CORRELATION OF THE LOWER CRETACEOUS STRATIGRAPHY OF NORTHEASTERN BRITISH COLUMBIA FROM FOOTHILLS TO PLAINS

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INTRODUCTION

The Lower Cretaceous of northeastern British Columbia consists of clastic sedimentary rocks having an accumulative thickness exceeding 3 000 metres in the Foothills and thinning northeastward in a wedge-like manner in the western Canadian sedimentary basin. These rocks are composed of detritus shed from an uplifted western source and provide an early record of the Laramide orogeny (responsible for the present Rocky Mountains). Most of the sedimentary sequence **prior** to the Cretaceous was more shelf like in character off the flank of an eastern source area, the Canadian craton. These pre-Cretaceous sedimentary rocks (quartzites, carbonates, cherts, and shales) were uplifted and eroded and their detritus transported eastward in Cretaceous time.

The table of formations that comprise the Lower Cretaceous of northeastern British Columbia is shown on Figure 25. Formation names marked with an asterisk are coal bearing and therefore at least in part non-*marine. The other formations are marine. It is apparent from the table that repeated marine transgressions* and regressions characterized Early Cretaceous time in this region, imparting a marine/nonmarine cyclicity to the sedimentary sequence. The marine influence is attributed to a Cretaceous boreal sea that periodically transgressed southeastward into Alberta. The alternating marine/continental character of the sedimentary pile created a geological environment favourable for the occurrence of both coal and hydrocarbons. The continental sedimentary units are generally fluvial-deltaic assemblages with associated coal seams and coarse clastic rocks. The marine units are predominantly silty shales and provide good cap rock for hydrocarbon entrapment.

The petroleum and coal industries have been very active in northeastern British Columbia during the last seven years. Both have been drilling Lower Cretaceous rock formations. The major Lower Cretaceous gas play in recent years has been the Elmworth-Deep Basin which trends northwest and is located in the Plains region near the British Columbia—Alberta border, south of Dawson Creek. Coal companies, on the other hand, have been actively exploring Lower Cretaceous rocks in the Foothills Belt where the formations are exposed at surface and are accessible for mining purposes. The target formations in both areas are nearly identical and information derived from one would most certainly help the exploration efforts in the other.

The purpose of this report is to compare the Lower Cretaceous rocks of the Foothills and Plains. Although some of the formation names are different, it is apparent that many of the lithologic units are essentially the same. This study was conducted from a broad, regional perspective and is more concerned with stratigraphic relationships between formations than their detailed sedimentologic descriptions. Most of the data on the stratigraphy under the Plains are derived from subsurface geophysical logs, supplemented in some cases by bit-cutting descriptions. Any sedimentologic descriptions given in this report are general in nature and were obtained from coal exploration drill cores and surface outcrops in the Foothills Belt.

