MEMOIR 317

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D. F. Stott

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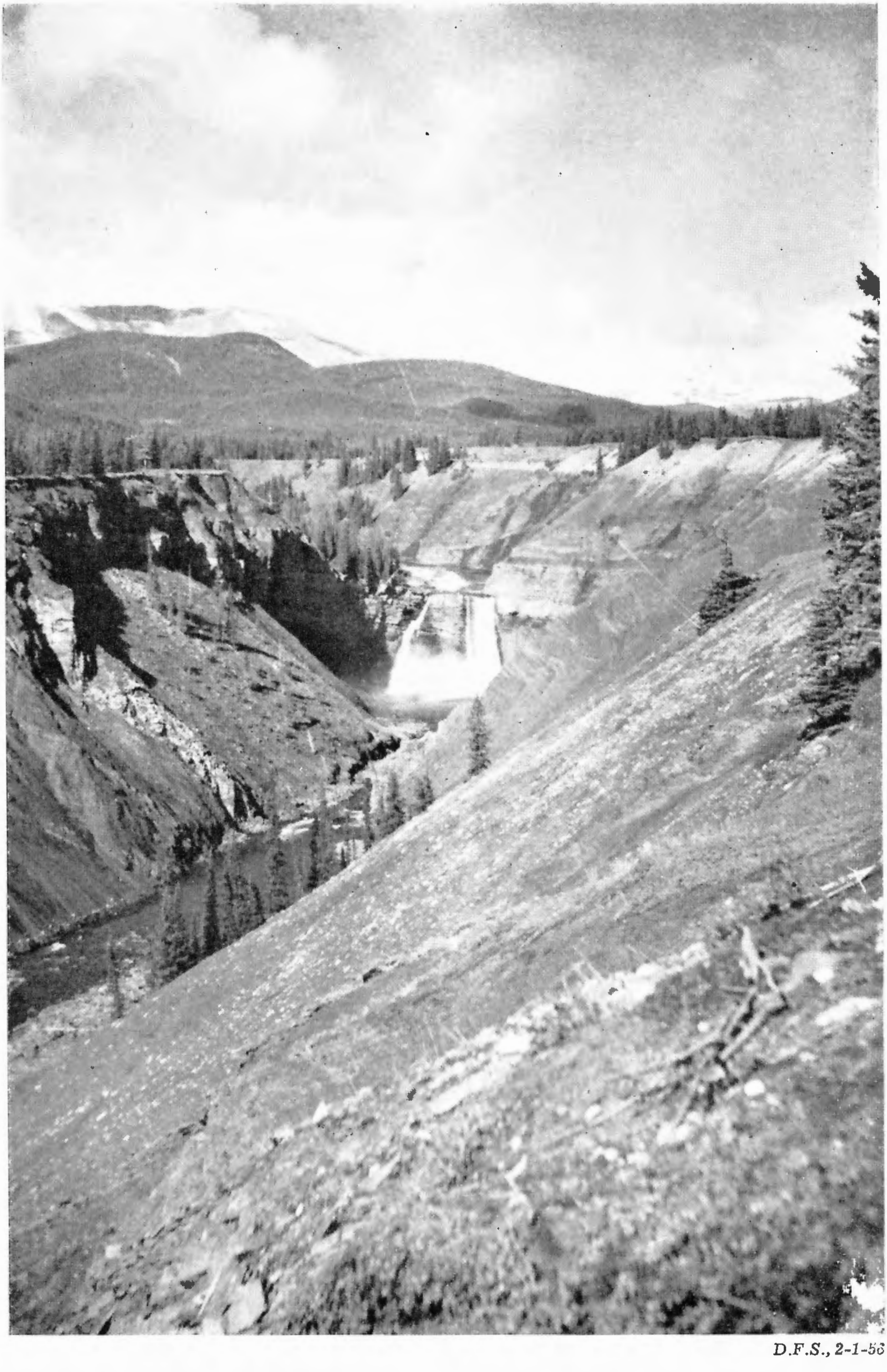

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Plate I. *Alberta group at Ram Falls, Cripple Creek map-area. Falls formed by Sturrock member, Cardium formation, on west flank of anticlinal fold. Shales above falls are part of Muskiki member, Wapiabi formation. Ram Range in the background.*

GEOLOGICAL SURVEY
OF CANADA

MEMOIR 317

THE CRETACEOUS ALBERTA GROUP AND EQUIVALENT ROCKS, ROCKY MOUNTAIN FOOTHILLS, ALBERTA

By
D. F. Stott

DEPARTMENT OF
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PREFACE

In the Rocky Mountain Foothills of Alberta, Cretaceous shales and sandstones, predominantly of marine origin, are assigned to the Alberta and Smoky groups. This memoir describes in detail the sequence from the United States border on the Forty-ninth Parallel to Smoky River on the Fifty-fourth Parallel. As the rocks are traced from one area to another, important facies changes occur that are significant for future petroleum exploration. The Cardium formation especially, which in the Pembina field forms one of Canada's largest potential petroleum reservoirs, is shown to have prospects of providing even greater reserves than are known at present.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, November 1, 1959

CONTENTS

PAGE

Illustrations

THE CRETACEOUS ALBERTA GROUP AND EQUIVALENT ROCKS, ROCKY MOUNTAIN FOOTHILLS, ALBERTA

Abstract

The Alberta group and equivalent rocks, of mainly Upper Cretaceous marine sandstones and shales, have been studied in the Alberta Foothills along the Canadian Rocky Mountains between latitude 49°00′ and 54°00′.

The Blackstone, Cardium, and Wapiabi formations, for which type sections are defined, compose the Alberta group. Equivalent beds overlying the sandstone of the Dunvegan formation in the northern Foothills have been assigned to the Smoky group which includes the Kaskapau, Cardium, and Wapiabi formations. Shales of the Fort St. John group underlying the Dunvegan formation are equivalent to the basal beds of the Blackstone formation. The Blackstone formation, consisting of the Sunkay, Vimy, Haven, and Opabin members, is predominantly marine shale. The Cardium formation, distinctive for its marine sandstones, also contains nonmarine beds which increase in thickness towards the northwest. It consists of the Ram, Moosehound, Kiska, Cardinal, Leyland, and Sturrock members. The Wapiabi formation, containing sideritic and calcareous shales and sandstones, is subdivided into the Muskiki, Marshybank, Dowling, Thistle, Hanson, Chungo, and Nomad members. The upper three members are equivalent to the basal beds of the Belly River formation in southern Alberta.

Cyclic sedimentation is evident in these rocks and two major cycles are defined: the basal one consists of the shales of the Blackstone formation and sandstones of the Cardium formation; the upper cycle consists of the shales and sandstones of the Wapiabi formation. These two major cycles contain minor cycles, which in turn are composed of subcycles. Sideritic shales were deposited under restricted conditions in a shallow, epicontinental sea, but calcareous shales were formed under more normal marine conditions. At the top of each of the two major cycles, sediments of brackish or lagoonal environments and of the epineritic zone are recognized.

This Cretaceous sequence contains rocks that range in age from the late Albian *Neogastroplites* zone to the Campanian *Scaphites hippocrepis* zone, or later. Major advances of the sea occurred in early Turonian and early Santonian time; major retreats occurred in late Turonian and late Santonian time.

Résumé

L'auteur a étudié dans les Contreforts des Rocheuses en Alberta, en bordure des montagnes Rocheuses, entre les parallèles 49 et 54, le groupe Alberta et des roches équivalentes, lesquels sont surtout composés de grès et de schistes marins du Crétacé supérieur.

Le groupe Alberta comprend les formations Blackstone, Cardium et Wapiabi. Des coupes types de ces formations y sont décrites. Dans la partie nord des Contreforts des Rocheuses, des couches équivalentes qui recouvrent le grès de la formation Dunvegan ont été placées dans le groupe Smoky qui comprend les formations Kaskapau, Cardium et Wapiabi. Les schistes du

groupe Fort St. John, sous-jacents à la formation Dunvegan, sont analogues aux couches de base de la formation Blackstone. Cette dernière, composée des niveaux Sunkay, Vimy, Haven et Opabin, est formée presque entièrement de schiste marin. La formation Cardium, composée des niveaux Ram, Moosehound, Kiska, Cardinal, Leyland et Sturrock, et caractérisée par la présence de grès marin, contient aussi des couches non marines dont l'épaisseur s'accroît en direction du nord-ouest. La formation Wapiabi, qui est formée de schistes et grès calcaries et sidériques, comprend les niveaux Muskiki, Marshybank, Dowling, Thistle, Hanson, Chungo et Nomad. Les trois niveaux supérieurs de cette formation correspondent aux couches de base de la formation Belly River du sud de l'Alberta.

La notion de cycle sédimentaire est apparente dans ces roches. Deux cycles majeurs bien distincts furent reconnus: le cycle inférieur est composé des schistes de la formation Blackstone et des grès de la formation Cardium, tandis que le cycle supérieur est formé des schistes et grès de la formation Wapiabi. Chacun de ces cycles est subdivisé en cycles mineurs, lesquels sont eux-mêmes subdivisés en sous-cycles. La déposition des schistes sidériques s'est effectuée dans des conditions restreintes dans une mer épicontinentale peu profonde, contrairement aux schistes calcaires dont les conditions de déposition en milieu marin ont été plus normales. A la partie supérieure de chacun des deux cycles majeurs, on a reconnu des sédiments déposés en des milieux saumâtres ou lagunaires et des sédiments de la zone épinéritique.

Cette succession crétacée contient des roches dont l'âge varie de la zone à *Neogastroplites* de l'Albien supérieur à la zone à *Scaphites hippocrepis* du Campanien ou remonte à une date postérieure. De vastes transgressions marines ont eu lieu au Turonien et Santonien inférieurs; cette région fit l'objet de régressions marines fort importantes au Turonien et Santonien supérieurs.

INTRODUCTION

The Alberta group and equivalent rocks consist of a sequence of shales and sandstones, predominantly of marine origin, and mainly of Late Cretaceous age. Some nonmarine beds are present but form only a minor part of the sequence. The Alberta group and its equivalents have been studied in a region approximately 400 miles long, covering more than 15,000 square miles (*see* Figs. 1 and 2). Studies have been made of numerous sections in surface outcrop within this area, and were directed towards providing detailed lithologic correlations of the strata, indicating their lateral variations, adding to their palæontological data, determining their general environment of deposition, and outlining their potentialities as possible sources of oil and gas.

During the course of these studies, the nomenclature has been revised to eliminate overlapping terminology developed in different areas. Type sections have been described for the Blackstone, Cardium, and Wapiabi formations, and the members within the formations have been named and defined with type sections.

A cyclic type of deposition was interpreted in these rocks and is described in some detail. Recognition of minor cycles within members has resulted in more refined correlation than heretofore attempted, and has proved useful in areas of rapid facies change.

Field Work and Acknowledgments

This report is based on a thesis submitted for the degree of Doctor of Philosophy in Princeton University. Research facilities and financial assistance were provided by that institution from 1954 to 1957, and Dr. E. Dorf and Dr. F. B. Van Houten, professors of geology, gave advice and constructive criticism during the course of the study.

The field work was initiated in 1954 under the direction of R. J. W. Douglas, and continued during the field seasons of 1955 and 1956, and for three weeks in 1957 when some critical exposures were re-examined between McLeod and Crowsnest Rivers.

The biostratigraphical part of this study is based on the fossil identifications of J. A. Jeletzky of the Geological Survey of Canada who has commented in detail on the regional correlations. Jeletzky's zonal and stage assignments have served as the basis of correlation except where otherwise stated. Microfaunal identifications were made by R. T. D. Wickenden.

Competent assistance was given in the field during the season of 1954 by R. Dawson, J. Hawryszko, and J. N. Arthur; in 1955 by J. W. Murray; in 1956, by M. N. Chernoff; and in 1957, by R. K. Broeder.

Dr. J. C. Sproule and Dr. C. R. Stelck kindly informed the writer of several well-exposed sections which proved useful in correlation. The writer has benefitted also from discussions with Dr. F. G. Fox.

For their assistance and many acts of kindness, the writer is indebted to Messrs. L. Bello, J. Kostynuk, C. Luger, C. St. Denys, Mr. and Mrs. S. Nelson, Mr. and Mrs. S. L. Nelson, and the forest rangers of the Eastern Rockies Conservation Board.

Access

The area from Entrance on Athabasca River to Muskeg ranger station, 70 miles north, is accessible from a forestry road. From this road, pack-trails follow the main streams. Some seismic roads have been cut, but are good for travel only when the ground is frozen.

The area between McLeod River and Brazeau River contained no roads, although one or two are now under construction there. Good forestry trails are present from which most sections can be reached by pack-horse. The fords on Brazeau River are dangerous during peak run-off, and local forestry officers or packers should be consulted as to the best crossing.

A forestry road, formerly a well-site road, is usable between Nordegg and Chungo Creek, a distance of about 20 miles. This road extends almost to Brazeau River but bridges were out during the field seasons. Sections west of the Bighorn Range may be reached by pack-trails. A new forestry road connects Nordegg in the north with the region around Bow River. As this road has been built in valleys of Wapiabi or Blackstone shales, sections are generally not far from the road. From Bow River southward forestry or seismic roads are present in all the major valleys, and travel is relatively easy with a vehicle built for rough roads.

Structural Geology

The Alberta group outcrops in the Foothills of the Canadian Rocky Mountains. The Foothills form a structural and topographic province in Alberta that extends from the International Boundary in the south to a region west of Peace River in British Columbia.

The western boundary of the Foothills is drawn at the eastern base of the Front Ranges which rise in steep cliffs of Palæozoic sedimentary rocks several thousand feet above the hills and valleys of the Foothills. The eastern edge of the Foothills may be drawn where the underlying Mesozoic and Palæozoic strata are not disrupted by faults.

Within the Foothills, a series of folds and faults extend northward from the southern boundary. These have an *en échelon* pattern which swings towards the west as they are traced northward. The strike of the faults and that of the axial planes of the folds vary. South of Crowsnest Pass, the general strike is northwest. A major deflection occurs north of the Pass, and the strike assumes a northerly direction. This deflection is associated with the Lewis thrust which, south of the Crowsnest Pass, causes Precambrian rocks to lie on Cretaceous rocks, and north of the Pass, causes Palæozoic rocks to lie on Cretaceous rocks. The trend continues to near North Saskatchewan River where the structures assume a northwesterly strike.

Deformation within the Foothills increases from east to west. Along the eastern side, open folds occur in late Cretaceous and Cenozoic sedimentary rocks, but the folds become more compressed, and more faults occur westward. The thrusts cause beds of much older age to lie upon Cretaceous rocks. Palæozoic rocks are exposed in 'outliers' beyond the Rocky Mountains proper, and are brought to the surface in large folds or thrust blocks of large displacement. These outliers have an *en échelon* pattern, as illustrated by the Bighorn and Nikanassin ranges.

A series of folded faults is found within the Foothills. The faults in the vicinity of Brazeau River have been described by Hake, *et al.* (1942)[1] and by Scott (1951). Within the region of these faults, numerous sections of the Alberta group are well exposed.

Historical Review

Southern and Central Foothills

The earliest reference to Cretaceous sedimentary rocks in the Foothills of Alberta was made in the *Palliser Report* by Hector (1861, 1863) who described the geology along Bow River. Although reference has been made by several geologists to Hector's use of the name *Cardium* for the Cretaceous marine shales along Bow River, no trace of this usage has been found in his publications. The earliest mention of Cardium shales is by Whiteaves (1895, p. 110) who identified fossils collected by Hector. He reported: "Six specimens in the collection, labelled 'Cardium shales, Old Bow Fort' contain numerous imperfect casts of the interior and moulds of the exterior of the shell of a small species of Cardium". Whiteaves indicated also that Hector visited Bighorn Creek near North Saskatchewan River in September 1858, and collected fossil specimens from the 'Ostrea shales'. These shales are probably equivalent to those referred to as Cardium shales on Bow River.

The other main reference in the nineteenth century to Cretaceous beds in southern Alberta was made by Dawson (1884) who, with McConnell, another pioneer geologist, described the lithology and structure of a large area south of Bow River. Dawson called some of the rocks the Laramie series and the Cretaceous series. Dawson's Cretaceous series consisted of the Fox Hills, Pierre, Belly River formations, and Dark Shales, but unfortunately his correlations with Cretaceous rocks of the United States were not correct. However, his report did indicate the extent of the Cretaceous rocks, and formed a basis for later work.

The first detailed description of the Cretaceous shales and sandstones was given by Cairnes (1906, p. 62) from the Moose Mountain district in the Foothills

[1] Names and/or dates in parentheses are those of references cited in Bibliography.

southwest of Calgary. He applied the names Claggett and Niobrara-Benton to the upper and lower shales (*see* Table I) because he considered them equivalent to shales of the same names in the United States. The beds overlying this sequence were equated with the Judith River formation, but later (1915) they were called Belly River. Cairnes wrote of the sandstones on Bow River (p. 62): "Specimens of *Cardium* resembling *C. speciosum* are very plentiful in this sandstone series and on that account Dr. Hector, in 1858, called the whole shale series the 'Cardium shales'." As Harris (1954) has pointed out, Cairnes (1907, p. 29) restricted the term Cardium to the sandstone member within the series, and therefore, the name as used thereafter was defined by Cairnes. The confusion in identification of the shales as Claggett and Niobrara-Benton is reflected in Cairnes' correlation of the Cardium sandstone, which is in the middle of the shales and actually below the Niobrara equivalent, with the Eagle sandstone which is above the Niobrara.

The stratigraphic relations were corrected by Rose who was working in the Highwood area. He stated (1920, p. 17c):

> The Cardium sandstone, however, does not lie at the top of the Benton shale nor is it to be correlated with the Eagle sandstone as suggested by Cairnes of the formations to the north. A heavy sandstone at the base of the Allison formation corresponds stratigraphically to the Eagle formation, and the shales between the Cardium sandstone and the base of the Allison formation, which Cairnes designated as belonging to the Claggett formation, are here included with the Cardium sandstone and the lower shales and sandstones, in the Benton formation.

Malloch (1911), working farther north in the Bighorn basin near North Saskatchewan River, gave a description of marine Cretaceous beds, and divided them into three formations to which he applied the names Blackstone, Bighorn, and Wapiabi. The shales of the Blackstone formation lying on the 'Dakota' formation[1] were overlain by bands of sandstone, shale, and conglomerate which comprised the Bighorn formation. The shales between the Bighorn formation and Malloch's Brazeau formation were placed in the Wapiabi formation. Malloch believed the sequence was not of precisely the same age as the similar beds described by Cairnes.

For the next twenty-five years, Cairnes' nomenclature was used in the south and Malloch's was favoured in the north. Slipper (1921, p. 8), working west of Turner Valley, observed a sandstone within the Benton formation about 700 feet above the base. The sandstone was designated the Lineham member, which is apparently equivalent to the Cardium formation of the present study.

In a study of the geology along Bow River, Rutherford (1927) showed that the term Benton applied to only a part of the Colorado group[2] as defined in

[1] The name 'Dakota' has been replaced by 'Blairmore'.

[2] Hayden (1876) and King (1876, 1878) originally included the Fort Benton, Niobrara, and Fort Pierre formations of the Cretaceous sequence in the Colorado group. A study of the fauna by Meek (1876) and work by White (1878) resulted in the restriction of the Colorado group to include only the Niobrara and Fort Benton formations. Cobban and Reeside (1952b) restricted its use to beds of Late Cretaceous age.

the United States, and considered the name Colorado to be more appropriate for the marine shales overlying the Blairmore formation[1]. He divided the Colorado group into the Lower Benton, Cardium, and Upper Benton formations. The designation of formational status to the Cardium sandstone was the first application of the name as a unit of formal stratigraphic rank. Rutherford suggested that the Bighorn formation and the Cardium formation were probably stratigraphically equivalent and of the same geologic age.

A further study of the Cretaceous rocks north of North Saskatchewan River by Warren and Rutherford (1928) resulted in a detailed palæontological report. Two of the zones established coincided approximately with lithologic units, and the names Barren zone and the overlying *Inoceramus labiatus* zone, were applied to the distinctive rock units by many geologists.

Farther south, in the Highwood-Turner Valley area, Hume (1930, p. 6B) proposed the new name Alberta for the marine shales between the Blairmore and Belly River formations. He stated:

> Since the so-called Benton formation of western Canada is obviously not the Fort Benton of the Missouri River sections and since the name Colorado shale is not applicable and has been used to include strata between the so-called Dakota and Montana, it is proposed to introduce a new name—Alberta shale—for the marine strata lying between the Blairmore and Belly River formations.

That Hume intended the Alberta shales to include rocks younger than those of Colorado age is clearly evident in his statement: "It has been shown that the upper part carries a marine Montana fauna, whereas the remainder of the formation is, so far as known, Colorado".

A regional study of the Alberta shales by Webb and Hertlein (1934) in the Foothills between Crowsnest Pass and Brazeau River has formed the basis of much of the more recent work. They suggested that the Alberta shale of Hume be elevated to group status and recognized three formations within the group (*see* Table I). They suggested that the names Blackstone and Wapiabi be extended to equivalent beds in the Alberta group but thought the name Bighorn should be replaced by Cardium. Within the Blackstone formation, four lithologic subdivisions were recognized and these were, in ascending order: Barren zone[2], *Inoceramus labiatus* zone, Rusty shale zone[2], Transition zone. Three unnamed members of the Cardium formation were outlined: a lower sandstone member, a middle shaly member, and an upper sandstone member. Four lithologic zones were established for the Wapiabi formation: Lower concretionary shale zone, Platy shale zone, Upper concretionary shale zone, Transition zone. It should be noted that the transition zones between shales and overlying sandstones were

[1] Leach (1912, Map 107A) used Blairmore for Lower Cretaceous sandstones which had previously been called Dakota. In recent years, the Blairmore rocks have been treated as a group by some geologists.

[2] Divisions of the younger Pierre shale had been called Barren zone and Rusty zone by G. K. Gilbert (1897: Pueblo Folio, Colorado; Geologic Atlas of United States, Folio 36, p. 3) and by C. S. Lavington (1933: Montana group in Eastern Colorado; Bull. Amer. Assoc. Petrol. Geol., vol. 17, No. 4, pp. 397-410).

included in the formation consisting predominantly of shale. In addition, a sandstone which occurs in the upper part of the Wapiabi formation in the Highwood River region was named the Highwood sandstone.

Another subdivision of the Alberta group was made by Hake, *et al.* (1942) in a report dealing mainly with a complex of folded thrusts near Brazeau River. The unravelling of these structures required a detailed knowledge of the stratigraphy. They included the transition zones with the overlying sandstone formations (*see* Table I). The Blackstone formation, containing those beds lying below the concretionary shales, consisted of the Barren zone, the *Inoceramus labiatus* zone, and the Hydrogen sulphide zone (the Rusty shale zone of Webb and Hertlein). The name Bighorn was used for the middle formation divided into the Transition zone, Lower sandstone, Lower shale, Middle sandstone, Upper shale, and Upper sandstone. The Wapiabi formation was subdivided as follows: Striped zone, Lower concretionary zone, Platy shale zone, Upper concretionary zone, and Blocky zone.

Scott (1951), in a study of folded faults south of Brazeau River in the same area, reverted to the main subdivisions and names of Webb and Hertlein, but also recognized, near the top of the Wapiabi formation, a siltstone unit which was equivalent to the Blocky zone of Hake, *et al.*

Lithologic descriptions of the Cretaceous marine rocks have been given by Evans (1930) for several sections between Bow River and North Saskatchewan River, and by Allan and Rutherford (1923, 1924) for outcrops between Saskatchewan and Athabasca Rivers. Additional palæontological data have been given by McLearn (1937).

In a preliminary report on the Alberta group, the author (Stott, 1956b) used divisions that were similar to those of Scott. The recognition of a siltstone unit in the basal part of the Wapiabi formation resulted in the descriptions of seven subdivisions for the formation.

Northern Foothills

Selwyn (1877) described Cretaceous rocks in the Smoky River area. G. M. Dawson visited the Pine and Smoky areas on an exploration trip between Port Simpson on the Pacific Coast and Edmonton in 1879 and recognized the Cretaceous age of the sandstones, conglomerates, and shales. He stated (1881, p. 114b): "I can see no reason to doubt that (the sandstone series) forms the coarse littoral portion of the Cretaceous rocks which spread so widely to the eastward." Dawson proposed the following subdivisions (*see* Table I), in descending order (p. 115b): Wapiti River sandstones—upper sandstones and shales with lignite coals; Smoky River shales—upper dark shales; Dunvegan sandstones—lower sandstones and shales with lignite and true coals; Fort St. John shales—lower dark shales. Fossils collected from near the top of the upper shales were identified as forms similar to those of the Pierre group of the Missouri region.

McLearn (1919b) described in some detail the Cretaceous sequence on Smoky River. He applied names used by Dawson to units which he designated as formations. Fort St. John was shortened to St. John (a suggestion that has not been followed). The Smoky River formation was "divided on lithologic grounds into three members, a lower shale, a middle sandstone—the Bad Heart sandstone, and an upper shale". The lower shale was said to contain paper-thin carbonaceous shales with concretions and thin-bedded sandstone. Fossils recognized at the top of this unit included *Inoceramus umbonatus* Meek and Hayden and *Inoceramus* cf. *I. deformis* Meek. McLearn stated: "The Bad Heart sandstone member consists of 10 to 25 feet of coarse sandstone, weathering reddish brown . . . The higher part at least of the upper shale member of the Smoky River formation is Montana."

The name Fort St. John has been used for different units of rock (McConnell, 1893; McLearn, 1919; McLearn, 1932) but in 1943, Wickenden and Shaw followed McLearn (1919b) and used the name for the stratigraphic succession between the Bullhead and Dunvegan rocks, and at the same time raised it to group rank.

The name Kaskapau was applied by McLearn in 1926 to the lower shale member of the Smoky River formation. McLearn and Henderson (1944; *see also* Crickmay, 1944) raised the Smoky River formation to group status (without specifically indicating their intentions) and proposed "that the name 'Smoky River' as formerly used, be shortened to 'Smoky'." McLearn and Kindle (1950, p. 102) indicated that "It is now the practice to treat the Kaskapau, Bad Heart, and Upper Shale as formations, and the Smoky as a group (McLearn and Henderson, 1944; Crickmay, 1944; Gleddie, 1949)".

McLearn and Kindle (1950, p. 102), in a summary of the geology of northwestern Alberta and northeastern British Columbia, made reference to the inclusion of the Bad Heart sandstone in the 'Bighorn' (Cardium) sandstone. Gleddie incorrectly correlated the Bad Heart formation, and included it in his Cardium formation. This misuse was pointed out by Stelck (1955), who used Cardium for beds approximately equivalent to the Cardium formation of southern Alberta. Stelck retained Bad Heart as a member of the Wapiabi formation. Harding (1955), in several stratigraphic cross-sections, showed the Bad Heart sandstone to be above the Cardium formation, and tentatively correlated it with "a glauconitic sandy zone high in the Lower Concretionary member of the Wapiabi formation". This correlation is substantiated by palæontological evidence obtained during the present study.

Both Gleddie and Stelck applied Kaskapau to the shale beds between the Dunvegan and Cardium equivalents, thus using the term for a smaller unit than originally defined by McLearn.

Gleddie (1949, 1954, p. 501) proposed that the name Chinook be applied to a littoral marine sandstone and sandy shale member occurring in the 'Wapiabi' below the basal sandstone of the overlying Wapiti formation. This sandstone is probably equivalent to the sandstone at the top of the Wapiabi formation farther south.

MacVicar (1924, p. 34), working between Athabasca and Smoky Rivers, named a "great thickness of dark massive shales" the Berland shales. From their described stratigraphic position, these beds are regarded as equivalent to the Alberta and Smoky groups, but the name has not been used.

Nomenclature

In a discussion of the stratigraphy of intertonguing rock units, the nomenclature should facilitate the description of the units. Such units should also be defined to meet the requirements of various scales of structural mapping. A system of nomenclature which satisfies the precise requirements of both can become unnecessarily complex, and accordingly some compromises are made to keep the nomenclature relatively simple.

In southern Alberta, marine Cretaceous rocks of the Foothills have been included in the Alberta group which consists of the Blackstone, Cardium, and Wapiabi formations. In the Peace River area, the equivalent sequence has been assigned to the Smoky group, the Dunvegan formation, and part of the Fort St. John group. In the northern Foothills, the nomenclature has developed in rather haphazard fashion, and contains several inconsistencies.

The use of Cardium and Bighorn for the same lithologic unit has been pointed out in the historical review. The designation Cardium sandstone or formation has been used for the sandstone unit in the southern Foothills, to a lesser extent in published reports in the central Foothills, and almost exclusively in northern Alberta. Many of the oil companies use this name in their subsurface studies. The term Bighorn formation has been used in the southern and central Foothills, and the Geological Survey of Canada has heretofore favoured its use in their reports.

In recent years, particularly since the discovery of major oil reservoirs in such fields as Pembina, the term Cardium has come into more general usage than Bighorn. Many workers have used Cardium in preference to Bighorn because the name Bighorn is pre-empted by the Ordovician Bighorn dolomite of Wyoming named by Darton in 1904, and they consider that Bighorn should not be used for a Cretaceous formation in Alberta. Nevertheless, the use of a palæontological name for a formation has been discouraged by the stratigraphic code (Ashley, *et al.*, 1933) in article 8: "Names based only on petrographic or palæontologic features are not to be used as formal names in place of geographic names." The preference for a geographic name is further emphasized in article 9: "In the application of names to formations, the rule of priority, that the first geographic name applied to any unit and duly published shall be accepted, shall generally be observed." Although both names are invalid according to the approved rules of nomenclature, introduction of a new name at this time would not be acceptable. To avoid further duplication of names, the Stratigraphic Committee of the Geological Survey of Canada has recommended that, in this instance, an exception be made to the approved rules and that the more acceptable name, Cardium, be adopted.

The complexities of nomenclature in the area where the southern formations are transitional with the more northerly ones were anticipated by Irish (1951, p. 25). He used the southern terminology, but realized that with more detailed stratigraphic and palæontological evidence, some modifications would probably be necessary.

The Dunvegan formation is recognized as far as Athabasca River, but farther south its characteristic sandstone changes to siltstone and equivalent beds are included in the basal Sunkay member of the Blackstone formation. Where the Dunvegan can be recognized, the overlying beds are referred to the Smoky group; and the boundary between the Smoky and Alberta groups is arbitrarily drawn at Athabasca River. As the Wapiti formation at the top of the Smoky group has approximately the same stratigraphic position as the Brazeau formation of this area, the interval between the Dunvegan and Brazeau formations is the same as that of the Smoky group in the Peace River area.

The Smoky shales, originally named by Dawson (1881, p. 115b), were later divided by McLearn (1919b, p. 4c; 1926, p. 119) into three members which have, in the course of time, attained formational rank (McLearn and Kindle, 1950, p. 102). These formations were, in ascending order, Kaskapau, Bad Heart, and "Upper Shale". In the region west of the type locality on Smoky River, the occurrence of the Cardium sandstone in the succession below the Bad Heart formation necessitates some modification of existing terminology. The shales between the Dunvegan and Cardium sandstones have been included in the Kaskapau formation (Gleddie, 1949, 1954; Stelck and Wall, 1954; Stelck, 1955; Stott, 1960a, 1961a, 1961b) although the Kaskapau formation as originally defined by McLearn (1926, p. 119) included beds that are equivalent to and younger than the Cardium formation. In areas where both Cardium and Bad Heart strata are recognized as formations, the intervening Muskiki shales are raised to formational status. The "Upper Shale" has been called the Wapiabi formation (Gleddie, 1949, 1954) but inasmuch as the type Wapiabi formation includes a much greater stratigraphic interval, a new formational name 'Puskwaskau' was proposed for this unit by Wall (1960, p. 6). This new name is applied to a similar stratigraphic succession that has been mapped in the Foothills from Smoky River to Mount Puggins (Stott, 1961b).

Table II

Table of Formations

Southern and Central Foothills				Description	Northern Foothills			
Series	Group	Formation	Member		Member	Formation	Group	Series
Upper Cretaceous	Alberta 2,000′–4,100′	Wapiabi 1,043′–2,146′	Nomad 90′–130′	Rusty weathering, rubbly shales, grading upwards into greenish grey shales and fine-grained, thinly bedded sandstones. Base is marked by band of pebbles.	Nomad 100′ ±	Wapiabi 1,550′ ±	Smoky 2,900′	Upper Cretaceous
			Chungo 135′–416′	Fine-grained, thickly bedded, light brown weathering sandstones (lithic arenites to quartz wackes), and dark grey siltstone with reddish brown weathering concretions.	Chungo 205′ ±			
			Hanson 0–232′	Dark grey, rusty weathering, blocky to rubbly shales, with reddish brown weathering sideritic concretions.	Hanson ?			
			Thistle 384′–778′	Dark grey to black, calcareous, platy to fissile shales, weathers grey to light grey, with thin, dense, bluish grey dolomitic beds.	Thistle 650′ ±			
			Dowling 101′–351′	Dark grey, rubbly to platy shales, weathers rust, with reddish brown weathering sideritic concretions.	Dowling 250′ ±			
			Marshy-bank 41′–104′	Dark grey, massive, argillaceous siltstone, with large reddish brown concretions; siltstone grades into sandstone.	Marshy-bank ?			
			Muskiki 144′–325′	Dark grey, rubbly to platy shales, weathers rust and has banded or striped appearance, some reddish brown sideritic concretions. Bed of coarse-grained, pebbly sandstone or pebble-conglomerate at base.	Muskiki 250′–275′			
			Sturrock 15′–166′	Fine-grained, thickly to thinly bedded sandstone (lithic arenite to quartz wacke), weathers rusty brown. In some regions, includes brackish and nonmarine, greyish and greenish shales.	Sturrock ?			

		Cardium 74′–357′	Leyland 30′–175′	Dark grey to black, rubbly to blocky shales, with reddish brown sideritic concretions.	Leyland ?	Cardium		
			Cardinal 0–35′	Dark grey, massive, argillaceous siltstone, with large, reddish brown concretions.	(Cardinal and Kiska members not recognized)			
			Kiska 0–37′	Dark grey to black, rubbly to blocky shales, with reddish brown sideritic concretions.				
			Moose-hound 0–134′	Greyish green to brown, carbonaceous, rubbly shales, friable carbonaceous sandstones, thin coal beds, minor conglomerate.	Moose-hound –134′			
			Ram 24′–103′	Fine-grained, thickly bedded sandstone (lithic arenite), weathers rusty brown.	Ram 40′–90′			
		Blackstone 262′–1,734′	Opabin 70′–213′	Dark grey, rusty weathering, blocky to rubbly shales, with reddish brown weathering sideritic concretions.	Opabin –300	Kaskapau 1,200′–1,500′		
			Haven 35′–319′	Dark grey to black, rubbly to platy shales, weathers rust, with yellow sulphur staining and fetid odour.	Haven 179′			
			Vimy 154′–605′	Dark grey to black, calcareous, platy to fissile shales, weathers light grey to white (silver-grey), with dense dolomitic limestone beds.	Vimy 500′–600′			
			Sunkay 15′–631′	Dark grey, rubbly to platy shales, weathers rust, with some argillaceous siltstone, few large kettle concretions, thin beds of coarse-grained sandstones, and pebble bed at the base.	Sunkay 125′–175′			
Lower Cretaceous				Medium- to coarse-grained, carbonaceous, crossbedded sandstone, with greyish green, nonmarine, carbonaceous shales, and also dark grey marine shales and siltstones, few oyster beds.		Dunvegan 210′–281′		
				Dark grey, rubbly to platy shales, weathers rust, with some argillaceous siltstone, few large kettle concretions, pebble bed at base.		Shales of the Fort St. John group 325′–400′		Lower Cretaceous

STRATIGRAPHY

In the Alberta group, the Blackstone and the Wapiabi formations consist of shale and are separated by arenaceous beds of the Cardium formation (Fig. 3). South of Muskeg River, the Smoky group contains the Kaskapau, Cardium, and Wapiabi formations. A shale sequence of the Fort St. John group is separated from the Kaskapau by the arenaceous Dunvegan formation. The formations have been divided into members as shown in the Table of Formations.

The Alberta group lies on beds included in the Blairmore and the Mountain Park formations. The Fort St. John shales are underlain by beds referred to the Luscar and Mountain Park formations. The Alberta group is overlain by the Belly River formation in southern Alberta and by the Brazeau formation farther north. The Smoky group beyond Smoky River is overlain by the Wapiti formation.

Cyclic units within individual members show a gradational change upwards from clay shale to siltstone. These cycles have been traced for great distances and are of value for the correlation within individual members, as is shown in the stratigraphic cross-sections (Figs. 3 to 14).

Detailed descriptions of many outcrop sections of the Alberta group and equivalent rocks are given in Appendix III. A tabular summary of thicknesses for measured sections of the formations and members is given in Appendix I. The number of each section corresponds to that shown on the index map (Fig. 1).

In the lithologic descriptions of individual formations and members, the discussion has been organized so that each is described from the northern Foothills towards the southern Foothills. Generally in this report, the Foothills are divided into three parts: the northern region from Smoky River to Athabasca River; the central region from Athabasca River to Bow River; the southern region from Bow River to the International Boundary. The writer hopes that such arrangement will aid the reader in following the geographic locations. This arrangement may also help to provide easier reference to restricted parts of the Foothills.

Fort St. John Group

The Fort St. John shale was originally named by Dawson in 1881. Wickenden and Shaw (1943) used Fort St. John as a group for the strata lying between the Bullhead group and the Dunvegan formation in the area southwest of Fort St. John. In the Peace River area the Fort St. John group contains the Shaftesbury (top), Peace River, Spirit River, and Bluesky formations (Badgley, 1952; Alberta Study Group, 1954).

The shales between the Mountain Park-Luscar and the Dunvegan formations are lithologically and palæontologically similar to the upper shales of the Fort St. John group. In the area of this study, the Fort St. John shales probably represent only part of the Shaftesbury formation of the group as it is known in the north. However, precise correlations have not been made, and until relationships are better established the shales are referred to as Fort St. John group without further subdivision.[1] The northern development of the group is not discussed in detail because most of it is older than the strata of the present study.

The lower contact of the shales of the Fort St. John group with the Mountain Park (?)-Luscar formation is distinct on Sulphur River. A bed of chert pebble conglomerate at the base of the shales is similar to that found at the base of the Blackstone formation throughout the southern Foothills. The upper contact of the Fort St. John group with the Dunvegan formation is gradational; fissile or rubbly shales grade upward into siltstone and sandstone in an interval 20 feet thick. The top of the group is drawn at the base of the lowest sandstone of the Dunvegan formation.

The upper shales of the Fort St. John group were measured in the Grande Cache area by Thorsteinsson (1952) who reported a thickness of 381 feet on Sulphur River upstream from Smoky River. The writer was unable to examine the section on account of high water, and Thorsteinsson's description is used in order to correlate the Blackstone equivalents into the area of the Fort St. John group.

In the Pierre Greys Lakes map-area, Fort St. John shales are poorly exposed on Susa Creek. The best exposure is on the south-flowing tributary of Cowlick Creek close to the western boundary of the map-area. The Fort St. John shale on Berland River at Adams Creek is faulted and folded. The only section measured was that on Little Berland River (section 5-19) where the interval is 325 feet thick. Exposures of the shales between Little Berland River and Athabasca River are poor and only a few feet of section are visible.

In the type section of the Blackstone formation on Bighorn River, strata considered equivalent to the upper shales of the Fort St. John group of the field area are about 320 feet thick. The interval is approximately the same thickness as that noted for the Fort St. John shales on Little Berland River (*see* Fig. 4).

Some of the shales of the Fort St. John group are silty, platy, and hard, but others are softer and rubbly. Interbedding of the silty shale and clay shales produce a ribboned or striped appearance. This surface expression, combined with the rusty weathering and reddish brown weathering concretions, is much like that of the basal part of the Sunkay member of the Blackstone formation which is apparently equivalent.

Cyclic units are developed by a gradual increase of silt content. Rubbly shales grade upward into blocky and platy shales which may grade into siltstone. The siltstones are platy and weather rust. Two cycles are recognized in the Fort

[1] More recent studies indicate that these shales are correctly termed 'Shaftesbury'.

St. John shale of the Little Berland section. They have been correlated (Fig. 4) with the basal cycles of the Blackstone formation in the Bighorn-Nikanassin area, and with the Fort St. John shale of the Sulphur River section which was described by Thorsteinsson (1952). The lower half of the overlying cycle is also included in the Fort St. John shale, but the upper sandy part is placed within the Dunvegan formation.

Age and Fauna

The only known fossils from the Fort St. John shales in the region of this study are those collected by Thorsteinsson (1952). These were "collected on Pearl Creek, a tributary of Sulphur River, 217 feet above the lower contact of the formation". Included in the collection are specimens of *Neogastroplites maclearni* Reeside and Cobban, which were identified and dated as latest Albian by Reeside and Cobban (1960).

Table III

Fauna from Shales of Fort St. John Group

(*after* Thorsteinsson, 1952)

Neogastroplites ex gr. *N. cornutus* (Whiteaves)	Gastropod, genus and sp. indet.
Neogastroplites ex aff. *N. cornutus* (Whiteaves)	Barnacles (cf. *Balanus* sp. indet.)
Neogastroplites sp. indet.	Fish scales (in masses)
?*Engenoceras* (s. lato) sp. indet.	Fossil wood (in masses)
cf. *Inoceramus* sp. indet.	

Dunvegan Formation

Dawson (1881) applied the name Dunvegan to the 'Lower Sandstones and Shales' in the valleys of the Peace and Pine Rivers. A section, described by Dawson, on Peace River west of the old Hudson's Bay Company trading post of Dunvegan is considered to be the type section (McLearn and Kindle, 1950, p. 96).

McLearn and Kindle (loc. cit.) summarized the general features: "The Dunvegan formation lies conformably between the Fort St. John group below and the Smoky group above, and consists of 350 to 1,200 feet or more of marine and nonmarine, light grey, massive, cross-bedded sandstones, flat ironstone concretions, thick shales, thin-bedded sandstone and shale, rare calcareous layers, and rare, thin coal seams."

The lower and upper boundaries of the Dunvegan formation in the Peace River area are transitional (Gleddie, 1954, p. 494). Similar relationships are found in the Alberta Foothills where the Dunvegan formation is transitional into the shales of the Fort St. John group, and the base of the formation is drawn at the base of the lowest siltstone unit. The upper contact is also somewhat transitional, but has been observed at only a few localities. It is drawn at the base of rusty silty shales that overlie massive siltstone or sandstone. The contacts are conformable.

The Dunvegan formation is well developed in the Fort St. John and Peace River areas, and has been traced northward to Liard River. Wickenden and Shaw (1943) reported it to be 1,200 feet thick in the Mount Hulcross-Commotion Creek area southwest of Fort St. John. South of Pine River, upper beds of the Dunvegan known as the Sukunka member (Spieker, 1921) were considered to be equivalent to the basal Kaskapau shales farther east (Stelck and Wall, 1954, p. 18). Beach and Spivak (1944) measured 461 feet in an incomplete section on Moberly River; farther east along Pouce Coupé and Peace Rivers, Gleddie (1949, 1954) measured 650 feet. He reported that the Dunvegan interval was 480 feet thick in Imperial Spirit River No. 1 well south of Spirit River; 400 feet near Peace River; and only 230 feet in the Amerada Crown OF 33-32 well south of Peace River. Therefore, the Dunvegan formation thins markedly towards the southeast in the direction of the field area.

Southeastward in the Alberta Foothills, the massive sandstones within the formation grade laterally into siltstone, and the siltstone grades into shale. Equivalent beds south of Athabasca River are included in the Blackstone formation because of this facies change.

There are several well-exposed sections of the Dunvegan formation near Smoky River. Thorsteinsson (1952) described a 281-foot section in the Grande Cache area on the north-facing escarpment of Syncline Hills and reported a thickness of 279 feet for a section on Sulphur River. On Susa Creek, just south-

D.F.S., 2-3-55

Plate II. *Dunvegan formation (D), junction of Adams Creek and Berland River, section 5–17. Fort St. John shales (F) are contorted on the left.*

D.F.S., 3-4-55

Plate III. *Upper beds of Dunvegan formation, Little Berland River, section 5–19. Top of formation lies to the left.*

west of McDonald Flats on Muskeg River, the formation is poorly exposed on both limbs of an anticline, but a composite section shows the thickness to be approximately 250 feet. A Dunvegan section in the Pierre Greys Lakes area, on the south-flowing tributary of Cowlick Creek, was reported by Irish (1951) to be 530 feet thick. The section includes a covered interval of 230 feet. The beds on this stream are very poorly exposed and may be repeated by faults concealed in the covered intervals. The writer measured 248 feet in the most westerly section on the tributary.

Several folded and faulted sections of the Dunvegan formation are exposed on Mahon Creek in the Pierre Greys Lakes area but none is complete. Irish (1951) mapped the western one of these as the 'Bighorn' (Cardium) formation but fossil collections include *Pleurobema dowlingi,* an index fossil of the Dunvegan formation, and the lithology is typical of the Dunvegan.

On Berland River at Adams Creek, a section (5-17)[1] of the Dunvegan formation is well exposed (Pl. II). However, the overlying and underlying shales are contorted, and stratigraphic relationships cannot be determined. The thickness is 270 feet.

A section of the Dunvegan formation was measured on Little Berland River (section 5-19) where it is well exposed. Although the upper part of the formation is very shaly (Plate III), the inclusion of two siltstone units gives the formation a

[1] Numbers in parentheses refer to stratigraphic sections described in Appendix III.

thickness approximating that near Smoky River. Only 210 feet can be considered as the Dunvegan formation.

The Dunvegan beds are mostly covered south of Little Berland River, which accounts for the lack of details of their relationship to the Blackstone formation. A few beds of Dunvegan sandstone are present on Moberly Creek. Lang (1947b) mapped the formation in the Moberly Creek map-area, and Irish (1947) mapped it to the west in the Moon Creek map-area. Lang (1947a) suggested that a massive siltstone near the base of the Blackstone on Solomon Creek in the Brûlé map-area was equivalent to part of the Dunvegan. This lends support to the correlation of the Dunvegan formation with part of the basal member of the Blackstone (Fig. 4).

In the type section of the Blackstone formation on Bighorn River, strata considered to be equivalent to the Dunvegan formation are about 175 feet thick. This thickness is slightly less than that of the Dunvegan on Little Berland River.

The Dunvegan consists of flaggy, brownish grey to greenish grey sandstones, interbedded with shales that contain much carbonaceous material and thin coal beds. Although much of the formation around Fort St. John is considered to be nonmarine, some brackish and marine beds are indicated by the fauna.

In the Grande Cache area, Thorsteinsson (1952) described the Dunvegan formation as "fine- to medium-grained calcareous sandstones, and quartzitic sandstones interbedded with dark grey siltstones and shales". Most of the sandstones are less than 10 feet thick, although one is 34 feet thick. These sandstones are separated by shale beds ranging in thickness from 25 to 50 feet. The sandstones are subgreywackes as they contain considerable matrix, but they consist mainly of quartz and chert. They are generally dark grey or brown, and in some places are carbonaceous. Laminations are characteristic and appear to be thicker than those of the Cardium sandstones. Small-scale crossbedding seems to be typical and is much more abundant than in the Cardium sandstones.

The shales vary considerably in lithology. Some are dark grey, weather rusty brown, contain reddish brown weathering concretions, are platy to fissile, and are very similar to those in the Sunkay member of the Blackstone formation. Other shales are brown to olive-green or black, and weather to a blocky or rubbly talus. Carbonaceous matter and plant fragments commonly occur. Thin beds of coal are found in some sections. A coquinoid bed, 3 feet thick, occurs in the middle of the formation on Little Berland River and has yielded *Pleurobema* cf. *P. dowlingi* McLearn and *Ostrea.*

Siltstones, found in the more easterly sections and on Little Berland River, are massive, dark grey, argillaceous, and contain reddish brown concretions. This type is present on Solomon Creek. Some of the siltstones tend to be crumbly and friable, contain carbonaceous fragments, and are brown to greenish brown. The massive siltstones are similar to marine siltstones in the Alberta group.

In a few sandstone beds, evidence of intrastratal flow is found in rounded, bolster-like structures, 12 inches by 24 inches in cross-section (Pl. V). The sand layers involved pinch and swell without much disturbance of the underlying beds.

D.F.S., 2-1-55

Plate IV. *Channelling in Dunvegan sandstone. Bedding is typical of Dunvegan in Muskeg River area.*

The overlying beds appear to be horizontal. The laminae in these structures reflect the same rounded curves as the surface of the structure.

Some channel fill was observed in the Dunvegan sandstone (*see* Pl. IV). In the section on Susa Creek, large scours have a wave-like profile and have been filled by sand. Above the channel fill, the beds appear to be conformable on the underlying unit.

The section on Sulphur River described by Thorsteinsson (1952) seems to be mainly nonmarine or brackish because of its carbonaceous content, but the presence of *Inoceramus dunveganensis* McLearn and *I. rutherfordi* Warren indicates that some of it is marine. The sections on Susa Creek contain a few thin coal beds. On Mahon Creek and the tributary to Cowlick Creek, the beds appear marine. The sandstone in the tributary contained numerous specimens of *Inoceramus* (*I. rutherfordi* was reported from this locality by Irish, 1951) and apparently is marine. The upper beds of the Little Berland section has an appearance similar to the basal Blackstone formation in the south, which is considered to be marine. Thus, in this general area, the Dunvegan formation seems to be partly marine and partly nonmarine. The thicker brackish or nonmarine beds occur farther west, and the marine sections are found to the east.

Two prominent sandstone units occur at the base of the formation on Sulphur River and several minor units of siltstone are present in the upper part. The Berland River section consists of numerous alternations of fine-grained laminated sandstone and rubbly, rusty weathering shale or platy siltstone. The

D.F.S., 2-4-55

Plate V

Intrastratal flow features in Dunvegan sandstone. Top of sandstone is top of one cycle. Note sharp change to shale.

lower sandy part is separated from the upper silty beds by about 100 feet of shale. The basal unit contains more sandstone and is correlated with the basal sandstone on Little Berland (Fig. 4) and Sulphur Rivers. Farther south in the type section of the Blackstone formation, two siltstones in the basal member are believed to be equivalent to the basal sandstones. Southward from Sulphur River, the upper sandstones become more silty and are not so prominent. The whole unit grades southward from a sandy facies with associated coal and oyster beds into marine shales and siltstones.

Age and Fauna

Collections made by Thorsteinsson (1952) and Irish (1951) from the Dunvegan formation include *Brachidontes multilinigera* Meek, *Inoceramus dunveganensis* McLearn, *Inoceramus rutherfordi* Warren, and *Pleurobema dowlingi* McLearn. These typical Dunvegan fossils are considered by Jeletzky to be of early late Cenomanian age. Fossils collected during the present study are listed in Table V[1]. Stelck and Wall (1955) outlined a sequence in which *I. dunveganensis* and *I. rutherfordi* lie below the zones of *Dunveganoceras* of late Cenomanian age.

[1] Faunal lists (Tables V to XX) have been compiled from the identifications of fossil collections by J. A. Jeletzky. Reference to earlier collections is not attempted in this report unless the earlier data are particularly significant. Most of the earlier collections are not located precisely in the stratigraphic column, and as a result, the faunas from different zones have sometimes been mixed.

Table V

Fauna of Dunvegan Formation

Fauna	GSC Location[3]				
	27032	27038	27054	27075	27096
Anomia anomoides Meek	—	—	c[1]	—	—
Corbula nematophora Meek	—	—	c	—	—
Inoceramus sp. indet.	—	—	—	—	x
Melania sp.	—	—	?	—	—
Ostrea sp. indet.	x[2]	x	x	x	—
Pleurobema dowlingi McLearn	—	—	c	c	—
Unio sp. indet.	?	—	—	—	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

Smoky Group

The Smoky group of the Peace River area extends westward into northeastern British Columbia (McLearn and Kindle, 1950, p. 103). Few descriptions have been published of this group between Peace River and Smoky River, which is the northern limit of this study.[1] The southern limit of the Smoky group is Athabasca River.

The Smoky group is very similar in lithology to the Alberta group, and consists of shale, sandstone, minor conglomerate, and thin beds of limestone. All its subdivisions extend southward into the Alberta group (Fig. 3), and the only marked changes are found in the Cardium formation and in the Marshybank member of the Wapiabi formation. Only the Kaskapau formation is described under a separate heading. As the other units of the Smoky group are continuous into the Alberta group, each is described under the major heading of the Alberta group.

Rocks of the Smoky group are exposed in two continuous sections within the Alberta Foothills. The section on Little Berland River (section 5-19) is the better one, although the transition beds at the top of the Wapiabi formation are not exposed, and the basal beds of the Kaskapau formation are slightly folded and faulted. The approximate thickness is 2,900 feet. Some of the beds on Muskeg River are not accessible and some are also faulted and folded. However, the general features of the different formations and members are readily visible.

[1]For summary of Smoky group north of Smoky River, *see* Stott (1960a, 1961b); *also* Stott (1962); *J. Alta. Soc. Petrol. Geol.*, vol. 10, No. 10, pp. 228-240.

The contact of the Smoky group with the underlying Dunvegan formation is gradational. Westward, the silt and sand content of the Smoky beds increases until, as shown by Stelck and Wall (1954, p. 18), part of the Smoky shales interfingers with Dunvegan-type lithology. Thus, the Dunvegan-Smoky contact lies at different stratigraphic levels in different areas.

Kaskapau Formation

The Kaskapau formation as originally defined included all the beds between the Dunvegan sandstone and the Bad Heart sandstone (McLearn, 1926, p. 119; McLearn and Henderson, 1944; McLearn and Kindle, 1950, p. 102). No type section has been specified although presumably it is on Smoky River where McLearn first described the succession. In the vicinity of Smoky River, the name Kaskapau is given to those beds between the Cardium and the Dunvegan formations. The Kaskapau formation is stratigraphically equivalent to part of the Blackstone formation (*see* Fig. 4) and may be divided into comparable members. The same names, Opabin, Haven, Vimy, and Sunkay, are extended from one formation to the other as there is no important difference in lithology within this region.

The contact of the Kaskapau formation with the Cardium formation is drawn at the base of the lowest massive sandstone. As a result, a few feet of interbedded sandstone and shale are usually present at the top of the Kaskapau formation. The contact of the Kaskapau shale with the Dunvegan formation is drawn at the top of the first massive siltstone or sandstone. As the sand content of the Dunvegan formation increases westward, the boundary is drawn at successively higher stratigraphic levels from one area to another.

The Kaskapau formation is exposed in the region around the towns of Peace River and Fort St. John, and has been mapped in the region of the Pine River-Peace River valleys. The name has not been used extensively in the area south of Grande Prairie, although Thorsteinsson (1952) used it in the Grande Cache area.

The thickness of the formation, like that of the other formations of this study, varies considerably at different localities. Stelck and Wall (1954, p. 7) reported: "Gleddie (1949, p. 521) gives an approximate thickness of 1,550 feet for the Kaskapau formation near Pouce Coupé and 900 feet in the vicinity of Spirit River. More recent subsurface work in the latter area suggests an overall thickness of about 1,100 feet to the base of the Badheart sandstone. In the Smoky River area, J. Y. Smith (Gleddie, ibid.) reports a thickness ranging from 520 to 600 feet".

Because of folds and faults in the lower part of the section on Little Berland River, a measuremuent of the total thickness was not obtained. The thickness is in the order of 1,200 feet. The section on Muskeg River was not measured, and only the upper part of the formation is exposed on Mahon Creek. In the Muskeg area, Irish (1951, p. 7) reported 1,800 feet of strata considered equivalent to the Kaskapau formation, and Greiner (1955, p. 5) reported 2,000 feet in Two Lakes map-area which is several miles northwest of Muskeg River. These thicknesses seem to be somewhat excessive; the thickness of 1,300 feet in the Grande Cache map-area estimated by Thorsteinsson (1952) is more reasonable. The interval between the Dunvegan and Cardium formations of 1,550 feet near Pouce Coupé, reported by Gleddie (1949, p. 521), is northwest of the Grande Cache area.

The Kaskapau formation, consisting mainly of shales, weathers more rapidly than the more resistant beds of the adjacent Cardium and Dunvegan formations. For this reason, valleys develop in the Kaskapau shales which parallel the structural trends. Along the streams, the slopes are more gently inclined than those of the sandstone formation, and are frequently covered with talus or vegetation.

Shales of the Vimy, Haven, and Opabin members are discussed under the major heading of the Blackstone formation. The rusty weathering shales of the Sunkay member, which lie between the calcareous shales of the Vimy member and the Dunvegan formation, are stratigraphically equivalent to only the upper part of the Sunkay member of the Blackstone formation. The shales are rubbly to platy, dark grey, rusty weathering, and contain a few concretions and silty bands. The beds are approximately 150 feet thick on Little Berland River, and equivalent beds in the Blackstone type section are 138 feet thick.

Webb and Hertlein (1934, p. 1392), who included all the beds equivalent to the Dunvegan formation and Fort St. John shale in the Blackstone formation, noted that: "In the Berland River district a generally sandier composition marks the inception of a northward change in sediments deposited in the Blackstone Sea." Whether they meant that all the Blackstone is sandier is not clear, although certainly their comments are true for the lower part which contains the Dunvegan sands. The writer did not find that the sand content of the beds included in the Kaskapau formation shows any marked increase over their equivalents farther south. On the other hand, the beds of the type section of the Blackstone formation appear to be sandier, especially in the Opabin member.

Age and Fauna

Fossils collected from the Kaskapau formation include *Prionocyclus (Collignoniceras)* cf. *P. woollgari* Mantell, *Scaphites* cf. *S. patulus* Cobban, and *Inoceramus* cf. *I. lamarcki* (Parkinson). The formation lying between the Dunvegan and Cardium formations is, therefore, considered to contain the zones of *Dunveganoceras* to the zone of *Prionocyclus woollgari* and perhaps later Turonian zones. It can then be dated as late Cenomanian to late Turonian.

Alberta Group

The Alberta group, originally defined in the Highwood River area, extends southward to the International Border and northward to Athabasca River. It comprises the Blackstone, Cardium, and Wapiabi formations. The Blackstone and Wapiabi formations consist predominantly of dark grey, silty shales and their individual members are characterized by limestone bands and sideritic concretions (*see* Table of Formations). The Cardium formation is a prominent sandstone in the middle of the group.

As shown in Figure 3, the Alberta group thins markedly towards southern Alberta. A composite section on Highwood River indicates a thickness of about 2,000 feet. On Ghost River, the thickness is at least 2,450 feet. On Burnt Timber Creek (unsurveyed tp. 30, rge. 8, W5) the Wapiabi and Cardium formations, most of the Blackstone formation, and the upper and lower contacts of the group are well exposed, and the thickness is approximately 3,200 feet. Composite sections from Bighorn and Thistle Creeks give approximate thicknesses of 4,100 and 3,800 feet, respectively. East of the Bighorn Range, the thickness of the group cannot be determined as a complete sequence of the Blackstone formation is not present, but the eastward convergence of the Cardium and the Wapiabi formations would indicate that the group is probably about 2,700 feet thick in that area.

Blackstone Formation

The basal beds of the marine Cretaceous sequence in the Bighorn Coal Basin were placed in the Blackstone formation by Malloch (1911), who stated: "The formation is very homogeneous, consisting throughout of dark grey calcareous shales . . . The only complete section across the shales is on the more southerly of the two main branches of Wapiabi Creek, and there the beds are crumpled."

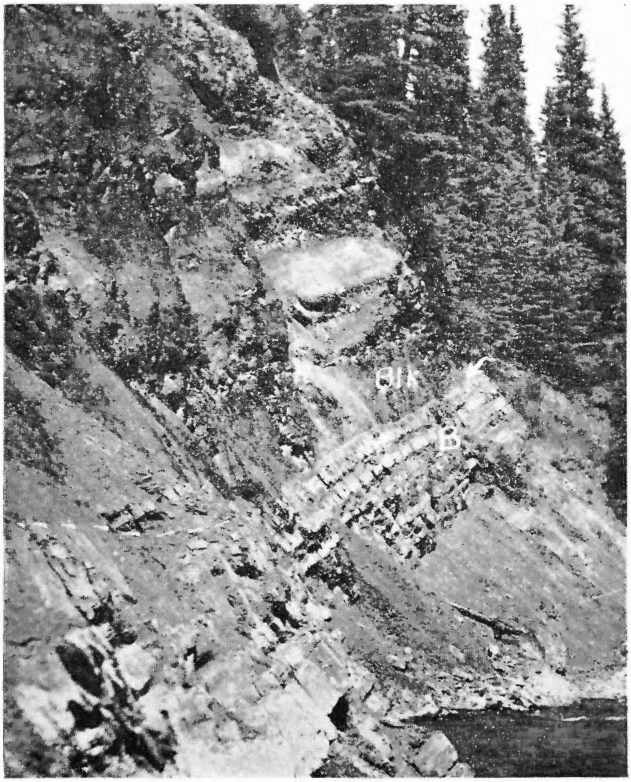
The section on Wapiabi Creek is faulted. Apparently Malloch did not realize that the well-exposed section on Bighorn River is almost free of faults and folds. These excellent exposures in sec. 30 (unsurveyed), tp. 39, rge. 17, W5 are selected as the type section. A small drag-fold is present near the top of the basal member, and the lower contact with the Mountain Park formation is faulted but displacement is small. The contact is exposed on the south side of the river; the fault evident on the north side at the contact lies somewhat higher or lower on the south side.

The type section is reached by the forestry pack-trail that follows the Bighorn River from near its junction with North Saskatchewan River. The section may be measured by crossing the river several times, but crossing is rather dangerous in periods of high run-off, particularly in May and June.

The Blackstone formation includes all those beds between the thickly bedded basal sandstones (Ram member) of the Cardium formation and the underlying nonmarine beds of the Blairmore or Mountain Park formations. More specifically, this definition places within the Blackstone formation the thinly bedded sandstones below the thickly bedded to massive basal Cardium sandstone on Bighorn River, Wapiabi Creek, Brazeau River, Thistle Creek, and Mackenzie Creek.

The beds underlying the Blackstone formation have been designated variously as the Blairmore formation, Mountain Park formation, and the Luscar and (?) Mountain Park[1] formations. These beds, of nonmarine origin, consist of greenish to brownish sandstones and shales which contain considerable carbonaceous material and coal beds. From Oldman River southward, the Blackstone shales lie on the Crowsnest formation of agglomerates and tuffs. In most sections, the Blackstone has a well-defined contact with the underlying formation (Pl. VI). A pebble layer, a few inches to a few feet thick, is generally present, which suggests a period of reworking and winnowing.

There is evidence of erosional unconformity in at least two sections. On Brazeau River below Lightning Flats where the Sunkay member (basal Blackstone) lies on greenish shales and siltstones of the Mountain Park formation (Pl. VII), a shale unit at the top of the Mountain Park formation increases in thickness as it is traced 1,000 feet into a small tributary. This change in thickness is not due to sedimentation but to truncation by the overlying Blackstone shales. On the northwest side of Littlehorn River in an overturned section, two beds of Mountain Park sandstone are cut off by Blackstone shale, the total relief being about 11 feet. On the southwest side, the relief appears to be 3 feet.

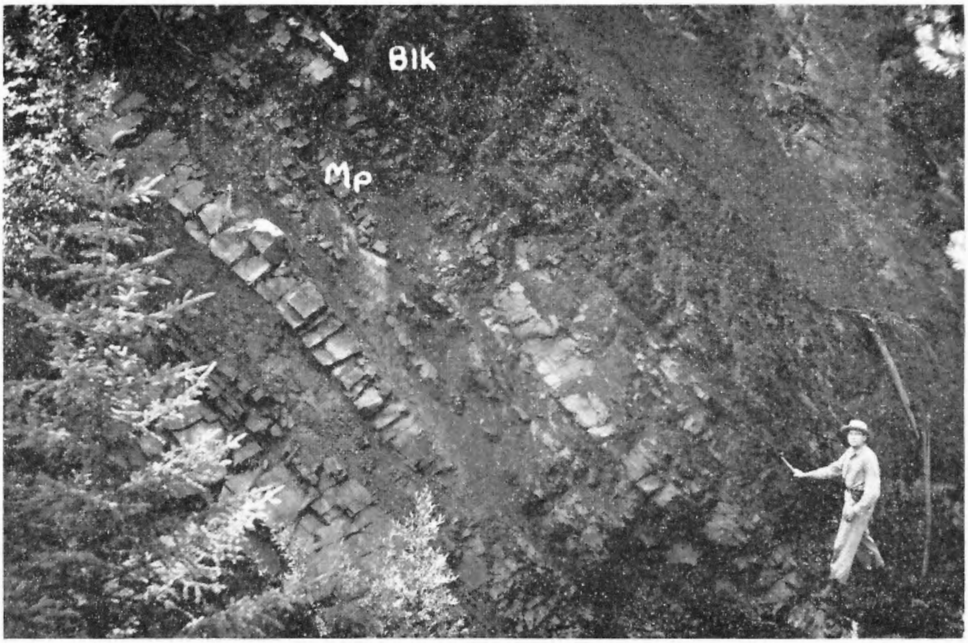


D.F.S., 6-6-56

Plate VI

Contact between Blackstone formation (Blk) and Blairmore formation (B), Sheep River, Dyson Creek map-area.

[1] North of Athabasca River, geologists have not recognized the Mountain Park type lithology as a unit distinct from the Luscar type lithology, and therefore have called the sequence the Luscar and (?) Mountain Park formations.



D.F.S., 7-4-54

Plate VII. *Unconformable contact between Blackstone formation (Blk) and Mountain Park formation (Mp), on tributary of Brazeau River.*

No evidence was found of a gradational boundary between the Blackstone and the underlying Blairmore or Crowsnest. In every section observed, the contact was well defined. The nonmarine green shales or volcanic rocks are not interbedded with the overlying pebble beds or black shales of the Blackstone formation. The regional relationships, distinct boundary, and lack of interbedding with the underlying rocks, the basal pebble beds, and the local unconformities all indicate that the basal Blackstone contact is disconformable.

The Blackstone formation is divided into four members which are, in ascending order, the Sunkay, Vimy, Haven, and Opabin. The type section of each is recognized in the type section of the Blackstone formation along Bighorn River. The members as defined correspond to the Barren, *Inoceramus labiatus,* Rusty shale, and Transition zones of Webb and Hertlein (1934). Those workers believed that the subdivisions were gradational into one another and that the selection of zonal contacts was arbitrary. This is not entirely correct, however, for the boundaries, as defined by the author, appear to lie at constant stratigraphic position throughout the Alberta Foothills. In poorly exposed sections, where talus and vegetation may obscure the contact, gradational features appear to be present. The Opabin member is, however, transitional into the overlying Cardium formation, and in this instance, the selection of a contact is arbitrary.

The shales of the Blackstone formation are easily eroded and usually form broad valleys between the prominent sandstone ridges of the Cardium and Blairmore formations. These valleys, some of which have been modified by glacial action, are wide with relatively flat bottoms; they form good pasture land for wild game and, in more recent years, for livestock. Moreover, these subsequent valleys provide general access to the area as most of the roads and pack-trails follow valleys in either the Blackstone or the Wapiabi shales.

The Blackstone formation has been traced from Castle River, south of Crowsnest Pass, to McLeod River. The upper part extends north of Athabasca River as the Kaskapau formation; the line of demarcation between the formations lies at the southern limit of the Dunvegan formation.

The Blackstone formation thickens from southeast to northwest (*see* Fig. 15), the thinnest section being on Lynx Creek (section 6-51) in the Carbondale area where a total of 262 feet was measured. The type section on Bighorn River is 1,734 feet thick, and the northernmost (composite) section on Thistle Creek is 1,411 feet. On Little Berland River (section 5-19) the Kaskapau and Dunvegan formations and the shales of the Fort St. John group, which are equivalent to the Blackstone formation, have a composite thickness approaching that of the Blackstone at its type locality. The greatest thickness of the Blackstone, west of the Bighorn Range at the headwaters of Bighorn River and Wapiabi Creek, is due to increased thickness of all the members.

Webb and Hertlein (1934) apparently did not observe a complete section of the Blackstone formation north of Ghost River. They suggested that the formation probably did not exceed 1,000 feet, but sections west of where those geologists worked reveal that the lower two members are much thicker than they estimated. Nevertheless, their estimate is reasonable for the area east of the Bighorn Range.

A thickness of 720 feet was estimated by Douglas (1950, p. 29) for the Blackstone formation in the Northwest Company Rice Creek well in Langford Creek map-area and only 430 feet between the Blairmore and Cardium formations in the Quaich Globe No. 1 well in Gap map-area. These thicknesses agree in general with measured thicknesses in the southern Foothills.

General variation in thickness across the regional strike cannot be determined, as complete sections are rare. However, on Sheep River, three sections within a distance of 15 miles indicate a decrease in thickness towards the east from 785 feet to 614 feet. The isopach map (Fig. 15) shows the general trends.

In general, the silt content is greater in the more westerly sections near the Rocky Mountains where siltstone beds and hard platy silty shales are abundant, than it is towards the east where the shales are rubbly, flaky, or fissile. All the shales contain abundant carbonaceous matter.

Age and Fauna

The Blackstone formation contains the zones of *Dunveganoceras* to *Prionocyclus woollgari* (*see* Tables VI to IX for faunal lists). Not all the standard zones of Cobban and Reeside (1952b) between late Albian and late Turonian time are recognized, but the formation is considered to include beds of this general age.

Type Section

Section 5-34. Blackstone formation, Bighorn River below junction of Littlehorn River, Bighorn map-area, Alberta.

Bed	Lithology	Thickness (feet)	Height above base (feet)
	CARDIUM FORMATION		
11	Overlying beds not completely exposed. Sandstone, fine-grained, grey; massive, homogeneous to laminated; knobbly in interval 11′-13′	15	81
10	Poorly exposed; appears to be sandstone as above	4	66
9	Sandstone, fine-grained, grey, tan weathering, slightly calcareous; beds 3″-6″ thick; a few concretionary zones near base	14	62
8	Sandstone, fine-grained, grey, slightly calcareous; knobbly; worm burrows, irregularly bedded	10	48
7	Sandstone, fine-grained; homogeneous to slightly laminated; beds 4″-6″	6	38
6	Siltstone, shaly, bedded, weathers yellowish tan; few thin concretions	6	32
5	Shale, platy to rubbly, rusty weathering; few concretions and concretionary beds at base	6	26
4	Shale, platy, rusty weathering; concretionary beds at 3′	7	20
3	Siltstone, argillaceous, sandy	2	13
2	Sandstone, fine-grained, grey, rusty tan weathering, slightly calcareous; laminated with a suggestion of crossbedding; beds 2″-4″ thick; concretionary zones	6	11
1	Sandstone as above; and 40% shale	5	5
	BLACKSTONE FORMATION		
	Opabin Member		
101	Shale, very silty, blocky; few concretionary beds and sandstone lenses at top, rusty weathering	9	1,734
100	Covered. Some dark grey, platy to rubbly shale, with concretions exposed near base	49	1,725
99	Sandstone, fine-grained, bluish grey, tan to brownish grey weathering, flaggy; somewhat concretionary; beds ½″-6″ thick; shale 5-10%	15	1,676
98	Siltstone, sandy, dark grey, well indurated; massive to bedded; grey weathering; with concretions 4″×1′	25	1,661
97	Siltstone, argillaceous; hard at top becoming slightly more shaly and blocky towards base; bedded appearance; concretions, 4″ × 1′	18	1,636
96	Siltstone, argillaceous, to shale, blocky, dark grey; becoming more shaly towards base; dark grey; slightly rusty weathering; concretions and concretionary beds	38	1,618
95	Shale, platy, dark grey, rusty weathering; siltstone, 40% at top, decreasing downward to 20%; few small concretions and thin concretionary beds at top	25	1,580
	Haven Member		
94	Shale and 50% siltstone, platy, rusty weathering	9	1,555
93	Shale, platy to rubbly, and 25% siltstone; rusty weathering, 1″ bentonitic shale at base	12	1,546

Bed	Lithology	Thickness (feet)	Height above base (feet)
92	Shale and 40% siltstone, rusty weathering	18	1,534
91	Shale, platy; and 10% siltstone	10	1,516
90	Shale and siltstone; 40% siltstone at top decreasing to 20% at base; rusty weathering; a few 6″ × 2′ limestone concretions, yellowish weathering	31	1,506
89	Shale and siltstone; 50% siltstone, decreasing to 25%; rusty weathering; rare limestone concretions, bentonite at 5′	20	1,475
88	Shale and 20% siltstone, platy, rusty weathering	11	1,455
87	Shale and 30% siltstone, rusty weathering; large limestone concretions, yellowish weathering	9	1,444
86	Shale and 40% siltstone, laminated; ½″-1″ beds; rusty weathering	21	1,435
85	Shale and 15% siltstone	3	1,414
84	Shale and 50% siltstone, ½″-2″ beds, laminated, platy, rusty weathering; yellowish sulphur stains	20	1,411
83	Shale and 30% siltstone	13	1,391
82	Shale and 50% siltstone, platy, rusty weathering	24	1,378
81	Shale and siltstone; 40% siltstone at top decreasing to 25% at base; rusty weathering	43	1,354
80	Shale and 40% siltstone, beds up to 2″ thick	7	1,311
79	Shale, platy at top becoming more rubbly below 35′, dark grey, rusty weathering; 20% siltstone; bedded appearance	68	1,304
	Vimy Member		
78	Limestone, dense, argillaceous, bluish grey, yellow weathering, laminated, massive	1	1,236
77	Shale, platy, black, calcareous, somewhat rusty weathering; some thinly bedded siltstone	14	1,235
76	Shale, platy to rubbly, slightly rusty weathering	14	1,221
75	Shale and 30% thinly bedded siltstone; black to dark grey; limestone lenses at top and base	20	1,207
74	Siltstone, 60%, and shale; platy, dark grey, calcareous	21	1,187
73	Limestone, shaly, platy, yellowish weathering	0.5	1,166
72	Shale, platy, silty, dark grey	8	1,165.5
71	Shale, very silty, platy; 6″ of extremely silty shale at top, dark grey, silver-grey weathering; 2″ laminated calcareous siltstone at base; a few small concretions	24	1,157.5
70	Shale, platy to rubbly, dark grey, silver-grey weathering	13	1,133.5
69	Limestone, shaly, platy	1	1,120.5
68	Shale, silty, platy, dark grey, silver-grey weathering; a few limy siltstone beds	28	1,119.5
67	Limestone, dense, argillaceous, laminated, yellowish weathering	0.5	1,091.5
66	Shale, platy, and 40% siltstone, ½″-2″ beds	16	1,091
65	Shale, platy, disk-shaped concretions; few thinly bedded limestone beds near base	21	1,075
64	Shale, very calcareous, almost shaly limestone, platy, some yellowish weathering	1	1,054
63	Shale, platy, dark grey to black, calcareous; 20% thin siltstone, a few thin limy beds; distinct break at base	18	1,053

Bed	Lithology	Thickness (feet)	Height above base (feet)
62	Shale and 40% siltstone, as above; 3″ limestone bed at base	26	1,035
61	Shale, platy; 20% thinly bedded siltstone; a few limy beds; silver-grey weathering	49	1,009
60	Shale, platy, calcareous, dark grey; 1′ limestone lenses at top and base and thin limestone beds scattered throughout. Across river part of whole interval is limestone	5	960
59	Shale, platy; 30% thinly bedded siltstone; a few limy 1″ beds and 6″-12″ disk-shaped concretions	4	955
58	Shale, platy to fissile, dark grey to black, calcareous, silver-grey weathering; basal 1′ very rubbly, rusty weathering	27.5	951
57	Shale and 30% siltstone; a few limy beds; some shale is rusty weathering	12	923.5
56	Siltstone, very calcareous to silty limestone; yellowish weathering	0.5	911.5
55	Shale, platy; 40% thinly bedded siltstone, 25% at base; calcareous, dark grey to black, silver-grey weathering; 6″-12″ disk-shaped concretions in upper 5′	21	911
54	Shale, platy, calcareous, with 1′ limestone lenses at top and in basal 1′; beds are 2″-6″ thick	6	890
53	Shale and 50% siltstone, decreasing to 25%, dark grey, silver-grey weathering	18	884
52	Limestone, dense, argillaceous, bluish grey, massive, laminated, yellowish weathering	1	866
51	Shale, dark grey, platy; 20% siltstone at top; shale becomes more fissile towards base, silver-grey weathering; a few limestone lenses	52	865
50	Limestone with 50% shale	0.5	813
49	Shale, platy to fissile; few thin siltstones in basal 4′	34.5	812.5
48	Limestone with 60% shale, very silty	2	778
47	Shale, platy; 30% siltstone; few disk-shaped concretions	5	776
46	Shale and 25% siltstone	9	771
45	Shale, soft, fissile, dark grey, silver-grey weathering	12	762
44	Shale, platy, dark grey, silver-grey weathering, calcareous; 30% thinly bedded siltstone; limy beds with 3″ bed at top	29	750
43	Limestone; beds 2″-6″, 25% shale; limestone is dense, argillaceous, bluish grey, yellowish weathering, laminated	2	721
42	Shale, platy, and 20% thinly bedded siltstone; 2″ limestone concretionary beds at 32′	39.5	719
41	Limestone, dense, argillaceous, bluish grey, laminated, yellowish weathering	0.5	679.5
40	Shale, platy, dark grey; disk-shaped limestone concretions	8	679
39	Shale, platy; a few limestone concretions	23	671
38	Shale, platy to fissile	11	648
37	Shale, fissile; topped by limestone concretions, 1′ × 4′	6	637
	Sunkay Member		
36	Shale, platy to papery, with 30% siltstone; 1″-2″ beds in upper 5′, calcareous; row of limestone concretions at 18′, slightly rusty weathering	42	631

Bed	Lithology	Thickness (feet)	Height above base (feet)
35	Shale, platy; 50% siltstone at top decreasing to 30% at base; rusty weathering, few concretions, 4″ × 6″; siltstone in ½″-1½″ beds; grades into underlying unit	38	589
34	Shale and 10% siltstone, platy to rubbly at base, rusty weathering	23	551
33	Shale and 50% siltstone, rusty weathering, a few concretions	14	528
32	Shale and 35% siltstone, rusty weathering; limy at top with 1′ × 5′ limestone concretions and 1′ × 3′ concretions at base	7	514
31	Shale, rubbly, rusty weathering; a few thin siltstones	14	507
30	Shale, and 50% siltstone in ½″-2″ beds, rusty weathering	18	493
29	Shale, fissile, soft, dark grey to black, yellowish grey weathering	12	475
28	Shale, fissile, soft, grey, with 2″ limy band at top and disk-shaped concretions at 8′	11	463
27	Shale, rubbly, rusty weathering	7	452
26	Shale, grey, fissile, soft, yellowish grey weathering	13	445
25	Shale, as above; and 20% siltstone	7	432
24	Shale, platy to rubbly, with 10% to 20% thin siltstone, rusty weathering	43	425
23	Shale and 50% siltstone, siltstone decreasing to 25% at base, rusty weathering; 1′ × 6′ concretion near top	24	382
22	Shale, platy to rubbly, rusty weathering	12	358
21	Shale and siltstone; siltstone, platy, 50% at top decreasing to 30%, rusty weathering; 2′ to 5′ limestone concretions at base, some limy beds	20	346
20	Shale and 15% siltstone, rusty weathering, rubbly at base; large 1′ × 3′-4′ limestone concretions, yellow weathering	25	326
19	Shale, rubbly; large limestone concretions	8	301
18	Shale, platy at top, becoming rubbly towards base, rusty weathering	24	293
17	Shale, platy to rubbly	8	269
16	Inaccessible. Shale, platy, rusty weathering, some 6″ × 18″ concretions; minor contortion near base	63	261
15	Shale, rubbly, rusty weathering; 2″ limestone bed at top; rare limestone concretions	12	198
14	Shale, platy; 25% siltstone; rusty weathering	16	186
13	Shale, rubbly, rusty weathering	3	170
12	Shale and 20% siltstone	6	167
11	Shale, rubbly, rusty weathering	4	161
10	Shale and siltstone, 25% siltstone at top decreasing to 10% at base	16	157
9	Shale, rubbly; a few thinly bedded siltstones	17	141
8	Sandstone to grit; concretionary with cone-in-cone structure; 30% shale	1	124
7	Shale and 40% siltstone to sandstone; rusty weathering	7	123
6	Shale, rubbly, rusty weathering	22.5	116
5	Limestone	0.5	93.5
4	Shale, platy to rubbly, rusty weathering; 2″ × 6″ limestone concretions	31	93
3	Siltstone, argillaceous, shaly, platy, bedded, dark grey	23	62

Bed	Lithology	Thickness (feet)	Height above base (feet)
2	Limestone, in 2′ × 4′ concretionary form; dense, argillaceous, bluish grey, yellow weathering	2	39
1	Shale, platy, to siltstone; dark grey, rusty weathering, more rubbly at base	37	37
	Fault contact; displacement small		
	MOUNTAIN PARK FORMATION		
	Sandstone, medium-grained, silty, greenish grey, with 6″ silty shale at base	3	16.5
	Sandstone, medium-grained, greenish grey, brown to greenish grey weathering, massive	3	13.5
	Siltstone, greenish to brownish grey, rubbly	2.5	10.5
	Siltstone, argillaceous, massive, dark grey, brownish grey weathering, carbonaceous	3	8
	Siltstone, argillaceous, rubbly, blocky, dark grey, greenish to brownish weathering	5	5

The marked change in thickness of the basal member from northwest to southeast is shown in the cross-section (Fig. 4). The change may be due partly to differential rates of sedimentation, but is largely due to the markedly time-transgressive nature of the basal deposits. In the Crowsnest area, the base of the Blackstone lies high in the late Cenomanian *Dunveganoceras* zone. Towards the north, the beds become increasingly older, and in the type section may be as old as the upper part of the zone of *Neogastroplites* (late Albian). The base of the Blackstone formation is, therefore, time-transgressive with progressive overlap from northwest to southeast along the Foothills.

