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PAPER 62-39

STRATIGRAPHY OF THE
LOWER CRETACEOUS FORT ST. JOHN GROUP
AND GETHING AND CADOMIN FORMATIONS,
FOOTHILLS OF NORTHERN ALBERTA
AND BRITISH COLUMBIA

(Report 6 figures, appendix)

D. F. Stott



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STRATIGRAPHY OF THE LOWER CRETACEOUS
FORT ST. JOHN GROUP AND GETHING AND CADOMIN FORMATIONS,
FOOTHILLS OF NORTHERN ALBERTA AND BRITISH COLUMBIA

INTRODUCTION

The Lower Cretaceous Fort St. John Group and the Gething and Cadomin Formations have been studied in outcrop sections between Smoky and Peace Rivers (Fig. 1). The rocks in the more southerly part of the region have been described in three previous reports (Stott, 1960a¹, 1961a, 1961b). This preliminary account gives additional information obtained in the vicinity of Peace River and presents columnar sections and palaeontological data pertaining to the succession. Descriptions of several outcrop sections are contained in the Appendix.

Field Work and Acknowledgments

Study of these Cretaceous rocks began in 1958 and continued during the summers of 1959, 1960, and 1961. During the first three years the work was carried out with pack-horses. During 1961 the use of a helicopter facilitated completion of the project and enabled the writer to re-examine several critical and important localities.

Discussions with other geologists interested in Cretaceous problems were most helpful. The writer is indebted to C.R. Stelck, J.H. Wall, G.B. Mellon, R.D. Hughes, J.K. Eccles, P. Ziegler, E.J.W. Irish and J. Muller. F.H. McLearn and R.T.D. Wickenden, who made earlier stratigraphic studies, were consulted at various times.

The fauna of the Fort St. John Group was identified by J.A. Jeletzky and E.T. Tozer. The former commented in detail on age assignments and regional correlations. The flora was identified by W.A. Bell, D.C. McGregor and F.M. Hueber. During 1958, McGregor spent approximately 6 weeks in the field with the writer, collecting many fossil plants.

Competent field assistance was given in 1958 by J.N. Dardick, H.N. Wilkinson and W.R. Emery; in 1959 by H.N. Wilkinson, T.J. Pinnacle and W.E. Koepke; in 1960 by A.A. Wilkins and J.P. Hill; and in 1961 by M.L. Larson. The helicopter used in

¹Names and/or dates in parentheses refer to publications listed in the References.

SERIES	UPPER CRETACEOUS		LOWER CRETACEOUS	
CENTRAL ALBERTA FOOTHILLS	ALBERTA GP.	Blackstone Formation	Mountain Park Formation	Luscar Formation
NORTHERN ALBERTA FOOTHILLS	Dunvegan Fm.	Shaftesbury Formation	Luscar Formation	Cadomin Fm.
PINE RIVER FOOTHILLS	Dunvegan Fm.	Cruiser Fm. Goodrich Fm. Hasler Fm.	Boulder Ct. Member Hulcross Member Gates Member Moosebar Formation	Gething Fm. Cadomin Fm.
PEACE RIVER FOOTHILLS	Dunvegan Fm.	Cruiser Fm. Goodrich Fm.	Hasler Formation Gates Fm. Moosebar Formation	Gething Fm. Cadomin Fm.
PEACE RIVER PLAINS	Dunvegan Fm.	Shaftesbury Formation	Paddy Mbr. Cadotte Mbr. Harmon Member Notikewin Mbr. Falher Mbr. Wilrich Mbr. Bluesky Fm.	Gething Fm. Cadomin Fm.
SIKANNI CHIEF RIVER	Dunvegan Fm.	Sully Fm. Sikanni Fm.	Buckingham Formation	Gething Formation
LIARD RIVER	Fort Nelson Fm.	Lépine Formation	Scatter Formation	Garbutt Formation
FORT LIARD	Fort Nelson Fm.	Sully Fm. Sikanni Fm.	Buckingham Formation	Buckingham Formation

Figure 2. Correlation of Lower Cretaceous rocks, of the northern Rocky Mountain Foothills region

1961 was supplied by Okanagan Helicopters Limited and was staffed by R. Burton, E. Haylock and K. Harding. The writer is also grateful to E. Moberly, I. Severson, R. Howatt, D. Dalgleish, F. Letendre, G. Rautenstrauch, H.A. Dalgleish, R. Cameron, J. Aird, O. Gauthier and C.J. Stojan.

STRATIGRAPHY

Lower Cretaceous rocks of predominantly marine origin in the vicinity of Peace River were included in the Fort St. John Group (Dawson, 1881; see also McLearn, 1918, 1923, 1932, 1945a; McLearn and Kindle, 1950). Farther south, these marine beds intertongue with continental sediments. Rocks closely related to that succession and lying immediately below are included in the Gething and Cadomin Formations. A succession containing oldest Cretaceous rocks, lying between the Cadomin Formation and the Jurassic Fernie Formation, does not form a part of this study.

The base of the succession (base of the Cadomin Formation) is an erosional unconformity that increases in magnitude toward the Plains and also northward beyond Peace River. In the western Foothills, underlying rocks of Late Jurassic and Early Cretaceous age include the Nikanassin, Monteith, Beattie Peaks, and Monach Formations¹. These rocks disappear northeast of that region and beds equivalent to the Cadomin Formation lie on older Mesozoic rocks.

Beds overlying the Fort St. John Group are included in the Dunvegan Formation and are conformable. A thick succession of transition beds is present in most areas. As shales of the Fort St. John Group grade laterally westward into sandstones that are included in the Dunvegan Formation, the upper contact is drawn at the base of successively higher sandstones in the western region.

CADOMIN AND GETHING FORMATIONS

The Cadomin and Gething Formations embrace a closely related succession and are, in reality, facies of one depositional sequence (Figs. 2, 5). Variation in thickness is therefore significant only when both units are considered together.

In the southern part of the region around upper Smoky River the Cadomin conglomerates generally occur as a basal succession. Farther north, however, this facies dominates in more westerly sections where almost the whole interval is conglomerate. Eastward from these sections the conglomerates grade laterally into the carbonaceous Gething facies. Several conglomeratic units are interbedded with finer sandstones and shale. In the southern part of the

¹The precise relationship between the Nikanassin Formation of the Alberta Foothills and the Monteith, Beattie Peaks, and Monach Formations of the Carbon Creek basin is not known, although they probably are closely equivalent. Warren and Stelck (1958) and Gussow (1960) have discussed some of the problems but more detailed studies are needed.

TABLE OF FORMATIONS

Series	Group	Formation	Thickness (feet)	Lithology	
Upper Cretaceous		Dunvegan	300-1,200	Marine and non-marine sandstone and shale	
	Lower Cretaceous	Fort St. John Group	Cruiser	350-800	Dark grey marine shale with sideritic concretions; some sandstone
Goodrich			50-1,350	Fine-grained, crossbedded sandstone; shale and mudstone	
Hasler			500(?) -1,500	Silty, dark grey marine shale with sideritic concretions; siltstone and sandstone in lower part; minor conglomerate	
Commotion					
Boulder Creek Member			240-560	Fine-grained, well-sorted sandstone; massive conglomerate; non-marine sandstone and mudstone	
Hulcross Member			10-450	Dark grey marine shale with sideritic concretions	
Gates ¹			220-900	Fine-grained, marine and non-marine sandstones; conglomerate; coal; shale and mudstone	
Moosebar			100-1,000	Dark grey marine shale with sideritic concretions; glauconitic sandstone and pebbles at base	
Gething			75-1,000	Fine- to coarse-grained, brown, calcareous, carbonaceous sandstone; coal, carbonaceous shale, and conglomerate	
Cadomin			45-600	Massive conglomerate containing chert and quartzite pebbles	

¹Gates sandstones in Peace River region are considered as a formation; farther south they are included in Gates Member of Commotion Formation.

region where the Cadomin conglomerate is a prominent ridge-former, it serves as an extremely useful map-unit. For mapping purposes in the northern part of the region where the conglomerate is more lenticular and much less prominent, equivalent beds are included as part of the Gething Formation.

Cadomin Formation

The Cadomin Formation (McKay, 1929, p. 9B; 1930, p. 1310) consists of conglomerates containing well-rounded pebbles, cobbles and boulders of extremely resistant rocks. The formation extends northward from its type locality near Athabasca River to Bullmoose Mountain just south of Pine River. Beyond there, a thick succession of coarse-grained pebbly sandstones occupies a similar stratigraphic position and extends north of Peace River.

Variation in thickness from one locality to another is due mainly to facies changes. The formation increases from 86 feet on Kakwa River to a maximum of more than 500 feet near Belcourt Lake. From there the conglomerate decreases to 146 feet south of Wolverine River and to 45 feet north of Wolverine River (Stott, 1960a, sec. 3). The thickness of the formation near Deadhorse Meadows was not obtained (see Fig. 5).

Conglomerate occurs in beds varying from 50 feet or more to a few inches. Some beds grade laterally into sandstone, revealing the lenticular nature of the conglomerate bodies. Bedding, where apparent, is commonly planar, although crossbedding is evident in many places. Pebbles, cobbles and boulders are well rounded and composed mainly of chert, quartzite, and quartzitic sandstone. Some carbonate, volcanic, and metamorphic fragments also occur. Most are grey, bluish grey, or white, but some are pink or red, green, and black. Pink and green types are most abundant near Belcourt Lake and disappear in the northern part of the region. The pebbles are embedded in a matrix of strongly cemented, coarse- to medium-grained sandstone. The largest boulders (as much as 15 inches) occur in the thickest sections, that is, on the western side of the Foothills. Maximum sizes decrease towards the eastern side of the Foothills. Accompanying the eastward change is a decrease in total amount of conglomerate and an increase in sandstone.