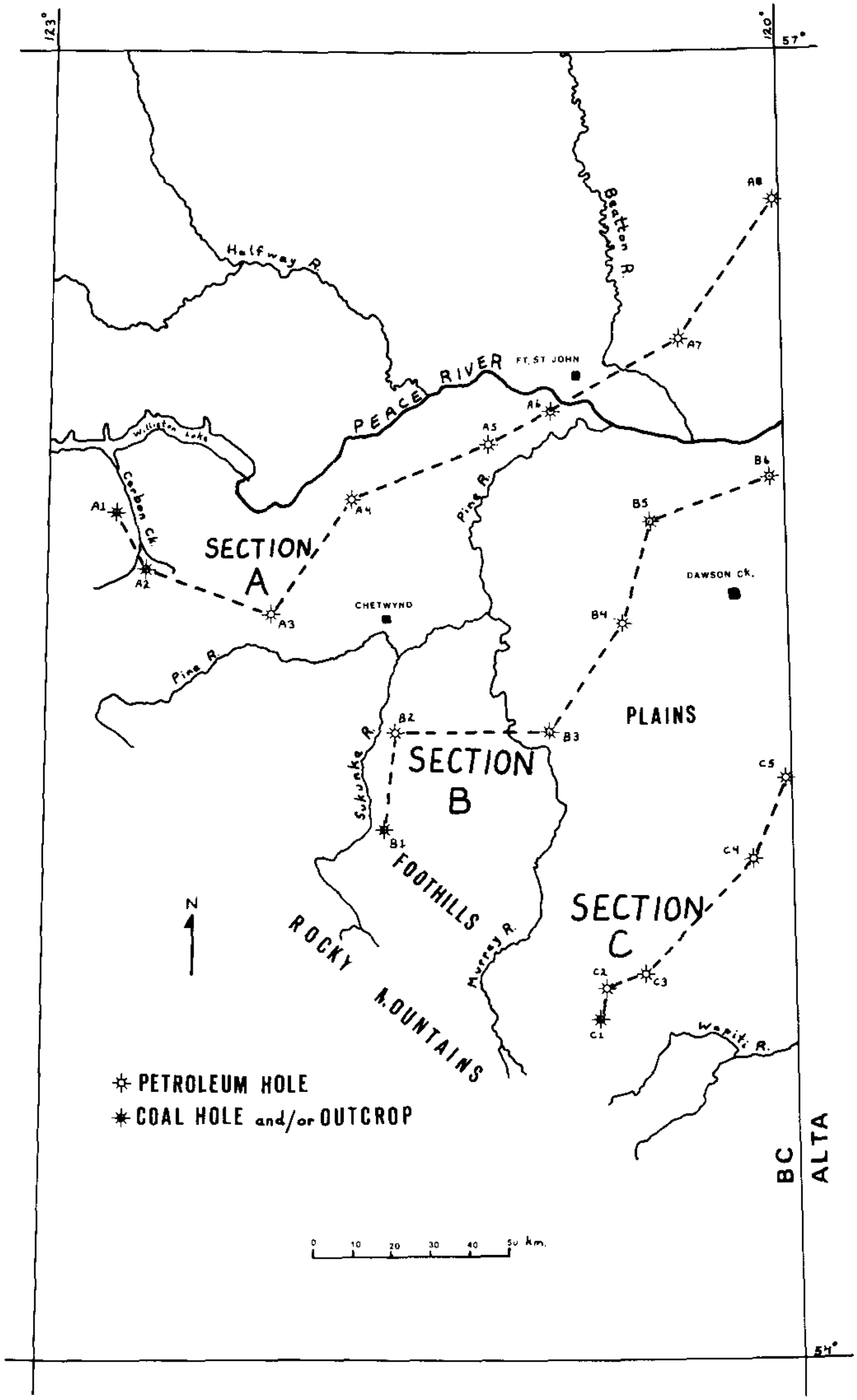

Figure 26. Map showing location of stratigraphic sections.

STRATIGRAPHIC SECTIONS

Three northeasterly stratigraphic sections A, B, and C, perpendicular to regional strike, have been constructed. The datum used is the Bluesky horizon at the top of the Gething Formation. These sections link the Lower Cretaceous surface rocks of the Foothills with their deep subsurface counterparts under the Plains (Fig. 26). The following review of formations lists formational names in the Foothills Belt in capital letters with the corresponding subsurface equivalents in brackets. The formations are listed from top to bottom, in the same order they would be encountered in a typical drill hole.

STRATIGRAPHIC REVIEW

BOULDER CREEK MEMBER (Paddy Member and Cadotte Member)

The Boulder Creek member is correlative with the Paddy and Cadotte members under the Plains. The upper contact with the overlying Shaftesbury shales is abrupt and marked by the first influx of sand and carbonaceous sediment. There is sometimes a thin conglomerate unit (less than 10 metres in thickness) near the top of the member. Where absent, this conglomerate is replaced by a dark, carbonaceous, silty mudstone containing small rounded chert pebbles. The upper or 'Paddy' part of the Boulder Creek member is continental and contains coal seams (Alberta Study Group, 1954). These seams are generally thin but at least one coal company has conducted a drill program with these coals in mind. The basal or 'Cadotte' portion of the Boulder Creek member consists of a thick, sandstone-conglomerate unit that coarsens upward and is easily recognizable on geophysical logs and from core descriptions.

The unit represents a classic prograding delta sequence which culminates with conglomerate overlain by coal measures above (Paddy member). At some localities the Cadotte has two or more of these coarsening upward cycles separated by local thin marine transgressions. Sandstones near the base of the Cadotte grade downward into prodelta silts and clays of the Hulcross member.

The Paddy is coal bearing well out into the Plains (section C). Northward, coal in the member is progressively further west on each section (Figs. 27, 28, and 29). The Cadotte is continuous over the entire area and is an important source of natural gas in the Dawson Creek area. In general, the Cadotte is thick where the Paddy is thin so except for the extreme eastern portions where there is significant thinning, the thickness of the Boulder Creek member as a whole is relatively constant.

HULCROSS MEMBER (Harmon Formation)

The Hulcross is a marine mudstone which weathers rusty brown and often displays laminae of very fine-grained sand. Ripple marks in some sand laminae suggest that the water depth was not great. In some areas the Hulcross is identical in sedimentary character to the Shaftesbury shales. The Hulcross (Harmon) thins in both easterly and southerly directions (Figs. 27, 28, and 29) until it pinches out completely in west-central Alberta (within the Luscar Formation; *see* Fig. 26).