Sunkay Member

The name Sunkay is proposed for the rusty weathering shales, siltstones and coarse-grained sandstones that comprise the basal member of the Blackstone formation. This member is equivalent to beds previously referred to as the Barren zone (Webb and Hertlein, 1934). Sunkay Creek from which the name is taken enters Bighorn River below the type section of the Blackstone formation, where a comparatively unfaulted section of the member is exposed.

This member is underlain by the Blairmore sandstones and shales and is overlain by the silver-grey weathering calcareous shales of the Vimy member. The upper contact is drawn at the top of the rusty weathering beds.

The Sunkay member is found throughout the southern and central Foothills (Fig. 15b). North of Athabasca River, the Dunvegan formation is equivalent to part of the type section of the Sunkay member, and therefore the interval of the Sunkay in the Kaskapau formation is less than that of the member as developed in the Blackstone formation (*see* Fig. 4).

The thickness of the Sunkay member decreases from 526 feet on Brazeau River (Pl. VIII) in the north to 15 feet on Castle River (Pl. X) in the south

(Fig. 15b). The maximum of 631 feet was obtained in the type section. This thickness is almost the same as that obtained for the total of the basal beds of the Kaskapau and Dunvegan formations, and the shales of the Fort St. John group which are considered to be equivalent on Little Berland River.

Clow and Crockford (1951) implied that this member is missing south of Crowsnest Pass by reporting *Inoceramus labiatus*, a guide fossil of the overlying Vimy member, at the base of the Blackstone shales. Although the fossil is found within a few feet of the base, the bentonite horizon is present and lies on at least 2 or 3 feet of typical rusty weathering, silty shales, which are included in the Sunkay member.

Variation of thickness across the regional strike is not well known because few sections are exposed in the area. On Sheep River, the Sunkay thins from 151 to 110 feet towards the east. If the trends of the member follow that of the group as a whole, then the member could be expected to thin towards the Plains. However, this eastward convergence is not expected to persist because marine shales of the Plains which were deposited somewhat earlier than those in the Foothills may be included, and thus increase the thickness of the interval between the nonmarine Cretaceous sediments and the overlying Vimy member. A thickening of this interval was shown by Scruggs (1956, Fig. 3) to be due to the presence of the Bow Island (Viking) sandstones.

The base of the member is usually marked by beds of pebbles or coarse-grained sandstone which vary in thickness from a few inches of pebbles in a

D.F.S., 7-3-54

Plate VIII. *Sunkay member of Blackstone formation (Blk), Brazeau River, section 4–54. Note cyclic development shown by more massive beds. Mountain Park formation (Mp) in immediate foreground.*

shaly matrix as on Wapiabi Creek (section 5-33) to 31 feet of massive, coarse-grained sandstone on Ghost River (section 6-18). Henderson (1945) reported 22 feet of basal sandstone on Fall Creek. The pebbles, composed mainly of chert, are well rounded, disk-shaped, and range in colour from white through shades of green and greyish blue to black. The beds of coarse-grained sandstone are generally massive and weather a distinctive maroon to olive-green.

A bed of fine-grained sandstone with numerous pelecypods lies below the pebble bed on Lynx Creek (Carbondale map-area). It is considered to represent a slightly earlier transgression than the overlying shales because it lies below the pebbles and a presumed disconformity. Clow and Crockford (1951, p. 33) included this bed in the Blackstone and reported that the pelecypods were *Exogyra laeviuscula* Roemer. Sandstone containing similar fossils have been reported at the base of the Blackstone formation elsewhere in the Carbondale map-area (Norris[1]) and Fernie (east-half) map-area (Price[2]).

The lower part of the Sunkay member is much siltier than the upper half. Thick units composed of 1-inch to 2-inch beds of siltstone are common, and contain large reddish brown or yellowish weathering 'kettle' concretions, as much as 4 feet long and 3 feet thick. A layer of coarse-grained sandstone which lies 40 to 50 feet above the base serves as a distinctive marker. The upper part of the Sunkay member, consisting mainly of fissile to platy shales, has a much less massive appearance than the lower part.

In the type section, seven cycles are recognized. Each cycle begins at the base with fissile to rubbly shale. The silt content increases towards the top until the shale becomes platy or grades into siltstone. The physiographic expression of these cycles is well illustrated in the section on Burnt Timber Creek (Pl. IX). The tops of the lower two cycles are marked by platy to flaggy siltstones, and the second cycle generally has thin lenses of coarse sandstone near the top. Some fish scales have been noted in association with these beds. The third cycle is not well developed but the fourth and fifth are prominent. The sixth contains much fissile to rubbly shale and the seventh has several subcycles which cannot always be correlated from one section to another. These cycles have considerable lateral extent (Fig. 4).

Cycles four to six are considered equivalent to the Dunvegan formation as it occurs north of Athabasca River. Although Stelck[3] recognized the Pouce Coupé sandstone on McLeod River by palæontological evidence, the precise stratigraphic sequence at that locality is uncertain because of fault repetitions. On McLeod River above the town of Mountain Park, 15 feet of argillaceous sandstone is exposed in the basal shales of the Blackstone formation. The basal beds of sandstone contain some carbonaceous remains. Overlying this unit is about 25 feet of dark rusty weathering shale which in turn is overlain by a bed of resistant argillaceous siltstone. These sandy beds may represent the Dunvegan facies.

[1]Norris, D. K.; personal communication.
[2]Price, R. A.; personal communication.
[3]Personal communication, March 18, 1957.

D.F.S., 3-6-56

Plate IX. *Cyclic development in Sunkay member of Blackstone formation shown by alternation of recessive and resistant beds. Contact with the Vimy member (V) is at left side of picture. Burnt Timber Creek.*

The correlation of beds within the Sunkay member between Bighorn River and Burnt Timber Creek is difficult (Fig. 4) as no completely exposed section is known in the area. The basal three cycles are recognized in one section near North Saskatchewan River, but the upper part of the section is badly faulted. A section on Smallpox Creek is complete but has covered intervals. It is, moreover, less than one half the thickness of the type section. The exposure on Cripple Creek contains numerous faults. The Ram River section appears to correlate well with the one on Burnt Timber Creek but, as the base is faulted, the correlation is questionable. Compared with the Smallpox section, the Ram section is believed to be almost complete, although it is faulted near the base. It is probable that the lower two cycles and possibly the third cycle of the type section disappear south of North Saskatchewan River. This apparent southward on-lap continues in the area between Highwood and Castle Rivers, where the fourth, fifth, and sixth cycles are not recognized.

An extremely thin section near the junction of Carbondale and Castle Rivers reveals 10 feet of typical rusty weathering Sunkay shale below the bentonite horizon and silver-grey weathering calcareous shales of the Vimy member (Pl. X). The shales lie above a bed of chert pebble conglomerate with cobbles as much as 3 inches in diameter. Three feet of pebbly shale lie between the conglomerate and the greenish agglomerates and tuffs of the Crowsnest formation.

Bentonite is rare in the Sunkay member. A few inches of bentonite lie above the basal coarse-grained sandstones on Ghost River.

Age and Fauna

In 1928, when Warren and Rutherford outlined fossil zones in the Colorado shale (Alberta group) of the Foothills, they established a 'Barren zone' which included the lower 200 to 500 feet. This Barren zone contained shales now placed in the Sunkay member.

The recognition of *Dunveganoceras* (*Acanthoceras*)[1] *albertense* (Warren) in the Barren zone by Webb and Hertlein (1934) was not of importance for widespread regional correlation at that time, because the fossil zones of the Cretaceous sediments in Western Canada had not been well established. Work since then by Warren and Stelck (1940), McLearn (1937, 1945), Stelck and Wall (1954), and others has shown that the *Dunveganoceras* fauna has a restricted range within late Cenomanian time, and can be used for zoning this stage.

Table VI

Fauna of Sunkay Member

Fauna	GSC Location[3]								
	24809	27069	27077	27094	27103	28169	28182	32862	32875
Dunveganoceras sp. indet.	—	x[2]	x	x	—	—	—	—	?
Inoceramus corpulentus McLearn	—	?	—	x	—	c[1]	—	c	x
Inoceramus fragilis Hall and Meek, s. lato	—	—	—	—	c	—	—	—	—
Inoceramus ex gr. *I. lamarcki* (Parkinson)	—	x	—	—	—	—	—	—	—
Inoceramus ex gr. *I. athabaskensis* McLearn	?	—	—	—	—	—	—	—	—
Fish scales	—	—	—	—	x	—	x	—	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

The *Dunveganoceras* zones (*see* Table VI for faunal list) are the only faunal zones that are definitely recognized in the Sunkay member. A large ammonite, considered similar to *D.* (*Acanthoceras*) *albertense* (Warren) was found by Webb and Hertlein in an exposure on Castle River where the member does not appear to be more than 20 feet thick. Warren and Stelck (Stelck and Wall, 1955, p. 64) reported that *D. parvum* Cobban, *D. conditum* Haas, *D. clowi* Warren and Stelck were found in the Blackstone shales near Cadomin. *D. hagei* Warren and Stelck was said to have been collected on Blackstone River, and *D. clowi* was also found on Castle River. In the type section, *Dunveganoceras* specimens were collected

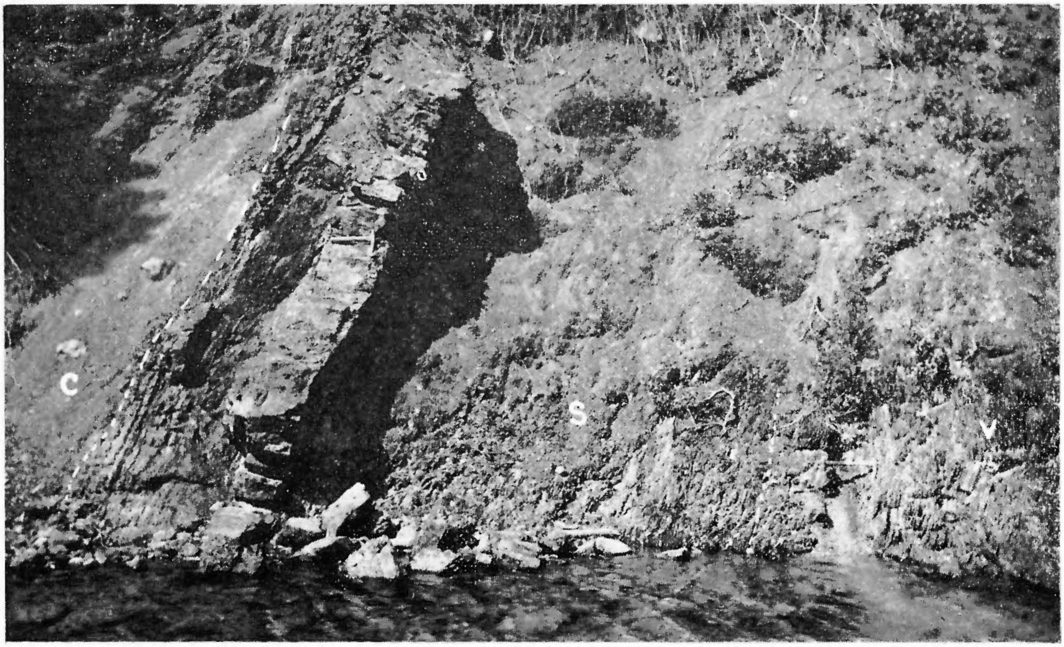
[1]In 1940, Warren proposed a new genus *Dunveganoceras* for specimens considered different from the true *Acanthoceras* (Warren and Stelck, 1940, p. 144).

385 feet from the base of the member and also about 45 feet from the top. Irish (1951) reported *Dunveganoceras* specimens from above the Dunvegan formation in strata now considered equivalent to the upper part of the Sunkay member of the type section. Therefore, although the record is meagre, the *Dunveganoceras* fauna has been recognized at various places throughout the Alberta Foothills, and indicates that the basal member of the Blackstone formation is at least of late Cenomanian age.

Some recent references (Clow and Crockford, 1951, p. 33; Stelck and Wall, 1954, p. 15) imply that the base of the Blackstone is in the *Inoceramus labiatus* zone of the Turonian stage. Stelck and Wall stated (op. cit., p. 15):

> In the Bragg Creek area, Alberta, *Inoceramus* cf. *labiatus* occurs within 50 feet of the base of the Alberta shales, and in the Castle River, Alberta, *Inoceramus labiatus* and *Watinoceras reesidei* occur within a few inches of the underlying beds (Crowsnest?).

The beds that are questionably referred to as Crowsnest are beds of bentonite at the base of the Vimy member, and these are separated from the agglomerates and tuffs of the Crowsnest formation by the typical pebble beds which are generally present at the base of the Blackstone formation. Stelck[1] clarified the relationships by stating that "*Dunveganoceras clowi* occurs below the tuff-bed that



D.F.S., 8-1-56

Plate X. *Sunkay member (S), Castle River, section 6–53. Beds are overturned. Contact with Crowsnest volcanics (C) on left overlain by coarse-grained sandstone and pebble-conglomerate. Hammer on right lies across bentonite at base of Vimy member (V). Shale between bentonite and conglomerate is rusty weathering.*

[1]Personal communication, March 18, 1957.

is found below *I. labiatus* and above the Crowsnest volcanics proper". In the Carbondale area, between the base of the Blackstone formation and the bentonites of the Vimy member, 1 foot to 20 feet of rusty weathering shales are found that are typical of the Sunkay member. It was apparently from these shales that *Dunveganoceras* specimens have been collected. The bentonite beds do not mark the base of the Blackstone formation but occur well above the base except in the area where the Crowsnest formation is present (*see* Fig. 4). *Dunveganoceras* indicates a Cenomanian age for the base of the Blackstone in this area.

Although no measurable sections of the Blackstone formation were found in the Bragg Creek area, sections were measured on Ghost River to the north and on Sheep River to the south, and these are along the depositional trends with the Bragg Creek outcrops. A minimum thickness of 110 feet of rusty weathering shales of the Sunkay member lies below the typical shales of the Vimy member on Sheep Creek. On Ghost River, the Sunkay has a thickness of 202 feet. It is unlikely that this member is missing in the Bragg Creek area, and as it lies below the *Inoceramus labiatus* zone, it would seem to be equally unlikely that the *I. labiatus* zone occurs at the base of the Blackstone formation in the Bragg Creek area.

The age of the lower part of the Sunkay member in the type section is not known, but some tentative age relationships may be suggested by lithologic correlation.

Cycles four and five of the Sunkay member in the type section are correlated through sections on Brazeau River and Little Berland River (*see* Fig. 4) with the Dunvegan formation in the region of the Muskeg and Smoky Rivers. Specimens of *Pleurobema dowlingi* McLearn were collected from the Dunvegan outcrop by the writer and specimens of *Inoceramus dunveganensis* McLearn were collected by Thorsteinsson (1952). Jeletzky commented on *P. dowlingi* as follows:

> This fauna is widespread in the Dunvegan formation of northeastern British Columbia and northwestern Alberta. It is considered tentatively to be approximately contemporary (? a brackish water to nonmarine facies) with the so-called *Inoceramus dunveganensis* fauna. Both faunas are now known to be of the early Upper Cenomanian age in terms of the international standard stages. This is indicated by their being either contemporary with or slightly younger than the *Acanthoceras* (*Eumphaloceras*) *athabascense* zone of the Lower Athabasca area on one hand and being overlain by the late Upper Cenomanian *Dunveganoceras* zone on the other.

Due to the time-transgressive nature of the base of the Blackstone, this lithologic zone probably occurs near or at the base of the formation south of Ram River.

Thorsteinsson (1952) collected *Neogastroplites* specimens about 200 feet above the lower contact of the Fort St. John shales in the Grande Cache area, thus dating the beds as Albian. The stratigraphic position from which the *Neogastroplites* fauna was collected is correlated on the basis of lithology (Fig. 4) with the second cycle in the basal Sunkay member of the Blackstone formation. As lithologic units may be time-transgressive, age determinations based on lithologic evidence is extremely tenuous, but some possibility exists that the basal Blackstone in the central Foothills is of Albian age. The occurrence of sandstone beds with some fish scales at the top of the second cycle of the Sunkay member also suggests an Albian age for the underlying shales. A 'fish-scale' marker has been used by Stelck (1950) as indicative of the Albian-Cenomanian boundary in the Peace River region where it occurs between the *Neogastroplites* zone and the overlying Cenomanian zones. As Stelck pointed out, zones of fish remains are known at several stratigraphic positions in the marine sequence, but such zones are not necessarily diagnostic. However, Stelck, *et al.* (1958, p. 23) correlate beds in the Nordegg area with the fish-scale sand marker bed of the Peace River region.

For many years, the position of the Early Cretaceous-Late Cretaceous boundary within strata of the Alberta Foothills has been in doubt. Precise determination has been hindered by the lack of diagnostic flora and fauna within the stratigraphic interval that contains this time horizon. The boundary problem is discussed by Jeletzky, and also Stelck, *et al.* (1958) who place the Albian-Cenomanian boundary above the *Neogastroplites* zones. The latter use the fish-scale beds of the Peace River region as a convenient marker.

On Sulphur River on the northern edge of the area, the boundary may be fairly well fixed as occurring somewhere within a zone from the base of the Dunvegan formation to within 200 feet of the base of the Fort St. John shales. This is based on the collection of *Inoceramus dunveganensis* and *Neogastroplites* from the Dunvegan and Fort St. John beds respectively. On purely lithological correlation, the boundary may be tentatively drawn at the sandstone bed of cycle two of the Sunkay member within the central Foothills. Marked thinning of the section occurs from North Saskatchewan River southward, and the beds below the grit horizon appear to feather out. As the flora in the upper part of the underlying Blairmore formation is of Albian age (Bell, 1956, p. 15), the Early Cretaceous-Late Cretaceous boundary probably is coincident with the contact of the Blairmore formation and the Blackstone formation in the vicinity of Bow River. The boundary becomes even more elusive where the Crowsnest formation occurs. It possibly lies within the volcanic beds, or is coincident with the contact between the Crowsnest and Blackstone formations.

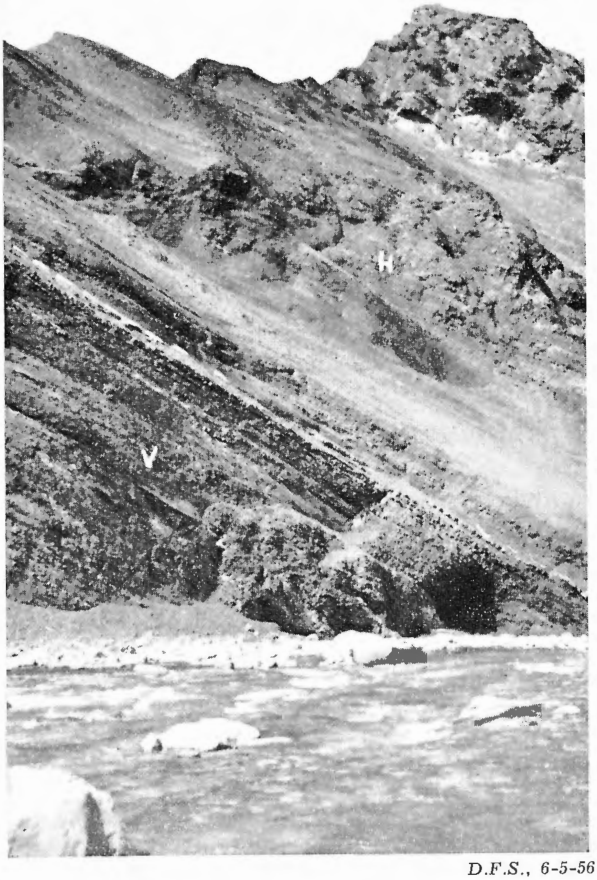
This tentative placement of the boundary would suggest that at the end of Albian and beginning of Cenomanian time, no marine sediments were being deposited in the area now occupied by the southern Foothills. Farther north, marine sedimentation continued from Albian time into Cenomanian time with little or no hiatus.

Vimy Member

Malloch's described section (1911, p. 23) of the Blackstone formation is on Wapiabi Creek near Vimy, a forestry locality, from which the member got its name. The member includes those beds formerly placed in the *Inoceramus labiatus* zone (Webb and Hertlein, 1934), and is characterized by its silver-grey weathering calcareous shale and by its yellow to buff weathering beds of dense argillaceous

D.F.S., 6-5-55

Plate XI. *Looking west on Bighorn River along type section of Blackstone formation. Beds in foreground are in Vimy member (V). Whitish bed in middle marks contact with Haven member (H). Opabin member (O) is visible in the distance at extreme left. Cliff above trees on river bank contains Ram member of Cardium formation (Ca).*



D.F.S., 6-5-56

Plate XII

Typical exposure of Vimy (V) and Haven (H) shales. Contact is at thin resistant band at water level on right. Sheep River, section 6–32.

dolomitic limestone. It contains all the beds between the underlying Sunkay member and overlying Haven member, both of which contain rusty weathering non-calcareous sediments. The type section of the Vimy is on Bighorn River (Pl. XI).

The conformable contact between the Vimy and Sunkay members is distinct in most sections; where not apparent, a persistent bed of bentonite near the base of the calcareous shales may be used as an approximation. A bed of dark silty dolomite, 1 foot to 2 feet thick, commonly occurs at or near the upper contact (Pl. XII), which is also conformable.

The Vimy member extends from Carbondale River to Muskeg River. Throughout this area, the rocks are mainly dark grey, calcareous shales, containing more silt in the west and more limestone in the east. The Vimy member, although defined in the type section of the Blackstone formation, extends across Athabasca River where it is included in the Kaskapau formation of the Smoky group (Figs. 3, 4).

The thickness of the member varies from 605 feet on Bighorn River (section 5-34) to 154 feet on Lynx Creek in the Carbondale area (section 6-51, *see* Fig. 15c). Exposures in most places contain several faults and folds so that the true stratigraphic thickness is difficult to obtain; almost all the sections shown in the cross-section (Fig. 4) contain small faults, and it is probable that their true thicknesses are somewhat smaller than those estimated.

Although the base of the Vimy member is involved in folding on Little Berland River, the thickness of the member is considered to be only slightly more than that measured for the overlying less contorted beds. The beds are horizontal in a large part of the folded zone but are vertical on either side, and the folding probably represents a flexure that did not repeat much of the member. No satisfactory section was found farther north, although 250 feet are exposed on Mahon Creek. A well-exposed section on Muskeg River near McDonald Flats, inaccessible because of high water, was estimated visually to be about 650 feet thick above the folds which occur near the base. Of the thicknesses measured, that of 605 feet in the type section is one of the most reliable. East of the Bighorn Range, all the exposed sections of Vimy shale contain faults. An apparently slightly faulted exposure on Blackstone River on close inspection revealed many faults which would produce errors in the determination of thickness.

In the canyon of Ram River, the Vimy member appears to be uninterrupted below the Cardium section, but the upper beds are faulted onto part of the stratigraphically higher Haven member. The repetition is not readily apparent even at river level. Thus, in this section, the measurement must be made on the second section which was found to be 447 feet thick. The section contains a few small drag-folds and faults for which some correction was made.

A fault is assumed at the base of the 450-foot section of the member on Burnt Timber Creek (6-9) but as the interval is covered, no evidence of such a fault was found. However, the inclusion of the covered interval as measured produces too large a thickness for the member compared to neighbouring sections. Farther east on Burnt Timber, another section, containing numerous covered intervals, gave a calculated thickness 100 feet less than that of the western section. Even so, this figure is greater than the thicknesses measured on Ghost and Ram Rivers.

The section on Ghost River is 287 feet thick. From an interpretation of the section as measured by Hume (1936), 309 feet of the beds he described would be in the Vimy member. Webb and Hertlein (1934) apparently based their thicknesses on the Blackstone units in this section, and suggested 300 feet for the calcareous shales.

The only reliable evidence of the eastward thinning of the member is provided by three sections, comparatively free from faults, on Sheep River. They show a thinning from 328 feet on the west to 254 feet on the east.

Two sections were measured on Lynx Creek, and both contain minor faults. The minimum thickness of 154 feet is considered to be more accurate.

The Vimy member is one of the most distinctive units of the Alberta group, and usually is easily recognized. Its shales are calcareous and typically weather silver-grey. Pyrite and organic material are abundant. The shales of the Thistle member in the Wapiabi formation are somewhat similar but are less calcareous and weather dull grey or even slightly rust rather than silver-grey. Another feature that characterizes the Vimy member is the silty aphanitic dolomitic limestone beds, 1 foot to 5 feet thick, that weather light buff to yellow. These beds are more continuous than similar ones in the Thistle member.

An exception to the usual silver-grey weathering is found on Muskeg River, where the Vimy member is somewhat rusty at the top but becomes more typical towards the base. The variation may indicate a change in character towards the north.

The shales of the Vimy member are platy to fissile. The platy shales are quite silty. The less silty shales are flaky or fissile, but the rubbly shales that are present in the other Blackstone members do not occur. Towards the eastern edge of the Foothills, the shales are flaky rather than platy, and only rare thin siltstone beds are found. In contrast, on the western edge as in the type section, the shales are platy and interbedded with thin siltstones and sandstones. The increase in coarser sediments is associated with an increase in thickness.

The lower half of the Vimy member contains abundant specimens of *Inoceramus labiatus* Schlotheim which seemed to thrive in these calcareous muds. Specimens may be found higher in the member but they are not as abundant. Ammonite specimens are not plentiful but occur as impressions with the *Inoceramus* specimens. Some of the better collections were obtained in the shaly limestone beds. In some of the limestone beds, small pelecypods (*Ostrea*) were fairly numerous, but most of the limy beds were not fossiliferous.

In the eastern sections on Sheep and Highwood Rivers, thin limestone beds are extremely numerous in the basal two units. These beds, being hard, give the section a banded or striped appearance, and have some similarity to the silty section along the western edge of the Foothills.

Some bentonite is present within the Vimy member, especially near its base. On Lynx Creek, in the Carbondale area, 4 feet of creamy to greenish white bentonite contains siliceous concretions which crack and chip into splintery fragments. This bentonite bed was found on Highwood and Oldman Rivers. Although not shown in the section on Sheep Creek (the section is badly folded at this horizon) the bed occurs in sections farther east. It was found on Ghost River, Burnt Timber Creek, and South Ram River. It is not exposed in the type section but it is present at the base of the Vimy member on Littlehorn River, a few miles to the west. Stelck[1] reported tuff at the base of these shales in the Peace River area. A bed in a similar stratigraphic position was reported in Glacier National Park by Cobban (1956, p. 1003) who traced it for 250 miles. If this is the same bed, as seems likely, it is a key marker throughout the Foothills. Other thin bentonites occur in the Vimy shales near the top of the member on Chungo Creek and in the area of Sheep and Highwood Rivers.

Six cycles are recognized in the Vimy member (Fig. 4) and within each of these, two or three subcycles may be present. The lower three cycles are 100 to 150 feet thick in the type section and are well developed. The shale near the base of each cycle is flaky or fissile but grades upwards into platy types. At the top, thin siltstone beds, one-half inch to 2 inches thick, are interbedded with the shale. Dense argillaceous dolomitic limestone, dark bluish grey and yellow weathering, commonly occurs at the base of the cycles. Because of this stratigraphic position, the limestones appear to correlate well from section to section, but they may be lenticular and not continuous as individual beds. Small disk-shaped concretions, 6 or 8 inches in diameter, and 2 or 3 inches thick, are common below the major carbonate beds. These weather yellowish grey, not the reddish brown of the Wapiabi or Opabin concretions, and have not yielded any fossils. The fourth cycle is rather thin, about 60 feet, and resembles a subcycle within the underlying thicker ones, but nevertheless, it may be traced over most of the area. The fifth cycle is about 150 feet thick in the type section. It is mainly shale with silt increasing slightly in the upper part. The sixth and uppermost cycle is more or less a transition zone between the Vimy and Haven members. It is less than 30 feet thick and contains shale that weathers somewhat rusty. One or two beds of limestone frequently occur at or near the top of the member. These cycles are traced at least from Little Berland River in the north to Highwood River in the south. In the Muskeg River section farther north, six cycles appear to be present, although the basal ones are not clearly defined.

Hume (1938, p. 11) described two sandstones in the Lower Alberta shale (Blackstone). One was a "coarse quartzitic sandstone known as the 'grit' " and is the coarse sandstone found at the base of the Blackstone formation. The other

[1]Personal communication, March 18, 1957.

sandstone was "about 300 feet above the base of the formation . . . a somewhat coarser sandstone known as the Jumping Pound member". The Jumping Pound member is not recognized as a formal unit in this report but seems to be equivalent to the upper part of cycle two of the Vimy member. On Sheep River (section 6-39), interbedded siltstone and shale appear to be equivalent. A three-inch band of laminated siltstone is the coarsest representative. Similarly, on Highwood River and Ghost River, the Jumping Pound 'sand' is represented by siltstone. Douglas (1950, p. 29) reported that 4 feet of fine-grained sandstone occurred about 300 feet above the base of the Blackstone formation in the Gap area, and suggested that it might be equivalent to the Jumping Pound sand of Turner Valley. In the Alberta Society of Petroleum Geologists' Lexicon (1954), the Jumping Pound sand is said to be about 200 feet thick as defined by electric logs. Such a thickness of sandstone is not present in the outcrop sections.

Age and Fauna

Most of the Vimy member belongs in the *Inoceramus labiatus* zone of the early Turonian stage. This zone was formally recognized by Warren and Rutherford (1928) who did not know the precise limits of the occurrence of the fossil, but who stated that it had not been found as high as the Cardium sandstones. Webb and Hertlein (1934) did not indicate the range of this fossil but listed it from only one lithologic unit.

Inoceramus labiatus Schlotheim (*see* Table VII for faunal list) occurs most abundantly in the lower part of the Vimy member. No specimens were collected below the bentonite near the base of the member, and this marker may possibly mark the lowest range of *I. labiatus*. None of the collections came from the top of the member. The species is apparently limited to the Vimy member and possibly restricted to the lower two thirds of the member.

The widespread bentonite layer within a few feet of the base of the member provides a key time horizon within this part of the Alberta group. It indicates that the base of the Vimy member is of the same age throughout this area, and also indicates that the top of the Sunkay member is not time-transgressive.

Cobban (1956) reported *Sciponoceras gracile* (Schumard) in a bentonite layer apparently at the same stratigraphic position within the Colorado shale of the Sweetgrass arch in Montana. The ammonite is the index of the lowermost faunal zone of the Turonian stage. The zone of *Sciponoceras gracile* has not been recognized in the area of this study. If it is present, it must occur near the contact of the Sunkay and Vimy members, because *Dunveganoceras* of the underlying zones and *I. labiatus* of the overlying zone have been collected from beds separated by only a small interval which includes the bentonite horizon. The suggested dating of the bentonite by *Sciponoceras gracile* would not conflict with the present palæontological evidence obtained from the Blackstone formation. Stelck and Wall (1954) reported a "white chalcedonic or nodular" band at the base of the black calcareous shales of the Kaskapau formation in the

Table VII

Fauna of Vimy Member

Fauna	GSC Location[3]																						
	24789	24800	27043	27046	27057	27072	27106	28057	28062	28070	28076	28083	28170	28171	28181	28205	28211	28212	28213	32869	32872	32873	32881
Baculites sp. indet.	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Metoicoceras sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	?	–	–	–	–	–	–	–	–
Prionocyclus (*Collignoniceras*) *woollgari* Mantell *sensu* Haas 1946	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[2]	–	–	–	–	–	x
Prionocyclus s. lato	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	?	–
Scaphites sp. indet. (*S. delicatulus* Warren?)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
Scaphites larvaeformis Meek and Hayden	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Scaphites larvaeformis var. *S. obesa* Cobban	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Watinoceras reesidei Warren	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Watinoceras sp. indet.	–	–	?	–	–	–	–	–	–	–	–	?	–	–	–	–	–	–	–	x	–	–	–
Inoceramus labiatus Schlotheim	c[1]	c	–	x	c	–	–	x	c	c	–	x	c	c	x	c	–	x	–	x	x	–	–
Inoceramus ex gr. *I. lamarcki* (Parkinson) s. lato	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Inoceramus sp. indet.	–	–	–	–	–	–	x	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–
Ostrea congesta Meek and Hayden	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	?	–	–	–
Fish scales	–	–	–	–	–	x	–	x	–	–	x	–	–	–	–	x	–	–	–	–	–	–	–

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

Peace River area. Stelck[1] considered that this tuff bed probably was also within the zone of *S. gracile.* This correlation would indicate that the layer may be traced for almost 900 miles from Peace River area to Glacier Park, a most useful time line indicating that the deposition of Vimy-type shales started at approximately the same time throughout Western Canada and northern Montana.

The *Inoceramus labiatus* zone also is characterized by the presence of *Watinoceras reesidei* Warren. Generally, only poor impressions of this ammonite are found. Most of the collections were made from the thinly bedded argillaceous, dolomitic limestone bands where large surface areas may be covered with impressions.

Some doubt arises as to the lowest range of *Prionocyclus* (*Collignoniceras*) *woollgari* Mantell, as the fossil has been reported in all the members of the Blackstone formation. Undoubtedly, some of the confusion has been caused by the wide variations found within the genus, which Haas (1946) has attempted to divide. The earlier identifications of *Prionocyclus woollgari* may have included forms no longer retained in the restricted species. Warren and Rutherford (1928) believed that *P. woollgari* was not associated with *I. labiatus,* but that it represented a higher zone. This zonation was refuted by Webb and Hertlein (1934, p. 1406): "Contrary to these ideas, the present writers find that *Prionotropis woollgari,* though rare, occurs only in the fine-grained, fissile shales in which *I. labiatus* generally abounds, and therefore marks neither a higher nor a lower zone than the latter species". Collections made during the present study support the suggested zonation of Warren and Rutherford. Specimens comparable to or referable to *P. woollgari* Mantell *sensu* Haas have been collected in the Haven and Opabin members, the upper two members of the Blackstone formation. The lowest occurrence of *P.* cf. *P. woollgari* was found 78 feet below the top of the Vimy member on Sheep River. It is clear that *P. woollgari* occurs in beds previously referred to as the *I. labiatus* zone. Whether a distinct boundary exists between the zone of *I. labiatus* and *P. woollgari* remains uncertain, but the zone of *P. woollgari* extends into the lithologic zone of *I. labiatus* as used by Webb and Hertlein.

Inoceramus labiatus is extremely valuable for regional and world-wide correlations, and marks a time of widespread marine transgressions. Although the Vimy member is distinctive lithologically, the fossil may be used as confirmation of the identification, and is of some value in the recognition of the Vimy member where it is confused with the Thistle member of the Wapiabi formation.

Haven Member

The name Haven, proposed for the third member of the Blackstone formation, is taken from a creek which drains from the southeastern side of the Bighorn Range into North Saskatchewan River west of Nordegg. The characteristic weathered surface of the Haven shales was responsible for the name 'Rusty shales' in previous reports. The type section is along Bighorn River.

[1]Personal communication, March 18, 1957.

The contact of the Vimy and Haven members appears gradational in some places, and where exposures are poor, the uppermost limestone bed in the Vimy member is used as the division line (Pl. XII) even though it is not always the top. The upper boundary of the Haven member is generally drawn below the last shale unit containing numerous concretions. Hard, platy siltstones are usually found at the top of the member.

The Haven shales extend southward from the type section to Castle River, and northward to Muskeg River (Fig. 15d) where they are included in the Kaskapau formation.

The most northerly section, measured on Little Berland River, was found to be 179 feet thick (section 5-19). In the Bighorn-Nikanassin area, the Haven member attains its greatest thickness. The type section is 319 feet thick, and on Thistle Creek (section 4-22) the member is 274 feet thick. On Wapiabi Creek (section 4-2) east of the Bighorn Range, a thickness of 137 feet was measured. The thickness on Burnt Timber and Ghost River was 240 and 203 feet, respectively. The Haven member in the area of Sheep and Highwood Rivers is between 125 and 160 feet thick, decreasing in thickness towards the east. On Lynx Creek, the separation of the Haven and Opabin members is somewhat difficult, but apparently about 35 feet of beds above the Vimy member belong in the Haven member.

Although each cyclic unit of the member increases in thickness westward, the most marked increase is in the upper 'transition' beds west of the Bighorn Range (*see* Fig. 4).

The Haven member consists of shales and thin siltstones which weather a dark rust due to the presence of pyrite and siderite. These shales frequently have a fetid odour, which property caused Hake *et al.* (1942) to name the sequence the hydrogen-sulphide zone. Yellowish sulphur stains are frequently seen, particularly in the more fissile shales of the member along the eastern edge of the Foothills. Large buff to yellow weathering, limestone lenses or concretions occur sporadically throughout the member and are locally fossiliferous.

The shales of the Haven member are dark grey to greyish black on a fresh surface, and contain abundant organic matter. They are platy to fissile when interbedded with siltstone but are usually rubbly (Pl. XIII). The rubbly nature contrasts with the more blocky weathering character of the Opabin and Wapiabi shales. The siltstones are thinly bedded and have a platy or flaggy appearance. Beds may be as much as 3 inches thick but are usually less. A few thin bentonite layers, generally less than a quarter of an inch thick, are present within the member. Near the junction of Wapiabi Creek and Blackstone River, bentonite layers occur at the top of the member.

Sideritic concretions within the Haven member are rather rare but are found in the siltier facies, especially on Bighorn River and Thistle Creek. They are reddish brown weathering and are usually smaller (2 by 3 inches) than those of the

Plate XIII

Upper beds of Blackstone formation, Wapiabi Creek. Ram sandstone (R) at top lies above Opabin member (O). Contact between Opabin shales and Haven shales (H) is about middle of picture.

D.F.S., 1-4-54

Opabin member. Elsewhere in the Haven member, the concretions are dolomitic and ellipsoidal, as much as 5 feet long and 2 feet thick, and weather greyish yellow.

In the Little Berland section (section 5-19), near the northern limit of the area, the member is typically developed and fairly well exposed. The upper part of the member is not visible on Muskeg River, but approximately 200 feet of typical Haven shale is exposed with a few sandy beds. On Mahon Creek, the exposure is covered with talus but a total thickness of 254 feet was measured.

The Maskuta Creek section (section 5-22) contains some silty shale but only a few siltstone beds. Farther south on Thistle Creek, thin laminated siltstone beds mark the top of the cycles. In the type section on Bighorn River, the cycles are well developed and the upper beds are as much as 50 per cent siltstone.

The silty character of the Haven member persists from Bighorn River southward to Ram River. On Burnt Timber Creek, a very silty, massive, unit is present at the top of the member. Less siltstone is found in Ghost River section. The western section on Sheep River (Pl. XII) contains as much as 50 per cent interbedded siltstone in some cycles, whereas the eastern sections consist mainly of rubbly, fissile shales with only a few beds of siltstone. The Lynx Creek (Carbondale area) sections contain rubbly shale.

Four cycles occur in the Haven member (Fig. 4). The lower three, between 75 to 100 feet thick in the western sections, are well developed and show a gradation from rubbly shale to thinly laminated siltstone. The three cycles have been traced over a large part of the Foothills. The uppermost cycle is a 'transition' unit below the concretionary shales of the Opabin member. It usually consists of beds slightly less silty than those of the third cycle, but has the uniform thin bedding of the Haven member which is not typical of the overlying member.

Age and Fauna

The Haven member is within the *Prionocyclus woollgari* zone which, according to Jeletzky, is of early late Turonian age in terms of the international standard stages.

Table VIII

Fauna of Haven Member

Fauna	GSC Location[3]							
	25076	27034	27055	27065	28071	28172	28187	28188
Prionocyclus (Collignoniceras) woollgari Mantell *sensu* Haas 1946	—	—	c[1]	c	x[2]	—	—	—
Prionocyclus (Collignoniceras) sp. indet.	x	—	—	—	—	—	—	x
Scaphites patulus Cobban	c	—	?	c	c	—	—	—
Scaphites sp. indet.	—	—	—	x	—	—	—	—
Inoceramus corpulentus McLearn	—	—	—	—	—	c	—	—
Inoceramus fragilis Hall and Meek	—	—	c	—	—	—	c	—
Inoceramus lamarcki (Parkinson)	—	—	—	c	—	—	—	—
Inoceramus lamarcki (Parkinson) s. lato	—	—	—	—	—	—	x	x
Inoceramus lamarcki (Parkinson) var. *I. apicalis* Woods	—	—	—	—	c	—	—	—
Inoceramus sp. indet.	x	—	x	x	—	—	x	—
Ostrea sp. indet.	—	—	—	—	x	—	—	—
Pteria sp. indet.	x	—	—	—	—	—	—	—
Gastropod	—	—	x	—	x	—	—	—
Fish scales	—	x	x	—	—	—	—	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

Specimens of *Prionocyclus* cf. *P. woollgari* Mantell (*see* Table VIII for faunal list) were collected from the Haven member in the type section of Bighorn River, on Little Berland River in the north, and from the top of the member on Sheep Creek in the Turner Valley area. An unidentified species of *Prionocyclus* was obtained from the same member on Luscar Creek. Associated with these specimens are forms comparable to *Scaphites patulus* Cobban. *Inoceramus corpulentus* McLearn, *Inoceramus fragilis* Hall and Meek and *Inoceramus lamarcki* (Parkinson) which are typical Turonian forms.

Although the zone of *Prionocyclus woollgari* may be useful in regional correlation with the standard of the western interior of the United States outlined by Cobban and Reeside (1952-6), its use in local correlation is of much less value. As it is known to range from the Vimy member to the Opabin member, it cannot be used to differentiate the upper three members of the Blackstone formation from one another. In complexly faulted and folded zones, lithologic characteristics must be relied upon in the recognition of the individual members.

Opabin Member

The concretionary shales underlying the thickly bedded sandstones of the Cardium formation and overlying the rusty weathering shales of the Haven member (Pl. XIII) are named the Opabin member, and contain the beds included in the Concretionary shale or Transition beds of earlier writers. The name is from Opabin Creek, which flows through the northwestern corner of the Bighorn area into the Brazeau River near Southesk cabin. The type section is an outcrop in the type section of the Blackstone formation on Bighorn River.

The lower boundary of the Opabin member is drawn, in most sections, at the base of the concretionary shales. In the more westerly sections, such as the type section of the member, a few small concretions also occur in the uppermost beds of the underlying Haven member. In these sections, the contact is drawn at the top of the hard platy siltstones of the uppermost cycle of the Haven member. The contact of the Haven and Opabin members is conformable and locally is gradational through 20 feet of strata. The upper beds of the Opabin are gradational into the Cardium formation (Pl. XV), and the upper contact is drawn at the base of the lowest thickly bedded sandstone of the Ram member.

The Opabin member has a distribution similar to the other members of the Blackstone formation and occurs throughout the Foothills belt (Fig. 15c). The average thickness is somewhat more constant than that of the other members, ranging from a minimum of about 70 feet on Lynx Creek (Carbondale area) to 213 feet on Little Berland River.

The Opabin member represents the transition from the shales of the Blackstone formation to the sandstones of the Cardium formation, and accordingly contains sediments that range from sandstone through siltstone to blocky and rubbly shales. The member typically contains large reddish brown weathering ironstone concretions. These shales with abundant concretions are in sharp contrast to the remainder of the Blackstone formation but are similar to those of the Wapiabi formation. The basal part of the member generally consists of dark grey, blocky shale or mudstone rich in dark organic material. The upper part of the Opabin member contains considerable quantities of massive, argillaceous siltstone and some sandstone.

In the Muskeg area, concretionary beds rather than individual concretions are dominant. This is a local variation because at Little Berland River, individual concretions are present. Concretionary beds were noted on Mackenzie Creek south of McLeod River.

A silty, thinly bedded sandstone, which Malloch (1911) originally included in the Bighorn formation on Wapiabi Creek, is stratigraphically equivalent to shales of the Opabin member in the eastern Foothills. This sandstone, included herein as part of the Blackstone formation, occurs on Littlehorn and Bighorn Rivers, Wapiabi, Thistle, and Mackenzie Creeks.

Two cycles and part of a third have been correlated within the Opabin member (Fig. 4). The third cycle contains the basal Cardium sandstone, and according to definition, only the lower shaly part of this cycle is placed in the Opabin member. The thinly bedded to flaggy sandstone at the top of the second cycle is 15 feet thick in the type section. The sandstone is fine grained with rather wavy or irregular bedding, and a few interbedded thin shale layers. Below this unit is sandy argillaceous siltstone, 25 feet thick, which has a massive appearance although it is bedded. Reddish brown weathering concretions 3 inches by 6 inches to a foot in cross-section, occur in both the siltstone and sandstone. The same unit on Wapiabi Creek (Pl. XIV) contains more uniformly bedded

D.F.S., 6-1-55

Plate XIV. *Looking west on headwaters of Wapiabi Creek. Sand facies of Opabin member of Blackstone formation. Sandstone on ridge line is basal member of Cardium formation.*

sandstone which is slightly laminated in beds 1 inch to 6 inches thick. This unit is somewhat shaly in the middle, and contains poorly developed concretions.

On Muskeg River, the Opabin member is quite silty with a massive siltstone bed about 100 feet from the top. Three or four thin sandstone beds are also present. The sandstone of the type section grades rapidly into siltstone and shale towards the east. Equivalent beds on Wapiabi Creek are dominantly shale (Fig. 8). A similar change is found as the sandy siltstone is traced eastward from Thistle Creek (Fig. 6). Southeastward to Ram River the sandstone becomes more argillaceous, and the unit grades into mudstone or shale. South of Ram River, the member maintains almost constant thickness and lithologic character. The cycles are not well developed in the southern Foothills but some slight changes in the shales can be noted. Most of the shale is blocky to rubbly, and slightly rusty weathering.

Age and Fauna

No marked faunal change occurs between the Haven and the Opabin members according to the collections made during this study. *Prionocyclus*

Table IX

Fauna of Opabin Member

Fauna	GSC Location[3]							
	24793	25077	25078	27036	27041	27064	27070	27073
Prionocyclus (Collignoniceras) woollgari Mantell *sensu* Haas 1946	—	—	—	—	—	c[1]	—	—
Prionocyclus (Collignoniceras) woollgari Mantell var. *P. typica* Haas	—	—	—	—	—	—	—	c
Prionocyclus (Collignoniceras) sp. indet	—	—	x[2]	—	—	—	—	—
Scaphites arcadiensis Moreman	—	—	—	—	—	c	—	—
Scaphites patulus Cobban	—	—	c	—	—	c	—	—
Anomia subquadrata Stanton	—	—	—	—	—	c	—	—
Inoceramus ex aff. *I. cordiformis* Sowerby	—	—	x	—	—	—	—	—
Inoceramus costellatus Woods	—	—	c	—	—	—	—	—
Inoceramus fragilis Hall and Meek	—	—	x	—	—	c	—	—
Inoceramus fragilis Hall and Meek var. *I. prairiensis* McLearn	—	—	—	c	—	—	—	—
Inoceramus lamarcki var. *I. apicalis* Woods	?	—	c	—	c	c	c	—
Inoceramus ex gr. *I. lamarcki* (Parkinson) s. lato	—	—	—	—	x	—	x	—
Inoceramus sp. indet	—	—	—	—	—	—	—	—
Pholadomya coloradoensis Stanton	—	?	—	—	—	—	—	—
Pteria sp. indet	x	—	x	—	—	—	—	—
Gastropod sp. indet	—	—	—	—	—	x	—	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

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D.F.S., 5-2-54

Plate XV. *Transition beds between typical shales of Blackstone formation (Blk) and sandstone of Cardium formation (Ca), Canyon Creek, section 4–12.*

woollgari Mantell has been collected from within the Opabin (*see* Table IX for faunal list) indicating that the member is also of early late Turonian age.

Only slight indication has been found of the occurrence of any of the specific zones which Cobban and Reeside (1952b) outlined between the zone of *P. woollgari* Mantell and *Inoceramus deformis* Meek. As will be shown later, part of the zone of *I. deformis* Meek and *Scaphites preventricosus* Cobban occurs within the Cardium formation. As *P. woollgari* has been found towards the top of the upper Opabin member, the zones of *P.* (*Collignoniceras*) *hyatti, Scaphites warreni, P. wyomingensis, S. nigricollensis,* and *S. corvensis* would seem to lie within a very short stratigraphic interval or else are not represented in the Alberta group.

Some evidence for the presence of *P. wyomingensis* in the Cardium formation is given by Stelck (1955, p. 134), who reported a comparable specimen from the formation on Highwood River. Stelck also reported that: "A small *Prionocyclus* regularly occurs approximately 175 feet below the base of the Cardium formation in the region of the Foothills between the Athabaska River and the Wapiti River in British Columbia. It seems to be related to *Prionocyclus macombi,* and is accompanied by *Scaphites warreni* Meek and Hayden." On the basis of the regional thickness of the Blackstone formation, this occurrence of *S. warreni* would be just above, if not within, the Haven member. As *P. woollgari* has been reported from both the Haven member and the overlying Opabin member, some overlap of the zone of *P. woollgari* and the zone of *S. warreni* may occur.

A specimen comparable to *Scaphites arcadiensis* Moreman from the Opabin member is suggestive of the zone of *Prionocyclus hyatti* because, according to Cobban (1951), *S. arcadiensis* is associated with fossils from the zone of *P. hyatti.* However, other specimens in the Opabin member are comparable to *Scaphites patulus* from the earlier zone of *P. woollgari.*

Cardium Formation

The term 'Cardium Shales' was used by Hector to identify beds from which fossil collections were made during the Palliser explorations (Whiteaves, 1895, p. 110). Cairnes (1907, p. 29) restricted the use of the term Cardium to a succession of sandstones within the shale series on Bow River. The name was used informally in southern Alberta until 1927, when Rutherford raised the unit to formational rank, although he did not point out that this change was being made. Rutherford (1927, p. 25) described the sequence as follows:

> The lower Benton formation is overlain, apparently conformably, by a thin formation known as the Cardium which consists of alternating sandstones and shales which grade uniformly into each other. The sandstones are usually light colored on fresh surfaces, fine-grained and well consolidated, and often carry beds of pebble conglomerate. The conglomerates are not persistent laterally, but occur more as lenses within the sandstone beds.

No type section was defined for the Cardium formation although Cairnes (1907, p. 27) described a generalized section from Bow River. Rutherford did not define a type section but stated that the formation was well exposed on Bow River. However, of the better exposed sections on Bow River none is suitable for a type section. The Cardium section at Kananaskis is faulted and another section, extremely well exposed in the canyon walls at Horseshoe Dam farther downstream, is mostly inaccessible.

The section which Malloch (1911, p. 23) described and which is designated herein as the type section of the Cardium formation was "measured on the more southerly of the two main branches of Wapiabi creek". This section is in tp. 41, rge. 18, W5, and outcrops just below the crossing from the main pack-trail to Vimy cabin. It is almost completely exposed, and may be measured with little difficulty during periods of normal stream flow. A more easily accessible section which can be used as a standard section is present below the falls on Ram River, tp. 36, rge. 13, W5 (section 5-45).

The type section is most easily reached by a forestry pack-trail which starts 12 miles west of Nordegg, follows up the Bighorn River, then swings north to Vimy cabin. The section may be reached from Mons cabin on the Blackstone River by following the forestry trail up George Creek, along the eastern side of the Front Range and down the north branch of Wapiabi Creek almost to Wapiabi Gap and then about 4 miles up the south branch to Vimy.

The upper contact of the formation has been defined previously (Stott, 1956b):

> The upper contact of the Cardium (Bighorn) formation is drawn at the top of the uppermost fine-grained sandstone unit and below the pebble and grit beds, which

D.F.S., 5-3-54

Plate XVI. *Cardium formation, Canyon Creek, section 4-13. Massive sandstone on left is Ram member (R), overlain by less resistant sandy nonmarine Moosehound (M). Siltstone of Cardinal member (Cd) in middle is underlain by Kiska shales (K) and overlain by Leyland (L). Sturrock member (S), not well developed, on the extreme right at ridge top.*

Plate XVII. *Cardium formation, Brazeau River, section 4-25. Sturrock member (S) at left underlain by concretionary Leyland member (L). Massive siltstone is Cardinal (Cd) underlain by small thickness of Kiska (K). Interbedded sand and shale of Moosehound (M) lies above thickly bedded Ram member (R). Contact with Blackstone formation (Blk) is on extreme right.*

D.F.S., 7-5-54

D.F.S., 3-1-55

Plate XVIII. *Ram member (R) of the Cardium formation, Little Berland River, section 5–19. Contact with Blackstone formation (Blk) on left. Moosehound member (M) lies to right.*

> are usually present within the basal shales of the Wapiabi formation. These grit beds are considered to be the deposits of the transgressing Wapiabi sea. The contact is sharp and well defined, although the upper surface of the Cardium (Bighorn) formation may be slightly uneven with pebbles embedded in reworked sand.

Harding (1955, p. 18) reported that the "Cardium formation has transitional contacts with the shales of the overlying Wapiabi formation and the underlying Blackstone formation, although locally within the Foothills, the contact with the Wapiabi is reported to be sharp". Although a gradational contact may be present in the subsurface, it is emphasized that the contact of the Cardium and the Wapiabi formations is well defined and very distinct in the Foothills between Crowsnest Pass and Smoky River.

The lower contact of the Cardium formation is drawn at the base of the thickly bedded sandstone. In the type section, only 32 feet of basal sandstone are included. Farther south on Ram River (section 5-45), the formation includes two thickly bedded basal sandstones that have a total thickness of 103 feet. The basal contact in the Highwood area is drawn below massive beds of sandy siltstone that are equivalent to the basal sandstones to the north. A transition zone from shale through interbedded shale and thinly bedded sandstone to massive sandstone is almost always present. This transition zone has been included in the Blackstone formation. In some sections, as on Little Berland River (Pl. XVIII), the change from interbedded sandstone and shale to thickly bedded sandstone is rather abrupt.

Type Section

Cardium formation, Nordegg map-area, Alberta, Wapiabi Creek, headwaters, southern tributary below Vimy cabin

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Upper contact is not exposed, although beds of Wapiabi formation lies less than 20 feet above sandstone.		
	CARDIUM FORMATION		
	Sturrock Member		
36	Sandstone, fine-grained, homogeneous, massive, slightly calcareous, rusty tan weathering, slightly laminated. Top surface has ¼"-½" pebbles and grit embedded in it	4	255
35	Covered	2	251
34	Sandstone, fine-grained, grey, rust to reddish weathering; not well exposed in basal 3′	8	249
33	Sandstone, fine-grained, grey, laminated, platy; concretionary; *Cardium*	11	241
32	Covered. Some platy, knobbly, argillaceous siltstone with concretions is exposed	15.5	230
31	Conglomerate; pebbles of chert, white, green, black, blue, ¼"-2½" rounded, in grit matrix	0.5	214.5
30	Sandstone, fine-grained, slightly argillaceous, laminated, massive, grey, rust to reddish brown weathering, slightly calcareous; 2"-1′ beds; few concretionary zones	26	214
29	Conglomerate, as above. Some detrital concretions and sandstone; cobbles up to 3"	1	188
28	Siltstone, sandy, argillaceous, hard, massive, rusty to greenish grey weathering; rusty concretionary spots; some concretions. Top surface covered with ammonites and pelecypods	7.5	187
27	Shale, rubbly, brownish grey	5	179.5
26	Sandstone, fine-grained, grey, carbonaceous, laminated, moderately calcareous	1	174.5
25	Shale, and thinly bedded sandstone	1.5	173.5
24	Sandstone, medium-grained to gritty at base, brownish grey, rusty brown weathering, calcareous, carbonaceous, especially on bedding surfaces, laminated, crossbedded	8	172
23	Sandstone, as above, and shale, 40%, calcareous, carbonaceous	9	164
22	Sandstone, medium- to coarse-grained, brownish grey, carbonaceous; and shale, 20%, platy, carbonaceous; many channel filling lenses. Sandstone pinches out up slope into very thin sandstone and platy shale	4	155
	Leyland Member		
21	Siltstone, argillaceous, brownish grey, flaggy, soft; shale, platy, 50%	9	51

Unit	Lithology	Thickness (feet)	Height above base (feet)
20	Shale, dark grey, rubbly, and interbedded siltstone, 25%, argillaceous, up to 1" beds	5	142
19	Covered	32	137
18	Shale, rubbly, dark grey, with row of 6" irregular concretions at top	8	105
	Cardinal Member		
17	Siltstone, argillaceous, dark grey, rusty weathering, shaly but bedding poorly defined; few large 1' irregular and 4" x 6" round concretions; very silty concretionary bed 2' from top	21	97
	Kiska Member		
16	Shale, very silty, blocky, dark grey, rusty weathering	3	76
	Moosehound Member		
15	Sandstone, very silty, platy, brown to grey, brownish grey weathering; beds 2"-6"; few concretionary beds near top. Shale, 10%. Upper 2' has carbonaceous remains, grass and poorly preserved leaves; basal beds become very argillaceous	6	73
14	Shale, very silty, platy, brown; siltstone, 30%, platy, brown weathering	3	67
13	Covered. Some brackish-water fossils and coal in talus. One band of platy argillaceous siltstone 4' above base	15	64
12	Sandstone, fine-grained, brown, rusty weathering, laminated, carbonaceous; beds 2"-1'	3	49
11	Talus covered. Brown to greenish grey, silty shale, rubbly; carbonaceous fragments	13	46
10	Sandstone, very coaly, dark grey to black, maroon to olive-green weathering	1	33
	Ram Member		
9	Sandstone, fine-grained, finely laminated, grey, clean, rusty tan weathering, few carbonaceous fragments in upper 6"; beds 6"-1', becomes medium-grained toward base; some crossbedding	12.5	32
8	Sandstone, fine-grained, grey to brownish grey, massive, knobbly, worm burrows	2	19.5
7	Sandstone, fine-grained, laminated, grey to brownish grey, crossbedded, rusty weathering	3.5	17.5
6	Sandstone, similar to bed 8	2.5	14
5	Sandstone, similar to bed 7	2	11.5
4	Sandstone, similar to bed 8	1.5	9.5
3	Sandstone, similar to bed 7	3	8
2	Sandstone, similar to bed 8	0.5	5
1	Sandstone, similar to bed 7	4.5	4.5
	BLACKSTONE FORMATION		
	Opabin Member		
20	Shale, platy to papery, rusty weathering, and siltstone, 30%, some concretionary beds	5	257

Bed	Lithology	Thickness (feet)	Height above base (feet)
19	Shale, platy, hard, rusty weathering	3	252
18	Covered. Some shale and thin siltstone exposed	28	249
17	Sandstone, fine-grained, grey, beds 2″-4″, and shale, 30%, dark grey; platy, rusty weathering	3	221
16	Siltstone, sandy, argillaceous, wavy bedded, dark grey; shale, 40%	4	219
15	Covered	30	215
14	Shale, and thin siltstone, 30%, rusty weathering, few concretionary beds	8	185
13	Shale, rubbly; concretionary beds	4	177
12	Shale, blocky, rusty weathering; irregular concretions 4″ x 1′ in rows	14	173
11	Shale, blocky, dark grey, rusty weathering; siltstone, 25%, 1″-2″ beds, laminated; few concretions	3	159
10	Shale, very silty, blocky, dark grey, rusty weathering, few thin siltstones; few small concretions and 1½″-2″ concretionary beds	8	156
9	Sandstone, fine-grained, laminated, bluish grey, grey weathering; beds 2″-1′, shale 5%, somewhat wavy; some 2″ x 1′ irregular concretions, reddish brown weathering	13	148
8	Sandstone to siltstone, laminated, wavy bedded; some well-defined sandstone beds at top, grey weathering; 4″ round concretions and 2″-3″ concretionary beds. One-foot concretionary bed with 50% shale at base	21	135
7	Siltstone, argillaceous, to sandy, bedded, dark grey, rusty weathering; slightly irregular reddish brown weathering concretions 4″-6″ × 8″-10″; grades into underlying unit	24	114
6	Siltstone, argillaceous, bedded; more shaly towards base	7	90
5	Siltstone, argillaceous, bedded, rusty weathering; few concretions; grades into underlying unit	5	83
4	Siltstone to shale, rusty weathering; small concretions	7	78
3	Siltstone, argillaceous at top with some well-indurated beds; becoming more shaly towards base; concretions 2″ × 4″-6″	29	71
2	Shale, platy, rusty weathering, few thin siltstones and small concretions	15	42
	Haven Member		
1	Shale, blocky, and siltstone, 30% platy, rusty weathering; grading downward into shale	27	27

Six distinctive members are recognized in the Cardium formation in the central part of the area. Three massive sandy units are separated by marine and nonmarine shales. The basal sand is the Ram member; the middle one, Cardinal; and the upper one, Sturrock. The lower shaly interval contains two members; the nonmarine Moosehound member and the partly equivalent marine Kiska member. The shale between the Cardinal and Sturrock members is named the Leyland member, All these members are well defined in the vicinity of Brazeau River (Pl. XVII), of Canyon Creek (Pl. XVI), and of Wapiabi Creek.

The type section, as described, does not contain all the strata that Malloch (1911, p. 23) included in his Bighorn formation. As the Cardium formation is defined herein to include only the thickly bedded basal sands, the lower thinly bedded to flaggy ones have been placed in the Blackstone formation. Thus, units 10 to 14 of Malloch's section are considered as part of the Blackstone formation.

The massive Cardium sandstones form prominent ridges. Frequently, the top and basal sandstones form two ridges separated by a small depression caused by the softer nature of the middle beds; the ridges may be traced easily on aerial photographs. Flat-lying parts of the formation produce prominent cliffs and mesa-like forms such as the one at Mountain Park. Broad synclines similar to those found along North Ram River are well outlined by the resistant beds.

The author has traced the Cardium from Drywood River, near the International Boundary, to Muskeg River 400 miles to the northwest. This confirms the pioneer work of Webb and Hertlein (1934) and of the many geologists who have mapped the area, but the present study has been directed towards a more detailed correlation within the formation throughout the Foothills. Published work of Irish (1951), Greiner (1955), Stelck (1955) and Stott (1960a, 1961b), and unpublished work of other geologists have indicated that the formation extends at least another 150 miles northwestward into the country of Pine and Peace Rivers. Some confusion was caused by the inclusion of the Bad Heart sandstone in the Cardium formation of this region (Gleddie, 1949), but Stelck (1955) and Harding (1955) showed that the Bad Heart sandstone is equivalent to beds above the Cardium formation.

The Cardium formation extends from the Front Range eastward across the Foothills belt into the Plains where it loses some of its distinctive character, but the stratigraphic interval occupied by equivalent beds may be traced, most easily by use of electric logs, for some distance eastward. The eastern margin of the formation has not been well defined and will require some detailed studies of subsurface data. Little is known of its eastern limits in the region between Muskeg and Athabasca Rivers. Southward from Athabasca River to Bow River, its eastern edge is better defined because of the intensive study caused by the discovery of oil in these beds in the Pembina area. From there southward, the sand limits have not been indicated in any published report of subsurface studies.

The thickest sections of the formation are found along the western edge of the Foothills. Eastward towards the plains, the formation decreases in thickness, due to thinning in all the members. On the headwaters of Thistle Creek (section 4-23), Bighorn River (section 5-34), and Wapiabi Creek (section 5-33), it is about 300 feet thick. The maximum thickness is 357 feet on Ram River (section 5-45). Farther south, sections at Horseshoe Dam on Bow River (section 6-22), Kananaskis River (section 6-23), and Sheep River (section 6-32) are slightly less, being about 300 feet. The minimum thickness, recorded on Drywood River (section 6-54), was 74 feet. In the northern part of the region, some thinning is evident in the section on Muskeg River (section 5-4) which is 225 feet thick and on Little Berland River which is 180 feet. Similar thicknesses were found on Chungo Creek (section 4-9) and Highwood River (section 6-43). The isopach map (Fig. 16a) is based on measured sections, and shows the general distribution and thickness of the formation.

Different thicknesses of the Cardium formation around Athabasca River, reported by Lang (1946, 1947), are as follows: map 963A, Moberly area, 475 feet; map 905A, Brûlé area, 485 feet; Memoir 244 (of which map 905A is a part), section on Maskuta Creek, 246 feet; section on Mount Solomon, 808 feet. Such variation in thickness is not consistent with the regional trends of the formation. The writer measured 248 feet in the Maskuta Creek section, which is in agreement with Lang's figure. Admittedly the section is not exposed at the top, but shales similar to typical Wapiabi shales are exposed above a short covered interval. Another Cardium section was found on the ridge above Mile 17 on the Solomon Creek road, and a total of 260 feet were measured. There, a fault is present at the top of the formation. Another 7 miles northwest, on Wildhay River, two sections measured 247 feet and 206 feet[1]. Lang showed only one section at this locality; he apparently believed both to be part

D.F.S., 7-1-56

Plate XIX. *Cardium formation, Sheep River, section 6–32. Wapiabi shale (W) in distance lies on lighter siltstone at top of Cardium formation (Ca). Three cliffs in right foreground are argillaceous siltstone lying on Blackstone formation (Blk).*

[1] This section is not well exposed at the base and may be thicker.

of one thick section. The general agreement of the writer's measured sections is more in keeping with the usual thickness of the Cardium formation. The inconsistencies as reported by Lang are believed to be due to an unrecognized fault that brings two complete sections into proximity from south of Mount Solomon across Wildhay River.

Several sections measured around Bow River indicate a greater thickness in that region than was previously reported. Evans (1930) gave thicknesses of 183 and 250 feet, but the first section was composite and some beds appear to have been omitted. Beach (1943, p. 44) reported that the Cardium formation was 195 feet thick on Kananaskis River and 227 feet thick in the area between Canyon Creek and Elbow River. The Kananaskis section was found to be more than 300 feet, which is comparable to nearby sections (*see* Fig. 5). Beach's other section was not found but, from the description, it appears that only the beds between the middle sandstone and the top were measured. This interval coincides in thickness and general lithology with the same interval on Kananaskis River.

In the Highwood River region, almost all sandstones in the centre of the Alberta shales have been included in the Cardium (Bighorn) formation although some workers have indicated that several beds might be equivalent to part of the Wapiabi formation. As early as 1930, Hume (p. 8B) suggested that the Cardium bands did not everywhere hold the same stratigraphic position. The Cardium section on McPhail Creek in the Highwood area was found by Allan and Carr (1947) to be 613 feet thick. The section as measured by the writer was found to be 282 feet thick, comparable to that obtained on Bow and Kananaskis Rivers. Apparently this interval corresponds to the lower half of the section described by Allan and Carr. The remainder of their section is thought to be part of the Wapiabi formation, and the sandstone in the upper part is considered to be a sand facies of the basal members of the Wapiabi formation. Sections farther south measured by Douglas (1958, p. 85) and Norris (1958, p. 15) are reported to be 648 feet and 515 feet, respectively. Both these sections are considered to contain sandstone equivalent to the basal part of the type Wapiabi formation, a possibility indicated in the discussions by both workers.

The Cardium formation is characterized by sandstones, but in many areas it contains a large percentage of shale. In the type section, marine and non-marine shales separate the basal and middle sandstone members, and marine shale is present below the upper sandstone. Northward (Fig. 5), the marine shales and the middle silty member are replaced by beds of carbonaceous shale and sandstone. Southward from the type section, the carbonaceous sediments are replaced by marine shales. Eastward from the type section and also from sections farther northwest (Figs. 6, 7, 8), the marine sandstones grade into siltstone and shale, and the carbonaceous shales grade into sandstones. A comparable gradation from sandstone to shale occurs in the southern area around Highwood River (Fig. 9).

The sandstones of the Cardium formation are mainly fine grained, siliceous, very finely laminated, and well cemented. Coarse sandstone occurs near Athabasca River but it is rare elsewhere. Chert grains are abundant but other lithic fragments are rare. Bedding varies from massive to platy. Conglomeratic beds are not abundant although they persist for many miles. The pebbles or cobbles are almost entirely chert with some rare quartzite and sandstone. The pebbles lie above thick sandstones and often are scattered through a shaly matrix. The shales are of marine, brackish-water, and fresh-water origin. The marine shales are dark grey, rusty weathering, and contain sideritic concretions. Other shales of greenish colour or of various shades of brown to black have been considered as nonmarine because of their carbonaceous content, fossil plants, and fauna of nonmarine invertebrates.

Age and Fauna

The Cardium formation is well dated only in the southern Foothills, and there the diagnostic fossils were collected near the top of the formation. In the northern part of the area, the formation is dated only by inference from the adjoining faunal zones (*see* Tables X to XIII for faunal lists). The formation lies above beds that contain fossils of the zone of *Prionocyclus woollgari*. It contains fossils of the late Turonian stage and is overlain by beds lying within either the Turonian zone[1] of *Scaphites preventricosus* Cobban or the Coniacian zone of *Scaphites ventricosus* Meek and Hayden. Therefore, the Cardium formation is of late Turonian to early Coniacian age.

The lower members of the Cardium formation have yielded a fauna chiefly significant for its ecological implications. The Ram member contains numerous marine specimens but yielded only *Inoceramus fragilis* Hall and Meek, *Inoceramus* ex gr. *I. lamarcki* (Parkinson), and *Cardium pauperculum* (Table X), all of which have long ranges. The Moosehound member contains a fauna (Table XI) of brackish-water and fresh-water invertebrates. Poorly preserved plant leaves also occur in the Moosehound member.

Ostrea lugubris Conrad, found in the Leyland member (Table XII), was considered by Cobban and Reeside (1952b) to occur in the zones of *Scaphites warreni and Prionocyclus wyomingensis*. Jeletzky has outlined an *Ostrea lugubris* zone (*see* Table IV) and indicates that it probably correlates with part or all of the United States western interior late Turonian zones between the *P. hyatti* and *S. corvensis* zones inclusive. The new zone replaces the *Cardium* zone of some geologists. The occurrence of comparable specimens in the Sturrock member in the Highwood region leaves the upward range of *O. lugubris* in doubt as the Sturrock member is known to lie within the *Scaphites preventricosus* zone in that area.

Diagnostic fossils have not been collected from the upper Cardium beds north of Bow River but *Scaphites mariasensis* Cobban, the index fossil of the

[1]Jeletzky, in a much later report, states that he now considers that the zone of *S. preventricosus* "may also be earliest Coniacian in age as thought by Cobban and Reeside (1952)."

lower subzone of *Scaphites preventricosus* zone, occurs in the basal Wapiabi (Muskiki) shale in northeastern British Columbia. At Sheep Creek in southern Alberta, *Scaphites* comparable with *S. mariasensis* Cobban and *S. impendicostatus* Cobban occur in the upper beds of the Cardium formation. These relationships indicate, according to Jeletzky, some diachronism of the Cardium-Wapiabi contact in the north-south direction. Nevertheless, farther south on upper Carbondale River, *S. mariasensis* Cobban was collected by Norris[1] from beds which he identifies on structural and lithological evidence as occurring in the lower part of the Wapiabi formation. It would appear that precise time relationships can be established only by additional data. At Sheep Creek in southern Alberta, *Scaphites* similar to *S. impendicostatus* Cobban and *S. ventricosus* Meek and Hayden *s. str.* occur in the basal Wapiabi shales in correct sequence indicating the absence of any significant hiatus. In the northern Foothills, where the upper Cardium beds are not precisely dated, any hiatus between Cardium and Wapiabi rocks is not readily evaluated.

Ram Member

The massive sandstone at the base of the Cardium formation comprises the Ram member, which is typically developed on Ram River just east of Ram Falls (Frontispiece). Although the type section is on Wapiabi Creek in the type section of the Cardium formation, the section (5-45) on Ram River is designated as a standard section because it reveals the greatest development of the member. At this locality two massive sandstones are separated by 22 feet of argillaceous siltstone.

The basal contact with the Blackstone formation is gradational but an arbitrary boundary is drawn at the base of the lower massive sandstone unit. In a few sections around Highwood River, the boundary is drawn below sandy siltstones that lie in an equivalent stratigraphic position. The upper contact of the member is sharp and well defined in most sections. Where overlain by the Moosehound member, the contrast between the fine-grained sandstone of the Ram and the carbonaceous sandstones and shales of the Moosehound is usually sufficient to draw a boundary; where overlain by the marine shales of the Kiska member, the contact is well defined. The contact with the Moosehound is probably conformable as deposition was likely continuous; the contact with the Kiska is considered to be disconformable although the hiatus probably was not great.

The Ram member is recognized from the extreme southern part of Alberta to the northern border of the field area, and probably extends much farther north. It is the most persistent member in the Plains, and although detailed correlations are not made in the present report, the Ram member apparently contains the producing sand of the Pembina field.

