LITHOTYPE CHARACTERISTICS AND VARIATION IN SELECTED COAL SEAMS OF THE GATES FORMATION, NORTHEASTERN BRITISH COLUMBIA (93P/3)

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KEYWORDS: Coal geology, Bullmoose mine, Gates Formation, coal lithotype, maceral, image analysis.

INTRODUCTION AND OBJECTIVES

A combined field and laboratory investigation of selected coals within the Gates Formation in the Rocky Mountain foothills, northeastern British Columbia, was undertaken during the summer of 1988, and continued in 1989, with the purpose of gaining a better understanding of the sedimentological factors controlling variations in coal composition. This project involves examination of both the organic and inorganic strata. The initial results of the organic aspect of the study are reported here.

Previous investigations of Gates Formation coals have been regional in scope (Kalkreuth *et al.*, 1989; Kalkreuth and Leckie, 1989), and have involved definition of bulk compositional characteristics. This investigation focuses on in-seam variation as well as between-seam variation. The primary objectives of the research are threefold: to determine the petrographic composition of coal lithotypes within the Gates Formation; to document lateral and stratigraphic variation in lithotypes and maceral composition; and, to interpret the sedimentological factors controlling lithotype and maceral distribution (coal sedimentology). It is anticipated that the results of this study will be used to develop a methodology for predicting variations in coal quality, and to gain a better understanding of the characteristics of the Lower Cretaceous wetland environments.

REGIONAL AND LOCAL GEOLOGIC SETTING OF STUDY AREA

The Lower Cretaceous (Albian) Gates Formation contains the thickest, most economically viable coal seams in the study area. The coals outcrop in the Rocky Mountain foothills in the vicinity of Tumbler Ridge (Figure 4-7-1). The regional geology was initially described by Stott (1968, 1982). Detailed sedimentological studies of the Gates Formation (Figure 4-7-2) were done by Leckie (1983) and Carmichael (1983, 1988).

The Lower Cretaceous strata consist of a series of transgressive-regressive clastic wedges deposited in response to periodic uplift of the Canadian Cordillera (Smith *et al.*, 1984). The Moosebar (marine) and Gates formations and their subsurface equivalents, the Wilrich, Falher and Notikewin members of the Spirit River Formation (Figure 4-7-2) form one of these major sedimentary packages. Within both formations there are coarsening-upward sequences corresponding to progradational cycles of an active delta complex. Leckie (1986a) documented seven cycles within the Moosebar and Gates formations. The coastline is interpreted to have consisted of a series of high-energy, wave-dominated arcuate or cuspate deltas, with a major depocentre existing in the Bullmoose Mountain – Mount Spieker area (Leckie, 1986a). There is extensive intertonguing of marine and nonmarine strata in the study area. The northern limit of economic coal deposits in the Gates Formation is in the vicinity of the Bullmoose mine leases; north of the Bullmoose properties, the formation consists primarily of marine-shelf sediments (Stott, 1982; Leckie and Walker, 1982).

The depositional environment of Gates Formation coals is discussed in Kalkreuth and Leckie (1989) and Kalkreuth *et al.* (1989). Kalkreuth and Leckie's research was regional in

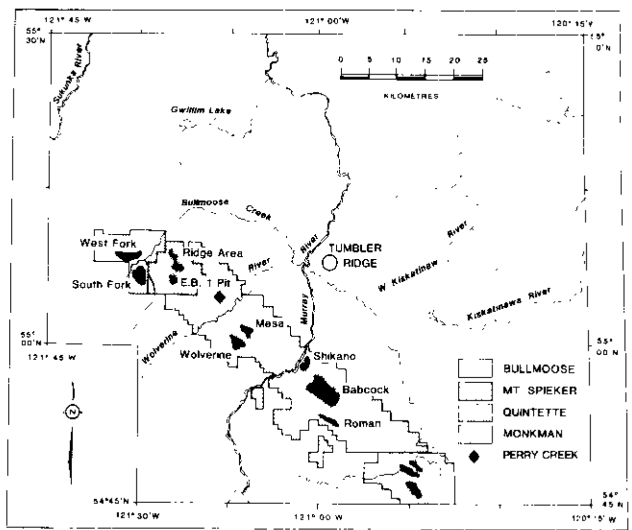

Figure 4-7-1. Location map of study area. Shaded areas indicate major coal leases. Diamond indicates location of outcrop sample of J seam on Perry Creek Road. Named areas are current production sites or areas of proposed development. Modified from Matheson (1986).