In the vicinity of Peace River Canyon (Sec. 1, Appendix) a succession of coarse-grained conglomeratic sandstone occurs below the Gething Formation in a corresponding stratigraphic position to the Cadomin Formation. The sandstones are similar to the matrix of the Cadomin conglomerate farther south and to the Cadomin beds immediately south of Wolverine River. They occur in massive 5- to 20-foot beds that weather reddish brown to grey. More than 500 feet was measured on Mount Gething and more than 660 feet is exposed on Butler Ridge. In the canyon, the uppermost beds of this unit can be seen to grade laterally into the Gething facies. It is possible that similar facies changes occur in the surrounding area and that much of the conglomeratic sandstone on Mount Gething and Butler Ridge is actually equivalent to the type Gething Formation. However, relationships are difficult to establish without better and more continuous exposures.

The Cadomin Formation is a piedmont facies of conglomerates and coarse-grained sandstones which grades easterly from the western Foothills into flood-plain deposits included in the Gething Formation. Throughout most of the Foothills region the flood-plain sediments are predominant, but in the vicinity of Belcourt Lake the thick succession of conglomerates indicates a dominant piedmont environment and near source-area.

In the Carbon Creek basin the coarse-grained sandstones equivalent to the Cadomin Formation lie above the Monteith, Beattie Peaks, and Monach Formations. The youngest fauna from these formations is reported by Jeletzky to be of late Valanginian age. The oldest known marine fauna above the Cadomin-Gething beds is reported to be middle Albian in age. Therefore, the Cadomin-Gething succession, in that region at least, can be dated as Hauterivian to Albian.

Gething Formation

The Gething Formation, comprising interbedded mudstone, coal, and sandstone, was defined by McLearn (1923, p. 4B) who measured and designated as type the well-exposed sections in the Peace River Canyon. Additional work was done in that area in 1944 by McLearn and Irish. Columnar sections, in which coal seams were used as key horizons and which showed the correlation of those sections, were illustrated by McLearn and Kindle (1950).

According to McLearn (1923, Fig. 2) and McLearn and Kindle (1950, Fig. 14) the type Gething Formation on Aylard Creek¹ and the north shore of Peace River is approximately 1,400 feet thick. In their diagrams the succession on Moosebar Creek is shown to lie almost at the top of the north shore exposures. However, the general attitude of bedding in the canyon indicates that the Moosebar Creek section must be equivalent to beds much nearer the base of the formation on the north shore. The exposures on Moosebar Creek apparently include all but about 200 feet of the Gething Formation. A revised correlation of these sections (Fig. 3) based on recent examination shows the thickness in the type region to be nearer 1,000 feet.

The Gething Formation extends southward from Peace River to upper Smoky River where equivalent beds are included in the basal part of the Luscar Formation. The Gething outcrops in the western Foothills and, because of the numerous incompetent coal beds, it is commonly faulted and folded. No complete section was found between the type area and Bullmoose Mountain. The formation thins southward, being 677 feet north of Wolverine River and 446 feet on Quintette Mountain.

¹"Aylard Creek" refers to a small tributary on the south side of Peace River between Gething and Moosebar Creeks. It should not be confused with the Aylard Creek that flows into Peace River at Gold Bar.

Sandstones of the Gething Formation are fine to coarse grained, generally carbonaceous, brown, laminated, and brown weathering. Crossbedding within the sandstones is apparent in stacks of platy to flaggy beds. Carbonaceous mudstones and siltstones are green, brown, or grey. Coal, present within the formation throughout the region, reaches its maximum development in the Peace River Canyon but disappears northward.

Collections of plants from the Gething Formation yielded the following species:

Coniopteris brevifolia (Fontaine) Bell
Cladophlebis parva Fontaine
Sphenopteris latiloba Fontaine
Ginkgo pluripartita (Schimper) Heer
Ptilophyllum (Anomozamites) montanense (Fontaine) Bell
Pterophyllum rectangulare Bell
Pterophyllum sp.
Ptilophyllum arcticum (Göppert) Seward
Nilssonia canadensis Bell
Elatides curvifolia (Dunker) Nathorst
Elatides splendida Bell
Elatocladus brevifolia (Fontaine)
Pityophyllum cf. P. nordenskiöldi (Heer)
Podozamites lanceolatus (Lindley and Hutton) Schimper

A similar flora from the "Gething Formation or from non-marine strata of the Bullhead group" was reported by Bell (1956). Additional forms reported by Bell include the following species:

Thallites zeilleri (Seward) Harris
Coniopteris berryi Bell
Cladophlebis strictinervis (Fontaine)
Cladophlebis virginensis Fontaine
Onychiopsis psilotoides (Stokes and Webb) Ward
Sagenopteris williamsii (Newberry) Bell
Baiera cf. B. gracilis (Bean) Bunbury
Ginkgo cf. G. lepida Heer
Stenorachis striolatus (Heer, pars) Nathorst
Phoenicopsis angustifolia Heer forma media Krasser
Pterophyllum plicatum Bell
Pseudocycas dunkeriana (Göppert) Florin
Pseudocycas sp. A. cf. P. unjiga (Dawson)
Athrotaxites berryi Bell
Elatocladus smittiana (Heer) Seward

Bell commented on the lack of thirteen significant species that occur in the Blairmore Group but stated (1956, p. 19): "The composition of the flora. . . leads to no other conclusion that it is of the same age as that of the flora of the Luscar and of the lower flora of the Blairmore, the age of this, as stated elsewhere in this report, is considered to be Aptian." Two of the missing species noted by Bell—Cladophlebis parva and Elatocladus brevifolia—are in the recent collections. This flora will be further discussed with that of the Commotion Formation.

The Gething Formation is correlated with the lower beds of the Luscar and Blairmore Formations.

A few marine shells were collected from the Gething Formation and these include:

Pecten (Entolium) sp. indet.

Thracia? sp. indet.

Pecten s. lato(?) sp. indet.

The occurrence of these fossils, although not significant in age determinations, does suggest the occurrence of marine tongues within the dominant continental sediments.

FORT ST. JOHN GROUP

The Fort St. John Group, as originally defined by Dawson (1881), comprised a succession of marine rocks in the vicinity of Peace River. The name has been applied to equivalent beds in northeastern British Columbia, northern Alberta, and the District of Mackenzie (Fig. 3). As a result of major facies variation, several different divisions have been made within the group. In the Peace River Canyon area it is divided, from the base upward, into the Moosebar, Gates, Hasler, Goodrich, and Cruiser Formations. Farther south in the vicinity of Pine River the succession is: Moosebar, Commotion, Hasler, Goodrich, and Cruiser Formations. In the Peace River plains, shales equivalent to those of the last three formations are included in the Shaftesbury Formation. Similarly, in the southernmost part of the Foothills considered in this study, beds above the Commotion Formation are not divisible, and are also included in the Shaftesbury Formation. Southward, beyond upper Smoky River, beds equivalent to the Gething, Moosebar, and Commotion Formations are included in the Luscar Formation. Other divisions, which are not described here, are used to the north (Fig. 3). (See also Kindle, 1944; Hage, 1944; Alberta Study Group, 1954; Stelck et al., 1956; Stott, 1960b.)

Distribution of the Fort St. John Group in the vicinity of Peace River is shown on recent maps of the Pine Pass area (Muller, 1961), the Charlie Lake area (Irish, 1958), and the Dawson Creek area (Stott, 1961a). The most detailed mapping in earlier years was by Wickenden and Shaw (1943) and Beach and Spivak (1944).

The Fort St. John Group thickens northwesterly along the Foothills. Near Deadhorse Meadows the group is approximately 2,300 feet thick, increasing to 3,456 feet near Belcourt Lake (Fig. 2). The maximum thickness of 4,812 feet is on Dokie Ridge (Stott, 1961b, Sec. 1). A comparable thickness is probably present near Peace River Canyon but the Hasler shales are not exposed and no complete section is known in that area.

Moosebar Formation

The Moosebar Formation, originally described in 1923 by McLearn, consists of marine shale and siltstone. In the type locality

at Contact Point at the southeastern end of Peace River Canyon, the formation is underlain by the Gething Formation and overlain by the Gates sandstones. The type section (Sec. 2) fully described for the first time in this report, is well exposed at the base but some of the upper beds are covered. However, much of the covered interval beneath the Gates sandstone is exposed on the north side of the river (Sec. 4).

The Moosebar Formation extends southeastward along the Foothills at least as far as Kakwa River. Mellon and Wall (1961) reported marine beds in a similar stratigraphic position at Cadomin in the Athabasca region, which indicates that equivalent beds may occur in the Foothills south of Smoky River.

The formation decreases in thickness between Peace River and upper Smoky River. In the type section it is approximately 950 feet thick. As pointed out by McLearn and Kindle (1950, p. 75), the type section is thinner than a section measured by Beach and Spivak (1944) on a tributary (Track Creek) of Gething Creek where there is more than 1,300 feet of beds; however some faulting is evident, and there may be some repetition. On Dokie Ridge (Stott, 1961b, Sec. 2) more than 950 feet of beds was measured but the basal part is faulted. Farther south in sections near Wolverine River the Moosebar has decreased to about 300 feet and on Mount Torrens only 139 feet is present.

Although the lower contact with the Gething Formation may be disconformable, there is no evidence of regional erosional unconformity. At Contact Point, 1 foot of pebbly sandstone lies abruptly on carbonaceous sandstone of the Gething and is in turn overlain by typical Moosebar mudstone. On Aylard Creek the upper surface of the Gething has some embedded pebbles and is directly overlain by Moosebar shale.

The basal shales of the Moosebar Formation are dark grey to black, rubbly to blocky, and contain ironstone concretions. Highly glauconitic argillaceous siltstone occurs near the base on Bullmoose Mountain and farther north beyond Peace River. The shales grade upwards into mudstone and siltstone that assume a brownish to greenish colour.