The member is thickest along the Front Ranges and tends to thin towards the east although the maximum thickness, as shown in the isopach map (Fig. 16b)

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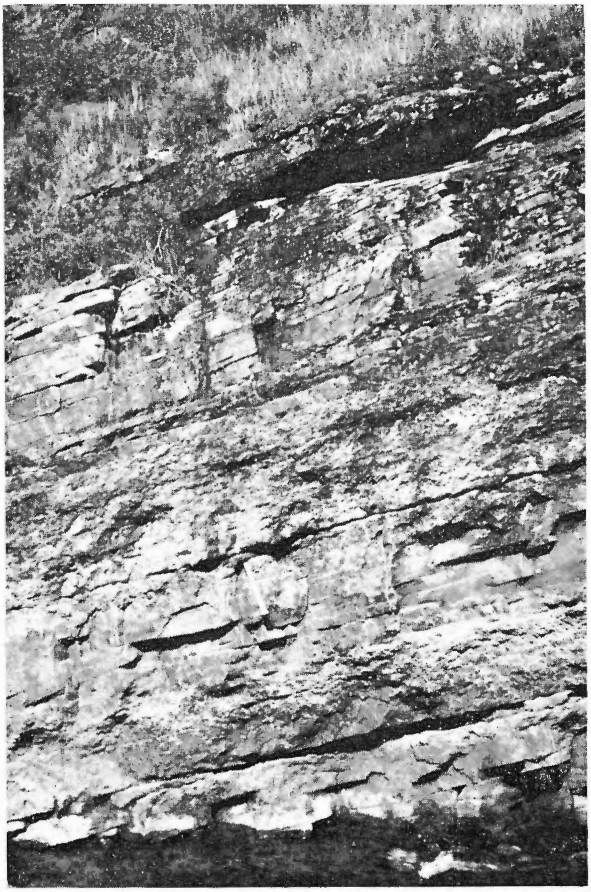
[1] Norris, D. K., personal communication, January 20, 1961. Fossil identification by J. A. Jeletzky.

lies to the east of the Bighorn Range. A maximum thickness of 103 feet was measured on South Ram River (section 5-45) and a minimum of 24 feet on Drywood River. The member varies between 40 and 90 feet in the region between Muskeg River and Athabasca River, but variations in an east-west direction are not known due to the lack of outcrops. They are somewhat better known between Athabasca River and North Saskatchewan River because of numerous repetitions in the folded-fault region around Brazeau River. Along the edge of the Front Range at the headwaters of Bighorn River (section 5-34), Wapiabi Creek (section 5-33), and Thistle Creek (section 4-23), the massive beds of the Ram sand are about 40 feet thick. The upper sand of the Ram member thickens eastward in this area, increasing from 32 feet on the headwaters of Wapiabi Creek to a maximum of 79 feet (Fig. 8). A similar development is found in the sections on Brazeau and Cardinal Rivers (Figs. 6 and 7).

The Ram member is predominantly sandstone although a siltstone facies is recognized as part of the member in southern Alberta. The sandstone is a fine-grained, tan or buff weathering, thick-bedded quartz arenite, as it consists mainly



D.F.S , 5-6-55

Plate XX

Bedding of the Ram member, Wapiabi Creek, section 5–33. Well-bedded, uniformly laminated units lie between reworked, mottled sandstone.

of chert and quartz with a small amount of matrix. Rare grains of feldspar and a few rock fragments are present but seldom exceed 5 per cent. Accessory minerals are not abundant. The quartz arenite has a 'welded' texture (Williams, *et al.*, 1954, p. 264) formed by the secondary growth of silica on the quartz.

The top of the Ram sandstone generally is free from channelling. It is frequently overlain by a thin coal layer, and in some places, by several inches of coaly sandstone. Carbonaceous fragments occur in some places within the upper few inches of the massive sandstone, but generally are not present in the underlying beds.

The beds within the Ram member average about 2 feet thick. Thin shale partings between the beds form only a minor proportion of the total thickness. These beds are generally uniform, although some large sweeping crossbeds or lens-like bodies do occur. In a few places, intrastratal flow structures are present in thick sand beds. The laminae of these structures are curved, and follow the external shape of the structure.

Fine uniform laminae are typical of the Ram sand, and produce a banded appearance. Small-scale crossbedding may also be present. Many of the sandstones are not laminated, and have been described as homogeneous. A peculiar internal structure, attributed to reworking by organisms, has been noted in several places. Beds, several feet thick, contain irregularly shaped lumps, tubes, and pods of sandstone which have distinct boundaries. These structures are irregularly distributed giving the rock a mottled appearance (Moore and Scruton, 1957, p. 2727). Such beds lie between regular layered ones, and frequently the sequence is repeated several times (Pl. XX). The alternation may indicate variation in the water depth in which the sediments were deposited for Moore and Scruton (op. cit., p. 2744) found that regular layers are typically developed nearer to the shore than the mottled structures.

Only one good example of graded bedding was observed in an apparently overturned section along the extreme western side of the basin. The gradation was from very coarse- to medium-grained sandstone. It is emphasized that graded bedding is not a common feature of the Ram sandstone.

Bedding planes sometimes are ripple-marked. Most of the ripple-marks are predominantly of the oscillation type but some are of the interference ("tadpole nests", Pettijohn, 1956, p. 185) type. Bedding planes also exhibit other markings of unknown origin, many of which appear to be tracks and trails of invertebrate organisms.

Many sideritic concretionary zones are present in the Ram sands but well-formed concretions are not conspicuous. These zones, which weather reddish brown, have indeterminate boundaries with the enclosing sandstone and contain many sand grains. Concretionary beds occur most commonly in the interbedded shales.

North of Ram River in the Bighorn region, the first or basal sandstone is represented by shale and siltstone (Fig 4). Some sandstone occurs in sections along Bighorn and Wapiabi Rivers, but the main body of sand, if present, is

Table X

Fauna of Ram Member

Fauna	GSC Location[3]					
	28791	25072	27071	27089	28089	28183
Cardium pauperculum Meek and Hayden	—	—	—	x[2]	c[1]	—
Inoceramus fragilis Hall and Meek	c	?	—	—	—	—
Inoceramus fragilis var. *I. prairiensis* McLearn	—	—	—	—	—	c
Inoceramus ex gr. *I. lamarcki* (Parkinson)	—	x	—	—	—	x
Inoceramus sp. indet. (cf. *I. dimidius* White)	—	—	x	—	—	—
Modiolus (*Brachidontes*) sp. indet.	—	x	—	—	—	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

assumed to be farther west. Towards Athabasca River, the first sandstone appears once more and can be traced to Muskeg River. The upper or second sandstone in this area is very persistent and uniform.

In the area to the east of the Bighorn Range, the massive second sandstone apparently grades into thinly bedded sandstone, which in turn is overlain by other units of massive sandstone (Fig. 8). A thin shale break at the top of the second sandstone forms the base of a third sandstone. This third sand does not extend as far to the west, so its thickness combined with the underlying unit produces a thicker unit in the east. Three sandstones above the first sandstone equivalent are recognized in the Ram member around Blackstone River. Where sandstones develop in the overlying Moosehound member, they may become indistinguishable from those of the Ram member.

Without additional data, the two sandstones in the Ram member on Ram River might be correlated with the sequence on lower Blackstone River. Such a correlation would not be correct, because in the section on Smallpox Creek (section 4-55), the first sandstone is represented only by shale and rather than continuing northward, the sand facies appears to curve westward (Fig. 18). The first sandstone on Ram River can be correlated with the westernmost sections (Fig. 5), and from there towards the east with a shale facies that lies below the second sandstone (Fig. 8). As the first Ram sandstone is not developed in the area around lower Blackstone River, equivalent shale beds are included in the Blackstone formation.

Southward, the lithology changes laterally (Fig. 5). Massive sandstone, present in the Burnt Timber and Fallen Timber areas, grades into siltstone farther south. On Bow River the second sandstone is very shaly (Pl. XXII) whereas the first sandstone is still well developed; both are represented by siltstone

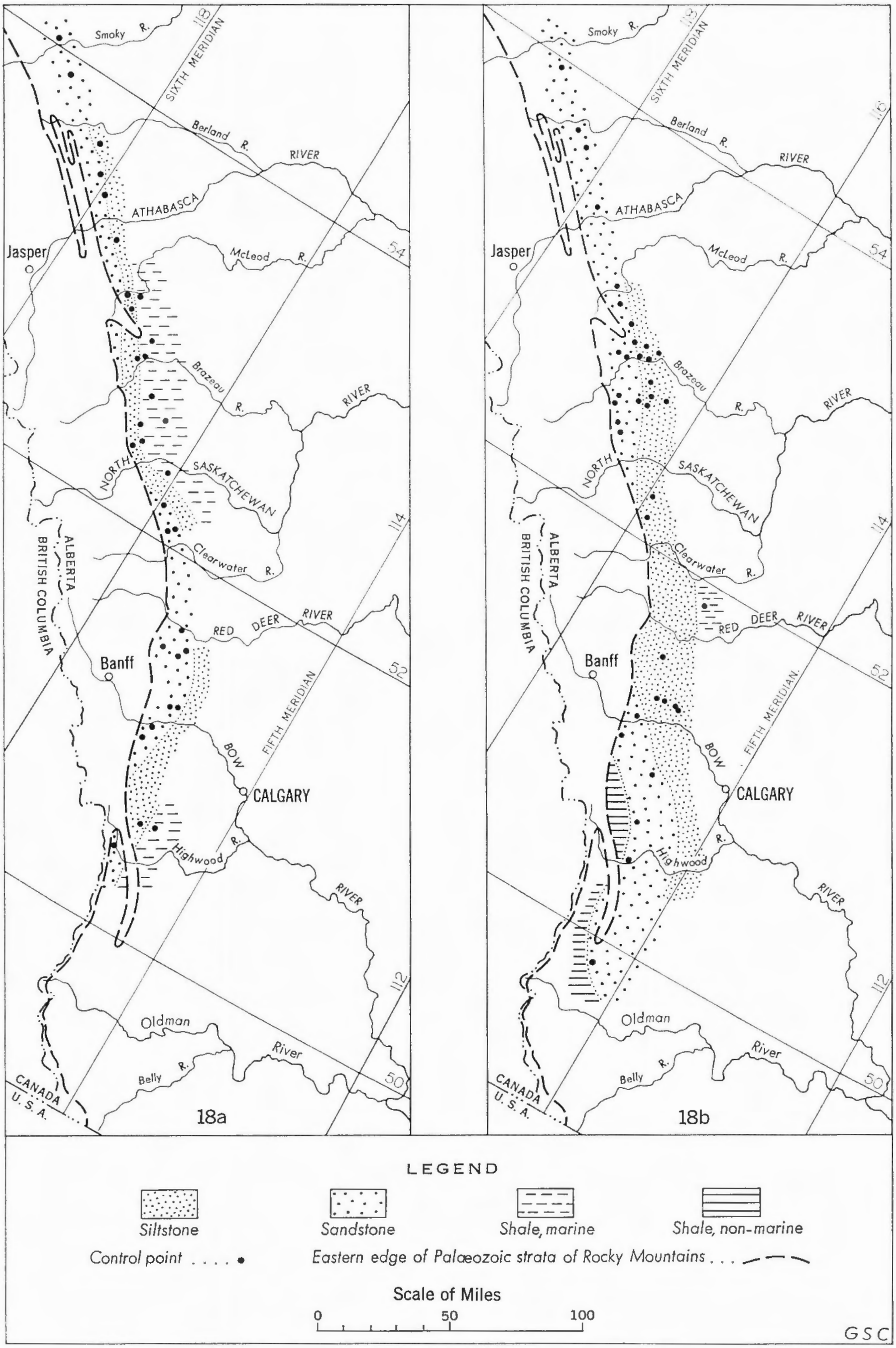


Figure 18 ***Distribution of lithologic facies during deposition of (a) the first sandstone of the Ram member, (b) the Chungo member.***

in the area of Sheep and Highwood Rivers. This gradation is particularly evident in the section on Sheep River (Pl. XIX) where the basal units grade into shale (Fig. 9). The basal sandstone in sections south of Highwood River is considered to be the Ram sandstone and it probably extends as far as Crowsnest Pass. From there on, the precise correlation is questionable, but on Lynx Creek and Drywood River, a sandstone unit at the base of the Cardium formation is correlated with the Ram member.

Moosehound Member

The Moosehound member comprises a sequence of nonmarine shales, siltstone, sandstone, and some coal that lies between the overlying concretionary shales of the Kiska member and the underlying thickly bedded sandstones of the Ram member (Pls. XVI, XVII). The name is derived from Moosehound Creek which flows into Brazeau River near the mouth of Cardinal River. In areas where the Kiska member is replaced by nonmarine beds, the Moosehound sediments are overlain by the Cardinal member. North of McLeod River, the Cardinal is not recognized, and the Moosehound is overlain by marine shales of the Leyland member or by marine sandstones of the Sturrock member (Fig. 5).

The type section of the Cardium formation serves also as the type section of the Moosehound member, although typical sections are found in the region near Moosehound Creek.

The occurrence of nonmarine beds in the Cardium formation has not been emphasized in previous reports. Webb and Hertlein (1934, p. 1399) suggested that a thin lignitic shale bed above the basal sandstone in the region between Blackstone and McLeod Rivers may have accumulated in a marginal swamp or lagoon. Rutherford (1925, p. 41) reported 85 feet of nonmarine beds in a section near Luscar Creek, and similar beds on North Brazeau (Cardinal) River. Hake, *et al.* (1942) noted some coal within the formation.

The contact of the Moosehound and Ram members is well defined and probably conformable. In many sections shales lie immediately above the sandstone. In other sections, carbonaceous to coaly sandstone may be present, but the contrast is great enough to permit the definition of a boundary. In sections near the Nordegg-Chungo forestry road, the contact is not so distinct. There, the sandstones of the Ram and Moosehound are similar. Nevertheless, a coaly shale or carbonaceous material is an indication of the change in lithology to rocks now included in the Moosehound member.

The upper contact, which may mark a hiatus, is usually distinct with abrupt change from the nonmarine shales to the overlying concretionary shales. Evidence of local erosion is present in a few sections. The upper contact does not appear to be at the same stratigraphic position in all sections, and lies at a higher stratigraphic position towards the west and northwest. In some sections, a thin pebble-conglomerate lies above the Moosehound rocks and is apparently related to the marine shales of the Kiska member.

The Moosehound member is recognizable from Muskeg River southward to North Saskatchewan River, and extends from the Front Range to beyond the eastern limit of the region. It is not recognized south of Ram River.

The member is thickest in the north and along the Front Range, and thins eastward. Its thickness ranges from about 134 feet on Muskeg River to 25 feet in sections on Cardinal River. Part of the decrease is caused by a facies change to sandstone which is included in the underlying Ram member.

One of the most interesting facies changes in the Alberta group is found within beds equivalent to the Moosehound member. Marine shales on the eastern side of the Foothills grade through sandstone into nonmarine sediments on the western side (Figs. 6, 7, 8). A similar change is noted in the Cardium formation northward from Ram River to Muskeg River (Fig. 5).

Along the Front Range, the Moosehound member consists of greenish to brownish, rubbly shale with thin beds of carbonaceous sandstone. The shale is generally soft and crumbly and contains a nonmarine invertebrate fauna; the sandstones vary from very fine grained to coarse grained, are friable to well indurated. Generally, the sandstones weather greenish to rusty, contrasting with the tan weathering Ram and Sturrock sandstones. Plant debris is abundant in some of the beds, and a few poorly preserved leaves of angiosperms have been collected. Much of the plant material resembles the blades of grasses or sedges. In the Blackstone River-Canyon Creek region, coal beds as much as 6 inches thick are present.

Dark grey concretionary marine shales lie directly on the greenish sediments east of the Bighorn Range, and the change in lithology is distinct. Pebbles or grit beds are not common above the contact. Occasionally 'cut-and-fill' or channel structures occur near the top of the lower facies. These concretionary shales, similar to those of the Blackstone and Wapiabi formations, are included in the Kiska member.

The section on upper Maskuta Creek (5-22) contains medium- to coarse-grained carbonaceous sandstone above the Ram member and is the only section of the Cardium formation which contains coarse-grained sandstone in quantity. Northward, this coarse sandstone appears to grade into fine-grained sandstone and then into nonmarine shales (Fig. 5). The interval on Solomon Creek contains much wavy to irregularly bedded, fine-grained sandstone. The sections on Wildhay River are mostly covered, but contain carbonaceous shales, siltstones, and sandstones.

Carbonaceous sandstone lies above the well-sorted Ram sandstones on Little Berland River (Pl. XVIII). As in the Bighorn area, these carbonaceous sands are probably very closely related to the depositional history of the Ram member, but because of the differences in lithology, they are included in the Moosehound. Greenish grey shales and some coal occur above the sandstone.

On Muskeg River, all the beds above the Ram member appear to be nonmarine except about 6 feet of sandstone at the top of the Cardium formation.

The nonmarine interval is predominantly shale but does contain some thin coaly beds and carbonaceous sands (section 5-4).

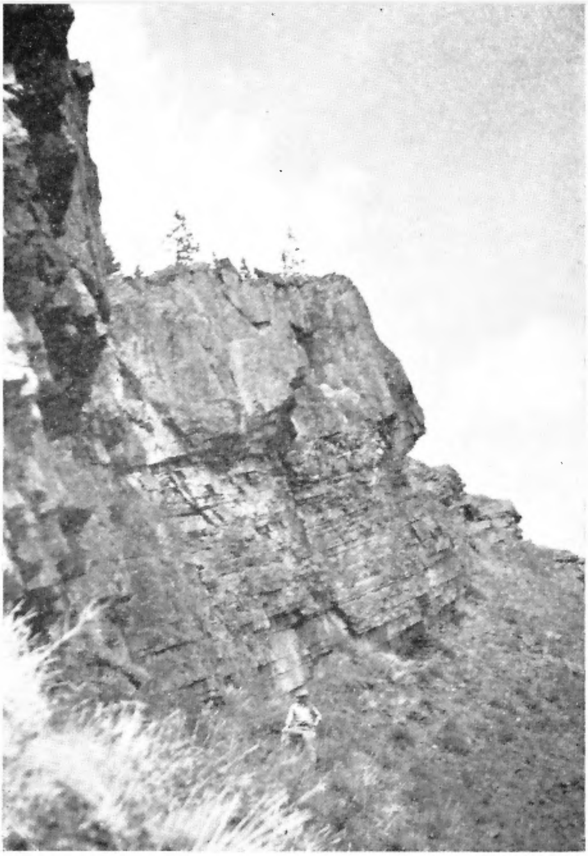
In the Ram River area south of the type section, dark grey concretionary marine shales extend from the top of the Ram member to the base of the overlying Cardinal siltstone. In the Cripple Creek (5-41) and Lynx Creek (Cripple Creek map-area) sections, this interval is not exposed so no record is available of the facies change which appears to be present between Ram River and Bighorn River (Fig. 5).

The next sections south of Ram River that might contain nonmarine beds are those on Burnt Timber Creek. Only the upper beds of the shale above the Ram member are exposed in the headwaters section; the interval that reasonably could be nonmarine is covered. Farther east, upstream from the forestry road, some carbonaceous siltstone above the top sandstone of the Ram member possibly corresponds to those found farther north but, without better exposures, the presence of nonmarine beds in the Cardium formation south of Ram River is uncertain.

From Burnt Timber Creek to Drywood River in the south, no nonmarine beds are known in the Cardium formation. In this region, the shales equivalent to the Moosehound member are all dark grey, rusty weathering, and contain numerous reddish brown weathering sideritic concretions. In the Sheep River area, massive siltstone units with thin pebble beds are equivalent, but are considered to be marine.

On Clearwater River in the axis of a syncline near Washout Creek, the basal Ram sandstone either contains at its top or is overlain by conglomerate (Pl. XXI). The conglomerate, 15 feet thick, consisting of chert pebbles and coarse-grained sandstone, lies on a 'transition' zone containing 2 feet of fine-grained sandstone with lenses of conglomerate. The pebbles are as much as an inch in diameter. The whole unit is bedded and weathers maroon to rust. Henderson (1945), who mapped the area, reported that this conglomerate was "inconspicuous or absent to the northeast". Conglomerate has been reported in the Cardium formation on Wilson Creek to the south, but the writer was unable to check this locality. It is probable that the conglomerate is related to the facies change from the sandstones of the Ram member to the carbonceous sediments of the Moosehound.

Some cyclic deposition is suggested in the nonmarine sections. Thin coal layers lie above beds of silt and sand which often contain plant fragments. The coal is overlain by grey shale which grades upwards into rubbly, greenish grey carbonaceous shale. This shale, in turn, grades into siltstone and sandstone, and the cycle is then repeated. However, coal is not always present above the sandstones, and sometimes is found above the shale beds. Some sands appear to have the same stratigraphic position for some distance, but commonly sands and coal appear in one section and are not present in a neighbouring one. Either the sands split into fine tongues, or they are lenticular.



D.F.S., 2-5-56

Plate XXI

Massive conglomerate above Ram sandstones of Cardium formation, Clearwater River.

Table XI

Fauna of Moosehound Member

Fauna	GSC Location[3]											
	24790	24796	24804	25073	25075	25093	25097	25098	27031	27074	4496	4497
Campeloma sp. indet.	–	–	–	–	–	–	–	–	?	–	–	–
Corbicula cf. *C. occidentalis* Meek and Hayden	–	c[1]	?	–	–	?	?	?	–	c	–	–
Corbicula cf. *C. obliqua* Whiteaves	–	–	–	–	–	–	?	–	–	–	–	–
Corbicula sp. indet.	–	–	–	?	–	–	–	x[2]	–	–	–	–
Corbula nematophora Meek and Hayden	–	–	–	–	–	–	–	–	–	c	–	–
Corbula ex aff. *C. nematophora* Meek and Hayden	–	x	–	–	c	–	–	–	x	–	–	–
Corbula subtrigonalis Meek and Hayden	–	x	c	–	c	c	c	x	c	c	–	–
Corbula penundata Meek and Hayden	–	–	c	–	–	–	–	–	–	–	–	–
Modiolus (*Brachidontes*) *multilingera* Meek	–	–	c	–	c	c	–	c	–	–	–	–
Melania sp. indet.	–	?	?	–	–	–	?	–	–	–	–	–
Modiolus (*Brachidontes*) sp. indet.	–	–	–	x	–	–	x	x	x	–	–	–
Ostrea sp. indet.	–	–	–	x	–	–	–	–	–	–	–	–
Unio sp. indet.	–	–	–	–	–	–	–	x	–	–	–	–
Gastropod, genus and species indet.	–	x	x	–	–	x	–	–	x	–	–	–
Angiosperm fragments	?	–	–	–	–	–	–	–	–	–	x	x

[1] c=comparable form
[2] x=specific form
[3] Locality of each collection is given in Appendix II

Correlation of a few beds within the member seems reasonable where their stratigraphic positions are approximately the same. Thus, the top of the main massive sand unit in the Solomon section (Fig. 5) appears to correlate with a coarse-grained sandstone on Maskuta Creek. Similarly, thin sands lie at about this horizon in sections farther north and could be equivalent to the Cardinal member of the south, but without better exposures such correlations are questionable and have not been made.

Kiska Member

The marine shales lying on the Moosehound member in the type section but on the basal Ram member in some sections and lying below the siltstone and sandstone of the Cardinal member are included in the Kiska member. The type section is located on Wapiabi Creek but a standard section is designated on Ram River (section 5-45). The name of the member is taken from Kiska Creek, a small stream which flows into North Ram River about 15 miles north of the standard section.

In sections north of Saskatchewan River, part of the Kiska member is replaced by the nonmarine shale of the Moosehound member. In this area, it therefore lies between the Cardinal and Moosehound members (Figs. 5, 6, 7, 8), and is thinner than in the southern sections. In the standard section and in more southerly sections, the Kiska lies on the Ram member. Pebbles or thin conglomerate mark the contact in many places and are suggestive of disconformable relationships. No precise palæontological data are available to delimit any break in the record that may be present, but probably little time was involved. Where the Kiska shale lies on the Moosehound sediments, as in the type section, the contact is generally distinct but pebbles are absent. The relationships appear to be conformable but may be disconformable. From east to west, the contact appears to lie higher stratigraphically. The upper contact of the Kiska with the Cardinal member is gradational, and is drawn at the base of the siltstone.

The Kiska member can be traced northward from Ram River as far as McLeod River. Its thickness seems inversely proportional to that of the Moosehound; as one thins, the other thickens. Eastward, the Kiska shales increase in thickness, so they appear as a tongue that pinches out towards the west (Figs. 6, 7, 8). The member, as traced southward from the type section, occupies the full interval between the Cardinal and Ram members and can be recognized as far south as Highwood River. At the headwaters of Wapiabi Creek (section 5-33), it is represented by only 3 feet of shale. Farther east beyond the Bighorn Range, the member averages about 20 feet. In the standard section on Ram River, 37 feet of shale are included in the Kiska member. The member is 34 feet thick on McPhail Creek in the Highwood region.

The Kiska member is a fairly uniform sequence of dark grey marine shales with sideritic concretions. It is very similar to other concretionary shale members of the Alberta group. On Ram River, the member consists of very argillaceous siltstone or mudstone, and the basal part is sandy. Farther south, the interval contains more rubbly shale although some siltstone is included in the member on McPhail Creek (section 6-40).

A thin layer of pebbles of silty beds in some sections appears to mark the base of a cycle. The top of the underlying cycle may correlate with the top of the Moosehound member in the Bighorn-Nikanassin area. The marine advance that ended the deposition of nonmarine beds over much of the area in the north may also be represented in the south.

Cardinal Member

The Cardinal member comprises beds of massive, argillaceous siltstone and sandstone that occur in the middle of the Cardium formation, and it is named from Cardinal River in the central Foothills where the member is typically developed. The type section is on Wapiabi Creek within the type section of the Cardium formation. This member is equivalent to the middle siltstone member of Hake, *et al.* (1942). The upper boundary is well defined with an abrupt change from the massive siltstone of the Cardinal to the shales of the overlying Leyland member and in many places is marked by pebbles. Generally the upper surface is somewhat concretionary and weathers reddish brown. The surface may be rough and bumpy but no suggestion of erosion was noted. The lower boundary is drawn at the base of the massive siltstone.

The Cardinal member extends southward from Thistle Creek in the central Foothills to the Crowsnest Pass region. In Thistle Creek (section 4-23) and Mackenzie Creek (sections 4-40, 4-41), it is replaced by nonmarine beds included in the Moosehound member. The Cardinal is well developed in sections farther east. In the north, this member is not recognized because nonmarine beds of the Moosehound member occur in an equivalent position.

The thickness of the member is relatively constant throughout the area although it does decrease eastward. It has a maximum of 35 feet on Red Deer River (section 6-8) and a minimum of 8 feet on Littlehorn River (section 5-37), but averages between 15 and 20 feet in most areas.

In the central part of the Foothills, the Cardinal is predominantly massive, argillaceous siltstone (Pls. XVI, XVII). However, from Burnt Timber Creek south to Dutch Creek, a thickly bedded, fine-grained sandstone is found in an equivalent position (Pl. XXII). This facies change in most marked on the western side of the Foothills. Along the eastern side, the member is typically siltstone and in some places grades laterally into shales as it does along Highwood and Sheep Rivers.

Northward from Wapiabi Creek, the Cardinal member is replaced by nonmarine beds of the Moosehound member (Fig. 5). It is not well exposed in the sections on Thistle Creek, but silty beds above the Moosehound are believed to belong to the Cardinal. The siltstone is present on Mackenzie Creek near McLeod River (section 4-43) but was not found on McLeod River (section 7-2). Farther

D.F.S., 5-2-56

Plate XXII. *Cardinal member (C), sand facies, lying above Kiska shales (K) and Ram units (R), Horseshoe Dam, Bow River.*

south on Mackenzie Creek (sections 4-40, 4-41), this member may be represented by a sand facies, but exposures are poor, and stratigraphic relationships can only be established with difficulty. North of McLeod River the Cardinal member is no longer recognizable, but sandstones in the middle of the northern sections may be equivalent.

The sandstone of the Cardinal member is fine grained, usually dark grey, because of the argillaceous matrix. Bedding, when present, is uniform, but more commonly is lacking. The quartz-rich sandstone weathers brown to buff. The siltstone is very argillaceous, dark grey, and in many places does not have distinct bedding. The weathered surface is typically green to maroon. Large reddish brown weathering concretions occur in rows within the member. Chert pebbles form a thin layer above the Cardinal member, and although they have been noted above the siltstone facies, they are more abundant above the sandstone. This chert-pebble conglomerate is similar to that found at the top of the formation. The top of the member is commonly cemented with sideritic concretionary material, and weathers rust or maroon. The surface is somewhat uneven but is not marked by channel cutting.

Leyland Member

A shale unit below the upper sandstone of the Cardium formation is named the Leyland member. The name is derived from a Canadian National Railways station which was the junction of lines to the coal mines of Mountain Park, Cadomin, and Luscar. The member is well exposed on McLeod River and along Luscar Creek within sight of Leyland station. The type section of the member is on Wapiabi Creek.

In most areas between McLeod River and Crowsnest Pass, the Leyland shales lie between the Cardinal and Sturrock members. However, north of McLeod River, they lie between the Moosehound and the Sturrock members, and occupy a smaller interval than they do farther south.

The upper boundary is drawn at the base of the thickly bedded sandstones of the Sturrock member. The upper contact is gradational and does not occupy the same stratigraphic position throughout the region. The lower boundary is placed at the base of the marine shale and may be marked by pebble beds.

The Leyland member is recognized from Wildhay River in the north to Castle River in the south, and is present across the Foothills. In general, it increases in thickness southward, and also from west to east across the Foothills. Most of the increased thickness is produced by facies change from sandstone to shale. In the north the member is about 30 feet thick, but on Sheep Creek it is more than 175 feet; in the Bighorn region, it thickens from about 50 feet in the west to about 90 feet in the east. Because the variations in thickness are due to facies changes and not so much to differing rates of sedimentation, the isopach map has been drawn to include all the beds between the Cardinal member and the top of the formation (Fig. 16d).

The Leyland and Kiska members are similar in many features. Both consist of silty, dark grey, concretionary shales; both are replaced by carbonaceous sandstone and greenish shales along the western side of the Foothills in the Bighorn-Nikanassin region; both have a sharp lower boundary, and a gradational upper boundary.

The Leyland member is not well developed north of McLeod River. However, several feet of shale in sections as far north as Wildhay River have been included in this member (Fig. 5).

In the Bighorn-Nikanassin region, the lower beds of the Leyland member are mainly dark grey shales with reddish brown weathering sideritic concretions. A siltstone, somewhat similar to the Cardinal member, lies above that member in some sections on Brazeau and Cardinal Rivers. The shale grades upwards into siltstone or platy shale, then rubbly shale may be repeated in the overlying cycle.

The change of facies in which dark shale grades laterally into sandstone and then into greenish carbonaceous shales and siltstones is well shown in sections from Thistle Creek to Canyon Creek (Fig. 6). A vertical lithologic change, found on the headwaters of streams between Bighorn River and McLeod River, is from dark grey, concretionary shale to sandstone and carbonaceous shales (Fig. 5). From Ram River south to the International Boundary, the major facies change in the Leyland member is from marine shale to marine siltstone and sandstone (Figs. 5, 9). Several cycles are characterized by a gradual change from rubbly

Table XII

Fauna of Leyland Member

Fauna	GSC Location[3]													
	26792	27100	28058	28059	28064	28065	28056	28086	28174	28176	28217	28179	28185	32874
Baculites ovatus Say s. lato	–	–	–	–	–	–	–	–	–	c[1]	–	x[2]	–	–
Scaphites impendicostatus Cobban	–	–	–	–	–	–	c	–	–	–	–	–	–	–
Scaphites mariasensis Cobban	–	–	–	–	–	–	c	–	c	–	–	–	–	–
Scaphites sp. aff. *S. mariasensis* Cobban	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Scaphites preventricosus Cobban cf. *S. typica*	–	–	c	–	–	–	–	–	–	c	c	?	–	–
Scaphites preventricosus Cobban var. *S. sweetgrassensis* Cobban	–	–	x	–	–	–	–	–	–	–	–	–	–	–
Scaphites preventricosus Cobban var.	–	–	x	–	–	–	–	–	–	–	–	–	–	–
Scaphites n. sp. aff. *S. mariasensis* Cobban	–	–	–	c	–	c	–	–	–	–	–	–	c	–
Anomia sp. indet.	–	x	–	–	–	–	–	–	–	–	–	–	–	–
Cardium pauperculum Meek and Hayden	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cardium sp. indet.	c	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus deformis Meek s. lato	–	–	–	–	?	c	c	–	–	–	–	–	–	–
Inoceramus deformis Meek var. *I. inconstans* Woods	–	–	–	–	–	–	–	–	–	?	–	–	–	–
Inoceramus dimidius White	–	–	–	–	–	–	–	–	–	–	–	c	–	–
Inoceramus fragilis Hayden and Meek	–	–	–	–	?	–	–	–	–	–	–	–	–	–
Inoceramus lamarcki (Parkinson)	–	–	c	–	–	–	–	–	–	–	–	x	–	–
Inoceramus lamarcki var. *I. cuvieri* Sowerby	–	–	c	–	–	–	–	–	–	–	–	–	–	x
Inoceramus lamarcki (Parkinson) s. lato	–	–	–	–	?	–	–	x	x	–	x	–	–	–
Inoceramus sp. indet.	–	–	x	–	–	–	x	–	–	–	–	–	–	–
Ostrea lugubris Conrad	–	x	–	–	–	–	–	–	–	–	–	–	–	–
Ostrea sp. indet.	–	x	–	–	–	–	–	–	–	–	–	–	–	–
Pteria sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gastropod, genus and species indet.	–	–	x	–	–	–	–	–	–	–	–	–	–	–
Macruran crustacean indet.	–	–	–	–	x	–	–	–	–	–	–	–	–	–

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

shale to platy shale or siltstone. Thin beds of pebbles or scattered pebbles in mudstone may lie above the top of some cycles.

The only section south of Athabasca River which may not have any shales of the Leyland member is the most westerly one on Mackenzie Creek (section 4-40). The section is poorly exposed but some coal beds and carbonaceous shales lie below typical Sturrock sandstone at the top of the formation. All the interval between the Ram sandstone and the uppermost sandstone may be nonmarine, in which case the interval would be similar to the thick Moosehound sections in the northern area.

A unique occurrence of cobbles was found in the central part of a section on Mackenzie Creek (section 4-41). Cobbles, 3 to 6 inches in diameter, were

D.F.S., 1-4-54

D.F.S., 1-5-54

Plate XXIII. *Cobbles scattered over upper surface of sandstone in Cardium formation, Mackenzie Creek, section 4–41.*

scattered over the upper surface of a sandstone and were overlain by shales similar to those of the Leyland member. These cobbles (Pl. XXIII), composed of chert of various colours, are well rounded and well sorted for their own size range.

Four cycles have been defined in the beds overlying the Cardinal member. These cycles are not identifiable in all sections but do appear to extend over a large area (Fig. 5). They are best developed in the sand facies of the Sturrock member where lithologic changes are greatest. The lowest of these coincides with the sandstone in the Highwood area between the Cardinal member and the uppermost Sturrock sandstone. The second is best developed between Ram River and Thistle Creek.

Sturrock Member

The uppermost fine-grained sandstone of the Cardium formation is designated as the Sturrock member. Named from Sturrock Creek, which flows into Wapiabi Creek east of the Bighorn Range, the member is typically developed at the headwaters of Wapiabi Creek. The lower boundary is drawn at the base of thickly bedded sandstone. In some sections, intervals of concretionary shale and carbonaceous sediments have been included in the member. The boundary between the Leyland and Sturrock members forms no persistent stratigraphic horizon (Figs. 5-9).

The Sturrock member, although less than 20 feet thick in some places, appears to extend southward to Carbondale River (Fig. 5). It is not present on Drywood River or on Castle River where the top of the Cardium formation is marked only by a thin pebble band, but in other sections the member is represented by massive sandy siltstone. This member is thickest along the western edge of the Foothills and thinnest on the eastern side. It shows its maximum development west of the Bighorn Range, and thins towards the south and north. The distribution and variation of the interval above the Cardinal member are shown on the isopach map (Fig. 16d). The Sturrock member ranges in thickness from 166 feet on Littlehorn River (section 5-37) to 15 feet on Chungo Creek.

Table XIII

Fauna of Sturrock Member

Fauna	GSC Location[3]																	
	24794	24795	24801	24805	25066	25067	25079	25086	25088	25090	25091	25094	27044	27066	28088	28090	28184	32883
Actinocamax aff. *A. strehlensis* Fritsch and Schloenbach	–	–	–	c[1]	–	–	–	c	–	–	–	–	–	–	–	–	–	–
Cardium pauperculum Meek and Hayden	–	x[2]	–	–	–	c	c	x	c	c	c	–	–	c	c	c	c	–
Cardium sp. indet.	x	–	x	–	x	–	–	–	–	–	–	x	–	–	–	–	–	x
Inoceramus fragilis Hall and Meek	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–
Inoceramus lamarcki var. *I. cuvieri* Sowerby	–	–	–	c	–	–	–	c	–	–	–	–	–	–	–	–	–	–
Inoceramus lamarcki (Parkinson) s. lato	–	–	–	–	–	–	–	–	–	x	–	–	x	–	–	–	–	–
Ostrea lugubris Conrad	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–
Ostrea sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–
Pholadomya ex gr. *P. coloradoensis* Stanton	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	c
Pinna sp. indet.	–	–	–	–	–	–	–	–	–	–	–	?	–	–	–	–	–	–
Pteria sp. indet.	–	–	–	–	–	–	?	–	–	–	–	–	–	–	–	–	x	–
Tellina sp. indet.	–	?	–	–	–	–	–	–	–	–	–	–	?	–	–	–	–	–
Trigonoarca obliqua Meek	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–
Gastropod, genus and species indet.	–	x	–	x	–	–	–	–	–	x	–	–	–	–	–	–	–	–
Fish scales	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Inoceramus cf. *lamarcki* var. *apicalis* Woods	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

As defined, the Sturrock member consists of sandstone with minor quantities of shale and some carbonaceous sediments. The nonmarine beds in the upper part of the formation west of the Bighorn and Nikanassin Ranges have been included in the member. In the more westerly sections, the Sturrock member contains many thickly bedded sandstones. Farther east, beds are from 2 feet to less than an inch thick, and do not have the massive appearance of the Ram sandstones (Pls. XXV, XXVI). On Cardinal, Brazeau (sections 4-31, 4-29) and

D.F.S., 3-2-55

Plate XXIV. *Sturrock member (S) of Cardium formation, Little Berland River, section 5–19. Basal shales of Wapiabi (W) are covered on the right and lie on coarse-grained sandstone. Contact between formations is below tallest dead tree. Covered interval on left contains Moosehound shales (M).*

D.F.S., 4-2-56

Plate XXV

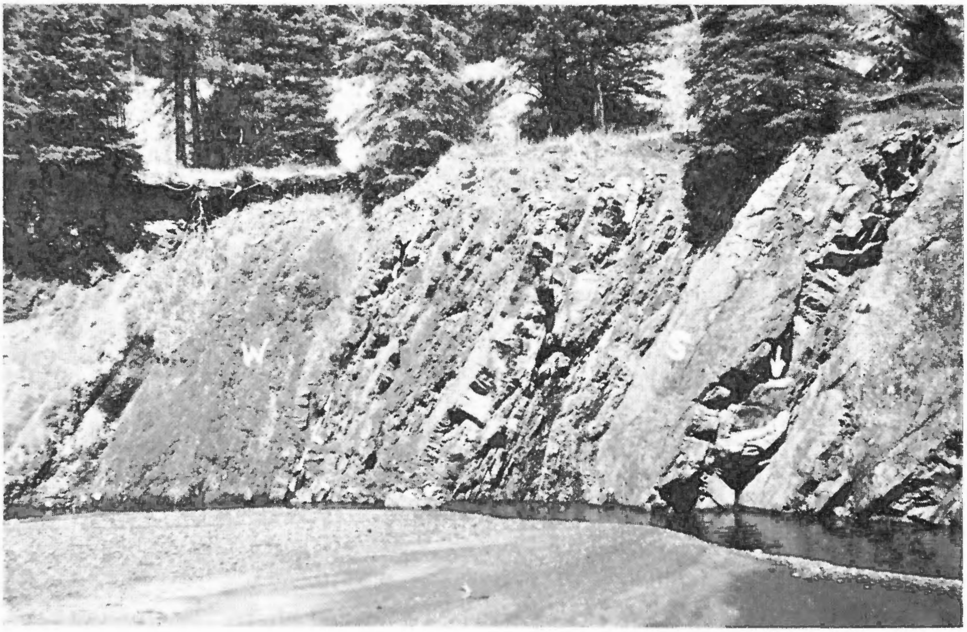
Sturrock member (S), Cardium formation, Burnt Timber Creek, section 5–9. Muskiki shales (M) of Wapiabi formation are on the right.

Blackstone (section 5-39) Rivers, a gradual increase in shale and decrease in sandstone is noted as the formation is traced eastward (Figs. 6, 7, 8). In the most easterly section, the member is represented by only a few beds of sandstone interbedded with shale.

Eastward, a local thickening develops in the upper beds. The member appears to thin towards the east, and then to thicken within a short distance (Figs. 6, 8). Apparently, the western sandstone is overlain by another sandstone which does not extend completely over the lower one. The overlap produces a thicker sand deposit and makes the upper part of the formation appear to thin westward.

The sandstone of the Sturrock member extends far southward. However, on Dutch Creek, a massive siltstone is present in an equivalent position. This massive siltstone is also found in a road-cut west of Coleman. On Lynx Creek (Carbondale area) only platy siltstone is found at the top of the Cardium formation, and similar beds occur on Sheep River (Pl. XIX) where pebbles mark the boundary between the Cardium and Wapiabi formations.

The sandstone is similar to that of the Ram member although it is classified as a quartz wacke because its matrix exceeds 10 per cent. Feldspar grains and rock fragments are not abundant. It is fine grained, grey to white, with a tan weathering surface.



D.F.S., 1-2-54

Plate XXVI. *Sturrock member (S), Cardium formation, Wapiabi Creek, section 4–5. Intrastratal flow structures on right. Ripple-marks on bedding surfaces. Coarse-grained sandstone beds of Wapiabi formation (W) lie to left of the centre of the picture.*

The top of the Sturrock member is usually concretionary and forms a resistant massive bed. Although the concretionary surface is bumpy and uneven, the surface is more or less planar without any erosional features. Pebbles may be embedded in the sand but more commonly lie above the fine-grained sandstone.

Wapiabi Formation

The Wapiabi formation was named by Malloch (1911) from Wapiabi Creek, one of the main streams in the region of the Bighorn Range. It included the shales between the sandstones of the Brazeau and Cardium (Bighorn) formations.

Malloch measured more than 1,300 feet of Wapiabi shales "on the more southerly of the two main branches of Wapiabi Creek", and stated (1911, p. 37) that "the total thickness is probably not far short of 1,800 feet." Examination of this section indicated that it is totally unsatisfactory for a type section, as neither upper nor lower boundary is now exposed, and much of the section is covered with vegetation or talus. The Wapiabi formation is not well exposed in the immediate vicinity of Malloch's original work and, because of its great thickness and occurrence in a strongly faulted area, few unfaulted sections are available. However, two complete sections are present along Thistle Creek, and the better exposed one in sec. 17, tp. 44, rge. 20, W5, on the west flank of a syncline, has been selected as the type section. A more easily accessible but much thinner section, typical of the formation, is on Blackstone River, tp. 42, rge. 18, W5.

Thistle Creek may be reached by forestry pack-trail from Mountain Park or Mercoal by way of Grave Flats, or from Nordegg by way of Mons and Southesk. The section is approximately 4 miles below the trail-crossing on Thistle Creek, and can be reached by a poor unmarked trail along the north bank.

The Wapiabi formation has different stratigraphic limits in the southern and central Foothills. In the area of the type section, it is defined as including all the beds between the coarse-grained, greenish grey sandstones of the Brazeau formation and the fine-grained sandstone of the Cardium formation. This definition, which includes in the Wapiabi formation the fine-grained, light brown weathering sandstone near the top of the formation, also includes the transition beds at the top and the pebble and coarse-grained sandstone beds at the base. In the southern Foothills around Sheep River, the formation occupies a smaller stratigraphic interval. It includes all the dark grey shales between the Cardium sandstones and the medium- to coarse-grained, carbonaceous sandstones of the Belly River formation. Subsequently, it will be shown that the basal two sandstones and overlying shale of the Belly River formation can be correlated with the upper three members of the Wapiabi formation where overlain by the Brazeau formation in the central Foothills.

Seven members have been recognized in the Wapiabi formation throughout most of the Foothills; from the base upwards, these are the Muskiki, Marshybank, Dowling, Thistle, Hanson, Chungo, and Nomad members.

Type Section

Section 4-52. Wapiabi formation, Grave Flats map-area, Alberta, west flank of syncline on Thistle Creek, sec. 17, tp. 44, rge. 20, W5. Described by R. J. W. Douglas, D. F. Stott, and D. C. Pugh.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
	Conglomerate and sandstone; top 27′ grey weathering; underlain by greenish grey shale and thinly bedded sandstone; rubbly and concretionary	77	
	Sandstone, dark brown weathering, calcareous, indurated	2	
	Sandstone, medium-grained, grey; massive bedded; some laminations and large crossbedding; friable	22	
	WAPIABI FORMATION		
	Nomad Member		
90	Siltstone and shale; uniformly bedded in alternating 2″-3″ beds	3	2,100
89	Sandstone, fine-grained, uniformly bedded, finely laminated; pinches out on south side	3	2,097
88	Siltstone and shale; greenish grey, in alternating ½″-1″ beds; siltstone, fine-grained, shaly, silty; unit has banded appearance	20	2,094
87	Sandstone, fine-grained, finely laminated, in 6″-1′ beds, alternating with 25% shale; silty	5	2,074
86	Siltstone, fine-grained; shale, silty; greenish grey; in alternating ½″-1″ beds; banded appearance	30	2,069
85	Sandstone, fine-grained, finely laminated; and silty shale; 1.5′ massive sandstone at base	7	2,039
84	Shale, greenish grey, rubbly; banded appearance of alternating shale and silt, poorly defined beds, 2″-3″ thick; 2′ limestone concretionary bed at 22′; more massive, homogeneous, and silty towards base	42	2,032
83	Limestone, silty to argillaceous; massive bedded, finely laminated and crossbedded; dense, dark grey on fresh surface; base sharp	6	1,990
82	Shale, silty, ½″ pebbles throughout	1	1,984
	Chungo Member		
81	Sandstone, medium-grained, grey; ½″ pebble conglomerate in top 2″, lustre mottling	3	1,983
80	Shale, silty, sandy, coaly	2	1,980
79	Sandstone, medium-grained, grey	2.5	1,978
78	Shale, coaly, sandy	0.5	1,975.5
77	Sandstone, fine-grained, brown; calcareous cement, rusty to reddish brown, weathering maroon or purplish; 2″ pebble conglomerate 9′ below top; massive bedded, some crossbedding; some poor		

Unit	Lithology	Thickness (feet)	Height above base (feet)
	laminations; more greenish grey below 12′; 2″ conglomerate, ¼″ pebbles at 35′; more greenish and brown to light brown weathering below, with some suggestion of crossbedding and laminations	52	1,975
76	Shale, soft, clayey, and thinly bedded; finely laminated sandstone, ripple-marked	3	1,923
75	Sandstone, fine- to medium-grained, very massive bedded, greenish grey; large crossbedding; in places well developed laminations; shale-pebble conglomerate, 2″ at 18′ and 23′ with flat silty shale pebbles 1″-2″; 0.5′ thinly bedded shaly partings at 44′ and at base	52	1,920
74	Sandstone, fine-grained, grey, finely and evenly laminated in 1′-3′ beds with thin shale partings	14	1,868
73	Siltstone, argillaceous, rubbly; iron-stained spots and interbedded shaly beds	12	1,854
72	Shale, silty	1	1,842
71	Siltstone, fine-grained, grey, finely laminated, in 4″ beds; shaly partings	2	1,841
70	Shale, silty, homogeneous and massive; iron-stain spots, alternating with 50% 2″-6″ siltstone beds; fine pebbles, ⅛″, in basal 2″	16	1,839
69	Grit to fine conglomerate; orange weathering concretions	1	1,823
68	Sandstone, massive bedded, fine- to medium-grained, greenish grey, laminated; large crossbedding; traces of maroon weathering	15	1,822
67	Sandstone, as above, and shale; silty, thinly bedded; iron-stain spots	3	1,807
66	Siltstone, argillaceous, massive, blocky to rubbly, with concretionary spots; 3″ concretionary bed 7′ below top; glauconitic	14	1,804
65	Shale, silty, massive, rubbly; rare concretions, gradational above and below	20	1,790
64	Siltstone, argillaceous, massive, rubbly with large concretions and iron spots; more shaly at 24′ and in beds that follow, dividing it into four to five subequal units	56	1,770
	Hanson Member		
63	Shale, very silty; three large concretionary beds	12	1,714
62	Shale, fairly fissile; numerous medium and large concretions	68	1,702
61	Shale, very silty, dark grey; numerous large concretions	27	1,634
60	Shale, very silty; rare concretions	22	1,607
59	Shale, silty, dark grey; some concretions	6	1,585
58	Shale, silty; rare concretions	12	1,579
57	Shale, silty, dark grey; numerous concretions	18	1,567
56	Shale, silty; some concretions	12	1,549
55	Shale, fairly silty; rare concretions	11	1,537

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Unit	Lithology	Thickness (feet)	Height above base (feet)
54	Shale, silty, dark grey; numerous concretions	18	1,526
53	Shale, fissile; rare concretions	8	1,508
	Thistle Member		
52	Siltstone and shale; 20% siltstone in ½″-1″ beds, alternating with thin to massive silty shale; rare concretions 5′ below top	20	1,500
51	Shale, silty; rare thin siltstones	11	1,480
50	Shale, silty and 15% siltstone; 1′ yellow-buff calcareous bed at top	27	1,469
49	Siltstone and 30% shale; some 2″-6″ thick beds, with thicker ones weathering yellow-buff	48	1,442
48	Shale and 30% siltstones; in ½″-2″ beds; shale is thinly bedded, silty, dark grey	43	1,394
47	Siltstone and 40% shale, as above	41	1,351
46	Shale and 25% siltstone, heavy bedded siltstone, 4″-6″ at top, large ripples; pelecypods	28	1,310
45	Sandstone, fine-grained, grey, in 2″-6″ beds, 40%, with silty shale and siltstones between	5	1,282
44	Sandstone and 50% shale, as above; less resistant towards base	16	1,277
43	Inaccessible but appears to be similar to overlying beds, 60% sandstone	70	1,261
42	Siltstone and silty shale similar to overlying beds; occasional 2″-3″ fine-grained sandstone bed, 6″ yellow weathering bed at base	45	1,191
41	Shale, thinly bedded, platy with 30% siltstone, weathers rubbly below 35′	77	1,146
40	Sandstone, fine-grained, medium grey, laminated, dense, in 1″-2″ beds with 40% silty shale	21	1,069
39	Limestone, silty, laminated, light yellow buff weathering, 6″ shale 6″ from top	3	1,048
38	Siltstone and shale, finely interbedded forming hard banded unit; siltstone, light grey	29	1,045
37	Shale, silty, platy; some bands of dense hard siltstone; unit has banded appearance	44	1,016
36	Siltstone and 50% shale; ¼″-½″ beds with occasional 4″-6″ sandstone, fine-grained	27	972
35	Shale, silty, and 25% siltstone; rather rusty weathering; 2′ limestone concretion at 20′ and 39′	43	945
34	Siltstone and 50% shale, thinly bedded	39	902
33	Shale, silty, platy; grading into laminated siltstone in upper 10′; some hard, dense siltstone beds in basal 30′	81	863
32	Shale, silty, rubbly, rusty weathering, dark grey	16	782
	Dowling Member		
31	Shale, silty, rusty weathering; 25% thin rusty weathering siltstones and rare concretions in rows; concretionary at top	55	766
30	Partly covered. Appears to contain less siltstone	20	711
29	Shale, silty, rusty weathering; 25%, thin, rusty weathering siltstones	25	691

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Shale; a few ½″ siltstone beds with larger irregular concretions	50	666
27	Shale, silty; concretions rare	15	616
26	Shale and thin siltstones; concretions common	27	601
25	Shale; concretions rare	20	574
24	Shale, silty, blocky to rubbly, less silty in basal 15′; some concretions 4″ and 4″-2′; large concretions contain pelecypod fragments	49	554
23	Covered. Shale, rubbly with concretions. Estimated	90	505
	Marshybank Member		
22	Siltstone, argillaceous, dark grey, blocky; concre-cretions 4″ and 12″-18″. Estimated	90	415
	Muskiki Member		
21	Shale, silty, massive, blocky; large 6″-1′ concretions, rather rare; seems more resistant than underlying beds	23	325
20	Shale, concretions common and rare, 5%, ¼″ siltstone beds	23	302
19	Siltstone and 20% shale; rare concretions, top 6″ and 1′ concretionary beds	25	279
18	Shale with 5% siltstone; ¼″ beds; scattered concretions, some in beds	45	254
17	Siltstone, thinly bedded; and 25% shale, in alternating ½″-1″ beds; top 10′ is rusty weathering, 6″ concretionary bed at top but no concretions in unit	18	209
16	Shale, grey; ⅛″-½″ siltstone layers; scattered concretions and concretionary beds, 5%; ¼″ bentonite at 19′	37	191
15	Shale, grey; scattered concretions	6	154
14	Shale, more resistant and siltier	10	148
13	Shale, grey, sub-fissile; beds of concretions; 4″ x 6″, ovoid, common; some 2″ beds of siltstone at top	27	138
12	Shale and 15% siltstone; in beds ½″-2″ thick with concretionary beds 2″-4″; rows of concretions	15	111
11	Shale, grey; concretions in beds	5	96
10	Shale, grey, sub-fissile, very rusty weathering	5	91
9	Shale, grey; common large 2″ x 1′ orange weathering concretions and 5% siltstone beds	11	86
8	Shale, grey; round to oval concretions; rare siltstone beds	9	75
7	Sandstone and shale	4	66
6	Siltstone and 25% shale; many concretionary beds at top and concretions throughout	12	62
5	Shale, grey, sub-fissile; rare 2″ x 4″ concretions	7	50
4	Shale, 30% siltstone, in underlying beds; 4″ x 2′ concretions	8	43
3	Shale, grey; 10%, ½″-2″ grey siltstone in beds and lenses	15	35
2	Shale, grey, massive to sub-fissile, grey weathering in basal part, rusty weathering at top	14	20
1	Siltstone, argillaceous; ¼″ pebbles near top	6	6
	Underlying beds—Cardium formation *See* Section 4 (Stott, 1956b)		

The Wapiabi formation overlies the Cardium formation with probably only slight disconformity. The boundary is well defined in most sections, with a distinct change in lithology from one formation to the other. The upper surface of the Cardium in some sections is wavy and irregular in appearance, and the top few inches of sandstone in some places contain pebbles, but evidence of deep erosion was not found. A zone of coarse material, ranging in thickness from less than an inch of small pebbles to several feet of large pebbles or tens of feet of coarse-grained sandstone lies at the base of the Wapiabi formation.

The Wapiabi formation extends from the International Boundary to Muskeg River, and its equivalents in the Smoky group occur near Pine River, 175 miles farther north. It is found along the Front Ranges and extends eastward beneath the Plains (Fig. 17).

The type section is 2,100 feet thick which is only slightly less than the maximum of 2,146 feet measured a short distance upstream. Because of repetition due to unrecognized faults, some measurements may be slightly greater than the true thickness. A composite section, 1,950 feet thick, in which several repeated units were omitted, was obtained on Bighorn River (section 5-38). The only section measured north of Athabasca River was that on Little Berland River (section 5-19) where several covered intervals leave some doubt as to the validity of the measured thickness of 1,550 feet. Most of a fairly well exposed section on Muskeg River was inaccessible because of high water. Irish (1952) stated that the Wapiabi formation is 1,000 feet thick in the Daniels Flats area to the north. This figure does not include about 450 feet of strata that Irish placed in the Cardium formation nor an additional 250 feet of the Brazeau formation that form the Chungo and Nomad members of this report. Including these beds, the total thickness of the Wapiabi formation is more than 1,600 feet, which agrees well with the measured section on Little Berland River. Complete sections of 1,820 and 1,299 feet were measured on Burnt Timber Creek (section 6-9) and Ghost River (section 6-21), respectively. A large part of the formation is exposed on Oldfort Creek but there the beds are flat lying with gentle warps and tear faults so that repetitions are suspected. Evans (1930), apparently by plane-tabling, obtained a thickness of 1,775 feet on Oldfort Creek but this thickness is approximate and may be greater than the true thickness.

Sections along the eastern margin of the Foothills are much thinner. A total of 1,035 feet was measured on Chungo Creek (section 4-8) and 1,043 feet on Wapiabi Creek (section 4-6); both measurements are corrected for fault repetitions. Sanderson (1939) plane-tabled the section on Chungo Creek above the forestry road, and reported a thickness of 1,400 feet. Although this thickness of Wapiabi beds is exposed, the Marshybank and Muskiki members are involved in several fault slices, and the correct thickness is much nearer 1,050 feet (section 4-8). An unfaulted section on Blackstone River (section 5-27) was 1,108 feet thick, which corresponds fairly well with the neighbouring ones. A short distance downstream below Lookout Creek junction, Allan and Rutherford (1924) measured 1,900 feet of beds. The section is poorly exposed and contains small faults, on one of which the lower third of the formation is almost entirely repeated. The thickness is probably close to that of section 5-27.

South of Bow River, the only complete section of the Wapiabi formation measured was on Highwood River east of Highwood Range. This section has a few minor faults, but a thickness of 1,050 feet is considered reasonably correct. Allan and Carr (1947) estimated 1,500 feet of Wapiabi shales on Carnarvon Creek in the Highwood area; Douglas (1950a, p. 28) estimated the formation to be 1,080 feet on the east side of the Gap map-area south of Highwood River. The isopach map (Fig. 17a) is necessarily generalized because of the limited number of complete sections. Even so, thickening of the formation towards the west is evident.

Malloch (1911, p. 37) described the Wapiabi shales as "... brown or dark grey, and somewhat arenaceous. They are very similar to the Blackstone, but contain concretions ... ." Early geologists considered the similarity of the Blackstone and Wapiabi shales so great in the Turner Valley region that they did not distinguish between them. Later, detailed studies indicated that subdivisions based mainly on weathering characteristics and concretionary content could be made.

The shales of the Wapiabi formation vary from fissile to rubbly and platy. They are dark grey, weather rusty, and contain abundant dark organic material. Glauconite occurs in the concretionary shales. Reddish brown weathering, sideritic concretions are plentiful in the basal and upper third of the formation. Dark grey, massive, argillaceous siltstone occurs in the lower part of the formation and also near the top of the formation. The sandstone is generally fine grained, thickly bedded, weathers light brown, and most is classified as quartz wacke. Thin bentonite layers occur throughout the formation but most are near the base. Beds of aphanitic, dense, argillaceous, dolomitic limestone in the central part resemble those of the Vimy member of the Blackstone formation. Carbonaceous material may be present in the beds transitional to the overlying formation. Coarse-grained sandstone with pebbles and cobbles of chert occurs at the base of the formation. A few other pebble beds are present throughout, the most persistent being the one at the top of the sandstone in the upper part.

In the Highwood-Crowsnest area, the Wapiabi formation is reported to contain numerous sandstones that are difficult to correlate with the various members recognized farther north. Apparently the formation contains much more sandstone in the south, but no complete section of it in this area is known for study.

A slight difference in attitude of beds on Littlehorn River (section 5-37) suggests an unconformable contact. Farther east, in sections such as those on Cardinal River (section 4-31), Blackstone River (section 5-39), and Sheep River (section 6-39), the change from one formation to the other is not as marked. The upper sandstone of the Cardium formation is thinly bedded and contains numerous thin beds of shale which is similar to the Wapiabi shales. This similarity of formations is even more noticeable in the eastern sections on Sheep and Highwood Rivers, and on Lynx Creek, where the upper Cardium beds are siltstone, and the only indication of the top of the Cardium formation is a thin bed of pebbles. On Drywood River (section 6-54), the pebble zone is found only after careful search because the shales above and below it are not markedly different.

The contact between the Wapiabi and Brazeau formations can generally be determined without difficulty although a transition zone is present in the upper part of the Wapiabi. The boundary is drawn at the base of the lowest thick, greenish grey, medium- to coarse-grained sandstone. Locally, this bed consists of chert pebbles or pebble-conglomerate. Underlying sandstones of the transition beds are greenish coloured, fine grained, and commonly soft and crumbly. Throughout most of the Foothills, the upper boundary of the Wapiabi appears to be approximately at the same stratigraphic position. In a few eastern sections, the transition beds are thicker, suggesting a gradation of the basal sandstones of the Brazeau formation into shales of the Wapiabi formation. From Sheep River southward, the boundary is drawn at the base of coarse-grained sandstone which is much lower stratigraphically than found farther north. The upper concretionary shales and fine-grained sandstones of the Wapiabi formation undergo a facies change to coarse-grained sandstone which is included in the Belly River formation. Therefore, although the boundary is still transitional, it lies within older beds. Thus, where the Wapiabi formation is overlain by the Belly River formation, the boundary is time-transgressive, becoming younger from southeast to northwest.

Age and Fauna

The Wapiabi formation is characterized by several zones of *Scaphites* (*see* Tables XIV to XX for faunal lists). The ammonites are not abundant and are poorly preserved. They are associated with species of *Inoceramus* which provide further confirmation of age relations. Six zones are present in the lower four members of the formation, which range in age from latest Turonian to Santonian. The upper members of the formation are not as well placed in the standard section of the Western Interior, but may be as young as Campanian.

Muskiki Member

A small tributary of Brazeau River known as Muskiki Creek provides the name for the basal member of the Wapiabi formation. The type section of the formation serves also as type section for the member. This member contains all the beds from the top of the fine-grained sandstone of the Cardium formation to the base of a massive siltstone subsequently defined as the Marshybank member. It consists predominantly of alternating beds of rubbly and flaky shale having characteristic weathered surface which was responsible for the designation 'Striped zone' by Hake, *et al.* (1942). The shale is locally concretionary. Included in the

Muskiki member are the basal beds of coarse-grained sandstone and pebbles which are as much as 20 feet thick.

The lower contact of the member is probably disconformable throughout the western Foothills and may be locally unconformable. The contact with the overlying member is gradational, the thinly bedded shales and siltstones of the Muskiki grading upwards into the massive Marshybank siltstone (Fig. 10).

The Muskiki member is found on Muskeg River and is easily recognized as far south as Ram River. Farther south, it outcrops on McPhail Creek west of the Highwood Range and is represented on Highwood and Sheep Rivers on the eastern edge of the Foothills.

The member thins towards the east and also towards the south, as shown on the isopach map (Fig. 17b). Sections on Thistle Creek (4-52) and Cripple Creek (5-42) are 325 and 312 feet, respectively. On Muskeg River the member appears thick, and on Little Berland River (section 5-19) it is 263 feet thick. Where identified in the south, it is between 150 and 175 feet thick. A minimum thickness of 145 feet was measured on Blackstone River (section 5-27).

The writer considers that basal coarse-grained sandstones here included in the Wapiabi formation were deposited in the advancing Wapiabi Sea, rather than being associated with the last phases of the retreating Cardium Sea. The stratigraphic relationships are similar to those of the basal grit of the Blackstone formation. In many sections, only a few inches of pebbles or scattered pebbles

D.F.S., 10-1-54

Plate XXVII. ***Muskiki member, Wapiabi formation, Brown Creek. Contact with the Cardium formation is on the extreme right.***

Table XIV

Fauna of Muskiki Member

Fauna	GSC Location[3]																																		
	24781	24784	24786	24802	25065	25081	25082	25101	25102	27052	27076	27082	27087	27088	27115	28052	28053	28055	28056	28060	28061	28067	28068	28073	28081	28092	28093	28173	28198	28201	28206	28208	28219	32861	32882
Baculites cf. *B. asper* Morton	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	c
Baculites ovatus Say s. lato	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	c	x	–	–	–	x	–	–	–	–	–	x	–	–
Baculites sp. indet.	x	–	–	–	–	–	–	x	–	–	x	–	x	–	–	–	x	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	x	–
Scaphites cf. *S. tetonensis* Cobban	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Scaphites impendicostatus Cobban	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Scaphites mariasensis Cobban	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–
Scaphites preventricosus Cobban	x²	c¹	–	–	?	–	–	c	–	–	x	–	–	–	–	–	–	c	–	–	–	–	–	–	?	–	–	–	–	–	–	c	–	–	–
Scaphites preventricosus Cobban var. *S. sweetgrassensis* Cobban	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scaphites ventricosus Meek and Hayden s. str.	–	–	–	–	–	–	–	–	–	–	–	x	–	x	–	–	–	–	–	–	–	–	c	–	–	c	–	–	c	–	–	–	–	x	–
Scaphites ex gr. *S. ventricosus* Meek and Hayden s. lato	?	–	–	–	–	?	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–	–	–	–	–	–	–
Scaphites indet.	–	–	x	–	–	–	x	–	–	–	–	x	–	–	x	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–
Inoceramus costellatus Woods	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus coulthardi McLearn	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus deformis Meek	c	–	–	–	–	–	–	–	–	–	c	–	–	–	–	c	c	–	–	–	–	–	–	c	x	–	–	–	–	–	–	–	–	–	–
Inoceramus deformis Meek (giant variety)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Inoceramus deformis Meek var. *I. inconstans* Wood	–	–	–	–	–	–	–	–	–	c	c	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	c	c	–	c	–	–	c	–	–
Inoceramus fragilis Hall and Meek	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–
Inoceramus involutus var. *I. exogyroides* Meek and Hayden	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	c	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Inoceramus leylandensis McLearn	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus involutus Sowerby	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus ex gr. *I. lamarcki* Parkinson	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus lamarcki var. *I. apicalis* Woods	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	c	–	–	–	–	–	–	–	–

Inoceramus lamarcki var. *I. capulus* Shumard	—	—	—	—	—	—	—	—	—	—	c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Inoceramus subquadratus Schlüter s. lato	—	—	—	—	—	—	—	—	—	—	—	—	c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Inoceramus ex gr. *I. involutus* Sowerby	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Inoceramus sp. indet.	x	—	—	—	—	—	—	—	x	—	—	—	—	x	x	x	x	—	x	x	—	x	—	x	x	—	—	—	—	—	x	—	—	—	—
Nucula sp. indet.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ostrea sp. indet.	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—	—	—	—	—	—	—	—	—
Tritonides huerfranensis Stanton	c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fish scales	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropod genus and species indet.	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	x	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

in shale are present. In other sections, particularly around Brazeau River, beds as much as 15 to 20 feet thick lie at the base of the formation. The greatest thickness of grit is the 40-foot basal unit on Bighorn River (section 5-38), which is composed of massive, greenish grey beds with pebbles scattered over the bedding surfaces. Zones of detrital concretionary material are present. Towards the base, the unit becomes shaly and bedded. The base is marked by 2 feet of gritty shale with lenses of conglomerate, and well-rounded, disk-shaped pebbles from one-eighth inch to 3 inches in diameter. Pebbles of chert predominate although some of quartzite and a few of sandstone occur in some localities.

The shales are fissile to platy, dark grey on a fresh surface and rusty where weathered. The resistant platy shales are interbedded with the more easily eroded fissile ones, giving the unit a banded appearance (Pl. XXVII). Concretions are more abundant in the siltier facies along the western border rather than in the shales of the eastern Foothills.

A considerable part of the Muskiki member is covered on Muskeg River, but about 90 feet of basal beds are exposed above the Cardium formation. These beds contain large reddish brown weathering concretions in the upper half. On Little Berland River, a similar succession appears to be present but is poorly exposed.

In the type section, platy siltstone beds form as much as 80 per cent of the upper part of the cyclic units within the member. Repeated gradation from shale to siltstone permits the definition of three cycles. Minor cycles cannot always be traced from one section to another and they are not correlated in the cross-sections. The lowest cycle in the type section is topped by platy, fine-grained sandstone, but this sandstone unit was not recognized in the more westerly section which is not so well exposed. The high silt content is typical of the sections along the western border of the Foothills, but on the eastern margin, the silt content is much less and shale predominates. Concretions in the shale and siltstone are from 3 to 6 inches thick and may be from 6 inches to 2 feet long.

Thin bentonitic beds occur throughout the member but are most numerous near the base. On Sheep Creek, twenty-two beds from less than one-quarter to one inch were observed. The bentonite is creamy white, and frequently is reddish brown along the contacts with the shale beds.

On McPhail Creek in the Highwood area, two sandstones that grade downward into siltstone are considered to lie within the basal part of the Wapiabi formation. The upper sandstone may be equivalent to the Marshybank member but as the Muskiki member is 244 feet thick on Sheep River (section 6-34) and 287 feet thick on Highwood River (section 6-46) to the east, it seems more likely that these sandstones, the upper of which lies 140 feet above the top of Cardium formation, are stratigraphically lower and should be included in the Muskiki member. The lower sandstone may lie in an equivalent position to the thin sandstone in the basal part of the Muskiki member in the type section.

In a few places thin pebble beds have been found within the Muskiki member several tens of feet above the basal conglomerate, but as no persistent layer is known, the beds apparently are only of local significance.

Age and Fauna

In most sections, the basal beds of the Muskiki member lie within the zone of *Scaphites preventricosus* Cobban and *Inoceramus deformis* Meek which, according to Jeletzky, is of latest Turonian age[1] (*see* Table XV for faunal list). The main part of the Muskiki member lies within the zone of *Scaphites ventricosus* Meek and Hayden and *Inoceramus involutus* (*I. umbonatus* Meek and Hayden). This zone is considered by Jeletzky to be of Coniacian age in terms of the International standard. The Muskiki member is, therefore, of late Turonian to Coniacian age.

I. involutus has not been recognized in any beds considered to lie within the *S. preventricosus* zone, and according to Jeletzky has a slightly more restricted range than *S. ventricosus.* Neither *I. involutus* nor *S. ventricosus* has been found in the Marshybank member nor has either been found in association with the *Scaphites depressus* fauna.

Marshybank Member

A unit of massive siltstone or fine-grained sandstone which lies approximately 200 to 250 feet above the base of the Wapiabi formation is defined as the Marshybank member. This particular subdivision was not recognized in any previous work, but was included in the Lower concretionary shale of Webb and Hertlein (1934), and Hake, *et al.* (1942). The name is from Marshybank Creek which flows into Brazeau River west of Canyon Creek. The member is typically developed in the Wapiabi type section on Thistle Creek.

The base of the member is drawn where the siltstone grades into shale or mudstone. The upper contact is usually distinct, and is marked by a change from massive siltstone to rubbly shale. The upper surface is commonly concretionary and in some sections is covered by pebbles. A thickly bedded sandstone, lying at the same stratigraphic position, is included in the member in the area south of Muskeg River.

The Marshybank member is best developed in the central Foothills near the Bighorn and Nikanassin Ranges but extends northward and southward through the Foothills. The member is recognized on Burnt Timber Creek, Sheep and Highwood Rivers in the south, although it is not well developed. Elsewhere in the south, outcrops are too poor to indicate its presence.

The Marshybank member varies little in thickness but does thin towards the eastern and southern part of the Foothills (Fig. 17). On Thistle Creek, a thickness of 90 feet was estimated; a comparable section on Bighorn River (section 5-38) measured 104 feet. On Blackstone River (section 5-27), the member is 80 feet thick, and on Highwood River (section 6-46), only 41 feet.

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[1]More recently, Jeletzky has indicated that the zone may also be earliest Coniacian.

In the type section, the member consists of massive argillaceous siltstone with large reddish brown weathering sideritic concretions, especially near the top of the member. The siltstone is dark grey, sometimes has a brownish hue, and weathers rusty. Bedding is not apparent in many sections although the rows of concretions serve to emphasize the planar elements that are present.

The top of the member is composed of a one-foot bed of a conglomerate of broken concretions and pebbles on the small tributary of Thistle Creek which the pack-trail descends from the south. The conglomerate has an argillaceous, silty matrix similar to the sediments of the underlying beds. In some sections, as on Bighorn River, the member is overlain by a pebble-conglomerate in a concretionary matrix.

A marked facies change is found north of the type section where a prominent sandstone is recognized as the Marshybank member. Irish (1951), in mapping the Pierre Greys map-area, included this sandstone in the Cardium (Bighorn) formation, but stratigraphic and palæontological evidence favours the present interpretation. Below the sandstone on Muskeg River is a shale sequence conservatively estimated to be about 250 feet thick, and considered to be the Muskiki member. Fossils from the shale indicate that it is of the same age as the basal Wapiabi shales, and support the identification of these beds as the Muskiki member. Fossils from immediately above this sandstone belong in the zone of *Scaphites depressus,* which occurs in and just above the Marshybank member farther south. The sandstone, which thins towards the south, has been traced from Muskeg River to Little Berland River, and from there to Moberly Creek (Pl. XXVIII). Palæontological evidence confirms the correlation. Some similarity in distribution exists between the Marshybank sandstone and the Dunvegan sandstone, which also undergoes a facies change southward.

On Muskeg River (section 5-5) the Marshybank member is composed mainly of sand similar to that found in the Cardium formation. Thirty-four feet of fine-grained sandstone lies below a concretionary cap. The concretionary surface is uneven and the depressions, which may be as much as 6 inches deep, are filled with chert pebbles. A bed of conglomerate, 3 to 4 inches thick, overlying the sandstone is exposed in the small tributary which enters Muskeg River at this point. The chert pebbles are one-quarter inch to 3 inches in diameter. A thin bed of chert pebbles occurs 6 feet below the top of the Marshybank member. The sandstone is grey to brownish grey and does not show laminations. It weathers a distinctive reddish brown, somewhat different from the rust to light brown of the Cardium sands. The beds are from 4 inches to a foot thick. Below the sandstone are 44 feet of thinly bedded sandstone, shale, and siltstone. The siltstone, which is similar to that found in the Marshybank member in the south, is dark grey, very argillaceous, and contains concretions 8 inches by 2 feet. The shale is silty and grades upwards into siltstone. Irregular rounded structures interpreted as burrows of organisms are plentiful in the siltstone.

D.F.S., 3-5-55

Plate XXVIII. *Sandstone in Marshybank member (M), Moberly Creek. Shales of the Dowling member (D) are on the right.*

At the junction of Véronique Creek and Muskeg River, several miles east of the McDonald Flats section, more than 80 feet of sandstone, siltstone, and shale were mapped by Irish (1951) as the Cardium (Bighorn) formation. This outcrop may be equivalent to the Marshybank member rather than to the Cardium formation. As the Véronique Creek section is in the centre of an anticline, lower beds are not exposed, and its stratigraphic relationships are not readily determined.

The Marshybank member on Little Berland River lies approximately 225 feet above the Cardium formation. The member is well exposed on the north side where the river cuts along strike, and it is also exposed on the south side. Only 15 feet of sandstone are present at the top. Below this, 30 feet of very silty shale are interbedded with thin, well-indurated siltstone bands.

Farther south on Moberly Creek, the sandstone is 7 feet thick (Pl. XXVIII), is slightly laminated and its upper surface is rather uneven. An overlying concretionary bed contains chert pebbles.

As the Marshybank member is traced southward from the type section, it grades from siltstone to shale. On Wapiabi Creek, it consists of bedded, very argillaceous siltstone. Pebbles lie above the member. Towards the east on Chungo Creek and Blackstone River near the forestry road, the member consists of argillaceous siltstone to mudstone. The westernmost section on Blackstone River is topped by a one-foot concretionary bed.

In the more southerly sections on Sheep and Highwood Rivers, the member is blocky, argillaceous siltstone to mudstone, but the underlying rubbly shales provide sufficient contrast to recognize the member.

Age and Fauna

The Marshybank member is characterized by *Scaphites* comparable with or referable to *S. depressus* Reeside (*see* Table XV). This species was not found below the base of the member, which, although no real lithologic break is known at this horizon, apparently marks a distinct faunal change. The *S. depressus* zone is considered by Jeletzky to be of early Santonian age.

The ammonites were fairly abundant in this member, and wherever the member was well exposed, numerous specimens were collected from the siltstone. This occurrence may be indicative of favourable ecological conditions.

Cardium cf. *C. pauperculum* Meek and Hayden is found in this member, and where present in a sand facies could cause a misidentification of the lithologic unit if it were considered diagnostic of only the Cardium formation. *C. pauperculum* usually is found in near-shore deposits, and indicates that this member probably was formed in relatively shallow water.

Table XV

Fauna of Marshybank Member

Fauna	GSC Location[3]									
	27067	27081	27083	27109	27112	28087	28094	28190	28204	32871
Baculites sp. indet.	—	—	—	—	—	—	—	—	x[2]	—
Scaphites depressus Reeside s. stricto	—	—	x	c[1]	—	—	—	—	—	x
Scaphites depressus Reeside var. *S. stantoni* Reeside	—	—	—	c	x	—	c	—	—	—
Scaphites ex gr. *S. ventricosus* Meek and Hayden s. lato	x	x	—	—	—	x	—	—	x	—
Anomia subquadrata Stanton	—	—	—	c	—	—	—	—	—	—
Cardium pauperculum Meek and Hayden	c	—	—	c	—	—	—	c	—	—
Inoceramus lamarcki var. *I. cuvieri* Sowerby	—	—	—	—	—	—	—	—	c	—
Inoceramus lamarcki var. *I. apicalis* Wood	—	—	—	—	—	—	—	—	c	—
Inoceramus sp. indet.	—	—	—	—	—	—	—	—	—	—
Pecten sp. indet.	—	—	—	x	—	—	—	—	—	—
Ostrea sp. indet.	—	—	—	x	—	—	—	—	—	—

[1]c = comparable form

[2]x = specific form

[3]Locality of each collection is given in Appendix II

Dowling Member

The Dowling member contains those beds of concretionary shale that are overlain by the calcareous shale of the Thistle member in the middle part of the Wapiabi formation and underlain by the siltstone or sandstone of the Marshybank member. A fording place on Brazeau River above Opabin Creek, known locally as Dowling ford[1], provides the name for this member.

The lower boundary of the member is placed at the distinct change in lithology from massive, argillaceous siltstone or sandstone to rubbly shales containing reddish brown weathering, sideritic concretions. The surface is frequently covered with concretions containing scattered pebbles. The contact is considered to be conformable but may be disconformable in some places. The upper contact, drawn where the shales become calcareous and no longer contain concretions, is conformable.

