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QUINSAM AND CHUTE CREEK COAL DEPOSITS (NTS 92F/13, 14)

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SUMMARY

This report covers part of an ongoing project that was begun in 1987 to bring knowledge of the Vancouver Island coal deposits up to date. The aim of these resource evaluation studies is to provide sufficient data and analysis to assist industry and government in assessing the potential of the Island coals for utilization in both traditional and new applications, such as coalbed demethanation. This paper presents the results of work in the Quinsam coalfield, which is part of the Comox sub-basin. There are two coal deposits of interest in the coalfield, Quinsam to the north and Chute Creek to the south.

The Quinsam and Chute Creek coal deposits occur in the Comox Formation, at the base of the Upper Cretaceous Nanaimo Group. The stratigraphy of the Comox Formation resembles that in adjoining areas, and three members are distinguished: in ascending order, Benson, Cumberland and Dunsmuir. Patterns of sedimentation, and hence of coal distribution, were controlled by the irregular topography of the pre-Cretaceous basement. Coal-measures are generally only gently deformed by block-faulting and tilting, with regional dips from 8 to 12° to the northeast. Three sets of faults have been mapped in the study area.

Potentially mineable coal beds at Quinsam and Chute Creek lie at different positions in the stratigraphic section. In the Quinsam area these coals are close to basement, in the Cumberland member, and are older than those of the Chute Creek area which lie near the top of the Comox Formation, in the Dunsmuir member. Coal-measures of the Cumberland member were probably deposited in back-swamps, while the Dunsmuir coals were formed in back-barrier lagoons.

The Quinsam coals can be correlated, with varying assurance, with coals in other parts of the Comox sub-basin. Given available data, the Chute Creek coals cannot be correlated with coals from outside the study area.

The Quinsam and Chute Creek coals straddle the boundary between high-volatile 'A' and 'B' bituminous rank. Mean-maximum vitrinite reflectance (R_{max}) values range from 0.52 to 0.85 per cent. Averaged proximate analysis (air-dried, raw coals) range as follows: residual moisture, 1.8 to 4.0 per cent; ash, 7 to 38 per cent; volatile matter, 27 to 40 per cent; fixed carbon, 34 to 54 per cent; and sulphur, 0.5 to 4.2 per cent.

The Brinco Coal Corporation is currently conducting both open-pit and underground mining operations at the Quinsam mine-site. These coals average 26.5 megajoules per kilogram (11 400 British thermal units per pound), 0.8 per cent sulphur, 36 per cent volatiles and 48 per cent fixed carbon. Ash content ranges from 9 per cent in open-pit operations to 17 per cent in underground operations.

The current total coal resource estimate for the Quinsam property is 23.3 million tonnes of open-pit reserves and 19.9 million tonnes of underground reserves, for a total of 43.2 million tonnes, of which 2304 million tonnes are proven. The total *in-situ* coal resource within the Chute Creek 'A', 'B', 'C' and 'D' coal beds, is 5.26 million tonnes. Of this, 3.35 million tonnes are considered to be potentially mineable.

Preliminary calculations suggest a potential coalbed methane resource of 30.1 billion cubic metres or 0.09 trillion cubic feet in the Quinsam sub-basin. This deserves consideration both as a possible on-site energy source and as a potential safety hazard in underground mining operations.

Much of the study area has been intensively drilled, and therefore is unlikely to contain undiscovered coal resources. The country lying east of Iron River and north of Woodhus Creek may contain additional resources in the Chute Creek coal zone and in the No.3 coal bed. The northern limit of mineable coal in the No.1 bed, downdip from Quinsam colliery, is unknown owing to lack of sufficiently deep drilling.

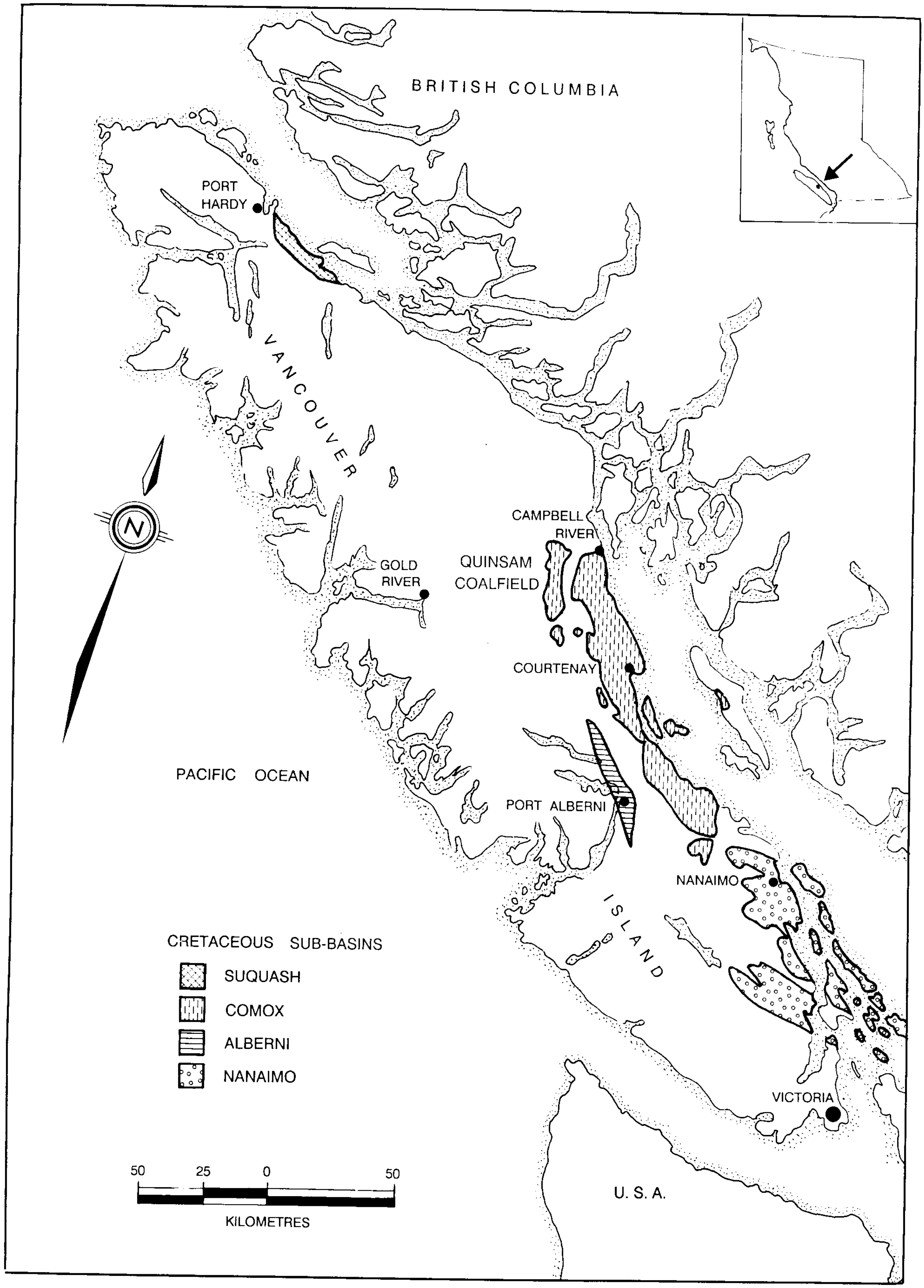

Figure 1. Cretaceous coal-bearing sub-basins of Vancouver Island.

INTRODUCTION

An integral part of the Vancouver Island coal resource study is to establish the critical geologic relationships of the coal deposits. This paper presents the results of work done in the Quinsam coalfield in an effort to establish the lateral extent of coal-bearing strata and the structural style of the coal measures.

LOCATION AND ACCESS

The Quinsam coalfield, covering 250 square kilometres, lies in the eastern foothills of the Vancouver Island Ranges, northwest of Courtenay and southwest of the town of Campbell River (Figure 1). Most of the coalfield lies within NTS map area 92F/14, with a small extension into 92F/13. The study area is covered by two British Columbia Geographic System map-sheets, 092F.083 and 092F.093.

Principal access in the northern part of the study area is Highway 28 which runs between Campbell River and Gold River (Figure 2). In the southern part, logging roads connect with the Highway 19. An extensive network of private forestry roads is maintained and controlled by Fletcher Challenge Canada Limited. Main roads are well maintained, but many of the branch roads are heavily overgrown and suitable only for walking. In the northeastern part of the area, many old logging-railway grades provide footpaths, a few of which may occasionally be negotiated by a four-wheel-drive truck.

PHYSIOGRAPHY AND OUTCROP DISTRIBUTION

Topography consists of gently rolling hills and plateaus which are often cut by steeply incised creek and river valleys, aligned in a northeasterly direction. Elevations in the area range between 220 to 675 metres. Almost all of the study area is forested, mostly with dense second-growth stands of conifers, where little light reaches the ground to support undergrowth. A large part of the area was logged during the 1950s. Older stands of timber often have a dense, foot-tangling undergrowth of shrubs and small trees, particularly along the banks of rivers and streams. A few patches of old-growth forest remain, such as along the eastern side of Iron River. Park-like conditions prevail in these ancient stands, and the ground surface is generally covered by moss and sparse salal.

Three major rivers flowing to the Strait of Georgia drain the area; Campbell River to the north, Quinsam River in the centre and Oyster River to the south. Iron River, Balsam Creek and Chute Creek flow into the Quinsam River and Woodhus Creek flows into the Oyster River. Isolated lakes and swampy patches are scattered throughout the area. Climate is mild and humid, but snowfall is heavy at higher elevations.

Thick deposits of sandy and gravelly outwash and compact stony till cover most of the study area, obscuring geological relationships, particularly in the low country along the southern shore of Campbell Lake. These unconsolidated sediments are (collectively) termed 'drift' in this paper. Exposures are generally limited to rivers, creeks and roadcuts, but a there are a few outcrops on steep hillsides which project above the unconsolidated drift. There are good bedrock exposures in the deeply incised valleys of major streams such as the Oyster River, Iron River and to some extent the Quinsam River. In the more rugged parts of the study area, particularly in the

Plate 1. Highwall of the Quinsam colliery, Pit 2N, looking to the north. The person in the photo is standing on the No.1 coal bed.

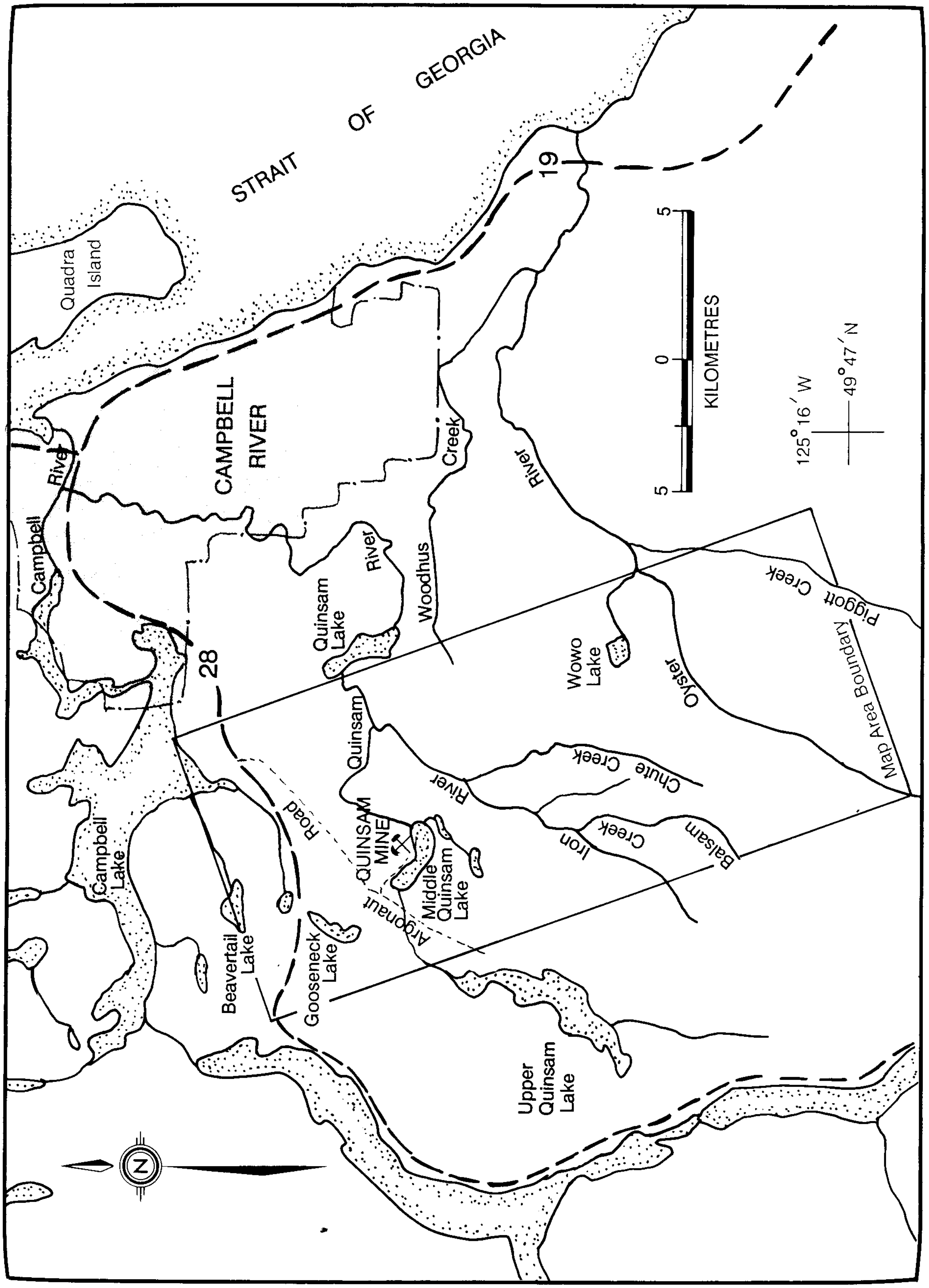

Figure 2. Detailed location map of study area.

Oyster River valley, bedrock is well exposed along forestry roads. The highwall of the Quinsam coal mine provides an excellent exposure (Plate 1).

HISTORY OF COAL EXPLORATION AND DEVELOPMENT

GENERAL BACKGROUND FOR VANCOUVER ISLAND

Coals of Late Cretaceous age along the east coast of Vancouver Island have been prospected and mined from 1849 to the present day. Indians on the northern part of Vancouver Island were responsible for first showing samples of Suquash coal from Beaver Harbour, 4.8 kilometres south of Port Hardy, to the Hudson's Bay Company in 1835 (Figure 1). In 1849, the company brought a party of coal miners from Scotland to begin producing steam coal for the shipping industry. The discovery of coal in the Nanaimo area by Joseph McKay in 1852 was also instigated by information from the native Indians. The better quality of coal in the Nanaimo area led the Hudson's Bay Company to close down its operations in the Suquash coalfield and move to this area.

In 1853 Sir James Douglas found coal float at the mouth of the Courtenay River, but the first coal bed in the Comox sub-basin was discovered by Robert Brown in 1864 on Brown's River. From 1875 to 1877 the Baynes Sound Colliery Company and the Perseverance Coal Company prospected showings in the Cumberland coalfield but did not proceed with large-scale mining. The Union Coal Company was granted coal properties in the Cumberland area by the provincial government in 1874. The company ran out of money before it could mine any coal, and in 1883 James Dunsmuir bought it out and formed the Union Colliery Company. Dunsmuir opened the Union Bay coal port in 1888 and commercial coal mining began in the Cumberland coalfield (Plate 2). Exploration and development of the Quinsam and Chute Creek coal deposits was delayed by the relative isolation

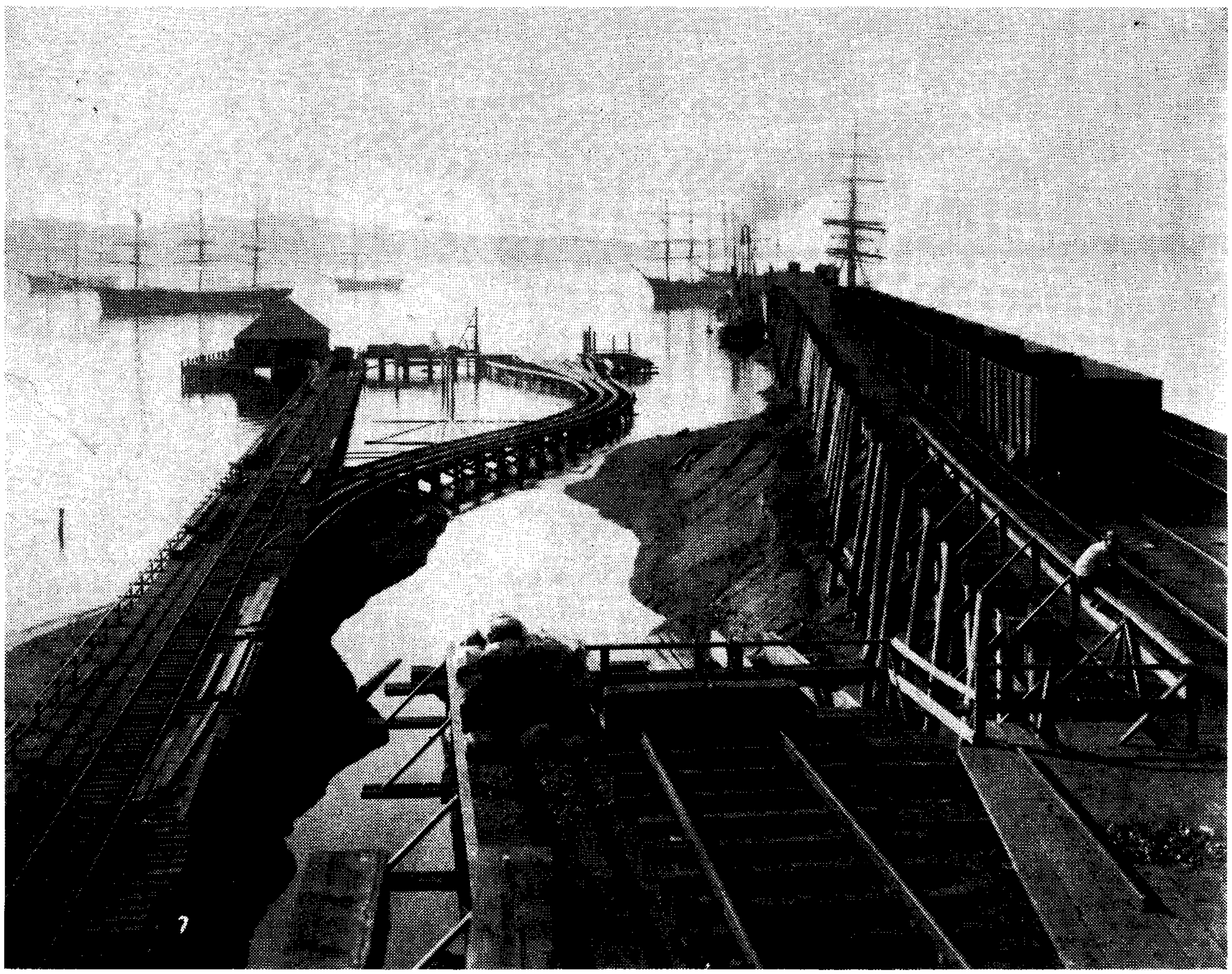

Plate 2. Union Bay Coal Port (circa 1890); photo courtesy of B.C. Archives and Records Service; Catalogue No. HP 11763.

of the area. The first good access was provided by logging railroads, which entered the area in the 1920s. Historical highlights of coal activity on Vancouver Island are listed in Appendix C.

Exploration at Quinsam

In 1905 Wellington Collieries Limited (owned by the Dunsmuirs) was granted clear title to coal and fireclay within the Esquimalt and Nanaimo Railway Land Grant, which included the Quinsam Lakes area. The Dunsmuirs had large amounts of good quality coal in more accessible areas which were close to the ports in Nanaimo and Union Bay, and therefore exploration and development in the Quinsam area was very limited at that time. Coal outcrops at Quinsam were discovered at some time prior to 1910 by geologists working for the Wellington Colliery Company (Forster Brown and Rees, 1910). The first examination of the coal, for which a record has been preserved, was done by Sutton (1913). Reports by Graham (1918), McKenzie (1918) and Rose (1922) further confirmed the presence of potentially mineable coal on Quinsam River, although they disagreed as to the thickness of the coal.

Canadian Collieries Company (Dunsmuir) Limited, which bought out the Dunsmuir Collieries in 1911, was experiencing depletion of its existing coal reserves in Nanaimo and Cumberland in the early 1950s. It expanded its operations into the Tsable River coalfield which is approximately 20 kilometres south of Cumberland (Figure 3). In addition to this, the company was actively seeking other deposits and looked to the Quinsam area as a potential resource. A.F. Buckham, chief geologist with Canadian Collieries from 1949 until 1960, conducted a drilling and mapping program to provide the first detailed assessment of the coal potential in this area. The first drilling at Quinsam, which was done in 1955, consisted of three widely spaced boreholes (CR-25, CR-27 and CR-29) to determine the stratigraphy in the area (Figure 4). However, by the late 1950s the coal mining industry of Vancouver Island was suffering from a lack of coal markets, caused by substitution of petroleum-based fuels in the railroad and shipping industries. Because of this, development in the Quinsam area was postponed.

In 1965 American Plywood Limited, a forerunner to Weldwood of Canada Limited, acquired all the assets of Canadian Collieries Company (Dunsmuir) Limited. In the early 1970s, oil prices were soaring and coal was again being considered as a source of energy. In 1973 Weldwood assessed the coal resource potential of the Quinsam area and in 1975 formed a partnership with Luscar Limited to explore for and develop reserves in the Quinsam coalfield.

More than 500 holes were drilled by Luscar between 1975 and 1980 by the project operators. The results of this exploration indicated reserves of approximately 34 million tonnes of high-volatile bituminous A coal. In 1976, Weldwood drove a short adit, locally known as Curcio's prospect (Figure 5), into the Quinsam No.1 coal bed at the east end of Middle Quinsam Lake. A sample of 6.3 tonnes of coal was taken for washability tests.

Luscar withdrew from the partnership in 1981 and Brinco Mining Limited took over its position. Brinco drilled 23 additional holes from 1982 until 1985. Three small test-pits were opened, both north and south of Middle Quinsam Lake. The largest was opened on the north side of the lake in December, 1985, allowing mining of a 10 000-tonne trial shipment of coal. This pit was later incorporated into pit 2N of Quinsam colliery. Because of the environmental sensitivity of the area, a public enquiry was undertaken to assure that the project was sound. In 1983, necessary permits were granted allowing the extraction and processing of one million tonnes of coal per year. In 1985, Brinco Mining Limited, operating as Quinsam Coal Limited, began production.

Early in 1986, Nuspar Resources Limited drove a short adit (the Iron River prospect) into the outcrop of the Quinsam No.3/4 coal bed, a short distance to the west of Iron River. The entry was driven at an angle to the full dip of the coal bed, in order to allow for its potential use as a conveyor road, in the event that full-scale mining operations ever took place (Craig Roberts, mine surveyor, personal communication, 1987). Nuspar has since forfeited its license in this area and no further work has been done in the adit.

Exploration at Chute Creek

Coal was discovered along the headwaters of Chute and Woodhus creeks in 1922 by J.D. McKenzie of the Geological Survey of Canada. Coal beds observed by McKenzie were no more than 0.6 metre thick, and it was not until the area was remapped by geologists working for CanDel Oil Limited (Cholach, 1981) that coals of potentially mineable thickness were discovered.

Subsequent drilling of 42 holes in conjunction with trenching and mapping by Candel, Sulpetro Oil Limited (Miller and Blanchflower, 1982) and Nuspar Resources Limited (Perry, 1984) outlined mineable reserves within the Chute Creek 'A, B, C, and D' coal beds, between Woodhus and Chute creeks.

Initial mining plans at Chute Creek were for a combined underground and open-pit operation (Norecol Environmental Consultants Ltd., 1985). The 'A' bed was exposed by stripping in the summer of 1986, and an adit (Roberts' prospect) was driven by Nuspar Resources late in autumn of the same year (Plate 3). The adit was intended to expose unweathered coal for analytical testing, and to provide a site for testing mining and roof-support methods in this thin coal bed. Roof support was by means of 0.9-metre grouted rebar bolts, spaced on a 1.2 by 0.9

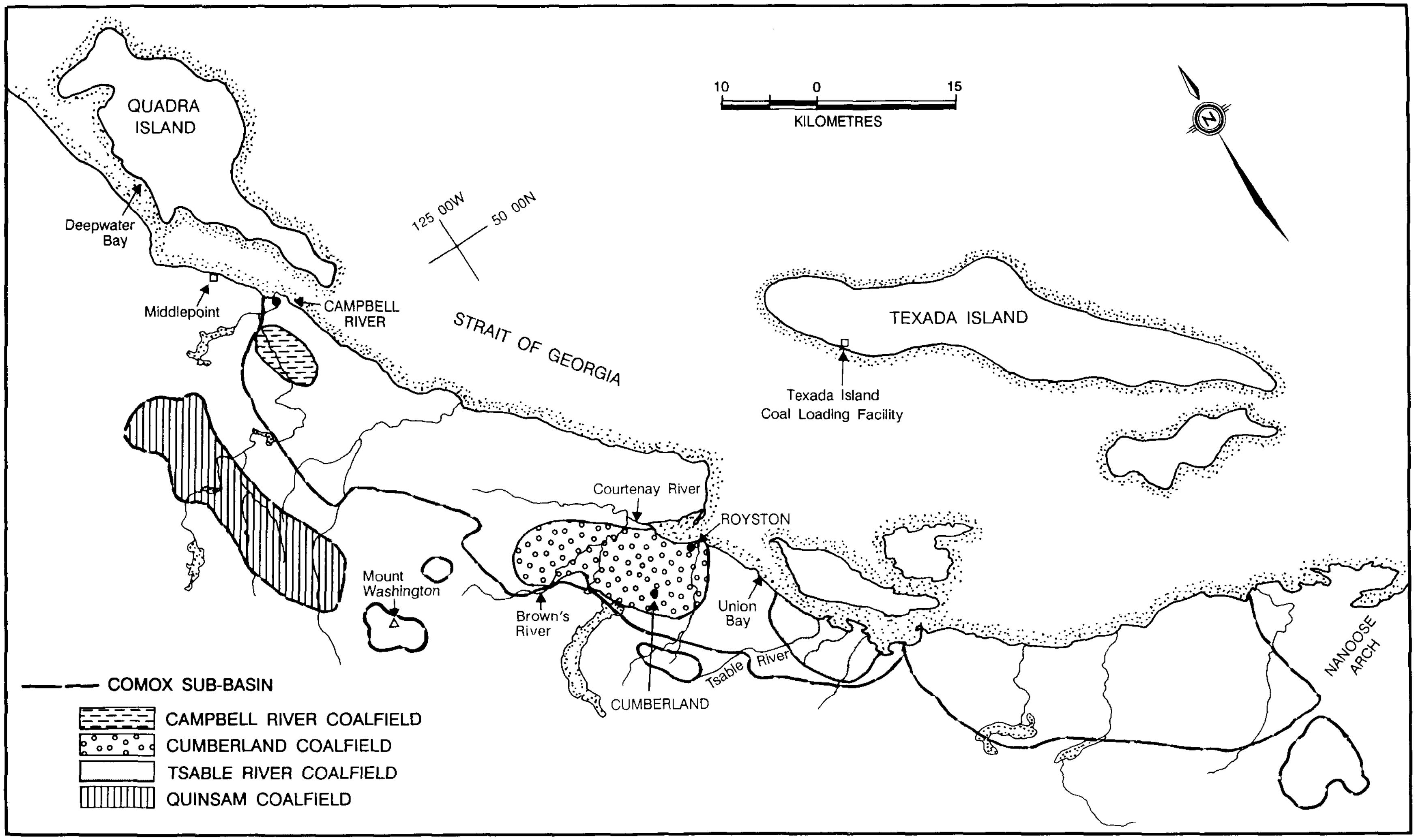

Figure 3. Coalfields in the Comox sub-basin and the Quinsam coalfield.

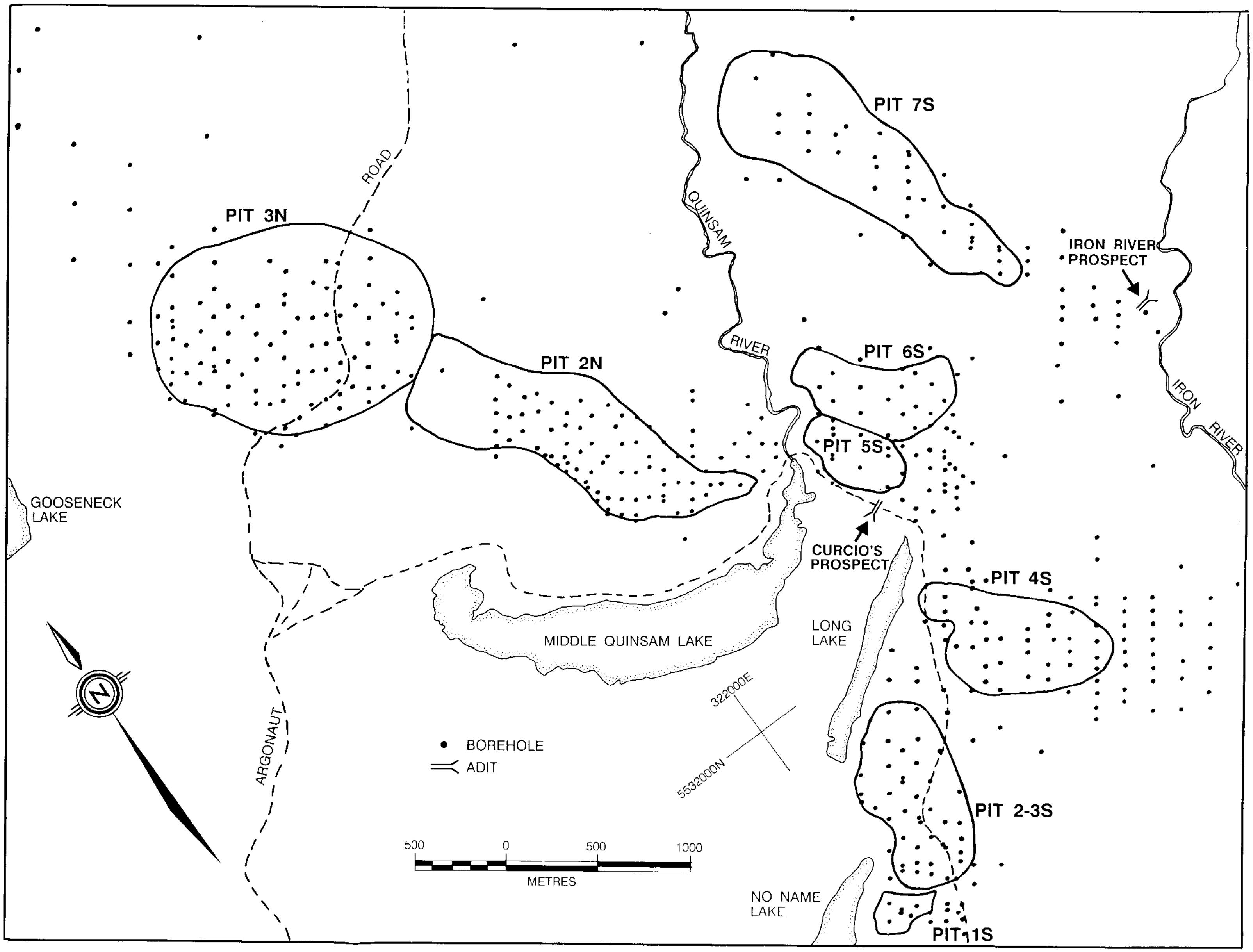

Figure 5. Quinsam area exploration map; indicating the drilling density and adit locations. The pits are reserve blocks of potentially mineable coal. Both surface and underground methods are necessary to mine these areas.