The Moosebar Formation contains the following fauna:

Aucellina aptiensis (d'Orbigny) Pompeckj(?)
Inoceramus sp. ex gr. I. cadottensis McLearn
Inoceramus(?) sp. indet.
Lemuroceras (s. lato) cf. L. irenense McLearn
Pecten (Entolium) sp. indet.
Pecten (Pseudamussium?) sp. indet.
Pleuromya sp. indet.
Dentalium sp. indet.
Starfish, genus and species indet.

The Lemuroceras was tentatively dated by Jeletzky as belonging to the Lemuroceras irenense subzone of mid-Albian age. L. irenense was reported by McLearn and Kindle (1950, p. 76) from near the top of the

formation in the Peace River Canyon. Foraminifera representative of the Marginulinopsis collinsi fauna dated as middle Albian were reported from the Moosebar interval on Belcourt Ridge by Mellon, Wall, and Stelck (1963, p. 67).

The Moosebar Formation is correlated with the Bluesky Formation and Wilrich Member of the Spirit River Formation of the Plains; with the Loon River and Clearwater Formations; and with the lower part of the Buckingham and Garbutt Formations.

Gates Formation

The prominent sandstone forming The Gates on Peace River east of Hudson Hope was designed as the "Gates Sandstone" by McLearn (1923), and it has been treated as a formation since that time. As indicated by McLearn and Kindle (1950), the stratigraphic relationship to underlying beds is unknown at that locality and other sandstones may occur below. Farther west, at Steamboat Island at the mouth of the canyon, two sandstones are included in the Gates Formation and relationships there are well exposed. These two sections are described for the first time (Secs. 3 and 4). McLearn did not extend his studies far beyond the canyon and therefore was unable to outline the distribution of the formation in detail, although he did suggest that the Gates sandstones were equivalent to the basal beds of the Commotion Formation on Pine River.

The Gates Formation was mapped from the exposures at Steamboat Island southwestward along Moosecall Lake to an anticlinal structure east of Mount McAllister. In that area a higher sandstone (Boulder Creek Member) appears above the Gates, and both units were followed to Dokie Ridge where they are included in the Commotion Formation. Inasmuch as the Gates Formation of the Peace River region is equivalent to the lower member of the Commotion Formation, the Gates is reduced to member rank in the vicinity of Pine River.

The Gates Formation as such, therefore, occurs only in the immediate vicinity of Peace River Canyon. It extends eastward toward Fort St. John but apparently grades laterally into shale northward as it has not been recognized as a mappable unit north of Peace River. Only about 60 feet of the formation is exposed at the type locality (Sec. 3). However, more than 225 feet outcrops at Steamboat Island (Sec. 4).

The Gates Formation in its type locality consists of massive to thick-bedded, fine-grained, well-sorted sandstone. Some interbedded shale and siltstone are included. Abundant glauconite gives some of the sandstone a greenish colour.

The following species were reported from the Gates Formation by McLearn and Kindle (1950, p. 76):

Beudanticeras sp.
Beudanticeras(?)
Lemuroceras(?)
Astarte portana
Ostrea

Pecten (Entolium)
Arctica(?)

Species reported by Stelck et al. (1956, p. 15) include:

Beudanticeras cf. B. mcconnelli (Whiteaves)
Entolium irenense McLearn
Protocardia alcesiana McLearn
Astarte portana McLearn
Lophidiaster cf. L. silentiensis McLearn

As the Gates Formation contains these fossils of mid-Albian age and is overlain by beds known to lie within the mid-Albian zone of Gastroplites, it apparently lies near or at the top of the generalized zone of Beudanticeras and Lemuroceras.

The Gates Formation is equivalent to the upper beds of the Spirit River Formation and to the middle beds of the Buckingham Formation.

Commotion Formation

The Commotion Formation, defined in the Pine River region by Wickenden and Shaw (1943), extends northward from its type locality toward Peace River. Although its characteristic features are retained north of Moberly River, the formation is not mappable in the Peace River valley where the upper member loses its resistant character. The Commotion Formation is, however, a mappable unit in the Foothills at least as far south as Kakwa River (Fig. 5).

Three members are recognized within the formation. The lower one is equivalent to the Gates Formation of the Peace River valley. The middle one is here designated as the Hulcross Member. The upper member is the "Boulder Creek Conglomerate" of Spieker (1921) and that name is therefore retained.

The Moosebar and Commotion Formations record two major marine incursions and regressions. The Moosebar and Gates constitute the lower cycle and the Hulcross and Boulder Creek the upper cycle of transgression and regression.

Gates Member

The lower member of the Commotion Formation (see Stott, 1961a, 1962b) includes beds equivalent to the Gates sandstone of Peace River (Fig. 5). Although the lithology varies considerably, it seems preferable to retain that name, thereby avoiding further duplication of nomenclature and emphasizing the regional correlation.

The lower beds of the member are gradational into the underlying Moosebar shales. The boundary rises stratigraphically from southeast to northwest (Fig. 4). The upper boundary appears to lie at a consistent stratigraphic level throughout the Foothills.

The Gates Member extends southward from Moberly River at least to Kakwa River. Equivalent beds beyond there have

been included in the middle part of the Luscar Formation. The Gates sandstones have not been recognized in surface outcrop north of Peace River.

The thickness of the member increases from 226 feet at Steamboat Island to a maximum of 873 feet near Belcourt Lake. Most of the increase is due to Moosebar shales grading into sandstone and carbonaceous sediments that are then included in the Gates Member.

The member contains a cyclic succession of sandstones, mudstones, siltstones, coal, and some conglomerate. In the southern part of the region most of the member was deposited in a continental environment, but in the Pine and Peace Rivers region much of it is marine. Basal sandstones, presumably mainly marine, are fine grained, laminated, brown, calcareous, and brown weathering. In the south, higher sandstones, showing greater variation in grain size, are commonly carbonaceous and contain abundant plant fragments. Coal is more abundant in the Kakwa-Belcourt region. Conglomerate is not a major constituent of the Gates Member but massive units do occur near Belcourt Lake and on Bullmoose Mountain.

The Gates Member (Formation) together with the underlying Moosebar constitutes the lower cycle of transgression and regression evident in the Moosebar - Commotion succession. The Moosebar Formation contains the offshore marine shales of the cycle. The transitional and continental facies are included in the Gates Member (Formation). These two stratigraphic units do not, as individual units, have uniform thickness, but when considered together, the thickness is relatively uniform or varies in a regular manner (Fig. 5). The maximum thickness of these combined units is about 1,300 feet on Dokie Ridge. The succession thins toward Peace River where the beds are mainly of the offshore marine facies. Thinning also occurs toward the south where continental sediments dominate.

The initial transgression, recorded in the Moosebar Formation, extended into the Foothills at least as far south as Kakwa River. There, near-shore sands marking the base of the Commotion Formation are separated from the Gething Formation by thin Moosebar shales, suggesting that marine conditions did not persist as long as in the northern area. The regressive marine sandstones, rising stratigraphically as the formation is traced northward (Fig. 5), formed the seaward edge of continental deposits. Thus, in the southern part of the region, a thick succession of carbonaceous sediments and coal accumulated, but farther north, only marine sandstones are present. In the Peace River region the sandstones occur only near the top of the sequence. These are extremely silty, representing the northernmost limits of sandstone deposition. The Gates sandstone apparently grades laterally into shale northward, and equivalent beds are included in the Buckingham Formation.

An extensive fossil flora was obtained from the Gates Member. A similar, although less representative, flora was reported by Mellon, Wall, and Stelck (1963, p. 68) from this succession on Belcourt Ridge. This flora includes the following species:

Coniopteris brevifolia (Fontaine) Bell
Cladophlebis virginensis Fontaine emend Berry
Cladophlebis virginensis Fontaine forma acuta Bell

Cladophlebis strictinervis (Fontaine)
Cladophlebis parva Fontaine
Gleichenites giesekianus (Heer) emend Seward
Sphenopteris (Ruffordia) göpperti (Dunker) Seward
Sphenopteris latiloba Fontaine
Sphenopteris newberryi Bell
Hausmannia (?)
Sagenopteris williamsii (Newberry) Bell
Sagenopteris mclearnii Bell
Ginkgo pluripartita (Schimper) Heer
Carpites (Ginkgo?) sp.
Stenorachis sp.
Phoenicopsis arctica (Heer)
Ptilophyllum (Anomozamites) montanense (Fontaine) Bell
Pterophyllum plicatum Bell
Pterophyllum validum (?) Hollick
Ptilophyllum arcticum (Göppert) Seward
Ptilophyllum robustum Bell
Pseudocycas sp. A. Bell cf. P. unjiga (Dawson)
Pseudocycas dunkeriana (Göppert) Florin
Nilssonina brongniarti (Mantell)
Nilssonina californica Fontaine
Nilssonina sp.
Ctenis borealis (Dawson)
Ctenopteris insignis Fontaine
Elatocladus brevifolia (Fontaine) Bell
Elatides curvifolia (Dunker) Nathorst
Elatides splendida Bell
Pityophyllum cf. P. nordenskiöldi (Heer)
Pityophyllum cf. P. longifolium (Nathorst) Moeller
Athrotaxites berryi Bell
Elatocladus (Metasequoia?) smittiana (Heer) Seward
cf. Sequoia condita Lesquereux
Sequoia condita Lesquereux (cone)
Cypassidium(?) gracile(?) Heer
Elatocladus acifolia Bell
Podozamites lanceolatus (Lindley and Hutton)
Sapindopsis belviderensis Berry
Araliaephyllum(?) sp.

