PETROGRAPHY AND PREDICTED COKE STABILITY OF HARBOUR SEAM CHANNEL SAMPLE FROM DONKIN TUNNEL OF SYDNEY COALFIELD, NOVA SCOTIA, COMPARED WITH 1979 OFFSHORE DRILLING RESULTS

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ABSTRACT

A detailed study of 23 increments of a 3.4 m thick channel sample collected in the first underground workings of the Donkin Reserve area gave the following results:

1. The petrographic profile correlates well with the profiles previously obtained on eleven borehole intersections of the Harbour seam. Seven of the eight petrographic intervals are present.
2. The rank of the coal with 0.90% Ro (H.V.-A. bituminous) fits in precisely with the rank data from adjoining boreholes.
3. A remarkably low ash coal with only 3.7% over a 2.8 m continuous section is represented. It is overlain by 0.5 m roof coal with 15% ash, and underlain by 0.2 m bench coal with 32% ash.
4. The corresponding sulphur data are as follows: 2.3% in the 2.8 m section, 5.2% in the roof-coal and 10.9% in the bench-coal.
5. From a detailed microscopic pyrite analysis, it has been calculated that in the seam total, 1.2% is residual (organic) sulphur and 2.1% pyritic sulphur. This means that the coal can be washed to about 1% sulphur.
6. In the washed product, an excellent metallurgical coal is represented. The calculated coke stability factor (from maceral and Ro data) is 40. It is higher than in the adjoining borehole samples, where factors from 30-35 were obtained. The difference is due to a greater percentage of inert macerals.

INTRODUCTION

As a result of the offshore drilling program carried out in 1978 and 1979, the Donkin Mine project was decided upon. It required an access rock tunnel rather than a slope, because the seams dip seaward and outcrop at the seafloor. Two tunnels were envisaged, of which Tunnel No. 2 intersected the Harbour seam at a distance of 3.4 km from its entrance. At the intersection, a 125 m long cross-cut was

