EUB/AGS Special Report 55

Petrography of Ardley Coals, Alberta - Implications for Coalbed Methane Potential

Alberta Energy and Utilities Board
Alberta Geological Survey

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Abstract

This report describes chemical and petrological characteristics of coal seams from the Ardley Coal Zone, Scollard Formation, Alberta and evaluates their coalbed methane (CBM) potential. The seams were sampled at mine sites west of Edmonton (Genessee, Highvale, Whitewood) and from outcrop sections in the Red Deer Valley, east of Red Deer. The seams were sampled 1) by full seam channel samples, which were subsequently analyzed by proximate analysis, determination of sulphur content, vitrinite reflectance and maceral analysis; and 2) by many lithotype samples from seam base to seam top to determine in-seam variations in petrographic composition.

The results indicate that all coals are subbituminous in rank and will not have generated thermally derived gas. However, biogenic gas may have been generated by interaction with circulating groundwater. Cumulative coal thickness at the locations studied is between 5 and 10 m, with individual seams having a thickness in excess of 3 m. These factors make the Ardley Coal Zone an exploration target in areas where increased coal rank at depth may have generated significant amounts of thermogenic gas. Also favourable for CBM exploration are the relatively low ash yields (11–21 wt. %) and sulphur contents (0.15–0.48 wt. %) in seams greater than 1 m in thickness.

The seams show significant differences in petrographic composition, with the highest vitrinite contents associated with the base of the coal zone (No. 6 seam at Highvale and Whitewood and No. 3 seam at Genessee). Predominant lithotypes in most seams are banded dull and dull, although some coals are characterized by predominance of banded coal and banded bright and bright lithotypes.

The comprehensive petrographic dataset on the Ardley Coal Zone presented in this report has demonstrated that

1) there exist significant compositional differences between the various seams; and

2) there exist significant in-seam compositional variations, both on the macroscopic (lithotype) and microscopic (maceral) level.

Based on previous studies, it is suggested that the brighter seams of the Ardley Coal Zone and the seams with the highest vitrinite contents will have the highest potential for gas generation and gas storage.

1 Introduction

The Ardley Coal Zone is the most extensive coal zone of the Alberta Plains (Allan and Sanderson, 1945; Campbell, 1967; Holter et al., 1975, Richardson et al., 1988). The coals are subbituminous near the surface, but may attain higher rank levels at greater depth, suitable for the formation and retention of economically producible coalbed methane (Rottenfusser et al., 1991; Dawson et al., 2000; Beaton et al., 2002).

Stratigraphically, the coal zone forms part of the Upper Cretaceous–Tertiary Scollard Formation, the youngest formation in the Edmonton Group (Gibson, 1977). Strata of the Ardley Coal Zone are dominated by argillaceous and benthonitic sandstone, siltstone and mudstone, with major coal seams greater than 3 m in thickness. The depositional environment is that of a fluvial upper delta plain–lacustrine setting (Dawson et al., 1985; Richardson et al., 1988), in which extensive and thick peat deposits accumulated. Thin bentonite layers occur frequently within the coal seams (Demchuk and Nelson-Gladiotis, 1993) and indicate that the peat-forming wetlands were exposed periodically to volcanic-ash falls.

This report focuses on a detailed petrographic description of coal seams collected from the Ardley Coal Zone west of Edmonton (Figure 1). The coal seams were sampled at three mine locations (Genessee, Highvale and Whitewood) that cover the complete coal-bearing interval of the Ardley Zone in these areas. The sample set consists of 28 full-seam channel samples, for which reflectance data, data from maceral analysis and results from proximate analysis are given.

In addition, each seam has been described in terms of lithotypes, followed by sampling of each lithotype to determine by maceral analysis the in-seam petrographic characteristics from seam base to seam top. The total number of analyzed seam subsamples is on the order of 430 samples, which form a comprehensive dataset for studies on the in-seam characteristics of Ardley coal seams.

The report also includes petrographic analysis of coal seams collected at outcrops in the vicinity of the Red Deer River (Knudson mine, Stamp pit, Ardley Bend).

For each mine location, spreadsheets have been created that contain petrographic data (macerals, vitrinite reflectance), data from proximate analysis and sulphur contents (Appendices 1–6), along with graphical displays consisting of a composite section showing variations in petrographic composition and coal quality for the entire coal-bearing interval and petrographic in-seam variations for each seam. The outcrop samples from the Red Deer River Valley are described petrographically in terms of full seam characteristics (Appendices 7–10).

The dataset reported here will define petrographic characteristics for the Ardley coal seams and will help in the evaluation of the CBM potential for those areas where the Ardley coal seams are at depth.

2 Sampling and Analytical Procedures

Coal seams exposed at the mine sites were sampled by collecting 1) full-seam channel samples of the whole seam, and 2) lithotype samples of individual seams with a minimum thickness of 1 cm. The lithotypes were defined as follows: B, Bright; BB, Banded Bright; BC, Banded Coal; BD, Banded Dull; D, Dull; F, Fibrous. The total number of coal samples is greater than 400. In addition, roof and floor rocks, as well as partings, were collected, but these have not yet been analyzed. The outcrop samples from the Red Deer River area were collected as full-seam channel samples.

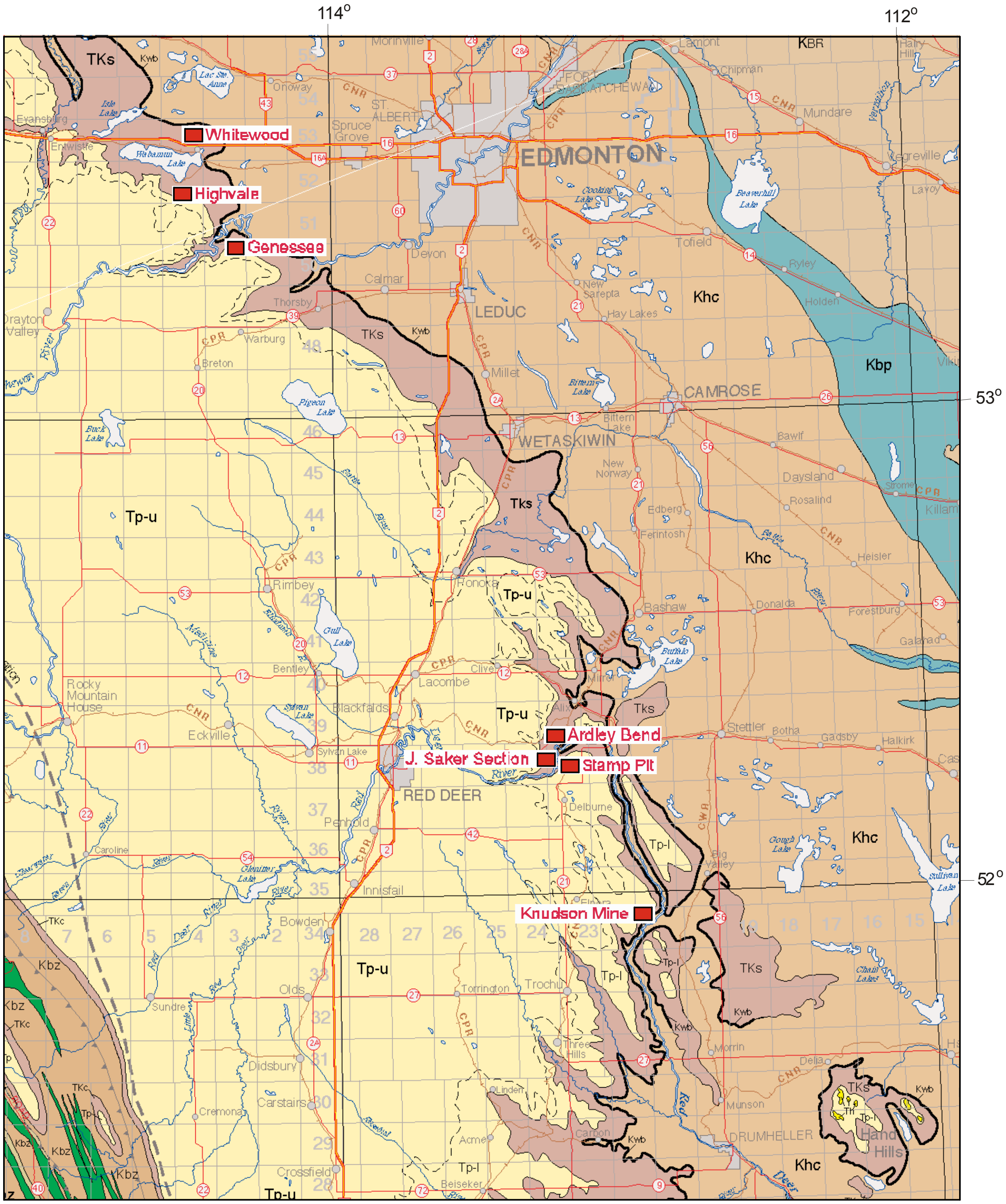

Figure 1. Location of mines on the Ardley Coal Zone west of Edmonton and outcrop locations sampled in the vicinity of the Red Deer River Valley. For exact location of individual samples, see UTM Easting and Northing in Appendix 1.

Analytical procedures included incident light microscopy (Bustin et al., 1989) to determine vitrinite reflectance and petrographic composition (macerals), proximate analysis (volatile matter, fixed carbon, ash) and total sulphur analysis according to ASTM standards. Representative subsamples are stored at the Geological Survey of Canada in Calgary if additional analysis is required.

3 Results

3.1 Genessee Mine

3.1.1 Full-Seam Channel Samples

Six coal seams are developed in the Ardley Coal Zone at the Genessee mine of which the No. 2 (Upper Main) and No. 3 (Lower Main) seams are the economically most important, with thicknesses of 2.89 and 1.60 m, respectively. Ash yields vary from 7.75 to 23.41 wt. % and sulphur contents range from 0.22 to 0.44 wt. % (Appendix 1).

There exist significant differences between the seams in terms of petrographic composition (Figure 2), with seams Nos. 1 and 2 relatively enriched in inert macerals, whereas No. 2 Rider, No. 2A and the Cloud seam are enriched in vitrinite macerals. Seam No. 3 has an intermediate composition. The reflectance values of 0.44%–0.52% random vitrinite reflectance in oil (Ro) indicate sub-bituminous rank (Appendix 1).

A summary of petrographic and chemical characteristics for the major seams at Genessee is given in Figures 2 and 3 and in Appendices 1 and 2.

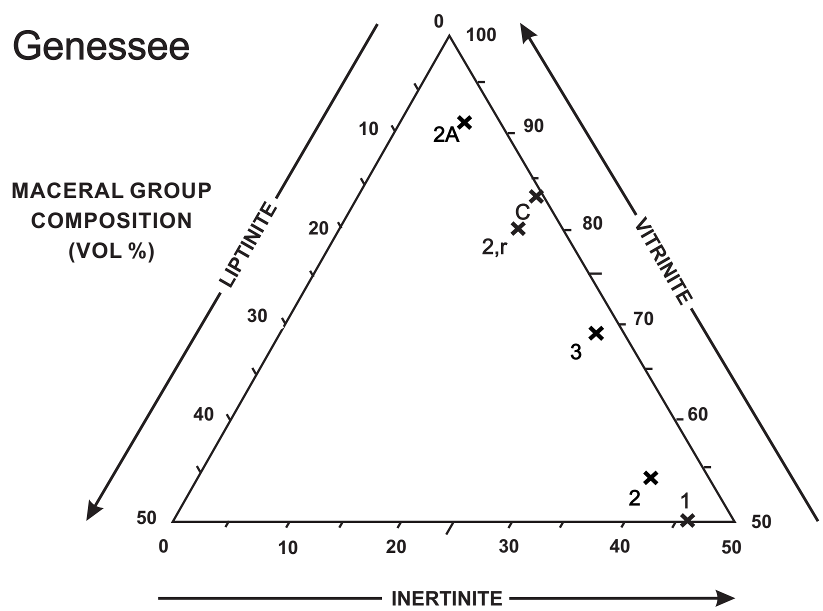

Figure 2. Ternary diagram showing maceral distribution of Genessee mine coals. Numbers refer to seam numbers; C refers to Cloud Seam.

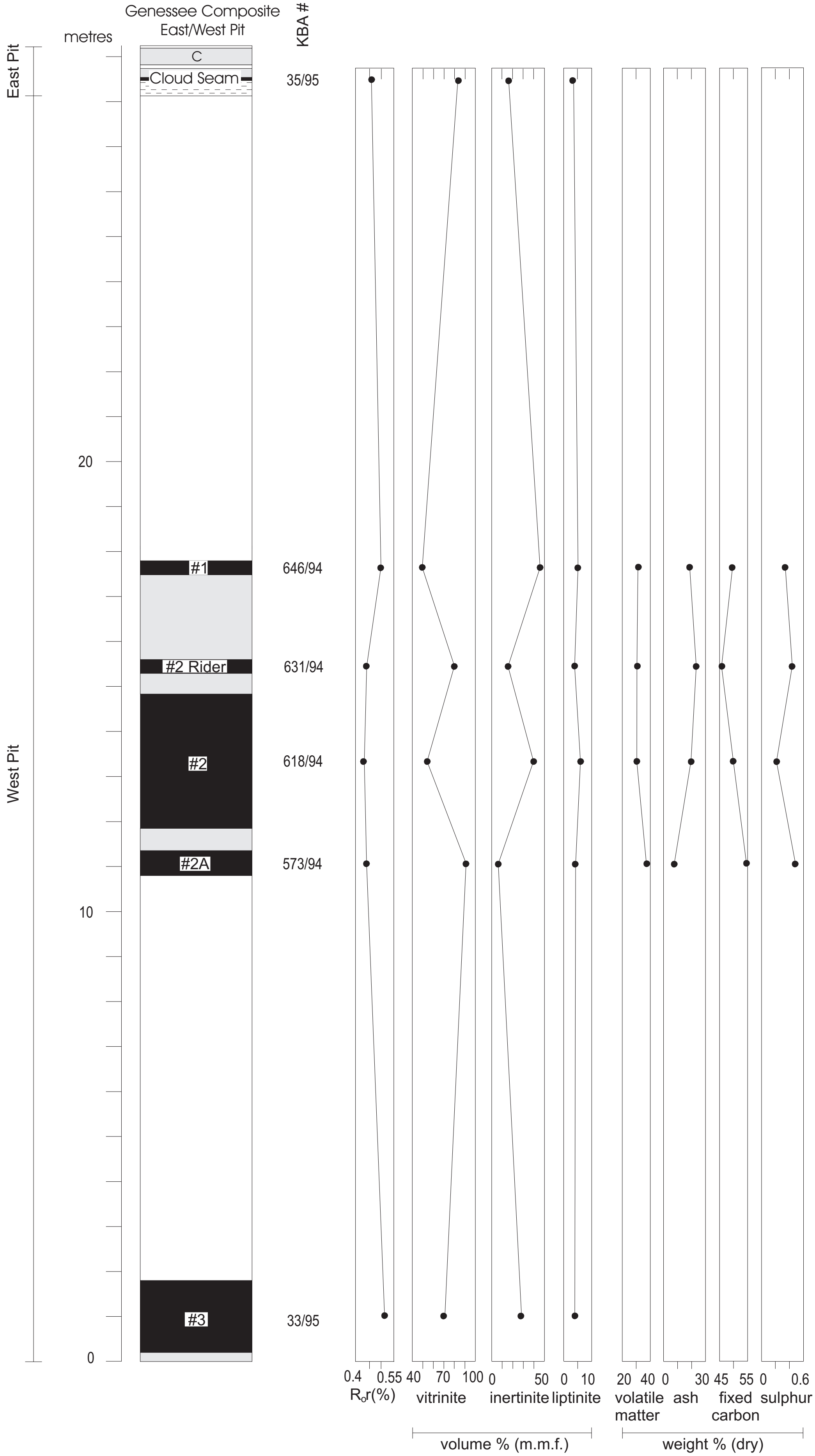

Figure 3. Composite section of the Ardley Coal Zone at the Genessee mine, showing full-seam characteristics. See Figure 4 legend for lithological description of associated strata.

3.1.2 Seam Subsection (Lithotype) Samples

Cloud Seam

The Cloud seam occurs at the top of the Ardley Coal Zone (Figure 3). The seam is laterally discontinuous and consists at the sample site of 7 cm of coal at the base, overlain by 20 cm of coaly mudstone (Figure 4). A detailed lithological log of over- and underlying strata, along with petrographic properties of the coal and the coaly mudstone, is given in Appendix 3.

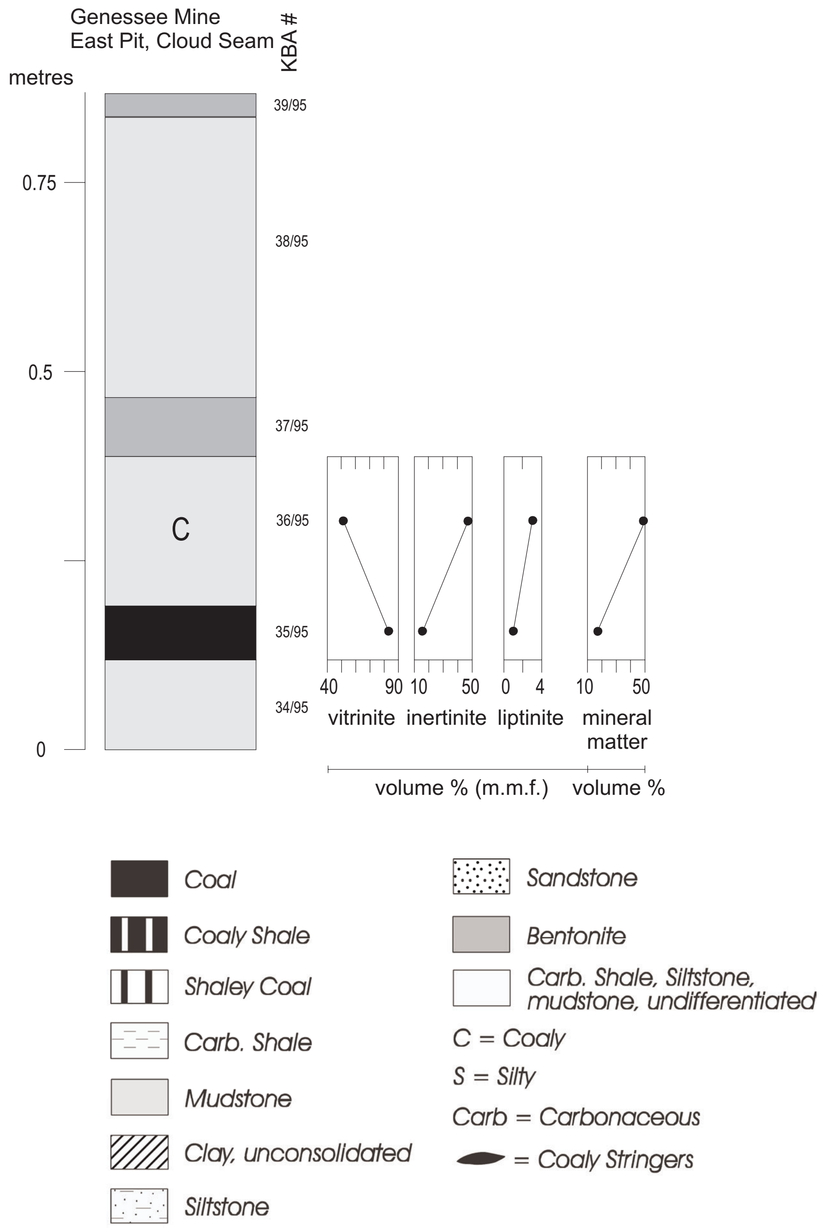

Figure 4. Cloud seam interval, Genessee mine, East pit and lithology of associated strata.

No. 1 Seam

Seam No. 1 has a thickness of 31 cm (Figure 5). Two thin rider seams (8 and 6 cm, respectively) are developed above the No. 1 seam and a thin coal (4 cm) occurs below (Figure 5). The seam is dominated by dull and banded dull lithotypes with a thin bright coal developed in the central part of the lower leaf (Figure 5). The overall lithotype distribution in seam No. 1 is as follows: B + BB = 32.6%; BC = 20.5%; BD + D = 46.9%. Vitrinite content is highest in the bright and banded bright lithotypes and lowest in the dull and banded dull lithotypes (Figure 5). A detailed lithological log of the No. 1 seam interval, along with petrographic properties of the coal lithotypes, is given in Appendix 3.

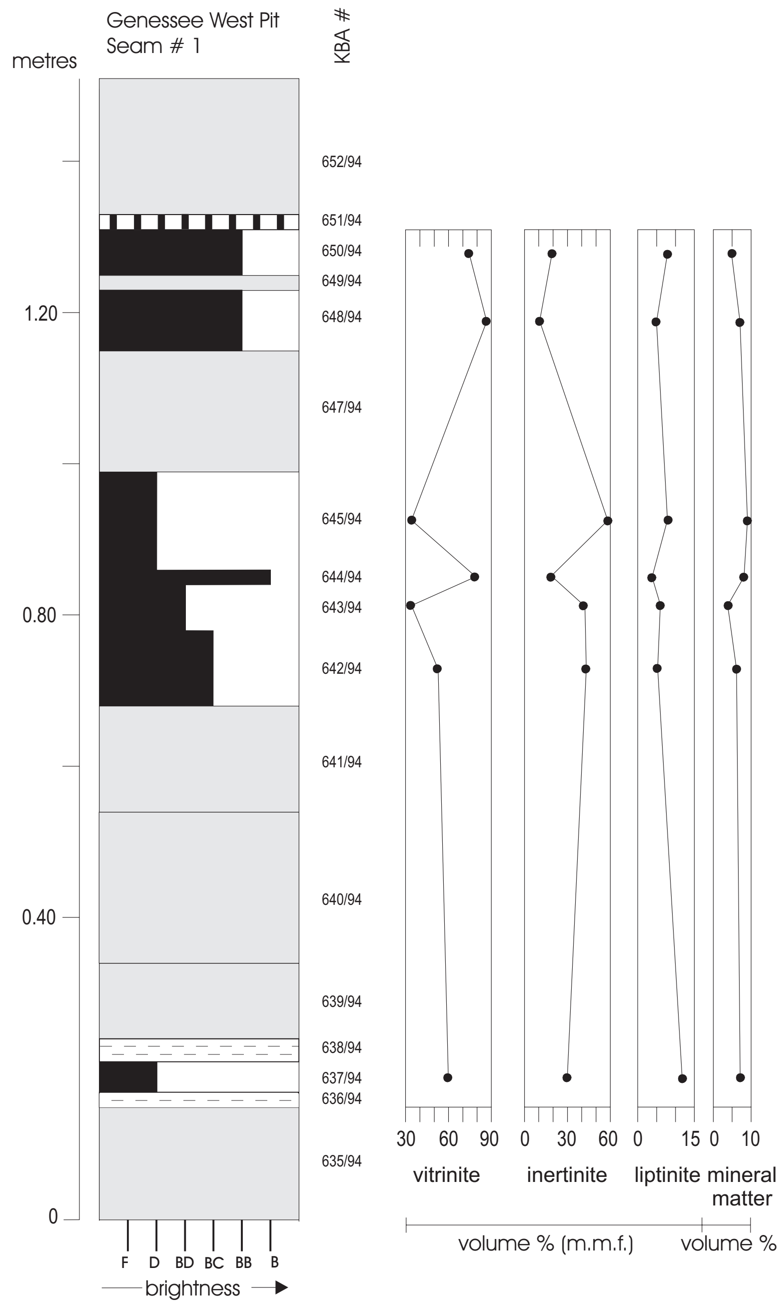

Figure 5. No. 1 seam interval, Genessee mine, West pit. See Figure 4 legend for lithological description of associated strata.

No. 2 Rider Seam

The No. 2 Rider seam is 0.34 cm thick (Figure 6), with a thin mudstone parting in the center. The seam is dominated by bright and banded bright lithotypes in the basal part of the seam and banded dull and banded coal in the upper (Figure 6). Two thin, fibrous layers occur at the seam base. The overall lithotype distribution in the No. 2 Rider seam is as follows: F = 10%; B + BB = 40%; BC = 23.3%; BD + D = 26.7%. Apart from the two fibrous layers at the seam base, vitrinite content appears to decrease toward the seam top (Figure 6). A detailed lithological log of the No. 2 Rider seam interval, along with petrographic properties of the coal lithotypes, is given in Appendix 3.

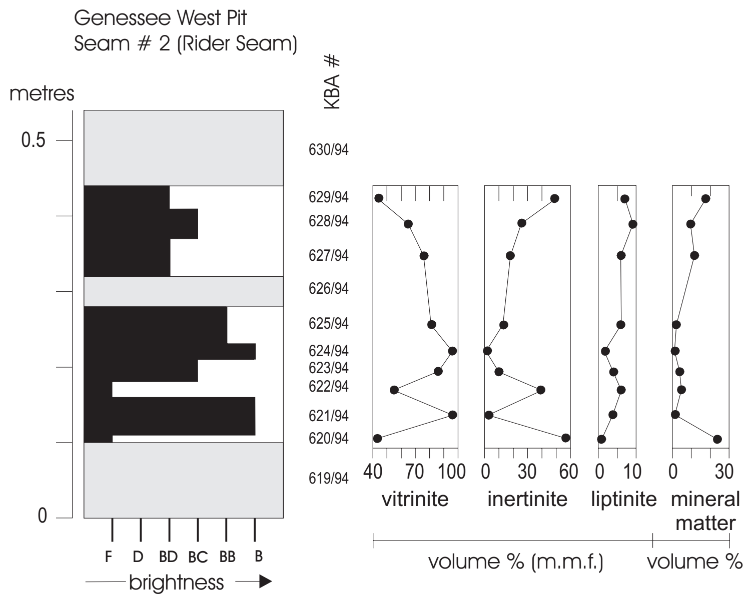

Figure 6. No. 2 Rider seam interval, Genessee mine, West pit. See Figure 4 legend for lithological description of associated strata.

No. 2 (Upper Main) Seam

The No. 2 seam has a thickness of 2.98 m (Figure 7), with frequent thin partings toward the top of the seam. The seam is dominated by dull and banded dull lithotypes and shows a dulling-upward sequence at the top (Figure 7). The overall lithotype distribution in seam No. 2 is as follows: B + BB = 18.5%; BC = 24.6%; BD + D = 56.9%. There is a general trend of decreasing vitrinite contents from seam base to seam top (Figure 7). A detailed lithological log of the No. 2 seam interval, along with petrographic properties of the coal lithotypes, is given in Appendix 3.

No. 2A Seam

The No. 2A seam is 55 cm thick (Figure 8), with a thin siltstone parting toward the top. The seam is dominated by banded coal showing a trend to duller lithotypes toward seam base and seam top (Figure 8). The overall lithotype distribution in seam No. 2A is as follows: F = 2%; B + BB = 20.4%; BC = 55.2%; BD + D = 22.4%. There is a general trend of decreasing vitrinite contents from seam base (except in the fibrous layer) to the parting at the seam top, followed by increasing vitrinite contents in the upper layers (Figure 8). A detailed lithological log of the No. 2A seam interval, along with petrographic properties of the coal lithotypes, is given in Appendix 3.

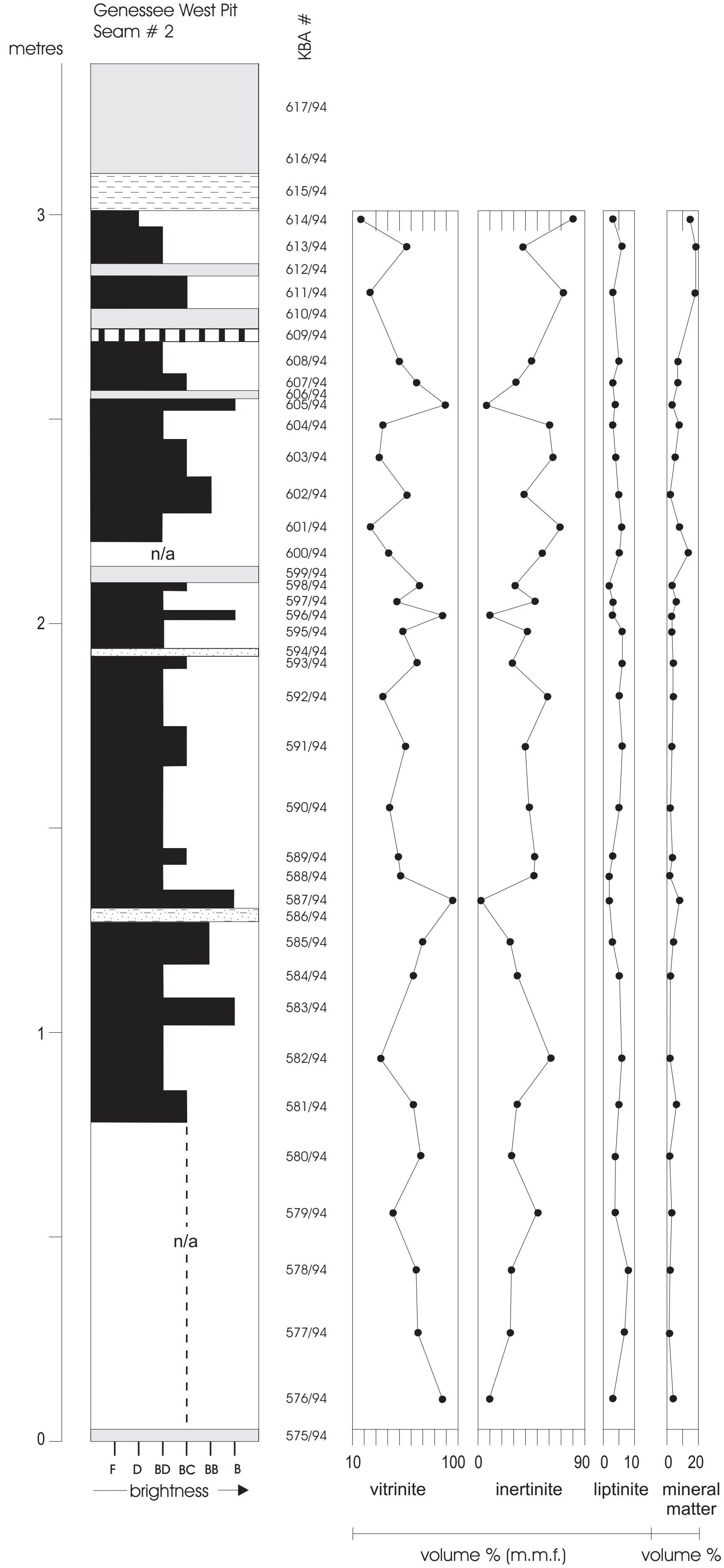

Figure 7. No. 2 Rider seam interval, Genessee mine, West pit. See Figure 4 legend for lithological description of associated strata.

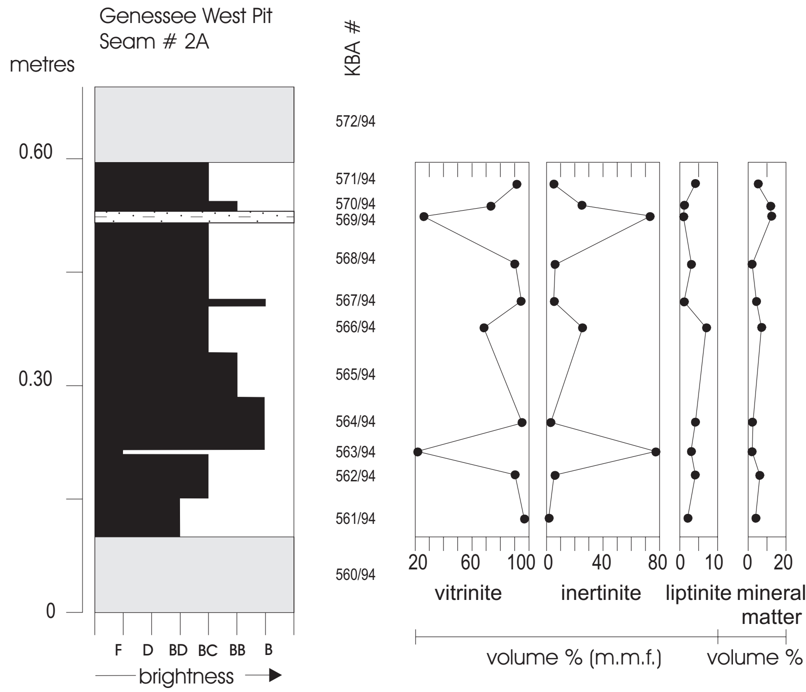

Figure 8. No. 2A seam interval, Genessee mine, West pit. See Figure 4 legend for lithological description of associated strata.