GATES MEMBER (Notikewin Formation and Falher Formation)

The Gates member in the Foothills Belt is equivalent to the Notikewin and Falher Formations under the Plains. The contact with the overlying Hulcross is abrupt and defined by the first influx of sand and carbonaceous sediment. There is often a thin, coarse conglomerate (less than 2 metres in thickness) at the top of the formation. This is followed by a sequence of thin sandstones, carbonaceous shales, and thin coals

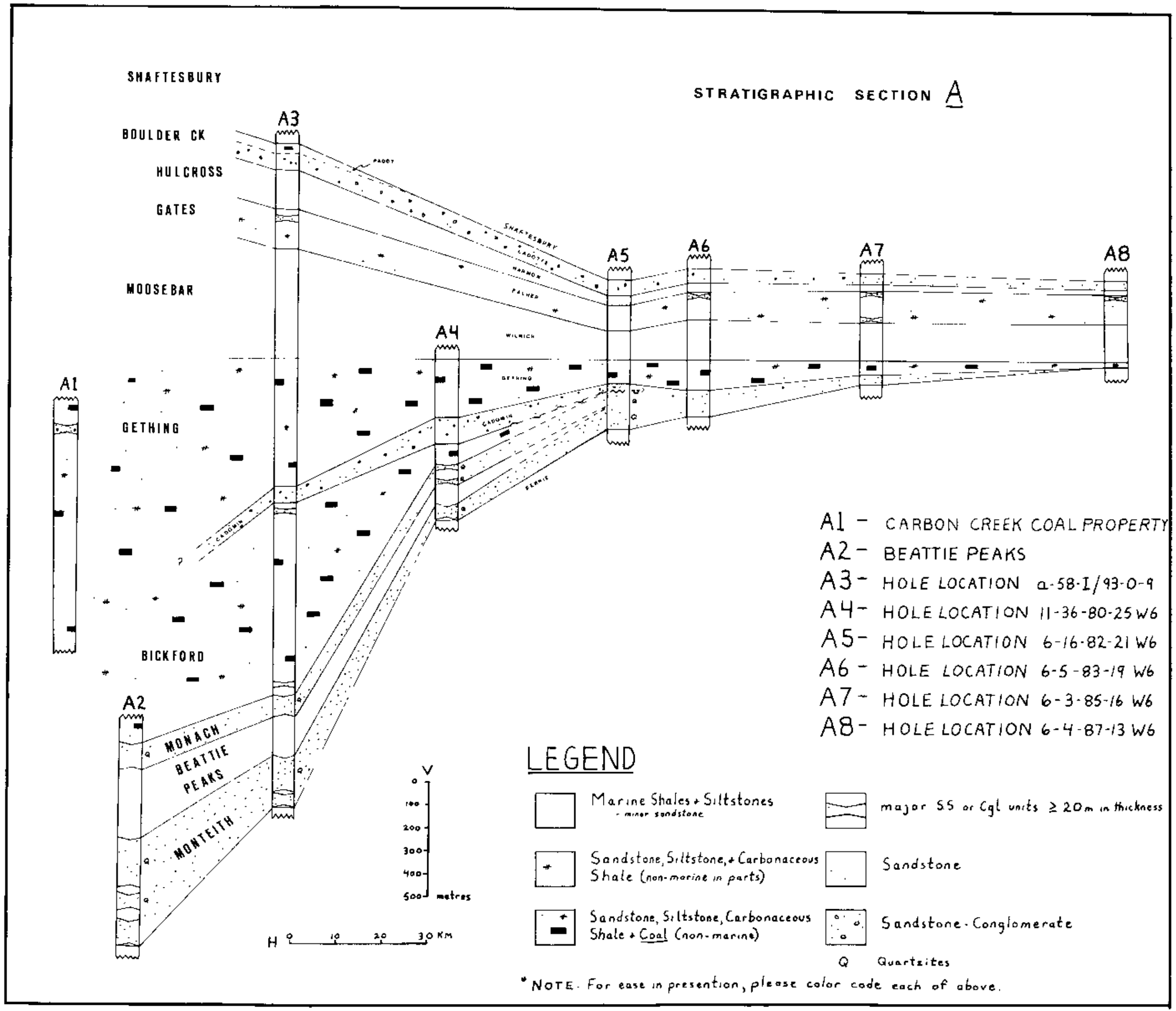

Figure 27. Stratigraphic section A.