The measurements at scattered localities show the Dowling member to be fairly uniformly distributed in a northwest-southeast direction, but indicate that it thins markedly across the regional trends (Fig. 17d). The type section on Thistle Creek has a thickness of 351 feet, which is the maximum known. Farther west, more than 340 feet of Dowling shales are exposed but the upper contact is covered. The minimum measurement of 101 feet was obtained on Blackstone River.

On Little Berland River in the north, only about 40 feet are exposed but the member probably is more than 200 feet thick. On Bighorn River (section 5-38) and Cripple Creek (section 5-42), south of the type section, the member is about 270 feet thick, and has a similar thickness on Burnt Timber Creek (section 6-9) and on Highwood River (section 6-46).

The Dowling member is very similar to the Opabin member of the Blackstone formation and to the Hanson member of the Wapiabi formation. The shale is dark grey, weathers rusty, and contains organic matter. Some thin, platy siltstones are interbedded with the shales, but the member does not have the strongly banded appearance of the Muskiki member. The section on Burnt Timber (Pl. XXIX) is typical.

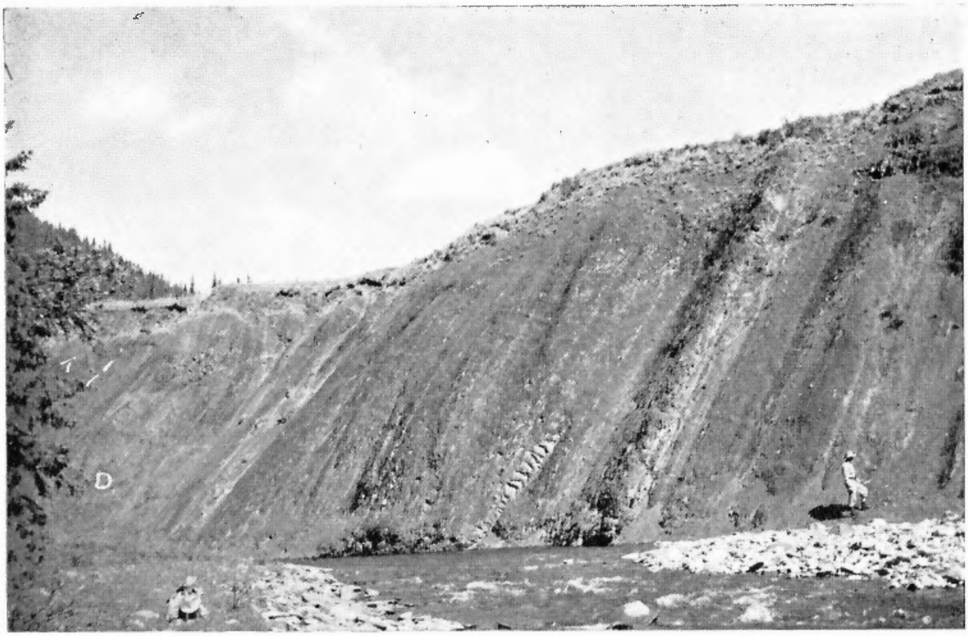
Large reddish brown weathering concretions are plentiful and are generally in rows rather than scattered. The less silty shales are almost devoid of concretions. Ammonites are commonly found in the concretions although they are almost present in the shale.

Two cycles are well developed throughout most of the region (Fig. 10), but are not so evident in the southern sections.

Age and Fauna

Two faunal zones recognized in the Dowling member are those of *Scaphites depressus* and *Scaphites vermiformis* (*see* Table XVI). Jeletzky recently recog-

[1]This ford is mentioned by Allan and Rutherford (1924, p. 3) who, like others, found it necessary because of high water to cross Brazeau River here rather than farther east.



D.F.S., 3-5-56

Plate XXIX. *Dowling member (D), Wapiabi formation, Burnt Timber Creek, section 6–9. Contact with overlying Thistle member (T) is on the extreme left.*

nized the latter between the underlying zone of *S. depressus* Reeside and the overlying zone *S. montanensis* Cobban.

Although a distinct change in lithology occurs between the Marshybank and the Dowling members, the break represents no great time interval as *S. depressus* is found in both members. The faunal change is about 100 to 150 feet above the base of the Dowling shales, but fossil collections were insufficient to determine a more precise position.

Jeletzky divided the zone of *Scaphites (Clioscaphites) vermiformis* Meek and Hayden as outlined by Cobban (1951, p. 2197) into the *S. vermiformis* and *S. montanensis* zones because he had found them to be representative of separate intervals. The collections made during this study indicate that *S. vermiformis* Meek and Hayden usually occurs by itself in the upper part of the Dowling member. According to Jeletzky, *S. depressus* Reeside sometimes is associated with *S. vermiformis,* but *S. depressus* has not been reported from the upper beds of the *S. vermiformis* zone. The mixed fauna may be expected in the lower part of the Dowling member.

The top of the Dowling member is apparently also the approximate top of the *S. vermiformis* zone for the fossils above are diagnostic of the *S. montanensis* zone.

The Dowling member, containing the upper part of the *S. depressus* zone and the *S. vermiformis* zone, is dated as early Santonian.

Table XVI

Fauna of Dowling Member

Fauna	GSC Location[3]															
	25074	27035	27039	27040	27056	27090	27095	27104	27110	27113	27116	28082	28087	28175	28186	28207
Baculites asper Morton	?	–	–	–	–	c[1]	–	–	–	–	–	–	–	–	–	–
Baculites ovatus Say	–	–	–	–	–	–	x[2]	–	–	c	–	–	–	–	–	–
Scaphites depressus Reeside s. stricto	–	–	–	–	–	–	–	x	–	c	c	c	–	c	–	–
Scaphites depressus Reeside var. *S. stantoni* Reeside	–	–	–	–	–	–	–	x	–	–	c	c	–	c	–	–
Scaphites ex gr. *S. depressus* Reeside	–	x	–	–	–	–	–	–	–	–	–	–	?	–	–	–
Scaphites (*Clioscaphites*) *platygastratus* Cobban	–	–	–	–	–	c	c	–	–	–	–	–	–	–	x	–
Scaphites saxitonianus McLearn	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–
Scaphites (*Clioscaphites*) *vermiformis* Meek and Hayden var. *S. toolensis* Cobban	–	–	–	–	c	x	–	–	–	–	–	–	–	–	–	–
Scaphites ex gr. *S. ventricosus* Meek and Hayden s. lato	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–	x
Scaphites sp. indet.	x	–	–	–	–	–	x	–	x	–	–	–	–	–	–	–
Inoceramus cardissoides Goldfuss	–	–	–	–	–	c	c	–	–	–	–	–	–	–	–	–
Inoceramus cordiformis Sowerby s. lato	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Inoceramus cordiformis Sowerby var. *I. haenleini* Müller	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–
Inoceramus lobatus Goldfuss	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–
Inoceramus coulthardi McLearn	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–
Inoceramus sp. indet.	–	x	–	–	–	x	–	x	–	–	–	–	–	–	–	–
Ostrea sp. indet.	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
Fish scales	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
Gastropod, genus and species indet.	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

Thistle Member

The thick sequence of platy calcareous shales, known previously as the Platy shale zone (Webb and Hertlein, 1934), is named the Thistle member after Thistle Creek where it is typically developed. This member is composed of the beds between the upper and lower concretionary beds of the Wapiabi formation. The lower contact, drawn at the base of calcareous shales and above concretions in the lower part of the formation, is conformable. The upper contact is drawn at the top of calcareous shales and below concretions in the upper part of the formation, and at the top of platy shale and/or siltstone. The banded appearance of the shales and siltstones at the top of the Thistle member is useful in determining the upper limit. In a few sections along the western side of the Foothills, such as those on Thistle Creek, precise determination is rather difficult because concretions occur in the platy shales. In these sections, the boundary is drawn at the top of the uppermost cycle of interbedded shale and platy to flaggy siltstone which contrast with the rubbly to blocky shale and mudstone of the overlying member (Fig. 10).

The Thistle member, the thickest and most easily recognized member of the Wapiabi formation, is found from the Muskeg River in the extreme north to Dungarvan Creek near Waterton in the extreme south. It probably extends well beyond the boundaries of the present study.

An apparent thinning southward and eastward may be noted from the isopach map (Fig. 17e) based on rather limited data. A maximum thickness of 778 feet was measured on Thistle Creek (section 5-25); the type section is 734 feet thick. A minimum thickness of 384 feet was found on Highwood River (section 6-46). In the north, the only measurement obtained was 650′± on Little Berland River (section 5-19) where the lower contact of the member is not exposed.

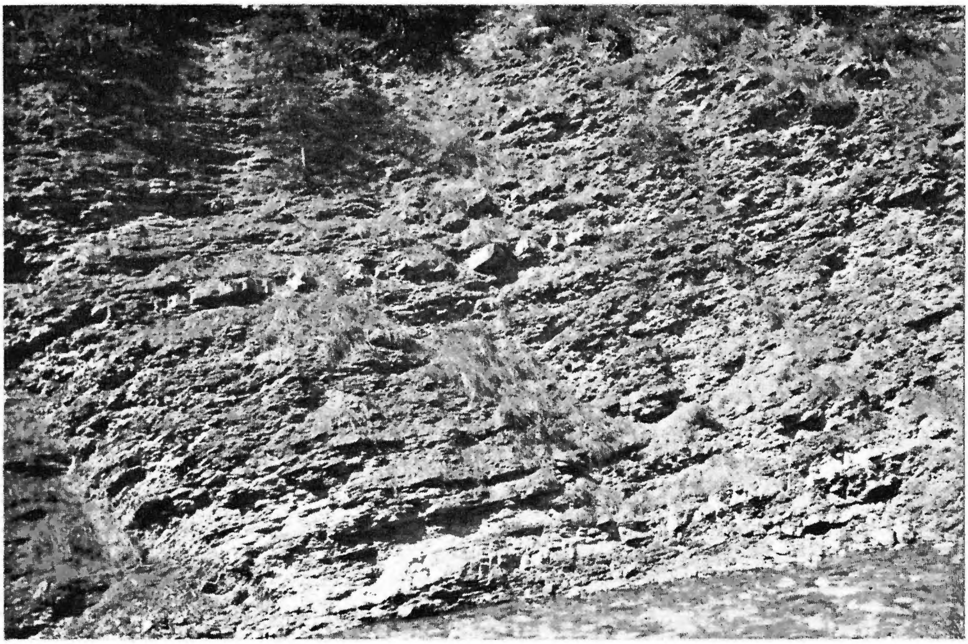
In contrast to other members of the Wapiabi formation, the Thistle contains almost no sideritic concretions, which in itself is a distinctive feature. In many sections, large (2 by 4 feet or more) lens-like bodies are composed of argillaceous, dolomitic limestone which weathers greyish yellow.

The shales of the Thistle member are fissile to platy, and the two types may be interbedded to give a banded appearance to the exposures. The shales are dark grey to almost black and weather grey or slightly rust. These calcareous shales, although much like those of the Vimy member, are not as fissile and appear to be siltier. They have neither such fine laminations nor the typical silver-grey weathered surface. The similarity between the Vimy and Thistle members is emphasized by the presence of dense argillaceous limestones. These, however, tend to be less massive and less persistent in the Thistle member.

In the western sections, particularly on Bighorn River and Thistle Creek (Pl. XXX), two cycles contain 40 to 50 feet of sandstone in one-to-two-inch beds and interbedded shales. Sandstone near the centre of the member is so persistent that it could be used to distinguish two major divisions of the Thistle member. The western sections contain much more sand and silt than the eastern ones.

Only the upper 283 feet of the member are exposed on Little Berland River. This outcrop consists mainly of platy to rubbly shale with little siltstone or sandstone. Laminated siltstone does occur near the base of the exposure but the section is predominantly a shale facies.

As previously noted, the sections west of the Bighorn and Nikanassin Ranges contain a sandy siltstone facies, but the eastern sections on Blackstone River, Wapiabi and Chungo Creeks contain more shale. The section on Cripple Creek, farther south, contains considerable siltstone as does the section on Burnt Timber Creek. The section on Highwood River appears to be largely shale with siltstone only a minor constituent.



D.F.S., 4-2-55

Plate XXX. *Beds of fine-grained sandstone in Thistle member of Wapiabi formation, headwaters of Thistle Creek, section 5–25.*

Six cycles (Fig. 10) have been recognized in the Thistle member from the Little Berland section to Highwood River. The lowest cycle contains several subcycles which can be correlated between two or three sections. The second cycle has sandstone at the top in sections between Burnt Timber and Thistle Creeks. The third cycle is the most prominent, and has a well-developed sand facies at the top in the area west of the Bighorn Range, and in that region, the whole cycle is very sandy. The upper three cycles are much smaller than the lower ones, but are sufficiently well defined to be traced easily.

Age and Fauna

The present study indicates that at least three faunal groups occur in the Thistle member (*see* Table XVII for faunal list). The lower two may be correlated with the zones of the Western Interior, but the upper one is not well dated.

The only collection of *Scaphites vermiformis* Meek and Hayden within the Thistle member was from Ghost River where a specimen was found just above the top of the Dowling member. As *S. vermiformis* was found near the top of the Dowling member in other areas, this occurrence does not seem to extend its range to any marked degree but does indicate that *S. vermiformis* may be found within the basal beds of the Thistle member. The present collections show no overlap of the zones of *S. vermiformis* and *S. montanensis*.

Table XVII

Fauna of Thistle Member

Fauna	GSC Location[3]																												
	24783	24788	25099	25103	25102	27037	27042	27060	27061	27062	27063	27068	27078	27079	27091	27092	27098	27099	27101	27102	27105	27108	27111	28069	28084	28194	28209	32860	32865
Baculites ovatus Say var. *B. haresi* Reeside	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–
Baculites ovatus Say s. lato.	–	–	–	–	–	–	–	–	–	–	x^2	c^1	–	–	x	x	x	–	–	–	–	x	–	c	–	–	–	x	x
Baculites sp. indet.	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scaphites (*Clioscaphites*) *montanensis* Cobban	–	c	–	–	–	c	–	–	–	c	–	–	–	–	–	x	–	x	–	–	c	–	c	c	–	?	–	x	–
Scaphites (*Clioscaphites*) *vermiformis* Meek and Hayden	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–
Scaphites ex gr. *S. ventricosus* Meek and Hayden s. lato.	–	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	x
Scaphites sp. indet.	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Anomia sp. indet.	–	?	–	–	–	–	–	–	–	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Anomia subquadrata Stanton	–	–	c	–	–	–	c	–	–	–	c	–	–	–	–	–	–	–	c	c	–	–	c	–	–	–	–	x	c
Inoceramus lobatus Goldfuss	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–
Inoceramus stenstrupi de Loriol	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus cardissoides Goldfuss	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus balticus Böhm.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–
Inoceramus sp. indet.	x	?	x	x	x	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pteria nebrascana Evans and Shumard	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	x	–
Pteria sp. indet.	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ostrea sp. indet.	–	–	x	–	–	–	–	–	–	–	x	x	?	x	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
Gastropod, genus and species indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Shark teeth	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ostrea congesta Conrad	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x
Cardium sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x

[1]c = comparable form [2]x = specific form [3]Locality of each collection is given in Appendix II

The *S. montanensis* Cobban fauna appears to be within the lower part of the Thistle member. Nevertheless, on Sheep Creek, a comparable form was found about 75 feet below the top of the member, considerably higher stratigraphically than any other specimens of the species. The general absence of *S. montanensis* Cobban in the upper part of the member is notable, and may indicate that other standard zones are present in the Thistle member[1]. The *S. montanensis* zone is considered by Jeletzky to be middle to early late Santonian in age. The upper part of the Thistle member contains forms comparable with *Baculites ovatus* Say var. *B. haresi* Reeside, *Inoceramus lobatus* Goldfuss, and *I. cardissoides* Goldfuss. The major range of this fauna in the Western Interior of the United States is from middle Santonian to early Campanian, and as these come from the lower range of their occurrence, a late Santonian age is tentatively suggested for the upper beds of the Thistle member.

Hanson Member

The concretionary shale that lies above the platy shales of the Thistle member and below massive siltstone or sandstone is included in the Hanson member. Hanson Creek, from which the name is taken, is located north of Brazeau River, and is one of the creeks flowing through the folded fault zone. The type section is in the Wapiabi type section on Thistle Creek.

The lower boundary of the member is drawn at the base of rubbly or blocky shales containing reddish brown weathering concretions; there is no indication of a hiatus, and the contact is conformable. The upper boundary is drawn at the base of massive siltstone and does not lie at the same stratigraphic horizon in all sections. From Sheep River southward on the west side of the Foothills, it is drawn at the base of massive, coarse- to medium-grained, greenish grey sandstone. In these sections, interbedded sandstone and shale and siltstone are included in the Hanson member.

The Hanson member can be traced southward from Muskeg River to Highwood River. It is readily recognized beneath the overlying sandstone member. Only a small thickness of these concretionary shales is present on Highwood and Sheep Rivers, and none occurs on Oldman River due to a facies change to sandstone (Figs. 10, 11).

The Hanson member thins from west to east (Figs. 12, 13) although its stratigraphic interval increases as the siltstone of the overlying member changes to shale. The member ranges in thickness from 232 feet on Thistle Creek (section 4-20) to 135 feet on Blackstone River (section 5-27). The isopach map (Fig. 17f) includes the whole interval between the Thistle member and the top of the Chungo sandstone, and therefore does not show the trends of the concretionary shale.

The shales of the Hanson member are very similar to those of the other Wapiabi concretionary shales and to the Opabin member of the Blackstone for-

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[1]This conclusion is confirmed by a later reappraisal by Jeletzky of GSC loc. 32860 which, he now states, contains the zonal index, *Desmoscaphites* cf. *erdmanni* Cobban.

mation. In general, they are somewhat blocky to rubbly, and are not as platy as those in some of the other members. They are commonly dark grey, although brownish grey in a few sections, and rusty where weathered. Concretions occur throughout the member, and generally are larger than those lower in the formation.

In the more southerly sections, such as on Burnt Timber Creek, the Hanson member contains some beds of siltstone which are very similar to those found in the overlying Chungo member. However, 20 to 30 feet of shale mark the top of the Hanson member. The siltstone is argillaceous, dark grey, and has a bedded appearance.

Six cycles occur in the interval between the Thistle member and the Nomad member at the top of the formation. The cycles have been traced over much of the region (Figs. 10, 11) but become less prominent as they are traced from west to east (Figs. 12, 13). The lower two cycles are predominantly shale except in the south where they contain sandstone. The upper cycles contain much more sandstone and in most sections are included in the Chungo member.

The faunas of the Hanson member are listed in Table XVIII. Age relationships are discussed with those of the Chungo member.

Table XVIII

Fauna of Hanson Member

Fauna	GSC Location[3]													
	27114	27480	28072	28078	28079	28091	28178	28189	28196	28199	28215	32876	32884	32885
Baculites ovatus Say var. *B. haresi* Reeside	–	–	c[1]	–	c	x[2]	c	c	c	x	x	–	–	x
Baculites ovatus Say	x	c	–	x	–	–	–	–	–	–	–	–	–	x
Placenticeras planum Hyatt	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Scaphites (*Clioscaphites*) sp. indet. (? *S. choteauensis* Cobban)	–	–	–	–	–	–	–	–	–	x	–	–	–	–
Scaphites sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cardium pauperculum Meek	–	c	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus lingus Goldfuss	–	–	–	–	–	–	–	–	–	–	x	–	–	–
Anomia subquadrata Stanton	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Ostrea sp.	–	–	–	–	–	–	–	–	–	–	–	x	x	–
Lingula sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	x

[1]c = comparable form

[2]x = specific form

[3]Locality of each collection is given in Appendix II

Chungo Member

The Chungo member of the Wapiabi formation is defined as those beds of siltstone and sandstone in the upper part of the formation which lie between a persistent conglomerate zone above and the concretionary shales of the Hanson member or, in the absence of Hanson beds, the calcareous shales of the Thistle member. In a few sections, nonmarine beds are present in the uppermost part of the member. The lower boundary is arbitrarily drawn at the base of the lowest massive siltstone. In southern Alberta the member loses its typical marine character, and contains coarse-grained carbonaceous, greenish grey sandstone. Inasmuch as this sandstone is typical of the Belly River formation, the Chungo equivalent in southern Alberta is included with that formation.

The name Chungo is taken from Chungo Creek, which is about 25 miles northwest of Nordegg. The type section is chosen on the west flank of a syncline on Thistle Creek in sec. 13, tp. 44, rge. 20, W5. Similar sections are well exposed both upstream and downstream.

Several different names have been applied to this sandstone because it is a distinctive and useful mapping unit. In 1946, Lang, in a report on the Brûlé map-area near the Athabasca River, stated:

> The Wapiabi is overlain by 95 feet of fairly hard, cliff-forming, grey, buff-weathering sandstone, which because of its distinctive, horizon-marking character is mapped as a separate member and called the Solomon sandstone. The lower half is thin-bedded and slabby and the upper half is massive. It contains Upper Cretaceous marine fossils. Analogous beds have been described at several localities to the south and variously called the 'Chungo member', 'Transitional member', 'Brazeau-Pierre', and 'Highwood sandstone', and have been classed by some writers as uppermost Wapiabi. The Solomon sandstone is here regarded as the base of the Brazeau, to which it bears more resemblance than to the underlying Wapiabi strata.
>
> The Solomon sandstone is overlain by 120 feet of softer dark green sandstone and sandy shale containing plant fragments.

The name Solomon is discarded because it has been pre-empted several times[1].

Although this sandstone member may be equivalent to the Chinook sandstone of Gleddie (1949), that name is not used because the correlation has not been established in the present study[2]. Furthermore, Gleddie did not publish a description of the type section, and precise stratigraphic relations of the Chinook sandstone are not known. Sanderson (1939), in a report on the geology of the Brazeau area defined as the Brazeau-Pierre formation those beds above the fissile platy shales of the Upper Colorado (Wapiabi) formation and below the Saunders, or what is now called the Brazeau formation, in the central Foothills. A type section on Chungo Creek was measured and described. This formation has not been accepted by later workers and is now abandoned. Webb and Hertlein (1934) did not recognize the upper siltstone member of the Wapiabi formation as a separate unit although they did describe the conglomerate at the top. Scott (1951) called this member the Siltstone zone, and Hake, *et al.* (1942), the Blocky zone. Lang, in his discussion, would seem to suggest that the name Chungo had been established but no record of its publication has been found. As it was ap-

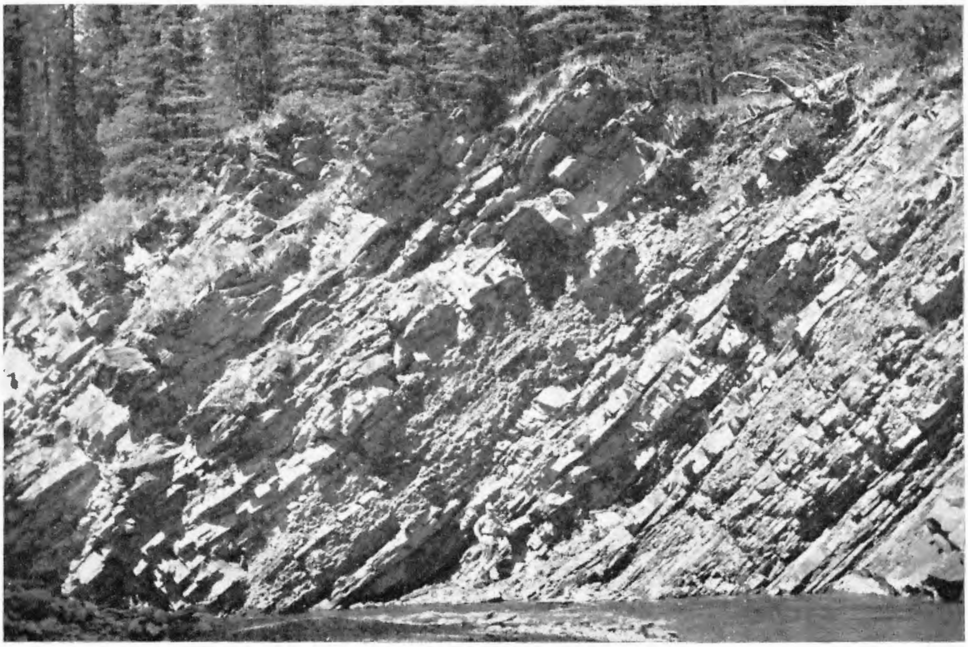
[1]Solomon has been used to designate gypsum in the Permian Summer group (G. P. Grimsley, 1899, Univ. Geol. Surv. Kans., vol. 5, pp. 58-61); for a formation in Alaska (P. S. Smith, 1910, U.S.G.S. Bull. 433, pp. 50-53); for a member of the Eocene Sequin formation of Texas (F. B. Plummer, 1933, Univ. Tex. Bull. 3232, pp. 530, 575-577).

[2]Later work indicates that the Chinook sandstone is equivalent at least to the lower part of the Chungo member. However, the type Chungo member may include younger beds.

D.F.S., 3-6-55

Plate XXXI. *Thickly bedded sandstone of Chungo member, Wapiabi formation, headwaters of Thistle Creek section 5–25.*

Plate XXXII. *Thinly bedded and argillaceous sandstone of Chungo member, Wapiabi formation, Blackstone River, section 5–28.*



D.F.S., 4-5-55

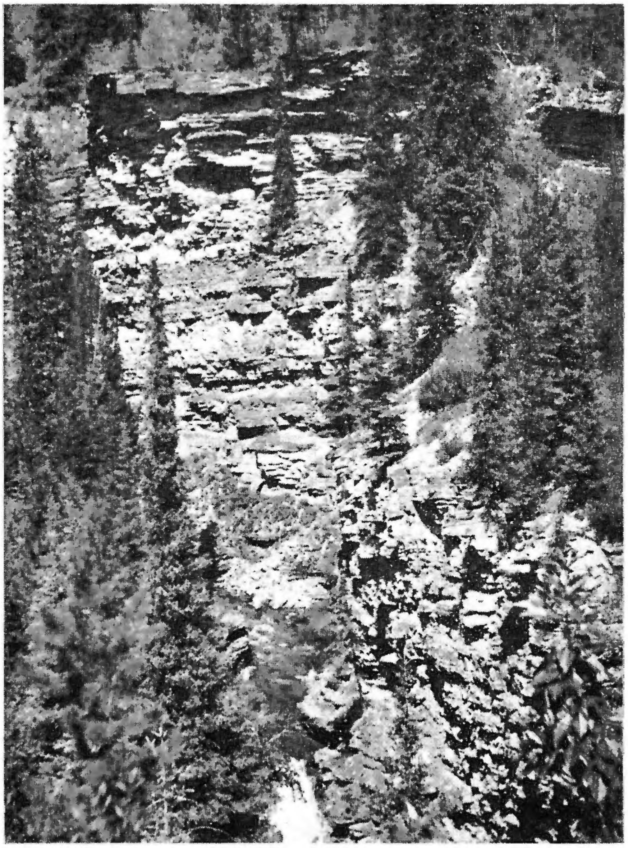


Plate XXXII

Chungo member, Wapiabi formation, Oldfort Creek near Bow River, section 6–25.

D.F.S., 5-6-56

Plate XXXIV. *Chungo member, Wapiabi formation, South Ram River, west of forestry road, section 5–44. Top of member is not visible.*

D.F.S., 8-6-55

parently applied to the upper sandstone or siltstone of the Wapiabi formation, its use at this time is not inconsistent.

The lower boundary of the Chungo member is gradational into the Hanson member, and does not lie at the same stratigraphic position in all sections. The upper contact of the Chungo member with the Nomad member is distinct and well defined where the sand facies of the Chungo member is present. In the eastern sections, the break between the members is not so distinct although the pebble bed is generally present. Although relationships are probably disconformable in the western sections, the absence of erosional features indicates that any hiatus was not prolonged. Farther east, deposition was probably almost continuous, but faunal evidence is lacking for age determinations of beds on either side of the contact.

Northward the Chungo member extends from the type section on Thistle Creek across Athabasca River to Muskeg River. It has been recognized east of the Bighorn and Nikanassin Ranges and southward to Oldman River (Fig. 10).

The member is 261 feet thick in the type section and 276 feet in the section to the west (5-25). On Mackenzie Creek (section 4-42) 288 feet were measured, but this may include beds repeated by faults. The minimum thickness of 135 feet was measured on Chungo Creek (section 4-8), and a maximum of 416 feet on Oldman River (section 7-6). In the north on Little Berland River (section 5-19), a thickness of 205 feet was measured; in the south on Oldfort Creek, the thickness is 171 feet. On the eastern side of the Foothills, the thickness is between 135 feet and 175 feet, but as the member grades into shale, its distinctive features disappear and it is no longer recognizable.

The isopach map (Fig. 17f) has been drawn to include both the Hanson and Chungo members. The map shows that the interval thickens westward, and also that it becomes thinner towards the southeast along the regional strike of the Foothills.

The Chungo member contains three sedimentary facies. In the western sections of the north half of the area, sandstone predominates. Siltstone is the dominant lithology in eastern sections and from North Saskatchewan River to Bow River. Greyish green shales with some thin coal beds occur near the top of the member in the area west of the Bighorn Range and in the Highwood area.

The Chungo sandstone is very fine grained and in many places is almost siltstone. It is classified as a quartz wacke. The sandstone is grey to brownish grey, weathers dull buff to brown, and contains carbonate fragments as well as calcareous cement. It does not have the rusty tan colour nor the 'welded' texture of the Ram sandstone. Glauconite occurs in the sandstone but is more abundant in the silty facies. The sand is flaggy to platy although some beds are 4 to 6 inches thick (Pls. XXXI, XXXII). The bedding is characteristic because it contrasts with the more massive beds of the Cardium formation. The fractures within the beds are frequently curved.

The upper part of the Chungo member consists of a sandstone facies from Muskeg River to Bighorn River. Eastward across the Foothills, the sandstone grades laterally into massive siltstone and then into bedded and shaly siltstone. This lateral variation is well illustrated in the Thistle Creek and Brazeau River sections (Fig. 12), and also in the George Creek, Blackstone River, and Chungo Creek sections (Fig. 13).

Southward from Bighorn River, on Cripple Creek and South Ram River (Pl. XXXIV), the member is mainly an argillaceous siltstone although a few sandstone beds are present. The member on Burnt Timber Creek and Ghost River is even more shaly, and the upper limit would be difficult to determine without the pebble bed. As the western edge of the Foothills is approached between Ghost River and Bow River, the member increases in sand content and assumes the thickly bedded character (Pl. XXXIII) that is typical farther north.

Southward from Bow River, the beds equivalent to the Hanson and Chungo members undergo a marked change. The Chungo sand becomes much coarser, changes from the typical brown of the north to the greyish green of the typical Belly River sediments, and loses its typical marine character. The beds equivalent to the Hanson member are sandier than those farther north, and are included in the Chungo member. Thus, the Chungo member increases in thickness southward as the Hanson member decreases in thickness and disappears. Accordingly, the whole interval between the top of the Thistle member and the base of the Nomad member is included in the Chungo member.

Southward, another major facies change occurs within the Chungo member. The uppermost sandstones grade into carbonaceous, greyish green shale with associated carbonaceous sandstones and thin coal beds. This development of beds considered to be nonmarine in the Chungo member is similar to that found in the upper part of the member in the region around the type section.

The interval on Highwood River near Longview (sec. 30, tp. 18, rge. 2, W5), which has been called the Highwood sandstone (Webb and Hertlein, 1934, p. 1402), is about 150 feet thick. The upper 60 feet is sandstone (Pl. XXXV) and the lower part is siltstone with some sandstone and shale. The sandstone is fine grained, laminated, weathers brown, and resembles the typical Chungo sand. The upper surface of the unit has scattered pebbles above it and embedded in it. Both the overlying and underlying beds are partly covered. The overlying beds appear to be faulted, and precise stratigraphic relationships are difficult to determine. Farther west (sec. 18, tp. 18, rge. 3, W5), the Thistle member is overlain by 75 feet of shale with concretions near the base and thin sandstone beds towards the top. This shale is overlain by about 85 feet of interbedded sandstone and shale, succeeded by 150 feet of medium-grained, greenish grey sandstone. This massive sandstone is capped by a layer of conglomerate overlain by about 100 feet of sandstone. The top of this upper sandstone correlates with the top of the Chungo member (Fig. 11) and the sandstone below the conglomerate with the Highwood sandstone (Fig. 14a). Therefore, the Highwood sandstone lies within the Chungo member, and in the more westerly sections forms part of a continuous sandstone succession. As the Chungo member is traced eastward, a tongue of shale appears in the middle separating the member into the Highwood sandstone and an upper sandstone. Stratigraphic relationships are more easily established on Sheep River where a western section (6-35) and an eastern section (7-3) are fairly well exposed (Fig. 14b).

West of the Bighorn and Nikanassin Ranges, nonmarine beds lie at the top of the Chungo member below the basal pebble-conglomerate of the Nomad member. On George Creek, very silty calcareous sandstone lies on coaly shales and carbonaceous shales. The nonmarine interval in the type section on Thistle Creek is only 8 feet thick and contains two beds of medium-grained sandstone and two beds of coaly shale. In the western section (5-25), the interval contains dark, rubbly shale underlain by 12 feet of thinly bedded sandstone with coaly streaks and fragments. In the most easterly section on Thistle Creek (4-20), the interval above the massive sandstone consists of 3 feet of shale and sandstone overlain by 5 feet of fine- to coarse-grained sandstone. The upper beds of sandstone have been irregularly eroded and a bed of conglomerate, ranging from a thin layer to as much as 4 feet, fills the uneven surface.

On Sheep River (section 6-35), a similar occurrence of nonmarine sediments is found at the top of the Chungo member. In this section, 25 feet of greyish green, rubbly shale and carbonaceous sandstone lies above thickly bedded sandstone and below a pebble bed. Farther east, the uppermost beds of the member are sandstone.

D.F.S., 7-4-55

Plate XXXV. *Highwood sandstone, Highwood River, section 6–44. Beds on right are part of Hanson member of Wapiabi formation.*

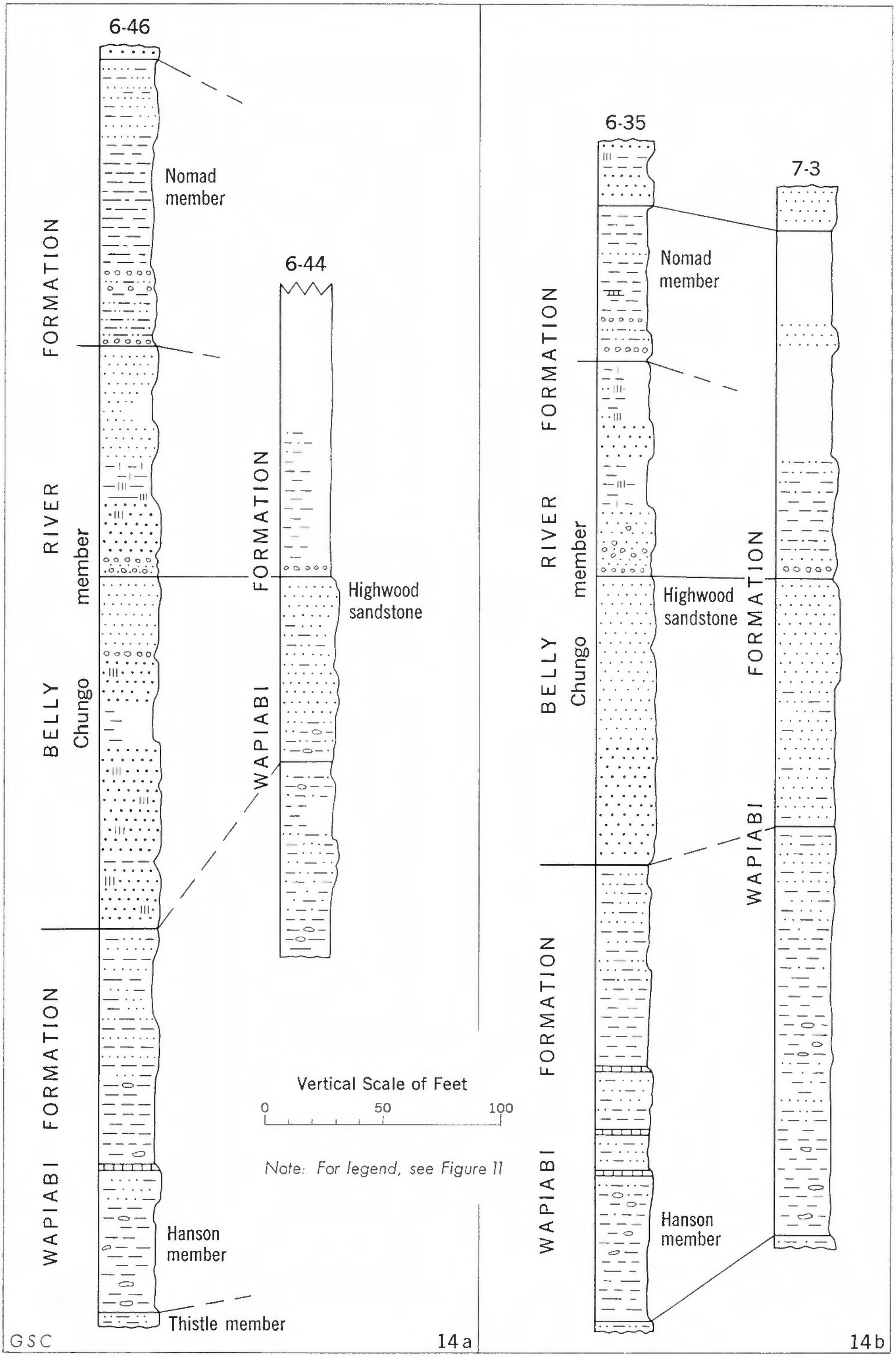


Figure 14. *Correlation of Highwood sandstone and Chungo member on (a) Highwood River; (b) Sheep River.*

A unique section of the Chungo member was found on a ridge south of the headwaters of Wapiabi Creek. The precise relationships are somewhat uncertain because the overlying and underlying beds are not exposed. Forty-eight feet of conglomerate overlies about 130 feet of fine-grained sandstone and shale having the typical characteristics of the Chungo member. The conglomerate consists of one-quarter to one inch chert pebbles, most of which are disk- or roller-shaped. Three feet of very fine, grey sand is found near the top. The upper 8 feet consists of chert pebbles in a matrix of fine, Chungo-like sand. It is possible that this conglomerate is related to the overlying beds, but thin conglomerates in the Chungo sandstone a few miles to the south suggest that it is part of the Chungo member.

Age and Fauna

The fossils of the Hanson and Chungo members are discussed together because no zonal distinction has been made between the two.

The most diagnostic fossil found in these beds is *Baculites ovatus* Say var. *B. haresi* Reeside (*see* Tables XVIII to XX for faunal list), which Cobban and Reeside (1952b) state has its lowermost range in the zone of *Desmoscaphites bassleri* Reeside and its upper ranges in the zones of *Scaphites hippocrepis* (DeKay) and *Baculites asperiformis* Meek. In reference to the collections containing *B. haresi,* Jeletzky stated:

> It would appear probable that the above lots represent the American zones of (1) *Scaphites* (*Clioscaphites*) *choteauensis* Cobban, (2) *Scaphites* (*Desmoscaphites*) *erdmanni* Cobban, and (3) *Scaphites* (*Desmoscaphites*) *bassleri* Reeside rather than correspond to this latter (3) zone alone. This is suggested by the apparently immediate superposition of some of them on the Platy Shale Zone (Thistle member, characterized by *S. montanensis*), by the presence of *Scaphites* resembling *S.* (*C*) *choteauensis* in one of the lots, and by the presence of *Placenticeras* cf. *planum* Hyatt in another lot. The rare records of *Desmoscaphites* in the upper Wapiabi should correspond with the zone of *B. ovatus* var. *haresi* Reeside.

Although there is no known occurrence of *S. hippocrepis* in the upper part of the Wapiabi formation, the correlation of the Chungo member with the Milk River sand, and therefore with the Eagle sand, suggests that this fossil which is typical of the Eagle fauna should be present in the Canadian section. Although Jeletzky considers the Chungo to be more closely related in age to the Telegraph Creek formation because of the lack of *S. hippocrepis,* he does state:

> On the other hand, it is equally impossible to deny the possibility of the uppermost beds of the Wapiabi formation being already of the *Scaphites hippocrepis* time, at least locally. It has already been pointed out that *Baculites ovatus* var. *haresi* Reeside, as well as *Placenticeras planum* Hyatt, do range into the *Scaphites hippocrepis* zone; they are, furthermore, more common there than in the underlying beds.

Other less diagnostic fossils of these members are forms similar to *Inoceramus lobatus* Goldfuss (= *I. lundbreckensis* McLearn), *Liopista undata* Meek and Hayden, *Pteria nebrascana* Evans and Shumard, and *Tancredia americana*

Table XIX

Fauna of Chungo Member

Fauna	GSC Location[3]																											
	24782	24785	24787	24797	24798	24799	24803	25069	25070	25071	25080	25083	25084	25085	25095	25096	27080	27086	28054	28075	28085	28168	28189	28191	28196	28210	28218	32868
Baculites ovatus s. lato	–	–	–	–	–	x[2]	c[1]	–	–	c	–	c	–	–	–	x	–	x	–	–	–	x	–	x	–	–	–	x
Baculites ovatus Say (large variety)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	x	–	–
Baculites ovatus Say var. *B. haresi* Reeside	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	c	x	x	–	c	x	x	–
Arctica sp. indet.	–	–	–	–	–	–	–	–	–	–	?	?	–	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–
Cardium sp. indet.	x	–	–	–	–	–	–	–	?	–	–	–	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–
Inoceramus lobatus Goldfuss var. *I. stenstrupi* de Loriol	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leptosolen sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lingula sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	x
Liopista undata Meek and Hayden	–	–	–	–	–	–	–	–	–	c	–	x	–	c	–	–	–	–	–	–	–	–	–	–	–	–	c	c
Lucina sp. indet.	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lunatia ex gr. *L. occidentalis* Meek and Hayden	–	–	–	–	–	–	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–
Modiolus sp. indet.	–	–	–	–	–	–	–	–	–	–	–	x	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Nucula sp. indet.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–
Ostrea sp. indet.	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pteria (*Oxytoma*) *nebrascana* Evans and Shumard	–	–	–	x	–	–	–	–	–	–	–	–	–	c	–	–	x	–	–	–	–	–	–	–	–	–	x	–
Tancredia americana Meek and Hayden	c	c	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tancredia sp. indet.	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tellina sp. indet.	–	–	–	–	–	–	–	–	–	–	–	?	?	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

Meek and Hayden. Jeletzky reports that the range of *I. lundbreckensis* McLearn is Santonian to early Campanian. The lowest range of *Liopista undata* Meek and Hayden is suggested by Cobban and Reeside (1952b) to be in the zone of *D. bassleri* Reeside.

As the discussion of the age and correlation of the Chungo and 'Highwood' sandstones involves reference to the Milk River formation, an outline is given of the general correlation of the upper members of the Wapiabi formation and possible equivalents in southern Alberta.

Although Hume (1930) specifically introduced the name 'Alberta shales' to replace the names Colorado and Benton because the upper part of the sequence was of Montana age, the name has been used in the subsurface for beds generally considered to be no younger than Colorado. Wickenden (1932) placed the upper contact of the 'Alberta shale' at the top of the First White Specks zone, and his example was followed by Russell (1946). Tovell (1956), in a detailed subsurface account of the Milk River and Pakowki formations of southern Alberta, emphasized that the Alberta formation of the Plains did not extend higher than the White Specks zone by defining the base of the Milk River formation at the top of the zone. Gries (1954, p. 450) indicated that the upper speckled shale is equivalent to the Niobrara formation at the top of the Colorado group. Therefore, the recent subsurface work places the Milk River formation immediately above the shales of Colorado age.

The 'First White Specks' zone is correlated with the Thistle member of the Wapiabi formation. Correlation of the Wapiabi section on Ghost River with sections in Jumpingpound field indicates that the stratigraphic position of the two units is equivalent. Although the White Specks zone has not been recognized in the exposed sections of the Foothills, this conclusion seems to be generally accepted. Gleddie (1954) indicated that the White Specks shale lies in the centre of the 'Wapiabi' formation on Smoky River, and this position would be in about the same stratigraphic position as the Thistle member. Harding (1955) stated that the First White Specks zone correlated with the Platy shale (Thistle member) of the Wapiabi formation. Williams (1956) showed on his correlation chart that the 'Solomon' (Chungo) sandstone is equivalent to the Milk River and that the uppermost beds of the Wapiabi formation are equivalent to the Pakowki. Scruggs (1956) correlated the 'Upper Speckled' shale with the middle part of the Wapiabi and showed the Milk River and Eagle as equivalent to the upper part of the Wapiabi. The White Specks zone has been considered equivalent to part of the Wapiabi by Wickenden (1945) and Thompson and Axford (1953).

From these correlations, it is apparent that the Alberta formation as presently used in the Plains is not equivalent to the Alberta group of the Foothills area but that its upper boundary is at the same stratigraphic level as the top of the Thistle member. The equivalents of the Hanson, Chungo, and Nomad members are apparently to be found in the Milk River and Pakowki beds which overlie the subsurface Alberta shales.

Tovell (1956) correlated the Milk River formation with a sand south of the Calgary area which he called the 'Highwood' sand. The correlation was not made to the Highwood sandstone at Turner Valley where Webb and Hertlein (1934, p. 1402) first named it. Tovell stated:

> The Pakowki formation can be traced with less certainty northwestward from the outcrop sections; data at hand suggest that the top of the Highwood sandstone, south of Calgary, is the same stratigraphic horizon as the top of the Milk River formation as it is known throughout most of the area This means that the shales overlying the Highwood sandstone and underlying the Belly River formation should be assigned to the Pakowki formation. Northward and eastward from Calgary and the area of Highwood sandstone development, the Pakowki formation, and the shales above the Highwood sandstone, grade into the upper part of the Lea Park formation. The Pakowki formation thins in a westward direction across the whole area and finally merges into some unknown portion of the Belly River formation.

The writer considers that Tovell is justified in the correlation of the Milk River sandstone with the sandstone approximately 400 to 450 feet above the White Specks zone but this sandstone is not equivalent to *the* Highwood sandstone of Highwood River. Tovell's isopach maps show that the Milk River equivalent should be approximately 400 feet thick in the Highwood area; the writer found less than 250 feet for the Highwood sandstone and the underlying concretionary beds.

The writer now believes, because of further investigations and particularly because of the significance of Tovell's report, that the position of the Highwood sandstone is below the Milk River sandstone and below the top of the Chungo member. The Highwood sandstone represents a lower sandstone tongue in the Wapiabi formation (Figs. 14a, 14b) that is not recognized as a distinct unit in the Foothills farther north. It should be recognized in the subsurface studies although the sand apparently undergoes a facies change to shale.

The Milk River and Chungo sandstones are believed to be equivalent, although definite palæontological evidence is lacking. The Milk River formation has been traced in outcrop into the Virgelle sandstone which lies in the zone of *Scaphites hippocrepis*. This fossil has not been recognized in the Wapiabi formation, but as previously discussed, the uppermost beds of the Wapiabi formation may lie within this zone. The correlation of the Chungo and Milk River sandstones, as suggested by Tovell's correlation of the sands below the Belly River, is logical and probably correct. The stratigraphic sequence above the calcareous shales, referred to as the Thistle member and White Specks zone in the Foothills and Plains respectively, is very similar in lithology and thickness. In both sequences, a transitional zone of concretionary shale extends upwards into fine-grained, evenly bedded, buff or tan weathering, sandstone. In both sequences, nonmarine beds at the top of the sandstone are overlain by a pebble bed. Although, as shown by Spieker (1949, pp. 69-70), such a sequence is not composed of independent variables but is a natural sequence which must be treated as one variable, the similarity of stratigraphic position and thickness cannot be disregarded. The major retreat recorded in each is brought to an end by a major advance of the sea which deposited marine sediments over nonmarine beds. Tovell found the Milk River formation to be between 400 and 450 feet in its thicker sections, and this thickness is approximately the same as that obtained for the combined Hanson and Chungo members in the Foothills. From these lines of evidence, the Chungo member is correlated with the sandstone of the Milk River formation, and the Hanson member, with the underlying concretionary shale.

Nomad Member

Between the coarse-grained sandstone of the Brazeau formation in the north (or the Belly River formation in the south) and the fine-grained sandstone or siltstone of the Chungo member of the Wapiabi formation is an interval of shales and siltstones. These sediments are included in the Wapiabi formation and are named the Nomad member. The name comes from a tributary of Cardinal River in the area to the northeast of the type section of the Wapiabi formation.

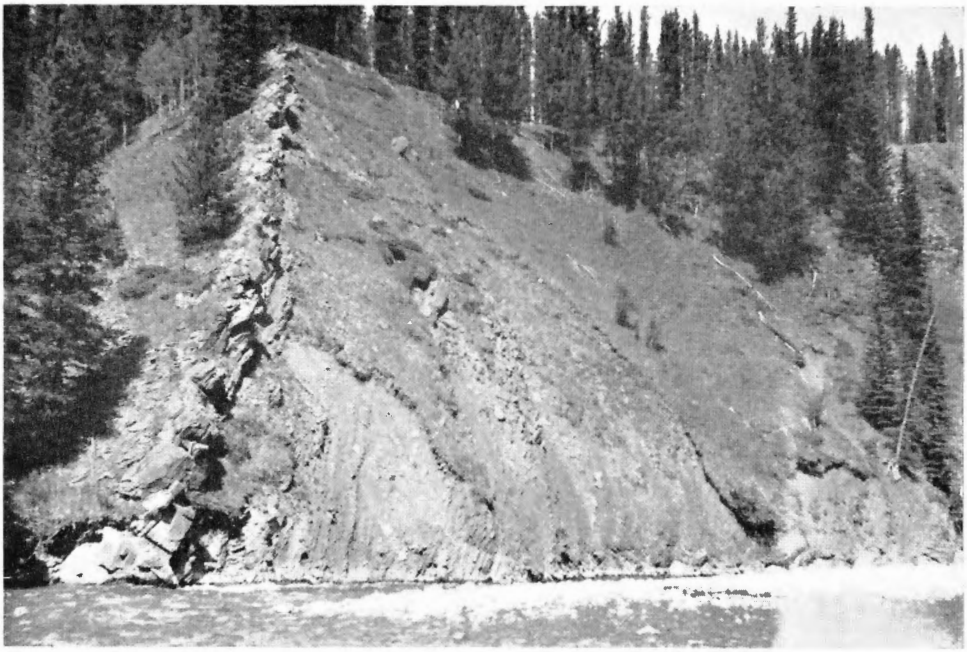
Although in the western sections, the Nomad member could be recognized as a separate mappable unit, in the more easterly sections it becomes increasingly difficult to distinguish from the underlying beds. For this reason, it is included with the Wapiabi formation. Erdmann (1946) apparently used the basal conglomerate as the basal marker of the Brazeau formation, and, as far as is known, was the only one to define the upper limit of the Wapiabi formation in this manner.

The lower contact of the Nomad member on the Chungo member is drawn below a pebble bed. A brief hiatus may have occurred but definite faunal evidence is lacking. The upper boundary is drawn at the base of a bed of coarse-grained sandstone in the Brazeau formation. In many sections, this sandstone has a chert-pebble conglomerate at the base. The upper boundary does not show any indication of erosion and the contact is considered to be conformable. In some exposures, the contact has a gradational appearance caused by the increasing number of fine-grained sandstone beds towards the top of the Nomad member. In a few places, small channel fillings are present but these are local features.

In those sections where the Chungo equivalent is included in the Belly River formation, the Nomad beds are also included in the Belly River formation. This marine member has not been recognized previously in the Belly River formation of the Foothills.

The Nomad is one of the most uniform units of the Alberta group. It varies in thickness from 90 to 130 feet throughout most of the Foothills but increases to as much as 170 feet in a few of the more easterly sections. The increase in thickness to the east is the result of a facies change in the basal beds of the Brazeau formation. The upper contact of the Nomad member lies slightly higher stratigraphically in the east than in the west. The general distribution and variation in thickness is shown in the isopach map (Fig. 17g).

In general, the Nomad member consists of dark grey shales and some siltstone and sandstone. As many of the beds have a greenish hue, they resemble



D.F.S., 8-2-54

Plate XXXVI. *Nomad member, Wapiabi formation, Thistle Creek.*

some of the shales of the Brazeau formation, and with the Chungo member, have been included in the overlying formation by many workers.

The conglomerate at the base of the member is similar to other conglomerates of the Alberta group. It is composed of chert pebbles which vary in size from one-eighth inch to 3 inches in diameter. These pebbles are rounded and fairly smooth. Although they have a black surface, fresh sufaces reveal that their colours range through various shades of green, white, grey, and blue. The pebble-conglomerate bed is rarely more than 4 feet thick, and generally is less than a foot thick. Above the conglomerate the shales are rubbly to platy, weather rusty, and have the typical appearance of the Wapiabi shales but contain few concretions (Plate XXXVI). The shales of the more westerly section may be greenish grey throughout, but in the eastern section greenish grey shales occur only in the upper part of the member.

On Thistle Creek and in neighbouring areas, a bed of argillaceous, aphanitic, dolomitic limestone overlies the pebble bed. The limestone weathers yellowish grey rather than the reddish brown of the concretions.

The thinly bedded sandstones that are included in the Nomad member are most abundant near the top. They are fine grained, laminated, and greenish grey. Beds are from an inch to a foot thick.

In the south half of the area along the eastern edge of the Foothills, the boundary between the Nomad and Chungo members is not as distinct as it is farther north. On Cripple Creek, pebbles and coarse-grained sand are disseminated through sandy siltstone which grades into typical Chungo lithology. In other sections, as on James River, a concretionary bed with scattered pebbles serves as a useful boundary.

The Nomad member is well exposed on Sheep Creek (section 6-35), Highwood River (section 6-46), and Oldman River (section 7-6) in southern Alberta. In these sections, 10 to 15 feet of siltstone lies above the basal pebble-conglomerate, and is gritty to pebbly. Specimens of *Baculites* have been found in the siltstone unit. Overlying the siltstone, a succession of rusty weathering shales is similar to shales in the lower part of the Wapiabi formation. They are overlain by carbonaceous, greyish green shale which contains beds of fine-grained, greyish green sandstone. The sand content increases upward, giving the upper beds a transitional appearance. Massive beds of coarse-grained sandstone lie above the Nomad member.

Age and Fauna

Microfauna obtained from the Nomad member on Highwood River included, according to Wickenden, several specimens of *Verneuilina bearpawensis* Wickenden. Wickenden commented that this diagnostic species occurs in the Pakowki equivalents above the beds correlated with the Milk River sandstones.

The range of the macrofauna (*see* Table XX for faunal list) may be from Santonian to early Campanian age. As this fauna lacks any diagnostic elements of the early Campanian, Jeletzky suggests a late Santonian age. The range of *Nucula* cf. *N. assiniboinensis* Landes is not known but Landes (Russell and Landes, 1940, p. 131) found that it was abundant in the Pakowki formation.

Table XX
Fauna of Nomad Member

Fauna	GSC Location[3]			
	25092	28203	32866	32870
Baculites ovatus Say (large variety)	—	x[2]	—	—
Baculites ovatus Say var. *B. haresi* Reeside	—	x	x	—
Modiolus sp. indet.	?	—	—	—
Mya sp. indet.	?	—	—	?
Nucula assiniboinensis Landes	c[1]	—	—	—
Cardium sp.	—	—	—	x
Trochammina sp.	—	—	—	—
Haplophragmoides sp.	—	—	—	—
Verneuilina bearpawensis Wickenden	—	—	—	—

[1]c = comparable form
[2]x = specific form
[3]Locality of each collection is given in Appendix II

The Nomad member is considered by the author to be equivalent to the Pakowki formation, and therefore to be of Campanian age.

Belly River Formation

The Belly River formation was originally described by Dawson (1884, p. 38c) who included a series of continental beds exposed on Belly River southwest of Lethbridge. Dawson indicated that these beds overlie the 'Lower Dark Shales' which he considered to be of Colorado age, and stated that the formation was overlain by Pierre shale. Stanton and Hatcher (1905) showed, by following continuous outcrop, that the beds on Milk River to which Dawson had applied the term 'Lower Dark Shales' were equivalent to the Claggett shales of central Montana, and therefore were not of Colorado age. Stebinger (1914) traced the Claggett shale, the Eagle and Virgelle sandstones to Milk River, illustrating once again that Dawson had included the equivalent beds at that locality in the Belly River formation. Dowling (1917) defined the beds equivalent to the Claggett shale as the Pakowki formation, and the equivalent of the Virgelle and Eagle sandstones as the Milk River formation. Williams and Dyer (1930) restricted the Belly River formation to beds above the Pakowki shales.

Although the term Belly River was abandoned by Russell and Landes (1940, p. 45) who replaced it with the Oldman and Foremost formations, the term has continued to be used where the sequence cannot be subdivided easily. It is used for those sandstones and shales lying above the dark shales of the Wapiabi formation and includes beds equivalent to the Milk River and Pakowki formations.

The basal contact of the Belly River formation, which is of immediate concern to this report, is gradational. The contact is not at the same stratigraphic position throughout the whole area, although it has a fairly uniform position over large parts of the Foothills. The contact of the Belly River and the Wapiabi formations is drawn above the Nomad member from Clearwater River south beyond Bow River. The contact is drawn at the base of sandstone equivalent to the Chungo member along the western margin of the Foothills from Sheep River southward. In both regions, the contact lies higher stratigraphically as the beds are traced eastward because of a facies change in the massive Belly River sandstones.

The Belly River formation is recognized in the Foothills from the International Boundary (Douglas, 1952) to about Clearwater River (Beach, 1942). North of the Nordegg area, partly equivalent beds have been placed in the Brazeau formation. The basal beds of the Belly River formation in southern Alberta are older than those in the north (Figs. 10, 11).

The Belly River formation is considered to be from 3,000 to 4,200 feet thick in the Oldman River area of southern Alberta (Douglas, 1950, p. 30). McKay (1939) believed that it was about 3,600 feet thick in the Red Deer River area, about the northern boundary of the formation.

A summary discussion of the formation has been given by Williams (1956). The Belly River formation in the vicinity of Oldman River has been described by Douglas (1950a, p. 30):

> Dark grey, thinly bedded, fine-grained, dark brown weathering sandstones mark the base. These strata are about 100 feet thick and are rarely exposed except along the rivers. Very massive, coarse-grained, thickly crossbedded, light grey sandstones interbedded with grey and green, silty shales overlie the transition beds. This zone is about 500 feet thick, but cannot be closely defined, as the upper sandstones are less massive and lose their persistent and ridge-forming characteristics. The remainder of the formation, with the exception of the uppermost 900 feet, consists of interbedded, fine- to medium-grained, crossbedded, grey to green sandstones, and grey and green, silty shales. The uppermost 900 feet of strata contain pale green weathering, green and grey shales; thin-bedded, fine-grained, grey sandstones; rubbly and concretionary argillaceous limestones; and minor carbonaceous shale and coal seams.

The basal 500 feet are considered to be equivalent to the Chungo member (Figs. 3, 10, 11).

PETROGRAPHY

Conglomerates

Conglomerates within the Alberta group have a remarkably similar composition and are restricted in their occurrence. They are commonly found above nonmarine sediments, such as the bed at the base of the Blackstone formation, or above fine-grained sandstone and below shale, as for example the conglomerate that marks the base of the Wapiabi formation and the base of the Nomad member. Beds of conglomerate rarely occur within the Cardium formation, but they have similar stratigraphic relationships in that they generally lie above sandstone and at the base of shale beds.

In composition, the pebbles and grains are predominantly chert but a few consist of quartzite, pegmatitic quartz, and more rarely, of sandstone and mudstone. The chert may be black or white, green, grey or blue. Some pebbles have pyritic centres, resembling the pyritic chert grains of the Sunkay grit.

The degree of roundness of the pebbles was not determined except by visual comparisons which indicate that most are in the rounded class (Pettijohn, 1956, p. 59), and many are well rounded. Sphericities were determined by the axial-ratio method (Krumbein, 1941). Most of the pebbles are in the discoidal class, although many are in the spherical or rod-shaped (roller) class. According to Krumbein's curves of sphericity (op.cit., Fig. 5), most of the pebbles have sphericities between 0.6 and 0.8.

Sandstones

The quartz arenites (Williams, Turner, and Gilbert, 1954, p. 304), of which the Ram sandstones are typical, are made up predominantly of quartz and chert. Rare grains of feldspar and a few rock fragments present seldom exceed 5 per cent. Accessory minerals are not abundant and were infrequently seen in thin section.

The very fine-grained sandstones of the Sturrock and Chungo members, which approach siltstone, contain more matrix. Those rocks containing more than 10 per cent matrix are classified as wackes (Williams, Turner, and Gilbert, 1954), but because of their lack of fragments of feldspar and rocks, they do not resemble the typical greywacke.

The quartz arenite of the Ram member has a 'welded' texture (Williams, *et al.,* 1954, p. 264) formed by the secondary growth of silica on quartz. A line of fine inclusions marks the outline of some of the original grains but in many grains the growth is in crystallographic continuity and is not evident. Adjacent grains form an interlocking aggregate resembling a quartzite. In the Stur-

Table XXI

Composition of Sandstones

Member	No. Samples	Quartz	Chert	Feld-spar	Rock frag-ments	Matrix	Carbonaceous fragments	Carbonate fragments	Carbonate Cement
Brazeau	3	43	25	3	7	15	3	2	1
Chungo	11	64	11		3	18	1	3	
Highwood	1	62	10		3	17			
Marshybank	2	65	7		5	18	2	3	
Sturrock	19	67	10		1	18	2	2	
Cardinal	5	77	10		2	9	2		
Moosehound	15	67	12		2	8	2	4	5
Ram	32	75	12		2	10	1		
Opabin	4	72	10			15	1		
Sunkay	4	43	45		4	4			4
Dunvegan	4	65	13		7	12	2	1	
Mountain Park	1	45	25	3	9	15	3		

rock and Chungo sands the abundant matrix apparently separated the grains from one another and the 'welded' texture is not nearly so evident. This difference in texture is a characteristic feature, and throughout much of the region can be used to differentiate the sands.

Quartz, the major constituent of the sandstone, is predominantly of one type. Most of the grains have no strain shadows, although a few have undulose extinction under crossed nicols. The inclusions, mostly 'dust' and a few small bubbles, are sometimes oriented in linear trends. This type of quartz is probably the normal igneous variety, and similar types having undulose extinction are modified igneous quartz (Krynine, 1940, p. 15). In several thin-sections, where the original grains are outlined by a border of small inclusions, the grains are commonly subrounded to rounded.

Chert grains are the second most abundant constituent of the sandstones. They are subrounded to rounded, but boundaries are often indistinct. The chert has an aggregate texture, and some contains spherulitic patches. Most of the grains do not have relict structures although some grains of carbonate are included. Many of the grains are colourless, but in thin section some are light to dark brown. The Sunkay grit contains brown chert grains which often have centres of pyrite with slightly ragged edges. The shape of these chert grains frequently reflects the shape of the pyrite mass.

Plagioclase feldspar is a minor constituent of the sands of the Alberta group, rarely exceeding 2 per cent. The feldspar grains are subrounded to subangular; most appear to be fresh, but some have been highly altered.

Muscovite, the common mica, occurs as flakes, which gives a sparkling lustre to bedding-plane surfaces of the rocks. Large flakes of mica are not common, although in a few places, small lenses less than an inch thick were composed almost entirely of muscovite.

Rock fragments are a minor constituent of the Alberta sands. These fragments are generally somewhat better rounded than the chert or quartz grains, but are about the same size; identification is often difficult because of their extremely fine texture. Many contain particles oriented along planes and resemble slate or schist. A few volcanic rock fragments occur in the Sunkay 'grit', some of which have trachytic textures whereas others contain small porphyritic or spherulitic inclusions.

Pyrite is commonly abundant as disseminated small euhedral cubes or as small aggregates in the Sturrock and Chungo sands, but is much less abundant in the Ram sand. The pyritic sands also contain the largest amounts of calcareous cement.

Few fragments of fossil shells were found in the arenites; most of the fossils are casts and moulds. Organic matter in the form of carbonaceous fragments and masses of dark material is present in most of the sands.

Glauconite[1] is abundant near the base of the Chungo member, with some grains occurring higher in the member. It is not generally noticeable in the more massive sandstone, but in the beds where it is abundant, its greenish colour is distinctive on the bedding planes. Glauconite is also present in sandy facies of other members.

The size distribution of Alberta sandstones is given in Table XXII. Some variation in grain size does occur within the group, but most of the sands are fine grained. Compared to the Ram member, the Moosehound sands are somewhat coarser and not so well sorted, whereas the Chungo and Sturrock sands are finer. All the sands are fairly well sorted, with the greatest proportion of the distribution falling within one Wentworth grade size. The overlying Brazeau and underlying Mountain Park sands appear to be much coarser than the Alberta sands, although the number of samples of these coarser types does not give a reliable comparison. Similarly, samples of the Sunkay 'grit' may not be sufficient for true comparison, but they do indicate considerable differences in size and sorting.

The average size and the degree of sorting vary considerably within individual members and also within the group as a whole. None of the sands forms a distinct group but all overlap in their size and sorting characters. The size and sorting indices are somewhat misleading because the matrix material was not included. Judging from the compositional study, the Chungo and Sturrock sands should have smaller means, and should have more skewness towards the fine sizes.

[1]Glauconite, as used here, refers to green pellets rather than to the definite mineral as determined by X-ray analysis.

Table XXII

Size Analysis of Sandstones

	No. Rocks	Phi Median Dia. ϕ_{50}	mm	ϕ_{84}	ϕ_{16}	Phi Deviation $\sigma\phi$	Phi Mean Dia. $M\phi$	$M\phi - Md\phi$	Phi Skewness
Brazeau	3	2.41	.19	2.91	1.88	.51	2.39	−.02	−.04
"Highwood"	1	3.40	.09	3.88	3.02	.43	3.45	.05	.11
Chungo	14	3.57	.08	4.07	3.14	.45	3.61	.04	.09
Marshybank	2	3.74	.07	4.27	3.34	.46	3.81	.07	.25
Sturrock	19	3.84	.07	4.37	3.42	.47	3.89	.05	.10
Cardinal	6	3.53	.09	4.01	3.11	.45	3.56	.03	.07
Moosehound	14	3.10	.12	3.69	2.64	.53	3.16	.06	.11
Ram	33	3.24	.10	3.79	2.84	.47	3.31	.07	.15
Opabin	4	3.75	.07	4.26	3.43	.42	3.84	.09	.21
Sunkay	2	1.78	.30	2.61	1.19	.71	1.90	.12	.17
Dunvegan	4	2.65	.16	3.31	2.19	.56	2.75	.10	.18
Mountain Park	1	2.50	.18	3.01	1.90	.56	2.45	−.05	−.09

Phi median diameter .... $Md\phi = \phi_{50}$

Phi deviation measure .... $\sigma\phi = \frac{1}{2}(\phi_{84} - \phi_{16})$

Phi skewness measure .... $Sk\phi = \dfrac{M\phi - Md\phi}{\sigma\phi}$

where $M\phi = \frac{1}{2}(\phi_{16} + \phi_{84})$ and ϕ_{16}, ϕ_{50}, ϕ_{84} correspond to the diameters in phi units of the 16th, 50th, and 84th percentiles respectively.

The Chungo sand lies within the main distribution of the sands, being slightly less skewed than the others. The Ram arenites trend towards slightly larger grain size. Although the number of samples is small, the nonmarine sands have a greater variation in size, slightly larger grain size, and are not as well sorted as the marine sands.

Heavy minerals identified from the Ram sandstone include rutile, tourmaline, leucoxene, zircon, pyrite, and garnet which were most abundant and found in most samples. Hornblende, anatase, andradite and almandine garnet, and aegirine are also present. A few grains were identified as kyanite and sillimanite.

Shales and Mudstones

In general, a claystone has been called a shale in field descriptions, and a laminated rather than fissile character is implied. The term mudstone has been used to describe blocky or massive rock considered to be nearer claystone than siltstone. If the rock has a high content of silt, the term siltstone was used.

The shales of the Blackstone and Wapiabi formations are similar in many respects. Weathering characteristics have been used in the description of these, and appear to be closely related to the size composition. The rubbly and fissile shales apparently contain much less silt than the platy or blocky types.

The shale of the Alberta group is commonly dark grey to greyish black. In outcrop, most of the beds weather rusty but the Vimy shales are a characteristic silver-grey. This is attributed to the oxidation of the iron sulphide which produced a white efflorescence considered to be melanterite or iron sulphate (Pettijohn, 1956, p. 363). Yellow sulphur staining is prominent in outcrops of the Haven member along the eastern side of the area.

The coarser part of many shale samples were examined under the binocular microscope. A striking feature was the abundance of black organic material that commonly forms irregular masses. Some flaky fragments were also noted. Mica, mainly muscovite, was found as very small flakes in almost all the samples. Most of the coarse part consisted of fine quartz, some of sand but generally silt size. Fine pyrite is present in samples from the Thistle and Vimy members, and much is concentrated around the organic masses; pyrite is less abundant in the other members. Glauconite is abundant in the shales and siltstones of the Chungo member and upper part of the Hanson member; traces of it were found in samples from the Dunvegan, Muskiki, Marshybank, and Leyland members.

The Vimy and Thistle shales are calcareous but the former appears to contain more calcium carbonate. The shales of the concretionary members are rarely calcareous, and never to the degree of the Vimy shales.

In thin sections, dark brown or black organic matter is seen to be abundant in the shales. In some sections, the organic matter forms irregular masses having no particular orientation, but occasionally it forms thin laminae between layers of silt and clay. The rock contains silt-size grains of quartz and chert, and brown, micaceous clay. A few larger grains of muscovite were noted.

X-ray identification of these rocks indicate the shales are composed mainly of the micaceous and expanding clay minerals (probably of the mixed-layer types), and include illite, montmorillonite, chlorite, and probably some kaolinite.

Concretions

Concretion[1] is applied to a mass which is usually ellipsoidal and which differs in composition from the surrounding rock. It is not used in the restricted sense of Pettijohn (1956) who used the term for concentrically laminated structures.

Concretions are prominent constituents of the Cretaceous shales. The ellipsoidal ones vary in length from two inches to more than 2 feet. They may be scattered randomly through the sediments, but in many parts of the section they occur in fairly uniformly spaced rows. In a few sections, thin concretions coalesce to form uniform layers. Some, especially those below the major sandstones, are more irregular in shape and tend to be more rounded than elliptical.

As determined by X-ray, most of the concretions are composed of siderite or what is more commonly called ironstone. In thin section, the rock is seen to be composed of a mosaic of small crystals with very fine clay material and some silt-size grains. The fresh surface appears dark bluish grey. The concretions

[1]An alternative term for these bodies is nodule, but nodule generally implies an irregular mass.

weather reddish brown, which probably represents the alteration of the siderite to limonite.

In some parts of the section, particularly in the basal members of the Wapiabi formation, ammonites are fairly abundant within the concretions. Large specimens of *Inoceramus* are common in the concretions of the Muskiki member.

A syngenetic or early diagenetic origin is indicated by the well-preserved fossils within the concretions, which otherwise would have been deformed by the weight of the overlying rocks (Tarr, 1921, p. 382; Weeks, 1957, p. 100). The volume of material is difficult to explain by epigenetic origin (Tarr, 1921, p. 383). The arrangement along one plane, and in successive planes is also considered to be suggestive of a syngenetic origin. The rounded forms of the concretions are attributed to insufficient material which collected into spheres instead of forming a stratum (Twenhofel, 1926, p. 507). The lack of laminae in these concretions and their aphanitic nature suggest that the carbonate may have recrystallized, but except for recrystallization the concretions are considered to be of syngenetic origin.

Dolomitic Limestone

The Vimy and Thistle members contain magnesium-rich carbonate layers which, as shown by X-ray analysis, approach dolomite in composition. Some similarity in the sedimentation sequence is noted between the dolomitic layers, which are considered to mark the base of a transgressive phase, and the dolomitic 'coal balls' which have been correlated with marine transgressions by Teichmüller and Werner (Fairbridge, 1957, p. 158). The dolomitic beds may indicate a brief period of nondeposition.

As the dolomitic layers are found in marine shales characterized by iron sulphide, a reducing environment is suggested for their formation (op. cit., p. 165). The beds were probably laid down as calcium carbonate which reacted with the magnesium in the connate water to form dolomite. The diagenetic change has resulted in the elimination of much of the original structure, leaving an aphanitic rock.

Cyclic Sedimentation within the Alberta Group

The Alberta and Smoky groups reveal a well-developed sequence of cyclical units. Similar cycles have been described in the Tertiary rocks of the Gulf Coast (Bornhauser, 1947) and in the sandy facies of the Cretaceous rocks of the Western Interior of the United States (Spieker, 1949; Young, 1955).

The stratigraphic cross-sections (Figs. 3-13) show the many repetitions from shale to siltstone in the Blackstone and Wapiabi formations, and from shale to littoral sands and coal-bearing rocks in the Cardium formation and the Chungo member. Westward a similar facies change is encountered.

Two major cycles, megacycles[1] (Moore, 1936, p. 29), in the Alberta and Smoky groups repeat a sequence from marine shale to littoral sandstone and coal-bearing beds. The megacycles contain, in terms used by Bornhauser (1947), transgressive and regressive phases separated by an inundative phase. He attributed this type of cycle to an "extended invasion of the continental borderland."

Part of the Fort St. John group and the Dunvegan formation probably represent a cycle of equivalent magnitude to the two megacycles outlined but this cycle is not treated in detail. L. S. Russell (1939, p. 98), in a discussion of land and sea movements in the late Cretaceous of Western Canada, suggested but did not elaborate, "three large series in which marine strata were succeeded by brackish water strata, and these by fresh water beds". The lower series included the sediments of the Alberta group and the two higher ones included younger Cretaceous beds.

The lower megacycle of the Alberta and Smoky groups includes the Blackstone, Kaskapau, and Cardium formations. The transgressive phase, including many oscillations, is represented by the marine Sunkay member which consists of siltstones, sandstone, and basal pebble-conglomerate, all typical of shallow-water sediments. The sea, already present in northern and eastern Alberta, spread southwestward, and reached the Crowsnest area considerably later than it reached areas farther east and north. The inundative phase characterized by the fine clastics and their associated limestones includes the Vimy and Haven members. The Opabin member marks the beginning of the regressive phase, and the sands and coal-bearing beds of the Cardium formation mark the end.

The second megacycle is found within the Wapiabi formation. In this one, the transgressive phase includes the concretionary beds of the lower three members, Muskiki, Marshybank, and Dowling. The Thistle member, similar to the Vimy member in so many respects, is the inundative phase. The regressive phase is represented by the Hanson and Chungo members.

These megacycles are similar in thickness as well as in lithology. The lower one is between 600 to 2,000 feet thick and the upper one is 1,000 to 2,000 feet thick. The transgressive phase of the lower one reaches a maximum of 650 feet and of the upper, 800 feet; the inundative phase, 600 and 775 feet respectively; and the regressive phase, 400 and 475 feet.

The transgressive phase is characterized by rusty weathering shales and siltstones, some sandstone, and concretions. The base is marked by a pebble-conglomerate which is relatively thin compared to the thickness of the megacycle. In each megacycle, cycles that appear minor in the central Foothills reach major proportions in the northern Foothills. These are the ones involved in the development of the Dunvegan and Bad Heart sandstones.

[1]Used in the sense of Moore's "megacyclothem" defined as "a repeated succession of cyclothems of differing character (indicating) a rhythm of larger order than that shown in the individual cycles.

The inundative phase is represented by dark grey shales which, in contrast to others, are calcareous and weather dull grey. Sideritic concretions are noticeably absent. Thin argillaceous dolomitic limestones are typical of this phase.

The lower part of the regressive phase is marked by rusty weathering concretionary shales and mudstones which grade upwards into siltstone or sandstone, depending on basin position. In the cycles that contain a sand facies at the top, coal-bearing beds may be present. The top of the regressive phase is marked by the conglomerate of the overlying cycle.

The Nomad member which overlies the Chungo member represents another major transgression. However, the cycle does not attain the same magnitude as the underlying megacycles because the rapid influx of coarse sediments caused a fairly rapid regression. In this cycle, the inundative phase is lacking.

The Wapiabi formation contains the best development of cycles of lesser magnitude than the megacycles. Three major ones are recognized, and each consists of a transgressive and a regressive phase. Such cycles correspond to the two phase cycle of Bornhauser which he considered to be characteristic of shoreline oscillations.

The lowest cycle is formed by the Muskiki and Marshybank members. The Muskiki, containing the basal conglomerate of the megacycle, marks the advance of marine waters across the Cardium sands, and the movement of the shoreline from east to west. The Marshybank, containing massive siltstone and sandstone, represents the retreat of marine waters and a shift of the shoreline towards the east.

The second cycle consists of the transgressive Dowling member and its counterpart, the Thistle member. Although the Thistle is considered as the inundative phase of the megacycle, it does contain much siltstone and sandstone near the top which is interpreted as a regressive deposit. The cycle could actually be divided, because the regressive phase of one of the subcycles is almost as pronounced as that of the main cycle.

The shales of the Hanson member form the transgressive phase of the third cycle and are followed by the regressive sands of the Chungo.

