GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 72-39

THE PETROGRAPHY OF THE COAL FROM THE BLAKEBURN STRIP MINE IN THE TULAMEEN COAL AREA, BRITISH COLUMBIA

(Report, 4 figures and 5 tables)

J. Roger Donaldson

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CONTENTS

Illustrations

ABSTRACT

A partial column of the 90-foot-thick seam from the Blakeburn Strip Mine in the Tulameen coal area was examined petrographically. This column was analyzed for lithotypes, microlithotypes and macerals as a preliminary study into Canadian coals of Tertiary age.

Nine additional spot samples through the seam section were examined for maceral content and reflective indices. Proximate analyses were carried out and used in conjunction with R_o indices for coke stability predictions. These indicated poor coking potential for this coal due to an overabundance of reactive components, which include a high percentage of resinite in certain parts of the seam.

Because this seam is overlain by a volcanic flow of olivine basalt, it was suspected that its higher rank was the result of metamorphic changes brought about by the lava.

However, evidence of contact metamorphism was not found, and the higher rank may be related to a greater depth of overburden in the centre of the coal basin together with an abnormally high geothermal gradient, the latter being caused by the volcanic activity in the region.

RÉSUMÉ

Une colonne partielle de la couche de 90 pieds d'épaisseur de la mine à ciel ouvert Blakeburn dans la région houillère de Tulameen a été étudiée au point de vue pétrographique. L'auteur analyse les lithotypes, les microlithotypes et les macéraux de cette colonne dans le cadre d'une étude préliminaire sur les charbons canadiens d'âge tertiaire.

L'auteur étudie la teneur en éléments macéraux et les indices de réflexion de neuf échantillons additionnels pris dans la coupe de la couche. Il a effectué des analyses quantitatives approximatives et a utilisé les résultats conjointement avec les indices R_o pour faire des prédictions sur la stabilité du coke. Les résultats indiquent un faible potentiel de cokéfaction de ce charbon en raison de la surabondance des éléments réactifs, qui comprennent un pourcentage élevé de résinite dans certaines parties de la couche.

Parce que cette couche est recouverte d'une coulée volcanique de basalte à olivine, on soupçonne son haut degré de houillification d'être le résultat de changements métamorphiques amenés par la lave.

Toutefois, on n'a pas trouvé de preuve de métamorphisme de contact, et le degré élevé de houillification peut être relié à l'épaisseur plus grande des morts-terrains au centre du bassin houiller accompagnée d'un gradient géothermique anormalement élevé, ce dernier étant causé par l'activité volcanique de cette région.