Bell, McGregor and Hueber, who identified these collections, considered them to be "Luscar (Aptian)" flora. Bell (1956, pp. 10, 11) stated: "The flora of the Luscar clearly belongs to the lower flora at Blairmore. . . . The age of the lower flora cannot be much earlier than that of the upper flora, which with some confidence may be assigned an Albian age. With no breaks in the stratigraphic sequence the earlier flora could be either early Albian or Aptian but the extreme rarity of dicotyledons within it, together with the survival of many species occurring in the Kootenay flora, certainly favours an Aptian age."

The lower Commotion flora occurs in beds equivalent to the upper Moosebar shales and the Gates Formation on Peace River from which the middle Albian ammonites Lemuroceras irenense and Beudanticeras have been reported. A gastropplitid from beneath one of the thickest sections of the Commotion Formation was tentatively considered by Jeletzky to be probably of general Albian age. The Gates Member of the Commotion Formation apparently lies within the generalized Lemuroceras and Beudanticeras zone which Jeletzky dates

as middle Albian. The middle Albian age of these beds is further confirmed by the dating of microfauna reported from underlying beds by Mellon, Wall, and Stelck (1963, p. 67). It is therefore apparent that the "Lower Blairmore - Luscar - Gething" flora extends upward into rocks of middle Albian age. It should be further noted that the Commotion flora includes most of the species found in the Gething Formation, and that the differentiation of these formations on the basis of floral evidence would be difficult. However, the more numerous species of the Gates Member may be significant. The very close similarity of the lower Commotion and lower Blairmore floras is probably significant in dating the more southerly succession.

Marine fauna collected from the basal sandstones of the Gates Member include:

gastroploid ammonite, genus and species indet.
gastroploid ammonite resembling early(?) representatives of
Gastrolites McLearn
Aucellina(?) sp. indet.
Pecten (Entolium?) sp. indet.
Ostrea sp. indet.
Gastropod, genus and species indet.

Hulcross Member

The middle member of the Commotion Formation, comprising dark grey, concretionary, marine shales is here named the "Hulcross Member". As it is poorly exposed in the type region of the Commotion Formation (see Stott, 1961b, p. 14), the type section is designated as that occurring north of Wolverine River (Stott, 1960a, Sec. 3, units 93-111). One of the best exposures of the member is on Starfish Creek (Sec. 5) just below Peace River Canyon, but overlying beds are not exposed and relationships are somewhat obscure.

The lower contact of the Hulcross Member with the Gates Member is distinct, commonly marked by a layer of chert pebbles, and appears conformable. The upper beds are gradational into the overlying member and do not lie at any persistent stratigraphic horizon (Fig. 5).

The Hulcross Member extends northward from near upper Smoky River to Peace River (Fig. 5). In the canyon, equivalent beds are included for mapping purposes in the Hasler Formation although they can probably be recognized as a distinct stratigraphic unit in subsurface much farther east.

The member decreases southward from its maximum of 437 feet on Starfish Creek (Sec. 5) and almost disappears near Kakwa River (Fig. 5).

The shales weather rusty and contain sideritic concretions. Basal shales are commonly rubbly but the siltier upper shales are platy and interbedded with siltstone.

Fossils collected from this member include:

Beudanticeras(?) sp. indet.

Gastroplites cf. G. allani McLearn
Gastroplites cf. G. kingi McLearn
Gastroplites nov. sp. ex. aff. G. liardense (Whiteaves)
Gastroplites sp. indet.
Pecten (Entolium?) sp. indet.
Pleuromya(?) sp. indet.

The Beudanticeras(?) specimen, from immediately above the Gates Formation on Peace River, was not definitely dated by Jeletzky because of its poor preservation. The Gastroplites fauna is considered by Jeletzky to be of late middle Albian age.

Boulder Creek Member

Spieker (1921) described a succession of conglomeratic beds along Commotion Creek¹ and called it the "Boulder Creek conglomerate member" of the Bullhead Mountain Formation. As pointed out by Wickenden and Shaw (1943, p. 5) the beds are not part of the Bullhead succession but occur much higher stratigraphically. It is now proposed to retain the name for those conglomeratic and carbonaceous beds that occur in the upper part of the Commotion Formation. The locality described by Spieker is part of the type locality of the Commotion Formation (Wickenden and Shaw, 1943; see also Stott, 1961b, pp. 10-12). Standard sections (Stott, 1961b, Secs. 1, 2, 4) give more complete details of thickness and lithology.

The Boulder Creek Member extends northward from Dokie Ridge across Moberly River toward Mount McAllister. East of there it is much less resistant and, as it does not form a mappable unit, it is not formally recognized in surface outcrop near Peace River Canyon. However, sandy beds at the top of the cliffs above Starfish Creek indicate that the member has not graded entirely into shale. Beds equivalent to higher Boulder Creek sandstones may be present but covered. The Boulder Creek Member extends southward along the Foothills almost to upper Smoky River.

The member is 556 feet thick on Dokie Ridge but thins southward due to convergence. The member is considered to be 241 feet thick near Deadhorse Meadows.

Sediments of the Boulder Creek Member are similar to those of the Gates Member south of Pine River, although coarse-grained sandstone and conglomerate are more abundant. The base of the member is generally marked by massive, fine-grained, well-sorted sandstone. The massive conglomerate, so characteristic of this member, is prominent throughout the region but is somewhat lenticular and not entirely consistent in its stratigraphic position. As originally described by Spieker (1921, p. K15), the conglomerate is composed of small pebbles of chert and quartz firmly cemented by silica. He pointed out the abundance of green chert but this type of pebble is

¹Spieker indicated in his text that the beds occurred in "Boulder Creek" but it is evident from his map, geological and geographical descriptions, that the conglomerates are those exposed in Commotion Creek. In more recent times, the creek west of Commotion Creek has been called "Boulder Creek".

distributed more widely through the stratigraphic succession than Spieker believed. Carbonaceous sediments, including some thin coal beds, lie above the conglomerate.

The Hulcross and Boulder Creek Members comprise another major depositional sequence of marine to continental sediments. The Hulcross Member contains the marine shale facies; the Boulder Creek Member contains the transitional, deltaic, and flood-plain facies. As one member thins the other thickens, and their total thickness increases gradually from southeast to northwest (Fig. 5). The Hulcross shales were deposited as far south as Deadhorse Meadows. They thicken northwestward at the expense of the overlying unit, until, as shown on Starfish Creek, much of the succession is marine shale (Fig. 5). In the south, thick beds of well-sorted sandstone apparently were deposited in the near-shore environment. Slightly younger beds of similar character were deposited farther north. Behind these near-shore sands, carbonaceous sediments were laid down in the deltaic and flood-plain environments. The shoreline gradually advanced northward over the offshore deposits and the sandstones reached their maximum development near Pine River; farther north they grade laterally into finer and siltier offshore sandstones.

A slightly larger flora was collected from the Boulder Creek Member than was obtained by Wickenden and Shaw (1943) and reported by Bell (1956, p. 37). The collections included the following species:

Cladophlebis frigida (Heer) Bell
Cercidiphyllum sp.
Platanus sp.
Pallurus sp.
cf. Cissites
Magnolia sp. (= Ficus fontainii? Berry)
Menispermites reniformis Dawson
cf. Artocarpidium cretaceum Ett
Cladophlebis cf. C. parva Fontaine
Rhamnus sp.
Unidentified conifer

A flora containing several species of angiosperms was reported by Mellon, Wall, and Stelck (1963, p. 70) from the upper Commotion Formation on Belcourt Ridge but its position relative to the Boulder Creek Member is not entirely clear. Bell (1956) tentatively assigned a late Albian age for the collections made by Wickenden and Shaw. The beds from which these plants were obtained are equivalent or lie just above marine beds from which the middle Albian Gastrolites fauna was obtained.

Fauna from the Boulder Creek Member include:

gastrolitid ammonite
Arctica sp. indet.
Unio (Pleurobema) ex. aff. U. (P.) dowlingi McLearn

Fossils from sandstone talus considered equivalent to the Boulder Creek Member on Starfish Creek are as follows:

Gastrolites cf. G. allani McLearn

Gastrolites n. sp. aff. G. liardense (Whiteaves)
gastrolitid ammonite, genus and species indet.
Lophidiaster cf. silentiensis McLearn
Inoceramus ex gr. anglicus Woods
Arctica(?) sp. indet.

Jeletzky dated this fauna as late middle-Albian in age.

Shaftesbury Formation

Throughout the Peace River Plains, the upper part of the Fort St. John Group is predominantly marine shale which is included in the Shaftesbury Formation. As defined by McLearn and Henderson (1944) the formation includes those beds lying between the Dunvegan and Peace River Formations (see Fig. 3). The Shaftesbury is stratigraphically equivalent to the interval between the Dunvegan and Commotion Formations in this area and to that between the Dunvegan and Luscar Formations in the Foothills near upper Smoky River (Stott, 1960a, 1961a). (See also Fig. 6.) The shales extend westward into the Foothills where the middle beds grade into sandstones of the Goodrich Formation. The shales underlying the Goodrich Formation are termed the "Hasler Formation", and the overlying shales, the "Cruiser Formation".

In the Peace River region where the Goodrich sandstones disappear, marine shales apparently occupy the entire interval between the Dunvegan and Gates Formations—an interval greater than the type Shaftesbury which was included by Irish (1958) in his 'Upper Shales' of the Fort St. John Group and was said to be between about 1,400 and 1,800 feet thick.

Due to poor exposures and lack of well-defined markers, it is difficult to establish correlations within the Foothills succession (Fig. 6) for purposes of comparing thickness and determining accurate facies variations of the interval between the Commotion and Dunvegan Formations. A satisfactory datum for comparison has not yet been found. The base of the succession (above the Boulder Creek Member) is probably at a persistent stratigraphic horizon but is not exposed in the northernmost section. The upper boundary lies within a gradational sequence and, therefore, is probably drawn at different stratigraphic horizons from one area to another.

