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GEOLOGY AND COAL RESOURCES OF THE CARBON CREEK MAP AREA, PEACE RIVER DISTRICT

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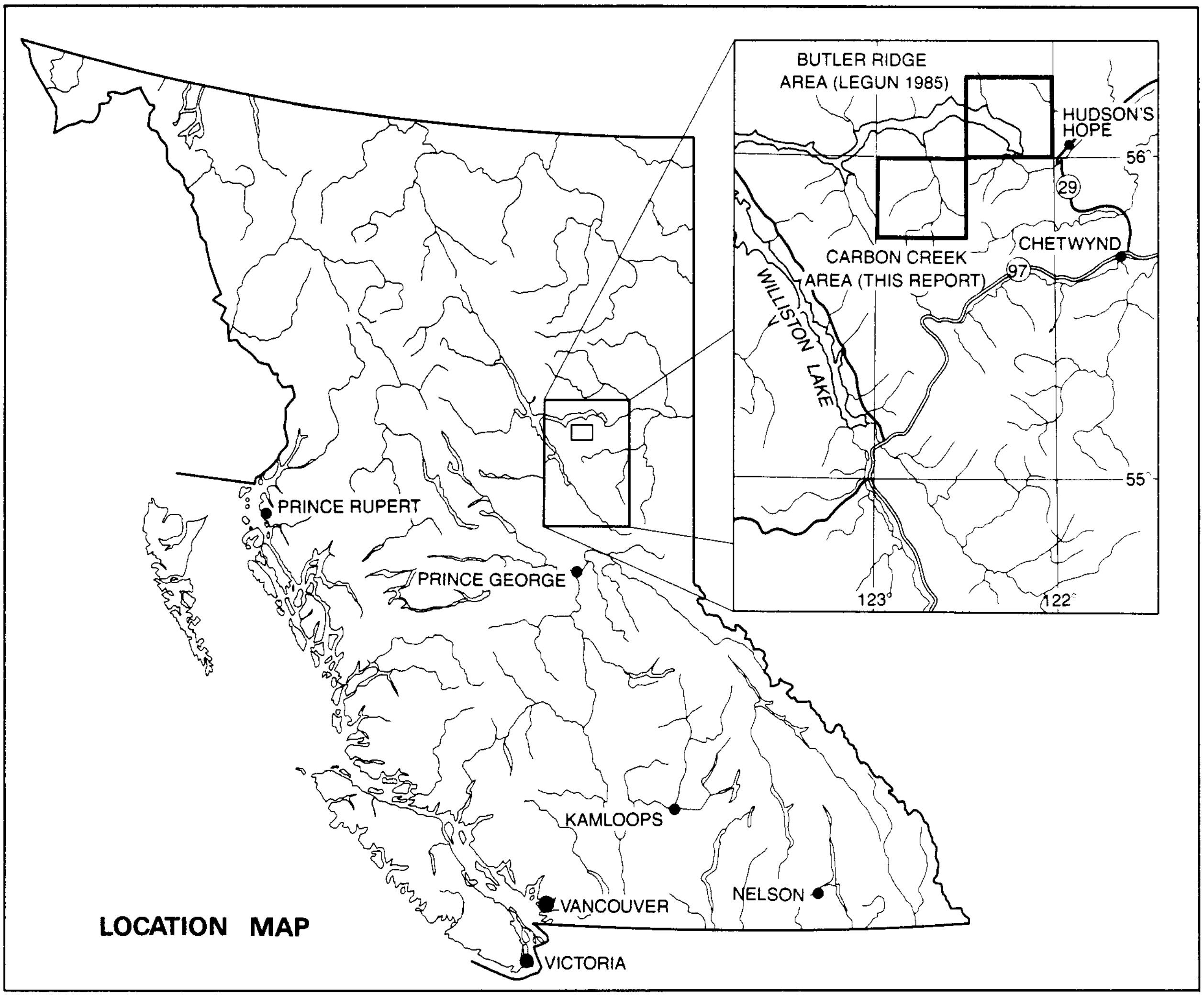

Figure 1. Location of Carbon Creek map area within general study area.

INTRODUCTION

STUDY OBJECTIVES

Mapping in the Carbon Creek area is part of a larger study of the Peace River Coalfield in the vicinity of Williston Lake (Figure 1). The study, initiated in 1983, is directed toward the publication of a 1:50 000 compilation map of the area together with reports on the stratigraphy, structural geology and sedimentology of Jurassic - Lower Cretaceous rocks with special reference to coal-bearing strata. The first product of the study was the publication of the Butler Ridge map sheet (94B/1) together with accompanying notes (Legun, 1985a). This map and report are the second contribution. Although this report focuses on the Carbon Creek area it also updates and draws upon the geology of the larger study area.

LOCATION, ACCESS AND PREVIOUS WORK

The centre of the Carbon Creek map sheet is located 40 kilometres west-southwest of the W.A.C. Bennett Dam in northeastern British Columbia (Figure 2). A road at the west end of the dam provides access to Carbon Creek from Hudson's Hope to the east. This road can also be reached from the south by following the Johnson Creek - Track Creek road which leaves Highway 29 at a point 19 kilometres south of Hudson's Hope.

The Carbon Creek road has been extended southward across McAllister Creek and up the Carbon Creek valley by Canfor Ltd. (a major logging company). A number of secondary exploration and logging roads branch off from this route. At the time of fieldwork (1984-1986) there was no road bridge across Carbon Creek and access to reclaimed exploration roads west of the creek was only possible by a footbridge (crossable by trail bike). It is possible to reach alpine areas of Mount Cowper, Mount Rochfort, The Monach, Beattie Peaks and Mount McAllister by following game trails or obscure foot trails up ridge slopes from high points on exploration roads. Helicopter access is much more convenient, particularly for the western part of the mapped area. Access for fieldwork was by helicopter, trail bike, or back-packing on foot. Ridge-top and creek-bottom traverses were made and the geology extrapolated across the forested slopes between. No persistent trails remain up the major creeks.

Over 50 separate traverses were completed in the course of fieldwork. Field data were integrated with previous work in a 1:50 000 compilation map. The only area not traversed by the writer is north of Seven Mile Creek.

Early work in the area is summarized in McLearn and Kindle (1950). Matthews (1947) produced the first map of the area which subdivided the Lower Cretaceous in some detail, introducing three new units: the Monteith, Beattie Peaks and Monach Formations. Stott (1967) defined the Minnes Group as consisting of these three units and added a fourth which was unnamed. The fourth unit, lying above the Monach Formation, was eventually named Bickford Formation (Stott, 1981). The overlying coal-measure sequence, consisting of the Cadomin and Gething Formations, was placed in the Bullhead Group (Stott, 1967).

In 1971 Utah Mines Ltd. obtained coal licenses covering the Carbon Creek syncline and carried out exploration, including 1:10 000-scale mapping, until 1982. In 1978 Utah Mines acquired additional coal licenses covering a separate major syncline to the west (West Carbon Creek property) and undertook mapping and drilling to 1982. Gulf Canada Resources Inc. held licenses on the south end of the structure in 1980 (Whiterabbit block of Goodrich property) and explored the property through 1982.

A stratigraphic and sedimentological study of Utah Mines' core was done by Gibson (1985). The Geological Survey of Canada (G.S.C.) has also released a map covering the Carbon Creek area at 1:50 000 scale (Open File 1032).

A comparison of maps by Utah Mines, Gulf Canada Resources and the Geological Survey of Canada demonstrated the need for a compilation and resolution of map-unit boundaries. Discrepancies in maps extend to the coal-bearing formations. For example, most of the area mapped as Gething Formation by Gulf Canada was interpreted as Bickford Formation by the G.S.C. Since the Cadomin Formation lies stratigraphically in between these two formations, resolving its trace on a compilation map was particularly important. Geological mapping by the writer was confined to the general area of the two major coal-bearing synclines and the intervening anticlinorium. Areas to the south and west, which are largely devoid of coal-bearing rocks, were not mapped.

The mapped area is bounded to the west by the Pardonet fault. An interesting karst terrain limestone (Triassic Bocock Formation) is exposed west of this fault. A major cave is present below Bocock Peak (Lowe, 1985; Yonge, 1985).

To the east the mapped area is bounded by the Carbon fault and rocks of the Fort St. John Group. The Butler Ridge map sheet (Legun, 1985a) adjoins the northeast corner. To the north progressively older rocks are exposed due to the southerly structural dips. The ridges overlooking Williston Lake are underlain by the Minnes Group forming the north border of the Carbon Creek and West Carbon Creek synclines.

The broad structural basins containing Gething coal measures do not persist to the south. They are replaced by geographically separate tightly folded and faulted synclines roughly on strike. Recent compilations of the area to the south (93O/10) include that of the Geological Survey of Canada (Open File 1032) and Gulf Canada Resources Inc. The two maps have serious stratigraphic discrepancies, similar to that of the Carbon Creek map area described previously.

The results of the present study supersede those in preliminary reports (Legun, 1983, 1985b, 1986) and have consequences for the subdivision of the Minnes Group in the Butler Ridge area.

ACKNOWLEDGMENTS

The writer was assisted alternately in the field in 1985 by Pat Desjardins, Paul Elkins and Hugh Christie, and in 1986 by Albert Terry and George Walker. Each provided cheerful assistance and worked capably and safely. Discussions with David Gibson and Donald Stott of the Geological Survey of Canada and staff of Utah Mines Ltd. and Gulf Canada Resources Inc. were appreciated.

STRATIGRAPHY AND LITHOFACIES

INTRODUCTION

The mapped area is underlain by Jurassic to Lower Cretaceous rocks that are assigned, in stratigraphic order, to the Fernie Formation, Minnes Group, Bullhead Group and Fort St. John Group. Subdivision into formations follows the terminology of Stott (1967, 1981). Formations above the Gates Formation (Fort St. John Group) are not subdivided.

Stratigraphic data are summarized in Tables 1 and 2 and located in Figure 3. Data from a large area peripheral to the map sheet is included in order to assess regional trends. One section was measured in detail by pogo stick in the course of fieldwork (Figure 4); the thickness of other sections was calculated from contacts mapped on airphotographs. In this method a photograph is chosen which has the mapped contacts lying as close to the airphotograph centre as possible, to minimize distortion. Calculations are made to adjust for the change in scale with elevation, and strike of the stratigraphic interval of interest. Calculations are facilitated by a short computer program written in BASIC and reproduced in Appendix A. It is adapted from formula in Ragan (1985, page 22) and Compton (1962, page 84).

The formations are described following in stratigraphic order from the oldest to the youngest.

FERNIE FORMATION

The Fernie Formation has limited exposure in the mapped area. The most accessible exposures are in roadcuts at the south end of Carbon Lake. A good section (as seen from the air) appears to be present just east of the peak on Battleship Mountain. The Fernie Formation is 190 metres thick in the Quasar et al Dunlevey well to the northeast (Figure 3, location 14). This is much less than the stratigraphic separation between Fernie exposures and the trace of the Carbon fault at Carbon Lake. Either some Triassic rocks (Pardonet Formation) are preserved against the fault, but not exposed, or the Fernie section is faulted.

The Fernie Formation consists of dark grey to brown shale and includes minor siltstones and fine-grained sheet sandstones. The sheet sandstones are parallel laminated and have sharp upper and lower contacts. The shale is generally mottled due to trace fossils. The lower contact of the Fernie Formation was not observed in the map area. The upper contact is transitional into the sandstones of the Monteith Formation and marked by the increase in proportion, thickness and number of sheet sandstone interbeds. This transitional interval is known as the "Passage Beds". In southeastern British Columbia the "Passage Beds" have been interpreted as storm-dominated shallow-marine deposits (Hamblin and Walker, 1979).

