COALFIELD GEOLOGY OF EASTERN VANCOUVER ISLAND (92F)

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INTRODUCTION

Revived interest in the coal deposits of Vancouver Island has stimulated a project to compile and analyze existing data and to provide a field update to determine critical geological relationships. The aim of the study is to provide sufficient data and analysis to assist government and industry in assessing the potential of the deposits with respect to new uses such as coal seam gas and coal water fuel, as well as traditional thermal applications.

Coals of Late Cretaceous age along the southeastern coast of Vancouver Island have been intensively prospected and mined from 1849 to the present day. Initial discoveries were made by Indians, who reported coal showings at Nanaimo to the Hudson's Bay Company. Development was rapid and coal mining in the Cumberland and Nanaimo areas was a mainstay of the Vancouver Island economy until the early 1950s, when production began to decline rapidly. Small mines have recently opened at Wolf Mountain and Extension (Nanaimo coalfield) and Quinsam (Quinsam coalfield). Much air-rotary drilling has been done since 1974, to locate and prove mineable coal deposits.

This report summarizes the findings of 13 years' mapping (surface and underground) and office study of the coalfields of eastern Vancouver Island together with reconnaissance mapping and sampling of the major coal deposits during the 1987 field season.

LOCATION

The study area occupies part of the eastern coastal plain of Vancouver Island, from Campbell River in the north to Mount Maxwell in the south (Figure 4-3-1). The Comox sub-basin is approximately 1230 square kilometres in area and the Nanaimo sub-basin encompasses about 780 square kilometres. The basins are accessible by coastal waterways, paved highways and secondary roads. The distribution of secondary access roads is dependent on logging development in the area and local population density.

Topography is fairly gentle though elevations range from sea level to 457 metres. Many rivers and creeks drain into the Strait of Georgia. Abundant thick underbrush covers most of the area and generally limits coal exposures to creeks and roadcuts. The climate is mild and humid, and snow is usually found only at higher elevations.

Campbell River, Courtenay, Port Alberni and Nanaimo are the major population centres. Small towns and resort areas are scattered along the coast. The logging and fishing industries form the economic base of the area.

PREVIOUS WORK

The earliest report to specifically address coalfield geology is that of Hector (1861), who described the early workings of the Hudson's Bay Company at Nanaimo. Mapping of the coal measures at Nanaimo and Comox was subsequently done by Richardson (1872, 1873, 1878) and Clapp (1912a, 1912b, 1914). Published reports by McKenzie (1922) and Buckham (1947a, 1947b) present only a small fraction of their findings; maps, notebooks and working papers are in the Provincial Archives of British Columbia (as Additional Manuscript 436). Muller and Atchison (1971) produced the most recent summary report on the Vancouver Island coals and there are many unpublished reports by company geologists. Reports by Morrison and Forster Brown (1910), Curcio (1975), Bickford and Lee (1980) and Perry (1981) are regional in scope. Many other reports dealing with individual properties are on file with the ministry.

CATALOGUING OF OLD BOREHOLE RECORDS

Log information for 600 coal exploration boreholes (1889 to 1975) was collected and entered in the following Coal Assessment Report files in Victoria:

(1) Report No. 720 — Nanaimo sub-basin (303 boreholes).
(2) Report No. 694 — Comox sub-basin (297 boreholes, 118 maps).

Information contained in the above reports originated from the Provincial Archives, the Nanaimo and Cumberland civic museums, the Engineering and Inspection Branch and the Geological Survey Branch of the Ministry of Energy, Mines and Petroleum Resources. Source data included old survey notebooks, mine plans, geological maps, borehole log notes and site surveys at recognizable borehole locations.

Efforts were made to ensure the collection of the most reliable of several versions of a given log, by checking

