OTHER INVESTIGATIONS

PRELIMINARY INVESTIGATIONS AS TO THE EFFECTS OF SHEAR ON COAL QUALITY IN SOUTHEASTERN BRITISH COLUMBIA (82)

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INTRODUCTION

In southeastern British Columbia coal seams of the Mist Mountain Formation were in part sheared and comminuted during Late Cretaceous and Tertiary tectonism. Extensive deposits of sheared coal exist, and even in areas of mild deformation the coal seams may be sheared locally (Bustin, 1979). The quality of the sheared coal varies markedly; it is commonly oxidized, even far from the present weathering horizon (Bustin, 1980), and locally it has a disproportionately large amount of ash and poor washability characteristics.

In order to document the effect of shear on coal quality, a study of sheared coal seams from southeastern British Columbia was undertaken. In conjunction with Fording Coal Limited two seams, locally referred to as the No. 5 and No. 7, were sampled in the Fording mine area, east of Elkford. In the mine area both the No. 5 and No. 7 seams are repeated by faulting. In the footwall of the fault the seams are virtually unsheared, but in the hangingwall the same two seams are pervasively sheared, thereby providing an opportunity to compare them to determine the effect of shear on the same seams in close proximity. Other samples were collected from the Vicary Creek area, north of Coleman, Alberta, Coal Mountain, Corbin, and Tent Mountain, directly north of Corbin.

This preliminary report documents the effect of shear on the washability characteristics of coal samples collected from the No. 5 and No. 7 seams at the Fording minesite. Some observations on sheared coal collected from other localities are also briefly considered.

METHOD OF STUDY

Samples of sheared and unsheared coal from the Fording minesite were crushed to 1.25 centimetres, then washability and proximate analysis were performed and heating value and free-swelling index (FSI) determined. The specific gravity (s.g.) separates of sheared and unsheared seams were further crushed to 0.8 millimetre and briquettes prepared and polished. The samples were then point counted to determine the relative abundance of the macerals. An average of 500 points per sample was counted. Additional samples of sheared coal from Vicary Creek, Alberta and Tent Mountain were also examined microscopically.

RESULTS

GENERAL DESCRIPTION

The extent of shearing of coal seams in the southeastern Cordillera is highly variable. In general there is a good correlation between the extent of structural deformation and degree of shearing of the coal. In areas such as Vicary Creek, however, comminution of the coal is largely the result of interstratal slip and the coal is locally pervasively sheared whereas the over and underlying strata may be essentially planar. The sheared coal seams consist of coarse to finely granular coal and rock partings; cleat, if ever present, has been largely or completely destroyed. The sheared coal is polished and pervaded by slickensided surfaces. Discrete, traceable shear surfaces are rarely present; rather, the coal has an over-all cataclastic fabric.

WASHABILITY ANALYSIS

The results of the washability analysis of the No. 5 and No. 7 seams are summarized in Tables 1 and 2.* On Figures 41 and 42 the characteristic washability curves for No. 7 seam are shown and on Figures 43 and 44 the characteristic washability curves for No. 5 seam are shown. The most noticeable difference between the sheared and unsheared seams is the greater amounts of ash and lower clean coal yields of the sheared coal. For example, if a coal with an 8-per-cent ash is required, the yield of No. 7 seam (unsheared) would be 87 per cent but sheared only 24 per cent; the specific gravity (s.g.) required for washing would be 1.67 per cent unsheared and 1.38 per cent sheared. The ash in the discard would be 58 per cent in the unsheared coal and 61 per cent in the sheared coal. The near density material of the coal would be 6 per cent if unsheared but 25 per cent if sheared. Similarly, if a coal with an 8 per cent ash is required of No. 5 seam the yield of the unsheared coal would be 81 per cent, which would require a specific gravity of separation of 1.46, the ash content of the discard would be 47 per cent, and the near density material would be 30 per cent. No. 5 seam sheared would yield 50 per cent, require a specific gravity of separation of 1.67, the ash content of the discards would be 85 per cent and the near density material would be 5 per cent. In addition, almost every specific gravity fraction of the sheared coal has a somewhat greater ash content than the unsheared coal (compare column 3, Direct Ash, of Tables 1 and 2 of the sheared and unsheared coal). Such results indicate that the ash of the sheared coal is more difficult to remove from the organic fraction than that of the unsheared coal. For example, the ash content of the 1.3 to 1.4 specific gravity fraction of No. 5 seam is 7.7 per cent unsheared and 8.2 per cent sheared; the same fraction of No. 7 seam has values of 8.9 per cent and 11.7 per cent respectively. The near density material (Tables 1 and 2) of the unsheared coal was found to be generally greater than that of the sheared coal, which indicates that the sheared coal is more amenable to separation if separation of these specific gravity fractions is necessary. Such results are, however, a product of the much lower total yields of the sheared coal in these fractions and do not reflect greater ease of washing.

Preliminary examination of the ash mineralogy indicates that it consists predominantly of kaolinite, quartz, and calcite. Additional studies to determine if a variation in the mineralogy of the ash exists are underway.

PROXIMATE AND SULPHUR ANALYSIS

The results of proximate and sulphur analysis of the No. 5 and No. 7 seams are summarized in Tables 1 and 2. The variation in volatile matter, with specific gravity of each seam, is shown graphically on Figure 45. Coal separates with a specific gravity less than 1.6 show little variation in composition between sheared and unsheared coal; in the fractions heavier than 1.6 specific gravity, the sheared coal has lower volatile matter

*Tables and figures are on pages 137 to 147 at end of text.

and generally lower fixed carbon contents than the unsheared coal. Such results are considered to reflect the small difference in ash content between sheared and unsheared coal in the less than 1.6-specific-gravity fractions as compared to the much greater abundance of ash in the sheared coal in the higher specific gravity fractions.

The sulphur content of all the analysed samples is low and there is no observable variation between the sheared and unsheared coal. In all seams sulphur decreases with increased specific gravity which indicates that sulphur is associated with the organic rather than the inorganic fraction.