MINNES GROUP

MONTEITH FORMATION

The Monteith Formation of the Minnes Group spans Jurassic to Lower Cretaceous time and overlies the Fernie Formation of Jurassic age. The Monteith Formation is well exposed on the east limb of the Carbon Creek syncline where it forms a line of peaks from Battleship Mountain to Mount McAllister. At Carbon Lake the surface trace descends to roadside. On Mount McAllister the synclinal limb flattens and the Monteith Formation has a subhorizontal attitude over an extensive area. Good exposures are also found on the western slopes of the Beattie Peaks. It is also present in the eroded core of the Carbon Creek anticlinorium but is poorly exposed. Its airphotograph signature, which contrasts with that of the recessive Beattie Peaks Formation shale, is easily traced in alpine terrain.

The Monteith Formation consists of thick beds of milky grey quartz arenite, dark grey to brown lithic arenites, wackes, dark grey siltstone and shale. Quartz arenite is more typical of the upper half of the formation. At several locations thick intervals of quartz arenite are separated by one or more shaly interbedded zones of mixed lithology, for example, at Mount McAllister (Figure 3, location 10), 740 to 800 metres in Quasar et al Dunlevy (Figure 3, location 14) and 1315 to 1370 metres in the gamma log of Czar et al Butler (Figure 3, location 19). One of

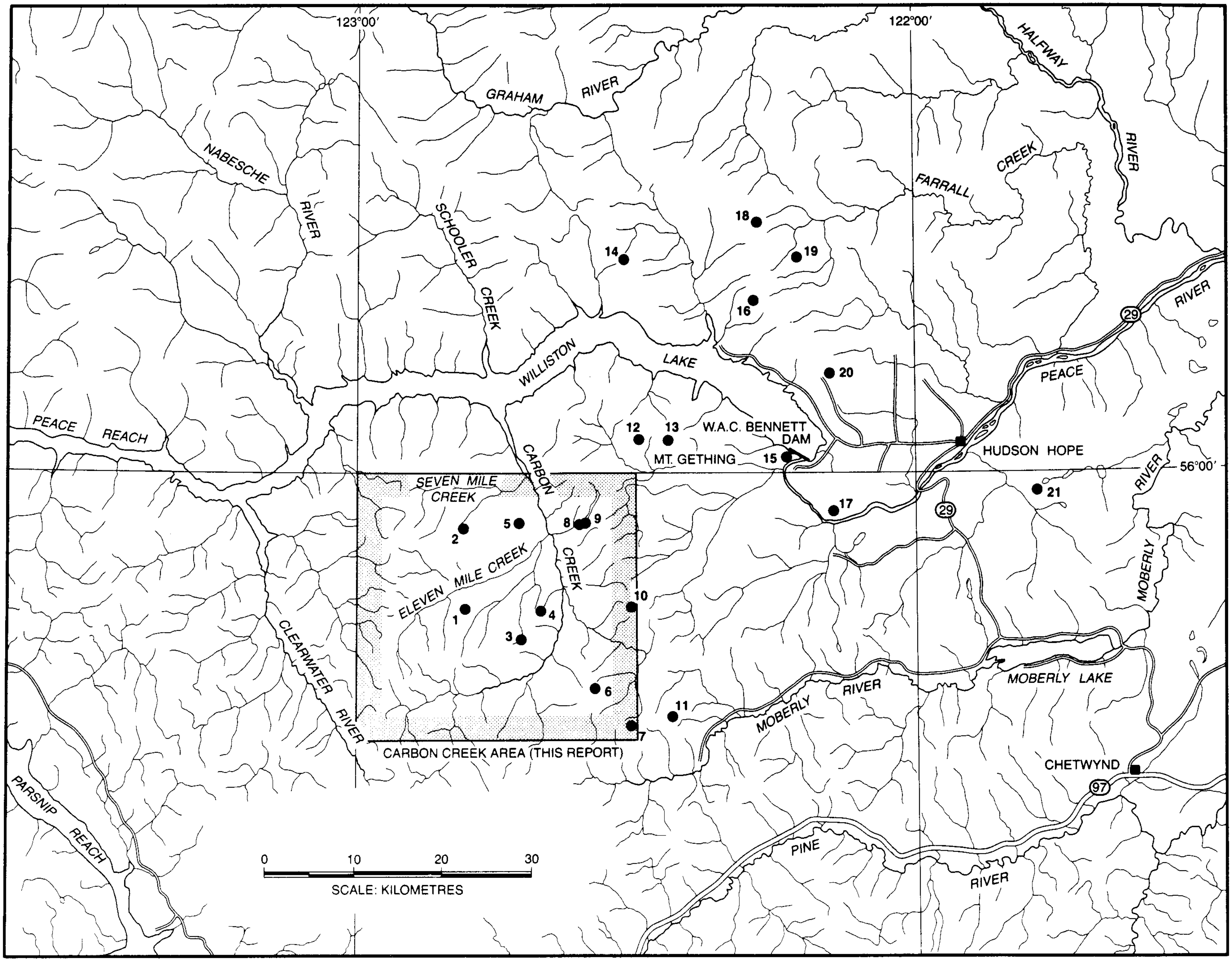

Figure 3. Numbered locations of stratigraphic thickness data.

TABLE 1
STRATIGRAPHIC THICKNESS DATA

Locations (*see* Figure 3)	Kg	Kcd	Kbi	Kmh	Kbp	Jkm	Jf	References
1 Eleven Mile Creek Ridge		268	148	442	400			
2 Mount Rochfort			407					
3 South Monach			>253					
4 The Monach			210	336				
5 Nine Mile Creek	1112							modified from Utah Mines 1982 report
6 Beattie Peaks				131	394 366-381	564		this report Hughes (1964), section No. 10
7 Mount Monteith			162	120	312			Hughes (1964), Fig. 2
8 Carbon Lake		284	331	129	284	504		
9 Quasar et al Carbon d-48-I, 93O/15						480	170	
10 Mount McAllister			256	122	272			
11 Mount Frank Roy				108	288			Hughes (1964), Fig. 2
12 Mount Gething	775		370			604		Jkm thickness from Beach and Spivak (1944)
13 East Mount Gething	670		310					Kg thickness from Utah Mines 1982 report, East Mount Gething property
14 Quasar et al Dunlevy a-40-L, 94B/1			195	495	190	495	190	
15 Peace River Canyon	550							Stott (1973), section 68-18
16 Butler Ridge			175					
17 Grant Knob			249					Hughes (1964), section No. 3 and Table II
18 Amax, D.D.H. BR-1	275							Hughes (1972)
19 Czar et al Butler d-59-J, 94B/1	324	255	188-219			312-343	175	
20 FPC-Richfield Brenot Creek No. 1 d-23-6, 94B/1			105			348		
21 West Canadian Moberly Lake 11-36-80-25, 93P/13	256	119	92			282	105	

these shaly intervals has caused some stratigraphic confusion east of the Carbon fault, where it has been incorrectly assigned to a thin Beattie Peaks Formation (Hughes, 1964; Karst, 1981). The matter is discussed in Stott (1967).

Quartz arenites of the Monteith Formation can form substantial cliffs. In geophysical logs several tens of metres of blocky gamma ray profile are evident. The quartz arenite is well sorted, often sugary in texture, is well indurated (but occasionally friable) and varies from fine sand to grit in grain size. Sedimentary structures are not easily discerned but include symmetric ripples and planar crossbedding. Low-angle crossbedding has also been noted as well as the U-shaped burrows of bivalves. The darker and less texturally mature arenites display parallel to low-angle crossbedding and ripple crosslamination.

In the Carbon Creek area the upper contact of Monteith quartz arenite with Beattie Peaks Formation shale is sharp. The Monteith Formation is 480 metres thick in the Quasar Carbon well (Figure 3, location 19). This compares with 504 metres calculated on surface adjacent to the well (Figure 3, location 8).

TABLE 2

STRATIGRAPHIC DISTRIBUTION OF SELECTED SEDIMENTARY FEATURES

Kg	Kcd	Kbi	Kmh	Kbp	JKm
		1	1		
(2)	(2)	2	2		2
3	3	(3)			
4	4	4			
5	5	(5)			
6	6	6			
			7	7	
8	(8)	8	(8)	8	(8)

Code:
1 low-angle crossbedded arenite
2 quartz arenite
3 trough crossbedded pebbly arenite
4 rooted arenite
5 coal
6 carbonaceous shale
7 Buchia-shell hash
8 trace fossils
( ) denotes uncommon

The Monteith Formation is a regressive marine sequence modified by secondary cycles of marine transgression and regression (shale to quartz arenite mini-cycles). Regression is typified by lengthy and extensive reworking of sediment giving rise to widespread deposits of texturally mature quartz arenites. No evidence of emergence is preserved.

BEATTIE PEAKS FORMATION

The Beattie Peaks Formation crops out on the east limb of the Carbon Creek syncline, on the mountain of the same name, and in the eroded core of the Carbon Creek anticlinorium. It forms a recessive zone between arenites of the Monach Formation above and the Monteith Formation below.

At Carbon Creek, the Beattie Peaks Formation is dominated by dark grey and brown shale with widespread surface mottling due to trace fossils. There are minor, thin interbeds of siltstone, arenite and ironstone. The arenites are usually parallel laminated but also display low-angle crossbedding and symmetric (wave) rippled surfaces. The formation coarsens upward with an increase in the number and thickness of fissile parallel-laminated arenite beds (similar to the Fernie-Monteith transition). The upper contact is transitional into the arenites of the Monach Formation, and placed where the arenite units become thick, closely spaced and prominent, forming resistant ledges visible on airphotographs. The thickness of the transition zone varies considerably and is thicker (up to 100 metres) where the overlying Monach Formation is thick.

The formation is calculated to be 394 metres thick at the Beattie Peaks (Figure 3, location 6). This compares with the 366 to 381 metres estimated by Hughes (1964, section 10). A similar thickness (400 metres) is present on Eleven Mile Creek ridge (Figure 3, location 1). In contrast, to the east only 272 metres is indicated at Mount McAllister (Figure 3, location 10) and 284 metres along the Carbon Lake road (Figure 3, location 8).

Hughes (1964) notes the presence of ammonites in the formation and this writer often observed Buchia-shell hash in the transition to the Monach Formation. The presence of ammonites suggests open marine conditions. The upward-coarsening cycle is indicative of marine shoaling.

MONACH FORMATION

The Monach Formation is exposed on the east limb of the Carbon Creek syncline and on high ground in the Carbon Creek anticlinorium where it forms the peaks of Mount Cowper, Mount Wrigley (Plate 1), The Monach and Beattie Peaks. In the anticlinorium it often outcrops on dip slopes giving the formation a larger areal distribution than its thickness would suggest. West of the West Carbon Creek syncline its thickness and distribution are poorly defined.

The Monach Formation is dominated by beds of arenite up to 20 metres thick, separated by a few metres of shale, usually not well exposed. The fine to coarse-grained arenite is light brown to orange in colour, typically flaggy and displays low-angle crossbedding, trough crossbedding, and minor planar crossbedding. Some units are rather massive and structureless at the base. Undulating beds suggesting hummocks or swales have been noted at the tops of others. Arenite units have sharp basal contacts and in vertical section form lenses hundreds of metres long. Mudstone rip-up clasts are common. Some arenites grade without bedding contact into quartz arenites, and quartz arenites have also been observed as white gritty lenses enclosed in arenite (Plate 3).

Quartz arenites occur as discrete units within the formation and range from a metre or less to 40 metres in thickness. They are coarse grained to gritty, sugary, indurated to friable, and occasionally fine upwards or interbed in finer and coarser layers. Sedimentary structures are not very apparent. The quartz arenites are not confined to any particular stratigraphic position in the formation, but are preferentially developed toward the top. Thick units can form local markers; one such unit is continuous from The Monach to Beattie Peaks, along the west limb of Carbon Creek syncline. It is 40 metres thick on the south flank of The Monach but missing on the north flank.

Massive and blocky jointed, greyish lithic arenites are also present toward the top of the formation where they interbed with quartz arenites or brownish flaggy arenites.

The upper contact of the Monach Formation with the Bickford Formation is defined as the change from thick-bedded quartzose sandstone to thin, cyclic units of alternating mudstone, siltstone and sandstone (Stott, 1981). At some localities it can be conveniently placed at the top of the last thick quartz arenite unit. At others the interbedded sequence of thin cyclic units precedes the last thick quartz arenite which must then be placed in the Bickford Formation. In some sections the transition is from a thick lithic arenite rather than a quartz arenite; it may also be gradational and marked by increasing thickness of shale interbeds (Figure 3, location 2, Plate 2).