Hasler Formation

The Hasler Formation in its type region (Wickenden and Shaw, 1943, p. 6; see also Stott, 1961b, p. 15) is a succession of marine shales lying between the Commotion and Goodrich Formations. Northward on Peace River and west of Hudson Hope, beds equivalent to the Hulcross and Boulder Creek Members of the Commotion Formation appear to be predominantly marine shale and, for mapping purposes, have been included in the Hasler Formation. No complete outcrop section of this expanded unit is known. However, the region where it can be mapped lies near Tworidge Mountain and northeastward to Peace River.

Prior to 1961 only one well-exposed section of the Hasler Formation was known in the Foothills—the one on Dokie Ridge (Stott, 1961b, p. 15); another section has now been studied near Belcourt Lake (Fig. 6 and Sec. 6). The thickness there, 818 feet, is only slightly less than that measured on Dokie Ridge.

Although the basal 3 feet of the Belcourt section is covered, the lower contact is evidently distinct, without gradational features. Pebbles are embedded in the upper sandstone of the underlying Commotion Formation. The upper beds of the Hasler are gradational into the overlying Goodrich sandstones.

As in the Dokie Ridge section, the lower half of the Hasler Formation near Belcourt Lake is extremely silty and contains units of platy siltstone. The upper part is predominantly rubbly, rusty-weathering, dark grey, concretionary shale. The thin conglomerates found in the upper part of the formation on Hasler Creek and Dokie Ridge were not noted in the Belcourt section.

The type Hasler Formation lies above Commotion beds containing the middle Albian zone of Gastropilites and below the Goodrich Formation containing fauna of the late Albian zone of Neogastropilites. It can, therefore, be dated as middle to late Albian. In the Peace River Canyon region, where the lower boundary is drawn at the top of the Gates Formation, the Hasler Formation includes a larger stratigraphic interval and its basal beds lie within the zone of Gastropilites.

Goodrich Formation

The Goodrich Formation (Wickenden and Shaw, 1943) extends northwestward from its type locality on Boulder Creek (see Stott, 1961b). North of Dokie Ridge the Goodrich sandstones are well exposed only on the northeast flank of Mount McAllister; farther east they form prominent ridges near Pete Lake¹ and Tworidge Mountain.

The Goodrich Formation attains a maximum thickness of 1,320 feet on Dokie Ridge (Stott, 1961b, Sec. 1). Prior to 1961, no complete section of the Goodrich was known south of Pine River and it was accordingly considered to grade laterally southward into shale near Wolverine River (see Stott, 1960a, 1961a, 1961b). The Belcourt Lake section (Sec. 6), examined in 1961, revealed 862 feet of sandstones and shales equivalent to the Goodrich Formation. Nevertheless, the Goodrich sandstones are not present in a well-exposed section near Deadhorse Meadows (see Stott, 1960a, Sec. 2). The disappearance of sandstone and carbonaceous sediments is attributed to a lateral change into shale (Fig. 6). On Murray River near the mouth of Wolverine River and northeast of Belcourt Lake, only about 50 feet of sandstone is included in the Goodrich Formation, indicating a northeastward facies change from Belcourt Lake. The formation also grades

¹Coarse-grained sandstone and conglomerate surrounding Pete Lake were mapped by Beach and Spivak (1944) as the Goodrich Formation. These are the upper beds of the Commotion Formation. The Goodrich sandstones occur high above the lake and were included in the Dunvegan Formation by Beach and Spivak.

laterally into shale in an eastward direction from Dokie Ridge, as no equivalent sandstone is recognized along Peace River. The resistant beds disappear in the vicinity of Cameron Lakes and are not present east of Hudson Hope.

The Goodrich sandstones are fine grained, laminated, brown, and brown weathering. Weathering of crossbedded units commonly results in stacks of platy sandstone. Some minor coarse-grained sandstone and conglomerate does occur within the formation. The section near Belcourt Lake contains more olive-brown carbonaceous mudstone and is less sandy than other exposures examined. Carbonaceous fragments are not generally abundant although a few fragments of angiosperm leaves were collected.

The Goodrich Formation is the greater part of the near-shore facies of the Shaftesbury sea. The shales found below the Dunvegan Formation near Fort St. John grade westerly and south-westerly into fine-grained sandstone. The maximum accumulation lies in the vicinity of Dokie Ridge and Mount McAllister. Western shorelines of this Shaftesbury - Goodrich sea extended southeasterly, probably along a depositional trend parallel to a line between Dokie Ridge and Belcourt Lake. The easternmost extension of the near-shore sands is approximated by a line extending from Hudson Hope through the mouth of Wolverine River.

The following fauna were obtained from the Goodrich Formation:

Bryozoan, genus and species indet.
Anomia sp. indet.
Arctica sp. indet.
Modiolus (Brachidontes) ex aff. M. fulpensis Stevenson
Modiolus sp.
Ostrea sp. indet.
Pholadomya(?) sp. indet.
Posidonia nahwisi (McLearn) var. goodrichensis (McLearn)
Posidonia cf. P. nahwisi (McLearn) var. goodrichensis (McLearn)
Pteria (Oxytoma) cf. P. camSELLi McLearn
Pteria (Oxytoma) cf. P. pinania McLearn
Tellina(?) sp. indet.
Protelliptio cf. P. hamili (McLearn)
Gastropod, genus and species indet.

Other species reported by McLearn and Kindle (1950, p. 82) include:

Pleuromya kissoumi
Tancredia stelcki
Pleuromya wickendeni
Lucina? goodrichensis
Posidonomya nahwisi var. moberliensis

The above fauna is considered by Jeletzky as the faunal facies of the generalized Neogastroplices zone. Stelck et al. (1956, p. 9) believed that Posidonomya moberliensis and P. goodrichensis, which they stated were found in the Goodrich and lower Sikanni sandstones, characterized zones older than any of the Neogastroplices zones proposed by them for beds previously placed in the generalized

Neogastrolites zone. That conclusion was however, not accepted by Jeletzky who commented as follows: "Although it is possible that Posidonia moberliensis and Posidonia goodrichensis range below Posidonia nahwisi s. str., these both forms mostly occur in association with either Neogastrolites selwini or N. cornutus. Both Goodrich and Lower Sikanni sandstones are definitely of Neogastrolites age.... The generalized Neogastrolites and Posidonomya nahwisi zone is considered to be of the late (? latest) Albian age in terms of the international standard stages."

Cruiser Formation

The Cruiser Formation (Wickenden and Shaw, 1943, p. 8) contains in its type locality near Pine River (see Stott, 1961b, p. 24) silty shales and siltstones of marine origin. It is exposed in only a few localities but has been mapped as far north as Peace River and southward toward upper Smoky River. In previous reports the formation was considered (Stott, 1960a, 1961a, 1961b) to extend southward only to Murray River, although equivalent beds were believed to be present much farther south. However, the Cruiser Formation, as shown by investigations in 1961, is present as a mappable unit near Belcourt Lake in the southwest corner of the region.

In contrast to the northerly section the base of the Cruiser Formation in the Belcourt section (Sec. 6) is well defined by a marked change in lithology from carbonaceous sandstone to shale. Some pebbles occur in the basal shale. Farther north on Dokie Ridge and Mount McAllister, the base of the formation has a gradational appearance, possibly due to poor exposures. In those sections, thinly interbedded sandstone and shale occur through several tens of feet, producing a more transitional appearance within the succession.

The upper boundary of the Cruiser Formation is distinct near Belcourt Lake where massive coarse-grained sandstone and conglomerate of the Dunvegan Formation¹ lie directly on the shale. Farther north, the upper boundary lies at the top of a thick succession of interbedded sandstone and shale.

The thickness of the Cruiser Formation varies considerably along the Foothills. Near Belcourt Lake it was found to be 419 feet. Farther north, 742 feet was included in the type section. To the west on Dokie Ridge it decreases to 361 feet. On Mount McAllister, 611 feet was included. These differences are mainly due to facies changes between both the overlying and underlying formations (Fig. 6). It would appear that the Cruiser Formation has different stratigraphic limits in every section examined. The only approximate guide to thickness variations in this part of the column is the combined interval between the Commotion and Dunvegan Formations. If these beds are considered as one unit, the interval decreases from a maximum on Dokie Ridge southeastward and eastward.

¹The Dunvegan Formation at this locality, where 80 feet of massive conglomerate and sandstone is exposed, is overlain by several large blocks of Palaeozoic rocks—remnants of a klippe related to the thrust rocks lying nearby.

Exposures of the Cruiser Formation are insufficient to determine in detail the facies variations along the Foothills. In the southern part of the area, as shown by the Belcourt section, the formation consists predominantly of dark grey silty shale. Similar beds occur in the type locality. Farther west on Dokie Ridge, some of these beds apparently grade laterally into silty sandstone and are, therefore, included in the Goodrich Formation (Fig. 6). As a result, the Cruiser Formation is thinner in the western Foothills. A similar section is partly exposed on Mount McAllister, indicating a north-westerly depositional trend. Farther east along Peace River the silty facies disappear. There the shales are flaky to rubbly and contain much sulphur and selenite.

The age of the Cruiser Formation is inferred from its position between formations that are well dated. The underlying Goodrich Formation contains the late Albian Neogastropilites fauna. The overlying Dunvegan Formation contains a fauna including Inoceramus dunveganensis McLearn and Unio (Pleurobema) dowlingi McLearn which Jeletzky considered to be of early Upper Cenomanian age. Thus the Cruiser Formation can be dated as latest Albian to early Cenomanian. It is correlated with the upper Shaftesbury shales of the Plains and the Sully Formation (Stott, 1960b) of the District of Mackenzie. It is probably equivalent to most of the shales between the "Fish Scale" marker-horizon and the Dunvegan Formation.