No. 3 (Lower Main) Seam

The No. 3 seam is the stratigraphically lowest of the Ardley coals exposed at the Genessee mine (Figure 3). The seam is 1.60 m thick (Figure 9), with thin mudstone partings near the base and top. The seam is dominated by dull and banded dull lithotypes showing dulling-upward sequences below the upper parting and the top of the seam (Figure 9). The overall lithotype distribution in seam No. 3 is as follows: F=0.7%; B+BB=28.34%; BC=21.72%; BD=D=49.3%. Vitrinite and inertinite contents generally follow the lighotype distribuiton, with vitrinite enriched in bright and banded bright lithotypes and inertinite enriched in the dull and banded dull lithotypes (Figure 9). A detailed lithological log of the No. 3 seam interval, along with petrographic properties of the coal lithotypes, is given in Appendix 3.

3.2 Highvale Mine, Pit 02S

3.2.1 Full-Seam Channel Samples

Six coal seams are developed in the Ardley Coal Zone at the Highvale mine, pit 02S, of which the No. 1 and 2 seams are the economically most important, with thicknesses of 2.10 m and 2.97 m, respectively. Seam 5 has a thickness of only 19 cm and was therefore not sampled for coal-quality analysis. Ash yields vary from 11.48 to 33.02 wt. % and sulphur contents range from 0.19 to 0.46 wt. % (Appendix 1).

There exist significant differences between the seams in terms of petrographic composition (Figure 10), with seams 1 to 4 relatively enriched in inert macerals (all >30 vol. %), whereas seam 6 is enriched in vitrinite macerals (75 vol. %). Seam No. 5 (not shown in Figure 10) has the highest inertinite content (47 vol. %). The reflectance values (0.40%–0.44% Ro) indicate sub-bituminous rank (Appendix 1).

A summary of petrographic and chemical characteristics for the major seams at the Highvale mine, pit 02S, is given in Figures 10 and 11 and in Appendices 1 and 2.

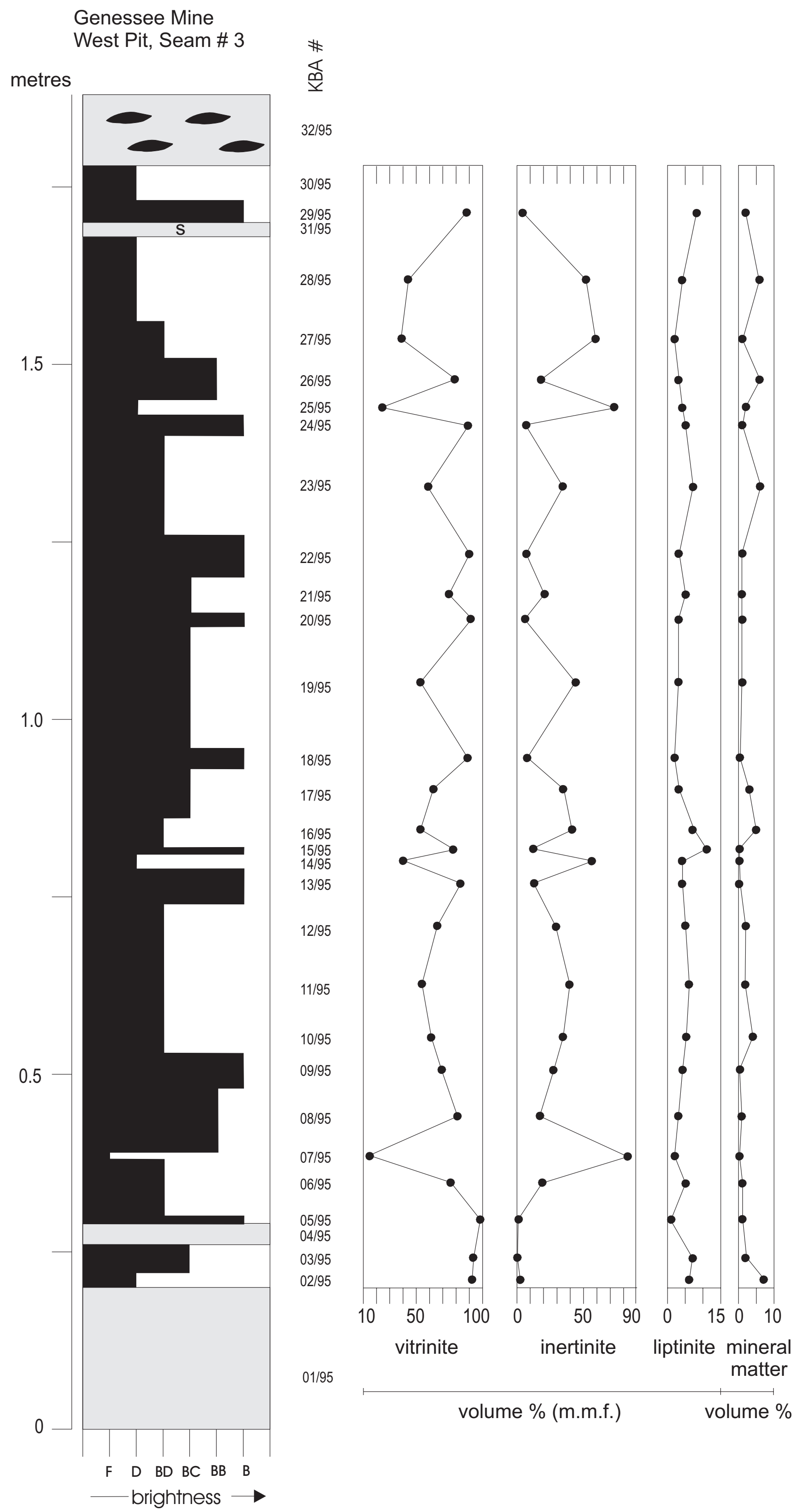

Figure 9. No. 3 seam interval, Genessee mine, West pit. See Figure 4 legend for lithological description of associated strata.

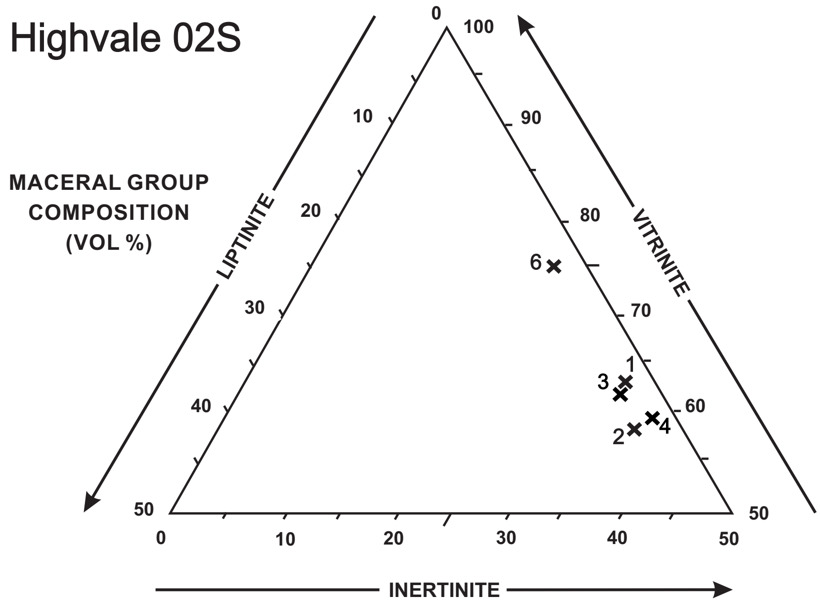

Figure 10. Ternary diagram showing maceral distribution of Highvale mine, pit 02S coals. Numbers refer to coal

3.2.2 Seam Subsection (Lithotype) Samples

Seam No. 1

Seam No. 1 occurs at the top of the Ardley Coal Zone (Figure 11) and has a thickness of 2.10 m. A thin silty mudstone parting occurs in the upper part of the seam (Figure 12). The seam is dominated by dull and banded dull lithotypes, alternating with thin bright and banded bright layers. There are brightening upward trends below the parting near the top of the seam and at the very top (Figure 12). The overall lithotype distribution in seam No. 1 is as follows: B + BB = 30.1%; BC = 22.5%; BD + D = 47.4%. Vitrinite content is highest in the bright and banded bright lithotypes and lowest in the dull and banded dull lithotypes (Figure 12). A detailed lithological log of over- and underlying strata, along with petrographic properties of the coal lithotypes, is given in Appendix 4.

Seam No. 2

Seam No. 2 has a thickness of 2.97 m (Figure 13). Thin partings occur predominantly in the upper part of the seam (Figure 13). The seam is dominated by dull and banded dull lithotypes and banded coal, alternating with thin bright and banded bright layers and fibrous coal. Within the seam there occur several brightening-upward and dulling-upward sequences, which are associated with highly variable vitrinite and inertinite contents (Figure 13). The overall lithotype distribution in seam No. 2 is as follows: F = 1.7%; B + BB = 29.7%; BC = 32.7%; BD + D = 35.8%. Vitrinite content is highest in the bright and banded bright lithotypes and lowest in the dull and banded dull lithotypes (Figure 13). A detailed lithological log of the seam No. 2 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 4.

Seam No. 3

Seam No. 3 is 0.65 m thick (Figure 14), with a thin carbonaceous shale parting at the base. A thin rider seam (4 cm) is developed 20 cm above the seam top. The seam is dominated by banded coal and shows dull coal in the central portion with brighter lithotypes towards seam base and top (Figure 14). The

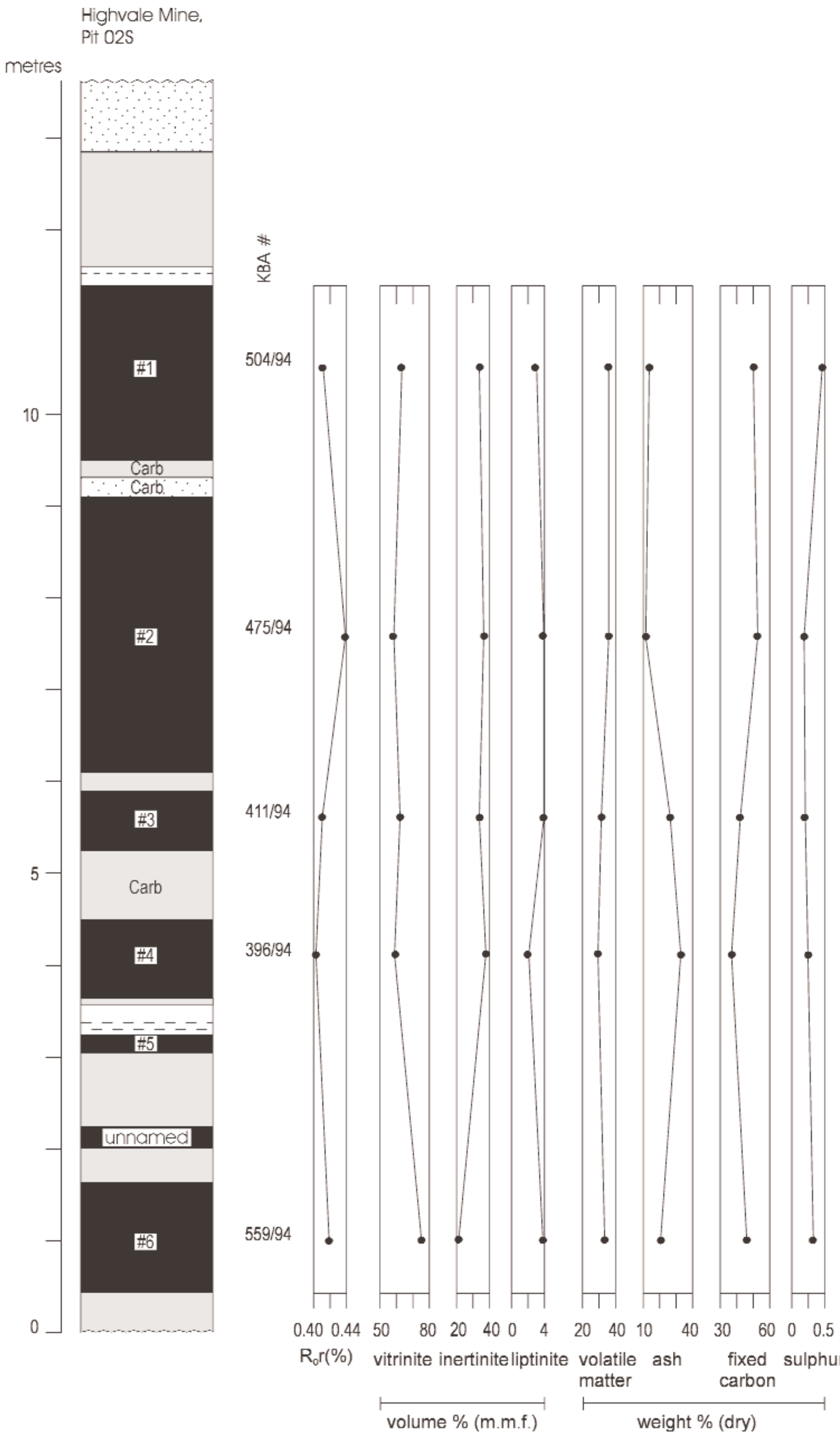

Figure 11. Composite section of the Ardley Coal Zone at the Highvale mine, pit 02S, showing full-seam characteristics. See Figure 4 legend for lithological description of associated strata.

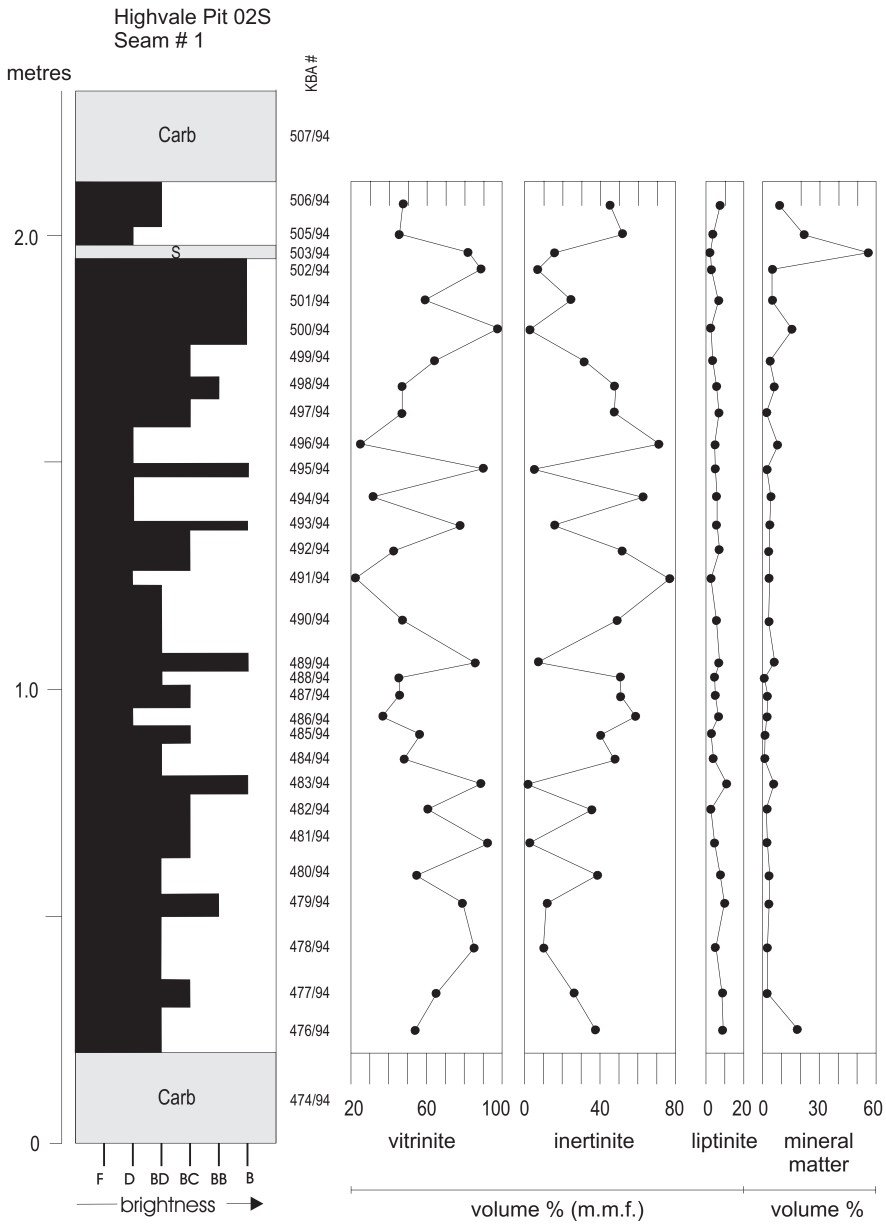

Figure 12. Seam No. 1 interval, Highvale mine, pit 02S. See Figure 4 legend for lithological description of associated strata.

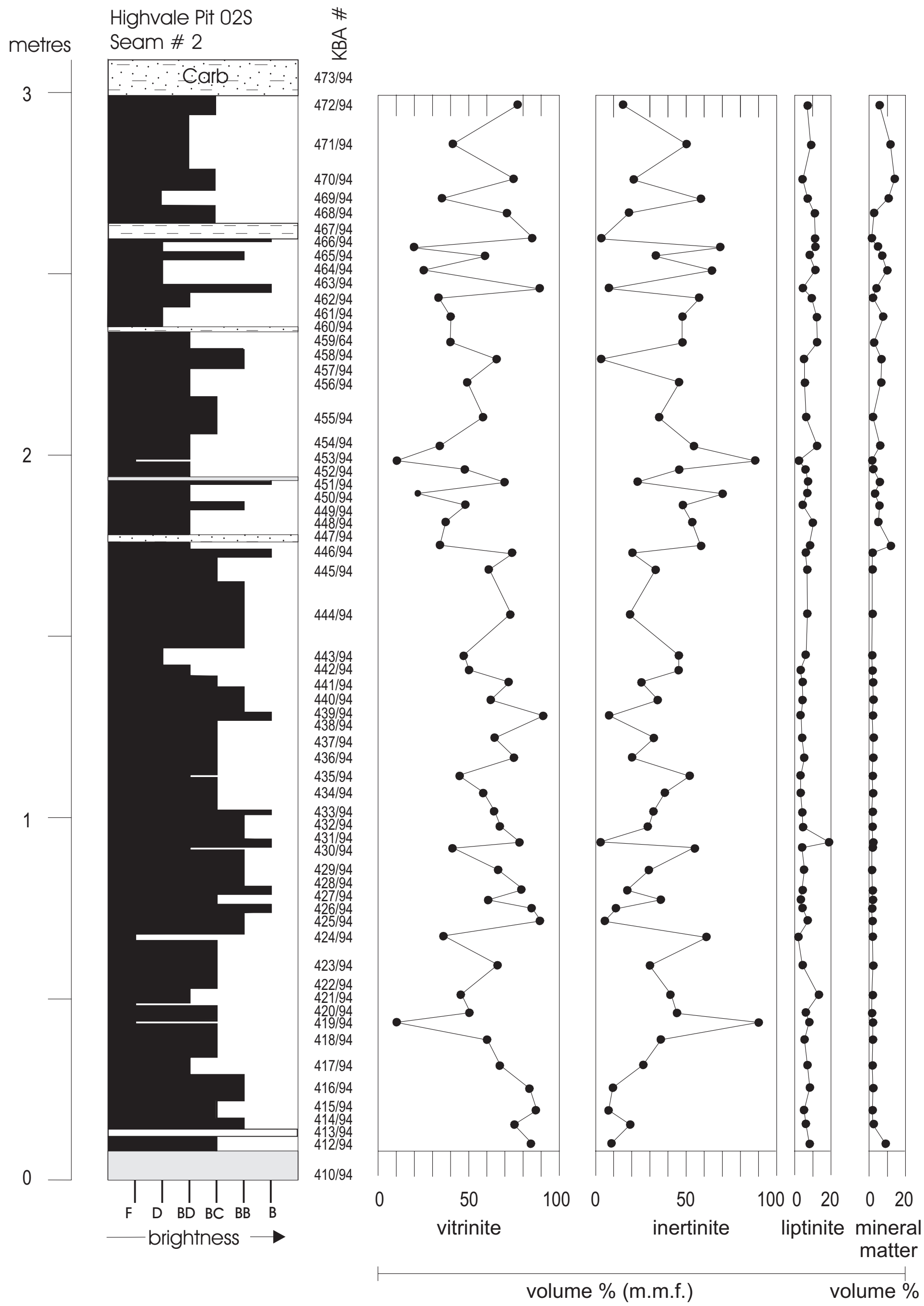

Figure 13. Seam No. 2 interval, Highvale mine, pit 02S. See Figure 4 legend for lithological description of associated strata.

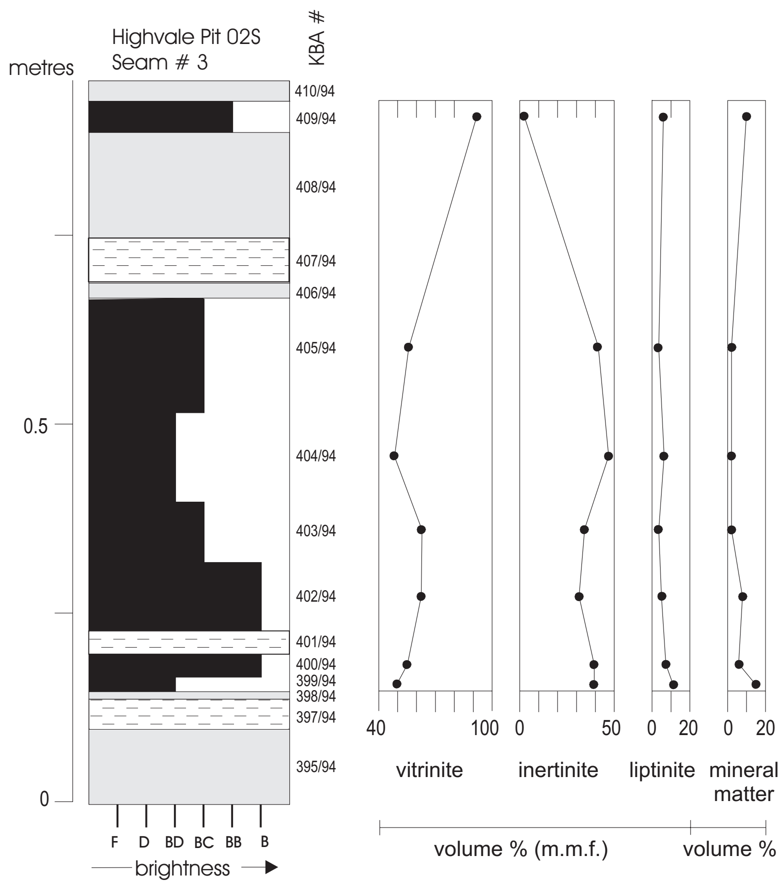

Figure 14. Seam No. 3 interval, Highvale mine, pit 02S. See Figure 4 legend for lithological description of associated strata.

overall lithotype distribution in seam No. 3 is as follows: B + BB = 30.1%; BC = 43.4%; BD + D = 26.5%. There is a trend to higher vitrinite contents near seam base and top and also in the Rider seam, whereas vitrinite content is lowest in the central part of the seam (Figure 14). A detailed lithological log of the seam No. 3 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 4.

Seam No. 4

Seam No. 4 has a thickness of 0.90 m (Figure 15). The seam is dominated by dull and banded dull lithotypes, followed by banded coal. It shows a brightening-upward sequence from seam base toward the central part, followed by a dulling-upward sequence toward the top (Figure 15). The overall lithotype distribution in seam No. 4 is as follows: B + BB = 6.4%; BC = 42.3%; BD + D = 51.3%. Vitrinite content is highest in the central part of the seam and decreases towards seam base and top (Figure 15). A detailed lithological log of the seam No. 4 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 4.

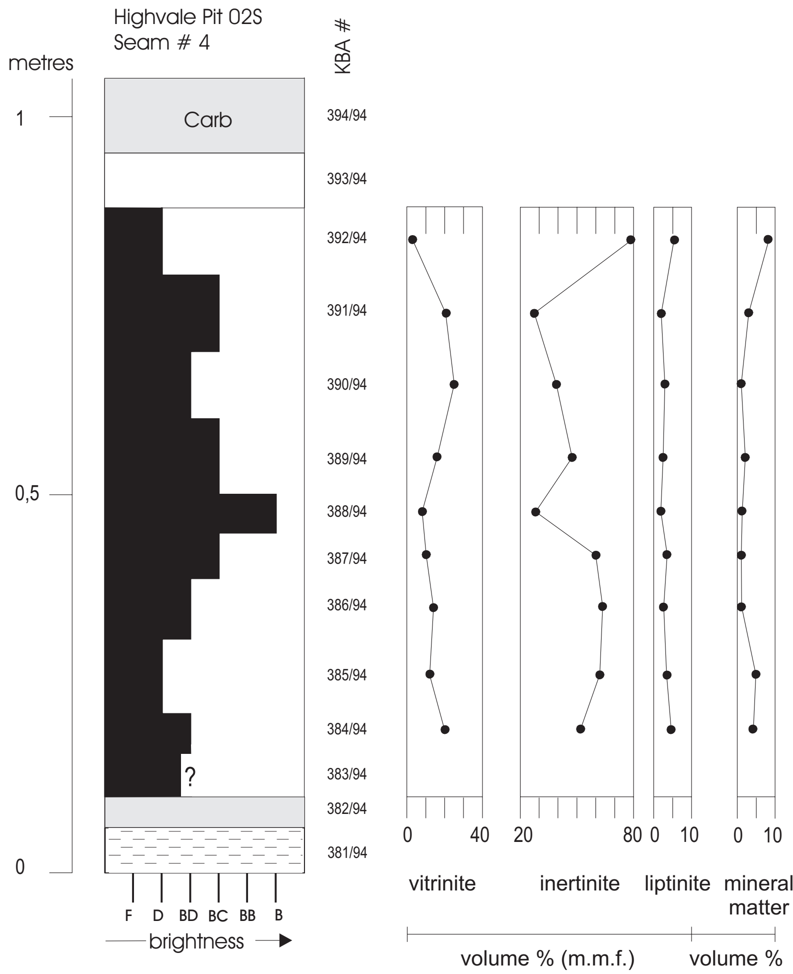

Figure 15. Seam No. 4 interval, Highvale mine, pit 02S. See Figure 4 legend for lithological description of associated strata.

Seam No. 5

Seam No. 5 is 0.19 m thick (Figure 16), with a 3 cm carbonaceous shale parting separating a lower and an upper layer. The lower layer is banded coal; the upper layer is banded dull. The overall lithotype distribution in seam No. 5 is as follows: BC = 50.0%; BD + D = 50.0%. A detailed lithological log of the seam No. 5 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 4.

Seam No. 6

Seam No. 6 is the stratigraphically lowest of the Ardley coals exposed at the Highvale mine, pit 02S (Figure 11). The seam is 1.20 m thick (Figure 17), with two carbonaceous siltstone partings in the central and top portions of the seam. The seam is dominated by dull and banded dull lithotypes, followed by banded coal. The seam shows a predominance of bright lithotypes for the basal part, whereas banded coal and banded dull coal dominate in the upper part (Figure 17). The overall lithotype distribution in seam No. 6 is as follows: B + BB = 25.8%; BC = 31.8%; BD + D = 42.4%. Vitrinite content is highest in the basal part of the seam and decreases toward seam top (Figure 17). A detailed lithological log of the seam No. 6 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 4.

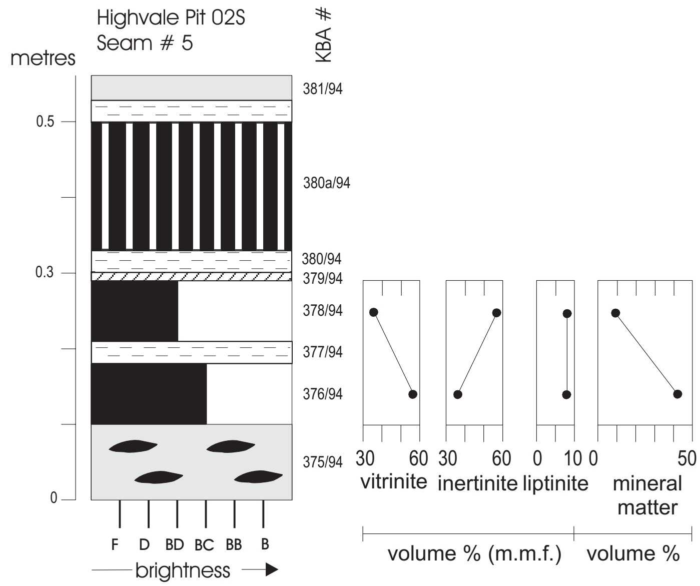

Figure 16. Seam No.5 interval, Highvale mine, pit 02S. See Figure 4 legend for lithological description of associated strata.

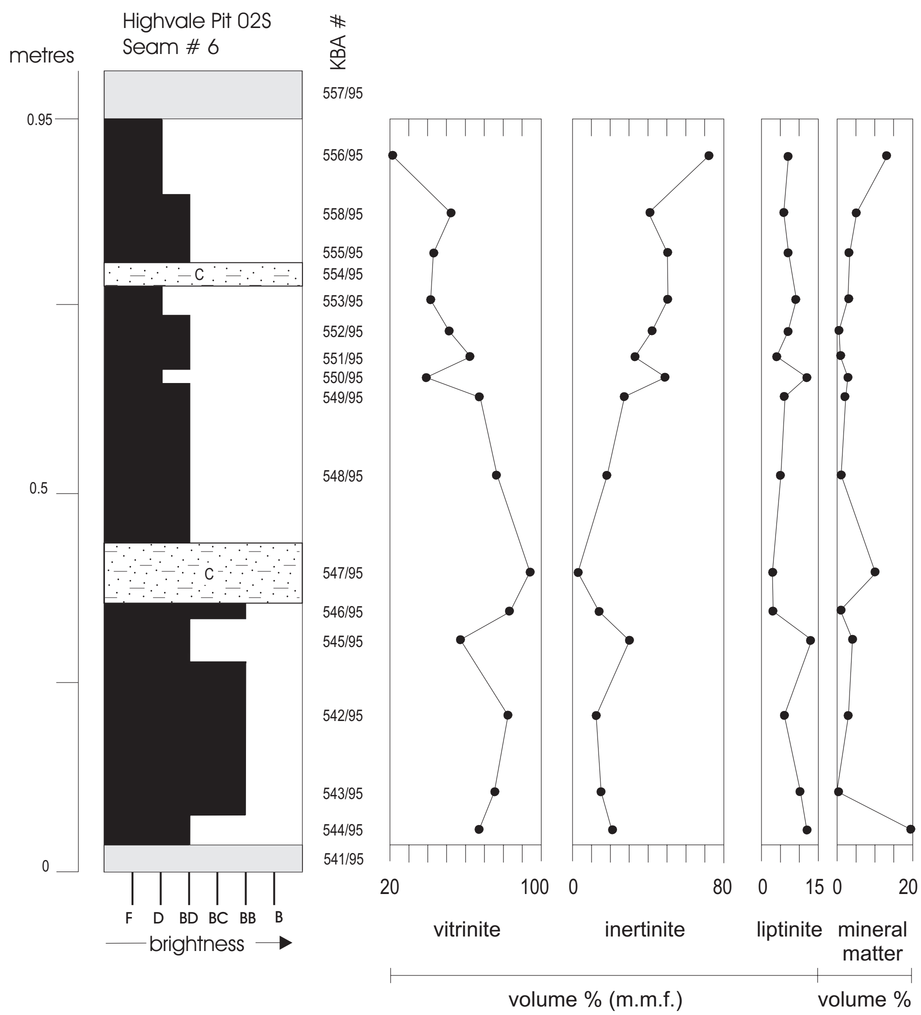

Figure 17. Seam No. 6 interval, Highvale mine, pit 02S. See Figure 4 legend for lithological description of associated strata.