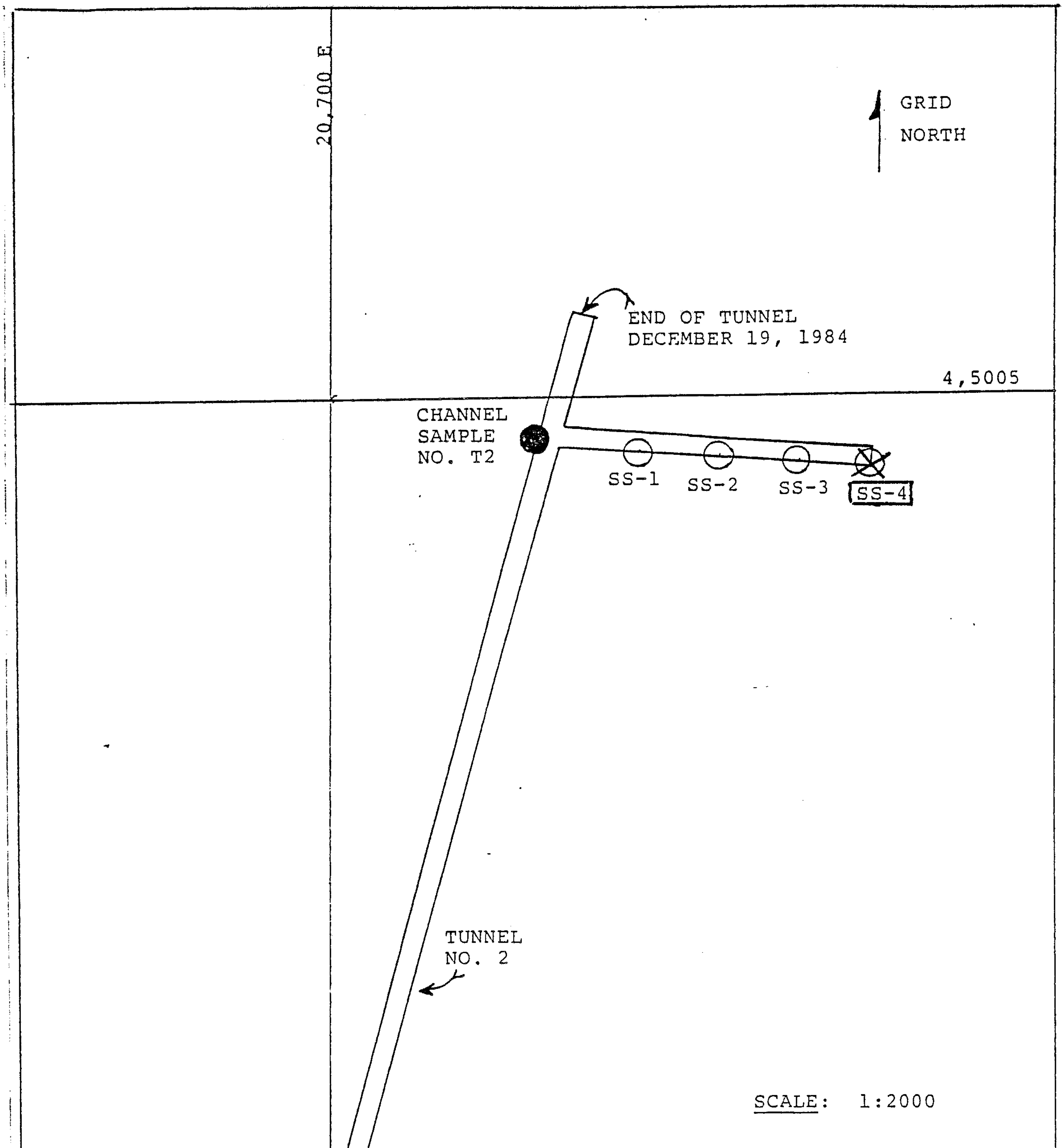

FIG. 1. PLAN SHOWING LOCATION OF CHANNEL SAMPLES IN DONKIN TUNNEL AND CROSS CUT

(S. Forgeron 1985)

driven from which four channel samples were collected in 1985 by S. Forgeron of the Geological Department of DEVCO. Of these samples, only the most easterly one, marked SS-4 was examined for this report (Fig. 1). It represents the first sample taken from underground workings in the Harbour Donkin Mine for petrographic study. Previous petrographic data were all obtained from borehole intersections and their accuracy, reliability and continuity can now be compared with actual coal face observations and complete channel sampling. The report discusses this comparison at some detail.

THE DONKIN RESERVE AREA

The Donkin Reserve area is situated at the eastern extremity of the Sydney coalfield. It occupies an offshore area of 100 square km that lies adjacent to old submarine workings on the Harbour and Phalen seams. The Reserve comprises a block of "demonstrated" coal resources with boundaries that have been drawn on the basis of the 2.4 km influence radii from boreholes that are used for this category. Eleven boreholes were drilled within this block during 1978 and 1979 from a drillship (Fig. 2). These holes ranged in depth from 262 to 843 m, and totalled 5811 m. They intersected four mineable seams that vary in thickness from 0.91-3.87 m. The total in-situ tonnage is calculated at 827,000,000 metric tons, of which 319,000,000 tons are present in the Harbour seam (Hacquebard, 1983).

The Harbour seam is the main producer in the Sydney coalfield and has been traced over the entire 50 km width of the field. It is the best developed seam in the region, possessing the least number of stone partings and best quality coal with respect to ash and sulphur content.

In the Donkin Reserve, the Harbour seam increases in thickness from less than 2 m in the west to a maximum of 3.87 m in the east (Fig. 3). This increase is the result of additional accumulations of coal in the upper part of the section, as has been

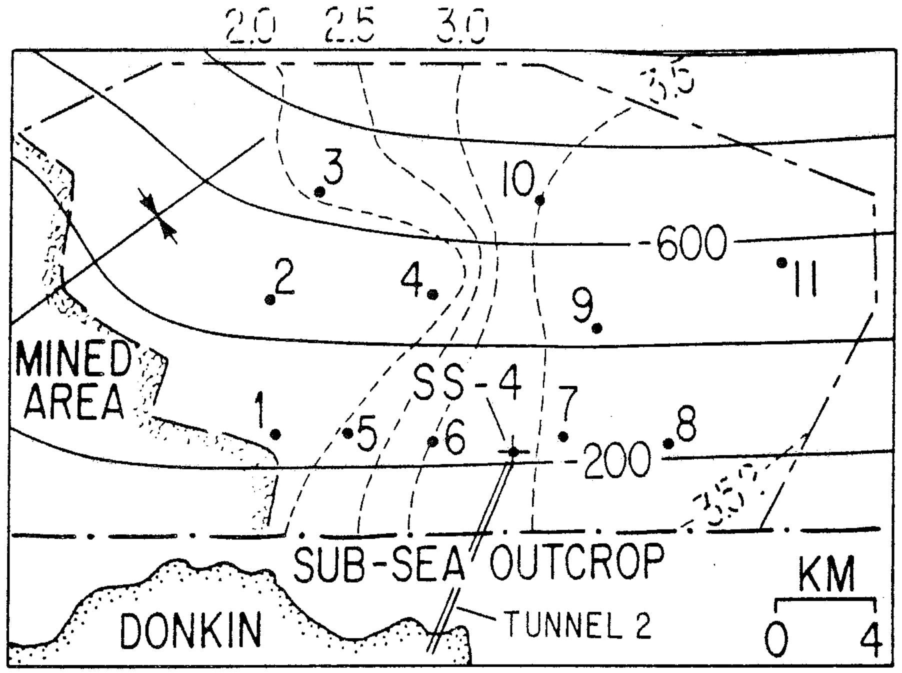

FIG. 2. LOCATION MAP-DONKIN RESERVE AREA
---- ISOPACHS AND —— CONTOURS, IN METRES

OFFSHORE BOREHOLES 1 TO 11 RELATE TO ORIGINAL NUMBERS AS FOLLOWS: 1=P2; 2=P1; 3=H8A; 4=H8D; 5=P4; 6=H6; 7=P3; 8=H7; 9=H8C; 10=H8; 11=H8B.