HEAT CONTENT AND FREE-SWELLING INDEX

The variation in heat content (calorific value) and free-swelling index (FSI) of No. 5 and No. 7 seams are given in Tables 1 and 2. Heat content and free-swelling index are plotted against specific gravity on Figures 46 and 47 respectively. The heat content of the sheared coal is generally less than that of the unsheared coal and the heat content of the seams decreases markedly in the higher specific gravity fractions. The free-swelling index also decreases with increasing specific gravity, but there is no consistent difference between the sheared and unsheared coal.

PETROGRAPHY

The petrography of the samples is summarized in Tables 1 and 2 and the relative abundance of vitrinite, on an ash-free basis, is shown graphically on Figure 48. The samples were point counted on an ash-free basis because of errors associated with estimating mineral matter in coal microscopically (Ting, 1978). The relative abundance of ash was obtained from the proximate analysis.

All the samples consist mainly of vitrinite, fusinite, and semifusinite; trace amounts of macrinite, micrinite, and exinite are present. In all the seams fusinite and semifusinite are most abundant in the 1.3 through 1.6-specific-gravity fractions. On an ash-free basis, vitrinite (Fig. 48) is most abundant in the less than 1.3-specific-gravity fraction, decreases in abundance, and passes through a minimum in the 1.4 to 1.5-specific-gravity fraction and then progressively increases in the heavier specific gravity fractions, the only exception being the 1.8 to 1.9-specific-gravity of No. 5 seam. Such changes in the relative abundance of vitrinite are controlled by the relative density of the macerals and their mode of occurrence: in the less than 1.3-specific-gravity fraction, vitrinite occurs as homogeneous fragments with only minor inclusions of fusinite and semifusinite; in the 1.3 through 1.6-specific-gravity fractions, larger fragments of fusinite, semifusinite, and virtinite occur (Fig. 49); in the greater than 1.6-specific-gravity fractions vitrinite occurs intercalated with or disseminated in argillaceous partings (Fig. 50). In this high specific-gravity fraction fusinite and semifusinite occur mainly as inclusions in the vitrinite or as isolated fragments; they are rarely intercalated or disseminated in the argillaceous partings. Vitrinite is concentrated in higher specific-gravity fractions because it is associated with argillaceous partings; it is concentrated in the less than 1.3-specific-gravity fractions because it is of lower density than either fusinite or semifusinite.

There is no consistent variation in abundance of the macerals between the sheared and unsheared coal. In No. 5 seam, vitrinite is less abundant in the lower specific gravity fractions of the unsheared than the sheared coal, but more abundant in the higher specific gravity fractions of the unsheared than in the sheared coal. In No. 7 seam the sheared coal has a greater abundance of vitrinite in every specific gravity fraction.

The microfabric of the sheared coal is generally similar to that of the unsheared coal. On a microscopic level the finely granulated, sheared coal consists of fragmented larger clasts with no evidence of internal deformation. Some samples of sheared coal from Tent Mountain contain aggregates of angular fragments of inertinite in a groundmass of vitrite or clarite. Here the inertinite components underwent brittle deformation whereas the clarite or vitrite were apparently plastically deformed. Ductile behaviour of the clarite and vitrite is also evident from the occurrence of microfolds of similar style and 'wild' folds (Fig. 51).

DISCUSSION AND CONCLUSIONS

The results of the preliminary investigation indicate that the sheared coal of No. 5 and No. 7 seams have a disproportionately large amount of ash and have lower yields on washing than the unsheared coal of the same seam. The relative increase in ash in sheared coal may be related to several factors. Sheared coal seams throughout the southeastern Rocky Mountains have numerous ash and rock partings; perhaps the presence of such partings facilitated interstratal slip and shearing through the seam; thus the high ash content of the seams may have promoted rather than been caused by shearing. In addition, shearing of the coal is accompanied by comminution and distribution of formerly discrete partings throughout the seam; this would have deleterious effects on washing because it would increase the proportion of fine ash. The apparent high ash content of some seams may be related to the increased difficulty in distinguishing and separating sheared roof and floor strata from the coal seam during mining.

The higher ash content observed in all the specific fractions of the sheared as compared to the unsheared coal may also be the result of greater abundance of ash and accompanied loss of efficiency in washing. Generally, the finer the size-consist of the coal the greater the mechanical separation of inorganic from organic fractions (*B.C. Ministry of Energy, Mines & Pet. Res.*, Coal in B.C., 1976). However, the sheared coal of this study, although much finer grained, contained more ash than the unsheared coal. Microscopic examination did not reveal any features to account for the poorer separation of the sheared coal. It is probable, however, that the finer size-consist of the sheared coal causes argillaceous partings to break down to a greater degree during washing and results in a further increase in the fine fraction which would result in poorer separation during washing. In sheared coal from Tent Mountain, plastic flow of the vitrite and clarite resulted in formation of local aggregates in which separation of the organic from the inorganic fractions would be exceedingly difficult; however, no such aggregates were observed in either No. 5 or No. 7 seams.

Some of the variation in quality of the coal observed with increasing specific gravity is undoubtedly the result of concentration of the macerals during washing. Inasmuch as the ash content and the abundance of macerals both vary with increasing specific gravity, their relative effects on coal quality cannot be assessed without further analysis.

ACKNOWLEDGMENTS

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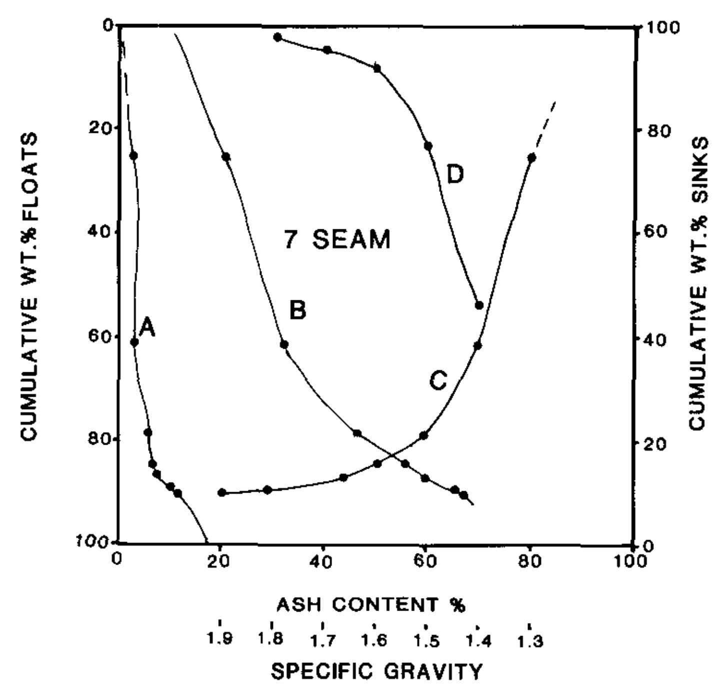


Figure 41. No. 7 seam washability curves:

A Clean coal curve – shows cumulative coal floating (yield) versus the average ash content of that coal (Cumulative Wt. % Floats axis is read against the Ash Content % axis).