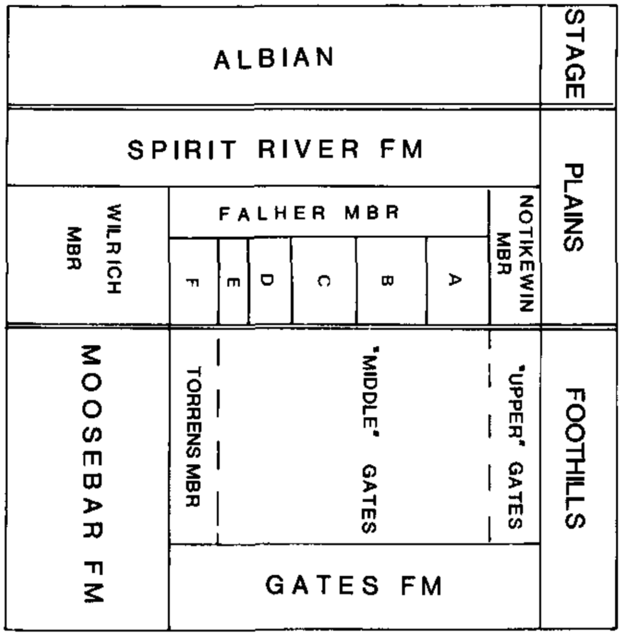

Figure 4-7-2. Stratigraphic chart of a portion of the Lower Cretaceous formations in northeastern British Columbia. Modified from Leckie (1986) and Carmichael (1988).

scope; whole-seam channel samples were collected from active mines throughout the Foothills trend, from Bullmoose southeastward to Mountain Park, Alberta. They interpreted the coals as having formed in protected environments shoreward of a high-energy, wave-dominated coastline. Coals formed in this environment are petrographically distinct, being composed of relatively low vitrinite (average 57 per cent), relatively high inertinite (average 42 per cent) and negligible liptinite concentrations. Semifusinite and inertodetrinite are the primary inertinite macerals. Petrographic (tissue preservation and gelification) indices indicate a predominantly forest-moor type wetland environment that allowed for extensive surface degradation of organic material.

Fieldwork in 1989 was centred in the Bullmoose mine area (Figure 4-7-1). Six seams of economic thickness are present at Bullmoose (Drozd, 1985), designated, from oldest to youngest, A1, A2, B, C, D and E. Rapid facies changes occur in the Bullmoose area. The Falher D, a thick, coarsening-upward marine unit occurring stratigraphically between the B and C seams at Bullmoose Mountain, is replaced by lagoonal (?) carbonaceous shale and siltstone 4 kilometres to the south, in the South Fork pit area (Leckie, 1986b). The paleoshoreline existed in the area just north of Bullmoose mine and was oriented roughly west-northwest. Predominantly nonmarine conditions appear to have prevailed in the Bullmoose Mine area.

METHODS

Research discussed in this report has both field and laboratory segments. Fieldwork involved section description, correlation and sample collection. Laboratory research focused on delineating the compositional characteristics of the individual coal lithotypes.

FIELD: SECTION CORRELATION AND SAMPLE COLLECTION

Fieldwork in 1989 was concentrated in the South Fork pit area of Bullmoose mine (Figure 4-7-1). Five Gates Formation coal seams, A1, B, C, D and E are exposed. Lithotypes of the seams were described according to a modified Australian classification scheme as bright, banded bright, banded coal, banded dull, dull, fibrous and sheared (Diessel, 1965; Marchioni, 1980; Lamberson and Bustin, 1989; Lamberson *et al.*, 1989; Lamberson *et al.*, 1989). A minimum thickness of 1 centimetre was used to delineate a lithotype. At least three sections of each seam, at different locations within the mine, were described. Wherever possible, representative samples of lithotypes were collected from each site.

Section profiles of each seam were drawn and an attempt was made to correlate zones using a minimum thickness of 1 centimetre. Lithotypes were subsequently regrouped and sections redrawn using a minimum thickness of 5 centimetres. Exceptions were made for the occurrence of fibrous coal and mudstone; the unique environmental significance of each of these lithologies is lost if combined with another lithotype. Two examples of section correlations are shown in Figures 4-7-3 and 4-7-4.

LABORATORY: MACERAL POINT-COUNT ANALYSIS

Lithotype samples collected from the Bullmoose and Quintette areas during the 1987, 1988 and 1989 field seasons were processed by two types of petrographic analysis: standard point-count and image analysis. Representative lithotype samples were crushed to -20 mesh, split and mixed with a polyester resin to make standard 2.54-centimetre petrographic pellets. The pellets were polished to a 0.05 micrometre aluminum oxide. Three hundred points were counted (mineral matter free) using the established maceral classification scheme (Bustin *et al.*, 1985). Mineral matter was counted separately. In total, 83 crushed particle pellets were examined. Percentage composition on a mineral matter free basis was calculated and averaged by lithotype (Table 4-7-1).

