1.2 m to 1.8 m as shown in Figure 2 and in petrographic sections 1 and 2 of Figure 4. East of the hinge line, in the present Lingan-Phalen colliery, the seam is between 2.2 and 2.9 m thick, and as indicated by sections 3, 4 and 5, contains five, or even six petrographic intervals. From the No. 26 reserve area only section 6 was available. It shows a reduction in thickness to 2 m because interval I is missing and interval V has become thinner. A further reduction in height is indicated in section 7, located in the Donkin area. It is due to a general thinning of the three intervals that are present.

All coals of the Sydney field can be classed as bright coal, and the Phalen seam particularly so because of its high vitrinite content. The "total reactives" (vitrinite + exinite + 1/3 semifusinite) of the seam-averages vary between 83 and 91%, averaging 87% in the seven sections examined (Table I). The vertical variations between the petrographic intervals of each section also is only minor, and much less than in the Harbour seam (Hacquebard and Avery, 1988). Only the differences in the inertinite content is worth noting, and this is essentially due to changes in the amounts of fusinite.

2. Pyrite and Sulphur Distribution

The amount of pyrite is not shown in the percentage diagrams of Figure 4. The macerals have been plotted on a pyrite-free basis. This was done to portray the pyrite separately and make possible comparisons with the chemically determined amount of sulphur.

Microscopically the pyrite was determined quantitatively with the point-count method and for each analysis 500 points were counted. The observations were made at 160x magnification under a dry objective, and the amount has been plotted on the left side of the diagrams in percent by volume (Fig. 5). Per seam-average it varies between 0.7 and 3.6% in the seven sections examined (Table II).

Table I: SEAM AVERAGE - MACERALS (% by volume) - Phalen seam

Section Nos:	1	2	3	4	5	6	7
vitrinite	83	80	81	82	83	87	80
exinite	6	4	4	5	2	0	2
semifusinite	5	3	3	6	5	3	4
inertinite	5	12	10	6	8	9	12
kaolinite	1	1	2	1	2	1	2

Table II: SEAM AVERAGE - PYRITE, SULPHUR AND ASH - Phalen seam

Section Nos:	1	2	3	4	5	6	7
Pyrite							
% by volume	0.7	1.7	2.9	1.2	2.1	2.0	3.6
% by weight	2.0	4.8	8.1	3.5	6.0	5.7	10.0
Sulphur (% by weight)							
pyritic S	0.9	2.0	3.4	1.5	2.5	2.4	4.2
residual S	0.9	0.8	-	0.9	1.2	1.2	-
total S	1.8	2.8	3.0	2.4	3.7	3.6	3.8
Ash (% by weight)	3.7	5.2	7.1	5.9	10.5	8.8	13.0