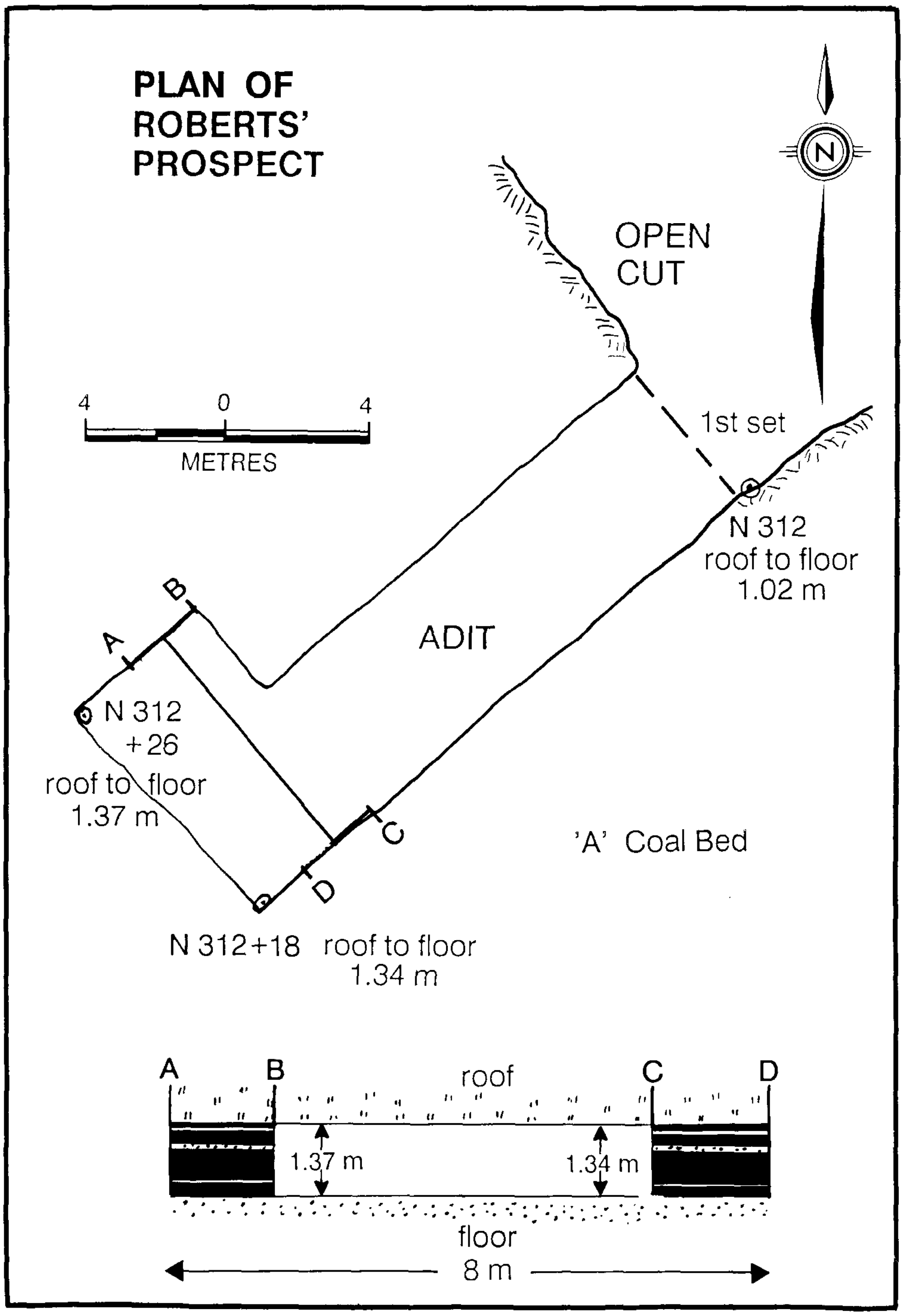

Figure 6. Plan view of Roberts Prospect, Chute Creek, with section through the face of the adit.

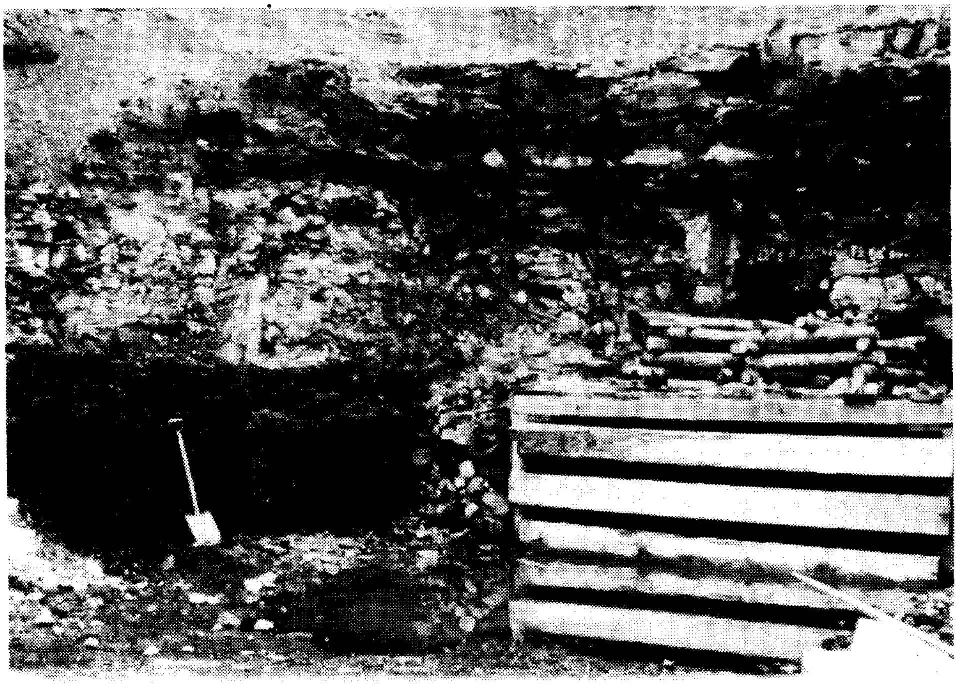

Plate 3. Boarded-up adit at Chute Creek, (Robert's prospect, *see* Figure 6). Exploration activity has ceased in this area. The shovel is leaning against the 'A' coal bed.

metre pattern. A slope was driven 4.6 metres wide down the full dip of the bed, until unoxidized coal was reached at 18 metres from the portal (Figure 6). At that point a short room was turned off to provide a bulk sample site in 1.34 to 1.37 metres of coal and to test roof conditions across wider spans. There has been no further work on the Chute Creek 'A' bed in regards to testing or to mine planning.

Following cessation of underground test mining in the 'A' coal bed at Chute Creek early in 1986 (Roberts' prospect adit), Nuspar began an exploration program aimed at delineating underground-mineable reserves in the stratigraphically lower Quinsam No.3 coal bed (Perry, 1986). Full results of this program have not been reported. Nuspar Resources Limited has ceased doing coal exploration in this area and the property is now dormant.

STUDY METHODS

DATA SOURCES

This paper is based primarily upon borehole information, taken from coal industry assessment reports in the files of the Ministry of Energy, Mines and Petroleum Resources. In addition, borehole records within the collections of the Provincial Archives of British Columbia were examined. Quinsam Coal Limited and Nuspar Resources, provided further borehole data. The drilling density is illustrated in Figures 5 and 15.

Most of the cored boreholes in the Quinsam and Chute Creek areas are either very shallow or were cored only through the major coal beds. However, nearly complete sections of the Comox Formation were cored in three deep holes which were drilled in 1955 by Canadian Collieries (Dunsmuir) Limited. Lithologic logs for these boreholes (CR-25, CR-27, CR-29) are presented in Appendix B. The core descriptions are taken from strip logs compiled by A. F. Buckham, Chief Geologist for Canadian Collieries. Buckham's descriptions are more complete than the widely distributed borehole summaries compiled by Curcio (1975).

There are geophysical logs for more than 500 boreholes drilled in the study area from 1974 onwards. The quality of these logs varies widely and is largely a function of the logging device used and the care with which the logs were run. Quality of lithologic logs varies as well, depending on the individual logging the core.

Structural and stratigraphic data was collected during three years of fieldwork in the Comox sub-basin. Because of the scarcity of good bedrock exposures, aerial photographs were used to link outcrop areas on the basis of photogeological patterns.

Coal analyses were obtained from assessment report files, archive collections, company reports and from various publications of the provincial (Dickson, 1948) and federal geological surveys. To supplement these data, samples were collected during the field seasons and analyzed.

DESCRIPTION OF WORK DONE

The geology of the study area was mapped on a reconnaissance basis, using 1:20 000-scale aerial photographs as a base. The main objectives were to establish the extent of coal-bearing strata, ascertain the structural style of the coal measures, measure detailed sections of coal exposures and determine the rank of the coal throughout this region. Stratigraphic sections of the

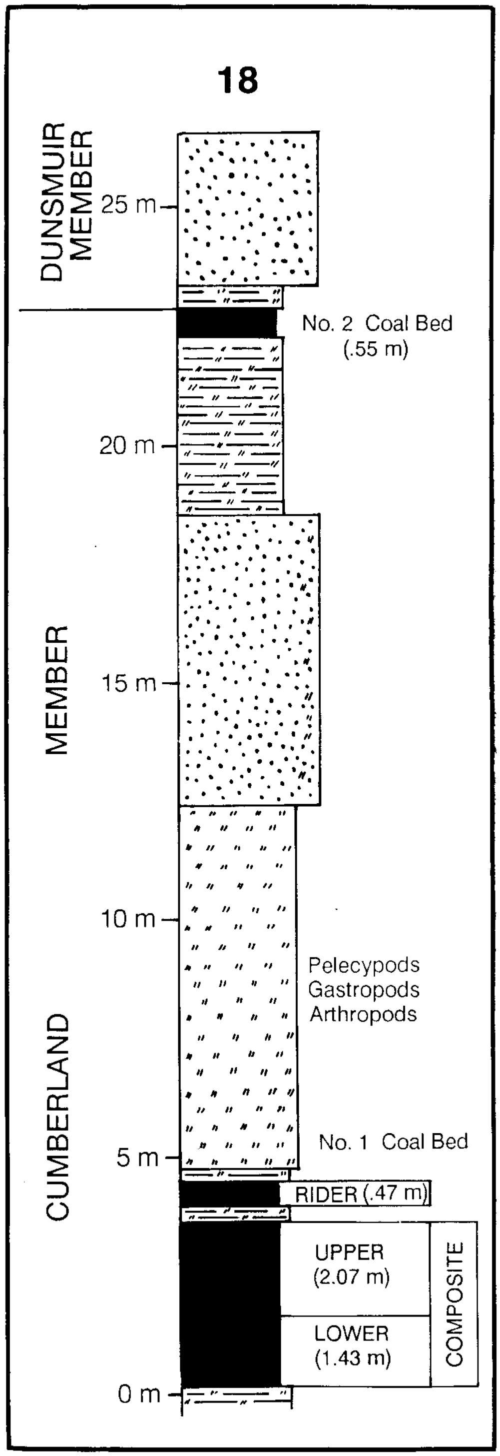

Figure 8. Section illustrating sample divisions for proximate analysis work from the Quinsam mine site, Station 18 (*see* Figure 7 for stratigraphic legend).

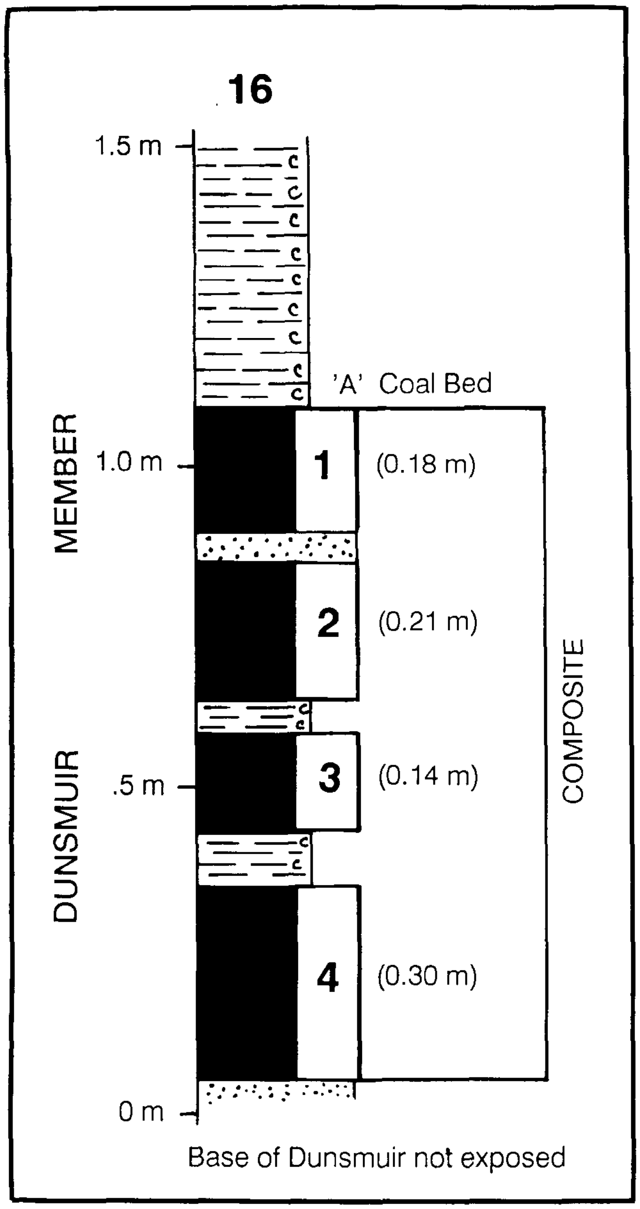

Figure 9. Section illustrating sample divisions for proximate analysis adjacent to Roberts' Prospect adit, Chute Creek, Station 16 (*see* Figure 7 for stratigraphic legend).

Comox Formation and its immediate basement, where exposed, were measured along Quinsam River, Iron River, Stone Creek and in the highwall of Pit 2N of the Quinsam Colliery. Detailed descriptions of these sections can be found in Appendix A. Geological and geophysical logs of exploratory boreholes were used to establish geological relationships under drift-covered areas. Figure 7 depicts the correlation of measured sections and selected, fully cored boreholes in the Quinsam area.

Thicknesses were measured perpendicular to bedding. Very thick covered intervals and major cliff-forming sandstones were measured by tape and compass methods, and their thicknesses later calculated by trigonometry. Where possible, thickness of cliff-forming units were checked by throwing the weighted tape over the cliff and successively measuring the heights of discernable lithological breaks.

Coal beds were described in detail, following the Australian "dull-bright" classification of hard coals (Berkman, 1982) as adapted for Canadian use by Hoffman *et al.* (1982). Samples of coal and associated sandstones were taken for petrographic analysis from all outcrops encountered. Fresh coal samples were taken from two locations for proximate and ultimate analysis as well as sulphur-form identification. Figures 8 and 9 show the sample breakdown for these coals from the Quinsam mine site, Station 18, and Station 16, adjacent to Roberts' prospect adit in the Chute Creek area (Figure 4).

An 18-kilogram sample of a tonstein was collected for dating (Station 46). Fossil assemblages were collected whenever possible. Geological features which could affect the strength and failure potential of roof and floor beds were examined following the methods of Das (1985) and Ellison (1979).

Plate 4. Example of coal interval that has been cleaned, measured, sampled, recorded and photographed; No.2 coal bed, station 44 (Figure 4).

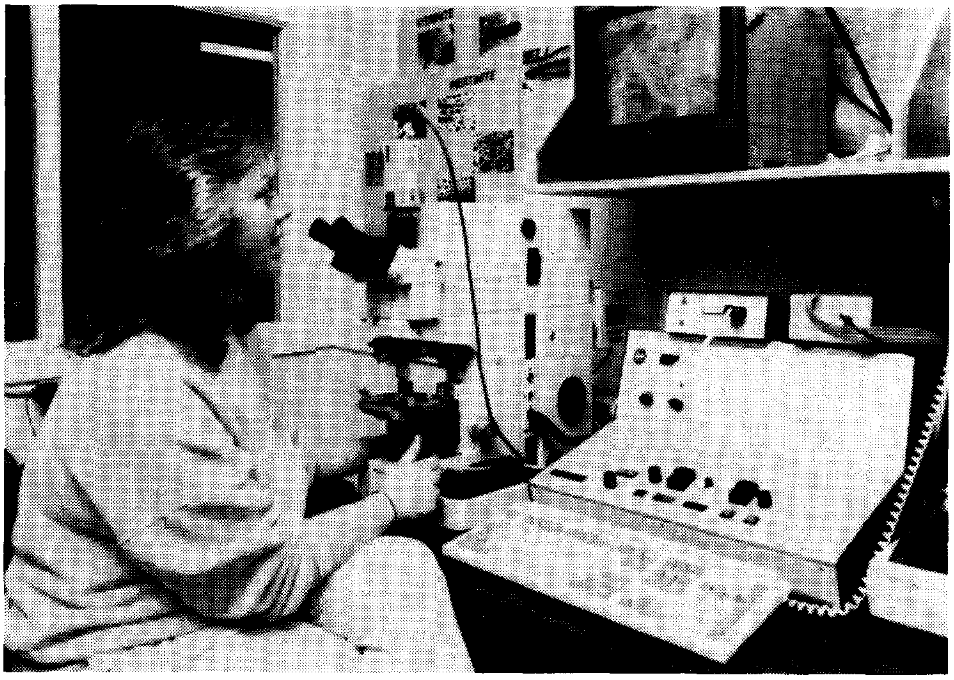

Plate 5. Vitrinite reflectance work, using the Leitz MPV-3 reflecting light microscope; Joanne Schwemler, Technician.

Coal Sampling Procedures

Preparation for sampling involved a search of various data sources to obtain outcrop locations. All coal intervals encountered in the field were sampled and multiple samples were taken at most outcrops. Weathered material was cleaned and, whenever possible, a channel sample was taken across the total seam thickness. Partings more than 1 centimetre thick were not included. All coal sample intervals were measured, photographed and described in detail (Plate 4) Sample locations were plotted on 1:20 000 air photos and transferred to 1:20 000 base maps.

Some additional sampling was performed on the No.1 Rider seam. Underground mining plans at Quinsam involved leaving the No.1 Rider coal seam as the roof support. Three grab samples were taken from the seam (top, middle and bottom) to ascertain the manner in which pyrite occurs in this coal.

ANALYTICAL PROCEDURES

Coal Quality

Three samples of fresh coal from the Quinsam area (Rider seam, upper seam and lower seam), and four from the Chute Creek adit location (1, 2, 3 and 4), were sent to Commercial Testing and Engineering Company in Vancouver for analysis (Figures 8 and 9). Proximate analyses, calorific value determination and sulphur forms analyses were run on the samples, as well as on a composite sample from the Chute Creek location. Composite samples from both locations also underwent ultimate analysis testing. All analyses were done in accordance with A.S.T.M. standards.

Pyrite Occurrence

Each of the three grab samples from the No.1 Rider seam at Quinsam mine were further divided into three pieces, one aligned parallel to the bedding plane and the other two perpendicular to each other and to the bedding plane. These nine pieces were each combined with a mounting medium, pelletized, polished and examined under a reflecting-light microscope to determine the type of occurrence of pyrite (*see* page 45).

Vitrinite Reflectance Determination

Eighteen coal samples selected for vitrinite reflectance tests were crushed using a mortar and pestle. The -20-mesh fraction was combined with a mounting medium, pelletized and polished. A Leitz MPV-3 reflecting-light microscope with an automated stage was used for reflectance determinations (Plate 5). On each sample, 50 randomly oriented vitrinite particles were measured for apparent maximum and minimum reflectance during a 360° rotation of the stage. These data were processed using an interactive computer program developed by Kilby (1988) to provide on-screen data interpretation. In all cases, mean maximum (R_{max}) and mean random (R_m) values were determined, and coals were assigned to ASTM rank categories following the limits defined by McCartney and Teichmuller (1972). Reflectance data from nine of the samples were also used to determine the length of the three principal reflectance axes, R_{max}, R_{int} and R_{min}, which describe the shape of the vitrinite reflectance-indicating surface (RIS). The lengths of the axes are then used to derive R_{st} (and R_{am}), reflectance parameters which can be used to classify the RIS (Kilby, 1988).

Heavy Minerals

Samples of a Comox Formation sandstone from the Quinsam River area and a skarn found near Iron River, both containing magnetite, were submitted to the Energy, Mines and Petroleum Resources laboratory in order to assess their potential for valuable heavy minerals such as gold (Stations N 124 and N 150, Figure 4). Both x-ray diffraction and fire-assay tests were run on these samples. In addition, more than 60 thin sections of Comox Formation sandstone were made in the ministry petrographic lab.

Dating

A total of 41 fossil samples, collected from five locations, were submitted to James W. Haggart of the Geological Survey of Canada in Vancouver for identification and interpretation. An 18-kilogram tonstein sample from Iron River was sent to Janet Gabites at The University of British Columbia for zircon uranium-lead dating (Station 46).

TABLE 1
TABLE OF FORMATIONS

SEDIMENTARY AND VOLCANIC ROCKS

Quaternary	Pliestocene and Recent	Drift	Till, Gravel sand, silt,clay
	Unconformity		
Cretaceous	Santonian	Nanaimo Group	
		Comox Formation	
		Dunsmuir Member	Sandstone; minor conglomerate; shale and coal
		Cumberland Member	Siltstone, shale and coal
		Benson Member	Conglomerate; minor red shale
	Unconformity		
Jurrassic	Pliensbachian	Bonanza Group	
		Upper Division	Fine-grained red and grey trachyte
		Middle Division	Fine-grained andesite, porphyritic basalt; minor trachyandesite
		Lower Division	Banded cherty siltstone and silty argillite; massive porphyritic andesite; cherty tuff
Triassic		Vancouver Group	
	Norian	Parson Bay Formation	Black argillite
	Carnian to Norian	Quatsino Formation	Fine-grained grey limestone
	Ladinian to Carnian	Karmutsen Formation	Fine-grained basalt and basalt breccia

INTRUSIVE ROCKS

Jurassic	Middle Jurassic (Bajocian?)	Quinsam Intrusions	Medium to coarse-grained granodiorite and quartz diorite; minor tonalite
	Early	Porphyry	Fine-grained
	Jurassic (Pliensbachian?)	dikes and rhyolite	porphyritic granite
Triassic	Late Triassic (Carnian?)	Gabbro dikes	Medium-grained gabbro

GEOLOGICAL SETTING

REGIONAL GEOLOGY

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 Tertiary Georgia basin, which is largely concealed beneath the waters of Georgia Strait. Suquash, Comox, Nanaimo and Alberni are coal-bearing sub-basins within the Georgia basin (Figure 1). Within these sub-basins, there are a number of distinct coalfields (Figure 3). The largest sub-basins (Comox to the north, Nanaimo to the south) are separated by a northeast-trending basement uplift, the Nanoose arch. In the Nanaimo sub-basin, in descending order, coal occurs in the Spray, Protection, Pender, Extension and Comox formations. In the Comox sub-basin, coal is confined to the Trent River and Comox formations (Bickford and Kenyon, 1988).

Unconformably underlying the coal-measures are basement rocks of Triassic and Jurassic age. Basement lithologies range from basalt, gabbro and volcanic breccia to coarsely crystalline marble, calcareous siltstone, skarn and granodiorite. Papers by Gunning (1931), Muller and Carson (1969), Carson (1973), Muller *et al.* (1981) and Eastwood (1984) present detailed discussions of the basement geology.

Basement rocks were locally strongly folded and faulted, and subsequently uplifted and eroded, prior to deposition of the coal measures. The irregular basement topography strongly influenced the deposition of the coal-bearing sediments of the Comox Formation. In contrast to the basement rocks, the coal measures are generally only gently deformed by block-faulting and tilting.

Throughout the Comox sub-basin, the coal measures are intruded by dikes, sills and pipes of porphyritic dacite of Late Eocene age. Adjacent to these intrusive bodies, the coal measures have been hardened and thermally metamorphosed. Coal rank increases markedly in the altered areas (Kenyon and Bickford, 1989).

DETAILED GEOLOGY

STRATIGRAPHY

The study area of 250 square kilometres, the Quinsam coalfield, lies in the northwestern corner of the Comox sub-basin (Figure 4). The sequence of rocks in the study area is shown in the Table of Formations (Table 1).

The Quinsam and Chute Creek coal measures are an erosional outlier of the Comox Formation, part of the Nanaimo Group, and they are correlated with the coal measures of the Campbell River, Cumberland and Tsable River coalfields as illustrated in Table 2 (Bickford and Kenyon, 1988). In contrast with complete sections in adjoining coalfields, the basal one-half to two-thirds of the Comox Formation has been preserved in the study area and overlying beds have been removed by erosion.

As in the Cumberland coalfield, three members are readily recognized within the Comox Formation of Quinsam coalfield: in ascending order, the Benson, Cumberland and Dunsmuir. The Benson member forms the base of the section, lying unconformably upon the basement rocks. The Cumberland member conformably overlies and locally interfingers with the Benson member. Where the Benson is absent, the Cumberland lies unconformably upon the basement. The Dunsmuir member overlies the other two members; its basal contact is abrupt and locally is erosional. Where the Cumberland is absent, the Dusmuir overlies either the Benson member or the basement.

TABLE 2
CORRELATION OF COALBEDS, COMOX SUB-BASIN

MEMBER	DEPOSIT			
	QUINSAM	CHUTE CREEK	WOODHUS CREEK	CUMBERLAND
DUNSMUIR				W
				X
		A-D		Y
	4	4		Z
	3	3	UPPER	1 (UPPER)
CUMBERLAND	2	2?	LOWER	2(FARM)
	1 RIDER			2A
	1			3
				3A
				4 (LOWER)

AGE

Results of paleontological work (Report No. JWH-1991-03 from James W. Haggart) are summmarized in Table 3. Zircons were noted in thin section from the kaolinitic tonstein sample collected at Station 46 in the Dunsmuir member (Plate 6). Results of the dating work by Janet Gabites indicate an age of 82.5±.1 Ma (Figure 10). Results of both paleontological and zircon uranium-lead dating concur that the sediments in the study area are Late Cretaceous in age.

BENSON MEMBER

The Benson member comprises dark green and brown conglomerates, with lesser amounts of greenish

TABLE 3
FOSSIL LOCATIONS AND DESCRIPTIONS

LOCATION (FIGURE 5)		UTM LOCATION EASTING	NORTHING	GSC LOCATION	FOSSIL IDENTIFICATION
N-294	#1	324320	5521100	C-167898	*Pterotrigonia?* sp., juvenile
	#2			C-167899	bivalve fragment, possibly *Cardita veneriformis* GABB, 1864
	#3			C-143651	*Pterotrigonia?* sp. juvenile
	#4			C-143652	*Pterotrigonia* sp., juvenile
N-314	#1	325335	5522650	C-143653	*Acteon?* or *Gyrodes?* sp., juvenile *Actaeonella?* sp. cf. *oviformis* GABB, 1869, juvenile *Acila (Trunacila)* sp. cf. *demessa* FINLAY, 1927
	#2			C-143654	*Acila (Trunacila)* sp. cf. *demessa* FINLAY, 1927 *Anchura* sp., juvenile bivalve shell fragments
N-319	#1	325720	5522215	C-143655	*Glycymeris?* sp., juvenile mold
	#2			C-143656	*Crassatella?* sp.
	#3			C-143657	*Glycymeris* sp. cf. *pacificus* (ANDERSON, 1902)
45	#1	322185	5530880	C-167880	*Meekia?* sp.
	#2			C-167881	*Trigonarca?* sp.
	#3			C-167882	*Mytilus?* sp., decapod fragment?
	#4			C-167883	trigoniid? bivalve
18	#1	322525	5533200	C-167852	crab carapace (see Plate 7)
	#2			C-167853	bivalve shells, articulated, indeterminate
	#3			C-167854	bivalves, juvenile, indeterminate
	#4			C-167855	anomiid bivalve?
	#5			C-167856	miscellaneous bivalve and gastropod fragments, indeterminate
	#6			C-167857	*Cymbophora?* sp.
	#7			C-167858	telliniid bivalve?
	#8			C-167859	bivalve fragment, indeterminate
	#9			C-167860	cf.*Thracia? subtruncata* MEEK, 1857, articulated
	#10			C-167861	*Cyprimeria lens* GABB, 1864, articulated wood fragment (see Plate 7)
	#11			C-167862	*Ostrea* sp. (see Plate 7)
	#12			C-167863	*Cyprimeria?* sp.
	#13			C-167864	gastropod, juvenile, indeterminate
	#14			C-167865	gastropod, juvenile, indeterminate
	#15			C-167866	cf.*Crassatella conradiana* (GABB, 1864)
	#16			C-167867	bivalve, indeterminate
	#17			C-167868	cf.*Crassatella* conradiana (GABB, 1864) articulated valves
	#18			C-167869	gastropod, indeterminate
	#19			C-167870	terebrid gastropod, juvenile, indeterminate
	#20			C-167871	bivalve, juvenile, indeterminate
	#21			C-167872	*Cyprimeria?* sp.
	#22			C-167873	*Cyprimeria?* sp.
	#23			C-167874	cf.*Mesostoma? newcombii* WHITEAVES, 1903
	#24			C-167875	bivalve, indeterminate
	#25			C-167876	cf.*Mesostoma? newcombii* WHITEAVES, 1903 (see Plate 7)
	#26			C-167877	cf.*Mesostoma? newcombii* WHITEAVES, 1903
	#27			C-167878	cf.*Mesostoma? newcombii* WHITEAVES, 1903 (see Plate 7)
	#28			C-167879	*Teredolites* sp. (in wood fragment) (see Plate 9)

Paleontological determinations by James W. Haggart, GSC, Vancouver

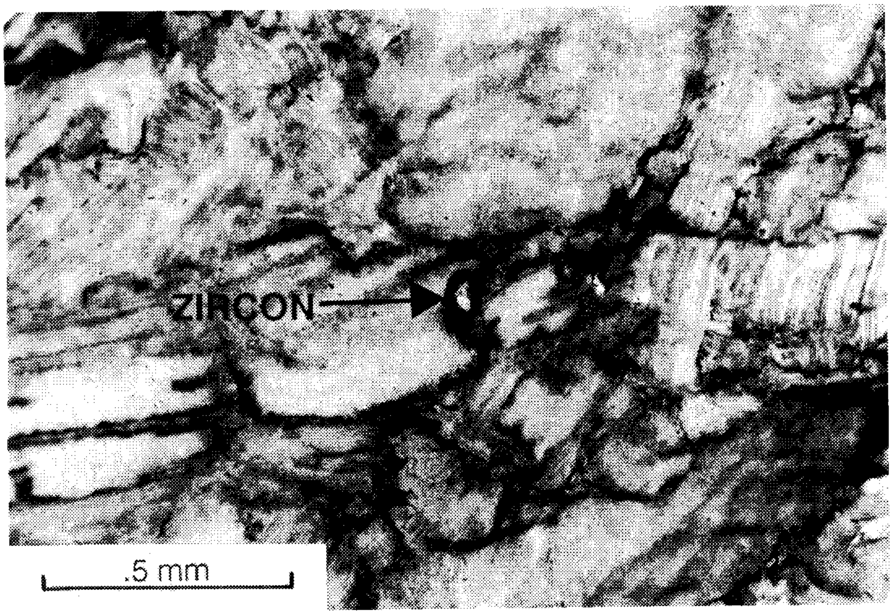

Plate 6. Photomicrograph of a kaolinitic tonstein, noting zircon, from Iron River, Station 46 (Figure 4).

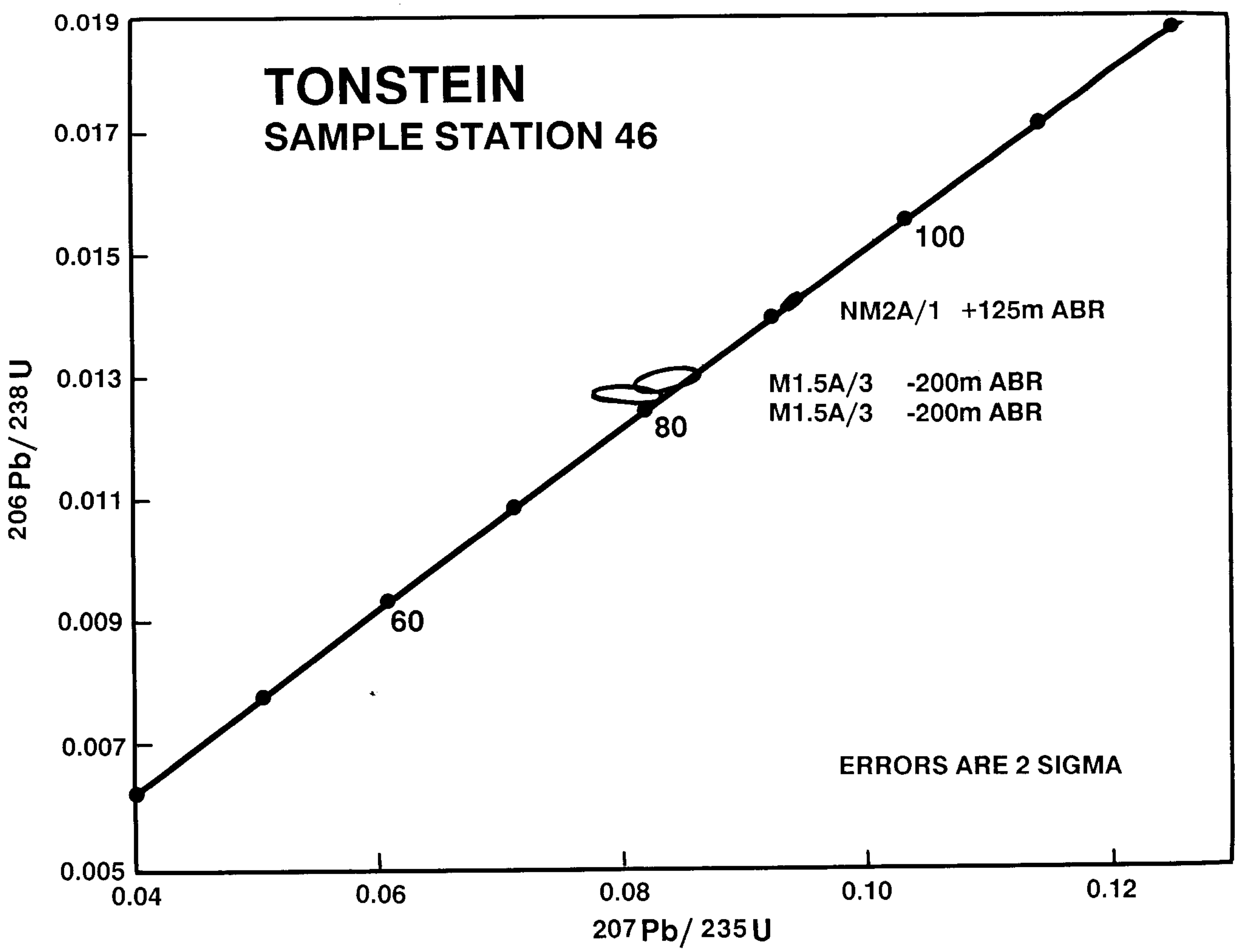

Figure 10. Graph illustrating results of the uranium-lead age-dating work; courtesy of Janet Gabites, U.B.C.

grey pebbly sandstones and red sandy siltstones or mudstones. Most of the framework clasts in the conglomerates are of volcanic rocks, mainly basalt and andesite. Occasional plutonic clasts are also present; they are mostly granodiorite with minor gabbro, although some clasts of true granite are present in the Benson conglomerates south of Oyster River.

