67-19

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 67-19 (Part A)

FERNIE AND MINNES STRATA NORTH OF PEACE RIVER, FOOTHILLS OF NORTHEASTERN BRITISH COLUMBIA

(Report, 2 figures and 11 plates)

D. F. Stott

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To expedite publication this report is being issued in two separate parts. Part A contains the main text, accompanied by photographs and page-sized figures. Part B contains measured sections, which would normally be included as an appendix, together with a pocket containing all the larger figures.

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Part A

Illustrations

Part B
(issued separately)

The figures listed below are included in the pocket of Part B of the report

ABSTRACT

The Fernie Formation and Minnes Group, ranging in age from Early Jurassic (Sinemurian) to Early Cretaceous (Valanginian), are described from outcrops in the Foothills between latitudes 56°00' and 57°40'. Some subsurface data are incorporated for correlation purposes.

The succession, having a maximum thickness of more than 2,800 feet along the western Foothills, decreases eastward and northward to an erosional edge. The Fernie Formation, comprising phosphatic, calcareous, and sideritic shales with some siltstone and sandstone, unconformably overlies Triassic strata. The Nordegg Member and five other informal lithologic units are recognized. These Jurassic rocks intertongue with and grade upward into the Minnes Group, predominantly marine in this region. The Minnes is herein raised to group rank to include the Monteith, Beattie Peaks, and Monach Formations. The Monteith Formation comprises fine- to coarse-grained quartzose sandstones with minor shale and thin conglomerates but grades northwesterly into more shaly sediments. The overlying beds in this region, being in part equivalent to the type Beattie Peaks, are referred to Beattie Peaks and (?) younger beds. The basal beds contain a succession of silty mudstones with many channel sandstones. These grade upwards into fine-grained sandstone. The uppermost beds include interbedded mudstone and fine-grained sandstone.

A regional erosional unconformity truncates these Cretaceous and Jurassic strata, bevelling successively older rocks in a northward and eastward direction. Throughout this region, the succession is overlain by the conglomeratic sediments of the Bullhead Group.

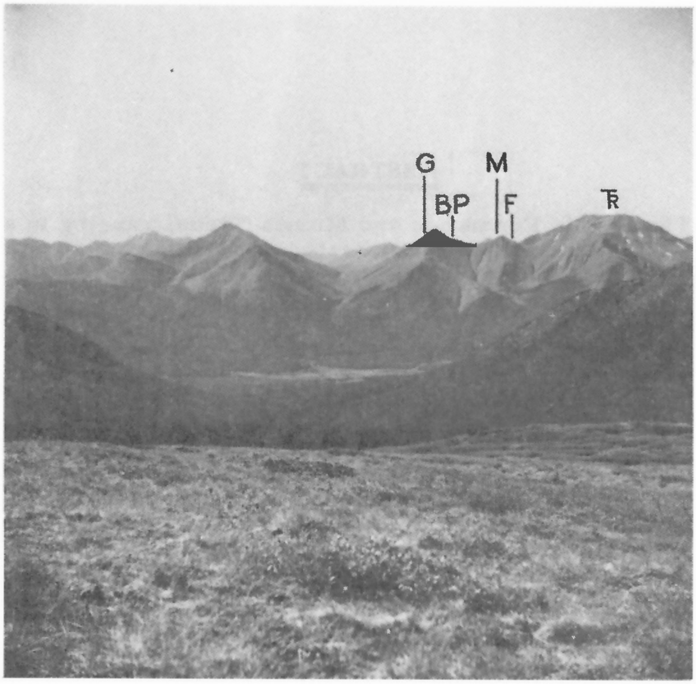

PLATE I Frontispiece (DFS 4-3-63).

Large syncline containing Fernie (F), Monteith (M), Beattie Peaks and (?) younger beds (BP), and Gething (G) Formations; looking south across Halfway River west of Mount Stearns. Core of anticlines on either side is formed by Triassic sediments.

FERNIE AND MINNES STRATA NORTH OF PEACE RIVER, FOOTHILLS OF NORTHEASTERN BRITISH COLUMBIA

INTRODUCTION

The Fernie Formation and Minnes Group in northeastern British Columbia comprise a thick succession of clastic sediments ranging in age from Early Jurassic (Sinemurian) to Early Cretaceous (Valanginian). These rocks are widely distributed and fairly well exposed in the Foothills (Frontispiece) between Peace River at latitude 56°00' and Prophet River at latitude 57°40'(Figs. 1, 2). Although the main discussion concerns outcrop sections, some subsurface information is incorporated for correlation purposes.

The present study was undertaken to determine the magnitude of a regional unconformity between those beds and the overlying Bullhead Group. The resultant data are more complete than any published to date as only the Fernie Formation of this region has been described. The occurrence of the younger formations north of their type area in the Carbon Creek basin between Peace and Pine Rivers has been only briefly discussed.

The Jurassic rocks occuring in the Foothills north of Peace River represent the most northerly exposures of these rocks in British Columbia. They are a continuation of beds occurring farther southeast along the Foothills and beneath the Peace River Plains where Jurassic sediments are covered by Cretaceous strata.

The overlying beds are related to those of the Carbon Creek basin and are a continuation of the Minnes and Nikanassin Formations of the Foothills to the south. The presence of such a thick succession of post-Fernie but pre-Bullhead beds provides an additional record of a little known episode of geologic time and a more complete understanding of the palaeogeography in this region.

FIELD WORK AND ACKNOWLEDGMENTS

This report is based on part of a large-scale regional stratigraphic study of Cretaceous rocks in northeastern British Columbia. The data given herein were obtained during the field seasons of 1961, 1962, and 1964. Helicopter transportation is the most practical means of access although part of the Trutch area was examined by means of packhorses in 1961. Field studies during the first two years were carried out in conjunction with Triassic studies undertaken by B.R. Pelletier who was also responsible for logistics during 1962. The cooperation of Pelletier and G.L. Goruk, his technical officer, made possible much of the mapping within the Trutch area. Their interest in mutual problems and numerous discussions have contributed considerably to the interpretation of Jurassic and Cretaceous stratigraphy. Studies in 1964 were a part of Operation Liard, a mapping project under the direction of G.C. Taylor.

In 1961, a helicopter was supplied by Okanagan Helicopters Limited and staffed by R. Burton, E. Haylock, and K. Harding. In 1962, the service of Foothills Aviation Limited was carried out by F. Nobels and J. Ward and in 1964, that of Bullock Wings and Rotors Limited, by J. Davies and M. Brown. The writer gratefully acknowledges the many courtesies of Texaco Exploration Company, Hudson Bay Oil and Gas Company, Capilano Helicopters Limited, and Associated Helicopters Limited.

The Triassic fauna was identified and dated by E.T. Tozer; the Jurassic fauna, by Hans Frebold; the Jurassic microfauna, by T.P. Chamney; and the Cretaceous fauna, by J.A. Jeletzky.

Many of the problems were discussed with P. Ziegler, J.K. Eccles, P. Dyson, B. Brady, J. Muller, E.J.W. Irish, H. Frebold, and T.P. Chamney.

Competent assistance in the field was given in 1961 by M.L. Larson; in 1962, by A.R. Clark and M.J. Osatenko; in 1964, by R. Armstrong, M. Wooding, D. Hetherington, and D. McDougall. The writer is also indebted to W. Boring, R. Cameron, O. Gauthier, A. Lamont, D. McDougall, R.L. Ross, I. Severson, and S. MacWhinnie, all of whom assisted in camp operations.

STRATIGRAPHY

The Jurassic Fernie Formation, dominantly shale, lies unconformably on Triassic sediments. The Fernie shales intertongue with and grade upward into quartzose sandstones of the Monteith Formation of the Minnes Group. The overlying succession of marine siltstone, sandstone, and mudstone, being in part equivalent to the type Beattie Peaks, is included in the Beattie Peaks Formation and (?) younger beds. The sequence is bevelled by a major regional erosional unconformity and, throughout the region, is overlain unconformably by the Lower Cretaceous Cadomin or Gething Formation of the Bullhead Group (see Stott, in press).

The Fernie and Minnes beds form a wedge-shaped deposit that is thickest in the western Foothills and thins to an erosional edge in the Plains to the east and also in the Foothills to the north. This wedge has been produced by pre-Bullhead erosion which has truncated the deposits, leaving the younger beds preserved in the west. In the southwest, the rocks immediately below the unconformity are no older than Valanginian. In the vicinity of Prophet River and northeastward beneath the Plains, the underlying beds are of Triassic age.

The maximum thickness of this sequence occurs along the western Foothills between Christina Falls and Halfway River (Fig. 3). In two sections (62-11 and 62-13)[1], the total is more than 2,800 feet and a similar thickness is known from Horseshoe Creek (section 62-1). Eastward beyond the Foothills and northward beyond Halfway River, the sequence decreases rapidly to the erosional edge (Figs. 4, 5).

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[1] Descriptions of outcrop sections are given in the Appendix.

TABLE OF FORMATIONS

Stratigraphic units				Lithology
Erosional unconformity				
Lower Cretaceous	Minnes Group 0-2,860'	Beattie Peaks and (?) younger beds 0-1,580'	Unit 3	Interbedded sandstone, siltstone and shale; carbonaceous in part
			Unit 2	Thick-bedded, fine-grained sandstone; some shale and siltstone
			Unit 1	Marine siltstone and mudstone with numerous channel-fill sandstones
		Monteith Fm. 0-718'	Unit 2	Massive, quartzose fine- to coarse-grained sandstone; some conglomerate
			Unit 1	Alternating units of thick-bedded, fine-grained sandstone and silty mudstones; few beds of conglomeratic sandstone
Jurassic		Fernie Fm. 0-791'	Unit 6	Thinly interbedded sandstone, siltstone and mudstone
			Unit 5	Dark marine sideritic shales
			Unit 4	Glauconitic siltstones and mudstones; some sideritic concretions
			Unit 3	Dark grey to black, rusty weathering marine shales; some fine-grained sandstone
			Unit 2	Black calcareous fissile papery shale
			Nordegg Member	Black calcareous interbedded siltstone and shale with thin dense black limestone; chert nodules and phosphatic chert
Erosional unconformity				

FERNIE FORMATION

Rocks of Jurassic age were first mapped as part of the "Fernie shales" by McEvoy and Leach (1902) but it was Leach (1903, 1912) who, in the Blairmore region, actually restricted the interval of the Fernie shales as presently used. Frebold, in numerous palaeontological papers, has outlined the succession in detail and established or retained several informal and formal stratigraphic members. Although most of those subdivisions were originally based primarily on lithological distinctions, Frebold has modified most of the units, defining their limits on palaeontological criteria so that they are, in reality, time stratigraphic units (zones). As a result, several different lithologies are now included in each of those units.

The Fernie shales at various times have been termed a formation or group. As no formations are recognized within the interval in the region of the present study, the Fernie shales are herein ranked as a formation. Furthermore, to avoid any implications of long-range correlations that may be incorrect, units are not specifically referred to previously established terminology with the exception of the Nordegg Member. Some of the other units used herein may be equivalent to the more southerly units but correlations remain tentative as detailed stratigraphic data from the intervening region is lacking.

Fernie shales in the vicinity of Peace River were briefly described by Williams and Bocock (1932), Beach and Spivak (1944), McLearn (1940), and McLearn and Kindle (1950). Recent mapping by Muller (1961) and Irish (1961, 1963) delineates the extent of the formation in the region (see Fig. 2). Jurassic rocks north of Peace River were first reported by Hage (1944) who examined outcrops in the vicinity of Pink Mountain and Sikanni Chief River. The distribution of these rocks in the Trutch map-area is shown by Pelletier and Stott (1963). Subsurface studies by Lackie (1958) indicate the distribution of those sediments in the Peace River Plains and those by Hamilton (1962) suggest correlations with surface exposures.

Throughout most of this region, the Fernie Formation lies disconformably on the calcareous sediments of the Triassic Pardonet Formation. Fossils obtained from uppermost Triassic beds south of Halfway River were assigned by Tozer to the zone of Monotis subcircularis and those from uppermost Triassic beds between Marion Lake and Nevis Creek, to the older Norian zone of Himavatites. McLearn (1960, p. 37) dated fossils from the uppermost Triassic beds on Sikanni Chief River east of Chicken Creek as being of the Himavatites zone. The oldest Jurassic fossils from the Fernie beds are dated by Frebold as Sinemurian. As no deposits of the Jurassic Hettangian stage (see Frebold, 1957, 1958) are known in this region, the basal contact of the Fernie represents a significant hiatus. The disappearance of beds lying within the Monotis subcircularis zone toward the north indicates pre-Fernie erosion and therefore, the boundary can be described as an erosional unconformity. Similar conclusions were reached by Pelletier (1964) from his studies of Triassic stratigraphy in the Foothills. Armitage (1962, p. 45), working in the Plains area east of this study, found similar relationships and stated "Post-Triassic erosion removed the youngest Triassic sediments prior to the deposition of the marine Jurassic Fernie shales".

Although the contact of the Fernie Formation with the underlying Pardonet Formation is commonly not exposed, a thin layer of breccia was observed in several widely separated places. Northeast of Mount Laurier (section 62-11), the basal one foot of calcareous siltstone contains small angular fragments of limestone and chert, sand grains, and comminuted fossil fragments. Between Chowade and Cypress Creeks (section 62-15), the lowermost beds are not exposed but sandy limestone and a thin layer of breccia occur within 5 feet of the Triassic limestone. The breccia was also noted on the west flank of the anticline on Sikanni Chief River below Chicken Creek, north of Mount Stearns (section 64-8), in samples from Imperial Windy Creek 11-23-8-22 and Sinclair Canadian Atlantic B-2-2 (3-20-82-20, W. 6) wells.

The upper beds of the Fernie Formation are gradational into the overlying Monteith sandstone. A thick succession of interbedded fine-grained sandstone and silty shale is included in the Fernie Formation. The contact is drawn at the base of the first thick succession of sandstone. This contact appears to rise in a northwestward direction (Figs. 4, 6), that is, it seems to occur at progressively higher stratigraphic levels from southeast to northwest. The assumed diachronism has not been substantiated by fossil evidence.

The Fernie Formation in the vicinity of Peace River, as shown by Muller (1961) and Irish (1961, 1963), does not extend far as continuous outcrop but occurs on the flanks of several small synclines (see also Fig. 2). It is present below the northern rim of the Carbon Creek basin and has a large thickness in the syncline extending from Bear Ridge southward beyond Pardonet Hill toward Pine River. Although Muller indicated the presence of more than 1,000 feet of these shales near Peace River, Irish suggested that north of the river their thickness is between 500 and 700 feet. Beyond Graham River, the Fernie occurs along northwesterly trending anticlines and synclines (Frontispiece). At the headwaters of Horseshoe Creek (section 62-1), a thickness of 767 feet was measured but probably is somewhat excessive due to small repetitions on minor faults. Farther north along the same structure, a more reliable thickness of 482 feet was obtained (section 62-15, Plate II). These measurements compare with 595 feet found north of Christina Falls (section 62-13). The Fernie appears to maintain a fairly constant thickness along strike, being 732 feet south of Halfway River (section 64-13) and 791 feet west of Mount Stearns (section 62-14). The Fernie Formation decreases farther north to about 350 feet near Trimble Lake (section 64-7) and to 247 feet near Besa River (section 64-14). That decrease has resulted from the development in strata equivalent to upper Fernie of sandstones that are included in the Monteith Formation.

Eastward thinning is indicated by sections between Mount Laurier and Pink Mountain (Fig. 4) where the most easterly complete section (62-5) is only 256 feet. Similar thinning is indicated north of Halfway River where the most easterly complete section (62-7) is 317 feet. The thickest accumulation of Fernie shales is, therefore, along a northwesterly axis extending from Christina Falls to Mount Stearns (Fig. 3), the formation thinning rapidly northeastward. Although the variations in thickness appear to be partly due to a facies change in which the shales grade northeasterly into sandstones, there is depositional thinning within the more easterly sections, which will be discussed more fully elsewhere in this report.

The Fernie Formation outcrops as far north as Richards Creek just south of Prophet River (Fig. 2) but was not recognized beyond there. The formation, although relatively thin, is recognized along the eastern Foothills as far north as Pocketknife River. The zero-edge of the formation (Fig. 7) is erosional and should not be regarded as the limit of the Jurassic seas in this region.