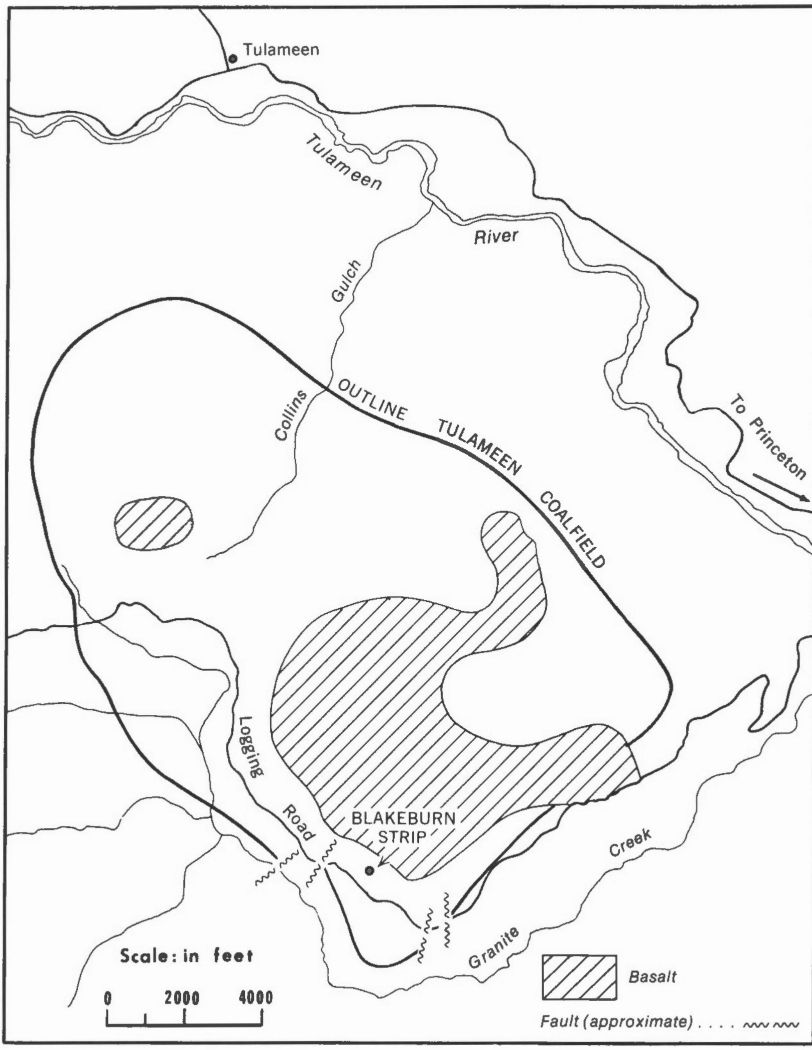

Figure 1. Index map, Tulameen coalfield, British Columbia

THE PETROGRAPHY OF THE COAL FROM THE BLAKEBURN STRIP MINE IN THE TULAMEEN COAL AREA, BRITISH COLUMBIA

INTRODUCTION

The coal deposits of the Tulameen coal area in south-central British Columbia have been known since 1885 when they were reported first by gold prospectors. Earliest mention of the deposits, found in a literature survey, was by W.F. Robertson in 1901. The area is located south of the Tulameen River approximately 4 1/3 miles south of Tulameen (Fig. 1).

The coalfield was described by Camsell (1913) to be roughly oval in shape, having its longer axis running northwest-southeast. In this direction it has a length of nearly 3 1/3 miles, whereas its greatest width is about 2 1/4 miles. The area underlain by the coal has been calculated to be 3,254 acres and, of the coal area, 1,070 acres are covered by a flow of volcanic rock. The coal is Tertiary in age.

The proximity of the lava to the underlying coal generated interest as to the possibility of contact metamorphism causing the coal to be upgraded in rank. Rank determinations were carried out with the aim of measuring the degree of metamorphism and, also, to evaluate the coking potential of the seam.

The age of the coal was also a point of interest since the petrography of Canadian Tertiary coals is not too well known. Dr. Yasuo Nakayanagi, a petrologist from the Coal Research Institute, Kawaski, Japan, with experience in Japanese Tertiary coals made a preliminary study of a 5 1/2-foot column of this seam. The results of this study are incorporated in this report. It is realized both by Dr. Nakayanagi and the writer that more study in this direction is required.

GEOLOGICAL OUTLINE

The geology of the Tulameen coal area has been adequately reported by Camsell, 1913; Strachan *et al.*, 1927; Mackay, 1947; and Shaw, 1952.

The coal measures rest in part unconformably on volcanic rocks of Triassic age and in part conformably on volcanic rocks of the Cedar volcanic series that are of Oligocene age. The total section is less than 2,500 feet thick and can be divided into three parts.

The lowest 600 feet are composed of sandstones interbedded with thin bands of shale. The middle part is made up of about 480 feet of fissile shale and contains the principal coal seams. The upper section contains a preponderance of sandstone associated with thin bands of shale and conglomerate beds (Camsell, 1913).

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Author's address: Geological Survey of Canada
601 Booth Street
Ottawa, Ontario.

The coal in the Blakeburn Strip Mine is overlain, in part, by thinly bedded shale. A flat-lying bed of olivine basalt covers both coal and shale members unconformably as is shown in figure 2. Here, the coal measures 90 feet in thickness and is split by numerous partings of a siliceous tuff. The coal is composed of intermittent blocky and friable layers and dips at 30° to the east.

SAMPLING, PREPARATION AND TERMINOLOGY

The first sample taken from the Blakeburn Mine consisted of a column sample 5 1/2 feet in height from the lower mid-section of the seam. Due to the nature and height of the seam, a complete column of the entire thickness could not be obtained readily.

The 5 1/2-foot column was cut into 35 smaller oriented sections and mounted in a plastic mounting medium. The finished sections represented the entire 5 1/2 feet of coal. These sections were polished for both a megascopic and microscopic examination which consisted of maceral and microlithotype determinations.

Figure 2 shows a section through the Blakeburn Mine where operations were carried out on two levels - the upper pit on the western side and the lower pit on the eastern side. From these two cuts, 13 spot samples were taken from selected intervals, and polished grain mounts were prepared. The position of these samples was related to two points of reference:

1. Their stratigraphic position across the thickness of the seam. They are represented by the nine "pie" diagrams in figure 4 and are numbered 1, 9, 3, 4, 7, 14, 21, 5 and 6.

2. The order of increasing vertical distance from the volcanics. They are shown in the reflectance column of figure 4 and include an additional four samples numbered 2, 12, 16 and 18.