DUNVEGAN FORMATION

The Dunvegan Formation, defined by Dawson in 1881, includes a succession of sandstone and interbedded shale above the Fort St. John Group and below the Smoky Group. The type section is presumably on Peace River near Dunvegan.

The Dunvegan Formation lies conformably on the Fort St. John shales. The shales grade upward through interbedded shale and fine-grained sandstone into medium- to coarse-grained sandstone. The boundary is drawn at the base of the first massive sandstone. The upper boundary is gradational in many sections and is drawn above the highest carbonaceous shale and massive sandstone. Some thin beds of platy sandstone are usually placed in the basal part of the Smoky Group rather than in the Dunvegan Formation.

The formation is not well exposed in the southern part of the region although a section of 333 feet was measured just north of Kakwa River. A second section, not as well exposed and probably including some repetition by a small fault, was measured above Deadhorse Meadows where a maximum of 544 feet was obtained. More than 900 feet of Dunvegan strata was measured on Mount McAllister.

ECONOMIC GEOLOGY

PETROLEUM AND NATURAL GAS

The Fort St. John Group contains rocks that have already proven to be reservoirs of petroleum and natural gas. The thick succession of predominantly marine rocks comprises potential source

and reservoir rocks. The development of stratigraphic traps, formed by sandstones enclosed by shales, is favoured by the type of inter-tonguing common throughout the group.

Considerable drilling has been done in the Plains northeast of the Foothills. To date, three fields—Dawson Creek, Sunrise, and Pouce Coupe—produce from the Cadotte sandstone (upper Commotion equivalent). Farther north beyond Peace River, several fields produce petroleum and natural gas from the Gething - Cadomin succession. Trends of facies indicate that an increased proportion of well-sorted marine sandstone should occur in the Plains north and east of the Foothills of British Columbia. As such rocks are favourable for the accumulation of petroleum and natural gas, additional discoveries in Cretaceous rocks may be anticipated.

As previously indicated, potential reservoir rock exists at several horizons within the Cretaceous succession. The conglomerates of the Cadomin Formation grade northwesterly into sandstone and deserve attention, as indicated by production north of Fort St. John. The Gething Formation also has considerable potential north of Peace River. In the area directly east of the present study the marine sandstones of the Commotion Formation are well sorted, may have favourable porosity, are widespread, and occur at several horizons. Of these, the lower sandstones of the Gates Member are among the most important as they are probably the most widely distributed. The fine-grained massive sandstones that commonly occur in the lower part of the Boulder Creek Member have many features similar to the sandstones of the Cardium Formation of the Alberta Foothills. It is possible that they were formed under similar depositional conditions and that there may be stratigraphic traps comparable to those found productive in Alberta. The Goodrich sandstones are generally siltier and finer grained than the underlying ones. Present data indicate that they do not extend very far into the Plains but, by virtue of their considerable distribution along the Foothills, they deserve some consideration as potential reservoir rocks.

COAL

Large deposits of subbituminous to bituminous coal are present throughout the Foothills in the Gething, Commotion and Dunvegan Formations. Although most of the coal in the area of Pine and Peace Rivers is found within the Gething Formation, similar deposits are now known in the Commotion Formation south of Pine River. Total reserves for the Foothills region are undoubtedly far greater than previous estimates for that region.

At present very little coal is being mined for commercial purposes from Cretaceous strata. Small tonnages are obtained from the Gething Formation at one mine near Peace River Canyon. No coal is mined for commercial purposes south of Peace River, although considerable exploration was carried out a few years ago on Hasler Creek and Pine River.

The coal occurs in beds ranging from thin laminae to some about 5 feet thick. Commonly, the seams are obscured by

talus and precise measurements are obtainable only by trenching. The areal extent of the seams is unknown due to the lack of closely spaced sections. However, the variation in thicknesses of the seams in the Peace River Canyon and their apparent lack of continuity suggest that individual coal beds are lenticular and have limited distribution.

Coal deposits of the Gething Formation in the Peace River Canyon and near Pine River were discussed in detail by McLearn and Kindle (1950, pp. 150-193); the reader is referred to that report for analyses and reserves. The present investigation indicates that the Gething Formation should be reduced in thickness to 1,000 feet. Accordingly, the number of seams is less than indicated by McLearn but the total coal reserves must still be very large.

The major coal deposits in the southern part of the region between upper Smoky and Murray Rivers are in the Commotion Formation. The Gething Formation, being considerably thinner, is not as important. Most coal seams occur in the Gates Member of the Commotion Formation. Some seams are also present in the upper beds of the Boulder Creek Member but do not appear to have been developed to as great an extent.

Some coal is present in the Dunvegan Formation throughout the Foothills, but thick seams were not seen.

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— APPENDIX —

Section 1. Cadomin Formation, head of canyon, Peace River, Halfway River map-area, British Columbia.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
End of exposure, top of canyon			
20	Sandstone, fine-grained, argillaceous; some lenses of coarse-grained sandstone; platy at base, massive at top; cleaner at top	17	343
19	Sandstone, medium- to coarse-grained, laminated, grey; thick-bedded; brown-weathering, conglomeratic at top	7	326
18	Covered	33	319
17	Sandstone, medium- to coarse-grained, laminated, brown to grey; becoming finer grained and bedded at base	29	286
16	Covered. Some argillaceous sandstone, siltstone, and coal near top	40	257
15	Sandstone, coarse-grained, and conglomerate; lensey; massive; cross-laminated; crossbedded; pebbles up to 1 inch	21	217
14	Mostly covered. Some fine-grained sandstone and platy siltstone near base	28	196
13	Sandstone, medium- to coarse-grained, laminated, cross-laminated, grey; massive; becoming medium-bedded at top; disseminated pebbles	34	168
12	Sandstone, fine-grained, laminated, brownish grey; massive but platy-weathering; dark brown- to grey-weathering	11	134
11	Sandstone, coarse-grained, becoming finer towards top; massive	16	123
10	Conglomerate; pebbles 1/8-1 inch, average 1/2 inch	3	107
9	Sandstone, medium-grained, laminated to homogeneous, brownish grey; massive; brown-weathering; coarser in upper 4 feet, with conglomerate	19	104

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
8	Mostly covered. Some fine-grained platy sandstone and mudstone	29	85
7	Sandstone, medium- to coarse-grained, laminated, dark grey; massive; brownish-grey-weathering; some large-scale crossbedding	18	56
6	Mudstone, silty, carbonaceous; lenses out downslope; some large concretions	3	38
5	Sandstone, coarse-grained, laminated, brown; flaggy-weathering; conglomeratic at top, pebbles up to 2 inches	5	35
4	Sandstone, medium-grained; becoming coarse-grained at top; massive; some scattered pebbles	8	30
3	Sandstone, coarse-grained to conglomeratic; massive	5	22
2	Sandstone, fine-grained, argillaceous, flaggy; some siltstone	3	17
1	Sandstone, coarse-grained to conglomeratic, brownish grey; massive; pebbles 1/8 inch to 1 1/2 inches, well-rounded; conglomerate is lensy; prostrate logs, plant fragments	14	14
River level			

Section 2. Moosebar Formation, type locality, south side of Peace River at Contact Point, Pine Pass map-area, British Columbia.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
Overlying beds inaccessible			
<u>Gates Formation</u>			
<u>1st Sandstone</u>			
	Sandstone, fine-grained, laminated, brownish grey; massive to thick-bedded; some silty beds. Estimated	35	35
<u>Moosebar Formation</u>			
36	Sandstone and shale interbedded; beds 3-6 inches; sandstone, fine-grained, laminated, brownish grey	4	957.5
35	Mudstone, silty; blocky	2.5	953.5
34	Sandstone, fine-grained, laminated, brownish grey; medium-bedded; some shale	3	951
33	Mudstone, silty; rubbly to blocky	17	948
32	Sandstone, fine-grained, laminated, grey; thin-bedded	2	931
31	Mudstone, dark grey, blocky	23	929
30	Mudstone; grading upwards into argillaceous siltstone	5	906
29	Mudstone, silty; blocky; grading upwards into argillaceous siltstone	13	901
28	Mudstone, silty; blocky; grading upwards into siltstone	27	888
27	Covered. Approximate (This interval is exposed on north side of river—see Section 4)	200	861
26	Mudstone, blocky	32	661

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
<u>Small fold</u>			
25	Inaccessible. Mudstone, rubbly at base; blocky towards top; few concretionary beds	35	629
24	Mudstone, black; blocky; bentonite at top	22	594
23	Mudstone, black; blocky; thin pyritic sandstone at base and top	20	572
22	Mudstone; blocky; few concretions	25	552
21	Mudstone, rubbly to blocky; row of concretions at top	32	527
20	Mudstone, dark grey; rubbly to blocky	35	495
19	Mudstone, dark grey, rubbly to blocky; somewhat rusty-weathering	30	460
18	Mudstone, rubbly to blocky; row of concretions at top; reddish-brown-weathering	20	430
17	Mudstone, black; rubbly to blocky; reddish brown concretions, 6 - 12 inches	17	410
16	Mudstone, black; rubbly to blocky at top; somewhat rusty-weathering	30	393
15	Mudstone, rubbly to blocky; somewhat rusty-weathering; thin bentonitic layer at top	30	363
14	Mudstone, dark grey; rubbly to blocky; thin bentonitic layer at top	29	333
13	Mudstone, dark grey; concretionary bed at top	35	304
12	Mudstone, dark grey; rubbly; few concretions	40	269
11	Mudstone, dark grey to black; rubbly to somewhat blocky at top; concretionary beds	37	229
10	Mudstone, dark grey; rubbly; rusty-weathering; thin bentonitic layers near	29	192