Sedimentary structures in the Monach Formation are indicative of high-energy conditions in a shallow-marine setting. Lower regime structures (ripples) are uncommon except at the very top of the formation where rippling, plant debris and surface grazing trails have been noted at the Bickford contact. Additional evidence of an overall energetic regime includes:

Abundant mud chips in arenite.
Abundant Buchia-shell hash.
Lack of bioturbated and burrowed beds indicating a mobile substrate.
Redeposition of coarse quartz sands as lenses in more lithic arenites.

The Monach Formation appears to represent deposits of wave-built shoals. The overall upward-coarsening cycle represented by the Beattie Peaks - Monach Formations could indicate progradation of a wave-dominated delta. However the expected delta environment of emergence, with distributaries, bays and backswamps, is replaced by quartz arenites, suggesting reworking of deposits into shallow sandbars and beaches.

The thickness of the Monach Formation varies within the study area. It is thick in the anticlinorium, reaching 400 metres or more with a thick underlying transition zone. Thickness trends west of the West Carbon syncline are uncertain. To the east a thinning trend is apparent. At Mount McAllister (Figure 3, location 10) the Monach Formation is 122 metres thick and at the Beattie Peaks (Figure 3, location 6) Hughes (1964, section 10) measured 131 metres. At both localities there is virtually no underlying transition zone and individual arenite units are thinner. The Monach is probably a more geometrically irregular deposit than previously thought.

The bivalve *Buchia* is very common in some stratigraphic sections and sparse in others. It may occur as coquina beds within the arenites or as dispersed shells; the degree of shell fragmentation varies considerably from one bed to another. The occurrence of beds with articulated shells preserved in the growth position is rare.

BICKFORD FORMATION

The Bickford Formation is distributed on the flanks of both major synclines and throughout the intervening anticlinorium. It overlaps the top of the box anticline at Mount Rochfort forming the mountain peak. At the south end of the anticlinorium it is preserved in two tight secondary synclines and as a caprock on a high ridge. East of the Beattie Peaks it forms a large dip-slope exposure at the south end of the Carbon Creek syncline.

The Bickford Formation is a sequence of interbedded arenites and shales. The arenites are generally darker and more lithic (salt and pepper) in appearance than arenites of the Monach Formation below or Cadomin Formation above. Light-coloured arenites akin to those in the Monach are also present. Quartz arenites are minor. Shales include carbonaceous shale, flaser shale, dark grey siltstones and mudstones. Thin beds of coal have been noted locally as well as thin beds of grit or pebbly grit.

The Bickford Formation does not have a good airphotograph signature and it is easily misidentified if observed in stratigraphic isolation. It is best mapped by defining the Cadomin Formation above and the Monach Formation below. Good exposures of the Bickford Formation can be found at:

The saddle southwest of The Monach (Figure 3, location 3; Plate 4).
The stream draining the northeast slope of the Beattie Peaks, particularly at 1065 to 1160-metre elevation.
A stream draining the northeast slope of Mount Cowper.
On the east flank of Mount Rochfort (Figure 3, location 2).

Large *Skolithos* and *Diplocriterion* burrows in argillaceous and flaser-rippled arenite can be seen on the road descending to Carbon Creek from Carbon Lake. The upper and lower contacts of the formation are poorly exposed at this readily accessible location.

The arenites of the Bickford Formation are thin to thick bedded, are fine to very coarse grained, and may form units 10 metres or more thick. Individual units vary from parallel sided to lenticular to channel in outline. The arenites are massive to crossbedded and this is reflected in the jointing pattern.

The Bickford Formation displays a wide variety of biogenic and sedimentary structures. Sedimentary structures include low-angle crossbedding, planar and trough crossbedding, current-ripple crosslamination, symmetric wave-ripple lamination (chevron structure), flasers and sole marks. Biogenic structures include large (2 centimetres diameter) single and double tube burrows (*Skolithos*, *Diplocriterion*), horizontal bisymmetric grazing trails (gastropod?), root casts, carbonized plant films, and vertical rod structures (up to a few centimetres long) that are either root casts or the trace fossil *Trichichnus*.

In the Carbon Creek area the Bickford Formation generally shows an increase in carbonaceous content up section. Thin coals have been noted but only toward the top of the formation. Its upper contact with the Cadomin Formation is marked by the appearance of thick and closely spaced pebbly arenites with channeled bases and abundant log casts. The lithology immediately below this contact varies from place to place. Three variations can be described as follows:

(1) Approximately 50 metres of coarse grey arenites in which pebbly zones, erosional channel bases and casts of wood debris are not apparent.

(2) Quartz arenite - for example, off the Carbon Creek road the contact of the Cadomin Formation and Bickford Formation can be followed up a small stream gully. A white sugary quartz arenite lies at the base of a pebbly arenite full of log casts. Below the quartz arenite is burrowed siltstone with *Skolithos*.

(3) Interbedded dark lithic arenite and shale of typical Bickford Formation lithology, with one or two isolated pebbly arenite channel bodies of "Cadomin" appearance.

In summary the lithological contrast at the Bickford/Cadomin boundary is sharp to broadly gradational.

The Bickford Formation varies from 148 to 331 metres in thickness in the map area and shows an inverse thickness relationship with the Monach Formation. It is probable that thick Monach arenites in the west thin and pass laterally into interbedded arenite and shale of the Bickford Formation to the east (east limb of Carbon Creek syncline). The following lithofacies are recognized in the Bickford Formation:

(1) Parallel to low-angle crossbedded arenites with a flaggy weathering habit. This facies includes some minor high-angle trough and planar crossbedding.
(2) Wave-rippled arenites.
(3) Rooted current-rippled crosslaminated arenites.
(4) Massive lithic arenites.
(5) Carbonaceous shales and siltstones.
(6) Noncarbonaceous shales and siltstones.
(7) Flaser shales, argillaceous arenites (wackes).
(8) Bioturbated arenites and shales.

A 253-metre section of the Bickford Formation was measured on one limb of a syncline southwest of The Monach (Figure 3, location 3; Plates 4, 5 and 6). The section ends in the core of the syncline below the contact with the Cadomin Formation. The section is reproduced in Figure 4 which illustrates the four facies relationships described following.

Facies Association A (0 to 50 metres): Shallow-marine Storm Deposits (Sublittoral Sheet Sandstones with Post-storm Reworking; Plate 6)

This sequence immediately above the Monach consists of clean and well-sorted low-angle crossbedded arenites up to 3 metres thick, interbedded with noncarbonaceous shale. Some arenites are lenticular and have sharp bases with sole marks at the base or sides. The top of an arenite is commonly rippled and draped with mudstone. The ripples are symmetrical, straight crested and continuous over several metres. They grade into or truncate the laminae below. Rippled surfaces show abundant grazing trails. Occasionally the top of a unit is undulating rather than rippled, with swaly crossbedding immediately below.

These sandstone beds are interpreted as being deposited from waning sediment-laden currents in shallow-marine conditions. Sole marks, parallel lamination, low-angle crossbedding and absence of bioturbation indicate rapid deposition under high-energy conditions such as waning storm activity. Each depositional event was followed by reworking (wave rippling, biogenic grazing) under quiet and reduced rates of sedimentation (mud drape and shale).

Facies Association B (50 to 95 metres): Nearshore Marine to Shoreface

Parallel-laminated and crossbedded arenites with rippled tops are still present in the interval 50 to 90 metres above the base. In addition there is a thick composite arenite and thin interbeds of grit. A significant amount of eroded and transported debris is evident, including wood casts, mud chips and carbonized plant debris. The combination of high-energy deposits with abundant transported plant debris and no signs of emergence is interpreted as a nearshore environment subject to wave action. The upper 20 metres of this interval is covered and its designation unclear.

Facies Association C (95 to 115 metres): Emergent Coast with Beach

The parallel-laminated and low-angle crossbedded arenites disappear in this interval and are replaced by rooted rippled arenites, a thick quartz arenite and a lateral accretion unit comprising low-angle inclined interbeds of bioturbated arenite and shale. Rooting indicates emergence. Textural maturity of the quartz arenite suggests a beach and the inclined interbeds of shale and arenite a shallow migrating (tidal?) channel.

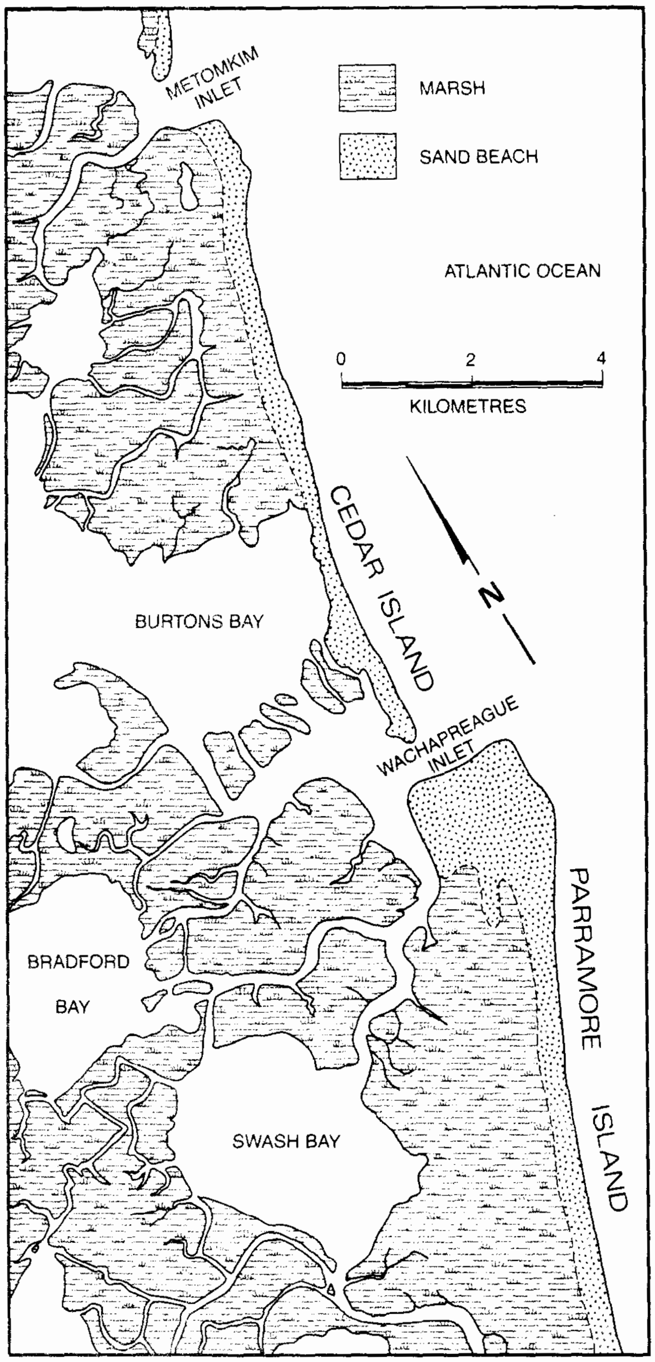

Figure 5. A modern analogue for deposits of the Bickford Formation.

Facies Association D (115 to 253 metres): Lagoonal Coastal Plain

This interval is characterized by a monotonous sequence of rippled crosslaminated arenite and shale. The shale displays flasers and shale also occurs as partings and lenses in the arenite. This is difficult to characterize and the separation of shale and arenite is portrayed more distinctly in the section than is actually the case in the field. Thin upward-coarsening cycles of shale to arenite are noted and the occasional arenite exhibits planar crossbedding.

Bifurcated root casts and matted fossil plant material are found in the arenites. The plant material includes reed-like forms. Arenites are often bioturbated and display subvertical rod-like structures. A 2-metre bed at 123 to 125 metres in the section consists of a mass of vertical tubes (Skolithos) up to 20 centimetres in length and 2 centimetres in diameter.