3.3 Highvale Mine, Pit 02N

3.3.1 Full-Seam Channel Samples

Six coal seams are developed in the Ardley Coal Zone at the Highvale mine, pit 02N, of which the No. 1 and No. 2 seams are the economically most important, with thicknesses of 3.10 and 3.42 m, respectively. Seam No. 5 was not sampled at this location. Ash yields vary from 9.10 to 22.26 wt. % and sulphur contents range from 0.15 to 0.34 wt. % (Appendix 1).

There exist significant differences between the seams in terms of petrographic composition (Figure 18), with seams 1, 2 and 4 being relatively enriched in inert macerals (39–45 vol. %), whereas seam 6 is enriched in vitrinite macerals (65 vol. %). The reflectance values (0.40%–0.44% Ro) indicate sub-bituminous rank (Appendix 1).

A summary of petrographic and chemical characteristics for the seams at the Highvale mine, pit 02N, is given in Figures 18 and 19 and in Appendices 1 and 2.

At the Highvale mine, pit 02N, no lithotype description for the seams is available, and no seam subsamples were taken.

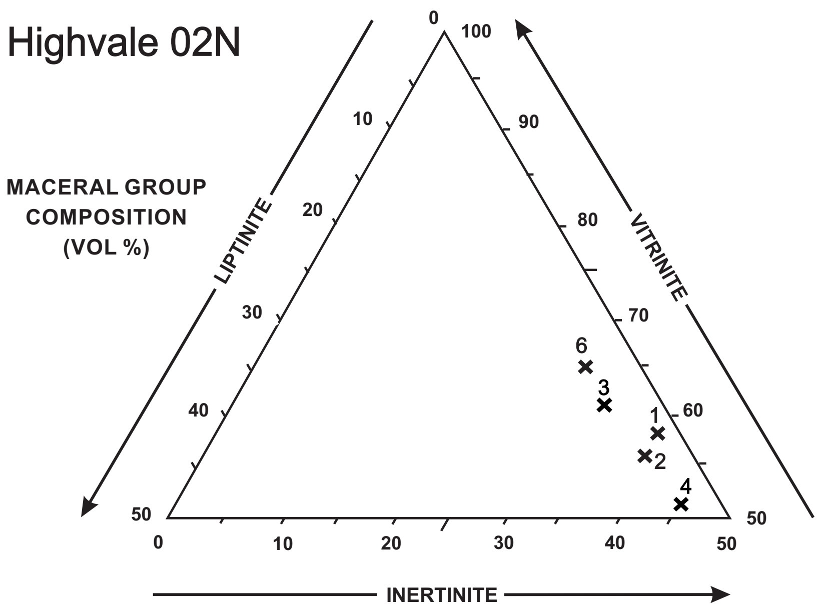

Figure 18. Ternary diagram, showing maceral distribution of Highvale mine, pit 02N coals. Numbers refer to coal seams.

3.4 Highvale Mine, Pit 03

3.4.1 Full-Seam Channel Samples

Six coal seams are developed in the Ardley Coal Zone at the Highvale mine, pit 03, of which the No. 1 and No. 2 seams are the economically most important, with thicknesses of 3.83 and 3.28 m, respectively. Seam 5 has a thickness of only 30 cm and was therefore not sampled for coal-quality analysis. Ash yields vary from 16.99 to 24.00 wt. % and sulphur contents range from 0.18 to 0.38 wt. % (Appendix 1).

There exist significant differences between the seams in terms of petrographic composition (Figure 20), with seams 1 to 4 relatively enriched in inert macerals (all >30 vol. %), whereas seam 6 is enriched in vitrinite macerals (75 vol. %). Seam No. 5 (not shown in Figure 20) has the highest inertinite content (50 vol. %). The reflectance values (0.43%–0.45% Ro) indicate sub-bituminous rank (Appendix 1).

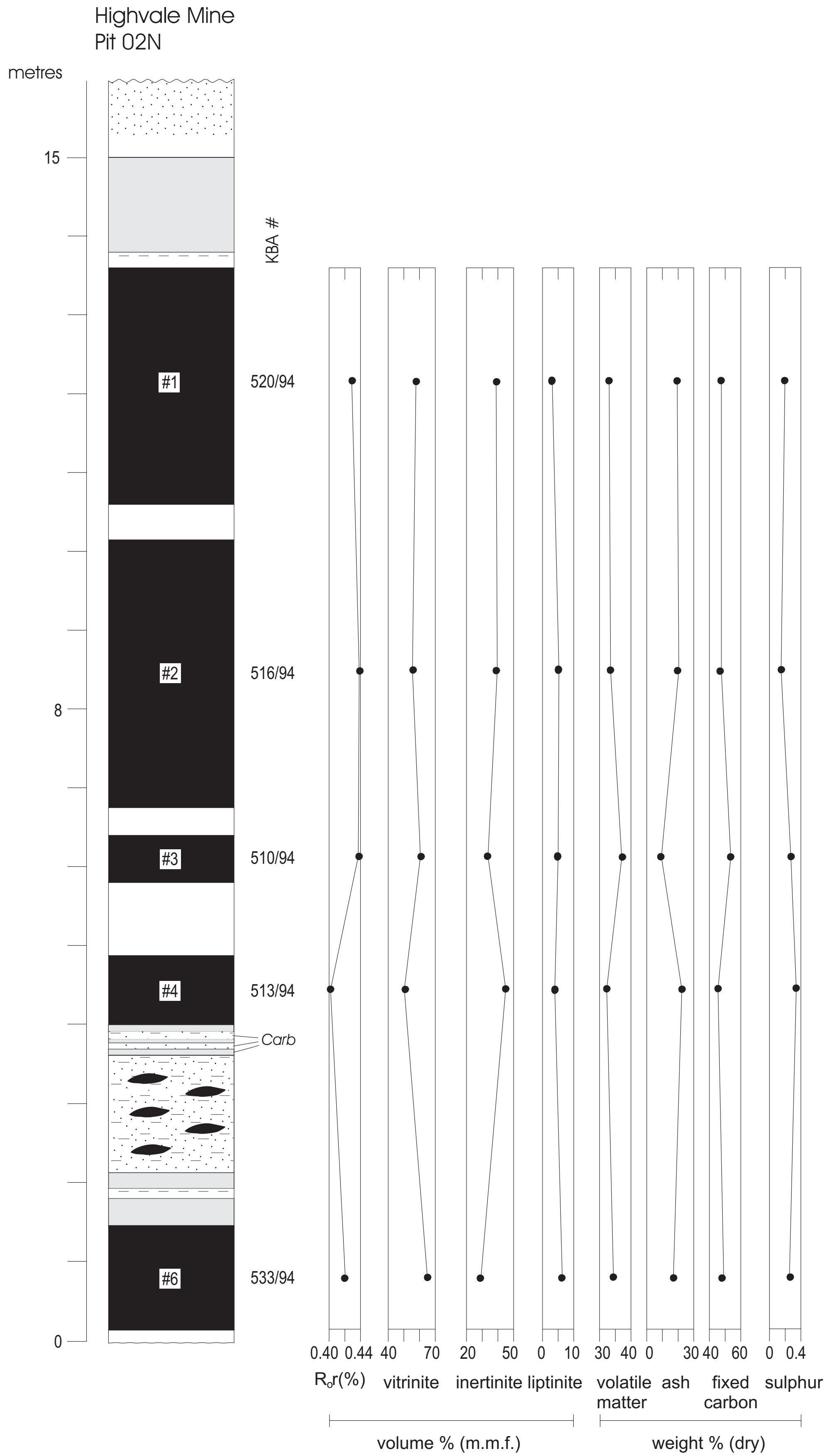

Figure 19. Composite section of the Ardley Coal Zone at the Highvale mine, pit 02N, showing full-seam characteristics.

A summary of petrographic and chemical characteristics for the major seams at the Highvale mine, pit 03, is given in Figures 20 and 21 and in Appendices 1 and 2.

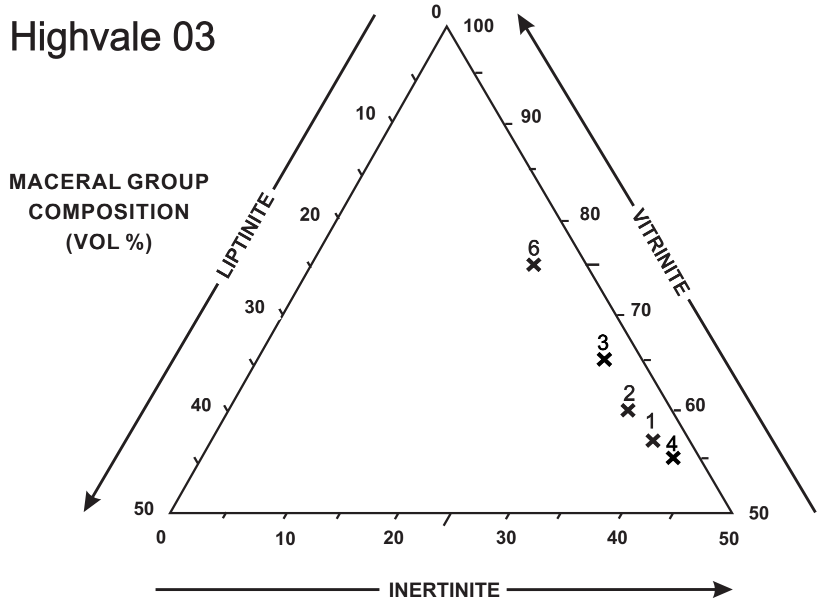

Figure 20. Ternary diagram showing maceral distribution of Highvale mine, pit 03 coals. Numbers refer to coal seams.

3.4.2 Seam Subsection (Lithotype) Samples

Seam No. 1

Seam No. 1 occurs at the top of the Ardley Coal Zone (Figure 21) and has a thickness of 3.83 m. The seam is characterized by a number of thin mudstone partings in its central part (Figure 22). A coaly siltstone layer at the top separates seam No. 1 from a thin rider seam (10 cm thick). The seam is dominated by banded coal (Figure 22). The overall lithotype distribution in seam No. 1 is as follows: B + BB = 27.3%; BC = 47.9%; BD + D = 24.83%. In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes (Figure 22). A detailed lithological log of over- and underlying strata, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

Seam No. 2

Seam No. 2 has a thickness of 3.28 m (Figure 23). The seam is dominated by dull and banded dull lithotypes (Figure 23), with a brightening- and dulling-upward sequence in the central part of the seam and a 5 cm thick fibrous layer near the seam top. The overall lithotype distribution in seam No. 2 is as follows: F = 1.5%; B + BB = 10.5%; BC = 29.6%; BD + D = 58.4%. There is a distinct trend to lower vitrinite contents from seam base toward the upper parting, whereas inertinite contents increase (Figure 23). A detailed lithological log of the seam No. 2 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

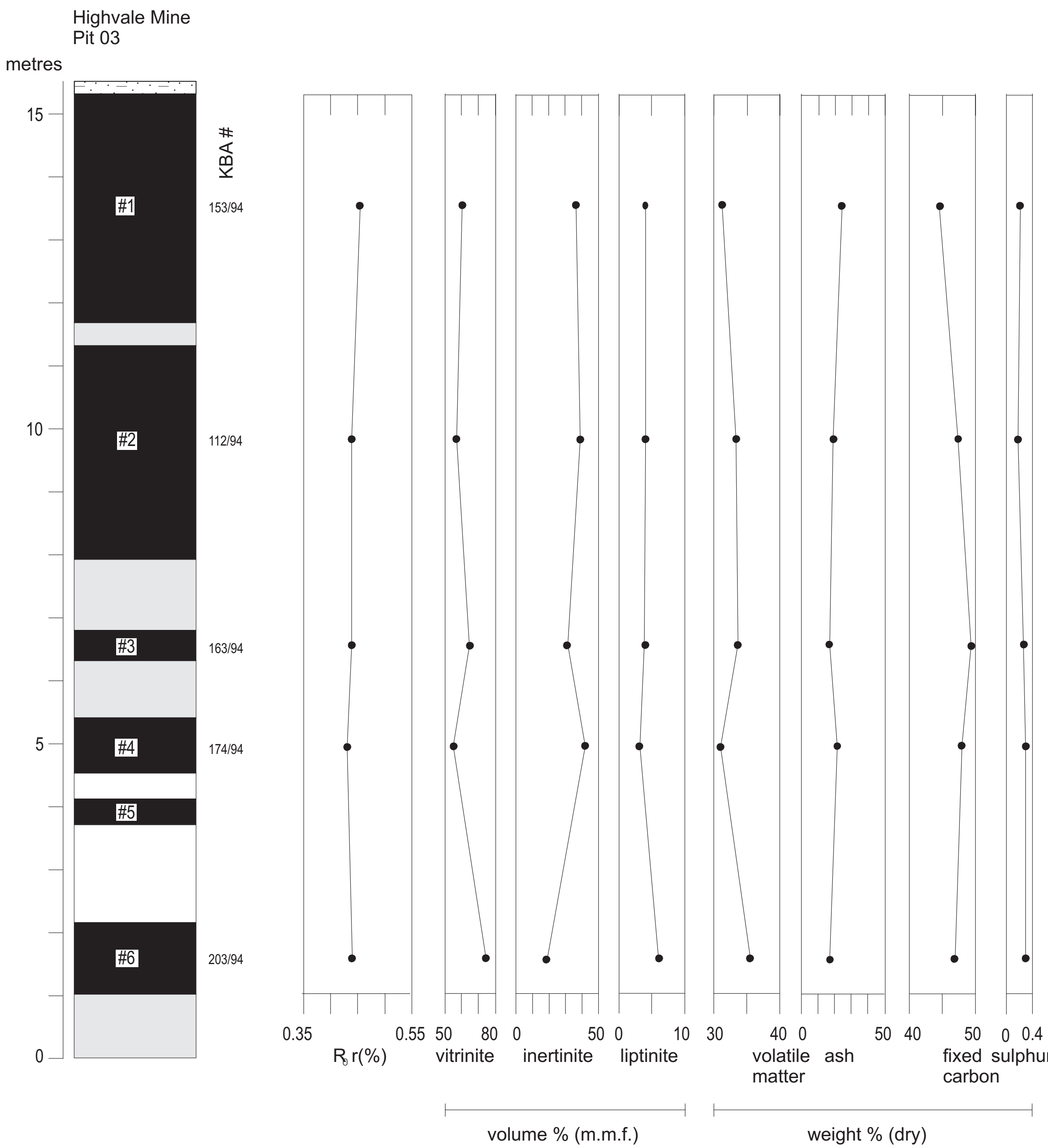

Figure 21. Composite section of the Ardley Coal Zone at the Highvale mine, pit 03, showing full-seam characteristics. See Figure 4 legend for lithological description of associated strata.

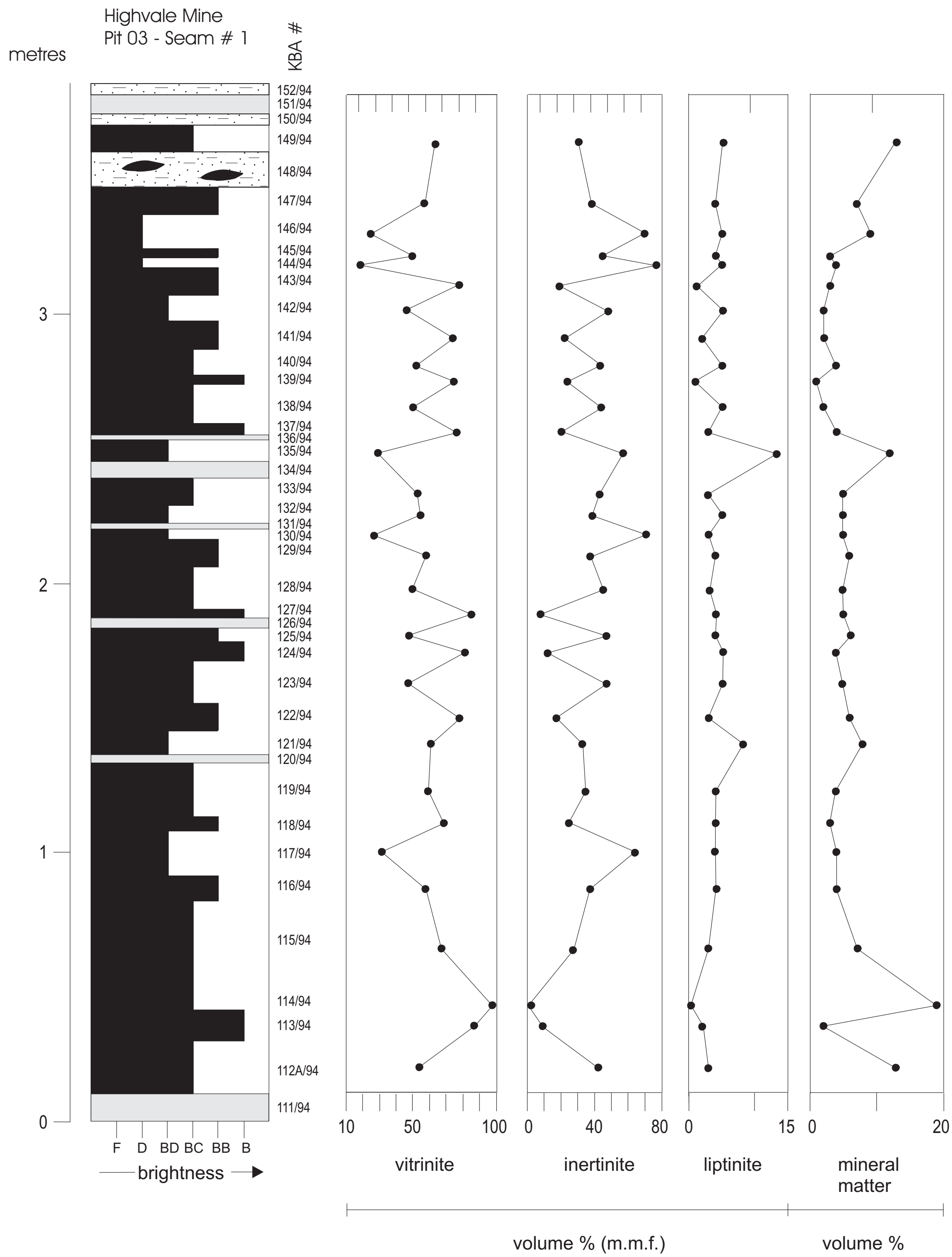

Figure 22. Seam No. 1 interval, Highvale mine, pit 03. See Figure 4 legend for lithological description of associated strata.

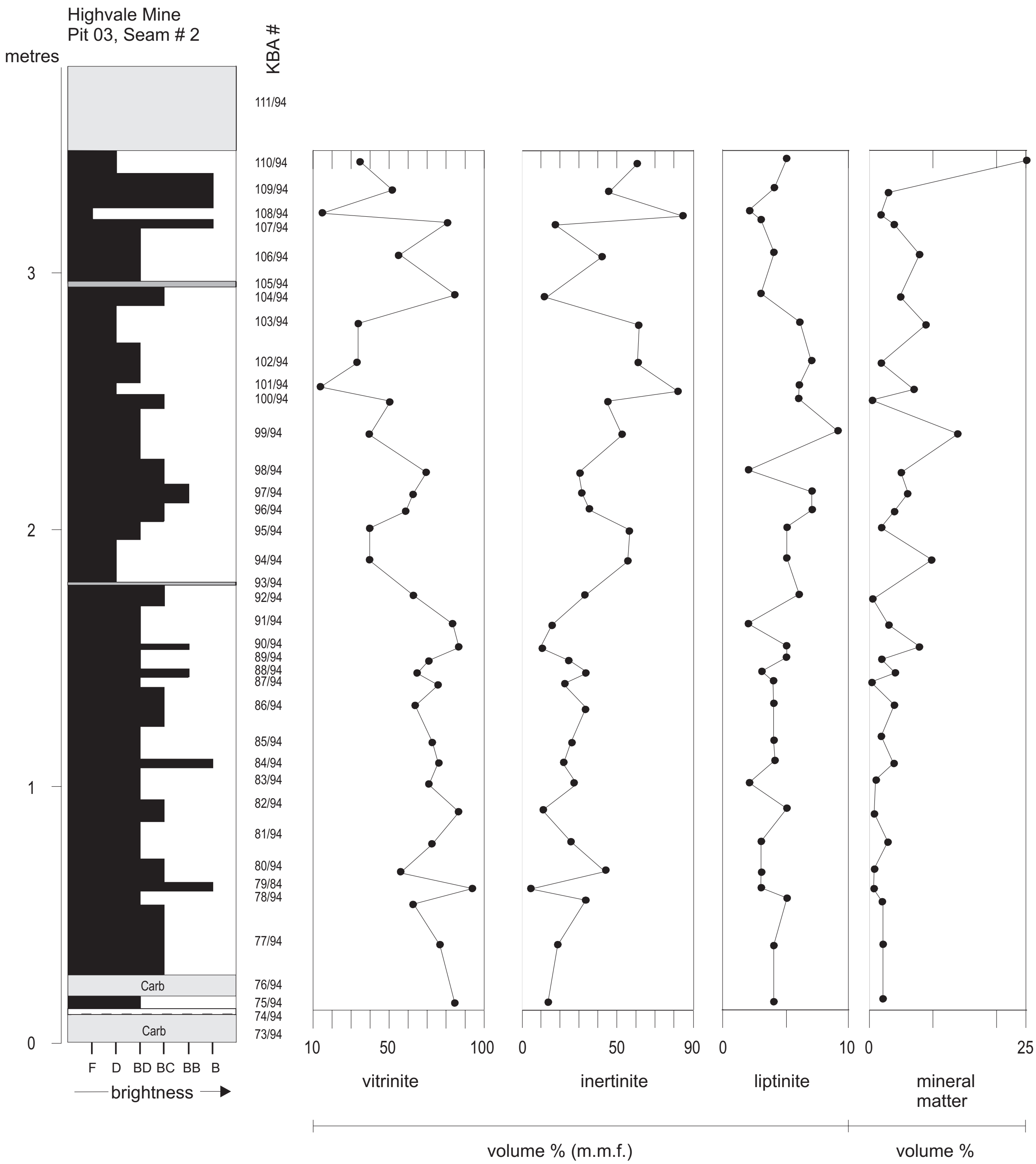

Figure 23. Seam No. 2 interval, Highvale mine, pit 03. See Figure 4 legend for lithological description of associated strata.

Seam No. 3

Seam No. 3 is 0.49 m thick (Figure 24). The seam is overlain by 50 cm of coaly siltstone-mudstone, which in turn is overlain by 12 cm of shaly coal (Figure 24). The seam is dominated by banded dull lithotypes (Figure 24), with a banded bright lithotype developed in the central part. The overall lithotype distribution in seam No. 3 is as follows: B + BB = 32.7%; BC = 20.4%; BD + D = 46.9. There is a distinct trend to lower vitrinite contents from seam base toward the seam top and the overlaying shaly coal (Figure 24). A detailed lithological log of the seam No. 3 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

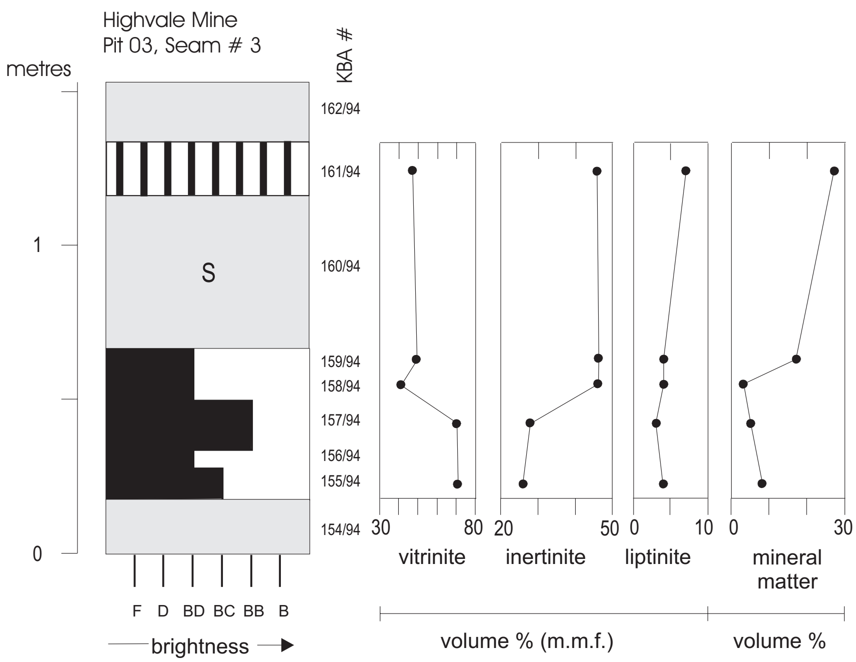

Figure 24. Seam No. 3 interval, Highvale mine, pit 03. See Figure 4 legend for lithological description of associated strata.

Seam No. 4

Seam No. 4 has a thickness of 0.82 m (Figure 25). The seam is dominated by dull and banded dull lithotypes (Figure 25), with banded coal developed in the central part. A thin fusain lens occurs in association with the central parting. The overall lithotype distribution in seam No. 4 is as follows: F = 1.3%; B + BB = 2.7%; BC = 38.7%; BD + D = 57.3%. There is a distinct trend to lower vitrinite contents from seam base toward the seam top and the overlaying shaly coal (Figure 25). In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content being highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes. A detailed lithological log of the seam No. 4 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

Seam No. 5

Seam No. 5 is 0.30 m thick (Figure 26). The seam is dominated by dull and banded dull lithotypes (Figure 26), with banded bright coal developed at seam base and near seam top. The overall lithotype distribution in seam No. 5 is as follows: B + BB = 23.3%; BC = 10.0%; BD + D = 66.7%. In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content being highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes (Figure 26). A detailed lithological log of the seam No. 5 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

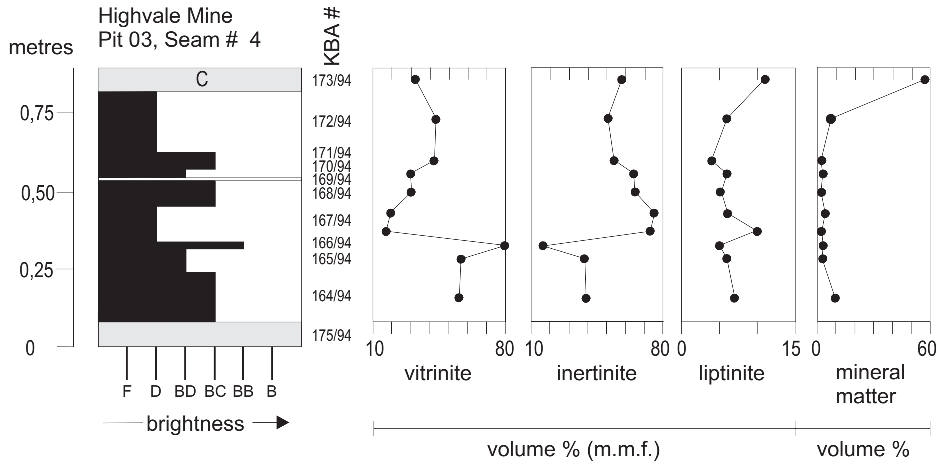

Figure 25. Seam No. 4 interval, Highvale mine, pit 03. See Figure 4 legend for lithological description of associated strata.

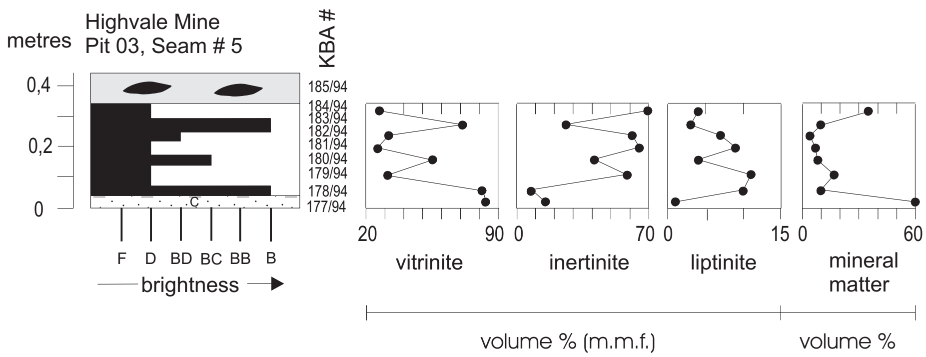

Figure 26. Seam No. 5 interval, Highvale mine, pit 03. See Figure 4 legend for lithological description of associated strata.

Seam No. 6

Seam No. 6 is the stratigraphically lowest of the Ardley coals exposed at the Highvale mine, pit 03 (Figure 21). The seam is 1.11 m thick (Figure 27), with a thin mudstone parting in the central part and a 5 cm siltstone parting at the top. It is dominated by dull and banded dull lithotypes (Figure 27), with banded coal and banded bright coal developed in the basal part, whereas banded dull coal dominates in the top part. The overall lithotype distribution in seam No. 6 is as follows: B + BB = 10.7%; BC = 37.9%; BD + D = 51.4%. In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content being highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes (Figure 27). A detailed lithological log of the seam No. 6 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

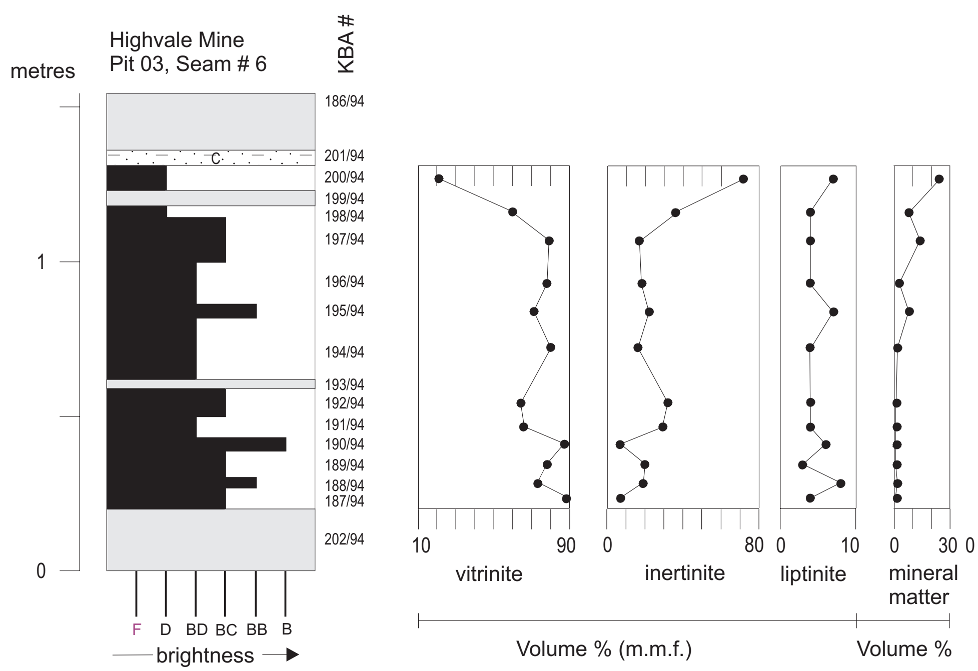

Figure 27. Seam No. 6 interval, Highvale mine, pit 03. See Figure 4 legend for lithological description of associated strata.