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	base; concretions, reddish-brown- weathering, 6 - 10 inches x 12 inches; fucoid markings		
9	Mudstone, dark grey; rubbly; somewhat rusty-weathering; few thin beds of siltstone at top	40	163
8	Mudstone, dark grey; rubbly; blocky at top; some concretions	15	123
7	Mudstone, dark grey to black; rubbly to blocky; some concretions, reddish- brown-weathering	27	108
6	Covered. Estimated	20	81
5	Mudstone, silty, dark grey; blocky	6	61
4	Covered. Approximately	35	55
3	Mudstone, dark grey, rubbly; few concretions, reddish-brown-weathering	17	20
2	Mudstone, silty, dark grey; blocky, rusty weathering; siltstone at top	2	3
1	Sandstone, fine- to medium-grained, dark grey; disseminated pebbles; 1/8 inch to 1 1/2 inches, chert, black, grey	1	1
<u>Gething Formation</u>			
	Sandstone, argillaceous, silty, dark grey; thick-bedded; rusty-weathering concre- tionary spots; plant fragments GSC loc. 5781 — <u>Coniopteris brevifolia</u> (Fontaine) Bell <u>Sphenopteris latiloba</u> Fontaine	11	11

Section 3. Gates Formation, at The Gates on Peace River, Charlie Lake map-area, British Columbia.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
<u>Hasler Formation</u>			
	Mudstone, rubbly, dark grey to black; some sideritic concretions GSC loc. 46526— <u>Beudanticeras</u> (?) sp. indet. <u>Pleuromya</u> (?) sp. indet.		
	Mudstone, dark grey to black, silty	2	
	Siltstone, very argillaceous, dark grey, massive; grades into overlying unit	4	
<u>Gates Formation</u>			
	Sandstone, fine-grained, argillaceous, dark grey; thick-bedded	6	
	On south side of river, upstream, most of upper sandstone is exposed but gap exists between these beds and those described above		
10	Sandstone, fine-grained, silty, brownish grey, platy	6	50.5
9	Shale, silty; interbedded argillaceous platy siltstone	9	44.5
8	Siltstone, sandy, to argillaceous sandstone, laminated	2	35.5
7	Mudstone, silty; interbedded siltstone	2	33.5
6	Sandstone, silty, laminated, brownish grey; platy	1	31.5
5	Mudstone; interbedded siltstone and shale	2	30.5
4	Sandstone, fine-grained, laminated	1	28.5
3	Interbedded shale, siltstone, and sandstone; beds 1/2 - 1 inch	0.5	27.5
2	Sandstone, fine-grained, laminated to homogeneous, brownish grey; massive; brown-weathering; few concretionary zones	15	27

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
1	Siltstone, argillaceous, dark grey to brown; platy to flaggy; some interbedded shale, silty	12	12
End of exposure			

Section 4. Gates Formation, north side of Peace River across from Steamboat Island, Pine Pass map-area, British Columbia.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
<u>Gates Formation</u>			
	Top of ridge, end of exposure (Upper beds exposed across river)		
29	Sandstone, fine-grained, laminated, grey to brownish grey; brown-weathering; massive but weathers platy	25	226.5
28	Sandstone, fine-grained, brownish grey to brown, silty; platy	15	201.5
27	Sandstone and interbedded siltstone, laminated, grey	10	186.5
26	Siltstone, argillaceous, blocky, laminated	5	176.5
25	Mudstone and sandstone, interbedded	9	171.5
24	Sandstone and shale interbedded; sandier at top; beds 1/2 inch to 3 inches	14	162.5
23	Mudstone, silty, and interbedded sandstone (40%); beds 1 inch to 2 inches; striped appearance	13	148.5
22	Mudstone; few thin platy beds of sandstone	10	135.5
21	Mudstone, silty; becoming blocky at top with thin siltstones	12	125.5
20	Mostly covered. Mudstone	20	113.5
19	Mudstone to argillaceous siltstone; dark grey; some argillaceous sandstone at top	4	93.5
18	Mudstone, rubbly to blocky; dark grey	6	89.5
17	Siltstone, argillaceous	2	83.5
16	Covered. Mudstone	19	81.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
15	Mudstone, silty; some interbedded sandstones	5	62.5
14	Sandstone and shale interbedded; beds 1 inch to 2 inches	5	57.5
13	Sandstone and shale interbedded; beds 2 - 3 inches	3.5	52.5
12	Sandstone, fine-grained, laminated, grey; platy to flaggy; grey-weathering	3	49
11	Mudstone, dark grey; becoming siltier at top	4	46
10	Siltstone, argillaceous; grading upwards into silty argillaceous sandstone, dark grey	7	42
9	Mudstone, silty, dark grey	6	35
8	Siltstone, grading upwards into argillaceous sandstone; glauconite	4	29
7	Sandstone, fine-grained, grey, laminated, pebbles on upper surface; glauconite	4	25
6	Sandstone, fine-grained, laminated; poorly bedded; glauconite	7	21
5	Sandstone, fine-grained, brownish grey; massive	3	14
4	Siltstone, argillaceous; platy	0.5	11
3	Sandstone, fine-grained; platy	1.5	10.5
2	Sandstone, fine-grained; channel-fill and slump structures	4	9
1	Sandstone, fine-grained; massive	5	5
<u>Moosebar Formation</u>			
21	Mudstone and interbedded sandstone (20%)	15	273.5
20	Mudstone, silty, to argillaceous siltstone, blocky	16	258.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
19	Mudstone, silty, to argillaceous siltstone, dark grey, blocky; interbedded laminated sandstone, (30%), beds 4 - 6 inches	9	242.5
18	Mudstone, dark grey; rubbly to blocky	10	233.5
17	Siltstone, sandy; blocky to massive	1	223.5
16	Mudstone, dark grey; rubbly to blocky	31	222.5
15	Mudstone, silty; grading upwards into siltstone, sandy, argillaceous	5	191.5
14	Siltstone, sandy, brownish grey, massive	3	186.5
13	Mudstone, dark grey; blocky; grey-weathering	8	183.5
12	Mudstone, very silty, dark grey; grading upwards into siltstone, sandy, massive, grey-weathering	10	175.5
11	Mudstone, very silty; grading upwards into siltstone, argillaceous, sandy, blocky to massive; round concretions, dark grey	18	165.5
10	Mudstone, silty, to siltstone, argillaceous, blocky; round pyritic concretions, dark grey	15	147.5
9	Siltstone to mudstone; blocky to massive; rusty-weathering; spots	18	132.5
8	Mudstone, very silty, to siltstone, argillaceous, dark grey; blocky to massive; limonitic concretionary spots	37	114.5
7	Mudstone, silty; rubbly to blocky; grading into argillaceous siltstone at top; round pyritic concretions, dark grey	18	77.5
6	Mudstone, silty; blocky	23	59.5
5	Mudstone, silty, to siltstone, argillaceous, dark grey	15	36.5
4	Mudstone, silty, dark grey; blocky; rare concretions	15	21.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
3	Siltstone, argillaceous, dark grey, blocky	4	6.5
2	Siltstone, concretionary; rusty- weathering	1.5	2.5
1	Siltstone, argillaceous, blocky, dark grey	1	1
End of exposure			

Section 5. Basal Hasler Formation (Hulcross equivalent), Starfish Creek, Pine Pass map-area, British Columbia

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Top of canyon wall, end of exposures		
27	Sandstone, fine-grained, grey, clean, laminated, thick-bedded. Estimated GSC loc. 46515 (from talus)— <u>Gastrolites</u> cf. <u>G. allani</u> McLearn <u>Gastrolites</u> n. sp. aff. <u>G. liardense</u> (Whiteaves) Gastrolitid ammonite, genus and species indet. <u>Lophidiaster</u> cf. <u>L. silentiensis</u> McLearn <u>Inoceramus</u> ex gr. <u>anglicus</u> Woods <u>Arctica</u> (?) sp. indet.	20	457
26	Mudstone, rusty-weathering, and sandstone (40%); beds 6 to 12 inches. Estimated	20	437
25	Mudstone, blocky, rusty-weathering; interbedded siltstone, concretionary layers	20	417
24	Mudstone, blocky; grading into argillaceous siltstone, rusty-weathering	18	397
23	Mudstone, rubbly, rusty-weathering; grading upwards into silty mudstone and argillaceous siltstone, rusty-weathering; some concretions	37	379
22	Mudstone, silty; blocky; rusty-weathering; sideritic concretions at top	9	342
21	Mudstone, rubbly, rusty-weathering at base; grading upwards into silty blocky mudstone; some sideritic concretions	37	333
20	Mudstone, rubbly, rusty-weathering; becoming blocky with argillaceous siltstone at top	15	296
19	Shale, rubbly, rusty; grading upwards into blocky mudstone with siltstone layers	10	281
18	Mudstone, rubbly, dark grey; rusty-weathering	13	271

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
17	Mudstone to shale; rubbly to platy; rusty-weathering; some beds of laminated siltstone; selenite	20	258
16	Mudstone, very silty, blocky; grading upwards into argillaceous siltstone, dark grey, rusty-weathering	35	238
15	Mudstone to argillaceous siltstone; blocky, dark grey; rusty-weathering	14	203
14	Mudstone, silty, blocky, dark grey to black; grading upwards into blocky to flaggy argillaceous siltstone	39	189
13	Mudstone, rubbly; becoming blocky at top	11	150
12	Mudstone, rubbly; rusty-weathering; somewhat blocky at top	21	139
11	Shale, rubbly; rusty-weathering; becoming somewhat blocky at top	14	118
10	Mudstone, rubbly at base; becoming blocky at top; rusty-weathering	10	104
9	Mudstone, blocky to rubbly; rusty-weathering	5	94
8	Mudstone, rubbly; rusty-weathering; grading upwards into blocky mudstone; 2 inch layer of bentonite 3 inches from top	10	89
7	Mudstone, rubbly, rusty-weathering at base; blocky at top	10	79
6	Mudstone, rubbly to blocky; rusty-weathering	5	69
5	Mudstone, silty, dark grey, blocky; rusty-weathering	7	64
4	Mudstone, rubbly, rusty-weathering, grades into overlying unit	11	57
3	Mudstone, silty; blocky; rusty-weathering; grading upwards into argillaceous siltstone; massive in upper 2 feet	13	46

