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INORGANIC MATTER CONTENT AND SPECIALIZED ELEMENT POTENTIAL OF THE NANAIMO AND COMOX COALFIELDS, VANCOUVER ISLAND* (92G, F, K)

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INTRODUCTION

The Nanaimo and Comox basins are the two major coal-bearing regions on Vancouver Island. Mining was begun in 1849 and 59 million tonnes were recovered from the Nanaimo, Comox and Suquash coalfields between then and 1914. While the Nanaimo basin is mostly mined out (Muller and Atchison, 1971), considerable resources remain in the Comox basin (154 million tonnes, inferred and indicated). Renewed interest in coal in the 1980s, and the subsequent opening of the Wolf Mountain mine in Nanaimo and the Quinsam mining operation in Comox, have led to a revival in geological investigation of these resources. The purpose of the present study is to examine the inorganic geochemistry of the Nanaimo and Comox coalfields and to assess the potential of these coal deposits for secondary uses such as the extraction of specialized elements. Preliminary results are given below.

GEOLOGY

The Nanaimo and Comox coalfields are located on the east coast of Vancouver Island in the Insular Belt of the Canadian Cordillera. The coal-bearing units are the Comox Formation (Comox) and the Extension and Protection formations (Nanaimo) of the Upper Cretaceous Nanaimo Group (Muller and Jeletzky, 1970; Muller and Atchison, 1971). The coal is high-volatile bituminous A and B in the Comox and Nanaimo basins respectively and is generally considered a thermal coal. Seams are overlain and underlain by shales and carbonaceous shales, and to a lesser extent sandstones. Varying numbers of shaly partings and lenses and light-weathering volcanic horizons are intercalated with the coal. Thicknesses of these units range from several millimetres to tens of centimetres. The Nanaimo Group unconformably overlies the Vancouver Group and Island Intrusions in the Comox basin and the Sicker Group, Karmutsen Formation and Island Intrusions in the Nanaimo basin. These units are exposed at the basin margins to the north, south and west (Figure 4-2-1), and represent probable sources for the conglomerate, sandstone and shale cycles, deposited in both marine and non-marine environments in the successor basin adjacent to the Coast plutonic complex (Yorath *et al.*, 1985). The Nanaimo basin and the several subfields and outliers which make up the Comox basin may represent erosional remnants of a once more extensive basin fill.

The structure in the coal-bearing basins is quite complex. The sedimentary section is shallow dipping and appears to be cut by numerous high and low-angle faults. A basin model and subsidence history are currently being constructed by T. England (personal communication, 1987).

METHODS

A field program carried out in July 1987 was designed to sample the major coal seams in a number of localities in the Nanaimo and Comox basins (Figure 4-2-1). Seventy-one samples were taken, 60 from the Comox basin and 11 from the Nanaimo basin. Recent excavations in the Comox area facilitated more extensive sampling, while the generally poor exposures in the Nanaimo region made sampling difficult. Channel samples across entire seams were taken at Quinsam, Hamilton Lake and Chute Creek, while grab samples were collected at Woodus Creek, Anderson Lake and all locations in the Nanaimo basin. Where possible samples were taken from fresh coal exposures, for example, recent open-pit faces at Quinsam and Chute Creek; however the majority of the seams sampled were weathered. All coal exposures were cleaned to a depth of at least 5 centimetres prior to sampling.

The samples were analysed as shown in Figure 4-2-2. X-ray defraction was carried out on unwashed samples at the British Columbia Ministry of Energy, Mines and Petroleum Resources by Y.T.J. Kwong and M. Chaudry. The abundance of amorphous material in the samples and the presence of poorly crystalline mineral phases make determination of relative proportions of minerals present difficult, however on the basis of peak intensity, a relative measure of mineral content was obtained. Samples for chemical analysis were crushed to −200 mesh and analysed by a variety of techniques including X-ray fluorescence (XRF), direct current plasma emission spectroscopy (DCP) and instrumental nuclear activation analysis (INAA). Portions of each sample were set aside for scanning electron microscope (SEM) and petrographic work to be carried out at a later date.