Volcanic clasts predominate in Benson conglomerates even where the underlying basement comprises plutonic rocks. This characteristic, which was first reported in the Tsable River coalfield by Atchison (1968), may be due to the relative resistance to disintegration of volcanic as compared to plutonic rocks. Isolated plutonic clasts within the conglomerates are often decomposed and soft, due to the alteration of feldspars to clay minerals.

The conglomerates are very thick bedded to massive, with large-scale, low-angle cut-and-fill structures. They occasionally exhibit low-angle planar cross-stratification. Framework sorting tends to be fair to good, and the conglomerates are usually framework supported with a sparse matrix of medium to coarse-grained sand. Abundant white calcite cement is present in some conglomerates, occasionally forming up to 20 per cent of the rock volume. Imbrication of framework clasts is often well developed, indicating a paleoflow to the west and southwest, which is also the case in other areas of the Comox sub-basin, which have a grand vector mean paleocurrent direction ranging between 224° and 237° (Bickford *et al.*, 1990).

The Benson member appears to have been deposited in incised, west to southwest-trending fluvial channels. The long axes of Benson framework clasts are parallel to bedding and perpendicular to paleoflow, indicating clast transport by rolling along a bed, consistent with a fluvial environment (Walker, 1984). These channels were locally flanked by fault scarps and alluvial fans. Within major channels, such as along the north bank of the Oyster River, the Benson may be as thick as 270 metres (Plate 7). Between major channels it is present as isolated patches and ribbons, locally up to 10 metres thick.

CUMBERLAND MEMBER

The Cumberland member comprises grey sandy siltstones, dark grey mudstones and medium-grained greenish grey sandstone with coal beds which locally attain mineable thicknesses. The major coals are the Quinsam No.1 and No.2 beds. A nearly complete section of the member is exposed in the high wall of Pit 2N, Station 18,

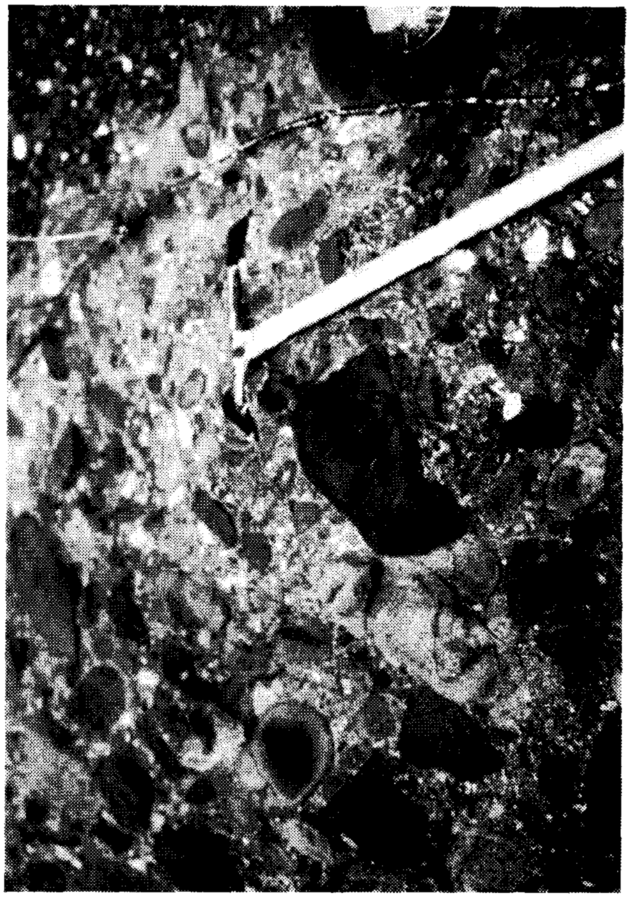

Plate 7. Benson conglomerate, Oyster River.

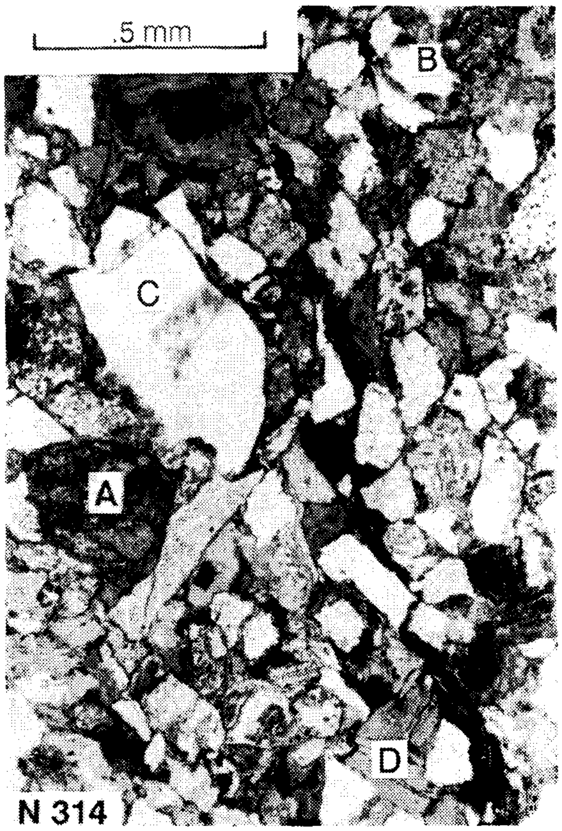

Plate 8. Photomicrograph of a Cumberland sandstone from Station N 314 (Figure 4); A - Volcanic rock fragment, B - Quartz, C - Plagioclase, D - Kaolinized feldspar.

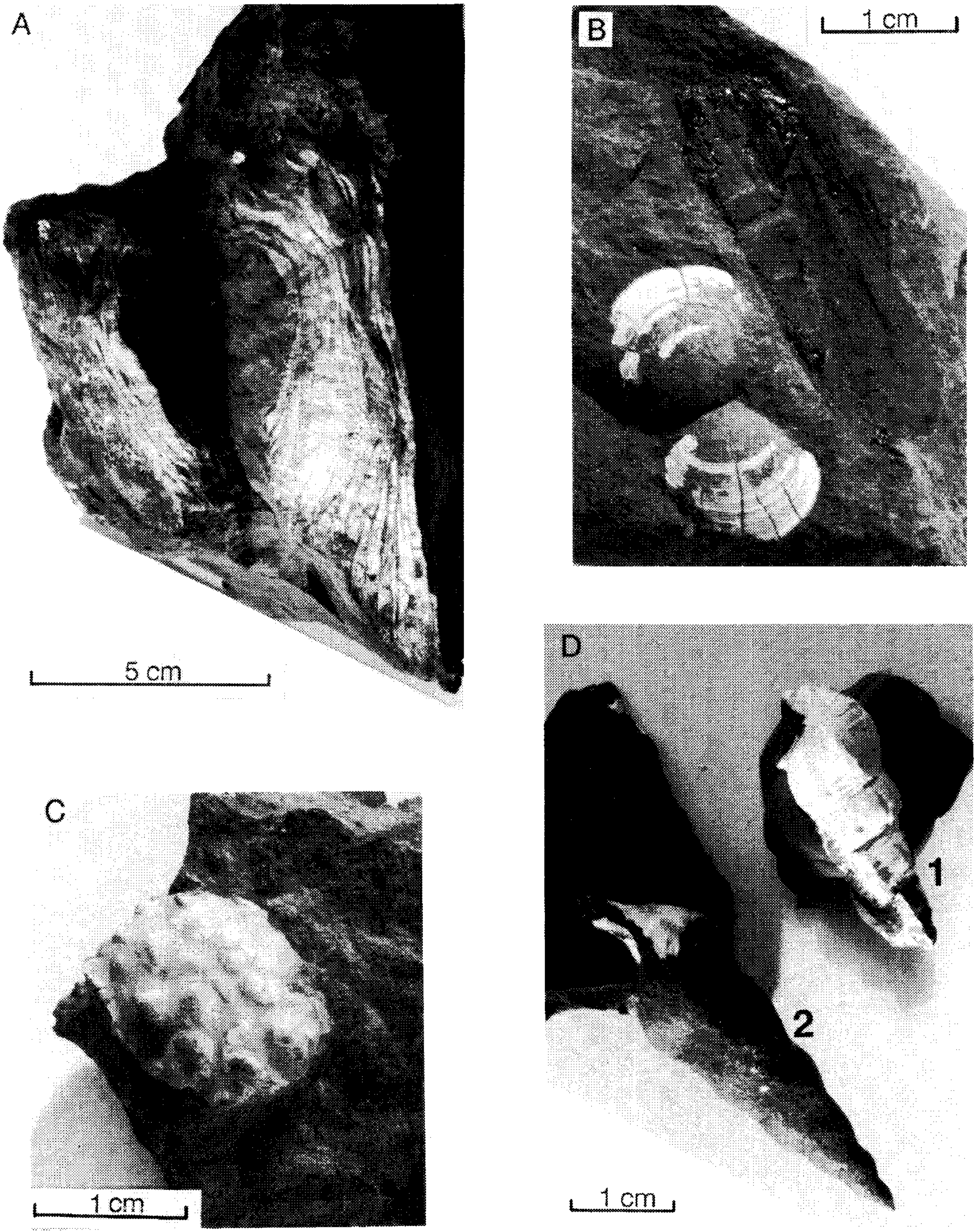

Plate 9. Fossils from Station 18 (Figure 4) above the No.1 coal bed; A: *Ostrea* sp. (GSC Loc. C-176862 Type, GSC 102375), B: *Cyprimera* lens GABB, 1864, (GSC Loc. C-176861 Type, GSC 102376), C: (GSC Loc. C-176877 Type, GSC 102377), D: cf. *Mesostoma? newcombii* WHITEEAVES, 1903, (GSC Loc. (1) C-176876 Type, GSC 102378 and (2) C-176878 Type, GSC 102379), *see* Table 3.

of Quinsam colliery (Figure 4). Complete cored sections were recovered from boreholes CR-25, CR-27 and CR-29 (Appendix B).

Sandstones of the Cumberland member consist of subequal amounts of volcanic rock fragments, plutonic quartz, plagioclase and kaolinized feldspar (Plate 8). Angular shape implies proximity to source. They are typically silty and poorly sorted, and are lenticular in form. The siltstones are similar in composition to the sandstones and contain plant fragments and shell debris, including bivalves, gastropods and crabs (Plate 9). The mudstones are variably carbonaceous and often contain silty laminae. Dark brown to black coaly mudstones are often found as partings within the coal beds, which are otherwise generally bright banded and clean. Soft, light grey mudstones occur beneath the coals; they exhibit abundant root traces and appear to be seat-earths to the coals. Southeastwards from Middle Quinsam Lake, near Stone Creek, the Cumberland member consists of distinctively hematitic-weathering dark grey siltstones and mudstones, with only minor coaly stringers at its top.

The Cumberland member appears to have been deposited under generally paralic conditions, along a coastal plain that was bounded by rolling hills of basement rocks. The lenticular sandstones were probably deposited by streams crossing the coastal plain, while the economic coals were deposited in peat swamps well removed from areas of clastic deposition. McCabe (1984) indicated that organic matter deposited in these types of low-lying swamps can accumulate into thick, high-quality peat and would reflect the underlying topography, as is evidenced by the No.1 coal bed.

The shell-bearing silty beds between the Quinsam No.1 and No.2 coals were probably deposited under estuarine conditions during a brief transgressive drowning of the coastal plain. The hematitic-weathering beds at Stone Creek overlie the thick Benson conglomerates. They appear to represent a distal alluvial-fan environment, between proximal alluvial fans of the Benson member and the coastal plain of the Cumberland member of the Middle Quinsam Lake area.

The thickness of the Cumberland member reflects the underlying basement topography. Its greatest thickness is attained near Middle Quinsam Lake, where it is 25 to 45 metres thick, and contains one or two mineable coal beds. In exposures along the south shore of Campbell Lake the Cumberland member is altogether absent, indicating that it pinches out to the north.

Eastward from Middle Quinsam Lake, isolated deep boreholes (CR-27 and CR-29, Appendix B) indicate that the Cumberland member interfingers with and pinches out within the Benson member. It also pinches out against the flanks of a large basement hill southwest of the confluence of Iron River and Chute Creek. Farther to the southeast at Stone Creek, the member is about 20 metres thick and contains no significant coal beds (Section No.4, Appendix A).

DUNSMUIR MEMBER

The Dunsmuir member comprises medium to coarse-grained, white or light grey to greenish grey sandstones, with minor siltstones, mudstones, conglomerates and coal beds which occasionally attain a mineable thickness. Major coals are the Quinsam No.3 and No.4 beds, near the base of the member, and the Chute Creek A, B, C and D beds which are stratigraphically higher (Table 2). Good sections of the Dunsmuir member are exposed along Quinsam and Iron rivers (Figure 7). Cored sections were recovered from boreholes CR-25, CR-27 and CR-29 (Appendix B).

In the northwestern part of the study area, near Middle Quinsam Lake, the Dunsmuir sandstones are typically medium to coarse grained and white to very light grey, locally weathering to pale yellow or pink tones. They consist of subequal amounts of plutonic quartz and plagioclase feldspar, with accessory hornblende and magnetite. Volcanic rock fragments are a minor constituent, perhaps 5 to 10 per cent of the framework grains near the Quinsam mine, but gradually increasing southward to 20 to 25 per cent along the lower reaches of Chute Creek, as illustrated in Plate 10.

Along the canyon of Quinsam River north of Middle Quinsam Lake, a thin but distinctive bed of fine-grained black sandstone is exposed at Station N 124 (Figure 4). It contains abundant magnetite, which locally comprises 50 per cent of the rock by volume. It is underlain and overlain by light grey sandstones containing minor heavy-mineral laminae.

Dunsmuir sandstones contain an abundant trace-fossil assemblage including *Thalassinoides, Ophiomorpha, Teredolites* and *Pelecypodichnus* (Plate 11). Body fossils are comparatively rare, but include *Ostrea, Inoceramus*, poorly preserved brachiopods, and trigoniid bivalves resembling *Myphorella* (Eastwood, 1984).

Conglomerates within the Dunsmuir member occur as thin bands and stringers (Plate 12). A fairly persistent conglomeratic horizon occurs at the immediate base of the member, in the roof of the Quinsam No.2 coal bed. Several thin conglomerate bands occur both above and below the Chute Creek coal beds, which are much higher in the member. Dunsmuir conglomerates are readily distinguished from Benson conglomerates by their characteristic abundance of plutonic clasts.

Dunsmuir mudstones and siltstones resemble those of the Cumberland member, but are much less abundant. Dunsmuir coals are somewhat dirtier than the Cumberland coals, in terms of both inherent ash content and amount of rock bands.

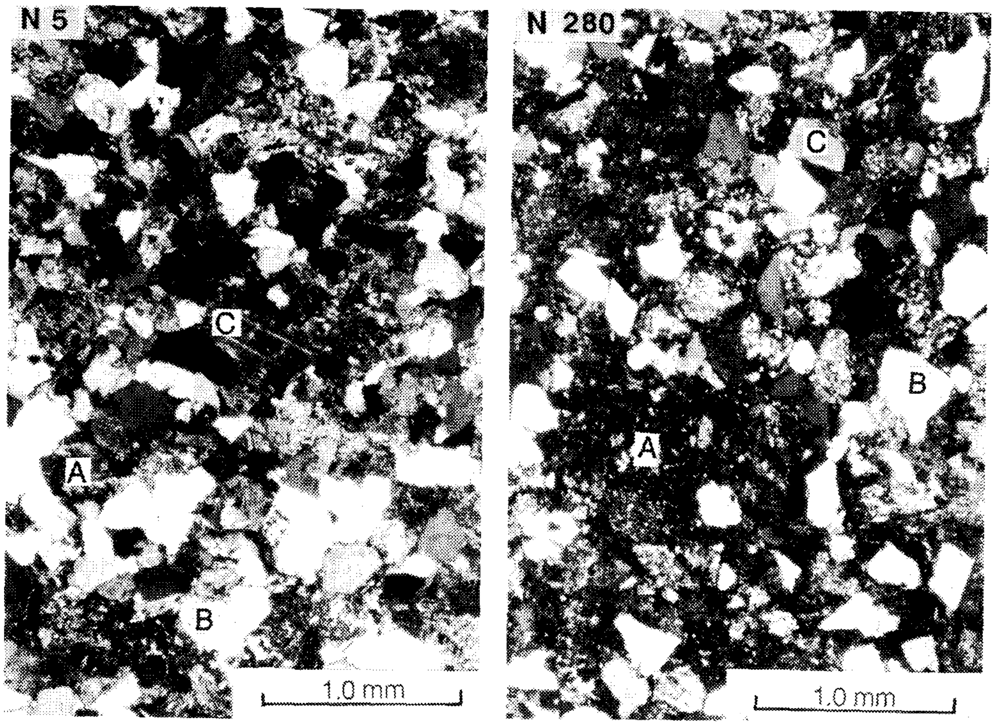

Plate 10. Photomicrographs of Dunsmuir sandstones (x-nicols), illustrating the increase in volcanic material from the north to the south of the Quinsam sub-basin, (Stations N 5 and N 280, Figure 4); A - Volcanic rock fragments, B - Quartz, C - Plagioclase feldspar.

Plate 11. Fossil from Station 18, above the No.2 coal bed (Figure 4); Teredolite sp., (GSC Loc. C-176879 Type, GSC 102380) *see* Table 3.

Plate 12. Pebble conglomerate (above dotted line in photo), Dunsmuir member, Quinsam River.

The Dunsmuir member appears to have been deposited under dominantly marine conditions, along a shallow sandy shelf which was bordered by a complex of beaches, spits and bars (Plate 13). Isolated hills of basement rocks remained exposed during at least the early stages of deposition of the member. Most of the shelf sandstones were deposited below fairweather wave base, but still within range of reworking by storm waves. The iron-rich sandstones probably represent an ancient beach placer.

The coals and associated mudstones were probably formed in back-barrier lagoons. Cotter's study (1982) of the Sabinas basin of northern Mexico, described coals of back-barrier origin as laterally extensive seams which could reach thicknesses of 3 metres, interbedded with bioturbated mudstone. He believed that the development of these seams took place during periods of long-term environmental stability. The thinner coals would be developed in areas subject to rapid progradation and periodic marine transgression (Plate 14). In general, these types of coal are high in sulphur and ash. This would appear applicable to the Dunsmuir coals. It is likely that the lagoons were sheltered from most clastic sedimentation but were occasionally overrun by turbid storm surges which deposited partings of sediment within the coal-forming peats.

The upper part of the Dunsmuir member has been removed by erosion throughout the study area. Its maximum preserved thickness, as indicated by boreholes, ranges from about 150 metres between Middle Quinsam Lake and Iron River, to about 230 metres west of Lukwa Lake.

STRUCTURE

An essentially monoclinal, northeast-dipping succession of Nanaimo Group rocks overlies complexly deformed basement in the study area. Although most minor structures within the basement rocks are truncated by the basal Cretaceous unconformity, they cause considerable local irregularity of the basement surface and therefore control the distribution of the basal Nanaimo Group.

Regional dip of the Nanaimo Group is 8° to 12° northeast. Along the northeastern side of the Quinsam coalfield, persistent southwest-verging, narrow asymetric synclines parallel the trace of the Boundary fault (Figure 4). Along the broad southwestern limbs of the synclines, regional dips prevail, but are much steeper along the narrow northeastern limbs, averaging 25° near Woodhus

Plate 13. Dunsmuir sandstone, Quinsam River, illustrating beach-foreshore bedding, with truncated sets of low-angle parallel-laminated sand. Scale is Sharon Chapman.

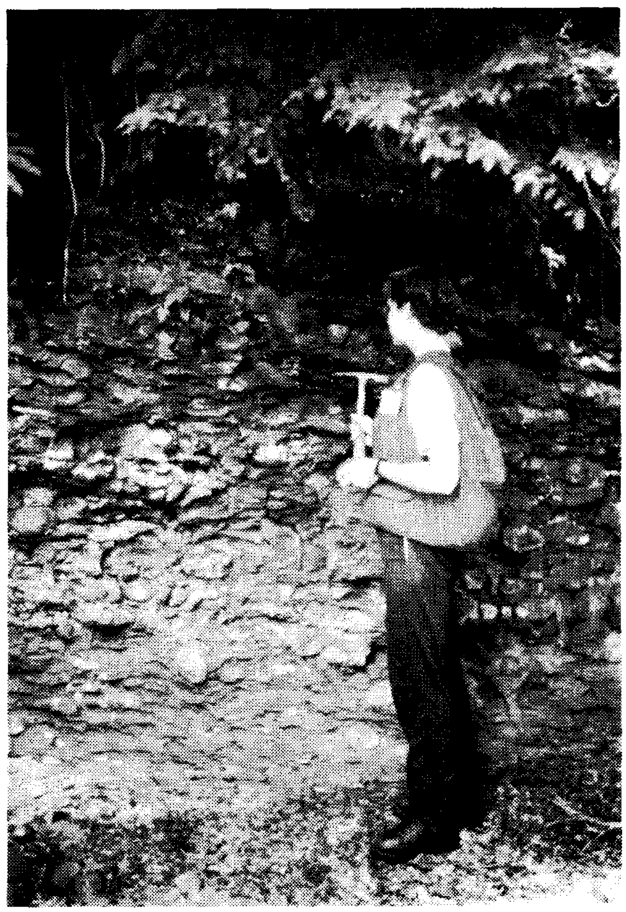

Plate 14. Concretionary mudstone, between No.3 and 3 Leader coal beds, Quinsam River.

Creek and steepening northwards to over 60° north of Quinsam River.

Several more localized folds have also been mapped, their extent constrained mainly by lack of outcrop. A southeast-trending anticline between Chute and Woodhus creeks appears to be linked *en echelon* with the synclines noted above. Two northeast-plunging synclines are also present along the height of land between Oyster River and Piggott Creek, and may be related to the southwestward termination of a tear fault (Oyster fault) with which they are roughly parallel.

Minor folds and buckles are common features of the outcrops of coaly and carbonaceous zones in the Comox Formation. Most of these features are probably due to downslope creep of weathered bedrock, although subglacial thrusting may also be responsible for the more intensely crumpled structures.

Bedding-plane shear is very common in the coaly zones of the Comox Formation. Shear is concentrated in thin partings between thick, clean, hard coal beds. The sheared partings are usually slickensided or pulverized, and are recessive in comparison to the adjoining coals. Soft, rooty seat-earth mudstones, where present beneath coals, are also often intensely sheared.

Exposures of faults in the study area are rare, being confined to road-cuts and canyon walls. Lack of fault exposure is probably the result of erosional processes, as suggested by Muller *et al.* (1981). Shattered rocks along faults are more readily attacked by fluvial or glacial erosion and are now usually concealed by elongate swamps or stream beds. Closely-spaced exploration drilling at the Quinsam coal property indicates that zones of faulting or shearing often underlie linear swamps.

As in the rest of the Comox sub-basin of Georgia basin, the Quinsam coalfield has undergone brittle, thick-skinned deformation, characterized by moderate to steep faults. Three sets of faults have been mapped in the study area, and their relative ages discerned from offsetting relationships. Classification of faults into sets is on a geometric basis, and not all faults fit unambiguously into one of the sets.

The oldest set (Set 1) comprises east-trending, steep extensional faults, which form a series of horst and grabens near Middle Quinsam Lake. Faults of Set 1 dip 45° to 65° to the north and south. Where seen in outcrop, they are expressed as clean breaks in the strata, locally occupied by thin veinlets of calcite. Normal drag is occasionally observed in incompetent units such as coaly shales in the hangingwall of Set 1 faults; drag folding does not extend farther than a few metres from the fault surfaces. In some cases, these faults display greater offset at the basement surface than they do higher in the Comox coal measures, resulting in thickening of the basal Cretaceous rocks on the downthrown sides.

The next oldest faults, Set 2, are northwest to north-trending, compressional faults which dip moderately to steeply to the northeast and east. One example, the Boundary fault, forms the eastern boundary of the Quinsam coalfield, and several more, including the Aldyth, Eden and Red Bed faults, are exposed along the northern wall of the Oyster River canyon. Faults of Set 2 dip 40° to 80° to the east. In outcrop, they are expressed as recessive shear zones up to 20 metres wide. Fault surfaces are marked by up to 15 centimetres of clayey gouge, bounded on either wall by up to a metre of fault breccia. Slickensides, where exposed, suggest that latest movement is subhorizontal, with a dextral strike-slip sense of shear.

The youngest faults, Set 3, are northeast to east-trending tear faults, with near-vertical dips. Two faults have been identified as belonging to Set 3: the Oyster fault in the southern part of the Quinsam coalfield and the Long Lake fault in the north-central part of the coalfield. A third fault may form the northern boundary of the coalfield along Beavertail Creek, although its mapped position is based solely upon a strong east-northeast-trending topographic lineament. Of these faults, only the Oyster fault is well exposed; its trace is marked by a shear zone, 5 to 10 metres wide, containing numerous closely spaced shear surfaces upon which dextral slickensides dip 10° to 15° to the northeast.

Pre-Cretaceous basement rocks are locally intensely sheared and isoclinally folded (Eastwood, 1984). Good exposures of these features occur in the canyon of Iron River (Plate 15). These basement structures are truncated by the basal Cretaceous unconformity and dislocated by faults of Set 1, and are therefore older than both.

Faults of Set 1 define a series of east-trending fault blocks. Some Set 1 faults were active as growth faults during the deposition of the basal Cretaceous Benson conglomerates. Fault-associated differential sedimentation may have continued during the Cretaceous, as lines of splitting and deterioration of the Quinsam coal beds are locally parallel to Set 1 faults. The faults of Set 1 were possibly formed during the initial episode of transtensional shear which resulted in formation of Georgia basin as a crustal downwarp.

Faults of Set 2 define the eastern and southern margins of the Quinsam coalfield. They are of post-Nanaimo Group age, as indicated by the absence of differential sedimentation across them. Folding associated with these faults is consistent with an early phase of southwest-verging thrust movement, while slickensides and rotated fault breccias suggest a later phase of dextral strike-slip movement. Similar displacement histories have been proposed by Massey and Friday (1989) for thrust faults of the Beaufort Cameron River system farther south in the Alberni area. Massey and Friday suggest that these thrusts

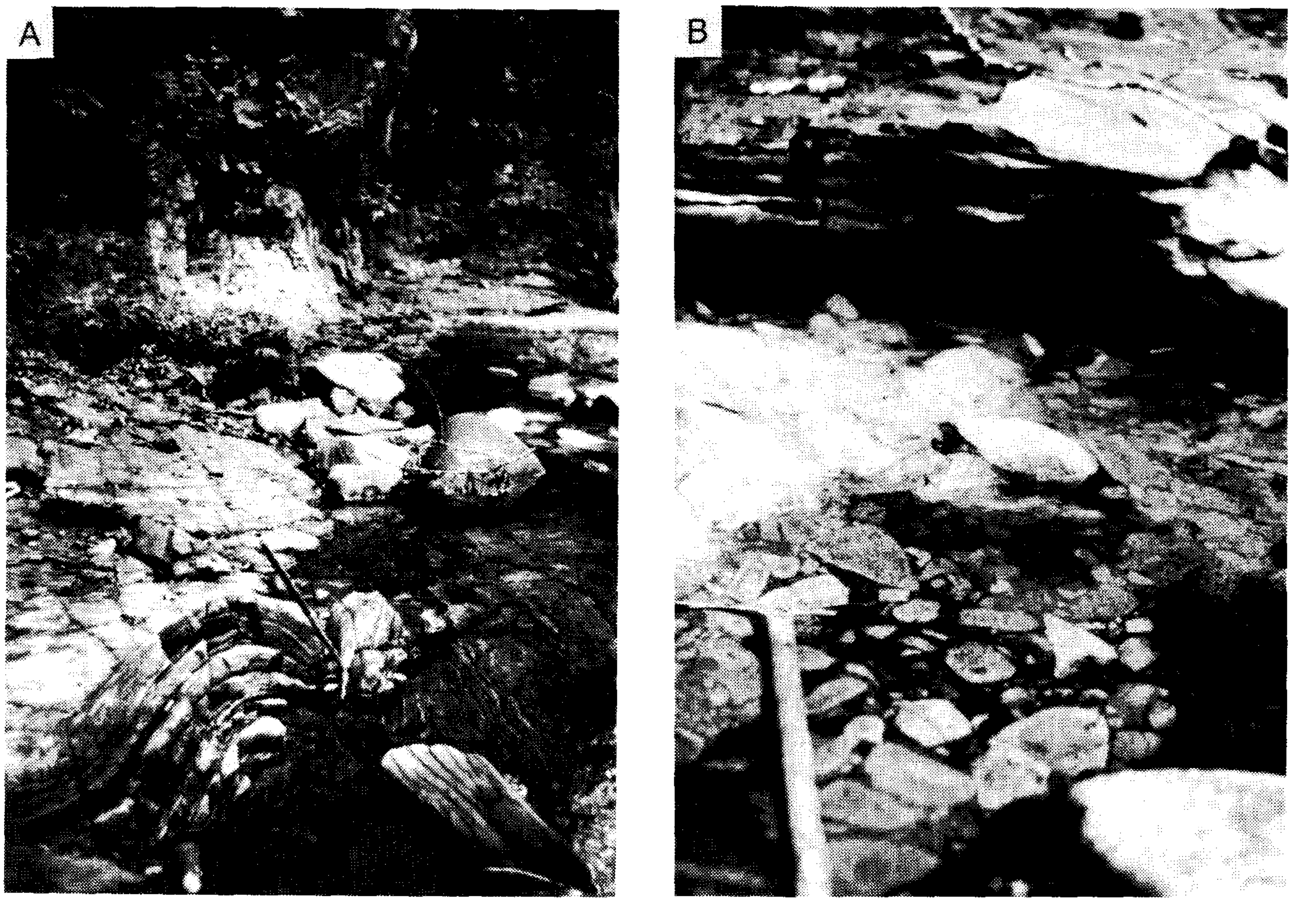

Plate 15. A: Sheared pre-Cretaceous basement rocks, Iron River, photo courtesy of Ward Kilby. B: Brecciated material lying unconformably on rocks in photo A.

are of early Tertiary age, which is consistent with offset relationships at Quinsam.

Faults of Set 3 cut all other faults and folds in the study area; they cut Nanaimo Group rocks but are in turn truncated by the basal Pleistocene erosional surface and are also overlapped by unbroken deposits of stony till in the Mount Washington area (adjoining the Quinsam coalfield to the southeast, Figure 3). Set 3 faults cut all other faults and also displace Late Eocene to Early Oligocene sills of the Catface plutonic suite, thus further establishing their relatively late age.

COAL BED DESCRIPTIONS

All of the Quinsam and Chute Creek coals are banded humic coals, of semibright to bright composition. Most are demonstrably of autochthonous origin, showing well-developed rooting in their floors, and having a laterally persistent banding of coal and partings. The upper Dunsmuir coals of the Quinsam area, including the No.4 and overlying beds, and at least locally the No.3 bed, contain a considerable amount of coarse organic material, often recognizable as individual coalified logs mixed with sandy sediment. These upper coals may therefore represent thick and laterally extensive accumulations of driftwood, with or without growth in place of salt-marsh peats.

Some of the coal beds contain thin bands of an unusual, rusty weathering, granular coaly mudstone, termed 'pelletstone' by Perry (1986). The pelletstone comprises fine to medium sand-size grains of dark grey, hard material with brown, rusty weathering dolomite or siderite rims, set in a matrix of black coaly mud. Pelletstone bands tend to pinch out laterally within a few hundred metres. They may represent altered tuffs, oolitic chemical precipitates or wind-blown sand deposits.