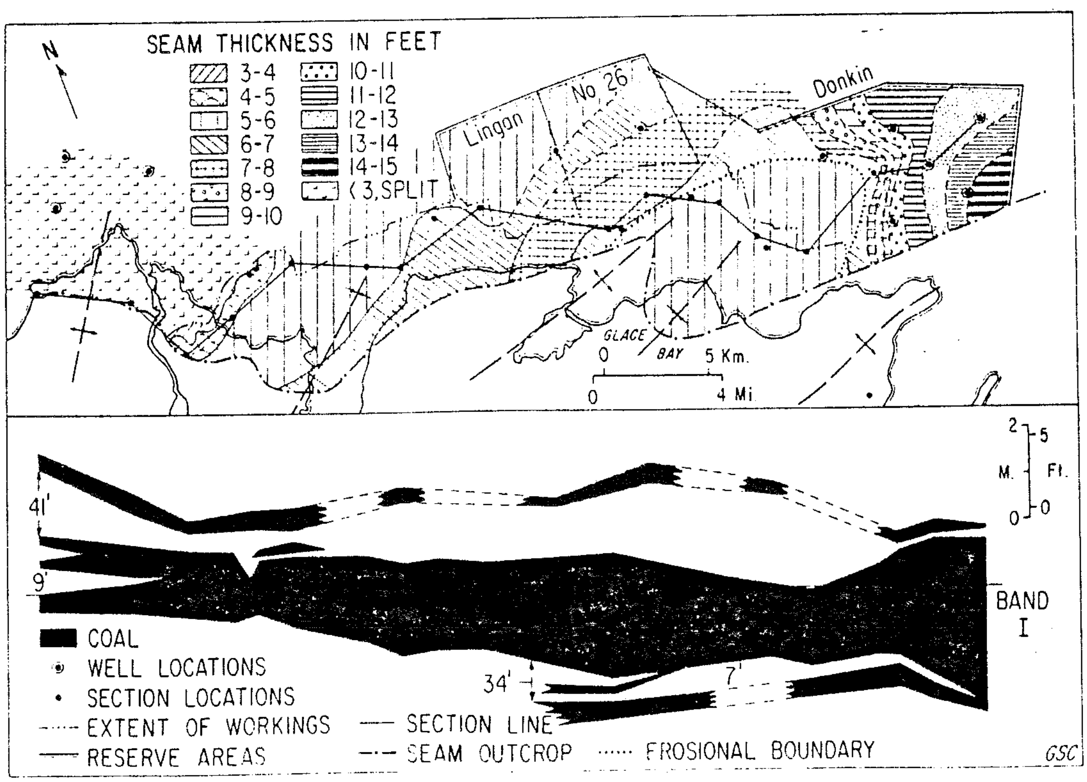

FIG. 3. Isopach map and cross-section of the Harbour seam, Sydney Coalfield (after Hacquebard, 1983).

deduced from the correlation of the petrographic diagrams (Hacquebard and Avery, 1982).

This increase in thickness is related to the geological environment and indicates that the Donkin Reserve contains the most favorable area of coal deposition in the known part of the Sydney coalfield. Nowhere else in this field has a coal thickness of 3.87 m been encountered.

SAMPLING AND PETROGRAPHIC PROCEDURE

Based on the megascopic log measured by F. Forgeron, channel sample SS-4 was collected in 23 increment samples, that varied in thickness from 3.8 cm to 24.1 cm. Megascopically, the seam is essentially a bright coal with several 3-4 cm thick durain bands in the upper and middle parts, and with thin fusain lenses throughout, but more abundantly in the lower half (Fig. 4). At 53.3 cm below the roof, there is a 3.8 cm thick stone parting, the only one present in the 3.45 m thick section. The roof and bench coals contain pyrite lenses that are occasionally several centimeters in thickness.

The petrographic examination of the 23 increment samples was carried out under reflected light on lucite-bonded grainmounts at 500 × and 160 × 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 (Fig. 5). The narrow increment plots were later combined into larger units, referred to as petrographic intervals (Fig. 6). In addition, separate pyrite and sulphur distribution diagrams were plotted of the same intervals (Fig. 8).