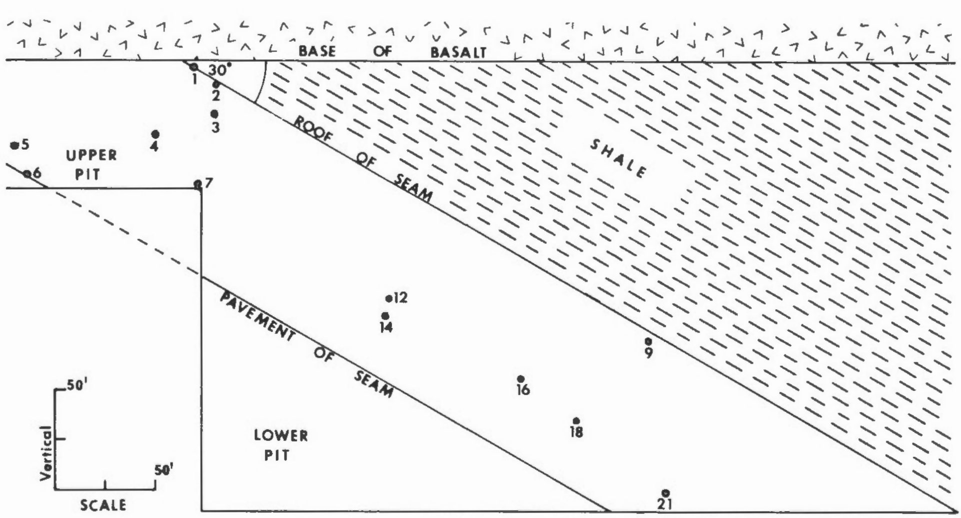

Figure 2. Sample locations in Main Seam, Blakeburn Strip Mine, Tulameen coal area, British Columbia

The microscopic analyses were carried out by incident light and the use of an oil immersion objective. A magnification of x250 was used for the maceral and microlithotype determinations, and x600 for the reflectance measurements on vitrinite.

In accordance with the definitions agreed upon by the International Committee for Coal Petrology (1963), the following can be said about the terminology of the coal constituents. Macerals are the basic petrographic constituents of coal and are analogous to the minerals of inorganic rocks. Microlithotypes are distinctive assemblages of macerals and are equivalent to "rock types" in the realm of inorganic petrology. The macerals identified were vitrinite, semifusinite, fusinite, micrinite, resinite and exinite. The amount of mineral matter also was determined. The microlithotypes identified in the study are listed in table 1 along with their content of constituent macerals.

MICROLITHOTYPES	PROPORTIONS OF CONSTITUENT MACERALS IN PER CENT BY VOLUME
Vitrite	95% vitrinite + minor amounts of other coal constituents
Vitrinertite V	50-95% vitrinite; 5-50% inertinite ("V", rich in vitrinite)
Vitrinertite I	5-50% vitrinite; 50-95% inertinite ("I", rich in inertinite)
Clarite	Must contain at least 95% vitrinite and exinite in varying proportions, but each > proportion of inertinite and neither must > 95%
Duroclarite	Vitrinite > 5%, exinite > 5%, inertinite > 5%. Vitrinite must exceed inertinite
Clarodurite	Vitrinite > 5%, exinite > 5%, inertinite > 5%. Inertinite must exceed vitrinite
Durite	Contains at least 95% inertinite and exinite
Fusite	Must contain at least 95% fusinite, semifusinite and sclerotinite

Table 1: Nomenclature and classification of microlithotypes (after International Handbook of Coal Petrography, 1963)

MEGASCOPIC EXAMINATION

Dr. Y. Nakayanagi was one of the first petrographers to study the coals of Tertiary age in Canada. For his preliminary study, the 5 1/2-foot column sample previously referred to was taken from one of the few competent sections in the seam.

The 35 oriented polished sections were examined under a hand lens and a seam profile, as shown in figure 3, was compiled. As the coal is normal banded, these bands were classified as to their vitrain content (bright, semi-bright or dull). Bands composed of coaly material in a shale matrix were classed as coaly shale, while bands barren of coaly material were classed as shale. The smallest band utilized in the above system measured 3 millimetres in thickness.

