British Columbia Geological Survey
Geological Fieldwork 1991

GEOLOGY AND ENERGY RESOURCE POTENTIAL OF THE TSABLE RIVER AND DENMAN ISLAND (92F/10, 11)

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KEYWORDS: Coal geology, stratigraphy, coal resources, coalbed gas, Comox Formation, Trent River Formation, Tsable River, Denman Island.

INTRODUCTION

Continued strong interest in the coal deposits and associated natural gas occurrences of eastern Vancouver Island and the northern Gulf Islands has stimulated the reexamination of critical geological relationships. The aim of this study is to provide accurate geological data to assist government and industry in assessing the remaining resource potential of the Vancouver Island coalfields, as well as identifying potential for new discoveries of natural gas associated with the coal measures.

This report presents preliminary results of one month's detailed geological mapping near Tsable River and on Denman Island.

LOCATION AND ACCESS

The study area includes Denman Island and part of the eastern coastal lowland of Vancouver Island, between Rosewall Creek in the south and Union Bay in the north (Figure 4-4-1). This area lies near the geographic centre of the Comox sub-basin of the Late Cretaceous Georgia Basin.

Access to the area is provided by a few paved highways and side roads, as well as a dense network of unpaved logging roads. Many of the bridges and culverts on the logging roads were washed out during torrential rains in the autumn of 1990, preventing vehicular access to large parts of the area.

Forestry is presently the only land-use near Tsable River, while land-use on Denman Island is divided between tree farms, dairy farms and rural residential subdivisions.

PREVIOUS WORK

The first recorded geological mapping in the study area was by J. Richardson (1873) of the Geological Survey of Canada. Coal deposits near Tsable River (Williams, 1924) were studied in detail by McKenzie (1922) and Buckham (1957). Denman Island was mapped by Usher (1952), Allmaras (1978) and Bell (1960). Remapping of the study area by the British Columbia Geological Survey began in 1987, and has continued through the autumn of 1991. (Bickford and Kenyon, 1988; Bickford *et al.*, 1990; Kenyon and Bickford, 1989).

STRATIGRAPHY

The coal measures of eastern Vancouver Island and the Gulf islands are part of the Nanaimo Group of Turonian to Maastrichtian age (England, 1990; Haggart, 1991). The rocks occupy the western erosional margin of the Late Cretaceous Comox sub-basin of Georgia Basin. The Comox sub-basin contains the Tsable River, Cumberland, Campbell River and Quinsam coalfields, together with several other minor coal showings (Bickford and Kenyon, 1988; Bickford *et al.*, 1990; Saunders *et al.*, 1974; Table 4-4-1).

TABLE 4-4-1
LITHOSTRATIGRAPHY OF LATE CRETACEOUS ROCKS WITHIN THE STUDY AREA

Formation:	Map Unit:	Member:	Description: Unit:
Lambert	15	—	Mudstone and siltstone; minor sandstone and argillaceous limestone. >115 m
			Abrupt contact
Denman	14	Norman Point	Sandstone; minor siltstone. 25 to 40 m.
			Intertonguing contact
	13	Graham	Conglomerate; minor sandstone and siltstone. 65 to 80 m
			Erosional contact
	12	Madigan	Sandstone; minor conglomerate and siltstone. 55 to 75 m
			Intertonguing contact
Trent River	11	Willow Point	Mudstone and siltstone; minor sandstone. 120 to 150 m.
			Abrupt contact
	10	Baynes Sound	Sandstone and siltstone; minor conglomerate. 10 to 60 m.
			Abrupt contact
	9	Royston	Mudstone and siltstone; minor sandstone. 50 to 220 m.
			Intertonguing contact
	8	Tsable	Mud-matrix conglomerate and pebbly siltstone. 5 to 140 m.
			Erosional contact
	7	Browns	Sandstone. 0 to 45 m.
			Intertonguing contact
	6	Puntledge	Mudstone and siltstone; minor sandstone. 100 to 130 m.
			Abrupt contact
	5	Cowie	Sandstone. 2 to 15 m.
			Abrupt contact
	4	Cougarsmith	Mudstone and siltstone; minor sandstone. 8 to 22 m.
			Intertonguing contact
Comox	3	Dunsmuir	Sandstone; minor siltstone and coal. 120 to 190 m.
			Erosional contact
	2	Cumberland	Siltstone, shale and coal; minor sandstone and gritstone. 30 to 90 m.
			Intertonguing contact
	1	Benson	Conglomerate; minor red shale and siltstone. 0 to 220 m.
			Erosional contact
Pre-Cretaceous Basement Complex:			
Karmutsen	V		Basalt, basaltic breccia and tuff.