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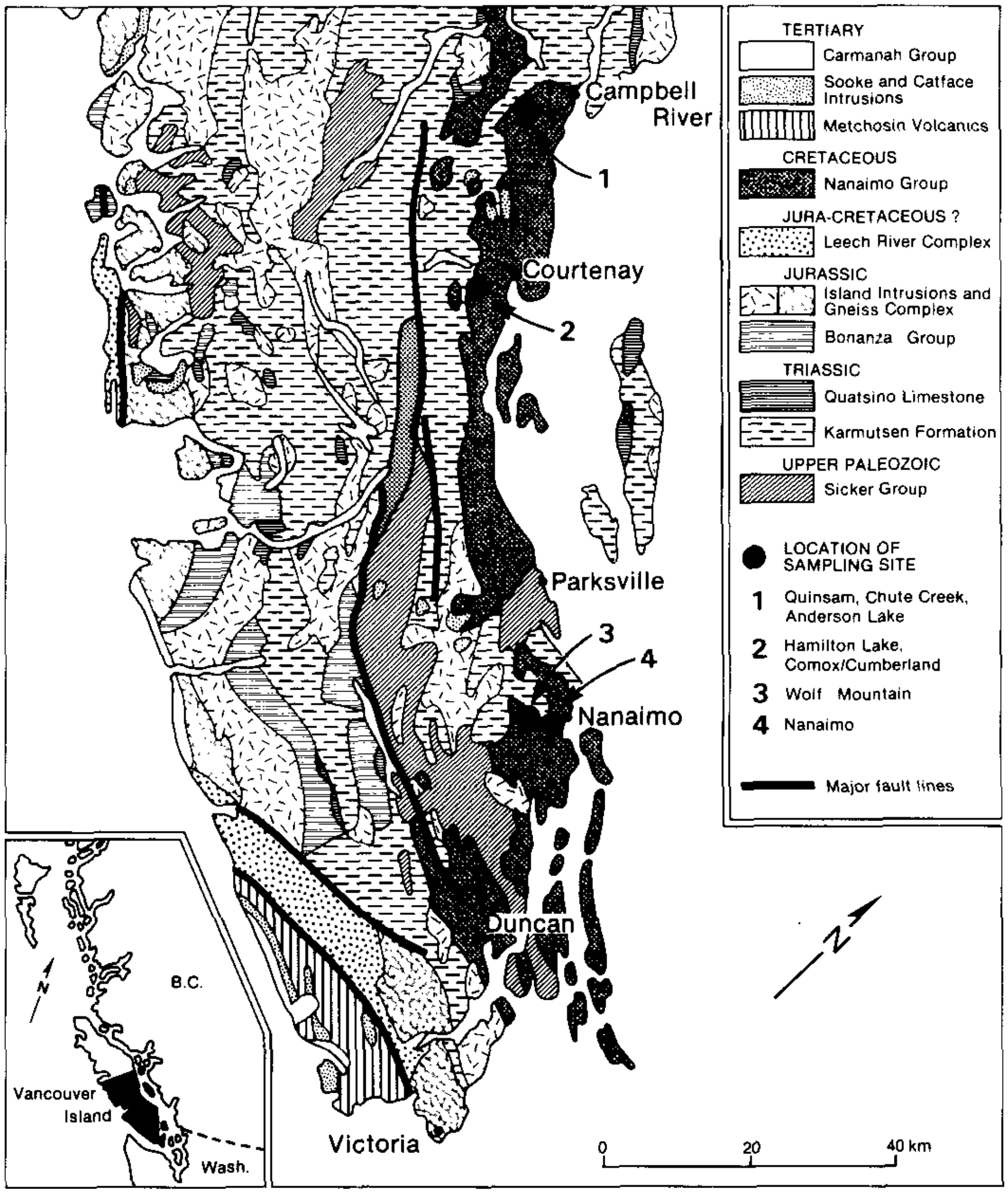

Figure 4-2-1. Geology and location of sampling sites in the Comox and Nanaimo coalfields.