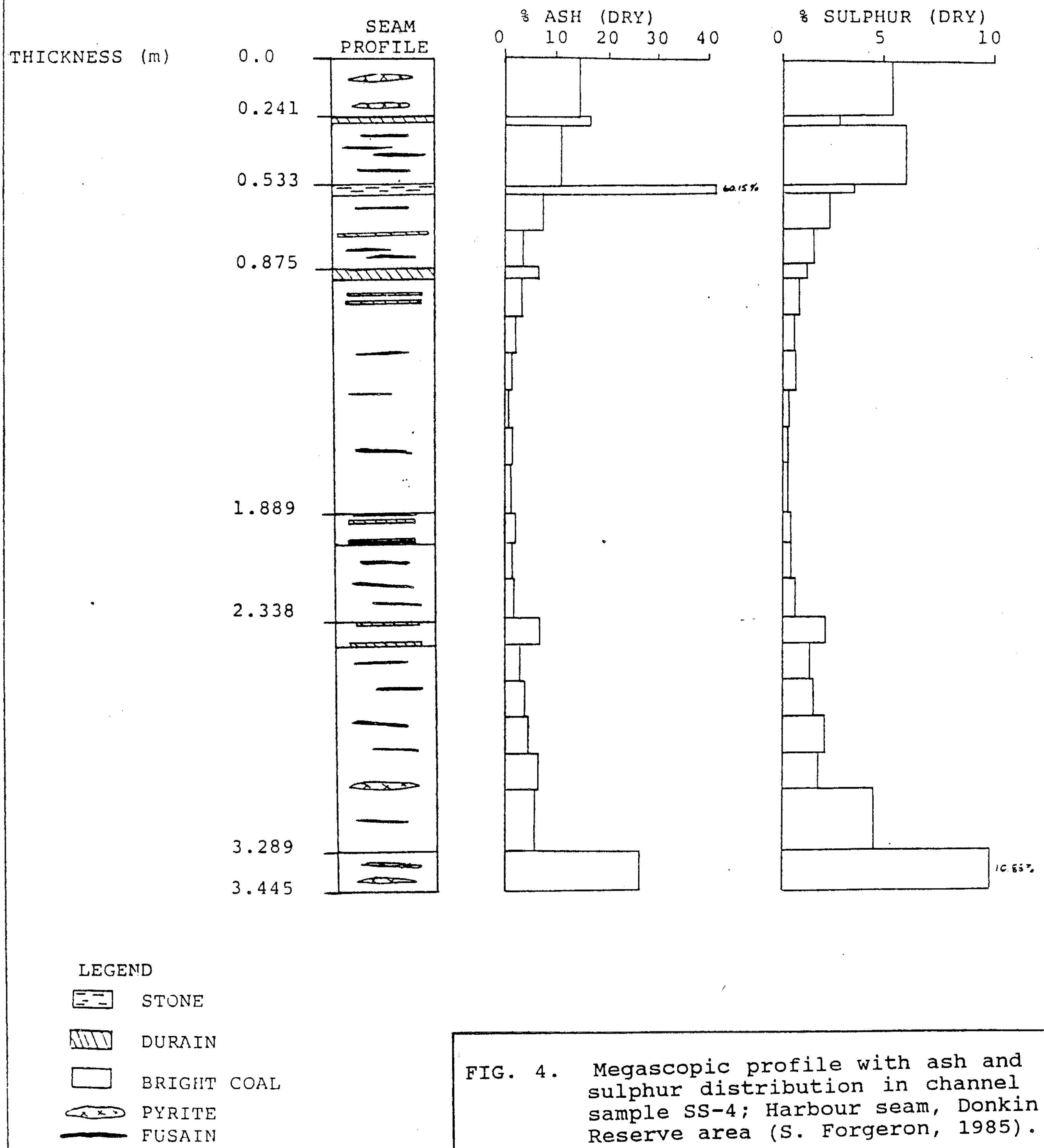

FIG. 4. Megascopic profile with ash and sulphur distribution in channel sample SS-4; Harbour seam, Donkin Reserve area (S. Forgeron, 1985).