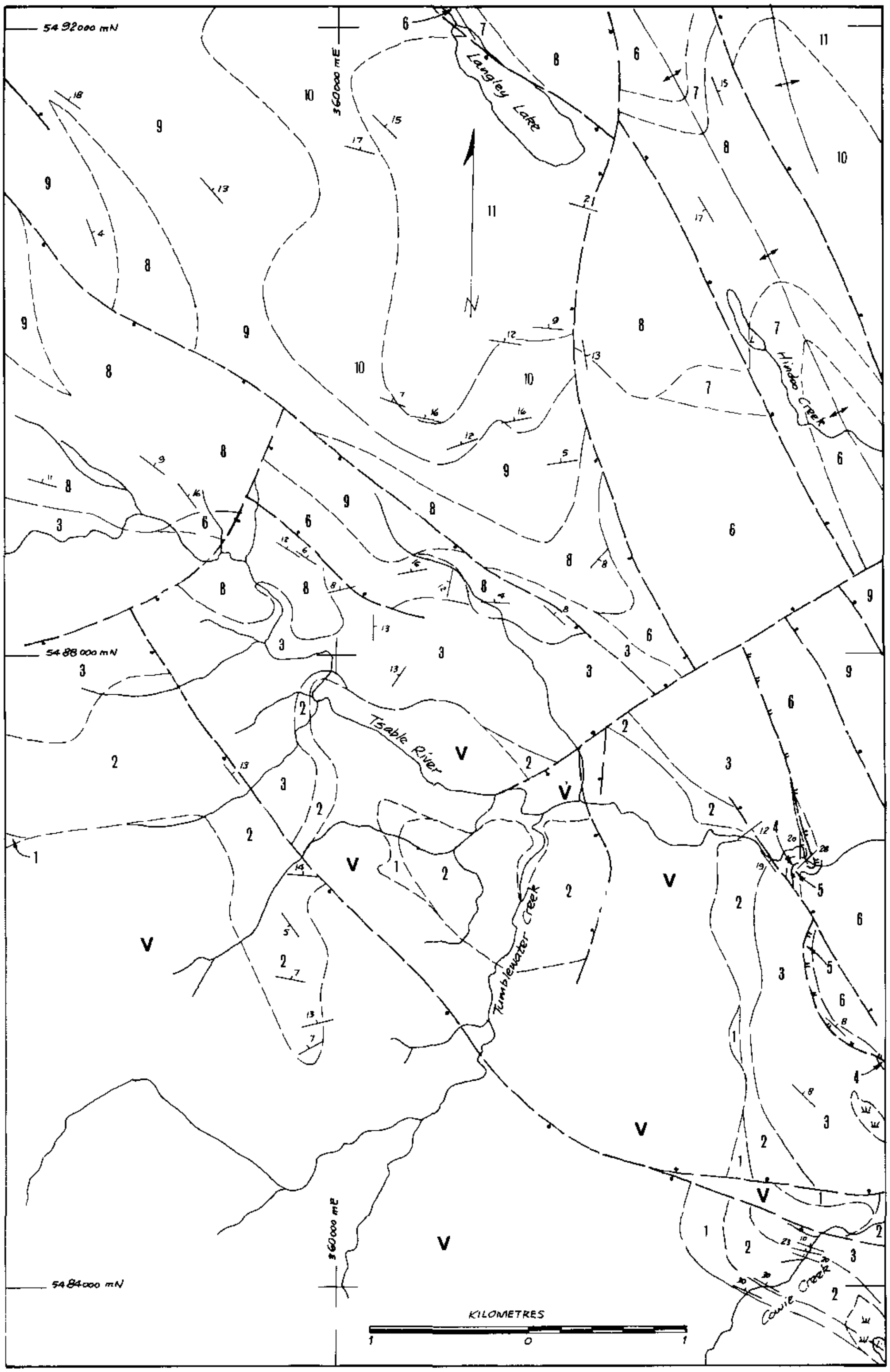