3.5 Whitewood Mine

3.5.1 Full-Seam Channel Samples

Six main and two minor coal seams are developed in the Ardley Coal Zone at the Whitewood mine, of which seam No. 3 is the economically most important, with a thickness of 3.40 m at the sample location. Ash yields vary from 11.00 to 39.77 wt. % and sulphur contents range from 0.18 to 0.45 wt. % (Appendix 1).

There exist significant differences between the seams in terms of petrographic composition (Figure 28), with seams 1, upper, 3A, 3X and 4 being relatively enriched in inert macerals (>40 vol. %), whereas seams 2 and 6 are enriched in vitrinite macerals (73 vol. %). The reflectance values (0.40%–0.43% Ro) indicate sub-bituminous rank (Appendix 1).

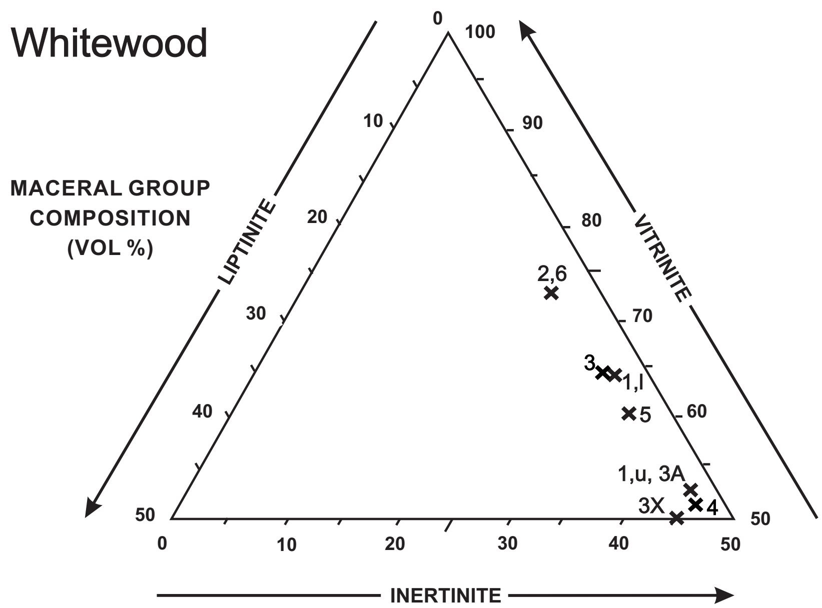

Figure 28. Ternary diagram showing maceral distribution of Highvale mine, pit 02S coals. Numbers refer to coal seams.

A summary of petrographic and chemical characteristics for the major seams at the Whitewood mine is given in Figures 28 and 29 and in Appendices 1 and 2.

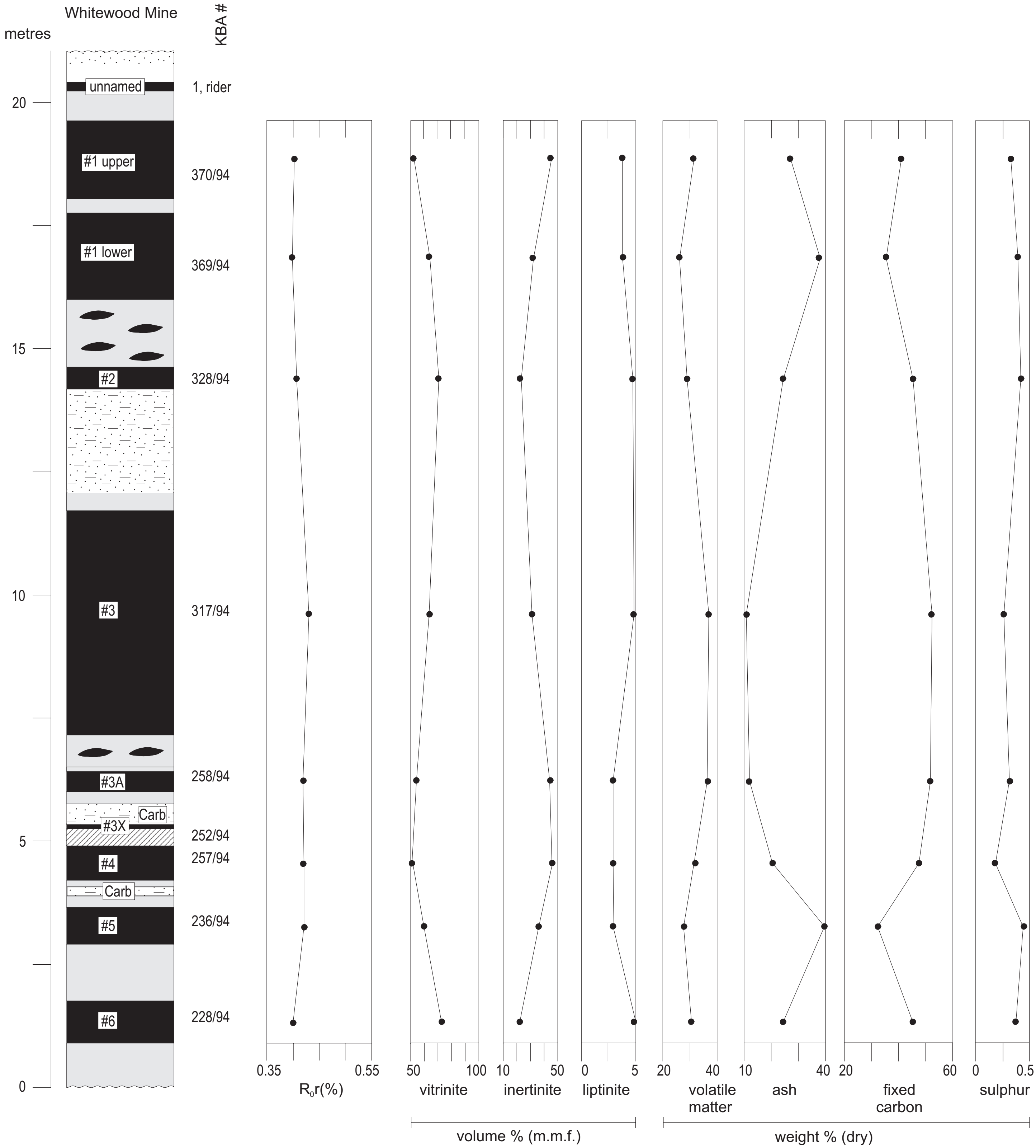

Figure 29. Composite section of the Ardley Coal Zone at the Whitewood mine showing full-seam characteristics. See Figure 4 legend for lithological description of associated strata.

3.5.2 Seam Subsection (Lithotype) Samples

Seam No. 1

Seam No. 1 occurs at the top of the Ardley Coal Zone (Figure 29) and has a total thickness of 3.53 m. The seam is subdivided into lower and upper seams, separated by a 29 cm thick mudstone parting (Figure 30, on next page). The upper seam is characterized by numerous mudstone and carbonaceous shale partings. The upper seam is overlain by a 16 cm thick rider seam, which is separated from the upper seam by 60 cm of brown mudstone. The seam is dominated by dull and banded dull lithotypes (Figure 30, on next page), with 7 cm of banded bright coal developed in the basal part. The overall lithotype distribution in seam No. 1 is as follows: B + BB = 6.7%; BC = 20.1%; BD + D = 73.1%. In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content being highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes (Figure 30, on next page). A detailed lithological log of over- and underlying strata, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

Seam No. 2

Seam No. 2 has a thickness of 0.42 m (Figure 31) and is dominated by banded coal (Figure 31). The overall lithotype distribution in seam No. 2 is as follows: B + BB = 14.3%; BC = 47.6%; BD + D = 38.1%. Vitrinite contents are highest in the central portion of the seam (Figure 31), whereas vitrinite decreases toward seam base and seam top; inertinite contents show the opposite trend. A detailed lithological log of the seam No. 2 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

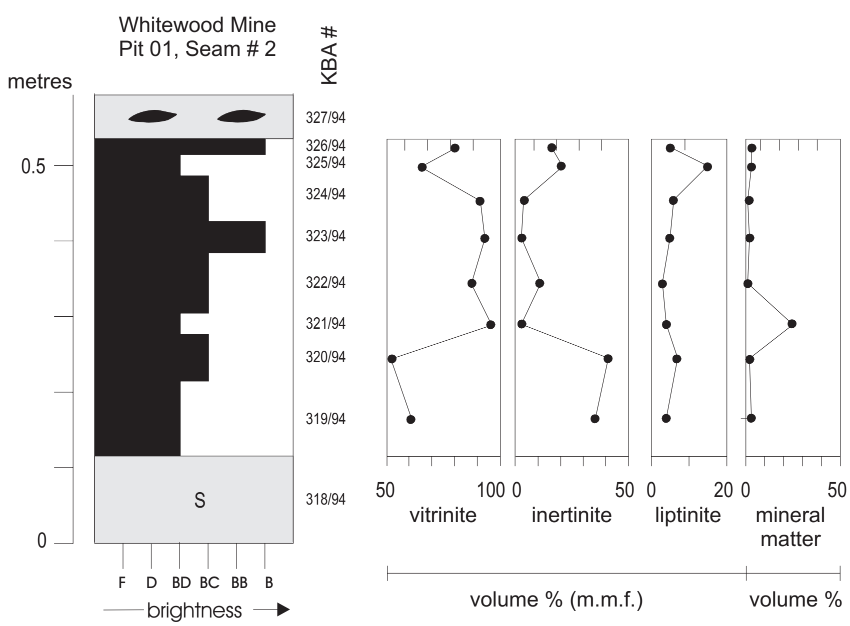

Figure 31. Seam No. 2 interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

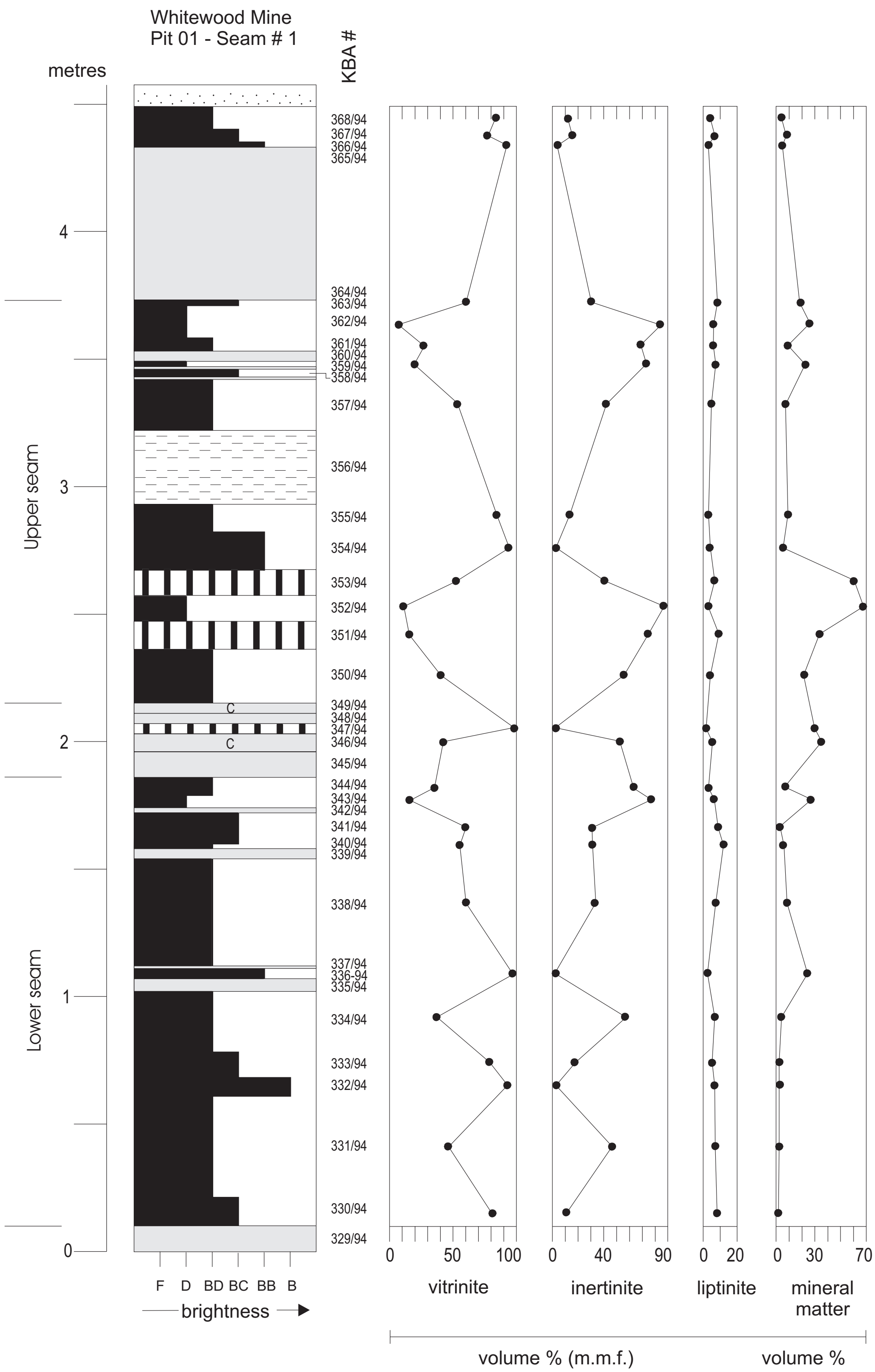

Figure 30. Seam No. 1 interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

Seam No. 3

Seam No. 3 is 3.40 m thick (Figure 32) and is overlain by 40 cm of mudstone, which in turn is overlain by 5 cm of bright coal (Figure 32). It is dominated by bright and banded bright lithotypes (Figure 32) and displays several in-seam dulling and brightening sequences. The overall lithotype distribution in seam No. 3 is as follows: B + BB = 36.9%; BC = 28.2%; BD + D = 34.9%. In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content being highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes (Figure 32). A detailed lithological log of the seam No. 3 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

Seam No. 3A

Seam No. 3A has a thickness of 0.42 m (Figure 33) and is dominated by dull lithotypes (Figure 33) that show a brightening upward-sequence toward the top. The overall lithotype distribution in seam No. 3A is as follows: B + BB = 8.1%; BC = 37.8%; BD + D = 54.1%. Associated with the brightening-upward sequence is an increase of vitrinite content from seam base to seam top and a decrease in inertinite macerals (Figure 33). A detailed lithological log of the seam No. 3A interval, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

Seam No. 3X

Seam No. 3X has a thickness of 0.09 m (Figure 34) and is composed of banded dull lithotypes. A detailed lithological log of the seam No. 3X interval, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

Seam No. 4

Seam No. 4 has a thickness of 0.69 m (Figure 35) and is characterized by three mudstone and carbonaceous shale partings. The seam is dominated by dull and banded dull lithotypes (Figure 35), occurring at seam top and in the lower part of the seam, whereas the upper part of the seam is dominated by banded coal. The overall lithotype distribution in seam No. 4 is as follows: B + BB = 3.2%; BC = 28.1%; BD + D = 66.7%. There is a general trend to decreasing vitrinite contents from seam base toward the center, followed by higher vitrinite contents in the upper part; inertinite contents show the opposite trend (Figure 35). A detailed lithological log of the seam No. 4 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

Seam No. 5

Seam No. 5 is 0.78 m thick (Figure 36). A 13 cm thick carbonaceous mudstone parting subdivides the seam in a lower and upper sub-seam. The seam is dominated by the banded dull lithotype (Figure 36), with thin banded bright coal at the seam base and above the major parting. The overall lithotype distribution in seam No. 5 is as follows: B + BB = 11.8%; BC = 13.6%; BD + D = 74.6%. In-seam variations in vitrinite and inertinite contents reflect largely the lithotype distribution, with vitrinite content being highest in the bright and banded bright lithotypes and inertinite content highest in the dull and banded dull lithotypes (Figure 36). A detailed lithological log of the seam No. 5 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 5.

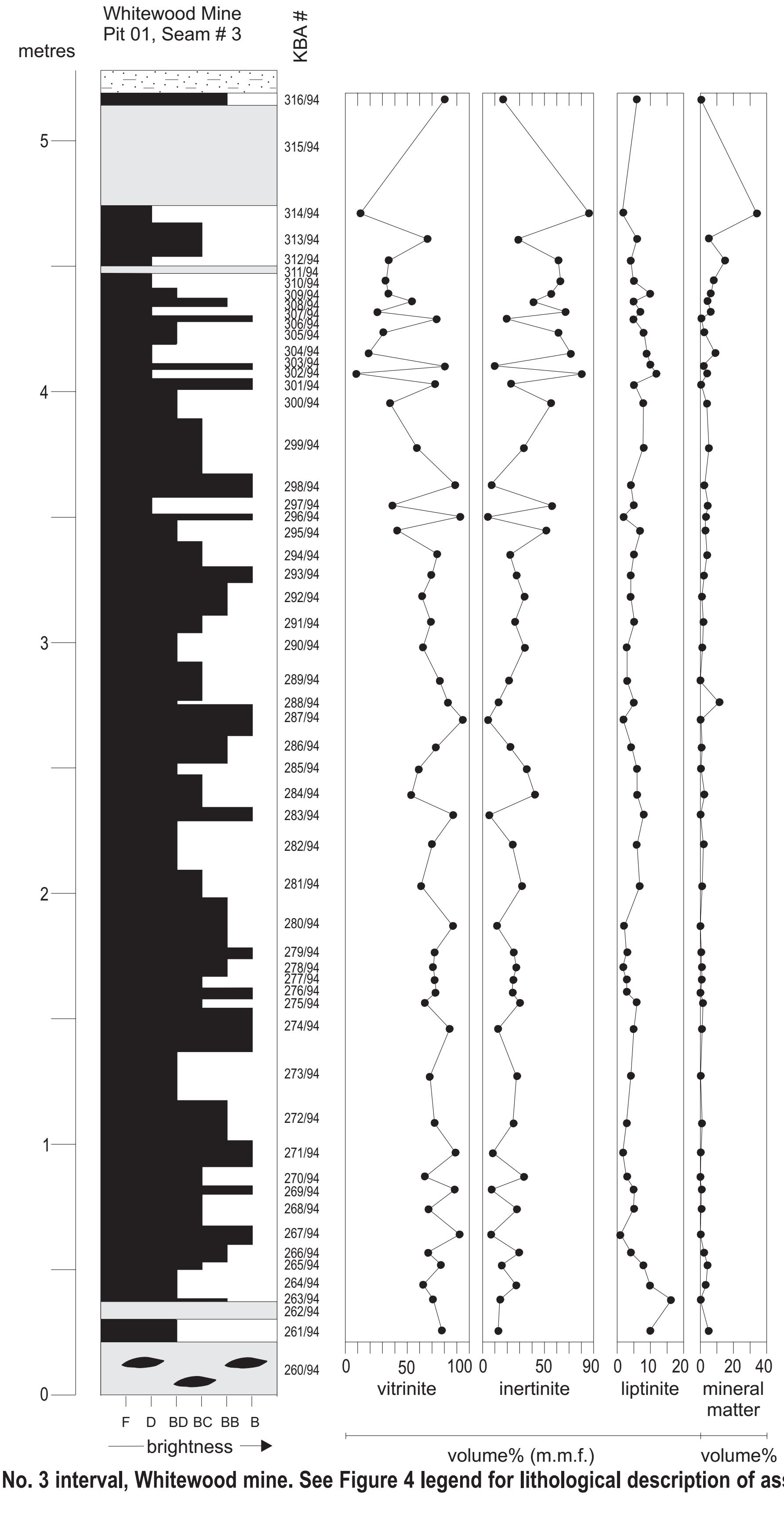

Figure 32. Seam No. 3 interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

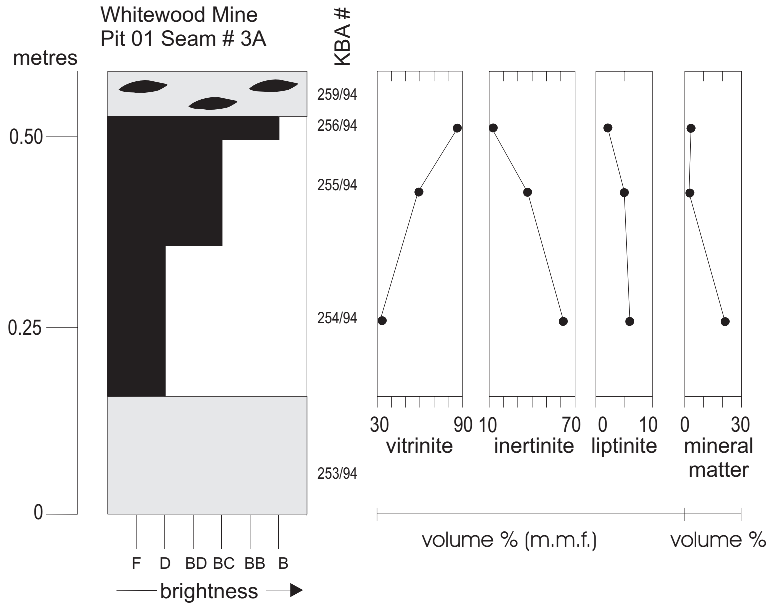

Figure 33. Seam No. 3A interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

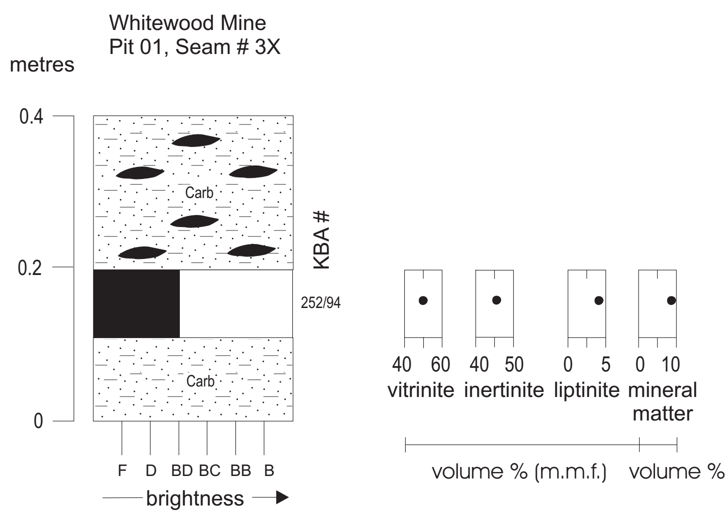

Figure 34. Seam No. 3X interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

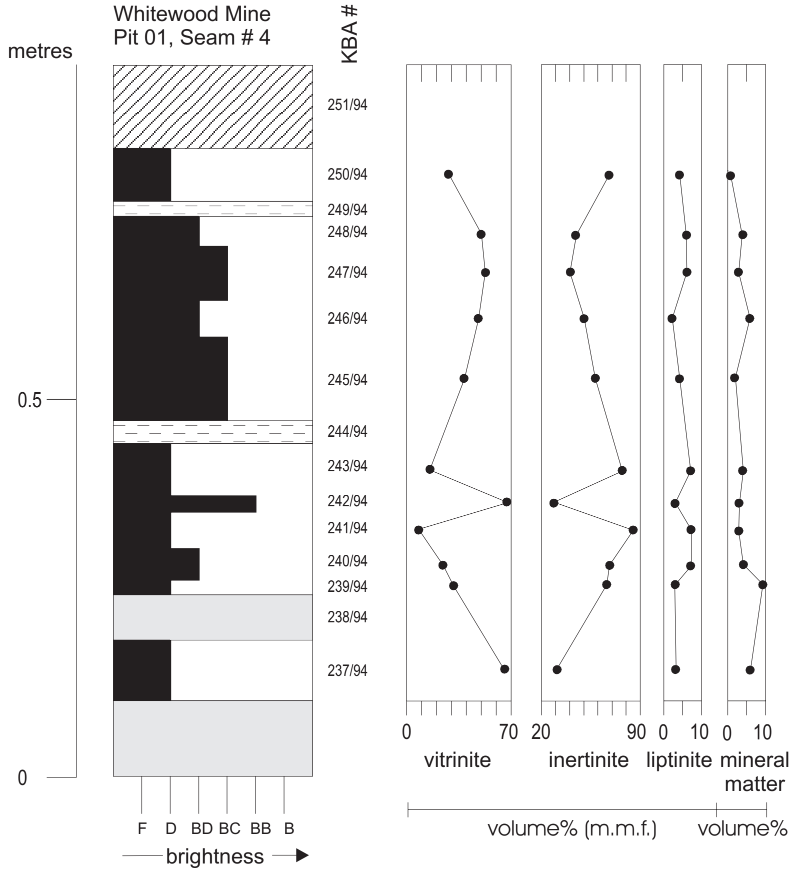

Figure 35. Seam No. 4 interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

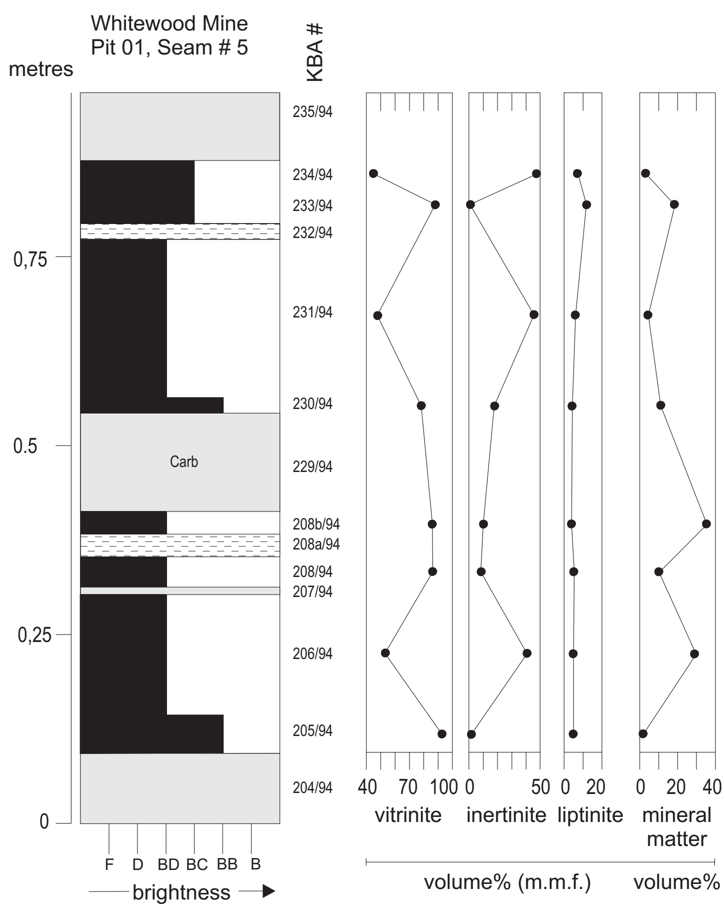

Figure 36. Seam No. 5 interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

Seam No. 6

Seam No. 6 is the stratigraphically lowest of the Ardley coals exposed at Whitewood (Figure 29). The seam is 0.85 m thick (Figure 37), with a thin mudstone parting in the central part. It is dominated by dull and banded dull lithotypes (Figure 37), with a distinct dulling-upward sequence at the seam top. The overall lithotype distribution in seam No. 6 is as follows: B + BB = 7.1%; BC = 27.1%; BD + D = 65.8%. Associated with the dulling-upward sequence at the seam top is a trend to lower vitrinite and increasing inertinite contents (Figure 37). A detailed lithological log of the seam No. 6 interval, along with petrographic properties of the coal lithotypes, is given in Appendix 6.

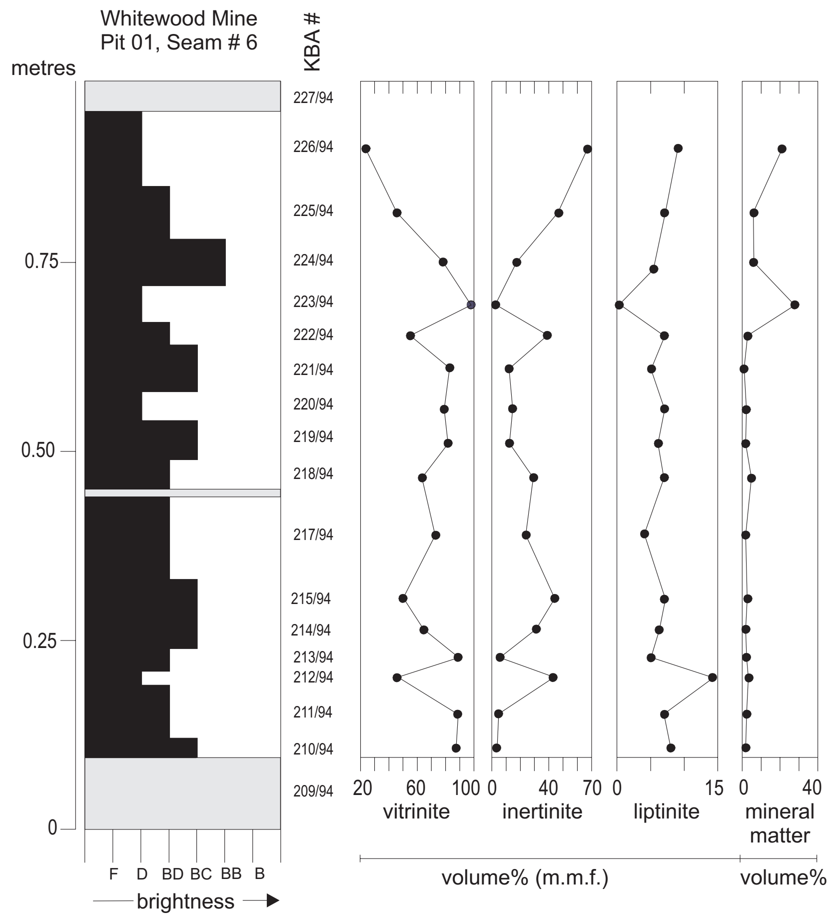

Figure 37. Seam No. 6 interval, Whitewood mine. See Figure 4 legend for lithological description of associated strata.

3.6 Petrography of Outcrop Section Coals, Red Deer River Valley

3.6.1 Knudson Mine

At the Knudson mine (*see* Figure 1 for location), a 10 m thick section of the uppermost Scollard Formation is exposed along the river bank (Figure 38). The section contains nine coal seams, ranging in thickness from 0.12 to 1.65 m, and is overlain by sandstone. These seams represent nine sub-seams of the Ardley No. 14 seam (Allan and Sanderson, 1945). The cumulative coal thickness in this section is more than the 1.5 m thickness that is generally reported for the No. 14 seam in this area (Gibson, 1977; Campbell, 1967). It seems possible that slumping along the river bank resulted in an increase of coal thickness.