RESULTS

MINERALOGY

Coals and sedimentary rocks in the Nanaimo and Comox basins contain a varied suite of minerals. Major mineral phases in the coal include calcite, kaolinite and quartz. Pyrite is commonly present and lesser amounts of dolomite, siderite, chlorite, ankerite, potassium feldspar, plagioclase, illite and montmorillonite were also noted in a few samples. Minerals in shales associated with the coals typically include pyrite, quartz, kaolinite and subsidiary marcasite, illite, plagioclase, potassium feldspar and chlorite.

The mineral content of unweathered coals from the Comox and Nanaimo basins is summarized in Table 4-2-1. While the basic mineralogy is the same in all areas, a number of variations are observed. The Quinsam coals contain the most restricted mineral assemblage – calcite, kaolinite, trace quartz and pyrite. Of these, pyrite is only present in the upper part of the seam. Associated with the pyrite nodules which occur in the upper seam are marcasite, rozenite, gypsum and

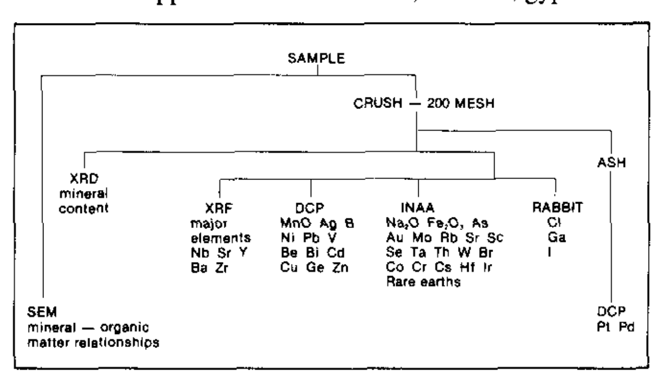

Figure 4-2-2. Flow diagram showing sample preparation and analytical methods.

TABLE 4-2-1
MINERAL MATTER IN UNWEATHERED COALS FROM THE NANAIMO AND COMOX COAL BASINS

		Calcite	Kaolinite	Quartz	Pyrite	Dolomite	Siderite	Ankerite	Montmoril-lonite	Other
Quinsam........ No. 1 Seam.	Upper	xxx	xx	tr	xx					
	Lower	xxx	xx	tr						
Chute Creek	Upper		xxx	tr	x	xx				
No. 1 Seam.. Quinsam? ..	Lower	xxx	x	xx	x	xx		x	x	
Nanaimo....... Wellington.. Seam..........		xxx	xx	xxx	tr	x		x	x	Plagioclase K-feldspar

TABLE 4-2-2
SUMMARY OF COAL GEOCHEMISTRY BY BASIN
(ppm except as indicated)