B Discard curve – shows ash content of discards at any particular yield of clean coal (Cumulative Wt. % Sinks axis is read against Ash Content % axis).

C Specific gravity yield curve – shows percentage material floating at any given specific gravity (Cumulative Wt. % Floats axis is read against Specific Gravity axis).

D Distribution curve – shows amount of material that occurs within ±0.1 of the specific gravity being considered; it expresses the ease with which a coal may be cleaned in a specific-gravity range. The more material that is within ±0.1 of the specific gravity used for washing the more difficult, the more difficult the separation (Specific Gravity axis is read against Cumulative Wt. % Floats axis). The Coal Task Force (1976) suggests the following classification: 7 to 10 per cent near density material, simple separation; 7 to 15 per cent near density material, moder-moderately difficult; 10 to 15 per cent near density material, difficult; 15 to 20 per cent density material, very difficult; 20 to 25 per cent near density material, exceedingly difficult; and greater than 25 per cent near density material, formidable.

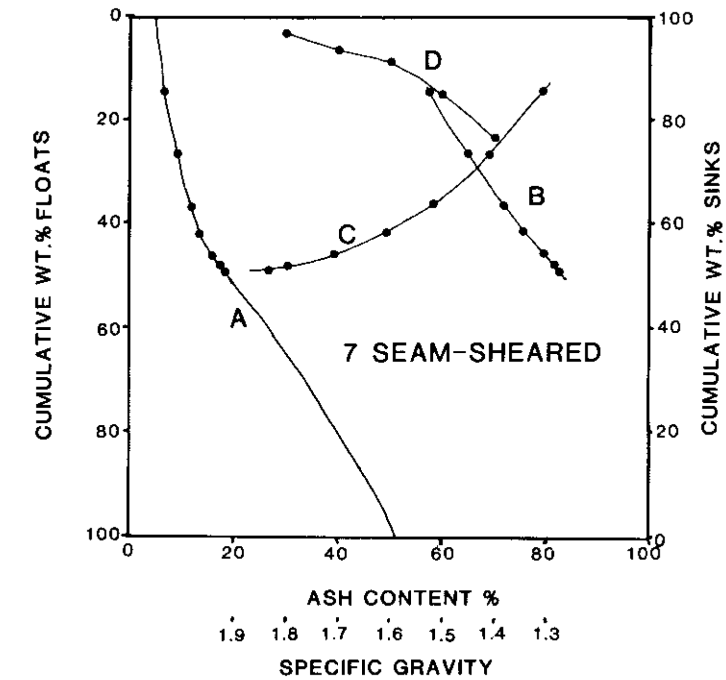


Figure 42. No. 7 seam-sheared washability curves. Refer to explanation of curves on Figure 41.

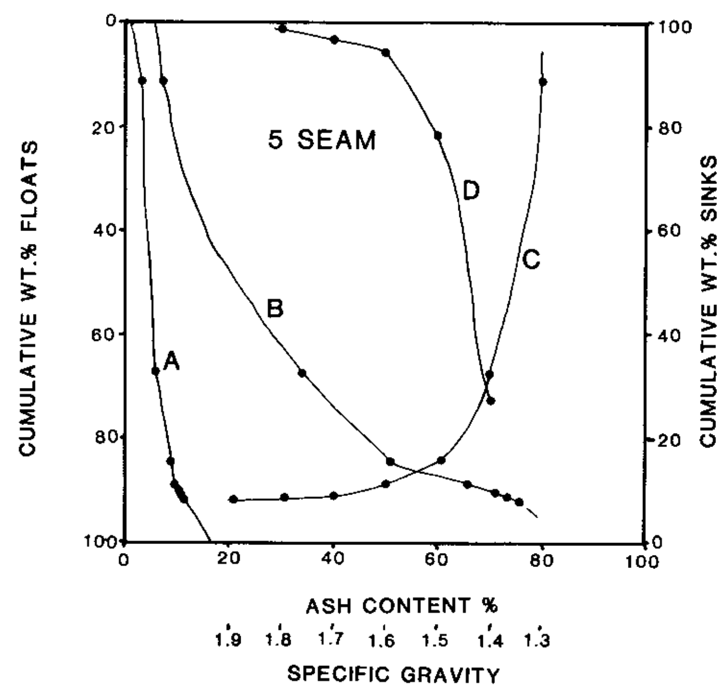


Figure 43. No. 5 seam washability curves. Refer to explanation of curves on Figure 41.