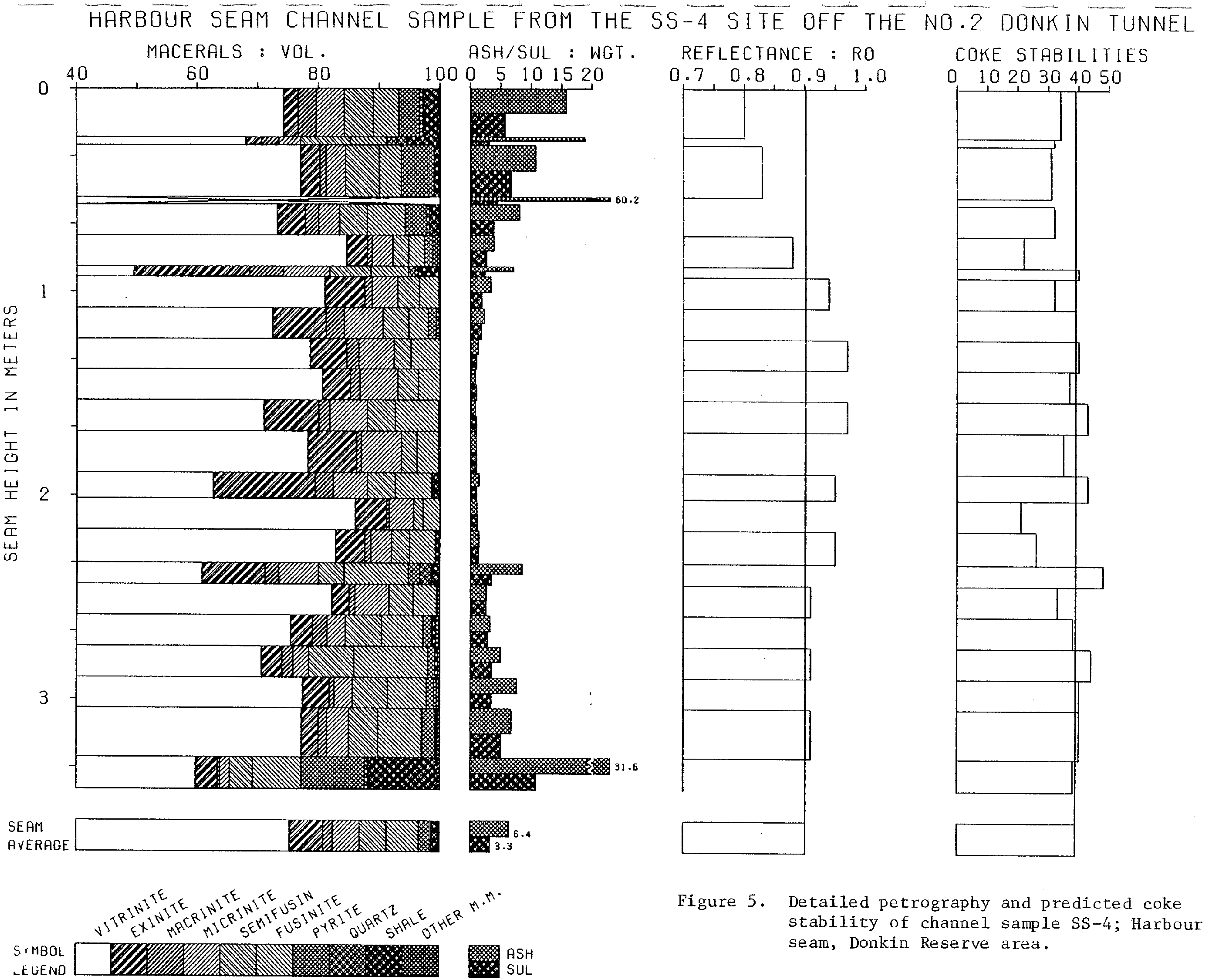

Figure 5. Detailed petrography and predicted coke stability of channel sample SS-4; Harbour seam, Donkin Reserve area.

PETROGRAPHIC STUDY

1. Maceral Composition

The percentage diagrams in Figure 6 show the vertical and lateral variations in maceral composition of the Harbour seam in petrographic intervals of similar types of coal. In its maximum development, where the seam exceeds 3.5 m in thickness, there are 7 or 8 intervals, as in sections 7 to 11. This is reduced to six intervals in the western sections, which are less than 2 m thick (shown in Figure 2 of Hacquebard's 1982 publication). The correlation of the petrographic diagrams explains the eastward increase in seam thickness. It is due to additional coal accumulations in the upper part of the section, which resulted from the deposition of intervals VII and VIII.

The presence of intervals VII and VIII in the diagram of SS-4 supports the above explanation, which was based on the petrographic correlation of borehole samples, rather than on in-situ coal observations. The absence of interval I in SS-4 is due to the separation of the bench coal from the main seam by at least 50 cm, and therefore was not sampled.

Petrographically the Harbour seam, like the other coal seams of the Sydney field, can be classed as a bright coal that is high in vitrinite, low in inertinite and has a modest amount of exinite. The "total reactives" (vitrinite + exinite + $\frac{1}{3}$ semifusinite) of the seam-averages vary only between 77 and 87%, with 83% occurring in sample SS-4. However, within each seam section some pronounced variations occur. These are manifested by the different petrographic intervals, notably those with increased content of inertinite, semi-fusinite and exinite, as in intervals IV, VI, and VIII (Fig. 6). Of these, the composition of interval IV is the most characteristic because it contains a durain band that consists of matted exinite. This band is typical of the Harbour seam and has been traced over the entire coalfield