	Comox Basin (22 samples)			Nanaimo Basin (10 samples)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Si (%)	5.93	1.030	19.78	8.422	0.670	19.70
Al (%)..	3.50	0.740	10.80	2.847	0.760	9.04
Ca (%).	1.65	0.100	6.07	1.734	0.640	3.38
Mg (%)	0.12	0.010	0.65	0.363	0.140	0.61
Na (%).	0.02	0.010	0.07	0.118	0.010	0.40
K (%)..	0.06	0.010	0.34	0.174	0.010	0.70
Fe (%)	1.51	0.050	8.55	0.676	0.400	1.53
Mn.......	45.38	4.800	166.00	61.950	4.200	129.00
Ti.........	0.25	0.030	0.80	0.152	0.030	0.43
P..........	0.16	0.010	0.74	0.062	0.010	0.23
As........	55.88*	0.400	580,00	3.810	2.000	6.90
Au (ppb)	10.14	1.000	88.00	4.700	1.000	14.00
B.......	70.00	10.000	130.00	106.000	10.000	270.00
Ba ..	108.64	10.000	480.00	499.000	120.000	820.00
Be	1.18	1.000	3.00	1.400	1.000	3.00
Br........	2.00	0.800	4.30	1.910	0.500	6.10
Cl.........	261.82	50.000	600.00	128.000	30.000	300.00
Co	4.17	1.100	15.00	4.050	1.800	10.00
Cr....	19.09	10.000	59.00	28.900	10.000	64.00
Cs....	0.44	0.100	2.20	0.690	0.100	3.50
Cu....	18.23	3.000	49.00	12.200	2.000	33.00
Ga........	6.50	5.000	14.00	5.900	5.000	13.00
Hf......	0.95	0.200	3.20	0.900	0.200	1.80
I..........	7.64	0.500	14.00	3.520	0.600	13.00
Mo.....	2.28	0.400	11.00	2.220	1.100	3.90
Nb ..	10.00	10.000	10.00	10.000	10.000	10.00
Ni.........	9.64	2.000	27.00	13.300	5.000	24.00
Rb.......	10.45	10.000	20.00	12.800	10.000	32.00
S..........	20 713.64	3 300.000	64 600.00	6 970.000	3 000.000	15 000.00
Sb....	0.59*	0.100	3.73	0.600	0.100	1.90
Sc ..	6.08	1.400	14.80	3.936	1.130	11.30
Se..	0.91	0.500	2.80	0.600	0.500	0.90
Sr.....	336.82	10.000	1 900.00	368.000	130.000	760.00
Ta........	0.27	0.100	0.70	0.360	0.100	0.60
Th ...	1.02	0.300	4.20	0.990	0.300	2.00
U...	0.60	0.090	2.17	0.737	0.230	1.37
V.........	43.18	4.000	130.00	31.800	6.000	100.00
W. ...	1.00	1.000	1.00	1.700	1.000	7.00
Y...	16.36	10.000	90.00	11.000	10.000	20.00
Zn....	11.27	2.000	40.00	9.600	1.000	38.00
Zr........	27.27	10.000	110.00	21.000	10.000	50.00
La....	5.23	1.400	12.10	4.250	1.400	7.40
Ce ..	10.34	2.900	24.50	8.650	2.800	18.00
Nd......	4.29	1.400	12.50	4.410	1.300	10.50
Sm .	1.10	0.370	3.17	0.910	0.320	2.32
Eu...	0.35	0.100	1.15	0.244	0.070	0.65
Tb....	0.18	0.050	0.52	0.137	0.050	0.44
Yb........	0.82	0.160	2.77	0.628	0.160	1.65
Lu.......	0.14	0.030	0.43	0.117	0.030	0.32
LOI (%)	86.14	64.900	94.20	84.410	66.900	96.00

* Abnormally high values As and Sb have not been included.

szomolnokite. The Chute Creek and Nanaimo coals have a more diverse mineral assemblage including dolomite, ankerite, plagioclase, potassium feldspar and montmorillonite in addition to calcite, kaolinite, quartz and pyrite. Considerable variations in the proportions of minerals present have been noted within these seams. For example, in the upper part of the main seam at Chute Creek, kaolinite is the most common mineral, with lesser dolomite, pyrite and trace quartz. In the remainder of the seam, calcite, quartz and dolomite are the major minerals and kaolinite, pyrite and ankerite occur to a lesser extent.

The most common mode of occurrence of the calcite is in the form of cleat and fracture fills. Pyrite occurs in nodules and also coating bedding-plane surfaces. Clay minerals and quartz occur disseminated throughout the coal, as a result of incorporation during deposition and in the early stages of coalification.

GEOCHEMISTRY

Thirty-two coal and 12 shale samples were analysed for 58 major and trace elements. Ag, Cd, Ge and Ir are below detection limits in all the samples analysed. For a number of other elements, notably Be, Ga, Nb, Se, W and Zr, "less than" values are frequently quoted. Where these occur the actual value is taken to be equivalent to the "less than" value. Pb, Pt and Pd values are not quoted as the samples are being rerun with lower detection limits. Results of the analyses are summarized, by basin, in Table 4-2-2. Compared with average values in the earth's crust (Krauskopf, 1967; Fairbridge, 1972) only As, Cl, Au, Mo, Se and I are enriched in the coals.