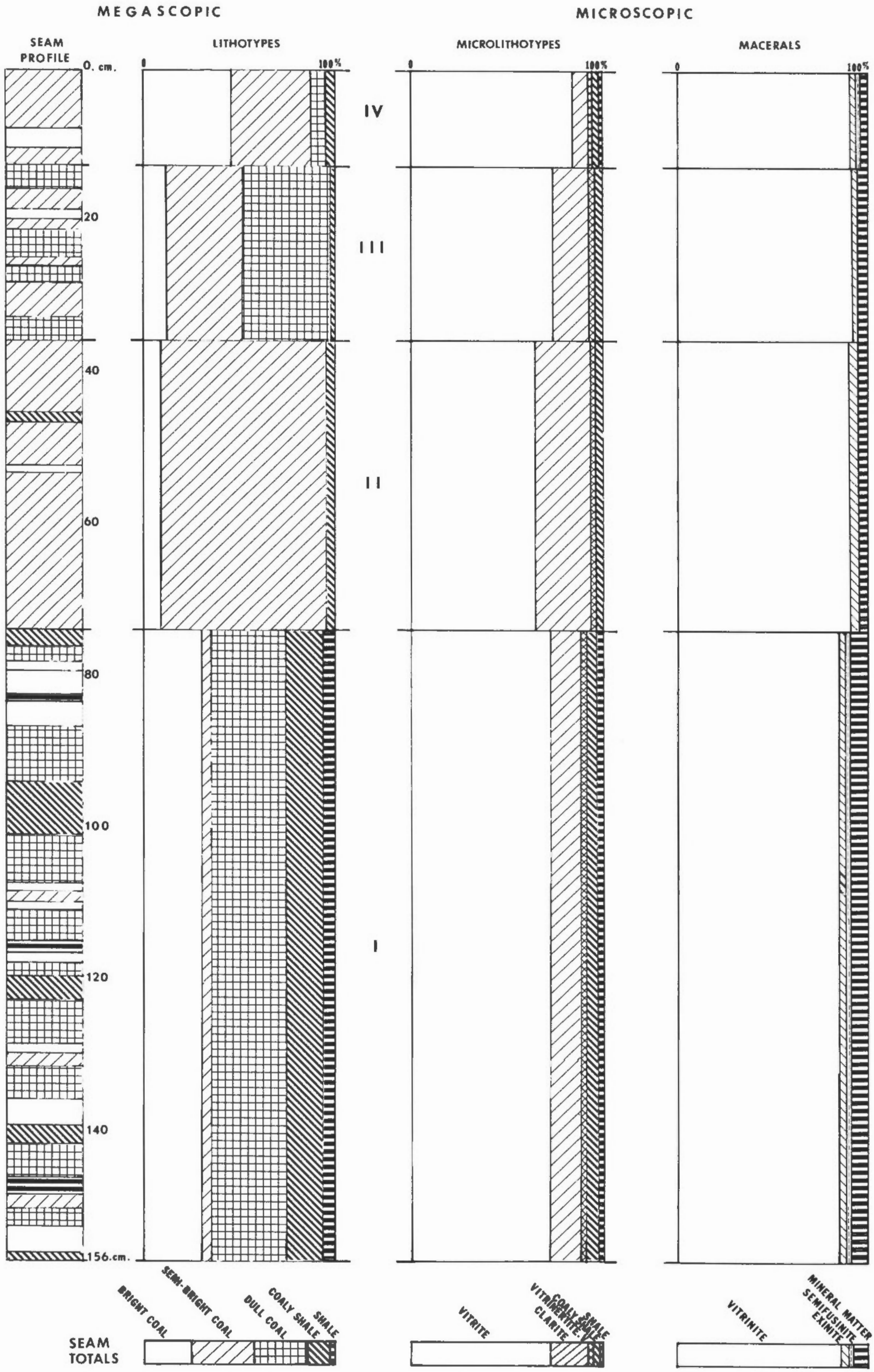

Figure 3. Petrographic Profiles of $5\frac{1}{2}$ foot Column Sample from Blakeburn Mine, Tulameen Coal Area, B.C.

From the profile, it was readily apparent that the various lithotypes (or banded ingredients) of like composition tended to concentrate at particular levels in the column. This made possible a grouping based on bands of similar composition so that the entire 5 1/2 feet of coal were subdivided into four petrographic intervals, each interval being composed of similar banded ingredients. From this, it was possible to calculate a percentage diagram for the lithotypes as shown in figure 3, on the left hand side.

The bright coal, in the percentage diagram, is composed of the so-called bright coal components, vitrain and clarain. Conversely, the dull coal is composed of the component durain. The semi-bright coal is an intermediate category half-way between the two.

From the percentage diagram it can be seen that in interval I, dull coal is slightly in excess of the amount of bright coal, while only 5 per cent of the total is semi-bright coal. In this interval, the coaly shale reaches a high value of 20 per cent. In the microscopic analysis to be described later, it was found that this interval was composed of approximately 80 per cent of the maceral vitrinite, the major constituent of bright coal. This is pointed out at this stage to show that mineral impurities, too small to be adequately observed with a hand lens, because of their size and dispersion, can give a dull appearance to a truly bright coal. This has been observed also in previous studies.