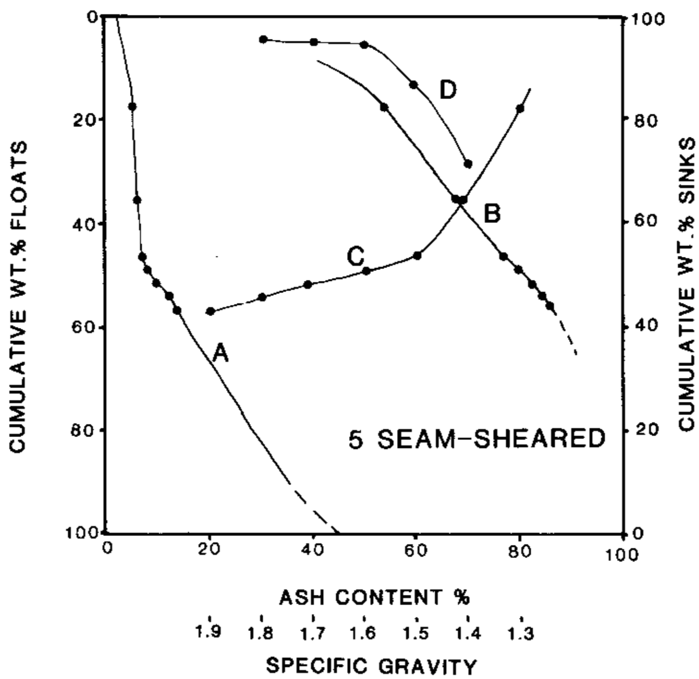
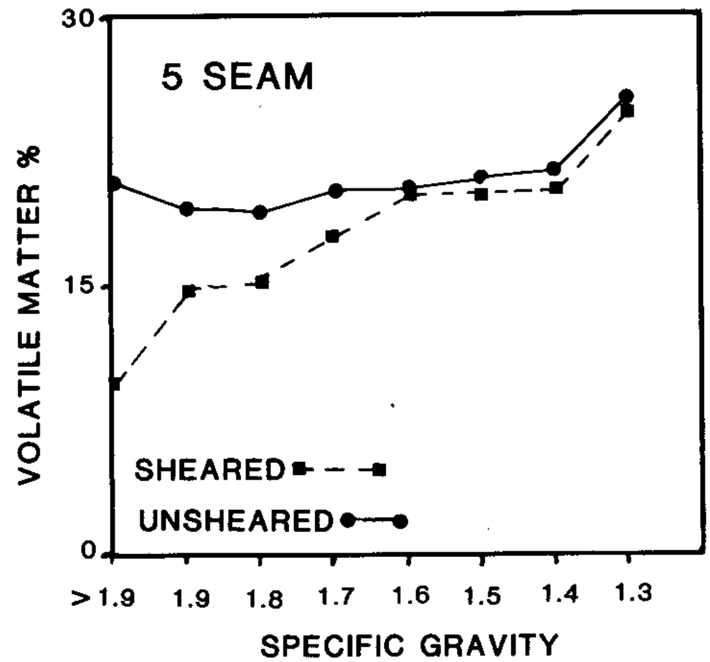


Figure 44. No. 5 seam-sheared washability curves. Refer to explanation of curves on Figure 41.



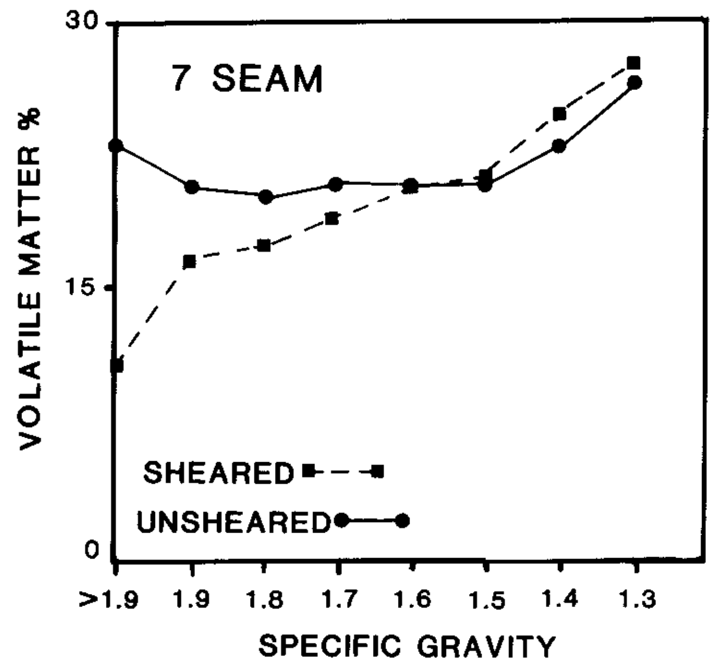


Figure 45. Volatile matter versus specific gravity of No. 5 and No. 7 seams, Fording mine area. In this and other diagrams a specific gravity of 1.3 indicates that the coal fraction floated on a liquid of 1.3 specific gravity; a specific gravity of 1.4 indicates that the coal fraction floated on a liquid of specific gravity 1.4 and sank in a liquid with a specific gravity of 1.3 and so on.