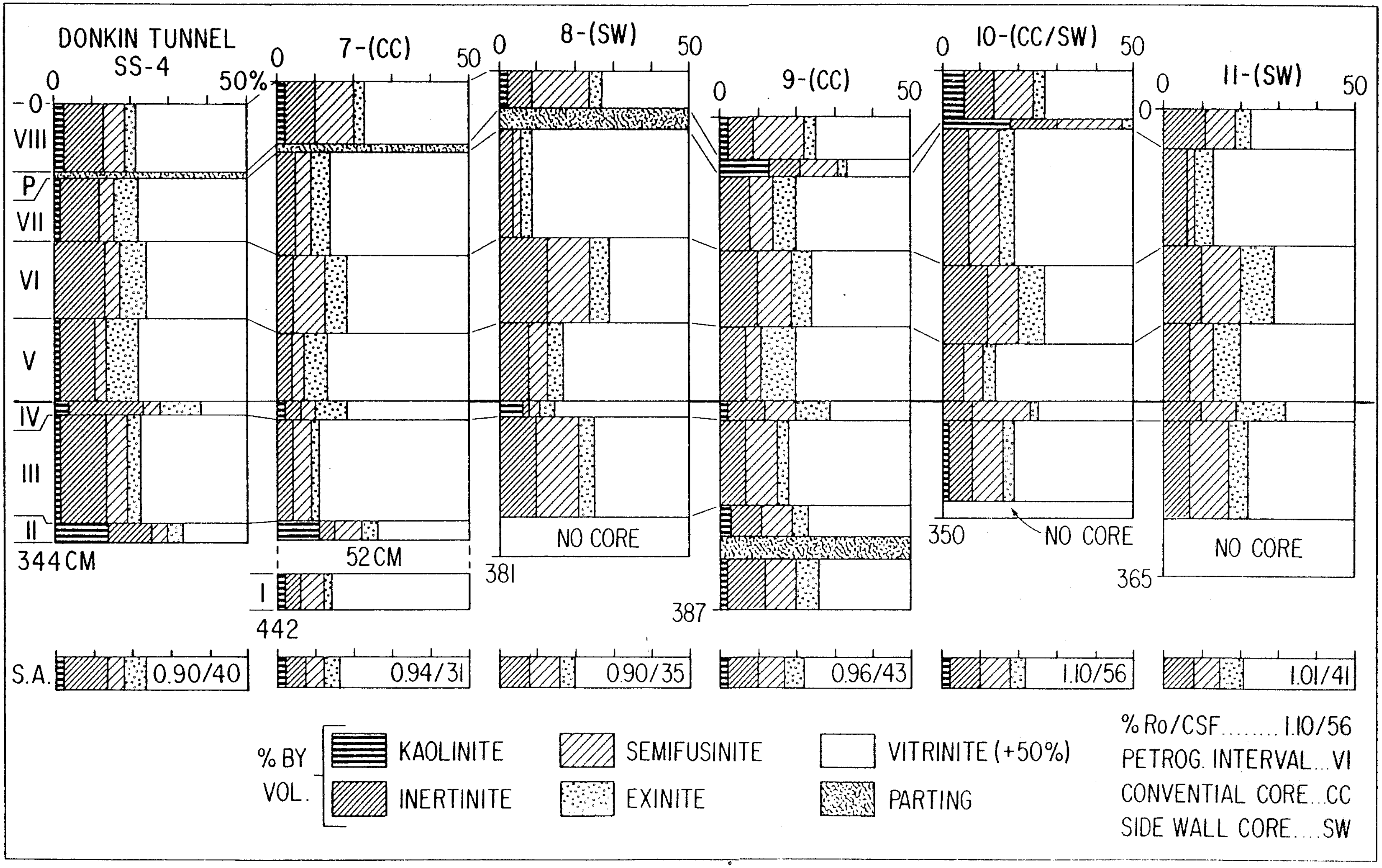

FIGURE 6. PETROGRAPHY HARBOUR SEAM, DONKIN AREA

(Hacquebard *et al.*, 1965). It is used here as the base line for the correlation of the different diagrams.

The lateral variations within the individual intervals of borehole samples 7 to 11 is generally only minor and indicates that conformity in maceral composition can be expected within the confines of the Donkin Reserve area. This result is supported by the diagram of sample SS-4, which compares well with those of the borehole samples. The same petrographic intervals from II to VIII are present, only the amounts of inertinite are generally somewhat higher, being 12% in the seam average, as against 5 to 8% in the others. This higher percentage probably is related to a greater recovery of fusinite (part of the inertinite maceral group) from the in-situ coal sample than from the borehole samples.

2. Rank Changes and Coke Stability Predictions

With a mean maximum Ro of 0.90% the rank of channel sample SS-4 fits in perfectly with the data previously recorded on the borehole samples (Fig. 7). They show that in the Donkin Reserve area, the Harbour seam has a rank of high volatile "A" bituminous coal, with vitrinite reflectance values that vary from 0.90-1.10% in the different sections. These data can be correlated with a change in volatile matter content of 36-31% when using the coal classification table of Teichmüller (1975).

The observed Ro variations are related to the subsurface depth of the seam, which increases seaward. The seam contours of Figure 7 show that at -200 m the rank is approximately equal to 0.90% Ro, whereas at -600 m, a value of about 1.00% was encountered. In addition, there are rank variations within each seam section that affect the coking properties, and that normally amount to three V-types. Each V-type denotes a change in reflectance of 0.10%, so that V8 ranges from 0.80-0.89% Ro, V9 from 0.90-0.99% Ro, etc. (Fig. 5).