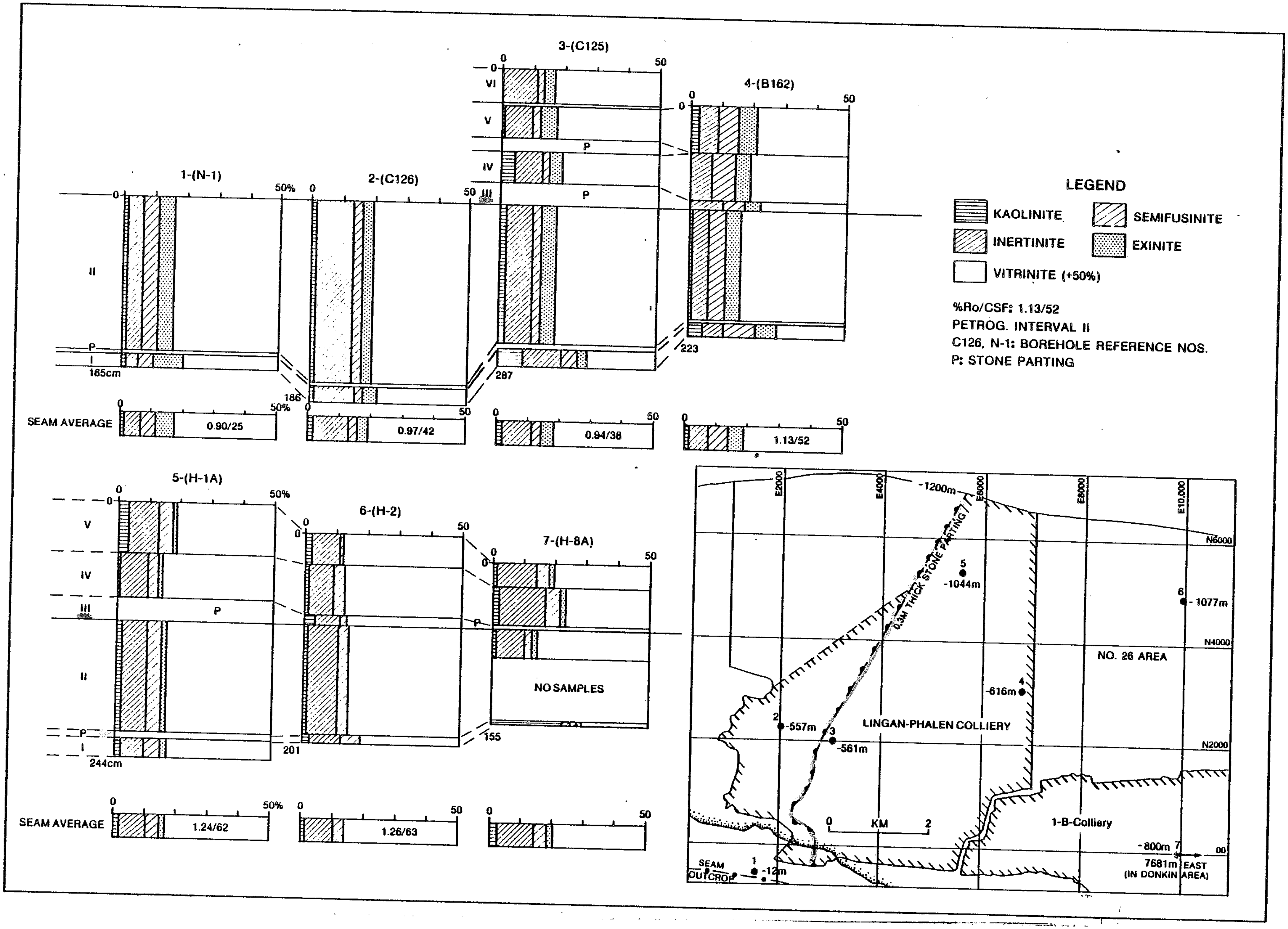

Figure 4. Petrography of Phalen seam in Lingan colliery and adjacent area.

The chemically determined total sulphur is shown in percent by weight on the right side. It shows a variation per seam-average of 1.8 to 3.8% (Table II). The portion of this contributed by the pyritic sulphur has been calculated from the amounts of pyrite. Also shown is the percent residual sulphur which is the portion left over when subtracting the pyritic sulphur from the total sulphur. Most of this will be organic sulphur, but it also includes sulphate sulphur and at least some pyritic sulphur derived from extremely finely divided pyrite (of particles that are 1 micron in size) that were not included in the point-count analysis. Therefore, the residual sulphur may be considered as that portion of the total sulphur that likely cannot be removed by coal cleaning processes.

Figure 5 shows that pyritic sulphur is the main contributor to the total sulphur content, comprising from 50-100% of the total amount. Complete pyrite removal, if this were possible, would produce a coal with a sulphur content of 1.2% or less in all sections, particularly in the main body of the seam comprising intervals II to IV, which represent about 3/4 of the total seam thickness.

The amount of pyrite varies considerably within each seam section, but in general the greatest concentrations occur in the bench and roof coals (intervals I, V and VI). As these parts are generally not more than 30 cm thick, it may be possible to leave them in place and through selective mining obtain a marked reduction in sulphur content. A very similar situation was observed in the Harbour seam (Hacquebard and Avery, 1988).

Apart from the pronounced vertical variations within each seam section, there also exists a regional variation in sulphur content. The columnar sections of Figure 2 indicate that both on the west and on the east side of the Lingan - No. 26 area the sulphur content shows a marked increase, namely from an average of 2% in the former to 3 and 4% in the latter.