LABORATORY: IMAGE ANALYSIS

Image analysis was performed using a Zeiss IBAS 2 system following a procedure modified from Pratt (1989a, b). The primary objective of this analysis was to determine bulk changes in maceral composition with respect to stratigraphic position. Oriented bench samples (stratigraphic direction preserved) representing the entire B seam were prepared for image analysis. The oriented blocks were sawn in half. Half of the block was embedded in a polyester resin and subsequently polished to a 0.05 micrometre aluminum oxide. In total 100 blocks were prepared. A line of traverse was determined which provided a profile of the block perpendicular to bedding, following the path illustrated in Figure 4-7-5. Four fields were evaluated along a horizontal plane. The stage moved one field vertically and then proceeded in

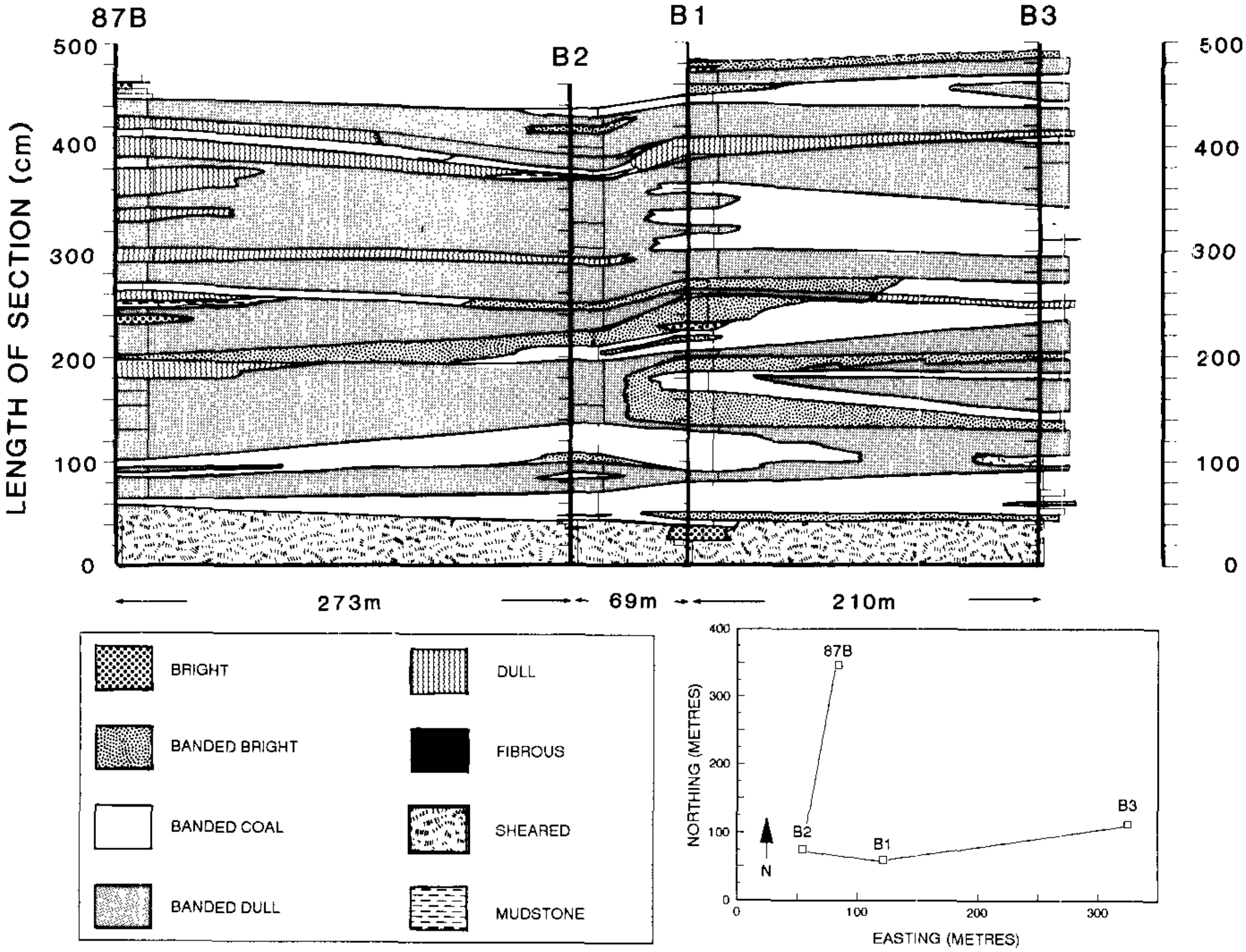

Figure 4-7-3. Section correlation for Bullmoose B seam. Datum for correlation is the floor of the seam. Inset map shows relative locations of section sites.

the opposite direction for four fields. This process was repeated across the vertical distance of the block. The distance between fields is 0.5 millimetre and each field represents an area of 0.19 square millimetres.