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

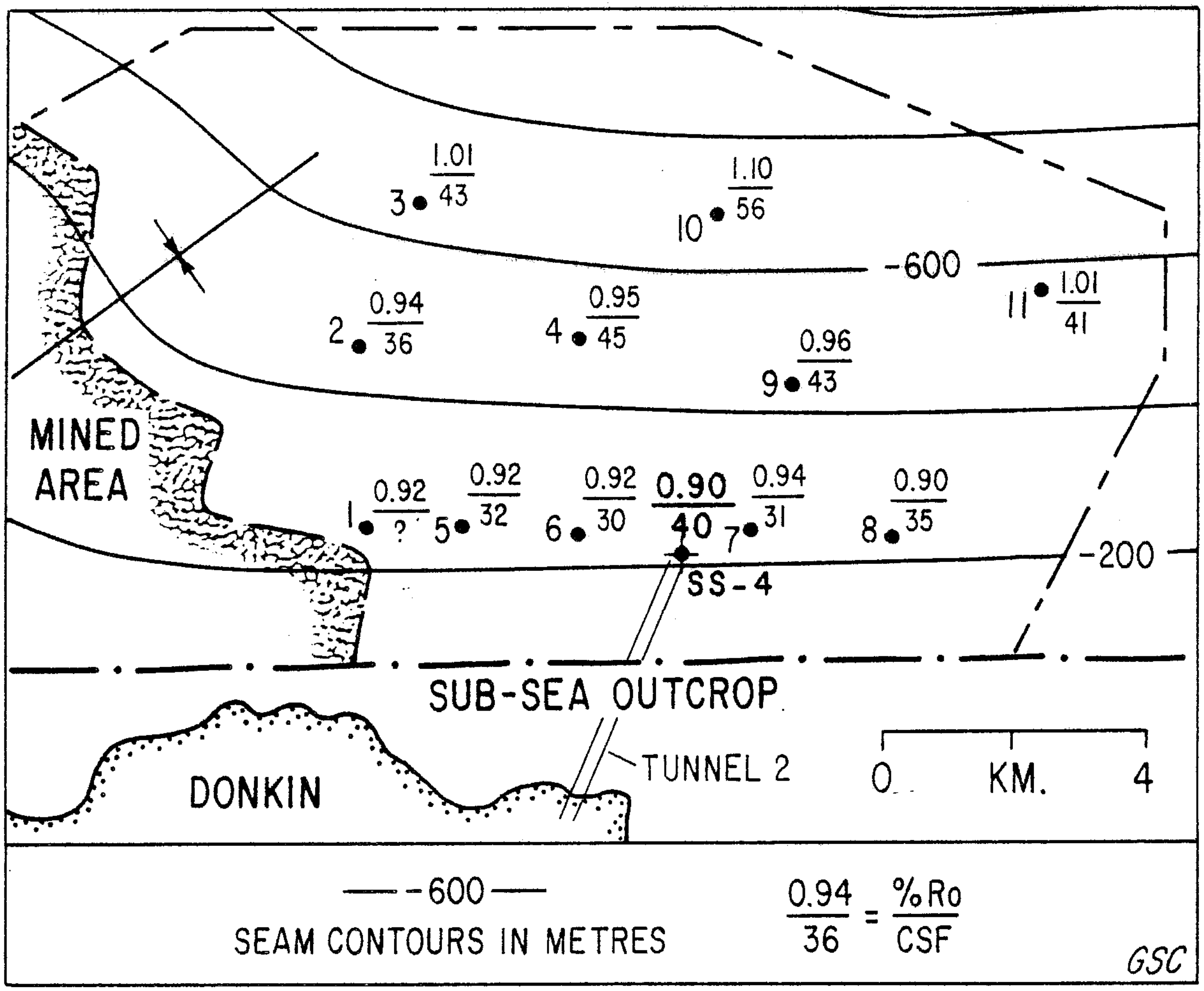

FIG. 7 REFLECTANCE AND COKE STABILITY DATA HARBOUR SEAM, DONKIN RESERVE AREA

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 + $\frac{1}{3}$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 CSF 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 has a surprisingly high CSF 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 favorable effect of an increase in rank on coke strength is clearly revealed in Figure 7. With a greater depth below the surface, the reflectance increases and this is accompanied by higher stability factors. For example, sample 6 at a depth of 237 m has an Ro of 0.92% and a CSF of 30, whereas sample 10 at a depth of 706 m has an Ro of 1.10% and a CSF 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 MV coal will no longer be necessary, because the commercially acceptable CSF of 56 has been reached (in sample 10).

3. Pyrite and Sulphur Distribution

The amount of pyrite is not shown in the percentage diagrams of Figure 6. 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 160 × magnification under a dry objective, and the amount has been plotted on the left side of the diagrams in percent by volume (Fig. 8).

The chemically determined total sulphur is shown in percent by weight on the right side. The portion of this contributed by the pyritic sulphur has been calculated from the amounts of pyrite. Also shown in 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 8 shows that pyritic sulphur is the main contributor to the total sulphur content, comprising from 62-92% of the total amount. Complete pyrite removal, if this were possible, would produce a coal with a sulphur content of 1% or less in nearly all sections, particularly in the main body of the seam comprising intervals IV to VII.

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, II and VIII)). 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.