One of the more noticeable trends in the results is that element concentrations are variable. Geochemistry varies between basins, for example, the mean values for Fe_2O_3, Al_2O_3, P_2O_5, TiO_2, S, As, Au, Cl, I, V, Y, Cu, Sc and rare earth elements (REE) are significantly higher in Comox coals than in Nanaimo coals, and the Nanaimo samples on average exhibit higher concentrations of SiO_2, MgO, Na_2O, K_2O, MnO, B, Ba, Cr, Ni, W and Cs.

In addition considerable variations are observed between seams within a basin. For example, six different seams were sampled in the Nanaimo basin. Variations in major and trace element contents in these samples are shown in Table 4-2-3. Some seams are considerably more enriched in certain elements than others, for example, Zn, V, Cs, Cu, Ga, Cr, Al, Fe, Cl, Rb, Mn, Th, Sb and Zr contents are highest in sample N87-9, the No. 3 seam of the Northfield Coal Measures (C.

TABLE 4-2-3
GEOCHEMISTRY OF NANAIMO COALS
(ppm except as indicated)

Samples	Si %	Al %	Ca %	Mg %	Na %	K %	Fe %	Mn	Ti	P	As	Au ppb	B	Ba	Be	Br	Cl
N87-1	2.17	1.72	0.98	0.14	0.02	0.02	0.51	47.6	0.05	0.05	2.9	1	10	320	3	1.6	30
N87-2	0.67	1.17	1.70	0.18	0.01	0.02	0.61	4.2	0.03	0.01	5.2	1	10	120	2	6.1	40
N87-3	2.91	1.58	1.29	0.59	0.14	0.03	0.47	63.8	0.07	0.02	2.0	2	270	330	1	1.5	220
N87-4	0.93	0.76	0.77	0.25	0.01	0.01	0.40	45.6	0.03	0.02	2.6	1	50	280	1	2.2	270
N87-5	6.83	2.39	2.69	0.36	0.07	0.14	0.72	69.7	0.13	0.03	3.9	7	130	460	1	1.1	90
N87-6	18.40	3.07	3.38	0.40	0.23	0.30	0.57	106.0	0.25	0.08	3.9	14	90	820	1	0.9	60
N87-7	5.47	1.96	3.11	0.34	0.05	0.09	0.52	49.1	0.09	0.15	2.8	6	140	540	1	1.5	60
N87-8	18.50	2.75	2.14	0.39	0.19	0.23	0.57	69.4	0.24	0.01	6.9	2	100	810	1	0.5	60
N87-9	19.70	9.04	0.64	0.61	0.06	0.70	1.53	129.00	0.43	0.02	3.3	6	60	700	2	0.8	150
NI MIX	8.64	4.03	0.64	0.37	0.40	0.20	0.86	35.1	0.20	0.23	4.6	7	200	610	1	2.9	300

Samples	Co	Cr	Cs	Cu	Ga	Hf	LOI %	I	Mo	Nb	Ni	Rb	S	Sb	Sc	Se	Sr
N87-1	4.4	10	0.2	6	5	0.6	93.2	0.6	3.0	10	6	10	3,600	0.9	4.41	0.5	570
N87-2	10.0	10	0.3	10	5	0.3	94.0	2.4	2.3	10	23	10	3,000	0.5	3.27	0.6	130
N87-3	2.4	10	0.3	8	5	0.5	91.6	1.1	1.1	10	10	10	5,400	0.2	1.98	0.6	240
N87-4	2.4	10	0.1	2	5	0.2	96.0	2.2	1.5	10	5	10	12,000	0.1	1.13	0.5	170
N87-5	5.6	20	0.5	10	5	0.9	85.7	12.0	2.4	10	13	10	15,000	0.9	3.27	0.8	320
N87-6	2.8	56	0.7	8	5	1.2	71.8	0.8	1.8	10	10	13	3,700	0.4	3.30	0.5	380
N87-7	1.8	10	0.2	7	5	0.9	87.0	13.0	1.6	10	8	10	11,000	0.3	2.12	0.6	620
N87-8	3.0	64	0.3	11	5	1.6	73.5	0.9	2.2	10	13	13	4,200	0.4	2.97	0.9	260
N87-9	4.8	56	3.5	33	13	1.8	66.9	1.4	3.9	10	21	32	4,300	1.9	11.30	0.5	230
NI MIX	3.3	43	0.8	27	6	1.0	84.4	0.8	2.4	10	24	10	6,700	0.4	5.61	0.5	760