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

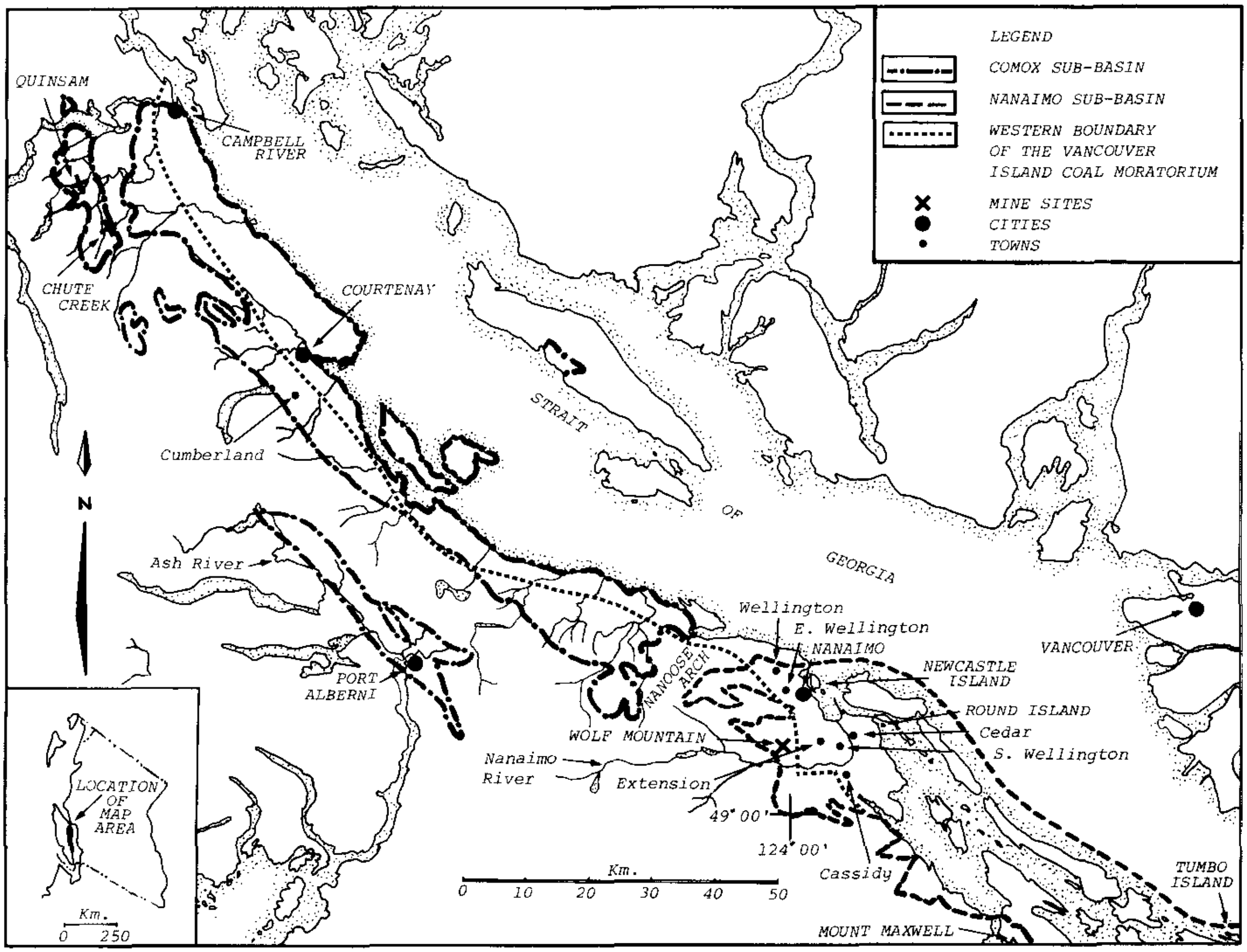

Figure 4-3-1. Location map, Vancouver Island coal basin.

against drillers' time sheets, site geologists' notes and mine managers' records. Most of the borehole locations are accurate within 50 metres and are available in computerized format.

COAL-MEASURE STRATIGRAPHY

The coal measures of eastern Vancouver Island are part of the Nanaimo Group of Santonian to Maastrichtian age (Jeletzky, in Muller and Jeletzky, 1970). These rocks occupy the western erosional margin of the Late Cretaceous Georgia basin, which is largely concealed beneath the waters of Georgia Strait. Two sub-basins (Comox to the north, Nanaimo to the south) are separated by a northeast-trending basement uplift, the Nanoose arch. Table 4-3-1 and Figure 4-3-2 show the component stratigraphic units of the Nanaimo Group, and Figure 4-3-3 depicts their changes along strike.

The two sub-basins will be discussed as separate entities. The Nanaimo sub-basin contains the Nanaimo coalfield, and minor coal showings at Tumbo Island and Mount Maxwell. The Comox sub-basin contains the Quinsam, Cumberland and Tsable River coalfields, together with minor showings at Ash River and Port Alberni.

NANAIMO SUB-BASIN

In the Nanaimo sub-basin, coal occurs in the Spray, Protection, Pender, Extension and Comox formations. Mines have been developed only in the Pender and Extension coals.

SPRAY FORMATION

The Spray Formation (Muller and Jeletzky, 1970) consists mainly of thin-bedded silty shales with thick lenses of sandstone and conglomerate. Boreholes on Tumbo Island encountered about 50 metres of dark shale containing a 1.5 to 2.4-metre coal bed; this coal-bearing unit forms the top of the Spray Formation.

PROTECTION FORMATION

The Protection Formation (Clapp, 1912a) in the Nanaimo area, contains three mappable members. From top down, these are the McMillan sandstone, Reserve coal measures and Cassidy sandstone.