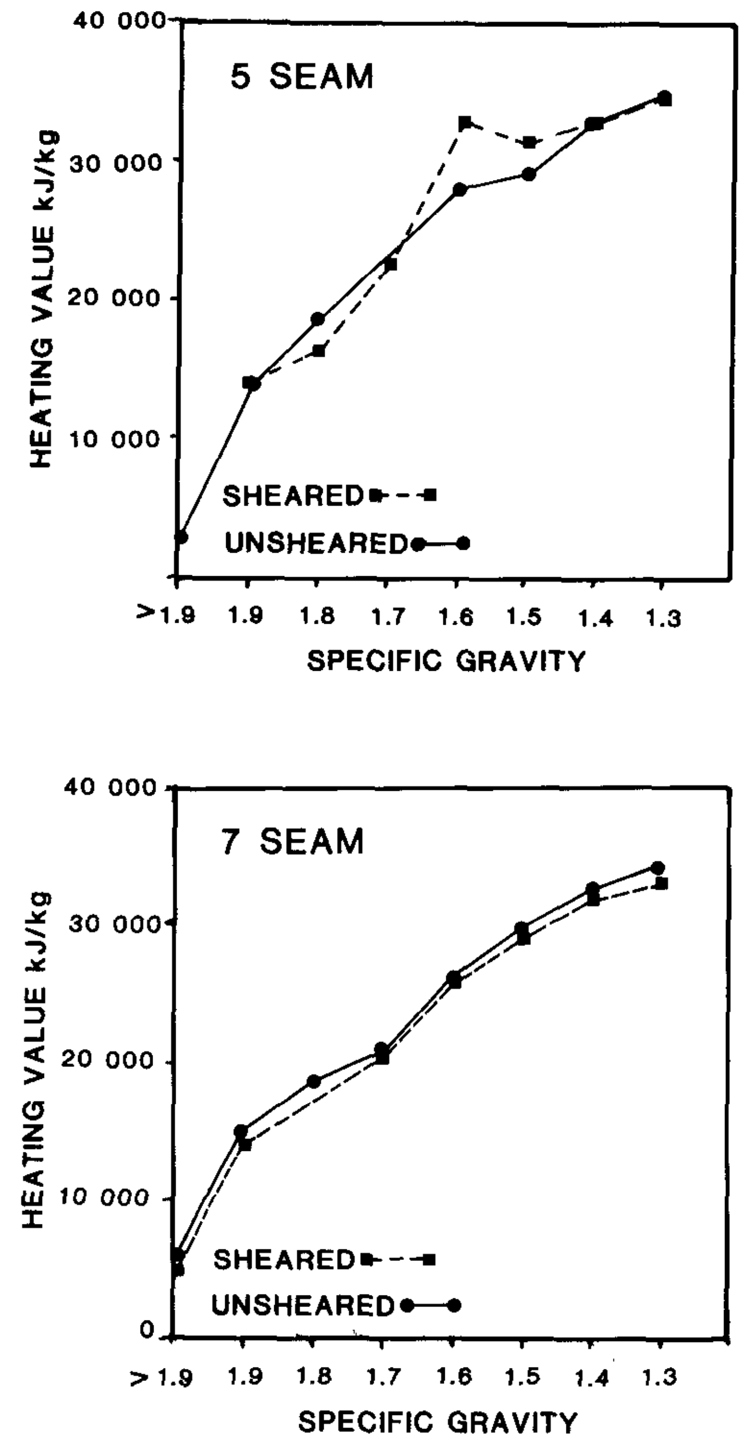
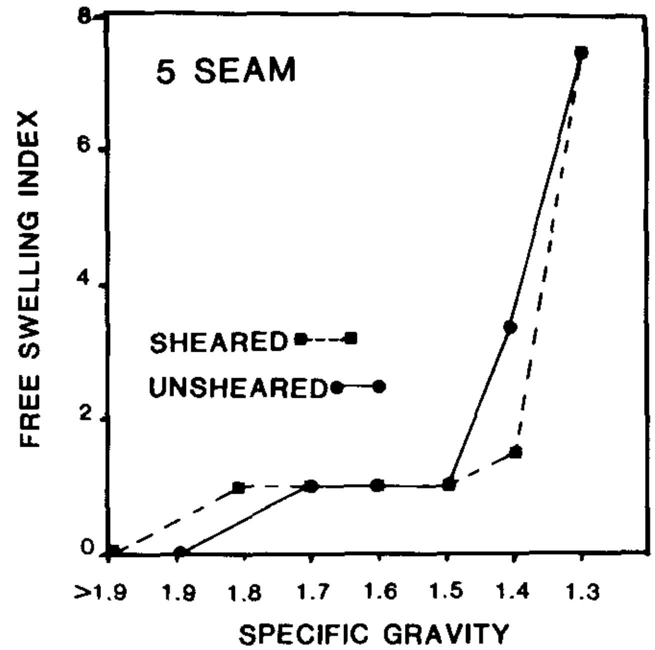


Figure 46. Heating value versus specific gravity of No. 5 and No. 7 seams, Fording mine area.



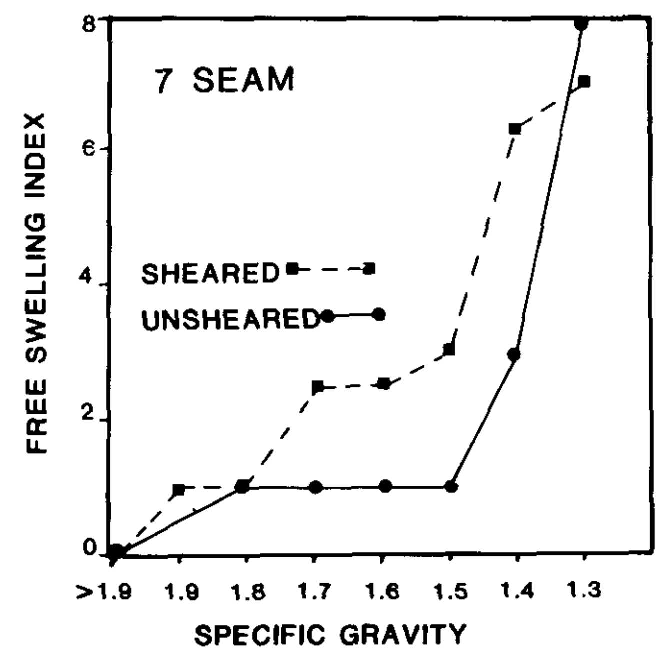


Figure 47. Seven free-swelling index versus specific gravity of No. 5 and No. 7 seams, Fording mine area.