Quinsam Area

In contrast to the "type" nomenclature of Comox Formation coal beds in the Cumberland coalfield, the Quinsam coal beds are numbered from the base upwards

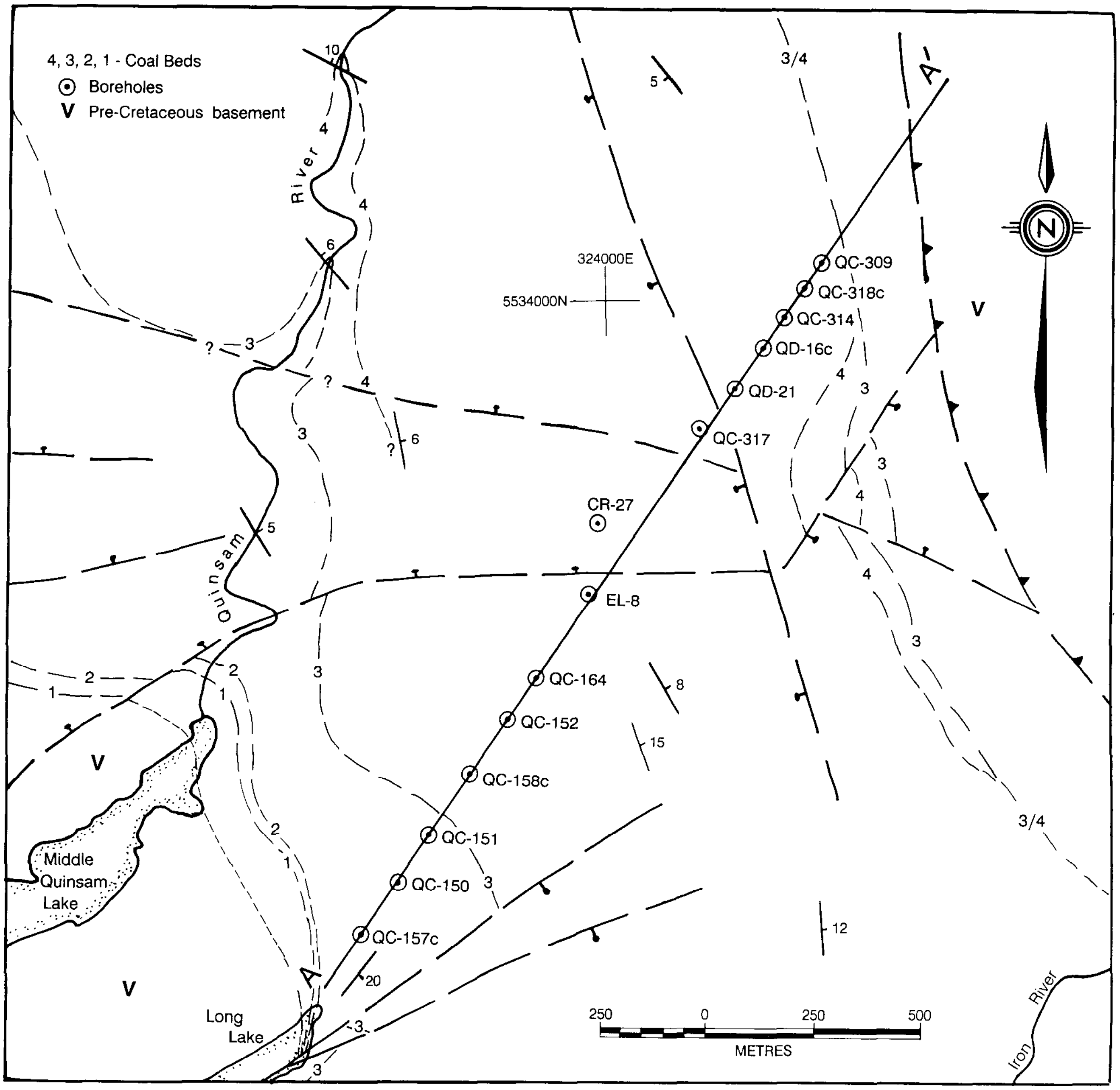

Figure 11. Locations of boreholes used for interpretive cross-section in the Quinsam area (*see* Figure 12).

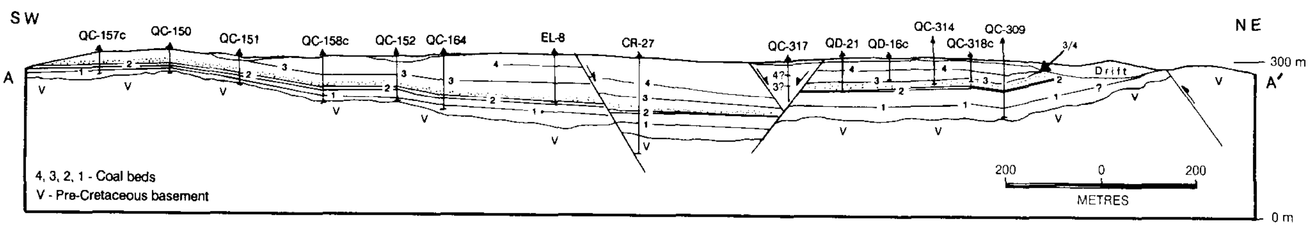

Figure 12. Cross-section through the Quinsam area, southwest to northeast, as indicated on Figure 11.

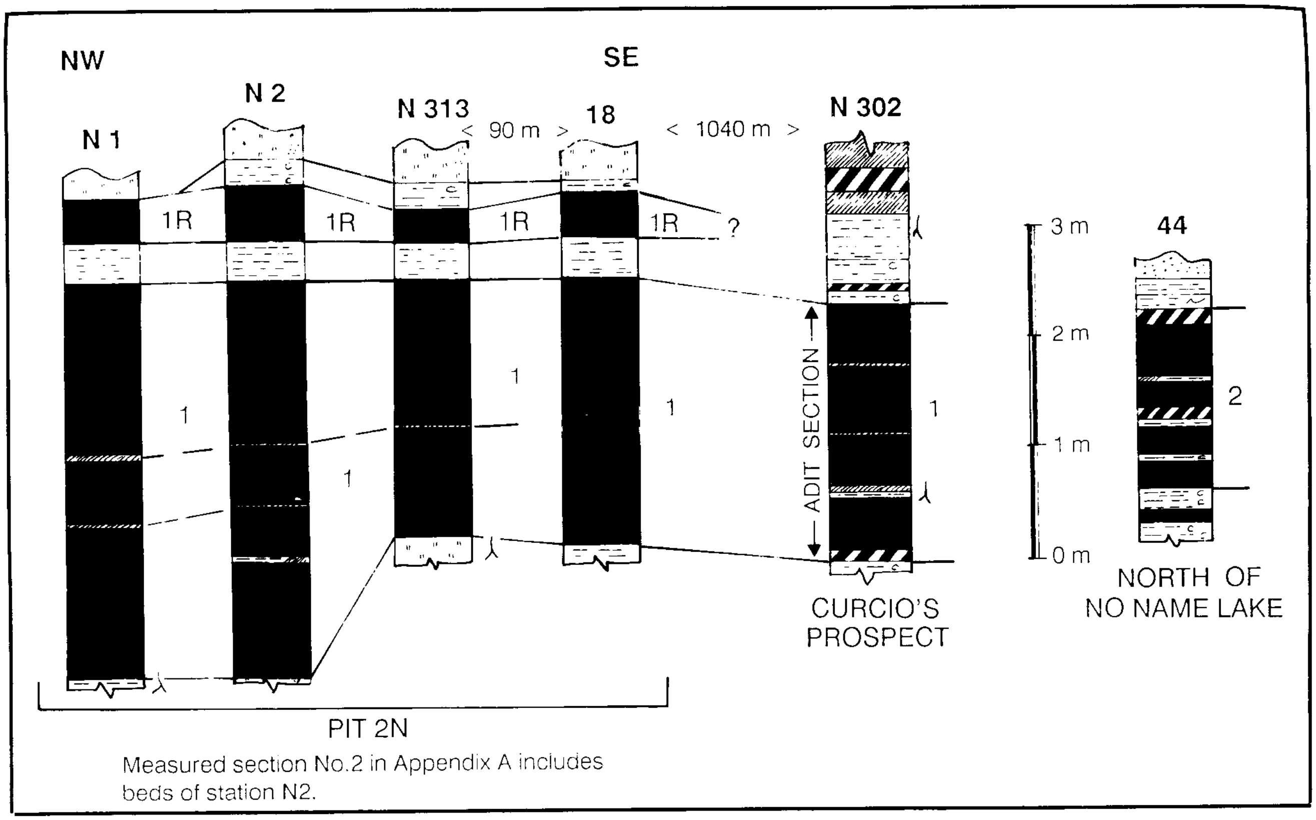

Figure 13. Detailed sections of coal beds No.1 and No.2 from the Quinsam area (*see* Figure 4 for station locations and Figure 7 for stratigraphic legends).

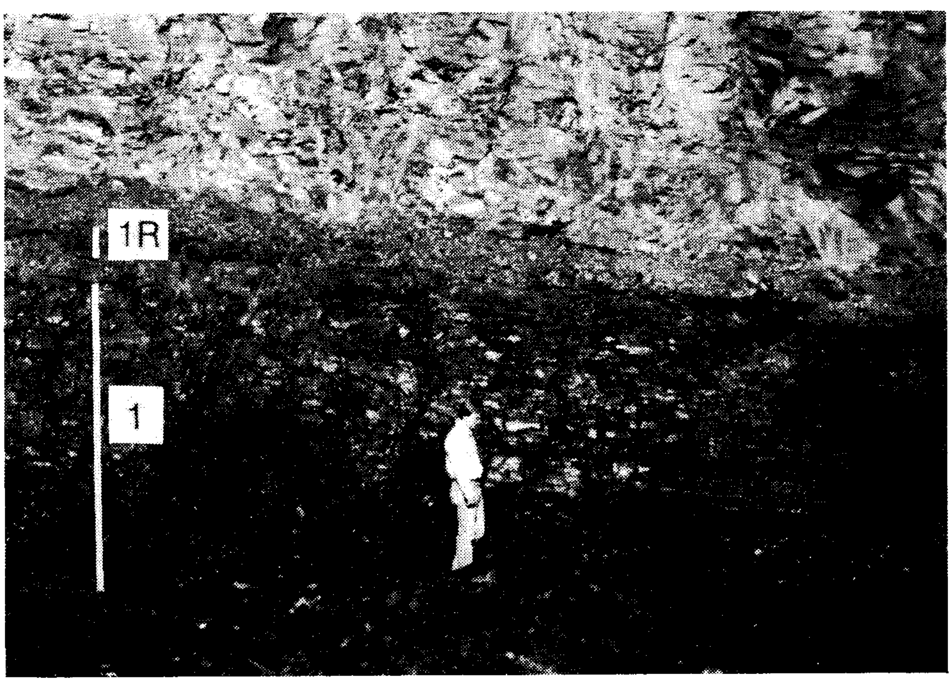

Plate 16. Pit 2N; No.1 coal bed (1) separated from the No. 1 Rider bed (1R) by a mudstone parting.

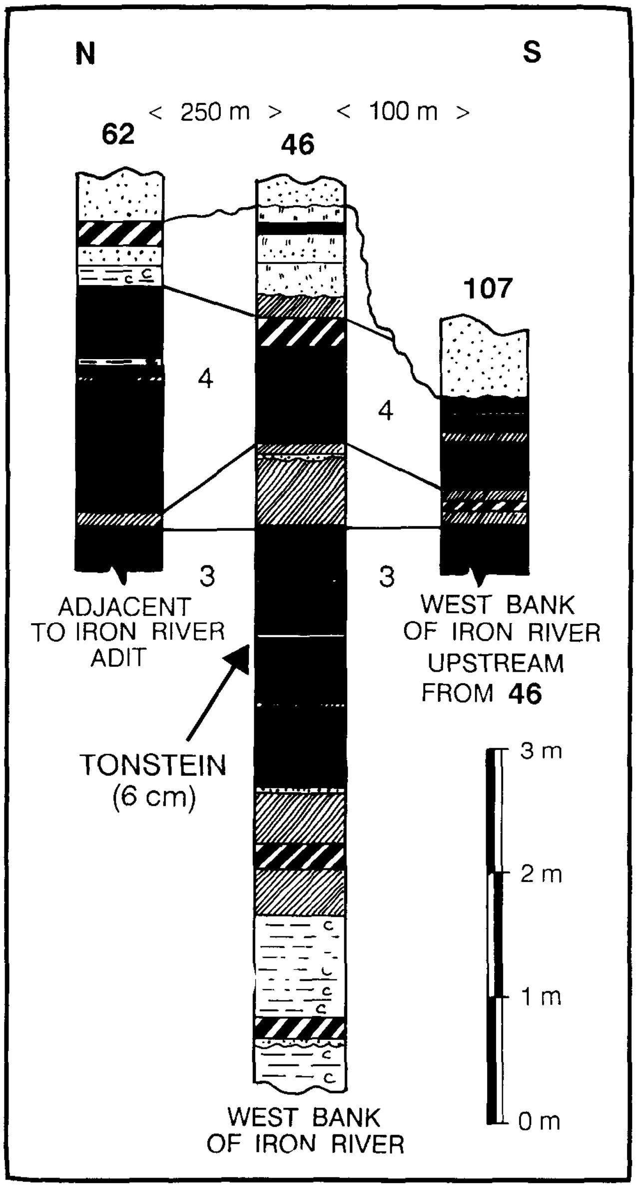

Figure 14. Detailed sections of coal beds No.3 and No.4 from the Quinsam area (*see* Figure 4 for station locations and Figure 7 for stratigraphic legend).

(Table 2). Stratigraphic correlations at Quinsam are illustrated in Figure 7; an interpretion of structure using borehole information is shown in Figures 11 and 12; coal-bed details from measured sections are shown in Figures 13 and 14.

NO.1 COAL BED

The No.1 coal bed is thick (usually 1.8 to 2.6 metres, locally thickening up to 5.2 metres) and consists of very hard, massive, bright-banded coal with minor thin bands of hard, black coaly mudstone and pelletstone. The rock bands within the No.1 bed do not readily part from the coal. The coal usually contains finely disseminated pyrite and locally contains abundant amber. Cleat is well developed but broadly spaced.

North of Middle Quinsam Lake, a thin (0.33 to 0.40-metre) but persistent bed of coal, designated the No.1 Rider, is present above the No.1 bed (Plate 16). The rider consists of moderately hard, bright-banded, blocky coal with abundant pyrite blebs and closely spaced cleats.

The parting between these two beds is 0.3 to 0.5 metre thick in the Quinsam mine (Pit 2N), north of Middle Quinsam Lake. Downdip to the north, the parting thickens to about 1.2 metres, while to the west towards Argonaut road (Figure 5), the parting rapidly thickens to about 13 metres. The No.1 Rider coal bed appears to merge with the overlying No.2 coal bed farther to the west. A thin (0.4 to 0.8 metre) coal with mudstone bands locally directly underlies the No.1 bed; this zone is designated the No.1 Leader bed. It is usually too impure to be considered mineable.

The No.1 bed is thickest and cleanest along its outcrop on the north and south sides of Middle Quinsam Lake. Several small, isolated basement highs interrupt and affect coal thickness of the No.1 bed in this area. Coal bed sections from locations in Pit 2N of the Quinsam colliery illustrate the effect of floor topography on coal thickness (Figure 13). In some cases these highs are bounded by areas of thin, impure coal. To the east of Middle Quinsam Lake and north of Long Lake, the No.1 bed thins and coalesces with the overlying No.2 bed; it is locally absent. Coal bed section N 302 (Figure 13) shows the close approach of the No.1 and No.2 beds at Curcio's prospect, east of Middle Quinsam Lake. Farther to the east, towards Iron River, the No.1 bed pinches out against the flank of a basement ridge.

The No.1 bed appears to be absent on the south side of the ridge at Chute Creek, either due to facies change and nondeposition, or due to this area having remained above base level during deposition of the coal-forming peat. To the west of Middle Quinsam Lake, the No.1 bed gradually thins and passes laterally into dark mudstone with coaly streaks. The westward limit of mineable coal is well defined by closely spaced boreholes, and lies a short distance west of the Argonaut road. The northward limit of the No.1 coal bed is not known. Boreholes east of Quinsam River show that it has thinned, but is still mineable. Boreholes west of the river, towards Lukwa Lake, stopped above the coal bed.

Where the No.1 Rider bed is present, the immediate roof of the No.1 bed is weak, sheared grey to brown mudstone of the Rider parting, overlain by the Rider coal. The main roof of the No.1 coal bed is moderately strong, laminated, grey to greenish grey siltstone with sandy streaks. This siltstone slakes readily in the presence of moisture and could cause unexpected roof failure. This factor was assessed carefully in planning the underground operations at the Quinsam mine.

Where the No.1 Leader bed is present, the immediate floor of the No.1 bed is moderately weak, interlaminated coal and coaly mudstone. The main floor of the No.1 bed is very weak, soft, light grey seat-earth mudstone, which grades down into sandy siltstone.

NO.2 COAL BED

The No.2 coal bed is a thin (usually 0.30 to 0.55 metre, locally thickening to 1.0 to 1.4 metres) bed consisting of dull and bright, moderately hard, blocky coal with numerous thin bands and streaks of black coaly mudstone. A section of the No.2 bed, at Station 44, north of No Name Lake, is shown in Figure 13.

The No.2 bed gradually pinches out to the north and west from Middle Quinsam Lake; far to the northwest at Beavertail Lake it is represented by dark mudstone with coaly streaks. To the south and east, the coal bed abuts against a basement high which extends from Iron River southwestward towards No Name Lake. On the southeastern side of this ridge, the No.2 coal bed is either absent altogether (*e.g.* along Stone Creek) or is represented by very thin coal bands (*e.g.* in isolated deep boreholes at Chute Creek). Its absence in this area may be due to a facies change to more oxidized alluvial fan deposits.

A thin (0.20 to 0.55 metre) bed of dirty coal, designated the No.2 Rider bed, locally occurs within 5 metres above the No.2 coal bed. The rider appears to be present as isolated pods which escaped erosion beneath the basal Dunsmuir sandstone. The immediate roof of the No.2 coal bed is usually a thin (0.3 to 0.6 metre) bed of moderately soft, fissile, compact, dark brown, locally glauconitic mudstone, overlain by strong, massive, light grey, coarse-grained sandstones of the basal Dunsmuir member.

NO.3 COAL BED

The No.3 coal bed is usually 2.4 to 3.4 metres thick. It consists of three or four thinner coal beds separated by persistent partings. No.3 coal is dull and bright to bright banded, hard and blocky, with abundant blebs and cleat fillings of pyrite. Partings are usually of dark grey to dark brown mudstone, locally becoming hard and silty.

The lowest coal leaf of the No.3 bed splits away to the west, towards Quinsam River. In this area it is recognizable as a separate thin bed (usually 0.45 to 0.7 metre thick), designated the No.3 Leader coal bed. An unusual feature of this bed is that its top locally contains sand-filled burrows which resemble *Teredolites* sp., indicating a period of exposure of the coal-forming peats to brackish waters.

Southeast of Long Lake, the No.3 bed contains numerous partings of hard carbonaceous sandstone, and fingers out eastward into sandstone with coal streaks. It pinches out to the northeast towards the Argonaut road. It extends southwards into the Chute Creek area, where it has been intersected by a few boreholes, as a group of two or three thin (0.45 to 0.75 metre thick) coals.

Its roof is very strong, medium to coarse-grained, light grey to greenish grey sandstone, which is arkosic in the north and of mixed arkosic and lithic composition in the south. The base of the roof is often erosive, marked by a thin lag of pebbles and coal spars. The floor is moderately strong, dark grey mudstone or siltstone, grading down into sandstone resembling that of its roof.

NO.3/4 COAL BED

This coal bed is a composite of the No.3 and No.4 coal beds, present only in a narrow strip along the northeastern outcrop of the coal measures between Iron River and Quinsam River. Its great thickness (3.3 to 4.8 metres) is the result of the stacking of both coal beds (Figure 7). It consists of dull and bright to bright-banded coal with numerous very thin streaks of black coaly mudstone. Its roof and floor are similar to those of the No.4 and No.3 coal beds, respectively. A distinctive fine-grained, light grey tonstein, 6 centimetres thick, was found in the No.3 coal bed at outcrop Station 46 (Figure 4). It was not apparent in the same seam on the Quinsam River.

Plate 17. Upper coal beds with interbedded sandstones and siltstones, Quinsam River, Station 30 (Figure 4).

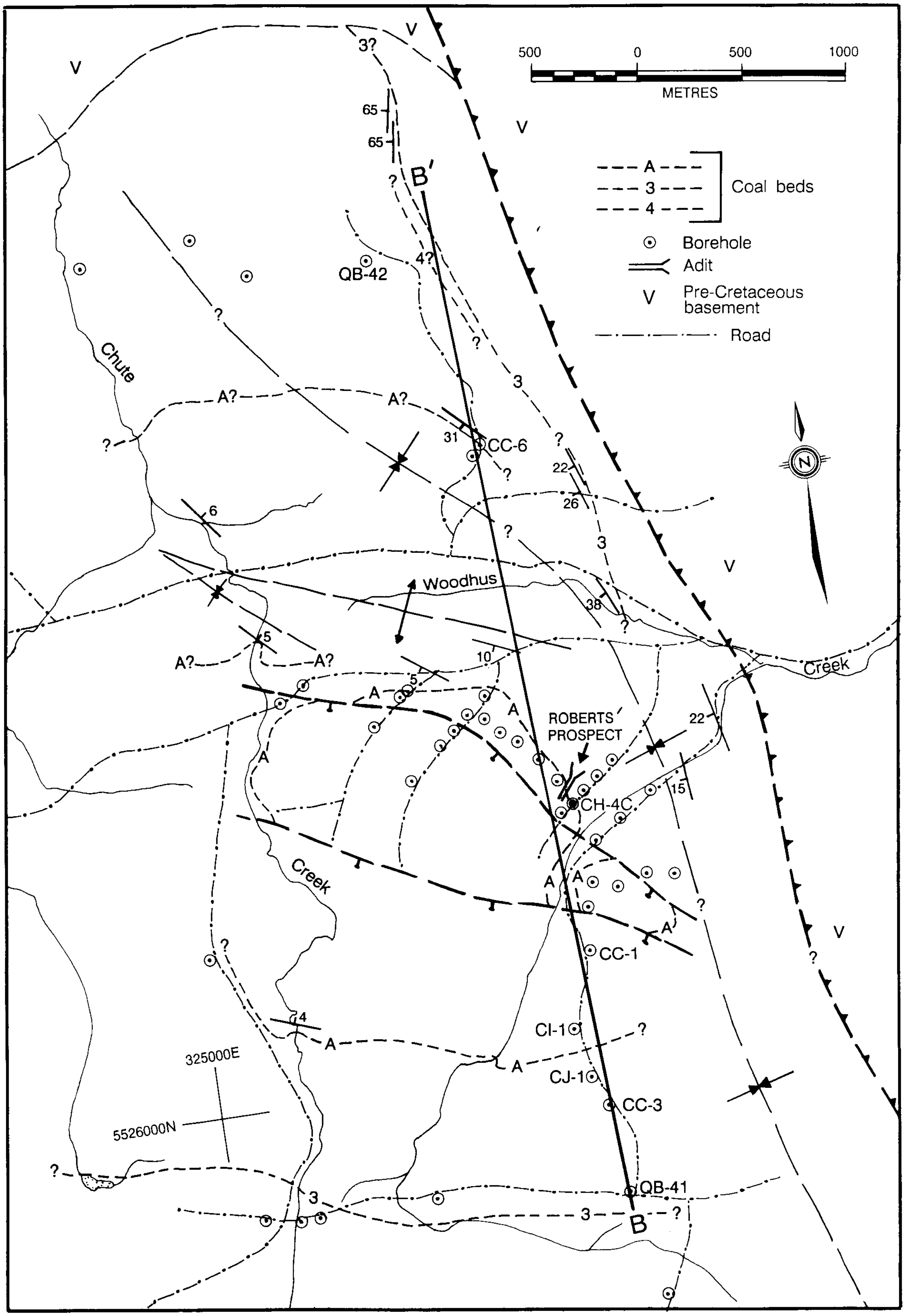

Figure 15. Locations of boreholes and adit used for interpretive cross-section in the Chute Creek area (*see* Figure 16).

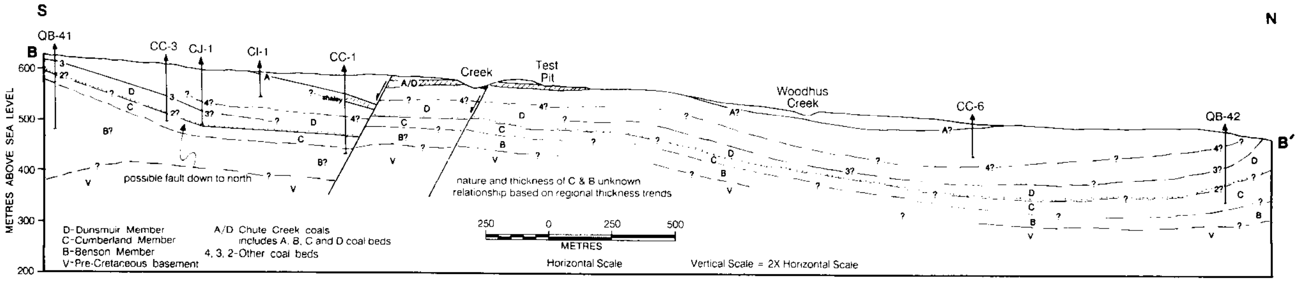

Figure 16. Cross section through the Chute Creek area, south to north (as indicated on Figure 15).

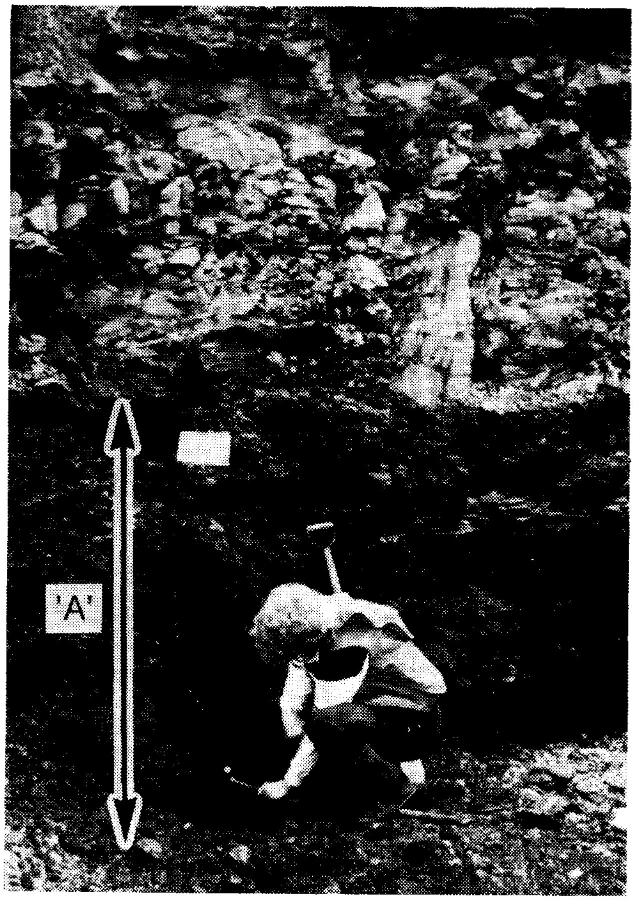

Plate 18. A coal bed, adjacent to Roberts' prospect, Chute Creek, Station 16 (Figure 4). Beds are being cleaned in this photo, in preparation for sampling.

NO.4 COAL BED

The No.4 bed is a thin (usually less than 1.2 metres thick) bed consisting of bright blocky coal with abundant pyrite blebs and occasional thin bands of brown and black coaly mudstone. It pinches out southwestward from the line which marks its split from the No.3 bed, and is therefore present only in the extreme northeastern part of the Quinsam area. It may extend at depth into the Chute Creek area, as one or two very thin coals. Its roof is strong, medium to coarse-grained light grey sandstone, often with a sharp, erosive base. Its floor is light greyish brown, soft siltstone, which grades rapidly downwards to sandstone.

UPPER COAL BEDS

Several coal beds are present above the No.4 coal bed along Quinsam River and in the boreholes south and west of Lukwa Lake. They are thin (0.2 to 0.6 metre) and typically consist of several closely spaced seams within interbedded sandstones and siltstones (Plate 17). No attempt has been made to study them in detail, owing to their limited exposure and thinness.

CHUTE CREEK AREA

Numerous coal beds are present in the upper Dunsmuir member at Chute Creek. They seldom attain thicknesses greater than 1.2 metres, and more often are less than 0.9 metre thick. An interpretation of their distribution, using borehole information, is shown in Figures 15 and 16.

A group of four coal beds, named in ascending order, 'D', 'C', 'B' and 'A', occupy a stratigraphic interval of 8 to 11 metres near the top of the Dunsmuir member. Several much thinner rider and leader coals are present within this zone and thin coals are also present both higher and lower in the section. All of the Chute Creek coals display well-developed cleat, usually carrying pyrite and calcite films. Perry (1986) has discussed this zone in greater detail than is possible in this report, and the comments made below are based largely upon his work. The Quinsam No.3 bed, and possibly the No.4 bed, are also present in the Dunsmuir member at Chute Creek. They are deeper in the section however, and lie beneath the bottoms of most of the boreholes (Figure 16).

'A' BED

The 'A' bed is the thickest (averaging 1.1 metres and locally exceeding 1.5 metres) of the four coals within the Chute Creek coal zone (Plate 18). It comprises dull and bright coal, with two thin but laterally persistent rock bands. These usually consist of carbonaceous mudstone and impure coal. Other lenses of coaly sandstone and mudstone are locally present. Typical sections of the 'A'

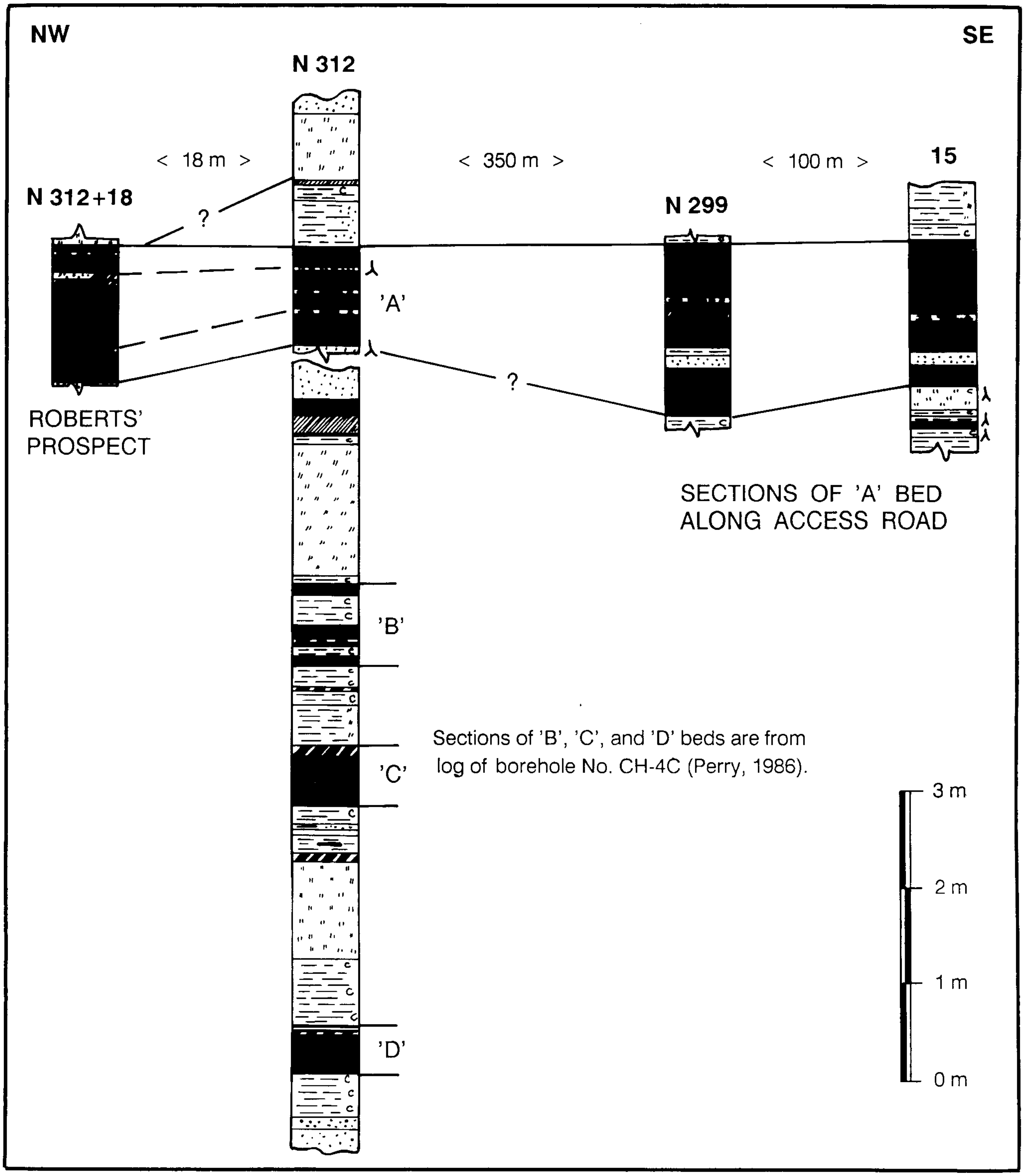

Figure 17. Details of coal beds A, B, C and D in the Chute Creek area, from measured sections and borehole data (*see* Figure 7 for stratigraphic legend).

bed are illustrated in Figure 17. Its roof is moderately strong and varies from dark carbonaceous mudstone and siltstone to fine-grained silty sandstone. Its floor is usually a thin but strong bed of fine to medium-grained rooted sandstone.

'B' BED

The 'B' bed is 0.34 to 1.02 metres thick, averaging 0.75 metre, and comprises blocky, bright-banded coal with two thin partings of carbonaceous mudstone, siltstone and dirty coal. Some of the coal is granular in texture and may represent drifted plant material. Its roof is dark carbonaceous to coaly mudstone and its floor is usually carbonaceous mudstone with bright coal bands, locally grading to silty mudstone or siltstone.

'C' BED

The 'C' bed is very thin (from 0.36 to 0.91 metre, averaging 0.55 metre) and comprises dull and bright coal with a central parting of dark carbonaceous mudstone and impure coal. Its roof is gradational and difficult to define, consisting of thin interbeds of impure coal and dark carbonaceous mudstone. Its floor is usually carbonaceous to coaly mudstone or siltstone, grading downwards to sandy siltstone or fine-grained sandstone.