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
2	Mudstone, dark grey, blocky; grey to rusty-weathering	8	33
1	Covered. Approximately	25	25
	<u>Gates sandstone</u> (see Section 4)		

Section 6. Hasler, Goodrich, and Cruiser Formations, ridge northwest of Belcourt Lake, Monkman map-area, British Columbia.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
Klippe of Palaeozoic limestone blocks rests on following beds			
<u>Dunvegan Formation</u>			
9	Conglomerate. Not well exposed	15	80
8	Conglomerate, pebbles 1/8 - 1 inch	10	65
7	Sandstone, coarse-grained, with some pebbles	8	55
6	Conglomerate, and some sandstone; massive; pebbles average 1/2 inch, some are 1 inch	16	47
5	Sandstone, coarse-grained	3	31
4	Conglomerate	6	28
3	Sandstone, coarse-grained	2	22
2	Conglomerate, massive; pebbles average 1/2 inch, some are 1 inch	9	20
1	Sandstone, very-coarse-grained; lenses and beds of conglomerate with pebbles up to 1 inch	11	11
<u>Cruiser Formation</u>			
15	Shale, very silty, with platy argillaceous siltstone increasing towards top; rusty-weathering. Conglomerate appears to have been deposited in channels	49	419
14	Shale, very silty, black, rusty-weathering; grades upward into argillaceous siltstone	22	370
13	Shale, silty, rubbly; rusty-weathering	12	348
12	Siltstone, argillaceous; interbedded silty shale	11	336

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
11	Shale, silty, dark grey to black; rubbly to platy; rusty-weathering	48	325
10	Shale, silty; rubbly, grading upwards into argillaceous siltstone	28	277
9	Covered	42	249
8	Partly covered. Shale, rubbly	27	207
7	Covered	84	180
6	Shale, black; rubbly; some concretions reddish brown-weathering	38	96
5	Shale, silty, black; blocky; sideritic beds	11	58
4	Covered. Shale talus	26	47
3	Shale, dark grey; platy; rusty-weathering	6	21
2	Covered	11	15
1	Shale, silty; platy; some siltstone, rusty-weathering	4	4
<u>Goodrich Formation</u>			
52	Sandstone, fine- to medium-grained, laminated, grey; thin- to thick-bedded; clean; few pebbles embedded in upper sandstone	18	862
51	Mudstone, very rubbly at base, becoming siltier at top; some siltstone	18	844
50	Mudstone; coquinoid siltstone at top GSC loc. 46530— <u>Ostrea</u> sp. indet. <u>Arctica</u> sp. indet.	3	826
49	Sandstone, fine-grained; olive-brown	1	823
48	Mudstone	6	822
47	Sandstone, fine-grained, argillaceous, laminated; olive-brown	5	816

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
46	Siltstone, sandy, argillaceous, blocky	6	811
45	Mudstone, olive-brown; some is carbonaceous	14	805
44	Siltstone	1	791
43	Mudstone	6	790
42	Covered. Probably mostly mudstone	300	784
41	Sandstone, coarse-grained at base, becoming finer-grained at top; grey; massive	20	484
40	Covered	8	464
39	Sandstone, medium-grained, laminated, cross-laminated, brownish grey, massive; brown-weathering	14	456
38	Covered	29	442
37	Sandstone, medium-grained, laminated, cross-laminated, brownish grey; massive; crossbedded; more thinly bedded towards top	15	413
36	Mostly covered. Mudstone	29	398
35	Mudstone, grading into siltstone, olive-brown to grey; blocky	10	369
34	Covered	16	359
33	Mudstone, olive-brown to grey; blocky; silty beds	13	343
32	Mudstone, grading into siltstone	10	330
31	Sandstone, argillaceous, olive-brown	2	320
30	Mudstone, olive-brown	8	318
29	Mudstone, grading into siltstone	10	310
28	Siltstone, argillaceous	2	300
27	Mudstone, blocky	5	298

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
26	Sandstone, fine-grained, olive-grey	2	293
25	Mudstone, grey; blocky; sideritic concretions	5	291
24	Sandstone, fine-grained, laminated	1	286
23	Mudstone, grey to olive-grey; blocky	13	285.5
22	Sandstone, fine-grained, olive-grey	4	272.5
21	Mudstone, grey, blocky	10	268.5
20	Sandstone, argillaceous, laminated, olive-brown	2	258.5
19	Mudstone, grey to olive-grey; siderite at base	12	256.5
18	Mudstone, grading upwards into siltstone; well-indurated; olive-brown	7	244.5
17	Sandstone, fine-grained, silty, olive-grey	2	237.5
16	Mudstone, olive-brown	8.5	235.5
15	Mudstone, grading upwards into silty, argillaceous sandstone	12	227
14	Sandstone, medium- to coarse-grained, laminated, cross-laminated; thick-bedded	4	215
13	Covered	11	211
12	Mudstone, olive-brown; grading upwards into platy siltstone	8	200
11	Sandstone, medium- to coarse-grained, grey to brownish grey, laminated, cross-laminated, carbonaceous; massive to thick-bedded, platy at top; brown-weathering; fragments of angiosperms	23	192
10	Mudstone, silty, and siltstone, argillaceous; sandy at top	9	169
9	Siltstone, sandy, argillaceous, brownish grey; massive	5	160
8	Covered	50	155

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
7	Sandstone, medium- to coarse-grained, brownish grey, laminated, cross-laminated	10	105
6	Covered	50	95
5	Sandstone, medium- to coarse-grained, laminated, cross-laminated, brownish grey	2	45
4	Mudstone, blocky; some sandstone at top GSC loc. 46514— Modiolus sp., Ostrea (?) sp., <u>Protelliptio</u> cf. <u>P. hamili</u> (McLearn)	12	43
3	Coal and coaly shale	1	31
2	Shale to mudstone; dark grey; blocky	10	30
1	Sandstone, fine-grained and argillaceous at base, becoming cleaner and medium-grained at top; grey to brownish grey; laminated, cross-laminated; thick-bedded to massive; brown-weathering; some small channel-fill structures at base	20	20
<u>Hasler Formation</u>			
25	Shale, rubbly, grading upwards into interbedded sandstone and shale. Sandstone, fine-grained, silty, grey, laminated; beds 2 - 3 inches; some concretions	25	818
24	Shale, rubbly, rusty-weathering; thin-bedded sandstone at top; reddish-brown-weathering concretions	34	793
23	Shale to mudstone, silty, blocky; reddish-brown-weathering concretions	21	759
22	Shale, rubbly, rusty-weathering; becoming siltier and blocky towards top; beds of concretions, reddish-brown-weathering	60	738

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
21	Shale, silty, dark grey; siltstone increasing towards top, forming 2- to 6-inch interbeds, rusty-weathering; few concretions	43	678
20	Shale, silty, with siltstone increasing towards top; rusty-weathering; few beds of sideritic concretions, reddish-brown-weathering	31	635
19	Shale, silty, with some thin beds of siltstone; rare sideritic concretions	19	604
18	Shale, dark grey, rubbly, rusty-weathering; some thin laminae of siltstone; rare sideritic bed	78	585
17	Shale, silty with some thin siltstone at top; bentonitic layer at base	75	507
16	Shale, silty, dark grey; some thin siltstone towards top	24	432
15	Shale, silty, rubbly to splintery, dark grey; rusty-weathering; some siltstone, increasing towards top	23	408
14	Shale, silty, rusty-weathering; thin siltstone beds at top	19	385
13	Siltstone and shale interbedded (50-50); rusty-weathering; beds 2-3 inches	20	366
12	Siltstone, sandy, laminated; platy to flaggy; beds 2 - 6 inches; some shale	25	346
11	Siltstone, finely laminated, some is cross-laminated; grey; rusty-weathering; beds 1/2 inch to 4 inches; some interbedded shale	30	321
10	Shale, silty, laminated, dark grey, rusty-weathering; platy argillaceous siltstone increases towards top	25	291
9	Siltstone, argillaceous, finely laminated and cross-laminated; platy; beds 1/2 inch to 2 inches; some platy shale (25%), rusty-weathering; banded appearance	35	266

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
8	Shale, silty, dark grey; fine laminae of grey siltstone; platy to rubbly; interbedded siltstone, becoming more abundant at top; striped appearance	66	231
7	Shale, silty and some siltstone; rusty-weathering; platy; banded appearance; siltstone content increases towards top	35	165
6	Siltstone, argillaceous, dark grey; bedded; rusty-weathering	9	130
5	Shale, dark grey to black, laminated, silty; rubbly to somewhat blocky; grading upwards into siltstone, argillaceous, rusty-weathering; rare concretions, reddish-brown-weathering	60	121
4	Covered	35	61
3	Shale, silty, laminated, black to dark grey; some interbedded siltstone, argillaceous, platy	18	26
2	Shale, silty, laminated, dark grey; platy; grey-weathering; rare concretions, reddish-brown-weathering	5	8
1	Covered	3	3

Commotion Formation

Contact with overlying shales is not exposed

Sandstone, medium-grained, carbonaceous, brown; thick-bedded; upper surface is irregular with bumps and hollows; patches of 1/8- to 1/2-inch well-rounded pebbles