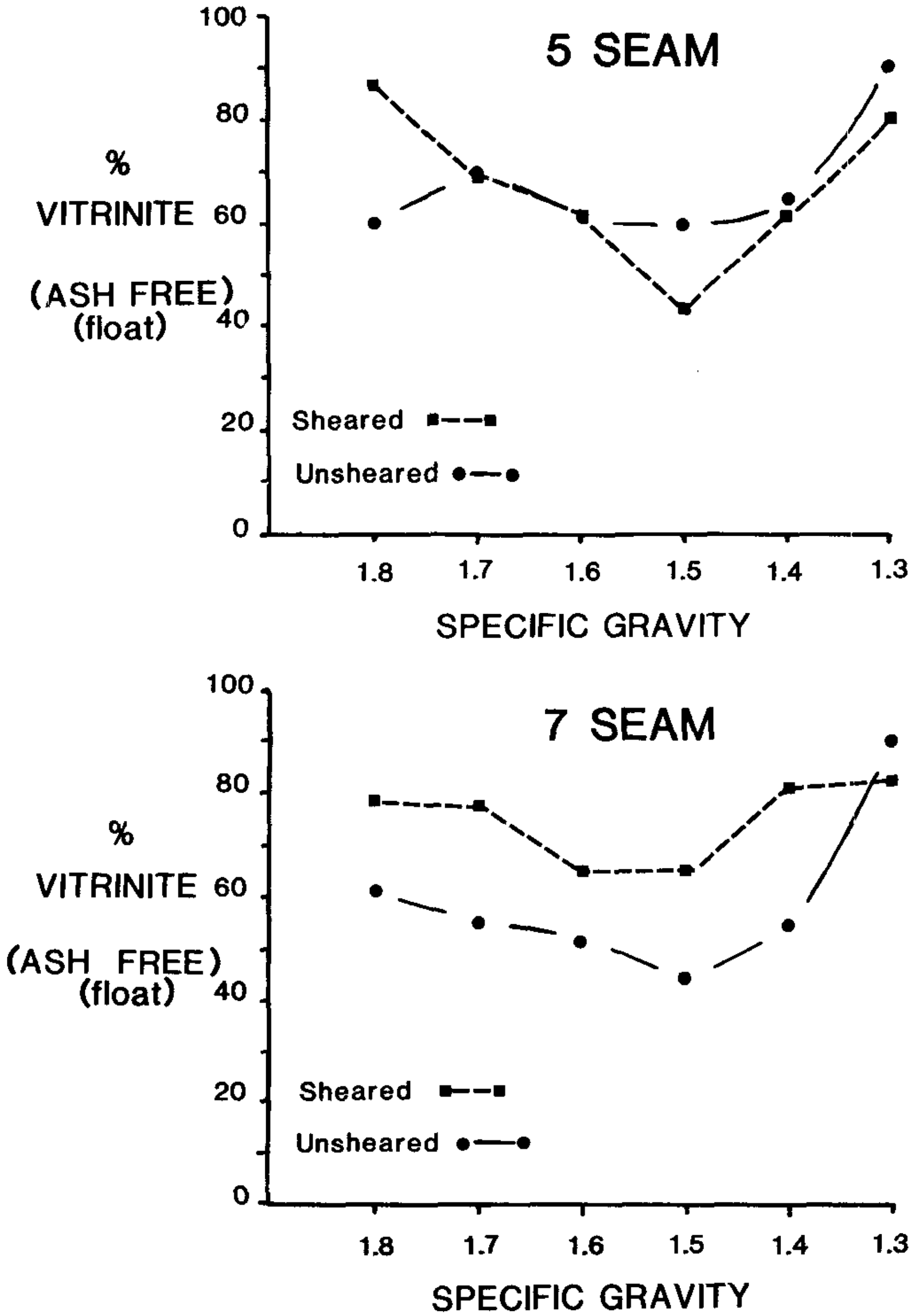


Figure 48. Vitrinite (ash-free basis) versus specific gravity of No. 5 and No. 7 seams, Fording mine area.

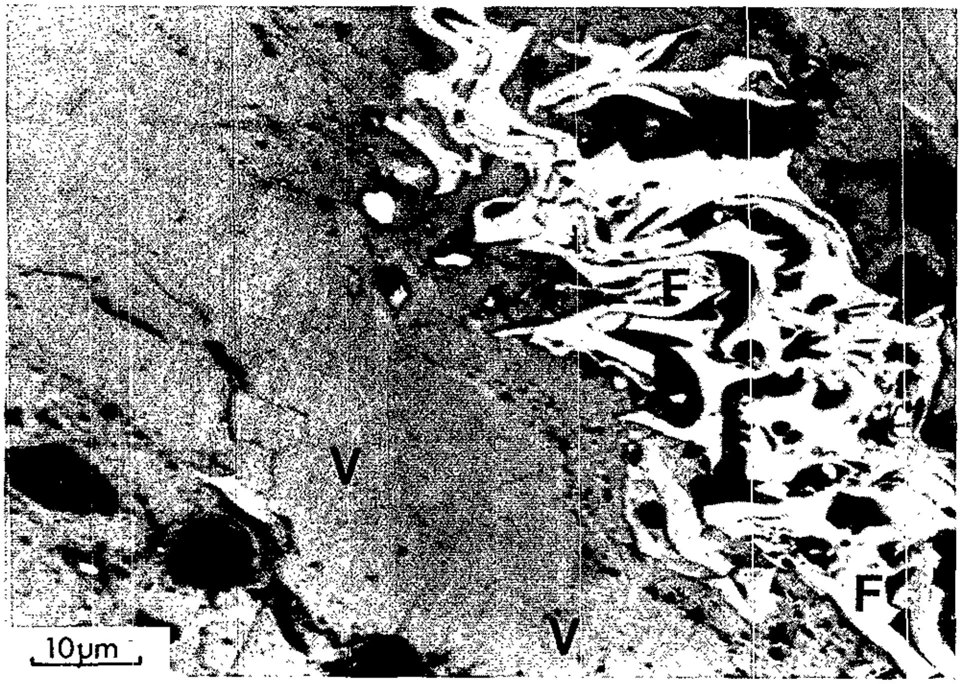


Figure 49. Vitrinite (V) and fusinite (F) in the 1.5 to 1.6 specific-gravity fraction of No. 5 seam, Fording mine area.

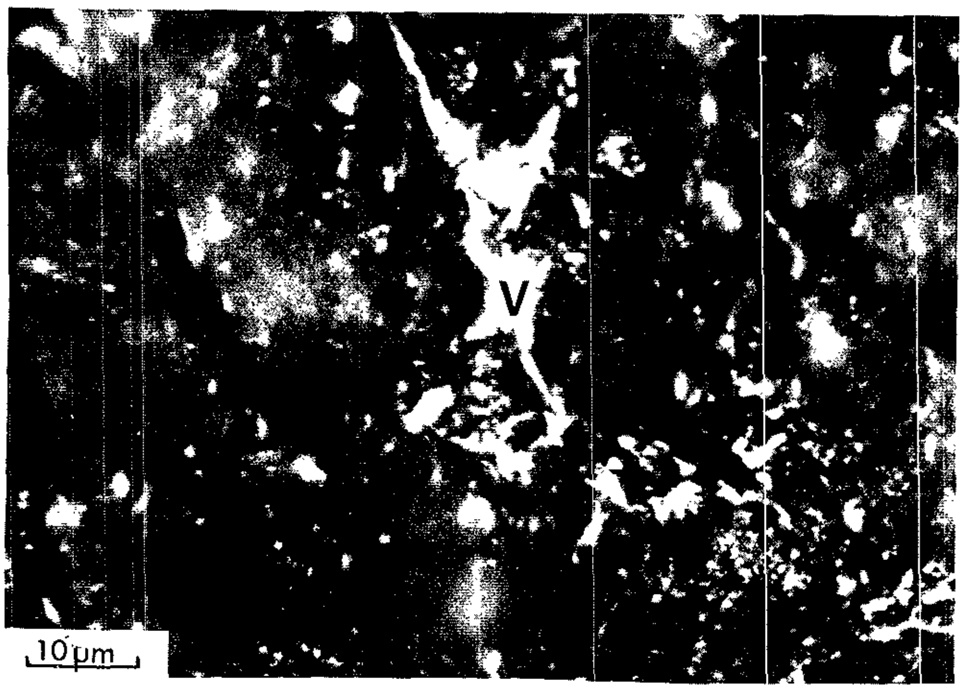


Figure 50. Finely disseminated vitrinite (V) in mineral matter (ash) in the 1.6 to 1.7 specific-gravity fraction of No. 7 seam, Fording mine area.