For the purposes of this report, the Fernie Formation is divided into six lithologic units (Plate II) that can be correlated in general with the succession of the southern Alberta Foothills. The basal unit of calcareous siltstone, limestone, and shale is lithologically similar to the Nordegg Member and, as such correlation is confirmed by fossil evidence, that member is formally recognized. The immediately overlying beds, included in Unit 2, contain black calcareous papery shale. Unit 3 consists of rusty weathering marine shales with some sandstone. Unit 4, a thin interval of glauconitic siltstone, is overlain by sideritic shales included in Unit 5. The thinly interbedded sandstone and mudstone of the upper part of the formation are included in Unit 6. It has not been possible to recognize all these units in every section as commonly much is talus- or grass-covered. Nevertheless, the units are lithologically distinctive and recognition of them in any future studies could be applicable in other areas and would probably be helpful in more refined correlations.

NORDEGG MEMBER

The Nordegg Member, as originally defined (Spivak, 1949, 1954, p. 222) or the Black Chert Member (Warren, 1934), consists, according to Spivak, "predominantly of black limestones and calcareous shales with abundant chert fragments and locally phosphatic nodules", and according to Frebold (1957, p. 8), contains a Sinemurian ("Arnioceras") fauna. The Nordegg Member was shown by Frebold to extend along the Foothills approximately as far north as Athabasca River and was reported from south of Pine River by Spivak (1954, p. 226). As the basal part of the Fernie Formation in the region north of Peace River is lithologically and faunally similar, the application of the name Nordegg is justified. Although that interval has been classified as a formation in a few reports, it is treated as a member herein as it does not form a readily mappable unit in outcrop.

The occurrence of Jurassic beds in the Trutch map-area was first noted by Hage (1944, p. 6). Examination of localities mapped by Hage indicates that most or all of the beds are those of the Nordegg Member. The Nordegg shales of the area near upper Peace River have not been described in detail although McLearn and Kindle (1950, p. 62) reported fossils of Early Jurassic age from shales on Black Bear Creek.

The Nordegg Member is the most widespread of the Fernie subdivisions, extending farther to the east and northeast than the other units. Its original extent is not known as its present limit is an erosional edge.

No exposures of the Nordegg Member were examined in the immediate vicinity of Peace River. North of Graham River, the member is well developed but, as it is not easily separated from overlying beds where exposures are poor, accurate thicknesses were obtained at only a few sections.

At the headwaters of Horseshoe Creek (section 62-1), the member has a total thickness of 157 feet. Farther north. the member thins to 133 feet near Chowade River (section 62-15), and to 84 feet north of Cypress Creek (section 62-10). It may also thin eastward where only 56 feet are exposed near Halfway River (section 62-5). Northward near Mount Stearns (section 64-9), the member is 209 feet thick but decreases farther east (section 62-7) to 122 feet. Beyond there at the headwaters of Nevis Creek (section 62-16), the member is at least 145 feet and is 150 feet north of Besa River (section 64-14). It probably is partly eroded in the eastern section near Nevis Creek (62-17) as only 85 feet separate Gething and Triassic sediments.

The eroded edge of the Nordegg Member was shown by Lackie (1958, p. 90) to extend northwesterly from Lesser Slave Lake toward Pink Mountain in the Foothills. Hage (1944, p. 6) reported a thickness of Jurassic shales (presumably mostly Nordegg) of 128 feet on Pink Mountain, 32 feet on Sikanni Chief River, and only 18 feet on a tributary of Minaker Creek. Present studies show that the eroded edge of the Nordegg Member extends northwesterly from approximately Pink Mountain toward the headwaters of Prophet River (Fig. 7). Shales shown by Hage (1944) as Jurassic around the Pocketknife anticline are considered now to be Cretaceous and no Jurassic sediments are believed to be present that far east.

The limestones of the Nordegg Member are very dense, argillaceous to silty, black to bluish black on a fresh surface and weather light grey to light brown. They occur mainly as platy to thin-bedded units although some massive-weathering beds are present at the headwaters of Horseshoe Creek. The siltstones are argillaceous, highly calcareous, hard, black, and finely laminated. They are commonly platy but range to thick-bedded. The shales are generally papery to platy, black and calcareous. Speckling, due to occurrences of small aggregates of white calcite grains is common in some of the shale. In thin sections, these aggregates show a definite alignment, indicating a very finely laminated texture not always evident megascopically. Calcite also occurs as cement, producing a well indurated shale or siltstone. As the proportion of carbonate increases, the rocks grade from calcareous shales and silty shales into argillaceous, silty limestone. Nodules and irregular layers of dark chert are common but rarely exceed 2 inches in thickness. Some of the chert weathers a distinctive light blue and is phosphatic.

Age and correlation

Fossils are not common in the Nordegg Member although impressions of Arniotites were locally abundant in a few thin beds at some localities. Cross-sections of belemnites were noted in the section near Horseshoe Creek. An undetermined pectinid species occurs fairly commonly and appears to be restricted, at least locally, to the Nordegg Member. Arniotites were collected at the section south of Cypress Creek and at the eastern section immediately south of Halfway River. Hage (1944, p. 6) reported "Arnioceras" from black shales along Sikanni Chief River. Poorly preserved imprints of ammonites were collected on Pink Mountain and Frebold commented that they were "probably Sinemurian".

Other fossils collected by Hage and tentatively dated as Early Jurassic by McLearn included:

Gryphaea sp.
Oxytoma cf. O. cygnipes Young and Bird
Pecten sp.
Rhynchonella sp.

Hamilton (1962, p. 5) reported that his collections from the region of the present study included the following forms dated as Early Jurassic (Sinemurian) and identified by G. Westermann:

(?) Epammonites sp.
Atractites sp.
cf. Atractites sp.
Liostrea sp.
Chlamys sp.
ostreids
pectinids
Pentracrinites cf. P. pustulatus (Quensted)
Posidonia sp.
Oxytoma aff. O. cygnipes Phillips

UNIT 2

A succession of black, calcareous shales overlies the Nordegg Member. These shales resemble shales of the Nordegg Member but the hard platy siltstones and limestones of the latter are not present. Where poorly exposed, these shales are not readily differentiated from the underlying member and, in some descriptions, may have been included with it. They may be equivalent in part to the Poker Chip shales of the Fort St. John region described by Lackie (1958).

The contact with the Nordegg Member appears abrupt. The recessive character of Unit 2 contrasts with the more resistant, banded beds of the Nordegg. North of Besa River (section 64-14), the basal one foot of Unit 2 contains sandstone with small fragments and pebbles of chert, strongly suggestive of a hiatus in deposition. A somewhat similar bed of breccia tentatively considered to mark the base of Unit 2 north of Mount Stearns (section 64-9) may represent the same hiatus. It seems probable that the contact between the Nordegg and Unit 2 is disconformable. The upper contact is commonly distinct although in a few sections the beds have a gradational appearance.

As this unit is commonly talus covered, accurate measurements are difficult to obtain. Lackie gives a thickness of 60 feet for the Poker Chip shales in the subsurface in the Blueberry area north of Fort St. John. In the Foothills, Unit 2 is 68 feet thick at Horseshoe Creek (section 62-1) and 23 feet north of Chowade River (section 62-15). It is not recognized in eastern sections along Halfway River and may be missing as a result of facies change or non-deposition as illustrated in Figures 4, 5 and 6. Nevertheless it is believed to occur throughout the western Foothills (Fig. 3). Exposures at the headwaters of Nevis Creek, at Marion Lake, and Pink Mountain are too poor to determine if this unit is present but only Nordegg beds are present in the easternmost Jurassic exposures along Sikanni Chief River.

The shales of Unit 2 are black, calcareous, and fissile to platy. Much of the shale splits into thin paper-like sheets. Rare beds of dense silty limestone and a few nodules of chert are also present. Some calcareous siltstone is also interbedded with the shales.

Age and correlation

Unit 2 may be equivalent to the Poker Chip Shale (Spivak, 1954, p. 227) or Paper Shale (Frebold, 1957, pp. 6, 11) as its stratigraphic position and lithology are similar. Lackie (1958) was able to differentiate the Poker Chip Shale in subsurface studies and it may be that equivalent beds are present in the Foothills to the west. Frebold (1957, p. 6) indicated that the Paper Shale and the Poker Chip shale of Turner Valley was of Toarcian age. As no diagnostic fossils were collected from Unit 2 in northeastern British Columbia, confirmation of its age and correlation is not definitely established.

UNIT 3

Rusty weathering shales, typical of much of the middle Fernie of this region, are included in Unit 3. Similar shales occur in the two overlying units and if Unit 4 is not exposed, the shales of Unit 3 and Unit 5 are not readily differentiated.

The lower contact with Unit 2, where well exposed, is distinct with an abrupt change from the black, calcareous shales to the overlying rusty weathering shales. That contact may be disconformable but palaeontological evidence is not available to determine the true relationship. The upper contact, drawn at the base of the overlying glauconitic siltstone or mudstone of Unit 4 appears conformable although the glauconitic sediments may mark a hiatus.

Unit 3 in the westernmost part of the Foothills attains a maximum thickness of 273 feet north of Christina Falls (section 62-13), its thickness is 181 feet to the north of Cypress Creek (section 64-13) and only 65 feet north of Besa River (section 64-14). The northwesterly variations in thickness (Fig. 3) appear to be the result of a facies change in which shales grade into sandstones that are included in the Monteith Formation. Unit 3 is also considered to thin eastward (Fig. 4) by depositional convergence.

The shales of Unit 3 are dark grey to black on fresh surfaces but weather rusty and break into small irregular fragments described as rubbly to blocky. They contain silt, numerous microscopic aggregates of pyrite and considerable black organic material. Yellow efflorescence and a fetid odour characterize many of the exposures. Some minor beds of sandstone occur in this unit. Sideritic concretions are present in some sections but do not occur everywhere. A few thin bentonitic layers were noted.

Glauconite occurs at the base of Unit 3 northeast of Mount Laurier (sections 62-11, 64-13, 62-10) in blocky mudstone and siltstone as dark emerald green pellets. This occurrence is similar to that in several subsurface sections (Fig. 9)[1] where it is found in black shales a few tens of feet above the Nordegg Member.

Age and correlation

A study of the microfauna from the rusty weathering shales overlying the Nordegg Member and calcareous shales of Unit 2 was undertaken by T.P. Chamney to establish regional correlations and age relationships, and also to determine the validity of the correlation of beds placed in Unit 3 throughout this region. Material from section 64-13 between Halfway River and Cypress Creek, one of the most sequentially sampled sections, was analysed for its content of microfossils and the results are incorporated in Tables 1 and 2. The fauna of the grab samples is listed within the appropriate section in the Appendix. The stratigraphic position of those lots are shown in Figures 4 and 5.

The provisional micropalaeontological subdivisions are designated by Zones A to G inclusive (Table 1) and according to Chamney "represent a quite valid microfaunal succession for reference in this area". Correlations and rock unit equivalencies were established by comparision with Chamney's existing control of the microfaunal succession in the Fernie from Coleman to Jasper and also in the southern Plains. The biochronological evidence is based on this comparison and the presence of index species recorded in column 1 of the micropalaeontological subdivisions (Table 1). Reference was also made by Chamney to the work of Tappan on microfauna from Alaska but as sample control for the latter study was limited to ten feet of core from the Topagoruk Test Well No. 1, 7,042-7, 052 feet, the true vertical ranges of her species were not well established. In the present study, the teilzone of Haplophragmoides canui Cushman, 1929, which was assigned to the Oxfordian by Tappan, has been extended downwards into the Callovian because the species is common to abundant in nearly every sample examined.

The microfauna recovered from shales of Unit 3, subdivided by Chamney into "Zones E, F, and G", were dated as Middle Jurassic[2]. According to Chamney, the fauna of "Zone G" is distinct from that of the overlying assemblage, and as there is an accompanying lithologic change from glauconitic sediments, some hiatus may be present between "Zone G" and "Zone F". "Zone G" is dated only by its position below the Callovian "Zone F", on which Chamney comments as follows:

> Monoceratina sundancensis at the base of "Zone F" is a common ostracode species recovered from the Callovian lower Rierdon Formation of the Plains which is the rock unit

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1 Descriptions of well sections shown in Figure 9 are given in Stott, (in press) Appendix.

2 Middle Jurassic, as used in Chamney's comments and in this report, includes the Callovian stage as discussed by Hans Frebold, 1963, Geol. Surv., Canada, Bull. 93, p. 1.

equivalent of the lower Grey Beds. The most valid microfaunal index species of the Callovian to the south are Marginulinopsis phragmites and Procytheridea exempla of the upper Grey Beds. These have not been recovered from the northeastern British Columbia samples examined to date. However, associated species, Citharina cf. C. fallax, Eogutulina spp. and Astacolus cf. A. dubius, are present and are a few of the guide species designated in this report as the microfaunal "Zone E".

On the basis of these assemblages, Chamney indicated that Unit 3 is equivalent to the Callovian Grey Beds and possibly to the older Bajocian Rock Creek Member of southwestern Alberta. This correlation is supported in general by the stratigraphic succession and lithology. In the south, the Rock Creek Member was originally defined by Warren (1934) as a 5- to 30-foot bed of calcareous sandstone. The term was later expanded by Frebold (1957, p. 15) to include "a uniform facies characterized by dark, almost black, rusty weathering shale with intercalations of some hard bands of sandy limestone or limy sandstone" overlying the Toarcian Paper Shales. Frebold dated his redefined Rock Creek Member as being Middle Bajocian, indicating a hiatus between it and the overlying and underlying sediments. Lackie (1958, p. 91) applied the name in northeastern British Columbia to a much greater succession of sandstone and shale that appears equivalent to most of Units 3 to 6 inclusive of this study. The Callovian Grey Beds were described by Frebold (1957) as grey, limy, somewhat sandy shales and grey shales with intercalations of sandstone. Although parts of Unit 3 weather slightly lighter than underlying and overlying beds, the distinctive lithology and colour found in southwestern Alberta is not evident in northeastern British Columbia.

The range of microfauna obtained from grab samples collected from rusty weathering shales included in Unit 3 near Halfway River (sections 62-10, 62-12, 62-7) indicate that the stratigraphic assignments are valid. The close relationship of this fauna collected at scattered localities show that these beds of the Fernie represent contemporaneous deposition. The presence of this fauna confirms that the eastward thinning of the Fernie shales is related to decreased deposition rather than to a major hiatus within the succession.

UNIT 4

Unit 4 is generally a single siltstone, abundantly glauconitic. However, in some places glauconitic mudstones extend upward from the siltstone and are also included in the unit. The thin glauconitic siltstone forms a marker horizon within the upper part of the Fernie and is a key bed for lithologic correlation within the succession.

These beds, not exposed in several of the measured sections, occur between Christina Falls and Cypress Creek. The northernmost occurrence is just south of Halfway River (section 64-13). The lithologic marker was not recognized north of Trimble Lake (section 64-7) nor beyond Besa River (section 64-14) although the base of the lowest sandstone at those localities appears to occupy the equivalent stratigraphic position (Fig. 3).

North of Christina Falls (section 62-13) and also east between Chowade and Cypress Creeks (section 62-15) and north of Cypress Creek (section 64-13), the marker bed is about one foot thick, consisting of highly glauconitic siltstone with numerous sand-size grains of quartz. It is overlain by rusty weathering mudstone. Near Halfway River (sections 62-10, 64-12), thin glauconitic siltstone occurring near the top of the Fernie shales may be equivalent.

The glauconitic siltstone at the base of Unit 3 is similar to that of Unit 4 and in some instances, especially in the thinner eastern sections, might be considered to be the same or to be closely related. However, regional stratigraphic relationships and microfaunal evidence indicate (Figs. 3, 4) that there is a marked increase in the over-all thickness of the Fernie interval in the western Foothills and that the two glauconitic intervals are distinctly separate. There is a slight indication that the thickness of beds between this glauconite marker and the Nordegg Member is decreasing in an easterly direction (see Figs. 4, 5). However, insufficient stratigraphic information is available to determine if that is indeed true and if so, whether the thinning is caused by erosion or depositional convergence.