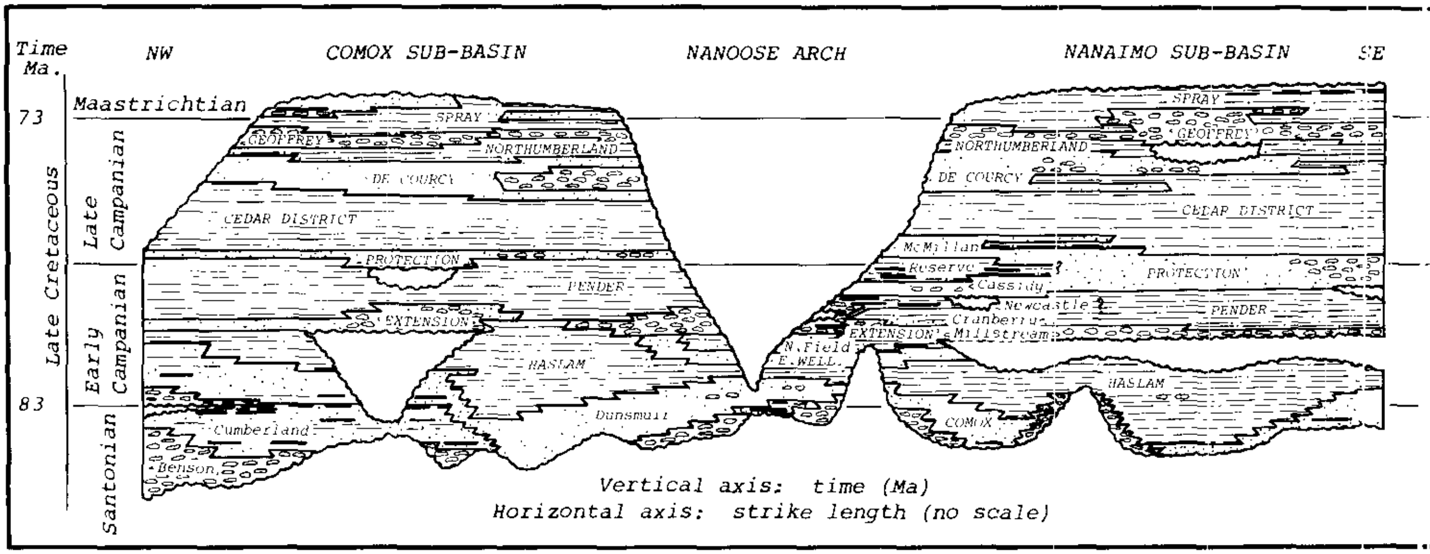

Figure 4-3-2. Stratigraphic relationships of the Nanaimo Group. Refer to Table 4-3-1 for legend.

The McMillan member is well exposed along the lower Nanaimo River, consisting of 60 to 90 metres of coarse-grained, thick-bedded, white arkosic wacke with thin interbeds of dark grey to greenish grey sandy siltstone.

The Reserve member crops out over the old workings of the Reserve mine near Cedar village, and also forms Round Island. It consists of 40 to 60 metres of green to brownish grey sandy siltstone and fine to medium-grained, medium-bedded, greenish grey lithic wacke with abundant lenses and pods of silty to carbonaceous mudstone and thin dirty coals. In the middle of the coal measures is the Cedar Bridge coal zone, comprising several closely spaced thin coals.

The basal Cassidy member outcrops in the Nanaimo River gorge at Cassidy. It consists of 80 to 105 metres of coarse-grained to gritty, thick-bedded to massive, white arkosic wacke and arenite, locally grading to quartzose pebble conglomerate.

Southwards from the Nanaimo coalfield, the Reserve coal measures appear to pinch out, and the McMillan and Cassidy sandstones are no longer separately mappable.

Pender Formation

The Pender Formation (Ward, 1978) consists of two mappable members in the Nanaimo coalfield, both initially given formational rank by Clapp (1912a) and subsequently reduced to members by Muller and Jeletzky (1970): the upper Newcastle coal measures, and the basal barren Cranberry shales.

TABLE 4-3-1
STRATIGRAPHIC UNITS OF THE NANAIMO GROUP

	Tertiary rocks of Whatcom Basin	
	DISCONFORMITY	
Maastrichtian	Spray Fm.	Dark shale; COAL
Late Campanian	(Boundary within Spray Fm.):	Classic turbidites, mostly shales
	Geoffrey Fm.	Conglomerate and sandstone
	Northumberland Fm.	Classic turbidites, mostly shales
	De Courcy Fm.	Sandstone and conglomerate
	Cedar District Fm.	Classic turbidites, mostly shales
Early Campanian	Protection Fm.	(Subdivided in Nanaimo coalfield)
	McMillan Mbr.	Sandstone and siltstone
	Reserve Mbr.	Siltstone and sandstone; COAL
	Cassidy Mbr.	Sandstone and conglomerate
	Pender Fm.	(Subdivided in Nanaimo coalfield)
	Newcastle Mbr.	Shale and conglomerate; COAL
	Cranberry Mbr.	Sandstone and siltstone
	Extension Fm.	(Subdivided in Nanaimo coalfield)
	Millstream Mbr.	Conglomerate; COAL
	Northfield Mbr.	Siltstone and sandstone; COAL
	East Wellington Fm.	Sandstone (Nanaimo sub-basin only)
	Haslam Fm.	Classic turbidites, mostly shales
	Comox Fm.	(Subdivided in Comox sub-basin)
	Dunsmuir Mbr.	Sandstone; COAL
	Cumberland Mbr.	Siltstone and sandstone; COAL
	Benson Mbr.	Conglomerate and red beds
	UNCONFORMITY	
	Older basement rocks, chiefly volcanics	