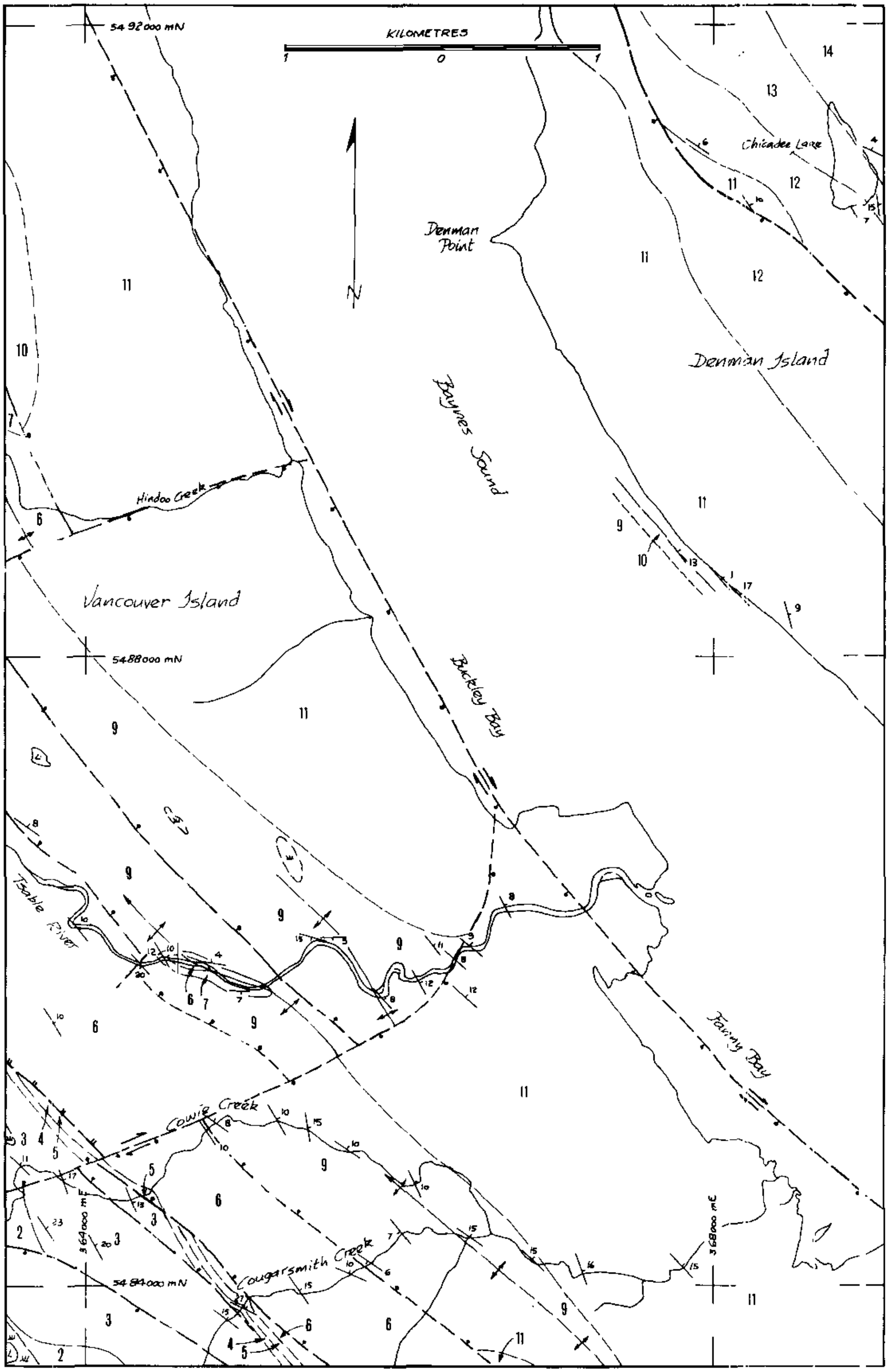