The interval appears to represent a low-energy mixed marine-continental environment. Weak sediment-laden currents, bioturbation and a lack of storm deposits suggest a degree of protection from the open sea and deposition in sheltered bays. A lagoonal model is proposed for this interval (Figure 5).

BULLHEAD GROUP

CADOMIN FORMATION

The Cadomin Formation defines the base of the coal-bearing Bullhead Group along the flanks of both major synclines and the intervening anticlinorium. Its airphotograph signature varies depending on the number, thickness and separation of its component arenite units. Where these units are closely spaced, the formation can be traced as distinct "sandstone-ribbed" ridges at the margin of the recessive Gething coal measures.

Large and prominent dip-slope exposures of stacked arenites of the Cadomin are present east of the Beattie Peaks. The basal contact with the Bickford Formation is exposed in the valley immediately to the north, at an elevation of 1510 metres. Good exposures of the Cadomin and Cadomin/Bickford contact are also present in small wavelength folds west of the West Carbon Creek syncline near the south fork of Eleven Mile Creek. The Cadomin is not well exposed along the Carbon Creek road west of Carbon Lake.

The Cadomin Formation is characterized by thick (up to 20 metres) units of arenite and pebbly arenite separated by thinner recessive intervals that include variably rooted siltstone, carbonaceous shale, fine-grained arenite and coal. Quartz and chert-pebbles occur in lenses or scattered throughout the arenite. They reach 5 centimetres in diameter but are usually a centimetre or less. They account for less than 10 per cent of the formation.

The proportion of resistant pebbly arenite units to recessive intervals varies laterally and vertically. The formation may consist of a closely spaced succession of stacked arenite units or of only a few stratigraphically separated pebbly arenites with a considerable thickness of recessive lithology in between. This is evident in exposures on the west flank of Mount Rochfort. Here the Cadomin Formation consists of basal conglomerates (clasts to 5 centimetres) separated from a thick arenite unit by more than 100 metres of coal measures (Plate 8). The G.S.C. and Utah Mines have mapped the thick arenite as a thin (60-metre) Cadomin Formation with the underlying coal measures assigned to the Bickford Formation. However to the south, the coal measures below the thick arenite are replaced laterally by pebbly arenites. It is clear that the entire 200-metre interval represented by conglomerate, coal measures and thick arenite should be assigned to the Cadomin Formation and traced southward as such.

The Cadomin Formation can be divided into a trough-crossbedded pebbly arenite facies, an interbedded (arenite and shale) coal measure facies and an uncommon quartz arenite facies.

Pebbly Arenite Facies (Fluvial Fan Deposits)

Pebbly arenite units are massive to trough crossbedded with sharp and erosional bases. Trough crossbedding is apparent, at times disrupted by a large amount of debris, including log casts and intermixed patches of sand and mud. The units are lens shaped, occasionally displaying a channel-edge outline. Conglomerate occurs preferentially at the base and the units tend to fine upward. Crude imbrication is sometimes noted.

Coal Measure Facies (Floodbasin and Overbank Deposits)

The coal measure facies is similar to that described for the Gething Formation, consisting of carbonaceous shale, rippled and rooted sandstones, and coal. The shales tend to be more sandy than the Gething Formation shales.

Quartz Arenite Facies (Beach?)

The occasional arenite in the Cadomin Formation approaches a quartz arenite in composition and displays little discernible sedimentary structure. One such arenite crops out on the eastern slopes of Mount Wrigley and another at the side of Carbon Creek logging road just south of the McAllister Creek bridge. The presence of this facies suggests reworking in a nonfluvial (?) depositional environment.

The Cadomin Formation has been intersected in two diamond-drill holes in the Carbon Creek area (CC 75-41 and CC 72-17) just north of the map sheet. Arenite units show a blocky profile on geophysical logs.

In the south half of the West Carbon Creek area Gulf Canada's diamond-drill hole 80-32 was spudded into the Cadomin Formation. Little information can be gained from the core which displays low bedding to core axis angles.

The Cadomin Formation represents separate fluvial fans that are partially coalesced laterally. Stacked channel deposits comprise the fan itself while interfan areas are dominated by coal measures. Quartz arenites may represent reworked deposits in standing water (?) at the edge of a fan.

The depositional relationship of the Cadomin Formation to the underlying Bickford Formation is not clear. Continuous sedimentation is suggested where the lithological transition is gradual and marked by upward stratigraphic increase in:

Grain size.
Carbonaceous content.
Channel deposits.

The upper contact of the Cadomin Formation with the Gething Formation is transitional and marked by a loss of thick pebbly arenites. Stratigraphically different arenites may define the Cadomin Formation contact from place to place. The thickness of the formation is generally 200 to 275 metres. The proportion of thick pebbly arenites does not increase to the west as might be expected; if anything the proportion of coal measures increases.

GETHING FORMATION (Plate 8)

The distribution of the Gething Formation in the Carbon Creek syncline is somewhat different from that presented in previous maps. The principal change is the extension of Gething coal measures up a plunging synclinal axis to the area of the Beattie Peaks, where exposures near a small lake mark the contact with the Cadomin Formation. South-southeast of the lake, the Gething Formation is preserved in fault slices and a small tight syncline. This interpretation is at variance with regional mapping by the Geological Survey of Canada, but in accord with local detailed mapping by Gulf Canada Resources. The West Carbon Creek syncline is broad in the north but tightens to the south; the trace of the bounding Cadomin Formation is evident both on the ground and in airphotographs. The Gething Formation coal measures continue to form the core of the syncline as it tightens southward. The assignment of the core of the syncline to the Bickford Formation by the Geological Survey of Canada is not supported by this study.

The Gething Formation consists of interbedded arenite, noncarbonaceous shale (siltstone, mudstone), carbonaceous shale and coal. Pebbly arenite is also present and some beds are calcareous or ferruginous.

Most arenite occurs as thin beds intimately interbedded with shale. Thicker beds may have sharp contacts against shale and form upward-fining or upward-coarsening sequences. The most significant composite arenite reaches 47 metres in thickness, lies between coal seams 52 and 53, and is well documented by drill holes in the Carbon Creek syncline.

Pebbly arenites are not restricted to any stratigraphic interval. On high ground in the core of the West Carbon Creek syncline they form channel bodies 50 to 100 metres in apparent width. These can be traced laterally into extensive sheet-like, crossbedded units of arenite, pebbly arenite and conglomerate.

Shales in the Gething Formation can form coal-free units of up to 40 metres thickness. Some interbedding with arenite is noted in such intervals.

The Gething Formation displays a variety of sedimentary and biogenic structures which includes ripple crosslamination, ripple drift, flaser and lenticular bedding, trough crossbedding, root casts, small vertical burrows, wood casts, comminuted plant debris, large delicate plant fragments (as carbon films), and slump and convolute bedding.

A study of core from the Gething Formation was not made. The reader is referred to Gibson (1985), and Kilby and Oppelt (1985) for detailed descriptions of lithofacies. The following descriptions are adapted from their work:

Arenite Facies

(1) **Major arenite unit**: This unit, up to 47 metres thick at Carbon Creek, has a sharp basal contact. Pebble lenses occur in the

middle and toward the top. Seam 52, a relatively high-sulphur coal, lies at its base. Gibson (1985) interprets the unit as the fill of a major distributary bay.

(2) **Coarse to medium-grained arenites with coal spar, wood casts, pebbly lenses and a scoured basal contact:** The units are trough-crossbedded and are upward fining and unburrowed. They are interpreted as deposits of alluvial channels or delta distributaries.

(3) **Fine-grained arenites with ripple cross-lamination and ripple drift (climbing ripples):** The units are often rooted, burrowed and may fine or coarsen upward. Their interpretation depends on relationships to other facies. Where they overlie (2) and fine upward, waning current activity in an alluvial channel is suggested. If they are lateral to (2) they are interpreted as crevasse splays marginal to the channel (crevasse splay deposits are wedge-like and can be bounded by coal). If the facies caps an upward-coarsening sequence, deposition of a small-mouth bar in a floodbasin is suggested.

Interbedded Arenite and Shale Facies

This facies varies from sandstone with flasers to mudstone with sandy lenses. It includes wavy bedded (sandstone or mudstone in equal proportion forming continuous layers) and siltstones. The beds are variably rippled, rooted and burrowed. Plant fossils and comminuted plant debris are evident. The facies represents floodbasin deposits with conditions of current and flood activity depositing sand, alternating with slack-water conditions when mud is deposited from suspension.

Mudstone Facies

This includes carbonaceous and noncarbonaceous mudstones. Noncarbonaceous mudstones are massive to faintly laminated and may contain megafossils. The carbonaceous content of carbonaceous mudstones varies from comminuted plant debris to layers of "matted" plant fossils and coal laminae. Burrowing and megafossils are locally present in the less carbonaceous varieties.

The mudstones are interpreted to represent swamp to lacustrine or interdistributary bay deposits, depending on the amount of carbonaceous material, and evidence of brackish or marine water deposition, such as high-sulphur coal or the presence of marine pelecypods.

Coal Facies

Coals display dull to moderately bright lustre depending on maceral content. The sulphur content is variable with a tendency to increase in the upper 200 metres of the section at Carbon Creek according to Gibson (1985). The influence of brackish water on peat bogs is suggested by the higher sulphur values. This is supported by the presence of marine bivalves in core from two drill holes.

Thickness of Gething Formation

Over 100 diamond-drill holes and a number of rotary-drill holes have been put down by Utah Mines Ltd. in the Gething Formation of the Carbon Creek syncline. Correlation between holes indicates a total exposed thickness of 1067 metres for the formation. Prior to drilling in 1981, it was thought that the collar of diamond-drill hole 72-13 was close to the Moosebar contact on the basis of nearby outcrops of mudstone and shale. However diamond-drill hole 81-88 intersected an additional 31 metres of strata, including a 2.2-metre coal seam (12 metres below the top) named seam 63. The subcrop of seam 63 is outlined in Plate 4 (Utah Mines Ltd., 1982). Strata above it occupy a small area of the ridge between Nine Mile and Ten Mile Creeks in the elevation interval of 1150 to 1200 metres.

A tentative correlation (Figure 6) can be made between diamond-drill hole 81-88 at Carbon Creek and rotary-drill hole 79-05 on the Adams property (formerly held by Crowsnest Resources Ltd.) east of the Carbon fault. The correlation is based solely on a 40-metre-thick arenite being present in both holes. No other arenite of this thickness is known from the drill-hole data of either area. If the correlation is accepted, the Moosebar contact lies 45 metres above the