Figure 51.

Scanning electron photomicrograph of a 'wild' fold developed in clarain from a sheared seam at Tent Mountain, British Columbia.

TABLE 1. NO. 5 SEAM

SUMMARY OF WASHABILITY DATA AND PROXIMATE ANALYSIS, SULPHUR ANALYSIS, HEAT CONTENT, PETROGRAPHY, AND FREE-SWELLING INDEX FOR THE DIFFERENT SPECIFIC GRAVITY FRACTIONS

5 SEAM

Specific Gravity	Washability Data: Direct		Weight of ash of total	Cumulative weight of ash	Cumulative floats		Sink weight of ash	Cumulative sinks		±0.1 Specific gravity distribution	
	Weight	Ash			Weight	Ash		Weight	Ash	S.G.	Weight %
<1.3	11.8%	2.8%	0.3%	0.3%	11.8%	2.8%	15.0%	88.2%	17.0%		
1.3-1.4	55.8	7.7	4.3	4.6	67.6	6.9	10.7	32.4	33.0	1.4	73.4%
1.4-1.5	17.6	17.4	3.0	7.6	85.2	9.0	7.7	14.8	52.0	1.5	21.5
1.5-1.6	3.9	19.1	0.7	8.3	89.1	9.5	7.0	10.9	64.2	1.6	5.6
1.6-1.7	1.7	32.0	0.5	8.8	90.8	10.5	6.5	9.2	70.6	1.7	2.3
1.7-1.8	0.6	42.3	0.3	9.1	91.4	10.7	6.2	8.6	72.0	1.8	0.8
1.8-1.9	0.4	50.4	0.2	9.3	91.6	10.9	6.0	8.4	71.4		
>1.9	8.2	73.4	6.0	15.3	100.	15.8					

5 SEAM

Specific Gravity	Proximate Analysis (Weight %): Internal Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Heat Content KJ/Kg	Petrography (Volume %): Vitrinite	Fusinite	Semifusinite	Ash	Free swelling Index
<1.3	1.2%	24.9%	71.1%	2.8%	0.4%	35,276	87%	2%	8%	3%	7½
1.3-1.4	1.1	21.6	69.6	7.7	0.4	33,050	58	17	17	8	2½
1.4-1.5	0.9	20.6	61.1	17.4	0.4	28,995	52	16	16	17	1
1.5-1.6	0.8	20.3	59.8	19.1	0.4	28,310	50	14	17	19	1
1.6-1.7	0.8	20.0	47.2	32.0	0.4	23,318	46	9	13	32	1
1.7-1.8	0.8	19.1	37.8	42.3	0.3	18,766	35	11	12	42	½
1.8-1.9	0.6	19.3	29.7	50.4	0.2	13,750					0
>1.9	0.3	20.4	5.9	73.4	0.1	3,052					0

5 SEAM SHEARED

Specific Gravity	Washability Data: Direct		Weight of ash of total	Cumulative weight of ash	Cumulative floats		Sink weight of ash	Cumulative sinks		±0.1 Specific gravity distribution	
	Weight	Ash			Weight	Ash		Weight	Ash	S.G.	Weight %
<1.3	17.6%	4.3%	0.8%	0.8%	17.6%	4.3%	44.0%	82.4%	53.4%		
1.3-1.4	17.6	8.2	1.4	2.2	35.2	6.3	42.6	64.8	65.7	1.4	29.0%
1.4-1.5	11.4	12.0	1.4	3.6	46.6	7.6	41.2	53.4	77.1	1.5	13.9
1.5-1.6	2.5	19.8	0.5	4.1	49.1	8.3	40.7	50.9	80.0	1.6	5.0
1.6-1.7	2.5	35.6	0.9	5.0	51.6	9.6	39.8	48.4	82.3	1.7	5.8
1.7-1.8	3.3	51.6	1.7	6.7	54.9	12.1	38.1	45.1	84.5	1.8	5.1
1.8-1.9	1.8	52.2	0.9	7.6	56.7	13.4	37.2	43.3	85.9		
>1.9	43.3	86.0	37.2	44.8	100.	44.9					

5 SEAM SHEARED

Specific Gravity	Proximate Analysis (Weight %): Internal Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Heat Content KJ/Kg	Petrography (Volume %): Vitrinite	Fusinite	Semifusinite	Ash	Free swelling Index
<1.3	1.1%	24.2%	70.4%	4.3%	0.4%	34,656	78%	6%	12%	4%	7½
1.3-1.4	1.1	20.5	70.2	8.2	0.4	33,345	57	28	7	8	1½
1.4-1.5	1.2	20.1	66.7	12.0	0.4	31,476	41	34	13	12	1
1.5-1.6	1.2	20.0	59.0	19.8	0.4	33,398	50	24	6	20	1
1.6-1.7	1.1	17.7	45.6	35.6	0.4	22,709	43	13	8	36	1
1.7-1.8	1.0	15.1	32.3	51.6	0.3	16,217	42	6	1	52	1
1.8-1.9	1.0	14.6	32.1	52.2	0.2	15,772					½
>1.9	0.5	8.9	4.6	86.0	0.1	2,350					0

TABLE 2. NO. 7 SEAM

SUMMARY OF WASHABILITY DATA AND PROXIMATE ANALYSIS, SULPHUR ANALYSIS, HEAT CONTENT, PETROGRAPHY, AND FREE-SWELLING INDEX FOR THE DIFFERENT SPECIFIC GRAVITY FRACTIONS