3. Rank Changes and Coke Stability Predictions

As is the case with the other coals at Sydney, the rank of the Phalen seam

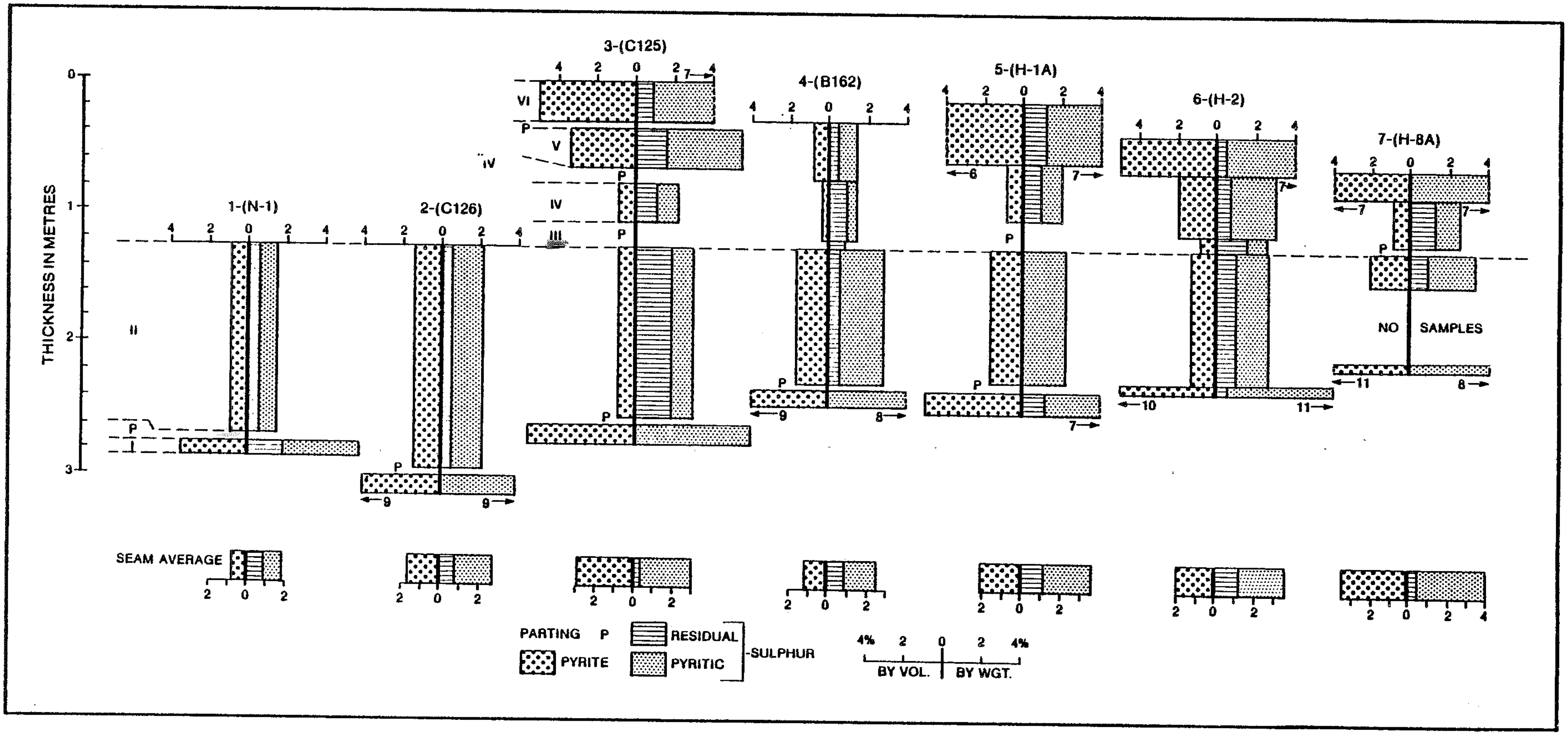

Figure 5. Pyrite and sulphur distribution in Phalen seam at Lingan colliery and adjacent area.

increases with the depth of mining, or with the distance from shore because the measures dip seaward. This is borne out by vitrinite reflectance measurements on ten samples within the Lingan - No. 26 area (Fig. 6). To a depth of about -600 m a high volatile "A" bituminous coal is represented, with Ro values from about 0.90% at the surface, to 1.13% in section 4. These reflectance data correlate with changes in volatile matter content of 36-31%, when using the coal classification table of Teichmüller (1975). Beyond a mining depht of 600 m, the rank increases from 1.13% Ro in section 4 to 1.24% in section 5 and 1.26% in section 6, which equals a decline in volatile matter content from 31 to 28%. Coals in this range are classed as medium volatile bituminous coal, and rank-wise are considered premium coking coals.

Significant conclusions can be drawn from the petrographic composition and the rank of the coal on its capacity to produce coke. A most important property for metallurgical use is the strength of coke, which is expressed by the coke stability factor (CSF) and is obtained from the tumbler test. Studies carried out in the 1960's by Shapiro, Gray and Eusner (1961) have shown that the CSF can be predicted from the maceral composition and the variation in vitrinite reflectance. For maximum coke stability at a given rank of coal a critical ratio of reactive macerals (vitrinite + exinite + 1/3 semifusinite) to inert macerals is required. In the Phalen seam, as is the case 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 CSF values can be obtained by additions of inert-rich constituents, particularly fusinite, and by blending with L.V. bituminous coal. This is supported by the observation that at the same Ro values the Phalen coal generally produces a stronger coke than the Harbour coal. For example, at about 0.94% Ro the CSF values are 38 for the Phalen seam and 31 for the Harbour seam. The reason most likely is the higher content of fusinite in the Phalen seam.