Age and correlation

The Callovian-Oxfordian boundary is drawn by Chamney at the base of Unit 4 (Table 1). The unit lies within his "Zone D" on which he comments as follows:

> "Zone D" designated as the Protistid microfaunal zone is more or less based on negative recovery but is faunibound by overlying Oxfordian equivalents and underlain by Callovian equivalents. Siliceous spheres of algal-like oogonia and pyritized radiolaria-like "cones" recovered from this interval might indicate the Radiolaria sp. 9D and Diatom sp. 1A zone of the basal Green Beds of the Fernie Formation in the southern Foothills.

The correlation of this glauconitic marker with the basal Oxfordian Green Beds is confirmation of the stratigraphic and lithologic evidence that favours such correlation of Unit 4. The Green Beds, an important unit in the southern Foothills, are recognized as far north as Jasper (Frebold, Mountjoy, Reed, 1959).

In parts of the Foothills, a hiatus is recognized at the base of the Oxfordian beds. The Green Beds near Jasper overlap and truncate the underlying Callovian Grey Beds, resting on the Rock Creek Member in a northeasterly direction (Mountjoy, 1962). Similar local relationships were noted in the central Foothills and southern Foothills (Frebold, 1957, 1963). It is possible that the glauconitic bed in northeastern British Columbia marks a similar disconformity but that is not substantiated by the available evidence. The basal sandstones near Besa River (section 64-14) considered equivalent to Unit 4 appear to lie disconformably on the underlying beds.

UNIT 5

Rusty weathering shales lying above the glauconitic sediments of Unit 4 are included in Unit 5. These shales are very similar to those of Unit 3 but contain more sideritic concretions and are siltier. Shales of Unit 5 appear to be conformable with the underlying glauconitic beds of Unit 4. They grade upward into and are, in part, laterally equivalent to Unit 6.

Unit 5 is extensive, being present in all but the easternmost sections where it was apparently removed by pre-Bullhead erosion. Its most northwesterly exposures in the western Foothills are in the vicinity of Mount Stearns (Fig. 5).

The greatest accumulation, 99 feet, is in the western Foothills near Halfway River (section 62-10). The unit thins in the eastern Foothills where the minimum thickness approaches 60 feet near Headstone Creek (sections 62-5, 62-7).

The shales of Unit 5 are similar to many Cretaceous marine shales. They are rubbly to blocky, somewhat silty, dark grey to black, weathering rusty to brownish grey. Limonitic staining from oxidation of iron sulphate may coat the weathered surfaces. The silt content of this unit increases upward, producing more massive to blocky mudstones.

Sideritic concretions, occurring either sporadically or in layers within the shales, weather reddish brown but are dark bluish grey on fresh surfaces. They vary in shape but approach flat spheroids.

Age and correlation

Unit 5 contains a microfaunal assemblage lying within "Zone C" (Table 1) dated as Late Jurassic by Chamney and considered to include equivalents of the Green Beds and part of the Passage Beds of southwestern Alberta. Fauna equivalent to that of the Green Beds of southern Alberta are represented to the top of unit 14 in section 64-13 which Chamney suggests is the approximate position of the Green Beds/Passage Beds contact. He states:

> *Aparchitacythere loeblichorum*, a common ostracode of the Oxfordian Swift Formation of the Plains, occurs in "Zone C" which straddles the suggested Green Beds/ Passage Beds contact.

The upper shales of Unit 5 may be in part equivalent to the lower shaly Passage Beds dated as late Oxfordian to early Kimmeridgian by Frebold. Farther south in the Pine Pass area, upper Fernie shales yielded *Buchia mosquensis* (Buch) which is considered by Jeletzky to be of middle to late (but not latest) Late Jurassic age, embracing Kimmeridgian to Portlandian time.

UNIT 6

The succession of interbedded sandstone, siltstone, and shale at the top of the Fernie shales is included in Unit 6 (Plate III). These beds are similar in lithology to the Passage Beds at the top of the Fernie in the southern Foothills and represent a transition from the predominantly shaly Fernie Formation to the overlying massive Monteith sandstones of the Minnes Group.

Both boundaries of unit 6 are gradational and neither form a persistent stratigraphic marker. The lower boundary is drawn at the first occurrence of fine-grained sandstone. The upper boundary is drawn at the base of massive to thick-bedded sandstone but is considered to lie below different sandstones from place to place.

Unit 6 is recognized throughout the Foothills except in the easternmost sections where the beds have apparently been eroded. It is recognized as far north as Nevis Creek but is apparently eroded in the more easterly section there and on Pink Mountain. Unit 6 has no uniform thickness but ranges from 240 feet near Horseshoe Creek (section 62-1) to 68 feet south of Halfway River (section 62-12).

The depositional sequence above the glauconitic marker of Unit 4 grades laterally and vertically from marine shales, included in the Fernie Formation, into well sorted massive sandstones included in the Monteith Formation. The shale facies is best developed in the vicinity of Mount Stearns. As the beds are traced northwestward and southeastward (Fig. 3) within the Foothills, sandstone facies gradually becomes more prominent. It is therefore apparent that marine conditions, represented now by the Upper Fernie shales, existed in the vicinity of Mount Stearns while transitional environments, represented now by the basal Monteith sandstones, were present farther to the northwest and southeast.

Unit 6 comprises many rhythmic units. Each of these contains mudstone at the base which becomes increasingly siltier toward the top and grades into argillaceous siltstone. The siltstone in turn becomes cleaner and sandier and locally grades into fine-grained sandstone. The sandstone or siltstone is overlain abruptly by shale of the next rhythmical unit. The proportion of sandstone to shale in each unit increases toward the top of the formation. This interbedding of sandstone and shale gives the unit a banded appearance. Bedding is rather indistinct in the shales but is well developed in the sandstones and siltstones. The bedding ranges from platy to thick-bedded and is relatively uniform and continuous. Small-scale crossbedding and crosslamination are present with these sediments.

The sandstones are predominantly fine-grained, quartzose, and finely laminated. They are grey to brownish grey in colour, and weather brownish to rust. The sandstones are similar in composition to the overlying Monteith sediments but are much finer grained and commonly more laminated. Many of the sandstones are ferruginous and the brown colour of the weathered surfaces is attributed to the products of iron oxidation. The sandstones occur in 1- to 8-foot units although thin shaly layers are commonly present.

In several of the measured sections, 6-inch to 1-foot beds of quartzose coarse-grained to conglomeratic sandstone occur within this unit.

Some of these may be continuous and serve as marker horizons. They do occur near the base of the unit within a fairly restricted interval that serves as a moderately reliable guide for lithologic correlation. The sandstone consists of subangular grains of quartz and quartzite with a few chert pebbles. The pebbles do not exceed one-half inch in diameter.

The siltstones are argillaceous to sandy and may be platy to massive. They are generally finely laminated. Some minor chanelling and crossbedding is present.

The shales vary from rubbly to blocky or platy and are generally silty. They are dark grey to brownish grey, weather rusty and contain numerous sideritic concretions.

Age and correlation

Unit 6 bears considerable resemblance to the upper Passage Beds of southwestern Alberta dated by Frebold as probably late Kimmeridgian to early Portlandian. It contains the youngest microfauna obtained by Chamney who comments:

> The uppermost microfaunal "Zone A" represents the highest stratigraphical position of sample material available for this study. The occurrence of *Lenticulina* cf. *L. dilecta* is similar to that in the uppermost Swift Formation (Oxfordian) of the Plains. The uppermost teilzone of this species has not been established and there is a possibility it could range upwards into the overlying Kimmeridgian. Its presence in the Fernie Formation of northeastern British Columbia, in association with *Nodosaria* cf. *N. corallina* and *Eogutulina* cf. *E.* sp. 2, correlates with the uppermost marine development of the upper Passage Beds of the southern Foothills geological province.

Palaeogeography

The palaeogeography of Jurassic seaways has been outlined in several reports by Frebold (1954, 1957, 1958) who emphasized the non-existence during Jurassic time of a "central Cordilleran geanticline" although he did not deny the presence of large islands in the interior of British Columbia. He postulated (1957, Fig. 5) that the maximum easterly marine transgression extended only slightly northeast of the region of this study; the coastline being approximated by a line through Fort Nelson and the town of Peace River. The existence of a coastline in that direction and open seas to the west indicate that Jurassic Fernie sediments would be derived mainly from an eastern source. That suggestion is partly corroborated (Lackie, 1958) by the eastward development of sandstones in middle Fernie strata of northeastern British Columbia and western Alberta. However, the available evidence does not entirely rule out a western source area, at least for part of the Jurassic north of Peace River. Other studies (Wheeler, 1961; Tipper, 1963; Campbell, 1966) in Yukon and central British Columbia indicate that, although marine troughs were present in the Cordilleran region during Jurassic time, land areas along their eastern margin lay between the troughs and the Fernie embayment of northeastern British Columbia. Such land areas could have contributed debris to the Fernie Formation. The general thickening of all the Fernie units from east to west and the increased development of sandstones in the most northwesterly and southwesterly regions suggest an abundance of sediment derived from a western source. Additional regional studies are required to resolve the problem.

The resemblance of the Jurassic succession north of Peace River to that of the southern Alberta Foothills suggests that similar events are recorded in northeastern British Columbia and furthermore that the depositional trends of the Jurassic sediments more or less parallel the present Foothills. The general conditions of deposition of the Sinemurian Nordegg Member extended north as far as Prophet River although the dominance of shale, in contrast to limestone and chert farther south, implies that more detritus was being supplied to the northern part of the basin. The monotonous succession of younger dark shales seems to indicate fairly uniform shallow marine deposition, with several minor regressions and transgressions recorded by the sandy glauconitic and pebbly beds. The hiatus, represented by the contact of the glauconitic bed of Unit 4 with the shales of Unit 3, apparently marks the sampe regional disconformity found at the base of the Oxfordian Green Beds elsewhere in the Foothills. As in the southern Foothills and at about the same time, deposition of Jurassic marine shales ceased when coarser clastic material spread across the basin, forming the massive sandstones of the overlying Monteith Formation.

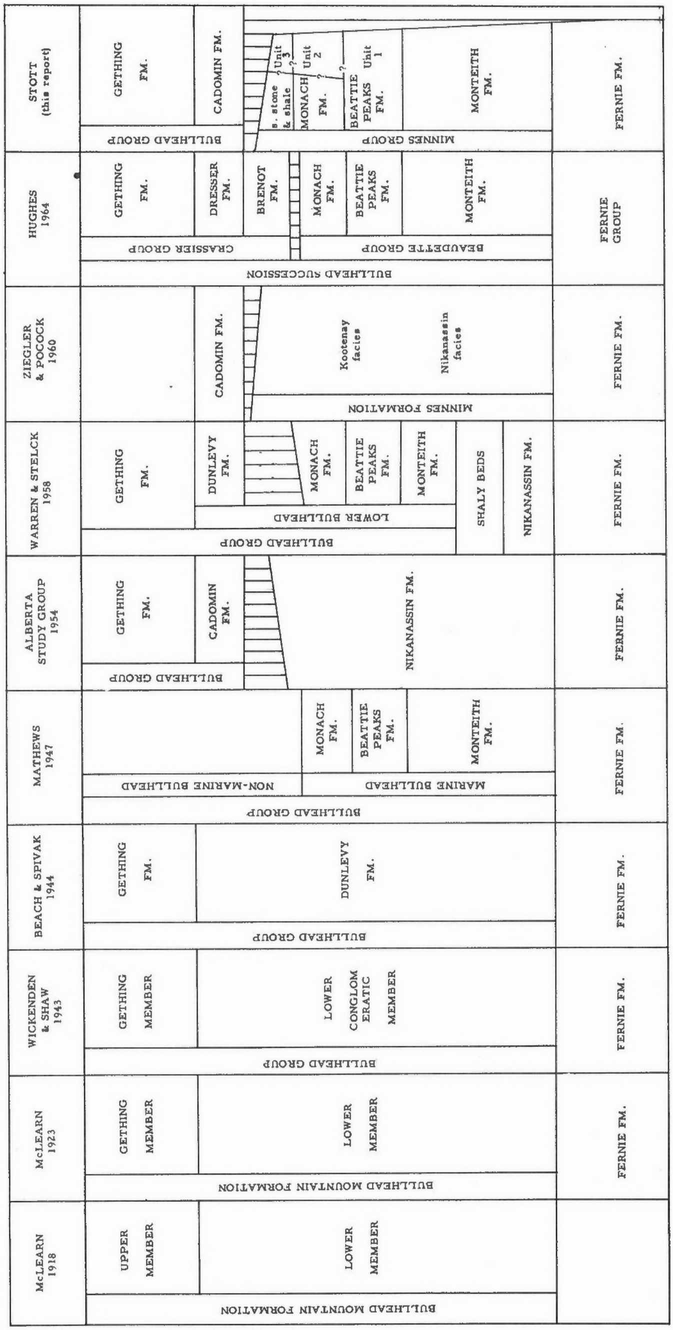

FIGURE 8. NOMENCLATURE OF JURASSIC AND LOWER CRETACEOUS ROCKS, NORTHEASTERN BRITISH COLUMBIA.

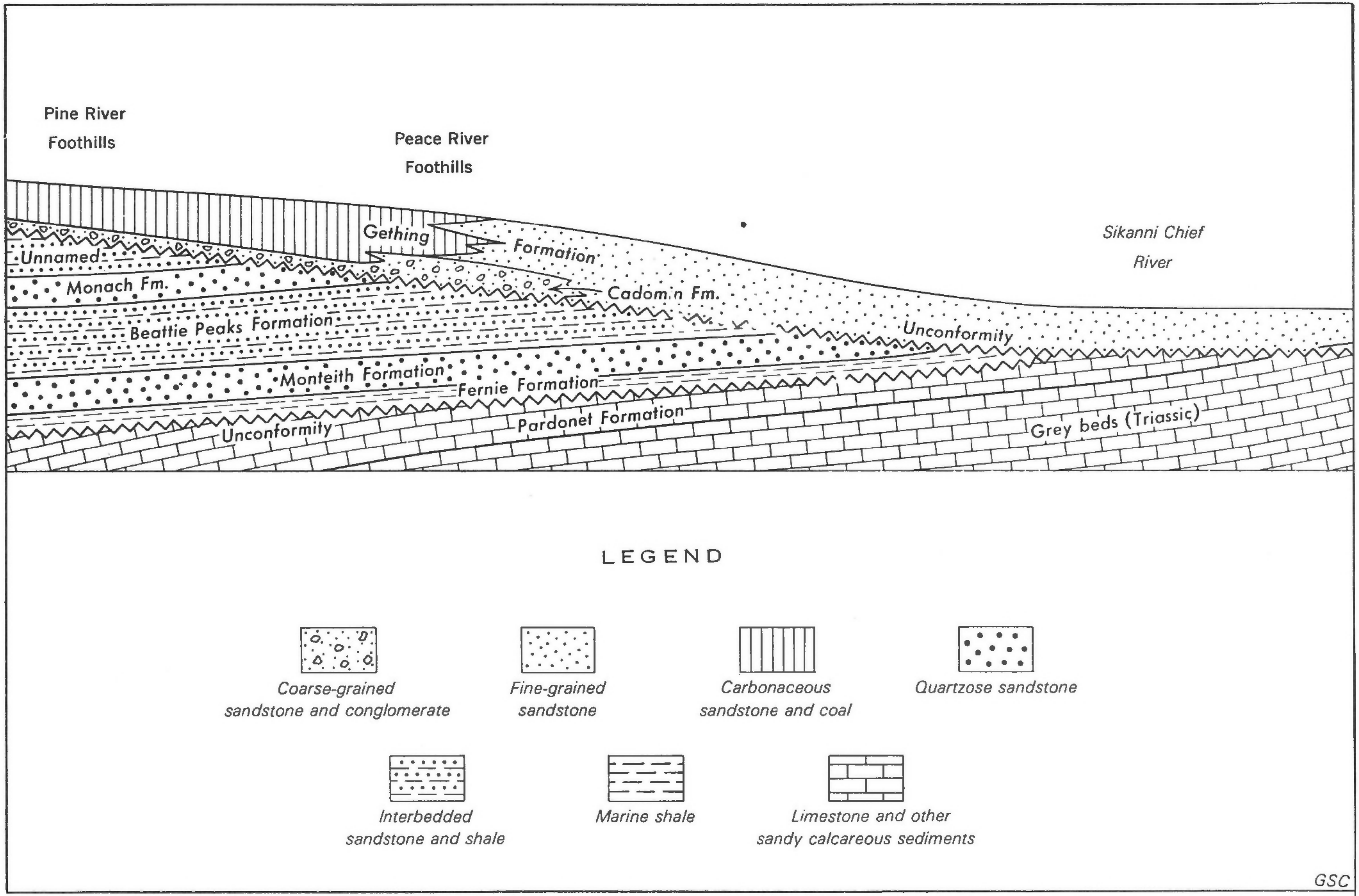

Figure 10. Schematic diagram illustrating relationships and unconformities of Upper Triassic, Jurassic, and Cretaceous formations, northeastern British Columbia

MINNES GROUP

The terminology of the predominantly sandy beds overlying the Jurassic Fernie shales has developed in several different areas (Fig. 8). As no widespread regional study nor detailed correlation has been made, no one terminology has been generally accepted for this succession. The name Nikanassin, established in the central Alberta Foothills by McKay (1929, 1930) has been extended north into the Foothills and Plains of the Peace River region, where it has been variously applied to units having differing stratigraphic limits (Warren and Stelck 1958; Ziegler and Pocock, 1960; Muller, 1961). More recently, Ziegler and Pocock (1960) proposed the name Minnes for somewhat similar rocks south of Pine River. The Bullhead succession of McLearn (1918; 1923) has been divided into different subdivisions in two closely related areas. A new classification has been proposed for these rocks by Hughes (1964). It is, therefore, necessary to consider the merits of these classifications (see Fig. 8) and, as discussed below, some modification of existing terminology has resulted.