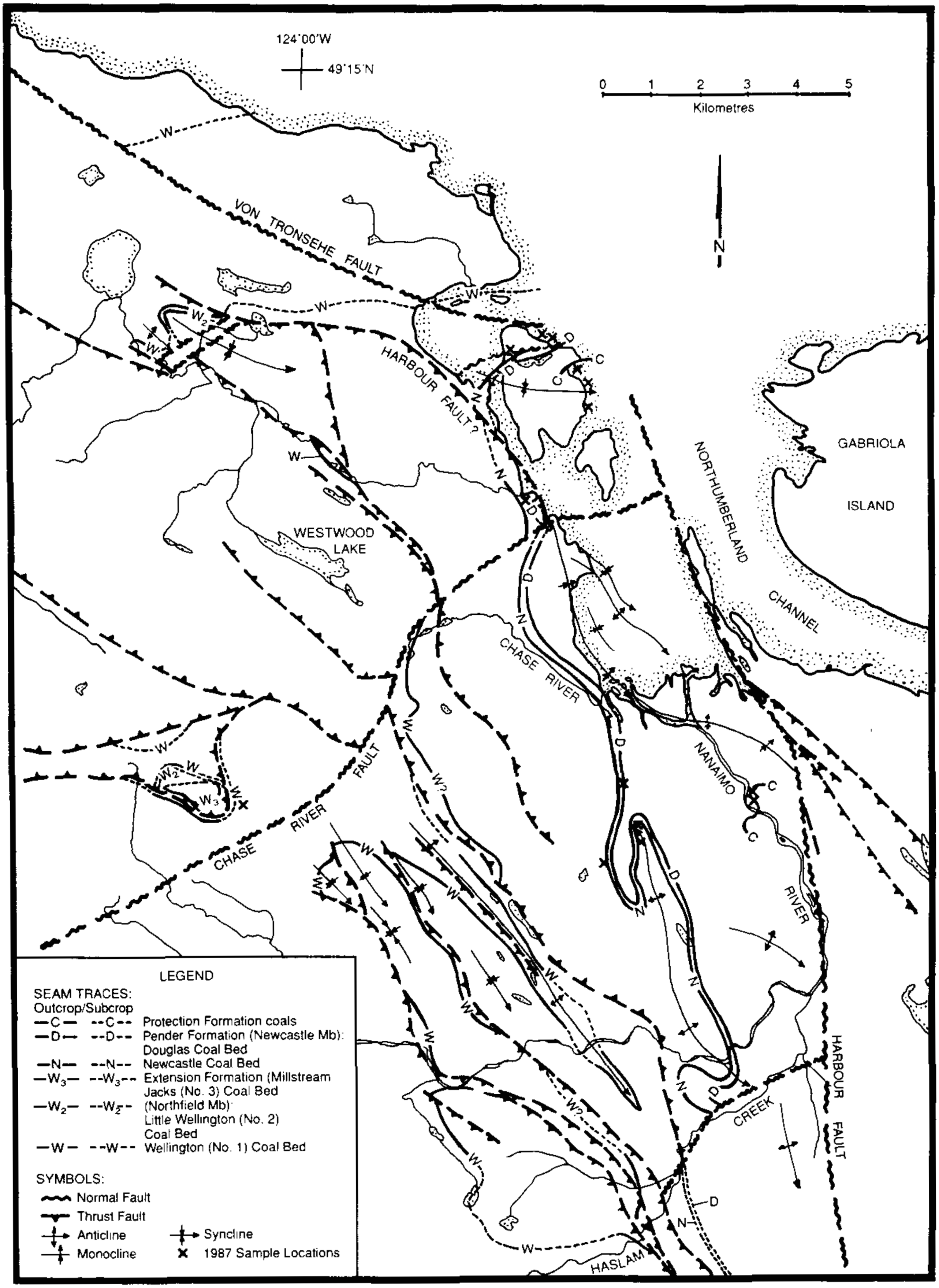

Figure 4-3-3. Coal seam traces, Nanaimo coalfield.

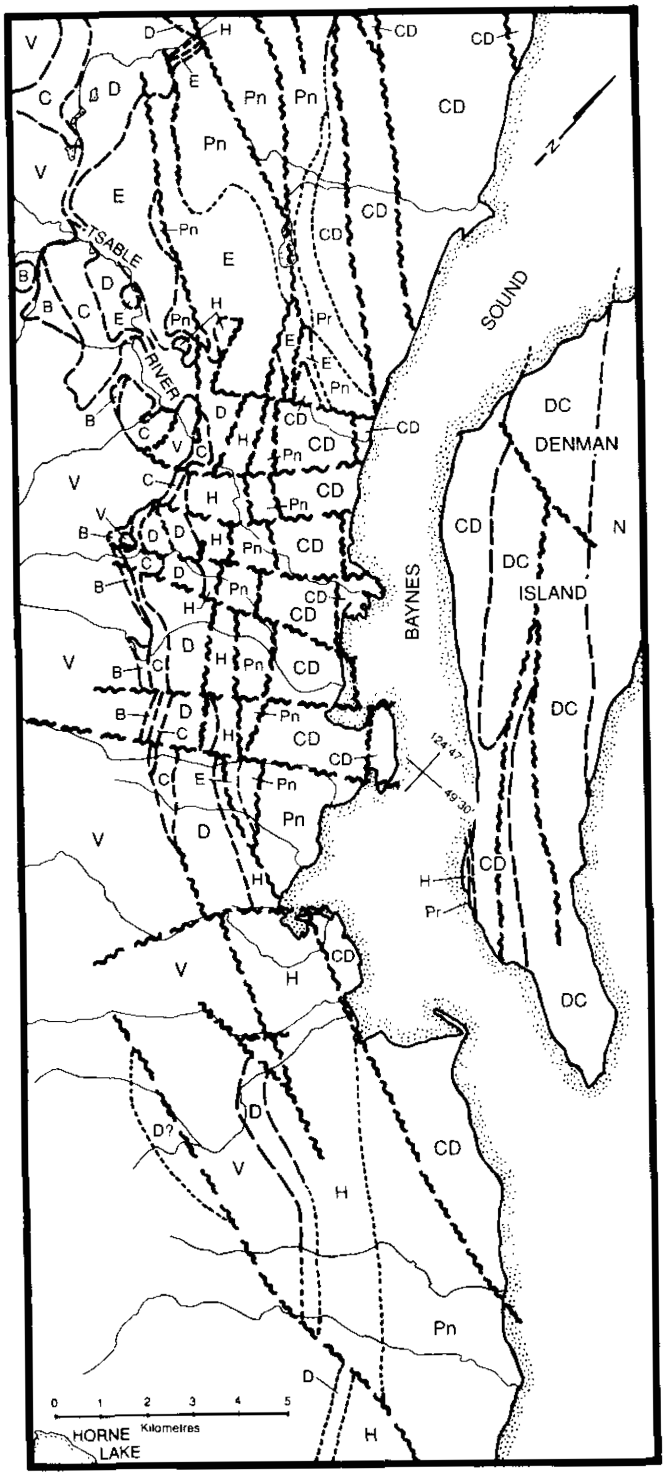

Figure 4-3-4a. Geology of the Comox sub-basin. Refer to Figure 4-3-4c for legend.