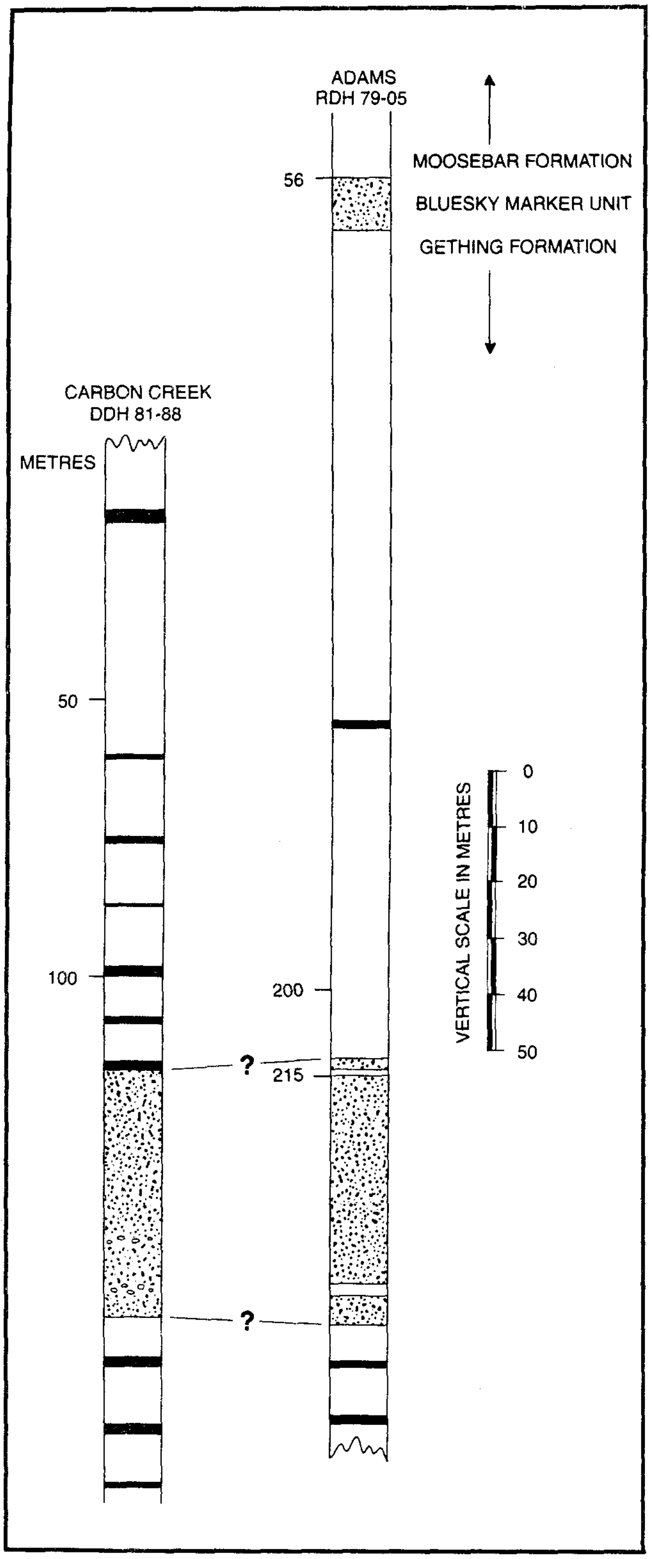

Figure 6. Correlation of the Gething Formation.

cored top of diamond-drill hole 81-88 and the total thickness of Gething strata initially deposited in the Carbon Creek area is 1112 metres.

The thickness of the Gething Formation in the West Carbon Creek area cannot be obtained from drill-hole data as only eight holes have been drilled, with incomplete stratigraphic overlap. However the stratigraphic section can be traced on the ground from the steeply dipping contact with the Cadomin Formation on the west side of Mount Rochfort, through a folded zone, to subhorizontal strata on a hill in the core of the West Carbon "box" syncline (Figure 7). Two hundred metres of strata lie above a shale marker unit outcropping at the 1620-metre elevation on the side of the hill. A total of 835 metres of strata underlies the shale where it reappears on the east side of the folded zone. Therefore the total thickness is 1035 metres, which is marginally less than is preserved in Carbon Creek.

Stott (Open File 1032) considers the 60-metre shale marker unit to be Moosebar Formation, even though the coal-free interval is only 40 metres thick and the shale is overlain by a further 200 metres of coal measures. No marine fossils have been found in the shale interval (David Gibson, personal communication, 1987). Stott assigns the overlying 200 metres of coal measures to the Gates Formation. However the Gates Formation is not known to have any coal north of the Pine River. Roadside exposures immediately east of the Carbon fault show the Gates Formation to consist of interbedded rubbly and bioturbated arenite (bivalve burrowings) and shale, devoid of carbonaceous content.

The shale unit is preserved in diamond-drill hole W.C.C. 82-8 in the interval 45 to 105 metres. This drill hole was collared in a dip-slope pebbly arenite that correlates southward with a channel conglomerate at the 1660-metre elevation on the east flank of the hill referred to previously. Since the top of the hill is at the 1820-metre elevation, about 160 metres of section are preserved above the drill hole.

STRUCTURE (Plates 1, 4 and 7)

Main fold structures in the mapped area consist of a pair of broad synclines separated by an anticlinorium. This folded sequence of Bullhead and Minnes Group rocks is bounded by major faults. To the west, the West Carbon Creek syncline is, in part, faulted against Triassic limestones on the Pardonet fault. To the east, Fernie shale on the east limb of the Carbon Creek syncline is faulted against Fort St. John Group shales on the Carbon fault. The Carbon fault zone consists of at least two separate faults. This is evidenced by mapping and from the log of the Quasar Carbon well (Figure 3, location 9) which records faults at depths of 1000 metres and 2030 metres.

Both major synclines tighten to the southeast with secondary folding and faulting. Both are doubly plunging, forming a canoe shape modified by topography. The structural style is typified by chevron folds but more rounded fold profiles also occur, for example, at depth below chevron anticlines (Plate 7).

CARBON CREEK SYNCLINE

Beds on the east limb of the Carbon Creek syncline dip at shallow to moderate angles to the west-southwest and are modified by some local kinking. Beds on the west limb are affected by faulting and secondary folding. A major fault truncates the Gething coal measures at Mount Rochfort. Steeply dipping beds of the Cadomin Formation are juxtaposed against shallow-dipping Gething Formation strata to the east. Using seam 40 of the Gething Formation as a marker, the top of the Cadomin Formation can be extrapolated to the fault. A vertical displacement of at least 350 metres is indicated (cross-section A-B on the 1:50 000 scale map of the Carbon Creek area). The fault(s) and associated tight folds can be traced northward to Mount Barr, just outside the map sheet. To the south, the trace of the fault on the east flank of Mount Wrigley is uncertain. Its throw is postulated to decrease and it is depicted as truncating part of the Cadomin Formation in cross-section C-D of the map.

Further to the south, the west limb of the syncline is folded and faulted in the vicinity of the south fork of Eleven Mile Creek. Here folds in the Cadomin Formation plunge and increase in amplitude northward (passing into faults?). To the south the amplitude decreases and the folds disappear.

Drilling has helped to define some of the faults affecting the Gething coal measures in the central part of the syncline. For convenience the faults are numbered 1 to 5 in cross-section C-D. The effect of faulting on two seams (No. 40, No. 52) is shown, based on structural contour data contained in Utah Mines' 1981 assessment report. Calculations show that fault 3, adjacent to diamond-drill hole 81-91, must dip greater than 60 degrees since the drill hole did not intersect the fault. Similar steep dips are suspected for the other faults.

Faults 2, 3, 4 are known, from drill-hole data, to be upthrown to the east. In cross-

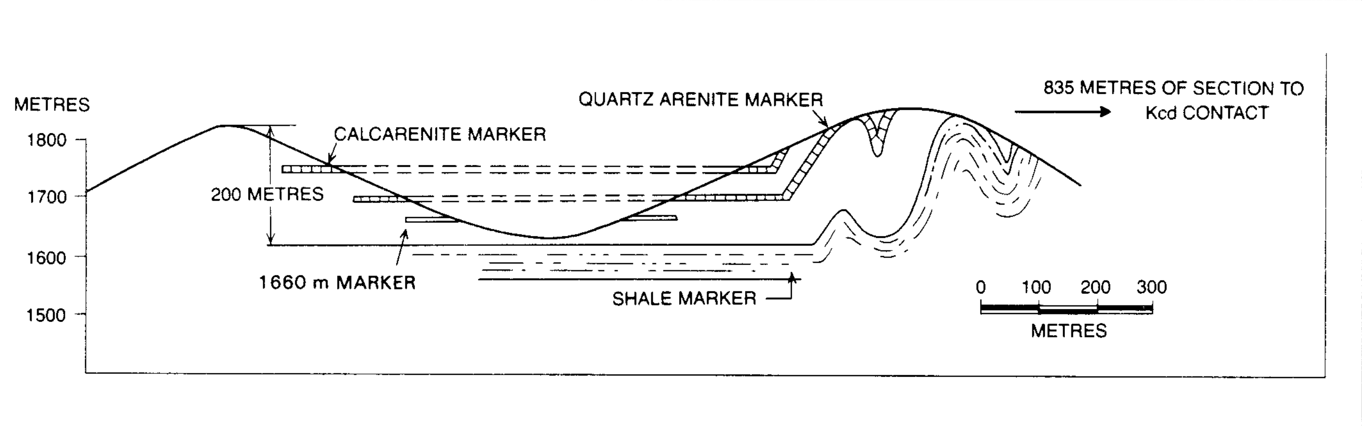

Figure 7. Correlation of Gething Formation strata through fold zone.

section A-B the vertical displacement of seam 40 is 180 metres on fault 2 and 20 metres on fault 4. In cross-section C-D the vertical displacement is 80 metres on fault 3. The vertical displacement of a seam varies along the strike of a fault. For fault 3 the vertical displacement of seam 40 varies from zero in the north, to 100 metres near Nine Mile Creek, to 40 metres near Eleven Mile Creek. It is postulated that faults further from the synclinal core have greater maximum displacement.

The trace of fault 2 south of Ten Mile Creek differs from that shown on Utah Mines' maps. It is correlated with a structural discontinuity further to the east and downslope on the flank of Mount Wrigley. The extension interpreted by Utah Mines is believed to be a separate structure (fault 1).

It is believed that faults 2, 3 and 4 dip to the east, making them high-angle reverse faults. They separate the coal measures into blocks of slightly differing dip. Fault 5 is postulated to be a high-angle reverse fault dipping to the west and thus defining at least one "pop-up" structure in the core of the syncline. Old cross-sections (McLearn and Kindle, 1950, Figure 16, page 180) along Eleven Mile Creek give support to the interpretation of a west-dipping fault.

An east-west-trending thrust is shown on Utah Mines' maps, immediately north of the lower reaches of Nine Mile Creek. In the vicinity beds dip gently to the south and define the plunge of a syncline. The axis of the syncline can be traced southward. It is offset near the confluence of the two forks of Eleven Mile Creek, and then persists southward as the main synclinal axis of the Carbon Creek basin. In the vicinity of McAllister Creek dips near the axis become steep, defining a north-plunging deep synclinal core, bounded by faults or kink folds. This core persists south to the Beattie Peaks where the structure tightens into numerous merging folds and thrusts. The synclinal axis does not swing to the east toward Mount McAllister, as shown on some maps. A separate syncline which opens and plunges northward underlies the western ridges of Mount McAllister.

COAL SEAM DISTRIBUTION

The subcrop of seam 40 defines the boundary of two areas of proven coal reserves located within the map area. Older strata outcrop to the north and west of the subcrop area. To the east across fault 5, seams 40 and above may be preserved in a folded zone. Seams ranging up to 1.6 metres in thickness are noted in McLearn and Kindle (1950, Figure 16, page 180 and Table IV, page 182) on the east side of the fault. To the south, on the ridge between the forks of Eleven Mile Creek, one diamond-drill hole (81-93) was spudded below seam 40 due to thick overburden. Seam 40 may yet be preserved nearby or downslope to the east, but its areal extent on this ridge would be small. Further to the south, on the east flank of The Monach, there is a large area seemingly favourable for the preservation of seams 40 and above. Two diamond-drill holes (75-55 and 75-65) were placed high in the stratigraphic section in a 1975 correlation chart, but omitted from subsequent charts. Thickness calculations, based on the Cadomin Formation contact on The Monach, suggest these drill holes were spudded about 400 metres lower in the section than previously thought. No thick coals were intersected. East of these holes, the bedding approaches a dip-slope situation and calculations suggest that the axis of the syncline is reached stratigraphically short of preservation of seam 40. West of the two drill holes there is some possibility that seams low in the stratigraphy (for example, Nos. 13, 14 and 15 which are important north of Seven Mile Creek) are in a near dip-slope situation. The interval is undrilled. Across the valley however, on the flanks of Mount McAllister, limited drilling in the same interval gave mediocre results (average coal thickness less than 1.5 metres, maximum coal intersection 1.8 metres).

CARBON CREEK ANTICLINORIUM (Plate 1)

The Carbon Creek anticlinorium is a simple box anticline in the north that becomes rounded to the south (Mount Wrigley). South of Mount Wrigley tight synclinal folds are developed.

The anticlinorium has a faulted east margin in the vicinity of both forks of Eleven Mile Creek. Along the south fork, beds dip to the west and yet older map units appear in that direction. A series of west-dipping reverse faults are postulated to explain this. More detailed work, particularly on the ridge between the forks, is needed to unravel the structure.