Interval II has a very homogeneous composition being made up almost entirely (96%) of semi-bright coal.

Interval III contains predominantly dull and semi-bright coal, 47 per cent and 40 per cent respectively. This interval contains only 12 per cent of bright coal but has the least amount of coaly shale (1%).

Interval IV has almost equal percentages of bright and semi-bright coal along with only 8 per cent of dull coal.

The entire megascopic profile is beneficial to the study of a given seam since it gives an insight to the general texture and stratification of the various bands found in coal seams. It is useful also as a rapid method of dividing a seam into intervals of similar overall composition. Material, representative of each of these four intervals, was crushed to -20 mesh and grain mounts prepared and polished for microscopic study.

MICROLITHOTYPE ANALYSIS

In the centre of figure 3 the microlithotype composition of the 5 1/2-foot column is illustrated. It shows a remarkable uniformity throughout the section, with vitrite and clarite being the main constituents. Closer scrutiny of these constituents, however, revealed that in this Tertiary coal it is possible to recognize different types of both vitrite and clarite.

Six types of vitrite occur in the Blakeburn coal, and these have the following characteristics.

(a) Common - This is the main vitrite type found in the column and conforms to the handbook definition.

(b) Mesophyllic - This is defined here as the vitrite that is found in the spaces between cuticles. If the mesophyllic zone is excessively wide, then the material is classed as in (a) above.

(c) Resin-telinite - When the cell lumens of ordinary telinitic vitrite are filled with resin, the vitrite is placed in the resin-telinite category.

(d) Fine vitrite - This type is composed of small particles of cutinite and vitrite along with some exinite and numerous clay minerals. These bands were all less than 10 microns in width.

(e) Semi-fusinitic - This vitrite type contains vitrinite, comparable, at least in part, to the pitted vitrinite described by Cameron and Botham (1966). Included in this category is vitrite containing obscure cloudy patches which are classed as semi-fusinitic vitrite.

(f) Suberinitic - Suberinitic vitrite is the least plentiful component. It is defined as a network of cellular material having the same colour as cutinite. This cutin-like material is found in the cell walls and is called cork. The thickness of these cell walls may range from thick to very thin.

For clarite, three types were recognized based on the dominance of specific macerals, namely cutinite-, sporinite-, and resinite-type clarite. The results of this enlarged microlithotype analysis are given in table 2.

VITRITE							CLARITE								
Interval	Common	Mesophyllic	Resin-telinite	Fine	Semi-Fusinitic	Suberinitic	Cutinite	Sporinite	Resinite	DUROCLARITE	VITRINERTITE V	FUSITE	COALY SHALE	SHALE	TOTAL
IV	66.6	0.7	11.7	2.5	3.9	-	2.1	5.7	0.4	0.4	1.4	-	2.8	1.8	100.0
III	54.1	4.5	7.9	5.5	2.8	0.7	6.6	6.9	4.5	1.0	1.7	0.7	2.8	0.3	100.0
II	48.1	6.6	2.1	3.1	4.9	-	23.2	5.6	1.0	0.3	1.7	1.0	2.1	0.3	100.0
I	47.2	5.2	12.4	6.4	2.0	-	14.0	3.6	-	-	1.6	-	4.0	3.6	100.0
Avg.	49.9	5.1	9.2	5.2	3.0	0.1	14.2	4.7	0.9	0.3	1.6	0.3	3.3	2.2	100.0

Table 2: Enlarged microlithotype analysis of 5 1/2-foot column from Blakeburn Strip Mine

The proposed sub-classifications bring out differences between the intervals that are not apparent in the main classes as plotted in figure 3. Intervals I and III, for instance, which have almost identical percentages of vitrite and clarite, show distinct differences in their subclasses. In I, the resin-telinite type vitrite is 12.4 per cent, as against 7.9 per cent in III. This is accompanied by 14 per cent cutinite-type clarite in I and 6.6 per cent in III.

From these preliminary results, which were obtained by Dr. Nakayanagi, it appears that, in future petrographic studies of Tertiary coals, a breakdown of the conventional microlithotypes vitrite and clarite into several subclasses is justified.

MACERAL ANALYSIS

The results of the maceral analysis of the 5 1/2-foot column are shown on the right hand side of figure 3 and listed numerically in table 3. The analytical method followed was that reported in the International Handbook (1963). The plastic grain mounts were examined using the 20-point graticule in the ocular with a magnification x250 under oil.