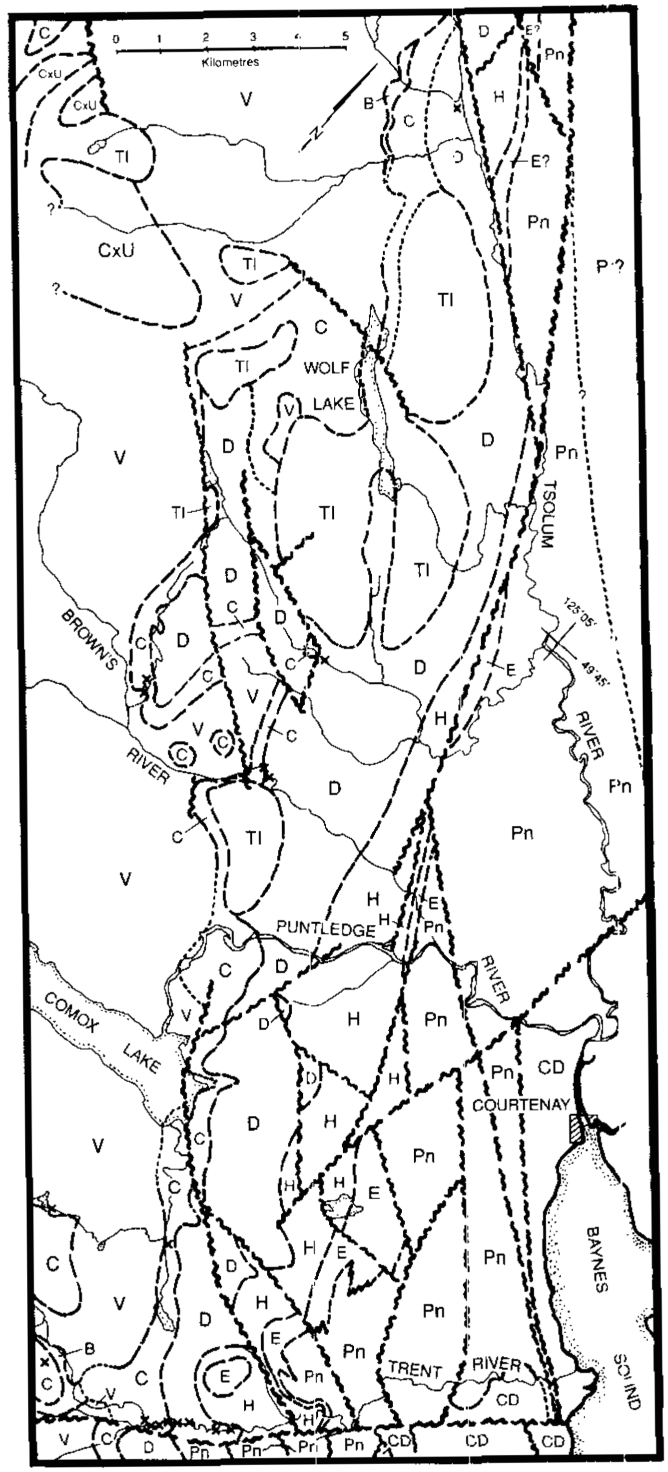

Figure 4-3-4b. Geology of the Comox sub-basin. Refer to Figure 4-3-4c for legend.