'D' BED

The 'D' bed is also very thin (from 0.48 to 0.67 metre, averaging 0.55 metre) and comprises bright and bright-banded coal with one or two thin central partings of dark carbonaceous mudstone. Its roof and floor are gradational, both consisting of dark carbonaceous to coaly mudstone with thin bands of bright coal.

COAL BED CORRELATIONS

Quinsam Coalfield

The Chute Creek coal zone is stratigraphically higher than the major coal beds of Quinsam. A correlation between the Chute Creek coal zone (above the No.4 coal bed) is possible, but not definite on the strength of the very limited data available for the upper Quinsam coals.

The Chute Creek 'D' bed, at the base of the Chute Creek coal zone, lies 50 to 80 metres above the Quinsam No.3 bed, based upon sparse deep borehole control. It also overlies a thin coal or group of two coals tentatively correlated with the No.4 bed; the interval between 'D' floor and No.4 roof is about 30 to 60 metres.

Outside of Study Area

Stratigraphic correlations outside the study area are based on the reliable Dunsmuir/Cumberland member contact and the persistent thick, clean sandstone or conglomerate unit at the base of the Dunsmuir member.

The Quinsam No.1 coal bed is probably correlative with the lower coal bed at Campbell River, and perhaps with the Comox No.3 coal bed (Table 2). The Quinsam No.2 coal is almost certainly correlative with both the upper coal bed at Campbell River and the Comox No.2 coal bed. The Quinsam No.3 coal bed appears to be correlative with the Comox No.1 coal bed.

PALEOPLACER DEPOSITS

An unusual type of black sandstone, rich in detrital magnetite, occurs locally within the Dunsmuir member north and east of Middle Quinsam Lake. It is exposed in outcrop along Quinsam River (Section No.1, Appendix A), and has also been intersected in three diamond-drill holes (CR-25, CR-27 and CR-29; Appendix B).

The stratigraphic position of the heavy-mineral sandstone occurrences is variable, suggesting that there are at least three separate lenses (Figure 7). The occurrence in Quinsam River canyon lies about 47 metres above the Quinsam No.4 bed. In the borehole intersections, the heavy-mineral beds occur as follows: in CR-27, about 9 metres below the Quinsam No.4 coal bed; in CR-29, about 21 metres above the coal bed; and in CR-25, about 22 metres above the coal bed.

The Quinsam River outcrop (N 124, Figure 4), includes a very thin band (0.05 m) of fine-grained black sandstone containing about 50 per cent magnetite, within a thicker unit (2.05 metres) of medium-grained brown-weathering sandstone containing about 10 per cent magnetite concentrated within many thin laminae. Above and below that unit are the typical medium to coarse-grained, light grey sandstones of the Dunsmuir member.

Magnetite bands were intersected in two drillholes in the Quinsam area. The thickest intersection carries 10 per cent magnetite, as thin bands, across an interval of 7.55 metres, in borehole CR-25. It is overlain by a few isolated magnetite-rich bands up to 0.15 metre thick. The thinnest drill intersection contains 10 per cent magnetite, as thin bands, across an interval of 0.61 metre in borehole CR-27.

Heavy-mineral sandstones were previously described in the Comox Formation at Mount Maxwell on Saltspring Island (Hanson, 1976), and in the Cretaceous Western Interior basin of Canada and the United States (Mellon, 1961; Houston and Murphy, 1970). They have been interpreted as fossil beach-placers, resembling the black sand deposits which form on some modern beaches.

Paleoplacer deposits can contain valuable minerals such as zircon, ilmenite, rutile or gold. Such mineral associations are common in fossil beach placers (Houston and Murphy, 1970), although the gold content varies widely.

One such deposit at Burmis, Alberta, contains 5 to 10 ppb gold (Cathyl-Bickford and Hoffman, 1987). Hanson's Saltspring Island deposit contains less than 5 ppb gold (Russ Wong, personal communication, 1987).

Higher grades, up to 1300 ppb gold, have been reported for fossil beach-placers in eastern Wyoming (Houston and Murphy, 1970).

HEAVY MINERALS

The most likely provenance of the heavy minerals is the Iron River magnetite-chalcopyrite skarn deposits, which straddle Iron River just north of the northernmost outcrops of the Quinsam No.3 coal bed (Young and Uglow, 1926; McCullough, 1974; Eastwood, 1984). Another possible source is the larger Iron Hill skarn, on the eastern shore of Upper Quinsam Lake. There is an association between sulphides, gold and silver in some skarn ores in British Columbia suggesting that the Iron River or Iron Hill skarns could also have yielded detrital gold for eventual concentration in paleoplacers.

Only limited heavy-mineral work has been done on sedimentary rocks in the Quinsam area, due to lack of outcrops. Some has been done on the coals. Van der Flier-Keller (1988) sampled the Quinsam No.2 coal seam in Pit 2N and noted concentrations of gold up to 88 ppb.

The x-ray diffraction report provided the following results for samples submitted for this study. Composition of the sample from Station N 124 (Figure 4) is hematite, magnetite, calcite, hydrogrossular, andradite and traces of chlorite, orthoclase? and quartz. The sample from Station N 150 is made up of magnetite, quartz, calcite, hydrogrossular, andradite, hematite, pyrite, gypsum, chalcopyrite(?) and illite(?). Gold content was 30 ppb and 160 ppb respectively. Preliminary investigation of the gold content does not indicate that the paleoplacers are potentially economic.

COAL AND COALBED METHANE RESOURCE POTENTIAL

COAL RESERVES AND RESOURCES

QUINSAM AREA

Various individuals have calculated coal reserve potential for the Quinsam area. The first to do so was Gray (1952), who reported probable reserves of 4.9 million tonnes and possible reserves of 28.4 million tonnes. This calculation was based upon outcrop data only, as the area had not yet been drilled. Based upon limited drilling and geological studies, Curcio (1975) reported proven strippable reserves (at 14:1 strip ratio) of 7.8 million tonnes, probable strippable reserves (at 14:1 strip ratio) of 8.4 million tonnes, probable underground-mineable reserves of 16.6 million tonnes, possible strippable reserves (at 10:1 to 30:1 strip ratios) of 47.5 million tonnes, and possible underground-mineable reserves of 105.1 million tonnes. Following more intensive drilling and geological mapping, (Ronaghan and Gardner, 1978 a, b and c; Barnstable, 1979), total reserves were estimated at 30.3 million tonnes, including 18.9 million tonnes of strippable reserves.

Current estimates of the Quinsam property by Brinco Coal Corporation include 23.3 million tonnes of open-pit reserves and 19.9 million tonnes of underground reserves for a total of 43.2 million tonnes, of which 23.4 million tonnes are proven.

CHUTE CREEK

Perry (1986) reported the total *in-situ* coal resource as 5.26 million tonnes, within the Chute Creek 'A', 'B', 'C' and 'D' coal beds. Of this resource, 3.35 million tonnes were considered to be potentially mineable. Within potential mine sites, strippable reserves were as follows: measured, 970 000 tonnes; indicated, 430 000 tonnes; and inferred, 800 000 tonnes. Only the 'A' bed was considered to have potential for underground mining. Within potential mine sites, underground-mineable reserves were as follows: measured, 770 000 tonnes; indicated, 370 000 tonnes; and inferred, 10 000 tonnes.

POTENTIAL FOR ADDITIONAL COAL DISCOVERIES

Because of the amount of exploration drilling, potential for additional coal discoveries is minimal at Quinsam and only fair at Chute Creek. The country lying between these two areas, however, has not been explored in detail. The eastward extension of the Quinsam No.3 coal bed, across the Iron River from the Quinsam Pit 7 reserve block, should be investigated further (Figure 4). The Chute Creek 'A' through 'D' coal beds may also be present in the undrilled area north of the existing Chute Creek reserve block. The downdip extension of the Quinsam No.1 coal bed, north of the Quinsam Pit 2 North reserves, has only been partially investigated. Moreover, most of the widely spaced boreholes in the vicinity of Lukwa Lake were abandoned before reaching the stratigraphic level of the No.1 bed.

Extension of geological mapping to the south and southeast into the Forbidden Plateau area should be considered, as there is a possibility of additional coal deposits in the essentially unexplored country along structural strike from the Quinsam and Chute Creek deposits. When detailed mapping of the Campbell River coal deposits (BCGS map sheets 92F.094 and 92F.084) is completed, it should be possible to firmly establish the relationships between the coal deposits on either side of the intervening basement massif.

COALBED METHANE

Recent interest in the coalfields of Vancouver Island for potential coalbed methane production, has resulted from successful exploration and development of this commodity in the United States. The Comox Formation can be considered both as a source (Murray, 1986a, b) and as a potential storage site for coalbed gas (Polak, 1972).

On a regional scale, the Comox Formation coals have been considered as potential producers of coalbed gas since 1940, when Canadian Collieries (Dunsmuir) Limited discovered gas in a coal exploration borehole at Royston, 28 kilometres southeast of Quinsam Lake (Figure 3). Commercial production did not result but local farmers used coalbed gas for heating and lighting farm buildings until as late as 1969 (Cathyl-Bickford, 1988).

Results of ongoing research involving coal quality, regional rank distribution and desorption testing indicate a potential economic gas resource in the Comox Formation. The presence of methane in the coals of Vancouver Island is corroborated by documented accounts (Annual Reports of the Minister of Mines) of numerous disasters involving gas-related explosions and fires in virtually all of the underground mines (Plate 19). 'Gassy' occurrences

Plate 19. Site of the 1887 explosion at the No.1 mine in Nanaimo, in which over 140 miners were killed, photo courtesy of B.C. Archives and Records Service; Catalogue No. HP 71704.

are noted in drill records and surface venting of gas has been noted in various reports on file with the Ministry.

Interest has been further fueled by the construction of a gas pipeline across Georgia Strait. This pipeline crosses the Comox and Nanaimo coalfields and could provide the necessary infrastructure to help make extraction of the methane resource economic. The pipeline does not extend to the Quinsam coalfield.

Occurrence of Coalbed Gas

Methane is both biogenically and thermally derived from coal and both coal beds and associated stratigraphy are potential reservoirs. The bulk of the gas generated within coal beds is subsequently expelled from the bed (Teichmuller, 1975) and thus becomes available to charge 'conventional' reservoirs. Although a large percentage of the methane generated by the coalification process escapes to the surface or migrates into adjacent reservoir rocks, a portion is trapped within the coal as adsorbed or absorbed molecules on the surface of micropores in the coal, as free gas existing within fractures or pores, and as dissolved gas in formation waters (Rightmire, 1984). Ability of gas to flow through a reservoir depends on various factors including permeability, cleat systems, structural controls, coal quality, coal-seam depth and hydrostatic pressure. Estimates of an *in-situ* methane resource require data concerning these parameters and knowledge of the amount of gas present per unit volume of coal, which can be determined by gas desorption tests. Test-well desorption data from the Nanaimo sub-basin (Figure 1) have indicated that coals can contain as much as 11.86 cubic metres of methane per tonne of coal (380 cubic feet per short ton) at depths of approximately 384 metres, with vitrinite reflectance values averaging 0.85 per cent. Gas samples taken were pipeline quality, 95 per cent methane, 4.5 per cent heavier hydrocarbons, and 0.5 per cent carbon dioxide (Kenyon and Murray, 1990).

Limited desorption testing has been done on other coal seams on the Island and the results from shallow depths show promise. These data cannot be published due to confidentiality regulations. There is a great deal of exploration work necessary in this field before resource potential can be accurately determined.

Quinsam Coalfield

The presence of thick coal in the study area has already been established by exploration, but no desorption tests have been done on any of the coal beds. The only gas show recorded near the Quinsam - Chute Creek study area is at Quinsam Lake (Figure 2). Gas seeps were reported at many sites along this lake by McKenzie (1918) and were believed to indicate the presence of coal under the lake.

Maceral determinations indicate that Quinsam coals contain predominantly vitrinite. Coals of this type are derived primarily from the woody constituents of complex terrestrial plants and contain dominantly Type III kerogen. They are considered to be dry-gas generating source rocks upon reaching thermal maturity (Meissner, 1984). Vitrinite reflectance (R_{max}) results place the coal rank of the Quinsam coalfield in the window of coalbed methane generation (Figure 18). The onset of significant thermogenic gas generation from coals occurs at fairly low rank:

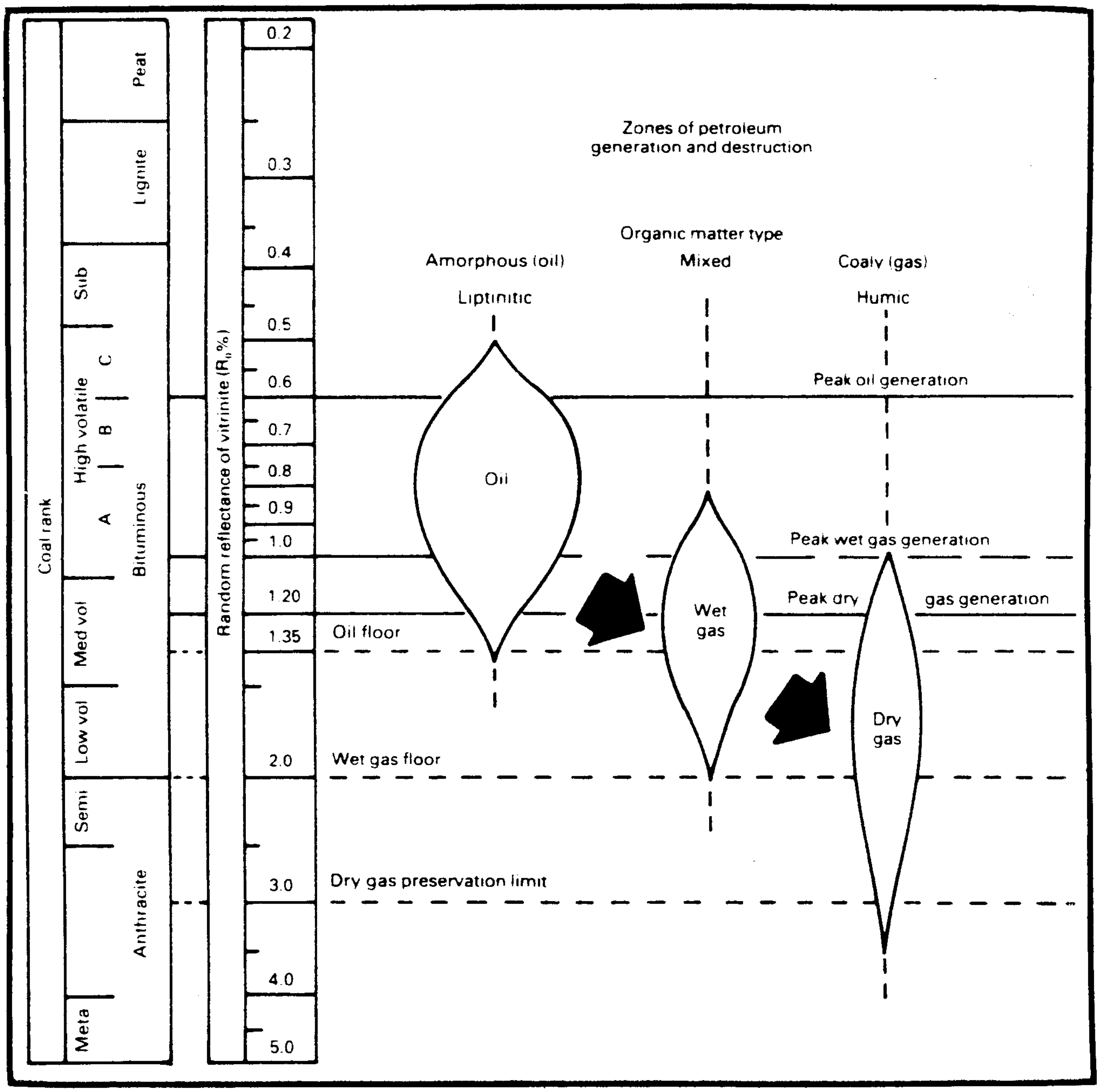

Figure 18. Correlation of coal rank scale with zones of petroleum generation (modified after Dow, 1977).

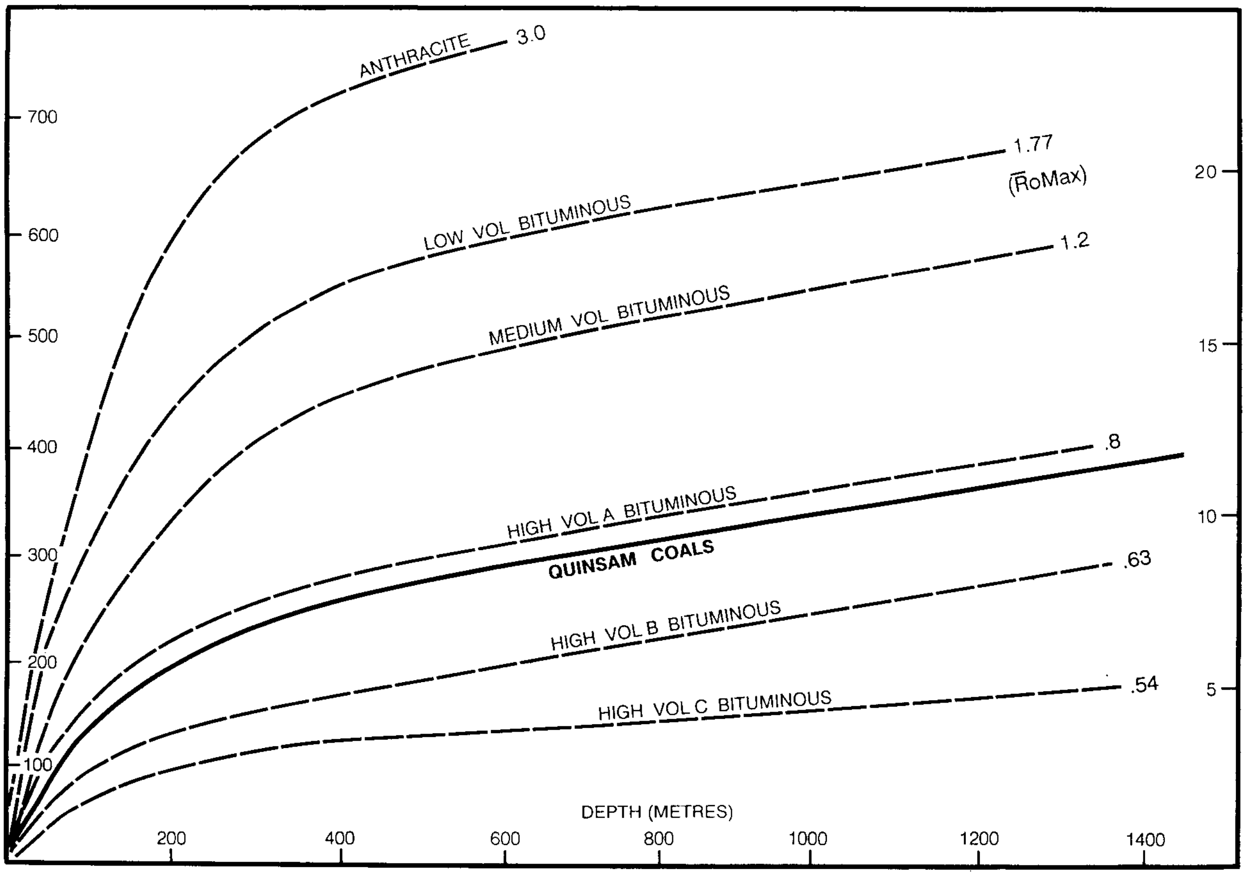

Figure 19. Methane retention by rank and depth (modified after Eddy *et al.*, 1982).

mean R_{max} of 0.73 to 0.85 per cent (Dow, 1977; Rightmire, 1984; Murray, 1986b). Peak gas generation occurs at R_{max} of 1.0 to 1.2 per cent (Dow, 1977). According to Teichmuller (1975), the threshold rank for important economic gas deposits occurs at an R_{max} of 1.0 per cent.

The thick siltstone roof of the Quinsam No.1 coal bed may have trapped gas that would otherwise have been expelled into adjacent porous rocks. The gas is probably also trapped by meteoric waters moving downdip within the cleats and fractures of the coal bed. Some of the sandstones of the Dunsmuir member show fair to good intergranular porosity at outcrop. The thick, clean sandstone underlying the Quinsam No.3 coal bed appears to have the most consistent porosity development, and is laterally and vertically extensive. Resistance logs of exploratory boreholes near Chute Creek show this sandstone is water-saturated.

RESOURCE CALCULATIONS

Eddy *et al.* (1982) produced a graph which allows one to predict the amount of methane retained in coal (cubic feet per ton) using two parameters, coal rank and depth. A conversion factor of .0312053 was used to calculate cubic metres per tonne (Figure 19). This number can then be multiplied by the known or inferred coal tonnages to provide a resource estimate. The necessary criteria to utilize this chart are available for the study area.

The most recent coal resource estimates (*see* under Coal Reserves and Resources) done by the exploration companies for the Quinsam and Chute Creek areas were rounded to 50 million tonnes of *in-situ* coal. This does not take into account coals outside these properties or, in the case of Chute Creek, deeper coals that were not intersected in shallow drilling programs.

Proximate analysis and vitrinite reflectance data for the Quinsam coalfield indicate that the coals straddle the boundary between high-volatile 'A' and 'B' Coal Quality. Coal depth was placed at 100 metres, which is the average value between outcrop (No.1 coal bed) and the base of the coal measures. These data were applied to the methane retention chart in Figure 19. Rank and depth indicate that the coal could produce approximately 4.68 cubic metres of methane per tonne of coal (150 cubic feet per ton). Utilizing this information, the known resources of approximately 50 million tonnes of coal would be expected to produce 23.4 billion cubic metres (BCM) of gas (0.07 trillion cubic feet; TCF).

The following formula, found in numerous American publications (*e.g.* Zuber and Kuuskraa, 1989), was used to determine the methane potential of coal in areas outside the known resources:

Gas in place (GIP) = Gas content (150 cubic feet/ton) x Net coal thickness (10 feet) x Coal density (1800 short tons) x Areal extent (81 square miles) = .02 TCF or 6.7 BCM.

In this equation, the average value of 10 feet representing coal thickness, allows for varying seam thicknesses and areas of no coal occurrence due to intrusive bodies, paleohighs and complex structure. A gas content of 150 cubic feet per ton was taken from the methane retention chart for the known resources. The value of 1800 short tons per acre foot represents the accepted density of bituminous rank coal.

Preliminary data suggest a potential total coalbed methane resource of 30.1 BCM or .09 TCF in the Quinsam coalfield. This information is important from a safety point of view when planning underground mining operations in the area, when one considers the past history of mining problems related to gas on Vancouver Island. Methane could also be considered as a potential energy source for operating the mine. The amount of methane retained by Quinsam and Chute Creek coals is limited by rank and depth. Hopefully more accurate estimates can be made of coalbed methane resources as more exploration work is done. Commercial production of coalbed gas has yet to occur in Canada, although interest is currently high.

TABLE 4
QUINSAM NO.1 COAL BED, PROXIMATE ANALYSES

	BASIS	M%	ASH%	VM%	FC%	S%	Calorific Value MJ/kg	Calorific Value BTU	FSI
AS MINED	ad	3.6	14.40	34.40	47.60	1.57			2
	d	xxx	14.94	35.68	49.38	1.63			
CLEAN COAL	ad	2.57	7.31	36.73	53.39	1.31			
	d	xxxx	7.50	37.70	54.80	1.34	31.2	13425	2

(NOTE: SAMPLES ARE FROM CURCIO'S PROSPECT)

TABLE 5
QUINSAM BOREHOLES, PROXIMATE ANALYSES

COAL BED	BASIS	M%	ASH%	VM%	FC%	S%	Calorific Value MJ/kg	Calorific Value BTU	FSI	N
NO.1 (NW AREA)	ad	2.78	12.78	36.06	48.46	0.70	27.4	11776	1.2	48
	d	xxxx	13.15	37.09	49.85	0.72				
NO.1 (SE AREA)	ad	2.42	18.04	34.69	44.86	0.99	26.0	11184	1.3	19
	d	xxxx	18.49	35.55	45.97	1.01				
NO.1 RIDER	ad	2.17	18.95	37.34	41.54	4.12	25.6	11001	1.4	21
	d	xxxx	19.37	38.16	42.46	4.21				
NO.2	ad	2.65	16.02	36.69	44.65	2.46	26.6	11415	1.6	27
	d	xxxx	16.46	37.69	45.87	2.53				
NO.3	ad	1.71	21.62	34.98	41.93	2.67	24.9	10702	1.5	36
	d	xxxx	22.00	35.59	42.66	2.72				
NO.4	ad	1.44	27.07	33.45	38.05	3.72	23.0	9907		4
	d	xxxx	27.47	33.94	38.61	3.77				

(NOTE: DATA ARE AVERAGED)

TABLE 6
QUINSAM NO.1 COAL BED, PROXIMATE ANALYSES

COAL SAMPLE	BASIS	M%	ASH%	VM%	FC%	S%	Calorific Value MJ/kg	Calorific Value BTU
RIDER SEAM	ad	3.59	16.90	35.94	43.57	2.23	25.1	10791
	d	xxxx	17.53	37.28	45.19	2.31	26.0	11193
NO.1 SEAM UPPER	ad	3.70	9.60	38.86	47.84	1.19	27.6	11862
	d	xxxx	9.97	40.35	49.68	1.24	28.6	12318
NO.1 SEAM LOWER	ad	3.98	8.16	38.14	49.82	0.44	28.4	12201
	d	xxxx	8.50	39.62	51.88	0.46	29.6	12707

(NOTE: 1987 SAMPLES, THIS STUDY)

COAL QUALITY

Although several test pits and adits have been excavated for bulk coal samples within the study area, records of the analytical work done are generally confidential. A number of trenches were dug at Chute Creek, but these data are probably not representative of fresh, unoxidized coal. Fortunately, numerous analyses have been done on borehole core from Quinsam and Chute Creek. In addition, analyses were performed on fresh coal samples obtained in this study during the 1987 field season.

Abbreviations for Tables of Analytic Data:

ad: air dried basis	d: dry basis
M: residual moisture	VM: volatile matter
FC: fixed carbon	S: sulphur
FSI: free swelling index	X: number of samples
BTU: British thermal units per pound	MJ/kg: megajoules per kilogram

PROXIMATE ANALYSIS AND CALORIFIC VALUE

QUINSAM AREA

Two adits have been driven for the purpose of bulk sampling and test mining at Quinsam, but we only have analytical results for one (Figure 4). In 1976, Weldwood opened Curcio's prospect in the No.1 coal bed east of Middle Quinsam Lake and north of Long Lake (Figure 4). The raw and cleaned coal analytical results for the bulk sample are listed in Table 4 (the sample included coal from both the No.1 and the No.1 Rider seam).

Core samples taken at Quinsam represent the entire recovered thickness of each coal bed, with the exclusion of partings greater than 25 millimetres thick. Their quality attributes (Table 5) therefore represent the best raw coal quality attainable by selective mining, without any allowance for dilution by roof and floor material and most rock partings. On an air-dried basis, residual moisture ranges from 1.44 to 2.78 per cent; ash 12.78 to 27.07 per cent; volatile matter, 33.45 to 37.34 per cent; fixed carbon, 38.05 to 48.46 per cent; and sulphur, 0.70 to 4.12 per cent. Calorific values for raw coals from boreholes range from 23.0 to 27.4 megajoules per kilogram (9907 to 11776 British thermal units per pound). No details are available regarding the washability and expected clean coal quality of core samples.

Proximate analysis results of sampling done on the Quinsam No.1 coal bed (Rider, No.1 Upper and No.1 Lower coal seams), collected at outcrop location 18 (Figures 4 and 8) during the 1987 field season, are listed in Table 6.

CHUTE CREEK AREA

Core samples taken at Chute Creek represent the entire recovered thickness of the coal beds, including partings. They therefore represent the raw coal quality attainable by mining the entire coal bed, without any allowance for dilution by roof and floor material. Table 7 presents the average quality (air-dry and dry) of raw coal from borehole cores, for coal beds 'A', 'B', 'C', and 'D'. Air-dried residual moisture ranges from 2.43 to 2.93 per cent; ash 16.92 to 37.28 per cent; volatile matter, 27.49 to 37.37 per cent; fixed carbon, 32.80 to 45.81 per cent; and sulphur, 0.57 to 3.08 per cent. Calorific values for raw coals from boreholes range from 18.5 to 26.2 megajoules per kilogram (7960 to 11 251 British thermal units per pound).

Washability tests were performed on composites of selected borehole intersections within the potentially mineable areas at Chute Creek (Perry, 1986). These test results represent the expected clean coal quality from a simple gravity separation of the raw coal from coal beds 'A', 'B', 'C', and 'D'. Table 8 presents the quality of the clean coal fraction from these tests (floats at specific gravity of 1.60). Residual moisture (air-dried) ranges from 1.83 to 2.48 per cent; ash, 8.04 to 10.53 per cent; volatile matter, 33.40 to 38.49 per cent; fixed carbon, 49.79 to 54.04 per cent; and sulphur, 0.76 to 2.64 per cent. Calorific values for washed coals range from 28.6 to 30.0 megajoules per kilogram (12 308 to 12 884 British thermal units per pound).

Proximate analysis results of sampling adjacent to the Chute Creek adit during the 1987 field season, are summarized in Table 9. These samples were taken from four distinct coal seams in the Chute Creek 'A' coal bed (Figure 9). Residual moisture (air-dried) ranges from 3.03 to 3.72 per cent; ash 7.0 to 22.07 per cent; volatile matter, 33.21 to 38.95 per cent; fixed carbon, 41.65 to 52.27 per cent; and sulphur, 1.39 to 3.16 per cent. Calorific values range from 24.3 to 30.0 megajoules per kilogram (10 446 to 12 879 British thermal units per pound).

QUINSAM COALFIELD

Proximate analysis and calorific value data classify the Quinsam and Chute Creek deposits as thermal-quality coals straddling the boundary between high-volatile 'A' and 'B' bituminous rank. All gradations from clean coal

TABLE 7
CHUTE CREEK BOREHOLES, PROXIMATE ANALYSES

COAL BED	BASIS	M%	ASH%	VM%	FC%	S%	Calorific Value MJ/kg	Calorific Value BTU	N
'A'	ad	2.90	16.92	34.37	45.81	1.76	26.2	11251	12
	d	xxxx	17.43	35.40	47.18	1.81			
'B'	ad	2.43	37.28	27.49	32.80	0.89	18.5	7960	8
	d	xxxx	38.21	28.17	33.62	0.91			
'C'	ad	2.44	20.44	33.69	43.44	3.08	24.9	10716	8
	d	xxxx	20.95	34.53	44.53	3.16			
'D'	ad	2.93	25.06	28.77	43.25	0.57	23.2	9980	6
	d	xxxx	28.82	29.64	44.56	0.59			

(NOTE: DATA ARE AVERAGED)

TABLE 8
CHUTE CREEK, PROXIMATE ANALYSES, CLEAN COAL

COAL BED	BASIS	M%	ASH%	VM%	FC%	S%	Calorific Value MJ/kg	Calorific Value BTU	FSI	N
'A'	ad	2.23	8.04	36.36	53.37	1.19	29.9	12849	2.2	6
	d	xxxx	8.22	37.19	54.59	1.22	30.6	13143		
'B'	ad	2.19	10.53	35.71	51.57	1.01	28.6	12308	2.0	4
	d	xxxx	10.77	36.51	52.72	1.02	29.3	12584		
'C'	ad	1.83	9.89	38.49	49.79	2.64	30.0	12884	4.0	4
	d	xxxx	10.07	39.21	50.72	2.69	30.5	13126		
'D'	ad	2.48	10.08	33.40	54.04	0.76	29.0	12470	1.5	3
	d	xxxx	10.34	34.25	55.41	0.78	29.7	12787		

(NOTE: FLOAT 1.60 S.G., DATA ARE AVERAGED)

TABLE 9
CHUTE CREEK ADIT, PROXIMATE ANALYSES

COAL SAMPLE	BASIS	M%	ASH%	VM%	FC%	S%	Calorific Value MG/kg	Calorific Value BTU
'1'	ad	3.24	7.00	37.49	52.27	1.75	30.0	12879
	d	xxxx	7.23	38.75	54.02	1.81	31.0	13310
'2'	ad	3.05	9.53	38.95	48.47	1.39	28.8	12395
	d	xxxx	9.83	40.18	49.99	1.43	29.7	12785
'3'	ad	3.72	13.76	34.89	47.63	1.66	28.3	11415
	d	xxxx	14.29	36.24	49.47	1.72	27.6	11856
'4'	ad	3.03	11.14	36.00	49.83	2.18	28.3	12160
	d	xxxx	11.49	37.12	51.39	2.25	29.2	12540
COMPOSITE	ad	3.07	22.07	33.21	41.65	3.16	24.3	10446
	d	xxxx	22.77	34.26	42.97	3.26	25.1	10777

(NOTE: 1987 SAMPLES, THIS STUDY, SEE FIGURE 9) to coaly rock are present. Results indicate the following range of values of raw coals throughout the Quinsam and Chute Creek areas, on an air-dried basis (excluding partings): residual moisture ranges from 1.8 to 4.0 per cent; ash, 7 to 38 per cent; volatile matter, 27 to 40 per cent; fixed carbon, 33 to 54 per cent; and sulphur, 0.5 to 4.2 per cent. Calorific values for raw coals (as received) range from 23 to 31.0 megajoules per kilogram (7960 to 13 310 British thermal units per pound).