The succession of sandstones, conglomerates, shales, and coal-bearing beds lying between Triassic rocks and marine Lower Cretaceous beds of the Moosebar Formation in the Peace River Foothills was called the Bull Head Mountain Formation by McLearn (1918). As later pointed out (McLearn and Kindle, 1950, p. 63), McLearn did not intend to include the Jurassic Fernie shales now known to be present but only meant to apply the name to the overlying beds. Bull Head Mountain Formation, when originally defined, was divided into upper and lower members and the former was later given the name Gething by McLearn (1923). The formation was raised to group status and the name was shortened to Bullhead by Wickenden and Shaw (1943). The lower formation was later named Dunlevy by Beack and Spivak (1944) who drew its upper boundary at the top of massive conglomerates and below the coal-bearing beds of the Gething Formation. All these workers considered that the entire Bullhead succession was largely, if not entirely, non-marine. In 1947, Mathews reported that a thick succession of marine beds occurred within the lower part of the Bullhead Group in the Carbon Creek basin. He divided these basal beds into three new formations; Monteith, Beattie Peaks, and Monach. According to Mathews (1947, p. 12) the upper or non-marine Bullhead included the Gething and the upper part of the Dunlevy Formation. Two new groups were proposed by Hughes (1964), with the major division being made at the top of Mathew's Monach Formation. The Beaudette Group was defined as including the Monteith, Beattie Peaks, and Monach Formations. The overlying Crassier Group included two new formations, Brenot and Dresser, and also the well established Gething Formation. Hughes suggested that the name Bullhead be retained in the meaning of a "super group" or succession to include the two new groups.

Outcrops examined in the Carbon Creek region, including continuous sections on Mount McAllister and Battleship Mountain, reveal that the three formations of Mathews are readily recognized. As previously stated (Stott, 1962) and as indicated by Hughes (1964), those formations are separated from overlying beds of massive coarse-grained, conglomeratic sandstones by a succession of thinly interbedded carbonaceous sandstones and shales. The conglomeratic sandstones are part of the Cadomin-Gething succession (Stott, in press) whose base is a widespread erosional unconformity. A similar succession occurs below conglomerate north of Peace River, and as the lithologic subdivisions are similar to those of the Carbon Creek basin, the names Monteith and Beattie Peaks are applied herein.

Near Peace River canyon the lower part of the Dunlevy Formation bears remarkable similarity to that outlined by Mathews. The massive conglomeratic sandstones below the Gething are included in the Cadomin Formation (Stott, in press). As also stated by Hughes (1964), that part of the Dunlevy Formation lying below the massive conglomeratic sandstones can readily be divided into the formations recognized in the Carbon Creek basin. The lower quartzitic sandstone is equivalent to the Monteith Formation; the overlying recessive interval, to Beattie Peaks; and the upper sandstones are apparently Monach. These subdivisions appear to be present in the section on Mount Gething described by Beach and Spivak (1944).

As the conglomeratic beds, originally included in the Dunlevy by Beach and Spivak (1944) are no longer retained in that unit by the writer, and as it can be subdivided for more practicable purposes of description into other named units, the term Dunlevy is abandoned. That practice, adopted by Hughes (1964), was recommended much earlier by the Alberta Study Group (1954, p. 277) who indicated that Beach and Spivak later considered that their lower Dunlevy Formation was largely equivalent to the Nikanassin Formation of the Alberta Foothills. The Study Group applied the term Bullhead Group to strata equivalent only to the Gething and Cadomin Formations and included the underlying beds in the Nikanassin Formation.

Although the recognition of two groups as suggested by Hughes (1964) is desirable, his proposed units are not entirely satisfactory. Hughes suggested the presence of a disconformity at the top of the Monach Formation and placed the contact between his Beaudette and Crassier Groups at that point. Although Hughes (1964, p. 29) did suggest the possibility of a hiatus between his groups, he did not recognize the major erosional unconformity at the base of the coarse-grained conglomeratic sandstones and considered the underlying so-called Brenot beds to be more closely related to the conglomeratic beds than to those of his Beaudette Group. As defined, his Crassier Group contains a major hiatus. The most logical place to divide the succession is at the erosional unconformity which marks a significant change in the depositional history of the whole region. As beds lying below the conglomeratic (Cadomin) sandstones are much more closely related to the underlying strata in their depositional history, it is preferable to include them in the basal group.

The validity of Hughes' Brenot Formation is dubious. The formation was defined in the French Petroleum-Richfield Brenot Creek No. 1 well in the eastern Foothills and extended westward into the Carbon Creek basin. The so-called Brenot Formation was considered to contain the carbonaceous sediments lying between the Monach sandstones and coarse-grained conglomeratic sandstones of the Carbon Creek basin. In the writer's opinion, the type Brenot beds are part of the Beattie Peaks Formation. The type Brenot, defined in subsurface, is considered to be miscorrelated with exposed beds occurring above the Monach in the Carbon Creek basin. As Hughes himself has pointed out, the Monach sandstone is missing in parts of the eastern Foothills and the whole succession is markedly reduced in thickness. It is believed that not only Monach beds but also any overlying sediments were eroded before deposition of the Cadomin conglomeratic sandstones. The thinning of the pre-corglomeratic beds is attributed mainly to erosion and not to convergence as suggested by Hughes. Thus, the writer's concept of the succession is not in agreement with that of Hughes

In a contemporary report (Stott, in press), the writer has restricted the Bullhead Group to include only the Gething and Cadomin Formations[1]. The writer does not like to extend the poorly defined and variously used term Nikanassin this far north. It is proposed that the better defined and dated Minnes Formation (Ziegler and Pocock, 1960) be raised to group rank to include beds occurring between the Fernie shales and Cadomin conglomerate, that is, the Monteith, Beattie Peaks, and Monach Formations and the overlying unnamed shaly beds of Carbon Creek basin.

In the type area at the headwaters of Kakwa River, the Minnes is composed of varying facies of both marine and continental origin. It is bounded at the base by the Fernie shale and at the top by the Cadomin Formation. It comprises shales, mudstones, silt, and sandstone, and the upper part contains carbonaceous sediments and beds of coal. In their discussion, Ziegler and Pocock (1960, p. 44) noted:

> It was observed in many parts of the Foothills that the occurrence of marine and non-marine facies developments of the sedimentary sequence between the Fernie and the Cadomin formations is extremely variable. Sections of the eastern foothills sections usually consist of a lower sequence of sediments, showing a marine character, whereas the upper sediments are of continental origin. Farther to the west and to the north it becomes more and more apparent that the two facies developments are strongly interfingering, i.e. marine and continental facies succeed each other laterally and vertically in the section.

The Minnes succession was considered by those workers to include beds of late Oxfordian to Barremian age.

MONTEITH FORMATION

The fine-grained and coarser quartzitic sandstones that occur above the Fernie shales are correlated with the Monteith Formation of the Carbon Creek basin and the name Monteith is therefore used throughout the area north of Peace River.

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[1] Hughes assigned the conglomerates and coarse-grained sandstones to a new formation which he called Dresser. There appears to be no real justification for the erection of a new formation as those rocks are stratigraphically equivalent to the Cadomin and have many lithological features in common. The term Cadomin has been used extensively in the Plains immediately east of the Peace River Canyon and also in the Foothills farther south (see Stott, in press). The present writer prefers to continue to use Cadomin as suggested by McLearn (1940) and the Alberta Study Group (1954).

Mathews (1947, p. 10) gave the name Monteith Formation to arenaceous beds resting with apparent conformity on shales and sandstones, believed by him to be the upper part of the Fernie Formation. He described the lower sediments as being arkosic sandstone separated by shale and shaly sandstone: the uppermost part as consisting of white quartzite. According to Warren and Stelck (1958, pp. 57, 58), the Monteith quartzitic sandstones were separated by more than 3,500 feet of Nikanassin sandstone and 500 feet of shale from the Fernie. The writer concluded, after examining the succession in the Carbon Creek basin and numerous exposures north of Peace River, that all the sandstones immediately above the Fernie should be included in the Monteith; a similar practice was followed by Hughes (1964).

Mathews took the name from Mount Monteith where the type section is presumably located. However, he stated that the formation had been examined "in greatest detail" on the western slope of Beattie Peaks. No description of the succession at either locality was published although Mathews stated that about 1,750 feet of beds were present at Beattie Peaks. The general succession at Beattie Peaks was described briefly by Hughes (1964, section 10).

The Monteith Formation is underlain gradationally by beds that are included in the Fernie shales. The base of the Monteith is drawn at the lowest thick-bedded sandstone unit, forming no persistent marker but lying at the base of different sandstones from one section to another. The Monteith is overlain by recessive shaly sediments of the Beattie Peaks Formation (Plate IV). The upper contact in the western Foothills (Fig. 3) is drawn at the top of the massive sandstones and is commonly marked by a thin conglomerate that appears to be closely related to the underlying beds. In sections farther east (sections 62-10, 64-11), the contact was drawn at a similar distinct change in lithology. However, in those sections, the contact lies at the top of a lower sandstone (Fig. 4) that is persistent in the subsurface of the adjacent Plains. The upper boundary, therefore, appears to maintain a persistent stratigraphic position along depositional trends but occurs above different sandstones as successive sandstones grade into shale in a northeasterly direction, that is, across the depositional trends. In sections of the formation in the eastern Foothills north of Halfway River, the Monteith is overlain by the Gething Formation. In that region, the upper boundary of the Monteith is an erosional unconformity that bevels downward in a northeasterly direction (Figs. 5, 6).

South of Peace River, the Monteith Formation forms prominent ridges that produce a high rim around the Carbon Creek basin (Fig. 2). The formation is well exposed along the eastern rim on such peaks as Mount McAllister (Plate V) and Mount Frankroy. Muller (1961) showed in the Pine Pass map-area that the formation extended southward beyond Pine River to Mount Le Hudette and Goodrich Peak. The distinctive Monteith quartzose sandstones have not been reported in more southerly regions. Sandstone and interbedded shales lying above the Fernie shales between Bullmoose Mountain and Smoky River were mapped as Nikanassin by the writer (Stott, 1960, 1961) and, in the vicinity of the headwaters of Kakwa River, were defined as the Minnes Formation by Ziegler and Pocock (1960). The Monteith, therefore, has not been identified beyond the southeastern limits of the Pine Pass map-area.

South of Peace River within the Halfway River map-area, the formation is recognized from the northern rim of the Carbon Creek basin as far eastward as Mount Gething (Fig. 2). In the eastern Foothills, it extends northward along a prominent east-facing escarpment on Butler Ridge between Peace and Graham Rivers. It can be recognized in the subsurface east of the Foothills (Fig. 9) but generally has been included in the undivided Nikanassin Formation. In the area north of Graham River, the Monteith Formation forms prominent ridges (Frontispiece) that outline a series of folds extending northward into Trutch map-area (Pelletier and Stott, 1963). The most westerly exposures occur northeast of Mount Laurier and near Mount Stearns. Beyond Halfway River, the pre-Bullhead unconformity bevels much of the succession and only the lower part of the Monteith occurs in more northerly exposures. The northernmost outcrop is between Besa River and Richards Creek. The easternmost outcrop is just east of Headstone Creek. Hage (1944) suggested that a small thickness of lowermost Cretaceous rocks were present on Sikanni Chief River but those beds appear to be part of the younger Gething Formation and all the Minnes beds and much of the Fernie Formation have been removed by pre-Bullhead erosion.

Mathews (1947) reported that the Monteith Formation was 1,750 feet thick on Beattie Peaks and not over 1,000 feet at Indian Head. Muller (1961) stated that the formation reached a thickness of over 2,000 feet in the Pine Pass map-area but did not specify the locality. Hughes (1964, p. 14) reported that the formation decreased from about 1,850 feet in the west to 943 feet in the eastern Foothills. The Monteith Formation was not measured by the writer in the area near Peace River. However, the thickness was determined to be 782 feet in West Canadian Moberly Lake 11-36-80-25, W6 well, only 25 miles east of Mount Gething. On Mount Gething, 1,467 feet of massive sandstone was described by Beach and Spivak (1944) in the lower part of the section, but the section there may be excessive as several faults were mapped by Irish (1961, 1963).

North of Peace River, the thicker sections are near Chowade River where the maximum of 718 feet occurs (section 62-15). In more easterly sections near Halfway River (sections 62-5, 62-7), much of the Monteith has been eroded and only a few hundred feet are present. The formation decreases to 558 feet near Mount Stearns (section 62-14), in the western Foothills. The decrease is apparently due to a lateral facies change from sandstone to shale that is then included in the Fernie Formation. Another facies change to sandstone farther north (Fig. 3) results in an increased thickness near Trimble Lake (section 64-7) of 977 feet. Only 501 feet of Monteith sandstone occur north of Besa River (section 64-14) and only 356 feet at the headwaters of Nevis Creek (section 62-16). This decrease northward and eastward is related to pre-Bullhead erosion which apparently removed the Monteith from more northerly regions.

The Fernie-Monteith succession forms a major sedimentary unit. The thickness of that succession remains remarkably constant along the western Foothills between Graham River and Mount Stearns. Variations from the maximum of 1,280 feet north of Christina Falls are in the order of only 50 to 100 feet. A marked thinning occurs to the northeast (Fig. 4) where the total interval decreases to 920 feet (section 62-10) and 871 feet (section 64-11). The decrease is attributed mainly to a lateral facies change from massive quartzose sandstones of the Monteith Formation to silty shales and siltstones included in the Beattie Peaks Formation (Fig. 4). However, as the upper beds of the Monteith are eroded along the eastern Foothills, the total variation cannot be determined. Correlation between the sections south of Halfway River and those farther north is tentative as the upper limit of the Monteith in that area is an erosional unconformity, and there are no diagnostic markers within the formation.

The Monteith Formation in the Carbon Creek basin and in the immediate vicinity of Peace River was examined only briefly and was not measured or described in detail. Consequently, only its general features in that region are summarized here. Mathews (1947, p. 10) described the greater part of the formation within the Carbon Creek basin as being

> ... made up of dark-grey arkosic sandstone, massive to flaggy, and in place(s) showing cross-bedding and ripple marks. This sandstone occurs in beds usually from 10 to 30 feet thick, each separated by a few feet of shale or shaly sandstone ... The uppermost 500 feet of the formation is made up of white quartzite, commonly stylolitic and locally vuggy.

Lower beds are well exposed on Mount Frankroy and the massive quartzose sandstones are equally well developed on Mount McAllister and Battleship Mountain. At Rainbow Rocks along Peace River east of Goldbar, the Monteith Formation consists of massive, white to grey, laminated sandstone with minor conglomerate. The uppermost beds include 2 feet of very coarse, friable quartzose sandstone. Farther east on Butler Ridge, several thick units of dark grey to black sandstone were noted. The grain size appears to increase upward and the sands also become darker in colour toward the top. Such a progressive change in size and colour was not so apparent at other localities. The grey to white weathering of most of the sandstones at these localities is typical of the formation throughout the region.