WEST CARBON CREEK SYNCLINE

The West Carbon Creek syncline has an open box-like shape in the north but tightens southwest of Mount Wrigley and persists to the north slopes of the Carbon Creek valley. In the north the limbs of the box syncline are steep dipping. The intersection of the limbs with flat-lying beds in the core is marked by a tight fold zone in the east limb and a fault/fold zone in the west limb. Diamond-drill hole 81-6, which intersected dipping beds at depth, suggests the width of the flat-lying core decreases with depth. The fault on the west limb is steep but its dip is unknown. On the basis of the anticline on the east, it is suspected the east side is upthrown. The axis of this fault is visibly offset by a small lateral fault.

COAL SEAM DISTRIBUTION

The surface trenches and eight drill holes put down by Utah Mines intersected numerous coal seams, most averaging less than 1 metre in thickness, with the maximum being 1.9 metres. According to Utah Mines (1982) the eight drill holes can be correlated within three groups but without stratigraphic overlap between groups. Without stratigraphic overlap the composite thickness cut by the eight holes is at least 1100 metres. To this can be added 160 metres of undrilled section lying above diamond-drill hole 82-8 (*see* Gething Formation) and an unknown thickness to the Cadomin contact, bringing the total to well over 1260 metres. This thickness is greater than that calculated by the writer from tracing the section on the ground (Figure 7).

It is probable that the eight drill holes do overlap stratigraphically. For example, holes 78-2 and 80-5 are approximately on strike and the dip is low (8 degrees), therefore the stratigraphic difference corresponds to the elevation change which is only 70 metres. However a 1981 chart shows a 250-metre stratigraphic separation without overlap. It is clear that the coal seams in the structurally favourable area of the West Carbon Creek syncline are inadequately correlated.

In the south half of the syncline Gulf Canada trenched one 3-metre coal seam. However the steep dips, tight structure and limited areal preservation of Gething Formation precluded further exploration activity.

REGIONAL TRENDS

MINNES GROUP: TRENDS TO THE EAST

The Minnes Group thins eastward into the plains region, ranging from more than 1550 metres in the West Carbon Creek area to 343 metres near the town of Hudson's Hope (Figure 1). The only formation of the Minnes Group that can be traced throughout the area is the Monteith, and this requires careful designation of its top (*see* Monteith Formation). Lithologic changes above the Monteith Formation east of the Carbon fault are described below by reference to a number of stratigraphic sections.

MOUNT GETHING: WEST FLANK (Locality 12, Figures 3 and 8)

A composite section (Figure 9) indicates that the Monteith and Cadomin Formations are separated by 370 metres of intervening strata. The top of the Monteith Formation is a clean, rippled coarse quartz arenite which is in sharp contact with brown shale typical of the Beattie Peaks Formation. Up-section however, the shale grossly alternates with thick units of low- angle crossbedded arenite. One such arenite unit, several tens of metres thick, forms the flat tabletop of Mount Gething. This tabletop unit lies 120 metres above the Monteith Formation. Above it an additional 30 metres is preserved on a low rise. To the west the tabletop arenite unit dips away and the section continues in poorly exposed beds with steepening dips, to the Cadomin Formation contact. The Minnes section above the tabletop arenite is 250 metres thick and appears to consist of lighter and darker rippled arenites, shale (±burrowing), rooted arenite and dark quartzitic siltstone.

MOUNT GETHING: EAST FLANK (Locality 13, Figures 3 and 8)

About 310 metres of section separates the Monteith and Cadomin Formations. The section consists of interbedded rippled arenite, shale, dark siltstone, low-angle crossbedded arenite and minor quartz arenite, together with fossil plant litter and minor coal spar. No interval of basal shale is evident nor is there any particular lithological trend. Thick arenites underlie the Cadomin Formation. These have been mapped as Monach Formation by Utah Mines but stratigraphic correspondence with the Monach Formation at Carbon Creek cannot be demonstrated.

SOUTH MOUNT GETHING (Figure 9)

The exposed section is 225 metres thick but a strike and dip discordance at the contact with the Monteith quartz arenite suggests the basal stratigraphy has been faulted out and the section is incomplete. This sequence is similar to that on the east flank of Mount Gething, consisting of interbedded rippled arenite with rooting (or *Trichichnus*?) brown siltstones, dark lithic arenite, low-angle crossbedded arenite and quartz arenite.

QUASAR DUNLEVY WELL (Locality 14, Figures 3 and 8)

The top of the Monteith Formation quartz arenite is at 490 to 495 metres depth. A lithological log of chip samples from the well indicates about 195 metres of section between the Cadomin and Monteith Formations consisting of brown siltstone, shale, grey-brown salt-and-pepper sandstone with carbonaceous and coaly laminae. No lithological trend is noted.

DISCUSSION

East of the Carbon fault, on the west flank of Mount Gething, major sandstone-shale cycles are developed in the Beattie Peaks Formation, probably indicative of marine shoaling to the east. The first signs of this shoaling trend are found immediately west of the Carbon fault where isolated sandstones up to 7 metres thick are found in the lower part of the formation at Mount McAllister. Though the top of the Beattie Peaks Formation cannot be adequately defined on Mount Gething, the eastward-thinning trend would suggest that something less than 280 metres of equivalent Beattie Peaks strata are preserved. Since the entire section on the west flank of Mount Gething is 370 metres thick, stratigraphic equivalents of the

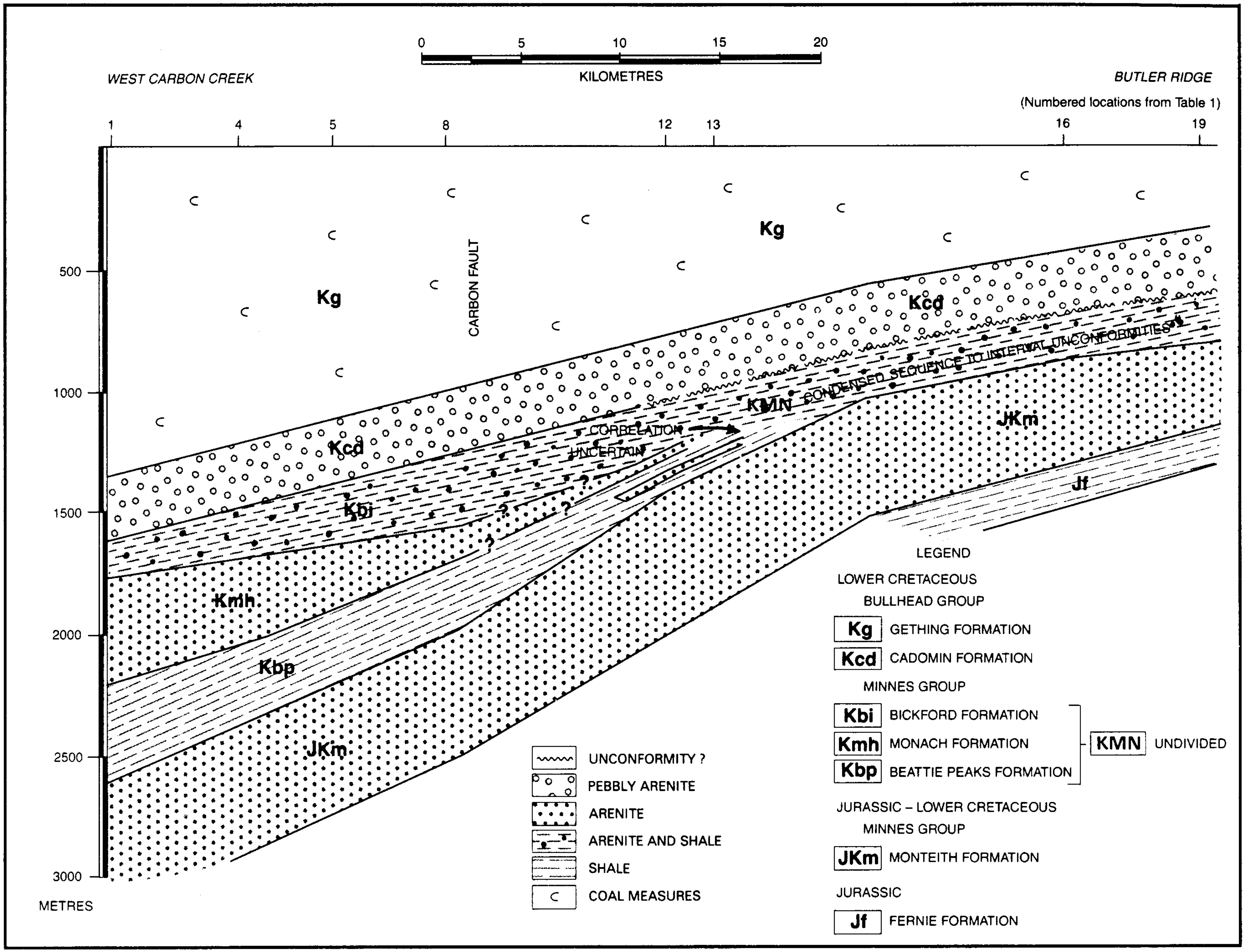

Figure 8. Generalized southeast-northwest stratigraphic section of Jurassic-Lower Cretaceous formations.

Monach and Bickford Formations are probably present but cannot be lithologically distinguished. In Figure 8 the Monach Formation has been interpreted as pinching out at Mount Gething, perhaps represented only by the arenite marker unit of Figure 9.

Sections further to the east do not show gross shale-sandstone cycles immediately above the Monteith. Shale intervals are thin and more completely interbedded throughout the stratigraphic section. Lithofacies typical of individual formations are found (for example, low-angle crossbedded arenites reminiscent of the Monach) but they are locally missing, vary in stratigraphic position and are not correlatable. This "patchwork" lithofacies indicates a rather complex shallow-marine to emergent depositional environment.

Trends in the Minnes Group above the Monteith Formation can also be considered in terms of the lithologic facies that underlie the Cadomin Formation from place to place. Their lithology is not consistent. In some locations east of the Carbon fault this stratigraphic interval is represented by massive to low-angle crossbedded arenites and minor quartz arenite. In other locations it is represented by interbedded wave-rippled arenites, rooted and burrowed siltstones. Another variation occurs at Portage Mountain where several tens of metres of coarse to gritty white quartz arenite lies below the Cadomin Formation and is separated from it by a few metres of interbedded coal measures and quartzitic siltstones. In many localities on Butler Ridge a metre or so of quartz arenite directly underlies the lowest pebbly arenite and is separated from it by thin carbonaceous laminae.

On the east flank of Mount Gething lateral tracing of the lowest pebbly arenite revealed stratigraphically lower and separate pebbly arenites along strike. This suggests Cadomin deposition began at slightly different times in different places. It does not however demonstrate a down-cutting erosional unconformity *per se*.

Biostratigraphic evidence for a regional unconformity at the base of the Cadomin Formation has been documented by Stott (1973) for the eastern margin of the foothills in northeastern British Columbia. Stott considers the Cadomin Formation to rest on the Beattie Peaks Formation at Bullhead Mountain. Legun (1984, 1985a) considered it to rest on the Monach Formation, but has subsequently (this paper) decided that the Minnes Group cannot be divided east of the Carbon fault, due to the facies changes evident at Mount Gething. These facies changes are generally indicative of shoaling and emergence in post-Monteith time.

The Minnes Group east of the Carbon fault and above the Monteith Formation is possibly a condensed sequence with internal unconformities reflecting periods of sediment starvation. The question of what proportion has been eroded and what proportion has thinned out by onlap and facies changes at the basin margin can only be resolved by biostratigraphic comparison of the Minnes succession at Carbon Creek and Bullhead Mountain.

MINNES GROUP: TRENDS TO THE NORTH, SOUTH AND WEST

Only a few pertinent comments will be made here in relation to more regional work by Stott (1984):

(1) In the Carbon Creek area there is no lithological evidence of a western margin to the marine embayment represented by Minnes Group shales (Beattie Peaks Formation). The Beattie Peaks shale continues to thicken in a western direction with no evidence of shoaling.