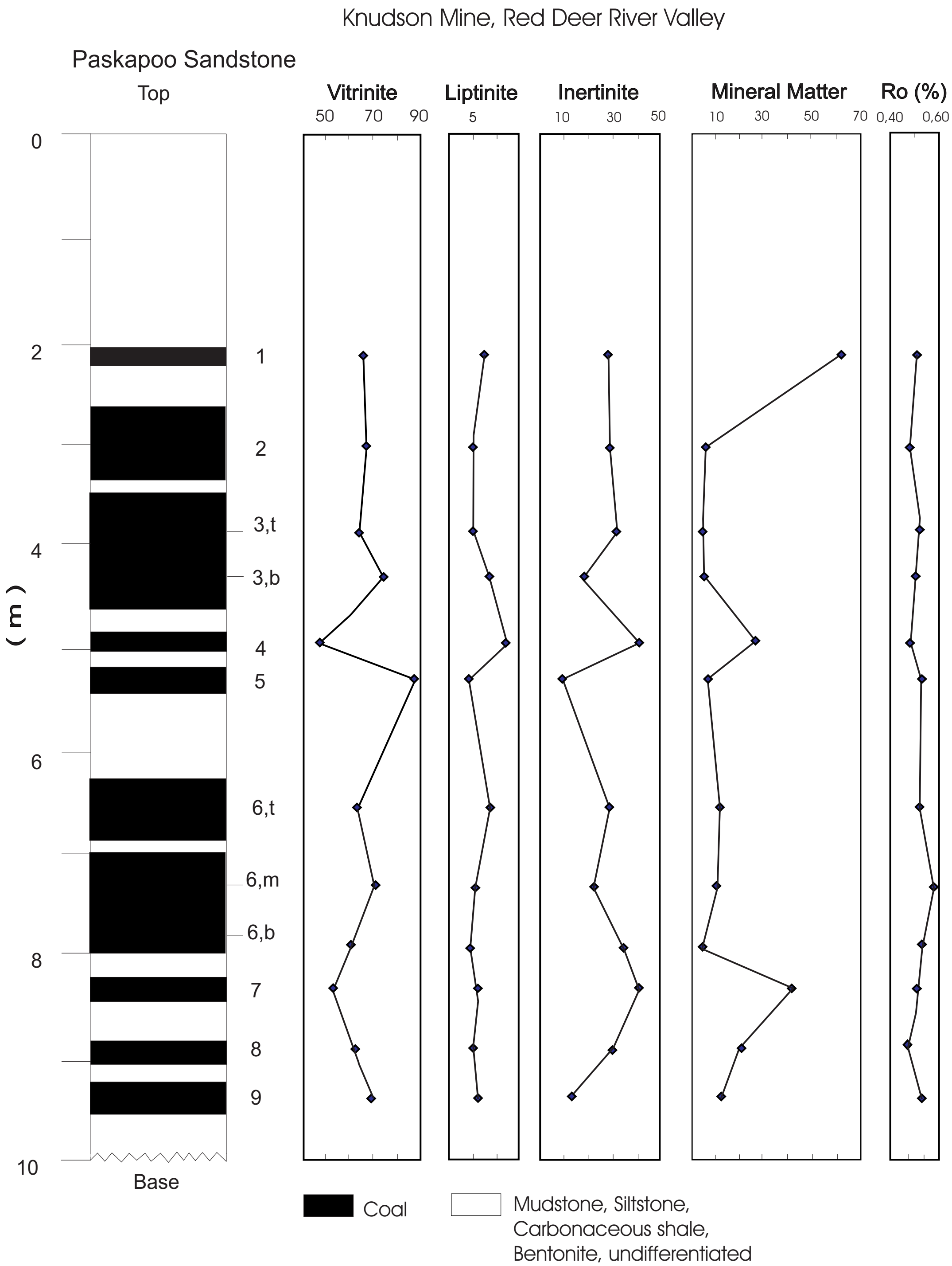

Figure 38. Knudson mine section showing petrographic composition of Ardley coal seams.

The ternary diagram (Figure 39) indicates relatively high vitrinite contents (maximum of 87 vol. %) for all coals. Inertinite content is greatest in seams 4 and 7 (41 vol. %); liptinite contents in seam No.5 are generally low (<10 vol. %), with the exception of seam No. 4 (12 vol. %). Mineral matter is relatively low in all samples except those from seams 1 and 7.

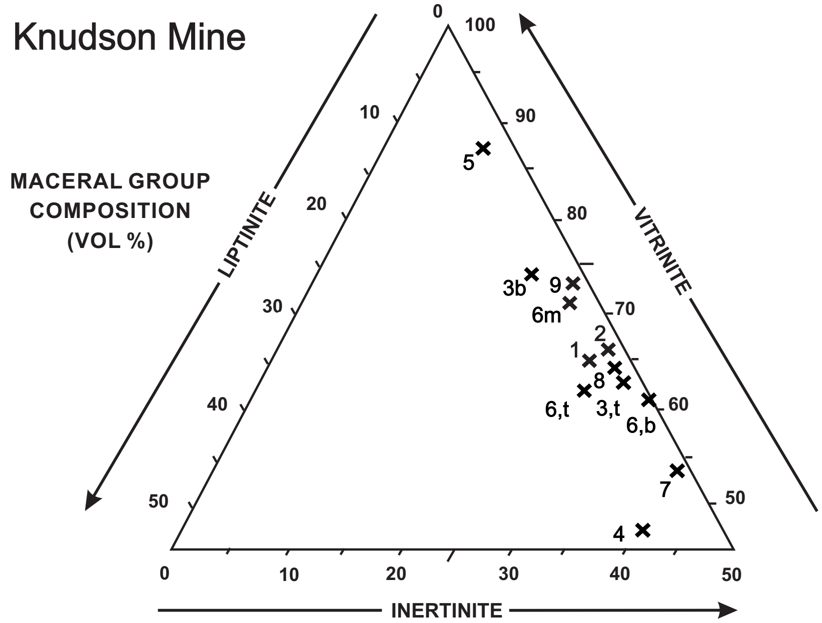

Figure 39. Ternary diagram showing maceral group distribution of Ardley coals, Knudson mine section.

Vitrinite reflectance values range from 0.48% to 0.58% Ro, indicating sub-bituminous coals. See Appendices 7 and 8 for further details on lithology and petrography at the Knudson mine section.

3.6.2 Stamp Pit Section

At Stamp pit, 22 m of the uppermost Scollard Formation is exposed along the access road leading to a shale quarry in the valley bottom. The section contains eight thin coal seams (Figure 40), ranging in thickness from 0.02 to 0.17 m. The red, burned mudstone at the base of this section is inferred to overlie the main, thick Ardley Seam (No. 14 of Allan and Sanderson, 1945).

The ternary diagram (Figure 41) indicates relatively high vitrinite contents (>80 vol. %) for all coals except those of seam No. 2, which has higher liptinite and inertinite contents. Mineral matter is relatively low except in seams 2, 3 and 4.

Vitrinite reflectance values range from 0.41% to 0.54% Ro, indicating sub-bituminous coals. See Appendices 8 and 9 for further details on lithology and petrography at the Stamp pit section.

3.6.3 Ardley Bend and J. Saker Section

Two coal seams were collected at the Ardley Bend and J. Saker section (*see* Figure 1 for location). The coal sampled at Ardley Bend represents the lower 0.45 m of the Ardley No. 14 seam, which is 2.1 m thick at this locality (Campbell, 1967). At the J. Saker section, 0.82 m of the 1.5 m thick Ardley No. 14 seam was sampled.

The ternary diagram (Figure 42) indicates relatively high vitrinite contents for most coal layers, with a maximum of 89 vol. % in sample No. 3 at Ardley Bend. Inertinite content is greatest in a sample of shaly

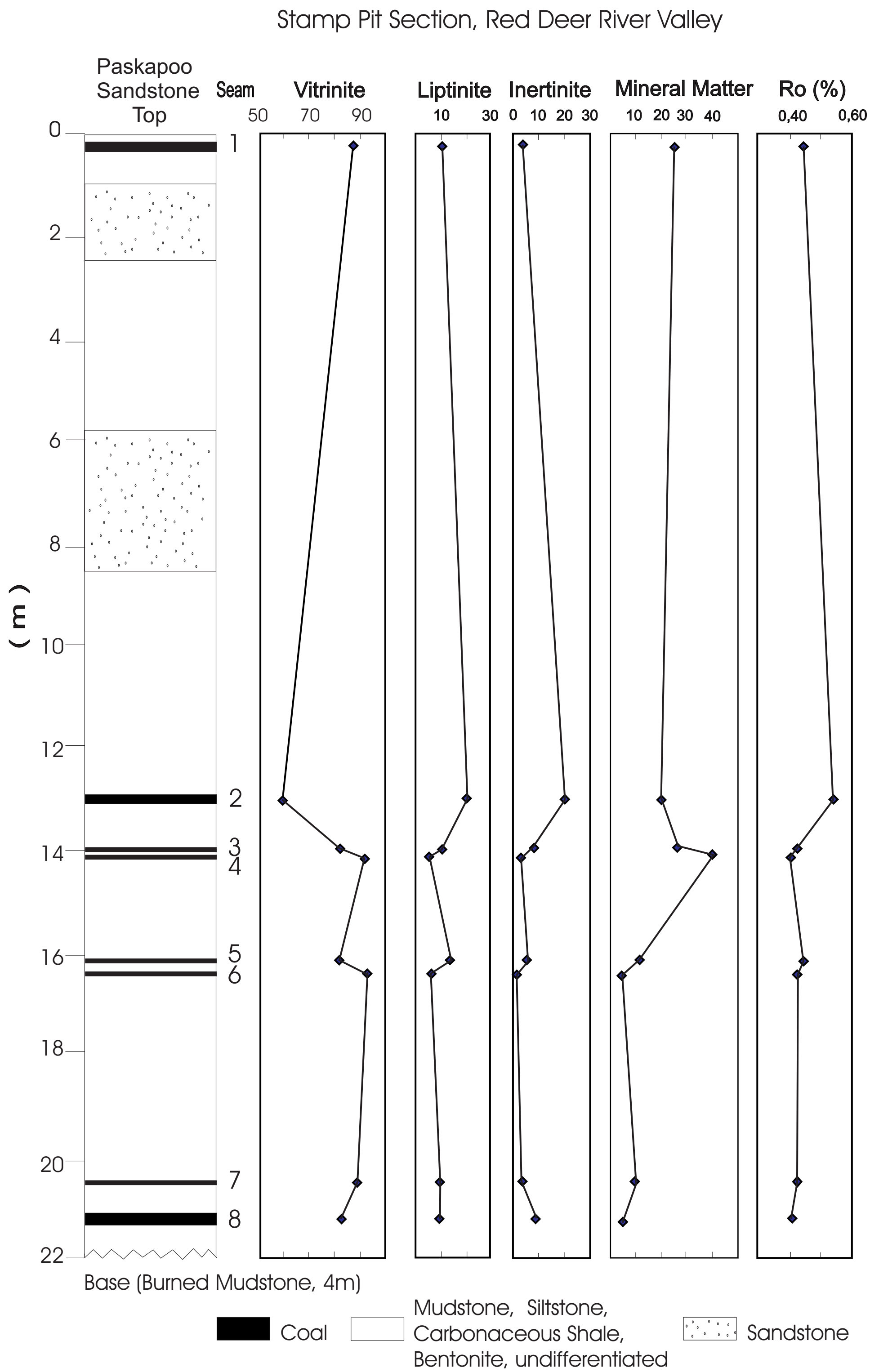

Figure 40. Stamp pit section showing petrographic composition of Ardley coal seams.

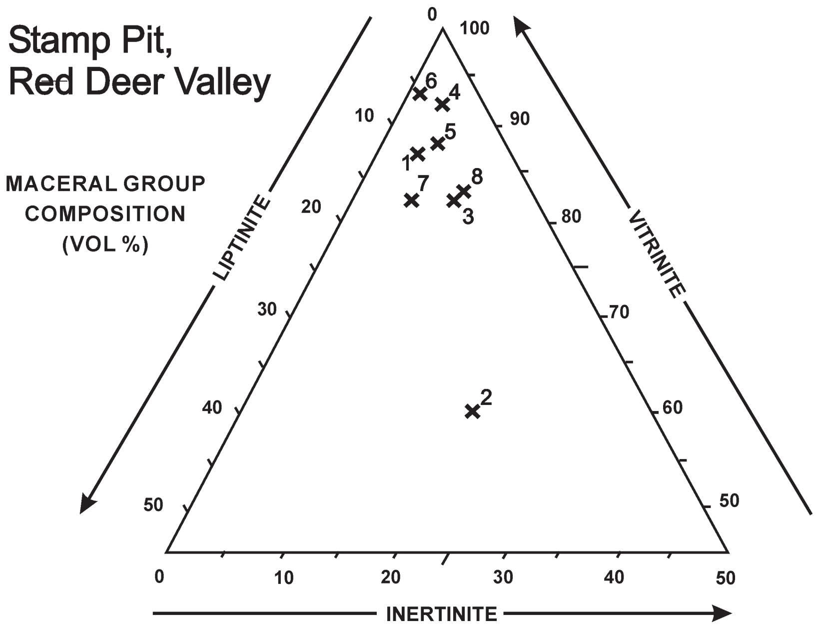

Figure 41. Ternary diagram showing maceral group distribution of Ardley coals, Stamp pit

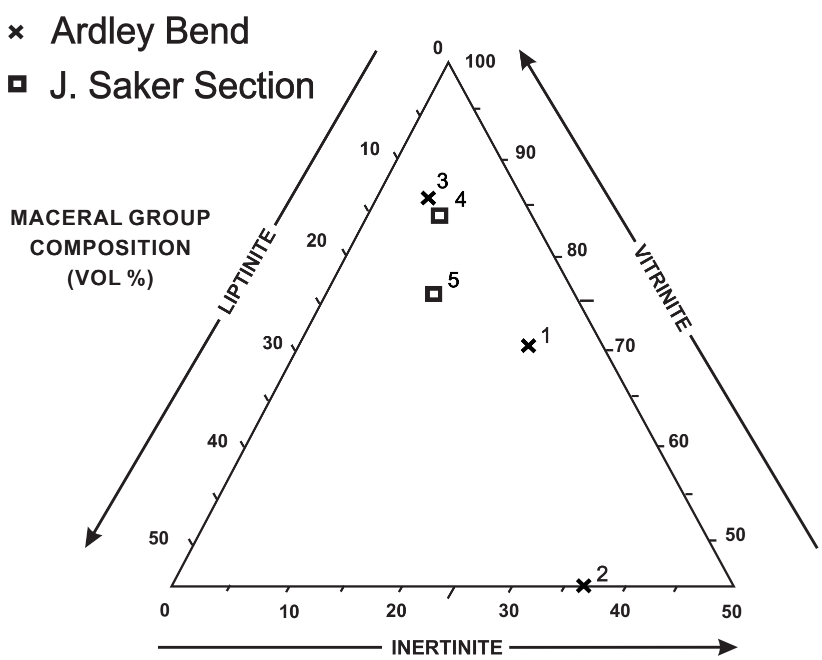

Figure 42. Ternary diagram showing maceral group distribution of Ardley coals, Ardley Bend and J. Saker section.

coal (No. 2, 37 vol. %). Liptinite contents are moderate (7–13 vol. %) and mineral matter is low (1–7 vol. %), except in the shaly coal (59 vol. %).

Vitrinite reflectance values range from 0.46% to 0.49% Ro, indicating sub-bituminous coals. See Appendices 8 and 10 for further details on lithology and petrography at the Ardley Bend and J. Saker sections.

4 Petrological Characteristics and CBM Potential of Ardley Coals

Evaluation of coalbed methane potential must take into account numerous geological parameters, such as coal distribution and thickness, reservoir depth, and hydrological and tectonic setting of the coal measures. From a coal petrographic perspective, coalbed methane content in coal seams is defined principally by three parameters: coal grade (mineral matter versus organic matter), coal rank (degree of coalification) and coal type (defined by variations in macerals). These parameters likewise play an important role in the methane adsorption and desorption capacities of coal seams.

It is obvious that, in coals dominated by high ash yields, very little gas will be formed from the remaining organic matter. In Canada, this relationship was first documented by Kalkreuth et al. (1994) in a study on Mist Mountain Formation coals of the Fernie Basin, where multiple seam samples had been taken for desorption testing. The lowest gas desorption values were always associated with high ash yields.

The effect of coal rank on thermally generated gas and desorption is well known (Kim, 1977; Eddy et al., 1982; Meissner, 1984), and it is commonly accepted that coals start to generate methane around 0.7 % Ro, producing large volumes of methane per unit of coal in higher rank bituminous coals and anthracite. Significant amounts of methane may also be formed in the early stage of coalification by methane-producing bacteria, but this biogenic gas is generally lost due to lack of overburden. Biogenic gas, however, may also form during burial associated with active groundwater systems (Clayton, 1998).

In iso-rank coals, vitrinite appears to have the highest gas-generation potential, and also appears to have the highest storage capacity, due to the huge amount of micropores associated with this type of organic matter. Lamberson and Bustin (1993), in a study on Gates coals from northeastern British Columbia, demonstrated that the brighter lithotypes (characterized by highest concentrations of vitrinite) in fact had the highest methane-adsorption capacities. The combined effects of ash yields, coal rank and organic-matter type on methane adsorption characteristics in a number of coal seams from the Western Canada Sedimentary Basin can be found in Dawson and Kalkreuth (1994) and Dawson (1995).

Desorption characteristics of coals are not only defined by petrographic characteristics, but are largely controlled by such additional parameters as micropore distribution, fractures and cleats, and the occurrences of diagenic minerals, all factors that principally control the permeability of the coal seams. Micropermeability in coal appears also to be related to its banding (lithotypes), with preferential horizontal migration of gas along lithotype boundaries (Dawson et al., 1994).

Studies of the microstructure of coals from the Bowen Basin, Australia (Faraj et al., 1996; Gamson et al., 1996) demonstrated that gas desorption characteristics of a coal seam are influenced by a combination of cleat- and fracture-filling diagenetic minerals and lithotype distribution. It was found that desorption rates are highest in bright lithotypes with a well-defined cleat network, while lowest desorption rates were associated with dull lithotypes, where fractures and cleats were mostly mineralized. Gas-desorption rates were found to increase in those dull lithotypes where unmineralized thick bands of wood fibres were encountered.

Taking the above criteria into account, the following general comments can be made regarding the CBM potential of the Ardley Coal Zone:

Coal Rank: As the coal seams investigated in this report contain sub-bituminous coal, they will not have generated any thermogenic methane. Biogenic gas will have migrated out of the coals due to their position at or near the surface. In the subsurface, however, coal of this rank may contain biogenic gas formed in active groundwater systems (Clayton, 1998), which would explain the gas content reported for these coals near the outcrop edge (A. Beaton, pers. comm., 2002).

Coal Thickness: Cumulative coal thickness (net coal) at the four mine sites range from 5.56 to 10.10 m (at Whitewood), with individual seam thicknesses in excess of 3 m. Cumulative coal thickness and individual seam thicknesses make the Ardley Coal Zone an exploration target for CBM, on the basis that similar coal distribution is encountered at depth, where increased levels of coal rank may have generated economically producible amounts of methane (Dawson et al., 2000).

Coal Grade (mineral matter content): Ash yields obtained for the full-seam channel samples (Appendix 1) range from 7.8 to 39.8 wt. %. Considering seams with a thickness of >1 m, the ash yields range from 11 to 21 wt. % (except for the No. 1 [upper] seam at Whitewood), with the cleanest coals occurring at Whitewood (No. 3 seam) and Highvale pit 02S (No. 2 seam). The low sulphur contents (0.15–0.48 wt.%) are also favourable for exploitation of the coals.

Coal Type (maceral distribution): As discussed in the section on petrographic characteristics of the full-seam channel samples, there exist significant differences in organic-matter type (macerals) between the seams, both locally, in terms of stratigraphic variations within the Ardley Coal Zone, and regionally, between the sample localities.

- At the Genessee mine, the highest vitrinite contents occur in the 2A, 2 Rider, 3 and Cloud seams (69–83 vol. %), whereas the main seam (No. 2) has only 54 vol. % vitrinite and 40 vol. % inertinite, the latter not considered to yield any significant amount of gas, except maybe for semifusinite.

- At the Highvale mine locations, the No. 6 seam from the base of the coal-bearing interval exposed at the mine sites always has the highest vitrinite contents (65 to 75 vol. %), whereas the No. 2 and No. 4 seams have substantially more inertinite macerals.

- At the Whitewood mine, vitrinite-rich coal also occurs at the base of the coal-bearing interval (No. 6 seam) and in the No. 2 seam at the top (73 vol. %). An intermediate position, in terms of vitrinite contents, is shown by seams 1 (lower), 3 and 5 (60–64 vol. %), whereas seams 1 (upper), 3X, 3A and 4 have a larger contribution of inertinite macerals (44–46 vol. %).

- The samples collected from outcrop sections in the Red Deer River Valley show high vitrinite contents for the thin coal seams collected at Stamp pit and Ardley Bend (all >70 vol. % vitrinite, except for two samples). At the Knudson mine, the vitrinite content is highly variable (47–87 vol. %).

Coal Type (lithotype distribution): In view of the relationships between gas desorption rates and lithotype distribution discussed above, the relative proportions for bright and banded bright, banded coal, banded dull and dull, and fibrous lithotypes were calculated for those locations where that information was available (Figures 43–45):

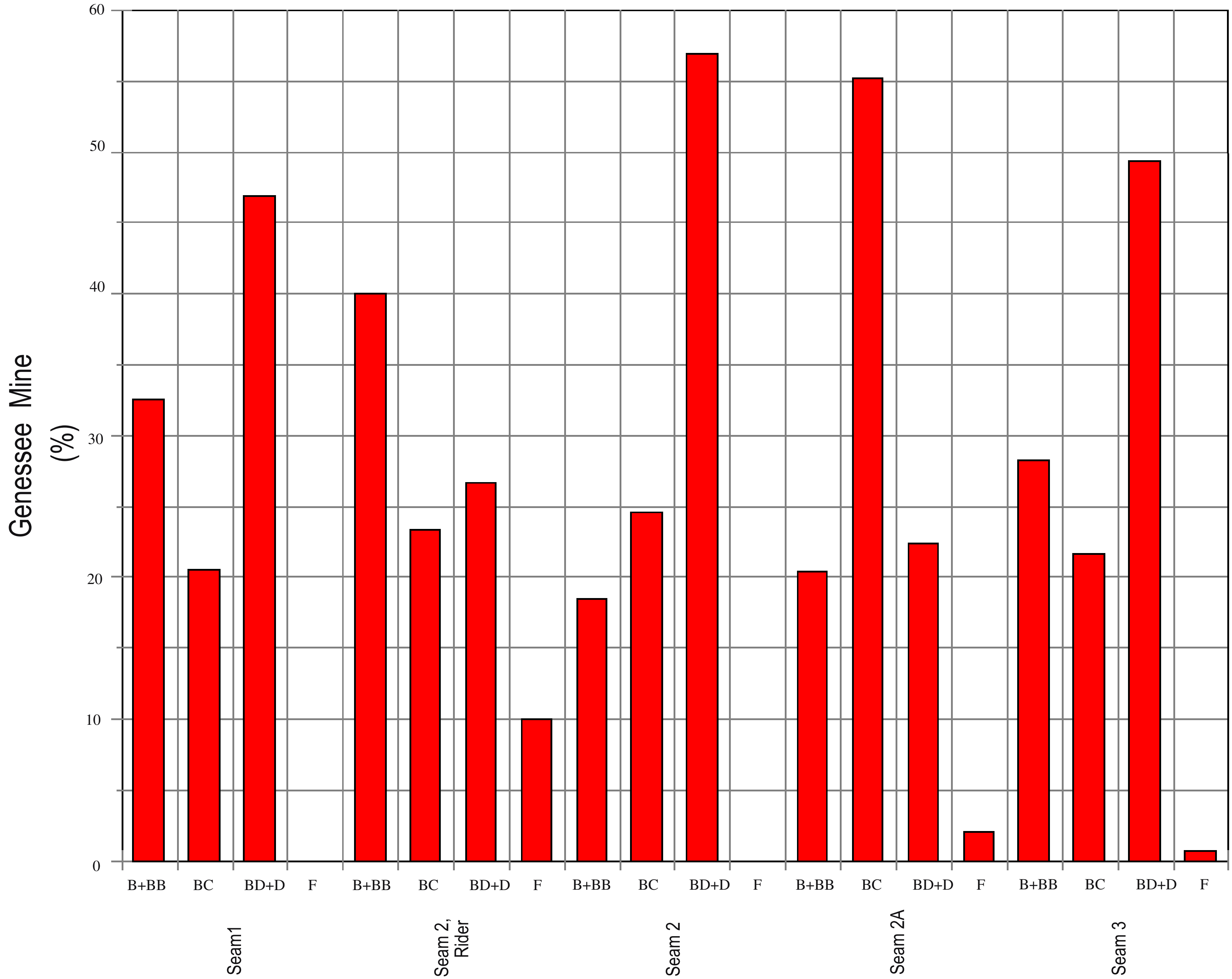

Figure 43. Lithotype distribution in Genessee mine coals. Abbreviations: B+BB, bright and banded bright; BC, banded coal; BD+D, banded dull and dull; F, fibrous.

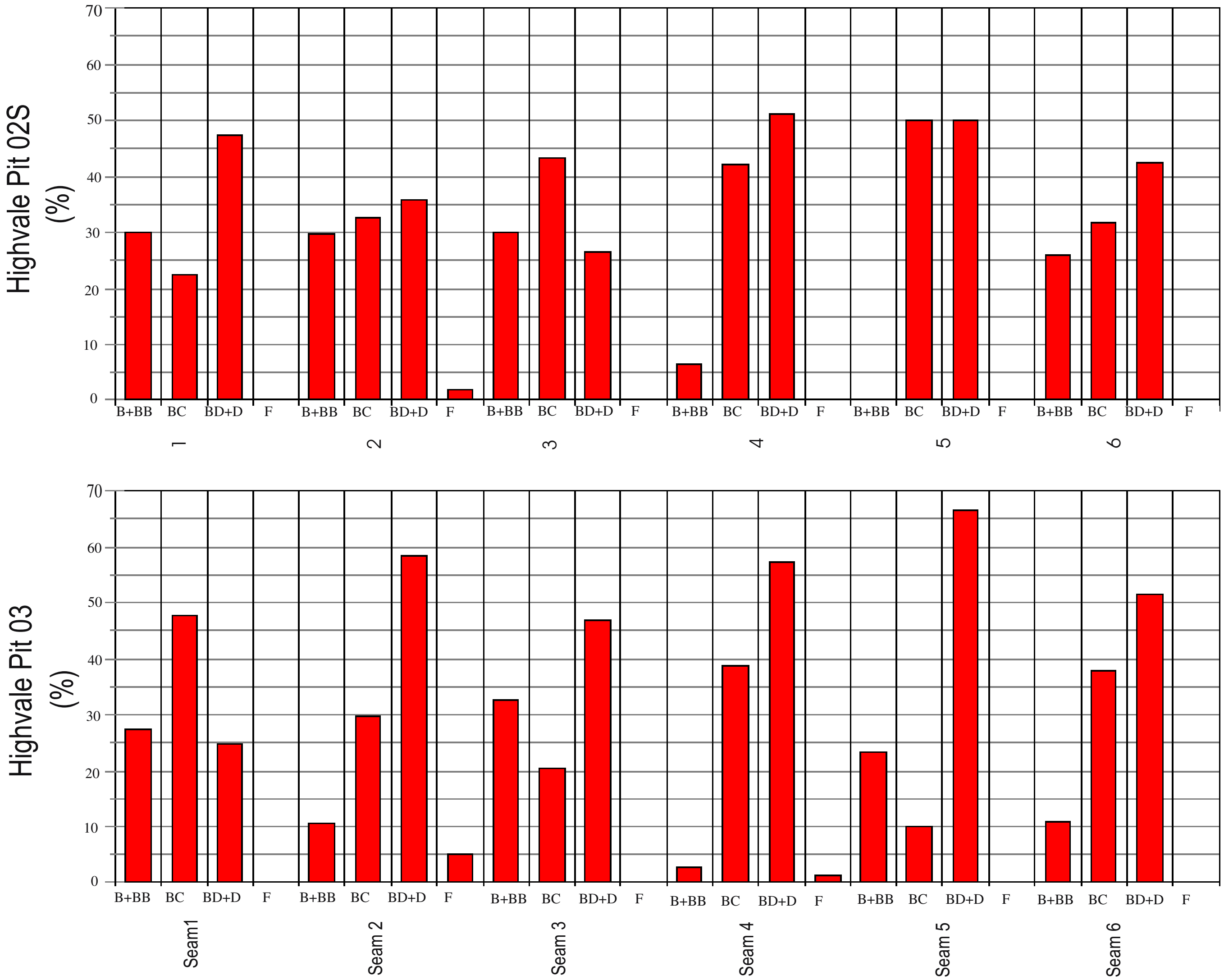

Figure 44. Lithotype distribuiton in Highvale mine coals. Abbreviations: B+BB, bright and banded bright; BC, banded coal; BD+D, banded dull and dull; F, fibrous.

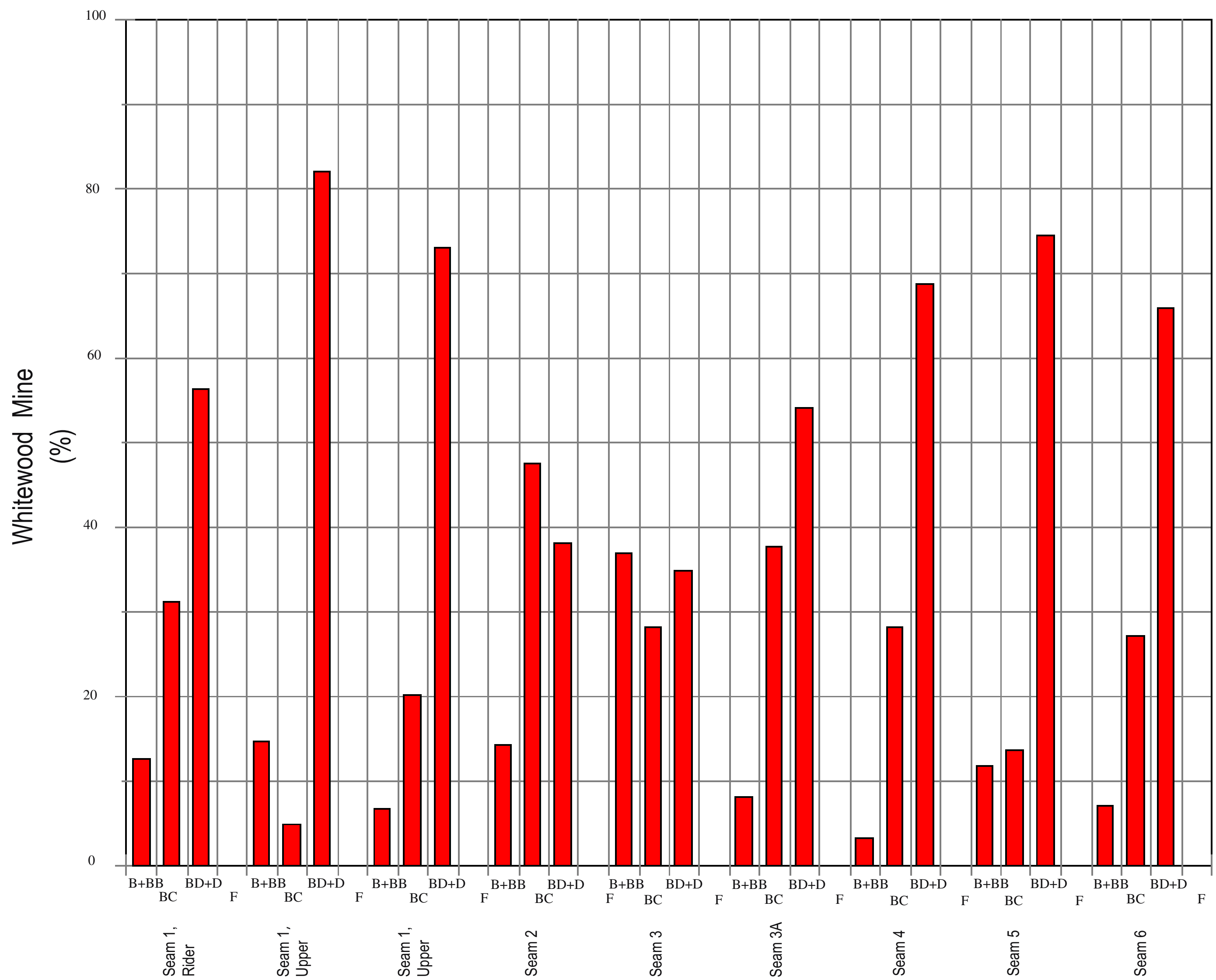

Figure 45. Lithotype distribution in Whitewood mine coals. Abbreviations: B+BB, bright and banded bright; BC, banded bright; BC, banded coal; BD+D, banded dull and dull; F, fibrous.

- At the Genessee mine (Figure 43), seam Nos. 1, 2 and 3 are dominated by banded dull and dull lithotypes, ranging from 47% to 57%. Seam No. 2A is dominated by the occurrence of bright and banded bright lithotypes (40%). Bright and banded bright lithotypes also occur in appreciable amounts in seam Nos. 1 and 3 (>25%).