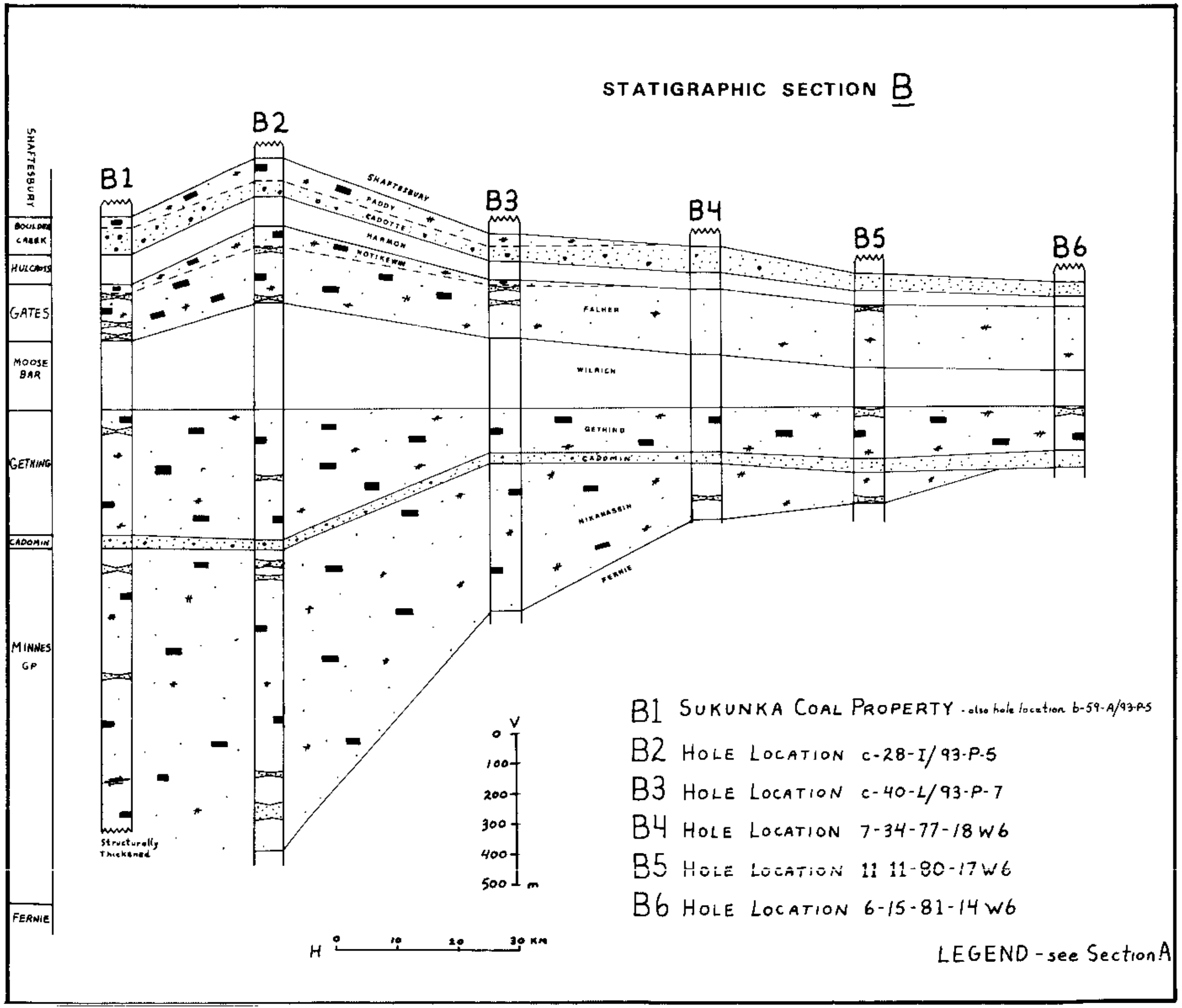

Figure 28. Stratigraphic section B.