Maceral	I	II	III	IV	Average
Vitrinite	84	90	92	91	89
Resinite	3	2	2	3	3
Sporinite	-	1	-	-	0
Exinite					
Cutinite	-	2	1	-	1
Micrinite	-	-	-	-	0
Sclerotinite	-	-	-	-	0
Semifusinite	1	-	-	1	0
Mineral Matter	12	5	5	5	7
Total	100	100	100	100	100

Table 3: Maceral distribution in four intervals of a 5 1/2-foot column from Blakeburn Strip Mine

From the results of the analysis, it can be seen that intervals II, III, and IV exhibit almost identical maceral compositions while interval I is set apart only by containing 12 per cent mineral matter.

No appreciable difference, therefore, exists in the total amount of individual macerals, but when expressed as maceral associations (the microlithotypes) then variations are apparent. The latter are a reflection of changes in the type of vegetation, whereas the former are the remains of the individual plant entities.

RANK DETERMINATION

The rank of the coal from the Blakeburn Mine has been classified as high volatile "B" bituminous (Hughes, 1954). This rank of coal does not fall within a favourable range for coking but it still possesses the best coking characteristics of all other coals tested from the Tulameen area. Since most coals of Tertiary age exhibit a rank equal to that of lignite, the higher rank of the Blakeburn coal was thought to be the result of the influence of the overlying basalt.

The chief changes effected by progressive metamorphism are well known. The present investigation was restricted to changes in the optical properties of the vitrinite component in the coal. To obtain these, the mean maximum reflectance index (R_0 index) of vitrinite was determined by using a photocell and amplification system attached to an incident light microscope. Since the reflective properties of vitrinite are proportional to the volatile matter content of the coal, the R_0 index is a means of determining the rank. The method and equipment are adequately described by Schapiro, Gray and Eusner (1961) and Bayer (1967).