North of Peace River, the Monteith sediments are similar to those of the Carbon Creek basin, consisting mainly of fine- to coarse-grained quartzitic sandstones. The sandstones are commonly massive to thick-bedded. Although the colours range through shades of brown to white and black, the beds commonly weather a distinctive dull grey.

The Monteith Formation is divided into two major units (Figs. 3-6). The division is made at the base of a persistent shaly interval that is overlain by massive sandstone and underlain by a thin unit of coarse-grained to conglomeratic sandstone. The lower unit, a shaly facies, comprises mainly alternating sandstone and shale. The upper one comprises much of the massive quartzose sandstones. It is stressed that each of these units contain facies that intertongue laterally with facies found in the other unit. Thus, the massive sandstones of the upper unit grade laterally into a shaly facies that is indistinguishable from the lower unit and separation of two distinct units is not always possible.

Although the lower unit of the Monteith Formation is quite variable in type and proportion of major rock types, it does maintain a similar character throughout the region. In most places, it consists of alternating units of fine-grained sandstone and silty shales. These units range from 5 to 50 feet thick and the proportion of the two main rock types vary greatly from one locality to another. In general, the beds are commonly platy to thin-bedded, laminated, and ripple-marked. Although shale and sandstone are thinly interbedded, much of the sandstone occurs in separate units with only minor beds of shale. The upper surfaces of the sandstone are usually distinct with a very abrupt change to the overlying shale. The sandstones are fine-grained to silty and well cemented with silica. They weather rusty brown, contrasting with the grey weathering sandstone at the top of the formation. The rusty weathered surface is due to products of iron oxidation. The relatively hard, silty, and non-calcareous shales commonly contain thin laminae or thin interbeds of siltstone. The shales are dark grey to black or shades of brownish grey, depending on the amount of silt present. The silt content of the shales appears to increase upward and the gradation from silty claystone through siltstone to sandstone is typical.

This lower unit is easily recognized immediately east of the outcrop belt in such wells as HB Cypress a-28-F (a-28-F/94-B-15) and HB Chowade b-18-J (b-18-J/94-B-10). It can be traced southeasterly into West Canadian Moberly Lake 11-36 well (11-36-80-25, W6).

A thick development of interbedded sandstone and shale is included in the lower unit northwest of Mount Stearns (Fig. 3). The sandstones are fine-grained, commonly thick-bedded and weather brown, resembling sandstones of the transitional beds between Fernie shales and massive Monteith sandstone elsewhere. These beds are considered equivalent in part to units 4, 5, and 6 of the Fernie, apparently representing the deposition of nearshore sediments in late Jurassic time. The upper beds of the basal unit in the most northerly exposures contain much shale, contrasting with the more massive Monteith beds farther south. The configuration of the shoreline at that time is not well delineated but it is possible that the sandstones between Mount Stearns and Richards Creek are part of a deltaic complex extending into the basin.

Massive quartzose sandstones of the upper unit include some silty shales. The sandstone consists almost entirely of quartz grains that range from fine- to coarse-grained. The sandstone varies from shades of brown to grey on a fresh surface but mainly weather grey. The development of secondary silica has produced a well cemented rock although much is somewhat porous and tiny vugs are present. Regular or uniform stratification is a characteristic feature of these upper sandstones. Crossbedding and crosslamination, found in the lower beds, is not common. Although some platy to flaggy bedding does occur, the dominant thick-bedded to massive sandstones (Plate V) contrasts with the thin-bedded character of the shaly facies. Fine laminations may also emphaze the horizontal bedding but in the better sorted sandstones, impurities are lacking and lamination is not evident.

Northward variations of the quartzitic facies characterize the Monteith Formation (Fig. 3). The upper beds of the Monteith consist predominantly of the massive quartzitic sandstone in the sections at Horseshoe Creek and near Chowade River. To the northwest, as near Mount Stearns, they pass into alternating units of very fine-grained sandstone and silty shale. It is evident (Figs. 3, 5) that the massive sandstones grade laterally northwesterly into the shaly facies. Not only is there a decrease in sandstone in the northwestern outcrops but there is also an accompanying decrease in grain size. In the southeastern sections, the sandstones are commonly

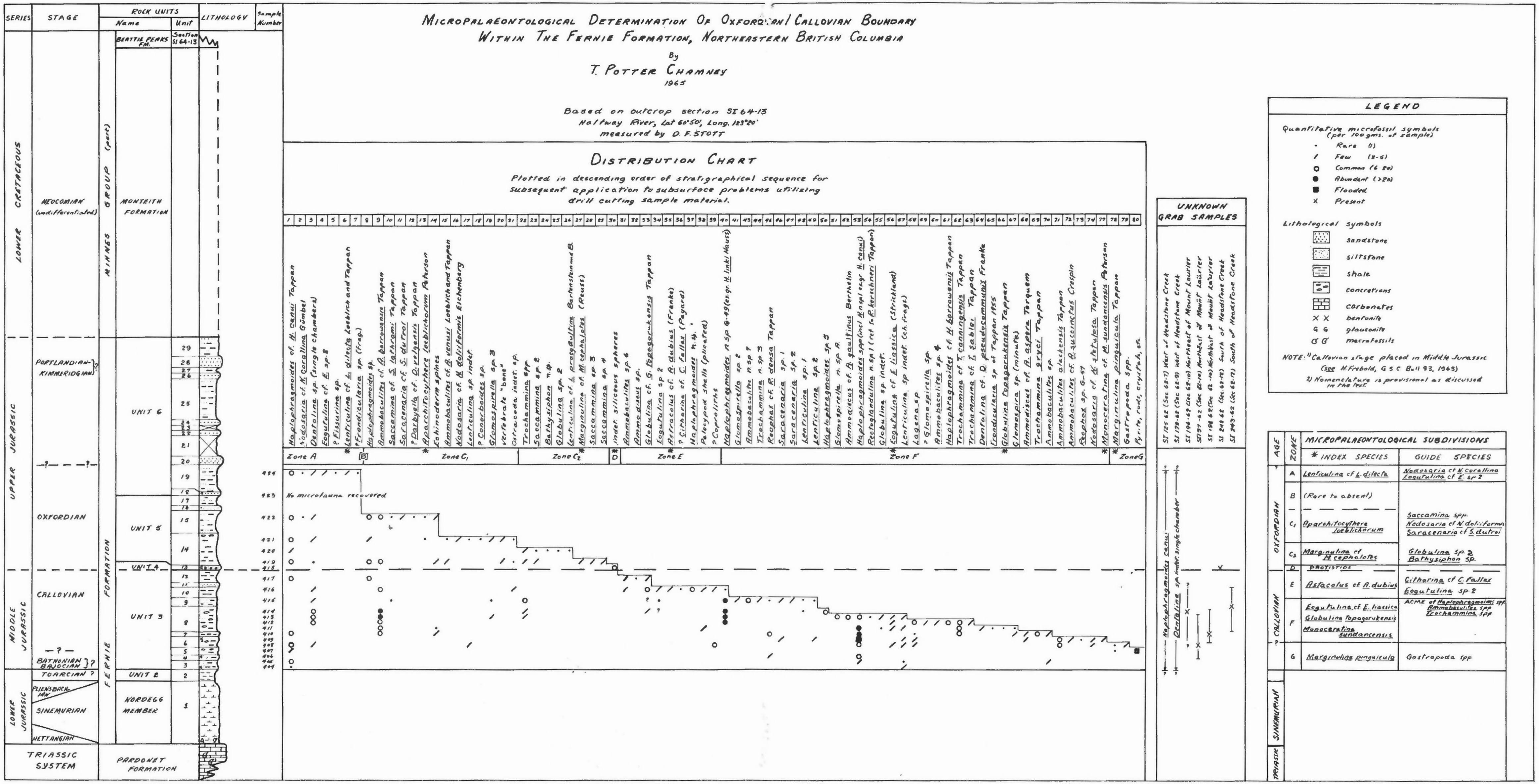

Table 1. Micropalaeontological Subdivisions

Chart No	AGGLUTINATED FORAMINIFERIDA	OXFORDIAN A	B	C1	C2	D	CALLOVIAN E	F	G
24	Bathysiphon n.sp.								
10	Saccammina cf. S lathrami Tappan			·	—	—	—	·	
23	S. sp. 2				/				
28	S sp. 3				/				
29	S. sp 4				/				
32	Ammodiscus sp								
52	A. cf A. gaultinus Berthelin							o	
68	A. cf A. aspera Terquem							o	
67	Glomospira sp (minute)							/	
59	Glomospirella sp. indet.							/	
19	G. sp. 3			/	—	—	—	/	
41	G sp. 2							/	
51	G sp. 4							/	
45	Reophax cf. R. densa Tappan							o	/
73	R. sp. G-57							·	
1	Haplophragmoides cf. H canui Tappan	o	—	o	o	—	o	o	●
8	H. n.sp.			o	o	—	o		
37	H. n.sp.						o		
46	H. n.sp G-49 ex.gr H. linki Nauss						X	■	X
50	H. n.sp. 5							o	
53	H. spp. incl. H. cf. H. canui in part							■	o
61	H. cf H. barrowensis Tappan							o	
9	Ammobaculites cf. A. barrowensis Tappan			o	o	—	o	■	
15	A. cf. A. venusi Loeblich and Tappan			/	/				
31	A. sp. 6						o		
43	A. sp. 7							o	
60	A. sp. 4							/	
70	A. sp. indet.							/	
71	A. alaskensis Tappan							o	o
72	A. cf. A. succinctus Creppin							/	
22	Trochammina sp. indet.				o	—	—	o	
44	T. n sp. 3							/	
62	T. cf. T. canningensis Tappan							●	
63	T. cf. T. sablei Tappan							/	
69	T. gryci Tappan							o	

Chart No	CALCAREOUS FORAMINIFERIDA	OXFORDIAN A	B	C1	C2	D	CALLOVIAN E	F	G
2	Nodosaria cf N corallina Gümbel	·	—	·					
16	N. cf. N. deliiformis Eichenberg			/					
74	N. cf N. stetulosa Tappan							/	/
*35	Astacolus cf. A. dubius (Franke)						/		
36	Citharina cf. C fallax (Payard)						·		
3	Dentalina sp indet (single chambers)	/	—	/	/	—	/	●	·
64	D. cf. D pseudocommunis Franke							/	
7	Frondicularia sp. indet.	·							
65	F. sp of Tappan 1955							·	
58	Lagena sp. 1							o	/
*6	Lenticulina cf L. dilecta Loeblich and Tappan	/							
17	L sp. indet.			·					
26	L cf L praegaultina Bartenstein & B.				·				
48	L sp 1							/	
49	L sp. 2							o	
57	L. spp single chambers							o	/
*27	Marginulina cf. M. cephalotes (Reuss)				/				
*78	M. pinguicula Tappan								/
11	Saracenaria cf. S. dutroi Tappan			/					
46	S. sp. 1 (6A)							o	
47	S sp. 2							/	
4	Eoguttulina cf. E. sp. 2	/							
34	E. sp. 2						/	·	
*56	E. cf. E. liassica (Strickland)							o	/
25	Globulina sp. 2				·				
33	G. cf. G. topagorukensis Tappan						o	/	
55	G. sp indet.							/	
*66	G. topagorukensis Tappan							·	
54	Rectoglandulina cf. R. kerschneri Tappan							·	
5	? Fissurina sp.	·							
12	? Darbyella cf. D. volgensis Tappan			·					
18	? Conorboides sp			·					
	OTHER MICROFOSSILS								
21	Ostracoda indet sp.			·	·	—	—	/	
*13	Aparchitocythere loeblichorum Peterson	/							
*77	Monoceratina cf. M. sundancensis Peterson							/	
*30	? Protistids - siliceous spheres					o			
20	Vertebrate "bone" ? Fish remains			/	/				
14	Echinoderm spines			/	/	—	—	/	
38	Pelecypoda shell fragments						/	/	
39	? Coproliths						/	o	
79	Gastropoda spp.								/
80	Abnormal accumulations of pyrite "rods", etc.								■

QUANTITATIVE LEGEND
Recovery per 100 grams of sample

·	Rare	(1)
/	Few	(2-5)
o	Common	(6-20)
●	Abundant	(>20)
■	Flooded	
X	Present	

Based on outcrop section SI 64-13, measured by D. F. Stott

Table 2. Systematic index to species and range chart, Fernie Formation, northeastern British Columbia.

medium- to coarse-grained and include minor conglomerate. Farther northwest, fine-grained, silty sandstone dominates. A similar facies change occurs in an easterly direction. Apparently the upper quartzose sandstones found in the western Foothills near Halfway River grade northeasterly into shale (sections 62-10, 64-11, Fig. 4). In subsurface, upper quartzose sandstones in Imperial Calvan Altares 83-A well (83-A/94-B-8) grade laterally into a shaly facies in such wells as HB Cypress a-28-F (a-28-F/94-B-15) and HB Chowade b-18-J (b-18-J/94-B-10).

Although conglomerate does occur within the Monteith Formation, its distribution is somewhat erratic. It occurs in two main intervals but beds do not appear to be continuous and cannot be used as marker horizons. The lower conglomeratic interval occurs in the basal unit and consists of several thin beds of conglomerate. These beds are commonly only a few inches thick. They occur not only within sandstone successions but also within shale beds. The second main conglomeratic interval occurs in the uppermost sandstones and is more persistent.

The conglomerates are composed of pebbles of clear quartz and some white quartzite. Black chert is generally not abundant in contrast with its great abundance in the overlying Gething Formation. The phenoclasts range in size from coarse sand grains to about 2 inches but no large cobbles were noted. Commonly, the pebbles are embedded in a medium- to coarse-grained sandstone matrix.

The Monteith sandstones can be divided into two main types, one characterized by abundant lithic grains and the other, by the dominance of quartz. The first group, classified as lithic arenites and lithic wackes, is characteristic of the sandstones where interbedded with shale. The second type is a quartz arenite or orthoquartzite and is typical of the massive sandstones and conglomerates of the upper Monteith.

The lithic sandstones contain three main constituents; quartz, detrital carbonate, and lithic fragments. Some sandstones contain little or no matrix of clay and are classed as arenites. Those containing more than 10 per cent matrix are classed aa wackes. Although Mathews (1947, p. 10) indicated that the lower sandstones in Carbon Creek basin were arkosic, feldspar is not abundant in thin-sections taken of rocks from the region north of Peace River.

The quartz of the lithic arenites is similar to that of the quartz arenites. It is generally not strained, may be clear or contain small dust-like inclusions, and commonly has secondary overgrowths.

The lithic fragments are predominantly those of resistant rock types, siliceous or cherty. Some of the fragments have a uniform mottled appearance with no inclusions and are considered to be derived from cherty limestones. Other similar grains contain small inclusions of carbonate or show small relict structures suggestive of fossil fragments, indicating they were probably derived from silicified fossiliferous limestones. Some grains show felted textures, flowage features, and other textures suggestive of volcanic debris.

The third major constituent of the lithic sandstones is detrital carbonate (Plate VI) which may form as much as 40 per cent of the rock. Much of the carbonate occurs as rounded grains formed by aggregates of fine crystals or as subangular grains without aggregate texture. Almost without exception, the carbonate grains are surrounded by a coating of limonite which commonly penetrates along cracks. In many samples, the calcite has been crushed and redistributed, crystallizing as a sparry cement.

The quartz arenites consist almost entirely of quartz grains. Very minor amounts of chert or lithic fragments are present but rarely exceed 5 per cent (Plate VI). This dominance of quartz is unusual, considering that lithic fragments are abundant in rocks both above and within the lower beds of the Monteith Formation. These quartz arenites are clean, well sorted sands, almost devoid any interstitial clay. Detrital constituents, other than chert, are rare but include feldspar and some carbonate. Traces of glauconite, occurring as small pellets, were found in a few sandstones.