Prior to doing the analyses, a number of individual fields were analyzed in order to determine the grey level thresholds between maceral groups. An example histogram is illustrated in Figure 4-7-6. Three threshold values (between liptinite, vitrinite, low-reflecting inertinite and high-reflecting inertinite) were identified at grey-levels corresponding to reflectances (per cent in oil) of 0.88, 1.24 and 2.00. During routine analysis, the frequency of occurrence of each maceral group for each field was determined from the reflectance histogram (Figure 4-7-6). The relative percentage of each group was then calculated. The percentage values were then averaged with the three other fields on the horizontal part of the traverse to yield an approximation of the average maceral composition of each 0.5-millimetre stratigraphic thickness of the block. The end result of the traverse is a maceral compositional profile of the block, displayed in a stacked bar fashion, as illustrated in Figure 4-7-7. The plotting program eliminated areas of the block with cracks or holes.

RESULTS AND PRELIMINARY CONCLUSIONS

FIELD OBSERVATIONS

In previous studies (Lamberson and Bustin, 1989; Lamberson *et al.*, 1989), some general characteristics of the lithotypes were described which may be expanded upon with the additional data gathered during the 1989 field season. The banded lithotypes predominate in all of the seams studied. Banded dull and banded coal are the most common in A1, B and C seams. Banded bright and banded coal are more common in D and E seams. Mudstone partings are rare, thin and lenticular when present in A1, B and E seams, whereas they tend to be thick and laterally extensive in C and D seams. Two types of banded dull and dull coal exist: a mineral-rich and a mineral-poor variety.

Fibrous coal occurs in accumulations thick enough to constitute a lithotype, however, it is quite rare. The thickest lens of fibrous coal found is 2.5 centimetres thick. Bright coal and fibrous coal are lenticular, which may reflect their origin from individual logs and stems. Banded bright coal

TABLE 4-7-1
MACERAL COMPOSITION

		BRIGHT (15)	BANDED BRIGHT (13)	BANDED COAL (15)	BANDED DULL (16)	DULL (7)	SHEARED (8)	ROCK (9)
TELOCOLLINITE	AVERAGE	6	11	9	8	5	10	16
	STANDARD DEV	6	8	8	8	6	5	15
TELINITE	AVERAGE	19	16	13	11	7	11	6
	STANDARD DEV	16	10	4	5	2	9	5
PSEUDOVITRINITE	AVERAGE	45	24	15	5	1	21	14
	STANDARD DEV	23	12	9	5	1	11	20
DESMOCOLLINITE	AVERAGE	17	21	28	22	16	28	4
	STANDARD DEV	17	10	11	12	7	15	4
VITRODETRINITE	AVERAGE	1	7	8	14	12	21	28
	STANDARD DEV	1	13	11	18	22	14	21
TOTAL VITRINITE	AVERAGE	89	80	72	61	42	91	68
	STANDARD DEV	9	10	14	19	25	4	35
SEMIFUSINITE	AVERAGE	4	9	12	17	28	2	5
	STANDARD DEV	5	7	7	10	13	2	5
FUSINITE	AVERAGE	3	4	7	6	10	3	5
	STANDARD DEV	3	3	7	4	13	2	8
INERTODETRINITE	AVERAGE	3	6	8	15	18	3	22
	STANDARD DEV	3	4	5	9	12	1	26
TOTAL INERTINITE	AVERAGE	10	19	27	39	57	8	32
	STANDARD DEV	9	10	14	19	24	4	35
SPORINITE	AVERAGE	0	0	0	1	1	0	0
	STANDARD DEV	1	0	0	1	1	0	0
TOTAL LIPTINITE	AVERAGE	1	0	1	1	1	1	0
	STANDARD DEV	1	0	1	0	1	1	0
TOTAL AVERAGES		100	100	100	100	100	100	100

NUMBER OF LITHOTYPE SAMPLES INDICATED IN ( )

often contains abundant thin lenses and laminae of fibrous coal.