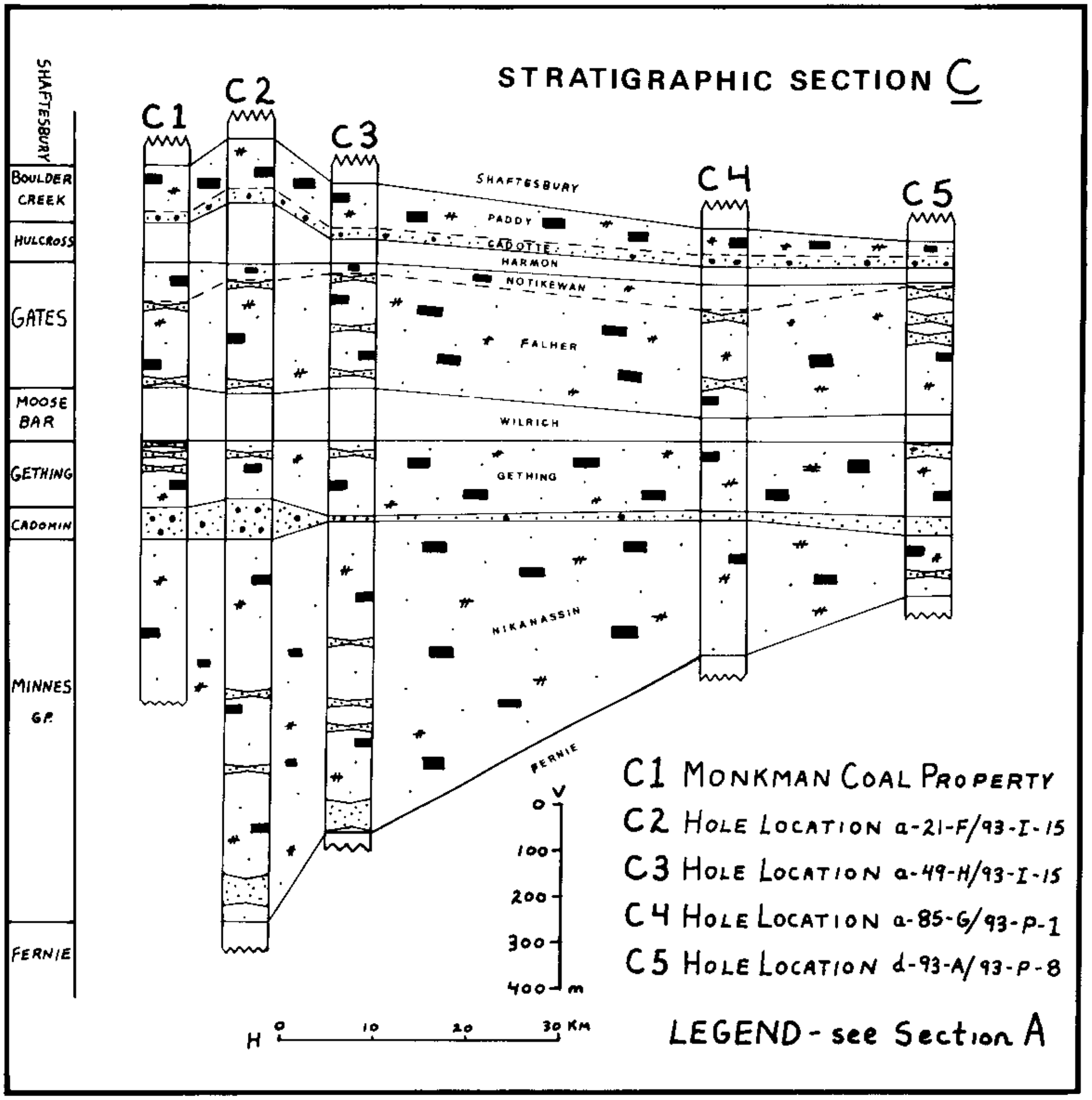

Figure 29. Stratigraphic section C.

which comprise the Notikewin. These thin, often high sulphur coals are not the important coal-bearing seams in the Gates member. Rather it is in the Falher Formation, which is marked by multiple, thick sandstone-conglomerate units and multiple, thick coal seams, that the coal is economically significant. The coarse sandstone-conglomerate units often coarsen upward, suggesting another prograding delta. There is some debate whether the thick sandstone-conglomerate units, which are the main producers in the Elmworth-Deep Basin gas field, represent prograding distributary mouth bars or prograding beaches (Armstrong and McLean, 1979). This author favours the interpretation that the large, sheet-like sandstone-conglomerates (that is, Falher A and B) represent beaches. The sand-gravel mixture is transported by the distributary channels and deposited as distributary mouth bars, then reworked by wave action and redistributed by long-shore drift to beaches adjacent to the delta front. These delta front beaches appear to have migrated back and forth over the lower delta plain in response to several minor marine transgressions, burying the peat swamps under sand and ensuring their preservation. The lowermost coarsening upward cycle at the base of the Gates member is continuous over most of the length of the Peace River Coalfield and has been named the 'Torrens member' by several coal companies. This thick sand unit grades down into silts and clays of the underlying Moosebar Formation.

The Gates member maintains a relatively constant thickness in each stratigraphic section; however, a definite thinning trend is evident in more northerly sections (*see* Figs. 27, 28, and 29). The coal-bearing character of the formation also diminishes northward until the Gates is essentially marine in section A. The coal measures also pinch out northward where the Gates becomes essentially marine (section A, Fig. 27). As would be expected, the large sandstone-conglomerate units decrease in frequency and grain size as the coals disappear. This suggests that exploration for gas in the Falher should be concentrated in areas where the Falher is coal bearing.

MOOSEBAR FORMATION (Wilrich Formation)

The Upper Moosebar (Wilrich Formation) is a closely interbedded sequence of very fine-grained sandstone, siltstone, and mudstone. Locally the sandstone layers have erosional bases and grade up into siltstone and mudstone over a distance of 10 to 20 centimetres. Zones of strong bioturbation are common and occasional small-scale slump structures are evident. The Upper Moosebar is commonly interpreted to be either intertital or prodelta. The author favours the prodelta viewpoint.

The Moosebar grades downward into dark grey mudstones that are much darker than the shales from the higher marine formations. Near the base of the Moosebar the mudstone becomes glauconitic. A multiple series of thin bentonite layers with microscopic volcanic textures are also common within the basal portion of the Moosebar (Duff and Gilchrist, in preparation). These ash layers are often noticeable on the gamma logs as local 'hot spots'; most are 2 to 3 centimetres in thickness but some reach 20 to 30 centimetres. They represent a distal explosive volcanic event not unlike the present Mount St. Helens eruption which had multiple releases of ash over a short time interval.

The Moosebar (Wilrich Formation) also thins in both east and south directions. However, the Moosebar is more persistent than the Hulcross and the marine horizon has been recognized as far south as Cadomin, Alberta, before pinching out within the Luscar Formation (Stott, 1974).