The original quartz grains appear to be rounded to well rounded although the development of secondary siliceous overgrowths has produced a more angular appearance. Depending on the abundance of matrix, welding and suturing of adjacent grains may have filled the pore space and developed a mosaic texture (Plate VII). The grains show normal optical extinction with little or no strain pattern. The shape of the grains appears to have been more nearly spherical than elongate but some degree of orientation is apparent in some sandstones.

Bitumen was noted in many of the sandstones, occuring in quantities ranging from very minor to abundant. In some, it was found as irregular pore fillings, in others it separated some of the grains (Plate VII) and in a few, it formed a matrix in which some of the sand grains appeared to float (Plate VII). Although traces of bitumen were found in the Monteith throughout its area of distribution, it is most abundant on Butler Ridge where the pronounced change from white to black shades of the sandstones can be attributed to the increase in content of bitumen.

Although only the more stable types of heavy minerals occur in these sediments, more varieties are present than in the overlying Gething and Fort St. John sandstones (see Stott, in press). Most of the grains are rounded to well rounded, indicative of previous erosion cycles. The Monteith assemblage is characterized by the abundance and varieties of tourmaline, two varieties of rutile, and pink zircons. The colours of the tourmalines include pink, blue, green, brown, and greenish brown. The deep yellowish orange rutile is more abundant than the "foxy" red that is common in younger Lower Cretaceous sediments. In addition, rare grains of apatite and colourless garnet are present.

Age and correlation

In the Carbon Creek basin, the base of the Monteith may be of late Tithonian age. A poorly preserved ammonite collected by Muller from the basal Monteith near Carbon Creek basin was tentatively identified by Jeletzky as *Pavlovia s. lato*. In the same general region, *Buchia piochii* (Gabb) and *Buchia cf. B. fischeriana* (D'Orbigny) were collected by Muller and Irish from sandstones occurring either at the top of the Fernie or at the base of the Monteith. Those collections were dated by Jeletzky as late Tithonian or Purbeckian (latest Jurassic) and may be correlated with fauna in the lower part of the Nikanassin Formation to the south. Some examples of Buchia, which according to Jeletzky may represent some part of the Buchia fischeriana zone of latest Tithonian age or the Buchia okensis zone of earliest Berriasian age, were collected by Hughes from beds he considered to be equivalent to lower Monteith on LeMoray Mountain. Jeletzky states that this is the oldest fauna reported from that stratigraphic interval. The youngest fauna, collected by Muller, from the Monteith of the Carbon Creek region includes Craspedites nov. sp. aff. C. payeri (Toula) and Buchia keyserlingi var. siberica (Sokolow), B. keyserlingi var. unchensis (Pavlow) and Buchia aff. B. volgensis (Lahusen). This fauna is dated by Jeletzky as either latest Berriasian or (?) of earliest Valanginian age.

Ammonites collected by H. Frebold from conglomeratic beds assigned to the upper Monteith of Carbon Creek area were originally identified tentatively by Jeletzky as Craspedities (Subcraspedites) ex aff. groenlandicus Spath. This identification was published by Warren and Stelck (1958, p. 58). Subsequently it was withdrawn by Jeletzky and the ammonites concerned were identified as Dichotomites (s. lato) cf. D. giganteus (Imlay, 1960) and dated as of mid- to (?) early Valanginian age in an unpublished fossil report. Tollia (Subcraspedites) cf. T. tolli and Buchia cf. B. keyserlingi found either in the upper Monteith or in the lowermost Beattie Peaks have been recently dated tentatively as of early Valanginian age by Jeletzky (personal communication). According to those collections, the Monteith south of Peace River can be dated as latest Jurassic to earliest Cretaceous. The continuity of the faunal succession within upper Fernie and Monteith beds indicates that the Jurassic-Cretaceous boundary in that region lies within a conformable sequence.

The faunal evidence obtained north of Peace River and the lithologic relationships suggested herein are difficult to reconcile with the succession of the type region. As previously discussed, shaly beds assigned to the Beattie Peaks near Halfway River (sections 62-10 and 64-11) are considered laterally equivalent to the upper beds (Unit 2) of the Monteith in the western Foothills. Yet Buchia n. sp. aff. inflata (Toula) was collected by the writer from those shaly beds (GSC lots 66029, 52200, 52218). Those fossils are dated by Jeletzky as mid- to late Valanginian, an assignment that is considerably younger than that suggested for the upper beds of the type Monteith. Furthermore, Buchia n. sp. aff. B. inflata (Toula, B. aff. B. crassicollis Keyserling, B. cf. B. keyserlingi (Trautschold) and B. cf. B. sublaevis (Keyserling) were obtained by the writer from large talus blocks derived from either uppermost beds of Unit 2 of the Monteith Formation or from lowermost Beattie Peaks (section 62-15, GSC lots 52220, 46516). That fauna was considered as being slightly younger than the former by Jeletzky who tentatively suggested the late rather than mid-Valanginian, correlating it with that of the middle to upper part of Beattie Peaks and Monach of type region. Although diachronous or tansgressive on-lap relationships might explain the apparent discrepancy, they have not been clearly demonstrated and such an explanation is not accepted at present by the writer. To equate those beds north of Peace River with upper Beattie Peaks and Monach of the type region implies that the overlying succession of almost 1,500 feet is younger than Monach. It is inconsistent to have the Monteith succession decrease from 1,800 feet in the type region to about 700 feet or less at Halfway River and then to have post-Monach beds increase from 750 feet at Mount Bickford (Hughes, 1964) to about 1,500 feet at Halfway River. It is even more difficult to accept such an increase when it is clearly evident that the succession is bevelled strongly in a northeasterly direction by the pre-Gething unconformity. Furthermore, Jeletzky has reported that Buchia n. sp. aff. B. inflata (Toula) is associated with Dichotomites (s. lato) cf. giganteus Imlay in conglomeratic beds[1] assigned to either the upper Monteith or lower Beattie Peaks. Thus, the discrepancy may not be as great as it seems. The incomplete information available about the early Lower Cretaceous succession in northeastern British Columbia was commented on by Jeletzky who also pointed out the lack of data on the exact vertical ranges of index fossils within the individual formations. There seems to be some possibility that range of Buchia n. sp. aff. B. inflata (Toula) in this region may be greater than presently surmised. Until such time as numerous and well preserved index fossils are collected sequentially from unfaulted sections, the faunal relationships will remain tenuous.

Beds included in the Monteith north of Peace River are considered by the writer to be equivalent to the type Monteith of Carbon Creek region. The lower boundary is probably diachronous. Between Mount Stearns and Richards Creek, it is considered to coincide with Unit 4 of the Fernie, equivalent to the Oxfordian Green Beds. Farther south, the formation lies above Unit 6 which may be as young as early Portlandian. Inasmuch as the Monteith is overlain by beds containing fauna of middle to late Valanginian age, the formation in the region north of Peace River may range in age from Oxfordian to early Valanginian.

Palaeogeography

Toward the end of Jurassic time and extending into the earliest Cretaceous, nearshore sand deposits of the prograding shoreline accumulated in the region of the present Foothills. The greatest thickness of sandstone occurs south of Cypress Creek whereas the marine shaly facies occurs to the north. Moreover, similar near-shore sands are well developed in the region of Carbon Creek, showing that the margin probably extended southward across Peace and Pine Rivers.

The general thickening of the succession appears to be to the south or southwest. The greatest concentration of sandstone in the eastern Foothills lies between West Cdn. Moberly Lake 11-36 well (11-36-80-25, W6) and Graham River, extending from there along the western Foothills to Mount Trimble. The thickness more than doubles between that trend and the Carbon Creek basin to the southwest. It seems obvious that the main source was in

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[1] Although Jeletzky, on the basis of faunal relationships, has implied that the conglomeratic beds are not at the base of the Beattie Peaks Formation, Frebold's original formational assignment placed them in the Monteith. Conglomerates do occur at the contact, between the Monteith and Beattie Peaks north of Peace River but were not encountered elsewhere in the lower several hundred feet of Beattie Peaks. Also, Hughes (1964) did not give any indication that conglomerates were present in the lower part of the Beattie Peaks.

that direction. The present study seems to indicate some increase in coarse quartzose sandstone in the lower Monteith toward the east near Halfway River (Fig. 4) and a similar situation was noted near Peace River by Hughes (1964, p. 14). Although such increased grain size might be used as a source indicator, it is difficult to postulate a source in that direction. Although Palaeozoic rocks were probably exposed in part of the area between this basin and the Canadian Shield, no rocks there have the essential constituents to supply either the vast quantity of detritus nor the coarse-grained quartz that was deposited in the Monteith. There is, of course, the remote possibility that such quartz-rich Precambrian sandstones as those of the Athabasca Formation (Fahrig, 1961) of northwestern Saskatchewan may have contributed detritus to the Monteith. An alternate possibility is that the margin of the basin was not parallel to the structural strike of the Foothills but was influenced by the northeast trending faults associated with the ancient Peace River Arch. As shown in another report (Stott, in press), the later Cretaceous Fort St. John embayments had an easterly to northeasterly trending margin near upper Peace River but the clastic material had a western provenance. It may be that a deltaic complex developed during Monteith deposition near the present eastern Foothills, resulting in the deposition of coarser sediments in that region.

BEATTIE PEAKS FORMATION AND (?) YOUNGER BEDS

Strata between the Monteith Formation and the pre-Bullhead unconformity in the region north of Peace River are equivalent in part to the type Beattie Peaks Formation. They may contain beds younger than those of the type Beattie Peaks, possibly including beds approximately equivalent to the type Monach Formation and also to overlying beds below the Bullhead Group. Lack of sufficient control sections and palaeontological data, however, prevents any detailed correlation of the upper beds with the type region. Furthermore, although these upper sandstones north of Peace River are somewhat similar to the Monach, they do not form a well defined, mappable formation (see Plates VIII, IX). As Muller (1961) was unable to distinguish typical Monach sediments throughout parts of the Pine Pass map-area, the Monach sandstones may be prominent only as a local facies in the Carbon Creek basin.

The Beattie Peaks Formation was defined by Mathews (1947, p. 11) as a succession of weakly resistant shales, shaly sandstone, and sandstone underlain by the ridge-forming quartzite member of the Monteith Formation. It was named from Beattie Peaks which is presumably the type locality. Although Mathews noted some plant fragments in the formation on Mount Frankroy, he considered (1947, p. 11) that the formation "is probably entirely marine".

The base of the succession north of Peace River lies abruptly on massive Monteith sandstones. In the western Foothills, the contact is drawn at the top of Unit 2 of the Monteith Formation. Farther east near Halfway River (sections 62-10, 64-11) and in such nearby wells as HB Cypress a-28-F (a-28-F/94-B-15) and HB Chowade b-18-J (b-18-J/94-B-10), shales and silty sandstones included in Beattie Peaks lie above sandstones considered equivalent to Unit 1 of the Monteith (Fig. 4). Thus, the lower boundary is drawn at the top of lower sandstones as the formation is traced northeasterly

The upper boundary is a regiona erosional unconformity that bevels the strata from south to north and west to east. The unconformity is discussed in greater detail in a following section.

The Beattie Peaks Formation was mapped previously in the Pine Pass map-area (Muller , 1961) which includes the Carbon Creek basin mapped first by Mathews (1947). Irish (1961, 1963), mapping north of Peace River, included all these beds in the undivided Bullhead Group. Equivalent beds in the vicinity of Peace River Canyon were included earlier in the Dunlevy Formation by Beach and Spivak (1944). They described a succession of interbedded sandstone and shale having a thickness similar to that included in the Beattie Peaks and (?) younger beds farther north. However, their section on Mount Gething includes a thick upper succession of medium- to coarse-grained sandstone that probably is partly or wholly equivalent to the type Monach Formation.

Reconnaissance mapping by the writer in the Halfway River and Trutch map-areas indicates that Beattie Peaks and (?) younger beds can be recognized and mapped as far north as Mount Stearns (Fig. 2). They form a broad, recessive succession between the prominent ridge-forming Monteith and Gething sandstones (Frontispiece, Plate IV). Beattie Peaks strata occur at Rainbow Rocks along Peace River but are almost or entirely missing farther east along Butler Ridge. North of Graham River, the shaly succession is partly exposed west of Horeshoe Creek and north of Christina Falls. It is recognized in the western sections along the Foothills but is not present along the eastern Foothills north of Cypress Creek. The most complete exposures are between Cypress Creek and Halfway River on the flanks of the syncline south of Mount Stearns. Only the basal beds are present west of Mount Stearns and the succession is not recognized elsewhere in the Trutch map-area.

The thickness of the Beattie Peaks, according to Mathews (1947, p. 11), is about 1,200 feet on Beattie Peaks, 750 feet at Indian Head, and 600 feet on Beaudette Creek south of Pine River. The formation, according to Muller (1961) is about 1,500 feet thick in the Pine Pass map-area but the locality was not specified. North of Peace River, the succession is in the order of 1,300 to 1,500 feet. The greater thickness of these beds in areas outside the Carbon Creek basin may possibly be due to the inclusion of beds equivalent to the type Monach and younger beds.

Although the upper beds of the succession are beveled by an erosional unconformity, the thickness remains relatively uniform along a line from Christina Falls northward to Halfway River (Fig. 3). The maximum thickness of 1,580 feet was measured north of Christina Falls (section 62-13). Northeast of Mount Laurier (section 62-11), 1,520 feet of strata occur between the Monteith and Gething sandstones. The best exposed section (section 62-10; Plate VIII) near Halfway River is 1,452 feet. A marked decrease was noted south of Cypress Creek (section 64-12) where only 1,126 feet are present. These sediments were apparently eroded almost completely along a line extending northwestward from the mouth of Cypress Creek to beyond Mount Stearns (Fig. 7), as only a few hundred feet are present in eastern exposures near Halfway River (sections 64-11, 62-12).

Three major units, probably sufficiently distinct to be assigned member status, are recognized (Plates VIII, IX). The lower one, consisting of silty mudstone and lenticular sandstones, is possibly equivalent to the type Beattie Peaks. The middle unit, of fine-grained sandstones, may be equivalent to the type Monach Formation. Although sandstones somewhat similar to the Monach are present, they are not as coarse-grained nor as readily differentiated from the enclosing strata as those of the type Monach. The upper succession of interbedded sandstone and shale may correlate with somewhat similar beds between the Monach Formation and Bullhead Group in the Carbon Creek basin.

In contrast to the Monteith Formation, the Beattie Peaks and (?) younger beds contain abundant wackes as well as arenites. Moreover, lithic fragments are much more numerous (Plate X) and may even dominate the over-all composition of some rocks. The higher content of dark rock fragments produces darker coloured rocks and limonite, resulting from oxidation of iron-bearing carbonates, produces shades of brown and brown weathered surfaces.

Quartz generally does not fall below 30 per cent of the total detrital material. Siliceous overgrowths are evident but welding is not so well developed as in the Monteith sandstones, as the presence of clay matrix inhibited its development. Lithic fragments comprise chert, dense siliceous volcanic and argillaceous rocks. Carbonate is common as detrital grains but rarely forms the cementing medium. Carbonaceous material is not abundant.

The heavy mineral assemblage is similar to that of the Monteith, containing much the same varieties of tourmaline, rutile, and zircon.

Unit 1

Strata of Unit 1 in the western Foothills are similar and probably equivalent to the Beattie Peaks Formation of the type region. The Beattie Peaks succession, fairly well exposed on the western slope of Mount McAllister comprises platy siltstone, sandstone, and shale, thinly interbedded. The sandstone occurs in 5- to 50-foot units, is thinly bedded, dark grey to brownish grey, very fine-grained, and finely laminated. Although some of the sediments appear carbonaceous, the reports by Muller (1961) and Hughes (1964) of such fossils as Buchia in equivalent strata within the Carbon Creek basin indicate that much of the succession is of marine origin. The thickness of sandstone units increases toward the top. Considerable festoon crossbedding is evident in the higher beds. In the Carbon Creek basin those beds grade upward into massive beds of medium- to coarse-grained sandstone that Mathews (1947) defined as the Monach Formation.

Although this succession is generally poorly exposed north of Peace River, its position between two more prominent sandstone units permits its delineation and measurement. At the headwaters of Horseshoe Creek (section 62-1), it is about 718 feet and a similar thickness of 703 feet is found farther west to the north of Christina Falls (section 62-13). Unit 2 is not recognized in western exposures north of Chowade River (sections 64-12, 62-11; see Fig. 3) and the whole succession of more than 1,000 feet is similar to Unit 1. A few hundred feet of basal beds are known to be present west of Mount Stearns (sections 62-14, 64-8) but the erosional edge of the Beattie Peaks apparently lies just slightly to the north.