Maceral Point Count Analyses

The averages and standard deviations of the maceral point count analyses by lithotype are reported in Table 4-7-1. Figure 4-7-8 graphically illustrates the average compositions. There is a marked decrease in vitrinite, with a concomitant increase in inertinite, from bright to progressively duller lithotypes. This variation appears in large part to reflect a decrease in the pseudovitrinite population. Among the vitrinite maceral group, there is an increase in the percentage of the more degraded vitrinite varieties, desmocollinite and vitrodetrinite, from the brighter to duller coals. In all lithotypes except sheared coal, semifusinite is the most abundant inertinite maceral. Micrinite and macrinite are nowhere abundant. In agreement with Kalkreuth *et al.* (1989) and Kalkreuth and Leckie (1989), there is very little liptinite in any of the lithotypes (1 per cent or less). The paucity of liptinite in these coals may be due to difficulties associated with its recognition at elevated coal ranks (medium volatile), or its near absence in the original wetland. Low liptinite concentrations have been noted in Gates Formation coals in the Cadomin-Luscar, Mountain Park area of southwestern Alberta (Kalkreuth and Leckie, 1989).

The composition of carbonaceous mudstones in the coal appears to be variable, but most closely resembles banded dull coal. Inertodetrinite is the most abundant inertinite maceral in these rocks. Sheared coals are consistent in composition, and most commonly resemble the bright coal lithotype.

The origin of psuedovitrinite has most commonly been attributed to oxidation (Kaegi, 1985). Its occurrence in the brighter, less degraded lithotypes raises questions as to the origin of the maceral in these coals.

Image Analysis

Preliminary image analysis results indicate a good correlation between the bulk maceral composition as determined by image analysis and by standard point-count analysis for each lithotype. Table 4-7-2 compares results obtained for maceral composition by image analysis and the bulk maceral composition averages obtained by point-counting. The most significant problem with the technique is in determining the percentage of liptinite. In image analysis, edge effects around cracks, holes, scratches, mineral matter etc., produce a gradation in values that are lower than the adjacent maceral. For this reason, liptinite values obtained by image analysis are higher than those obtained by point-counting and often reflect mineral matter concentration (Pratt, 1989a, 1989b).

Section Correlations

Section correlations for B seam and D seams are illustrated in Figures 4-7-3 and 4-7-4. The two seams differ in lithotype composition and stratigraphy, reflecting what are interpreted to be differences in depositional conditions. Throughout the time the peats were being deposited, the paleoshoreline is