The pyrite and sulphur distribution pattern in sample SS-4 conforms closely with that observed in borehole sections 7 to 11 (Fig. 8). The greatest concentrations

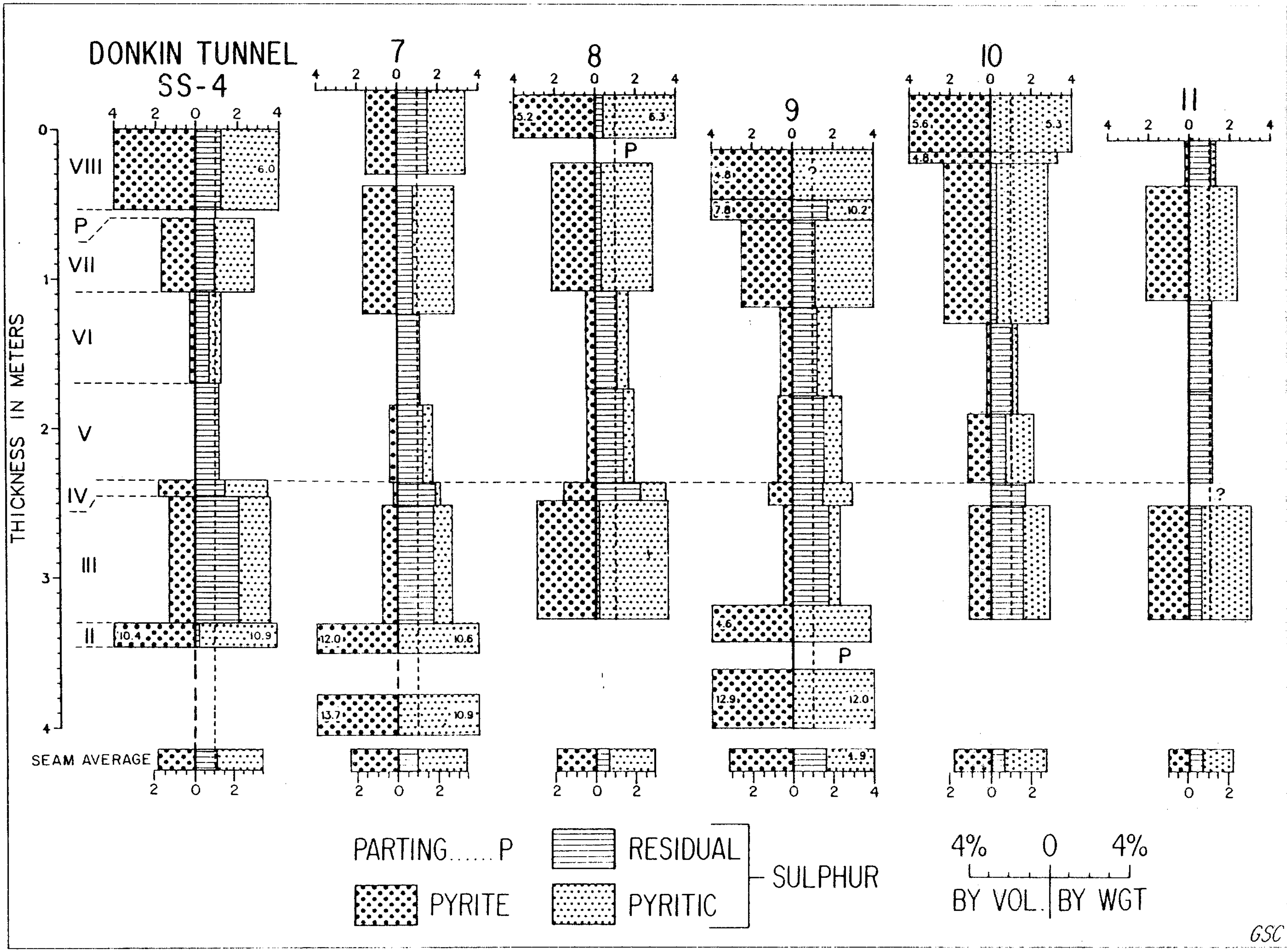

FIGURE 8. PYRITE AND SULPHUR DISTRIBUTION HARBOUR SEAM, DONKIN RESERVE AREA

occur here also in intervals II and VIII, where amounts of 4 to 10.9% have been recorded.

The cleanest part in all sections is represented by the central portion of the seam, comprising intervals V and VI, and varying in thickness between 1.10 and 1.30 m. In SS-4, this part has 0.18% pyrite and 1.16% sulphur; it measures 1.26 m.

Apart from the pronounced vertical variations within each seam section, there also exists a regional variation in the sulphur content. In general, the amount decreases towards the east; the boundary between the high and low sulphur area lies approximately along the 2.5 m coal isopach of Figure 2. West of this line, in sections 1 to 5, the sulphur content of the seam-average is between 4 and 5.5%, whereas in sections 6to 11 it is 3% or less.

As was mentioned previously, the sulphur can very likely be reduced to 1% or less through coal cleaning processes, resulting in an acceptable product for metallurgical use. Therefore, the eastern half of the Donkin Reserve area (including SS-4) has a potential reserve of metallurgical coal, which, according to the calculations of Hacquebard and Forgeron (1979), contains 90 millions tons of recoverable coal.

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