7 SEAM

Specific Gravity	Washability Data: Direct											Proximate Analysis (Weight %)				Sulphur	Heat Content KJ/Kg	Petrography (Volume %)				Free Swelling Index
	Direct		Weight of ash of total	Cumulative weight of ash	Cumulative floats		Sink weight of ash	Cumulative sinks		±0.1 Specific gravity distribution												
	Weight	Ash			Weight	Ash		Weight	Ash	S.G.	Weight %	Internal Moisture	Volatile Matter	Fixed Carbon	Ash			Vitrinite	Fusinite	Semifusinite	Ash	
<1.3	25.4%	3.6%	0.9%	0.9%	25.4%	3.6%	16.1%	74.6%	21.6%			2.2%	26.4%	67.8%	3.6%	0.8%	34,935	87%	5%	5%	4%	8
1.3-1.4	35.9	8.9	3.2	4.1	61.1	4.	12.9	38.6	33.4	1.4	54. %	1.4	22.7	67.0	8.9	0.6	32,391	49	22	20	9	3½
1.4-1.5	18.0	16.9	3.0	7.1	79.4	5.6	9.9	20.6	48.0	1.5	23.2	0.9	20.7	61.5	16.9	0.5	29,176	37	30	17	17	1
1.5-1.6	5.2	24.4	1.3	8.4	84.6	6.8	8.6	15.4	55.8	1.6	8.5	0.6	20.3	54.7	24.4	0.4	25,880	40	21	16	24	1
1.6-1.7	3.3	34.0	1.1	9.5	87.9	7.8	7.5	12.1	61.9	1.7	5.1	1.1	20.4	44.5	34.0	0.5	21,505	37	21	8	34	1
1.7-1.8	1.8	40.8	0.7	10.2	89.7	8.5	6.8	10.3	66.0	1.8	2.9	1.4	19.8	38.0	40.8	0.5	18,919	37	16	6	41	1
1.8-1.9	1.1	49.3	0.5	10.7	90.8	11.8	6.3	9.2	68.5			1.0	20.4	29.3	49.3	0.4	15,059					½
>1.9	9.3	67.8	6.3	17.0	100.	17.0						0.3	22.8	9.1	67.8	0.2	5,774					0

7 SEAM SHEARED

Specific Gravity	Washability Data: Direct											Proximate Analysis (Weight %)				Sulphur	Heat Content KJ/Kg	Petrography (Volume %)				Free Swelling Index
	Direct		Weight of ash of total	Cumulative weight of ash	Cumulative floats		Sink weight of ash	Cumulative sinks		±0.1 Specific gravity distribution												
	Weight	Ash			Weight	Ash		Weight	Ash	S.G.	Weight %	Internal Moisture	Volatile Matter	Fixed Carbon	Ash			Vitrinite	Fusinite	Semifusinite	Ash	
<1.3	14.0%	5.1%	0.7%	0.7%	14.0%	5.1%	49.3%	86.0%	57.3%			1.9%	27.0%	61.0%	5.1%	0.7%	33,814	78%	9%	7%	5%	7
1.3-1.4	12.1	11.7	1.4	2.1	26.1	8.1	47.9	73.9	64.8	1.4	22.6%	1.4	24.1	62.8	11.7	0.5	31,370	71	4	12	12	6½
1.4-1.5	10.5	17.4	1.8	3.9	36.6	10.8	46.1	63.4	72.7	1.5	15.7	1.1	20.7	39.2	17.4	0.5	29,206	55	12	16	17	3
1.5-1.6	5.2	23.3	1.3	5.2	41.8	12.6	44.8	58.2	76.9	1.6	8.6	1.0	20.2	53.9	24.9	0.5	26,140	48	15	11	25	2½
1.6-1.7	3.4	39.7	1.3	6.5	45.2	14.8	43.5	54.8	79.3	1.7	5.7	0.8	18.8	40.7	39.7	0.4	20,929	47	7	6	40	2½
1.7-1.8	1.3	48.4	0.6	7.1	47.5	16.5	42.9	52.5	81.7	1.8	3.5	0.8	18.0	32.8	48.4	0.3	17,181	40	2	9	48	1
1.8-1.9	1.2	56.1	0.7	7.8	48.7	17.5	42.2	51.3	82.2			0.8	16.2	26.9	56.1	0.3	14,279	38	3	3	56	1
>1.9	52.3	80.8	42.2	50.0	100.	50.1						1.0	10.3	7.9	80.8	0.2	4,809	17	1	1	81	0

TABLE 1. TWO-WAY CONTINGENCY TABLE ROCK TYPE (PROVENANCE) VERSUS STREAM VELOCITY FOR STREAM SEDIMENT SAMPLES (NTS 82F)

ROCK AND AGE COMBINED	N.E.	STAGNT	SLOW	MOD.	FAST	TORRNT	OTHER
GRNT35	1		46	245	177	16	
SYNT42	1		2	15	6	1	
ANDS34			7	34	21		
LMSN12			1	4	4		
SLTE10			3	17	31		
ARGL33			1	15	15		
QRTZ45	6	6	34	145	124	3	
GNSS30	4	2	15	33	18	1	
SLTE32			1	13	16	3	
SCST32			2		8		
TILL			1	5	1		
SLTE46			6	24	27	4	
QRTZ12		1		9	20	2	
ARGL45		1	2	29	23	3	
SCST10			4	14	16		
ANDS46				2	2	1	
CGLM46				1	4		
SHLE12				4			
DLMI45			1	6	2		
ANDS32				4	2		
	WATER FLOW RATE 44						

TABLE 2. TWO-WAY CONTINGENCY TABLE FOR GROUPED DATA*

	Velocity Category			
Rock Type	Slow	Moderate	Fast	Totals
GRNT, SYNT	48(48.5)	260(242.5)	183(200)	491
ANDS	7(7.1)	40(35.6)	25(29.3)	72
SLTE	10(13.6)	54(68.2)	74(56.2)	138
ARGL	3(8.4)	44(42)	38(34.6)	85
QRTZ	34(32.8)	154(164.0)	144(135.2)	332
GNSS	15(6.5)	33(32.6)	18(26.9)	66
Totals	117	585	482	1184

$X^2_{(.05;\ d.f.\ 10)} = 18.31$

* Number in brackets are expected values