GETHING FORMATION (Bluesky Formation and Gething Formation)

The Moosebar Formation ends abruptly against sandstone at the top of the Gething Formation. This material is commonly conglomeratic and invariably glauconitic at the top of the Gething. In northwestern

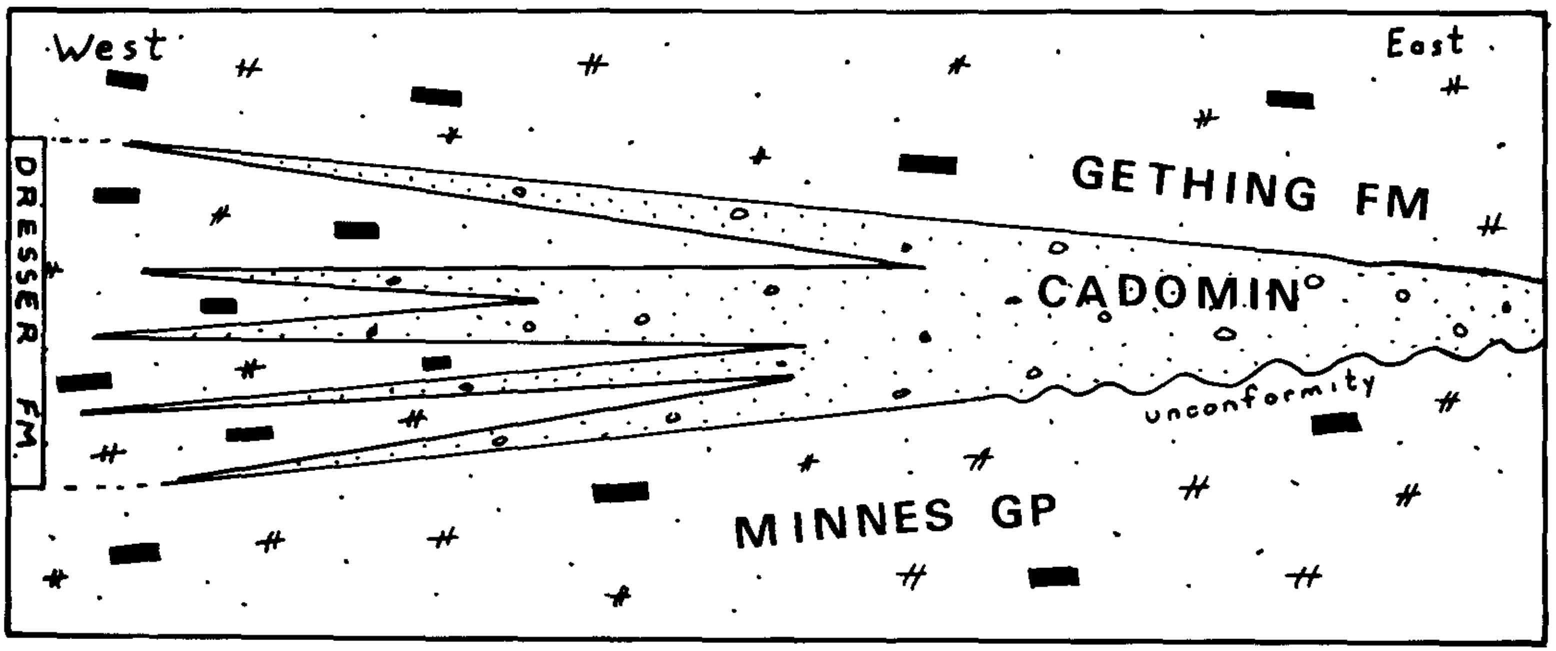

Figure 30. East-west facies relationship of the Cadomin Formation.

Alberta this upper unit has formation status (Bluesky Formation) but in northeastern British Columbia it is so variable in thickness (0.1 metre to 25 metres) that it is referred to as a stratigraphic horizon. When thick, the Bluesky is a very coarse conglomerate having well-rounded quartzite phenoclasts up to 15 centimetres across in a sandstone matrix. When thin (less than 1 metre in thickness), the Bluesky is characteristically a locally carbonaceous, silty mudstone, having small, black, polished chert pebbles that are less than 2 centimetres in diameter. The Bluesky is an important oil and gas producer in the Fort St. John area and probably represents a beach facies, created by the rapidly transgressing Clearwater Sea. A coarsening upward character is noted in some localities.

The Bluesky is a transitional unit and there is some debate whether it should be placed within the Moosebar or the Gething Formations. In this report the Bluesky has been placed in the Gething Formation because of its coarse clastic character and because it is easy to recognize on geophysical logs. Therefore, it is a convenient way to define the top of the Gething.