As in the megacycles, the lower and upper cycles are similar in magnitude and general characteristics. The maximum thickness of the lower cycle is approximately 425 feet, and of the upper, 400 feet. The middle cycle is more than twice as large, being 1,100 feet thick. The transgressive phases are characterized by fissile to rubbly shales containing reddish brown weathering concretions and some platy siltstone. The regressive phases are characterized by massive or platy siltstones and sandstones.

The major cycles, especially those of the Wapiabi formation, where dating is best, appear to be of the same general age throughout the Foothills. The first cycle of the Wapiabi formation contains *Scaphites preventricosus* and *S. ventricosus* at the base and *S. depressus* at the top. These faunal zones have been identified in the northernmost section and in the southern sections. The middle cycle with its overlapping zones of *S. depressus* and *S. vermiformis* at the base and *S. montanensis* at the top is just as extensive. The upper unit, although not dated by regional zones, does, however, contain a local fauna that is similar throughout the area. The time equivalence of the subcycles is much less certain as the zonation by megafossils is not sufficiently refined.

Within the cycles, minor cycles or subcycles contain only two phases, transgressive and regressive. The subcycles have been shown on the cross-sections and form the framework of the lithologic correlations (Figs. 4-13). In the members composed dominantly of shale, each of the subcycles consists of rubbly or fissile shale at the base which grades upward into platy shale, siltstone or even sandstone. The top of the subcycles is usually distinct but is not as sharp as those of the major cycles. As deposition was probably continuous from one subcycle to the next, a short interval of gradation rather than an abrupt change is to be expected.

These minor cycles vary from 50 to 225 feet in the thickest sections and are approximately half as thick in the thinnest sections. In the shale formations, the maximum average thickness is about 100 feet. In the Cardium formation, where the subcycles are well defined by the changes from sandstone to shale, they are remarkably uniform. In the thickest sections, most of them are about 60 feet thick, but range up to as much as 80 feet. In thinner sections, the subcycles are reduced more or less proportionately to the overall thickness of the formation.

The Cardium formation contains the best illustration of these subcycles. The underlying Opabin shales of the Blackstone formation and the sands of the Ram member form the lowest subcycle. This one is followed by the shale of the Kiska member and the silt or sand of the Cardinal member. The uppermost cycle contains the Leyland and Sturrock members. Within the Ram member, two smaller cycles are prominent and are traced throughout the length of the area. The middle subcycle records at least two oscillations in the southern area. In the north, they are obscured by the intertongue of lagoonal deposits. Four minor cycles have been indicated in the upper subcycle of the Leyland and Sturrock members, although others representing smaller oscillations are present in some sections.

Thus, the rocks of this study present a sequence of cycles that record oscillatory movements of the shorelines. Although the shorelines tended to shift in one direction over a long period, minor advances and retreats occurred within each major advance and retreat. Although the type of cycle found in the Alberta and Smoky groups may be explained by changing positions of the shoreline, the cause of the movements is more obscure. Climatic changes (Brough, 1928; Wanless and Shepard, 1936; Wheeler and Murray, 1957), sea-level fluctuations (Suess, 1906, p. 539), and diastrophism (Geikie, 1882, p. 722; Hudson, 1924; Weller, 1930, 1931, 1956; Sears, *et al.*, 1941; Pike, 1947; Spieker, 1949; Russell, 1939) have been said to be responsible for shifting shorelines.

From the evidence present in the sedimentary sequence and from the consideration of the many ideas on the origin of cyclic sedimentation, some suggestions are made as to the origin of the Alberta group. Widespread orogenic movements accompanied by batholithic intrusions are known to have occurred towards the end of the Jurassic period and continued into early Cretaceous time. As the orogeny decreased in intensity, subsidence of the basin was controlled by isostatic adjustments. At the same time, eustatic changes in sea-level, probably related to much greater movements in some part of the earth's crust, caused world-wide transgression of continents by marine waters. In Alberta, subsidence in the basin was accompanied by uplift in the source area, both movements being of an epeirogenic or regional nature. As the sea withdrew or as it was forced back a widespread sand deposit extended well into the basin. The development of the trough along the western margin of the basin was probably due to greater movements of subcrustal material in the zone of greatest isostatic adjustment accompanied by basement faulting.

CORRELATION

Local and regional correlations of the Alberta group are made possible by many faunal indices used in the zonation of Cretaceous rocks of the Western Interior of Canada and the United States. The facies of the Alberta group are correlated with equivalent strata in other regions to show some of the relationships of Upper Cretaceous strata in the Foothills to the sediments of late Cretaceous seas in Western Canada and the United States. The correlation chart (Table IV) summarizes the suggested relationships; for more detailed discussion of fauna correlation *see* Jeletzky (*in press*).

Several species, previously considered to have a fairly restricted range, occur in three or more members of the succession and are not so reliable for zonation as has sometimes been suggested. Jeletzky, in his discussions, particularly stresses the considerable range of *Inoceramus* ex. gr. *I. lamarcki* (Parkinson), *Cardium pauperculum* Meek and Hayden, and the group of *Inoceramus cardissoides* Goldfuss, *I. lobatus* Goldfuss, and *I. stenstrupi* de Loriol. *I. fragilis* s. lato Hall and Meek is found as low as the basal part of the Sunkay member and as high as the Muskiki member. *Inoceramus* ex. gr. *I. lamarcki* Parkinson ranges from the Sunkay member to the Marshybank member. *Anomia subquadrata* Stanton was found in the Opabin, Marshybank, and Thistle members. *Cardium pauperculum* Meek and Hayden occurs in the Cardium formation, but is known to range below the zones of *Dunveganoceras* (Cobban and Reeside, 1952b). It is found in the Hanson member and the genus was collected from the Nomad member. Therefore, *C. pauperculum* can be expected from the base of the Alberta group to the top. *Baculites ovatus* s. lato Say ranges from the Cardium formation to the upper limits of the Wapiabi formation, and is not diagnostic unless it is more closely identified. The group of *I. cardissoides* Goldfuss, *I. lobatus* Goldfuss, and *I. stenstrupi* de Loriol are found in the Thistle, Hanson, and Chungo members, and although they are useful in the identification of the upper part of the Wapiabi formation, they cannot be used to separate the members nor to establish a refined age within the standard zones.

Correlation with Rocks of Northern Alberta, Northeastern British Columbia, Yukon, and Northwest Territories

As the Alberta group and equivalent strata are continuous with beds in the Peace River and Fort St. John areas, approximately 200 miles to the northeast and northwest respectively, correlation might be expected to be rather simple. However, Smoky River more or less marks a zone of facies changes throughout the Upper Cretaceous marine section, and although equivalent faunal zones are recognized in both areas, the equivalent strata are somewhat different. Farther north in Alberta, northeastern British Columbia, Yukon, and Northwest Territories, the lack of detailed studies makes correlation with these areas difficult. Much of the work done in this region has been of a reconnaissance nature and, although the presence of Cretaceous beds has been demonstrated at many localities, no unified report of the Cretaceous sequence has yet been published.

The lowest zone recognized in rocks of this study is that of *Neogastroplites* in the shales of the Fort St. John group in the Grande Cache area. As previously discussed, these shales are correlated with the lower part of the Sunkay member of the type region. The Fort St. John shales are correlated with the Shaftesbury formation from which Gleddie (1949, 1954, p. 492) reported *Neogastroplites* in a fish scale bed of that formation. The shales of the Shaftesbury formation are described as silty to sandy with a few ironstone concretionary bands. The upper part, above the 'fish-scale sand' is stated by Gleddie (1954, p. 494) to vary in thickness from 182 feet in the east to 405 feet in the west. General lithology and thickness compare with beds considered equivalent in the Sunkay member of the central Foothills. The Fort St. John shales may also be tentatively correlated (*see* McLearn and Kindle, 1950, p. 94) with the Cruiser formation of Peace and Pine Rivers, the upper part of the Sikanni formation as defined along Sikanni Chief River by Hage (1944), the upper part of the Lépine formation as defined on Liard River by Kindle (1944), and the Sully formation of the southwestern Northwest Territories (Stott, 1960b).

The Dunvegan formation, in the region studied, is probably equivalent to the Dunvegan formation of the Peace River region and to the Fort Nelson formation farther north (*see* Stott, 1960b). As shown by Stelck and Wall (1955, Fig. 5), the Dunvegan formation of the northeastern region is probably not of the same age everywhere but, in general, lies between the *Neogastroplites* zone and the *Inoceramus labiatus* zone. It is approximately equivalent to the middle upper part of the Sunkay member of the Blackstone formation. *Pleurobema dowlingi* McLearn, *I. rutherfordi* Warren and *I. dunveganensis* McLearn are the guide fossils and are tentatively considered by Jeletzky to be equivalent with the *Acanthoceras* fauna of Cenomanian age (*see also* Stelck and Wall, 1955). The thickness of the Dunvegan formation varies greatly, being 400 feet near Peace River town and 230 feet in the Amerada Crown OF 33-32 well (Gleddie, 1949, p. 495). The beds in the Blackstone formation considered equivalent to the Dunvegan formation are about 175 feet thick. Beds overlying the Dunvegan and containing the *Dunveganoceras* fauna are referred to as transition beds by Gleddie, who indicated that they vary in thickness from 300 to 75 feet. Equivalent beds in the Sunkay member have a maximum thickness of 175 feet.

Strata that may be equivalent to the upper members of the Blackstone formation and to the Cardium formation are not well known. The Smoky group includes all beds between the Dunvegan formation and the Wapiti group, but its distribution north of Smoky River has not been well outlined[1]. *Watinoceras* and

[1]*See* Stott (1960a, 1961b), *also* Stott (1962): *J. Alta. Soc. Petrol. Geol.*, vol. 10, No. 10, pp. 228-240.

Inoceramus labiatus, which indicate correlation with the Vimy member, were found by Williams and Bocock (1932) on Tuskoola Mountain southwest of Fort St. John. The Vimy member is correlated directly with the 'White Speckled shale' found in subsurface as both contain *I. labiatus.* The Cardium formation has been traced northward towards Pine River by the author and its erosional edge south of Peace River has been outlined by Harding (1955, Fig. 7).

The only indication that beds as old as the Cardium are represented farther north is given by Stelck (1955) who stated: "The upper Cardium conglomerate in this area (near Liard River) lies directly on the Fort Nelson conglomerate and, indeed, may contribute in no small measure to the uppermost conglomerate, of the Fort Nelson conglomerate". In a personal communication, Stelck indicated that the correlation rests on lithological evidence only. Other authors (Williams, 1944; Kindle, 1944; Hage, 1945) considered that the Fort Nelson was an extension of the Dunvegan formation. However, such a correlation does not eliminate the possibility that the upper part of the Fort Nelson contains equivalents of the basal Wapiabi conglomerate. The Fort Nelson formation is overlain by the Kotaneelee which is considered to be of the same age as the Wapiabi. Henderson suggested that equivalents of the Baytree member were present in the Kotaneelee formation on Petitot River, but this correlation was based on lithologic similarities and stratigraphic position. Without better faunal evidence, this correlation is extremely tentative for such conglomerates and sandstone may occur elsewhere, as, for example, those above the Bad Heart sandstone. The beds between the Dunvegan formation and the base of the Wapiabi may be missing in the area near Liard River. Stelck (1955) attributed the missing strata to erosion, but the shoreline may have been to the east of this area and the gap may be due to nondeposition, or equivalent beds may be present but unrecognized in the basal beds of the Kotaneelee formation.

Hume and Link (1945) report that *Watinoceras, Scaphites,* and *Inoceramus labiatus* have been collected from Cretaceous beds in the Norman Wells region of the Northwest Territories. Beds equivalent to parts of the Alberta and Smoky groups are therefore present in the Mackenzie River area.

The extension of the name Wapiabi into the Peace River plains has resulted in some erroneous correlations. The type Wapiabi formation is equivalent to those beds between the top of the Cardium formation and the Wapiti formation. The Muskiki member correlates with the shale beds below the Bad Heart sandstone and above the Cardium formation. Stelck (1954) showed that this unit is characterized by the *Scaphites preventricosus* and *S. ventricosus* faunas, which are also present in the Muskiki member. The Bad Heart sandstone of the Peace River region has been shown by Stelck (1955) and Harding (1955) to be stratigraphically higher than the Cardium formation. The calcareous Thistle member is correlated with an upper 'White Speckled Shale' (Gleddie, p. 501). From the general stratigraphic succession, the Chungo member is probably equivalent to the Chinook sandstone. The name Chinook was proposed by Gleddie (1949) for a "littoral marine sandstone and sandy shale member containing glauconite" at the top of the Wapiabi formation. Gleddie correlated the sandstone with the Milk River formation, the 'Solomon' and 'Highwood' sandstones. Fossils from the upper part of the succession in Peace River area are similar to those obtained from the upper part of the Wapiabi, and include *Inoceramus lundbreckensis* McLearn, *Desmoscaphites bassleri* Reeside, *Baculites aquilaensis* Reeside, *Baculites ovatus* var. *B. haresi* Reeside.

The Wapiabi formation may be correlated in general with the Kotaneelee formation along Liard River. The Kotaneelee formation contains the *Scaphites ventricosus* fauna (Stott, 1960b) and the *Inoceramus lundbreckensis* fauna (Hage, 1945) which characterize parts of the Wapiabi formation.

Correlation with Rocks of the Western Plains of Canada

Marine Cretaceous deposits of the Canadian Western Plains are not well zoned and their correlation with Foothills strata is tentative. The Alberta group is correlated with the Lloydminster shale (Nauss, 1945, p. 1616) of the Vermilion region about 250 miles northeast of the central Foothills. The Vimy member is correlated with the lower speckled shale from which Nauss reported *Inoceramus labiatus*. Shales above the lower speckled shale probably correlate with the upper part of the Blackstone formation, with the Cardium formation, and with the basal part of the Wapiabi formation. The Thistle member of the Wapiabi formation is correlated with the upper speckled shale of Nauss. The lower part of the Lea Park shales, described by Nauss (1945, p. 1619) is correlated with the Hanson, Chungo, and Nomad members of the Wapiabi formation.

The Alberta group and equivalent rocks of the Foothills can be correlated with the Ashville, Favel, and Vermilion River formations in Manitoba which were described by Wickenden (1945). Beds lying below the Vimy member are correlated with the Ashville formation which contains *Inoceramus dunveganensis* of Cenomanian age and a microfauna which Wickenden indicated was also found in the Fort St. John group in the Peace River area. The Vimy member is correlated with the Keld member which contains *Inoceramus labiatus* and consists of grey speckled shale. The presence in the Cardium formation of belemnoids comparable with *Actinocamax* aff. *A. strehlensis* Fritsch and Schloenbach suggests the correlation of these beds with the Assiniboine member of the Favel formation of Manitoba. Jeletzky reported that *Actinocamax* sp. aff. *A. strehlensis* is apparently restricted to the Favel formation but emphasized that only a few collections were available for the determination of the vertical range. The Wapiabi formation is equivalent to most of the Vermilion River formation. The lower Morden member of the Vermilion River formation is composed of dark grey, noncalcareous shale and corresponds partly to Nauss' unit that occurs between the two speckled shales. If the upper part of the Favel formation is equivalent to the Cardium formation, the Morden member would be equivalent to the basal Wapiabi shales. The Thistle member appears to be equivalent to the Boyne member which consists of 40 to 140 feet of calcareous speckled shale with *Scaphites ventricosus* and *Inoceramus* cf. *I. lundbreckensis* (Wickenden, 1945, p. 42). The Pembina member of the Vermilion River formation contains 30 to 70 feet of noncalcareous shales and some bentonite and is apparently equivalent to the upper part of the Wapiabi formation but may also contain beds that are younger.

Faunal evidence indicates the presence of beds equivalent to a large part of or all the Alberta group in Cretaceous sections along Athabasca River north of Edmonton. Collections from the 'Colorado shales' of this area contained *Inoceramus lobatus-cardissoides, Scaphites ventricosus, Inoceramus labiatus,* and *Prionocyclus* cf. *P. woollgari* Mantell (Wickenden, 1949).

The La Biche shales on Athabasca River north of Edmonton are considered equivalent to much of the Alberta group. Although the correlation is limited by few fossil collections, such forms as *Acanthoceras athabascense* Warren and Stelck (Stelck and Wall, 1955), possibly *Scaphites ventricosus* and the *Inoceramus lundbreckensis* fauna (Feniak, 1944) suggest the presence of beds equivalent to the whole Alberta group.

In the southern plains of Alberta, the basal part of the Alberta (Colorado) shale was referred to as the Blackleaf member (Yarwood, 1931; Spratt, 1931; Russell and Landes, 1940), and the lower sandstones were included in the Bow Island formation by Glaister (1959, p. 627). These marine beds, lying below beds containing *Inoceramus labiatus* are about 700 feet thick which contrasts with the small thickness of marine shale below the zone of *I. labiatus* directly west in the Foothills area. Although most of the Bow Island sandstone is obviously older than the basal Blackstone of the extreme southern Foothills, its precise relationship to the Sunkay member in the type section is unknown.

Correlation with the Western Interior of the United States

A brief summary is given for the correlation of the Alberta group and equivalent strata in Alberta with the Standard of the Western Interior of the United States and with the Standard of the Gulf Coast as outlined by Cobban and Reeside (1952b).

The base of the section, containing *Neogastroplites,* is correlated with the upper part of the Mowry shale and the Washita group of the Comanche series. The unfossiliferous interval between this zone and the Dunvegan formation corresponds to part of the Belle Fourche shale. The Dunvegan formation, tentatively considered to be equivalent to the *Acanthoceras* zones, would be equivalent to the top of the Belle Fourche shale, and part of the Woodbine of the Coastal Plain. These basal beds of the Alberta group would seem to be equivalent to some part of the Bootlegger member of the Blackleaf formation of Montana (Cobban, *et al.,* 1959, p. 89). The zones of *Dunveganoceras* are correlated with the lower part of the Greenhorn limestone. The *Inoceramus labiatus* zone of the Vimy member is also found in the Cone calcareous member of the Marias River shale of Montana (Cobban, *et al.,* 1959), the Pfeifer limestone member of the Greenhorn limestone and in the Eagle Ford shale. The zone of *Prionocyclus (Collignoniceras) woollgari* is equivalent to the Fairport cherty member of the Carlile shale and is also found in the Cone calcareous member. The main part of the Cardium formation apparently correlates with the upper part of the Carlile shale, but because no characteristic fossils have been found, the members cannot be closely correlated. The Muskiki member, containing *Inoceramus deformis, Scaphites preventricosus,* and *S. ventricosus* is equivalent to the Fort Hays Limestone member, the lower part of the Smoky Hill member of the Niobrara formation, and the Kevin Shale member of the Marias River shale (Cobban, *et al.,* 1959). The Marshybank, Dowling, and Thistle members represent the upper part of the Kevin shale and approximately the remainder of the Niobrara formation which contains such diagnostic fossils as *Clioscaphites montanensis* Cobban and *C. vermiformis* (Meek and Hayden). The upper part of the Wapiabi, including the Hanson and Chungo members, is considered to have been deposited at about the same time as the Telegraph Creek and Eagle formations, although definite palæontological evidence is lacking. The Nomad member may correspond to the Sharon Springs member of the Pierre shale. Thus, the Alberta group and equivalent rocks may include beds slightly older than the Colorado group, and do contain beds equivalent to all the Colorado group and to the lower part of the Montana group. Beds of the Gulf section which are considered equivalent include the Woodbine formation, the Eagle Ford shale, the Austin Chalk, and probably the lower part of the Taylor marl. Therefore, the Alberta group includes the lower part of the Gulf series.

In terms of the European stages, the Alberta group and equivalent rocks probably range in age from latest Albian to early Campanian.

PALAEOGEOGRAPHY

The Alberta group and equivalent rocks contain deposits of lagoonal, littoral, and neritic origin. At any given time, all these environments may have been present within the area of deposition, but in the Foothills area usually only one or two environments prevailed during any one time interval. Although the deposits accumulated in a large basin which had a western shoreline, the near-shore and beach deposits of most of the Alberta group were west of the present eastern limits of the thrusted rocks of the Rocky Mountain ranges.

The facies of the Alberta group and equivalent rocks indicate that the source of the sediments lay to the west of the present outcrops. The greatest development of lagoonal deposits in the Cardium formation lies towards the west, and the barriers lie to the east (*see* Figs. 19a, 19b). The marked thickening of the sections towards the west, the gradual increase in sand content in that direction, the change from shale through sandstone to brackish-water facies and coal beds likewise indicate a western source.

The source area of these sediments, probably an area of low to moderate relief undergoing rather deep weathering in a warm humid climate, apparently contained sedimentary rocks and may have had some metamorphic rocks with some igneous, volcanic, and pegmatitic bodies. The high content of quartz and chert suggests that the Alberta sands were derived from older sedimentary rocks or low-rank metamorphic rocks (Pettijohn, 1956, p. 287). Such a concentration of quartz and chert with only minor feldspar could develop by the deep weathering of a region of low relief. The well-rounded grains and chert pebbles probably reflect previous erosion cycles. The chert could have been derived from Palæozoic cherty limestones. The parent material of the shales probably included 'degraded illite', kaolinite, and montmorillonite. The degraded illite could have been derived from older marine sediments (Grim, 1953, p. 343; Keller, 1956); kaolinite, as a product of deep weathering in a humid climate (Grim, 1953, p. 343; Keller, 1956); montmorillonite, as a product of volcanic activity (Grim, 1953, p. 357). Iron, which is abundant in all the sediments, and silica may be produced by deep weathering of an area of low to moderate relief under warm humid conditions (Gill, 1927; James, 1954). Magnesium and potassium, necessary in the formation of montmorillonite and illite, may have been derived from deep weathering (Grim, 1953, p. 343; Keller, 1956). Sulphur, which must have been available in either organic or chemical material for the development of pyrite, may have been derived from volcanoes (Bateman, 1951).

The heavy minerals and the rounding of the minerals, particularly of tourmaline, zircon, and rutile is generally considered (Pettijohn, 1956, p. 513; Krynine, 1946) as evidence of previous sedimentary cycles. The garnets and hornblende are typical of metamorphic rocks. Euhedral zircon is considered to

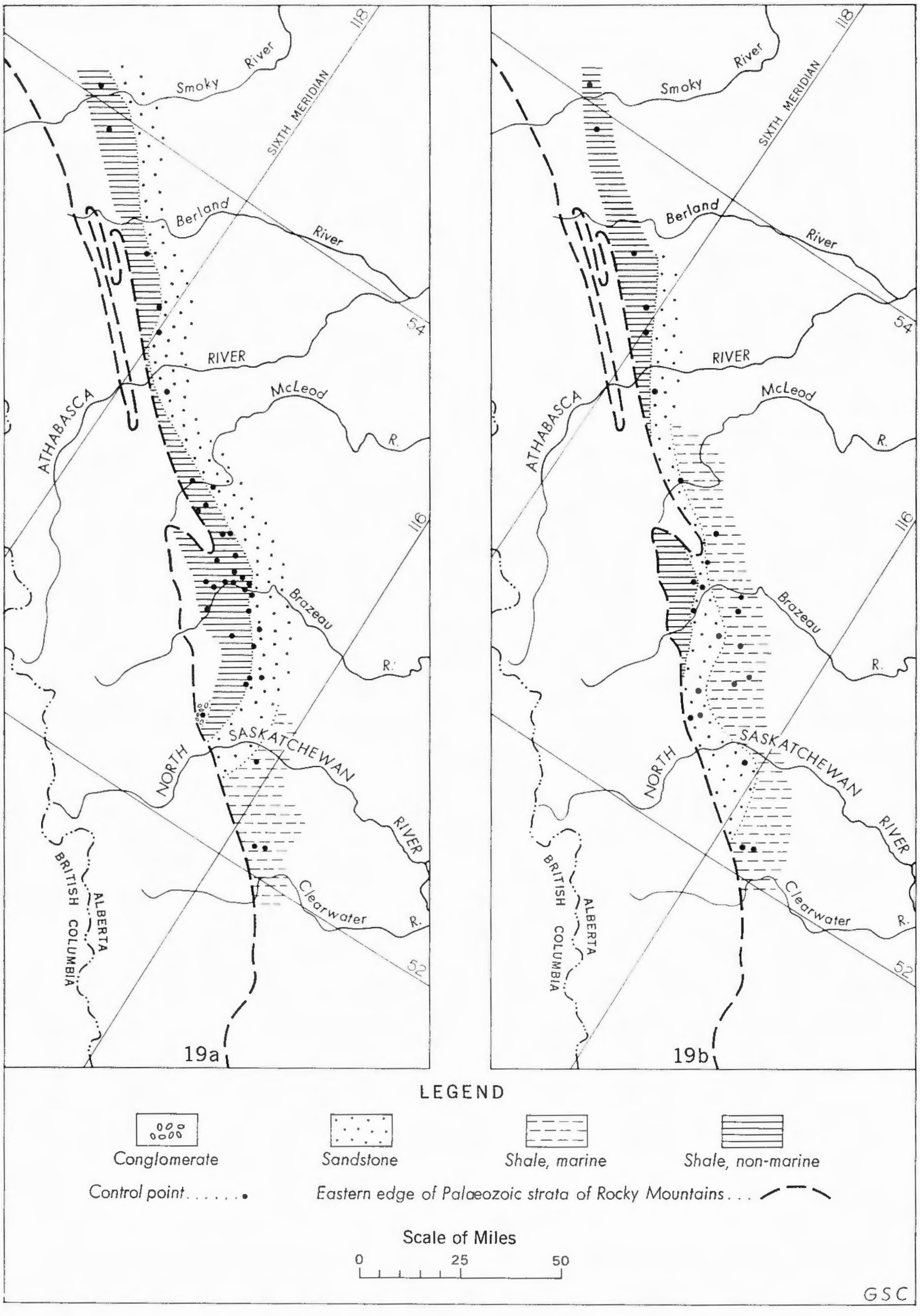


Figure 19. ***Distribution of lithologic facies during deposition of (a) the early Moosehound sediments; (b) the Leyland member.***

represent an acid igneous or volcanic source (Pettijohn, 1956) and the small amount of plagioclase feldspar would also indicate such a source. Blue tourmaline (indicolite) suggests a pegmatitic source (Krynine, 1946). The hyacinth zircons may have been originally derived from the Purcell lava (Beveridge and Folinsbee, 1956).

The general features of the source area of the late Cretaceous sediments are found in the area to the west of the Rocky Mountain Trench, although relief was probably less than that of the present. Source rocks probably included sedimentary and metamorphic rocks, and also chert-rich types which may have been Palæozoic carbonate rocks. In addition, as igneous pebbles first appear in Lower Cretaceous sediments (Rose, 1917; Douglas, 1950, p. 23; Roots, 1954, p. 190), the Nelson and Cassiar-Omineca batholiths had apparently been unroofed and were likely contributing clastic material to the east during late Cretaceous time.

Sediments of the Transitional Environment

The sands and associated sediments of the Alberta group are considered to have formed in the transitional environment. Lohse (1955, p. 100) emphasized that "The sedimentary products of the transitional environment are not merely paralic, i.e., interfingering of continental and marine (Tercier, 1940; cf. Schuchert, 1928); nor, are they merely mixtures of the two. The sands, the muds, faunal assemblages, and mineral suites of this environment are, in the final character, a distinct third group."

Near-shore Sediments

Three criteria for finding ancient shorelines and beaches (Bass, 1936, p. 92; Pettijohn, 1956, p. 606) are considered in the attempt to determine the environment of the Alberta sands. The first includes palæontological data; the second, areal patterns; and the third, structures and textures.

The faunal content is one of the best indications that the Cardium formation contains sediments deposited along ancient shorelines. The local abundance of *Cardium* and other marine forms such as *Inoceramus, Tancredia, Pteria,* suggests that marine conditions prevailed during the formation of some of these beds. Yet such forms as *Corbula, Unio, Brachidontes,* and *Corbicula,* as well as coal beds, indicate fresh-water or brackish-water environments. The Cardium marine sands pass laterally into beds containing coal and brackish-water fauna (Figs. 5 to 9). Similarly, in the Chungo member, siltstones and sandstones containing marine fossils grade into coal-bearing beds (Figs. 10 to 13). These members, accordingly, contain deposits laid down in the transitional zone between marine and nonmarine environments.

The areal pattern of the sands suggests they be interpreted as beach and offshore deposits (*see* Figs. 18, 19). The sands are distributed along linear trends, with finer shales flanking their eastern side and coal-bearing beds lying on their western side. The sandstones, which may be traced over a distance of 350 miles and probably even farther, have linear, gently curving trends that resemble continuous shorelines.

The continuity of beds, a most remarkable feature, is well illustrated by the sandstones (Figs. 3 to 13), many of which are not more than 20 feet thick and extend throughout the region. Eastward towards the marine environment, the sands grade into siltstone and shale. Their persistence along the depositional strike and the change across the depositional trends suggest that they were sorted and deposited by waves and currents acting in shallow water.

The relative thinness of the sandstones and their uniform laminae are typical of recent beach deposits, according to Thompson (1937, p. 744). Unlike the beaches studied by Thompson, those of the Alberta group are continuous for long distances. Uniform, parallel, and finely crossbedded laminae, characteristic of the Alberta sandstones, are found in recent beaches (Van Straaten, 1954a, p. 70; McKee, 1954, p. 7; Martens, 1939, p. 215).

Features, such as oscillation ripple-marks, 'worm burrows', tracks and trails, which are common in the Alberta sandstones, are characteristic of shallow water although also known in deep water (Van Straaten, 1954a). The interbedding of regular layered and mottled or reworked sandstone is indicative of shallow-water, near-shore deposits (Moore and Scruton, 1957).

The general absence of large-scale channels suggests that numerous erosional streams were not present in this environmental setting. Deposition below water level would explain the absence of wash-outs, but does not explain the lack of distributary channels that could be expected in a deltaic complex.

The Alberta sands, which have sorting coefficients between 1.0 and 2.0, fall within the class of well-sorted sediments (Trask, 1932, p. 72; Hough, 1942, p. 19; Payne, 1942, p. 1707) and are typical of beach sands. The sands, which lie between quartz arenite and quartz wacke in composition, correspond to beach sands that develop where the rate of subsidence and the rate of supply are about equal (Krumbein and Sloss, 1951, p. 208). Winnowing or reworking of the sands under mildly unstable conditions, at or near wave base, by repeated sorting action would produce such a composition (Pettijohn, 1956, p. 300; Williams, *et al.,* 1954, p. 320). Such well-sorted, fine-grained sands, consisting mainly of quartz, are found on beaches of barrier islands (Shepard and Moore, 1955, p. 91).

Relatively few examples of deposits interpreted as ancient beaches or barrier bars have been described (Pettijohn, 1956, p. 606) to which the Alberta sands may be compared. Diagnostic features of barrier beaches (Bass, 1936, p. 104) found in the Alberta sands include the narrow elongate shape of the sand bodies (*see also* Brewer, 1928, p. 606), the shapes in cross-section, parallel bedding, and the occurrence of marine fossils in the sands. Additional features found in the Alberta group that were interpreted by Dickey, *et al.* (1943) as characteristic of barrier-beach deposits include the thickness of the sand units, which varied between 15 and 130 feet; scarcity of heavy minerals; silica cement and secondary growths of silica. The intertonguing of marine and nonmarine facies, the gradational lower boundaries and well-defined upper boundaries of sandstones, the persistence and lithology of the sandstones are remarkably similar to Cretaceous rocks which were interpreted as near-shore and beach deposits by Pike (1947), Sears, *et al.* (1941), Spieker (1949), and Young (1955).

The Alberta sands have sizes and sorting that are similar to beach and near-shore sediments of the modern Gulf Coast and California coast. Beach sands were shown by Inman and Chamberlain (1955, p. 117) to be well sorted and to have a mean between 0.125 and 0.095 mm; the Ram sands closely approach these measures. Many of the Alberta sands fall within the size range of sands lying farther offshore to depths of 100 feet, as they range from 0.11 to 0.075 mm.

The sandy beds of the Alberta group correspond to deposits of the unda[1] environment of Rich (1951, p. 2). The coarser grain size, thin bedding and cross-bedding are typical. Wave action in fairly shallow water is indicated by oscillation ripple-marks and by the sorting of the sandstones. Rich remarked (p. 5) that complete sorting could be prevented by subsidence or excess of supply.

As the sandstones of the Alberta group, such as the Ram and Chungo members, apparently mark the shoreline at various intervals of time, they represent the littoral and the upper part of the epineritic environment. The littoral environment which extends from the region of low tide to high tide occupies a very narrow zone, and as the sands can be traced for several miles into the basin, a large part of these must have been deposited in the epineritic environment.

Conglomerates

The thin basal conglomerates and coarse sands of the Alberta group, composed mainly of chert and quartz, are considered to have the character of modern beach concentrates. In describing similar deposits, Pettijohn (1956, p. 256) suggested that "many of these conglomerates probably are the deposit of a transgressive beach over a surface of low relief". Similar conglomeratic accumulations at the base of deposits of a transgressive sea have been described by Stamp (1927, p. 565) and Dickey, *et al.* (1943, p. 31). Twenhofel (1947, p. 123) stated: "In general, an occurrence of well-rounded gravel of considerable distribution suggests, but does not prove, that deposition was over neritic bottoms . . . . If marine gravels are deposited under conditions of a rising sea-level, patches would ascend in the section with most moving landward as sea-level rose".

The maturity of the Alberta conglomerates is indicated by roundness (Wentworth, 1922, p. 75; Twenhofel, 1947, p. 120; Pettijohn, 1956, p. 66) and by the concentration of chert. Such concentrations of mechanically durable and chemically inert particles are produced by the reduction of less durable material in stream transport (Plumley, 1948, p. 575), or under conditions of low relief

[1]Unda environment, "part of floor which lies in the zone of wave action and in which the bottom is repeatedly stirred and reworked by storm waves."

where most of the source rock is reduced to sand and clay (Pettijohn, 1956, p. 253). The chert may be derived from limestone or from reworked older conglomerates.

The sphericity of the pebbles reflects the condition of deposition, and the mixture of different shapes is related to the depositional history. The disk-shaped and roller-shaped pebbles would be stable in the same environment because the particles of the same sphericity will behave in a similar manner under given conditions (Krumbein and Sloss, 1951, p. 80). Disk-shaped pebbles are considered to be typical of beach deposits but could also be the result of original shape rather than of wave action (Martens, 1939, p. 210; Wentworth, 1922, p. 75). The flat pebbles would tend to remain on shore because sorting action would remove spherical pebbles most easily (R. D. Russell, 1939, p. 35). Disk shapes to elliptical or spherical shapes are usually found in particles of long transportation (Twenhofel, 1947, p. 120).

Conditions necesssary for the preservation of beach gravels would include a very rapid rise of sea-level so they would not be eroded or moved shoreward. Twenhofel (1947, p. 125) suggested that such deposits would have a patchy distribution, "lie over wave-eroded surface, and the gravels should be the basal conglomerate of marine or lacustrine deposits."

Lagoon and Swamp Sediments

The Moosehound member, part of the Sturrock member, and the upper part of the Chungo member contain shales and sandstones, which, because of their composition, texture, and faunal content, are believed to represent lagoonal and marsh deposits. Thin layers of coal that occur throughout these beds are indicative of a swamp-like environment. As Pettijohn (1956, p. 495) stated: "the prevailing view favors the accumulation (of coal) in place in large fresh water swamps."

The associated fauna is one of the best sources of evidence of the environmental setting. As previously outlined, and as Jeletzky commented, the collections "contain a peculiar association of brackish- or fresh-water pelecypods and gastropods". *Brachidontes* and *Corbula* of the present are found in polyhaline bays behind barrier beaches in the Gulf Coast (Ladd, *et al.,* 1957, pp. 628-629). *Brachidontes* was said to be a dominant form in the shallow-water reefs.

Features such as burrows, tracks and trails of invertebrate animals, wave-ripples, laminations of sand and muds, may all be formed above and below the low-tide level (Van Straaten, 1954b). The deposition of coal indicates growth in place which is suggestive that the floor of deposition was near water level.

The coating of sand grains by clay particles and the abundance of aggregates of pyrite crystals, so characteristic of the Moosehound sands, are said by Van Straaten (1954a, pp. 92, 93) to be typical of brackish-water deposits found in marshes, swamps, and lagoons. Detrital carbonate grains, which are abundant in the Moosehound sands, also are typical of a brackish-water environment (Van Straaten, 1954a, p. 27).

Features found in the Alberta Moosehound member that are comparable to Recent lagoonal deposits (McKee, 1954, p. 35) are: lack of well-defined strata in many places but dominantly horizontal laminae; the sand deposits are texturally like those of the barrier; some strata contain accumulations of shells; vegetable matter is abundant. Other features, such as clayey sand and oyster reefs were found by Shepard and Moore (1955, p. 90) to be typical of lagoonal deposits.

The Moosehound sediments resemble those 'lagoonal deposits' described by Young (1955, pp. 198-199) who included "the rocks of the lagoons, estuaries, flood plains, swamps and lowlands". Similar features include uniform bedding in some with lack of bedding in other rocks; high organic content and coal beds; faunal content. Young stated that the transverse extent of the swamps probably averaged about 50 miles which is much farther than similar beds of the Alberta group may be traced because of the thrusts of the Rocky Mountains.

The theories of deposition of the Cardium sediments and overlying conglomerate presented here are not in agreement with those of Beach (1955), Passega (1957), and deWit (1957), who suggested that the sediments were distributed by turbidity currents. Few, if any, of the characteristics of sediments attributed (Heezen and Ewing, 1952; Kuenen, 1950; Natland and Kuenen, 1951) to deposition by turbidity currents are found in sediments of the Alberta group. Shallow-water features such as regular layers, mottles, and homogeneous sediments (Moore and Scruton, 1957), emphasized by the presence of shallow-water fauna and coal, are not characteristic of the environment of turbidity currents. A shallow-water origin for these Cretaceous sandstones, has been also postulated by deWiel (1956), Hunt (1957), Michaelis (1957) and Mountjoy (1957).

Sediments of the Marine Environment

Most of the sediments of the Alberta group were deposited in a marine environment. Ammonites, such as *Scaphites* and *Baculites,* which are found in the shales, are generally considered to live only in marine conditions (Scott, 1940, p. 300). Their widespread distribution indicates open seas and lack of barriers, at least most of the time, between the Arctic Ocean and the epicontinental seaway in which these sediments were deposited.

The Canadian Western Interior Upper Cretaceous sea had connections with the Arctic Ocean (Jeletzky, 1950, p. 23) as shown by the distribution of *Actinocamax* and *Inoceramus labiatus* Schlotheim, as well as *Inoceramus* cf. *I. flaccidus* White and *Scaphites* sp. (aff. *ventricosus* Meek and Hayden). Jeletzky stated:

> At the same time the presence of such North American Santonian and Lower Campanian forms as *Inoceramus* from the group *cardissoides* Goldfuss, *Inoceramus stenstrupi* Loriol, *Baculites ovatus* Say, *Baculites obtusus* Meek and Hayden, and

Scaphites hippocrepis De Kay in northern Siberia, Pay Hoy Peninsula, and the northern Urals, and of *Inoceramus stenstrupi* Loriol and *Inoceramus patootensis* Loriol in Western Greenland, suggests that this connection persisted during the whole of Santonian and possibly also during Lower Campanian time.

The area of deposition of beds equivalent to the Alberta group, as indicated by palæontological data, extended from Manitoba across the Interior Plains into northeastern British Columbia. The seaway had an open connection with the Arctic areas and during most of the time (at least from Turonian onward) had connections through the Western Interior of the United States with the present Gulf region (Reeside, 1957, pp. 520-528). Accordingly, the depositional site was that of a broad sea lying within the interior of the North American continent.

A shallow epicontinental sea was considered favourable for the development of black shales by Twenhofel (1939, p. 1187). Reducing conditions could exist at a depth from 40 to 250 metres and black muds could form along coasts where currents were feeble (Strom, 1939, p. 368).

Some shales of the Alberta group resemble those of the euxinic environment which is characterized by a high content of carbon and iron sulphide and a very low oxidation-reduction potential (Pettijohn, 1956, p. 622). If ammonites were benthonic in habit as suggested by Scott (1940, p. 321), the bottom conditions were not completely unfavourable to life, and were not entirely typical of euxinic conditions. The dark colour of the shales is attributed to organic material (Raymond, 1942, p. 660) and iron sulphides (McCarthy, 1926, p. 36), which indicate oxygen deficient bottom conditions.

Warm equable climatic conditions are assumed for the time in which these shales were deposited as such conditions lead to the absence of deep oceanic circulation, a requirement necessary for the development of stagnant conditions (Twenhofel, 1939, p. 1187; Strom, 1939, p. 368; Fleming and Revelle, 1939, p. 101). As pointed out by Fleming and Revelle (loc. cit.): "Deep water ventilation will be suppressed and stagnation made easier whenever there is a stable density stratification in the water near the surface. Thus, whenever the surface waters have high constant temperature, convective overturning will be impossible and turbulent exchange greatly inhibited." Although the climate which existed during the time of deposition of the Alberta group and its equivalents cannot be deciphered for the whole sequence because of insufficient data, some indications are present for part of it. The Dunvegan flora (Williams and Bocock, 1932) was considered by Dorf[1] to suggest a warm-temperate to subtropical climate with about 50 inches of rainfall. Plants collected from the Cardium formation by Greiner[2] were believed by Dorf and Fry[3] to be indicative of a warm-temperate climate. A small collection of fossil plants from the upper

[1]Paleobotanist, Princeton University, personal communication, 1957.

[2]Formerly of the Geological Survey of Canada. Fossils collected in Two Lakes map-area, Alberta, were identified by Fry. Fossils may have been collected from sandstone younger than Cardium.

[3]Paleobotanist, formerly with the Geological Survey of Canada.

part of the Milk River formation (Williams and Dyer, 1930), which is believed to be equivalent to the upper part of the Wapiabi formation, were indicative, according to Dorf, of a humid-warm-temperate climate. The upper Milk River beds have yielded a reptilian fauna (Russell and Landes, 1940) which probably lived in at least a warm-temperate environment. Therefore, the floral and faunal evidence suggest that the sediments of the Alberta group were deposited under warm-humid climatic conditions.

Most of the shales of the Alberta group resemble the pro-delta and off-shore clays of the Mississippi area which were described by Scruton (1955, pp. 38-39). The Alberta deposits and their environments of deposition resembled also in many ways those outlined in a discussion of marine environments by Rich (1951, p.2). Some of the dark grey or black shales correspond to the fondo[1] environment in that they are characterized by fine terrigenous material, fine laminations, and were deposited under toxic conditions. The uniform thin bedding and repeated variations of silt and shale, which are found in most shale members, more nearly correspond to Rich's clino[1] environment. Although by definition a sloping surface is an essential part of this environment, Rich commented that some gradients may be "so low that the beds might not readily be recognized as having been laid down in a clino environment, and so low as to preclude even the sliding of soft muds and the intrastratal flowage of 'quick' silts." Although scattered evidence of intrastratal flowage has been found in the sand beds of the Alberta group, its infrequent occurrence is suggestive of very gentle slopes.

Glauconite in these sediments indicates an origin in marine waters of normal salinity, under slightly reducing conditions which are favoured by the presence of organic matter, and its formation is favoured in the upper part of the 10 to 400 fathom interval in cooler waters, and in bottom muds of high iron content (Cloud, 1955, p. 490). Glauconite may form also in the oxidizing zone and under less reducing conditions than siderite (Teodorovich, *see* Chilingar, 1955, p. 766). Conditions of formation of glauconite in Cretaceous sediments were probably similar to those on the open shelf of the Gulf of Mexico (*see* Shepard and Moore, 1955, p. 95) and in open marine waters of the Gulf of Paria (*see* Van Andel and Postina, 1954, p. 160).

The occurrence of siderite in these Cretaceous shales indicates mildly oxidizing conditions with a low pH value or mildly reducing conditions if the system was more strongly alkaline, and abundant siderite indicates a pH of 7.0-7.8, and mildly reducing conditions with Eh of 0-0.2 (Krumbein and Garrels, 1952, p. 26). In contrast, the formation of pyrite is favoured by a reducing environment and generally indicates stagnant conditions (loc. cit.). Those Cretaceous sediments that contain siderite are believed to have formed under near-shore, mildly oxidizing

[1]The fondo environment was defined as the level deeper part of the basin; the fondoform was the topographic unit, the main floor of the water body. The clino environment is "the sloping part of the floor which extends from wave base down to the more or less level deeper parts".

marine conditions. The siderite problem was treated in some detail by Teodorovich (Chilingar, 1955, p. 762) who concluded: "The deposition of siderite and leptochlorite facies occurs in the near-shore (also near island) belts of marine and rarely fresh water basins. They are characterized by alternating arenaceous silty, argillaceous, and less commonly, carbonate sediments deposited in very shallow to moderately shallow depths." The iron necessary for the widespread deposition of iron compounds is considered to be derived from deep weathering (Gruner, 1922, p. 453; Gill, 1927, p. 726; James, 1951, p. 264), under tropical or subtropical conditions.

The calcareous, pyritic shales of the Alberta group represent an environment lying farther from shore than the sideritic facies. They indicate an open marine, reducing environment which maintained an alkalinity of 7.8, the most favourable for the precipitation of calcium carbonate (Krumbein and Garrels, 1952, p. 25). The precipitation of calcium carbonate was favoured also by warm, shallow waters in a slowly subsiding basin (*see* Cloud and Barnes, 1948, p. 36). Cooler oceanic waters sweeping into the shallow depths were warmed thus causing the precipitation of calcium carbonate (*see* Illings, 1954, p. 1).

The identification of the clay minerals by X-ray revealed that the Alberta shales consist of a combination of illite, montmorillonite, and chlorite. Illite and chlorite are typical of marine shales (Weaver, 1956, p. 200; Grim, 1953, p. 351). Mixed layer illite-montmorillonite, and chlorite-montmorillonite are more likely to form by marine diagenesis than are pure illite and chlorite clays (Weaver, 1956, p. 202).

The clay minerals probably reflect their source to some extent because the clay mineral complex is commonly inherited from the parent material (Van Houten, 1953, p. 77; Weaver, 1958, p. 258). Illite, for example, may be derived from existing rocks (Keller, 1956, p. 2703). If the climate was warm as previously suggested, potassium and magnesium would be leached from the rocks leaving degraded illite or even kaolinite (Grim, 1953, p. 342). "Mixed-layer illite-montmorillonite appears to form by the alteration of montmorillonite under marine conditions" (Weaver, 1958, p. 261). The montmorillonite may have been derived from volcanic ash, as suggested for Cretaceous rocks of western United States by Grim (1953, p. 356).

HISTORICAL GEOLOGY

Deposition of the Lower Cretaceous nonmarine sediments, represented by the Blairmore formation and equivalent rocks, gradually came to an end as a great epeirogenic movement in the mid-continent allowed the invasion of marine waters. This invasion, which began in early Cretaceous time (McLearn, 1944), advanced slowly from the northeast until much of the present area of the Plains and Foothills was inundated. The shorelines apparently trend north in the central part of the area, but curve northwestward in the northern part. The isopach maps of the Blackstone members (Fig. 15) show a definite south to slightly southwest trend from Calgary. The general pattern began to change near the beginning of Wapiabi deposition (Fig. 17). Precise trends of the older members are not known. Nevertheless, the upper members show that the trend south of Calgary had shifted to the southeast, more or less paralleling the trend of the mountain front in this area. A similar divergence of trends is found in the subsurface Cretaceous deposits (Roessingh, 1957). These trends, although not always parallel to the present regional ones, are similar to the structural trends developed by the later Laramide mountain building. The great bulge in the Lewis thrust in the extreme south is reflected in a similar pattern of marine deposits of the Upper Cretaceous. Apparently a low positive area was present in the vicinity of southeastern British Columbia during most of the epoch. As the Laramide structures also parallel the Rocky Mountain Trench, the depositional trends follow that tectonic feature. The distribution pattern suggests that the Laramide tectonic trends were already established in early Late Cretaceous time and that the structural framework influenced the deposition to a large degree.

In the northern part of the field area, the earliest marine rocks are those of the Fort St. John shales. They represent a marine advance from the north or northeast during the time of *Neogastroplites* of the late Albian stage. The invasion from the north spread southward into the United States in late Albian time (Reeside, 1957, pp. 516-518). The sea, advancing slowly southwestward, did not reach the Crowsnest area until later Cenomanian time as represented by the *Dunveganoceras* zones.

The southern part of the Foothills in the vicinity of Crowsnest Pass was above sea-level during late Albian and early Cenomanian time. Whether continental-type deposits formed or whether erosion was active during this interval is unknown. It is possible that the upper part of the Blairmore formation of the southern Foothills represents a nonmarine facies of the Fort St. John shales. The volcanic rocks of the Crowsnest formation are believed to have been laid down earlier than most of the Blackstone formation because little volcanic material is present in the lowest marine shales of the field area.

The deposits of the Sunkay member, laid down in the Late Albian-Early Cenomanian seaway, are quite silty, which suggests that the shoreline was not far distant. Ironstone shows that the environment was of low alkalinity and that circulation with the open ocean was not complete. Several minor regressions are indicated by the coarsening of the clastic material from shales to siltstone.

In the northern part of the area, transitional deposits are found in the Dunvegan formation. There, records of several oscillations are evident, with marine conditions intertonguing with swamp environments, and beach sand extends over off-shore muds. Due to the lack of sufficient sections, the exact nature of the transitional environment is not known, although McLearn (1945) suggested a deltaic complex for the Dunvegan formation farther north.

The earliest Turonian zone of *Sciponoceras gracile* Shumard has not been recognized in the Canadian section, but may be present. No indication of sea withdrawal or of erosion is present at the top of the Sunkay member. The overlying Vimy member contains the *Inoceramus labiatus* zone and the lowest part of the *Prionocyclus woollgari* zone of Turonian age.

The change from the rusty shales of the Sunkay member to the silver-grey calcareous shales of the Vimy member is due to changing chemical environment. More open marine conditions with better circulation of the sea water would bring the alkalinity up to 7.8, that of normal sea water, and allow the precipitation of calcium carbonate. In the north, the Vimy shales are less calcareous which suggests that conditions there were somewhat less alkaline and perhaps represent sediments deposited nearer shore.

While limy muds were accumulating along most of the area of the present Foothills, farther south near Highwood River beds of dolomitic limestone were forming. The increase in lime content implies a decrease in the supply of detrital sediments and may indicate that the source area was reduced or that the depositional site was farther removed from the source.

During the time of deposition of the lowest Vimy shales, a volcanic eruption (or eruptions) spread ash over the entire area. The ash bed thickens in the area of the Crowsnest formation and probably represents volcanism related to the earlier Crowsnest phase. Little evidence exists of widespread volcanic activity during the deposition of the remainder of the member.

Conditions during the time of *Prionocyclus woollgari* (middle Turonian) resulted in a change from the calcareous deposits of the Vimy member to the noncalcareous muds which finally produced the Haven member. The environmental change was gradual but fairly rapid as the transition zone is thin compared to the thickness of the two members.

The Haven shales, typified by their rusty colour and yellow staining, were deposited under reducing conditions, and represent a transition from the calcareous shales to the sideritic concretionary shales. The open marine conditions of earlier times had apparently ceased to exist, the water became less alkaline, and the fine clay being deposited formed a fetid mud. The area of greatest deposition during this time was in the region of the Bighorn Range. Farther south around Crowsnest Pass, either subsidence was slight or little clastic material was being supplied to the basin.

Further change in the chemistry of the sea water is reflected in the concretionary shales of the Opabin member. The concretions first appear in the sandy upper part of the Haven member in western sections. As the basin was filled, the floor was built up into the zone of circulating waters, thus ending the stagnant environment, and producing slightly oxidizing to slightly reducing conditions which favoured the precipitation of siderite.

Along the western edge of the sea, near-shore deposits were forming, one of which is exposed between the headwaters of Bighorn River and Thistle Creek. The thinly bedded sandstone represents the greatest retreat found within the member, although indications are present of several less pronounced ones. Several fluctuations from retreat to advance occurred, but finally retreating tendencies prevailed.

Towards the end of Turonian time, sufficient detrital material was being carried into the basin to overcome the subsidence and to start the slow upward and outward building of the shore which eventually pushed far to the east. Subsidence did not cease altogether as 400 to 500 feet of sediment accumulated in some areas. Deposition began to exceed subsidence, and as sand covered the near-shore area, the strand moved slowly outward. The change from off-shore muds to near-shore sands was gradual, for a transition zone of 15 to 30 feet exists in many places. As more material was brought in by rivers, the shore deposits began to form somewhat farther out, and eventually built a compound unit. Submergence after the main Ram sands were deposited caused off-shore muds to be laid down on the near-shore sands in the southern Foothills. There, the marine Kiska member lies directly on the Ram. Farther north, the advance is recorded by the development of barrier bars. Gradually barriers rose above the surface, forming lagoons on the shoreward side (Fig. 19a). The lagoons slowly filled with clays, silts and organic material. Marshy conditions prevailed long enough for plants to gain a foothold and furnish a thin layer of peaty material. The numerous intertongues of clays and coal show that the cycle was repeated several times.

A minor retreat, recorded in the middle of the Kiska member in the southern Foothills, probably also occurred farther north. The advance that followed swept inland, covering most of the lagoonal deposits between North Saskatchewan River and McLeod River.

Farther north, the shoreline trends northwestward from Maskuta Creek, but only lagoonal deposits are represented in the outcrops. Apparently the rate of submergence and the rate of supply in this area were roughly balanced so a continuous sequence of sand was built upwards instead of gradually spreading laterally.

South of Clearwater River, argillaceous sand is present in the Cardinal interval, showing that the beach had curved slightly southeast from Bighorn and Ram

Rivers. The shoreline is traced southward across Burnt Timber Creek to Bow River and McPhail Creek. From there, it apparently trends due south towards Carbondale River.

The Leyland member records essentially a major advance and the beginning of the third major retreat of the Cardium sequence. The advance, similar to the others of the Alberta group, was apparently rapid. North of McLeod River, the shoreline still lay to the east of the present outcrops, so the lagoonal and swamp deposits continued to form in this area. Apparently the strand line was comparatively stationary due to a balance between subsidence and deposition.

The final regression is recorded in the Sturrock member. The thin-bedded and lensing character of the sands and their increased content of clay indicate that they lie to the east of the major accumulation of sands, and represent, in most sections, only the pinch-out of the main deposit.

In the Highwood area, the more central part of the basin is found in the exposed sections. There, minor oscillations in the final retreat have formed a somewhat thicker and younger deposit than is represented at the top of the Cardium formation on McPhail Creek. The occurrence of the *Scaphites preventricosus* zone in Cardium and Wapiabi beds suggests that the sea never entirely left the plains area and that deposition was probably continuous from Turonian time into Coniacian time.

The readvance of marine waters over the deposits of the Cardium formation occurred during the latest Turonian time in southern Alberta. This advance throughout the Foothills is shown by the presence of the *Inoceramus deformis* and *Scaphites preventricosus* fauna in sections from Muskeg River to near Highwood River. As the sea moved westward, a pebble deposit formed on the older sand surfaces. In some places, this deposit assumed the proportions of beaches and probably does mark shorelines of the early Wapiabi sea. The greatest development appears in the Bighorn-Thistle Creek area.

During the early deposition in this expanded basin, volcanic activity was renewed, for more than twenty beds of bentonite are found in the Highwood area. Less ash is found farther north, suggesting that the source was located in the south.

Once more as the basin filled with dark muds, a retreat of major proportions recorded in the Marshybank member, brought the shoreline eastward. More argillaceous sediment was dumped in the area of the central Foothills, whereas farther north, sand marks the shoreline in the area of Muskeg and Little Berland Rivers. In the south, only silty muds were deposited, indicating that the shore was well to the west.

The Dowling member records a marine advance in Santonian time. The advance, still within the zone of *Scaphites depressus,* marks a deepening of the basin by more rapid subsidence, which continued into the time of *S. vermiformis.*

The central part of the Wapiabi is marked by calcareous shales without ironstone concretions. As in the Vimy member, this change is attributed to more open circulation, the return to normal alkalinity and conditions that favoured the precipitation of calcium carbonate rather than of iron carbonate. The invertebrate fauna of the zone of *S. montanensis* indicates a middle Santonian age.

The major retreat of the shoreline eastward began after the time of *S. montanensis*. This trend continued during the deposition of the Hanson and Chungo members with several reversals. The precise time that the retreat started is not known, but it is believed to be late Santonian. During this time, the shoreline moved out as far as the area of the present Foothills (Fig. 18b), and a thick sand sequence developed. This sand unit, in the area of maximum development, is actually thicker than the Cardium sands, and is attributed to a more balanced rate of subsidence and supply. As the shoreline moved eastward, lagoonal or swamp conditions developed along the western edge and coal deposits formed, showing that these lagoons had some duration. In the south, the shoreline, represented by the Milk River sand, extended much farther east across Alberta (Tovell, 1956).

As subsidence once more dominated, presumably in Campanian time, the sea moved inland over the near-shore, beach, and lagoonal beds deposited in the preceding regressive phase. Marine muds of the Nomad member were laid down on the earlier sands. These first deposits were similar to other Wapiabi sediments and are suggestive of relatively shallow water. However, sideritic concretions are lacking, and this may indicate more reducing conditions. These marine conditions did not continue for as long a period as they had after previous major transgressions. Tectonic movements in the west resulted in the production of the coarse clastics of the Brazeau and Belly River formations, which, by rapid influx, forced the sea to retreat quickly.

ECONOMIC GEOLOGY

Shale

Shale from the Thistle member of the Wapiabi formation has been used by the Canada Cement Company at Exshaw in the manufacture of cement and by the Alberta Ytong Manufacturing Company for a lightweight building stone. The quarries of these companies are located west of Seebe on the south side of Bow River.

Shales for similar operations elsewhere in Alberta could be obtained almost anywhere in the Alberta Foothills, as the Thistle member has much the same character throughout the area and outcrops in many places.

Petroleum and Natural Gas

The first commercial petroleum from Cardium sandstones was produced after Socony-Seaboard Pembina No. 1 well was completed in 1953. Since that time, the Cardium sandstones have been productive in the following fields: Pembina, Willesden Green, Willesden Green West, Alhambra, Rocky Mountain House, Keystone, Leafland, Garrington, Bonnie Glen, Calgary, and Crossfield. In December 1960, 2,965 wells were capable of producing from the Cardium formation in these fields which are located between Athabasca and Bow Rivers about 50 miles from the eastern edge of the Foothills. Pembina, the largest field, is located about 60 miles southeast of Edmonton and 280 miles north of the International Border.

Cumulative production from the Cardium sandstones has been nearly 204 million barrels of petroleum and more than 170 billion cubic feet of natural gas (December, 1960). Recoverable reserves have been estimated to be nearly two billion barrels of petroleum and over one trillion cubic feet of gas. The gravity of the oil is 37°API.

The Alberta group has many features that are favourable for the production and accumulation of petroleum. The essential elements of a reservoir—the rock, pore space, and the 'trap'—are found in the Cardium formation and may be present in other sandstones of the group. Source beds, required to supply the petroleum, are associated with the sandstones.

Ancient deposits of beaches or barrier bars have been considered (Griffiths, 1952, p. 214) as meeting the requirements of sand reservoirs, which must be porous, permeable, and have sufficient size to assure long production. In the Cardium formation, near-shore sand deposits have been traced for almost 400 miles (Fig. 18a), and in the vicinity of the Pembina field, the known width exceeds 50 miles. Although minor breaks undoubtedly occur in this deposit, its distribution is extremely favourable for large pools.

Porosity and permeability of the sands are most important factors in reservoirs, and likely the field observations of these properties of the Cardium sandstones have been largely responsible for the earlier lack of interest. In outcrop, the sands are well cemented and 'tight'. Patterson and Arneson (1957, p. 942) reported that sands from the Pembina field appear to be 'tight' but have an average porosity of 15 to 20 per cent and an average permeability of 20 to 25 millidarcys.

The type of sandstone and the grain size of the Ram member lie well within limits considered to be favourable for the accumulation of oil. Griffiths (1952, p. 214), in a survey of grain sizes in known oil fields, found that the most abundant reservoir sands were quartzose low-rank greywackes between 0.25 and 0.0625 mm. The petrographic studies of the Ram sandstones and some of those of the Sturrock and Chungo members reveal that these sandstones lie within this group.

The Cardium sands are enclosed by impermeable shale which forms an excellent stratigraphic trap. Besides, the beds have been tilted upwards on the off-shore side (Harding, 1955; Patterson and Arneson, 1957), thus forming a structural trap as well.

In the Alberta group, possible reservoir rocks consist of the near-shore deposits of well-sorted subgreywacke to quartz arenites forming an inclined wedge between marine shales. Reservoir rock, nevertheless, is not enough; a source rock must be present. From the numerous theories of the origin of oil, one may conclude that marine muds deposited under reducing conditions would be a favourable source (Levorsen, 1954, p. 513; Russell, 1951, p. 177). In the Alberta group, the dark marine shales were probably the major contributor.

In outlining possible areas for new discoveries, the area between Bow River and Pembina need hardly be mentioned because of the number of fields there now in production. The great development of sandstone in the vicinity of South Ram River may extend well into the basin so that in this area a suitable thickness would occur east of the disturbed belt.

Prospects of production from the Ram sandstone south of Bow River do not appear particularly favourable. Apparently the major accumulation of sand lay to the west of the eastern edge of the present Front Range. The fine silt and high content of matrix in this region would seriously interfere with recovery. Some of the upper sands may extend farther east, particularly near Elbow River, but even these become shaly to the south. Certainly in the vicinity of Turner Valley, the Cardium formation does not have the characteristic features of good reservoir rock.

The region between Athabasca River and Muskeg River (and probably even farther north) holds promise of new discoveries. If, as now believed, sand barriers exist to the east of the line of outcrops that were examined, suitable reservoir rocks are present in that area. The thickness of the nonmarine sequence suggests also that a relatively thicker sandstone sequence may be found than that south of Athabasca River. If, as seems to be so on Maskuta and Solomon Creeks, the sandstones form a vertical succession (because of a more uniformly subsiding basin), they probably will not have the lateral extent of the Ram member farther south, and their distribution may be difficult to determine.

The Dunvegan formation is not well enough known in this area to suggest its potentialities. Sandstones within the formation are present near Muskeg River, but their distribution is largely unknown, other than that they do not appear to extend far southward.

The Sturrock sandstone does not have much promise of production in the central Foothills but may be more favourable in the southern Foothills. It becomes much more argillaceous to the east and grades into mudstone, as the sections on Brazeau and Blackstone Rivers (Figs. 6, 8) well illustrate. Only a thin pebble bed, lying above shale, represents the top of the Cardium formation in the Pembina field (Harding, 1955; Nielsen, 1957, p. 67). Farther south, the Sturrock member is better developed and is the most prominent sandstone around Bow River.

The Chungo sandstone, similar in many ways to the Sturrock sandstone, may be a satisfactory reservoir in the southern Foothills but is less favourable farther north. The finer sizes and greater content of matrix would cause recovery difficulties. Furthermore, the distribution of this sand tends to show it is not as favourable as the Ram member. The Chungo sandstone thins rapidly towards the east, grading into very shaly siltstone well within the Disturbed Belt. Thus, from North Saskatchewan River to Athabasca River, the Chungo member probably would be argillaceous siltstone in areas east of the major thrusts (Fig. 18b). Its distribution north of Athabasca River is not well known, but sand facies are present near the Muskeg road. Drilling operations to the east would probably encounter this sandstone, but the grain size and porosity would be close to the limit of a producing zone. South of Ghost River, the Chungo sandstone apparently trends southeastward towards Lethbridge. Sandstone facies may be expected in the subsurface of this region, and favourable accumulations could be present. Grain size and sorting of the Chungo member in this region also favour the presence of reservoir rock.

In conclusion, rocks of the Alberta group are known to hold tremendous reserves and are major producers of petroleum and natural gas in Alberta. Prospects of new developments appear excellent and these rocks are expected to yield a large part of Canadian production in the future.

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APPENDIX I

Location of Sections and Summary Thicknesses of Members

Section	River/Creek	Location	Wapiabi	Cardium	Blackstone	Fort St. John	Dunvegan	Sunkay	Vimy	Haven	Opabin	Ram	Moosehound	Kiska	Cardinal	Leyland	Sturrock	Basal Conglomerate	Muskiki	Marshybank	Dowling	Thistle	Hanson	Chungo	Nomad
4-1	Saskatchewan	tp.39,rge.15,W5	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-2	Wapiabi	tp.41,rge.17,W5	—	—	—	—	—	—	—	137	147	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-3	Wapiabi	tp.41,rge.17,W5	—	210	—	—	—	—	—	119+	161	48	18	17	20	85	22	3	—	—	—	—	—	—	—
4-4	Wapiabi	tp.42,rge.17,W5	—	259	—	—	—	—	—	—	—	65	19	28	18	101	28	3	—	—	—	—	—	—	—
4-5	Wapiabi	tp.41,rge.17,W5	—	230	—	—	—	—	—	—	—	50	23	19	21	93	24	7	—	—	—	—	—	—	—
4-6	Wapiabi	tp.42,rge.17,W5	1118	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	78	66	159	356	190	135	134
4-7	Wapiabi	tp.41,rge.17,W5	—	—	—	—	—	304+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-8	Chungo	tp.43,rge.17,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	91	45	74+	410−	141	135	139
4-9	Chungo	tp.43,rge.17,W5	—	220	—	—	—	—	—	—	—	52	26	20	15	84	23	6	—	—	—	—	—	—	—
4-10	Chungo	tp.43,rge.17,W5	—	206	—	—	—	—	—	—	—	35	48	18	11	79	15	—	—	—	—	—	—	—	—
4-11	Chungo	tp.43,rge.17,W5	—	—	—	—	—	—	—	—	—	24	37	23	6	—	—	—	—	—	—	—	—	—	—
4-12	Canyon	tp.44,rge.19,W5	—	209	—	—	—	—	—	—	—	44	—	25	15	87	19	—	—	—	—	—	—	—	—
4-13	Canyon	tp.44,rge.19,W5	—	224	—	—	—	—	—	—	—	45	26	26	12	96.5	18.5	6	—	—	—	—	—	—	—
4-14	Chungo	tp.43,rge.17,W5	—	—	—	—	—	—	—	240	125+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-15	Brown	tp.44,rge.19,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-16	Brown	tp.44,rge.19,W5	—	244	—	—	—	—	—	—	—	28	?	?	12	102	38	6	—	—	—	—	—	—	—
4-17	Chungo	tp.43,rge.18,W5	—	251	—	—	—	—	—	—	—	29	50	9	20	91	62	12	—	—	—	—	—	—	—
4-18	Brazeau	tp.44,rge.20,W5	—	242	—	—	—	—	—	—	155+	17	?	?	?	108−	47	13	—	—	—	—	—	—	—
4-19	Thistle	sec.20,tp.44,rge.21,W5	—	235	—	—	—	—	—	—	—	35	47	—	9?	75−	78	6	—	—	—	—	—	—	—
4-20	Thistle	sec.21,tp.44,rge.20,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	232	238	101
4-21	Thistle	sec.17,tp.44,rge.20,W5	—	253	—	—	—	—	—	—	—	38	49	—	27?	32+	107	22	—	—	—	—	—	—	—
4-22	Thistle	sec.17,tp.44,rge.20,W5	—	—	1411	—	—	—	514	248	183	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4-23	Thistle	sec.13,tp.44,rge.21,W5	—	273	—	—	—	—	—	—	191	42	63	—	14?	41	113	14	—	—	—	—	—	—	—
4-24	Brazeau	sec.25,tp.44,rge.20,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	174	104
4-25	Brazeau	sec.25,tp.44,rge.20,W5	—	255	—	—	—	—	—	—	—	56	54	7	20	82.5	35.5	7	—	—	—	—	—	—	—
4-26	Brazeau	sec.26,tp.44,rge.20,W5	—	220	—	—	—	—	—	—	—	38	41	7	18	81	35	3	—	—	—	—	—	—	—
4-27	Brazeau	tp.44,rge.19,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	204	167.5	117
4-28	Cardinal	tp.45,rge.20,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	136	186	104
4-29	Brazeau	tp.44,rge.19,W5	—	238	—	—	—	—	—	—	—	57	35	9	24	76	35	21	—	—	—	—	—	—	—
4-30	Brazeau	tp.44,rge.19,W5	—	245.5	—	—	—	—	—	—	—	68	25	18	19	82	33.5	3.5	—	—	—	—	—	—	—
4-31	Cardinal	tp.45,rge.19,W5	—	242	—	—	—	—	—	—	—	68	27	12	23	83	29	14	250	—	—	—	—	—	—
4-32	Cardinal	tp.45,rge.19,W5	—	268.5	—	—	—	—	—	—	—	84	36	8	20	97.5	23	4	—	—	—	—	—	—	—
4-33	Cardinal	tp.45,rge.19,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	43+	162
4-34	Cardinal	tp.45,rge.20,W5	—	247	—	—	—	—	—	—	134	62	47	16	16	77.5	27.5	12	—	—	—	—	—	—	—
4-35	Hanson	tp.45,rge.20,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	185	172
4-36	Hanson	tp.45,rge.20,W5	—	255+	—	—	—	—	—	—	—	71	54	14	13	101	2+	—	—	—	—	—	—	—	—
4-37	Pembina	tp.46,rge.21,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	172	131
4-38	Pembina	tp.46,rge.21,W5	—	231	—	—	—	—	—	—	—	27	55	15+	18	78	38	—	—	—	—	—	—	—	—
4-39	Pembina	tp.46,rge.22,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	202	102
4-40	Mackenzie	tp.46,rge.22,W5	—	208+	—	—	—	—	—	—	—	21	—	—	—	—	20+	—	—	—	—	—	—	—	—

4–41	Mackenzie	tp.47,rge.22,W5	—	216	—	—	—	—	—	—	200	27	—	—	—	—	—	24	—	—	—	—	—	—	—
4–42	Mackenzie	tp.46,rge.22,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	288	—
4–43	Mackenzie	tp.47,rge.23,W5	—	232	—	—	—	—	—	—	—	34	70	—	12	84	32	15	—	—	—	—	—	—	—
4–44	Mountain Park	sec.27,tp.45,rge.23,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	71	—	—	—	—	—	—	—	—
4–45	Luscar	sec.17,tp.47,rge.23,W5	—	231	—	—	—	—	—	—	156	32	76	—	—	84	39	6	—	—	—	—	—	—	—
4–46	McLeod	tp.47,rge.22,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	253	96
4–47	Smallpox	tp.39,rge.15,W5	—	—	—	—	—	—	—	—	147	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4–48	Brown	tp.43,rge.18,W5	—	—	—	—	—	—	—	—	—	82	—	16	12	—	—	—	—	—	—	—	—	—	—
4–49	Brown	tp.43,rge.18,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	191	108
4–50	Chungo	tp.43,rge.18,W5	—	—	—	—	—	—	263+	269	166.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4–51	Cardinal	tp.45,rge.20,W5	—	256	—	—	—	—	—	—	119	67	50	8	14	68	49	7	—	—	—	—	—	—	—
4–52	Thistle	sec.17,tp.44,rge.20,W5	2100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	325	90	351	734	214	261	125
4–53	Cardinal	tp.45,rge.20,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	160	153	111
4–54	Brazeau	sec.26,tp.44,rge.20,W5	—	—	—	—	—	426	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4–55	Smallpox	tp.39,rge.15,W5	—	220	—	—	—	—	—	—	—	30	—	25	18	97	50	19	—	—	—	—	—	—	—
4–56	Saskatchewan	tp.39,rge.15,W5	—	—	—	—	—	—	—	186?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–1	Solomon	tp.51,rge.27,W5	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–2	Maskuta	tp.49,rge.26,W5	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–3	Muskeg	tp.57,rge. 5,W6	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–4	Muskeg	tp.57,rge. 7,W6	—	225	—	—	—	—	—	—	—	85	—	—	—	—	—	—	—	—	—	—	—	—	—
5–5	Muskeg	tp.57,rge. 7,W6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	78	—	—	—	—	—
5–6	Muskeg	tp.57,rge. 6,W6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	84	118
5–7	Susa	tp.57,rge. 7,W6	—	—	—	—	124+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–8	Susa	tp.57,rge. 7,W6	—	—	—	—	161+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–9	Sulphur	tp.56,rge. 8,W6	—	—	—	—	143+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–10	Cowlick	tp.56,rge. 7,W6	—	—	—	116+	58+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–11	Cowlick	tp.56,rge. 7,W6	—	—	—	—	248	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–12	Mahon	tp.56,rge. 5,W6	—	—	—	—	—	—	250+	254	117	89	—	—	—	—	—	—	—	—	—	—	—	—	—
5–13	Mahon	tp.56,rge. 5,W6	—	—	—	—	80+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–14	Mahon	tp.56,rge. 5,W6	—	—	—	—	89+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–15	Mahon	tp.56,rge. 5,W6	—	—	—	—	91+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–16	Mahon	tp.56,rge. 5,W6	—	—	—	—	128±	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–17	Berland	tp.54,rge. 4,W6	—	—	—	—	381	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–18	Moon	tp.54,rge. 3,W6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	127	159
5–19	Little Berland	tp.53,rge. 3,W6	1466+	188	1506+	325	227	145	437+	192	200	37	111	—	—	—	40	—	236	45?	139	677−	175−	194	—
5–20	Wildhay	tp.53,rge.27,W5	—	186	—	—	—	—	—	—	—	47	—	—	—	—	21	12	—	—	—	—	—	—	—
5–21	Wildhay	tp.53,rge.27,W5	—	245?	—	—	—	—	—	—	—	70	—	—	—	—	15	13	—	—	—	—	—	—	—
5–22	Maskuta	tp.49,rge.26,W5	—	248	—	—	—	—	—	—	—	58	98	—	—	11	81	—	—	—	—	—	—	—	—
5–23	Solomon	tp.51,rge.27,W5	—	253	—	—	—	—	—	—	—	59	104	—	—	26	64	—	—	—	—	—	—	—	—
5–24	Mount Solomon	tp.51,rge.27,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	96+	108
5–25	Thistle	sec.14,tp.44,rge.21,W5	2146	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	319+	120−	341+	778	188	288	112
5–26	Blackstone	tp.42,rge.20,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	142	—

Sec-tion	River/Creek	Location	Wapiabi	Cardium	Blackstone	Fort St. John	Dunvegan	Sunkay	Vimy	Haven	Opabin	Ram	Moosehound	Kiska	Cardinal	Leyland	Sturrock	Basal Conglomerate	Muskiki	Marshybank	Dowling	Thistle	Hanson	Chungo	Nomad
5–27	Blackstone	tp.42,rge.18,W5	1108	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	145	80	101	328	135	187.5	131 5
5–28	Blackstone	tp.42,rge.18,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	185	285	128
5–29	Blackstone	tp.42,rge.18,W5	—	265?	—	—	—	—	—	—	—	51	31?	18	18.5	88.5	76.5	14.5	—	—	—	—	—	—	—
5–30	George	tp.41,rge.19,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30+	272	51+
5–31	George	sec.26,tp.41,rge.19,W5	—	—	—	—	—	339+	240+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–32	Wapiabi	tp.40,rge.18,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	134+	48?
5–33	Wapiabi	tp.40,rge.18,W5	—	255	—	—	—	291+	303+	326	157	32	41	13	21	54	104	—	—	—	—	—	—	—	—
5–34	Bighorn	tp.39,rge.18,W5	—	—	1734	—	—	631	605	319	179	—	—	—	—	—	—	40	—	—	—	—	—	—	—
5–35	Bighorn	tp.39,rge.18,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	355	—
5–36	Littlehorn	tp.39,rge.18,W5	—	—	—	—	—	282+	168.5+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–37	Littlehorn	tp.39,rge.18,W5	—	300.5	—	—	—	—	—	—	109+	32	29.5	16	8	49	166	12	—	—	—	—	—	—	—
5–38	Bighorn	tp.39,rge.18,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40	416	104	269	751	118+	—	—
5–39	Blackstone	tp.42,rge.17,W5	—	258.5	—	—	—	—	—	—	160	79.5	32	16	11	95	24.5	—	—	—	—	—	—	—	—
5–40	Cripple	tp.37,rge.14,W5	—	—	—	—	—	654−	362+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–41	Cripple	tp.37,rge.14,W5	—	313	—	—	—	—	—	—	—	96	—	49?	14	94	60	—	—	—	—	—	—	—	—
5–42	Cripple	tp.37,rge.14,W5	1952	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	312	76	261	643+	333−	219	108
5–43	South Ram	tp.36,rge.13,W5	—	336	—	—	—	—	—	—	—	—	—	—	—	—	29	3	—	—	—	—	—	—	—
5–44	South Ram	tp.36,rge.14,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	207	—
5–45	South Ram	tp.36,rge.13,W5	—	357.5	—	—	—	—	—	250	166	103	—	37	23	129.5	65	—	—	—	—	—	—	—	—
6–1	Chungo	tp.43,rge.17,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	164	—
6–2	South Ram	tp.36,rge.13,W5	—	—	—	—	—	225.5+	448.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–3	Lynx	tp.36,rge.13,W5	—	—	—	—	—	132+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–4	Lynx	tp.36,rge.14,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	67	237	273+	—	—	—
6–5a	James	tp.33,rge. 8,W5	—	23+	—	—	—	—	—	—	—	—	—	—	—	—	—	3	172	—	—	—	—	—	—
6–5b	James	tp.33,rge. 8,W5	—	67+	—	—	—	—	—	—	—	—	—	—	—	—	—	3.5	95+	—	—	—	—	—	—
6–6	James	tp.32,rge. 8,W5	—	211	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–7	James	tp.32,rge. 9,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−250	124
6–8	Red Deer	tp.31,rge. 9,W5	—	267	—	—	—	—	—	—	—	79?	—	47	35	90.5	15.5	—	—	—	—	—	—	—	—
6–9	Burnt Timber	tp.39,rge. 8,W5	1820	278	1257	—	—	266	640	240	111	51	—	43	32	94	58	—	278	33	318	678	254?	169	90
5–10	Burnt Timber	tp.30,rge. 8,W5	—	282	1238	—	—	301	—	—	—	53	—	60	21+	110	38	8	—	—	—	—	—	—	—
5–11	Red Deer	tp.31,rge. 9,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	353+	—	—	—
6–12	Burnt Timber	tp.29,rge.10,W5	—	293+	—	—	—	—	—	—	94	78	—	51	30	71	63	—	—	—	—	—	—	—	—
6–13	Ghost	sec.33,tp.26,rge. 7,W5	—	308	—	—	—	—	—	—	—	49	—	62	16	119	62	—	—	—	—	—	—	—	—
6–14	Fallen Timber	tp.29,rge. 8,W5	—	296	—	—	—	—	—	—	—	58	—	55	23	137	28+	—	—	—	—	—	—	—	—
6–15	Ghost	sec. 4,tp.27,rge. 7,W5	—	302.5	—	—	—	—	—	—	—	48	—	?	?	?	53	—	—	—	—	—	—	—	—
6–16	Ghost	sec. 3,tp.27,rge. 7,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–17	Ghost	sec. 3,tp.27,rge. 7,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	64.5?	3	—	—	—	—	—	—	—
6–18	Ghost	sec. 4,tp.27,rge. 7,W5	—	—	846	—	—	202	287	203	154	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–19	Ghost	sec.32,tp.26,rge. 7,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–20	Ghost	sec. 5,tp.27,rge. 6,W5	—	154?	—	—	—	—	—	—	—	—	—	—	—	—	—	6″	—	—	—	—	—	—	—

6–21	Ghost	sec. 5,tp.27,rge. 6,W5	1299	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.5	148+	?	?	468	—	—	99
6–22	Bow	tp.25,rge. 8,W5	—	303.5	—	—	—	—	—	—	—	41	—	56	24	134	48	—	—	—	—	—	—	—	—
6–23	Kananaskis	sec.15,tp.23,rge. 8,W5	—	353?	—	—	—	—	—	—	—	48	—	49	34	160?	58	13	—	—	—	—	—	—	—
6–24	Kananaskis	sec.12,tp.23,rge. 8,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–25	Oldfort	tp.25,rge. 8,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	170	171	91
6–26	Jumping pd	sec.31,tp.24,rge. 4,W5	—	83+	—	—	—	—	—	—	—	—	—	—	—	—	—	0.5	137.5	—	—	—	—	—	—
6–27	Jumping pd	sec. 3,tp.23,rge. 5,W5	—	—	—	—	—	—	—	—	113+	27	—	—	—	—	—	—	—	—	—	—	—	—	—
6–28	Bow	tp.25,rge. 8,W5	—	—	—	—	—	—	—	—	—	49	—	37	24	—	—	—	—	—	—	—	—	—	—
6–29	Elbow	tp.22,rge. 6,W5	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–30	Elbow	sec.24,tp.22,rge. 6,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	117+	32	—	—	—	—	—	—	—	—
6–31	Elbow	tp.22,rge. 5,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	165	113	—
6–32	Sheep	tp.19,rge. 5,W5	—	242	—	—	—	—	—	—	—	30	—	36.5	27	119.5	29	—	—	—	—	—	—	—	—
6–33	Sheep	tp.19,rge. 5,W5	—	—	785	—	—	151	328	162	144	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–34	Sheep	tp.19,rge. 5,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	302	35	—	—	—	—	—
6–35	Sheep	tp.19,rge. 5,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	196	213	65
6–36	Sheep	tp.19,rge. 5,W5	—	263	—	—	—	—	—	—	—	37	—	43	24	139	20	—	—	—	—	—	—	—	—
6–37	Sheep	tp.19,rge. 5,W5	—	—	889	—	—	176	443?	138	132	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–38	Sheep	sec.24,tp.19,rge. 4,W5	—	274	—	—	—	—	—	—	139	27	—	?	?	?	—	14	144	25?	—	—	—	—	—
6–39	Sheep	sec.20,tp.19,rge. 3,W5	—	229	614	—	—	110	254	134	116	31	—	?	?	?	18	—	160	40	—	—	—	—	—
6–40	McPhail	tp.17,rge. 6,W5	—	282	—	—	—	—	—	—	114+	25.5	—	55.5	24	56	121	6	—	—	—	—	—	—	—
6–41	Highwood	sec. 3,tp.17,rge. 4,W5	—	?	—	—	—	—	—	—	—	38	—	55	28	—	—	6	—	—	—	—	—	—	—
6–42	Highwood	sec. 4,tp.17,rge. 4,W5	—	294.5?	—	—	—	—	—	—	—	34	—	60	25	—	—	5.5	—	—	—	—	—	—	—
6–43	Highwood	sec.14,tp.17,rge. 4,W5	—	224	—	—	—	—	—	—	—	25	—	55	12	—	—	—	—	—	—	—	—	—	—
6–44	Highwood	sec.30,tp.18,rge. 2,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	82	159
6–45	Highwood	sec.28,tp.18,rge. 3,W5	—	—	705	—	—	184	261	152	108	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–46	Highwood	sec. 7,tp.18,rge. 3,W5	1055	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	287	46	180	384	158	256	119
6–47	Oldman	tp.13,rge. 5,W5	—	309.5?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–48	Dutch	tp.11,rge. 4,W5	—	—	—	—	—	—	—	—	—	28	—	39.5	14	—	—	—	—	—	—	—	—	—	—
6–49	Lynx	sec.12,tp. 6,rge. 4,W5	—	153.5	—	—	—	—	—	—	—	19	—	33.5	16	—	—	—	—	—	—	—	—	—	—
6–50	Lynx	sec.12,tp. 6,rge. 4,W5	—	—	338.5	—	—	25+	183	27	103.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–51	Lynx	sec.11,tp. 6,rge. 4,W5	—	—	262	—	—	6.5	154.5	34	69	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–52	Castle	sec.21,tp. 5,rge. 3,W5	—	108.5	—	—	—	—	—	—	103	30.5	—	—	—	—	—	—	—	—	—	—	—	—	—
6–53	Castle	sec.14,tp. 6,rge. 3,W5	—	—	—	—	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–54	Drywood	sec.18,tp. 4,rge.30,W4	—	74	—	—	—	—	—	—	—	24	—	—	—	—	—	—	—	—	—	—	—	—	—
7–1	McLeod	sec.17,tp.47,rge.23,W5	—	251	—	—	—	—	—	—	—	30	98	—	—	88	35	—	—	—	—	—	—	—	—
7–3	Sheep	sec.19,tp.19,rge. 3,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	95	285	74
7–6	Oldman	sec.28,tp.10,rge. 2,W5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	416	82

APPENDIX II

Location of Fossil Collections

GSC Loc.	Location
24781	Section 4-5, unit 6, Muskiki member, Wapiabi formation. Wapiabi map-area, 1 mile below junction of Wapiabi and Sturrock Creeks on west flank of anticline in Cardium formation, 45 feet from base.
24782	Section 5-25, Chungo member, Wapiabi formation. Grave Creek map-area, upper Thistle Creek, sec. 14, twp. 44, rge. 21, 80 feet below top of member.
24783	Section 5-25, Thistle member, Wapiabi formation. Grave Flats map-area, upper Thistle Creek, sec. 14, twp. 44, rge. 21.
24784	Section 4-18, Muskiki member, Wapiabi formation. Pembina Forks map-area, Brazeau River, ½ mile above junction of Race Creek, 20 feet from base of member.
24785	Section 4-20, unit 31, Chungo member, Wapiabi formation. Grave Flats map-area, lower Thistle Creek, 25 feet from top of member.
24786	Section 5-25, Muskiki member, Wapiabi formation. Grave Flats map-area, upper Thistle Creek, sec. 14, twp. 44, rge. 21, just above Cardium formation.
24787	Chungo member, Wapiabi formation. Grave Flats map-area, lower Thistle Creek, sec. 13, twp. 44, rge. 21.
24788	Section 5-25, Thistle member, Wapiabi formation. Grave Flats map-area, Alberta, upper Thistle Creek, sec. 13, twp. 44, rge. 20, base of member.
24789	Section 4-22, unit 16, Vimy member, Blackstone formation. Grave Flats map-area, Alberta, lower Thistle Creek, sec. 13, twp. 44, rge. 20, 325 feet below top of member.
24790	Section 4-31, unit 9, Cardium formation. Pembina Forks map-area, Cardinal River, 4 miles upstream from Brazeau River.
24791	Section 4-23, unit 13, Opabin member, Blackstone formation. Grave Flats map-area, upper Thistle Creek, sec. 13, twp. 44, rge. 21.
24792	Section 4-23, unit 41, Cardium formation. Grave Flats map-area, upper Thistle Creek, sec. 13, twp. 44, rge. 21.
24793	Section 4-23, unit 8, Opabin member, Blackstone formation. Grave Flats map-area, upper Thistle Creek, sec. 13, twp. 44, rge. 21.
24794	Section 4-23, unit 46, Cardium formation. Grave Flats map-area, upper Thistle Creek, sec. 13, twp. 44, rge. 21.
24795	Section 4-17, unit 34, Sturrock member, Cardium formation. George Creek map-area, Chungo Creek, 3 miles east of gap in Bighorn Range.
24796	Section 4-32, unit 7, Moosehound member, Cardium formation. Pembina Forks map-area, Cardinal River, 6 miles above Brazeau River.
24797	Section 5-25, Chungo member, Wapiabi formation. Grave Flats map-area, upper Thistle Creek, sec. 14, twp. 44, rge. 21.
24798	Section 4-35, unit 24, Chungo member, Wapiabi formation. Grave Flats map-area, Hanson Creek, on east flank of syncline.
24799	Section 4-35, unit 31, Chungo member, Wapiabi formation. Grave Flats map-area, Hanson Creek, east flank of syncline.
24800	Vimy member, Blackstone formation. Pembina Forks map-area, Cardinal River, 4 miles upstream from Brazeau River.
24801	Section 4-36, unit 1, Sturrock member, Cardium formation. Grave Flats map-area, Hanson Creek.
24802	Section 4-31, unit 12, Muskiki member, Wapiabi formation. Pembina Forks map-area, Cardinal River.
24803	Section 4-33, unit 24, Chungo member, Wapiabi formation. Pembina Forks map-area, Cardinal River, 1 mile above junction with Brazeau River.
24804	Section 4-17, unit 11, Moosehound member, Cardium formation. George Creek map-area, Chungo Creek, 3 miles from gap in Bighorn Range.
24805	Section 4-16, unit 14, Sturrock member, Cardium formation. Pembina Forks map-area, Brown Creek headwaters.
24806	Wapiabi formation. Wapiabi map-area, Dorothy Creek.
24808	Cardium formation. Pembina Forks map-area, Brown Creek.
24809	Section 4-1, unit 2, Sunkay member, Blackstone formation. Nordegg map-area, small gully south side of Saskatchewan River, 2 miles west of bridge.