The residual moisture content of all coals is low (range of 1.8 to 4.0 per cent), but appears to be typical of previously reported Comox Formation data (Saunders *et al.*, 1974).

The Quinsam No.1 coal bed is locally suitable for production of unwashed thermal coal, owing to its low-raw ash content and its lack of rock bands. Coal presently being mined at the surface in Pit 2N is of this nature. During transportation, the coal produces very few fines. Coal mined underground is being washed to meet market specifications.

The coal product from the Quinsam mine averages 26.5 megajoules per kilogram (11 400 British thermal units per pound), 0.8 per cent sulphur, 36 per cent volatiles and 48 per cent fixed carbon, with ash content ranging from 9 per cent in open-pit operations to 17 per cent in underground operations.

Air-dried calorific values for the Quinsam and Chute Creek coals vary as a function of their ash content. This is most evident in Table 9 where the samples range from coal with 22.07 per cent ash and a calorific value 24.3 megajoules per kilogram (10 446 British thermal units per pound) to coal with 7.0 per cent ash and a calorific value of 30.0 megajoules per kilogram (12 879 British thermal units per pound). Most of the coals can probably be cleaned to meet the Japanese thermal-coal specification of 25.1 megajoules per kilogram (10 800 British thermal units per pound, as-received), but yields will certainly vary.

TABLE 10
QUINSAM NO.1 COAL BED, ULTIMATE ANALYSIS (DRY BASIS)

% CARBON	72.42
% HYDROGEN	5.13
% NITROGEN	0.97
% CHLORINE	0.02
% SULPHUR	0.92
% ASH	9.33
% OXYGEN(DIFF)	11.21
% TOTAL	100.00
% EQUILIBRIUM MOISTURE	5.25

(NOTE: 1987 SAMPLES, THIS STUDY)

TABLE 11
CHUTE CREEK COMPOSITE, ULTIMATE ANALYSIS (DRY BASIS)

% CARBON	71.73
% HYDROGEN	4.97
% NITROGEN	1.17
% CHLORINE	0.00
% SULPHUR	1.85
% ASH	10.78
% OXYGEN(DIFF)	9.50
% TOTAL	100.00
% EQUILIBRIUM MOISTURE	4.98

(NOTE: 1987 SAMPLES, THIS STUDY)

ULTIMATE ANALYSIS

Very limited ultimate analysis data are available for the Quinsam coalfield. Results of sampling by Matheson (1989) and values presented in Tables 10 and 11, indicate the coal has fairly low sulphur and nitrogen contents. Because of this, it is probable that environmental problems associated with combustion will be relatively easy to overcome.

SULPHUR

Proximate analyses (Tables 4, 5, 6, 7, 8 and 9) include sulphur percentages for the Quinsam and Chute Creek coals. In addition, Tables 12 and 13 contain details of sulphur forms from two coal outcrops (Locations 18 and 16, Figure 4). It is evident that raw sulphur contents are quite variable in the Quinsam coalfield.

In this discussion, low-sulphur coals are defined as having less than 1 per cent sulphur, moderate-sulphur coals are those with greater than 1 per cent but less than

TABLE 12
QUINSAM NO.1 COAL BED, SULPHUR FORMS

COAL SAMPLE	PYRITIC	SULFATE	ORGANIC	TOTAL%
RIDER SEAM	1.29	0.11	0.91	2.31
NO.1 SEAM-UPPER	0.51	0.04	0.69	1.24
NO.1 SEAM-LOWER	0.05	0.01	0.40	0.46

(NOTE: 1987 SAMPLES, THIS STUDY)

TABLE 13
CHUTE CREEK, COAL BED 'A', SULPHUR FORMS

COAL SAMPLE	PYRITIC	SULFATE	ORGANIC	TOTAL%
'1'	0.50	0.04	1.27	1.81
'2'	0.29	0.01	1.13	1.43
'3'	0.67	0.03	1.02	1.72
'4'	1.02	0.07	1.16	2.25

(NOTE: 1987 SAMPLES, THIS STUDY)

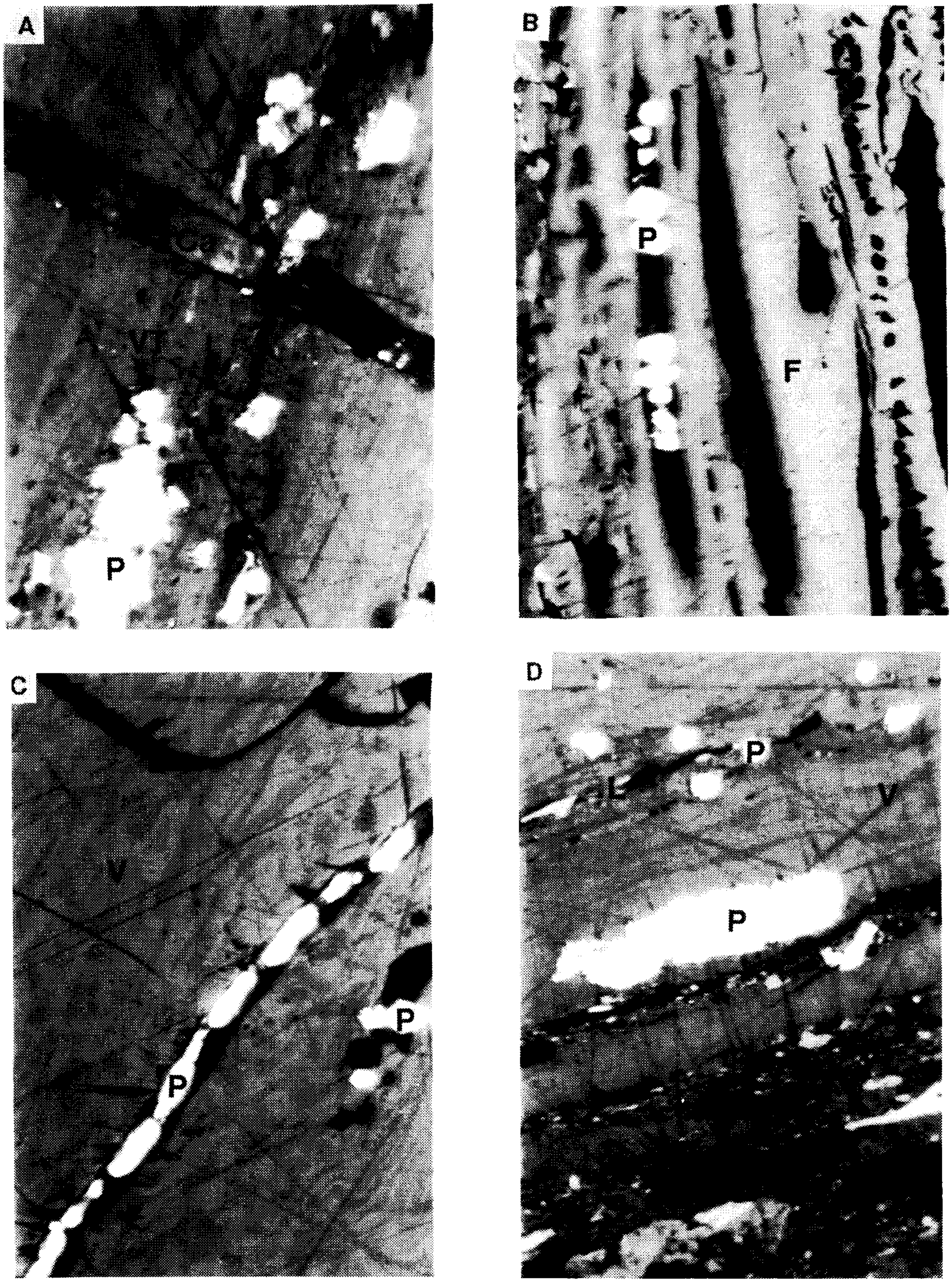

Plate 20. Photomicrographs illustrating the occurrence of pyrite in No.1 Rider Seam, Quinsam colliery. A:Cleat in vitrodetrinite filled with calcite. Pyrite lineation perpendicular to cleat direction. B: Framboidal pyrite deposited in cavities of fusinite. C: Secondary pyrite in cleat and cavity of vitrinite. D: Massive framboidal pyrite intergrown with vitrinite. Framboidal pyrite aligned with liptinite. (P-pyrite, V-vitrinite, VT-vitrodetrinite, F-fusinite, Ca-calcite, L-liptinite; magnification, 50X).

2 per cent sulphur, and high-sulphur coals have at least 2 per cent sulphur. This usage follows current Japanese practice for thermal coals. Sulphur content of the Cumberland member coals ranges from 0.70 to 4.12 per cent (higher values are found in the No.1 Rider seam), on an air-dried basis, while the Dunsmuir member coals range from 0.57 to 3.72 per cent.

The Quinsam No.1 seam has a low sulphur content in Pits 2N and 3N (Table 5, Figure 5). The southeast pit areas have values slightly above 1 per cent (dry basis) and therefore are amenable to washing for sulphur reduction, assuming that the pyritic and organic sulphur ratios are similar in this area (Table 12). The Quinsam No.2, No.3 and No.4 beds are more difficult to beneficiate and they do not readily yield clean products with less than 2 per cent sulphur (dry basis; Engler, 1977).

The Chute Creek 'A' bed yields moderate-sulphur products and reduction is limited by the large percentage of organic sulphur (Table 13). However, in coal bed 'A', ratios between pyritic and organic sulphur change as one moves down section, and this would allow for some sulphur reduction during beneficiation, which is evidenced by the data in Tables 7 and 8. The Chute Creek 'B' bed displays a different beneficiation characteristic; the sulphur content is increased by washing (Perry, 1986), changing the category from low to moderate-sulphur coal. There are no data on sulphur form for bed 'B'. The 'C' bed yields a high-sulphur coal, which is reduced somewhat by washing. The Chute Creek 'D' bed has a consistently low sulphur content, and does not require washing for sulphur reduction.

Pyrite Occurrence, No.1 Rider Seam, Quinsam

Microscopic examination of the coal samples from the No.1 Rider seam indicates that pyrite is abundant (Plate 20). In general, this pyrite is framboidal and aggregated rather than disseminated. The framboids are usually intergrown with the vitrinite macerals. Pyrite in the form of fine grains or fine concretions also occurs and is noted elsewhere as being particulary common in the microlithotypes containing a high proportion of vitrinite (Mackowsky, 1975). Pyrite was also deposited in the cavities of fusinite, and may occur as stringers which are aligned with liptinite macerals and perpendicular to cleats. Cleat spaces are generally filled with calcite, but some pyrite is evident in cleats, cracks and fissures. Vitrinite macerals include collinite, desmocollinite and vitrodetrinite (International Committee for Coal Petrology, 1963), and inertinites include fusinite and semifusinite.

In general, coals deposited in paralic basins are richer in pyrite than those in limnic basins (Mackowsky, 1975). The pyrite high content of the No.1 Rider is characteristic of seams which have been influenced by marine transgressions. Coals overlain by marine strata have a high sulphur content due to the availability of sulphate ions and the moderating pH of the marine waters. Primary iron sulphide occurs as nodules and fine crystals, which is evidenced in the No.1 Rider seam (Teichmuller and Teichmuller, 1982). In addition, there is some evidence of minor secondary iron sulphides deposited in fractures and cleats.

Potential acid generation from pyrite in the No.1 Rider seam on the Quinsam property is of importance due to the fact that this seam is being left in place as a roof support for the underground workings. Examination of samples from this seam indicates that the pyritic material is mostly distributed throughout the coal matrix, and is not concentrated along cleats (Plate 20). Moreover, the cleats are usually filled with calcite, which would potentially neutralize any acidic waters that might be produced.

SWELLING PROPERTIES

Most of the Quinsam and Chute Creek coals are non-caking, although they usually agglomerate to some extent. In the Cumberland member, the Quinsam No.1 bed has a free swelling index (FSI) of 0.5 to 2.0, and the No.2 bed has an FSI of 1.0 to 1.5. The Quinsam No.3 bed, in the Dunsmuir member, has an FSI of 1 to 3 (company reports). Average FSI values from borehole samples, of the Quinsam area coal beds are listed in Table 5. No tests have been reported for the Quinsam No.4 bed. The Chute Creek 'A', 'B' and 'D' coals have an average FSI of 1.5 to 2.2 (Table 8). The Chute Creek 'C' bed has moderate caking power, with an FSI of 4.

The modest coking power of the Quinsam and Chute Creek coals should not pose a difficulty to their marketing as thermal coals, in which a maximum FSI of 4 is tolerable. Coals with FSI greater than 2.5 may be suitable for coke production, provided that their sulphur can be held to less than 1 per cent and their ash to less than 10 per cent. The Chute Creek 'A' bed may be washable to these specifications; the other coals either lack sufficient coking power or have irreducibly high sulphur contents.

RANK DISTRIBUTION

Limited exposures in the Quinsam coalfield provided 18 sample locations for vitrinite reflectance studies (Figure 4). Data are summarized in Table 14. Mean maximum reflectance values (R_{max}) range from 0.52 to 0.85 per cent. Mean random values (Rm) range from 0.44 to 0.79 per cent. This implies that the coals span the range from high-volatile bituminous 'C' to high-volatile bituminous 'A', based solely on reflectance data. However, the two data points with reflectance values falling in the high-volatile bituminous 'C' category were from fairly dirty samples high in the section (Sample locations 30 and 109,

TABLE 14
SAMPLE LOCATION AND VITRINITE REFLECTANCE DATA
QUINSAM COALFIELD
UTM ZONE 10

SAMPLE NO.	UTM EASTING	UTM NORTHING	ELEVATION (METRES)	VITRINITE REFLECTANCE VALUES(%) MEAN MAX	MEAN RANDOM
15	326810	5526960	564	.81	.76
16	326750	5527350	526	.71	.66
18	322525	5533200	351	.79	.69
29	323610	5534845	237	.79	.77
30	323490	5534650	239	.59	.54
31	323380	5534520	240	.75	.72
32	323350	5534100	242	.63	.59
44	322280	5531420	314	.72	.67
45	322185	5530880	338	.77	.72
46	325065	5532420	274	.85	.79
62	325030	5531580	287	.74	.70
63	325005	5529120	450	.69	.57
65	325385	5528020	515	.64	.61
67	325400	5528230	501	.72	.67
107	324940	5532340	274	.61	.59
109	324250	5530780	360	.52	.50
121	326320	5530685	500	.78	.77
122	325200	5525140	666	.77	.76

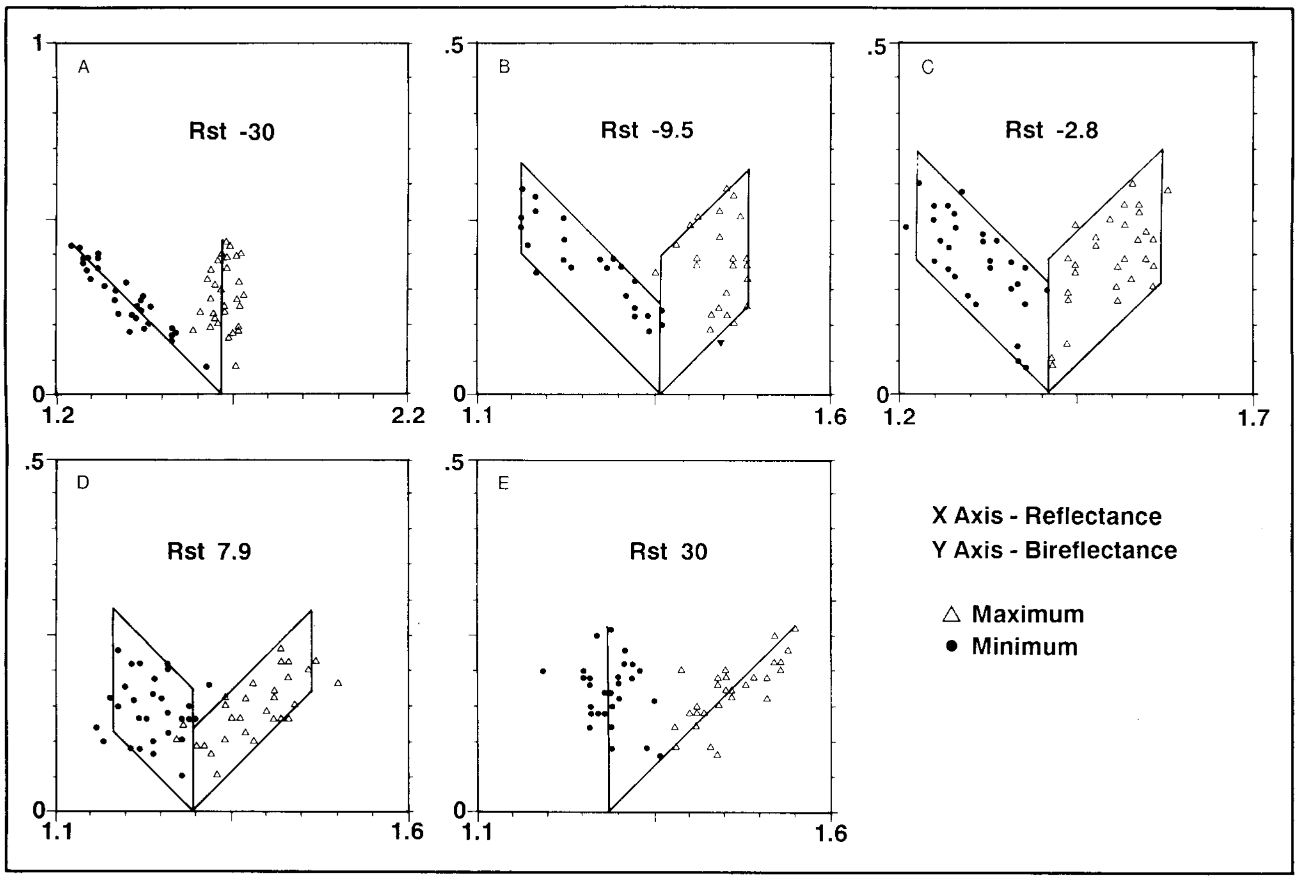

Figure 20. Interpreted reflectance crosspolts of five natural vitrinite samples which span the range of uniaxial negative to uniaxial positive. Rst parameter is displayed (after Kilby, 1988). A: uniaxial negative, B and C: biaxial negative, D: biaxial positive, E: uniaxial positive.

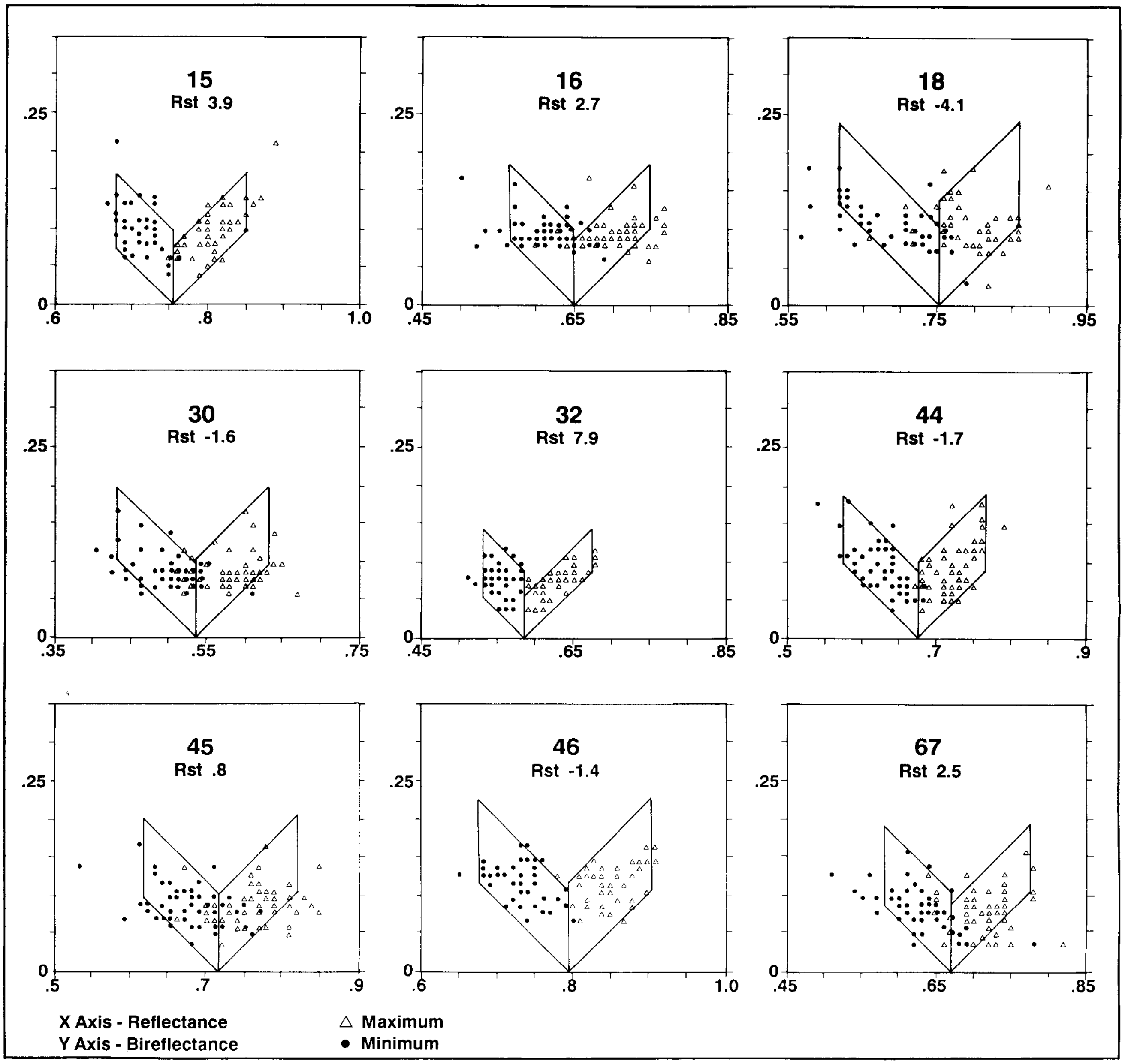

Figure 21. Interpreted reflectance crossplots of nine vitrinite samples from the Quinsam area illustrating biaxial negative and positive characteristics with Rst parameters displayed (*see* Figure 4 for sample locations).

Figure 4). The bulk of sample data spans the high-volatile bituminous 'A' to 'B' range, which is also reflected in the proximate analysis results.

Reflectance generally increases down-section (Hilt's Law) with some scatter, which could be attributed to analytical or sample variability or to the difference in heat flow characteristics of different rock types (Grieve, 1987). This is consistent with the rest of the Comox sub-basin although complex coalification patterns are apparent in this region, in general due to overprinting by thermal events associated with regional plutonism (Kenyon and Bickford, 1989). The highest R_{max} value in the Quinsam coalfield is from location 46 on the Iron River (0.85 per cent), which is somewhat anomalous considering that the beds sampled (No.3/4) are high in the coal-measures section. Local frictional heating associated with proximity of a large thrust fault (Boundary fault, Figure 4) may be responsible for the anomalous reflectance value from this coal.

A comparison of reference crossplots (Figure 20; Kilby, 1988), with crossplots for nine coal samples from the study area (Figure 21), indicate that the Quinsam

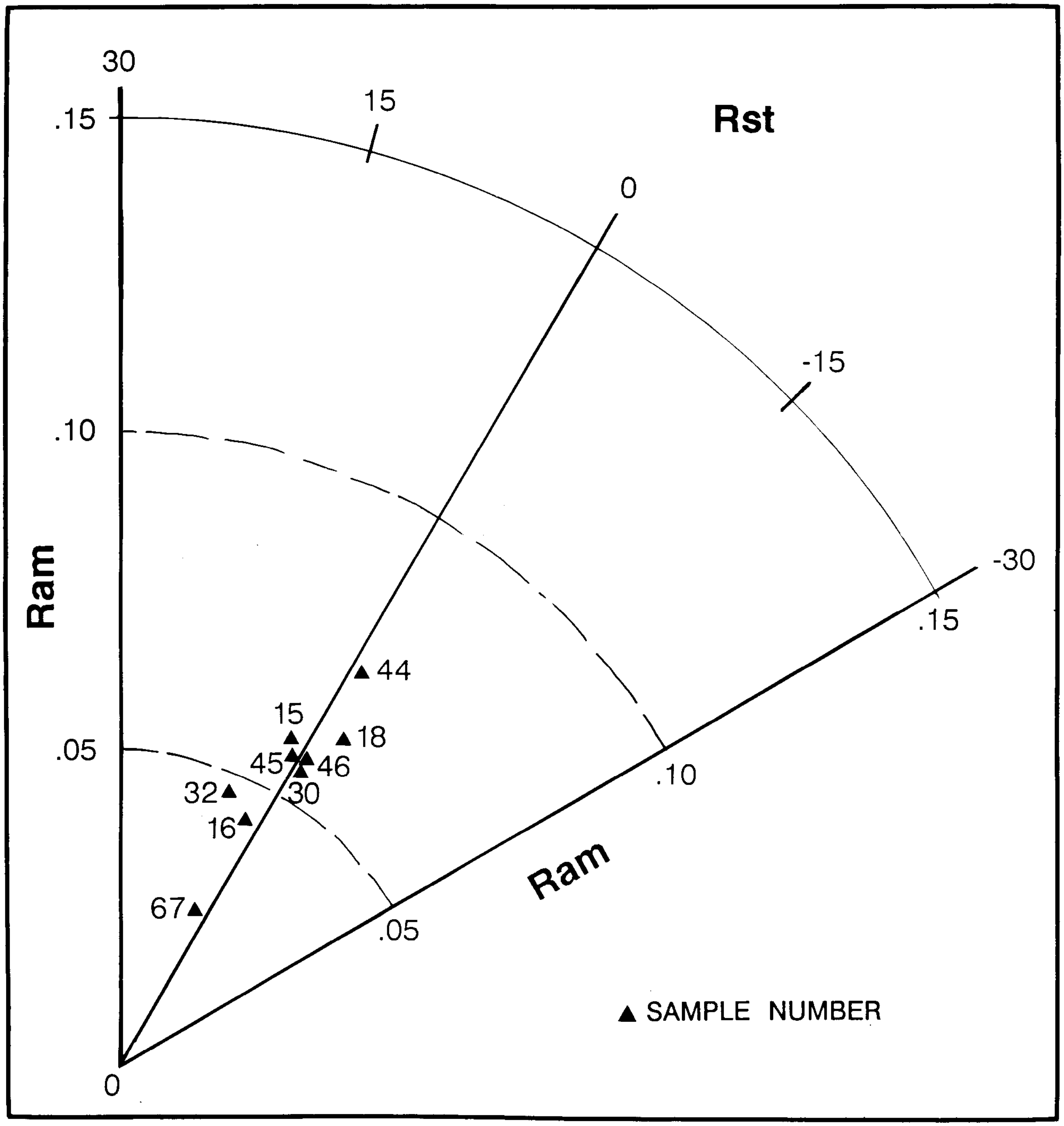

Figure 22. Working scale RIS classification chart from Kilby, (1988). Graphical interpretation of Rst values presented in Figure 21.

coals have biaxial negative and positive reflectance-indicating surfaces, with reflectance style values (Rst) of -4.1 to +7.9 (Figure 22).

Kilby (1986) indicates that development of optical biaxiality in vitrinites is due to the presence of stress in a direction not perpendicular to bedding during coalification. Thus, the shapes of reflectance-indicating surfaces are influenced by time, temperature and tectonics. If the surface is not uniaxial negative which is the case here (Figures 21 and 22), the assumption can be made that some syntectonic coalification occurred.

THE QUINSAM COAL MINE

MINING

The Brinco Coal Corporation (previously Quinsam Coal Limited) operates the Quinsam mine. Currently, it is mining the No.1 coal bed, in Pit 2N, north of Middle Quinsam Lake, by both open-pit and underground methods (Figure 4). Thickness of coal in the active pit ranges from 3.3 to 4.2 metres. The deliverable coal product from the Quinsam mine averages 26.5 megajoules per kilogram (11 400 British thermal units per pound), 0.8 per cent sulphur, 36 per cent volatiles and 48 per cent fixed carbon, with ash content ranging from 9 per cent in open-pit operations to 17 per cent in underground operations.

Considerable scope exists for both the extension of open-pit mining along strike from the existing site and for underground mining, at depths of 90 to 150 metres, to the north of the open-pit area (Barnstable, 1980). Additional drilling will probabaly be required to establish the full extent of underground reserves. Future open-pit plans involve diminished activity in Pit 2N, and development of Pits 1, 2 and 3S.

In the open-pit operation, topsoil is removed and stockpiled by bulldozers, and the bedrock overlying the No.1 coal bed is drilled and blasted prior to removal by shovels and trucks (Plate 21). No attempt is made to recover the No.2 coal bed, which is present near the top of the mine highwall but is thin, impure and oxidized (Section 2, Appendix A). The highwall is maintained at a slope of 60° to 65°. It appears to be standing well, except for some slaking and ravelling of the Cumberland siltstones immediately above the No.1 coal bed. A steeper slope (locally up to 85°) has been cut in the basal Dunsmuir sandstones above the No.1 coal bed. The sand-

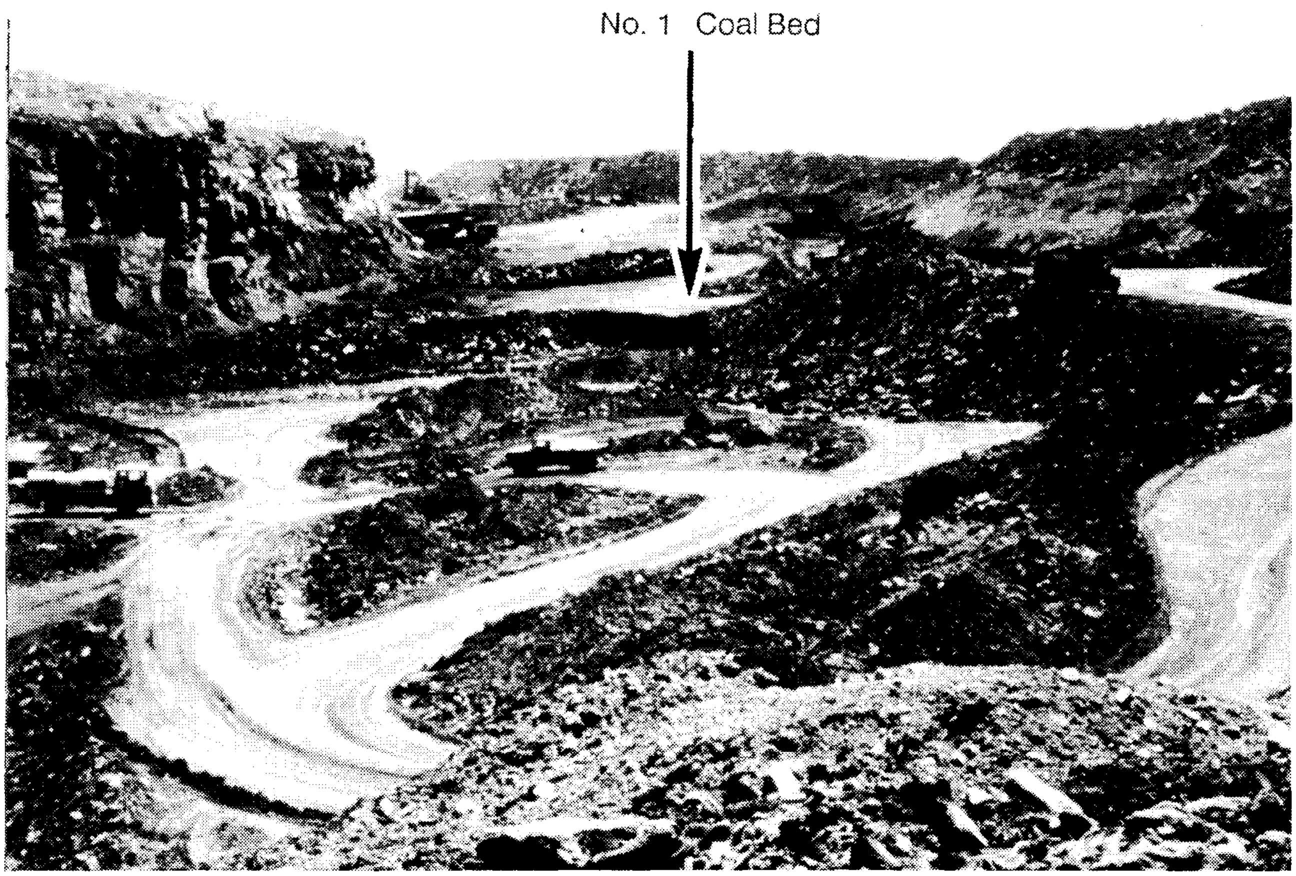

Plate 21. Open pit mining operation in Pit 2N on the Quinsam property. All the material on top of the No.1 coal bed has been removed in preparation for removing this seam.