Samples	Ta	Th	U	V	W	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
N87-1	0.5	0.8	1.37	12	7	10	4	10	7.3	11.5	5.0	1.13	0.31	0.23	1.07	0.19
N87-2	0.3	0.8	0.68	12	2	10	4	10	3.1	7.9	5.8	1.32	0.41	0.11	0.92	0.16
N87-3	0.4	0.8	0.29	14	1	10	2	10	2.9	5.3	3.0	0.47	0.09	0.05	0.26	0.04
N87-4	0.4	0.3	0.79	6	1	10	1	10	1.4	2.8	1.3	0.32	0.07	0.05	0.16	0.03
N87-5	0.1	0.9	0.61	30	1	10	9	20	4.3	8.9	4.4	0.74	0.28	0.11	0.41	0.10
N87-6	0.6	1.1	0.63	34	1	10	12	30	3.4	6.5	2.0	0.51	0.16	0.05	0.44	0.07
N87-7	0.1	0.6	0.23	20	1	10	11	10	3.7	6.5	3.7	0.59	0.11	0.05	0.33	0.07
N87-8	0.5	1.1	0.71	30	1	10	8	40	1.9	5.4	1.9	0.46	0.17	0.05	0.42	0.08
N87-9	0.3	2.0	1.37	100	1	20	38	50	7.4	18.0	10.5	2.32	0.65	0.44	1.65	0.32
NI MIX	0.4	1.5	0.69	60	1	10	7	20	7.1	13.7	6.5	1.24	0.19	0.23	0.62	0.11

Key to Samples:
N87-1 Reserve seam—Cedar Bridge.
N87-2 Reserve seam.
N87-3 Douglas seam.
N87-4 Newcastle seam—Fiddick's mine.
N87-5 Wellington seam—Wolf Mountain.
N87-6 Wellington seam.
N87-7 Wellington seam.
N87-8 Wellington seam.
N87-9 No. 3 seam—Northfield coal measures.
NI MIX Newcastle seam.

Bickford, personal communication, 1987). High values also occur in the Wellington seam, samples N87-6 and N87-8. These samples contain tonstein bands and elevated element contents may be due to the presence of inorganics introduced from a volcanic source. The tonstein bands are generally obvious and may be readily removed during cleaning. Clean samples from the same seam have low values of the elements listed above but show elevated iodine concentrations. The Douglas seam is enriched in boron and chlorine. Variations between seams are also present in the Quinsam area. For example, the main seam, No. 1, has the highest CaO, I, S and Sr values. Seam No. 2 is most enriched in gold, and seam No. 3 contains maximum values of SiO_2, As, B, Ba, Cr, Cu, Hf, Mo, Sc, Zn, Zr, Ta and V.

In addition to variations in chemistry between basins and between seams within basins, considerable variations are observed within a single seam both laterally and vertically. This is illustrated by examining the changes in chemistry through a channel section of the Quinsam No. 1 seam. The majority of trace elements including As, Zn, Mo, Cu, Ni, V, Au, Rb, Sc and major element oxides such as SiO_2, Al_2O_3, TiO_2, MgO, K_2O, Na_2O and Fe_2O_3 show an overall trend of decreasing concentration from top to bottom of the seam. Values are highest in the roof and floor and in the carbonaceous shale partings within the seam. Bromine and chlorine values remain constant with depth and iodine values increase.