GSC Loc.	Location
25065	Section 4-25, unit 2, Muskiki member, Wapiabi formation. Grave Flats map-area. Brazeau River, 1 foot from base.
25066	Section 4-25, unit 9, Sturrock member, Cardium formation. Grave Flats map-area, Brazeau River, sec. 25, twp. 44, rge. 20.
25067	Section 4-26, unit 3, Sturrock member, Cardium formation. Grave Flats map-area, Brazeau River, 5 feet from top.
25069	Section 4-28, unit 32, Chungo member, Wapiabi formation. Grave Flats map-area, Cardinal River, 35 feet from base.
25070	Section 4-24, unit 7, Chungo member, Wapiabi formation. Grave Flats map-area, Brazeau River, 58 feet below top.
25071	Section 4-24, unit 5, Chungo member, Wapiabi formation. Grave Flats map-area, Brazeau River, 80 feet from top.
25072	Section 4-31, unit 5, Ram member, Cardium formation. Pembina Forks map-area, Cardinal River, 4 miles upstream from Brazeau River.
25073	Section 4-31, unit 10, Moosehound member, Cardium formation. Pembina Forks map-area, Cardinal River, 4 miles upstream from Brazeau River.
25074	Muskiki member, Wapiabi formation. Grave Flats map-area, Brazeau River.
25075	Section 4-13a, unit 26, Cardium formation. Pembina Forks map-area, Canyon Creek.
25076	Section 4-45, Haven member, Blackstone formation. Cadomin map-area, McLeod River, junction of Luscar Creek, 100 feet from top.
25077	Section 4-31, unit 5, Opabin member, Blackstone formation. Pembina Forks map-area, Cardinal River, 4 miles upstream from Brazeau River.
25078	Section 4-23, unit 8, Opabin member, Blackstone formation. Grave Flats map-area, upper Thistle Creek.
25079	Section 4-8, unit 72, Sturrock member, Cardium formation. Wapiabi Creek map-area, Chungo Creek, 1 mile upstream from road, on east flank of Brazeau syncline.
25080	Section 4-49, unit 42, Chungo member, Wapiabi formation. Pembina Forks map-area, Brown Creek at bridge.
25081	Section 4-8, unit 71, Muskiki member, Wapiabi formation. Wapiabi Creek map-area, Chungo Creek, 1 mile upstream from road, on east flank of Brazeau syncline.
25082	Section 4-31, unit 14, Muskiki member, Wapiabi formation. Pembina Forks map-area, Cardinal River, 4 miles upstream from Brazeau River.
25083	Section 4-6, unit 29, Chungo member, Wapiabi formation. Wapiabi Creek map-area, Wapiabi Creek, 2 miles downstream from junction of Wapiabi and Sturrock Creeks, west flank of Brazeau syncline.
25084	Section 4-46, unit 11, Chungo member, Wapiabi formation. Cadomin map-area, McLeod River, 1 mile east of junction with Luscar Creek, west flank of syncline.
25085	Section 4-46, unit 10, Chungo member, Wapiabi formation. Cadomin map-area, McLeod River, 1 mile east of junction with Luscar Creek, west flank of syncline.
25086	Section 4-5, unit 35, Sturrock member, Cardium formation. Wapiabi Creek map-area, Wapiabi Creek, 1 mile downstream from junction of Wapiabi and Sturrock Creeks.
25087	Wapiabi formation. George Creek map-area, Brown Creek headwaters, 2nd main tributary from south, 3 miles above mouth.
25088	Section 4-3, unit 2, Sturrock member, Cardium formation. Wapiabi Creek map-area, Wapiabi Creek, below junction with Sturrock Creek.
25089	Hanson member, Wapiabi formation. Pembina Forks map-area, junction of McCormick and Brown Creeks, east of southernmost corner of map-area.
25090	Section 4-4, unit 5, Sturrock member, Cardium formation. Wapiabi Creek map-area, Wapiabi Creek, 1½ miles below junction with Sturrock Creek.

GSC Loc.	Location
25091	Section 4-43, Sturrock member, Cardium formation. Coalspur map-area, Alberta, Mackenzie Creek, 1 mile above junction with Little Mackenzie Creek.
25092	Nomad member, Wapiabi formation. Coalspur map-area, Mackenzie Creek, 2 miles above junction with McLeod River.
25093	Section 4-4, unit 19, Moosehound member, Cardium formation. Wapiabi Creek map-area, Wapiabi Creek, 1½ miles below junction with Sturrock Creek.
25094	Section 4-38a, unit 1, Sturrock member, Cardium formation. Grave Flats map-area, Pembina River, downstream from trail.
25095	Section 4-39, unit 12, Chungo member, Wapiabi formation. Grave Flats map-area, Pembina River ¼ mile east of western limit of map-area.
25096	Section 4-37, unit 18, Chungo member, Wapiabi formation. Pembina River, east flank of syncline.
25097	Section 4-5, unit 11, Moosehound member, Cardium formation. Wapiabi Creek map-area, Wapiabi Creek, 1 mile downstream from junction with Sturrock Creek.
25098	Section 4-10, unit 25, Moosehound member, Cardium formation. Wapiabi Creek map-area, Chungo Creek, 1 mile downstream from bridge.
25099	Thistle member, Wapiabi formation. George Creek map-area, Brown Creek headwaters.
25100	Wapiabi formation. Pembina Forks map-area, Blanchard Creek, 1 mile above mouth.
25101	Muskiki member, Wapiabi formation. Wapiabi Creek map-area, Blackstone River, 1 mile east of bridge, 25 feet from base.
25102	Muskiki member, Wapiabi formation. Wapiabi Creek map-area, Blackstone River, 1 mile east of bridge, about 200 feet above base.
25103	Thistle member, Wapiabi formation. Nordegg map-area, north side of Saskatchewan River.
25104	Thistle member, Wapiabi formation. Nordegg map-area, north side of Saskatchewan River.
25105	Section 4-6, Brazeau formation. Wapiabi Creek map-area, Wapiabi Creek, west flank of Brazeau syncline, 6 feet above base.
27031	Section 5-33, unit 22, Moosehound member, Cardium formation. Wapiabi Creek, below Vimy cabin.
27032	Section 5-17, unit 3, Dunvegan formation. Adams Creek map-area, Berland River at Adams Creek.
27033	Section 5-22, Cardium formation. Maskuta Creek, southwest of Entrance map-area.
27034	Section 5-12, unit 13, Haven member, Blackstone formation. Pierre Greys map-area, Mahon creek below Isaac Creek.
27035	Section 5-25, unit 29, Dowling member, Wapiabi formation. Grave Flats map-area, Thistle Creek.
27036	Section 5-22, Blackstone formation. Maskuta Creek, southwest of Entrance map-area.
27037	Section 5-25, unit 46, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek.
27038	Section 5-10, unit 9, Dunvegan formation. Pierre Greys map-area, south flowing tributary of Cowlick Creek.
27039	Section 5-25, unit 19, Wapiabi formation. Grave Flats map-area, Thistle Creek.
27040	Dowling member, Wapiabi formation. Moberly map-area, Moberly Creek.
27041	Section 5-22, Haven member, Blackstone formation. Maskuta Creek, west of Entrance map-area.
27042	Section 5-25, unit 42, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek.
27043	Section 5-34, unit 63, Vimy member, Blackstone formation. Nordegg map-area, Bighorn River.
27044	Section 5-34, unit 6, Cardium formation. Nordegg map-area, Bighorn River.
27045	Section 5-37, unit 18, Cardium formation. Nordegg map-area, Littlehorn River.

GSC Loc.	Location
27046	Section 5-34, unit 71, Vimy member, Blackstone formation. Nordegg map-area, Bighorn River.
27047	Section 5-45, unit 13, Cardium formation. Cripple Creek map-area, South Ram River.
27048	Section 5-34, unit 80, Vimy member, Blackstone formation. Nordegg map-area, Bighorn River.
27049	Section 5-43, unit 6, Cardium formation. Cripple Creek map-area, South Ram River.
27050	Section 5-43, unit 10, Cardium formation. Cripple Creek map-area, South Ram River.
27051	Section 5-43, unit 16, Cardium formation, Cripple Creek map-area, South Ram River.
27052	Section 5-42, unit 4, Muskiki member, Wapiabi formation. Cripple Creek map-area, Cripple Creek.
27053	Vimy member, Blackstone formation. Nordegg map-area, Bighorn River, below junction with Littlehorn River.
27054	Section 5-14, unit 3, Dunvegan formation. Pierre Greys map-area, Mahon Creek, west of Isaac Creek.
27055	Section 5-34, unit 44, Haven member, Blackstone formation. Nordegg map-area, Bighorn River below junction with Littlehorn River.
27056	Section 5-25, unit 26, Dowling member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27057	Section 5-34, unit 89, Vimy member, Blackstone formation. Nordegg map-area, Bighorn River below junction with Littlehorn River.
27058	Section 5-33, unit 16, Cardium formation. Nordegg map-area, Wapiabi Creek, below Vimy cabin.
27059	Cardium formation. Nordegg map-area, Wapiabi Creek below Vimy cabin.
27060	Section 5-25, unit 43, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27061	Section 5-25, unit 36, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27062	Section 5-25, unit 33, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27063	Section 5-25, unit 41, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27064	Section 5-34, unit 35, Opabin member, Blackstone formation. Nordegg map-area, Bighorn River, below junction with Littlehorn River.
27065	Section 5-19, unit 19, Haven member, Blackstone formation. Moon Creek map-area, Little Berland River.
27066	Section 5-37, unit 43, Cardium formation. Nordegg map-area, Littlehorn River.
27067	Section 5-19, Marshybank member, Wapiabi formation. Moon Creek map-area, Little Berland River.
27068	Section 5-38, unit 55, Thistle member, Wapiabi formation. Nordegg map-area, Bighorn River.
27069	Section 5-19, unit 4, Kaskapau formation. Moon Creek map-area, Little Berland River.
27070	Section 5-33, unit 9, Opabin member, Blackstone formation. Wapiabi Creek, below Vimy cabin.
27071	Section 5-33, unit 33, Cardium formation. Wapiabi Creek headwaters, below Vimy cabin.
27072	Section 5-19, Vimy member, Blackstone formation. Moon Creek map-area, Little Berland River.
27073	Section 5-33, unit 48, Opabin member, Blackstone formation. Nordegg map-area, Wapiabi Creek headwaters, below Vimy cabin.
27074	Section 5-19, unit 5, Moosehound member, Cardium formation. Moon Creek map-area, Little Berland River.

GSC Loc.	Location
27075	Section 5-19, unit 10, Dunvegan formation. Moon Creek map-area, Little Berland River.
27076	Section 5-4, unit 2, Muskiki member, Wapiabi formation. Pierre Greys map-area, Muskeg River, 1½ miles upstream from McDonald Flats.
27077	Section 5-34, unit 109, Sunkay member, Blackstone formation. Nordegg map-area, Bighorn River, below junction with Littlehorn River.
27078	Section 5-25, unit 50, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek.
27079	Section 5-25, unit 49, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27080	Section 5-44, Chungo member, Wapiabi formation. Cripple Creek map-area, South Ram River above falls.
27081	Section 5-5, unit 4, Marshybank member, Wapiabi formation. Pierre Greys map-area, Muskeg River, 1½ miles upstream from McDonald Flats.
27082	Section 5-25, unit 17, Muskiki member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27083	Marshybank member, Wapiabi formation. Nordegg map-area, Wapiabi Creek, above Vimy cabin.
27084	Section 5-37, unit 19, Cardium formation. Nordegg map-area, Littlehorn River.
27085	Section 5-41, unit 33, Cardium formation. Cripple Creek map-area, Cripple Creek.
27086	Section 5-35, unit 84, Chungo member, Wapiabi formation. Nordegg map-area, on ridge north of Bighorn River, near junction with Littlehorn River.
27087	Section 5-25, unit 6, Muskiki member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27088	Section 5-37, unit 5, Muskiki member, Wapiabi formation. Nordegg map-area, Littlehorn River.
27089	Section 5-37, unit 1, Ram member, Cardium formation. Nordegg map-area, Littlehorn River.
27090	Section 5-25, unit 24, Dowling member, Wapiabi formation. Grave Flats map-area, Thistle Creek.
27091	Section 5-25, unit 61, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27092	Thistle member, Wapiabi formation. Pierre Greys map-area, Muskeg River, 2 miles above McDonald Flats.
27093	Fort St. John shale, Moon Creek map-area, Little Berland River.
27094	Section 5-34, unit 97, Sunkay member, Blackstone formation. Nordegg map-area, Bighorn River, 2 miles downstream from junction with Littlehorn River.
27095	Section 5-5, Dowling member, Wapiabi formation. Pierre Greys map-area, 2 miles above McDonald Flats on Muskeg River.
27096	Section 5-4, Dunvegan formation. Pierre Greys map-area, Susa Creek, near junction with Muskeg River.
27097	Section 5-25, unit 64, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27098	Section 5-25, unit 62, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27099	Section 5-25, unit 46, Thistle member, Wapiabi formation. Grave Flats map-area, Thistle Creek, most westerly section.
27100	Section 5-33, unit 9, Cardium formation, Nordegg map-area, Wapiabi Creek, below Vimy cabin.
27101	Section 5-19, unit 19, Thistle member, Wapiabi formation. Moon Creek map-area, Little Berland River.
27102	Section 5-38, unit 37, Thistle member, Wapiabi formation. Nordegg map-area, Bighorn River.
27103	Section 5-33, unit 99, Sunkay member, Blackstone formation. Nordegg map-area, Wapiabi Creek headwaters, below Vimy cabin.
27104	Section 5-38, unit 17, Dowling member, Wapiabi formation. Nordegg map-area, Bighorn River.

GSC Loc.	Location
27105	Section 5-38, unit 33, Thistle member, Wapiabi formation. Nordegg map-area, Bighorn River.
27106	Section 5-33, unit 80, Vimy member, Blackstone formation. Wapiabi Creek headwaters, below Vimy cabin.
27108	Section 5-38, unit 68, Thistle member, Wapiabi formation. Nordegg map-area, Littlehorn River.
27109	Section 5-19, unit 5, Marshybank member, Wapiabi formation. Moon Creek map-area, Little Berland River.
27110	Section 5-19, unit 15, Dowling member, Wapiabi formation. Moon Creek map-area, Little Berland River.
27111	Section 5-19, Thistle member, Wapiabi formation. Moon Creek map-area, Little Berland River.
27112	Section 5-38, unit 18, Marshybank member, Wapiabi formation. Nordegg map-area, Bighorn River.
27113	Section 5-38, unit 24, Dowling member, Wapiabi formation. Nordegg map-area, Bighorn River.
27114	Section 5-38, unit 71, Thistle member, Wapiabi formation. Nordegg map-area, Littlehorn River.
27115	Section 5-38, unit 12, Muskiki member, Wapiabi formation. Nordegg map-area. Bighorn River.
27116	Section 5-42, unit 11, Marshybank member, Wapiabi formation. Cripple Creek map-area, Cripple Creek.
27480	Hanson member, Wapiabi formation. Cripple Creek map-area, Cripple Creek.
28052	Section 6-39, Muskiki member, Wapiabi formation. Turner Valley map-area, Sheep River.
28053	Section 6-39, Muskiki member, Wapiabi formation. Turner Valley map-area, Sheep River.
28054	Section 6-21, unit 49, Chungo member, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28055	Section 6-9, unit 14, Muskiki member, Wapiabi formation. Burnt Timber Creek, west flank of syncline.
28056	Section 6-29, unit 5, Muskiki member, Wapiabi formation. Bragg Creek map-area, Elbow River.
28057	Section 6-37, unit 19, Vimy member, Blackstone formation. Dyson Creek map-area, Sheep River, east side of syncline.
28058	Section 6-30, unit 6, Cardium formation. Bragg Creek map-area, Elbow River.
28059	Section 6-32, unit 22, Cardium formation. Dyson Creek map-area, Sheep River, west flank of syncline.
28060	Section 6-29, unit 4, Muskiki member, Wapiabi formation. Bragg Creek map-area, Elbow River.
28061	Section 6-29, unit 6, Muskiki member, Wapiabi formation. Bragg Creek map-area, Elbow River.
28062	Section 6-33, unit 13, Vimy member, Blackstone formation. Dyson Creek map-area, Sheep River.
28063	Section 6-32, unit 15, Cardium formation. Dyson Creek map-area, Sheep Creek.
28064	Section 6-14, unit 26, Cardium formation. Fallen Timber Creek.
28065	Section 6-36, unit 20, Cardium formation. Dyson Creek map-area, Sheep Creek, east flank of syncline.
28066	Section 6-30, unit 3, Cardium formation. Bragg Creek map-area, Elbow River.
28067	Section 6-34, unit 11, Muskiki member, Wapiabi formation. Dyson Creek map-area, Sheep River.
28068	Section 6-34, unit 7, Muskiki member, Wapiabi formation. Dyson Creek map-area, Sheep Creek.
28069	Section 6-35, unit 4, Thistle member, Wapiabi formation. Dyson Creek map-area, Sheep Creek.

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GSC Loc.	Location
28070	Section 6-33, unit 14, Vimy member, Blackstone formation. Dyson Creek map-area, Sheep River.
28071	Section 6-39, Haven member, Blackstone formation. Turner Valley map-area, Sheep River.
28072	Section 6-21, unit 37, Hanson member, Wapiabi formation. Wildcat Hills map-area, Ghost River below junction with Wapairous Creek.
28073	Section 6-9, unit 11, Muskiki member, Wapiabi formation. Burnt Timber Creek, west limb of anticline.
28074	Section 6-20, unit 8, Cardium formation. Wildcat Hills map-area, Ghost River.
28075	Section 6-19, unit 21, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28076	Section 6-18, unit 30, Vimy member, Blackstone formation. Wildcat Hills map-area, Ghost River.
28077	Section 6-15, unit 20, Cardium formation?, Wildcat Hills map-area, Ghost River.
28078	Section 6-19, unit 22, Chungo member, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28079	Section 6-9, unit 66, Hanson member, Wapiabi formation. Burnt Timber Creek.
28080	Section 6-9, unit 85, Chungo member, Wapiabi formation. Burnt Timber Creek.
28081	Muskiki member, Wapiabi formation. Dyson Creek map-area, Sheep River.
28082	Section 6-34, unit 21, Dowling member, Wapiabi formation. Dyson Creek map-area, Sheep River.
28083	Section 6-18, unit 21, Vimy member, Blackstone formation. Wildcat Hills map-area, Ghost River.
28084	Section 6-21, unit 12, Thistle member, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28085	Section 6-16, unit 18, Chungo member, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28086	Section 6-14, unit 22, Cardium formation. Fallen Timber Creek.
28087	Section 6-9, unit 19, Marshybank member, Wapiabi formation. Burnt Timber Creek, west flank of anticline.
28088	Section 6-14, unit 35, Cardium formation. Fallen Timber Creek.
28089	Section 6-14, unit 5, Ram member, Cardium formation. Fallen Timber Creek.
28090	Section 6-9, unit 41, Cardium formation. Burnt Timber Creek, west flank of anticline.
28091	Section 6-16, unit 2, Hanson member, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28092	Section 6-34, unit 15, Muskiki member, Wapiabi formation. Dyson Creek map-area, Sheep River.
28093	Section 6-17, Muskiki member, Wapiabi formation. Wildcat Hills map-area, Ghost River.
28094	Section 6-9, unit 17, Muskiki member, Wapiabi formation. Burnt Timber Creek, west flank of anticline.
28168	Section 6-1, unit 5, Chungo member, Wapiabi formation. Wapiabi Creek map-area, Chungo Creek, about 2 miles below Home Brazeau No. 5 well.
28169	Section 6-2, unit 13, Sunkay member, Blackstone formation. Cripple Creek map-area, South Ram River.
28170	Section 6-2, unit 26, Vimy member, Blackstone formation. Cripple Creek map-area, South Ram River.
28171	Section 6-2, unit 15, Vimy member, Blackstone formation. Cripple Creek map-area, South Ram River.
28172	Section 6-45, unit 37, Haven member, Blackstone formation. Turner Valley map-area, Highwood River.
28173	Section 6-38, Muskiki River, Wapiabi formation. Dyson Creek map-area, Sheep River.
28174	Section 6-32, unit 24, Leyland member, Cardium formation. Dyson Creek map-area, Sheep River.

GSC Loc.	Location
28175	Section 6-43, unit 12, Marshybank member, Wapiabi formation. Dyson Creek map-area, Sheep River, east flank of syncline.
28176	Section 6-38, unit 9, Cardium formation. Dyson Creek map-area, Sheep River.
28177	Section 6-49, unit 10, Cardium formation. Carbondale map-area, Lynx Creek.
28178	Section 6-46, unit 52, Hanson member, Wapiabi formation. Turner Valley map-area, Highwood River.
28179	Section 6-45, unit 12, Cardium formation. Turner Valley map-area, Highwood River.
28180	Wapiabi formation. Flathead map-area, Kate Creek, from beds beneath Lewis thrust.
28181	Section 6-2, unit 36, Vimy member, Blackstone formation. Cripple Creek map-area, South Ram River.
28182	Section 6-2, unit 8, Sunkay member, Blackstone formation. Cripple Creek map-area, South Ram River.
28183	Section 6-8, Cardium formation. Red Deer River, near forestry bridge.
28184	Section 6-40, unit 35, Cardium formation. McPhail Creek, west of Highwood map-area.
28185	Section 6-43, unit 12, Cardium formation. Pekisko Creek map-area, Highwood River.
28186	Section 6-4, unit 9, Dowling member, Wapiabi formation. Cripple Creek map-area, Lynx Creek.
28187	Section 6-45, unit 35, Haven member, Blackstone formation. Turner Valley map-area, Highwood River.
28188	Section 6-33, unit 28, Haven member, Blackstone formation. Dyson Creek map-area, Sheep River.
28189	Section 6-31, unit 7, Hanson member, Wapiabi formation. Bragg Creek map-area, Elbow River.
28190	Section 6-40, unit 10, Muskiki member, Wapiabi formation. McPhail Creek, west of Mount Head map-area.
28191	Section 6-7, unit 19, Chungo member, Wapiabi formation. Marble Mountain map-area, James River, near junction with Willson Creek.
28192	Section 6-6, base of Muskiki member, Wapiabi formation. James River.
28193	Section 6-31, unit 14, Wapiabi formation. Bragg Creek map-area, Elbow River.
28194	Section 6-35, Thistle member, Wapiabi formation. Morley map-area, Oldfort Creek.
28195	Section 6-7, unit 8, Chungo member, Wapiabi formation. Marble Mountain map-area, James River, near junction with Willson Creek.
28196	Section 6-7, unit 14, Chungo member, Wapiabi formation. Marble Mountain map-area, James Creek, near junction with Willson Creek.
28197	Section 6-8, unit 4, Cardium formation. Marble Mountain map-area, James River.
28198	Section 6-8, Muskiki member, Wapiabi formation. Red Deer River, near forestry bridge.
28199	Section 6-31, unit 1, Hanson member, Wapiabi formation. Bragg Creek map-area, Elbow River.
28200	Section 6-48, unit 8, Cardium formation. Gap map-area, Dutch Creek.
28201	Section 6-8, Muskiki member, Wapiabi formation. Red Deer River, near forestry bridge.
28202	Section 6-48, unit 6, Cardium formation. Gap map-area, Dutch Creek.
28203	Section 6-25, unit 47, Nomad member, Wapiabi formation. Morley map-area, Oldfort Creek.
28204	Section 6-25, Marshybank member, Wapiabi formation. Morley map-area, Oldfort Creek.
28205	Vimy member, Blackstone formation. Gap map-area, Dutch Creek.
28206	Section 6-8, Muskiki member, Wapiabi formation. Red Deer River.
28207	Section 6-25, Dowling member, Wapiabi formation. Morley map-area, Oldfort Creek.

GSC Loc.	Location
28208	Section 6-26, unit 10, Muskiki member, Wapiabi formation. Jumpingpound map-area, Jumpingpound Creek.
28209	Section 6-25, unit 2, Thistle member, Wapiabi formation. Morley map-area, Oldfort Creek.
28210	Section 6-35, unit 10, Hanson member, Wapiabi formation. Dyson Creek map-area, Sheep Creek.
28211	Section 6-39, Vimy member, Blackstone formation. Turner Valley map-area, Sheep River.
28212	Section 6-50, unit 5, Vimy member, Blackstone formation. Carbondale map-area, Lynx Creek.
28213	Section 6-33, unit 16, Vimy member, Blackstone formation. Dyson Creek map-area, Sheep Creek.
28214	Section 6-49, unit 9, Cardium formation. Carbondale map-area, Lynx Creek.
28215	Section 6-35, unit 14, Hanson member, Wapiabi formation. Dyson Creek map-area, Sheep River.
28216	Section 6-23, unit 31, Cardium formation. Morley map-area, Kananaskis River.
28217	Section 6-49, unit 10, Cardium formation. Carbondale map-area, Lynx Creek.
28218	Section 6-25, unit 22, Chungo member, Wapiabi formation. Morley map-area, Oldfort Creek.
28219	Section 6-5, unit 11, Muskiki member, Wapiabi formation. Marble Mountain map-area, James River.
4496	Section 4-31, unit 10, Moosehound member, Cardium formation. Pembina Forks map-area, Cardinal River.
4497	Section 4-13, unit 12, Moosehound member, Cardium formation. Pembina Forks map-area, Canyon Creek.

APPENDIX III

Selected Sections

Section 4-6. Wapiabi formation, Wapiabi map-area, Alberta, 2 miles downstream from junction of Wapiabi and Sturrock Creeks, on western flank of Brazeau syncline.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
3	Sandstone, greenish grey, carbonaceous, medium- to coarse-grained, beds 4″-18″	30	36
2	Siltstone, argillaceous, dark grey; massive; with abundant pelecypods. GSC loc. 25105	3	6
1	Sandstone, similar to bed 3, massive	3	3
	Contact is sharp. Brazeau surface is slightly uneven. Thin beds of brown, sandy clay occur between formations.		
	WAPIABI FORMATION		
	Nomad Member		
48	Shale, 60%, silty, blocky, dark grey; siltstone, very argillaceous, dark grey, in beds 3″-6″	3	1,118
47	Shale, silty, rubbly to blocky, dark grey	2	1,115
46	Sandstone, medium- to fine-grained, medium grey; homogeneous; some carbonaceous material; traces of laminations	2	1,113
45	Shale, silty, to argillaceous siltstone, with dark grey concretions and silt beds	4	1,111
44	Sandstone, 30%, dark grey, fine-grained; finely laminated; interbedded shale, silty at top becoming less silty and rubbly at base	6	1,107
43	Sandstone, 40%, fine-grained, finely laminated in beds 1″-4″ thick; shale is blocky to hard and platy, very silty; some dark grey concretions	14	1,101
42	Shale, slightly less silty than overlying beds; sandstone, 10%; some dark grey, silty concretions	8	1,087
41	Shale, silty, and interbedded sandstone, 20%, fine-grained, argillaceous; concretions, 1″×2″-3″, dark grey	12	1,079
40	Shale, less silty, but still blocky; rusty weathering	6	1,067
39	Sandstone, fine-grained; massive; rusty weathering	1	1,061
38	Shale, blocky, very silty, with sandstone bands, 1″-2″ thick, 20%; some concretions, 2″×4″, dark grey, silty	10	1,060
37	Shale, silty, becoming somewhat platy towards base; rusty weathering; rare concretions in last 8′ and few sandstone bands in upper 10′	32	1,050
36	Sandstone, fine-grained; massive	1	1,018
35	Shale, very silty, to argillaceous siltstone; massive appearance	2	1,017
34	Shale, rubbly, fairly silty at top, with concretions, 2″ × 4″-6″	6	1,015
33	Shale, very silty, blocky with few concretionary zones. Concretions are 3″×6″. Shale is less silty in basal 3′	20	1,009
32	Shale, silty, to argillaceous siltstone; rusty grey weathering	5	989

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Chungo Member		
31	Sandstone, fine-grained; massive	1	984
30	Shale, very silty, with few concretions, 3″×6″	6	983
29	Shale, silty, blocky, dark grey; beds have massive appearance	35	977
28	Siltstone, argillaceous, grading into very silty shale at base; glauconite. Four-inch bed of medium grey, fine-grained sandstone at 10′. GSC loc. 25083	22	942
27	Shale, silty, becoming slightly less silty towards base, dark grey; weathers rusty tan; some concretions, 8″-12″, at top of bed	28	920
26	Siltstone, argillaceous, dark grey; massive appearance with 2″ beds finely laminated, medium-grained, fine-grained sandstone at top; concretions, 6″×12″-18″, somewhat irregular; glauconite	7	892
25	Shale, very silty, with three bands of concretions, 1′×2′	10	885
24	Shale, silty, blocky, dark grey, with concretions, 6″-9″×12″-18″, some cannonball concretions	21	875
23	Siltstone, argillaceous, blocky, dark grey; with some concretions, 8″×12″	5	854
	Hanson Member		
22	Shale, very silty, blocky, dark grey; more silty beds at 16′; grading into less silty towards base. Some large concretions	36	849
21	Shale, rubbly, somewhat silty, medium to dark grey; concretions, 6″×1′-2′ in bands	64	813
20	Shale, similar to above; rare concretions 3″-4″×8″, more plentiful in basal 35′; few thin siltstone lenses	90	749
	Thistle Member		
19	Shale, hard, platy to rubbly; paper-thin lenses and bands of siltstone, giving platy appearance; weathers rusty	47	659
18	Dolomitic bed, silty, bluish grey; weathers yellowish olive-green	1	612
17	Shale, platy, with thin laminated siltstone, grey; weathers rusty grey to grey	56	611
16	Covered interval, occupied by stream valley. Possibility of small fault in this interval	175 approx.	555
15	Shale, fairly silty, platy, dark grey	23	380
14	Shale, dark grey, siltier than overlying beds; few concretions at base	19	357
13	Covered	35	338
	Dowling Member		
12	Shale, platy to rubbly; few concretions 3″×1′	36	303
11	Shale, silty, blocky to rubbly; large concretions	31	267
	Fault		
10	Shale, finely rubbly; thin siltstone lenses and a few concretions; weathers rusty	19	236

Unit	Lithology	Thickness (feet)	Height above base (feet)
9	Shale, rubbly; thin siltstone beds; numerous concretions, 3"×6"-1'	31	217
8	Shale, rubbly, somewhat siltier than overlying beds; thin siltstone beds and numerous large concretions	42	186
	Marshybank Member		
7	Shale, very silty, blocky, dark grey; rusty weathering	66	144
	Small fault; repetition of beds of unit 6		
6	Shale, very silty, blocky	31	
	Muskiki Member		
5	Shale, rubbly; rusty weathering	20	78
4	Shale, silty, blocky to rubbly	30	58
3	Shale, rubbly; rusty weathering	14	28
2	Shale, very silty, blocky, dark grey	11	14
1	Two-foot concretionary zone with irregular concretions, underlain by 1 foot of shale with pebble layer at base	3	3
	Contact with Cardium formation.		

Section 4-13A. Cardium formation, Pembina Forks map-area, Alberta, Canyon Creek, 1 mile south of junction with Brazeau River.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	WAPIABI FORMATION		
2	Shale, rubbly; rusty weathering	15	
1	Shale, silty; platy siltstones; concretions, 4" × 6"-2'. Pebble horizon at base and also 6' above base	20	
	CARDIUM FORMATION		
	Sturrock Member		
34	Sandstone, hard, fine-grained in 2"-3" beds; silty shale, 50%; concretionary bed at top	7	224
33	Sandstone, light grey; laminated, crossbedded, thinly bedded	3	217
32	Shale, silty, with 3" sandstone in centre	1	214
31	Sandstone, light grey, fine-grained; laminated	1.5	213
30	Shale, silty	1.5	211.5
29	Sandstone, as above, with few shale beds	2	210
28	Shale, very silty to siltstone	1	208
27	Sandstone, fine-grained; laminated	1.5	207
	Leyland Member		
26	Shale, very silty	1.5	205.5
25	Shale, to siltstone, blocky with 6" bed of sandstone at base and 3½'	7	204
24	Sandstone, light grey, fine-grained; laminated	2	197
23	Shale, very silty, grading into siltstone at top; 2"-3" beds of hard, fine-grained sandstone (20%) at intervals of 6"-1'	21	195

Unit	Lithology	Thickness (feet)	Height above base (feet)
22	Shale, silty, blocky, dark grey, with concretions, 3″ × 6″-1′	25	174
21	Shale, very silty, blocky, dark grey, with few concretionary zones, 8″-10″ wide	28	149
20	Concretionary bed	1	121
19	Shale, silty, dark grey; rusty weathering	2	120
18	Concretionary bed with grit and pebbles	1	118
17	Shale, grading into siltstone in upper 5′, less silty towards base; concretions, 8″-12″ × 1′-1½′, and 8″ concretionary bed at base	8	117
	Cardinal Member		
16	Siltstone, very argillaceous; knobbly to massive; some concretions	12	109
	Kiska Member		
15	Shale, very silty, grading into siltstone at top; large irregular concretions	3	97
14	Shale, blocky, very silty; few concretions	13	94
13	Shale, rubbly to blocky; some concretions	10	81
	Moosehound Member		
12	Sandstone, brownish grey, fine-grained; homogeneous, laminated; concretions and few thin shale breaks. Basal 1′ contains plant fragments	8	71
11	Shale, silty, contains 1′ of coaly shale, 1′ from top with plant fragments on upper layers. Basal greenish, blocky shale contains pelecypods. GSC loc. 25075	5	63
10	Sandstone, fine-grained, light grey; homogeneous to finely laminated. Few shale breaks	5	58
9	Sandstone, carbonaceous, light to medium grey, medium-grained; laminated	4	53
8	Shale, silty	10″	49
7	Sandstone, bluish grey, fine-grained; homogeneous, irregularly bedded	8″	48.1
6	Shale, silty; coaly in basal 6″	1.5	47.5
5	Sandstone, very carbonaceous, dark grey, fine-grained, with 4″ coal at base	1	46
	Ram Member		
4	Sandstone, light grey, fine-grained; carbonaceous inclusions at top	6	45
3	Sandstone, light grey, fine-grained; porous, large crossbedding	17	39
2	Concretionary bed with shale at top and bottom	0.5	22
1	Sandstone, light grey, fine-grained; massive-bedded; some laminated and crossbedded	21.5	21.5
	BLACKSTONE FORMATION		
8	Sandstone, 50%, fine-grained; massive with some laminations; shale, silty. Beds are 4″-6″ thick	2	33
7	Shale, and thinly bedded sandstone, 40%	4	31
6	Sandstone, light grey, fine-grained; few thin shale beds	4	27

Unit	Lithology	Thickness (feet)	Height above base (feet)
5	Shale and thinly bedded sandstone, finely interbedded; some concretionary bands	7	23
4	Siltstone, very argillaceous, blocky; grading into thinly bedded sandstone at base	5	16
3	Sandstone, light grey, fine-grained; laminated, thinly bedded	3	11
2	Shale to siltstone, with some thin beds of sandstone and 1′ of sandstone at 3½′	5	8
1	Sandstone, light grey, fine-grained; homogeneous	3	3

Section 4-20. Chungo member, Wapiabi formation, Grave Flats map-area, Alberta, Thistle Creek, eastern side of syncline. Described by D. F. Stott, R. J. W. Douglas.

	BRAZEAU FORMATION		
3	Sandstone, fine-grained, greenish grey; dark brown weathering; calcareous	3	28
2	Sandstone, greenish grey, medium-grained; massive bedded, laminated, crossbedded; with carbonaceous material and mica flecks; rather soft weathering towards base	21	25
1	Sandstone, fine-grained; finely and evenly laminated; plant fragments on bedding; separated from overlying beds by 2″ carbonaceous flecked silty shale, and split into two beds by 0.5′ silty, greenish grey shale	4	4
	WAPIABI FORMATION		
	Nomad Member		
43	Sandstone, grey, fine-grained; finely laminated; splits into thin beds alternating with silty bedded shale. Basal 1′ more massive	5	571
42	Shale, silty, and siltstone, greenish grey; thinly bedded, alternating in 1″-3″ beds	17	566
41	Three 1′ sandstone beds as above, with interbedded siltstone and shale as above	7	549
40	Shale, silty, and siltstone, greenish grey; thinly bedded, alternating in 1″-3″ beds	13	542
39	Siltstone, 50%, and shale. Siltstone occurs in 3″ beds, alternating with 2″-3″ silty shale. Basal 1′ is massive bed of fine-grained sandstone. Some iron-stain spots, especially in siltstone. Unit has tendency to weather rusty	8	529
38	Shale, silty, rubbly; greenish grey to slightly rusty weathering; poorly bedded with somewhat harder rubbly siltstone. Two-inch limestone bed at 26′	29	521
37	Siltstone, grey to greenish tinge; suggestive of bedded appearance; somewhat rubbly, with silty shale	10	492
36	Dolomite, silty, cryptocrystalline, black; fine laminations, crossbedding, and slump structures on weathered surface; light brown weathering. Top contact is gradational. Base is sharp	4.5	482

Unit	Lithology	Thickness (feet)	Height above base (feet)
35	Shale, with pebbles	0.5	477.5
34	Conglomerate of chert pebbles ¼″-¾″ with gritty matrix; lies unconformably on beds below	4	477
	Chungo Member		
33	Sandstone, fine-grained; homogeneous; rusty tan weathering, with 2″ pebble zone 1′ from top. On north side of creek, the conglomerate is 0′-2′ thick, and cuts down sharply into underlying beds. Below this is 5′ of sandstone, fine- to coarse-grained, rusty brown weathering with 2″ zone of pebbles, less than ½″ in diameter. This is followed by 3′ of grey shale, sub-fissile with 1′ sandstone in centre	3	473
32	Sandstone, brown, fine-grained; homogeneous to slightly laminated, massive; dark rusty maroon weathering. Pebble zone at top	13	470
31	Shale, dark grey, platy, with 2″ concretionary siltstone near base	0.5	457
30	Sandstone, brown, fine-grained; slightly laminated, massive, with few pebbles 1′ from top	3	456.5
29	Shale; concretionary siltstone	0.5	453.5
28	Sandstone, light grey, greenish tint, fine-grained; massive, slightly laminated; weathers light greenish grey	16	453
27	Sandstone, greenish grey, fine-grained; massive; greenish grey weathering	12	437
26	Sandstone, greenish grey, fine-grained; finely laminated; more thinly bedded but has massive appearance; crossbedded	17	425
25	Sandstone, medium grey, slight greenish tint, fine-grained; massive	5	408
24	Sandstone, medium grey, greenish, fine-grained, platy; laminated	6	403
23	Sandstone, argillaceous, knobbly, dark grey; somewhat irregularly bedded	2.5	397
22	Sandstone, massive, hard, medium grey; laminated	0.5	394.5
21	Sandstone, argillaceous and silty, dark grey; wavy bedded, with few more massive laminated beds and rare concretions. Few ½″-1″ shaly partings at base	15	394
20	Sandstone, 75%, and silty shale; concretionary zones in basal 3′	10	379
19	Siltstone, argillaceous, blocky, dark grey, with some well indurated lenses 1″-4″ of laminated sandstone	14	369
18	Sandstone, fine-grained, brownish grey; rusty weathering; platy, with few pebble patches at top. Some pelecypods	6	355
17	Sandstone, fine-grained, greenish grey; greenish weathering; platy; laminated	9	349
16	Siltstone, argillaceous, quite hard and sandy at top, gradually becoming more argillaceous towards base. Some concretions, 4″-8″-12″	19	340
15	Shale, very silty, blocky, dark grey, with concretions 6″×8″-12″	14	321

Unit	Lithology	Thickness (feet)	Height above base (feet)
14	Sandstone, very argillaceous and silty; massive; knobbly weathering; 2′ concretionary zone at base	27	307
13	Sandstone, argillaceous; massive, laminated, slightly irregularly bedded	4	280
12	Shale, silty, dark grey, with concretionary zone at base	2	276
11	Sandstone, argillaceous, fine-grained; laminated, irregular to massive beds	2	274
10	Siltstone, argillaceous, blocky; concretions. GSC loc. 24787	5	272
9	Shale, silty, blocky; concretions 6″×8″	4	267
8	Siltstone, argillaceous; basal 2′ more shaly	12	263
7	Siltstone, argillaceous; dark grey, basal 2′ more shaly	9	251
6	Siltstone, argillaceous; dark grey, more shaly base	10	242
	Hanson Member		
5	Shale, silty; massive to rubbly; large concretions, rare, irregular	46	232
4	Shale, silty; grey, large irregularly shaped concretions	45	186
3	Shale, silty; massive, homogeneous, but in part with poorly defined siltstone; more massive and resistant than underlying and overlying beds; rare large oval concretions arranged in bands and at top surface. Top contact is gradational	41	141
2	Shale, silty; grey, large irregularly shaped concretions 6″ × 1′-2′ in bands 5′-6′ apart	67	100
1	Shale, silty; thinly bedded siltstones in beds up to 2″, 20%; rarer concretions in base and in bands 2″ × 6″, oval, towards top	33	33

Section 4-21. Cardium formation, Grave Flats map-area, Alberta, Thistle Creek, east flank of syncline, near Brazeau River.

	WAPIABI FORMATION		
4	Sandstone, coarse-grained, light grey, with concretionary upper surface; reddish brown weathering. Basal 1′ is almost all concretionary	8	22
3	Shale, sandy to gritty, with bands of concretions, 8″ × 12″-18″. Less sandy in basal foot	7	14
2	Sandstone, coarse-grained, light grey, grading into concretions in some zones; massive; rusty weathering	4	7
1	Sandstone, coarse-grained, 60%; and shale. Sandstone is thinly bedded, and contains some pelecypod fragments	3	3
	CARDIUM FORMATION		
	Sturrock Member		
33	Sandstone, fine-grained, brownish grey; rust to maroon weathering; slightly laminated, massive with 6″ concretionary band at 18′	24	253

Unit	Lithology	Thickness (feet)	Height above base (feet)
32	Shale, silty, dark grey; banded appearance with 3″ × 6″ concretions at base	3	229
31	Sandstone, fine-grained, light grey; slightly laminated, massive bedded; rusty weathering; 2″-3″ concretionary bands, poorly developed, at base	8	226
30	Siltstone, 40%, very argillaceous; shale, dark grey, bedded appearance	8	218
29	Sandstone, fine-grained, bluish grey; finely laminated; 1′ bed at top, 2′ bed at base, with shale partings in centre; few 2″ × 4″ concretions at base	5	210
28	Sandstone, fine-grained, bluish grey, in 4″-6″ bands, 50%; and silty shale. Unit has banded appearance	8	205
27	Sandstone, 25%, and shale as above	12	197
26	Sandstone, fine-grained, light brownish grey; weathers deep rusty grey; homogeneous, massive	7.5	185
25	Shale, silty, papery, dark grey; underlain by 3″ sandstone, fine-grained, very thinly bedded	0.5	177.5
24	Sandstone, fine-grained, light grey; rusty tan weathering; massive	4	177
23	Shale, silty, platy; grading into sandstone in some zones	1	173
22	Sandstone, fine-grained, light grey; massive; rusty weathering; cut and fill on basal surface	3	172
21	Sandstone, 50%, fine-grained, light grey; laminated, crossbedded; and shale	1	169
20	Shale, greenish to brownish grey; coaly in upper 2″ (not continuous) and at 2′	3.8	168
19	Siltstone, greenish grey; porous; some plant fragments	1.5	164.5
18	Shale, silty, blocky, greenish to brownish grey; plant fragments in basal foot of chocolate brown shale	3	163
17	Siltstone, greenish to brownish grey; blocky, becoming platy towards base; plant fragments at top	2	160
16	Sandstone, brownish grey, dirty, fine-grained; massive; rusty grey weathering	4	158
15	Sandstone, fine-grained, grey; laminated; thinly bedded to shaly, with plant fragments	3	154
14	Sandstone, fine-grained, brownish grey; laminated, massive, with few 1″-2″ thinly bedded sandstone partings	5	151
	Leyland Member		
13	Shale, silty, dark grey; in upper 7′, shale is platy and contains few hard siltstones, remainder is blocky to rubbly with few concretions	32	146
	Cardinal Member (?)		
12	Shale, silty, dark grey (mostly covered)	27	114
	Moosehound Member		
11	Sandstone, fine-grained, brownish grey; massive	2	87
10	Shale, brownish to greenish grey (mostly covered)	7	85
9	Sandstone, 75%, medium fine grained, brownish grey; homogeneous. Beds are 4″-12″ thick	7	78

Unit	Lithology	Thickness (feet)	Height above base (feet)
8	Siltstone, sandy, greenish	4	71
7	Sandstone, coarse to gritty, with concretionary band at base	2	67
6	Shale (mostly covered), some appear to be greenish grey. Greenish sandstone occurs at 20′ and coaly shale 5′ from top	27	65
	Ram Member		
5	Sandstone, medium-grained; massive, carbonaceous inclusions	20	38
4	Shale, coaly and thin-bedded sandstone	1	18
3	Sandstone, fine-grained, light grey; laminated, massive, large crossbedding; tan weathering	6	17
2	Shale, silty, dark grey; some platy sandstone	3	11
1	Sandstone, fine-grained, light grey; laminated, massive	8	8
	BLACKSTONE FORMATION		
	Shale, silty, dark grey; concretionary bands; upper 5′ contains hard dense sandstone bands, 50%; section becomes more silty at 50′, then decreases towards base	113	194
	Siltstone, argillaceous, platy, banded appearance. Hard beds are more abundant in upper half and contain some concretions	81	81

Section 4-22. Blackstone formation, Grave Flats map-area, Alberta, Thistle Creek, sec. 24, tp. 44, rge. 21, W5.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BLACKSTONE FORMATION		
	Opabin Member		
55	Shale, silty, platy; 40% sandstone, fine-grained, bluish grey, laminated	8	985
54	Shale, silty, platy; a few sandstone bands, 5%	18	977
53	Sandstone, 60%, 2-4″ beds, fine-grained, bluish grey, laminated; silty shale	4	959
52	Shale, silty; few concretions, bedded	9	955
51	Sandstone, 40%, ½″-1″ beds; shale	6	946
50	Shale, silty, dark grey, blocky	14	940
49	Shale, less silty, more rubbly	4	926
48	Shale, silty, blocky, becoming less silty towards base, with concretionary bands and concretions, 2″ thick; some ½″-1″ sandstone bands	47	922
47	Siltstone, sandy, dark grey; irregularly bedded; some concretions	12	875
46	Shale, very silty, grading into argillaceous siltstone, platy, bedded appearance, dark grey; rare beds ½″-1″ of harder siltstone	35	863
	Haven Member		
45	Siltstone, argillaceous, platy, dark grey; rusty weathering; finely laminated; few concretionary zones; concretions, 4″×1′, rusty orange weathering, some dark grey, 2″×3″	13	828

Unit	Lithology	Thickness (feet)	Height above base (feet)
44	Shale, silty, dark grey; grading into siltstone at top, platy; a few bands of laminated siltstone near base with 6″ siltstone at base	18	815
43	Shale, silty, rubbly, with thin lenses of siltstone; unit has striped appearance; some yellow sulphur stains	35	797
42	Shale, silty, rubbly to platy, with ½″-1″ band of laminated siltstone, 10%	26	762
41	Shale, blocky to rubbly, dark grey; rusty weathering; some yellow sulphur stains; bedded appearance, with a few harder silty beds; less silty towards base	27	736
40	Shale, silty, blocky to rubbly; beds of laminated siltstone in upper 4′, 10%; unit is rusty weathering; yellow sulphur stains; some platy, papery shale in basal 2′	26	709
39	Shale, rubbly; rusty weathering, yellow stains; papery towards base, with limestone concretions 1′ × 5′ at top	63	683
38	Shale, silty, blocky to rubbly, with thin ½″-1″ hard bands siltstone, 10%	20	620
37	Shale, blocky to rubbly; bedded appearance; rusty weathering, yellow stains	21	600
36	Shale, silty, blocky; more massive appearance with a few hard siltstone beds; rusty weathering; somewhat less silty towards base	25	579
	Vimy Member		
35	Shale, platy, silty; somewhat rusty weathering	5.5	554
34	Dolomite, dark bluish grey, laminated; yellowish tan weathering; massive, aphanitic	2.5	548.5
33	Shale, silty, papery to platy, dark grey; slightly rusty weathering	18	546
32	Dolomite, yellow tan weathering, dark bluish grey; thinly bedded, lensy	1	528
31	Shale, calcareous, platy, papery, dark grey; slightly rusty weathering	8	527
30	Dolomite, yellow tan weathering; lenticular	0.5	519
29	Shale, calcareous, silty; interbedded siltstone, laminated, platy, grey weathering	32.5	518.5
28	Shale, calcareous, less silty than overlying bed; bedded appearance; grey weathering	53	486
27	Dolomite, laminated; yellow tan weathering	1	433
26	Shale, calcareous, platy, silty; rusty grey weathering	27	432
25	Dolomite, dark bluish grey, aphanitic; laminated	0.5	405
24	Shale, calcareous, papery to somewhat blocky, dark grey; slightly rusty weathering	34.5	404.5
23	Dolomite, dark bluish grey; laminated; yellow tan weathering	1	370
22	Shale, calcareous, silty, platy, with finely laminated siltstone; less silty towards base, grey weathering; some concretions	27	369
21	Shale, silty, platy, papery to rubbly, dark grey; slightly rusty weathering; more platy in basal 6′	25	342
20	Dolomite, with 3″ shale in centre	1	317

Unit	Lithology	Thickness (feet)	Height above base (feet)
19	Shale, with silty laminae, calcareous, dark grey; grey weathering; concretions in upper 10′	53	316
18	Dolomite, dark bluish grey; laminated; yellow tan weathering	0.7	263
17	Shale, platy, silty laminae, calcareous, dark grey; grey weathering; less silty towards base; concretions in upper 4′	27.3	262.3
16	Shale, calcareous, platy to papery, dark grey; grey weathering; less silty than overlying beds. GSC loc. 24789	31	235
15	Shale, silty, platy with silty laminae and hard calcareous siltstone beds ½″-1″	11	204
14	Dolomite, and 50% shale	1	193
13	Shale, platy, dark grey, silty laminae; 5% bands of calcareous siltstone; hard, dense, bluish grey, laminated; unit weathers rusty towards base	36	192
12	Dolomite, argillaceous, bluish grey; laminated; yellow tan weathering	1	156
11	Shale, platy to papery, grey weathering; concretions in upper 5′	24	155
10	Dolomite, argillaceous, bluish grey	0.5	131
9	Shale, platy, few limestone lenses	30	130.5
8	Dolomite	0.5	100.5
7	Shale, platy; a few concretions towards base	39	100
6	Dolomite, laminated; yellow tan weathering	0.5	61
5	Shale, silty, platy to papery	11.5	60.5
4	Dolomite	1	49
3	Shale, silty, platy	7	48
2	Dolomite	1	41
	Sunkay Member		
1	Shale, platy to blocky, dark grey; somewhat rusty weathering	40	40

Section 4-23. Cardium formation, Grave Flats map-area, Alberta, upper Thistle Creek.

	WAPIABI FORMATION		
3	Grit, grey, with pebbles ¼″-½″, and small concretions 1″-2″ which appear to be detrital, also 2″×6″-1′, concretionary beds; some concretions contain pebbles	8	14
2	Partly covered. Appears to be silty shale with some large 1′ × 2′ limestone concretions with grit; reddish brown weathering	5	6
1	Concretionary bed, capping underlying bed; reddish brown weathering with patches and lenses of gritty sandstone, becoming finer grained towards base	1	1

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CARDIUM FORMATION		
	Sturrock Member		
52	Sandstone, fine-grained, argillaceous streaks, massive bedded, grey; dark rust weathering. Lower contact has unconformable appearance with thin irregular beds of coarse sandstone and broken concretions	6	273
51	Sandstone, laminated, medium-grained, somewhat carbonaceous in zones, light grey, slight greenish cast, massive beds 6″-1′, with 2″ carbonaceous bed in centre, and well-developed small-scale crossbedding	5	267
50	Sandstone, medium- to fine-grained, light to medium grey, becomes darker towards base; buff weathering; homogeneous, thickly bedded	10	262
49	Sandstone, fine-grained, brownish grey, dirty; thinly bedded	2	252
48	Shale, platy to sub-fissile, brownish grey	3	250
47	Sandstone, fine-grained, dark grey; 6″-8″ at top, more thinly bedded towards base, with interbedded thin shale beds in basal 5′ which grade into sandstone towards the northeast	18	247
46	Sandstone, very fine grained; medium grey. Beds 2″-6″, laminated, crossbedded; few poorly developed concretionary bands; tracks and trails. GSC loc. 24794	7	229
45	Sandstone, fine-grained, dirty, brownish grey; laminated, with 2″-6″ beds; some thin shale breaks at top, becomes more massive and less laminated towards base; few poorly developed concretionary bands	6	222
44	Sandstone, fine-grained, dirty, brownish grey; shale, 50%, sub-fissile, more shaly towards base; poorly developed concretions	7	216
43	Shale, silty, dark grey; sandy to gritty with 2″-3″ lensy pebble-conglomerate at 3′. Pebbles ½″-1″ scattered through unit. Some concretionary bands with grit; 1′ concretionary band at base contains pebble-conglomerate which grades into pebbly siltstone and shale towards the northeast	6	209
42	Shale, rubbly, soft, greenish brown	2	203
41	Sandstone, argillaceous, fine-grained, brownish grey, dirty; greenish brown weathering; carbonaceous streaks. GSC loc. 24792	3	201
40	Shale, rubbly, silty, greenish to brownish grey	10	198
39	Sandstone, argillaceous, fine-grained, brownish to greenish grey; greenish weathering; carbonaceous streaks	1.5	188
38	Shale, rubbly, brownish to greenish grey; becoming carbonaceous towards base	3	186.5
37	Sandstone, argillaceous, carbonaceous, fine-grained; fairly massive 3″-6″ beds with silty partings and 2″-6″ beds, more rubbly towards base	3	183.5
36	Shale, silty, brownish grey; becoming carbonaceous towards base	3	180.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
35	Sandstone, carbonaceous, medium grey; irregularly bedded, lensy, brownish grey	0.5	177.5
34	Sandstone, medium- to fine-grained, light grey; finely and evenly laminated, massive 6″ beds, fairly clean	4	177
33	Sandstone, similar to above, more evenly bedded and laminated, with ripple-marks in basal 1′	5	173
32	Sandstone, fine-grained; slightly laminated, more thinly bedded, 2″-4″	5	168
31	Sandstone, fine-grained, brownish grey; slightly laminated; massive; in masses suggestive of channel filling; thin sandstone and shale beds	3	163
	Leyland Member		
30	Sandstone to siltstone, 50%, brownish grey; finely laminated, thinly bedded, ½″-1″ with dark grey silty carbonaceous shale; poorly developed concretions at base	15	160
29	Siltstone, 35%, similar to above, and slightly silty shale with limestone concretions, 2″ × 4″, associated with the siltstone; some concretionary bands towards base	16	145
28	Shale, rubbly, dark grey; slightly rusty weathering; concretions and concretionary bands	10	129
	Cardinal Member (?)		
27	Shale, silty, more massive than overlying beds, dark brownish grey; rusty weathering; much more silty to sandy at base; poorly developed concretions and rare concretions 6″ ×18″, oval, in upper 10′	14	119
	Moosehound Member		
26	Shale, rubbly, silty, brownish green. Sharp contact with overlying beds	2	105
25	Sandstone, fine-grained, medium grey; finely laminated, massive bedded; greenish brown weathering; 3″-4″ concretionary capping, thins to 1′ towards northeast	3	103
24	Shale, rubbly, brownish grey to dark grey	3	100
23	Shale, silty, blocky to crumbly, greenish brown, rusty	9	97
22	Sandstone, lensy, fine-grained; carbonaceous partings and coaly fragments; finely laminated	2	88
21	Sandstone, more massive than overlying beds, somewhat irregularly bedded, coaly laminae, and fragments, with few thin silty partings	4	86
20	Shale, carbonaceous with plant fragments, and few thin coaly streaks, dark brown	2	82
19	Shale, rubbly to blocky, greenish brown	1	80
18	Covered	5	79
17	Shale, silty, rubbly to crumbly, brownish green	3	74
16	Sandstone, silty, soft greenish grey, fine-grained, rusty brown weathering, knobbly	1	71
15	Shale, blocky to rubbly, dark brownish grey	1	70
14	Sandstone, soft, silty, carbonaceous, greenish tan, fine-grained	1	69

Unit	Lithology	Thickness (feet)	Height above base (feet)
13	Shale, blocky, rather soft, brownish grey. Partly covered	3	68
12	Shale, soft, rubbly, brownish green	1	65
11	Limestone concretionary band	1	64
10	Shale, rubbly, silty, brownish grey, somewhat concretionary	2	63
9	Covered	12	61
8	Shale, brownish grey, sub-fissile; brownish weathering; somewhat concretionary	1	49
7	Covered	5	48
6	Sandstone, fine-grained, grey; massive, coaly, plant streaks; dark rusty weathering	1	43
	Ram Member		
5	Sandstone, medium to fine-grained, grey; massive, slightly laminated	4	42
4	Sandstone, fine-grained, light grey; finely and evenly laminated; massive 4″-6″ beds, becomes slightly thinner bedded towards base and shows some crossbedding. Concretionary band, poorly developed at 10′ and base. At base, 2′ sandstone lens with fissile grey shale, channel fill?	20	38
3	Shale, silty, platy, dark grey, with alternating thin siltstones	5	18
2	Sandstone, very fine grained, light grey; dense, massive beds 2″-4″, with plant imprints	13	13
	Blackstone Formation		
	Opabin Member		
24	Siltstone, argillaceous to sandy, massive, dark grey; with limestone concretionary beds, and concretions 3″-4″ × 1′	15	272
23	Shale, silty, blocky; rusty weathering	5	257
22	Shale, silty, blocky to rubbly; rusty weathering; with concretionary zones and beds	18	252
21	Sandstone, fine-grained; finely laminated, and crossbedded; maroon rusty weathering; beds 2″-4″, with few small 1″-2″ concretions	1.5	234
20	Siltstone, grey; finely and evenly laminated at top, with silty shale. Unit becomes more shaly towards base with some poorly developed concretions	12.5	232.5
19	Shale, silty, blocky, dark grey; with common concretionary zones and beds	4	220
18	Shale, silty, blocky, dark grey; rather massive	6	216
17	Concretionary bed containing shale and chert pebbles, rusty to reddish brown weathering	1	210
16	Siltstone, very argillaceous to shaly, dark grey, platy; irregularly bedded; finely laminated; crossbedded; reddish brown concretions and concretionary beds	10	209
15	Siltstone, finely laminated; crossbedded, well bedded; shale and beds of reddish brown concretions	12	199
14	Siltstone and alternating platy shale, dark grey; few concretionary bands	10	187

Unit	Lithology	Thickness (feet)	Height above base (feet)
13	Sandstone, fine-grained, light grey; homogeneous, to slightly laminated; beds 1″-6″; slightly calcareous; rare concretionary bands, poorly developed; ripple-marks; *Inoceramus*	7	177
12	Sandstone, similar to above, with 1″-3″ shaly partings; finely laminated and crossbedded	4	170
11	Sandstone, fine-grained, dirty grey; finely laminated; two 2″ concretionary bands. Basal 1′ is shaly, thinly bedded	3	166
10	Siltstone, argillaceous, dark grey; irregularly bedded; concretionary band	4	163
9	Sandstone, light grey, fine-grained; finely laminated, crossbedded; with silty laminae and partings and some limestone concretionary beds	4	159
8	Siltstone, sandy, banded appearance, quite sandy at top, becoming argillaceous towards the base, dark grey; rusty weathering; few 1″-2″ concretionary bands. GSC locs. 25078, 24793	33	155
7	Shale, silty	10	122
6	Siltstone, argillaceous, banded; slightly irregularly bedded; concretions and concretionary bands	13	112
5	Siltstone, as above; some hard well-indurated, finely laminated bands, 10%; 3″×6″ concretions and concretionary bands, ½″-1″	11	99
4	Shale, silty, blocky, dark grey; bedded and banded appearance; rare 3″ concretions	7	88
	Haven Member		
3	Siltstone, argillaceous, dark grey; evenly bedded, massive; rusty weathering; with few small concretions. More shaly in basal 6′ but has hard 3″ siltstone bed at base	16	81
2	Shale, silty, platy, to argillaceous siltstone with few harder bands. Unit has banded appearance, weathers rusty, and contains few concretions	15	65
1	Shale, silty, platy, dark grey; rusty weathering; some large 8″×2′ concretions	50	50

Section 4-27. Chungo member, Pembina Forks map-area, Alberta, Brazeau River, 1 mile below Coast Creek, east flank of syncline.

	BRAZEAU FORMATION		
1	Sandstone, medium-grained, greenish grey; massive; carbonaceous inclusions	15 est.	15
	WAPIABI FORMATION		
	Nomad Member		
30	Covered	25	488.5
29	Sandstone, fine-grained, dark greenish grey; homogeneous; massive at top, more thinly bedded towards base	7	463.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Shale, silty, grey, greenish cast; with 2′ sandstone, fine-grained, greenish, at base	9	456.5
27	Shale, silty, greenish grey, rubbly to thinly bedded; and sandstone, 30%, laminated, fine-grained	9	447.5
26	Shale, silty, brownish to greenish grey; thinly bedded with some siltstone and concretionary bands. Basal 3′ more silty and massive bedded	15	438.5
25	Shale, greenish to brownish grey, with thin silty bands; weathers rusty green; bedded appearance	12	423.5
24	Shale, rubbly to blocky, dark grey, brownish; siltstone in basal 8′, fine-grained, laminated, ½″-1″ beds	29	411.5
23	Concretionary band with gritty, shaly sandstone and few ¼″-½″ chert pebbles	2	382.5
22	Shale, silty, dark grey; blocky; to argillaceous siltstone. Rare pebbles disseminated through silt	9	380.5
	Chungo Member		
21	Sandstone, medium-grained, grey, greenish to brownish cast; carbonaceous inclusions; massive	2.5	371.5
20	Shale, greenish grey; thinly bedded	3	369
19	Sandstone, in 2″-6″ beds, fine-grained; greenish brown weathering	2	366
18	Shale, silty, rubbly, greenish grey	2	364
17	Sandstone, in 2″-6″ beds, fine-grained, alternating with rubbly 1″-2″ shale, 30%	7	362
16	Siltstone, 5%, and shale, becoming more sandy and massive towards base, laminated. Basal 6′ is glauconitic	12	355
15	Sandstone, grey, fine-grained; laminated, in 4″-1′ beds, with shale, 10%, rubbly	7	343
14	Siltstone, argillaceous, dark grey; crossbedded, irregularly bedded to massive, 8″-12″ beds; shaly in interval 16′-19′; rare concretions in siltstone	25	336
13	Siltstone, argillaceous, dark grey; massive; greenish to brownish grey weathering	19	311
12	Siltstone, argillaceous, with concretionary bands at top; massive to thinly bedded	35	292
11	Siltstone, harder, massive, with five bands of concretions and sandy glauconite. Basal concretionary bed is 2′ thick	11	257
10	Siltstone, argillaceous, dark grey; massive; rusty spots, laminated, well indurated	11	246
9	Concretionary bed	1	235
8	Siltstone, argillaceous; massive; rusty spots, rusty green weathering, with concretions	17	234
7	Shale, silty, blocky, to argillaceous siltstone, less resistant than overlying beds. Some concretions	9	217
6	Siltstone, argillaceous, dark grey, with 6″ × 1′ concretions at base	4	208
	Hanson Member		
5	Shale, thinly bedded; slightly rusty weathering; concretions 4″-6″ × 1′-2′	85	204
4	Shale, thinly bedded, silty, dark grey; some concretions 3″ × 6″-8″	18	119

Unit	Lithology	Thickness (feet)	Height above base (feet)
3	Shale, rubbly to thinly bedded, dark grey; more silty in upper 15′; concretions 3″ × 6″; pelecypods	60	101
2	Siltstone, ½″-1″ beds, alternating with shale, 60%; concretions 2″-3″ × 6″-12″	29	41
1	Shale, silty, dark grey; concretions 6″ × 1′	12	12

Section 4-31. Cardium formation, Pembina Forks map-area, Alberta, Cardinal River, 4 miles upstream from Brazeau River.