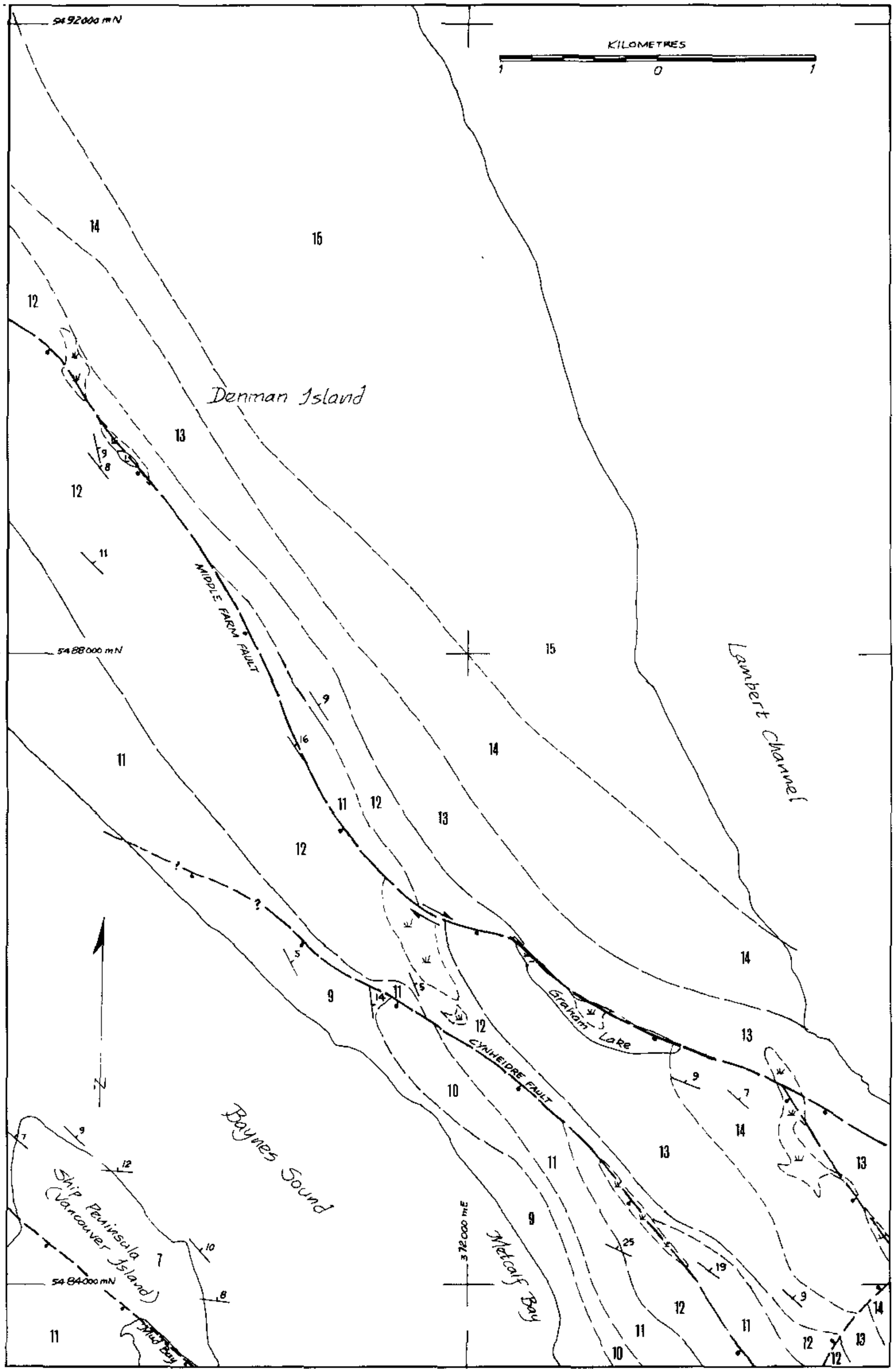