DISCUSSION AND CONCLUSIONS

Although the results presented here are preliminary, a number of conclusions concerning the inorganic matter content and specialized element potential can be made. The coals are generally comparable to other western Canadian coals in terms of inorganic matter contents, however variations in major and trace element contents between and within basins are considerable. Within the Nanaimo and Comox coals, two groups of elements can be identified: (1) those which are enriched in shales, carbonaceous shales and coals with high ash contents, for example, arsenic, vanadium and molybdenum and (2) elements such as iodine, bromine and chlorine with distributions that bear no obvious relationship to the ash content of the coal.

On the basis of Pearson correlation coefficients, the associations or modes of occurrence of elements can be examined (Van der Flier-Keller and Fyfe, 1985, 1987). Statistical analysis of the results shows that for coals from the Nanaimo and Comox basins SiO_2, Al_2O_3, TiO_2, K_2O, Cr, Cs, Cu, Ga, Hf, Mo, Ni, Rb, Sc, Ta, Th, U, V, Zn, Zr and the rare earth elements are strongly correlated, indicating that these elements are associated with coal ash and particularly with silicate mineral phases. Molybdenum, sulphur and zinc are associated with iron. Iodine shows a weak correlation with calcium, and a large number of elements are negatively correlated with loss on ignition (LOI). LOI can be used as an approximate measure of organic content. Although many elements are associated with a single phase in the coal, others may occur in a variety of ways, for example, associated with the organic matter and the clay minerals. This will result in lower correlation coefficients than when elements are associated with a single phase.

COAL QUALITY

The samples analysed in this study have not been cleaned or upgraded in any way prior to analysis. In terms of coal quality, two points are important: the concentrations of elements and minerals in the coal (discussed above) and the ease with which these phases may be extracted. This depends largely on the mode of occurrence of the inorganic phase, for example, associated with the organic matter or with the sulphides in the coal. A large number of elements present in the Nanaimo and Comox coals appear to be associated with the silicate mineral phases. Ease of extraction of these elements cannot be evaluated until further research is carried out to determine grain size and degree of dissemination of these minerals and their relationship to the organic portion of the coal.

SPECIALIZED ELEMENT POTENTIAL

Of the elements analysed (results for several elements are not yet available), none are significantly enriched throughout the entire area examined. Elevated values for certain elements are, however, found in isolated samples. For example, arsenic values are extremely high (up to 1400 ppm) in Anderson Lake coal. Gold is enriched in the Quinsam No. 2 seam (88 ppb), and antimony concentrations of 110 ppm were determined in a sample from Chute Creek. More detailed sampling and analysis will be required to establish whether these anomalies are widespread or restricted to isolated samples.

REFERENCES

Fairbridge, R.W., Editor (1972): The Encyclopedia of Geochemistry and Environmental Sciences, *Van Nostrand Reinhold Co.*, New York, N.Y., Encyclopedia of Earth Sciences Series, Volume IVA.

Krauskopf, K.B. (1967): Introduction to Geochemistry, *McGraw-Hill*, New York, 721 pages.

Muller, J.E. and Atchison, M.E. (1971): Geology, History and Potential of Vancouver Island Coal Deposits, *Geological Survey of Canada*, Paper 70-53.

Muller, J.E. and Jeletzky, J.A. (1970): Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia, *Geological Survey of Canada*, Paper 69-25.

Van der Flier-Keller, E. and Fyfe, W.S. (1985): Uranium-thorium Systematics of Two Canadian Coals, *International Journal of Coal Geology*, Volume 4, pages 335-353.

Van der Flier-Keller, E. and Fyfe, W.S. (1987): Geochemistry of Two Cretaceous Coal-bearing Sequences: James Bay Lowlands, Northern Ontario, and Peace River Basin, Northeast British Columbia, *Canadian Journal of Earth Sciences*, Volume 24, pages 1038-1052.

Yorath, C.J., Clowes, R.M., Green, A.G., Sutherland Brown, A., Brandon, M.T., Massey, N.W.D., Spencer, C., Kanasewich, E.R. and Hyndman, R.D. (1985): LITHOPROBE 1: Southern Vancouver Island: Preliminary Analyses of Reflection Seismic Profiles and Surface Geological Studies, *in* Current Research, Part A, *Geological Survey of Canada*, Paper 85-1A, pages 543-554.