	WAPIABI FORMATION		
7	Shale, rusty weathering; some laminated siltstone; few large 6″×18″ concretions. Lies sharply on underlying unit	8	22
6	Shale, dark grey; rusty weathering; with ¼″-¾″ pebbles; concretionary grit, 20%	1	14
5	Shale, silty, dark grey; rusty weathering; with few lenses of grit; few pebbles scattered throughout	3	13
4	Concretionary coarse-grained sandstone; reddish brown weathering; with some shale	2	10
3	Shale, silty; rusty weathering; few pebbles and grit lenses	4	8
2	Concretions, 6″×2′; reddish brown weathering; with sandy shale and pebbles	1	4
1	Shale, silty, blocky with 4″ zone of pebbles at base, ⅛″-1″	3	3
	CARDIUM FORMATION		
	Sturrock Member		
33	Sandstone, fine-grained, grey; homogeneous, massive 4″-1′ beds; rusty tan weathering. Upper surface is irregular, bumpy, has scattered pebbles and top 2″-3″ is dirty, somewhat gritty	4	242
32	Sandstone, fine-grained, thinly bedded; and silty shale	1	238
31	Sandstone, fine-grained, brownish grey; homogeneous, massive bedded; rusty tan weathering	7	237
30	Shale, silty; and thinly bedded sandstone	1	230
29	Sandstone, fine-grained, brownish grey; massive	2	229
28	Shale, silty; and thinly bedded sandstone, fine-grained, laminated	2.5	227
27	Sandstone, fine-grained, grey; massive	1.5	224.5
26	Sandstone, laminated; and shale, 30%	4	223
25	Sandstone, silty, fine-grained, grey; brownish grey weathering; and shale, 40%, silty; poorly developed concretionary beds	6	219
	Leyland Member		
24	Siltstone, grey; laminated, crossbedded, some harder beds, beds not too well defined; and shale, 25% 1′ hard siltstone at base	6.5	213
23	Siltstone, argillaceous, to silty shale, dark grey; few well indurated siltstone beds with poorly developed concretions. Four-inch siltstone bed at base	6.5	206.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
22	Siltstone, argillaceous; rusty weathering; blocky to bedded; few well indurated siltstone beds and concretions	7	200
21	Shale, thinly bedded, dark grey; with few siltstone beds, not well indurated	8	193
20	Shale, thinly bedded, to blocky, dark grey; slightly rusty weathering; with concretions, 3″×2′, irregular, reddish brown weathering	21	185
19	Shale, silty, blocky to thinly bedded; rusty weathering; rare large irregular concretions	29	164
18	Concretionary zone with 40% silty rusty shale and gritty sandstones. Some pebbles in concretions	5	135
	Cardinal Member		
17	Siltstone, argillaceous, dark grey; massive; greenish rust weathering, becomes more bedded towards base, some concretions near top and large 1′×3′ concretions at 15′ and 12′. Grades into underlying bed	23	130
	Kiska Member		
16	Shale, silty, blocky, becoming rubbly at base with 3″×18″ concretions	12	107
	Moosehound Member		
15	Shale, brownish grey; greenish brown weathering; thinly bedded; sandy concretionary zone in top foot, poorly developed concretionary zones below	3	95
14	Sandstone, argillaceous, fine-grained, laminated, medium grey; crossbedded; greenish tan weathering, massive	4.5	92
13	Shale, greenish grey; greenish brown weathering; grading into brown carbonaceous shale with plants	1.5	87.5
12	Coal	2	86
11	Sandstone, fine-grained, dirty grey; greenish brown weathering; coal fragments; becoming very silty at base	2	84
10	Shale, silty, blocky with some coaly shale and pelecypods. GSC loc. 25073	2	82
9	Sandstone, fine-grained, medium grey; greenish brown weathering; laminated; carbonaceous inclusions; crossbedded at base and contains plants. GSC loc. 24790	2	80
8	Shale, brown, carbonaceous in zones	2	78
7	Sandstone, argillaceous, carbonaceous, dirty; brown weathering; massive, laminated; crossbedded at base	1.5	76
6	Shale, brown, silty with coal lenses throughout, with 1′ coaly siltstone at base, "cut and fill" base	6.5	74.5
	Ram Member		
5	Sandstone, fine-grained, grey; laminated, massive, 4″-3′ beds; buff weathering; crossbedded "cut and fill" at 20′, 23′; more laminated at base, GSC loc. 25072	37	68

Unit	Lithology	Thickness (feet)	Height above base (feet)
4	Sandstone, very fine-grained, bluish grey; laminated, crossbedded, 1″-4″ beds with silty shale, 50%; more silty in basal 7′	16	31
3	Sandstone, fine-grained, grey; massive, laminated, crossbedded; with shale parting above basal 1′	6	15
2	Alternating shale, and thinly bedded sandstone, 50%, fine-grained, laminated, crossbedded	2.5	9
1	Sandstone, fine-grained, grey; laminated, crossbedded, massive	6.5	6.5
	BLACKSTONE FORMATION		
9	Siltstone, blocky, some well indurated 1″-2″ beds; rusty weathering; with concretions	7	42
8	Sandstone, fine-grained; laminated, crossbedded, large lensy masses; poorly developed concretions	3	35
7	Sandstone, fine-grained; thinly bedded, laminated, more massive at base, crossbedded; with some shale, 25%	5	32
6	Sandstone, very fine grained; irregularly bedded, laminated; and shaly siltstone	4	27
5	Siltstone, thinly bedded, fairly hard, ½″-1″; beds have the appearance of massive siltstone; rare concretions, GSC loc. 25077	6	23
4	Siltstone, laminated, hard to shaly; some shale; concretions at top	5	17
3	Siltstone, silty, argillaceous, to silty shale	5	12
2	Siltstone, laminated, hard; and shale, concretionary at top	3	7
1	Shale, silty, dark grey	4	4

Section 4-32. Cardium formation, Pembina Forks map-area, Alberta, Cardinal River, 6 miles upstream from Brazeau River.

	WAPIABI FORMATION		
34	Concretions, 35%, reddish brown weathering, gritty with pebbles, and shale; basal 1½′ is argillaceous siltstone with few pebbles; pelecypod fragments	4	4
	CARDIUM FORMATION		
	Sturrock Member		
33	Sandstone, fine-grained, brownish grey, dirty; tan weathering; massive, homogeneous to slightly laminated, some large crossbedding	6	268.5
32	Sandstone, fine-grained, grey; laminated, thinly bedded, 50%, and alternating shale, silty	3	262.5
31	Sandstone, fine-grained, brownish grey, homogeneous, 4″-12″ beds, crossbedding; some thinly bedded sandstone and shale breaks; suggestion of concretionary beds	7	259.5
30	Sandstone, fine-grained, brownish grey, dirty; homogeneous; beds 2″-6″ separated by silty shale; 20%	7	252.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Leyland Member		
29	Siltstone, argillaceous; beds 2"-3", fairly well indurated; poorly developed concretions; becomes slightly more shaly towards base	21	245.5
28	Shale, silty, blocky; thinly bedded; with few hard siltstone beds and poorly developed concretionary beds	7	224.5
27	Shale, silty; thinly bedded; with numerous concretions, 2" × 1½' to beds	8	217.5
26	Shale, very silty, blocky, dark grey; thinly bedded to massive; rare poorly developed concretions	8	209.5
25	Shale, silty, dark grey; thinly bedded, with concretions 6"×2' and some smaller	34	201.5
24	Shale, very silty, hard, platy, bedded; rusty weathering; with large concretions and concretionary band 6"-8" thick at top, with few ¼"-1" pebbles	10	167.5
23	Siltstone, argillaceous; massive, with shale beds, ½"-1", and well-indurated 1" siltstone beds. Unit has banded appearance	8	157.5
22	Concretionary zone, sandy; reddish brown weathering; with pebbles. Six inches of shale at base with numerous chert pebbles, ¼"-1"	1.5	149.5
	Cardinal Member		
21	Siltstone, argillaceous, dark grey; massive; rusty to greenish weathering with some concretions; more shaly in interval 13'-15'; in basal 10' is silty shale	30	148
	Kiska Member		
20	Mostly covered. Shale	8	118
	Moosehound Member		
19	Sandstone, argillaceous, brownish grey; finely laminated, crossbedded; greenish brown weathering; silty laminae	3	110
18	Shale, rubbly, carbonaceous, brown	0.5	107
17	Shale, coaly	0.5	106.5
16	Shale, rubbly, brown; greenish brown weathering	1	106
15	Shale, coaly	0.5	105
14	Shale, rubbly, carbonaceous, brown	1.5	104.5
13	Sandstone, lenses out up and down slope, fine-grained, brownish grey; coaly fragments at top; massive; greenish tan weathering	1	103
12	Shale, rubbly, greenish brown. Partly covered	3	102
11	Siltstone, carbonaceous, argillaceous, brown; greenish brown weathering; laminated, thinly bedded	3	99
10	Partly covered. Shale, blocky, greenish brown; some coal	4	96
9	Sandstone, fine-grained, brownish grey; laminated, crossbedded; greenish tan weathering; massive, coaly fragments	3	92
8	Shale, greenish brown; greenish weathering, to dark grey, rusty weathering; thinly bedded; some small concretions	3	89

Unit	Lithology	Thickness (feet)	Height above base (feet)
7	Concretionary bed with pelecypods and gastropods. GSC loc. 24796	0.5	86
6	Shale, very coaly at top, less so at base	1	85.5
5	Siltstone, extremely coaly	0.5	84.5
	Ram Member		
4	Sandstone, grey, fine-grained; laminated to homogeneous, massive, large crossbedding; 1′ coarse sandstone with pebbles at 23′; pelecypods near base	33	84
3	Sandstone, thinly bedded, silty; and shale, 40%, in alternating 1″-2″ beds, becomes more silty towards base, with concretionary bands	18	51
2	Sandstone, grey, fine-grained; laminated, crossbedding, massive; thinly bedded sandstone and shale in interval 5′-7′, more massive at base; rusty tan weathering	14	33
1	Sandstone, grey, fine-grained, to siltstone; laminated, crossbedded, 2″-6″ beds; tan weathering; shale partings, 25%	19	19
	BLACKSTONE FORMATION		
35	Siltstone, argillaceous, bedded, dark grey; rusty weathering; some 6″ × 1′ concretions; becomes more shaly towards base	19	19

Section 4-43. Cardium formation, on Mackenzie Creek, 1½ miles upstream from McLeod River.

	WAPIABI FORMATION		
23	Concretionary sandstone, coarse-grained; reddish brown weathering	15 approx.	15
	CARDIUM FORMATION		
	Sturrock Member		
22	Sandstone, fine-grained, grey; slightly laminated, massive; tan weathering; some large crossbedding, slightly concretionary in a few beds. Some shale and thin-bedded sandstone associated with crossbedding. 6″ shale, silty, platy, at 18′	32	232
	Leyland Member		
21	Siltstone, argillaceous, bedded, dark grey; with 1′ of sandstone at 1′, 6″ at 3′, and 6″ at 5′. Sandstone, fine-grained, laminated	6	200
20	Inaccessible, siltstone, argillaceous, dark grey; bedded; with rare sandstone bands near top, and concretions 4″ × 6″ - 1′ towards base. Unit has massive appearance	40 est.	194

Unit	Lithology	Thickness (feet)	Height above base (feet)
19	Siltstone, argillaceous, dark grey; massive; numerous concretions, and zone of pebbles, ¼"-1½", at base	9	154
18	Shale, silty, somewhat rubbly; thinly bedded; with thin beds of well-indurated siltstone, concretionary	6	145
17	Shale, slightly rubbly, dark grey; thinly bedded; rusty weathering	17	139
16	Shale, very silty; bedded; rusty weathering	6	122
	Cardinal Member		
15	Siltstone, argillaceous, dark grey; massive to bedded; greenish rust weathering; concretionary beds	12	116
	Moosehound Member		
14	Sandstone, silty, soft, greenish grey; greenish rust weathering; becomes shaly in part, concretionary.	2.5	104
13	Shale, rubbly, silty, light greenish grey; rusty on weathered surface	3	101.5
12	Sandstone, fine-grained, silty, rather soft, light grey, greenish tinge; not well bedded	2	98.5
11	Shale, rubbly, brown	1	96.5
10	Sandstone, silty, light grey, fine-grained; lensy	1.5	95.5
9	Shale, silty, brown; greenish brown to rusty weathering; few small concretions; very carbonaceous from 8' to 10'	10	94
8	Covered. Talus contains carbonaceous shale near top, underlain by greyish and yellowish brown shale	7	84
7	Shale, silty, blocky, grey; yellowish brown weathering	1	77
6	Siltstone, soft, light grey, sandy; topped by concretionary bed	5	76
5	Sandstone, grey, fine-grained; greenish tan weathering; carbonaceous and coaly inclusions, concretionary spots	2	71
4	Partly covered. Shale, blocky, brown	18	69
3	Sandstone, fine-grained to medium-grained at base, grey; laminated, massive; brownish grey weathering; carbonaceous inclusions	12	51
2	Shale, blocky, brown to brownish grey; coaly in basal 1'	5	39
	Ram Member		
1	Sandstone, fine-grained, laminated, rather dirty at top, cleaner towards base. Beds are 6"-1½', rusty tan weathering. Basal contact is sharp with no typical transition beds	34	34
	Lies on approximately 150' of bedded silty shale (inaccessible) with concretionary beds, ½"-2", with very few concretions. Whole zone is quite silty.		

Section 4-54. Sunkay member, Blackstone formation, Grave Flats map-area, Alberta, Brazeau River, upstream from Lightning Flats, sec. 26, tp. 44, rge. 20, W5. Described by R. J. W. Douglas.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Vimy Member		
40	Shale, fissile, black	3	504
39	Dolomite, in 2″ beds with 1″-2″ shale partings. Dolomite is aphanitic, dark grey, finely laminated, silty, argillaceous	1	501
38	Shale, fissile, black, with 2″ limestone at base; some fine silt laminae in the shale	2	500
37	Shale, fissile, black	13	498
36	Shale, with 3″ limestone concretions and small *Inoceramus labiatus* in the shale	2	485
35	Shale	5	483
34	Covered	15	478
33	Shale, fissile, black; with silt laminations and a few 2″ silty limestone bands at base; single limestone concretion near base	8	463
32	Shale, fissile, black; with single limestone concretion	5	455
31	Shale, fissile, black; similar to above but weathering rusty at top of exposure	24	450
	Sunkay Member		
30	Siltstone, grey, fine-grained; thinly bedded; interbedded gradationally with 50% silty shale in ½″-2″ beds; rusty weathering	8	426
29	Shale, and 20% siltstone as above; ½″ bands	5	418
28	Shale, and 30% siltstone	5	413
27	Siltstone, and 60% shale, ½″ alternating bands	19	408
26	Covered	9	389
25	Siltstone and shale; 60% shale at top, becoming less silty in basal 14′, 80% shale	22	380
24	Shale, and 40% thin siltstone beds; several flat limestone concretions, 4″ × 1′; brown weathering; sharp contact at top and base	12	358
23	Shale, fissile, grey; rusty weathering; rare 2″ grey concretions	16	346
22	Shale, and 30% siltstone; gradational into overlying beds	11	330
21	Shale, fissile, grey; rusty weathering; rare ½″ siltstone beds	21	319
20	Shale, and 20% siltstone; rare 4″ concretions	11	298
19	Shale with about 5% siltstone; fairly sharp contact at base	9	287
18	Shale and siltstone; siltstone 30% in top 5′ decreasing to 10% at base. Single large concretion, 6″×2′ at base	16	278
17	Shale, and 20% siltstone; decreasing downward	14	262
16	Shale, and 20% siltstone; siltstone decreasing downward, 6″×2′ limestone slabs in base	15	248

Unit	Lithology	Thickness (feet)	Height above base (feet)
15	Siltstone and 50% shale; shale decreasing downward, somewhat gradational with underlying beds; siltstone beds are 1"-3" thick at top and 1" thick at base; rusty weathering	15	233
14	Shale, fissile; rusty weathering; several 4"×1' concretions	37	218
13	Shale, fissile; 15% thin ½" siltstone beds, and 2×4' kettle concretions	7	181
12	Shale, fissile, grey; rusty weathering, with a few flat 2"×1' concretions; thin siltstones, less than 5%; 1" beds, brown weathering, iron stain	36	174
11	Siltstone, argillaceous, rubbly; massive bedded; with 2" fine-grained sandstone 2' below top, and line of 2'×6' kettles 6' below top; greenish grey weathering	14	138
10	Shale, silty, with several 1"-2" siltstone bands	4	124
9	Shale, fissile, grey; rusty weathering; with some 2"×6" concretions	16	120
8	Siltstone, argillaceous, massive, with 2" bed of concretions near top; 4×8' to 6×6' zone of kettle concretions below; grades into underlying beds	20	104
7	Shale, banded	35	84
6	Siltstone, argillaceous, massive; alternating shale beds, ½"-3" thick, 70% siltstone, fine-grained, finely laminated, decreasing downward	20	49
5	Shale, fissile, dark grey; fine silt laminae	6	29
4	Shale, fissile, softer than overlying and underlying beds	2	23
3	Shale, fissile, dark grey; more massive	8	21
2	Shale, fissile, dark grey	6	13
1	Shale, silty, and siltstone; rusty weathering	7	7
	MOUNTAIN PARK FORMATION		
	Shale, rubbly, greenish brown weathering	7	18
	Sandstone, thins down slope from 2.5 to 1'	2.5	11
	Shale, green; thinly bedded with 4"×1' concretions	2.5	8.5
	Sandstone, massive	6	6

Section 5-4. Cardium formation, Pierre Greys map-area, north side of Muskeg River, 1½ miles above MacDonald Flats. Excellent section exposed across river but inaccessible because of high water.

	WAPIABI FORMATION		
3	Shale, silty, rubbly to blocky, dark grey; rusty weathering; bedded, with large concretions 6"×1'	45	91
2	Shale, rubbly to platy; with few small concretions at top. GSC loc. 27076	43	46
1	Conglomerate, sandy and shaly matrix, concretionary; reddish brown weathering, irregularly bedded; chert pebbles ⅛"-1"	3	3

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CARDIUM FORMATION		
	Contact is sharp but zone of pebbles 3″-4″ occurs at top of sandstone		
	Sturrock Member		
34	Sandstone, grey, fine-grained; massive, homogeneous with 2″-3″ chert-pebble conglomerate at base	6.5	225
	Moosehound Member		
33	Shale, coaly	1	218.5
32	Shale, rubbly, olive-grey; rusty to reddish brown weathering	4.5	217.5
31	Shale, carbonaceous, black to dark grey	1	213
30	Shale, very silty, dark grey; blackish weathering	3	212
29	Sandstone, argillaceous; rusty weathering; pinches and swells	2	209
28	Shale, rubbly, carbonaceous; limonitic weathering; few coaly patches	10	207
27	Sandstone, greenish brown; reddish brown weathering; concretionary, coaly streaks at base, somewhat irregularly bedded	4	197
26	Shale, olive-grey to carbonaceous; very coaly at top	2.5	193
25	Sandstone, concretionary, silty; greenish brown weathering	1	190.5
24	Shale, silty, rubbly, olive-grey	11.5	189.5
23	Siltstone, argillaceous, greenish brown; rusty weathering	1	178
22	Shale, silty, rubbly, partly covered	14	177
21	Concretionary zone, very silty and rubbly	1	163
20	Shale, partly covered, silty, argillaceous, olive-grey	16	162
19	Siltstone, argillaceous, greenish brown; coaly streaks, concretionary; grading into sandstone at base	5	146
18	Shale, partly covered, silty, argillaceous, olive-grey	19	141
17	Siltstone, shaly, rubbly, greenish brown to grey; concretionary at top	5	122
16	Shale, rubbly, olive-grey; carbonaceous to coaly in basal 4′	9	117
15	Siltstone, argillaceous; carbonaceous streaks	1	108
14	Shale, partly covered, rubbly, olive-grey	5	107
13	Sandstone, grey, fine-grained; laminated; rusty orange weathering, carbonaceous streaks in upper 3″	2	102
12	Shale, mostly covered	12	100
11	Sandstone, inaccessible	2	88
10	Shale, inaccessible	1	86
	Ram Member		
9	Sandstone, rusty weathering; bedding 1′-3′. Inaccessible. Two feet of conglomerate at base, pebbles ¼″-1″	20	85

Unit	Lithology	Thickness (feet)	Height above base (feet)
8	Sandstone, grey, fine-grained; rusty to tan weathering; homogeneous to slightly laminated, massive bedded, 1′ to 3′, micaceous, appears to become dirtier towards base, shows some fine even laminations on weathered surface; rare pebbles ¼″-½″ scattered along bedding planes, suggestion of crossbedding in a few places. Six-inch shaly break at 14′. Poorly developed concretionary zone approximately 3′ above base	28	65
7	Shale, rubbly, dark grey; with concretionary sandstone in 3″-6″ beds	2	37
6	Sandstone, grey, fine-grained; slightly laminated, more shaly interbeds in basal 3′. Partly covered	8	35
5	Sandstone, grey; laminated; poorly developed concretions; with few shaly interbeds	4	27
4	Sandstone, fine-grained; massive 1′-2′ beds, slightly laminated and crossbedded; concretionary towards base; rests sharply on underlying unit	4.5	23
3	Shale, rubbly, dark grey; and sandstone, 40% interbedded, beds 2″-6″. Sandstone, fine-grained, grey; laminated	4.5	18.5
2	Sandstone, fine-grained; laminated, crossbedded; concretionary zones, with some silty dark grey shale, 20%	6	14
1	Sandstone, and shale, 50-50. Sandstone, fine-grained, laminated, grey, crossbedded; shale, silty, dark grey. Beds 2″-4″. Few concretionary zones	8	8
	End of exposures.		

Section 5-5. Marshybank sandstone, Pierre Greys map-area, Alberta, north side of Muskeg River, 2 miles above MacDonald Flats.

7	Sandstone, fine-grained; homogeneous; reddish to rusty tan weathering; with 3″-4″ conglomerate at 6′, pebbles ⅛″-1½″, beds 4″-1′	34	78
6	Siltstone, argillaceous to shaly; bedded; large concretions 8″×2′; few channel fillings, 3′×5′, of sandstone; few sandstone lenses	8	44
5	Shale, very silty, bedded, dark grey; zone of silty knobbly concretions at 7′; more shaly at base	11	36
4	Siltstone, argillaceous, shaly; knobbly concretions; shaly at base; traces of worm burrows near base. GSC loc. 27081	7	25
3	Sandstone, bluish grey, fine-grained; homogeneous; poorly bedded. Basal 4′ are interbedded with shale	6	18
2	Shale, very silty, dark grey; bedded; row of concretions at 5′; worm burrows at top	8	12
1	Siltstone, argillaceous, dark grey; bedded; channel fillings	4	4
	End of exposures.		

Unit	Lithology	Thickness (feet)	Height above base (feet)

Section 5-6. Chungo member, Wapiabi formation, Pierre Greys map-area, Alberta, 2½ miles above MacDonald Flats on Muskeg River.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
	Sandstone, massive, greenish weathering. Inaccessible	30 est.	232
	WAPIABI FORMATION		
	Nomad Member		
12	Shale	20 est.	202
11	Shale, with concretionary beds	70 est.	182
	Chungo Member		
10	Siltstone to shale; massive to bedded, brownish grey weathering; large concretions, 1½′ × 2′	16	112
9	Shale, silty; becoming more resistant at top	12	96
8	Sandstone, fine-grained; tan weathering; laminated to homogeneous; beds 4″-1′	42	84
7	Sandstone, fine-grained; laminated; beds 8″-1′ separated by shale partings	7	42
6	Siltstone, sandy, grey; laminated, massive	7	35
5	Sandstone, silty, very fine grained; well indurated, massive at top, becoming slabby to platy at base; shaly from 9′-10′; glauconitic in lower part	14	28
4	Siltstone, argillaceous, grey; thickly bedded; some concretions	4	14
3	Siltstone, argillaceous, grey; laminated, bedded; shows some crossbedding	4	10
2	Shale, very silty, dark grey	4	6
1	Siltstone, argillaceous, brownish grey; laminated; concretions	2	2
	End of exposure.		

Section 5-17. Dunvegan formation, east half of Adams Creek map-area, Alberta, on southeast side of Berland River at Adams Creek.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	KASKAPAU FORMATION		
3	Shale, hard, papery to platy, dark grey; rusty weathering; some poorly developed concretionary zones; some fine siltstone bands. Grades into underlying unit	17	65
2	Shale, silty, blocky, dark grey; bedded; rusty weathering; some beds of argillaceous siltstone	31	48
1	Shale, platy, hard at top, becoming more papery towards base; rusty weathering. Rests sharply on underlying unit	17	17

Unit	Lithology	Thickness (feet)	Height above base (feet)
	DUNVEGAN FORMATION		
36	Siltstone, argillaceous; bedded; greenish grey weathering; with thin well-indurated beds and a few poorly developed concretions. Whole unit has banded appearance and grades into underlying unit	10	381
35	Shale, very silty at top, rubbly at base, banded with well-indurated siltstone; rusty weathering. Rests sharply on underlying unit	18	371
34	Sandstone, brownish grey, fine-grained; greenish tan weathering; massive; beds not well defined. Top surface is irregular, base is sharp	8	353
33	Shale, 35%, and sandstone as above in beds ½"-4" thick	2.5	345
32	Siltstone, sandy, massive, dirty, dark grey; greenish grey weathering; somewhat bedded; 6"-8", poorly developed concretionary zones	6.5	342.5
31	Shale, rubbly to platy, dark grey; bedded; few concretionary beds ½"-1"; grades into underlying unit	11	336
30	Siltstone, argillaceous and arenaceous, dirty; massive; some suggestion of bedding concretions towards base; grades into underlying unit	6	325
29	Shale, blocky, with few thin hard beds towards top, rubbly at base, dark grey; rusty weathering	36	319
28	Shale, fairly blocky at top, more rubbly at base; rusty weathering; rare small concretions	19	283
27	Shale, dark grey; rusty weathering; blocky at top, becomes rubbly to sub-fissile at base, very rare thin siltstones near top. Rare concretions, 6"×1', oval, reddish brown weathering	48	264
26	Sandstone, silty, fine-grained, dirty; somewhat wavy bedded, 3"-4" beds, with interbedded shale; numerous burrow structures	10	216
25	Shale, rubbly to blocky, dark grey; with concretionary zones and siltstone, 10%, at top. Siltstone is sandy, greenish brown; thinly bedded, somewhat concretionary	10	206
24	Siltstone, argillaceous, dark grey to greenish brown; massive to bedded; rusty weathering. Top and base appear gradational	5	196
23	Partly covered. Shale, bedded, platy to rubbly, dark grey; few 1" concretionary beds near top	11	191
22	Siltstone, sandy, grey, dirty; trace of laminations, massive, some suggestion of wavy bedding	3	180
21	Siltstone, thinly bedded, ⅛"-¼", argillaceous, dirty, with some bands of well-indurated siltstone, shaly interbeds, grades into underlying unit	6	177
20	Shale, silty, platy, somewhat soft, brownish grey	7	171
19	Siltstone, argillaceous, sandy, greenish brown; greenish rust weathering; massive, knobby weathering, small concretions on upper surface. Basal 1' is more sandy	2.5	164
18	Shale, silty, platy, rather soft, brownish grey; becomes less silty in basal 4'; some small 1" concretions	7.5	161.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
17	Siltstone, argillaceous, grey; brown to rusty weathering; thinly bedded; small concretions and thin concretionary beds. Some shaly interbeds. Grades into underlying unit	5	154
16	Shale, rubbly to platy, grey; with small 1" concretions	8	149
15	Sandstone, silty and argillaceous, greenish brown; greenish rust weathering; massive at top and base with 1' shale and thinly bedded sandstone in middle	3.5	141
14	Shale, silty, rubbly to blocky, grey; brownish grey weathering; few concretions and silty lenses	4	137.5
13	Sandstone, fine-grained; laminated beds 3"-6" with uneven surfaces, and interbedded shale, 15%; greyish brown weathering	5	133.5
12	Siltstone, shaly, grey; bedded; some concretionary siltstone beds; grades into underlying unit	4	128.5
11	Shale, blocky, dark grey; bedded; with 1"-2" concretionary beds	13	124.5
10	Sandstone, fine-grained, greenish brown	1	111.5
9	Shale, rubbly, dark grey	3	110.5
8	Sandstone, grey, fine-grained, dirty; brownish grey weathering; laminated, beds 6"-18". Some interbedded shale and thinly bedded sandstone, 10%. Sandstone becomes thinly bedded (flaggy) towards base and somewhat cleaner. Unit does not have massive appearance	14	107.5
7	Sandstone, as above but in large rounded kettle-like forms with curved bedding. Interbedded shale and thinly bedded sandstone, 20%	4.5	93.5
6	Sandstone, argillaceous, silty, greenish brown; 50%; and shale, bedded, grey, grades into underlying unit	6	89
5	Shale, rubbly, grey; with less than 5% sandstone in upper 5'; rusty reddish brown weathering; concretionary beds. Unit has striped appearance	26	83
4	Shale, very silty, blocky, dark grey; rusty weathering; somewhat bedded, with rare large concretions	7	57
3	Shale, rubbly, dark grey; rare concretions	26	50
2	Siltstone, sandy, dirty, dark grey; massive at top, somewhat bedded toward base; large crossbeds at base; grades into underlying unit	7	24
1	Shale, very silty and massive at top, grading downward into rubbly shale; rusty weathering; few 2"-3" bands of concretions	17	17
	Remainder of exposure is folded and faulted.		

Section 5-19. Smoky group, Dunvegan and 'Ft. St. John' formations, Moon Creek map-area, Alberta, Little Berland River.

SMOKY GROUP

Overlying beds not exposed.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	WAPIABI FORMATION		
	Chungo Member		
	Upper contact not visible.		
50	Not well exposed. Sandstone, grey, fine-grained; weathers rusty brown; laminated, deeply weathered. Beds 1″-3″	5	1,466
49	Sandstone, grey, fine-grained; rusty brown weathering; laminated, beds 2″-6″, deeply weathered	4	1,461
48	Covered	7	1,457
47	Sandstone, similar to above, beds 1″-4″. Not well exposed in basal 8′	14	1,450
46	Sandstone, fine-grained; laminated, massive, beds 1′-2′; rusty brown weathering	21	1,436
45	Covered. Appears to be sandstone, fine-grained, grey to brownish grey, dirty; more thinly bedded than above, 2″-4″	8	1,415
44	Sandstone, grey, fine-grained, dirty; brownish grey weathering; beds 4″-10″. One-foot zone of thinly bedded sandstone at 5′. Some concretionary zones in basal 6′	17	1,407
43	Covered	4	1,390
42	Sandstone, fine-grained, as above; 4″ concretionary zone in centre with shale	2.5	1,386
41	Sandstone, silty, blocky, dark grey; irregularly bedded	2	1,383.5
40	Sandstone, finely laminated, grey; rusty tan weathering; suggestion of crossbedding; beds 4″-8″	3.5	1,381.5
39	Sandstone, silty, grey; irregularly bedded; 8″ sandstone at 2′; trace of worm burrows	4	1,378
38	Sandstone, grey, fine-grained; laminated, beds 6″-10″	2.5	1,374
37	Siltstone, sandy, grey, dirty; irregular to wavy bedding; grades into underlying unit	6.5	1,371.5
36	Shale, very silty at top, becoming less so towards base, blocky, dark grey; few small silty concretions, 1″-2″	12	1,365
35	Siltstone to sandstone, argillaceous, grey; rusty tan weathering; poorly bedded	4	1,353
34	Shale, very silty, to argillaceous siltstone, blocky, dark grey; rusty weathering	13	1,349
33	Covered	14	1,336
32	Shale, blocky, brownish grey; with thin sandstone, 10%, and concretionary zones	5	1,322
31	Sandstone, grey, fine-grained; laminated, massive; rusty weathering	2	1,317
30	Sandstone, 60%, grey, fine-grained; laminated; rusty-orange weathering; and shale, silty. Sandstone is more abundant in basal 4′. Beds are 1″-2″ at top, 4″-6″ near base	16	1,315
29	Shale to siltstone, blocky, grey; bedded; rusty weathering	12	1,299
28	Siltstone, sandy, grey; rusty weathering; somewhat bedded; grades downward into underlying unit	15	1,287
	Hanson Member		
27	Shale, very silty, to siltstone, argillaceous, grey; bedded; some small 1″-2″ concretions; glauconite	11	1,272
26	Covered	164	1,261

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Thistle Member		
25	Shale, rubbly to blocky, dark grey; rusty weathering	13	1,097
24	Shale, blocky, with thin well-indurated sandstone beds. Shale is dark grey, rusty weathering, has banded appearance, rubbly in interval 7′-9′	21	1,084
23	Shale, platy; rusty weathering; with thin indurated siltstone beds, ¼″-1″; few rare concretions	79	1,063
22	Inaccessible. Shale, blocky, dark grey; rusty weathering; bedded; few concretions, some laminated siltstone in upper 7′	22	984
21	Shale, blocky to platy, dark grey; rusty weathering	13	962
20	Shale, rubbly to blocky; rusty weathering; with thin siltstone, 40%	98	949
19	Shale, platy; rusty weathering; with 50% laminated siltstone in upper 10′. Lensy band of very fossiliferous limestone at top. GSC loc. 27101	36	851
18	Covered. GSC loc. 27111	395	815
	Dowling Member		
17	Shale, blocky to rubbly, dark grey; rusty weathering; with some concretions as much as 2′ long with pelecypods	50	420
16	Shale, very silty, dark grey; bedded; rusty weathering; with concretions 3″×18″-24″	16	370
15	Shale, rubbly, dark grey; rusty weathering; few concretions more concentrated in interval 20′-25′, appears to become more blocky towards base. GSC loc. 27110	53	354
14	Partly covered. Shale, rubbly, dark grey; with some concretions. 6″ of gritty shale, pebbles and conglomerate at 13′	20	301
	Marshybank Member		
13	Sandstone, very fine grained, bluish grey; laminated, massive; rusty tan weathering	1.5	281
12	Sandstone, fine-grained, downslope grades into shale, brownish grey, silty; worm burrows	2	279.5
11	Sandstone, fine-grained, grey; rusty tan weathering	1	277.5
10	Sandstone, fine-grained, grey; laminated; rusty tan weathering; beds 4″-10″, somewhat concretionary. Shale at top and 6″ bed at 3½′	5	276.5
9	Shale and sandstone, 50-50, grey; rusty weathering; irregularly bedded. Beds 1″-2″. GSC loc. 27067	2	271.5
8	Sandstone, very fine grained, grey; tan weathering; laminated, massive; extremely well indurated	2	269.5
7	Shale, rubbly to papery, dark grey	0.5	267.5
6	Sandstone, as above	1	267
	Muskiki Member		
5	Shale, very silty with thin, hard, siltstone beds in upper upper 5′, becomes less silty at base, dark grey; rusty weathering; concretions with pelecypods appear below 7′. GSC loc. 27109	30	266

Unit	Lithology	Thickness (feet)	Height above base (feet)
4	Shale, rubbly, dark grey; rusty weathering; no concretions	8	236
3	Mostly covered. Basal 65′ contains shale, platy to papery, dark grey; rusty weathering; a few very thin hard siltstones and rare concretions 6″ × 1′-2′	220	228
2	Grit, concretions and shale; somewhat bedded; reddish brown weathering	3	8
1	Siltstone, argillaceous to gritty, bedded, more shaly towards base; rusty tan to reddish brown weathering; few concretions	5	5
	CARDIUM FORMATION		
	Sturrock Member		
34	Sandstone, very fine grained, bluish grey; brownish grey weathering; laminated, massive; irregular bumpy upper surface	3.5	188
33	Sandstone, fine-grained, grey, laminated, 75%, and platy shale. Sandstone beds are ½″-1′, shale beds are 2″-4″	5.5	184.5
32	Sandstone, very fine grained, bluish grey; laminated, massive; rusty tan wathering; "cut and fill" upper surface	1.5	179
31	Sandstone, 50%, as above, some concretions, and shale, platy to papery, "cut and fill" to depth of 1′ at base. *Cardium*	3	177.5
30	Siltstone, argillaceous to shaly, dark grey; rusty weathering; bedded; few concretions	4	174.5
29	Sandstone, very fine grained, brownish grey; massive; rusty weathering; 5″ conglomerate at top with cobbles up to 6″ × 4″ × 3″	8	170.5
28	Sandstone, concretionary, 50%, and shale, thin, papery, dark grey	1.5	162.5
27	Sandstone, fine-grained, grey; finely laminated, massive; rusty tan weathering; few poorly developed concretionary zones	13	161
	Moosehound Member		
26	Coal, black, highly sheared	0.5	148
25	Sandstone, fine- to medium-grained, brownish grey; rusty orange weathering; massive; carbonaceous fragments, suggestion of "cut and fill" base	3	147.5
24	Sandstone, fine-grained, brownish grey; yellow brown weathering; beds 4″-1′, fairly massive appearance; laminated; carbonaceous	8.5	144.5
23	Sandstone, fine-grained, brownish grey; yellow brown weathering; laminated; slightly carbonaceous; thinly bedded especially at top	3	136
22	Sandstone, similar to above, carbonaceous, with 6″ shale at top and few thin interbeds. Basal 3′ is massive. Lower surface is covered with small ½″-1″ concretions	5	133
21	Shale, platy to papery, dark grey; somewhat rusty weathering; some hard silty beds near top	8	128

Unit	Lithology	Thickness (feet)	Height above base (feet)
20	Covered	14	120
19	Sandstone, silty, brownish grey; rusty grey weathering; beds 2″-4″ with interbedded silty shale	3	106
18	Shale, blocky, very silty, grey; rusty grey weathering	3	103
17	Siltstone to sandstone, concretionary, grey; rusty weathering	1	100
16	Shale, blocky, brown. Not well exposed	6	99
15	Siltstone, sandy, concretionary, grey; rusty weathering	1	93
14	Not well exposed. Shale, brownish grey, blocky at 11′; coal 1′ above base	21	92
13	Siltstone, sandy, carbonaceous, brownish grey	0.5	71
12	Not well exposed. Shale	12	70.5
11	Sandstone, fine-grained, carbonaceous; laminated; orange weathering	2	58.5
10	Shale, papery, dark grey; small concretions	2	56.5
9	Coaly shale	0.5	54.5
8	Siltstone, rubbly, grey, carbonaceous	1	54
7	Sandstone, fine-grained, brownish grey; irregularly bedded, massive; with 6″ shale at base, small concretions	2	53
6	Sandstone, medium-grained, grey; rusty tan weathering; massive; irregular uneven upper surface, few coaly fragments near base. Upper 6″ is laminated	6.5	51
5	Shale, blocky, dark grey; rusty weathering; concretions at 1½′ with pelecypods. Pelecypods also in shale below 6″ coal at base. GSC loc. 27074	4	44.5
	Ram Member		
4	Sandstone, fine-grained, grey to white; homogeneous, massive to bedded. Appears to be clean break between this and lower sandstone	3.5	40.5
3	Sandstone, fine-grained, grey; rusty brown weathering; homogeneous, some suggestion of fine laminations, massive; beds 6″-1′. Three-inch concretions and shale at 13′. Some bedding surfaces show small cut and fill features	25.5	37
2	Shale, silty, platy, and well-indurated siltstone, 50-50, with 6″ concretionary zone in centre	2.5	11.5
1	Sandstone, fine-grained, grey; rusty tan to orange weathering; laminated; in 2″-12″ beds; and shale, 40%, platy, dark grey	9	9
	KASKAPAU FORMATION		
	Opabin Member		
31	Shale, dark grey; and siltstone, 50%, laminated, dark grey, rusty weathering, banded appearance	7	829
30	Concretionary bed	1	822
29	Shale, dark grey; very silty at top; less so towards base	5.5	821
28	Concretionary bed; reddish brown weathering	0.5	815.5
27	Shale very silty at top, dark grey; with concretionary beds	9	815
26	Covered	21	806

Unit	Lithology	Thickness (feet)	Height above base (feet)
25	Siltstone, sandy, bluish grey; grey weathering; laminated; becoming more argillaceous and shaly towards base, bedded appearance with 2″-6″ concretionary beds, reddish brown weathering	19	785
24	Siltstone to silty shale, dark grey; slightly rusty weathering; massive to bedded; concretionary beds at top and base	11	766
23	Shale, blocky at top, more rubbly towards base, dark grey; rusty weathering; concretions and concretionary beds	23	755
22	Shale, blocky, very silty, dark grey; rusty weathering; 2″-3″ concretionary beds fairly numerous	34	732
21	Covered	69	698
20	Shale, platy, dark grey; rusty weathering; with few rare concretions and concretionary beds	13	629
	Haven Member		
19	Shale, very silty, platy, dark grey; rusty weathering; banded appearance; few thin hard siltstone beds. GSC loc. 27065	28	616
18	Mostly covered. Some platy shale; rusty weathering; rare concretions	56	588
17	Shale, not well exposed, mostly talus	95	532
	Vimy Member		
16	Dolomite, dense, argillaceous, blue grey; yellow weathering	1	437
15	Shale, dark grey; rusty weathering; mostly talus covered	67	436
14	Dolomite, as above; few thin shaly beds especially in upper 1′	4.5	369
13	Shale, platy, more rubbly towards base, dark grey; somewhat rusty weathering; few thin siltstone beds. Concretions at 28′	36.5	364.5
12	Dolomite, blue grey, aphanitic	1	328
11	Shale, platy, dark grey; rusty weathering; some fairly silty beds	53	327
10	Shale, platy, dark grey; rusty weathering; with few 2″ argillaceous limestone and siltstone beds; grades into underlying unit	41	274
9	Shale, rubbly to platy; rusty weathering	18	233
8	Dolomite, beds 8″-12″ with shale, 10%. Limestone is aphanitic, blue grey; yellow weathering	3	215
7	Shale, rubbly to blocky; somewhat less rusty weathering than previously; rare thin silty limestone beds	29	212
6	Dolomite, with shale, 40%	2	183
5	Shale, platy to rubbly; rusty weathering; few thin limestone lenses	30	181
4	Covered	14	151
3	Shale, rubbly; rusty weathering; talus covered	64	137
2	Covered	23	73
1	Shale, talus covered	50	50
	Contorted zone.		
8	Shale, rubbly; rusty weathering	25	
7	Dolomite bed, dense, bluish grey	1	
6	Covered	26	

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Sunkay Member		
5	Shale, rubbly; rusty weatheing	56	155
4	Shale, rubbly to papery; rusty weathering. GSC loc. 27069	45	99
3	Covered	12	44
2	Shale	6	32
1	Covered	26	26
	DUNVEGAN FORMATION		
16	Siltstone, sandy, argillaceous; bedded to massive; rusty weathering	8	230
15	Shale, silty, blocky; bedded; some concretions	38	222
14	Shale, very silty; massive; rusty weathering; almost argillaceous siltstone	19	184
13	Shale, blocky to rubbly at base; rusty weathering	34	165
12	Siltstone, argillaceous; massive; rusty weathering	7	131
11	Shale, very silty and massive at top, less so towards base; bedded appearance; few concretions and concretionary beds	24	124
10	Oyster coquina, with argillaceous matrix. GSC loc. 27075	3	100
9	Sandstone, medium-grained, dark grey; rusty brown weathering; massive, beds 1′-3′	37	97
8	Sandstone, 50%, fine-grained, lensy; and shale, interbedded	5	60
7	Shale, blocky, dark grey; more massive at base; somewhat rusty weathering	26	55
6	Sandstone, irregularly bedded, 3″-4″, 80%; and shale	6	29
5	Sandstone, fine-grained, grey; laminated; brownish grey weathering; platy, 1′ of bedded shale at 2½′	7	23
4	Shale, platy to siltstone	3	16
3	Sandstone, fine-grained, grey; brownish grey weathering; laminated; weathers platy	3	13
2	Shale, platy; with 15% sandstone	4	10
1	Sandstone, fine-grained, grey; brownish grey weathering; laminated; weathers platy on fault slice to west	6	6
	FORT ST. JOHN GROUP		
10	Covered	83	325
9	Shale, blocky to rubbly; rusty weathering; rare concretions	9	242
8	Shale, very silty, (almost siltstone) very blocky; bedding not well defined; few concretions	17	233
7	Shale, rubbly to platy; rusty weathering; 4″ concretionary bed at top	26	216
6	Covered	45	190
5	Shale, platy, dark grey; rusty weathering; banded appearance	54	145
4	Shale, rubbly to platy; rusty weathering; some yellow sulphur staining	26	91
3	Shale, rubbly, more platy at top; rusty weathering; with few concretionary beds	30	65

Unit	Lithology	Thickness (feet)	Height above base (feet)
2	Shale, rubbly; bedded appearance; rusty weathering; more massive towards top, some harder beds. Concretionary zone at top	29	35
1	Covered	6	6
	MOUNTAIN PARK-LUSCAR FORMATION		
	Contact not seen		
3	Sandstone, grey, fine- to medium-grained; greenish grey weathering; massive	1	13
2	Covered	7	12
1	Sandstone to siltstone, massive at top, rubbly towards base, greenish grey; grey weathering	5	5
	Contorted zone.		

Section 5-22. Cardium formation, Entrance map-area, Maskuta Creek, western limb of syncline, tp. 49, rge. 26, W5.

Overlying beds not exposed.

	CARDIUM FORMATION		
	Sturrock Member		
17	Not well exposed. Sandstone, fine-grained, grey, laminated; 40% shale in beds 2″-8″	13	248
16	Sandstone, fine-grained, grey; laminated; beds 4″-10″; some shaly beds	11	235
15	Shale, blocky, dark grey; bedded; a few hard siltstone and concretionary beds	18	224
14	Sandstone, fine-grained, laminated, well-indurated; beds 4-1″, concretionary; 50% siltstone, shaly, dark grey	13	206
13	Sandstone, grey, very coarse grained; homogeneous to laminated, cherty; massive; grey weathering; bedding not well defined; finer grained at top	26	193
	Leyland Member		
12	Shale, silty, grey; concretions; 1′ sandstone in middle with trace of carbonaceous remains	11	167
	Moosehound Member		
11	Sandstone, coarse-grained, brown; brownish grey weathering; homogeneous to laminated, massive; traces of worm burrows; "cut and fill" break at 25′	46	156
10	Sandstone, medium- to coarse-grained, brownish grey; brownish grey weathering; slightly carbonaceous; homogeneous to laminated; beds 4″-6″; some shale beds	9	110
9	Sandstone, fine-grained, silty; soft and siltier towards base; some shaly beds, 10%	6	101
8	Covered. Soft, platy shale at base	19	95

Unit	Lithology	Thickness (feet)	Height above base (feet)
7	Sandstone, medium-grained, brownish grey; rusty tan weathering; laminated; beds 6"-12". GSC loc. 27033	15	76
6	Sandstone, thinly bedded; 50% shale	3	61
	Ram Member		
5	Sandstone, grey, fine-grained, slightly laminated; rusty tan weathering; massive to bedded; somewhat concretionary	23	58
4	Sandstone, fine-grained, grey; rusty tan weathering; homogeneous; a few shaly intervals	5	35
3	Sandstone, 40%, grey, very fine grained, laminated, rusty tan weathering, concretionary; shale, 60%, dark grey, platy; a few concretionary beds	17.5	30
2	Sandstone, fine-grained, grey, somewhat concretionary; 1' beds; few shaly breaks at base	5.5	12.5
1	Sandstone, fine-grained, grey, laminated, rusty tan weathering; and 50% shale, platy, somewhat shaly in lower half; few small concretions	7	7
	BLACKSTONE FORMATION		
	Opabin Member		
	Shale, blocky, dark grey; rusty weathering; concretionary beds and concretions	32	
	Shale, rubbly to blocky, dark grey; rusty weathering; some concretions. GSC loc. 27036	16	
	Siltstone, argillaceous, bedded; rusty weathering; some concretions	4	
	Shale, blocky, rusty weathering, bedded; concretions	34	

Section 5-23. Cardium formation, Brûlé map-area, Alberta, Solomon Creek road, Mile 17.5, in gully on ridge.

CARDIUM FORMATION

Top contact is not exposed.

Sturrock Member

32	Sandstone, fine-grained, grey; brownish grey weathering; finely laminated; somewhat concretionary; beds 4"-6"; few shaly breaks	10	253
31	Siltstone, argillaceous, dark grey, hard	2	243
30	Sandstone, fine-grained, grey; brownish grey weathering; laminated; crossbedded; concretionary at base	3	241
29	Shale to siltstone, laminated, grey; few small concretions	2.5	238
28	Sandstone, fine-grained, grey, laminated, concretionary; brownish grey weathering; irregularly bedded	1.5	235.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
27	Mostly covered. Thinly bedded sandstone and shale with concretions exposed near base	20	234
26	Sandstone, fine-grained, brown; brownish grey weathering; homogeneous; concretionary; massive. Up and down slope, sandstone grades into thinly bedded sandstone and shale. Basal 6′ is channel filling	11	214
25	Shale, silty, grey; and sandstone, 50%, fine-grained, finely laminated, grey, grey weathering, concretionary, argillaceous. One foot of sandstone at base	9	203
24	Sandstone, fine-grained, laminated, brown; brownish grey weathering; carbonaceous remains; massive	2	194
23	Shale, platy, dark grey; and thinly bedded sandstone, 40%	1.5	192
22	Sandstone, fine-grained, brown; brownish grey weathering; laminated, massive	1.5	190.5
	Leyland Member		
21	Shale, rubbly to blocky, rusty brown to grey; rusty grey weathering	3	189
20	Covered	23	186
	Moosehound Member		
19	Sandstone, fine-grained, brown; reddish brown weathering; finely laminated, massive	5	163
18	Shale, brownish grey, platy	2	158
17	Covered	28	156
16	Sandstone, fine-grained, grey; brownish grey weathering; laminated, massive beds 6″-2′	11	128
15	Sandstone, medium-grained, brown; brown weathering; laminated, massive; some suggestion of cross-bedding	35	117
14	Shale, blocky, brownish grey	1	82
13	Sandstone, argillaceous, brown, fine-grained; laminated	1	81
12	Covered	5	80
11	Sandstone, fine-grained, brownish grey; laminated; bedding 1″-4″	5	75
10	Sandstone, fine-grained, knobbly	1	70
9	Sandstone, fine- to medium-grained, brown, laminated	1	69
8	Sandstone, fine-grained; knobby to bedded, irregularly bedded	5	68
7	Sandstone, fine-grained; laminated, massive	1	63
6	Covered, weathered back	3	62
	Ram Member		
5	Sandstone, medium-grained, grey; rusty tan weathering, laminated; beds 4″-24″, suggestion of cross-bedding, gradually becomes fine-grained below 10′	29	59
4	Shale, platy, dark grey	1	30
3	Sandstone, fine-grained, grey; laminated; rusty tan weathering; concretionary, beds 6″-1′	8	29

Unit	Lithology	Thickness (feet)	Height above base (feet)
2	Sandstone, 40%, fine-grained, laminated, grey; and shale, slaty, dark grey; some concretions, beds 2″-12″	8	21
1	Sandstone, fine-grained, grey; rusty weathering; laminated, massive; some concretionary beds. Basal 2′ has 2″ shale at top	13	13
	BLACKSTONE FORMATION		
4	Sandstone, fine-grained, laminated, 40%; and shale, very silty to siltstone; concretions and concretionary beds. Shale is dark grey, rusty grey weathering; grades into underlying unit	7	60
3	Shale, platy, dark grey; rusty weathering; rubbly in basal 10′; some thin siltstone at top	32	53
2	Shale, very silty, dark grey; with beds of argillaceous and laminated siltstone; rare concretions; grades into underlying unit	15	21
1	Shale, blocky, dark grey; concretions 4″×18″	6	6
	End of exposure.		

Section 5-25. Wapiabi formation, Grave Flats map-area, Thistle Creek, most westerly section.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
10	Sandstone, medium- to coarse-grained, greenish tan; medium bedded; yellowish grey weathering	30 est.	124
9	Conglomerate, gravel- to pebble-grade, greenish tan; yellowish grey weathering	12	94
8	Shale, silty, dark greenish grey; with six greyish green, brown weathering, thinly bedded, very fine grained sandstone beds; and 1½′ band of medium grey, fine-grained sandstone, 6′ above base	50 est.	82
7	Sandstone, fine-grained, medium grey; brown weathering; with some plant remains and a little conglomerate. 1′ concretions, yellow weathering, 3′ below top	11	32
6	Sandstone, soft, green; finely laminated	5	21
5	Sandstone, medium-grained, dark greenish grey; brown weathering	2	16
4	Covered	2	14
3	Sandstone, medium-grained, medium grey; fairly massive bedded; purplish brown weathering	8	12
2	Covered	2	4
1	Alternating bands of fine-grained sandstone, coarse-grained sandstone and concretionary chert conglomerate. Unit is greyish green	2	2
	WAPIABI FORMATION		
	Nomad Member		
117	Shale, rubbly, dark grey; greenish brown weathering	8	2,146
116	Sandstone, medium-grained, greenish grey; thinly bedded; brownish grey weathering	6	2,138

Unit	Lithology	Thickness (feet)	Height above base (feet)
115	Covered	10	2,132
114	Sandstone, medium-grained, greenish grey; brownish grey weathering; thinly bedded	6	2,122
113	Covered	10	2,116
112	Sandstone, fine-grained, medium grey, hard; brown weathering, medium bedded	5	2,106
111	Sandstone, fine-grained, greenish grey; reddish brown weathering; thinly bedded; with 25% rubbly shale partings	5	2,101
110	Shale, rubbly, dark greenish grey; brown weathering; very thin siltstones	3	2,096
109	Sandstone, fine-grained, greenish grey; reddish brown weathering; thinly bedded; greyish green rubbly shale	4	2,093
108	Shale, rubbly; with very thin sandstone and siltstone beds	5	2,089
107	Sandstone, very fine grained, medium grey; reddish brown weathering; banded	1	2,084
106	Shale, fissile, grey, with 10% thin silty beds	14	2,083
105	Shale, rubbly, grey; interbedded with siltstones, 50%; grey, reddish brown weathering; grading downwards to 90% siltstone at base. GSC loc. 24782	20	2,069
104	Siltstone, shaly, grey; blocky with a bed of 4″ calcareous concretions 2′ above base	3	2,049
103	Dolomite, argillaceous, dark grey; massive bedded; yellow weathering	4	2,046
102	Siltstone, calcareous, banded, dark grey; greyish yellow weathering, thinly bedded	3	2,042
101	Shale, blocky, dark grey; yellowish grey weathering; with reddish brown weathering siltstone concretions (3″) at middle and base of section	4	2,039
100	Concretionary bed; reddish brown weathering; gritty sandstone	1	2,035
	Chungo Member		
99	Shale, dark grey; brown weathering; rubbly	8	2,034
98	Sandstone, fine-grained, pale grey; rusty brown weathering; thinly bedded; with coal streaks and fragments. Coaly in basal 1′; pinches out across river	12	2,026
97	Sandstone, medium-grained, crossbedded, medium-bedded, slightly brownish grey; reddish brown weathering	23	2,014
96	Sandstone, fine- to medium-grained, deep reddish brown weathering; thinly bedded	10	1,991
95	Sandstone, fine- to medium-grained, brown; reddish brown weathering; massive bedded	34	1,981
94	Sandstone, fine-grained, medium grey; brownish grey weathering; fairly massive-bedded; banded, with few concretionary beds. Several shaly partings in section. GSC loc. 24797	24	1,947
93	Sandstone, fine- to medium-grained, brownish grey; with few concretions	2	1,923
92	Poorly exposed. Thin sandstone, brownish grey, fine-grained, near top. Dark grey, rubbly shale below	18	1,921

Unit	Lithology	Thickness (feet)	Height above base (feet)
91	Sandstone, coarse-grained, grey; cross-bedded; yellowish grey weathering	4	1,903
90	Sandstone, fine-grained, greenish brown; dark, rusty brown weathering; massive-bedded	22	1,899
89	Shale, dark grey; fissile with thin siltstone bed	1	1,877
88	Sandstone, fine-grained, medium grey; brownish grey weathering. Basal bed is laminated, cross-bedded and glauconitic. Two beds of dark grey fissile shale occur at centre and base. Beds 89 and 88 are lensy, grade into thin shale and sandstone beds both up and down slope	4	1,876
87	Siltstone, concretionary, glauconitic; rusty grey weathering; irregular lenses surrounded by highly glauconitic shale	1	1,872
86	Siltstone, argillaceous, dark grey; brownish grey weathering; massive	5	1,871
85	Siltstone, argillaceous, dark grey; concretionary beds; well indurated in upper 10′	24	1,866
84	Shale, silty, rubbly, dark grey; reddish brown weathering concretions	22	1,842
83	Siltstone, argillaceous to sandy, greenish grey; grey weathering; concretions	19	1,820
82	Siltstone, grey, argillaceous; yellowish grey weathering; with concretionary beds; well indurated in upper 1′; shaly at base	8	1,801
81	Siltstone, argillaceous, dark grey; irregularly bedded; well indurated; large concretions especially at top	6	1,793
80	Siltstone, argillaceous; more shaly than overlying beds	3	1,787
79	Siltstone, argillaceous, dark grey; irregularly bedded; well indurated with large concretions at top	6	1,784
78	Siltstone, to silty shale; few small concretions and 1′ bed at 3′	5	1,778
77	Siltstone, argillaceous; well indurated; large concretions at top. Siltstone is irregularly bedded	3	1,773
76	Siltstone, argillaceous, becoming more shaly towards base; bed of concretions at 2′	12	1,770
75	Siltstone, argillaceous; well indurated; concretions	1	1,758
74	Siltstone, argillaceous, to silty shale, with bed of large concretions at 2′	7	1,757
73	Siltstone, argillaceous, shaly, dark grey; 2″ concretionary bed at top; rare concretions 3″ × 6″	4	1,750
	Hanson Member		
72	Mostly covered. Shale	9	1,746
71	Siltstone, argillaceous, to very silty shale, dark grey; bedded; few concretions 4″ × 8″	4	1,737
70	Shale, blocky, silty, dark grey. Not too well exposed	5	1,733
69	Shale, blocky, very silty, dark grey; concretions 6″ × 6″-18″	11	1,728
68	Shale, blocky, dark grey; no concretions	9	1,717

Unit	Lithology	Thickness (feet)	Height above base (feet)
67	Shale, blocky, dark grey, very slightly calcareous; concretions 6″×8″; orange weathering; traces of large pelecypod fragments in shale and concretions; grades into underlying unit	24	1,708
66	Shale, blocky, dark grey; few concretions 6″×18″, some 3″ × 3″	6	1,684
65	Covered	120	1,678
	Thistle Member		
64	Shale, silty, platy to blocky, dark grey; bedded; rare band of well-indurated siltstone; concretions 3″ × 4″-6″. GSC loc. 27097	22	1,558
63	Shale, rubbly, dark grey; bedded; few concretions 2″ × 6″	11	1,536
62	Shale, platy with thin bands of well-indurated siltstone, 50%, slightly calcareous, laminated, grey; concretions 3″×1′, reddish brown weathering. Upper half is more concretionary than lower half. GSC loc. 27098	29	1,525
61	Shale, platy, dark grey, with very thin interbedded siltstone, 30%, bedded appearance; concretions 3″ × 6″-8″. GSC loc. 27091	30	1,496
60	Shale, platy, dark grey; siltstone, 15%, banded appearance; rare concretions	17	1,466
59	Shale, platy, dark grey; somewhat rusty weathering; with thin siltstone bands, 40%	10	1,449
58	Shale, silty, platy, hard, dark grey; with thin bands of well-indurated siltstone; rare concretions; more shaly in basal 3′, with thin bentonite 1′ from base lying on 2′ concretionary zone	11	1,439
57	Shale, platy, dark grey; with thin siltstone, 40%	7	1,428
56	Shale, blocky to platy, dark grey	3	1,421
55	Shale, platy, dark grey; with siltstone, 40%, thin, well indurated, slightly calcareous	13	1,418
54	As above, topped by 1½′ (maximum) lensy dolomitic limestone, buff weathering, argillaceous	15	1,405
53	Shale, as above, with 1′ lensy limestone at top, not continuous	44	1,390
52	Shale, platy, dark grey; with thin sandstone, 50%, fine-grained, flaggy	27	1,346
51	As above, less sandy in basal 5′	30	1,319
50	Shale, platy, dark grey; and sandstone, 60%, fine-grained, laminated, crossbedded, thinly bedded, calcareous, less sandstone at base. GSC loc. 27078	37	1,289
49	Sandstone, very fine grained, laminated, grey, calcareous; buff weathering; topped by 1″-2″ fine conglomerate with sharks' teeth, fish scales. GSC loc. 27079	1	1,252
48	Shale, platy, dark grey; with thin siltstone, 35%	9	1,251
47	Shale, and siltstone as above, shaly	41	1,242
46	Shale, platy, dark grey; with very fine sandstone to siltstone, 50%, laminated, some bands of sandstone up to 3″. GSC locs. 27097, 27037	37	1,201
45	Not well exposed. Shale, platy, with siltstone bands; becoming more rubbly towards base; rusty weathering	74	1,164

Unit	Lithology	Thickness (feet)	Height above base (feet)
44	Shale, platy to papery, hard; few thin siltstones; rusty weathering	18	1,090
43	Sandstone, fine-grained, grey; laminated, irregularly bedded, thinly bedded and crossbedded; 2″ coquina of small pelecypods at 9′. GSC loc. 27060	28	1,072
42	Dolomite, argillaceous, dense, blue grey; yellow weathering. Upslope this increases to 2′ at expense of overlying beds. GSC loc. 27042	1	1,044
41	Shale, platy, dark grey; and siltstone, 40%, laminated, well indurated, slightly calcareous; few lenses of argillaceous limestone. GSC loc. 27063	22.5	1,043
40	Dolomite, dense, argillaceous, bluish grey; yellow weathering; laminated, massive	1.5	1,020.5
39	Shale, very silty, platy to flaggy, dark grey, slightly calcareous	14	1,019
38	Covered	15	1,005
37	Shale, platy; thin siltstone; somewhat rusty weathering	19	990
36	Shale, platy, with siltstone, 40%; few bands of fine-grained sandstone, calcareous, grey; grey weathering; laminated. GSC loc. 27061	26	971
35	Shale, platy; rusty weathering; and siltstone, 20%; topped by 6″-1′ dense argillaceous limestone	12	945
34	Covered. Some shale, platy; rusty weathering exposed	80 approx.	933
33	Shale, platy to blocky, bedded; rusty weathering; siltstone bands, 20%. GSC locs. 27062, 24788	52	853
32	Shale, platy; with bands of sandy siltstone, hard, well indurated, slightly calcareous; large limestone concretions, 1½′ × 4′, at 15′	21	801
	Dowling Member		
31	Shale, rubbly to blocky, dark grey; few siltstone beds, and rare concretions 3″×1′	9	780
30	Covered.	50 approx.	771
29	Shale, somewhat platy at top, becoming more rubbly toward base, dark grey, rusty weathering; few concretions 2″ × 5″-6″; very slightly calcareous; fragments of large pelecypod shells. GSC loc. 27035	47	721
28	Shale, rubbly to blocky, dark grey; rusty weathering; rare concretions	19	674
27	Covered	15	655
26	Shale, rubbly, dark grey; rusty weathering; slightly calcareous; concretions 3″ × 6″-12″. GSC loc. 27056	37	640
25	Shale, platy to rubbly, dark grey; bedded; rusty weathering; slightly calcareous; 4″ round concretions and rare concretionary band; 10% siltstone bands	14	603
24	Shale, platy to rubbly; rusty weathering; small concretions 2″ × 4″. GSC loc. 27090	15	589
23	Shale, rubbly; rusty weathering; 3″ limestone band in centre; no concretions	11	574

Unit	Lithology	Thickness (feet)	Height above base (feet)
22	Shale, platy to rubbly, dark grey; rusty weathering; with concretions 2″-3″ × 6″-12″, some irregularly shaped	46	563
21	Covered. Some rusty shale with concretions exposed.	42	517
20	Shale, platy to rubbly, dark grey; rusty weathering; few concretions at top, rare towards base	23	475
19	Shale, platy to rubbly, slightly calcareous; dark grey; rusty weathering; irregular concretions. GSC loc. 27039	13	452
18	Covered	120 approx.	439
	Muskiki Member		
17	Shale, platy to rubbly, dark grey; rusty weathering; some thin siltstones; concretions 3″-4″×8″-12″. GSC loc. 27082	46	319
16	Shale, platy to rubbly, dark grey; rusty weathering; few concretions mainly in rows	18	273
15	Shale, platy to rubbly, dark grey; rusty weathering; few siltstone beds, irregular concretions 3″×6″-12″	32	255
14	Shale, platy; rusty weathering; with siltstone, 15%; few concretions 3″ × 12″	20	223
13	Shale, rubbly, dark grey, rusty weathering; with concretions 3″-6″×1′-2′ and concretionary beds, reddish brown weathering	30	203
12	Shale, platy to rubbly, dark grey; rusty weathering; rare hard 1″ siltstone beds; no concretions	9	173
11	Shale, rubbly, dark grey, rusty weathering; bedded appearance, with concretions 2″×6″-1′, reddish brown weathering	38	164
10	Shale, rubbly, dark grey; rusty weathering; no concretions	18	126
9	Covered	28 approx.	108
8	Shale, as above, with concretions 2″×6″, some silt beds	7	80
7	Shale, platy to rubbly, dark grey; rusty weathering; rare concretions, few 1″-2″ siltstone beds	12	73
6	Shale, platy, dark grey; rusty weathering; small concretions. GSC loc. 27087	13	61
5	Shale, as above, rare concretions	14	48
4	Covered	20 approx.	34
3	Grit, grey, with pebbles ¼″-½″ and small concretions 1″-2″ which appear to be detrital; also 2″×6″-1′ concretionary beds; some concretions have gradational contact with grit and contain pebbles; some thinly bedded grit and shale	8	14
2	Partly covered. Appears to be silty shale with some large 1′×2′ limestone concretions with grit; reddish brown weathering	5	6
1	Concretionary bed, capping underlying bed; rusty to reddish brown weathering with patches and lenses of sandstone; becoming finer grained towards base	1	1

Section 5-27. Wapiabi formation, George Creek map-area, Alberta, Blackstone River, east flank of syncline, 8 miles below Mons Cabin, tp. 42, rge. 18, W5.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
	Sandstone, medium-grained, greenish grey; laminated; brownish to greenish grey weathering; beds 6-8″, 20% shaly siltstone	2	
	Siltstone and 50% shale, greenish grey; irregularly bedded	2	
	Sandstone, medium-grained, greenish grey; greenish grey weathering; slightly laminated, carbonaceous, massive; suggestion of crossbedding	11	
	WAPIABI FORMATION		
	Nomad Member		
71	Shale, rubbly, dark grey; 50% very thinly bedded siltstone, greenish to brownish grey, slightly calcareous	4	1,108
70	Sandstone, calcareous, grey, fine-grained; brownish grey weathering; in beds 4-8″ thick; 40% shale, dark grey, rubbly	7	1,104
69	Shale, platy to rubbly, silty, greenish grey; 50% thin siltstone, some 1″ bands in upper 4′	8	1,097
68	Sandstone, fine-grained, grey, laminated, very calcareous, brown weathering; 50% shale, rubbly in 1-6″ beds	9	1,089
67	Shale, platy to blocky; rusty to greenish grey weathering; bedded appearance	12	1,080
66	Sandstone, argillaceous, dark grey, very fine grained, dirty; rusty brown weathering; laminated; beds 1-4″; grades into underlying unit	4	1,068
65	Shale, very silty; 40% very fine grained sandstone or siltstone; greenish grey to rusty weathering; calcareous	8	1,064
64	Shale, slightly calcareous, platy to rubbly, dark grey; rusty weathering; a few 1″ concretionary bands	19	1,056
63	Shale, slightly calcareous, blocky to rubbly, dark grey; rusty weathering	23	1,037
62	Shale, rubbly to blocky, dark grey; 4″×12″ concretions at top and rare concretionary beds	12	1,014
61	Limestone, dolomitic, argillaceous, bluish grey; aphanitic, laminated; buff weathering; concretionary at base	2.5	1,002
60	Shale, blocky, dark grey; few concretions	7	999.5
59	Sandstone, coarse grained, concretionary; very pebbly in upper 6″, grades into underlying unit	3	992.5
	Chungo Member		
58	Shale, very silty to sandy, dark grey; rusty to greenish grey weathering; poorly developed concretionary areas	12	989.5
57	Sandstone, slightly calcareous, fine-grained, grey; rusty grey weathering; 20% shale	7.5	977.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
56	Siltstone, argillaceous, blocky; 50% shale, very silty, dark grey; bedded appearance	12	970
55	Sandstone, fine-grained, grey; rusty grey weathering; laminated, massive	2	958
54	Siltstone to sandstone; grey; laminated, bedded; some concretions	9	956
53	Sandstone, fine-grained, silty, laminated, very slightly calcareous, grey; grey weathering; bedding not well defined; some concretions	9	947
52	Sandstone to siltstone, grey; massive, bedding very poorly defined; grey weathering; more shaly toward base	11	938
51	Siltstone, argillaceous, dark grey; laminated, bedded	10	927
50	Siltstone to sandstone, very slightly calcareous, fine-grained, grey, argillaceous; massive with 6″×2′ concretions at top; more bedded at base; grades into underlying unit	6	917
49	Siltstone, sandy to argillaceous, shaly, calcareous; bedded; rare concretions near top	15	911
48	Shale and 50% argillaceous siltstone, dark grey, bedded	4	896
47	Siltstone, argillaceous, dark grey; massive	7	892
46	Shale to siltstone, blocky, dark grey; 3″ × 6-8″ concretions at top and base	4	885
45	As above, no concretions	8	881
44	Shale, calcareous, very silty, blocky, dark grey; 6″×24″ concretions in bands	16	873
43	Shale, blocky to rubbly, dark grey; a few thin siltstone beds; rare concretions; basal 2′ slightly siltier	13	857
42	Siltstone, argillaceous, shaly, dark grey; more shaly towards base	8	844
41	Concretionary zone with 6″ siltstone in centre; glauconite	2	836
40	Shale, blocky, dark grey; more rubbly toward base; rare concretions	9	834
39	Siltstone to shale, bedded, dark grey, glauconitic; concretionary spots, concretions 3-6″ × 5-24″	19	825
38	Shale, rubbly; concretionary zone in centre	3	806
37	Siltstone to shale	6	803
36	Siltstone, argillaceous, dark grey; massive	8	797
	Hanson Member		
35	Shale, very silty, blocky; concretions 6″×24″	12	789
34	Poorly exposed. Shale with concretions	49	777
33	Partly talus covered. Shale, rubbly, dark grey; irregular concretions, 6″ × 8-24″	74	728
	Thistle Member		
32	Shale, platy to rubbly; 25% thin siltstone, dark grey; concretions 2-3″ × 6-8″; basal 4′ without concretions	39	654
31	Shale, rubbly	4	615
30	Shale, platy to rubbly; 25% thin siltstones, rusty weathering; no concretions except for zone at top	19	611
29	Shale, platy, more rusty weathering than above; thin limestone zone at 22′	33	592

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Dolomite zone, platy, argillaceous, aphanitic, bluish grey; yellow weathering	1	559
27	Shale, platy, dark grey; 30% thin siltstone, slightly calcareous; rare sandstone bed at base	20	558
26	Dolomite, aphanitic, argillaceous, bluish grey; yellow weathering	1	538
25	Shale, platy, dark grey; 35% siltstone, very thinly bedded; rusty weathering; slightly calcareous; limestone lens 4′ from top	47	537
24	Sandstone, fine-grained, laminated, calcareous, in 1-2″ beds; 50% platy shale	36	490
23	Dolomite, aphanitic, argillaceous	1	454
22	Shale, platy, dark grey; 30% thinly bedded platy siltstone	24	453
21	Partly covered. Six inches limestone lenses at top, platy shale	18	429
20	Shale and 40% siltstone	12	411
19	Dolomite, lenses; papery shale	1	399
18	Shale, platy, 40% thinly bedded siltstone	23	398
17	Shale and 50% siltstone; somewhat rusty weathering	18	375
16	Covered	31	357
	Dowling Member		
15	Shale, rubbly, dark grey; rusty weathering; concretions 3 × 6″ and 1′ concretionary beds	13	326
14	Shale, platy; rusty weathering; concretions, 3″ × 1′	5	313
13	Covered	22	308
12	Shale, blocky to rubbly, dark grey; rusty weathering; a few concretions 4 × 12″	61	286
	Marshybank Member		
11	Concretionary zone with 50% shale	1	225
10	Siltstone, argillaceous, massive to bedded, dark grey, grey weathering, concretionary spots; large 1-3′ concretions in centre, orange weathering	26	224
9	Siltstone to silty shale, dark grey; 6″ × 2′ concretions near base	8	198
8	Siltstone, dark grey, massive, rusty weathering; more bedded at base, some 4″×8″ concretions near base	45	190
	Muskiki Member		
7	Shale, platy; 50% thin siltstone; concretions 3″ × 6-8″	24	145
6	Shale, rubbly; rusty weathering; concretions, 2″×6″	16	121
5	Shale and 30% siltstone; basal part more rubbly with concretions	21	105
4	Shale and 40% siltstone; rusty weathering; concretions 4″×8″	22	84
3	Shale, blocky to platy, rubbly; 30% thinly bedded siltstone; 1″ bentonite at base, some concretionary beds	48	62
2	Shale, rubbly, dark grey; rusty weathering; a few small concretions	13	14
1	Siltstone to sandstone; concretionary, argillaceous; 50% shale	1	1
	Underlying beds—Cardium formation.		

Section 5-28. Chungo member, Wapiabi formation, George Creek map-area, Alberta, Blackstone River, east flank of syncline about 5 miles downstream from Mons Cabin.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
	Sandstone, medium-grained, greenish grey; grey weathering; massive; 1″-2″ beds, carbonaceous, slightly calcareous	11	11
	WAPIABI FORMATION		
	Nomad Member		
38	Shale, greenish grey, platy, with thinly bedded siltstone, 20%	24	598
37	Shale, as above, and platy siltstones, 50%, argillaceous, carbonaceous, greenish grey, few 2″ siltstone beds at top	13	574
36	Sandstone, very fine grained, silty, greenish grey, argillaceous; laminated; carbonaceous	6	561
35	Sandstone and shale, 50-50, greenish grey; irregularly bedded	4	555
34	Sandstone, fine-grained, very silty and argillaceous, calcareous, greenish grey; and shale, 50%, grey; rusty weathering; beds 1″-4″, carbonaceous. Sandstone grades into siltstone towards base	16	551
33	Shale, blocky to rubbly, dark grey; rusty weathering; few thin siltstones at top, calcareous	33	535
32	Siltstone, argillaceous, grey; bedded; grey weathering; rare concretions, slightly rusty weathering	27	502
31	Dolomite, argillaceous, aphanitic, bluish grey; yellow weathering; laminated; somewhat slabby	4	475
30	Concretionary bed, with some grit, pebbles, and shale	1	471
	Chungo Member		
29	Sandstone, calcareous, fine-grained, grey; brownish grey weathering; concretionary in upper 1½′ which is irregularly bedded	3	470
28	Siltstone, sandy, dark grey; irregularly bedded; concretionary spots; some concretions	4	467
27	Sandstone, fine-grained, grey; grey weathering; laminated; beds 1″-4″ somewhat wavy, basal part very thinly bedded, concretions	6	463
26	Sandstone, argillaceous, fine-grained, grey; laminated; some fine crossbedding; slightly calcareous; less than 5% shale; 4″ shale break at 7½′; "cut and fill" base	10	457
25	Shale, silty, and sandstone, 50%, concentrated in basal part; glauconite	4.5	447
24	Sandstone, very slightly calcareous, grey, fine-grained; laminated; crossbedded, beds 2″-1′	4	442.5
23	Shale, silty, sandstone, 50%	2	438.5
22	Sandstone, very slightly calcareous, grey, fine-grained; laminated; crossbedded	2	436.5
21	Sandstone, and shale, 50-50	2.5	434.5
20	Sandstone, fine-grained, grey; laminated	3	432
19	Siltstone, argillaceous, grey; laminated; irregularly bedded especially at base	8	429

Unit	Lithology	Thickness (feet)	Height above base (feet)
18	Sandstone, fine-grained; finely laminated; some suggestion of crossbedding, beds, 8″-2′; shaly intervals, 10%	15	421
17	Sandstone and siltstone interbedded, very argillaceous, grey; beds 2″-4″, irregular; tends to weather back	13	406
16	Sandstone, fine-grained, grey; laminated, massive; grey weathering; slightly calcareous; some bolster-type bedding	7	393
15	Siltstone to sandstone, beds 2″-6″, grey; tends to weather back	19	386
14	As above; 1″ band of bentonite (?) at base; estimated	42	367
13	Siltstone, argillaceous, dark grey, slightly calcareous; bedded; row of concretions at base	8	325
12	Siltstone, very sandy at top, becoming less massive and bedded at base, dark grey; 4″ concretionary bed at 9′	10	317
11	Siltstone, very sandy at top, less so at base	16	307
10	Shale, blocky, dark grey; 1½′ concretionary zone at top; concretionary spots, glauconite and concretions scattered throughout; row of concretions at base	6	291
9	Shale, blocky to rubbly, dark grey; rusty weathering; row of concretions near base	16	285
8	Siltstone, argillaceous; massive to bedded; concretionary spots; some large concretions below 20′	44	269
7	Siltstone, shaly; 6″-8″ concretions	3	225
6	Siltstone, argillaceous, dark grey; massive; somewhat bedded 11′-13′; some large 1′ concretions	20	222
5	Siltstone, argillaceous, dark grey; bedded; rusty weathering; rows of large concretions	17	202
	Hanson Member		
4	Shale, very silty, blocky, dark grey; rusty weathering	7	185
3	Shale, blocky, dark grey; rusty weathering; concretions, 6″ × 1′, irregular; some fragments of large pelecypods in basal concretions. Interval is talus covered	106	178
2	Shale, blocky to rubbly, dark grey; no concretions	54	72
1	Shale, blocky to rubbly; with concretions	18	18

Section 5-30. Chungo member, Wapiabi formation, George Creek map-area, Alberta, George Creek, most northerly tributary at headwaters.

Beds immediately above not exposed.