At Rainbow Rocks, much of the Beattie Peaks Formation is covered but appears to consist of numerous sandstones separated by recessive beds. The sandstones there are fine-grained, brown, platy, show considerable crossbedding, and contain some carbonaceous material. Toward the top, more thickly bedded and better sorted sandstones occur which may be equivalent to Unit 2. Farther upslope, the coarse-grained conglomeratic sandstone of the Bullhead Group forms a prominent cliff, marking the upper limit of Minnes strata.

Farther north, Unit 1 is commonly almost or completely covered or only the sandstones outcrop. North of Christina Falls (section 62-13), the basal 128 feet were measured in a small gully to the north of the main ridge. The part exposed consists mainly of silty mudstone with interbedded argillaceous to sandy siltstone. Some very fine-grained laminated sandstone occurs in thin beds. The lower contact at that locality is well defined by the occurrence of the recessive shaly beds overlying thick-bedded sandstone and lenticular conglomerate of the Monteith.

The most completely exposed section is south of Halfway River (section 62-10). The basal shaly beds included in the Beattie Peaks at that locality are at present considered by the writer to be equivalent to massive quartzose sandstone of Unit 2 of the Monteith Formation (Figs. 4, 5); the variation being attributed to a lateral facies change. An alternative correlation could be made by equating the top of the quartzose sandstones in section 62-10 with the top of Unit 2 in such localities as sections 62-11 and 62-15 (Figs. 4, 5), thereby indicating a fairly rapid decrease in deposition northeastward. However, as relationships established in subsurface demonstrate that upper quartzose sandstones in such wells as West Canadian Moberly Lake 11-36 (11-36-80-25, W6) and Imperial Calvan Altares 83-A (83-A/94-B-8) grade laterally into shaly beds in HB Cypress a-28-F (a-28-F/94-B-15) and HB Chowade b-18-J (b-18-J/94-B-10), it seems more likely that a similar facies change occurs in equivalent beds slightly farther to the northwest.

Although the basal 50 feet in section 62-10 do not outcrop, the contact is indicated by a recessive interval above typical massive Monteith sandstones. At that locality, the lower unit consists of an alternating succession of silty mudstone and fine-grained sandstone (Plate VIII). The sandstones are grey, finely and uniformly laminated, generally siliceous, and weather brown to rusty. These sandstones range from platy to thick-bedded and commonly do not form continuous beds. Rather, they occur as lenticular bodies, having many characteristic features of channel-fill. Commonly, the boundaries are sharp and the enclosing beds show definite evidence of having been eroded. In other places, some of the sandstones can be seen to interfinger and grade laterally into mudstone. The tops of the sandstones are generally sharp and straight but the base may be curved. The mudstones are extremely silty and grade upward into sandstone in many places. These rocks weather blocky to flaggy and rusty in colour. In the upper part of the unit, much of the rock is argillaceous siltstone showing fine lamination. Thin beds of shell debris occur sporadically throughout the more shaly beds. Most of the debris appears to be comminuted pelecypods but large fragments of belemnites are fairly abundant. The presence of the belemnites and Buchia indicate that this unit is marine.

Unit 2

The middle unit (2) comprises fine-grained, well-sorted sandstone that may be equivalent to the Monach Formation of the Carbon Creek basin where the Monach conformably overlies the thinly interbedded sediments of the Beattie Peaks. According to Mathews (1947, p. 11) the Monach comprises a succession of medium- to coarse-grained quartzose sandstones with some minor mudstone and siltstone, 300 to 400 feet thick. Coarse-grained sandstone in the upper succession on Mount Gething described by Beach and Spivak (1944, p. 4) is probably equivalent. The formation was not recognized by Hughes (1964) at Grant Knob in Peace River canyon nor is it present in the West Canadian Moberly 11-36 well a few miles farther east (Fig. 3).

North of Peace River, Unit 2 is well developed only along the western Foothills (Fig. 3). Although some sandstone at Rainbow Rocks may possibly represent lower beds of this unit it seems likely that equivalents of Unit 2 were removed by pre-Bullhead erosion. Exposure in this part of the succession does not permit accurate definition throughout much of the region but the unit is approximately 180 feet thick at the headwaters of Horseshoe Creek (section 62-1). A succession of 261 feet occurs farther west, to the north of Christina Falls (section 62-13). An increased thickness near Cypress Creek (section 62-2) to 561 feet may be due to the inclusion of additional strata in the succession. The unit is not well developed in the westernmost section (64-12, 62-11) near Mount Laurier. In the next section east (62-10), 175 feet of sandstone is well exposed, apparently being equivalent to the lower part of the unit of section 62-2. The unit is not recognized north of Halfway River and presumably was eroded in pre-Bullhead time. The erosional edge is drawn near Halfway River, trending southeastward beyond the Foothills toward Peace River canyon.

The basal contact of Unit 2 is not well exposed but seems gradational. It appears to be drawn at the base of different sandstones from one section to another and forms no persistent marker.

The upper boundary appears to be more persistent although its position may vary slightly in the stratigraphic succession. The boundary is commonly marked by the occurrence of coarse-grained sandstone and a few pebbles. Hughes (1964, p. 17) assumed a disconformity was present at the top of the Monach, but that assumption is not substantiated by lithologic evidence nor by available palaeontologic data.

Although much of the section is not well exposed, the sandstones included in Unit 2 appear to increase both in number and total thickness from Halfway River southward to Peace River. This increase in thickness appears to be accompanied by a decreased thickness in the underlying unit. The sandstones of Unit 2 apparently grade laterally northward into mudstones similar to those of Unit 1.

Some of the sandstones are coarse-grained but most are fine-grained. They are grey to brown in colour and commonly weather brownish grey. Carbonaceous material is not abundant. The sandstones are commonly finely laminated and show considerable fine crosslamination.

The sandstone units range from 2 to 60 feet and are separated by recessive units (presumably shale) of a few inches to 30 feet. Bedding is generally thin to flaggy although thicker units may have a massive appearance. The thin-bedded character results in less resistant units and the whole interval tends to weather back almost as much as the overlying and underlying shaly units.

Sandstones of Unit 2 are composed predominantly of quartz grains although chert and other lithic fragments are more abundant than in the Monteith sandstones (Plate X). The grains are well cemented by siliceous cement. Minor chert conglomerate, occurs as small lenticular masses in some sandstones.

Unit 3

The upper unit (3) is not well exposed, forming a recessive interval between the sandstones of Unit 2 and the prominent conglomeratic sandstones of the overlying Gething Formation. The succession contained in this interval may be equivalent to a thick succession of interbedded sandstone and shale overlying the Monach Formation in the Carbon Creek basin.

The lower boundary appears to be drawn above a fairly persistent conglomeratic sandstone although it may vary slightly, being drawn above slightly different sandstones from place to place. The contact is not well exposed but is drawn at the base of shaly beds overlying resistant sandstone. The upper boundary is the pre-Bullhead unconformity which is discussed in detail in the following section.

Unit 3 is well defined in only three sections. It is thickest (616 feet) in the most westerly section (62-13) north of Christina Falls. It decreases eastward to 555 feet at Horseshoe Creek (section 62-1) and to 319 feet between Chowade and Cypress Creeks (section 62-2) on the eastern side of the Foothills. It is not recognized north of Halfway River. The eastward thinning and northward disappearance of this unit is attributed to pre-Bullhead erosion.

In the Carbon Creek basin, sandstones overlying the Monach Formation are fine-grained, brown, finely laminated, crossbedded, and thin-bedded to flaggy. Some of the sandstones are similar to typical Nikanassin sandstones farther south, being extremely finely laminated, black, carbonaceous, limonitic, and weathering orange-brown. The interbedded shales are rubbly to platy, dark olive brown to black, and commonly carbonaceous. No evidence of thick coal seams was noted although coal could be present in the covered intervals. These beds were included by Mathews (1947) in his non-marine Bullhead and are considered by some to be equivalent to the Gething Formation. However, examination of that area indicates that they occur below coarse-grained conglomeratic sandstones at the base of the Bullhead Group.

Unit 3 is similar to Unit 1, and where Unit 2 is not present, no subdivision is made within the succession. Fine-grained, thick-bedded sandstones, 4 to 30 feet thick, are interbedded with recessive units, 5 to 80 feet thick. These recessive units presumably contain argillaceous sediments, and mudstone and argillaceous siltstone are exposed at some places. Near Christina Falls, this unit appears to contain a larger percentage of sandstone. Eastward from there, at the headwaters of Horseshoe Creek, the sediments contain considerable carbonaceous material and one thin layer of coal. The sandstones of this unit are similar to those of Unit 2 but are generally not as thick. Their composition is similar although carbonaceous debris and lithic fragments may be more abundant.

Age and Correlation

The Beattie Peaks and Monach Formations of the Carbon Creek basin are considered to be of Valanginian age. Fauna reported by Hughes (1964) from the Beattie Peaks include Buchia keyserlingi f. typ. and Polyptychites cf. P. keyserlingi. The latter is considered by Jeletzky to be of late early Valanginian age. Buchia keyserlingi f. typ. fauna is now believed by Jeletzky to be essentially of early Valanginian age. As far as known, typical B. keyserlingi et var. and B. sublaevis (Keyserling) are restricted to the Beattie Peaks Formation. Hughes obtained Buchia n. sp. aff. inflata (Toula) and Dichotomites (sensu lato) cf. D. giganteus (Imlay) from the Monach in the type region but Jeletzky considers that this fauna may range through most or (?) all of the Beattie Peaks and all of the Monach Formation. Muller collected B. inflata, B. nov. sp. aff. inflata and B. ex aff. crassicolis from those beds. The association of those forms was considered by Jeletzky to indicate a late middle or early late Valanginian age.

Fauna obtained from Unit 1 and basal beds of Unit 2 of the Beattie Peaks and (?) younger beds include

- Acroteuthis cf. A. subquadratus (Roemer)
- Acroteuthis sp. indet?
- Cylindroteuthis? sp. indet.
- Buchia cf. B. keyserlingi (Trautschold)
- Buchia cf. B. bulloides (Lahusen)
- Buchia aff. B. crassicollis (Keyserling) s. str.
- Buchia cf. B. sublaevis (Keyserling)
- Buchia n. sp. aff. B. inflata (Toula)
- Belemnitacea, genus and species indet.
- Inoceramus prisms
- Inoceramus? sp. indet.

This fauna was commented on by Jeletzky as follows:

> Buchia n. sp. aff. inflata (Toula) and other Buchia ...form part of a fauna widespread in the Peace River region. This Buchia fauna appears to be younger than the Polyptychites ex gr. keyserlingi and Buchia keyserlingi fauna, which occurs in the lower part of the Beattie Peaks

> Formation (at Mount Frankroy). This fauna is considered to be mid- to late Valanginian in age in terms of the international standard stages. It is known to range through middle to upper part of (the) Beattie Peaks Formation and right through the Monach Formation of the Carbon Creek area.

That fauna occurs within the lower 300 feet of the Beattie Peaks in sections from Horseshoe Creek to west of Mount Stearns (Fig. 3). None of the collections obtained during this project was assigned by Jeletzky to the supposedly older fauna of Buchia keyserlingi and Polyptychites ex. gr keyserlingi. It would seem that the latter fauna is either not represented or should occur lower in the succession, that is, within the quartzose sandstones assigned to the Monteith Formation. However, as pointed out in the discussion of the age and correlation of the Monteith Formation, faunal successions and relationships are not yet firmly established. As no fossils have been obtained from the thick upper beds of the Beattie Peaks of this region, considerable doubt exists to their age and precise correlation. Nevertheless, it is apparent that fauna similar to that of the type Beattie Peaks and Monach Formations is present also in lithologically similar beds north of Peace River.

Palaeogeography

The readvance of marine conditions over the Monteith sandstones occurred during early to middle Valanginian time. These transgressive deposits are marked by numerous channel deposits and bank-like accumulations of shell debris. The alternation of silty mudstones and sandstones and the channel-like structures are similar to Recent delta-front and delta-platform deposits of the Mississippi River (Scruton, 1960; Fisk, 1961).

The extent of this marine embayment is largely unknown as much of the record has been removed by pre-Bullhead erosion. Nevertheless, it did extend southward beyond Peace River and eastward beyond the edge of the Foothills. A thick succession of Minnes beds near Kakwa River, described by Ziegler and Pocock (1960) may contain equivalent marine rocks and therefore the southern limits of the embayment is assumed to lie to the south of the Carbon Creek basin.

The better sorted sandstones of Unit 2 are indicative of high energy, nearshore conditions and regression. Lack of stratigraphic control does not permit accurate placement of the margins of the sea but the increased amount of sandstone south of Halfway River suggests a distribution similar to the Monteith environments. If the type Monach is equivalent, its coarser sediments imply a shoreline position in the Carbon Creek basin.

Beds of Unit 3, containing some coal and more carbonaceous material than the underlying units, are, in part non-marine and probably represent, in part, deltaic facies developed as the marine embayment became even less extensive. The occurrence of more sandstone in the western Foothills is suggestive of shoreline environments. Somilar conditions may have existed in the region of Carbon Creek where carbonaceous sediments occur above the Monach sandstone. Without more data, much of the palaeogeography is extremely conjectural.

In summary, the sediments of the Minnes Group were apparently deposited in a narrow trough bordering a western source. The deposition of thick sandstone successions indicates a rapidly subsiding but also rapidly filling basin from late Jurassic time into earliest Cretaceous. This development was related to the rapidly rising Nevadan orogenic belt which disrupted the Cordilleran geosyncline and separated the mid-continent from the Pacific. The southern limits of the marine embayments in which these sediments were deposited were apparently controlled by the Peace River arch which may mark the northern limit of strong Nevadan movements. The Minnes strata were finally truncated by an unconformity which represents a major erosional interval during Hauterivian to (?) Aptian time. The unconformity records an uplift related to the last phase of the Nevadan orogeny.

PRE-BULLHEAD UNCONFORMITY

A regional erosional unconformity separates the Minnes and Bullhead Groups as redefined. The unconformity lies at the base of the Cadomin conglomerates or equivalent Gething sandstones and above successively older beds northward from Peace River and eastward from the Foothills to the Plains. This unconformity, also present south of Peace River, has been discussed by McLearn (1944), McLearn and Kindle (1950), Warren and Stelck (1958), Loranger (1958, 1960), Ziegler and Pocock (1960), Gussow (1960) and Stott (in press)

In the Carbon Creek basin, the conglomeratic beds of the Bullhead Group lie on Minnes beds younger than the Monach Formation. Farther east, those beds and the Monach sandstones are not present at Rainbow Rocks along Peace River although apparently beds equivalent to the Monach are present on Mount Gething. On Butler Ridge and in West Canadian Moberly Lake 11-36 well, the Bullhead Group is in contact with strata low in the Beattie Peaks Formation. The Monteith beds disappear eastward (Stott, in press; Fig. 9) and the unconformity bevels successively older beds of the Fernie Formation. Northward, the Bullhead lies successively on Beattie Peaks strata between Graham and Halfway Rivers (Plate IX), on Monteith sandstones south of Sikanni Chief River, on Fernie shales between there and Richards Creek (Plate XI), and on Triassic rocks farther north (Fig. 10). Similar relationships occur from west to east near Halfway River (Figs. 4, 6). The Bullhead lies on beds probably younger than Monach just northeast of Mount Laurier, and then lies successively on beds equivalent to Beattie Peaks, the Monteith Formation, and finally on basal Fernie beds at Pink Mountain. To the north, Bullhead strata lie directly on the Triassic succession.

Several thousand feet of sediments have apparently been removed along the eastern Foothills and Plains by this pre-Bullhead erosion. More than 3,000 feet of sediments occuring between the Fernie and Bullhead conglomeratic sediments in the Carbon Creek basin (Mathews, 1947, Muller, 1961), are entirely missing in the east near the Alberta-British Columbia boundary. Over 2,800 feet of beds were measured between Triassic and Bullhead strata northeast of Mount Laurier (Plate IX) but the sequence decreases to zero northeastward between there and Pocketknife anticline and northward between Halfway River and Richards Creek. The more or less uniform thickness of overlying Bullhead sediments suggest that no major topographic features were present on the erosional surface. Some erosional features on the pre-Bullhead surface, such as drainage channels, might be anticipated but were not observed.