The favorable 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

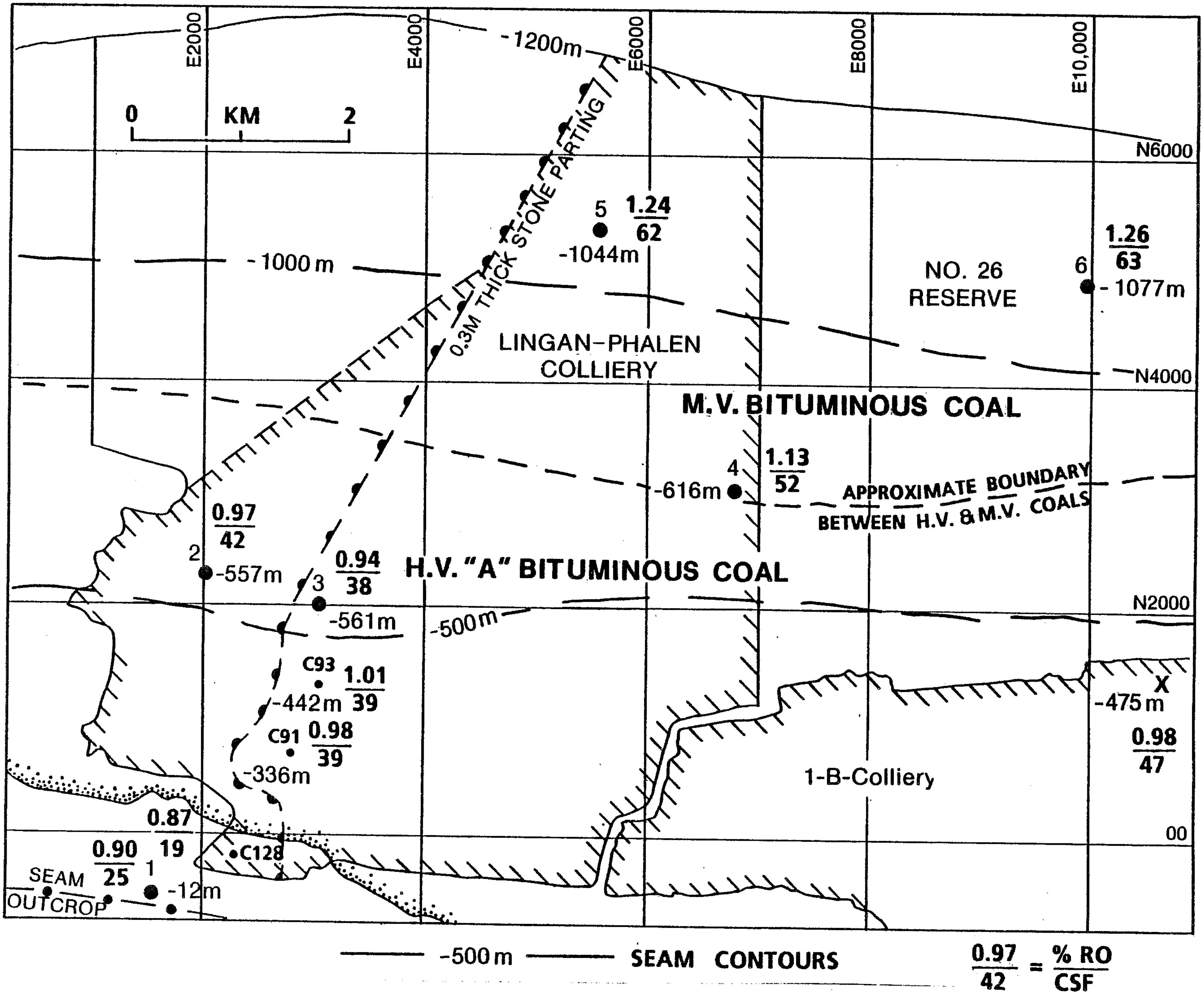

Figure 6. Rank and coke stability data, Phalen seam, Lingan - No. 26 area.

this is accompanied by a higher stability factor. For example, section 1 at a depth of -12 m has an Ro of 0.90% and a CSF of 25, whereas section 5 at a depth of -1044 m has an Ro of 1.24% and a CSF of 62.

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 600 m blending with imported L.V. coal will no longer be necessary, because a commercially acceptable CSF of 52 has been reached (in section 4).

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