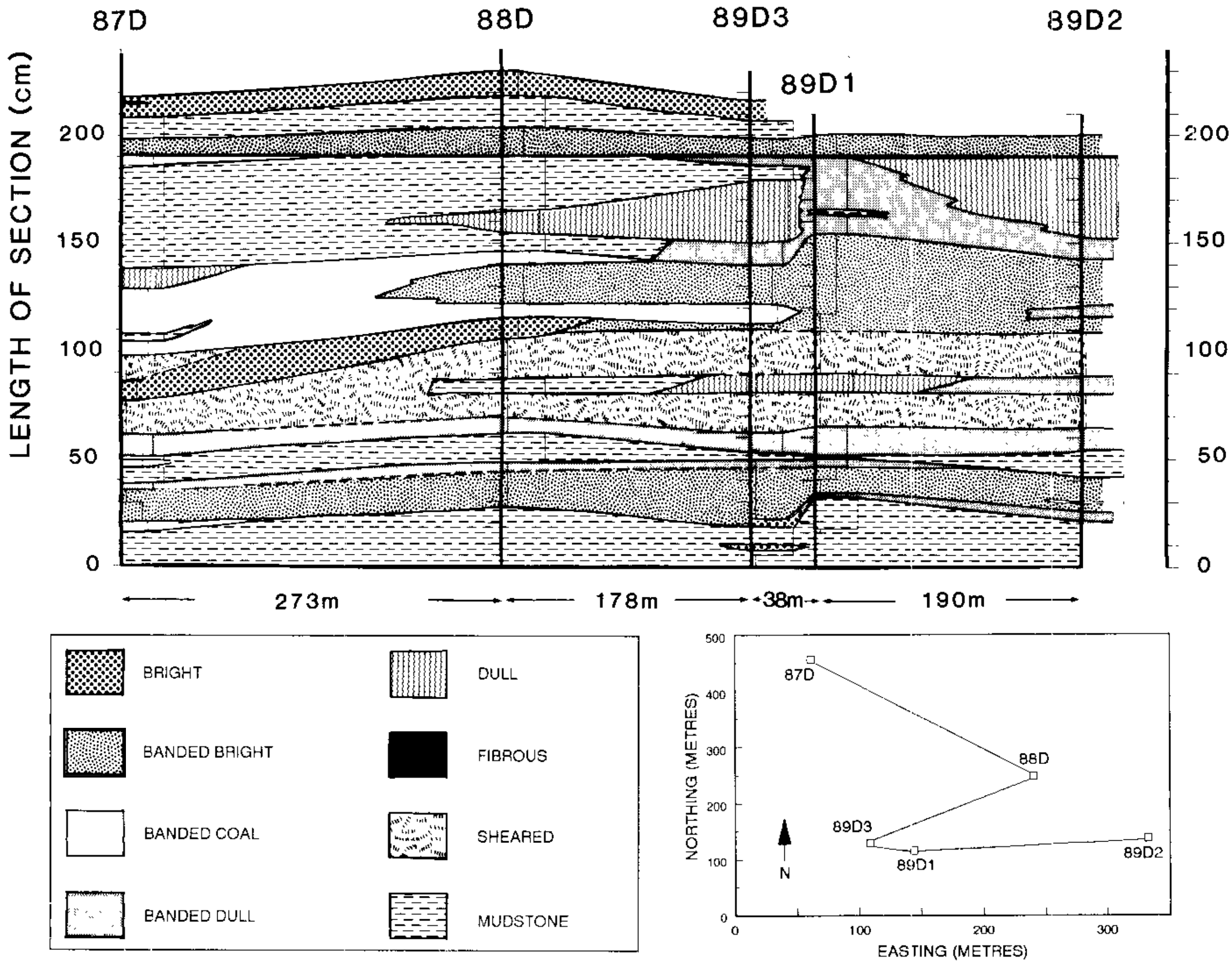

Figure 4-7-4. Section correlation of Bullmoose D seam. Location for seam base problematic in some locations. Datum for correlation is the base of a banded bright layer occurring across the section line, near the top of the seam. Inset map shows relative section locations.

interpreted to have been located immediately north of Bullmoose Mountain; a major fluvial channel was located in the Mount Spieker area (Leckie and Walker, 1982; Leckie, 1986a, b). The proximity of these two features may have influenced coal stratigraphy.

Within the B seam (Figure 4-7-3), banded dull coal is the only lithotype which can be consistently correlated through the section; the other lithotypes are more restricted in their areal distribution. In all of the sections examined the basal part of B seam is sheared, although the thickness of the sheared interval varies. In sections 87B, 89B2 and 89B1 there is a general increase in the percentage of the duller lithotypes from the base to the top of the seam. The trend is not as well developed in 89B3. There is also a decrease in the duller coal lithotypes from north to south. No significant mudstone interbeds are present.

The B seam appears to have developed in an area protected from clastic input. However, degradation levels appear to have been quite high (as evidenced by the predominance of the duller lithotypes). Depositional conditions were variable from south to north and east to west, as well as from the onset to cessation of the peat-forming episode.

D seam (Figure 4-7-4) is dominated by banded bright coal, sheared coal and mudstone interbeds. Unlike the B seam, the brighter lithotypes and mudstone layers are correlative across the section. The sheared zone averages about 50 centimetres thick, and is found approximately 0.5 metre above the base of the seam.

Within the unsheared zones of D seam there is a cyclic repetition of lithotypes. Banded bright coal is stratigraphically succeeded by mudstone and dull coal, followed by a return to banded bright or bright coal. This cyclic repetition is interpreted to represent fluctuations in wetland type due to repeated influx of clastic material from adjacent fluvial channels.

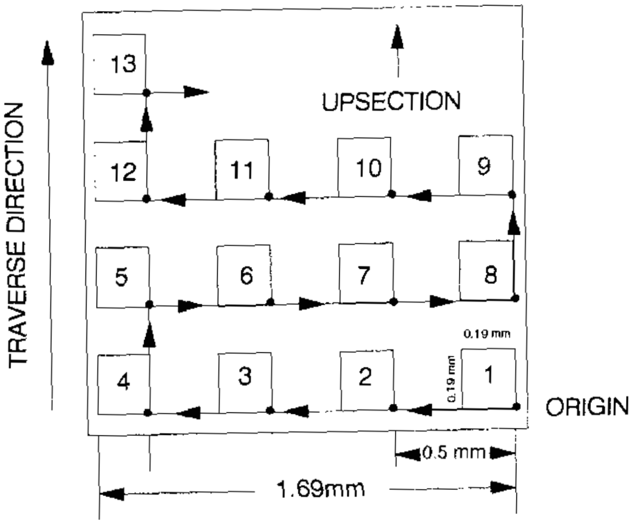

Figure 4-7-5. Traverse path of microscope on coal block during image analysis. Not to scale.