Figure 4-4-1. Geological map of the Tsable River and Denman Island study area.



5492000 mN
KILOMETRES
1 0 1
14
13
Chicadee Lake
12
11
Denman Point
N
Denman Island
Baynes Sound
10
Hindoo Creek
Vancouver Island
9
5488000 mN
Buckley Bay
Tsable River
Fanny Bay
Cowie Creek
Cougarsmith Creek
364000 mE
368000 mE
5484000 mN


KILOMETRES
1
0
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5492000 mN
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5484000 mN
372000 mE
Denman Island
Lambert Channel
Baynes Sound
Ship Peninsula (Vancouver Island)
Metcalf Bay
Graham Lake
MIDDLE FARM FAULT
CYNHEIDRE FAULT
N

Subdivision of the Trent River Formation

The Trent River Formation is divided into seven members within the study area. In order from base to top of the formation, they are the Cougarsmith, Cowie, Puntledge, Browns, Tsable, Royston, Baynes Sound and Willow Point members.

The Cougarsmith member (Unit 4) is a new unit, comprising the basal mudstones and siltstones of the Trent River Formation, in those areas where the overlying Cowie sandstones are present. The name Cougarsmith is derived from Cougarsmith Creek, where a nearly complete section of the member is exposed. The Cougarsmith member is 18 to 22 metres thick in the area between Tsable River and Cougarsmith Creek. The Cougarsmith mudstones and siltstones were probably deposited in sheltered lagoons on the landward side of barrier islands or offshore bars.

The Cowie member (Unit 5) is also a new unit, comprising thick-bedded to massive sandstones which overlie the Cougarsmith member. These sandstones were first recognized as an informal, unnamed unit by McKenzie (1922). The name Cowie is derived from Cowie Creek, near the centre of the presently mapped extent of the member. The member is 12 to 15 metres thick in the area between Tsable River and Cougarsmith Creek. The Cowie sandstones were probably deposited as a complex of barrier islands or offshore bars.

The Baynes Sound member (Unit 10) was first proposed by England (1989) for sandstones and conglomerates on the western shore of Denman Island southeast of Denman Point. Sandstones and conglomerates, probably correlative with the Baynes Sound member, are also exposed on hills to the east and west of Langley Lake on Vancouver Island, where they were previously mapped by Bickford and Kenyon (1988) as the Protection Formation. The name Baynes Sound is derived from the body of water which lies between Vancouver and Denman Islands. The Baynes Sound member is 15 to 60 metres thick near Langley Lake, and 10 to 25 metres thick on Denman Island. It was probably deposited in a submarine fan, with the conglomerates possibly representing submarine channel fills.

The Willow Point member (Unit 11) is a new unit, comprising sedimentary rocks previously mapped as the Cedar District Formation in the Comox sub-basin (Bickford, *et al.*, 1990). It consists of dark grey mudstone and siltstone with occasional thin, graded beds of sandstone. The name Willow Point is derived from Willow Point on the east coast of Vancouver Island, southeast of the town of Campbell River. The member is 120 to 150 metres thick on the western side of Denman Island (Davidson *et al.*, 1965; Mahannah, 1964), where it is well exposed in wave-cut benches and sea cliffs. It was probably deposited in a distal submarine fan environment.

Subdivision of the Denman Formation

The Denman Formation has been divided into three members, following suggestions made by Bell (1960) and Allmaras (1978). From bottom up, the three members are named Madigan, Graham and Norman.

The Madigan member (Unit 12) is a new unit, comprising thick-bedded to massive, medium to coarse-grained, light grey to greenish grey sandstones with occasional thick interbeds of siltstone and minor pebble conglomerate. The Madigan sandstones are generally poorly sorted, and locally contain very coarse disseminated grains of quartz sand. The name Madigan is derived from the historic Madigan farm in the central valley of Denman Island. The member is 55 to 75 metres thick on the western side of Denman Island, where it forms a prominent east-dipping cuesta ridge. It was probably deposited below wave base, in a continental shelf environment.

The Graham member (Unit 13) is a new unit, comprising thick-bedded to massive, locally trough-crossbedded conglomerates, with occasional thin to medium lenticular interbeds of sandstone and siltstone. The name Graham is derived from Graham Lake on Denman Island, where the conglomerates are well exposed. Clast sorting in the Graham conglomerates is fair to good; clasts are well rounded and consist of large pebbles to cobbles of basalt with minor granodiorite, sandstone, shale and red chert. Framework a-b imbrication is locally well developed. Indicated paleocurrent directions range from 025° to 200°, averaging 114°. The basal contact of the Graham member is generally erosional, while its top contact is gradational by intertonguing with the overlying Norman Point sandstones. The member is 65 to 80 metres thick on Denman Island. It was probably deposited in submarine channels, incised within older continental-shelf deposits.

The Norman Point member (Unit 14) is also a new unit, comprising medium to thick-bedded, medium to coarse-grained, light grey sandstone with occasional interbeds of dark grey siltstone. The name Norman Point is derived from the point of land south of Ford Cove on Hornby Island, where the sandstones are well exposed. The top contact of the Norman Point with the overlying Lambert Formation is abrupt. The Norman Point member is 25 to [illegible]5 metres thick on eastern Denman Island, and at least 40 metres thick at Norman Point. It was probably deposited below wave base, in a continental-shelf environment.