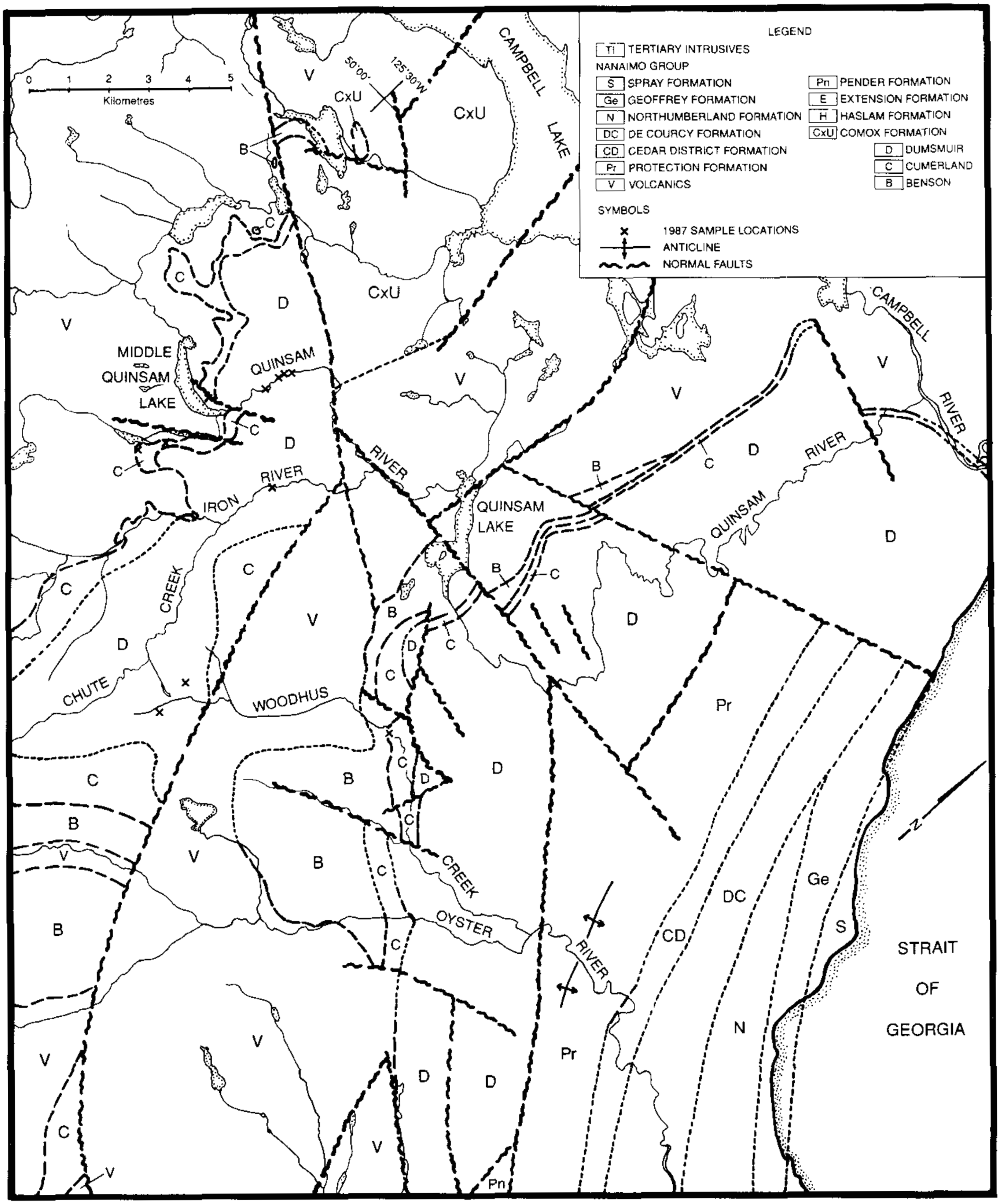

Figure 4-3-4c. Geology of the Comox sub-basin.

The Newcastle member consists of 50 to 60 metres of dark grey mudstone and coal, with thick wedges and lenses of light grey, coarse-grained quartz-lithic arenite and pebbly gritstone. Three coals are present, from top down, the River, Douglas and Newcastle beds.

The River or Douglas Rider bed is the most discontinuous of the Pender coals. It is known to be mineable only at South Wellington and Cassidy, where it consists of up to 2.1 metres of dirty coal with numerous bands of black coaly mudstone.

The Douglas coal bed varies laterally in thickness from a few centimetres to over 18 metres. Bands of black coaly shale are difficult to distinguish from clean coal. The coal is generally sheared and broken.

The Newcastle or Lower Douglas coal bed marks the base of the Newcastle member. It maintains a consistent thickness of about 1 metre, and consists of several thin coal leaves separated by bands of black coaly dirt and hard grey mudstone. A white-weathering ash band forms a persistent marker near the top of the coal bed.

The Cranberry member consists of 150 to 195 metres of dark green, coarse-grained volcanic wacke and green and grey sandy siltstone. Lenses of greenish grey chert-pebble conglomerate are a minor component; they are concentrated in the basal third of this unit. Occasional thin (approximately 10-centimetre) coals have been intersected by drilling, however they are not laterally persistent and may be merely coalified driftwood.

Extension Formation

The Extension Formation (Clapp, 1912a) may be mapped as two new units: the upper, barren Millstream conglomerate and the basal Northfield coal measures.

The Millstream member consists of 120 to 150 metres of thick-bedded to massive, quartz-chert-volcanic conglomerate, ranging from pebbly grit to cobbles. It is well exposed along the northeast side of the Millstream River, near Wellington, and also crops out on either side of the Extension Valley and at Wolf Mountain. Several thin coal beds are locally present, accompanied by lenses of greenish grey siltstone. The base of the Millstream is often a scour surface.

TABLE 4-3-2
CORRELATION OF COMOX COALS, COMOX SUB-BASIN

	DEPOSIT				
MEMBER	**Quinsam**	**Chute Creek**	**Woodhus Creek**	**Cumber-land**	**Tsable River**
Dunsmuir member				W	
				X	
				Y	
	4	A, B		Z	
	3	C, D		1 (Upper)	30
Cumberland member	2		Upper	2 (Farm)	20 (2)
	1 Rider		Lower	2a	15
	1			3	10 (3)
				3a	
				4 (Lower)	

The Northfield member consists of 10 to 30 metres of brownish grey sandy siltstone and fine quartz volcanic sandstone, bounded at the top by the No. 2 coal bed, and at the base by the Wellington coal bed.

The No. 2 or Little Wellington coal bed is usually thin and dirty, with an average thickness of 0.7 metre.

The Wellington coal bed is the thickest and cleanest of the Nanaimo coals, averaging about 1.9 metres in thickness, inclusive of minor dirt bands. Its floor is marked by a distinctive rooty bed. Detailed mapping suggests that the Wellington is a composite of three thin coal leaves, each of which displays great lateral persistence. The workable section is determined by the thickness of the intervening dirt bands, as well as by relict floor topography.

COMOX SUB-BASIN

In the Comox sub-basin, known mineable coal is confined to the Comox Formation. The younger coarse clastic units, which are coal bearing at Nanaimo, are mostly barren due to a northward facies change from paralic to open marine. Thin coals have been reported in water wells in the Spray Formation near Campbell River, but more work will be needed before their mineability can be accurately assessed. The Comox coals have been extensively worked in the Cumberland and Tsable River coalfields, prospected at Ash River and Port Alberni, and are currently being test-mined at Quinsam.

A correlation chart of the Comox coals, based on lithological and geophysical data, is presented as Table 4-3-2.