(2) Continental beds appear to occupy progressively lower parts of the Bickford Formation to the south, or in other words, the Bickford Formation shows a greater marine influence to the north. This is evidenced as follows:

At the measured section southwest of The Monach signs of emergence (that is, rooting) are restricted to the interval starting 110 metres above the Monach Formation. South of the map area at Mount Bickford, Stott (1981) shows coaly intervals beginning at 81.5 metres above The Monach Formation.

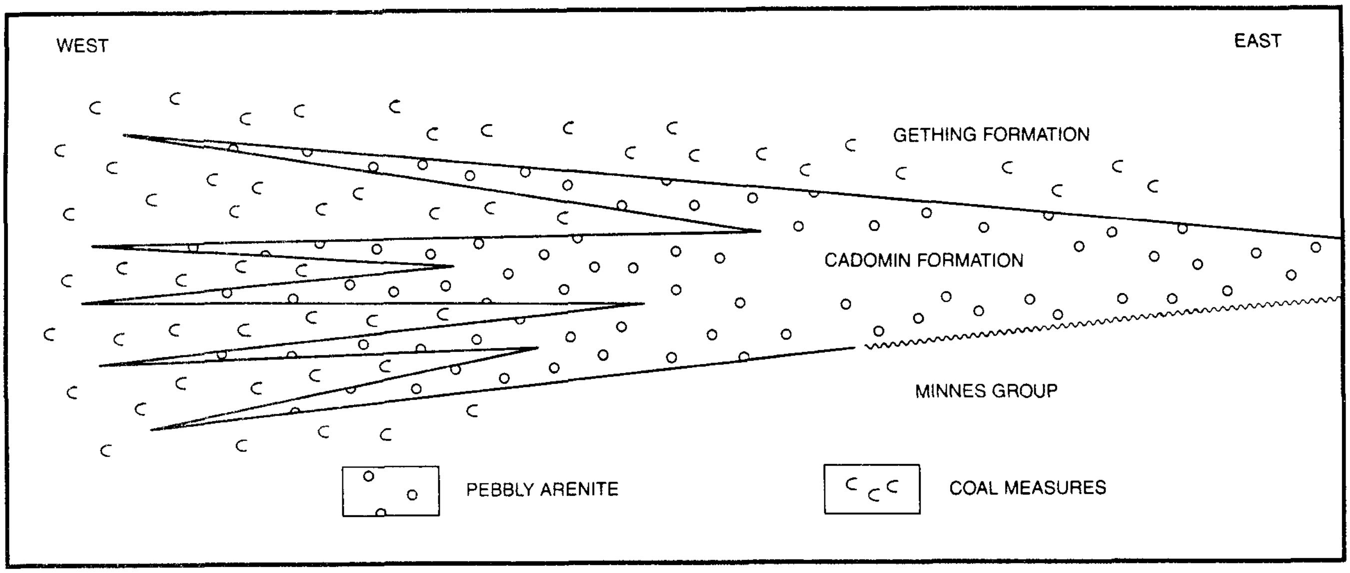

Figure 8a. East-west facies relationships of the Cadomin Formation as envisaged by Karst (1981).

In a railway cut 3.2 kilometres southwest of Beaudette Creek, Hughes (1967) notes almost a metre of coal resting directly on quartz arenites of the Monach Formation.

(3) The entire Minnes Group becomes slowly more carbonaceous (continental) southward and southeast of the Burnt River (some 80 kilometres to the southeast of the Carbon Creek area) such that individual formations can no longer be distinguished.

(4) According to Stott (1967) the Monteith and Beattie Peaks Formations change little in character north of the Peace River but the equivalent Monach Formation sandstones pass laterally into mudstones. This suggests the marine embayment represented by Minnes Group deposits may have been more extensive and deeper to the north. The trend in fact is for every formation of the Minnes Group and Bullhead Group to maintain or increase a marine character northward. A consequence of this would be a strong east to west component in shoreline trends for these deposits.

BULLHEAD GROUP

The thickness of the Bullhead Group varies significantly in the region, thickening westward as does the Minnes Group below it. The thickening trend is exhibited in the Gething Formation and not the Cadomin Formation as mapped. The Cadomin Formation is more difficult to define on lithological grounds to the west. There is an increase in the proportion of recessive coal measures in the Cadomin Formation to the west as well as an increase in the stratigraphic separation of pebbly arenites, making the upper contact rather arbitrary. It is quite possible that a few hundred metres of lower Gething strata in the west together with the Cadomin Formation are time equivalent to the 200 to 260 metres of designated Cadomin Formation in the east (Figure 8a).

The immediate source and transport direction of Cadomin sediment are uncertain in the Carbon Creek area, given there is no lithological thickening or increase in clast size in a westward direction. The time equivalence of the Cadomin Formation in the Carbon Creek area and areas to the south is also in doubt, given the correlation of tonstein time markers by Kilby (personal communication, 1987).

Near Hudson's Hope (Figure 3, location 21) the Gething Formation is 250 metres thick. In Peace River Canyon (Figure 3, location 15) Stott (1973) measured 550 metres (section 68-18). Utah Mines estimated 670 metres on the east flank of Mount Gething (Figure 3, location 13). On the west

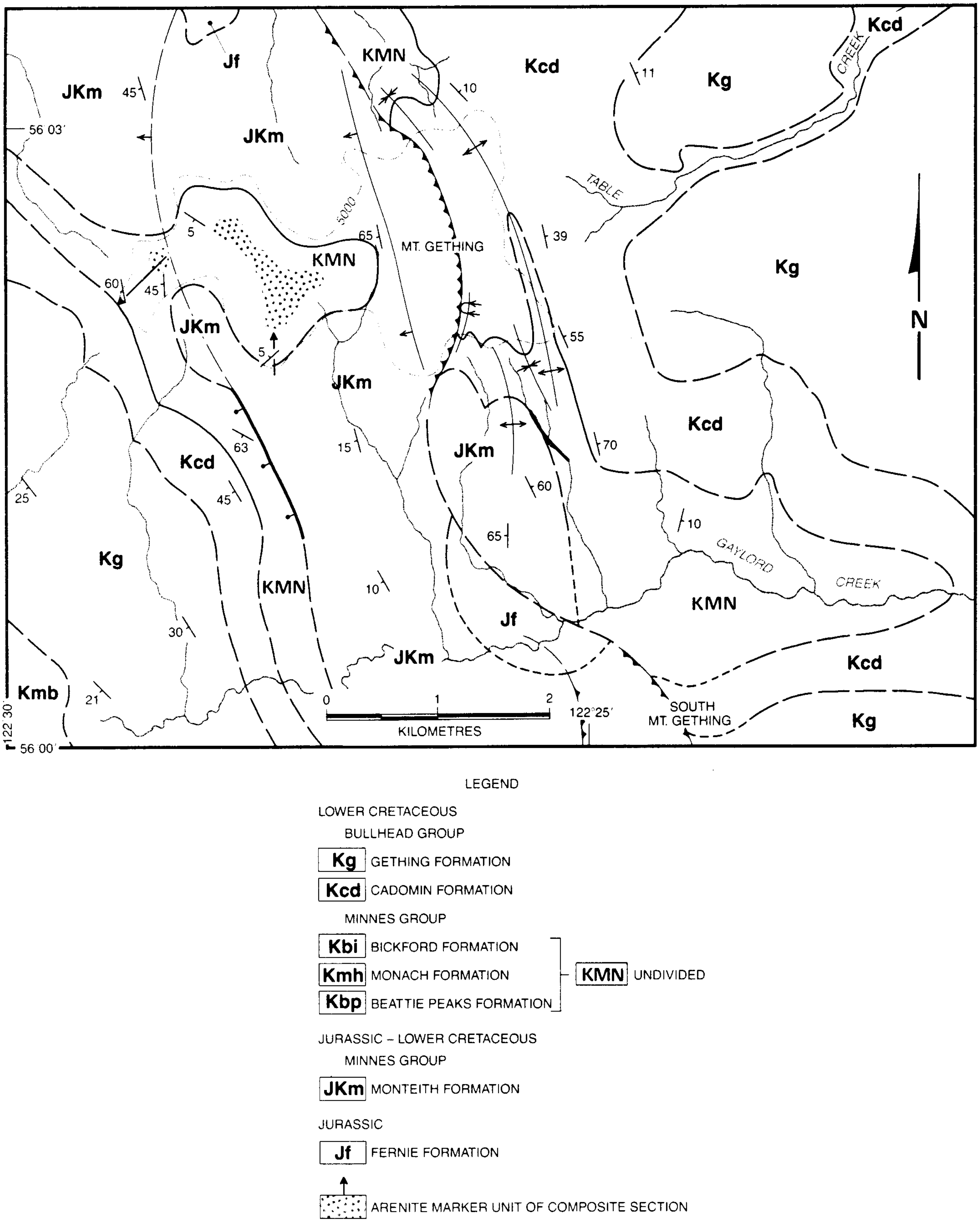

Figure 9. Revised geology of Mount Gething area and location of composite section.

flank this writer estimates 775 metres from airphotograph interpretation. At Carbon Creek an original thickness of 1112 metres is indicated. An isopach map in Stott (1968, page 31, Figure 10) shows the Bullhead Group thins north and south from the Peace River Canyon, defining an east-west basin of deposition. The additional data in this report indicates the basin is even more trough-like in form to the west.

East and north of the Williston Lake area the Gething Formation becomes marine. The eastern correlation into marine strata is shown by Kilby and Oppelt (1985) and the northern by Stott (1973). In the Butler Ridge area thick conglomerates (Bluesky unit) mark the transition of the stratigraphically highest Gething strata from continental to marine character.

COAL SEAM DISTRIBUTION

Gething Formation coals of the Peace River Canyon area can be correlated west and southwest toward the Carbon fault. Confidence is greatest for the Trojan seam which has a tonstein marker associated with it. The Trojan has been intersected in drill holes over a large area between Gaylard Creek and Johnson Creek. At Mount Johnson in the Peace River Canyon it averages 1.8 metres thick in six drill holes (range 1.3 to 2.9 metres). It is washed out by a southwest-trending channel body in part of the Bri-Dowling property where it otherwise averages 1.8 metres net coal in 24 drill holes (range 1.0 to 2.9 metres). At South Mount Gething where relatively few holes have been drilled, it ranges from 3 metres thick (SMG 80-11) to a metre or less in d-79-1 and d-79-2. It is thin in the Gaylard Creek area to the north (±1.5 metres).

The Titan seam (or its equivalent) appears to thicken from the Peace River Canyon area southwest to Bri-Dowling where it averages 2.18 metres thick in six holes (range 1.87 to 2.38 metres). Further to the southwest it is 4.5 metres thick in SMG 78-1 and SMG 80-11 (this is the thickest coal intersection in the region) but apparently thinner in adjacent holes (d-79-1 and d-79-2) where the correlation is uncertain.

Utah Mines identified the Louise, Milligan and Riverside seams on their East Mount Gething property. The Riverside ranges from 0.7 to 3.15 metres in thickness and averages 1.78 metres.

The Peace River Canyon coals cannot be individually correlated across the Carbon fault to the Carbon Creek property. If the correlation in Figure 8 is correct, seams such as the Titan, Trojan and Falls might have their counterpart in the stratigraphically highest seams of diamond-drill hole CC 81-88.

In the Carbon Creek syncline, one of the better developed seams, seam 52, averages 1.59 metres net coal in 45 holes (range 0.33 to 2.35 metres). The best average coal thickness is in the northern reserve area (just outside the map area) where seam 15 averages 2.05 metres in 22 holes (range 3.26 to 1.04 metres).

In summary, the maximum average thickness (net coal) of a coal seam in the Carbon Creek - Peace River Canyon region is not known to exceed 2.2 metres. Coals rarely exceed 3 metres and the average thickness of the best seam on each property is about 1.8 metres.

Plate 1. View from Mount Wrigley along limb of fold.