STRUCTURAL GEOLOGY

The dominant structural feature of the study area is an east-dipping homocline within the sedimentary rocks of the Nanaimo Group. The regional dip of the sedimentary rocks is 10° to 15° northeast. The homocline is disrupted by three sets of faults as well as local folds.

Set 1 consists of subparallel, northwest-striking faults, which have various combinations of extensional and dextral strike-slip displacement. Near Tsable River, most of the northwest-striking faults dip steeply to the northeast, with the exception of several faults on the north bank of the Tsable River, southwest of Langley Lake, which dip to the southwest. On Denman Island, the northwest-striking faults dip steeply to the southwest, and have extensional offset down to the southwest. Taken as a whole, the northwest-striking faults may be the surface manifestation of a 'flower structure', underlain at depth by a major strike-slip shear zone.

Set 2 consists of near-vertical cross-faults which strike to the northeast and east, and appear to be younger than the northwest-striking faults. The cross-faults have apparent sinistral strike-slip displacements ranging from less than 100 to perhaps 1000 metres.

Set 3 consists of bedding-plane shear zones, which are of indeterminate age relative to the other two fault sets. Bedding-plane shears are well exposed in shales and coal beds in the canyons of Tsable River and Cowie Creek and were also encountered in the underground workings of Tsable River colliery.

Sedimentary rocks of the Nanaimo Group are sheared, cleaved and strongly jointed adjacent to the faults, particularly adjacent to the northwest-striking faults.

COAL RESOURCE POTENTIAL

The Comox No. 2 and No. 3 coal beds are of mineable thickness in the Tsable River area. The cover over these two coal beds increases rapidly to the east and northeast of their outcrops, and is approximately 550 metres thick along the western shore of Baynes Sound, and 675 to 950 metres thick on Denman Island. Previous coal mining operations on Vancouver Island have worked at depths as great as 540 metres, although at these depths the miners encountered severe strata control problems such as floor heave and spontaneous outbursts of gas and coal. It is unlikely that coal will be mined beneath Baynes Sound or Denman Island within the foreseeable future.

Considerable exploratory drilling has been done along the outcrop of the Comox coal beds between Tsable River and Cougarsmith Creek. Most boreholes have been shallower than 300 metres, and current industrial interest in the area appears to be concentrated on the open-pit mining potential of the Comox coals.

The Comox No. 2 coal bed lies near the top of the Cumberland member of the Comox Formation. It was extensively worked in the Tsable River colliery, which was abandoned in 1966 due to exhaustion of accessible reserves. The Comox No. 2 coal bed is a composite of up to five individual coal plies, separated by thin partings of grey silty mudstone and black carbonaceous to coaly mudstone. Some of the coaly mudstone partings are sheared and soft, and they locally grade into low-density canneloid mudstone stony coal.

The coal of the No. 2 bed is bright to bright banded, and is generally blocky and hard. Some plies of platy or laminated coal are occasionally present within the coal bed; such platy coal makes a noticeable contribution to the waste dump at Tsable River colliery, where it was rejected as being unmarketable due to its "shaly" appearance. The No. 2 coal bed ranges in thickness from 1.2 to 4.2 metres within the mined area, and boreholes indicate similar thicknesses elsewhere in the study area. The lower part of the bed often consists of inferior, dirty or "bony" coal, with ash contents greater than 25 per cent.

The Comox No. 3 coal bed lies near the middle of the Cumberland member. The rock parting between the No. 2 and No. 3 coal beds is 10 to 20 metres thick, and consists of a coarsening-upward unit of mudstone, sandy siltstone and sandstone. The coal bed is a composite of at least three individual coal plies, separated by thin partings of black carbonaceous and coaly mudstone. The partings are generally sheared and flaky, while the coal itself is bright banded, and locally sheared and platy.

Boreholes indicate that the No. 3 coal bed is 1.0 to 4.1 metres thick within the study area (Saunders *et al.*, 1974). The upper and lower contacts of the coal bed are often gradational, marked by thin interbeds of coal and mudstone.

The Comox coals at Tsable River are of high-volatile A bituminous rank. Significant down-dip increase in coal rank at Tsable River is unlikely, given the predeformational timing of coalification in the area (Kenyon and Bickford, 1989).