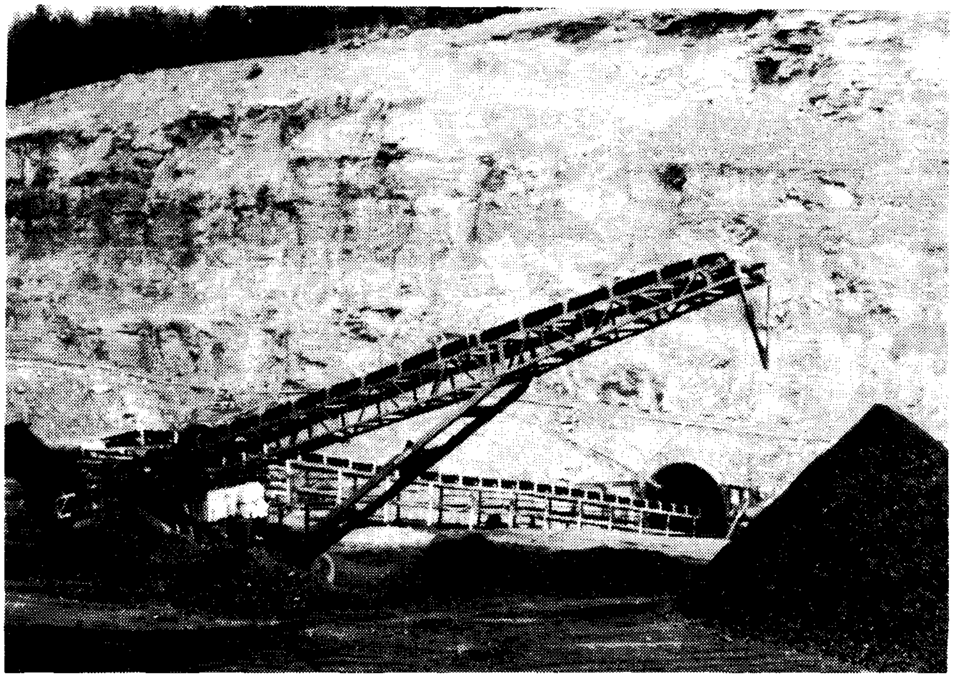

Plate 22. Underground mine entrance at Quinsam, Pit 2N. A conveyor belt transports the mined coal to the surface via this portal.

stones are standing well, except for occasional small toppling failures which appear to be related to a joint pattern. A cutoff ditch has been excavated along the top of the highwall, to prevent surface water from running over the working face.

Run-of-mine coal from the open-pit is crushed and screened at the minesite, and shipped without further preparation.

Underground testing began in late 1989, with the development of three portals in the No.1 coal seam, approximately 30 metres below the top of the highwall. These tunnels were driven 60 metres into the highwall at the southeast tip of Pit 2N, and then were interlinked. Coal is removed with a 'continuous miner', using conventional room and pillar techniques. Shuttle cars deposit the coal on a conveyor belt which carries it to surface via one of the portals (Plate 22). Worked tunnels and drifts are approximately 3 metres high and 5 metres wide. The No.1 Rider seam has been left in place and is secured with wire mesh and roof bolts. A heavy media wash plant began operation in early February, 1991, as coal from the underground operation is higher in ash than that from the open-pit, and therefore needs processing.

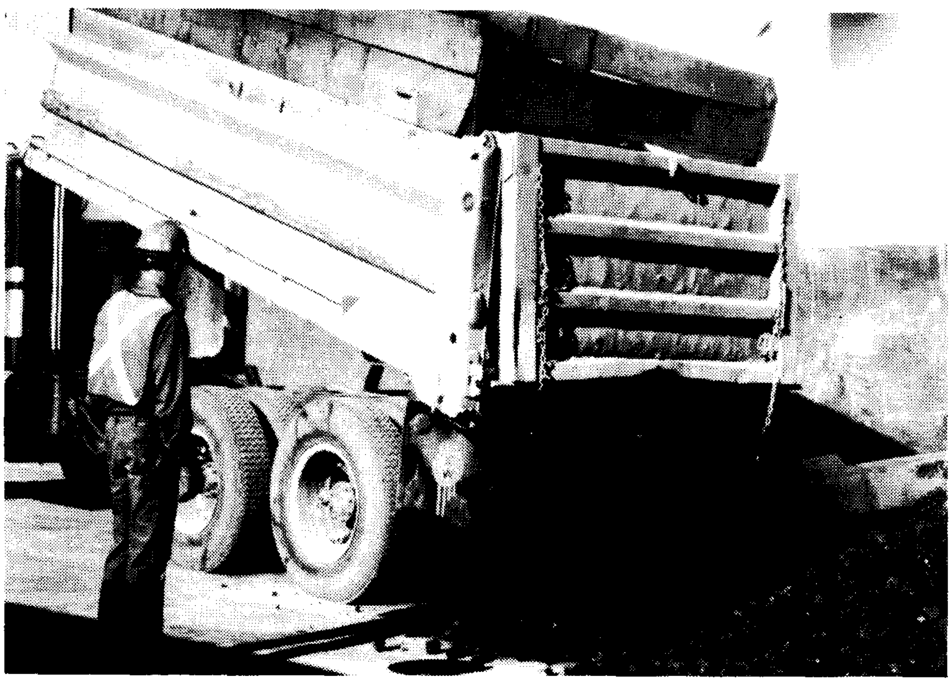

Plate 23. Trucks, transporting the coal from the minesite, drive onto the barges to unload their cargo at the docking facility at Middlepoint.

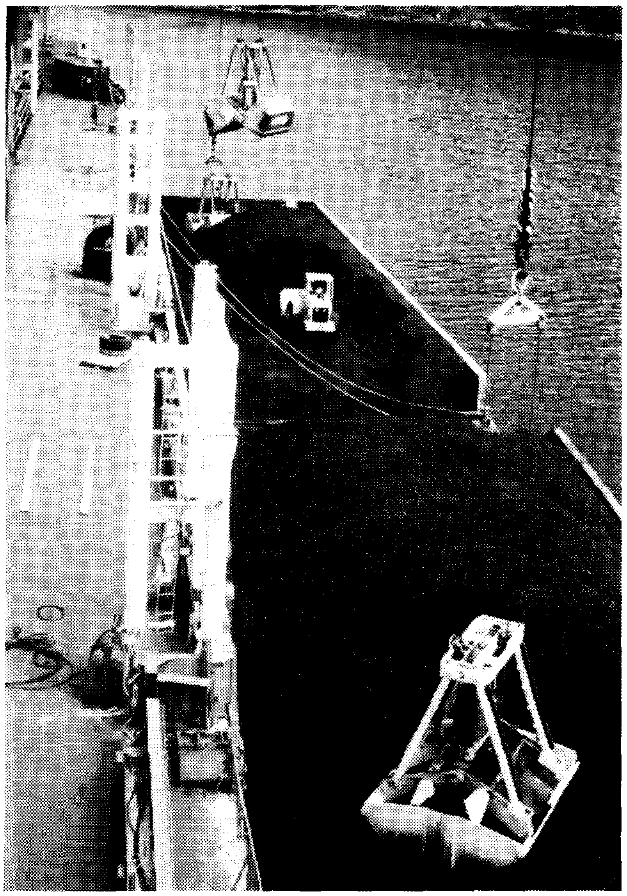

Plate 24. A Korean ship loading coal, from barges towed from Middlepoint, on a ship bound for Japan. The new facility at Texada Island has replaced this method.

INFRASTRUCTURE

Coal is trucked from the minesite to tidewater at Middle Point, a docking facility 8 kilometres north of Campbell River (Figure 3), where it is loaded onto barges (Plate 23). When the company first began exporting coal, it was necessary to tow the barges from Middle Point to the Fraser River on the mainland, where the coal was once again loaded into trucks and hauled to Westshore Terminals' Roberts Bank coal port near Vancouver. Requirements for large shipments necessitated a more efficient method of transport. For a time, Deepwater Bay, off Quadra Island, served as a berth for Panamax-sized vessels (Figure 3). Coal was loaded directly from the barges onto these cargo ships (Plate 24).

In order to increase shipping volumes, the Brinco Coal Corporation has secured an agreement with Ideal Cement Limited to use its loading facility on Texada Island, 65 kilometres south of Middle Point. Necessary upgrading of the facility was completed by the coal company in June, 1990. Coal is now barged directly to Texada Island. Panamax-size vessels are loaded at this facility, which can handle 15 000 tonnes of coal per day (Plate 25). Most of the coal is exported to Japan, but several industrial companies on the mainland provide local markets.

PRODUCTION

Mining officially began in 1985, with markets limited to local cement plants and pulp and paper mills. The first overseas exports were shipped in 1988. During an 8-month period, February to September, three trial shipments totalling 88 000 tonnes were sent to Japan. Total production for 1988 was 150 000 tonnes. Coal sales in 1989 amounted to 200 000 tonnes, of which 180 000 tonnes were shipped overseas, mainly to Japan. Thermal coal produc-

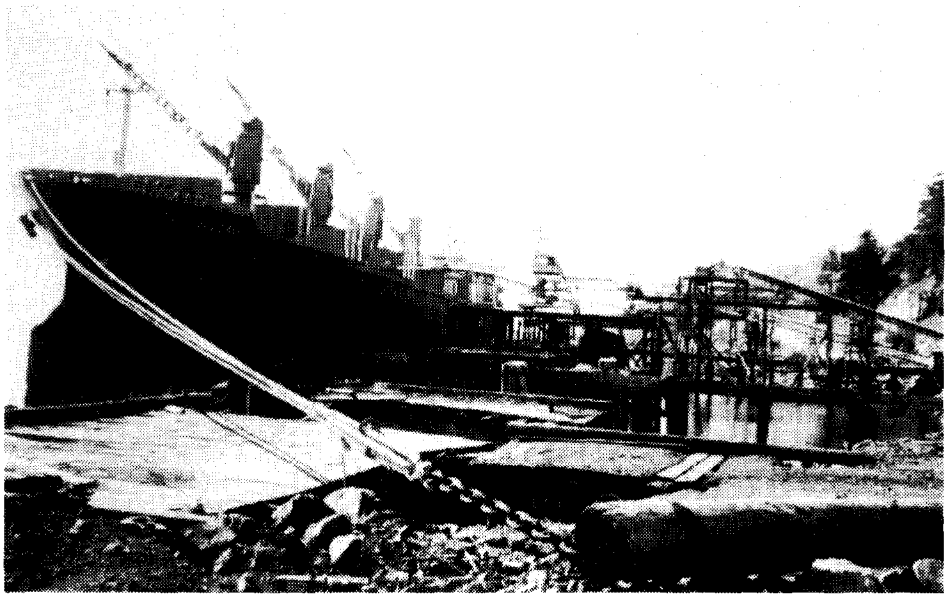

Plate 25. The new coal loading facility on Texada Island: photo courtesy of Jack Cann, Brinco Coal Corporation.

tion reached 250 000 tonnes in 1990, utilizing coal from both open-pit and underground mines. Underground operations are expected to contribute as much as half of the anticipated production of 400 000 to 500 000 tonnes in 1991.

Brinco Coal Corporation operates under a limited production permit which allows the company to mine up to 1 000 000 tonnes of coal per year. Its production strategy depends on available markets and the respective costs of the open-pit and underground operations.

With a coal resource base estimated at 43.2 million tonnes, and a current maximum coal extraction permit of a million tonnes per year, the mine should be operational for more than 40 years.

CONCLUSIONS

The Quinsam coalfield, which includes both the Quinsam and Chute Creek coal deposits, is an erosional outlier of the Comox Formation, at the base of the Upper Cretaceous Nanaimo Group; age of these sediments is further supported by fossil evidence and uranium-lead dating carried out during the course of this study.

Correlations can be made between the Quinsam coalfield and other parts of the Comox sub-basin. Three mappable lithologic units of member rank are distinguished: in ascending order, Benson, Cumberland, and Dunsmuir. The upper part of the Dunsmuir member has been eroded in the study area. The irregular topography of the pre-Cretaceous basement controlled patterns of sedimentation, and hence of coal distribution.

The Benson member conglomerates were deposited in west to southwest-trending fluvial channels. Abundant paleocurrent indicators indicate a paleoflow direction to the west and southwest, similar to other areas in the Comox sub-basin. Further work is required to assess whether paleocurrent directions are consistent throughout the entire Comox sub-basin. The Coast Range is the possible source area for the Benson conglomerate.

The Cumberland member coals appear to have been deposited in backswamps, under generally paralic conditions along a coastal plain, bounded by rolling hills of basement rock. Paleotopography controlled the extent of deposition. During this time period, there was a brief transgressive drowning of the coastal plain.

The Dunsmuir member coals appear to have been deposited in back-barrier lagoons, under dominantly marine conditions, along a sandy shelf which was bordered by a complex of beaches, spits and bars. Iron-rich sandstones in this member probably represent ancient beach placers. Analyses of these placers did not yield high gold contents.

Three sets of faults have been mapped in the study area. Set 1 comprises east trending, steep, extensional faults which dip 45° to 65° to the north and south and which form a series of horsts and grabens. Set 2 comprises northwest to north-trending compressional faults, which dip moderately to steeply to the northeast and east. Set 3 comprises northeast to east-trending tear faults, with near vertical dips. Coal measures are generally only gently deformed by block-faulting and tilting, with regional dips from 8° to 12° to the northeast. Some bedding-plane shear is seen in coaly zones, usually concentrated in thin partings between thick, clean, hard coal beds.

Most of the Quinsam and Chute Creek coals are autochthonous (formed by peat growth in place). Some of the uppermost Quinsam coals are partially allochthonous (formed by accumulations of transported plant debris). The Chute Creek coal zone, A to D beds, is stratigraphically higher than the major beds of the Quinsam deposit.

The Quinsam and Chute Creek coals straddle the boundary between high volatile 'A' and 'B' bituminous rank. The range of proximate analysis data on raw coals throughout the entire coalfield is: residual moisture, 1.8 to 4.0 per cent; ash, 7 to 38 per cent; volatile matter, 27 to 40 per cent; fixed carbon, 34 to 54 per cent, sulphur, 0.5 to 4.2 per cent, calorific values, 23 to 31.0 megajoules per kilogram.

The range of vitrinite reflectance (R_{max}) values is minimal in the study area is 0.52 to .85 per cent. In the Quinsam coalfield, as well as other parts of the Comox sub-basin, Rst values indicate that all coals are biaxial, which implies syntectonic coalification.

The current total coal resource estimate for the Quinsam property (coal beds No.1, 2 and 3) is 23.3 million tonnes of open-pit reserves and 19.9 million tonnes of underground reserves for a total of 43.2 million tonnes, of which 23.4 million are proven. If Quinsam produces at the rate allowed by its limited production permit, the mine will operate for approximately 40 years.

The total in situ coal resource within the Chute Creek 'A', 'B', 'C' and 'D' coal beds, is 5.26 million tonnes. Of this resource, 3.35 million tonnes are considered to be potentially mineable. Work in this area has ceased and it is unlikely that this property will be developed in the near future.

The amount of coalbed methane retained by Quinsam coals is limited by rank and depth. Preliminary data suggests a potential coalbed gas resource of 30.1 billion cubic metres or 0.09 trillion cubic feet in the Quinsam coalfield.

Potential for additional coal discoveries is minimal at Quinsam, and only fair at Chute Creek. Boreholes near Lukwa Lake were abandoned before reaching the stratigraphic level of the Quinsam No.1 coal bed. This bed, north of Pit 2N, and the Quinsam No.3 coal bed across the Iron River from Pit 7S, need further investigation. The Chute Creek 'A' through 'D' coal beds may also be present in the undrilled area north of the existing Chute Creek reserve block.

Unexplored country to the south and southeast, along structural strike from the study area, should be investigated for potential coal deposits. Detailed mapping of the Campbell River coalfield would firmly establish relationships between this area and the Quinsam coalfield.

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APPENDIX A

MEASURED SECTIONS

MEASURED SECTION NO.1. ALONG QUINSAM RIVER
Top of section: UTM (ZONE 10) 323630 E, 5534960 N, at station **N 123**.
Base of section: UTM 323365 E, 5534100 N, at station **N 132**.

Map-sheet: BCGS 92F.093

Unit	Description COMOX FORMATION: DUNSMUIR MEMBER:	Thickness (m)	Height (m)
66	Sandstone - fine to medium-grained, light grey, brown-weathering, hard	0.70	154.27
65	Sandstone - fine-grained, brown-weathering; silty and carbonaceous at top.	0.34	153.57
64	Sandstone - medium-grained, green, brown-weathering, glauconitic, friable, fair to good intergranular porosity.	0.82	153.23
63	COAL - dull, dirty, shaly	0.06	152.41
62	Sandstone - medium to coarse-grained, white, rusty-weathering, coaly at top with log imprints. Hummocky top surface, maybe sand waves?	0.15	152.35
61	COAL - dull and bright, dirty.	0.03	152.20
60	Sandstone - fine-grained, light grey, brown-weathering, medium-bedded, spheroidal-weathering, rooty, with abundant log imprints.	0.94	152.17
59	COAL - dull and bright, sandy, dirty, platy. station 29.	0.30	151.23
58	Sandstone - medium to coarse-grained white, rusty-weathering, arkosic, friable, rooty at top. Fair intergranular porosity.	0.24	150.93
57	Sandstone and COAL -sandstone as above with abundant lenses of bright coal.	0.05	150.69
56	Sandstone - medium-grained, arkosic a single hummocky bed.	0.18	150.64
55	COAL - bright banded, sandy.	0.06	150.46
54	Sandstone - fine to medium-grained, brown-weathering, granitic, abundant plant debris; coaly and rooty at top.	0.08	150.40
53	COAL - bright banded, sandy.	0.03	150.32
52	Sandstone - fine to medium-grained, light grey, brown-weathering, granitic, abundant plant debris; coaly and rooty at top.	0.14	150.29
51	COAL - bright banded, with sandy lenses.	0.11	150.15
50	Sandstone - medium-grained, light grey, brown-weathering, with abundant plant debris; coaly and rooty at top.	1.40	150.04
	(Concealed interval) - river gravels.	28.77	148.64
49	Sandstone - medium-grained, white, massive.	10.00	119.87
48	Sandstone - medium-grained, light grey, brown-weathering, medium-bedded, with abundant heavy mineral laminae towards base.	0.90	109.87
47	Sandstone - fine-grained, black, dense, estimated 50% magnetite.	0.05	108.97
46	Sandstone - medium-grained, light grey, brown-weathering, with minor heavy mineral laminae.	0.67	108.92
45	Sandstone - medium to coarse-grained, white, granitic, friable; trough crossbedded at top. Good intergranular porosity.	1.07	108.25

43	Siltstone - dark grey to black, coaly.	0.05	89.97
42	Sandstone - medium to coarse-grained, strongly rusty-weathering, as above.	0.25	89.92
41	COAL - bright banded.	0.05	89.67
40	Sandstone - medium-grained, dark grey, carbonaceous.	0.02	89.62
39	COAL -bright banded. station 30.	0.09	89.60
38	Sandstone - medium-grained, dark grey, carbonaceous.	0.03	89.51
37	COAL - dull and bright, dirty.	0.06	89.48
36	Siltstone - dark grey, carbonaceous, rooty. Gradational base.	0.15	89.42
35	Sandstone - very finegrained, silty, medium to dark grey.	0.12	89.27
34	Sandstone - medium-grained, white, rusty-weathering, massive at top, large-scale low-angle crosslamination and scaley cross-stratification near base.	18.20	89.15
33	Sandstone - medium to coarse-grained, white, light brownweathering, thick-bedded with high-angle trough cross-laminae weathering out into platy stacks.	9.00	70.95
32	Sandstone - medium to coarse-grained, light grey, in part rusty brown weathering; thick-bedded to massive.	17.84	61.95
	--- *Roof of Quinsam No.4 coal bed* ---		
31	COAL - bright banded, hard. station 31.	0.32	44.11
	--- *Floor of Quinsam No.4 coal bed* ---		
30	Sandstone - medium-grained, light brown, rusty-weathering, platy to flaggy.	0.46	43.79
29	Mudstone - dark brown, carbonaceous, with bright coaly streaks.	0.06	43.33
28	Sandstone - medium-grained, light brown, rusty-weathering, flaggy, occasional low-angle trough crossbeds.	0.85	43.27
27	Sandstone - fine-grained, carbonaceous, silty, fissile.	0.24	42.42
26	Sandstone - medium to coarse-grained, light grey; top contains large symmetrical ripplemarks, striking 090o and Thalassinoides burrows.	3.00	42.18
25	(Concealed interval) - occasional exposures of sandstone as above.	8.50	39.18
24	Sandstone - medium to coarse-grained, light grey, brownish grey weathering, platy, hummocky cross-stratified; rare stringers of grit, composed of granules, mostly 4-8 mm range, some pebbles to 15 mm, of quartz, dark chert and basalt.	7.50	30.68
23	(Concealed interval) - stony till.	4.50	23.18
22	Sandstone - medium to coarse-grained, white, granitic, clean, medium planar beds with grit stringers marking their bases; herringbone crosslamination (indicated paleocurrents NW/SE); moderately cemented, fair to good intergranular porosity.	6.00	18.68
21	(Concealed interval) - stony till	4.50	12.68
20	Sandstone - medium-grained, white, orange-weathering.	2.40	8.18

	--- Roof of Quinsam No.3 coal bed ---		
19	COAL - bright banded, hard.	0.11	5.78
18	Mudstone - black, coaly, intensely sheared, soft.	0.09	5.67
17	COAL -bright banded, hard. station 32	0.69	5.58
16	Mudstone - black, coaly, intensely sheared, soft; 'mining dirt'.	0.03	4.89
15	COAL - dull and bright, hard. Channel sample GSC 1312.	0.44	4.86
14	Mudstone - dark brownish-grey, rooty at top, becoming silty below. Occasional thick bright coal bands. Gradational base.	0.40	4.42
13	Siltstone - medium grey, hematitic-weathering, sandy, soft.	0.21	4.02
12	Mudstone - black, coaly, fissile.	0.17	3.81
11	COAL - dull and bright.	0.09	3.64
10	Mudstone - black, coaly, fissile, hard.	0.12	3.55
9	COAL - dull and bright, hard. Channel sample GSC 1313.	0.49	3.43
8	COAL - stony.	0.06	2.94
	--- Floor of Quinsam No.3 coal bed ---		
7	Mudstone - dark brownish grey, rusty-weathering, silty, with scattered thick bright coal bands. Gradational base.	0.70	2.88
6	Sandstone - fine-grained, dark brownish-grey, carbonaceous, concretionary. Gradational base.	0.15	2.18
5	Sandstone - fine-grained, brown-weathering, silty, platy, granitic, with abundant plant trash.	0.91	2.03
	--- Roof of Quinsam No.3 Leader coal bed ---		
4	COAL - bright-banded, with abundant sandstone-filled burrows.	0.06	1.12
3	COAL - bright banded, hard.	0.58	1.06
	--- Floor of Quinsam No.3 Leader coal bed ---		
2	Mudstone - brown, carbonaceous, platy.	0.18	0.48
1	Sandstone - fine-grained, medium grey, carbonaceous, rooty, bioturbated.	0.30	0.30

MEASURED SECTION NO.2. IN HIGHWALL OF PIT 2N, QUINSAM COLLIERY
Top of section: UTM (ZONE 10) 322050 E, 5533590 N, in drainage ditch at crest of highwall; at station **N 2.**

Map-sheet: BCGS 92F.093

Unit	Description	Thickness (m)	Height (m)
	COMOX FORMATION: DUNSMUIR MEMBER:		
28	Sandstone - very coarsegrained, grey; scattered grit of chert, quartz, dark volcanic rock or argillite, abrupt base with mudstone rip-up clasts.	1.52	26.54
27	Sandstone - coarse-grained, clean, medium-bedded, light grey, orange-weathering, trace glauconite, mudstone rip-ups at base; erosional.	1.68	25.02
	COMOX FORMATION: CUMBERLAND MEMBER:		
26	Mudstone - dark grey and compact at top, rusty-weathering, becoming dark green to black below, with large sand-filled burrows, a few coaly streaks, sandy and glauconitic in basal 0.1 m.	0.46	23.34
	--- *Roof of Quinsam No.2 coal bed* ---		
25	COAL - dull banded, weathered, soft.	0.34	22.88
24	Mudstone - brown, rusty-weathering.	0.06	22.54
23	COAL - dull banded, weathered, soft.	0.15	22.48
	--- *Floor of Quinsam No.2 coal bed* ---		
22	Mudstone - brownish-grey, soft;seat-earth.	0.21	22.33
21	Mudstone - dark brown to black, carbonaceous, with coaly streaks.	0.79	22.12
20	Mudstone - light brownish grey, silty, with tiny plant fragments.	1.83	21.33
19	Mudstone - dark brown to black, reddish brown weathering.	0.91	19.50
18	Sandstone - very fine grained, silty, grey, gradational base.	6.10	18.59
17	Siltstone - grey, sandy, notably clean, essentially a micro-sandstone; with occasional lighter weathering, resistant ribs, perhaps sandstone bands? Abundant shell debris, of pelecypods including Ostrea, turritellid gastropods, crabs and barnacles. Ferruginous concret-ions are concentrated in discreet bands. Most contain plant fragments, but some contain shell debris. When fresh, the basal siltstone appears to be otherwise massive, but weathered blocks on the pit floor are flaggy weathering.	7.77	12.49
16	Mudstone - dark brown, carbonaceous, with abundant thin bright coal bands and white and yellow sulphate bloom.	0.23	4.72
	--- *Roof of Quinsam No.1 Rider coal bed* ---		
15	COAL - bright banded, platy; abundant sulphate bloom; visible pyrite.	0.47	4.49
	--- *Floor of Quinsam No.1 Rider coal bed* ---		
14	Mudstone - brownish-grey, abundant plant debris.	0.37	4.02

	--- Roof of Quinsam No.1 coal bed ---		
13	COAL - bright banded.	0.34	3.65
12	COAL - bright, with abundant pyrite and contorted calcite veinlets.	0.17	3.31
11	COAL - dull and bright.	0.41	3.14
10	Mudstone - black, coaly, hard with white specks; light-weathering.	0.02	2.73
9	COAL - bright banded.	0.50	2.71
8	Mudstone - coaly, as above.	0.02	2.21
7	COAL -bright banded, blocky.	0.52	2.19
6	Mudstone - coaly, as above.	0.02	1.67
5	COAL -bright banded.	0.44	1.65
4	Mudstone - chocolate brown, coaly, intensely sheared and wet.	0.05	1.21
3	COAL -bright banded.	1.04	1.16
	--- Floor of Quinsam No.1 coal bed ---		
2	Mudstone - light grey to white, very soft and slippery; rooted.	0.09	0.12
1	Mudstone, silty, harder, with abundant plant stems and Metasequoia fronds.	0.03	0.03

MEASURED SECTION NO.3. ALONG IRON RIVER
Top of section: UTM (ZONE 10) 325010 E, 5532420 N, at top of west cutbank, at station **N 113**.
Base of section: UTM 325160 E, 5532470 N, downstream at station **N 114**.

Map-sheet: BCGS 92F.093

Unit	**Description** **COMOX FORMATION: DUNSMUIR MEMBER:**	**Thickness (m)**	**Height (m)**
52	Mudstone - black, carbonaceous, platy, compact.	0.60	21.02
51	Sandstone - medium-grained, light grey, arkosic, rusty-weathering, massive.	2.80	20.42
50	Sandstone - as above but flaggy and planar crossbedded; medium to coarse-grained, white. Erosional base.	0.60	17.62
49	Siltstone - dark grey, sandy, intensely bioturbated.	0.12	17.02
48	COAL - dull and bright, hard.	0.11	16.90
47	Siltstone - dark grey, sandy, scattered bright coal streaks, grading down to fine-grained silty sandstone at base.	0.23	16.79
46	Siltstone - as above, grading down to sandstone, as above, Intense rusty weathering. Abundant bright coal steaks at top; scattered coalified logs. Erosional base.	0.26	16.56
45	Mudstone - black, coaly, intensely sheared.	0.17	16.30
	Note: Units 45 through 49 are cut out to the south along Iron River by the sandstones of Unit 50.		
	--- Roof of Quinsam No.4 coal bed ---		
44	COAL - dull banded, dirty, slightly sheared.	0.21	16.13
43	COAL - bright banded, contorted; thins southwards from 0.37 to 0.26 m.	0.32	15.92
42	COAL - bright banded, hard, clean.	0.43	15.60
	--- Floor of Quinsam No.4 coal bed ---		
41	Mudstone - black, coaly, fissile, tough.	0.12	15.17
40	Sandstone - medium-grained, dark grey, forms isolated lenses up to 0.05 m thick, scouring down into underlying mudstone.	0.03	15.05
39	Mudstone - black, coaly, as above.	0.52	15.02
	--- Roof of Quinsam No.3 coal bed ---		
38	COAL - dull banded, sheared.	0.09	14.50
37	COAL - dull and bright.	0.34	14.41
36	Mudstone - black, coaly, sheared.	0.02	14.07
35	COAL - dull banded. Channel sample GSC 1314 (units 35,37,38)	0.42	14.05
34	TONSTEIN station 46	0.06	13.99
33	COAL - dull and bright, hard. station 46	0.40	13.59
32	Mudstone - black, coaly; abundant thin bright coal bands.	0.50	13.09
31	COAL - dull banded, hard.	0.29	13.04
30	COAL - dull and bright. Channel sample GSC 1315 (units 30,31,33)	0.35	12.75
	--- Floor of Quinsam No.3 coal bed ---		
29	Sandstone - fine-grained, dark grey.	0.05	12.40
28	Mudstone - black, coaly, with abundant thick bright coal bands.	0.40	12.35

27	COAL - stony.	0.18	11.95
26	Mudstone - black, coaly, tough.	0.37	11.77
25	Mudstone - dark brown to black, carbonaceous, abundant thick, bright coal lenses; bioturbated.	0.82	11.40
24	COAL - dirty, platy.	0.15	10.58
23	Sandstone - fine-grained, brown, carbonaceous, with abundant plant debris, including ?Geonomites fronds. Scours into underlying unit; pinches out to north.	0.06	10.43
22	Mudstone - dark brownish-grey to black, mostly carbonaceous, with 15% silty and sandy lenses, abundant plant debris; rooty. Scoured base.	1.07	10.37
21	Sandstone - fine-grained, light brown, arkosic, rooty at top. Scoured base.	0.41	9.30
20	Mudstone - black, coaly, scattered thick, bright coal bands.	0.64	8.89
19	Sandstone - light brownish-grey, as above but no roots; planar-laminated. A crevasse splay?	0.15	8.25
18	Mudstone - coaly, as above, with scattered thick, bright coal bands.	0.49	8.10
17	Sandstone - fine-grained, ill-sorted, carbonaceous, pinches and swells; maybe large flasers?	0.03	7.61
16	COAL - bright, dirty, with mudstone streaks.	0.06	7.58
15	Mudstone - coaly, as above.	0.61	7.52
14	Siltstone - dark brownish grey, sandy, carbonaceous, with scattered thick, bright coal bands. Gradational base.	0.73	6.91
13	Sandstone - fine-grained, brown, arkosic, rooty, scoured base. Patchy intense bioturbation, mud-filled Pelecypodichnus burrows. Scattered well-rounded cobbles of rotten white granodiorite (maximum 80 mm).	0.40	6.18
12	Siltstone - as above, bioturbated.	0.43	5.78
11	COAL - stony.	0.03	5.35
10	Mudstone - dark brown to black, carbonaceous, scattered thick, bright coal bands.	0.21	5.32
9	COAL - stony.	0.05	5.11
8	Siltstone - as above, grading down to fine-grained sandstone as below. Gradational base.	0.27	5.06
7	Sandstone - fine-grained, brownish grey, arkosic, bioturbated.	0.55	4.79
6	Mudstone - dark grey, silty, carbonaceous, patchily bioturbated.	0.64	4.24

COMOX FORMATION: BENSON MEMBER:

5	Breccia/conglomerate - mostly subangular and tabular but some more rounded cobbles and boulders (maximum 750 mm) of banded argillite or cherty tuff, and about 20% cobbles of basalt, in a sparse matrix of fine-grained silty sand; the whole rock showing intense ankeritic alteration. Abrupt base.	0.50	3.60
4	Siltstone - black, sandy, carbonaceous. pebbly. Gradational base.	0.30	2.10
3	Breccia/conglomerate - as above. Erosional base.0.90	1.80	
2	Sandstone - fine-grained, poorly sorted, abundant blocky grit of kaolinized feldspar; alternating bleached, pale green		

	patches and iron-stained, brown patches. Patchy ankeritic and silicic alteration. Spheroidal weathering. Erosional base.	0.90	0.90
	BONANZA GROUP:		
1	Tuff - banded, very fine grained, cherty, striped yellowish brown and greenish-grey; resembles banded blocks found in overlying breccia. Crumpled and warped.		

MEASURED SECTION NO.4. ALONG STONE CREEK
Top of section: UTM (ZONE 10) 323120 E, 5528090 N, at top of northeast cutbank; at station **N 163**.
Base of section: UTM 323005 E, 5528350 N, at junction of creek with Iron River; at station **N 167**.
note: offsetting borehole: Luscar Chute Creek **QB-38.**

Map-sheet: BCGS 92F.083.