The Gething is largely a sequence of continental coal measures consisting of coal, carbonaceous mudstone, fine-grained sandstone, and abundant siltstone. Generally sedimentary cycles of the fining upward type, like these, suggest a strong fluvial environment. Most of the good Gething coals are located in the upper part of the formation where it is associated with several thin, marine sedimentary tongues (Duff and Gilchrist, in preparation). These marine tongues are usually mudstone containing the marine pelecypod *Entolium irenense.*

Both sections A and B show a thinning trend for the Gething in a northeastern direction. In section C, however, the Gething Formation has relatively constant thickness. In that section, the Gething has several unusually thick sandstone-conglomerate units that approach 20 metres in thickness. Recently, a gas strike was made in one of these units along the Deep Basin trend (Oilweek, 1980).

CADOMIN FORMATION (Cadomin Formation)

The type Cadomin was defined near the Alberta town bearing that name more than 50 years ago. As described by MacKay (1929), the Cadomin consisted of massive conglomerate 'composed of flattened and well-rounded pebbles of black, white, and green chert, white and grey quartzites, and quartz, which range in diameter from ¼ to 3 inches.' A major disconformity was recognized at the base of the formation. Subsequently, the Cadomin has been traced over much of central and northern Alberta and northeastern British Columbia. In the study area, the Cadomin in the subsurface under the Plains resembles that in the type section. At surface to the west, however, the formation apparently 'fingers-out' into multiple conglomeratic sandstone units separated by appreciable thicknesses of coal measures (Fig. 30).

The contact between the Gething and Cadomin Formations is gradational. Arbitrarily, it is placed at the top of the first thick sandstone-conglomerate unit in a succession of sandstone-conglomerate units in which the coarse units are thicker than the intervening coal measures. This problem could be avoided by adopting the stratigraphic term Dresser Formation for the Foothills Belt northwest of the Sukunka River. Hughes (1964) describes the Dresser Formation as multiple 5 to 15-metre beds of medium-grained sandstone, grits, and local conglomerate separated by coal measures of similar thickness.

Although there is a major unconformity at the Cadomin's base in the subsurface to the east where there is an obvious truncation of Nikinassin rocks (Figs. 27, 28, and 29), there is no field evidence of a major unconformity in the Foothills to the west (Fig. 29).

MINNES GROUP (Nikinassin Formation)

In northeastern British Columbia the Cadomin is underlain by a significant succession of coal measures. This fact was first recognized by highes in 1964 and he proposed that these continental rocks be called the Brenot Formation. Earlier workers such as Beach and Spivak (1944) did not distinguish the Cadomin Formation in the Peace River area but refer to a thick succession of sandstones and carbonaceous shale that is nonmarine in parts, overlying the marine shales of the Fernie Formation. This unit, which has beds of coal and conspicuous conglomerate at the top, was called the Dunlevy Formation. Stratigraphically it was placed below the Gething (Fig. 25). More recent work by Stott has emphasized the marine portion of these rocks which underlie the upper coal-bearing member. This upper coal-bearing member was left unnamed by Stott (1968) but is subsequently referred to as the Bickford Formation in his open file maps for northeastern British Columbia.

These coal measures, which lie below the Cadomin Formation, are the dominant lithostratigraphic unit of the Minnes Group. In the subsurface this nonmarine unit is referred to as the Nikinassin and extends well out into the Plains, especially in sections B and C. Sandstones within the Nikinassin are important gas producers in some areas (for example, Grizzly Valley). Coal seams are locally frequent but generally thin (less than 2 metres in thickness).

Underlying the upper coal-bearing unit are marine formations of the Monach, Beattie Peaks, and Monteith Formations respectively. First described by Mathews (1947) from what is now their type locality of Beattie Peaks, these units do not persist eastward in the subsurface; consequently they were never adopted by the petroleum industry. These formations are also increasingly difficult to recognize in the Foothills Belt south of the Burnt River. In the Pine Pass-Williston Lake area, however, they are prominent, easily distinguished, and marine. The Monach Formation consists of fine-grained, very thin-bedded sandstone with coarse-grained to conglomeratic quartzose sandstone interbeds near the top of the unit. Characteristically white, sugar-like, coarse-grained 'quartzite' (quartzose sandstone) caps the unit. At times the 'quartzite' displays large pelecypod burrows and large wood casts on the upper bedding surface. The contact with the overlying Bickford coal measures is abrupt and, at several localities, subtly irregular, suggesting that the base of the Bickford Formation is an unconformity.

The Beattie Peaks Formation is a recessive unit of interbedded shale and very fine-grained argillaceous sandstone. Dark-coloured worm tracks are common on some bedding surfaces. At several localities there were lenticular sandstone beds, less than 1 metre in thickness, with erosional bases and occasional pebbles and broken belemnite fragments near the bottom. These lenses appear to be graded and may have been deposited from turbidity currents.

The Monteith Formation is predominantly a fine grained to very fine-grained sandstone unit with thick intervals of very fine-grained, 'milky-grey' quartzites. The unit is very resistant but contains occasional recessive shale interbeds. The Monteith Formation is generally finer grained than the Monach (especially the quartzites) and the two can usually be distinguished on that basis. The base of the Monteith Formation is drawn at the bottom of the last major sandstone before the dark grey, Fernie-type shale interbeds become the dominant lithology.