Most of the drilling within the Tsable River coalfield has been confined to the vicinity of the outcrops of the Comox coal beds. Very little drilling has been done to establish the down-dip continuity of the coals at depths greater than approximately 300 metres. The few deep boreholes suggest that the Comox coals may become dirtier to the east (Buckham, 1957) and the aggregate thickness of coal may be somewhat less than that near the outcrops.

Buckham (1957) reported an unclassified reserve of 6.2 million tonnes for coal in place along the outcrop belt between Tsable River and Cougarsmith Creek.

GAS RESOURCE POTENTIAL

Gas has been reported from a few deep coal exploration boreholes in the Tsable River area. The best show was in the Alvensleben Tsable River ATR-1 borehole (Cathyl-Bickford, 1991), which encountered gassy coal at a depth of approximately 550 metres. Drilling of ATR-1 was suspended in 1914 due to excessive gas pressure in the hole. The borehole was subsequently put into service as an unlicensed gas well, serving a forestry camp, and continued to produce gas until its casing was sheared off by a landslide in 1984.

Given sufficient maturation, an organic-rich source rock will generate hydrocarbons which will migrate to fill all accessible pore spaces. In order to form a significant gas accumulation, the source rock must be in communication with a reservoir rock within an effective trap. The source of the Tsable River gas is probably the coal beds of the Comox Formation. The coals, having attained a high-volatile A bituminous rank, are sufficiently mature to have generated significant quantities of thermogenic methane due to progressive devolatilization of the coal during burial and heating with the subsiding Georgia Basin.

Although black, carbonaceous to coaly mudstones are associated with the coals, the overall thickness and organic matter content of the mudstones are much less than those of the coals. Mudstones are therefore not expected to have been significant sources of gas within the study area.

Gas which has been generated by a maturing coal bed is partially adsorbed by the coal, while a portion of the gas is released by the coal and exists in the free state within micropores and fractures in the coal bed (Das *et al.*, 1991). The fate of the free gas depends upon the nature of the roof and floor of the coal bed from which it was generated. If the coal is bounded by permeable rocks such as conglomerate or sandstone, the free gas will migrate from the coal bed and either accumulate in a structural or stratigraphic trap elsewhere in the basin, or be lost by escape to the atmosphere.

Possible carrier beds and reservoirs for coal-sourced gas include the sandstones of the Dunsmuir and Cowie members. The Cowie member is of particular interest as it displays good to excellent framework sorting, and has fair to good intergranular porosity. The Dunsmuir sandstones are interbedded with coals and carbonaceous mudstones, and are therefore in effective communication with sources of gas. The Cowie sandstones are stratigraphically isolated, and it is more difficult to envisage an effective migration pathway from the Comox coals into the Cowie sandstones without involving vertical migration of gas along faults. The sandstones and conglomerates of the Benson and Cumberland members are either too discontinuous or too poorly sorted to constitute effective reservoirs for gas.

Adequate seals over the Dunsmuir and Cowie sandstones are provided by the mudstones and siltstones of the Trent River Formation. Significant structural traps are probably present on the upthrown sides of the major northwest-trending faults on Denman Island.

Drilling depths to the top of the Dunsmuir sandstone under Denman Island will be approximately 500 to 800 metres. Although these are shallow depths compared with most gas fields, they are typical of the depth range of most coalbed gas prospects.

Production of coalbed gas by desorbtion may be practicable wherever the coal is at depths greater than 200 metres, regardless of the presence or absence of a structural or stratigraphic trap (Das *et al.*, 1991). Such traps may, however, enhance the development potential of coalbed gas wherever porous reservoir rocks are in contact with coal beds. Close association of clastic reservoir rocks and coal beds affords improved economics for coalbed gas production (Wyman, 1984), as gas may diffuse into adjacent reservoir rocks if a pressure differential is established during production, thus increasing the effective drainage area of each coalbed gas well.

ACKNOWLEDGMENTS

Lodging was provided by Dennis Lavalle and Sandy Melnyk on Denman Island, and by Jane Larsen and Kelly Brooks in Courtenay. Seth Brooks and Tallis Jovanka provided cheerful assistance in the field. John Eden at Macmillan Bloedel provided the key for gated logging roads near Tsable River. Anne Corddry of the Denman Island Forestry Committee and David Shaw at Fletcher Challenge accommodated an endless series of requests for prints of base maps. William Hodge and Mike Gallo of the British Columbia Ministry of Environment, Lands and Parks provided water-well records which were essential to deciphering the geology of drift-covered areas. Kate Slater and John Newell provided technical criticism and editing for this article.