The position of the contact between the Bullhead Group and the underlying sediments is commonly distinct and readily determined. In the more southerly part of the region and particularly around Peace River, prominent conglomeratic beds of the Cadomin Formation rest abruptly on the argillaceous recessive beds of the Minnes group without gradation. North of Graham River, the thick conglomerates of the Cadomin are replaced by massive sandstones included in the Gething. The contact with the underlying recessive shales of the Minnes or Fernie remains distinct. However, in a few places where the Gething lies directly on the massive upper sandstones of the Monteith sediments, the contact is more difficult to define because of some similarity of lithology. It appears that part of the Monteith sandstone has been reworked and redeposited within the Gething sediments. Nevertheless, the occurrence of conglomerates and increasing abundance of chert is generally sufficient evidence to differentiate the two sandstones. In some places, particularly near Nevis Creek, fine- to very fine-grained quartzose sandstones resemble some Monteith sandstones but are overlain with no apparent break by typical Gething sediments and therefore were included in the Gething Formation. It was concluded that since the Monteith could contribute only quartz-rich detritus that the basal Gething sandstones would be similar but reduced in grain size.

As illustrated in cross-sections (Figs. 4, 5, 6, 9; *see also* Stott, *in press*, Figs. 3-5), the unconformity is regionally angular but that relationship is not generally apparent in surface outcrop (Plates IX, XII) where the sequence commonly has a conformable appearance. No deep channelling was noted.

The youngest known fossils below the unconformity in the Carbon Creek basin are those from the Monach Formation dated by Jeletzky as middle to late Valanginian. Fossils of Valanginian age characteristic of the Beattie Peaks Formation were collected from many localities north of Peace River. The Monteith fossils of the Carbon Creek area were dated by Jeletzky as Berriasian to early Valanginian. The Bullhead Group, therefore, in the more westerly part of the region, rests on beds as young as middle to late Valanginian age; in the eastern Foothills, on early Valanginian to Berriasian beds; and eastward on the Plains or northward beyond Halfway River on the Jurassic and finally on Triassic sediments. These relationships indicate that the major erosional period was in post-Valanginian time. As the overlying Bullhead can be dated as pre-middle Albian by its position below dated marine Bucking horse shale, the major erosional period can be dated as occurring within the interval of Hauterivian to (?) Aptian.

ECONOMIC GEOLOGY

Cretaceous rocks of the Foothills and Plains are generally noted for their production of coal, petroleum, and natural gas. Although coal is present within post-Fernie sandstones farther south in the Foothills, the

Minnes Group of this region is predominantly marine and contains only a few thin coal seams. The major economic interest, therefore, is in the petroleum and gas possibilities.

Cretaceous sandstones are productive in several fields east of the Alaska Highway and north Fort St. John on the Plains. Some of the petroleum and gas is obtained from quartzose sandstones that may be equivalent to the Monteith Formation of the Foothills. In 1964, gas was discovered in Nikanassin sandstones (Minnes equivalent) within the Foothills south of Pine River in Gray Oil PRP NW Grizzly C-25-A well (C-25-A/93-I-15). No production has been obtained from Cretaceous sediments in wells drilled within or near the Foothills north of Peace River.

Even though there is a lack of production from these sediments in the region between the Foothills and the Alaska Highway, the presence of dried bitumen and porous strata suggest that that region may have potential. Some decrease in porosity and permeability by cementation, may occur, however, where the strata are deformed within the Foothills.

The Monteith sandstones and equivalent strata are fairly widespread in northeastern British Columbia, being present in subsurface southeast of Pine River and extending northwesterly along the Foothills for 100 miles. The eastern limit of those rocks lies slightly east of the Alaska Highway trending southeastward from near Pink Mountain to Peace River at the British Columiba-Alberta boundary. Determination of the erosional edge will be critical in determining potential areas. The Monteith sandstones occur mainly as sheet-like deposits that can be expected to be encountered throughout most of the region outlined. Some indications were noted of a southeastward facies change to carbonaceous and shaly sediments that would reduce the overall thickness of porous rock. Near its erosional limit, the upper, more massive and porous part is reduced by pre-Bullhead erosion.

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PLATE II (DFS 4-5-63)

Fernie Formation on south side of Triangulation Station with elevation 6,596 feet, Halfway map-area, south of Cypress Creek. Nordegg Member (N) forms more prominent unit at lower left. Units 2-6 are exposed along side of gully. Upper beds are transitional into overlying Monteith sandstones (M). Section 62-15.

PLATE III (DFS 3-1-63)

Transition beds at top of Fernie Formation, peak east of Headstone Creek (section 62-7). Contact with Monteith occurs near top of gully. Uppermost beds are Gething.

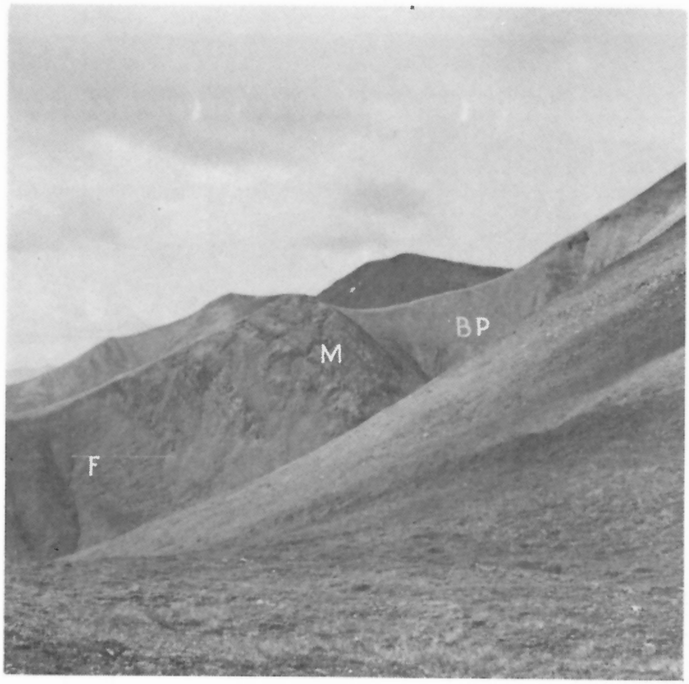

PLATE IV (DFS 3-8-63)

Typical topographic expression of Fernie (F), Monteith (M), Beattie Peaks and (?) younger beds (BP); looking south on ridge between Halfway River and Cypress Creek (section 62-10).

PLATE V (DFS 6-4-61)

Massive beds of Monteith quartzose sandstone; east side of Mount McAllister, Carbon Creek basin.

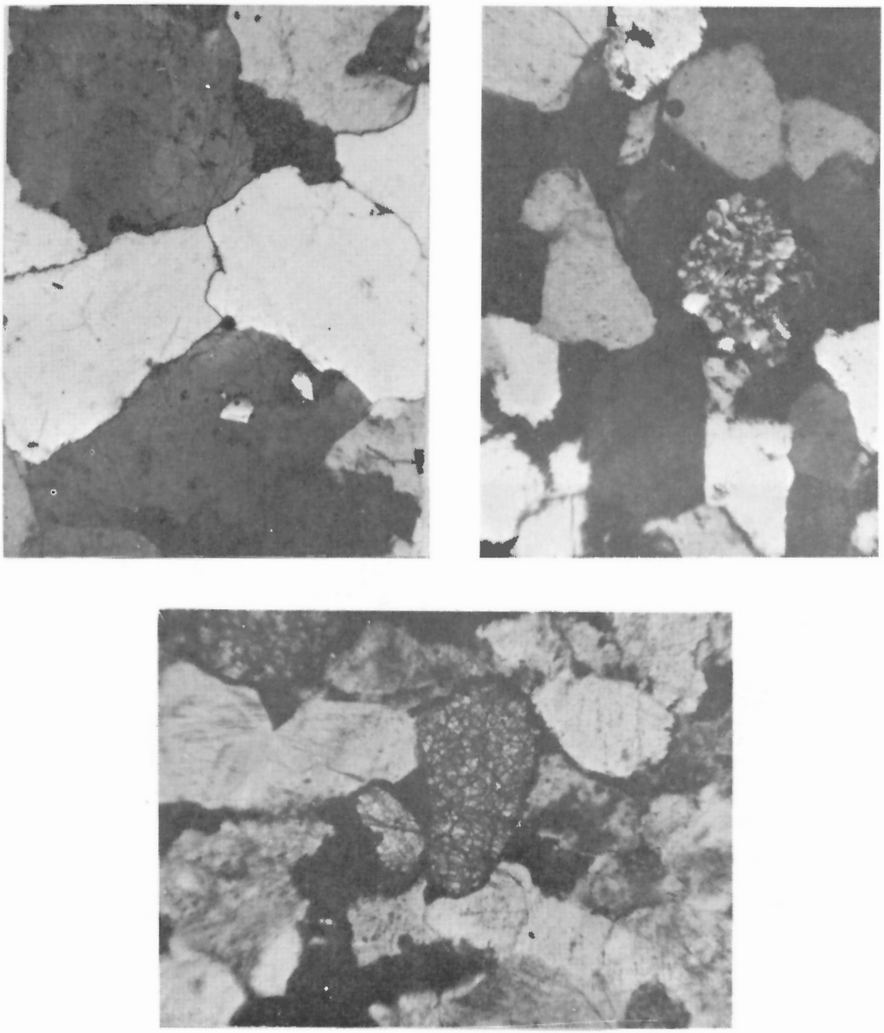

PLATE VI

Microphotographs of Monteith sandstones

a. Quartzose arenite, showing the development of siliceous overgrowths and resultant "welding" of grains and filling of pore-space. x30.

b. Quartzose arenite, with minor grains of chert. x30.

c. Lithic arenite composed predominantly of quartz but containing chert and carbonate detritus. x30.

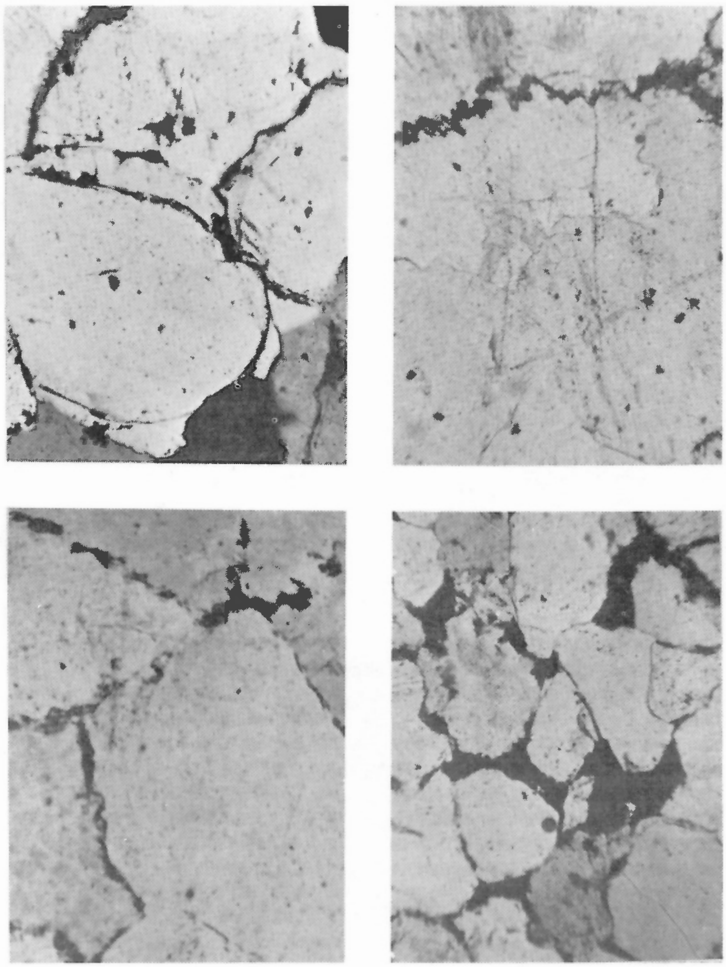

PLATE VII

Microphotographs of Monteith sandstones

a. Well rounded grains of quartz showing development of secondary silica. x90.

b. Prominent suturing developed along edges of quartz grains. x90.

c. Bitumen forms incomplete rims around quartz grains and fills pore spaces. x90.

d. More abundant bitumen surrounds and separates many grains. x30.

PLATE VIII (DFS 3-7-63)

Well exposed section of Beattie Peaks and (?) younger beds showing typical interbedding of silty sandstone and mudstone of Unit 1; looking northwest toward headwaters of Halfway River (section 62-10). Thick-bedded fine-grained sandstone (2) lies below interbedded recessive sandstone and shale (3) toward top of ridge at left. Uppermost beds to right of snow patches are basal conglomerates and sandstones of Gething Formation (G).

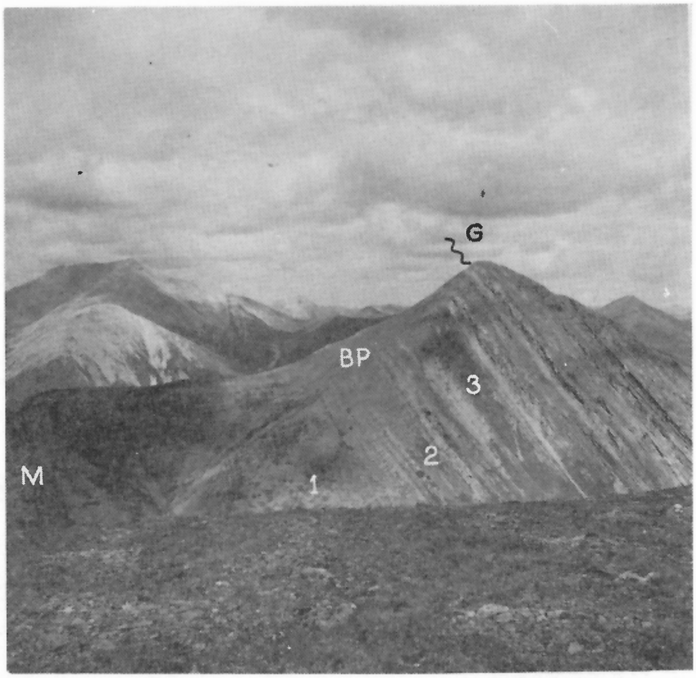

PLATE IX (DFS 3-12-63)

Unconformity between Gething Formation (G) and underlying Beattie Peaks and (?) younger beds (BP) occurs just to left of the main peak; note the lack of any marked discordance within the succession. Low ridge at base of Beattie Peaks formed by Monteith sandstones (M). Units of Beattie Peaks and (?) younger beds (1-3) are not too well defined here.

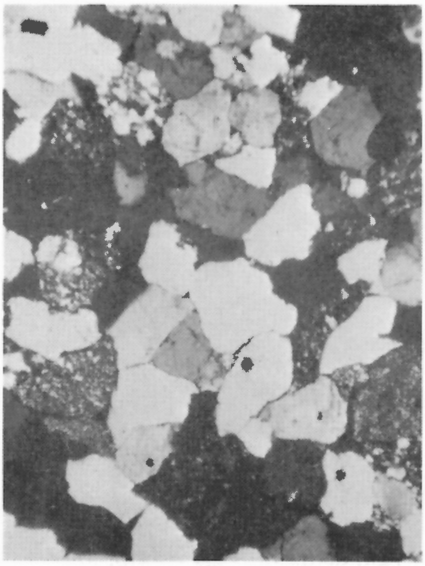

PLATE X ·

Microphotographs of upper Minnes sandstones

a. Lithic arenite composed of quartz and chert, showing general texture and cementation of grains. x30.

b. Lithic arenite composed of quartz and chert, showing varieties of siliceous cherty fragments and the "welding" of grains. x90.

PLATE XI

Fernie Formation (F) below major unconformity at base of Gething Formation (G), ridge east of Marion Lake. Underlying beds are Triassic (Tr). Note that Gething beds still parallel the underlying strata despite the removal of the thick succession of Minnes strata as seen in Plate IX.