Unit	Description	Thickness (m)	Height (m)
	COMOX FORMATION: DUNSMUIR MEMBER:		
13	Sandstone - fine-grained, greenish grey, flaggy; some very thin bedded, shaly-weathering zones; occasional low-angle cut-and-fill structures. Scattered plant debris, and occasional clusters of rounded pebbles to 25 mm, of basalt and granodiorite	6.00	49.80
12	Sandstone - very fine to fine-grained, dark greenish grey, very thin-bedded, swaley cross-stratification (paleoflow 328o). Pebble lenses increase downward from 2 to 5% of section; maximum 100 mm, of hornblende granodiorite which resembles that of the Quinsam intrusions.	7.50	----
	--- *Extensional fault: a clean break, attitude: 004/66 E. Downthrow to east, approximately 45 m, based on section in nearby drillhole (QB-38).---*		
11	Sandstone - fine-grained, greenish grey, pebbly, with fragments of Ostrea and entire small gastropods.	1.50	36.30
	COMOX FORMATION: CUMBERLAND MEMBER:		
10	Siltstone/Mudstone - thinly interbedded dark grey siltstone and black, carbonaceous mudstone, with thin laminae of bright coal.	0.90	34.80
9	Siltstone - dark grey, slightly reddish weathering, sandy, very thin planar beds; tough and compact; scattered plant trash.	5.20	33.90
8	(Concealed interval) - probably siltstoneas above.	1.50	28.70
	COMOX FORMATION: BENSON MEMBER:		
7	Conglomerate - dark green, composed of rounded pebbles, 20 to 65 mm, mostly of basalt with some dark chert or rhyolite, rare pink quartz and granodiorite; brown-weathering sandy matrix.	3.00	27.20
6	Sandstone - coarse-grained, light grey at top, becoming greenish grey below; mixed granitic and basaltic composition, with increasing proportion of basaltic material towards base; thick-bedded, low-angle cut-and-fill structures.	12.20	24.20
5	Conglomerate - dark green, as above, composed mostly of subrounded to rounded pebbles of basalt and minor black chert.	1.50	12.00
4	(Concealed interval) - probably conglomerate as above.	1.50	10.50
3	Siltstone - dark grey, hard, compact, with large ferruginous concretions and scattered coalified plant debris.	3.00	9.00

2	(Concealed interval) - probably siltstone as above.	6.00	6.00
	BONANZA GROUP?:		
1	Basalt - fine-grained, greenish grey, blocky.		

APPENDIX B

DETAILS OF BOREHOLE LOGS USED FOR CORRELATION PURPOSES

LOG OF CANADIAN COLLIERIES (DUNSMUIR) LTD. QUINSAM CR-25

Location: on Argonaut road, north of Middle Quinsam Lake.
Coordinates: UTM (ZONE 10) 322940 E., 5536690 N.
Legal description: in Block 41, Comox land district, approx. 240 m east, 480 m south of SE corner of Block 530. Collar elevation: 281.94 m
Logged by: C.F. Miller and A.F. Buckham, 1955

Description	Depth (m)
Overburden (not cored)	42.37
COMOX FORMATION: DUNSMUIR MEMBER:	
Sandstone - medium-coarse, light grey.	44.96
Sandstone - coarse, grey, with a few 1/4 inch pebbles.	45.42
Sandstone - medium coarse.	45.72
Sandy shale - brown, speckled, with coal markings.	45.87
Sandstone - medium, grey, with a few shale streaks; broken.	46.48
Sandstone - medium, grey becoming green.	50.65
COAL (poor recovery)	50.85
COAL and Shale	51.05
Sandstone - medium, white, with several thin bands of carbonaceous shale and coal specks.	51.51
Sandstone - medium, white; broken.	52.27
Sandstone - medium, white, with much carbonaceous shale matrix.	52.33
COAL - (poor recovery)	52.73
Sandstone - medium, white, with thin coal markings.	53.34
COAL and Sandstone - thickest seam 2 inches.	53.49
Sandstone - medium, light grey, with coal markings.	53.95
Sandstone - medium, light grey.	55.32
Sandstone - medium-coarse, green, with streaks and bands to 6 inches wide, of Fe3O4.	57.76
Sandstone - medium coarse, white; broken.	59.89
Sandstone - medium coarse, white.	61.87
Sandstone and COAL - sandstone as above, with 25% coal in veinlets to 1/4 inch.	62.13
Sandstone - medium, green, with a few bands to 6 inches wide, with much Fe3O4.	63.60
Sandstone - medium, white.	64.21
Sandstone - medium, green, with thin bands of Fe304	71.76
Sandstone - with dark carbonaceous shale matrix and several 1/2 inch coal markings.	71.98
Sandstone - medium-coarse, white.	75.59
Sandstone - medium-coarse, grey, with a few coarser bands and some lighter and darker bands; broken from 78.33 m to 79.25 m and from 81.69 m to 81.99 m.	82.91
Sandstone - coarse, white, with scattered crystalline pebbles to 2 inches in diameter.	87.91
Shale - black, carbonaceous.	87.93
COAL - dirty.	88.04
Sandstone - medium, with bands of coal to 1/4 inch.	88.34
Sandstone - medium.	92.30
Sandy shale - dark, speckled, with coal markings.	92.43
Shale and COAL	92.56

Sandy shale and sandstone - with coal lenses.	92.71
COAL	92.76
Sandstone - medium, laminated.	93.45
--- *Roof of Quinsam No.4 coal bed* ---	
COAL	93.73
Shale and COAL	93.78
--- *Floor of Quinsam No.4 coal bed* ---	
Sandstone - medium-coarse, yellowish.	97.23
Sandstone - medium, white.	99.44
Sandstone - coarse, white, faintly yellowish.	102.49
Sandstone - medium-coarse.	103.25
Sandstone - medium and coarse, banded, crossbedded, with streaks and lenses of dark sandy shale.	110.44
Sandstone - medium-fine, grey, with large irregular blebs of yellow sandstone, also streaks of sandy shale.	112.60
Intraformational conglomerate - sandstone as above, within sandy shale as below.	112.75
Sandy shale - black, with coal markings to 1/8 inch.	113.69
Sandy shale and COAL - carbonaceous sandy shale, with 25% coal in thin lenses.	114.30
Sandy shale - black, with coal markings.	115.21
Sandstone - medium, greyish-yellow, with blebs of brown sandstone and tiny scattered shale specks.	119.33
Shale - black, carbonaceous, with many thin coal markings.	119.71
--- *Roof of Quinsam No.3 coal bed* ---	
COAL	120.02
--- *Floor of Quinsam No.3 coal bed* ---	
Shale - black, carbonaceous, with many thin coal markings.	120.40
Sandstone - medium-coarse, white, with sandy shale matrix.	121.77
Sandstone - medium-coarse, white, with a few shale streaks.	125.58
Shale - carbonaceous, with coal and sandstone streaks; broken.	126.01
Sandy shale and shale - black, with coal marks.	126.62
--- *Roof of Quinsam No.3 Leader coal bed* ---	
COAL	127.28
--- *Floor of Quinsam No.3 Leader coal bed* ---	
Shale - black, carbonaceous, with many coal marks to 1/4 inch.	127.64
Sandy shale - dark grey, with a few coal marks to 2 inches in diameter and thin laminae of fine sandstone.	128.57
Sandstone - medium, with a blotchy dark shale matrix.	130.10
Shale - with a few coal markings.	130.33
Shale - black, carbonaceous, with many thin coal markings.	130.38
COAL and Shale	130.63
Sandstone - medium-coarse, white.	144.22
Sandstone - medium; broken.	145.14
Sandstone - medium.	146.53
Sandstone - coarse, yellowish, with a few crystalline pebbles; broken.	147.37
Sandstone - medium, with streaks of sandy shale.	153.92
Sandstone - with shale streaks.	155.40

COMOX FORMATION: CUMBERLAND MEMBER:

--- Roof of Quinsam No.2 Rider coal bed ---	
COAL and Shale	155.45
--- Floor of Quinsam No.2 Rider coal bed ---	
Shale - with coal markings.	155.96
Sandy shale	156.87
--- Roof of Quinsam No.2 coal bed ---	
Shale and **COAL**	156.97
COAL	157.12
COAL and shale	157.18
--- Floor of Quinsam No.2 coal bed ---	
Shale - with coal marks.	157.63
Sandy shale	157.94
COAL	157.99
Shale - with coal marks.	158.04
COAL	158.17
Shale - dark, with coal marks.	158.27
Shale	161.62
Shale - with coal marks.	162.00
--- Roof of Quinsam No.1 Rider coal bed ---	
Shale and **COAL**	162.05
COAL	162.21
--- Floor of Quinsam No.1 Rider coal bed ---	
Shale	164.84
Sandy shale	166.37
Shale - with sandstone bands.	168.20
Shale - with coal marks; broken.	168.81
Shale - brown, with coal marks; broken.	168.86
Shale - with coal marks.	169.26
--- Roof of Quinsam No.1 coal bed (equivalent)? ---	
Shale and **COAL**	169.39
--- Floor of Quinsam No.1 coal bed (equivalent)? ---	
Shale - broken.	174.35
Shale	175.56
Sandy shale	176.17
Sandy shale - red.	176.78
Sandy shale	179.22
Sandstone - fine.	180.44
Sandstone - with bands of fine conglomerate; coal marks at 182.27 m.	182.27

COMOX FORMATION: BENSON MEMBER:

Conglomerate - fine.	184.71
Shale	185.62
Shale - red.	188.06
Sandstone - fine	189.28
Conglomerate - fine.	190.50
Shale - red.	191.41
Sandstone - fine, with coal marks.	191.72
Sandy shale	193.55
Conglomerate	195.68
Conglomerate - broken.	198.12
Conglomerate - green, broken.	208.18

LOG OF CANADIAN COLLIERIES (DUNSMUIR) LTD. QUINSAM CR-27

Location: northeast of Middle Quinsam Lake.
Coordinates: UTM (ZONE 10) 323940 E., 5533520 N.
Legal description: in Block 120, Comox land district; approx. 320 m west and 30 m north of NE corner of Block 98. Collar elevation: 311.0 m
Logged by: C.F. Miller and A.F. Buckham, 1955

Description	Depth (m)
DRIFT:	
Overburden (not cored)	3.35
COMOX FORMATION: DUNSMUIR MEMBER:	
Sandstone - coarse, white, with a few small scattered crystalline pebbles.	32.06
Sandy shale - speckled, with a few coal markings.	33.22
Sandstone - coarse, grey, with shale lenses nd small pebbles.	35.05
Sandstone - coarse, white, with lenses and bands of dark shale. A few small crystalline pebbles.	46.02
Sandstone - medium coarse, grey, with few bands of medium-fine conglomerate.	47.98
Shale - faint brown streak.	48.31
--- Roof of Quinsam No.4 coal bed ---	
Shale and bony **COAL**.	48.49
COAL - very poor quality.	48.59
--- Floor of Quinsam No.4 coal bed ---	
Sandstone - medium, white, with shale bands with coal markings.	49.71
Shale - with thin sandstone layers and tiny coal marks.	49.99
Sandstone - medium, grey, with tiny coal markings.	50.60
Shale - bony.	50.65
COAL	50.70
Sandy shale - with thin coal markings and lenses of medium sandstone.	52.22
Sandstone - medium-coarse, with a few shaly blotches.	57.30
Sandstone - medium, yellowish, with 10% Fe_3O_4 in thin bands.	57.91
Sandstone - medium, white, laminated.	58.67
Shake - top half speckled, sandy.	59.28
Sandstone - medium, blotchy and banded.	65.84
Sandstone - coarse, green.	67.97
Sandstone - coarse, white, with a few scattered crystalline pebbles, somewhat broken.	79.10
Sandstone - coarse, grey, faint banded.	81.36
--- Roof of Quinsam No.3 coal bed ---	
COAL and Shale	81.46
COAL	81.56
Shale and **COAL**	81.69
Shale - with several thick coal marks.	82.40
COAL - with thin bony bands.	83.11
Shale, brown, and **COAL**	83.31
COAL	83.62

Shale and **COAL**	83.69
COAL	84.30
--- Floor of Quinsam No.3 coal bed ---	
Shale - with coal lenses to 3/8 inch thick.	84.56
Shale - hard, brown streak, with sandy lenses and a few coal partings.	86.26
--- Roof of Quinsam No.3 Leader coal bed ---	
COAL - with a few thin shale partings.	86.89
COAL, bony, and shale.	87.04
--- Floor of Quinsam No.3 Leader coal bed ---	
Sandy shale, grey, with considerable coal lenses to 1/2 inch thick.	89.31
COAL	89.46
Sandstone - medium coarse, white.	92.96
Sandstone - coarse, white, with a few scattered small crystalline pebbles.	102.72
Sandstone - medium-coarse, with a blotchy matrix and a few small shale fragments.	108.20

COMOX FORMATION: CUMBERLAND MEMBER:

Shale - brown, with many coal marks.	108.41
--- Roof of Quinsam No.2 Rider coal bed ---	
COAL and bone	108.71
--- Floor of Quinsam No.2 Rider coal bed ---	
Shale - with sandstone grains and layers.	109.32
Sandstone - medium, faintly laminated.	111.94
Sandy shale - with sandstone grains and layers. Fairly numerous coal lenses to 1/2 inch.	114.30
--- Roof of Quinsam No.2 coal bed ---	
COAL - with thin shale bands.	114.68
Shale	114.93
COAL	115.04
Shale	115.16
COAL	115.42
Shale	115.47
COAL	115.52
--- Floor of Quinsam No.2 coal bed ---	
Shale - with coal markings.	115.67
Sandy shale	117.20
Shale - with coal markings.	118.72
Sandy shale	119.63
Shale - with coal markings.	120.42
COAL	120.62
Shale - with coal markings.	121.16
Sandstone - fine-grained, blotchy, laminated with medium sandstone.	123.60
Sandstone - coarse, white, with many small crystalline pebbles.	128.47
COAL	128.63
Shale - brown, with coal markings.	128.73
Shale	129.03
Shale, bony, and **COAL**	129.13
Shale - with some sandy layers.	129.59
Sandy shale - dark grey, faint brown streak, with small carbonaceous bands with small coal markings.	135.38
--- Roof of Quinsam No.1 coal bed ---	
COAL	135.92
Bone and **COAL** - with some sand grains.	136.25
--- Floor of Quinsam No.1 coal bed ---	
Sandy shale - with some coal markings, sheared.	136.86
Sandstone - medium.	137.16

Sandy shale - with scattered coal markings and carbonaceous layers, broken.	142.85
Sandy shale - maroon.	148.03
Sandy shale - grey.	148.84
Sandstone - medium, with bands of sandy shale.	149.63
Conglomerate - with crystalline pebbles to 1/2 inch diameter.	149.76
Sandy shale - grey.	151.89
Sandstone - medium, with bands of speckled shale. A few bands of coarse sandstone near the bottom.	155.91

QUINSAM INTRUSIONS:

Diorite - altered, grey-white.	156.06
Diorite	196.90

LOG OF CANADIAN COLLIERIES (DUNSMUIR) LTD. QUINSAM CR-29

Location: northeast of Middle Quinsam Lake.
Coordinates: UTM (ZONE 10) 324480 E., 5532630 N.
Legal description: in Lot 242, Comox land district; approx. 235 m east and 380 m south of NW corner of Lot 242.
Collar elevation: 312.0

Logged by C.F. Miller and A.F. Buckham, 1955

Note: Geophysical logs available for offsetting well,
Luscar Quinsam **QB-53**.

Description	**Depth (m)**
DRIFT:	
Overburden (not cored)	2.44
COMOX FORMATION: DUNSMUIR MEMBER:	
Sandstone - medium, with dark blotchy shaly matrix.	6.63
Sandstone - coarse, white, with pebbles to 3/4 inch.	7.54
Sandstone - coarse, white.	9.75
Sandstone - medium, with dark shaly matrix as above.	10.36
Sandstone - coarse, white.	15.72
Conglomerate - medium, white, broken.	15.93
Sandstone - coarse, white, with 2 inch pebbles at base.	22.86
Sandstone - coarse, white, broken.	24.38
Sandstone - coarse, white.	25.09
Conglomerate - fine, white.	26.21
Sandstone - coarse, white.	26.69
Sandstone - as above, with large irregular masses of grey sandy shale. Broken.	26.82
Sandstone - very coarse, white, with a few thin bands and laminations of very fine, grey sandstone.	31.39
Sandstone - very coarse, white, broken.	32.92
Sandstone - very coarse, white.	35.05
Sandstone - very coarse, white, with a few tiny pebbles.	36.58
Sandstone - as above, with a few thin bands of sandy shale and fine conglomerate with grey matrix.	42.47
Sandstone - very coarse, white, with numerous bands of fine conglomerate and also a few thin bands of grey medium sandstone.	48.29
Sandstone - medium-grained, mostly grey, with a few thin bands becoming grey conglomerate.	51.54
Sandy shale - grey, very sandy, speckled with white sandstone grains.	52.53
Sandstone - very coarse grained, white.	65.25
Sandstone - medium, greenish, with much Fe_3O_4 in last 1.52 m.	69.21
Sandstone - coarse, white.	74.22
Marcasite and **COAL**	74.24
Sandstone - coarse, white.	75.19
COAL and Shale - with much sulphur.	75.29
Shale - carbonaceous, speckled, with marcasite and coal markings.	75.44
Sandstone - coarse, white, broken.	80.16
COAL - with some bone and sandstone.	80.34
COAL - bony, with some marcasite.	80.44
Sandstone - coarse, white, with thin bands of bone and **COAL**.	80.77
Sandstone -coarse, white.	82.09
Sandstone - as above, with numerous bands 1 to 3 inches wide of bone and **COAL**.	83.23
Sandstone - coarse, white.	89.82
--- Roof of Quinsam No.4 coal bed ---	
COAL	90.02
Sandstone and **COAL**	90.22
COAL	90.35
Sandstone	91.57
COAL	91.62
Sandstone - with coal markings.	92.45

COAL - with sandstone layers.	92.76
COAL	93.06
--- Floor of Quinsam No.4 coal bed ---	
Shale - dark, becoming speckled below.	93.47
Sandstone - coarse, white.	95.27
Sandy shale - grey, slightly speckled.	95.45
Sandstone - coarse, white.	100.15
Conglomerate - fine, white, with pebbles to 1 inch; with bands of sandstone as above.	103.99
Sandstone - medium-coarse, grey.	106.68
Sandy shale - grey, with coal markings.	108.03
Sandstone - medium, grey, with shaly matrix and a few coarse coal marks.	109.55
Sandstone - coarse, white.	111.15
Sandstone - medium, grey, with shaly matrix.	111.43
Sandstone - coarse, white. Broken at 111.25 m.	114.71
Sandy shale - grey, very sandy, a few coal markings.	115.19
Sandstone - medium, with grey shaly matrix.	115.95
Sandstone - coarse, white.	118.80
Sandy shale - grey, with coal markings.	120.52
Sandstone - coarse, white.	121.13
Sandstone - medium-coarse, white.	122.05
Sandy shale - black, speckled, broken.	122.43
Sandstone - medium-coarse, green	130.45
Sandstone - medium-coarse, white, a few bands are very coarse.	136.07
Sandstone - coarse, white, with a few scattered shale fragments; somewhat broken.	147.14
--- Roof of Quinsam No.3 coal bed ---	
COAL	148.51
Shale and **COAL**	148.59
COAL	149.35
Shale - brown.	149.63
COAL and shale	149.71
Shale	149.96
COAL	150.70
COAL and shale	150.90
--- Floor of Quinsam No.3 coal bed ---	
Shale	152.78
Sandstone - medium-coarse, white.	153.70
Shale - black, gritty, bony, brown streak.	153.78
Sandstone - medium, white, with coarser bands.	158.06
Sandstone - coarse, white, with bands of fine conglomerate.	165.89
Sandstone - medium, white.	168.02

COMOX FORMATION: CUMBERLAND MEMBER:

Shale - with coal markings.	169.55
Conglomerate - fine.	170.15
Shale - with coal markings.	172.29
Conglomerate	172.90
Sandy shale - with coal markings.	173.20
Conglomerate	173.51
Shale - with coal markings and bands of conglomerate.	175.34
Shale	176.56
Conglomerate	176.86
Sandy shale	177.47

COMOX FORMATION: BENSON MEMBER:

Conglomerate	178.99
Sandy shale	181.13
Conglomerate	181.43
Sandstone and shale	182.04
Conglomerate	182.35
Sandy shale	182.65

Conglomerate	183.57
Shale	184.79
Sandy shale - with bands of fine conglomerate.	188.44
Conglomerate - medium-fine, with angular pebbles to 1/2 inch diameter. Last 15 cm contains much sandy shale. Broken.	189.97
Sandy shale - grey, with coarse sandstone grains. One 1/4 inch coal marking.	190.93
Sandy shale - dark, with angular conglomerate pebbles and thin bands. Few calcite and coal marks.	193.68
Conglomerate - medium, mostly diorite pebbles in small quantity of reddish sandy matrix. Broken.	202.16
Sandy shale - red, with a few bands of fine conglomerate.	202.52
Conglomerate - coarse, as above.	203.28

APPENDIX C

HISTORICAL HIGHLIGHTS OF COAL ACTIVITY ON VANCOUVER ISLAND

(These data are compiled from a large number of different sources: museum archives, company reports, Ministry files and personal communications.)

SUQUASH/NORTH ISLAND

1835	Coal is first reported by native Indians at Beaver Harbour, near Port Hardy.
1836	Beaver Harbour coal is examined by the Hudson's Bay Company.
1839	Indians start digging coal from outcrops at Suquash.
1846	Indians mine 60 tonnes of coal from outcrop at Beaver Harbour.
1849	Hudson's Bay Co. miners sink test pits at Beaver Harbour. One shaft is 21 m deep.
1850	Coal is first reported at Quatsino Sound.
1851	Boyd Gilmour drills the first borehole at Suquash.
1865	North Pacific Coal Co. mines 40 tonnes of coal at Quatsino Sound.
1894	Landale's group finds thicker coal at Quatsino Sound.
1908	Pacific Coast Coal Company discovers the Suquash Main coal bed by exploration drilling.
1915	Suquash Colliery is closed.
1920	Suquash Colliery is reopened.
1926	Suquash Colliery is closed.
1952	Suquash Colliery is reopened briefly for examination by Hope Engineering Ltd.
1974	B.C. Hydro drills Suquash.
1981	Abcon drills Suquash.

COMOX SUB-BASIN

1852	Sir James Douglas finds coal float at the mouth of the Courtenay River.
1864	A Vancouver Island exploring expedition, led by Robert Brown, finds coal on Browns River (probably the Comox No. 2 bed).
1866	Coal is discovered on Tsable River (probably the Comox No. 1U 1L beds).
1866	The Black Diamond Coal Company drives the first adits on Tsable River under Lansdale's supervision.
1871	Formation of the Union Coal Co. (discovery of coal on Perserverance Creek.
1872	Trench and adit work is done at Perserverance Creek.
1875	The Baynes Sound Coal Co. drives cross-measures drift at Baynes Sound Colliery on Tsable River, which produces 600 tonnes of coal.
1883	Robert Dunsmuir buys out Baynes Sound Coal Company and Union Coal Company, and forms the Union Collier Company.
1888	A port facility is opened at Union Bay and commercial mining begins.
1897	The town of Cumberland is incorporated (previously it was the community of 'Union').
1888	Dunsmuir opens the Union Colliery at Cumberland.
1889	Robert Dunsmuir dies.
1908?	Coal is discovered at Hamilton Lake.
1911	Dunsmuirs sell their collieries to the Canadian Colliery Co. (Dunsmuir) Ltd.
1917	Adits are driven on Browns River near Anderson Hill.
1917?	More coal is discovered on Tsable River.
1921	Coal is discovered on Anderson Creek.
1943	Adit is driven by Stan Lawrence on Tsable River; no mineable coal is found.
1945	Lawrence and Bill Herd drive an adit further up the Tsable River; this later becomes the water level for Tsable River Colliery.
1947	The Number Five mine, Comox Colliery, is closed.

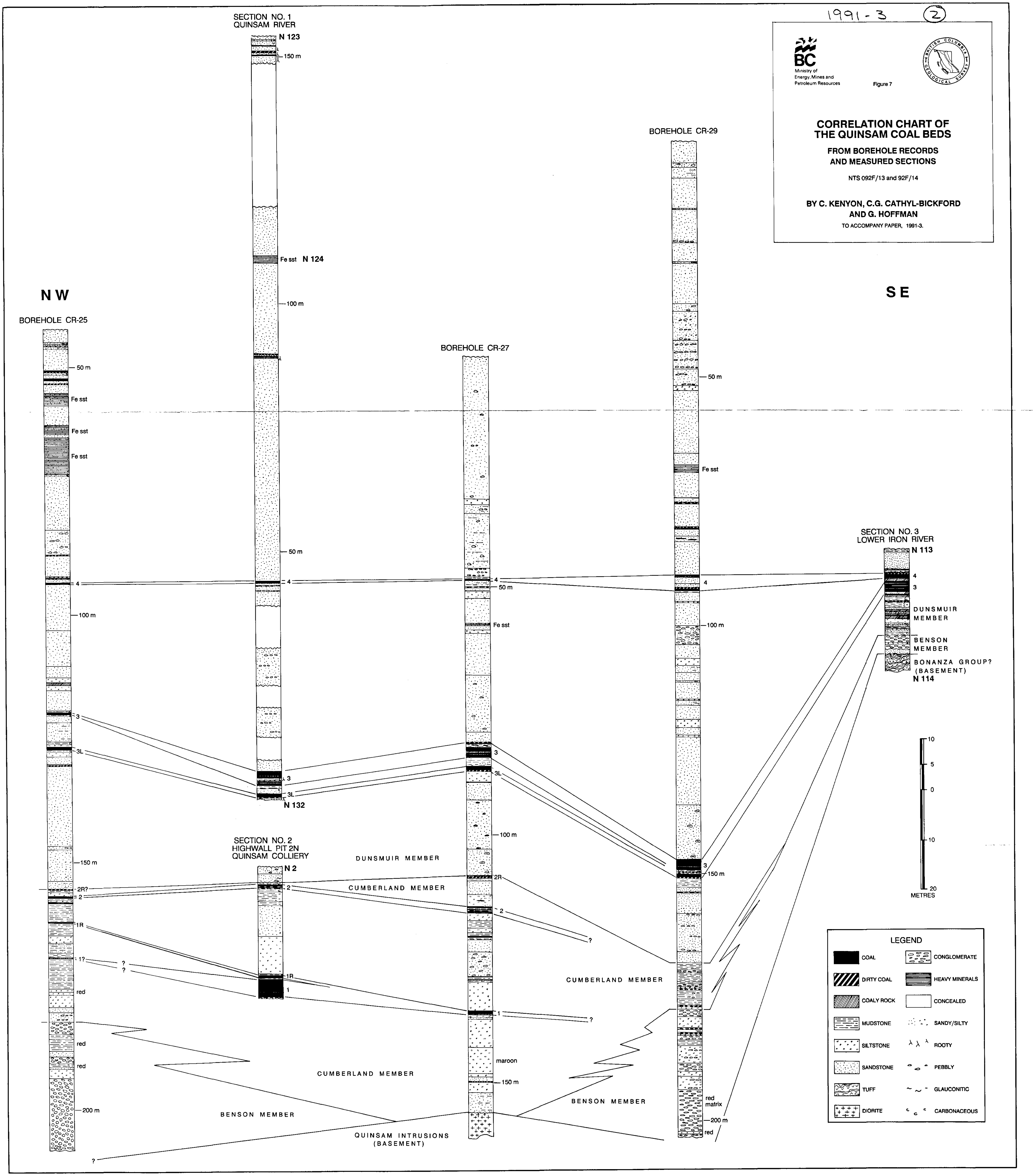
1947	The Tsable River colliery commences commercial production.
1948?	Bill Herd drives an adit at Cowie Creek.
1953	The Number Eight mine, Comox colliery, is closed.
1960	Miners take over the Tsable River colliery.
1966	The Tsable River colliery is closed.
1975?	Eric Roberts drives adits at Hamilton Lake, Quinsam and Holiday Hill.
1985	Brinco Mining Ltd., operating as Quinsam Coal Ltd. begin open-pit mining.
1986	Eric Roberts drives adits at Chute Creek and Iron River.

NANAIMO SUB-BASIN

1849	Indians report coal on shoreline to the Hudson's Bay Co. in Victoria.
1850	Indians deliver the first load of coal fron Nanaimo to Victoria. Joseph McKay, working for the Hudson's Bay Co. discovers an outcrop of the Douglas coal bed.
1852	Production from the Douglas coal bed is 100 to 120 tonnes.
1852	The Newcastle coal bed is discovered on Commercial Inlet.
1853	Coal outcrop is found at Chase River.
1853	The first adit into the Newcastle coal bed is driven on Newcastle Island.
1856	The longwall face caves on Newcastle Island and the mine is closed.
1863	The Douglas pit is opened which is the first large-scale mine at Nanaimo.
1869	Robert Dunsmuir discovers the No.2 coal bed at Wellington.
1870	Dunsmuir drives the "Original Entry" into the No. 2 coal bed at Wellington and drills near Departure Bay.
1871	Dunsmuir discovers the Wellington coal bed at Wellington.
1895	Coal is discovered at Extension.
1900	The Wellington colliery is closed.
1914	Coal is reported at Wolf Mountain.
1938	The Nanaimo colliery is closed.
1944	The Timberlands colliery is closed.
1947	Coal is reported at Blackjack Lake.
1953	The Nunber Ten Wellington-Extension, the last large mine, is closed at South Wellington.
1967	The last small mine closes at Wellington.
1979?	Teck Corporation drives an adit in the No.2 coal bed at Wolf Mountain.
1980-81	Much activity in the Nanaimo area. Esso Resources Limited and Gulf Canada Resources Limited drill test holes. Gulf finds coal at Wolf Mountain.
1982	Netherlands Pacific Limited drills step-out wells at Wolf Mountain and announces a commercial discovery.
1984	Wolf Mountain colliery opened.
1984	Novacorp drills coalbed gas wildcat wells at Morden. Thick coal is found in the Douglas bed near Cedar village.
1987	The Wolf Mountain colliery is closed.

1991-03 ①

BC
Ministry of Energy, Mines and Petroleum Resources
BRITISH COLUMBIA GEOLOGICAL SURVEY
Figure 4
GEOLOGY OF THE QUINSAM COALFIELD
NTS 092F/13 and 92F/14
BY C. KENYON, C.G. CATHYL-BICKFORD AND G. HOFFMAN
TO ACCOMPANY PAPER, 1991-3.
Scale 1:20 000
500 0 500 1000
METRES
LEGEND
UPPER CRETACEOUS
Comox Formation:
D Dunsmuir Member: Sandstone; minor conglomerate; shale and coal.
C Cumberland Member: Siltstone, shale and coal.
B Benson Member: Conglomerate; minor red shale.
PRE-CRETACEOUS
V Basement
SYMBOLS
COAL BEDS
1 Quinsam No.1
2 Quinsam No.2
3 Quinsam No.3
4 Quinsam No.4
3/4 Quinsam No.3 and No.4 together
A Chute Creek 'A'
LITHOLGGIES
brec breccia
bst brec basalt breccia
bst pil basalt pillows
COAL coal outcrop
cgl conglomerate
cly sst coaly sandstone
crm bst crumbled basalt
gran granodiorite
hb qtz drt hornblende quartz diorite
lst limestone
shr arg sheared argillite
shr bst sheared basalt
shrg shearing
sst sandstone
sst fl sandstone float
st rub sandstone rubble
till overburden
tuff volcanic tuff
Tr Triassic
wth bst weathered basalt
OTHERS
Contact Boundary
Bedding; inclined, sheared
Thrust faults
Normal faults
Anticline
Syncline
N 5 / 46 Station Location
X Outcrop location
Vitrinite reflectance location
Borehole
F Fossil locality
Campbell Lake
Beavertail Creek
Beavertail Lake
324000 E
5540000 N
Miller Creek
Snakehead Lake
Lukwa Lake
Gooseneck Lake
Quinsam River
Middle Quinsam Lake
Long Lake
LONG LAKE FAULT ZONE
No Name Lake
Iron River
Dam River
Woodhus Creek
Stone Creek
Chute Creek
BOUNDARY FAULT
RED BED FAULT
Wowo Lake
Basam Creek
Oyster River
OYSTER FAULT
EDEN FAULT
ALDYTH FAULT
Adrian Creek
Piggott Creek
320000 E
5520000 N
No. 2 coalbed?
thick drift cover
probably faulted, shr bst
fault probable
thrust slices
red beds


1991-3 (2)
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Ministry of Energy, Mines and Petroleum Resources
BRITISH COLUMBIA GEOLOGICAL SURVEY
Figure 7
CORRELATION CHART OF THE QUINSAM COAL BEDS
FROM BOREHOLE RECORDS AND MEASURED SECTIONS
NTS 092F/13 and 92F/14
BY C. KENYON, C.G. CATHYL-BICKFORD AND G. HOFFMAN
TO ACCOMPANY PAPER, 1991-3.
NW
SE
SECTION NO. 1 QUINSAM RIVER
N 123
N 124
N 132
BOREHOLE CR-25
BOREHOLE CR-27
BOREHOLE CR-29
SECTION NO. 2 HIGHWALL PIT 2N QUINSAM COLLIERY
N 2
SECTION NO. 3 LOWER IRON RIVER
N 113
N 114
Fe sst
50 m
100 m
150 m
200 m
4
3
3L
2R
2R?
2
1R
1?
1
?
red
maroon
red matrix
DUNSMUIR MEMBER
CUMBERLAND MEMBER
BENSON MEMBER
BONANZA GROUP? (BASEMENT)
QUINSAM INTRUSIONS (BASEMENT)
10
5
0
10
20
METRES
LEGEND
COAL
DIRTY COAL
COALY ROCK
MUDSTONE
SILTSTONE
SANDSTONE
TUFF
DIORITE
CONGLOMERATE
HEAVY MINERALS
CONCEALED
SANDY/SILTY
ROOTY
PEBBLY
GLAUCONITIC
CARBONACEOUS