REFERENCES

Allmaras, J.M. (1978): Stratigraphy and Sedimentology of the Late Cretaceous Nanaimo Group, Denman Island, British Columbia; unpublished M.Sc. thesis, *Oregon State University.*

Bell, G.L. (1960): Geological Report of the Hornby and Denman Islands Areas, Permits 796 and 799; *Charter Oil Company Limited,* unpublished report.

Bickford, C.G.C. and Kenyon, C. (1988): Coalfield Geology of Eastern Vancouver Island; *in* Geological Fieldwork 1987, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Paper 1988-1, pages 441-450.

Bickford, C.G.C., Hoffman, G.L. and Kenyon, C. (1990): Geological Investigations in the Coal Measures of the Oyster River, Mount Washington and Cumberland Areas, Vancouver Island; *in* Geological Fieldwork 1989, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Paper 1990-1, pages 431-437.

Buckham, A.F. (1957): Report on Cowie Creek Area, *Canadian Collieries Resources Ltd.,* unpublished report.

Cathyl-Bickford, C.G. (1991): Coal Geology and Coalbed Methane Potential of Comox and Nanaimo Coal Fields, Vancouver Island, British Columbia; *in* Coalbed Methane of Western North America, Schwochow, S.D., Murray, D.K. and Fahy, M.F., Editors, *Rocky Mountain Association of Geologists,* pages 155-162.

Das, B.M., Nikols, D.J., Das, Z.U. and Hucka, V.J. (1991): Factors Affecting Rate and Total Volume of Methane Desorbtion from Coalbeds; *in* Coalbed Methane of Western North America, *Rocky Mountain Association of Geologists,* pages 69-76.

Davidson, A., Peach, H.B. and Ferrie, D.J. (1965): Upper Cretaceous and Tertiary Sediments, Eastern Vancouver Island and Gulf Islands, British Columbia; *Shell Canada Limited,* unpublished report.

England, T.D.J. (1989): Lithostratigraphy of the Nanaimo Group, Georgia Basin, Southwestern British Columbia; *in* Report of Activities, *Geological Survey of Canada,* Paper 1989-1E, pages 197-206.

England, T.D.J. (1990): Late Cretaceous to Paleogene Evolution of the Georgia Basin, Southwestern British Columbia; unpublished Ph.D. thesis, *Memorial University of Newfoundland.*

Haggart, J.W. (1991): A New Assessment of the Age of the Basal Nanaimo Group, Gulf Islands, British Columbia; *in* Report of Activities, *Geological Survey of Canada,* Paper 91-1E, pages 77-82.

Kenyon, C. and Bickford, C.G.C. (1989): Vitrinite Reflectance Study of Nanaimo Group Coals of Vancouver Island; *in* Geological Fieldwork 1988, *B.C. Ministry of Energy, Mines and Petroleum Resources* Paper 1989-1, pages 543-552.

Mahannah, R.S. (1964): Report on 1963 Surface Geological Mapping along the East Coast of Vancouver Island, the Alberni Area, and the Gulf Islands, B.C. *Shell Canada Limited,* unpublished report.

McKenzie, J.D. (1922): The Coal Measures of Cumberland and Vicinity, Vancouver Island; *Canadian Institute of*

Mining and Metallurgy, Transactions, Volume 25, pages 382-411.

Richardson, J. (1873): Report on the Coal Fields of Vancouver and Queen Charlotte Islands; *Geological Survey of Canada*, Report of Progress, 1872-1873, pages 32-65.

Saunders, C.R., Howey, H.O. and Campbell, D.D. (1974): Report on the Reserves and Mining Costs of the Comox Coalfield, Vancouver Island, B.C.; *Dolmage Campbell and Associates Ltd.*, unpublished report.

Usher, J.L. (1952); The Ammonite Faunas of the Upper Cretaceous Rocks of Vancouver Island, British Columbia; *Geological Survey of Canada*, Bulletin 21.

Williams, T.B. (1924): The Comox Coal Basin; unpublished Ph.D thesis, *University of Wisconsin*.

Wyman, R.E. (1984): Gas Resources in Elmworth Coal Seams; *American Association of Petroleum Geologists*, Memoir 38, pages 173-187.