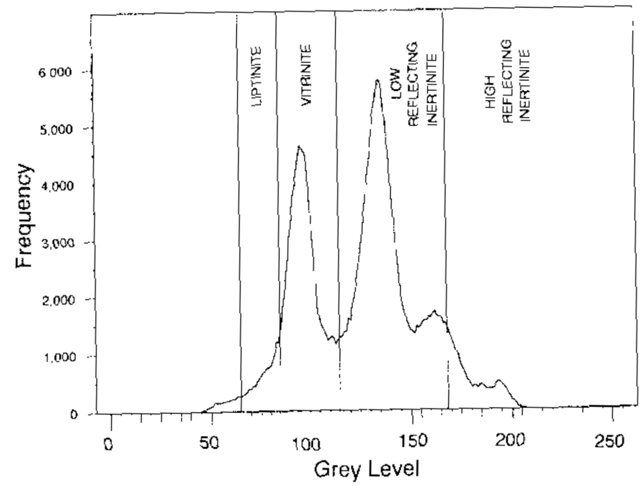

Figure 4-7-6. Grey-level histogram of a field enriched in low-reflecting inertinite showing location of compositional thresholds.

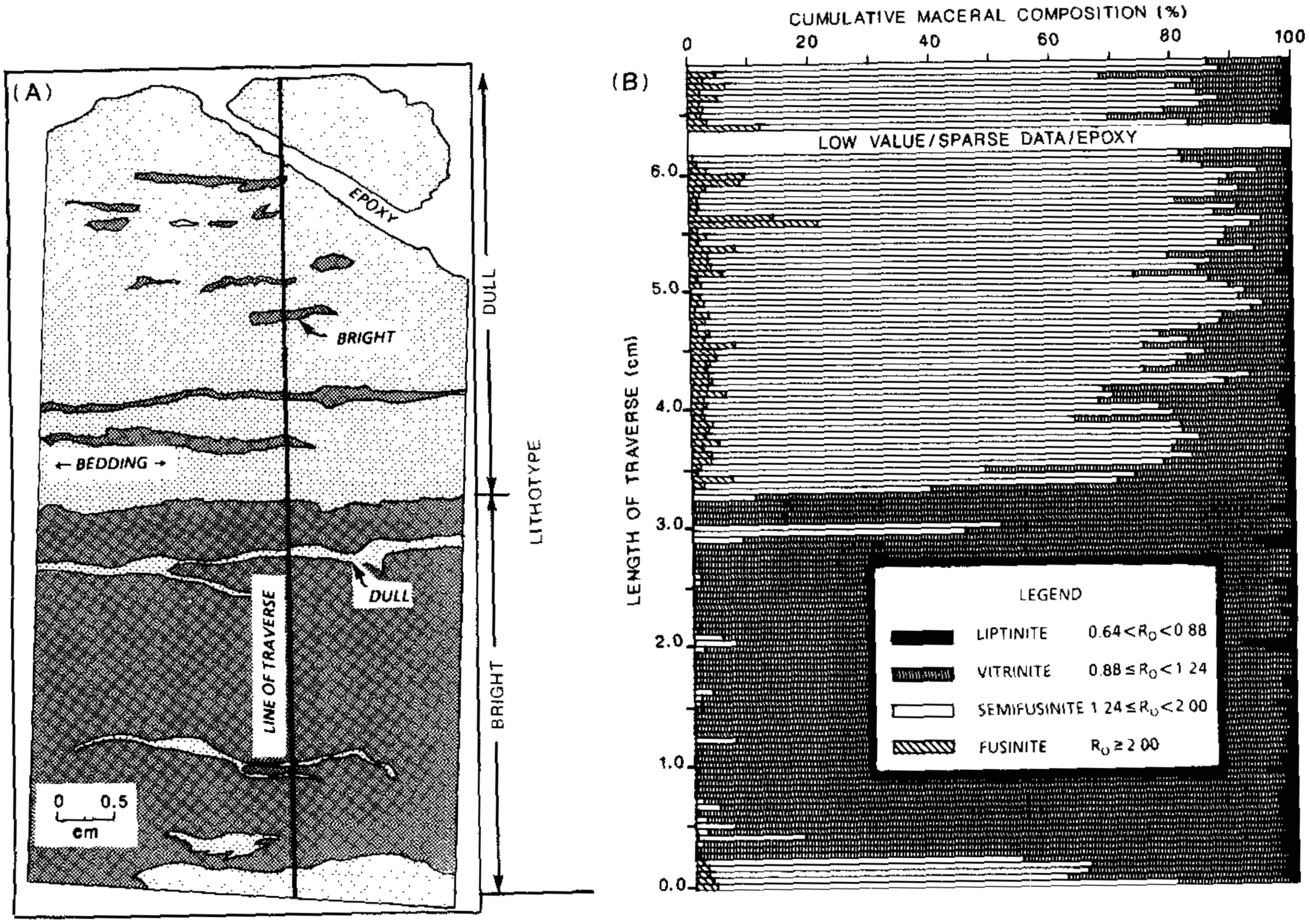

Figure 4-7-7. (A) Schematic drawing of coal block B66a showing location of bright and dull layers. (B) Image analysis plot of block B66a showing compositional changes along line of traverse.

TABLE 4-7-2
COMPARISON OF MACERAL COMPOSITION

	DATA SOURCE	BLOCK NUMBER	VITRINITE	LOW REFLECTING INERTINITE	HIGH REFLECTING INERTINITE	LIPTINITE
BRIGHT	PC	N/A	89	4	6	1
BANDED BRIGHT	PC	N/A	80	9	10	0
BANDED COAL	PC	N/A	72	12	15	1
BANDED DULL	PC	N/A	61	17	21	1
DULL	PC	N/A	42	28	28	1
SHEARED	PC	N/A	91	2	6	1
BANDED COAL	IA	B21	81	27	2	2
BANDED DULL	IA	B21	69	27	2	2
BRIGHT	IA	B43a	82	8	1	10
DULL	IA	B43a	61	26	10	3
FUSAIN	IA	B43a	23	29	42	6
SHEARED	IA	B14	97	1	1	3
BANDED DULL	IA	B14	67	29	4	1
FUSAIN	IA	B14	33	36	27	5
BANDED COAL	IA	B14	56	39	3	2
BRIGHT	IA	B66a	92	7	1	1
DULL	IA	B66a	15	79	4	2

PC=POINT COUNT IA=IMAGE ANALYSIS

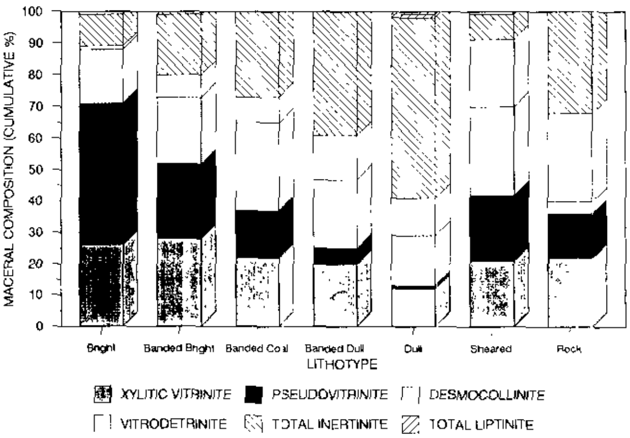

Figure 4-7-8. Average maceral composition by lithotype (volume per cent), mineral matter free basis, as determined by traditional point counting methods. Xylitic vitrinite = (telinite + telocollinite).

SUMMARY

Mapping lithotype variations within the coal seams at the Bullmoose mine provides a framework for interpreting the characteristics of the original wetland environments. Coal seams in the mine area differ from one another in terms of their seam stratigraphy. In addition, variations are present within each seam, implying that depositional conditions were not uniform throughout the original wetland environment. Distance from the paleoshoreline or active fluvial channels is believed to have been a major factor controlling seam compositional variations.

Lithotypes appear to be compositionally distinct, with a decrease in vitrinite content from the brighter to duller lithotypes. The results of this study suggest that a variety of wetland environments were present; each lithotype may reflect one, or several different environments. Two wetland types, one open to clastic input and the other protected from clastic input, are illustrated by the D and B seams, respectively.

FUTURE RESEARCH

Future research will concentrate on analyzing more lithotype samples in order to more precisely characterize their maceral composition. In addition, an investigation into the occurrence and characteristics of pseudovitrinite, which is inordinately abundant in the bright and banded bright lithotypes, will be undertaken. Because the coals are composed of banded coal and banded dull lithotypes, the pseudovitrinite is not abundant when considered on a whole-seam basis. The seam stratigraphy, as determined by the lithotype correlations, will be further interpreted in terms of the enclosing clastic strata.

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