- At Highvale mine, pit 03 (Figure 44), seam Nos. 2, 3, 4, 5 and 6 show a predominance of banded dull and dull lithotypes (47–67 vol. %). Seam No. 1 is predominantly banded coal, but also contains appreciable amounts of bright and banded bright coal (27 vol. %). The lithotype distribution at Highvale mine, pit 02S, is similar, although seam No. 1 has a higher proportion of banded dull and dull lithotypes, whereas the proportion of dull lithotypes is reduced in seam No. 2 and banded bright and bright lithotypes varieties are somewhat higher.

- At the Whitewood mine, most seams show a predominance of dull and banded dull lithotypes (Figure 45), more than 70% in seam Nos. 1 (upper), 1 (lower) and 5. Banded bright and bright lithotypes make only minor contributions to the overall coal composition in most seams (Figure 45), except in seam No. 3, where the bright lithotypes constitute 37% of the total. Banded coal (composed of thin, alternating dull and bright layers) is abundant in seam Nos. 1, 2, 3A and Rider (>25%).

5 Conclusions and Recommendations

The comprehensive petrographic dataset on the Ardley Coal Zone presented in this report has demonstrated that

- there are significant compositional differences between the various seams; and
- there are also significant in-seam compositional variations, on both the macroscopic (lithotype) and microscopic (maceral) levels.

From a petrographic viewpoint, these variations in petrographic characteristics will have an effect on the gas generation and storage capacities of the coals. The compositional differences will likely also affect the gas desorption characteristics of the Ardley coals.

Future investigations on the CBM potential of the Ardley coals should include

- selection of cored Ardley coals from depth, where rank levels are such that the coals are in the gas generation window, preferably material for which gas desorption values are available;
- petrographic and physicochemical analysis of full-seam channel samples and subsections obtained from core; petrographic analysis would include vitrinite reflectance measurement, maceral and microlithotype analysis, and description of lithotypes; physicochemical analysis would include proximate and ultimate analysis, and determination of porosity and permeability;
- gas adsorption isotherm experiments on selected seams and seam subsections; and
- use of coal cuttings from petroleum exploration wells to define regional rank (vitrinite reflectance) variations of the Ardley Coal Zone.

6 References

Allan, J.A. and Sanderson, J.O.G. (1945): Geology of the Red Deer and Rosebud sheets, Alberta; Alberta Research Council, Report 13, 115 p.

Beaton, A., Pana, C., Chen, D., Wynne, D. and Langenberg, C.W. (2002): Coal and coalbed methane potential of Upper Cretaceous–Tertiary strata, Alberta Plains; Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2002-06.

Bustin, R., Cameron, A., Grieve, D. and Kalkreuth, W. (1989): Coal petrology – its principles, methods and application; Geological Association of Canada, Short Course Notes, Volume 3, 276 p. (3rd edition).

Campbell, J.D. (1967): Ardley Coal Zone in the Alberta Plains; Alberta Research Council, Report 67-1, 28 p.

Clayton, J.L. (1998): Geochemistry of coalbed gas – a review; International Journal of Coal Geology, v. 35, p. 159–173.

Dawson, F.M., Marchioni, D.L., Anderson, T.C. and McDougall, W.J. (2000): An assessment of coalbed methane exploration projects in Canada; Geological Survey of Canada, Bulletin 549, 217 p.

Dawson, M. (1995): Coalbed methane: a comparison between Canada and the United States; Geological Survey of Canada; Bulletin 489, 60 p.

Dawson, M. and Kalkreuth, W. (1994): Coal rank and coalbed methane potential of Cretaceous/Tertiary coals in the Canadian Rocky Mountain Foothills and adjacent Foreland: 1. Hinton and Grande Cache areas, Alberta; Bulletin of Canadian Petroleum Geology, v. 42, p. 544–561

Dawson, M., McCandish, K., Godfrey, T., Nikols, D. and Fenton, M. (1985): The Ardley Coal Zone; Canadian Society of Petroleum Geologists, Coal Division, Field Trip 1, Sept. 20/21, 1985.

Dawson, M., Ryan, B., Pratt, K. and Clow, J. (1994): Coalbed Methane Micropermeability Project; unpublished final report, Geological Survey of Canada, Calgary, 80 p.

Demchuk, T. and Nelson-Gladiotis, D. (1993): The identification and significance of kaolinite-rich bentonite in the Ardley Coal Zone, Wabamun, Alberta, Canada; Bulletin of Canadian Petroleum Geology, v. 41, p. 464–469

Eddy, G., Rightmire, C. and Byren, C. (1982): Relationship of methane content with coal rank and depth: theoretical versus observed; Proceedings of Unconventional Gas Recovery Symposium, Pittsburgh, Pennsylvania, Society of Petroleum Engineers/Department of Energy 10800, p. 117–122.

Faraj, B., Fielding, C. and Mackinnon, D. (1996): Cleat mineralization of Upper Permian Baralaba/Rangal coal-measures, Bowen basin, Australia; *in* Coalbed Methane and Coal Geology, Gayer and Harris (ed.), Geological Society, Special Publication 109, p. 151–164

Gamson, P., Beamish, B. and Johnson, D. (1996): Coal microstructure and secondary mineralization: their effect on methane recovery; *in* Coalbed Methane and Coal Geology, Gayer and Harris (ed.), Geological Society, Special Publication 109, p. 165–179.

Gibson, D. (1977): Upper Cretaceous and Tertiary coal-bearing strata in the Drumheller–Ardley region, Red Deer River Valley, Alberta; Geological Survey of Canada, Paper 76-35, 41 p.

Holter, M.E., Yurko, J.R. and Chu, M. (1975): Geology and coal reserves of the Ardley Coal Zone of central Alberta; Alberta Research Council, Report 75-7, 41 p.

Kalkreuth, W., Abercrombie, H. and Burchard, K. (1994): The coalbed methane potential of Jurassic/Cretaceous coals from the Fernie Basin, British Columbia, Canada; Erdöl und Kohle, Erdgas, Petrochemie, Bd. 47, Heft 4, p. 134–139.

Kim, A. (1977): Estimating methane content of bituminous coalbeds from adsorption data; United States Bureau of Mines, Report of Invesitigation 8245, 22 p.

Lamberson, M. and Bustin, R. (1993): Coalbed methane characteristics of Gates Formation coals, northeastern British Columbia: effect of maceral composition; American Association of Petroleum Geologists Bulletin, v. 77, no. 12, p. 2062–2076.

Meissner, F. (1984): Cretaceous and Tertiary coals as source for gas accumulations in the Rocky Mountain area; *in* Hydrocarbon Source Rocks of the Greater Rocky Mountain Region, Denver, Colorado; Rocky Mountain Association of Geologists, p. 401–432.

Richardson, R.J.H, Strobl, R.S., Macdonald, D.E., Nurkowski, J.R., McCabe, P.J. and Bosman, A. (1988): An evaluation of the coal resources of the Ardley Coal Zone, to a depth of 400 m, in the Alberta plains area; Alberta Research Council, Alberta Geological Survey, Open File Report 1988-02, 96 p.

Rottenfusser, B., Langenberg, W., Mandryk, G., Richardson, R., Fildes, B., Olic, J., Stewart, S., Eccles, R., Evans, C., Spelrem, M., Sprecher, B., Brulotte, M., Gentzis, T., Wynne, D. and Yuan, L.P. (1991): Regional evaluation of the coal bed methane potential in the plains and foothills of Alberta: stratigraphy and rank study; Alberta Research Council, Alberta Geological Survey, Special Report SPE-7, 126 p. plus addenda.

Appendix 1. Petrographical and chemical seam characteristics at Genessee, Highvale and Whitewood mines

				MACERAL	ANALYSIS (m.m.f.)	(VOL%)	PROXIMATE	ANALYSIS	(wt.%)		EAST.	NORTH.
MINE	SEAM	(cm)	Ro (%)	VITRINITE	INERTINITE	LIPTINITE	VM	FC	ASH	S (wt.%)		
GENESSEE	Cloud	7	0.45	83	16	1					682760	5911815
GENESSEE	1	31	0.49	50	46	4	31.53	49.52	18.94	0.28	681120	5912715
GENESSEE	2 Rider	34	0.44	80	16	4	30.78	45.80	23.41	0.44	681220	5912715
GENESSEE	2	298	0.43	54	40	6	30.26	49.87	19.88	0.22	681520	5912715
GENESSEE	2A	55	0.44	91	6	3	37.52	54.73	7.75	0.48	681920	5912715
GENESSEE	3	160	0.52	69	28	3					681160	5912465
HIGHVALE PIT 02S	1	210	0.41	63	34	3	36.04	50.27	13.69	0.46	664351	5925670
HIGHVALE PIT 02S	2	297	0.44	58	37	4	35.23	52.37	11.48	0.19	665088	5925772
HIGHVALE PIT 02S	3	65	0.41	62	34	4	31.68	42.06	26.25	0.19	664652	5925673
HIGHVALE PIT 02S	4	90	0.40	59	38	2	29.70	37.28	33.02	0.25	664653	5925673
HIGHVALE PIT 02S	5	19		45	47	8					664672	5925673
HIGHVALE PIT 02S	6	120	0.42	75	21	4	33.24	46.05	20.71	0.32	664752	5925678
HIGHVALE Pit 02N	1	310	0.43	58	39	3	32.99	47.70	19.31	0.20	660502	5929281
HIGHVALE Pit 02N	2	342	0.44	56	39	5	33.51	47.09	19.41	0.15	660542	5929343
HIGHVALE Pit 02N	3	60	0.44	61	33	5	37.22	53.69	9.10	0.27	660542	5929333
HIGHVALE Pit 02N	4	89	0.40	51	45	4	32.12	45.60	22.26	0.34	660573	5929368
HIGHVALE Pit 02N	6	131	0.42	65	29	6	34.52	48.38	17.11	0.27	660394	5929139

Appendix 1. Petrographical and chemical seam characteristics at Genessee, Highvale and Whitewood mines

				MACERAL	ANALYSIS	(VOL%)	PROXIMATE	ANALYSIS	(wt.%)		EAST.	NORTH.
					(m.m.f.)							
MINE	SEAM	(cm)	Ro (%)	VITRINITE	INERTINITE	LIPTINITE	VM	FC	ASH	S		
										(wt.%)		
HIGHVALE Pit 03	1	383	0.45	57	39	4	31.33	44.67	24.00	0.21	653517	5932410
HIGHVALE Pit 03	2	328	0.44	60	36	4	33.42	47.31	19.27	0.18	653606	5932404
HIGHVALE Pit 03	3	139	0.44	65	31	4	33.68	49.33	16.99	0.27	653606	5932404
HIGHVALE Pit 03	4	49	0.43	55	42	3	31.03	47.76	21.21	0.38	653812	5932448
HIGHVALE Pit 03	5	30		42	50	8					653812	5932448
HIGHVALE Pit 03	6	111	0.44	75	19	6	35.47	46.90	17.62	0.30	653812	5932448
WHITEWOOD	1, upper	148	0.40	52	45	4	27.77	32.46	39.77	0.45	662800	5940540
WHITEWOOD	1, lower	176	0.42	64	32	4	31.83	47.45	20.72	0.18	662800	5940540
WHITEWOOD	2	42	0.42	73	22	5	36.59	51.64	11.76	0.32	662790	5939890
WHITEWOOD	3	340	0.42	64	31	5	36.87	52.13	11.00	0.26	663150	5942320
WHITEWOOD	3A	42	0.43	53	44	3	30.4	45.33	24.27	0.37	663150	5942310
WHITEWOOD	3X	9		50	46	4					663150	5942300
WHITEWOOD	4	69	0.41	51	46	3	29.81	45.99	24.12	0.43	663150	5942290
WHITEWOOD	5	78	0.40	60	36	3	26.25	35.81	37.94	0.40	663150	5942280
WHITEWOOD	6	85	0.40	73	22	5	31.40	41.30	27.40	0.34	663100	5942270

note: maceral data for seam # 5 at Highvale calculated from weighted seam sub-samples

note: data for proximate analysis and sulphur contents reported on dry basis

Appendix 2. Petrography of full-seam channel samples at Genessee, Highvale and Whitewood mines

					VITRINITE								INERTINITE						LIPTINITE							MINERALS				
MINE	SEAM	Ro(%)	KBA #	PELLET #	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL		Qtz	Clay	Car	Pyr	TM
GENESSEE	Cloud	0.45	35/95	236 /95	1	50	3	24		5		83	2	2	13			16	1					1	100	5	12	1	0	34
GENESSEE	No 1	0.49	646/94	1891 /94		19	2	26		2		49	13	19	14			46	4					5	100	4	3			7
GENESSEE	No 2 Rider	0.44	631/94	1892 /94	1	50	5	22	1	2		81	4	6	5			16	2			1		4	100	1	4			5
GENESSEE	No 2	0.43	618/94	1893 /94	1	30	3	17		2		53	18	10	11	1		40	4		1	1		6	100	2	3	1	1	7
GENESSEE	No 2A	0.44	573/94	1894 /94	1	62	4	24				91	3	1	1			6	3					4	100	1	2			3
GENESSEE	No 3	0.52	33/95	235 /95		45	5	19				69	8	13	5	1		28	3					4	100	1	1			2
HIGHVALE PIT 02S	1	0.41	504 /94	1587 /94	1	40	1	19		2	1	63	13	10	12		0	34	2		0	1		3	100	1	7	2	0	10
HIGHVALE PIT 02S	2	0.44	475 /94	1558 /94	1	31	3	22	0	1	1	58	18	7	12	0	0	37	3	0	1	1		4	100	2	2			3
HIGHVALE PIT 02S	3	0.41	411 /94	1501 /94	3	36	2	17		4		62	12	14	8	0		34	3		1		0	4	100	4	7	4		15
HIGHVALE PIT 02S	4	0.40	396 /94	1493 /94	2	35	2	15		5	0	59	12	9	16		1	38	1		1	0		2	100	8	8	4		21
HIGHVALE PIT 02S	6	0.42	559 /94	1889 /94	0	40	3	29	0	3		75	10	3	8	0		21	3			1		4	100	3	4	2		9
HIGHVALE PIT 02N	1	0.43	520 /94	1594 /94	1	33	2	20		1	0	58	14	10	13	1	0	39	2	0		0	1	3	100	3	5	1		9
HIGHVALE PIT 02N	2	0.44	516 /94	1572 /94	1	32	4	16	0	2	0	56	12	9	16	1	1	39	3	1	1	1		5	100	3	8	1		11
HIGHVALE PIT 02N	3	0.44	510 /94	1590 /94	2	29	3	27			0	61	16	7	9	0	0	33	5	0		0		5	100	0	1	0		2
HIGHVALE PIT 02N	4	0.40	513 /94	1591 /94	2	27	3	18		2		51	15	11	19	1	1	45	3	0		1		4	100	2	9	1		11
HIGHVALE PIT 02N	6	0.42	533 /94	1890 /94	3	31	3	28	1	0		65	13	7	10	1		29	5		0	0		6	100	4	2			6
HIGHVALE PIT 03	1	0.43	153 /94	1245 /94		38	2	14	0	1	0	57	13	9	15	1	0	39	3	2	0	1	0	4	100	2	9	2		13
HIGHVALE PIT 03	2	0.44	112 /94	1220 /94	1	32	5	20	0	2		60	12	8	14	2	0	36	3			1		4	100	1	7	0	1	9
HIGHVALE PIT 03	3	0.44	163 /94	1262 /94	0	42	2	17	1	3	0	65	8	10	13	0		31	3	0		0		4	100	2	7	2	0	12
HIGHVALE PIT 03	4	0.40	174 /94	1264 /94	0	31	2	18	0	4		55	14	11	15	1	1	42	3		0	0		3	100	1	8	6		15
HIGHVALE PIT 03	6	0.42	203 /94	1285 /94	1	43	2	28	1	1	0	75	6	6	7	1		19	4	1	0	1	1	6	100	3	5	0		8
WHITEWOOD	1upper	0.40	370 /94	1392 /94	1	32	4	12		3		52	8	11	26			45	3			1		4	100	5	22		0	27
WHITEWOOD	1 lower	0.42	369 /94	1391 /94	1	43	2	17	1		0	64	16	6	9	0	0	32	2	0	0	0		4	100	1	8			9
WHITEWOOD	2	0.42	328 /94	1371 /94	0	48	4	18		1	1	73	5	10	6	0	0	22	3	0	1	1		5	100	1	2			3
WHITEWOOD	3	0.43	317 /94	1361 /94		44	4	16			0	64	11	9	9	0	0	31	4	0	0			5	100	2	2			4
WHITEWOOD	3A	0.42	258 /94	1406 /94	1	30	2	16		3	1	53	17	12	16			44	2			1		3	100	4	4	1		10
WHITEWOOD	3X	0	225 /94	1306 /94		26	2	19		2		50	16	8	19	0	2	46	3			1		4	100	4	5	1		9
WHITEWOOD	4	0.41	257 /94	1305 /94	0	27	1	16	0	6		51	15	13	17		1	46	3		0	0		3	100	5	5	2		13
WHITEWOOD	5	0.40	236 /94	1402 /94	1	32	4	18	1	5		60	9	12	15			36	2	0	1		0	3	100	3	20	1		25
WHITEWOOD	6	0.40	228 /94	1420 /94	0	39	2	30	0	1		73	6	6	9			22	4			0		5	100	1	10	0	0	12

Abbreviations used for coal macerals and mineral matter

Ct=Collotelinite	Sf=Semifusinite	Spo=Sporinite	Qtz=Quartz	KBA # = field number of sample
Cg1=Corpogelinite(in-situ)	F=Fusinite	Cut=Cutinite	Clay=Clay Minerals	Pellet # = number assigned by Geological Survey of Canada to identify pellets, prepared for
Cd=Collodetrinite	Id=Inertodetrinite	Res=Resinite	Car=carbonate	microscopic analyses; the pellets are stored at the GSC facilities in Calgary, Alberta
Cg2=Corpogelinite(detrital)	Mac=Macrinite	Sub=Suberinite	Pyr=Pyrite	
Vd=Vitrodetrinite	Mic=Micrinite	Ld=Liptodetrinite	TM=Total Mineral matter	
TV=Total Vitrinite	TI=Total Inertinite	TL=Total Liptinite	Oth=Other Liptinite	

Note: Maceral data are reported on a mineral matter free basis (normalized to 100 Vol%)

Appendix 3. Lithological log and petrography of coal seam subsections at Genessee Mine

						VITRINITE								INERTINITE					LIPTINITE						MINERALS				
SEAM	LITHOLOGY	(cm)	KBA #	PELLET	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	TI	Spo	Cut	Res	Sub	TL	TOT	Qtz	Clay	Car	Pyr	TM
CLOUD, top	benthonite	3	39/95																										
CLOUD	mudstone	37	38/95																										
CLOUD	benthonite	8	37/95																										
CLOUD	coaly mudst.	20	36/95	237	/95		34	1	9		7		51	6	7	33		47	2				2	100	4	46		1	50
CLOUD	coal	7	35/95	236	/95	1	50	3	24		5		83	2	2	13		16	1				1	100	5	12	1		17
CLOUD, base	mudstone	34	34/95																										
1, top	d.-gr.mudstone	20	652/94	143	/96																								
1	shaley coal	2	651/94	144	/96																								
1	BB	6	650/94	147	/95	1	36	7	28		1	1	73	6	6	8		19	5	1		2	8	100	1	4			5
1	br.mudstone	2	649/94	145	/96																								
1	BB	8	648/94	146	/95		56	5	25				86	3	5	3		10	3		1	1	4	100	1	5			7
1	br. mudstone	16	647/94																										
1	D	13	645/94	145	/95		13	1	18	1	1		34	10	25	23	1	58	7			1	8	100	4	5			9
1	B	2	644/94	144	/95		53	2	22		1		78	6	9	4		18	3				3	100	1	7			8
1	BD	6	643/94	143	/95		21	2	30				53	10	19	11	1	41	5		1		5	100	0	3			4
1	BC	10	642/94	142	/95		21	2	28		1		52	10	15	18	1	43	5			1	5	100	3	4			6
1	br.-gr.mudstone	14	641/94	147	/96																								
1	grey mudstone	20	640/94	148	/96																								
1	d.-gr.mudstone	10	639/94	149	/96																								
1	carb. shale	3	638/94	150	/96																								
1	D	4	637/94	141	/96		23	2	33	1			59	6	10	13	1	30	9			0	10	100	2	4		2	7
1	carb. shale	2	636/94	151	/96																								
1	br.-gr.mudstone	15	635/94	152	/96																								
1	coaly mudstone	10	634/94	153	/96																								
1, base	br.-gr.mudstone	20	633/94	154	/96																								
2 Rider, top	gr.-silty mudst.	80	632/94																										
2	br. mudstone	10	630/94	155	/96																								
2	BD	3	629/94	140	/94	1	15	5	20	1	2		44	7	26	15	1	49	4		1		5	100	1	17		1	18
2	BC	4	628/94	139	/94		26	3	34	1	1		65	3	7	15	1	26	7	1		2	9	100	2	8			10
2	BD	5	627/94	138	/94	1	38	7	28	1	2		76	5	5	8		18	3	2		2	6	100	3	8			11
2	br. mudstone	4	626/94																										
2	BB	5	625/94	137	/94		28	7	44	2			81	2	3	7		13	4	1			5	100	1	1			2
2	B	2	624/94	136	/94		84	5	7	0	0		96	1	1	0		2	1		1	1	2	100					0
2	BC	3	623/94	135	/94	1	58	7	18	1	1		86	4	4	3		10	2		1	1	4	100	2	1			4
2	F	2	622/84	134	/94	1	37	2	13	2		1	55	5	27	7		39	5				5	100	4	1			5
2	B	5	621/94	133	/94	2	79	10	5				96	1	1	1		3				1	1	100		2			2
2	F	1	620/94	132	/94	15	23				5		43	28	25	4		57					0	100	19		4		23
2 Rider, base	d.-br.mudstone	10	619/94	156	/96																								
2, top	br. mudstone	20	617/94	157	/96																								
2	bl.mudstone	7	616/94	158	/96																								
2	carb. shale	9	615/94	159	/96																								
2	D	4	614/94	131	/95		10	1	5		1		17	9	49	21		80	2			1	2	100	6	9			15

For abbreviations of macerals and minerals see Appendix 2

Appendix 3. Lithological log and petrography of coal seam subsections at Genessee Mine

								VITRINITE								INERTINITE					LIPTINITE						MINERALS		
SEAM	LITHOLOGY	(cm)	KBA #	PELLET	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	TI	Spo	Cut	Res	Sub	TL	TOT	Qtz	Clay	Car	Pyr	TM
2	BD	9	613/94	130	/95		34	1	16		4		55	7	15	16	1	38	4		2	1	6	100	6	11	3		20
2	brown shale	3	612/94																										
2	BC	8	611/94	128	/95		13	1	9		3		25	20	26	26		72	2				2	100	12	6			18
2	br. mudstone	5	610/94	160	/96																								
2	shaley coal	3	609/94	161	/96																								
2	BD	8	608/94	127	/95		25	1	23				50	21	11	11	1	45	4			1	5	100	1	6			7
2	BC	4	607/94	126	/95	1	40	6	18				65	6	11	15		32	2			1	3	100	4	3	1		7
2	brown shale	2	606/94																										
2	B	3	605/94	125	/95	1	80	4	4				89	2	3	2		7	1		2	1	4	100	1	3			3
2	BD	7	604/94	124	/95	1	25		10		1		36	19	14	26	1	60	3				3	100	4	4			7
2	BC	9	603/94	123	/95		15	3	14		1		33	28	23	11	1	63	3	1			3	100	1	4			5
2	BB	9	602/94	122	/95		42	4	10	1		1	56	14	14	10	1	39	3		1	1	5	100	1	1			2
2	BD	7	601/94	121	/95	2	9	1	12		1		25	15	23	30		69	5			1	6	100	3	4			8
2		6	600/94	120	/95	1	22	1	16		1		41	11	14	28	1	54	4			1	5	100	7	7			14
2	brown shale	4	599/94	162	/96																								
2	BC	2	598/94	119	/95	1	39	6	22				67	15	12	3	1	31	1			1	1	100		3			3
2	BD	5	597/94	118	/95	1	16	2	30				48	24	15	9		48	2			1	3	100	1	5			6
2	B	2	596/94	117	/95	1	59	14	10			2	86	3	5	2		10	1		2	1	3	100	1	3			3
2	BD	7	595/94	116	/95	1	34	5	12	1			53	21	14	6	1	42	4		1	1	5	100	1	2			3
2	coaly siltst.	2	594/94	163	/96																								
2	BC	3	593/94	115	/95	1	35	5	24	1			65	10	12	7		29	4		1	1	6	100		2	2		3
2	BD	14	592/94	114	/95		13	2	21	1			36	23	17	16	2	59	4				4	100	2	2			4
2	BC	10	591/94	113	/95	2	41	4	7				54	9	13	18		40	3			2	5	100	2	1			3
2	BD	20	590/94	112	/95	1	20	3	17				42	17	16	19	1	53	4		1		5	100	1	1			2
2	BC	4	589/94	111	/95		22	2	24				49	19	14	12	2	48	2		1		3	100	2	1			3
2	BD	6	588/94	110	/95	1	28	2	19				51	13	18	14	2	47	2				2	100	1				1
2	B	5	587/94	109	/95	2	80	7	4		3		96			1		2			1	1	2	100	2	1	5		8
2	coaly siltst.	3	586/94	164	/96																								
2	BB	10	585/94	108	/95	1	48	3	18		1		70	7	16	3	1	27	1	1			3	100	1	1	2		4
2	BD	8	584/94	107	/95		25	5	32				62	13	14	6		33	5				5	100	1	1			2
2	B	7	583/94	106	/95	MISSING SAMPLE							0										0	100					
2	BD	16	582/94	105	/95	1	17	1	14		1		34	21	14	23	3	61	5				5	100	1				1
2	BC	8	581/94	104	/95	1	47	4	11		1		62	9	14	10	1	33	2		2	1	5	100			5		5
2	coal	15	580/94	103	/95		46	3	18			1	68	10	13	4	1	28	3				3	100		1			1
2	coal	15	579/94	102	/95		23	1	20		1	1	45	16	19	13	3	50	4			1	4	100	1	2			3
2	coal	15	578/94	101	/95		42	5	16			1	63	7	8	11	2	28	6		2		8	100	1				1
2	coal	15	577/94	100	/95		38	3	24				65	5	12	8		27	5		1		7	100					
2	coal	15	576/94	99	/95	1	63	3	20				87	1	6	4		10	1			1	2	100	1	1	1		3
2, base	d.-gr.mudstone	3	575/94	165	/96																								
2A, top	mudstone	10	572/94	166	/96																								
2A	BC	5	571/94	98	/95	1	40	8	41	1		1	91	2	3	1		5	3	1		1	4	100	2	3			5
2A	BB	2	570/94	97	/95	2	44	3	24	1			73	13	11	2		25			1		1	100		1			12
2A	F,B,siltstone	2	569/94	96	/95	2	8		16				26	19	45	8	1	73	1				1	100		1		1	12
2A	BC	10	568/94	95	/95	2	58	6	24				90	3	1	2		6	2	1			3	100		2			2
2A	B	1	567/94	94	/95	1	76	3	13	1			94	2	2	1		5				1	1	100	1	4			5
2A	BD	6	566/94	93	/95	2	34	2	29		1		68	8	8	7	1	25	4			2	6	100	1	5			6

For abbreviations of macerals and minerals see Appendix 2

Appendix 3. Lithological log and petrography of coal seam subsections at Genessee Mine

						VITRINITE								INERTINITE					LIPTINITE						MINERALS				
SEAM	LITHOLOGY	(cm)	KBA #	PELLET	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	TI	Spo	Cut	Res	Sub	TL	TOT	Qtz	Clay	Car	Pyr	TM
2A	BC	6	565/94	92	/95																			100					
2A	BB	7	564/94	91	/95		69	2	23				94		1			2	2	1		1	4	100		2			2
2A	F	1	563/94	90	/95		11	1	8				20	7	56	14		77	2				2	100		1			1
2A	BC	6	562/94	89	/95	2	70	7	9		1	1	90	1	3	2		6			3	1	4	100	2	1	3		6
2A	BD	5	561/94	88	/95	1	68	10	17	1			97						1			1	2	99	1	1	2		4
2A, base	d.-gr.mudstone	10	560/94	167	/96																								
3, top	mudstone	20	32/95																										
3	D	5	30/95	234	/95	1	24	2			4		30	10	25	35		70						100	8	27			35
3	B	3	29/95	233	/95	1	73	12	2				88	1	1	2		4			3	4	8	100		1	1		2
3	silty mudstone	2	31/95		/95																								
3	D	12	28/95	232	/95		21	1	22				44	20	16	14	1	52	3				3	100	1	5			6
3	BD	5	27/95	231	/95	1	22	2	13			1	39	21	22	14	2	59	1			1	2	100	1				1
3	BB	6	26/95	230	/95	1	66	4	6		2		78	8	7	4		18	1		1	1	3	100	1		4		6
3	D	2	25/95	229	/95	1	12	1	9				24	26	36	11		73	2	1			3	100		1			1
3	B	3	24/95	228	/95	2	65	14	6			1	89	3	3	1		7	1		2	1	5	100		1			1
3	BD	14	23/95	227	/95	1	26	5	27			1	59	15	11	5	2	34	5	1		1	7	100		5			5
3	B	5	22/95	226	/95	2	67	13	7			1	90	2	3	2		7	1		1	1	3	100		1			1
3	BC	5	21/95	225	/95	1	40	7	25	1			74	10	7	4		21	2		1	1	5	100					0
3	B	2	20/95	224	/95	5	73	4	8			2	91	3	1	2		6	1			2	3	100		1			1
3	BC	17	19/95	223	/95	1	27	2	23				53	18	19	6	1	44	3				3	100		1			1
3	B	3	18/95	222	/95	3	65	7	13			1	89	3	4	2		8		1	1	1	2	100					
3	BC	7	17/95	221	/95	2	32	5	24			1	63	11	15	7	1	34	2				2	100		2			2
3	BD	4	16/95	220	/95	2	18	3	28	1		1	53	10	15	14	1	41	6			1	7	100		5			5
3	B	1	15/95	219	/95	3	65	5	5				78	5	4	2		12	2		7	2	11	100					
3	D	2	14/95	218	/95		17		21				39	15	22	18	1	56	2			1	3	100					
3	B	5	13/95	217	/95	3	63	6	9			1	83	4	6	2		13	1		3		4	100					
3	BD	7	12/95	216	/95	2	28	3	32				65	8	9	11	1	29	4				4	100	1				1
3	BD	10	11/95	215	/95	1	23	2	27	1		1	54	10	15	13		39	5			1	6	100	2	1			2
3	BD	4	10/95	214	/95	1	30	5	24			1	61	13	11	10		34	4			2	5	100	3	1			4
3	B	5	9/95	213	/95	1	43	6	17			1	68	7	11	9		27	3				3	100					
3	BB	9	8/95	212	/95		46	6	28			1	80	4	8	4		17	2				2	100		1			1
3	F	1	7/95	211	/95		5	1	8				15	7	69	7		83	2				2	100					
3	BD	8	6/95	210	/95	1	43	5	25	1			76	4	8	6		19	4			1	5	100	1	1			1
3	B	1	5/94	209	/95	1	76	6	13	1		1	98			1		1				1	1	100		1			1
3	mudstone	3	4/95		/95																								
3	BC	4	3/95	208	/95	2	73	7	12			1	93						2	1	1	4	7	100		2			2
3	D	2	2/95	207	/95	1	41	13	34	1	1		92	1				2	3	3			6	100	2	4		1	7
3, base	mudstone	20	1/95		/95																								