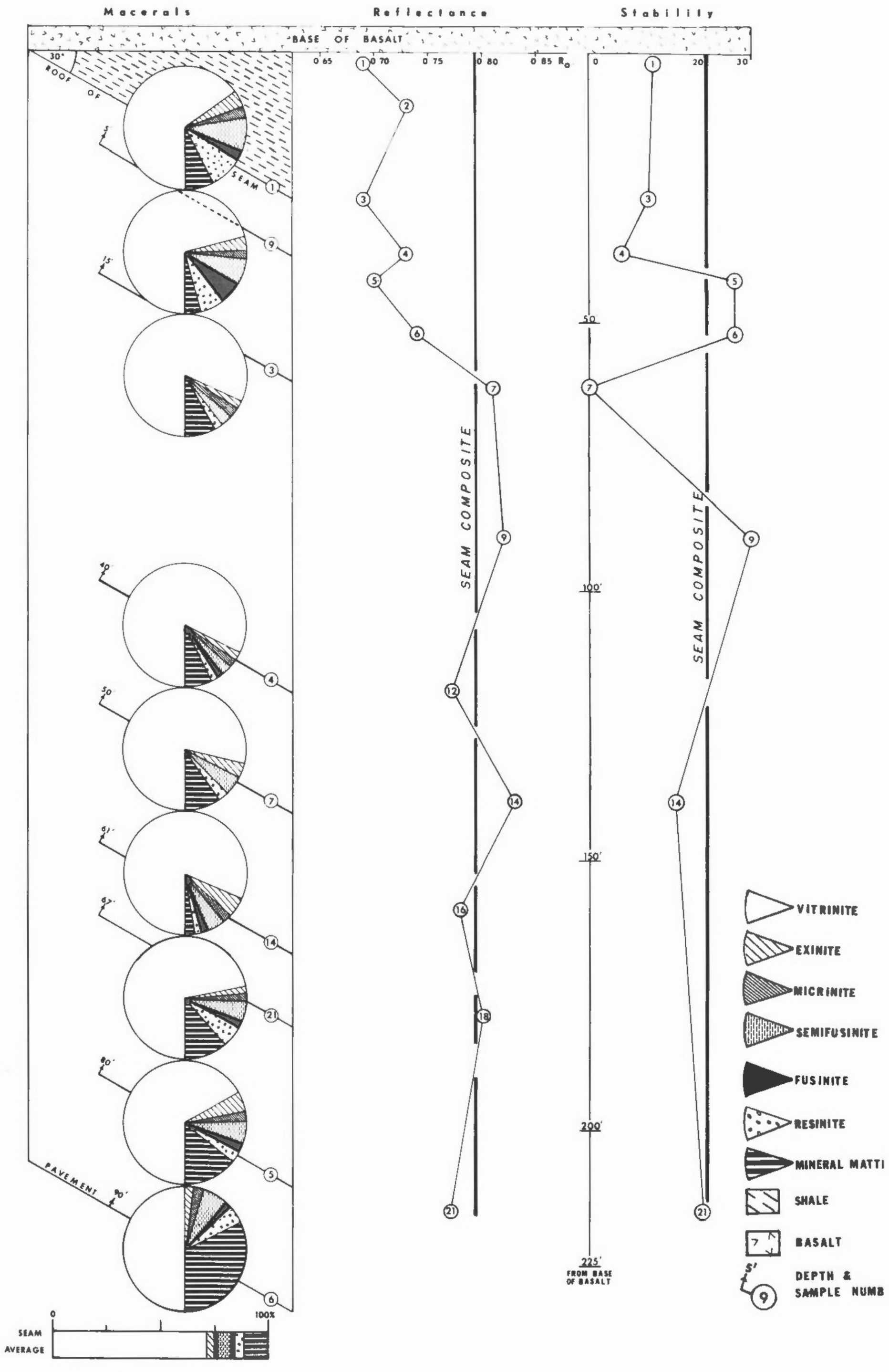

Figure 4. Petrographic composition of Main Seam, Blakeburn Strip Mine, showing average reflectance and predicted coke stability.

Figure 4 shows that the R_o index of the coal increased from 0.69 in sample 1 to 0.81 in sample 7 which represents a vertical depth of 62 feet below the basalt. The average R_o value for this distance is 0.72. Below this depth and down to 225 feet, the average R_o increases to 0.80. This pattern is contrary to that anticipated because of the position of the overlying basalt. If the influence of the basalt had altered the rank of the coal by contact metamorphism, then the higher R_o value would be found near the top of the seam.

The change of coals from low rank to a higher rank is usually the result of increased heat and depth of burial, and a greater depth of burial would normally occur near the centre of the coal basin than at the periphery. Therefore, because of the excessive thickness of the seam and because the total thickness of the coal measures is greater near the mine than in other parts of the field (Shaw, 1952), it is thought that the Blakeburn Mine is located near the centre of the original basin.

Apart from the greater heat derived at greater depth of burial, the Blakeburn coal was also in a position to retain this heat for a long time because of the low thermal conductivity of the enclosing rocks. These are mainly shale and coal, which according to the observations of Damberger (1968) have a low thermal conductivity.

Due to the volcanic activities in the general area of the Tulameen coalfield, both before and after the deposition of the coal measures, a high geothermal gradient probably existed. With a high gradient, differences of only a few hundred feet in overburden will have a favourable effect on the rank of coal.

The higher rank of the Blakeburn coal is, therefore, explained not by contact metamorphism, but by greater depth of burial in conjunction with an abnormally high geothermal gradient.

CALCULATION OF COKE STABILITY

Calculation of the predicted coke stability of the coal required maceral analyses, ash and sulphur data and reflectance indices. The latter is performed on the vitrinite component only. These determinations were made and the results shown in tables 4 and 5, and in figure 4, the maceral studies having been made on only nine of the spot samples. The calculated stabilities of these nine samples are shown on the right hand side of figure 4.

The petrographic method of coke stability calculations is described in detail by Schapiro *et al.*, 1961. This method is based on the assumption that macerals can be divided into two groups, namely reactives and inerts. The reactives include vitrinite, exinite and resinite while the inerts include fusinite, micrinite and mineral matter; 1/3 of the total amount is treated as a reactive and 2/3 as inert. Semifusinite is considered as a semi-reactive and is treated as such in coke calculations. The petrographic method of coke strength prediction also assumes that there is an optimum ratio of reactives to inerts for maximum strength and this ratio changes for different ranks of coal. An imbalance of this ratio in favour of the reactive elements produces a weak frothy coke. Conversely, an imbalance in the opposite direction also will produce a weak coke because of a lack of sufficient bonding material that the reactives contribute.

From the graph showing the predicted stabilities, it can be seen that there is considerable variation in the coke potential of this seam. A predicted stability in the range of from 50 to 60 would yield a desirable product. The coal

SPOT SAMPLE NO.	DEPTH	VITRINITE	EXINITE	RESINITE	MICRINITE	SEMIFUSINITE	FUSINITE	MINERAL MATTER	TOTAL
1	0'	65	4	9	3	9	2	8	100%
9	5'	71	3	6	2	7	6	5	100%
3	15'	82	1	2	3	4	0	8	100%
4	40'	83	2	2	1	3	1	8	100%
7	50'	79	4	2	0	5	0	10	100%
14	61'	82	5	2	1	6	1	3	100%
21	67'	73	1	6	2	6	1	11	100%
5	80'	67	5	3	2	6	2	15	100%
6	90'	50	2	5	2	7	1	33	100%

Table 4: Maceral distribution in nine spot samples from Blakeburn Strip Mine. (For location *see* Figs. 2 and 4)

under study did not reach this optimum, but ranged from 0 in sample 7 to a high of 30 in sample 9. The seam composite of 22 was determined by making a composite sample from the 9 spot samples as representative of the seam and therefore is not a mathematical average.