Comox Formation

The Comox Formation may be subdivided into three mappable units; from top down, they are the Dunsmuir sandstone, Cumberland coal measures and Benson conglomerate (Figure 4-3-4). The top two units are new.

The Dunsmuir member is well exposed along the canyons of the Trent and Browns rivers, and crops out over the old Dunsmuir mines at Cumberland. It consists of 120 to 150 metres of thick-bedded, medium-grained, white, quartz feldspar arenites with widely spaced and thin but persistent interbeds of dark grey shale and coal. From top down, the coals are dsignated the W, X, Y, Z and No. 1 seams.

The W, X, Y and Z coal beds are spaced roughly equally through the top two-thirds of the Dunsmuir. They are typically about 30 centimetres thick. The No. 1 coal bed is about 25 metres above the base of the Dunsmuir. Its thickness is consistent (0.75 to 2.1 metres). The roof is a strong massive sandstone and the floor is a dark grey shale.

The Dunsmuir appears to thicken northward into the Quinsam and Campbell River areas. Here it is finer grained, containing more siltstone and shale interbeds and fewer thick sandstones. Numerous thin coals have been found by drilling, but coals of mineable thickness appear to be confined to the westernmost areas such as Quinsam (Quinsam No. 3 and No. 4 beds) and Chute Creek ('A' bed). The base of the Dunsmuir is locally marked by a bed of coarse, dark green, volcanic-pebble conglomerate. The top contact of the Dunsmuir in the Campbell River area is still under investigation, hampered by lack of continuous outcrop sections.

The Cumberland member is well exposed along the canyons of Perseverance (Coal) Creek near Cumberland, and the Trent and Browns rivers. It consists of 30 to 150 metres of dark grey siltstone, carbonaceous shale, sandstone and coal. The sandstones are markedly lenticular, and pinch out or interfinger with the siltstones. The carbonaceous shales and coals form fairly persistent coal zones. In the Cumberland coalfield the major coal beds, from the top down, are numbered 2, 3a and 4. Minor beds are the 2a and 3. The following coal bed descriptions focus on the Cumberland coalfield with comments on correlation with the other coalfields.

The No. 2 bed is the most persistent of the Cumberland member coals. It consists of 0.75 to 1.5 metres of dull and bright coal with thin bands of hard, black carbonaceous shale. Its roof is a hard, but fissile, dark grey carbonaceous siltstone, and its floor is a strong, light grey, rooty, sandy siltstone. A correlative bed in the Tsable River coalfield has a thickness of 1.8 to 4.2 metres. Coal occurs at this horizon in the Quinsam coalfield, as the Quinsam No. 2 (averaging 1.5 metres) and Woodhus Creek Upper (averaging 1.6 metres) beds.

The No. 2a bed consists of 0.3 to 0.6 metre of coal, with a roof and floor of siltstone. It thickens to the north and is best developed north and west of the Oyster River. It is correlated with the Woodhus Creek Lower (up to 3.6 metres thick) and the Quinsam No. 4 (averaging 2.9 metres thick) beds.

The No. 3 bed consists of 0.9 to 1.5 metres of coal and black shale. The roof and floor vary from siltstone to massive sandstone. It thickens to the south of Cumberland and attains a thickness of up to 4.2 metres in the Tsable River coalfield.

The No. 3a bed consists of 1.3 to 1.6 metres of coal and partings of dirty coal and sandstone. It has a hard sandstone or shale roof and a sandstone floor.

The No. 4 bed is the thickest coal at Cumberland, but its distribution is interrupted by basement paleohighs projecting up as hills above the level of the coal bed. It consists of 1.2 to 2.4 metres of dull and bright coal, with thin dirt bands, chiefly of black coaly shale. Its roof is a weak carbonaceous shale and its floor varies from pale green seat-earth mudstone to brown ferruginous siltstone.

The Benson member (Clapp, 1912a; as revised by Muller and Jeletzky, 1970) is a basal conglomerate unit which infills the irregularities of the basement surface. It consists of up to 300 metres of dark green and brown, basaltic cobble to boulder conglomerate with lenses of red, green and brown shale, siltstone, volcanic wacke and rare thin coals (probably of drift origin). It does not contain mineable coal beds. Its age is uncertain, owing to the lack of diagnostic fossils, although its baked appearance in some exposures suggests that it might be markedly older than the overlying coal measures.

COAL QUALITY

The majority of the Comox and Nanaimo coals are of high-volatile A bituminous rank, although local variations do occur.

Proximate analyses ran on "as received basis" samples for run-of-mine coals have yielded the following value ranges for Comox and Nanaimo coals:

Moisture content	0.6–5.2%
Volatile matter	28.1–41.9%
Fixed carbon	38.1–63.6%
Ash	6.7–26.4%
Sulphur	0.4– 3.7%
BTU	10 414–13 925

TABLE 4-3-3
1987 COAL SAMPLE LOCATIONS

NANAIMO SUB-BASIN

Sample No.	UTM Easting	UTM Northing	Elevation (m)	Source of Sample
87-01	435940	5440525	19	Reserve measures
87-02	435960	5440450	20	Reserve measures
87-03	433430	5440910	30	Douglas coal bed?
87-04	433670	5439675	60	Newcastle coal bed
87-05	433625	5439800	60	Newcastle coal bed
87-06	425575	5440625	570	Wellington coal bed, No. 1 seam
87-07	424550	5440715	670	Wellington coal bed, No. 3 seam
87-08	429100	5443475	120	Wellington coal bed, Rider seam
87-19	432850	5448925	0	Reserve measures
87-20	432700	5449400	0	Reserve measures
87-21	432180	5449900	0	Douglas coal bed?
87-22	432160	5449985	0	Newcastle coal bed
87-23	432860	5448525	0	Newcastle coal bed
87-24	431340	549480	40	Newcastle coal bed
87-25	431410	5449525	20	Newcastle coal bed
87-26	431630	5446490	10	Newcastle coal bed
87-27	433060	5439280	102	Newcastle coal bed

COMOX SUB-BASIN

Refer to Table 4-3-2. To avoid interpretation problems, coal measures outside the Cumberland area are labelled as "coal beds".