For abbreviations of macerals and minerals see Appendix 2

Appendix 4. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 02S

						VITRINITE							INERTINITE						LIPTINITE							MINERALS				
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOTAL	Qtz	Clay	Car	Pyr	TM
1, top	carb. sh	20	507 /94																											
1	BD	10	506 /94	1589	/94	5	28	4	8		3	48	10	7	27	0		45	5	0		2		7	100	3	6		0	9
1	D	4	505 /94	1588	/94		20	5	17		3	45	1	7	43			51	1		1	2		4	100	14	7		1	22
1	D	3	503 /94	1586	/94	7	39	4	20		13	82	2		14			16				2		2	100	14	42			56
1	B	5	502 /94	1585	/94	1	54	22	9	1	2	89	1	2	4	0	0	7	1		1	2		3	100	1	3		1	5
1	B	12	501 /94	1584	/94	3	23	10	21	0	1	59	17	9	7	1		34	3		1	3		7	100	1	4		1	5
1	B	2	500 /94	1583	/94		88	8	1			97	1			1	1	2		1		1		2	100	0		11	3	15
1	BC	7	499 /94	1582	/94	9	30	7	18	0	1	65	14	9	8	0	1	31	3		1	0		4	100		4			4
1	BB	5	498 /94	1581	/94	5	20	4	16	0	2	47	8	15	22	0	1	47	5			1		6	100	1	5		1	6
1	BC	6	497 /94	1580	/94	3	35	4	4		1	47	10	16	20	0	0	47	6		0	1		7	100		2		1	2
1	D	8	496 /94	1579	/94	2	9	3	7		3	25	15	22	31	1	0	70	4			1		5	100	2	7			8
1	B	3	495 /94	1578	/94	5	70	12	2	1		90		2	3			5	1		3	2		5	100		1		1	2
1	D	10	494 /94	1577	/94	0	20	2	9	0		32	16	19	25	1	1	62	6			0		6	100	2	2			4
1	B	2	493 /94	1576	/94	1	61	4	11		0	78	2	4	8		2	16	1		4	1		6	100		2	1	2	4
1	BC	9	492 /94	1575	/94	1	21	3	16	1		42	13	25	11	2	1	51	5		1	1		7	100	0	3		0	3
1	D	3	491 /94	1574	/94	0	6	1	13		0	21	21	35	18	2		76	2		0	0		3	100		2		1	3
1	BD	15	490 /94	1573	/94	2	26	6	13			47	14	13	17	2	1	48	3		2	0		6	100	0	2		0	3
1	B	4	489 /94	1572	/94	1	75	5	5	0		86	0	2	3	0	1	7			7	0		7	100		2	3	1	6
1	BD	3	488 /94	1571	/94	0	19	4	21	2		45	15	20	13	2	0	50	3	0	1	1		5	100		1		0	1
1	BC	5	487 /94	1570	/94	1	24	5	15			45	16	22	10	2	0	50	2		1	2		5	100	0	1		0	2
1	D	4	486 /94	1569	/94		9	2	24			35	18	25	12	4		58	6	1		0		7	100	0	1		1	2
1	BC	4	485 /94	1568	/94	1	42	3	10			56	9	25	6	1		40	2		1	0		3	100	0	1		0	1
1	BD	7	484 /94	1567	/94	2	22	2	22	0		48	15	19	12	1		47	4			0		4	100				0	0
1	B	25	483 /94	1566	/94		87	1	1			89						0			11			11	100			5	2	6
1	BC	10	482 /94	1565	/94	0	33	4	23	1		61	14	11	8	2	0	35	1		1	1		3	100		2			2
1	?	4	481 /94	1564	/94	2	71	16	3			92	1	1	1			3			3	2		5	100			1	1	2
1	BD	8	480 /94	1563	/94	1	24	6	23		0	55	10	17	10	1		38	5		1	2		8	100		3			3
1	BB	5	479 /94	1562	/94	1	59	6	12	1		79	3	5	1		1	11	1		8	1		10	100		2		1	3
1	BD	14	478 /94	1561	/94	3	49	6	25	2		85	2	4	3	0	1	10	2		1	2		5	100	1	2			2
1	BC	6	477 94	1560	/94	1	46	4	14	0		65	6	9	10	0	0	26	5		2	3		9	100	1	1		1	2
1	BD	10	476 /94	1559	/94	1	29	4	19	0	0	54	2	14	20			37	6		1	2		9	100	5	12	1	0	18
1, base	carb. mudst.	10	474 /94																											
2, top	carb.siltst.	42	473 /94																											
2	BC	5	472 /94	1557	/94	1	51	17	6	1	1	77	2	4	9	0		15	1		1	5		7	100	0	5			6
2	BD	15	471 /94	1556	/94		13	1	28			41	11	19	17	3		50	7		0	2		9	100	2	10			12
2	BC	6	470 /94	1555	/94		42	0	31		1	75	2	7	12	0		21	1		0	2		4	100	9	3	1	1	14
2	D	4	469 /94	1554	/94	0	1	19	13		1	35	9	20	27	1		58	5	0	0	2		7	100	4	8			11
2	BC	5	468 /94	1553	/94	0	56	5	7	0	1	71	4	7	6	1		18	0	1	7	3		11	100	1	1		0	3

For abbreviations of macerals and minerals see Appendix 2

Appendix 4. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 02S

								VITRINITE							INERTINITE							LIPTINITE						MINERALS		
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOTAL	Qtz	Clay	Car	Pyr	TM
2	carb.shale	4	467 /94																											
2	B	1	466 /94	1552	/94	2	65	17	1		1	85	1	1	2			3	1	1	6	3		11	99					0
2	D	3	465 /94	1551	/94	0	8	1	9	1	1	20	19	18	30	2		69	10	0		1		11	100	4	1	0		5
2	BB	2	464 /94	1550	/94		38	6	12	3		59	5	5	23		0	33	7			1		8	100		7			7
2	D	7	463 /94	1549	/94	1	10	2	11	1	1	25	20	15	27	2		64	8			3		11	100	0	9		0	10
2	B	2	462 /94	1548	/94	2	75	11	1			89	1		4	2		7		1		3		4	100	1	3			4
2	BD	4	461 /94	1547	/94	1	11	5	16		1	33	14	12	29	2	1	57	7	1		2		9	100	1	1			2
2	D	6	460 /94	1546	/94		18	1	20		0	40	8	10	30	0		48	10	1	0	1		12	100	7	1			8
2	siltstone	1	459 /94																											
2	BD	5	458 /94	1593	/94		17	2	21			40	10	7	28	3		48	9		1	2		12	100	2	1			3
2	BB	5	457 /94	1545	/94	3	40	4	17		1	65	4	8	17	1	1	30	4			1		5	100	1	6			7
2	BD	8	456 /94	1544	/94		26	2	20		0	49	9	18	17	2		46	4	0	0	1		5	100	2	4			7
2	BC	10	455 /94	1543	/94		36	6	16		0	58	11	10	12	2		35	4		1	1		6	100	1	1	0		2
2	BD	7	454 /94	1542	/94	0	10	2	21	1	1	34	11	17	25	1		54	10	0		1		12	100	5	1	0		6
2	F	0.5	453 /94	1541	/94		3		6			10	3	78	6	1		88	2	1				2	100					0
2	BD	4	452 /94	1540	/94		23	3	20	1		48	7	19	19	1		46	4	1	0	1		6	100	1	1			2
2	mudstone	0.5																												
2	B	1	451 /94	1539	/94		49	11	9		1	70	2	10	8	2	0	23	5	1		1		7	100	3	4			6
2	BD	5	450 /94	1538	/94		14	1	7		1	22	19	25	26	1		70	5		1	1		7	100	2	1			3
2	BB	2	449 /94	1537	/94		35	2	10	0	0	48	14	18	12	2	1	48	3		0	1		4	100	4	2			6
2	BD	7	448 /94	1536	/94		23	3	11		1	37	7	19	24	2	1	53	6	1	2	2		10	100	3	2			5
2	siltstone	2	447 /94																											
2	BD	2	446 /94	1535	/94	0	14	1	17		1	34	21	15	21	2		58	6		1	1		8	100	6	6	1		12
2	B	2	445 /94	1534	/94	1	50	6	17	0		74	9	6	5			20	1		4	2	0	6	100	1	0			1
2	BC	7	444 /94	1533	/94	1	22	7	30	1		61	16	10	7	0		33	5		0	1		7	100	0	1			2
2	BB	18	443 /94	1532	/94	3	50	10	10		1	73	6	8	3	2	0	19	3		2	2		7	100		2			2
2	D	5	442 /94	1531	/94	1	20	3	22	1		47	18	21	5	1		46	3		3	0		6	100		0			0
2	BD	3	441 /94	1530	/94	0	20	3	25	2		50	16	21	9			46	2		1	1		3	100		1			1
2	BC	3	440 /94	1529	/94	2	42	12	15	1		72	8	6	10	0	0	25	2		1	1		4	100		1			1
2	BB	7	439 /94	1528	/94	1	42	6	12		0	62	11	12	11			34	2			1		4	100	1	1			2
2	B	2	438 /94	1527	/94	3	61	22	4	1		91	1	3	2	1	1	7			2	1		3	100		2			2
2	BC	10	437 /94	1526	/94	1	25	14	23	0		64	15	9	8	1	0	32	2		1	1		4	100		1			1
2	BC	5	436 /94	1525	/94	0	36	14	22	2		75	6	7	6	1	0	20	3		1	1		5	100	1	1			2
2	BD	1	435 /94	1524	/94		25	4	15	1	0	45	16	25	9	1	0	52	2	0	1	1		3	100				0	0
2	BC	9	434 /94	1523	/94		22	7	27	1	0	58	11	23	3	1	1	38	1	0	1	0		3	100	1	1			1
2	B	1	433 /94	1522	/94	1	33	7	23	1	0	64	14	12	5			32	1		2	1		4	100	0	1			2
2	BB	7	432 /94	1521	/94	3	30	9	24	1		67	14	9	5	1		29	2	0	0	1		4	100	0	2			2
2	B	2	431 /94	1520	/94	1	64	8	4			78	2	2				3			16	3		19	100					0
2	BD	1	430 /94	1519	/94	0	18	4	18		0	41	33	16	4	1		55	3		0	0		4	100	1	0			1
2	BB	10	429 /94	1518	/94	0	38	9	18	1		66	11	12	4	1	1	28	3	1	1	1		5	100		0			0
2	B	2	428 /94	1517	/94	1	63	5	11			79	2	8	4		3	17	2		1	2		4	100		0			0

For abbreviations of macerals and minerals see Appendix 2

Appendix 4. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 02S

						VITRINITE							INERTINITE						LIPTINITE							MINERALS				
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOTAL	Qtz	Clay	Car	Pyr	TM
2	BC	3	427 /94	1516	/94	1	34	4	21	1		61	14	14	7	0		36	2		0			3	100		1			1
2	B	2	426 /94	1515	/94	0	67	7	10	1		85	3	5	3			11			3	1		4	100		0			0
2	BB	6	425 /94	1514	/94	0	70	11	6	0		89	1	2	1		1	5		0	5	2		7	100	0			0	1
2	F	2	424 /94	1513	/94		10	3	22	1		36	24	32	6			61	2			0		2	100				0	0
2	BC	3	423 /94	1512	/94	1	37	5	22	1		66	13	9	7	1		30	3	0		1	0	4	100		1			1
2	BD	4	422 /94	1511	/94	0	18	3	23	2		46	13	13	13	2		41	9		1	4		13	100	1				1
2	F	1	421 /94	1510	/94							0	22	78				100						0	100					0
2	BC	4	420 /94	1509	/94	1	26	4	18		1	50	11	23	8	2		44	4		1	0		6	100	1	1			1
2	F	1	419 /94	1508	/94		4	0	5	0		10	11	75	4			90	0					0	100					0
2	BC	9	418 /94	1507	/94	2	24	3	30	1	1	60	11	16	7	2	0	36	3		0	2		5	100	0	1			2
2	BD	5	417 /94	1506	/94	0	28	7	30	2	1	67	7	11	8	0		26	3		0	3	0	7	100					0
2	BB	7	416 /94	1505	/94	0	57	13	11	1		83	3	5	1		0	9	1		3	4		8	100	1	1			2
2	BC	5	415 /94	1504	/94	5	55	12	15	1	0	87	2	2	3		0	7	2		2	2		5	100					0
2	BB	3	414 /94	1503	/94	1	48	6	17	1	1	75	3	9	8			19	3	0		2		6	100	1	1			2
2	carb.shale	2	413 /94																											
2	BC	4	412 /94	1502	/94	2	52	10	18	1	2	84	2	4	2	0		8	5	0		2		8	100	0	8	1		9
2, base	mudstone	10	474 /94																											
3, rider	BB	4	409 /94	1500	/94	4	63	15	10	0		92	1	0	0			2				6		6	100		3	7	1	10
	mudstone	14	408 /94																											
	carb.shale	6	407 /94																											
3, top	mudstone	2	406 /94																											
3	BC	15	405 /94	1499	/94	2	28	5	13	1	1	50	14	12	14	1	0	41	6		2	1		8	100		1	0		2
3	BD	12	404 /94	1498	/94	1	20	3	21	1	1	48	18	17	11	1	0	47	4		1	1		6	100		2			2
3	BC	8	403 /94	1497	/94	2	34	4	21	1	1	63	11	16	6	1	0	34	2			1		3	100		1	0		2
3	B	9	402 /94	1496	/94	2	44	2	14	0	1	63	7	15	9	0	0	31	4			1		5	100	3	2	4		8
3	carb.shale	3	401 /94																											
3	B	3	400 /94	1495	/94	2	31	2	19	0	1	55	7	16	15		0	39	5			1		7	100	2	3	1		6
3	BD	2	399 /94	1494	/94	1	20	3	23	1	3	50	5	10	24			39	7		0	3		11	100	6	8	0		15
3, base	mudstone	1	398 /94																											
	carb. shale	4	397 /94																											
	mudstone	4	410 /94																											
	carb. mudst.	78	394 /94																											
4, top	carb.shale	7	393 /94																											
4	D	9	392 /94	1492	/94	0	5		3		2	10	34	20	22	1	0	78	10		0	0		11	100	1	7			8
4	BC	10	391 /94	1491	/94	1	34	11	21	1	1	69	11	11	5	0	0	27	3		1			4	100	1	1	2		3
4	BD	9	390 /94	1490	/94	2	20	6	25	1	0	55	19	12	8	0	0	39	4		0	1	0	6	100		1			1
4	BC	10	389 /94	1489	/94	1	23	8	16	1		48	18	19	8	1		47	3	1	1	1		5	100	0	2			2

For abbreviations of macerals and minerals see Appendix 2

Appendix 4. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 02S

						VITRINITE							INERTINITE						LIPTINITE							MINERALS				
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOTAL	Qtz	Clay	Car	Pyr	TM
4	B	5	388 /94	1488	/94	2	43	13	8	1	1	68	9	10	7	1	1	28	4			0		4	100		1			1
4	BC	6	387 /94	1487	/94		18	6	10			33	22	21	13	3	0	60	7		0	0		7	100		1			1
4	BD	8	386 /94	1486	/94	1	13	2	14	0	2	32	25	22	16		1	63	5			0		5	100		1			1
4	D	10	385 /94	1485	/94	1	15	2	12	1	1	31	14	25	22	1		62	7		0	0		7	100	1	3	0		5
4	BD	4	384 /94	1484	/94	1	13	1	20	1	3	39	16	24	10		1	52	8			1		9	100	0	3		0	4
4	BC	7	383 /94																											
4, base	mudstone	4	382 /94																											
	carb.shale	7	381 /94																											
	coaly shale	23	380A/94																											
	carb.shale	3	380 /94																											
5, top	clay	1	379 /94																											
5	BD	8	378 /94	1483	/94	1	18	5	11		1	35	12	25	19	0		57	4	1	1	2		8	100	1	8	0	1	9
5	carb.shale	3	377 /94																											
5	BC	8	376 /94	1482	/94	2	30	5	11	1	7	56	3	19	14			36	2		2	3	2	8	100	3	39			42
5	carb. Mudst.	10	375 /94																											
5	mudstone	70	374 /94																											
5	carb.shale	13	373 /94																											
5	D	10	372 /94	1481	/94	2	21	3	6		3	35	9	11	33	0		54	7	1	1	2		11	100	4	19	1	1	24
5, base	clay	15	371 /94																											
6, top	mudstone	20	557 /94																											
6	D	10	556 /94	378	/95	3	11	1	4		1	21	26	15	31	0	1	72	5		1	0		7	100	8	3	1	13	
6	BC	6	558 /94	377	/95	2	21	2	27	1		52	19	14	8			41	3	2	1	1		6	100	1	4	0	5	
6	BD	3	555 /94	376	/95	1	13	1	26	0	0	43	19	16	13	1		50	4	1		1		7	100	0	2		3	
6	carb.siltst.	3	554 /94									0						0						0	0				0	
6	D	4	553 /94	374	/95	3	13	3	22		1	41	17	12	20	1	1	50	7	1	1	0		9	100	2	1	0	3	
6	BD	4	552 /94	373	/95	1	12	4	33	1		51	16	11	13	2	0	42	6	0		1		7	100	0	0		0	
6	BC	3	551 /94	372	/95	3	38	6	14	1	0	62	13	11	9	0	0	33	3	0	0	1		4	100	0	1		1	
6	D	2	550 /94	371	/95	0	8	5	23	2	1	39	17	10	18	3	1	49	10	1		1		12	100	3	0	0	3	
6	BD	3	549 /94	370	/95	1	23	9	33	1	1	67	7	6	11	2	1	27	4	0	0	2		6	100	1	1		2	
6	BC	18	548 /94	369	/95	1	33	9	32	1	1	76	9	3	6	1		18	2	0		4		5	100	0	1		1	
6	carb.siltst.	8	547 /94	368	/95		79	9	6	0		94	1	0	2			3	1		2			3	100	4	1	5	10	
6	BB	2	546 /94	367	/95	2	43	10	26	0	1	83	6	4	4	0		14	2	0	0	1		3	100	0	1		1	
6	BD	6	545 /94	366	/95	1	20	7	28	0	1	57	8	7	13	1	1	30	8	1	0	4		13	100	1	3		4	
6	BB	14	542 /94	365	/95	1	27	7	44	2	1	82	3	4	3		1	12	4	0	0	2		6	100	1	2		3	
6	BB	6	543 /94	364	/95	0	44	5	23	1	1	75	4	3	8	1		15	4		1	4	1	10	100	0			0	
6	BD	4	544 /94	363	/95	1	22	2	34	2	6	67	3	1	15	2		21	5	1	2	2	3	12	100	10	10	1	20	
6, base	mudstone	20	541 /94																											

For abbreviations of macerals and minerals see Appendix 2

Appendix 5. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 03

						VITRINITE								INERTINITE						LIPTINITE						MINERALS			
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	Qtz	Clay	Car	TM
	mudstone	4	152 /94																										
	carb.siltst.	10	151 /94																										
1, top	siltstone	4	150 /94																										
1	BC	10	149 /94	1244	/94	1	33	2	25	1	2	1	65	5	9	16	0	1	30	3			1	1	5	7	7		13
1	siltstone	13	148 /94										0						0						0				
1	BB	10	147 /94	1243	/94	1	47	3	4	1	2	1	58	11	8	18	0	1	38	4				0	4	1	6		7
1	D	13	146 /94	1242	/94		12	1	9		4	0	25	20	12	35	1	1	70	4				1	5	4	5		9
1	BB	3	145 /94	1241	/94	0	39	3	9				51	14	14	14	1	2	45	2		1	0	1	4	1	1		3
1	D	4	144 /94	1240	/94		5		12	0	1		19	27	20	28	1	0	76	4				0	5	1	3		4
1	BD	10	143 /94	1239	/94	1	68	6	4	0	0	1	80	5	9	4	0	0	19	0		0	0		1		3	0	3
1	BD	10	142 /94	1238	/94	0	27	1	18	0	0		47	12	15	18	2	1	48	5			0		5	1	1		2
1	BB	10	141 /94	1237	/94	0	59	8	7	0	0	1	76	4	5	11	0	2	22	1		0	1		2	0	2		2
1	BC	10	140 /94	1236	/94		28	2	22	1		0	53	14	14	13	1	0	43	4			1	1	5	1	3	1	4
1	B	3	139 /94	1235	/94	2	50	4	18			2	76	7	6	8	1	1	23	1					1		1		1
1	BC	15	138 /94	1234	/94		25	2	24		0	0	51	15	19	9	1		44	4			0	0	5	1	1	0	2
1	B	4	137 /94	1233	/94	1	50	2	24		1	1	78	4	10	6			20	1	0			1	3	3	1	0	4
1	mudstone	2	136 /94										0						0						0				
1	BD	8	135 /94	1232	/94		13	1	13	0	4		30	12	20	24	1		57	8			0	4	13	8	4	0	12
1	mudstone	6	134 /94										0						0						0				
1	BC	10	133 /94	1231	/94	1	26	1	25	1			54	11	24	7	1		43	3	0		0		3	0	4		5
1	BD	7	132 /94	1230	/94	1	31	2	22		0	1	56	9	13	16	1		39	3	1	0	1	1	5	3	2		5
1	mudstone	2	131 /94										0						0						0				
1	BD	4	130 /94	1229	/94		12	0	12	1	2		27	24	16	29	1		70	3					3	3	1		5
1	BB	10	129 /94	1228	/94	1	31	3	24		1	0	59	18	9	9	1		37	3	0		1		4	1	5		6
1	BC	16	128 /94	1227	/94	2	22	4	22	1	1	0	51	14	18	12	1		45	2			1		3		5		5
1	B	3	127 /94	1226	/94	2	62	15	6		1	1	87	2	2	4			8	2		2			4	2	1	1	5
1	mudstone	4	126 /94										0						0						0				
1	BB	5	125 /94	1225	/94	1	21	6	17	2	2	0	49	14	19	14	1	0	47	3			1		4	0	5	0	6
1	B	7	124 /94	1224	/94	2	56	10	12	1	0	2	83	5	3	3	0	0	12	2	0	1	2		5		4		4
1	BC	16	123 /94	1223	/94	1	22	3	21	0	1	1	48	16	19	12	0		47	4			1	0	5		4	0	5
1	BB	10	122 /94	1222	/94		60	5	7		5	2	80	4	6	7	0		17	3	0			0	3	1	2	4	6
1	BD	9	121 /94	1221	/94	1	29	2	27	1	1	2	62	8	8	14	1	1	31	6	1		1	0	8	3	5	0	8
1	mudstone	3	120 /94										0						0						0				0
1	BC	20	119 /94	1219	/94	0	33	3	21	1	1	0	61	7	14	13	1	0	35	3			1		4	0	3		4
1	BB	5	118 /94	1218	/94	2	53	7	8	0	0	1	70	5	6	11	0	2	25	4			0		4		2	0	2
1	BD	17	117 /94	1217	/94	1	15	0	15	0	1		32	17	25	21	1	1	64	3			0		4	2	2		4
1	BB	9	116 /94	1216	/94		40	5	12		0	0	59	9	15	13	0	2	38	3	0	0			4	2	1		4
1	BC	37	115 /94	1215	/94	2	41	7	17	0		1	69	9	10	9	0	1	28	3			0		3	1	6		7
1	BC	4	114 /94	1214	/94		74	8			17	1	100						0	0					0	10		9	19
1	B	11	113 /94	1213	/94	0	64	14	8	0	1	2	89	3	3	2		0	9	1		1	0		2	0	1	1	2
1	BC	20	112 /94	1212	/94		28	2	20		4		55	6	25	10	0	0	42	3				0	3	5	5	3	13

For abbreviations of macerals and minerals see Appendix 2

Appendix 5. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 03

						VITRINITE								INERTINITE						LIPTINITE						MINERALS			
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	Qtz	Clay	Car	TM
1, base	mudstone	13	111 /94																										
2, top	mudstone	20	111 /94																										
2	D	9	110 /94	1211	/94		22	2	8		3		34	4	11	45			60	1	1		2	1	5	9	11	4	25
2	B	13	109 /94	1210	/94	0	33	7	10		0	1	51	6	15	24	1	0	45	3			0	1	4	1	2	0	3
2	F	5	108 /94	1209	/94	1	7	0	6		1		14	20	46	16	1		84	1				1	2	1	0	1	2
2	B	3	107 /94	1208	/94	1	69	5	5		0		80	4	8	3		2	17	1		1			3	1	1	3	5
2	BD	21	106 /94	1207	/94	2	30	3	20	1	0		55	7	19	13	2	1	41	4		0			4	1	4	2	7
2	bentonite	2	105 /94										0						0						0				
2	BC	7	104 /94	1206	/94	1	59	11	9	1	0	3	84	1	5	6		1	12	1		0	2	1	3	1	3	1	5
2	D	15	103 /94	1205	/94		16	1	13	1	2	0	33	16	14	29	1	2	61	5				1	6	6	2	0	9
2	BD	15	102 /94	1204	/94	1	15	1	16			0	33	12	19	27	0	2	60	6				1	7	1	1	1	2
2	D	5	101 /94	1203	/94	1	5		6	0	2		13	22	23	34	2	1	81	5	0	0			6	4	1	1	7
2	BC	5	100 /94	1202	/94	1	34	2	13		1	0	50	10	11	23	0	1	44	4			1	2	6				0
2	BD	20	99 /94	1201	/94		15	1	22		1	1	39	10	15	26	0	1	52	7	0		1	1	9	5	4	6	15
2	BC	10	98 /94	1200	/94	1	50	3	13	0	1		69	8	9	10		1	29	1	0	0		0	2		4	1	5
2	BB	7	97 /94	1199	/94	1	40	4	16	0	1		62	7	11	12	0	1	31	5	0	0	1	1	7	1	3	1	6
2	BC	7	96 /94	1198	/94	1	35	3	17	0	1		58	10	14	11		0	35	5	0	1	1	1	7	1	1	2	4
2	BD	7	95 /94	1197	/94		17	2	18		1	0	39	16	15	24	0	0	56	4			0	0	5	1	0	0	2
2	D	17	94 /94	1196	/94	0	16	2	19		2	0	39	16	14	24	1	0	55	5			0	1	5	4	1	4	10
2	bentonite	1	93 /94										0						0						0				
2	BC	8	92 /94	1195	/94	0	31	3	26	1		0	62	9	10	10	1	1	32	3	0	1	1	0	6				0
2	BD	15	91 /94	1194	/94	1	50	6	24	0		1	83	4	7	3	0		14	1	0	1			2	0		3	3
2	BB	2	90 /94	1193	/94		71	4	10		2		86	4	2	3		1	8	1		3		1	5			8	8
2	BD	8	89 /94	1192	/94	1	30	10	28	1		0	70	7	10	8	0		25	4	0		1		5		2		2
2	BB	3	88 /94	1191	/94	2	31	6	23	0	0	1	64	9	18	6	0		33	2	0		0	0	3		3	0	4
2	BD	4	87 /94	1190	/94	0	50	6	17	0		1	75	8	6	7		0	21	4	0	0			4		0		0
2	BC	15	86 /94	1189	/94	0	34	5	22	1	1		63	10	13	9	1	0	34	3		1	0	0	4	2	2		4
2	BD	13	85 /94	1188	/94	1	35	8	26	1		1	72	6	11	6	1	1	25	2			1		4		2	0	2
2	B	3	84 /94	1187	/94	2	39	5	27	1		1	75	10	8	3	0	0	21	4		0			4	0	4		4
2	BD	13	83 /94	1186	/94	1	40	5	23	1		0	70	11	10	6			27	1		0	0		2	0	1		1
2	BC	8	82 /94	1185	/94	1	61	10	12	0	0	1	86	1	6	1			9	1		4	0		5		1		1
2	BD	16	81 /94	1184	/94	1	43	5	22	0	1		72	6	12	6		0	25	2	0	0	0		3	0	2		3
2	BC	9	80 /94	1183	/94	1	31	3	18	1			55	15	21	6	1		42	2	0	0			3	0	1		1
2	B	3	79 /94	1182	/94	1	76	8	8	1			93	1	2	1		0	3	1	0	2			3		1		1
2	BD	6	78 /94	1181	/94	1	31	5	22	1		1	62	13	13	7	1	1	34	4		0			5		2		2
2	BC	27	77 /94	1180	/94	0	45	5	26	0	1	1	78	6	3	8	1	0	###	3				1	4	1	0		2
2	carb. mudst.	8	76 /94										0						0						0				
2	BD	5	75 /94	1179	/94	2	46	5	29	1	1		84	2	3	7			12	3		0	0	1	4	1	1		2
2, base	mudstone	3	74 /94																										

For abbreviations of macerals and minerals see Appendix 2

Appendix 5. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 03

						VITRINITE								INERTINITE						LIPTINITE						MINERALS			
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	Qtz	Clay	Car	TM
	shaley coal	12	161 /94	1251	/94		22	4	16	0	4		46	12	8	26	0	0	46	7					7	2	22	2	27
3, top	siltstone	50	160 /94										0						0						0				
3	BD	8	159 /94	1250	/94	0	27	2	15	1	3	0	49	20	11	14	0	1	47	3		1			4	2	13	2	17
3	BD	9	158 /94	1249	/94		22	1	25	0	0	0	50	19	16	10	0	1	46	3		0	0	0	4	0	2		3
3	BB	16	157 /94	1248	/94		51	2	12	0	3	1	69	6	8	15			28	2		0	0		3	2	1	3	5
3	BD	6	156 /94										0						0						0				
3	BC	10	155 /94	1247	/94		40	4	24	0	1	0	70	7	7	11	0	1	26	3		0	0		4	3	4	2	8
3, base	mudstone	28	154 /94																										
4, top	coaly mudst.	7	173 /94	1263	/94	1	21	3	1	1	4		32	9	13	36			58	7			1	3	11	4	50	2	56
4	D	20	172 /94	1261	/94	2	24	2	14	0	1		43	18	14	18	0	1	51	5		0	0	0	6	1	6		7
4	BC	5	171 /94	1260	/94	1	21	1	18		0		42	30	14	9	1	1	54	4					4		1		1
4	BD	3	170 /94	1259	/94	1	11	2	15		0		30	29	14	16	2	4	64	5	0		0	1	6	1	2		3
4	F	1	169 /94	1257	/94	1	13	1	14	1	1		30	24	19	20	1	1	65	5					5	0	1		2
4	BC	8	168 /94	1256	/94	1	6	1	11		1		19	29	9	35	1	2	75	6				0	6	2	2		4
4	D	12	167 /94	1255	/94	0	5	1	9	1		1	17	27	15	29	2	1	73	9	0		1	0	10				0
4	BB	2	166 /94	1254	/94	2	49	10	17	2			79	3	4	5	1	4	16	2	0	2	1		5		3		3
4	BD	8	165 /94	1253	/94	1	32	4	20	0	1		56	13	11	13	0	1	38	5	1		1		6	1	2		3
4	BC	16	164 /94	1252	/94	1	39	1	11	0	2		55	9	17	12	0		39	6		0		0	7	5	3		9
4, base	mudstone	8	175 /94																										
5, top	mudstone	10	185 /94																										
5	D	5	184 /84	1272	/94	1	10	2	11		3		27	24	22	23	0		69	3			1		4	8	24	2	35
5	B	4	183 /94	1271	/94	3	47	3	15	1	0	2	71	8	12	6	1		26	2		0	1	0	3	1	9	0	10
5	BD	3	182 /94	1270	/94	1	15	1	14		1	0	32	19	20	21	0		61	6				1	7	2	3		4
5	D	5	181 /94	1269	/94	0	12	1	11		2		26	22	18	24	1		65	8		0		1	9	2	5		7
5	BC	3	180 /94	1268	/94	1	35	3	14	0	1	0	55	12	10	19	0	0	41	3			1	0	4	3	5		8
5	D	7	179 /94	1267	/94	1	13	3	12		3	0	31	17	10	31	0		58	10			1	0	11	9	8		17
5	B	3	178 /94	1266	/94	1	49	4	26	0	0	1	82	1	2	5			8	4	1	0	4	1	10	4	5	1	10
5, base	coaly siltst.	5	177 /94	1265	/94		51	8	9	1	15		84	1	2	11			15	0				0	1	12	46	2	60
6, top	siltstone	5	201 /94																										
6	D	8	200 /94	1284	/94		6	0	9		6		21	20	18	32	2		72	6			0	1	7	7	15	3	24
6	mudstone	5	199 /94										0						0						0				
6	D	4	198 /94	1283	/94	2	25	1	30	0	2		60	15	12	9	0		36	3	0			1	4	1	4	3	8
6	BC	14	197 /94	1282	/94	3	52	3	18	0	3	1	79	7	5	5			17	2		1		1	4	2	6	7	14
6	BD	14	196 /94	1281	/94	2	36	1	38	1	1		78	6	6	6			18	2	0	0	0	1	4	0	3		3
6	BB	4	195 /94	1280	/94	1	45	6	19		1	1	71	4	4	14		1	22	5		0	1	1	7	6	2	1	8
6	BD	20	194 /94	1279	/94	1	46	5	27	0	0	0	80	5	4	7	0		16	4	0		0		4	1	1		2
6	mudstone	3	193 /94										0						0						0				
6	BC	9	192 /94	1278	/94	0	24	1	37	1			64	14	11	7	0		32	4	0			0	4	1	1		1