SUMMARY

The Lower Cretaceous sedimentary sequence exposed at surface in the Foothills Belt of northeastern British Columbia continues into the subsurface of the Plains with only occasional changes in sedimentary character. The sedimentary changes that do occur are useful indicators of regional paleoenvironments. Both coal and petroleum exploration could benefit from the examination of open file geologic information from both areas. The coal companies would receive continuous stratigraphic information from top to bottom of the Lower Cretaceous sedimentary pile at certain localities. This would help unravel their sedimentary sequences in structurally complicated areas or areas where surface outcrop is sparse. The petroleum companies would have access to abundant diamond-drill core from the same formations they are actively exploring. The relative close-spaced aspect of this drilling would provide a three-dimensional view of porous intervals that are necessary for determining reservoir geometry. The British Columbia Ministry of Energy, Mines and Petroleum Resources through its Charlie Lake core storage facility and the open files in Victoria offers this geologic information to those concerned.

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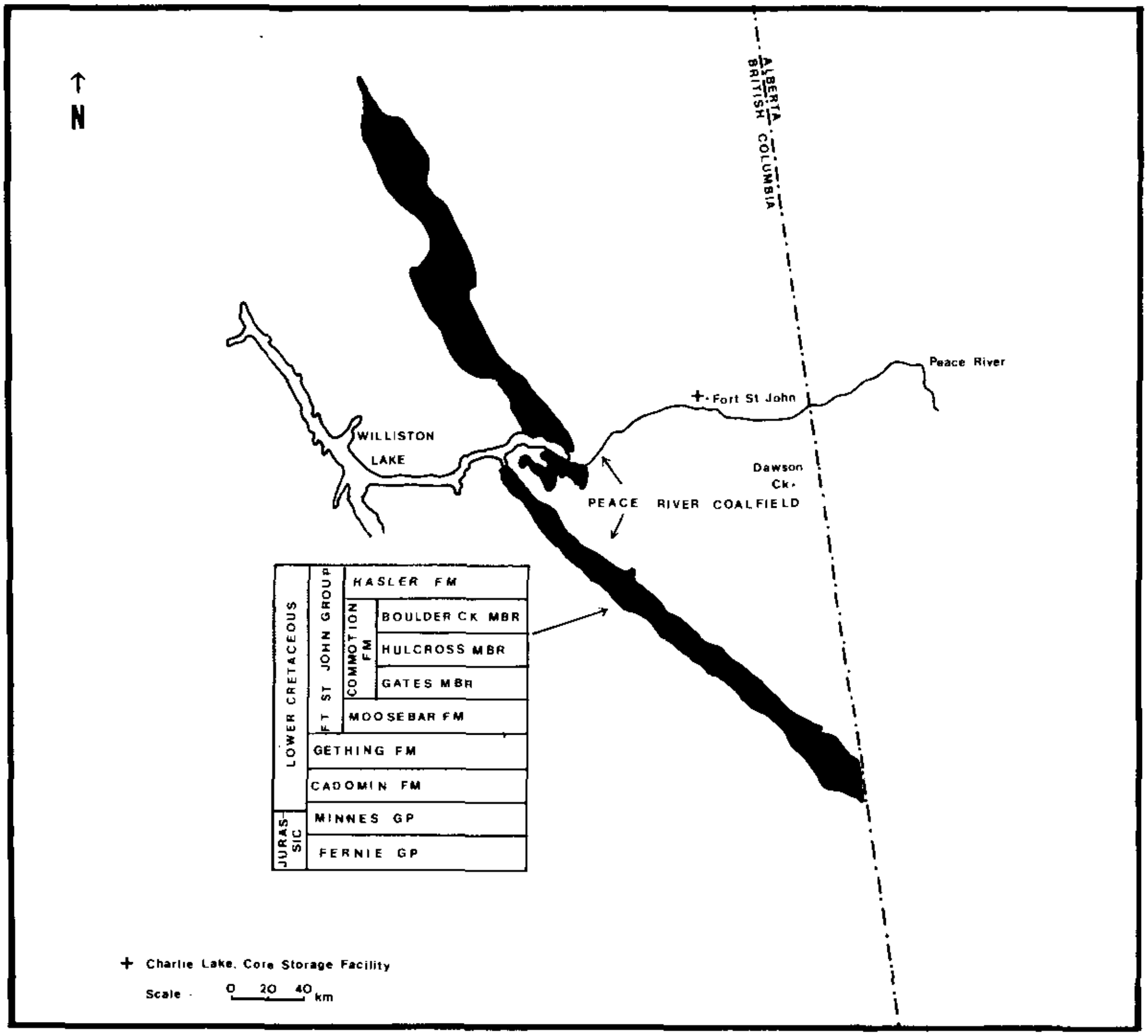

Figure 31. The Peace River Coalfield and location of the Charlie Lake storage facility.