Sample No.	UTM Easting	UTM Northing	Elevation (m)	Source of Sample
87-09	351900	5493290	475	No. 4 seam
87-10	349500	5495880	555	Nos. 3 and 3a seams
87-11	351960	5497100	180	No. 4 seam
87-12	343600	5506270	478	No. 2a seam?
87-13	343620	5506180	450	No. 3a seam?
87-14	340660	5520450	90	X seam
87-15	326770	5526320	564	A coal bed?
87-16	326750	5527350	526	A or B coal bed?
87-17	331250	5530000	210	Lower coal bed?
87-18	322525	5533200	351	No. 1 coal bed
87-29	323600	5534840	238	No. 4 coal bed
87-30	323490	5534650	239	No. 4 coal bed
87-31	323365	5534550	241	No. 4 coal bed
87-32	323350	5534100	242	No. 3 coal bed
87-33	346100	5509100	195	No. 2 seam
87-34	355700	5494580	175	X seam
87-35	354610	5493900	232	No. 2 seam
87-36	354590	5493770	235	No. 2 seam
87-37	354330	5493560	240	No. 3a seam
87-38	347045	5506255	150	No. 2 seam
87-39	346870	5506410	162	No. 2a or 3 seam?
87-40	355480	5494410	190	Y seam
87-41	355090	5494290	198	Z seam
87-42	354820	5493940	228	No. 1 seam
87-43	354520	5493630	238	No. 3 seam
87-44	322280	5531420	314	No. 2 coal bed
87-45	322185	5530880	338	No. 2 coal bed
87-46	325065	5532420	274	No. 3 coal bed?
87-47	354345	5493490	255	No. 4 Rider seam
87-48	354200	5493410	270	No. 4 seam

Little is known concerning the coking potential of the Comox and Nanaimo coals, owing to the paucity of modern analyses. Free-swelling index (FSI) data are available for some coals sampled after about 1950. The Wellington coal bed has an FSI of 2 to 4, when unoxidized. The Comox No. 2 coal has an FSI of 6 to 9 at Tsable River and Cumberland. Maximum fluidities of the No. 2 coal are 400 to 12 500 dial divisions per minute, at mean vitrinite reflectances of 0.7 to 0.85. Both the Wellington and the Comox No. 2 coal have potential as components in coking-coal blends.

During the 1987 field season, 114 samples were collected from 48 locations. Sample location information is presented in Table 4-3-3. Grab, channel or ply samples were taken depending on the type of exposure. Petrographic studies of these coals are in progress. Proximate and ultimate analyses will be run on selected coal samples. The analytical results will be reported at a later date.

ECONOMIC CONSIDERATIONS

Over a 100-year period which ended in 1953, a total of 46.3 million tonnes of coal was mined in the Nanaimo area. The Comox coalfield had produced 18.6 million tonnes of coal when mining ceased in 1967. Wolf Mountain mine in the Nanaimo sub-basin produced 17 200 tonnes of clean thermal coal over a 4-month period in 1986. This mine is inactive at present. Quinsam Coal Limited is presently operating under a Limited Production Permit and is providing small shipments of coal to local markets.

Vancouver Island coals have been attracting considerable attention lately. The proximity of tidewater is a major factor in making the deposits attractive. Exploration data indicate that potentially mineable coal resources exist in the eastern coal basins, both of coking and thermal grades. Island coal deposits are being considered for uses other than traditional applications. Quinsam coals are currently being investigated for use in the area of coal gasification. Coal seam methane gas potential studies are presently being conducted in both the Nanaimo and Comox sub-basins.

On September 2, 1987, the provincial government gave approval to selectively issue coal licences within the northeast Vancouver Island licence moratorium area (*see* Figure 4-3-1) which will allow additional exploration in this district.

FURTHER WORK

Investigations of coal quality, petrographic composition and rank are continuing in Victoria. A detailed study of the Quinsam coal deposit is planned for the 1988 season.

The Wellington coal bed in the Nanaimo coalfield is the subject of an M.Sc. project at The University of British Columbia. Detailed mapping of mine workings will lead to a better understanding of the short and medium-range variation of the Wellington coal, and by analogy, certain coals of the Pender and Comox formations. It should become possible to delineate geological hazards in advance of mining, thus enhancing the safety and economics of coal mining on Vancouver Island.

Detailed geological maps of the Comox and Nanaimo coalfields are being compiled. Data available for these maps include outcrop descriptions (from both historic and current work), drill records and mine plans. Release of these maps is anticipated in early 1988.

ACKNOWLEDGMENTS

David Chamberlain and Brian Young of the Provincial Archives of British Columbia provided critically useful information. Glenn Rouse of The University of British Columbia provided coal samples from old mines. The owners and operators of Wolf Mountain colliery provided access to their mine. Steve Gardner of Quinsam Coal provided data and assistance in sampling the Quinsam area. With Peter Hacquebard, he helped define the stratigraphy of the Wellington coal bed near Extension. Georgia Hoffman, Sharon Chapman, C. Day and JoAnne Schwemler provided field assistance; the latter is doing the petrographic analysis.

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