Of the nine spot samples plotted, number 7 has the lowest predicted coke stability. From the maceral diagram (Fig. 4) it can be seen that this sample is composed of the macerals vitrinite, exinite, resinite, and semifusinite. All of these are classed as reactive macerals with the exception of semifusinite which is treated as a semi-reactive. The only truly inert material is the mineral matter. The resultant calculated stability of 0 is attributed to a deficiency of inert macerals; that is, an imbalance in the reactive-inert ratio toward the reactives.

On the other hand, sample number 9 demonstrates the highest stability calculated. This sample is composed of the macerals vitrinite, exinite and resinite which belong to the reactive category, semifusinite which is a semi-active, along with micrinite and fusinite which are inerts. Although this sample falls far short of a desirable stability figure, it still has the highest stability encountered in the seam. This high figure of 30 is due to the presence of the inert macerals which give strength to the coke. The mineral matter present, though classed as an impurity, contributes to this inert content.

	AS RECEIVED				DRY		
No. of Spot Samples	Moisture	Ash	Volatile Matter	Fixed Carbon	Ash	Volatile Matter	Fixed Carbon
1	3.57	9.16	34.42	52.85	9.50	35.69	54.81
3	3.03	9.09	33.03	54.85	9.37	34.06	56.57
4	3.17	11.78	31.64	53.41	12.17	32.68	55.15
5	3.09	18.73	31.43	46.75	19.33	32.43	48.24
6	3.28	29.38	27.36	39.98	30.38	28.29	41.33
7	3.27	12.24	21.38	63.11	12.65	22.10	65.25
9	5.09	8.23	31.61	55.07	8.67	33.31	58.02
14	2.67	10.83	29.54	56.96	11.13	30.35	58.52
21	2.41	12.77	32.24	52.58	13.09	33.04	53.87

Table 5: Proximate analyses of spot samples from Blakeburn Strip Mine (for location of samples *see* Figs. 2 and 4) (analyses performed by W.J. Montgomery, Fuels Research Centre, Mines Branch, Ottawa)

The composite seam sample produced a stability factor of 22. This factor is the most important as it represents the stability of the seam as a whole and not as a sum of its parts. The maceral composition of the seam shows 81 per cent of the reactive macerals, 8 per cent of the inerts and 11 per cent mineral impurities. These macerals show that there is an imbalance in ratio of reactives to inerts at this rank stage which is detrimental to the production of a strong coke.

In the coal studied, the ratio of inerts present to the optimum inerts required for the reactive components fall far short of the desirable figure of 1. A deficiency of inerts decreases coke strength because there is not enough to depress the formation of large vacuoles and add strength to the coke-cell walls. Therefore, the very low stability factor is due to the bright nature of the coal which only imparts swelling characteristics to the resulting coke.

Of the macerals contributing to the high percentage of reactives in the coal, vitrinite is by far the most predominant. The percentages of the other macerals are compatible with those found in other analyses of bright coals with the possible exception of resinite. Coals possessing 5 per cent or more of this maceral are considered to be high in resinite. The fact that four samples from different levels in this seam reached or exceeded this figure would class these samples as high resinous coal.

In general, there are two classes of resin found in coal, the visible and "invisible" types. The former can be seen with the unaided eye and occurs as amber nodules in the coal. The latter is the type found in the Blakeburn coal and it can be seen only under the microscope.

Resins in coal contain a high percentage of hydrogen and oxygen and so contribute to the overall volatile matter content of the coal. They also belong to the reactive group of macerals and, therefore, in the Blakeburn coal would tend to increase the total percentage of reactive to the detriment of its coking characteristics.

The "invisible" resinite is found in the coal as cell filling in vitrinite and as elliptical spheres in semifusinite. The type found as a cell filling varies in colour from dark grey to that of the surrounding vitrinite. Stach (1968) states that the elliptical resin bodies can lose their resinous characters by polymerisation and may be transformed into grey vitrinite and in a petrological analysis would have to be assessed as vitrinite or, more strictly, as semi-vitrinite. Hacquebard and Tibbetts (1960) found that the two varieties of vitrinite, namely telinite and collinite, along with resinite appeared to have different swelling properties. The best relation with the F.R.L. swelling index appeared to be with telinitic vitrinite. As resinite is possibly the most volatile of all macerals it would contribute to the swelling index of a coal. Therefore, the high resin content of this coal is a further contribution to the reactive-inert imbalance.

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