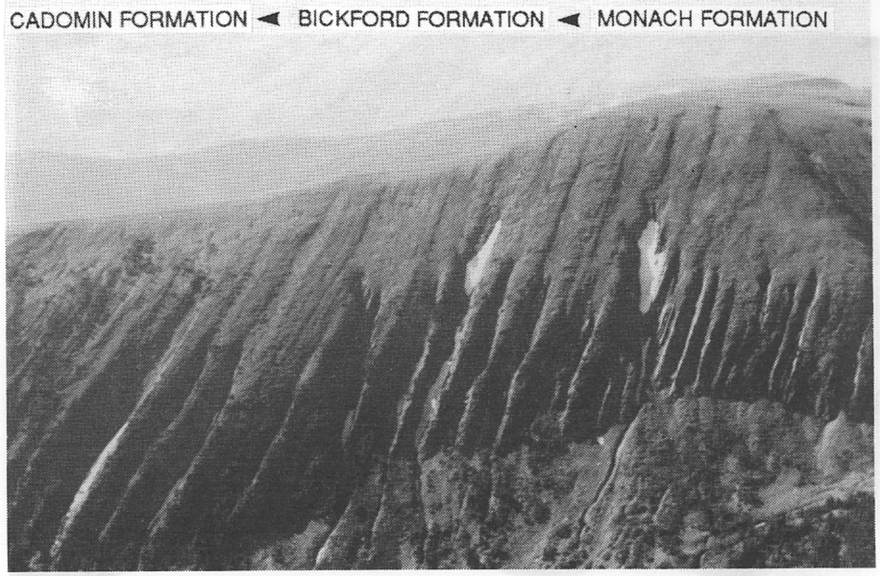

Plate 2. Steeply dipping beds of the Monach to Cadomin Formation interval at Mount Rochfort.

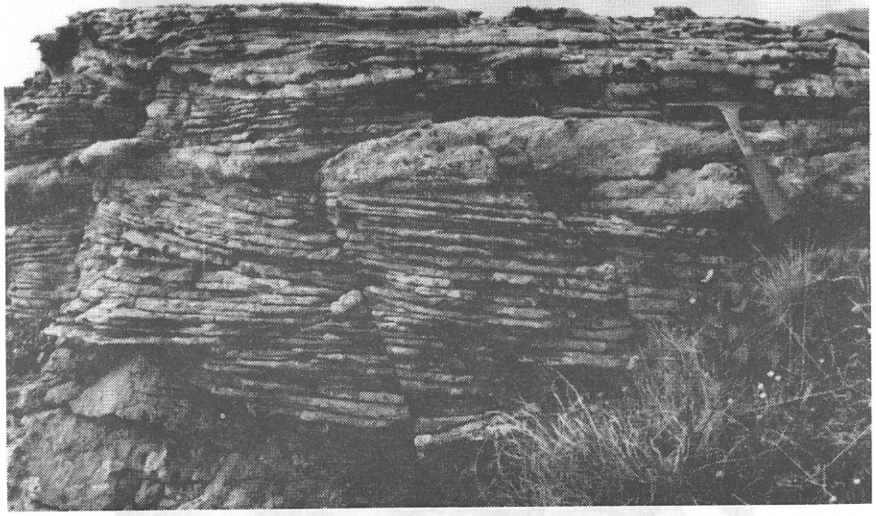

Plate 3. Crossbedding in the Monach Formation.

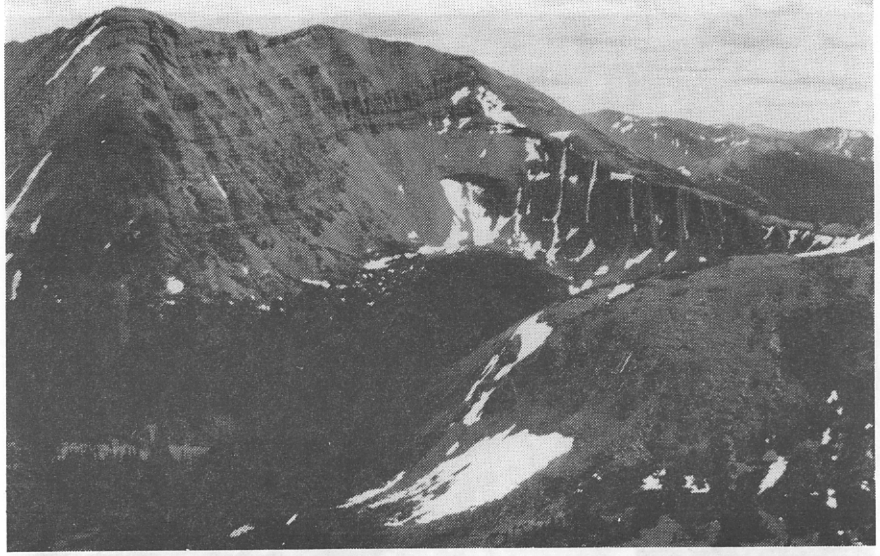

Plate 4. View across head of the valley of the south fork of Eleven Mile Creek.

Plate 5. Interbedding in the Bickford Formation.

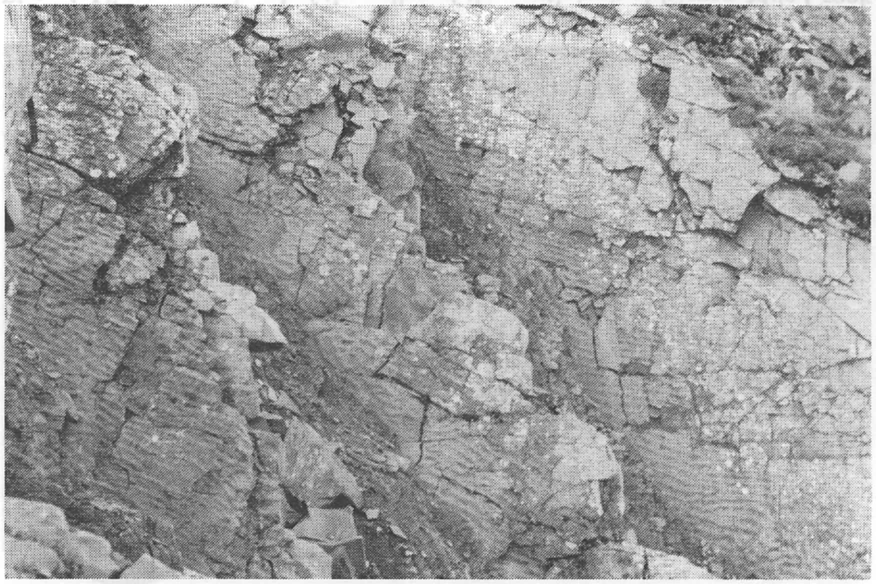

Plate 6. Wave-rippled surfaces in the Bickford Formation.

Plate 7. Kink fold geometry.

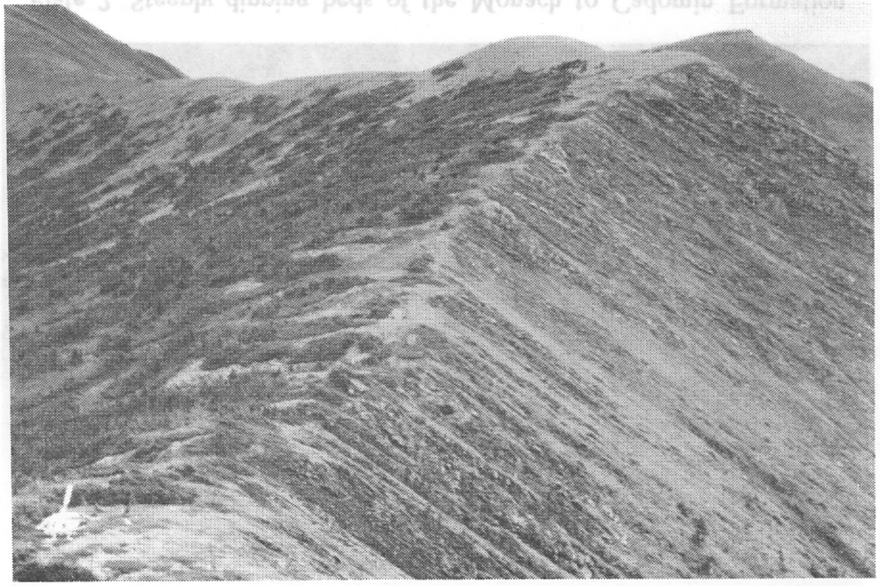

Plate 8. Steeply dipping beds of Gething Formation west of Mount Rochfort.

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APPENDIX A
SECTION THICKNESS FROM AIRPHOTOGRAPHS

```
1  REM ANDREW LEGUN
2  PRINT:PRINT:PRINT
3  PRINT "     SECTION THICKNESS FROM AIR PHOTOS":PRINT:
   PRINT
4  PI=3.14159/180
5  REM CHECK FOCAL LENGTH OF AIR PHOTO LENS IN CM.
6  F=30.54
7  INPUT "NO. OF SECTIONS ",N
10  INPUT "SCALE AT CONTROL ELEVATION ",SC
20  INPUT "CONTROL ELEVATION IN M. ",CE:PRINT:PRINT
22  FOR I=1 TO N
24  Z=1
30  INPUT "BED DIP IN DEGREES ",D
40  INPUT "A.P. DIST. IN CM. ",A
50  INPUT "ELEVATION AT CONTACTS ",E1,E2
60  INPUT "STRUCTURAL BEARING ",B
65  REM VERTICAL DISTANCE
70  V=ABS(E1-E2)
75  REM HORIZONTAL DISTANCE
80  H=.01*A*(SC-100/F*((E1+E2)/2-CE))
84  INPUT "ARE DIP & SLOPE INCLINED SAME DIRECTION? (Y/N) ",A$
85  IF A$<>"Y" AND A$<>"N" THEN 84
86  IF A$="Y" THEN Z=-1
88  D=PI*D:B=PI*B
90  T=H*SIN(B)*SIN(D)+Z*V*COS(D)
100  PRINT "SECTION ";I;" IS ";CINT(T);" METRES THICK.":PRINT
110  NEXT I
120  END
```

Figure 4. Measured section of the Bickford Formation at South Monach

Ministry of Energy, Mines and Petroleum Resources
GEOLOGICAL SURVEY BRANCH
TO ACCOMPANY PAPER 1988–3
GEOLOGY OF THE CARBON CREEK AREA

PROVINCE OF BRITISH COLUMBIA
Ministry of Energy, Mines and Petroleum Resources
GEOLOGICAL SURVEY BRANCH

FIGURE 2
PAPER 1988 – 3

GEOLOGY OF THE CARBON CREEK AREA

93O/15

GEOLOGY BY ANDREW LEGUN

kilometres 0 1 2 3 kilometres
SCALE 1:50 000

LOWER CRETACEOUS

FORT ST. JOHN GROUP

Kfsj	UPPER FORT ST. JOHN GROUP
Kmb	MOOSEBAR FORMATION

BULLHEAD GROUP

Kg	GETHING FORMATION
Kcd	CADOMIN FORMATION

JURASSIC – LOWER CRETACEOUS

MINNES GROUP

Kbi	BICKFORD FORMATION
Kmh	MONACH FORMATION
Kbp	BEATTIE PEAKS FORMATION
Jkm	MONTEITH FORMATION
Jf	FERNIE FORMATION

TRIASSIC

ʀ̄	

Sugary quartz arenite beds ......
Geologic boundary: defined, approximate, assumed
Bedding attitude: horizontal, inclined, overturned
Thrust fault – teeth in direction of dip on upthrust side: defined, approximate
Fault
Syncline: defined, approximate
Anticline: defined, approximate
Syncline or anticline (arrow indicates plunge)
Monocline or kink fold (north limb relatively flat)
Anticline and syncline (overturned)
Diamond-drill hole ●
Minesite ⚒
Coal exposure(s) (thickness in metres) ×
Gas wellsite ○
Direction of glacial striae

ONLY DRILLHOLES REFERENCED IN TEXT ARE SHOWN ON MAP