For abbreviations of macerals and minerals see Appendix 2

Appendix 5. Lithological log and petrography of coal seam subsections at Highvale Mine, Pit 03

							VITRINITE							INERTINITE						LIPTINITE						MINERALS			
Seam	Lithology	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	Qtz	Clay	Car	TM
6	BD	7	191 /94	1277	/94		26	2	37	2			66	9	10	10	0		29	3		0	1	0	4	0	1		1
6	B	4	190 /94	1276	/94	1	41	7	34	3	0		87	2	1	4		0	7	4	1		0		6		1		1
6	BC	9	189 /94	1275	/94	1	41	3	31	2			78	8	8	5			20	2	0	0	0		3	0	1		1
6	BB	3	188 /94	1274	/94	1	31	3	37	2	0		73	5	6	7	1	0	19	7		0	1		8	2			2
6	BC	7	187 /94	1273	/94		56	4	27	2		1	89	3	1	3			7	3	0			1	4		1		1
6, base	mudstone	30	186 /94																										

For abbreviations of macerals and minerals see Appendix 2

Appendix 6. Lithological log and petrography of coal seam subsections at Whitewood Mine

						VITRINITE								INERTINITE						LIPTINITE						MINERALS					
SEAM	LITHOLOGY	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOT	Qtz	Clay	Car	Pyr	TM
1, Rider top	sandstone																														
1, Rider	BD	9	368 /94	1401	/94	2	45	8	27	1	2		85	5	5	2	0		12	2	0	0	1		4	100	0	4			4
1, Rider	BC	5	367 /94	1400	/94	1	31	6	38	1			78	3	6	5	0		15	3	0	1	2	0	7	100	1	7			8
1, Rider	BB	2	366 /94	1399	/94		67	9	16	0	1		93	1	1	2			4	1	0	1	1	0	3	100	1	4			5
1, Rider base	mudstone	60																													
1, Upper top	mudstone																														
1, Upper	BC	2	363 /94	1398	/94	2	38	4	15	0	2	0	61	5	6	19	0		30	2	1		5	1	9	100	3	16			19
1, Upper	D	13	362 /94	1397	/94		6	0	1		2		9	14	25	45			84	1	0		2	3	6	100	4	22			26
1, Upper	BD	5	361 /94	1396	/94	1	14	1	11		1		27	13	23	31	1		68	4			1	1	6	100	3	6	0		9
1, Upper	mudstone	4	360 /94																												
1, Upper	D	2	359 /94																												
1, Upper	mudstone	1																													
1, Upper	BC	3	358 /94	1395	/94	1	9	1	6		2	0	20	3	31	38			73	5			1	2	8	100	7	15	1		23
1, Upper	mudstone	1																													
1, Upper	BD	20	357 /94	1393	/94	1	30	3	17	1	2		53	6	18	17	0		41	3		0	0	1	5	100	1	8			8
1, Upper	carb.Shale	29	356 /94																												
1, Upper	BD	11	355 /94	1390	/94	6	59	8	8		3		84	1	9	3			13			2	1		3	100	2	6	1	1	9
1, Upper	BB	15	354 /94	1389	/94	4	73	7	8		2		94	1	1	1			3	1		2	1		4	100	1	3	1		5
1, Upper	shaley coal	10	353 /94	1388	/94	1	23	7	18		3		53	6	9	25			40	2				5	7	100	3	55	2	0	60
1, Upper	D	10	352 /94	1387	/94		6		2		3		11		19	67			86					3	3	100	6	58	4		68
1, Upper	shaley coal	11	351 /94	1386	/94		10	1	2		3		16	4	17	54			74	3			2	6	10	100	5	28	1	0	34
1, Upper	BD	21	350 /94	1385	/94	2	25	3	7	1	2	0	41	12	18	25	1		55	3		0	1	1	4	100	2	20	0		22
1, Upper base	Coaly muds.	4	349 /94																												
Parting	mudstone	4	348 /94																												
Parting	shaley coal	4	347 /94	1384	/94		55	8	5		30		98		1	0			1			0			0	100	7	4	17	0	29
Parting	Coaly mudst.	7	346 /94	1383	/94	1	22	3	6		10		42	3	22	27			53	2			0	3	5	100	5	25	4	1	35
1, Lower top	mudstone	10	345 /94																												
1,Lower	BD	7	344 /94	1382	/94	1	18	3	12	0	1		35	11	33	17	2		63	2		0			3	100	2	2	3	0	7
1,Lower	D	5	343 /94	1381	/94		9	1	5		1		16	11	32	34			77	4			0	2	6	100	8	20			27
1,Lower	mudstone	2	342 /94																												
1,Lower	BC	12	341 /94	1380	/94	3	29	5	21	1	1	0	59	7	12	13	1		32	6	0	0	2	1	9	100	0	2	1		3
1,Lower	BD	2	340 /94	1379	/94	2	25	2	26	1	1		55	8	11	13	0		32	10			3		12	100	3	2			5
1,Lower	mudstone	4	339 /94																												
1,Lower	BD	42	338 /94	1378	/94	1	39	3	16	0	1		60	9	11	13	1		33	4	1		1	1	7	100	1	7	0		8
1,Lower	mudstone	1	337 /94																												
1,Lower	BB	4	336 /94	1377	/94		69	2	4		22		97		2	0			2			1			1	100	6	3	15		24
1,Lower	mudstone	5	335 /94																												
1,Lower	BD	24	334 /94	1376	/94		20	1	16		1		37	12	27	19	1		58	4	0	0	1		6	100	1	3			4
1,Lower	BC	10	333 /94	1375	/94	1	39	4	34	0			78	6	8	3	0		17	2	1	1	2		5	100	0	0			1
1,Lower	B	7	332 /94	1374	/94	1	75	13	4	0			92	1	1	0			2	1		4	1		6	100	0	0	1		2
1,Lower	BD	40	331 /94	1373	/94	0	22	2	21		1		46	11	21	14	1	0	47	7			0	0	7	100	1	1			2

For abbreviations of macerals and minerals see Appendix 2

Appendix 6. Lithological log and petrography of coal seam subsections at Whitewood Mine

								VITRINITE							INERTINITE						LIPTINITE						MINERALS				
SEAM	LITHOLOGY	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOT	Qtz	Clay	Car	Pyr	TM
1,Lower	BC	11	330 /94	1372	/94	1	62	4	14			0	81	2	7	2			11	2	2	1	3		8	100					0
1, Lower base	mudstone	140	329 /94																												
2, top	mudstone	42	327 /94																												
2	BB	2	326 /94	1369	/94	1	60	4	14	0		1	80	3	9	3			15	3		1	1		5	100	0	3			3
2	BD	3	325 /94	1368	/94	0	24	3	35	2			65	3	5	11	0		20	11		1	2	2	15	100	2	1			3
2	BC	6	324 /94	1367	/94	1	65	5	18	0	0	0	91	0	0	1			2	2	1		3		6	100	0	1			1
2	B	4	323 /94	1366	/94	3	66	17	7	0	0		93	0	0	1			1	0	0		5		5	100		1	0	1	2
2	BC	8	322 /94	1365	/94	2	63	7	12			3	87	3	5	2	0		10	1	0	0	0		3	100			1		1
2	BD	3	321 /94	1364	/94	1	74	2	4		13		96	0		0			1	0		3			4	100	3	1	21		25
2	BC	6	320 /94	1363	/94		22	4	25	0	1	0	52	15	14	11	1		41	4	1	0	2	0	7	100	0	1		0	2
2	BD	10	319 /94	1362	/94	3	30	3	25		1		61	11	13	11	0		35	3		1	1		4	100	1	2			3
2, base	mudstone	45	318 /94																												
3, Rider	BB	5	316 /94	1360	/94	2	48	4	25		1	1	80	4	4	6	1		14	4		1	1	0	6	100	0	1	0		1
3, top	mudstone	40	315 /94																												
3	D	7	314 /94	1359	/94		6		5		1		12	10	11	64	2		86	1			0	1	2	100	8	26			34
3	BC	13	313 /94	1358	/94	2	39	4	20	0	0	0	66	5	8	15	1		29	4		0	1		6	100		5			5
3	D	4	312 /94	1357	/94	1	16	0	16		2		35	12	14	34	1		61	2	1		1	0	4	100	8	6	1		15
3	mudstone	3	311 /94																												
3	D	6	310 /94	1356	/94		15	1	15	0	1		32	15	12	31	4		63	3	0		1		5	100	4	4			8
3	BD	4	309 /94	1355	/94	1	16	1	16		1	0	35	13	10	32	1		55	10			1		10	100	3	3			6
3	BB	3	308 /94	1354	/94	1	41	2	9	0	0	0	54	7	11	22	1	0	41	4	0	0	0		5	100	1	3		0	4
3	D	4	307 /94	1353	/94	2	14	0	8		3		26	21	14	31		1	67	7		0	0		7	100	2	4		0	6
3	B	2	306 /94	1352	/94	1	54	8	9			1	74	2	3	14	0	2	21	2	1	1	1	1	5	100					0
3	BD	9	305 /94	1351	/94	0	11	1	18		0	0	31	16	16	28	1	1	61	6			1	0	8	100	1	1			2
3	D	8	304 /94	1350	/94	0	10	1	8		1		19	17	18	35	1		71	7	1		1	0	9	100	9	1			9
3	B	2	303 /94	1349	/94	1	66	2	10	0		0	80	2	1	7			10	1	0	8		0	10	100	1	0			2
3	D	4	302 /94	1348	/94		4	0	4		1		9	23	22	33	2		80	10	0		1	0	12	101	3	1			4
3	B	4	301 /94	1347	/94		56	1	16		1		73	3	7	11	1		22	4		0	1		5	100	0				0
3	BD	12	300 /94	1346	/94		16	1	19	0		0	36	13	18	23	2		55	6	0		2		8	100	2	2	0		4
3	BC	22	299 /94	1345	/94	0	33	2	22		1	0	58	11	12	9	1		33	6			2		8	100	2	3			5
3	B	9	298 /94	1344	/94	2	70	9	6			3	89	1	3	3			7	1	0	2	2		4	100		2			2
3	D	7	297 /94	1343	/94	0	18	1	17	0	2		38	18	12	25	1		56	4	0		1	0	5	100	3	1			4
3	B	2	296 /94	1342	/94	2	71	15	4			1	93	1	2	2	0		4	0			2	0	2	100		3			3
3	BD	9	295 /94	1341	/94	1	19	3	17	1	2	1	42	19	9	22	1		51	5			2	0	7	100	2	1			3
3	BC	10	294 /94	1340	/94	2	43	4	23	1		1	74	7	8	6	1		22	3			2	0	5	100	2	3			4
3	B	6	293 /94	1339	/94	1	44	4	18	1		0	69	11	8	8			27	2	0	0	1		4	100	1	1			2
3	BB	13	292 /94	1338	/94	2	36	4	19	1	0	0	62	15	13	6	0		34	2	0		1	0	4	100	0	0			1
3	BC	7	291 /94	1337	/94	1	40	3	24	1	0		69	10	8	7	0	1	26	4	0		0		5	100	0	1			2
3	BD	12	290 /94	1336	/94	2	31	4	26	0			63	14	13	6	1		34	1			1	0	3	100		0		0	1

For abbreviations of macerals and minerals see Appendix 2

Appendix 6. Lithological log and petrography of coal seam subsections at Whitewood Mine

						VITRINITE								INERTINITE						LIPTINITE							MINERALS				
SEAM	LITHOLOGY	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOT	Qtz	Clay	Car	Pyr	TM
3	BC	15	289 /94	1335	/94	1	53	7	14	0			76	8	7	4	1		21	1	1	0	0		3	100		0			0
3	BD	2	288 /94	1334	/94		60	3	20	0	1		83	6	4	1	1		12	2	0	2	0		5	100	3	1	7		11
3	B	12	287 /94	1333	/94	2	76	13	4	0		0	95	0	2	1			4	0		1	0		2	100					0
3	BD	5	286 /94	1331	/94	1	30	6	21	1			59	16	12	7	0		35	4	0		2	0	6	100		0		0	0
3	BB	11	285 /94	1332	/94	0	43	5	23	1			73	9	8	7			23	2	0	0	1		4	100	0	0		0	1
3	BC	13	284 /94	1330	/94	1	28	1	23	0		0	53	16	11	12	1	0	42	4	0		1	0	6	100	1	1			2
3	B	3	283 /94	1329	/94	1	73	7	6	0			87	2	2	1	0		5	1		5	2		8	100		0			0
3	BD	20	282 /94	1328	/94	1	38	3	26	1	0		70	11	6	7	0		24	4	0	0	0	0	6	100	0	2			2
3	BC	11	281 /94	1327	/94	1	36	2	21	0			61	14	8	8	2		32	6	0		0		7	100	0	1			1
3	BB	20	280 /94	1326	/94	1	71	7	7	0			87	4	2	4	1		11	0		2			2	100					0
3	B	4	279 /94	1325	/94	0	54	4	13			1	72	9	7	7	1	0	25	2		0	0		3	100	1	0			1
3	BB	7	278 /94	1324	/94	2	47	5	15	1	0	1	71	10	10	6		0	27	1		1	0		2	100	0	0			1
3	BC	5	277 /94	1323	/94	1	40	5	24			1	72	11	8	5	2		25	2		0	1		3	100		1			1
3	B	4	276 /94	1322	/94	0	51	5	16	0	0	1	73	8	10	4	1		24	1	0	1	0	0	3	100	0	0			0
3	BC	4	275 /94	1321	/94	1	28	5	29			0	64	11	10	7	2		30	3	0	0	2		6	100	1	2			2
3	B	17	274 /94	1320	/94	1	63	6	13	0	0	1	84	4	1	3	1	1	12	1	0	2	1		5	100	0	0		0	1
3	BD	20	273 /94	1319	/94	1	34	4	28	0	0	0	68	10	12	5		1	28	3		0	0		4	100	0				0
3	BB	16	272 /94	1318	/94	2	51	3	14	1		0	72	10	9	5	1		25	1	0	1	1		3	100	0			1	1
3	B	10	271 /94	1317	/94	1	65	10	10	1		2	89	4	4	1			8	1		1	1		2	100		0			0
3	BC	8	270 /94	1316	/94	2	33	5	23	0	0	0	64	14	11	7	0	0	33	1	0	0	1	0	3	100		0			0
3	B	3	269 /94	1315	/94	2	13	60	11			1	88	3	2	2		0	7	1	0	3	1		5	100	0	1			1
3	BC	13	268 /94	1314	/94	0	39	5	22	0		0	67	8	12	7	0		28	3	1		0	0	5	100	1	0		0	1
3	B	7	267 /94	1313	/94	3	73	10	3			3	92	2	2	1		2	7	1			1		1	100			0		0
3	BB	7	266 /94	1312	/94	2	41	3	20	0	0	1	67	10	12	6	1		29	3	0	1		0	4	100	0	1		0	2
3	BC	3	265 /94	1311	/94	1	42	2	30	1	2	1	77	6	5	5		0	15	3	1	2	2	1	8	100	2	1	1		4
3	BD	12	264 /94	1310	/94	1	30	5	26		1	0	63	5	9	12	1		27	7		0	0	2	10	100	3	1			3
3	BB	1	263 /94	1309	/94		44	6	19	2	0		71	1	3	10			14	9	1	0	4	2	16	100	0				0
3	mudstone	7	262 /94																												
3	BD	9	261 /94	1307	/94	1	45	5	23	3	2		78	2	3	6	1	1	12	6		1	3	1	10	100	1	2	1	1	5
3, base	mudstone	70	260 /94																										sid		
3A, top	mudstone	6	259 /94																												
3A	B	3	256 /94	1405	/94	3	70	7	6		0		87	2	5	5			12	1		1			2	100	0	3			3
3A	BC	14	255 /94	1404	/94	1	35	3	20				59	11	19	6	1		37	4	0		1		5	100	1	1	0	1	2
3A	D	20	254 /94	1403	/94	0	16	2	11		3		32	9	23	29	1	0	62	4			2	1	6	100	4	17			21
3A, base	mudstone	21	253 /94																												
3X, top	carb silt	20																													
3X	BD	9	252 /94	1306	/94		26	2	19		2		50	16	8	19	0	2	46	3	0		1		4	100	4	5	1		9
3X, base	carb.silt	11																													
	white clay	14																													

For abbreviations of macerals and minerals see Appendix 2

Appendix 6. Lithological log and petrography of coal seam subsections at Whitewood Mine

								VITRINITE						INERTINITE						LIPTINITE						MINERALS					
SEAM	LITHOLOGY	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOT	Qtz	Clay	Car	Pyr	TM
4, top	clay	11	251 /94																												
4	D	7	250 /94	1304	/94	1	16	3	8		1		28	25	20	23	0		68	3			1		4	100					0
4	carb. Shale	2	249 /94																												
4	BD	4	248 /94	1303	/94	1	17	1	30	0	0	0	50	18	16	10		0	44	5	0		1	0	6	100	1	3		0	4
4	BC	7	247 /94	1302	/94	0	25	3	24	1	0		53	12	16	12	1		40	6			0		6	100	1	2	0		3
4	BD	5	246 /94	1301	/94	1	27	2	15	0	1		48	8	30	12	0		50	2					2	100	4	2			6
4	BC	11	245 /94	1300	/94	1	14	3	20	1	0		39	24	21	12	1	0	58	2			1	1	4	100	0	1		0	2
4	carb.shale	3	244 /94																												
4	D	7	243 /94	1299	/94		7	1	7		1		16	32	19	23	3	1	77	6				0	7	100	1	3			4
4	BB	2	242 /94	1298	/94	7	48	9	3	0		1	68	7	5	13	0	4	29	2			1	0	3	100	0	3			3
4	D	5	241 /94	1297	/94	0	3	0	2	0	1	0	8	39	18	26	2		85	7				0	7	100	1	2			3
4	BD	4	240 /94	1296	/94	1	13	0	9		2		25	26	17	23	1	2	68	6		0			7	100	1	3			4
4	D	12	238 /94	1295	/94	1	16		12		2	1	32	19	28	17	1	1	66	3	0				3	100	5	4	1		10
4	mudstone	6	238 /94																												
4	D	8	237 /94	1294	/94	3	45	5	11		1	1	66	7	6	18		1	31	2			1	0	3	100	5	1	0		6
4, base	mudstone	10	236 /94																												
5, top	mudstone	16	235 /94																												
5	BC	3	234 /94	1293	/94	1	22	5	16	1	0		45	20	13	14	1	0	48	3		1	2	1	7	100	1	3			3
5	BC	5	233 /94	1292	/94	2	75		2		9		88						0	1		9		2	12	100	9		9		18
5	carb.shale	2	232 /94																												
5	BD	21	231 /94	1291	/94	2	30	1	15		1		48	17	15	14	1		46	5		0	0		6	100	1	3			4
5	BB	2	230 /94	1290	/94	1	43	4	29		1		78	4	8	5	0	1	18	2			2		4	100	7	4		0	11
5	carb. mudst.	13	229 /94																												
5	BD	3	208/94b																												
5	carb. Shale	3	208/94a																												
5	BD	4	208 /94	1288	/94	2	44	8	28	2	3	0	86	2	4	2			9	2			2	1	5	100		10	1		10
5	mudstone	1	207 /94																												
5	BD	16	206 /94	1287	/94	2	30	2	8	0	11	0	53	5	12	24	0		41	4			0	1	5	100	6	21	2		29
5	BB	5	205 /94	1286	/94	2	63	10	16	1		1	93	1	0	1			2	2	0		2		5	100	0	1			1
5, base	mudstone	10	204 /94																												
6, top	mudstone	4	227 /94																												
6	D	10	226 /94	1419	/94		15		6		3		24	11	20	36	1		68	3			1	4	9	100	7	12	1		21
6	BD	7	225 /94	1418	/94	1	24	19			2		46	10	22	14	1		47	4		1	1	2	7	100	0	6			6
6	BB	6	224 /94	1417	/94	2	38	7	30	0	1	1	78	4	8	4	1		17	3	1	1	1		5	100	1	5			6
6	D	5	223 /94	1416	/94	1	61	5	3		28		98	2	1	1			3						0	100	5	1	22		28
6	BD	3	222 /94	1415	/94	2	25	4	23	1	1		55	10	17	11	1	0	39	4		0	1	1	7	100	1	1	1		3
6	BC	6	221 /94	1414	/94	1	38	4	41	0			83	5	3	4		0	12	3	0	0	2		5	100		0	0	0	1

For abbreviations of macerals and minerals see Appendix 2

Appendix 6. Lithological log and petrography of coal seam subsections at Whitewood Mine

								VITRINITE								INERTINITE					LIPTINITE					MINERALS					
SEAM	LITHOLOGY	(cm)	KBA #	Pellet	#	Te	Ct	Cg1	Cd	Cg2	Vd	Gel	TV	Sf	F	Id	Mac	Mic	TI	Spo	Cut	Res	Sub	Oth	TL	TOT	Qtz	Clay	Car	Pyr	TM
6	D	4	220 /94	1413	/94	1	26	4	48	1			79	6	5	3			14	4	1		2	1	7	100	1	1			2
6	BC	5	219 /94	1412	/94		28	3	49	1	0		82	3	5	5	9		12	2	0		1	3	6	100	1	1			2
6	BD	4	218 /94	1411	/94		27	1	35	1	1	0	64	8	11	11			29	4	0		1	1	7	100	2	4			5
6	mudstone	1																													
6	BD	11	217 /94																												
6	BC	9	214 /94	1308	/94	1	29	2	31				64	8	11	12	0		31	4	1	0	1		6	100	1				1
6	BD	3	213 /94	1409	/94	0	51	7	28	2			89	1	3	2	0	0	6	2		1	1	2	5	100		1			1
6	D	2	212 /94	1408	/94	4	24	3	12		2		45	6	18	18	1		42	7		3	2	2	14	100	1	2			3
6	BD	7	´211 /94	1407	/94	0	55	3	30	1			89	1	1	2			4	3	1	1	2	0	7	100	1	1			2
6	BC	3	210 /94	1289	/94	2	51	8	26	0		1	88	1		2		0	3	4	1		2	0	8	99	0		0		1
6, base	mudstone	10	209 /94																												
Note: In samples with high vitrodetrinite and carbonate content the "vitrodet" is fractured telovitrinite in cleats or fractures with carbonate infill																															

For abbreviations of macerals and minerals see Appendix 2

Appendix 7. Petrographic characteristics of coals at Knudson Mine section, Red Deer Valley

Locality	Lithology	Thickness	KBA #	Pellet #	Seam #	Vitrinite	Liptinite	Inertinite	Mineral	Ro (%)	Easting	Northing
		(m)							Matter			
Knudson Mine	Paskapoo (top)											
Knudson Mine	mudst./siltst.	2.00									363200	5753520
Knudson Mine	mudstone	0.03	65/95								363200	5753520
Knudson Mine	shaley coal	0.12	64/95	291/95	1	65	7	28	61	0.51	363200	5753520
Knudson Mine	mudstone	0.40									363200	5753520
Knudson Mine	coal	0.80	63/95	290/95	2	66	5	29	5	0.48	363200	5753520
Knudson Mine	mudstone	0.07									363200	5753520
Knudson Mine	coal	0.55	62/95	288/95	3, t	63	5	32	4	0.52	363200	5753520
Knudson Mine	coal	0.55	61/95	286/95	3, b	74	8	18	4	0.50	363200	5753520
Knudson Mine	benthonite	0.15									363200	5753520
Knudson Mine	mudstone	0.09									363200	5753520
Knudson Mine	coal	0.20	60/95	285/95	4	47	12	41	16	0.48	363200	5753520
Knudson Mine	mudstone	0.15									363200	5753520
Knudson Mine	coal	0.20	58/95	284/95	5	87	4	9	7	0.53	363200	5753520
Knudson Mine	mudstone	0.20	57/95								363200	5753520
Knudson Mine	carb. shale	0.15	56/95	279/95						0.53	363200	5753520
Knudson Mine	mudstone	0.25	55/95								363200	5753520
Knudson Mine	mudstone	0.10	54/95								363200	5753520
Knudson Mine	carb. shale	0.10	53/95								363200	5753520
Knudson Mine	coal	0.62	52/95	275/95	6, t	63	8	29	11	0.52	363200	5753520
Knudson Mine	mudstone	0.03	51/95								363200	5753520
Knudson Mine	coal	0.50	50/95	273/95	6, m	71	6	23	10	0.58	363200	5753520
Knudson Mine	coal	0.50	49/95	272/95	6, b	61	4	35	5	0.54	363200	5753520
Knudson Mine	benthonite	0.15	48/95								363200	5753520
Knudson Mine	coal	0.22	47/95	270/95	7	53	6	41	36	0.51	363200	5753520
Knudson Mine	mudstone	0.40	46/95								363200	5753520
Knudson Mine	coal	0.20	45/95	268/95	8	64	6	30	20	0.48	363200	5753520
Knudson Mine	mudstone	0.07	44/95								363200	5753520
Knudson Mine	coal	0.27	43/95	266/95	9	72	6	33	13	0.53	363200	5753520
Knudson Mine	mudstone, base	0.18	42/95								363200	5753520

Appendix 8. Petrography of coal seam channel samples collected from outcrop sections, Red Deer River Valley

						VITRINITE							INERTINITE						LIPTINITE						MINERALS			
LOCALITY	**SEAM**	**KBA #**	**PELLET #**	**Te**	**Ct**	**Cg1**	**Cd**	**Cg2**	**Vd**	**Gel**	**TV**	**Sf**	**F**	**Id**	**Mac**	**Mic**	**TI**	**Spo**	**Cut**	**Res**	**Sub**	**Ld**	**TL**	**Qtz**	**Clay**	**Car**	**Pyr**	**TM**
STAMP PIT	1	´693/94	´84/95		82	1	4				87	0	1	1	1		3	6	1			3	10	0	24	1		25
STAMP PIT	2	´688/94	´83/95		52		6		2		60	1	9	8	1	1	20	10		2	1	7	20	1	46		2	49
STAMP PIT	3	´683/94	´81/95		64	2	16				82	2	3	3		0	8	6	0	0		4	10	0	17		9	26
STAMP PIT	4	´681/94	´80/95		78	1	13				92		2		1	1	3	4	1			1	5		36		4	40
STAMP PIT	5	´678/94	´79/95		57	2	23				82	2	1	1		1	5	6	4		0	3	13	0	9		2	11
STAMP PIT	6	´676/94	´78/95		77	2	14		0		93	1					1	3	2	1			6		3	1		4
STAMP PIT	7	´668/94	´77/95		68		18		2		88	1	1	1	1		3	6	0	1		2	9	1	9			10
STAMP PIT	8	´662/94	´75/95		58	1	24				83	1	3	3	1		8	6	1			2	9	1	4			5
KNUDSON MINE	1	´64/95	´291/95		61	1	2		1		65	2	9	17			28	5				2	7		61			61
KNUDSON MINE	2	´63/95	´290/95		52	4	10				66	4	17	8		1	29	3				2	5	1	4			5
KNUDSON MINE	3, t	´62/95	´288/95		50	3	9		1		63	4	16	12	1		32	5		1			5		4			4
KNUDSON MINE	3, b	´61/95	´286/95		57	4	12		0			1	13	8	1		22	2	0	0	1	3	6		13			13
KNUDSON MINE	4	´60/95	´285/95		31	3	11		2		47	5	21	15			41	6	1			5	12	1	15			16
KNUDSON MINE	5	´58/95	´284/95		69	7	10		1		87	1	2	6		0	9	2	0			1	4	1	6			7
KNUDSON MINE	6, t	´52/95	´275/95		44	4	15		1		63	4	13	10	0	2	29	5	0		1	2	8	1	10			11
KNUDSON MINE	6, m	´50/95	´273/95		51	4	16				71	6	15		1	0	23	5				1	6		10			10
KNUDSON MINE	6, b	´49/95	´272/95		46	3	9		1		61	4	18	13		1	35	3				1	4	1	4			5
KNUDSON MINE	7	´47/95	´270/95		36	3	11		4		59	6	22	13		1	41	4				2	6	1	35			36
KNUDSON MINE	8	´45/95	´268/95		50	5	7		3		64	3	12	13	1		30	3				3	6		20			20
KNUDSON MINE	9	´43/95	´266/95		57	4	12		0		72	1	13	8	1		22	2	0	0	1	3	6		13			13
Ardley Bend	1	´69/95	´296/95		50	5	14		3		72	3	10	10		0	21	5		1	1	1	7	1	4			5
Ardley Bend	2	´68/95	´295/95		31	2	13		2		49	1	13	24			38	10				3	13	2	56		1	59
Ardley Bend	3	´67/95	´294/95		72	8	9		0		89	1	1	2			4	4	0	0		3	7					2
Ardley Bend																												
																								5	22		0	27
J. Saker Section	4	´73/95	´299/95		55	4	16		1		76	2	5	6	0	0	13	7	0	0	0	4	11	1	6			7
J. Saker Section	5	´71/95	´298/95		67	13	7		1		88	1	1	1			4	6			1	1	8		1			1

For abbreviations of macerals and minerals see Appendix 2

Appendix 9. Petrographic characteristics for coal seams at Stamp Pit, Red Deer Valley

Locality	Lithology	Thickness (cm)	KBA #	Pellet #	Seam #	Vitrinite	Liptinite	Inertinite	Mineral Matter	Ro (%)	Easting	Northing
Stamp Pit	coal	17	693/94	84/95	1	87	10	3	25	0.44	346400	5793800
Stamp Pit	carb. shale	14	688/94	83/95						0.48	346400	5793800
Stamp Pit	coal	5	685/94	82/95	2	60	20	20	49	0.54	346400	5793800
Stamp Pit	coal	7	683/94	81/95	3	82	10	8	26	0.42	346400	5793800
Stamp Pit	coal	2	681/94	80/95	4	92	5	3	40	0.40	346400	5793800
Stamp Pit	coal	6	678/94	79/95	5	82	13	5	11	0.44	346400	5793800
Stamp Pit	coal	12	676/94	78/95	6	93	6	1	4	0.42	346400	5793800
Stamp Pit	coal	7	668/94	77/95	7	88	9	3	10	0.42	346400	5793800
Stamp Pit	mudstone	58	663/94	76/95						0.44	346400	5793800
Stamp Pit	coal	13	662/94	75/95	8	83	9	8	5	0.41	346400	5793800

Appendix 10. Petrographic characteristics for coal seams at Ardley Bend, Red Deer River Valley

Locality	Lithology	Thickness (m)	KBA #	Pellet #	Seam #	Vitrinite	Liptinite	Inertinite	Mineral Matter	Ro (%)	Easting	Northing
Ardley Bend												
top	mudstone	0.36	70/95	297/95							345660	5797680
	coal	0.40	69/95	296/95	1	72	7	21	5	0.46	345660	5797680
	shaley coal	0.14	68/95	295/95	2	50	13	37	59	0.49	345660	5797680
	coal	0.17	67/95	294/95	3	89	7	4	2	0.47	345660	5797680
base	mudstone		66/95								345660	5797680
J. Saker Section												
top	carb. shale	0.25									345820	5793880
	coal	0.20	73/95	299/95	4	88	8	4	1	0.46	345820	5793880
	carb. Shale	0.05									345820	5793880
	coal	0.20	71/95	298/95	5	76	11	7		0.47	345820	5793880
base	mudstone		70a/95								345820	5793880