Nomad Member

22	Dolomitic limestone, argillaceous, bluish grey; aphanitic, laminated; yellow weathering; somewhat platy	4	353
21	Shale, very pebbly. Mostly covered	3	349

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Chungo Member		
20	Sandstone, very silty, brownish grey, fine-grained; grey weathering; massive; quite calcareous	4	346
19	Mostly covered. Some calcareous sandstone as above, coal and shale	17	342
18	Sandstone, very silty and argillaceous, concretionary, brownish grey; grey weathering; massive	14	325
17	Covered	9	311
16	Sandstone, medium-grained, grey; homogeneous; massive; rusty to reddish weathering	12	302
15	Sandstone, fine to medium-grained, argillaceous, deeply weathering; brown, rusty to reddish weathering; laminated, platy appearance; fairly massive; concretionary bands in lower half	24	290
14	Covered	6	266
13	Sandstone, fine-grained, argillaceous, grey; grey weathering; laminated; massive; platy appearance	8	260
12	Covered, weathered back. Some platy sandstone exposed on hillside	23	252
11	Sandstone, medium-grained, massive, homogeneous, brown at top; becoming somewhat cleaner and grey towards base; carbonaceous fragments; shaly interval at base	17	229
10	Sandstone, fine- to medium-grained, deeply weathered, slightly calcareous, brown; dark reddish brown weathering; laminated, platy appearance; massive; some concretions in basal 5′	19	212
9	Talus covered. Upper part (14′) appears to be platy sandstone and shale, then 7′ shale, and 3′ fine grained sandstone at base	24	193
8	Siltstone, argillaceous, shaly; large concretions; grading downward into blocky shale	26	169
7	Shale, blocky, dark grey; 4″ × 6″ concretions. Three concretionary bands in basal 10′	24	143
6	Shale, blocky, dark grey, some 1″-1½″ concretionary beds; reddish brown weathering	9	119
5	Covered. Basal 15′ consists of argillaceous siltstone which grades into shale	35	110
4	Siltstone, argillaceous, bedded, dark grey; rusty to greenish grey weathering; large concretions	17	75
3	Shale, blocky, dark grey; weathers back	14	58
2	Siltstone, sandy and argillaceous, massive becoming bedded and shaly towards base, concretions 6″ × 1′	14	44
	Hanson Member		
1	Shale, dark grey, blocky; with concretions 4″×6″-1′. End of exposure.	30	30

Sections 5-35, 5-38. Wapiabi formation, Nordegg map-area, Alberta, Bighorn River.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	On ridge.		
	Overlying beds not exposed.		
	Chungo Member		
96	Sandstone, fine-grained, deeply weathered, brown; rusty to reddish brown weathering; flaggy; 6″ conglomerate at 16′	21	355
95	Conglomerate, chert pebbles ¼″-½″, rounded	2	334
94	Sandstone, fine-grained, platy, brownish grey; brownish grey weathering	36	332
93	Sandstone, fine-grained, platy, brownish grey; brownish grey weathering	31	296
92	Sandstone, fine-grained, platy, brownish grey. Partly covered	24	265
91	Sandstone, coarse-grained, grey; weathers round and smooth; trace of conglomerate at top	12	241
90	Sandstone, fine-grained, grey; laminated, massive, weathers platy; rusty weathering	49	229
89	Shale, and thinly bedded sandstone	1	180
88	Sandstone, fine-grained, argillaceous, brownish grey; brownish grey weathering; laminated	2	179
87	Siltstone, argillaceous, sandy, dark grey; brownish grey weathering; laminated	9	177
86	Sandstone, argillaceous, grey; brownish grey weathering; laminated	3	168
85	Siltstone, argillaceous, sandy, dark grey; brownish grey weathering; laminated	4	165
84	Covered. Some dark grey, blocky shale with concretions exposed in basal 20′. GSC loc. 27086	94	161
83	Siltstone, bedded, dark grey, irregular concretions; orange weathering	12	67
82	Siltstone, massive at top, more bedded at base; few concretions, rusty concretionary spots	10	55
81	Siltstone, massive to bedded at base; some irregular concretions	7	45
80	Siltstone, massive; large concretions at top and in rows	6	38
79	Siltstone; bedded to blocky shale, dark grey; few concretions	9	32
78	Siltstone, argillaceous, massive to bedded; dark grey; concretions 6″×1′; reddish brown weathering	12	23
77	Shale, very silty to argillaceous siltstone, dark grey; slightly rusty weathering concretions 4″×1′; reddish brown weathering	11	11
	Hanson Member—continues in river		
76	Shale, platy to rubbly, dark grey, slightly calcareous; somewhat rusty weathering; concretions 2″-4″× 6″-1′, reddish brown weathering, in rows and scattered	27	162

Unit	Lithology	Thickness (feet)	Height above base (feet)
75	Shale, slightly calcareous, platy, dark grey; with thinly bedded siltstone 25% decreasing to 10%; double row of concretions at top 3″×4″-6″; scattered concretions, reddish brown weathering	31	135
74	Shale, very silty, blocky, dark grey; slightly rusty weathering; somewhat massive in appearance, 1″ siltstone bed at top and in centre, 3″×1′ round concretions, reddish brown weathering	13	104
73	Shale, platy to rubbly, dark grey; few concretions 3″×6″, some 3″×1′ at base	38	91
72	Shale, blocky, dark grey; concretions 3″-4″×1′; reddish brown weathering	9	53
	Thistle Member		
71	Shale, blocky, very silty; few bands of well-indurated siltstone at top; scattered concretions toward base	31	751
70	Shale, platy to rubbly; with thinly bedded siltstone, 40% in upper 5′; few concretions	13	720
69	Shale, dark grey; and thinly bedded siltstone, 30% decreasing to 20%; banded appearance with 2″×3″ scattered concretions	29	707
68	Shale, and siltstone, 50% decreasing to 30%, dark grey, banded appearance; few concretions and concretionary bands. Zone of shear at base. GSC loc. 27108	30	678
67	Shale, platy to rubbly; and thinly bedded siltstone, 30%, banded appearance; few concretionary siltstone bands	36	648
66	Shale, and siltstone, 40%; some concretionary siltstone bands, 2″. Shear zone at base	21	612
65	Dolomitic band, platy, laminated; yellow weathering; few shaly intervals	1	591
64	Shale, and siltstone, 30%; 2″ bentonite at base	16	590
63	Shale, and siltstone, 50%, platy to flaggy, dark grey	10	574
62	Dolomite, lenses out into shale	1	564
61	Shale, platy, and siltstone, 40%, dark grey with 1″ bentonite at base	5	563
60	Shale, platy to rubbly; and siltstone, 30%, dark grey	26	558
59	Siltstone to sandstone, 60%, laminated; and shale, platy; thin bentonite at 8′	13	532
	Fault in section, measurement continued below repeated beds.		
58	Sandstone and shale, 50%, platy, flaggy, dark grey	4	519
57	Sandstone, 70%, fine-grained, laminated, grey, flaggy; and shale, platy, dark grey; beds ½″-2″	11	515
56	Shale, and siltstone to sandstone, flaggy	20	504
55	Sandstone, flaggy; and shale, 50%; limestone zone in centre, very fossiliferous. Shear zone at base. GSC loc. 27068	16	484
54	Shale, and siltstone to sandstone, 40%, beds ½″-2″, dark grey	7	468
53	Sandstone, fine-grained, laminated, argillaceous, beds 1″-3″, few limy yellow weathering beds; and shale, 40%, dark grey, platy. Shear zone at base	17	461
52	Shale, and sandstone to siltstone, 40%, platy; few laminated bands	25	444

Unit	Lithology	Thickness (feet)	Height above base (feet)
51	Shale, and siltstone, 40%, dark grey, platy	23	419
50	Shale, and siltstone, 50%; few beds of sandstone 2"-3"	10	396
49	Shale, and siltstone, 40%	13	386
48	Shale, and siltstone, 30%; few beds of laminated siltstone at top; all dark grey	20	373
	Fault zone. Section continues below contorted beds. Gap may occur in section.		
47	Shale, and siltstone, 25%, dark grey, platy	13	353
46	Dolomite, dense, argillaceous, bluish grey; yellow weathering	1	340
45	Shale, and siltstone, 15%; few laminated beds	9	339
44	Shale, and siltstone, 10%; shale is rubbly, rusty weathering	24	330
43	Shale, and siltstone, 40%; bentonite at 5'	16	306
42	Sandstone, fine-grained, laminated, bluish grey, slightly calcareous; and shale, 40%, slaty, dark grey, beds ½"-2"	18	290
41	Sandstone, and shale, 50%, as above	16	272
40	Shale, platy, dark grey, and flaggy sandstone, 40%	21	256
39	Dolomite, dense, argillaceous; yellow weathering; swells to 2'	1	235
38	Shale, rubbly; and siltstone, 10%	7	234
37	Shale, and siltstone, 30%; 2"-3" bands of siltstone at base. GSC loc. 27102	15	227
36	Shale, and siltstone, 30%	44	212
35	Shale, and laminated siltstone, 40%	6	168
34	Shale, platy to rubbly; few thin siltstone beds	9	162
33	Shale, and siltstone, 40%, in ½"-3" beds. GSC loc. 27105	17	153
32	Dolomite zone	1	136
31	Shale, platy, rusty weathering; and siltstone, 40%; thin bentonite at base	47	135
30	Shale, platy; few thin siltstone beds	7	88
29	Shale, and siltstone, 30%, platy; few limy beds	43	81
28	Shale, very silty, platy, dark grey; and thin siltstone, 20%	38	38
	Dowling Member		
27	Shale, platy, dark grey; and few 2"×6"-1' concretions	45	269
26	Shale, rubbly, rusty weathering; few thin siltstone bands; few 2" × 1' concretions; traces of *Scaphites* and fish scales	42	224
25	Shale, platy to rubbly; numerous small concretions	33	182
24	Shale, and siltstone, 30%, platy, rusty weathering; numerous 2"-3" × 6"-1' concretions, orange weathering. GSC loc. 27113	34	149
23	Shale, rubbly, rusty weathering; with 1"-2" bands of laminated siltstone, 10%; rare concretions becoming more numerous near base	23	115
22	Shale, rubbly; rusty weathering	23	92
21	Concretionary conglomerate and shale with small pebbles	1	69
20	Shale, blocky at top becoming rubbly at base; numerous small concretions	52	68
19	Shale, very silty, blocky, dark grey; rusty weathering; large irregular orange weathering concretions	16	16

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Marshybank Member		
18	Siltstone, argillaceous, massive, dark grey, reddish brown weathering; with 3″-6″ × 6″-1′ concretions, upper surface has red weathering concretions. GSC loc. 27112	26	104
17	Siltstone, bedded, argillaceous, dark grey, with concretions. Break at 41′. GSC loc. 27104	62	78
16	Siltstone, shaly, bedded, dark grey; 2″ × 1′ concretions	16	16
	Muskiki Member		
15	Shale, blocky to rubbly; rusty weathering; few siltstone beds	16	416
14	Shale, blocky; rusty weathering; irregular concretions of varying size	79	400
13	Shale, platy to blocky; few concretions; thin bentonite at base	22	321
12	Shale, platy to rubbly; bedded appearance; concretions in rows. GSC loc. 27115	37	299
11	Shale, platy to rubbly; rusty weathering; rare concretions	26	262
10	Shale, platy to rubbly; rusty weathering; with concretions	40	236
9	Shale, blocky; small concretions	39	196
8	Shale, dark grey, blocky; concretions 3″ × 1′	8	157
7	Shale, platy; with 3″ concretionary capping with disk-shaped pebbles	36	149
6	Shale, platy, dark grey	23	113
5	Covered	50	90
4	Grit, greenish grey, platy towards base, with small ¼″-½″ chert pebbles and zones of detrital concretionary material	4	40
3	Grit, greenish grey, massive, suggestion of bedding; maroon weathering; scattered pebbles along bedding surfaces	17	36
2	Grit, more bedded than above, with some tendency to more shaly intervals; small scattered concretions; rare pebbles	16.5	19
1	Shale, gritty with pebbles up to 2″; lenses of conglomerate	2.5	2.5
	Contact with Cardium formation.		

Section 5-37. Cardium formation, Nordegg map-area, Alberta, Littlehorn River.

	WAPIABI FORMATION		
9	Shale, dark grey; reddish brown weathering; few concretions	24	145
8	Shale, dark grey; rusty weathering; numerous concretions	25	121
7	Shale, and siltstone, 20%, platy; rusty weathering	22	96
6	Shale, and siltstone, 30%; numerous thin concretions	11	74

Unit	Lithology	Thickness (feet)	Height above base (feet)
5	Shale, dark grey, rusty weathering; and siltstone 20%; numerous concretions 1″-2″ × 6″-8″. GSC loc. 27088	25	63
4	Shale, and siltstone, 35%; rusty weathering	8	38
3	Shale, dark grey, rusty weathering, blocky to rubbly, few concretions	18	30
	This contact has the appearance of an unconformity with 2′ to 3′ relief.		
2	Siltstone, argillaceous, dark grey, with concretions, pebbly at base and gritty lenses	11	12
1	Conglomerate, chert pebbles ¼″-2″ disk-shaped, rounded	1	1
	CARDIUM FORMATION		
	Sturrock Member		
49	Siltstone, sandy; laminated, massive	2	300.5
48	Sandstone, coarse-grained, brownish grey; laminated, crossbedded; brownish grey weathering	3	298.5
47	Coal and coaly shale, black	1.5	295.5
46	Sandstone, fine-grained, grey to brownish grey; laminated, massive; maroon to rusty weathering	5	294
45	Sandstone, fine-grained, grey; grey to reddish grey weathering; laminated, massive; 6″ zone at base with 3″-4″ concretionary band and shale	11	289
44	Sandstone, fine-grained, grey, clean; grey to reddish grey weathering; massive, laminated; few concretionary zones	18.5	278
43	Sandstone, fine-grained, concretionary, grey; rusty tan weathering; laminated, and shaly intervals 10%. GSC loc. 27060	4	259.5
42	Shale, and thinly bedded sandstone, 50%, concretionary, and few large sandstone lenses	4	255.5
41	Sandstone lenses with shale, 10%	1	251.5
40	Shale, and thinly bedded sandstone	1	250.5
39	Siltstone to sandstone, grey; laminated, concretionary	1	249.5
38	Shale, blocky, dark grey and siltstone, 30%; numerous 2″×6″-12″, reddish brown weathering concretions; siltstone grades into concretionary masses	9	248.5
37	Sandstone, fine-grained, grey; finely laminated; beds 2″-1′, concretionary, shaly in towards 20%	7	239.5
36	Sandstone, fine-grained, grey; laminated; concretionary, very argillaceous and silty in upper 1′	5	232.5
35	Sandstone, grey; laminated; few shaly breaks, beds 3″-4′, 2″ concretionary zone at top	2	227.5
34	Siltstone, argillaceous, blocky, grey; more laminated at top; few pebbles at base; grades into underlying unit	9	225.5
33	Siltstone, argillaceous, dark grey, with scattered pebbles; part of basal 1′ almost conglomerate; concretionary	5	216.5
32	Conglomerate, concretionary, chert pebbles, ¼″-1″	1.5	211.5
31	Sandstone, fine-grained, deeply weathered, brown; reddish to maroon weathering; massive beds 1″-2′	19	210

Unit	Lithology	Thickness (feet)	Height above base (feet)
30	Conglomerate and sandstone, chert pebbles, white, grey, green, blue, black, rounded, mainly disk-shaped, ¼″-1″, in sand matrix and lensing into sandstone; somewhat concretionary	4	191
29	Sandstone, fine-grained; laminated	0.5	187
28	Shale, and thinly bedded sandstone	1.5	186.5
27	Sandstone, fine-grained, grey; laminated	1.5	185
26	Shale and thinly bedded sandstone	0.5	183.5
25	Sandstone, fine-grained, wavy bedded, grey; few small red weathering concretions; shale, 25%	7	183
24	Sandstone, fine-grained, grey; laminated; in 2″-4″ beds with shaly partings	2	176
23	Sandstone to siltstone, grey; laminated, wavy bedded; and shale, 40%	6	174
22	Sandstone, fine-grained, grey; laminated	0.5	168
21	Siltstone to sandstone, grey; wavy bedded; shale, 40%	8	167.5
20	Sandstone, medium-grained, grey; wavy bedded, beds 2″-6″	2	159.5
19	Sandstone, fine-grained, grey; homogeneous to laminated, thickly bedded; tan weathering; sharp clean break, 10′ from base; beds 6″-12″. GSC loc. 27084	23	157.5
	Leyland Member		
18	Sandstone, fine-grained, rusty weathering, channel fill structures; and shale, 50%. GSC loc. 27045	10	134.5
17	Shale and thinly bedded siltstone, 50-50	6	124.5
16	Shale, rubbly, dark grey, rusty weathering; and few thin concretionary siltstones, 5-10%	13	118.5
15	Shale, rubbly, dark grey; slightly rusty weathering; few 2″ × 6″ concretions	20	105.5
	Cardinal Member		
14	Siltstone, argillaceous, and very silty shale, blocky, dark grey, rusty weathering; numerous concretions, irregular, reddish brown weathering, and row of concretions at top	8	85.5
	Kiska Member		
13	Shale, blocky, dark grey; rusty weathering	16	77.5
	Moosehound Member		
12	Grit, grey to brownish grey; reddish to tan weathering; laminated, crossbedded, massive; very sharp well defined upper and lower contact	14	61.5
11	Shale, rubbly, dark grey to black; with concretionary zones at 2½′ and 5′	6	47.5
10	Sandstone, fine-grained, brownish grey, carbonaceous; laminated, massive	2	41.5
9	Sandstone, brownish grey, fine-grained, carbonaceous; laminated, thinly bedded in top 10″ with 60% shale, basal part massive	2	39.5
8	Siltstone, very argillaceous, platy but massive appearance; beds 2″-6″ with interbedded silty grey shale. Siltstone weathers greenish rust	2.5	37.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
7	Shale, black, fissile; grey weathering	2	35
6	Shale, platy; brown, carbonaceous; rusty weathering	1	33
	Ram Member		
5	Sandstone, fine-grained, grey; rusty tan weathering; laminated, massive at top; shows some fairly large scale crossbedding at base. Upper surface is carbonaceous to coaly	17.5	32
4	Sandstone, knobbly, fine-grained, grey; laminated; top surface has "cut and fill" features	3.5	14.5
3	Sandstone, laminated, uniformly bedded	2	11
2	Sandstone, fine-grained, grey, knobbly, slightly calcareous; some laminated sandstone interbedded at top	3	9
1	Sandstone, fine-grained, grey; laminated; rusty brown weathering; beds 1″-4″, rare chert pebbles on bedding surfaces. GSC loc. 27089	6	6
	BLACKSTONE FORMATION		
	Opabin Member		
18	Siltstone, argillaceous, to very silty shale, bedded; rusty weathering; few 3″ × 1′ orange weathering concretions	6	109
17	Shale, platy at top, more rubbly below 5′; rusty weathering; 1″-2″ reddish brown weathering concretionary bands	15.5	103
16	Shale, rubbly at top, more silty at base with thin siltstone beds; rusty weathering; few small concretions	9	87.5
15	Sandstone, very fine grained, grey; rusty weathering; beds 1″-2″ laminated, slightly irregular; shaly break in centre	1	78.5
14	Siltstone, argillaceous, blocky to knobbly, dark grey; rusty to greenish grey weathering; few small concretions	4	77.5
13	Siltstone, argillaceous, to very silty shale, blocky, dark grey; rusty weathering	5	73.5
12	Shale, rubbly, dark grey; rusty weathering; few thin concretions	7	68.5
11	Shale, blocky, dark to brownish grey; reddish brown weathering; with 10% bands of 1″-2″ laminated siltstone	8	61.5
10	Shale, blocky to rubbly; dark to brownish grey; rusty weathering	4	53.5
9	Shale, blocky, dark grey; reddish to rust weathering; with concretions	9	49.5
8	Shale, blocky, dark grey; rusty weathering; with ½″-1″ siltstone band, 25%; laminated; few concretions	9	40.5
7	Conglomerate, shaly at top; chert pebbles, ¼″-1″, rounded	1	31.5
6	Sandstone, fine-grained, grey to brownish grey, slightly argillaceous; homogeneous, beds 3″-1″, some crossbedding, more massive at top; few thin shaly intervals towards base	17	30.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
5	Sandstone, fine-grained, grey; laminated, massive with 3″ thinly bedded sandstone at top; concretionary zones	6	13.5
4	Concretionary sandstone zone; brown weathering	1	7.5
3	Sandstone, fine-grained, grey; laminated	1	6.5
2	Sandstone, fine-grained, grey; laminated; rusty tan weathering; beds 2″-6′, few shaly intervals near base	2.5	5.5
1	Sandstone, fine-grained, brownish grey; brown weathering; laminated; beds 4″-1′, slightly argillaceous	3	3
	End of exposure.		

Section 5-39. Cardium formation, Wapiabi map-area, Alberta, Blackstone River, first section downstream from bridge.

	Overlying beds of Wapiabi formation. GSC loc. 25101.		
	CARDIUM FORMATION		
	Sturrock Member		
25	Sandstone, silty, grey; somewhat wavy bedded to platy; irregular concretions on upper surface. (This has a somewhat transitional appearance, although break between Cardium sandstone and Wapiabi shale is distinct.)	1	258.5
24	Sandstone, fine-grained, grey, well indurated; concretionary, beds 3″-4″; with shale, 20%; concretionary upper surface	1	257.5
23	Sandstone, fine-grained, grey; rusty tan weathering; slightly concretionary; basal 10″ is 60% shale with thinly bedded sandstone	3.5	256.5
22	Sandstone, fine-grained, grey; slightly laminated, rusty tan weathering; beds 2″-1″, few small silty concretions on bedding surfaces and shale, 30%. (3″ shale at 1.25′; 1′ shale and thinly bedded sandstone below 2.5′; 6″ shale at 4.5′; 3″ shale and thinly bedded sandstone below 6′; silty interval between 8′ and 9′.)	9	253
	Leyland Member		
21	Sandstone to siltstone, argillaceous, grey; wavy bedded; few concretions	10	244
20	Siltstone, to shale, argillaceous, dark grey; slightly rusty weathering, bedded; rows of concretions in basal 10′; 1″ fissile shale at base, sharp break	27	234
19	Siltstone to shale, hard at top, more shaly at base; bedded; 2″ × 6″ concretions; grades into underlying unit	8	207
18	Shale, blocky, dark grey; rusty weathering; bedded appearance; concretions 2″-3″ × 6″-1′, reddish brown weathering	23	199

Unit	Lithology	Thickness (feet)	Height above base (feet)
17	Siltstone, argillaceous, blocky, dark grey; rusty weathering; concretionary in lower part. Upper contact is gradational. More bedded at base; grades into underlying unit	20	176
16	Shale, blocky, dark grey; rusty weathering; few concretions	13	156
15	Concretions, 30%, and blocky shale. Concretions at base have floating sand grains, gritty surface and few pebbles	4	143
	Cardinal Member		
14	Siltstone, sandy, argillaceous, grey; rusty weathering; massive; concretionary on upper surface, with scattered ½″-1″ pebbles, concretionary spots, scattered concretions; shaly at base	11	139
	Kiska Member		
13	Shale, blocky, dark grey; rusty weathering; few 6″×1′-2′ reddish brown weathering concretions	16	128
	Moosehound Member		
12	Shale, blocky, rubbly, brown; with 1″ coaly shale at base	1	112
11	Sandstone, fine-grained, grey; tan to grey weathering; beds 2″-3″ somewhat flaggy, shaly break at 11′; slightly more massive in basal 4′ with cut-fill base; carbonaceous remains in upper 2′ and on upper surface	18	111
10	Shale, platy to rubbly, dark grey; with 30% platy siltstone in upper 5′; grades downward into more rubbly shale; has rust to brown weathering, carbonaceous remains	13.5	93
	Ram Member		
9	Sandstone, fine-grained, grey; brown weathering; laminated; carbonaceous remains in upper 3′, beds 2″-3″, upper surface has ½″ pebbles and concretions	5	79.5
8	Sandstone, fine-grained, cherty, grey; laminated, massive; 6″-2′ beds, 6″ shale break at base	13	74.5
7	Sandstone, fine-grained, grey, laminated; tan weathering, massive	16	61.5
6	Concretionary zone. Trace of carbonaceous fragments	0.5	45.5
5	Sandstone, fine-grained, grey, laminated; tan weathering; massive	11.5	45
4	Shale, and sandstone, 25%, platy	1.5	33.5
3	Sandstone, fine-grained, calcareous, grey; laminated, massive; with 6″ shale and thinly bedded sandstone at base	6	32
2	Sandstone, fine-grained, grey; laminated; tan weathering; with basal 1.5′ more thinly bedded with some shale	22	26
1	Sandstone, fine-grained, grey; laminated; tan weathering	4	4

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BLACKSTONE FORMATION		
8	Siltstone, argillaceous, grey; rusty weathering; bedded; concretions	9	100
7	Siltstone to shale, dark grey; rusty weathering	6	91
6	Siltstone, argillaceous, dark grey; few concretions	2.5	85
5	Sandstone to siltstone in upper 2′ with well-indurated sandstone bed at top; grades downward into argillaceous siltstone; few concretions	12	82.5
4	Siltstone, argillaceous, dark grey; well-indurated band at base; bedded appearance; few concretionary beds	6.5	70.5
3	Shale, blocky, dark grey; rusty weathering; few concretions	12	64
2	Shale, platy at top, more rubbly towards base; numerous concretions	33	52
1	Shale, rubbly; rusty weathering; concretions in basal 6′	19	19
	End of exposure.		

Section 5-42. Wapiabi formation, Cripple Creek map-area, Alberta, Cripple Creek.

Uppermost beds described on small northern tributary, remainder on Cripple Creek.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BRAZEAU FORMATION		
	Sandstone, coarse-grained, carbonaceous, greenish grey; massive; grey weathering	22	130
	WAPIABI FORMATION		
	Nomad Member		
100	Sandstone, fine-grained, platy, brownish grey; grey weathering	3	1,952
99	Sandstone to siltstone, brownish grey, platy to crumbly; concretionary-like structures	6	1,949
98	Shale, and sandstone, 40%; shale, rubbly, brownish grey; sandstone as above	4	1,943
97	Shale, and sandstone, 40%; sandstone, fine-grained, brownish grey; laminated, platy to massive; 2″-6″ beds; base has structure of channel filling	19	1,939
96	Sandstone, grey; brown weathering, laminated, bolster-like structures; shale, 25%	3	1,920
95	Shale, rubbly, dark grey, to brownish grey; with sandstone, as above; channel fillings 25%	5	1,917
94	Shale, and siltstone, 50%, laminated, grey; rusty weathering; banded appearance	3	1,912
93	Shale, rubbly, dark grey; brownish grey weathering, thinly bedded; siltstone, 5%	11	1,909
92	Shale and siltstone, 40%, bands 1″-2″; rusty weathering; concretionary	7	1,898
91	Shale, rubbly, dark grey; brownish grey to rusty weathering	38	1,891

Unit	Lithology	Thickness (feet)	Height above base (feet)
90	Conglomerate, pebbles ¼"-½", rounded, in sandstone matrix; grades into underlying unit	6	1,853
89	Grit, dark grey, cherty; rusty weathering	3	1,847
	Chungo Member		
88	Siltstone, sandy, argillaceous, dark grey; somewhat bedded; grey weathering	7	1,844
87	Siltstone, argillaceous, dark grey; bedded; grey weathering; rusty concretionary spots	7	1,837
86	Sandstone, fine-grained, silty to argillaceous, well cemented; with lenses of coarser sandstone, dark grey, massive; few small concretions	2	1,830
85	Partly covered. Shale and siltstone, bedded	14	1,828
84	Siltstone, argillaceous, bedded, hard, dark grey; 2"-3" concretionary zone at base	17	1,814
83	Siltstone, sandy, argillaceous, hard, dark grey; grey weathering; more argillaceous at base. GSC loc. 32868	10	1,797
82	Siltstone to silty shale, dark grey; bedded	8	1,787
81	Sandstone, fine-grained, grey; grey weathering; laminated; rare concretionary zone, beds 6"-1'; shaly intervals, 5%	8	1,779
80	Sandstone, argillaceous, dark grey; bedded; some channel fillings	3	1,771
79	Siltstone, argillaceous, sandy at top, dark grey; bedded	9	1,768
78	Sandstone, fine-grained, dark grey, grey weathering; laminated. In three beds	3	1,759
77	Siltstone, sandy, argillaceous, hard, bedded, grey; grey weathering; some concretions	9	1,756
76	Sandstone, very fine grained, grey; laminated; brown weathering; three beds; shaly intervals, 10%	4	1,747
75	Siltstone, argillaceous, sandy; bedded; concretionary siltstone beds in basal 8', with shale partings 1"-2", 10%	18	1,743
74	Sandstone to siltstone, very argillaceous, brownish grey; tan weathering; massive to platy	3	1,725
73	Sandstone, fine-grained, argillaceous, brownish grey; tan weathering; laminated, massive	3.5	1,722
72	Siltstone, argillaceous, blocky, brownish grey; brown weathering; 6" silty sandstone at base	17.5	1,718.5
71	Shale, very silty, blocky, brownish grey; brown weathering; few beds of indurated siltstone; and rare concretionary bed	20	1,701
70	Siltstone to shale, dark grey; grey weathering; 1' concretionary zone at 5' and at 10'	14	1,681
69	Shale, very silty, blocky to argillaceous siltstone, dark grey	5	1,667
68	Siltstone, argillaceous, dark grey, rusty weathering; bedded	4	1,662
67	Siltstone, argillaceous, dark grey; grey weathering; massive	5	1,658
66	Siltstone, argillaceous, dark grey; bedded to massive; topped by 6" reddish brown concretionary bed	2	1,653

Unit	Lithology	Thickness (feet)	Height above base (feet)
65	Sandstone to siltstone, argillaceous, dark grey; laminated, massive	1.5	1,651
64	Siltstone, argillaceous, dark grey; massive	1.5	1,649.5
63	Sandstone, very fine grained, argillaceous, grey, well cemented; rusty weathering; laminated	1	1,648
62	Siltstone to sandstone, bedded, dark grey	1	1,647
61	Sandstone, very fine grained, argillaceous, grey; laminated, massive	1	1,646
60	Siltstone, sandy, argillaceous, dark grey; bedded	2	1,645
59	Siltstone, sandy, argillaceous, dark grey; massive; concretionary bed in centre	3.5	1,643
58	Concretionary zone, reddish brown weathering, very knobbly	0.5	1,639.5
57	Siltstone, argillaceous, dark grey, bedded; becomes blocky at base; few 3″ × 6″ reddish brown weathering concretions, grades into underlying unit	14	1,639
	Hanson Member		
56	Shale, blocky, dark grey; becoming rubbly at base; some 2″ × 4″ concretions and 6″ concretionary band at top	35	1,625
55	Covered	9	1,590
54	Siltstone, argillaceous, dark grey; round irregular reddish brown weathering concretions	16	1,581
53	Shale to argillaceous siltstone, dark grey; blocky; rusty concretionary spots	8	1,565
52	Mostly covered. Shale	17	1,557
51	Siltstone, argillaceous, to silty shale, bedded, dark grey; concretions 4″-6″ × 1′; reddish brown weathering	14	1,540
50	Shale, very silty, blocky, dark grey; 6″-1′ × 1′-3′ irregular reddish brown weathering concretions in rows; grades into underlying unit	40	1,526
49	Shale, blocky, dark grey; with similar concretions	21	1,486
48	Shale, blocky; with 6″ × 1′ orange weathering concretions. GSC loc. 27480	22	1,465
47	Shale, blocky to slightly rubbly, dark grey; 3″-4″ × 6″-1′ reddish brown weathering concretions	26	1,443
	Thistle Member		
46	Estimated covered interval	125	1,417
45	Shale, and siltstone, 25%, dark grey; rusty weathering; platy	26	1,292
44	Shale, and siltstone, 40%; rusty weathering, platy	8	1,266
43	Shale, and siltstone, 20%, decreasing to 10%, platy, dark grey; thin bentonite (?) at base	29	1,258
42	Shale, and siltstone, 40%, decreasing to 25%, dark grey, platy; beds of siltstone ½″-1″	18	1,229
41	Shale, and siltstone, 50%, platy, grey	16	1,211
40	Shale, and siltstone, 35%, platy; rusty weathering	32	1,195
39	Dolomite, argillaceous, dense, bluish grey; yellow weathering; lenses out up slope	2	1,163
38	Shale, and siltstone, 50%, decreasing to 40%, platy	14	1,161
37	Shale, and siltstone, 50%	8	1,147

Unit	Lithology	Thickness (feet)	Height above base (feet)
36	Shale, and siltstone, 40%, platy, dark grey; sharp break at base	28	1,139
35	Shale, and siltstone, 50%, few beds of sandstone, fine-grained, laminated, bluish grey, 1"-2"	28	1,111
34	Shale, and siltstone, 50%; beds of sandstone 10% in upper 15'; silt content decreases towards base and beds become platy	59	1,083
33	Estimated covered interval	150	1,024
32	Shale, platy; rusty weathering; ½"-1" siltstone bands, 10%	30	874
31	Shale, and siltstone, 30%, rusty weathering	10	844
30	Shale, platy to rubbly; rusty weathering	29	834
29	Shale, and siltstone, 30%, few 1"-2" well-indurated beds at top, platy at base	15	805
28	Shale, and siltstone, 20%	13	790
27	Siltstone, argillaceous, shaly, dark grey; bedded, massive	8	777
26	Shale, and siltstone, 50%, decreasing to 10%, platy; rare limy concretionary bed	46	769
25	Mostly covered. Rubbly, rusty weathering shale	27	723
24	Shale, platy to rubbly; rusty weathering	14	696
23	Shale, and siltstone, 30%, decreasing to 10%; rusty weathering	19	682
22	Shale, rubbly; rusty weathering	14	663
	Dowling Member		
21	Shale, and siltstone, 20%; rusty weathering; few reddish brown weathering concretions 3"-6" × 1'	21	649
20	Shale, and siltstone, 30%; rusty weathering; reddish brown weathering concretions 2"-4" × 6"-1'	32	628
19	Shale and siltstone as above. Fragments of large pelecypods in concretions	12	596
18	Shale, platy to rubbly; rusty weathering; no concretions	40	584
17	Shale as above with thin concretions	6	544
16	Covered	9	538
15	Shale, platy; few thin siltstone beds; 2" × 6" concretions	20	529
14	Covered. Some shale and concretions exposed	56	509
13	Shale, very silty, blocky to platy; rare concretions	47	453
12	Shale, silty, blocky, platy; 6" × 1'-2' concretions especially at base	18	406
	Marshybank Member		
11	Siltstone, argillaceous, dark grey; massive to bedded; 4" × 3' reddish brown weathering concretions. GSC loc. 27116	14	388
10	Siltstone, argillaceous, dark grey; bedded, blocky at base; concretionary upper surface 6" × 1' concretions, grades into underlying unit. GSC loc. 32871	16	374
9	Shale, blocky at top, rubbly at base; few concretions	27	358
8	Siltstone, argillaceous, bedded; grades into blocky shale at base; some concretions	19	331

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Muskiki Member		
7	Estimated covered interval	75	312
6	Shale, silty, platy to blocky; siltstone, 20%, decreasing to 10%; concretions	55	237
5	Estimated covered interval	20	182
4	Shale, platy, dark grey; thin concretions and concretionary bands. GSC loc. 27052	46	162
3	Shale, rubbly; concretions 3″ × 6″; reddish brown weathering	32	116
2	Shale, platy to rubbly; few concretions	34	84
1	Estimated covered interval	50	50
	Sandstone of Cardium formation.		

Section 5-45. Cardium formation, Cripple Creek map-area, South Ram River, first complete section east of forestry road.

	Overlying beds of Wapiabi formation consist of platy shale and very thin siltstone, rusty weathering.		
6	Sandstone, coarse-grained, concretionary; reddish-brown weathering; with pebbles up to 1″ on upper surface	1.5	15.5
5	Sandstone, coarse-grained, shaly matrix; irregular wavy bedding	1	14
4	Sandstone, coarse-grained, concretionary; reddish-brown weathering	1.5	13
3	Shale, very sandy, bedded; scattered pebbles up to ½″; some reddish-brown weathering concretions; grades into underlying unit	4	11.5
2	Siltstone, argillaceous, sandy to gritty, dark grey; rusty concretionary spots; bedded appearance	7	7.5
1	Shale, sandy, with scattered pebbles up to 1″	0.5	0.5
	CARDIUM FORMATION		
	Sturrock Member		
33	Siltstone, brownish grey, platy ½″-1″ beds; and shale, 30%, brownish to rusty weathering; rusty concretionary spots	12	357.5
32	Sandstone, fine-grained, grey; laminated, wavy bedded; ½″-3″ beds; rusty concretionary spots	4.5	345.5
31	Sandstone, fine-grained, grey, laminated, 4″-6″ beds; siltstone, 60%, wavy bedded; siltier at base	5	341
30	Sandstone, fine-grained, bluish grey; rusty tan weathering; laminated; beds 4″-1′, more massive beds separated by 2″-3″ thinly bedded sandstone; some crossbedding	7	336
29	Siltstone, argillaceous, shaly at base, wavy, platy, grey	4	329
28	Sandstone, fine-grained, grey to bluish grey; laminated, massive; concretionary; *Cardium* on upper surface. Top surface appears to have channels filled by overlying shale	12	325

Unit	Lithology	Thickness (feet)	Height above base (feet)
27	Sandstone as above, slightly more platy weathering; and shale 20%; *Cardium*. GSC loc. 27047	6	313
26	Shale, and thinly bedded sandstone, 50%, 2"-3" beds	1	307
25	Siltstone, argillaceous to sandy	9	306
24	Sandstone, very fine grained, bluish grey, laminated, beds 4"-6", concretionary zones; and shale, 10%. GSC loc. 32883	4.5	297
23	Sandstone, laminated, bluish grey, concretionary zones; siltstone, 10%, in upper half	5	292.5
	Leyland Member		
22	Sandstone, 50%, as above, in 2"-6" beds, concretionary zones; and platy, irregularly bedded siltstone	6	287.5
21	Siltstone, argillaceous, shaly, blocky, dark grey; rusty weathering, 2" × 6" concretions; grades into underlying unit	9	281.5
20	Shale, blocky, dark grey; rusty weathering; few thin concretions	20	272.5
19	Siltstone matrix, very gritty, extremely concretionary; reddish brown weathering; few scattered pebbles	2	252.5
18	Siltstone, gritty, very concretionary especially in basal 3'; reddish brown weathering; scattered ¼" pebbles; grades into underlying unit. GSC loc. 32874	6	250.5
17	Siltstone, argillaceous, somewhat gritty, few scattered pebbles especially in concretions, more shaly at base; reddish brown weathering concretionary spots	15	244.5
16	Sandstone, and shale, 50%, platy to papery; rusty weathering	2	229.5
15	Sandstone, fine-grained, laminated, brown weathering, lensy; and shale, 20%	1	227.5
14	Siltstone, very argillaceous to blocky shale, bedded appearance, dark grey; reddish brown weathering concretionary spots	5	226.5
13	Sandstone, fine-grained, bluish grey, laminated, rusty weathering; and shale, 20%, beds 2"-4"	1.5	221.5
12	Siltstone, argillaceous, dark grey, bedded; some concretions; grades into underlying unit	11	220
11	Shale, very silty at top, blocky to rubbly at base, dark grey; concretionary zone at top, with few concretionary beds and rare concretions	44	209
10	Shale, almost siltstone; rusty weathering	2	165
	Cardinal Member		
9	Siltstone, argillaceous, rusty weathering; massive; few concretions 6" × 2'; more shaly interval 13'-14' and 18'-19'; grades into underlying unit	23	163
	Kiska Member		
8	Siltstone, argillaceous, shaly, bedded; more rubbly at base; rusty weathering; grades into underlying unit	18	140
7	Shale, blocky to rubbly, rusty weathering; 4" concretionary bed at 11' with floating sand grains; shale below is somewhat gritty with few pebbles	19	122

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Ram Member		
6	Sandstone, fine-grained, dark grey; rusty weathering; homogeneous; 4″-2′ beds, irregular bedding surfaces	13	103
5	Sandstone, fine-grained, grey; homogeneous to laminated, beds 6″-2′; tan weathering; thin shale to break at 5′ and 20′; somewhat concretionary; few small pebbles in concretions at 20′	30	90
4	Siltstone, argillaceous, platy, laminated; grading downward into platy shale with 1″-2″ bands of laminated siltstone; 1′ sandstone at top separated from overlying beds by rusty shale	22	60
3	Sandstone, fine-grained, grey, laminated, beds 4″-1′ in top 6′, more platy at base; shale, 10%; some concretions; somewhat wavy bedded, does not have massive appearance; rests sharply on underlying unit	12	38
2	Sandstone, fine-grained, grey; one foot in centre laminated, separating massive beds with suggestion of worm reworking	7	26
1	Sandstone, fine-grained, grey; laminated, beds 6″ to massive; weathers yellowish	19	19
	BLACKSTONE FORMATION		
	Opabin Member		
64	Siltstone, argillaceous, dark grey; massive; rusty weathering; more bedded at base; 1′ × 2′ reddish brown weathering concretions; grades into underlying unit	18	1,090
63	Siltstone, argillaceous, bedded; grading downward into blocky and rubbly shale; rare concretions	21	1,072
62	Shale, rubbly; rusty weathering; concretionary bed at top	8	1,051
61	Siltstone, argillaceous to silty shale, bedded appearance; platy, rusty weathering; 4″-6″ × 1′-2′ reddish brown weathering concretions	7	1,043
60	Shale, blocky to rubbly; rusty weathering; with few beds of laminated siltstone	9	1,036
59	Shale, platy, very silty, dark grey; rusty weathering; banded appearance; concretionary beds; grades into underlying unit	22	1,027
58	Shale, blocky to rubbly; rusty weathering; concretionary beds	17	1,005
57	Shale, very silty, platy; concretions, and concretionary beds	18	988
56	Shale, blocky, dark grey; rusty weathering; some concretions	20	970
55	Shale, blocky to rubbly; rusty weathering; few concretions	26	950
	Small displacement		
	Haven Member		
54	Shale, rubbly; rusty weathering	10	924
53	Shale and siltstone, 30%; rusty weathering	23	914

Unit	Lithology	Thickness (feet)	Height above base (feet)
52	Shale, platy, rusty weathering; 1′-2′ × 2′-4′ yellow weathering limestone concretions	18	891
51	Shale, and siltstone, 25%, decreasing towards base; band of laminated siltstone at top; all rusty weathering; rare limestone concretions, 3″ limestone bed at base	46	873
50	Shale, and siltstone, 40% decreasing to 20%; rusty weathering; rare limestone concretions	55	827
49	Shale, platy; rusty weathering	31	772
48	Shale, rubbly at base; and siltstone, 20%; rusty weathering; rare limestone concretions	28	741
47	Shale, and siltstone, 25%; thin bentonite at 7′	14	713
46	Shale, platy; and thinly bedded siltstone, 15%, dark grey	25	699
	Vimy Member		
45	Limestone, dense, bluish grey; yellow weathering. GSC loc. 32881	1	674
44	Shale, silty, platy, dark grey; silver-grey weathering; few thin limestone beds at base	5	673
43	Dolomite, argillaceous, blue grey, aphanitic; tan weathering; massive, laminated	1	668
42	Shale, platy, silty, dark grey; and some siltstone; silver-grey to rusty weathering	22	667
41	Shale, silty, platy to flaky, dark grey	5	645
40	Shale, rubbly, dark grey; rusty weathering	10	640
39	Shale, dark grey, silver-grey weathering; and siltstone, 40%, with 1′ oval concretions	17	630
38	Dolomite, aphanitic, argillaceous; tan weathering; platy to shaly at the base	0.5	613
37	Shale, platy, dark grey; and siltstone, 50%, banded appearance; silver grey weathering; becomes less silty at base	39.5	612.5
36	Dolomite, argillaceous, blue grey, aphanitic; tan to buff weathering; laminated. GSC loc. 28181	1	573
35	Shale, dark grey, silver-grey weathering; and siltstone, 40%, 1″ in thickness; more shaly in basal 9′. GSC loc. 32873	21	572
34	Dolomite, very argillaceous and platy	1	551
33	Shale, dark grey, silver-grey weathering; and siltstone, 40%, platy; few small concretions	25	550
32	Shale, silty, platy, dark grey, silver-grey weathering; and siltstone, 25%	12	525
31	Shale, dark grey, silver-grey weathering; and siltstone, 30%	17	513
30	Shale, dark grey, silver-grey weathering; and siltstone, 40%, less at base; few 1″ calcareous siltstone beds	18	496
29	Shale, platy, dark grey; and siltstone with 1″ beds; very banded appearance	11	478
28	Shale, platy to flaky, silty, dark grey; silver-grey weathering	13	467
27	Dolomite, aphanitic, argillaceous, platy and shaly; yellow to tan weathering	1	454
26	Shale, platy to flaky, dark grey; silver-grey weathering; rare siltstone beds with thin limestone at base	34.5	453

Unit	Lithology	Thickness (feet)	Height above base (feet)
25	Dolomite, dense, argillaceous, 4″ at top, 6″ at base, and shale in centre	2	418.5
24	Shale, platy to flaky, dark grey; silver-grey weathering	8.5	416.5
23	Dolomite, dense, blue grey; yellow weathering	0.5	408
22	Shale, platy, calcareous, dark grey	2.5	407.5
21	Dolomite, dense, argillaceous; yellow tan weathering. GSC loc. 32872	1	405
	Fold in section-anticline and syncline, beds omitted. Measured below dolomite bed.		
20	Shale, platy to flaky, dark grey; silver-grey weathering; few thin siltstone beds	52	404
19	Shale, platy and siltstone, 30%, few thin dolomitic beds at top, dark grey; silver-grey weathering; more rubbly at base. GSC loc. 32869	28	352
	Shear zone of approximately 10′.		
18	Shale, platy to flaky, dark grey; silver-grey weathering	44	324
17	Dolomite, and shale, 50%	1	280
16	Shale, flaky to rubbly, dark grey; slightly rusty weathering	8	279
15	Shale, flaky to rubbly, dark grey, somewhat rusty weathering; and siltstone, 20%; some 1″ bands. GSC loc. 28171	20	271
14	Bentonite, white to cream with tan weathering; calcareous to siliceous milky white concretions	1	251
13	Shale, flaky, dark grey; silver grey to rusty weathering; few concretions	11	250
12	Dolomite, argillaceous, silty; concretionary in form. GSC loc. 28169	2.5	239
11	Shale, platy to flaky, dark grey; somewhat rusty weathering	11	236.5
	Sunkay Member		
10	Siltstone, laminated, grey and shale, 40%; with large 6′ × 1′ limestone concretions; less silty in basal 10′	39.5	225.5
9	Shale, rusty weathering, and siltstone, 40%, in ½″-1″ beds; becomes more shaly at base	22	186
8	Shale, rusty weathering, and siltstone, 30%; rare large concretions; more shaly at base. GSC loc. 28182	49	164
7	Shale, rusty weathering, and siltstone, 40%; rare large concretions; more shaly at base. Shale is platy to flaky	20	115
6	Shale, platy to flaky; rusty weathering	19	95
5	Siltstone, argillaceous, dark grey, and gritty; rusty weathering	4	76
4	Shale, and siltstone, 30%; rusty weathering	17	72
3	Shale, platy to rubbly at base; rusty weathering; large concretions at 11′	21	55
2	Shale, rusty weathering; and siltstone, 40%, more shaly at base	25	34
1	Siltstone, argillaceous, dark grey; rusty weathering; somewhat gritty; upper 2′ massive. GSC loc. 32862	9	9
	Section is faulted.		

Section 6-9. Alberta group, Burnt Timber Creek, 4 miles west of forestry road.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BELLY RIVER FORMATION		
3	Sandstone, medium-grained, greenish grey; massive, thickly bedded, homogeneous; considerable chert	6	39
2	Mostly covered. Rubbly shale at base, carbonaceous, greenish grey; dark brown weathering	26	33
1	Sandstone, medium-grained, greenish grey; brown weathering; and interbedded platy shale, 20%; upper 1′ concretionary	7	7
	ALBERTA GROUP		
	WAPIABI FORMATION		
	Nomad Member		
95	Mostly covered. Appears to be shale, rubbly	33	1,820
94	Shale to mudstone, silty, dark grey; rusty to greenish weathering	17	1,787
93	Dolomite, argillaceous, aphanitic, bluish grey; buff weathering	1	1,770
92	Shale, to mudstone, rubbly; brownish weathering	11	1,769
91	Concretionary siltstone, buff weathering; not a dense limestone	1	1,758
90	Partly covered. Shale, pencil fragments to rubbly; brownish weathering	24.5	1,757
89	Grit to siltstone, argillaceous, dark grey; very concretionary; reddish brown weathering; massive	2.5	1,732.5
	Chungo Member		
89	Siltstone, argillaceous, gritty, dark grey; some concretions	4	1,730
88	Siltstone, sandy to gritty, argillaceous, dark grey; 6″ concretions; grades into underlying bands	1	1,726
87	Siltstone, argillaceous, dark grey; bedded, some concretionary beds	8	1,725
86	Siltstone, argillaceous, shaly, dark grey; few scattered concretions; more shaly at base	15	1,717
85	Siltstone, argillaceous; dark grey concretionary spots; bedded; more shaly in basal 8′. GSC loc. 28080	17	1,702
84	Sandstone, fine-grained, brownish grey; brown weathering; laminated, massive; argillaceous at base; some concretions	4	1,685
83	Siltstone, sandy, argillaceous, dark grey	7.5	1,681
82	Concretionary zone, reddish brown weathering	0.5	1,673.5
81	Sandstone, fine-grained, grey; laminated	1	1,673
80	Inaccessible. 4′ sandstone at top, grading downward into argillaceous siltstone	15	1,672
79	Siltstone, very argillaceous, dark grey; bedded, 2″ × 3″ concretions	11	1,657
78	Mudstone, silty, blocky, dark grey; some concretions	5	1,646
77	Siltstone, laminated, grey; and shale, interbedded, dark grey; bedded appearance, more shaly at base. Bentonite at 11.5.		

Unit	Lithology	Thickness (feet)	Height above base (feet)
76	Siltstone, laminated, 60%, grey; and shale, dark grey, blocky to rubbly. Bentonite at base	8	1,629
75	Shale, rubbly, dark grey; rusty weathering	3	1,621
74	Shale, with siltstone at top, grading into rubbly shale at base; few concretions	4	1,618
73	Siltstone, and platy shale, 60%, grades downward into silty to rubbly shale	15	1,614
72	Sandstone, argillaceous, silty, dark grey; grey weathering; concretionary spots	4	1,599
71	Shale, dark grey, with concretions	1	1,595
70	Siltstone, argillaceous, dark grey, bedded; shaly at 5′ and base	12	1,594
69	Siltstone, argillaceous, dark grey, bedded; few concretions; blocky at base	14	1,582
68	Siltstone, dark grey, argillaceous, massive; concretionary at top	7	1,568
	Hanson Member		
67	Mudstone, blocky, dark grey; rusty weathering; with concretions, becomes rubbly at base	55	1,561
66	Siltstone, argillaceous, dark grey, bedded; some laminated lenses; large concretions. GSC loc. 28079	59	1,506
65	Siltstone, argillaceous, becoming more shaly at base; large reddish brown weathering concretions	38	1,447
64	Mudstone, silty, dark grey, blocky to rubbly; 6″ × 1′ concretions	19	1,409
63	Siltstone, to mudstone, blocky, dark grey; 4″ × 6″-1′, reddish brown weathering concretions; bentonite at base	40	1,390
62	Mudstone, silty, with few siltstone beds; few concretions	43	1,350
	Thistle Member		
61	Shale to mudstone, platy and argillaceous siltstone interbedded, 70-30	16	1,307
60	Siltstone, laminated, platy to 2″ bands, 50%; and shale, platy	20.5	1,291
59	Dolomite, aphanitic, argillaceous; with shale, 30%	1.5	1,270.5
58	Siltstone, and shale, platy, laminated	45.5	1,269
57	Sandstone, fine-grained, laminated, grey	0.5	1,223.5
56	Siltstone, laminated; and shale, 50%	15.5	1,223
55	Dolomite, argillaceous, pinches out downslope	1.5	1,207.5
54	Shale, and siltstone, platy, 40%; more shaly at base	49	1,206
53	Siltstone, and shale, 40%; banded appearance	15	1,157
52	Shale, and siltstone, 30%	22	1,142
51	Siltstone, and shale, 50%, more shale at base, laminated, grey, platy	43	1,120
50	Shale, and siltstone, 40%, less siltstone at base; shale becomes much more flaky	29	1,077
49	Dolomite, aphanitic, argillaceous; tan weathering	1	1,048
48	Shale, and siltstone, 30%, dark grey	48	1,047
47	Siltstone to sandstone, and shale, 40%	13	999
46	Shale, and siltstone, 30%	19	986
45	Sandstone, fine-grained, laminated, grey, 1″-2″ beds; and shale, 30%	3	967

Unit	Lithology	Thickness (feet)	Height above base (feet)
44	Siltstone, and shale, 50%; grades into shale at base	20	964
43	Dolomite, aphanitic, argillaceous, bluish grey; yellow weathering; laminated	1	944
42	Covered	26	943
41	Shale, and siltstone, 30%	24	917
40	Sandstone, fine-grained, laminated, platy	5	893
39	Siltstone, and shale, 60%, platy, dark grey; more shale at base with 4" argillaceous dolomite at base	54	888
38	Shale, silty, platy, dark grey	29	834
37	Siltstone, and shale, 60%; bentonite at 18'	26	805
36	Siltstone, and shale, 75%	30	779
35	Shale, rubbly, dark grey	3	749
34	Siltstone, and shale, 20%, 1"-2" bands	20	746
33	Shale, platy, rubbly at base	28	726
32	Covered	16	698
31	Shale, and siltstone, 25%, very shaly at base	27	682
30	Shale, and siltstone, 40%, grading into rubbly shale at base	26	655
	Dowling Member		
29	Covered. Lower 8' appears to be concretionary shale	38	629
28	Siltstone, argillaceous, bedded, dark grey; with 3" × 6" reddish brown weathering concretions	12	591
27	Shale, very silty, dark grey; 2"-3" × 6"-1' concretions; few beds of laminated siltstone 1"-2"; pelecypod fragments in concretions	18	579
26	Shale, dark grey, platy to rubbly; rusty weathering	17	561
25	Shale, rubbly; rusty weathering; few thin siltstones; concretions and concretionary beds	16	544
24	Shale, platy to rubbly, dark grey; rusty weathering; with 1"-2" × 6"-1' reddish brown weathering concretions	11	528
23	Shale, silty, platy; rusty weathering; with lensy concretionary beds and small concretions	14	517
22	Shale, rubbly; rusty weathering; with 3" × 6"-1' concretions	13	503
21	Shale, rubbly; rusty weathering; very few concretions	14	490
20	Shale, silty, platy to rubbly; with thin concretions	12	476
19	Shale, blocky to rubbly, dark grey; no concretions. GSC loc. 28087	9	464
18	Mudstone, silty, blocky, with bands of irregular, reddish brown weathering concretions; slightly more shaly below 20'	45	455
17	Mudstone to argillaceous siltstone, blocky, dark grey; bedded appearance; concretions at top. GSC loc. 28094	12	410
16	Shale and siltstone, platy, with bands of concretions, shaly at base. Bentonite at 5' and 37'. 10" concretionary zone at 22'	87	398
	Marshybank Member		
15	Siltstone and shale, rusty weathering; more shaly at base; concretionary beds	33	311

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Muskiki Member		
14	Shale to mudstone, blocky to rubbly; scattered concretions. GSC loc. 28055	57	278
13	Shale, rubbly; rusty weathering; few irregular concretions; striped appearance	26	221
12	Shale, somewhat siltier than overlying beds, rubbly; with concretions and concretionary beds, more shaly at base	17	195
11	Shale, silty, platy to rubbly; with 4″ × 8″-12″ concretions; bedded appearance. GSC loc. 28073	28	178
10	Shale, rubbly, bedded appearance, dark grey	10	150
9	Siltstone, and shale, 60%, few concretions; banded	26	140
8	Shale, dark grey, blocky to rubbly; rusty weathering	13	114
7	Shale, and some siltstone; rusty weathering; some concretionary zones	16	101
6	Shale, rubbly; rusty weathering; bedded appearance; few thin siltstone bands; 4″ bentonite at base	19	85
5	Shale, flaky to rubbly at base; rusty weathering	29	66
4	Shale, gritty, and gritty sandstone, grey; with $\frac{1}{8}$″-$\frac{1}{4}$″ chert pebbles	0.5	37
3	Concretionary zone, reddish brown weathering	0.5	36.5
2	Shale, silty, sandy; rusty weathering; with concretions	22	36
1	Siltstone, argillaceous, dark grey, bedded; pebbles in upper 2′, more shaly in basal part; fragments of large pelecypods	14	14
	CARDIUM FORMATION		
	Sturrock Member		
42	Sandstone, fine-grained, homogeneous, grey; upper 1′ somewhat concretionary; beds 6″-1′; some "bolster" structure at base	4	278
41	Sandstone, fine-grained, grey, laminated; rusty tan weathering; beds 2″-4″; upper bedding surfaces covered with *Cardium*. GSC loc. 28090	6.5	274
40	Siltstone, sandstone, and shale, interbedded, beds up to 6″, laminated, more shale at top	2.5	267.5
39	Sandstone, fine-grained, grey; laminated; rusty tan weathering	1	265
38	Shale, dark grey, with lensy sandstone at base	2	264
37	Sandstone, fine-grained, grey; tan weathering; laminated, massive	2	262
36	Sandstone, thinly bedded, crossbedded, brown weathering; and shale, 30%	2	260
35	Sandstone, fine-grained, laminated; channel filling at base	2	258
34	Sandstone, fine-grained, laminated; and platy, silty, shale, 50%	4	256
33	Siltstone, sandy, grey; grey weathering; thinly and irregularly bedded; 2″ thin shale at base	12	252
32	Siltstone, sandy, laminated, grey; beds as much as 2″, with concretions, bedded appearance	7	240
31	Sandstone, fine-grained, laminated, beds 1-2″; grey weathering; with concretions and concretionary bands; grades into underlying beds	5	233

Unit	Lithology	Thickness (feet)	Height above base (feet)
30	Sandstone, fine-grained, silty, somewhat argillaceous; with reddish brown weathering concretions; grades into underlying unit	8	228
	Leyland Member		
29	Siltstone, sandy to argillaceous at base, grey; grey weathering; with concretions	7	220
28	Siltstone, argillaceous to shale; concretions at top	1	213
27	Sandstone, fine-grained, laminated; concretionary zone in centre	1	212
26	Siltstone, argillaceous, dark grey, sandy at top; two large concretionary zones near top	15	211
25	Siltstone, argillaceous, laminated; laminated lenses in upper 6′; more argillaceous at base with 3″ × 6″ concretions, dark grey, bedded appearance	32	196
24	Shale to mudstone, silty, dark grey, blocky to rubbly	19.5	164
23	Concretionary layer with chert pebbles on top and in concretions; reddish brown weathering	0.5	144.5
22	Mudstone, blocky, silty, dark grey; concretions	10	144
21	Siltstone, argillaceous, bedded, dark grey, concretionary spots; rusty weathering; few scattered pebbles; more shaly in basal 4′	8	134
	Cardinal Member		
20	Siltstone, to sandstone, massive, laminated, concretionary, very micaceous surfaces, bedded appearance; grades into underlying unit	12	126
19	Siltstone, sandy, laminated, grey, bedded; becomes argillaceous at base with concretions and concretionary beds	18	114
18	Siltstone, argillaceous, massive; brownish weathering	2	96
	Kiska Member		
17	Siltstone, argillaceous, bedded, to mudstone; rusty weathering; concretions; becomes shaly at base	13	94
16	Mudstone to shale; blocky to rubbly; rusty weathering; few concretions	20	81
15	Siltstone, to sandstone, laminated, grey, carbonaceous; rusty weathering; irregularly bedded	10	61
	Ram Member		
14	Sandstone, fine-grained, grey; homogeneous; brown weathering; 2″-6″ beds	9	51
13	Shale and siltstone, carbonaceous	1	42
12	Sandstone, grey, fine-grained; homogeneous; somewhat silty	1.5	41
11	Shale, flaky, carbonaceous	0.5	39.5
10	Sandstone, fine-grained, laminated; brown weathering	2	39
9	Shale, platy to flaky, dark grey	0.5	37
8	Sandstone, fine-grained, laminated; brown weathering	1	36.5
7	Siltstone and shale, irregularly interbedded; rusty weathering; concretionary beds, fairly massive at base	6	35.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
6	Siltstone, sandy, argillaceous; massive; with concretions; grades into siltstone (*below*)	3	29.5
5	Siltstone, argillaceous to shaly, dark grey; bedded; some concretions	7	26.5
4	Sandstone, fine-grained, grey; homogeneous to laminated, beds 1′-2′	6.5	19.5
3	Sandstone, argillaceous, to siltstone at base; brown weathering; very concretionary at base	4	13
2	Sandstone, fine-grained, grey; laminated, beds 1′-2′, some thinly bedded zones	7	9
1	Siltstone, argillaceous, dark grey; brown weathering; massive	2	2
	BLACKSTONE FORMATION		
	Opabin Member		
62	Shale and sandstone, 50%, interbedded; shale, dark grey, rubbly, rusty weathering; sandstone, fine-grained, tan weathering, laminated, 1′ at base	9	1,257
61	Mudstone, blocky to rubbly; rusty weathering; few concretions; grades into mudstone (*below*)	8	1,248
60	Mudstone, to shale, rubbly; rusty weathering; rare reddish brown weathering concretions	29	1,240
59	Shale, very rubbly; rusty weathering; concretionary zones	65	1,211
	Haven Member		
	(Fault-top cycle is repeated, beds omitted.)		
58	Siltstone, and shale, 60%; rusty weathering; shaly in basal 5′	15	1,146
57	Siltstone (70%, decreasing to 25% at base) and shale, platy; rusty weathering; few concretions and concretionary beds at base; whole has banded appearance	35	1,131
56	Shale, rubbly; rusty weathering	29	1,096
55	Siltstone, 30%, and shale, platy; rusty weathering; banded appearance	92	1,067
54	Shale, platy to rubbly; rusty weathering	26	975
53	Siltstone and shale, platy; rusty weathering; large limestone concretion at base	43	949
	Vimy Member		
52	Siltstone and shale, platy; somewhat rusty weathering	30	906
51	As above, but silver grey weathering	34	876
50	Dolomite, shaly, argillaceous, platy; yellowish grey weathering	1	842
49	Shale, platy, dark grey; silver grey weathering	31	841
48	Dolomite, argillaceous, aphanitic; buff weathering; laminated	1	810
47	Shale; some siltstone, platy	24	809
46	Shale, platy, dark grey; silver grey weathering	17	785
45	Dolomite, argillaceous, aphanitic; laminated	1	768
44	Shale, and siltstone, 40%, platy, dark grey; silver grey weathering; laminated	38	767

Unit	Lithology	Thickness (feet)	Height above base (feet)
43	Shale, and siltstone, 30%; bands of laminated siltstone; slightly less silty at base; *Inoceramus labiatus*	49	729
42	Dolomite, aphanitic, laminated	1	680
41	Shale, platy, dark grey; some thin siltstone beds; few concretions at top	40	679
40	Dolomite, argillaceous; platy to thinly bedded, laminated	1	639
39	Siltstone and shale, 50%, platy; 4″ limestone at 11′	15	638
38	Dolomite, aphanitic, argillaceous; laminated	2	623
37	Siltstone and shale, 50%; 4″ laminated siltstone band at top; less silty at base	4	621
36	Shale, platy; some siltstone; silver grey weathering	25	617
35	Mostly covered	44.5	592
34	Dolomite, aphanitic, argillaceous	0.5	547.5
33	Shale, platy	0.5	547
32	Dolomite, aphanitic; buff weathering	0.5	546.5
31	Shale, platy, dark grey; silver grey weathering; almost fissile at base; thin limestone at 36′	60	546
30	Covered	213	486
29	Bentonite, soft, grey to white	1	273
28	Mostly covered. Shale	5	272
27	Dolomite	1	267
	Sunkay Member		
26	Shale, and siltstone, 30%, platy; rusty weathering; limestone concretion at base	27	266
25	Siltstone, and shale, 40%, platy; rusty weathering; lensy; siltstone at base	26	239
24	Shale, platy; rusty weathering	15	213
23	Siltstone, and shale, platy; rusty weathering	13	198
22	Shale, platy to rubbly; large limestone concretion at base; few thin siltstone bands	16	185
21	Siltstone and shale, 50%, platy; rusty weathering	8	169
20	Shale, platy to rubbly; rusty weathering	3	161
19	Siltstone, and shale, 60%, platy; rusty weathering	3	158
18	Shale, platy	6	155
17	Siltstone, and shale, 60%, platy; rusty weathering	10	149
16	Shale, rubbly; rusty weathering	13	139
15	Siltstone, banded; rusty weathering; laminated; grades into siltstone and shale (*below*)	7	126
14	Siltstone and shale, 50%, platy; rusty weathering	11	119
13	Siltstone, and shale, 20%; rusty weathering	7	108
12	Siltstone, and shale, 25%; sandstone band at top; rusty weathering	9	101
11	Siltstone, argillaceous to sandy, micaceous, grey; ripple-marked upper surface; 2″ bentonite at base	2	92
10	Siltstone, and shale, 60%; rusty weathering	5	90
9	Sandstone, coarse-grained, dark grey	1	85
8	Sandstone, gritty to argillaceous, dark grey; rusty weathering; very argillaceous to silty in basal 5′	9	84
7	Shale, platy, rubbly; rusty weathering	14	75
6	Siltstone, grey; laminated	1	61
5	Shale, rubbly; rusty weathering; large kettle concretions	12	60
4	Shale, platy to rubbly; large concretion at base	24	48

Unit	Lithology	Thickness (feet)	Height above base (feet)
3	Shale, rubbly; rusty weathering	18.5	24
2	Sandstone, coarse-grained, dark grey; "cut-and-fill" base	1.5	5.5
1	Siltstone, argillaceous; rusty weathering; 4" pebble zone at base	4	4
	BLAIRMORE FORMATION		
7	Shale, green, soft; weathers rusty	6	35
6	Shale, green; not as weathered as above; some silty lenses	12	29
5	Siltstone, green; sandy at top, shaly at base	3	17
4	Shale, red or maroon to green, rubbly	4	14
3	Shale, green, very rubbly	5	10
2	Siltstone to mudstone, greenish grey, blocky	3	5
1	Mudstone, rubbly, light greenish grey	2	2
	Remainder inaccessible.		

Section 6-12. Cardium formation; headwaters of Burnt Timber Creek, Alberta.

	Beds overturned, top not exposed.		
	Sturrock Member		
27	Siltstone, sandy, and shale; few sandstone beds	5	293
26	Sandstone, fine-grained, grey; tan weathering; laminated, slightly concretionary; traces of *Cardium*	4	288
25	Sandstone, lenses, fine-grained; thinly bedded, laminated; and shale, 30%; traces of *Cardium*	14	284
24	Shale, platy to blocky, dark grey	5	270
23	Sandstone, silty; thinly and irregularly bedded; shaly partings, 20%	11	265
22	Sandstone, fine-grained; laminated, massive, slightly concretionary	3	254
21	Siltstone, to sandstone, thinly bedded; and shale, 30%; rare 3"-4" sandstone beds	6	251
20	Sandstone, fine-grained; laminated, beds 1'-2'; some concretionary zones and few shaly partings	15	245
	Leyland Member		
19	Covered	32	230
18	Shale, platy to rubbly, dark grey	13	198
17	Siltstone, argillaceous; rusty weathering; grading into rubbly shale at base	8	185
16	Siltstone, argillaceous; bedded; grading downward into blocky mudstone	18	177
15	Pebble zone; chert pebbles as large as 1"	0.5	159
	Cardinal Member		
14	Siltstone, argillaceous, sandy, dark grey; bedded appearance; few concretions near top	8	158.5
13	Sandstone, argillaceous, silty, grey; massive	5.5	150.5
12	Sandstone, fine-grained; 1' beds at top, becoming more thinly bedded with shale partings at base	7	145

Unit	Lithology	Thickness (feet)	Height above base (feet)
11	Siltstone, argillaceous, dark grey; more shaly at base	8	138
10	Sandstone, silty, argillaceous, dark grey; rusty weathering	1	130
	Kiska Member		
9	Shale, platy to rubbly, dark grey	19	129
8	Shale, rubbly, dark grey; few thin concretions and 1′ sandstone lenses	10	110
7	Covered	22	100
	Ram Member		
6	Sandstone, fine-grained; rusty tan weathering; massive	10	78
5	Sandstone, grey; rusty tan weathering; thickly bedded, homogeneous	17	68
4	Siltstone, argillaceous, dark grey; rusty weathering; laminated	7	51
3	Shale, platy, almost argillaceous siltstone, dark grey; bedded appearance; beds of concretion 4″ × 1′	17	44
2	Sandstone, fine-grained, grey; tan weathering; beds 1′-1½′	6	27
1	Sandstone, fine-grained; thinly bedded, 1″-2″; some thicker beds, laminated	21	21
	BLACKSTONE FORMATION		
4	Siltstone, argillaceous, dark grey; bedded; few concretions	16	94
3	Covered	45	78
2	Shale, platy to rubbly, with concretions	17	33
1	Mudstone, blocky, dark grey	16	16

Section 6-13. Cardium formation; Ghost River, second section from western side, Wildcat Hills map-area, Alberta

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Pebble bed present on top of formation.		
	Sturrock Member		
42	Sandstone, fine-grained, grey; tan weathering; laminated; few small shale pebbles on bedding surfaces; thickly bedded chert pebbles on upper surface	14	308
41	Siltstone and shale, 50%; some sandstone at top. Not well exposed	10	294
40	Sandstone, fine-grained, grey; laminated, thinly bedded	6	284
39	Mostly covered. Appears to be siltstone with lenses of sandstone	9.5	278
38	Sandstone, fine-grained; laminated, thinly bedded; concretionary with shale partings, 30%	7	268.5
37	Covered. Appears to be shale	5	261.5
36	Sandstone, fine-grained, grey; grey to tan weathering; laminated to homogeneous, thickly bedded	5	256.5
35	Sandstone, fine-grained, grey; tan weathering; laminated; in 3″-4″ beds with shale, 50%	5.5	251.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Leyland Member		
34	Shale to siltstone, argillaceous, grey; bedded; with few thin sandstones	5	246
33	Sandstone, fine-grained, grey; tan weathering; laminated, slightly concretionary	1	241
32	Shale, dark grey, silty; with 4″ sandy siltstone at base	2	240
31	Shale, dark grey, rubbly; some concretions; slightly more silty at base	29	238
30	Mostly covered. Shale, rubbly, dark grey; with concretions	15	209
29	Siltstone to silty shale; bedded appearance	10	194
28	Siltstone, argillaceous, sandy to top, dark grey	17	184
27	Poorly exposed. Shale, dark grey, rubbly	26	167
26	Shale, platy to rubbly; rusty weathering; few small concretions; bentonite 1½″ from base	13	141
25	Concretionary zone, slightly gritty	1	128
	Cardinal Member		
24	Siltstone, 30%, and shale; rusty weathering; bedded appearance; chert pebbles at base as large as 1″	16	127
	Kiska Member		
23	Shale, rubbly; rusty weathering; slightly more blocky at base	14	111
22	Siltstone, argillaceous; scattered pebbles of chert	3	97
21	Siltstone, argillaceous, to shale; rusty weathering; inregularly bedded; few disseminated pebbles at top	10	
	(Unit 15 is repeated).		
20	Shale to mudstone, blocky; rusty weathering; few reddish brown weathering concretions	12	
19	Shale, dark grey, rubbly; rusty weathering	8	
18	Covered. Few exposures of shale. Fault believed to be present	16	
17	Mudstone, silty, blocky, dark grey	3	
16	Mudstone, silty, blocky; few scattered pebbles, more at top	6	
15	Siltstone, argillaceous, somewhat shaly; rusty weathering; bedded; more massive in upper 3′, with scattered pebbles; upper surface covered with small chert pebbles	16	94
14	Mudstone, dark grey, blocky; rusty weathering; some concretions	8	78
13	Mudstone, dark grey, blocky; rusty weathering	17	70
12	Conglomerate; basal and upper 1′ in shaly matrix; centre cemented and bedded	3	53
11	Concretionary bands, sandy at top	1	50
	Ram Member		
10	Shale, silty; brownish grey weathering	3	49
9	Shale, platy to rubbly; rusty weathering; and siltstone, 30%, platy; laminated bands; 6″ black argillaceous siltstone at base—(coaly?)	18	46

Unit	Lithology	Thickness (feet)	Height above base (feet)
8	Sandstone, fine-grained, grey; tan weathering; laminated, 1′ beds; coaly(?) at top	5	28
7	Sandstone, and shale, rubbly; interbedded; 1′ sandstone bed at top, fine-grained, laminated	3	23
6	Siltstone, argillaceous, laminated; and shale, irregularly bedded	4	20
5	Sandstone, fine-grained, brownish grey; rusty weathering; thickly bedded, laminated	7	16
4	Sandstone, fine-grained, brownish grey; laminated; thin shale at top and base; shale, fissile, rusty weathering	1.5	9
3	Sandstone, fine-grained, brownish grey; rust to buff weathering; laminated	2.5	7.5
2	Shale, platy to rubbly; rusty weathering; and sandstone, 30%, fine-grained; laminated; 1″-2″ bands, 6″ at base—(thin coal at top?)	3	5
1	Sandstone, fine-grained, brownish grey; buff weathering; massive, laminated	2	2
	See Section 6-18 for underlying Blackstone formation.		

Section 6-18. Blackstone formation; Ghost River, Wildcat Hills map-area, Alberta, sec. 4, tp. 27, rge. 7, W5.

	Opabin Member		
51	Shale, platy to rubbly; thin laminated siltstone, 25%, dark grey; rusty weathering; few large concretions	11	846
50	Shale, rubbly; rusty weathering; few silty bands	18	835
49	Shale to mudstone, blocky to rubbly; rusty weathering; bedded appearance; yellow staining	7	817
48	Shale to mudstone, rubbly; rusty weathering; large 1′ × 2′-3′ reddish brown weathering concretions	12	810
47	Shale, rubbly to blocky, dark grey; rusty weathering	8	798
46	Mudstone, blocky, dark grey; rusty weathering; large concretion at base	8	790
45	Shale to mudstone, rubbly; rusty weathering; 6″×10″ concretions at base	16	782
	Small shear.		
44	Shale, rubbly; rusty weathering; siltier at top; some concretions	29	766
43	Shale, slightly blocky at top, rubbly at base; rusty weathering; few concretions	18	737
42	Shale, dark grey; rather platy at top, becomes very rubbly at base; rusty weathering; rare concretions; 4″ concretionary bed at base	11	719
41	Mostly covered. Some rubbly shale in top 5′; platy shale at base	16	708
	Haven Member		
40	Siltstone, platy; argillaceous to very silty shale, dark grey; rusty weathering; bedded; grades into siltstone and shale (*below*)	12	692

Unit	Lithology	Thickness (feet)	Height above base (feet)
39	Siltstone, 30%, and shale, rubbly, dark grey; rusty weathering; banded appearance	10	680
38	Shale, rubbly; rusty weathering; slightly siltier at base, few thin siltstone beds at top; few reddish brown weathering concretions	37	670
37	Siltstone, 30%, and shale, platy, rusty weathering; bedded appearance; thin bentonite at 6½′ and 7′	13	633
36	Shale, platy to rubbly, hard, rather flaky; rusty weathering	18	620
35	Shale, rubbly to somewhat blocky; rusty weathering; yellow staining	20	602
34	Shale, flaky to rubbly; rusty weathering	23	582
33	Siltstone, platy, argillaceous, dark grey; rusty weathering	10	559
32	Mostly covered. Small contorted zone	60	549
	Vimy Member		
31	Siltstone and shale, platy, dark grey; silver grey weathering	17	489
30	Shale, platy with 6″ laminated limestone at top and base; fish scales. GSC loc. 28076	2	472
29	Shale, very silty, platy, dark grey; silver grey weathering	61	470
28	Dolomite, very argillaceous, soft; laminated	1	409
27	Shale, platy, silty at top; grading downward into flaky, fissile shale, dark grey; silver grey weathering; large limestone concretion 10′ from base	62	408
26	Dolomite, somewhat platy; laminated	1	346
25	Shale, slightly platy at top, fissile at base; concretions near top	13	345
24	Shale, platy; some thin crossbedded siltstone, dark grey; silver grey weathering	27	332
	Slight shear.		
23	Shale, flaky to fissile, dark grey; silver grey weathering	30	305
22	Shale, flaky; few thin siltstone beds	16	275
21	Shale, flaky to fissile, dark grey; silver grey weathering; few thin siltstone beds at top; large limestone concretions. GSC loc. 28083	48	259
20	Bentonite, greyish white; reddish to yellow in basal 2″	1	211
19	Shale, platy, silty; slightly rusty weathering	8	210
	Sunkay Member		
18	Shale, 65%, and siltstone, platy; rusty weathering	16	202
17	Shale, platy; some siltstone at top, more flaky at base; rusty weathering	24	186
16	Shale; some siltstone, platy; rusty weathering	16	162
15	Shale, platy to rubbly; rusty weathering; banded appearance; almost fissile at base (slight shear in basal part)	12	146
14	Siltstone, 40%, and shale; more shaly at base; rusty weathering	9	134
13	Siltstone, sandy, argillaceous, grey; massive	2	125
12	Siltstone, sandy, argillaceous; thin shale partings, 20%, dark grey; grey weathering; beds 4″-6″	8	123
11	Shale, platy to rubbly; rusty weathering	17	115

Unit	Lithology	Thickness (feet)	Height above base (feet)
10	Shale, platy; rusty weathering; grades into rubbly shale (*below*)	19	98
9	Shale, rubbly; rusty weathering	25	79
8	Shale, platy, becoming rubbly at base; rusty weathering; 3″ bentonite at base	23	54
7	Grit and coarse-grained sandstone, dark grey; greenish weathering; thickly bedded; few shale partings	8	31
6	Siltstone, and shale, platy; rusty weathering	3	23
5	Grit, coarse-grained sandstone and conglomerate, grey; massive	3	20
4	Shale, rubbly, and sandstone, 50%	4	17
3	Sandstone, medium- to coarse-grained, grey; carbonaceous fragments on upper surface	2	13
2	Sandstone, coarse-grained, grey; massive; slightly laminated conglomerate 2′ from base	10	11
1	Irregular thickness of chert pebbles in sandy matrix	0.5-1	1
	BLAIRMORE FORMATION		
7	Mudstone, greenish grey; weathers rust	3	61
6	Mudstone, rubbly, silty, greenish grey; grading into very soft powdery clay	8	58
5	Shale, flaky, black; thin bed of bentonite at base	1	50
4	Siltstone, argillaceous, hard, grey; 6″ shale in middle	2	49
3	Mudstone, rubbly to powdery, greenish grey	6	47
2	Shale; maroon weathering	3	41
1	Sandstone, silty, soft, medium-grained, greenish grey; interbedded with shale, greenish grey	38	38

Section 6-21. Wapiabi formation; Ghost River, Wildcat Hills map-area, Alberta, secs. 5 and 6, tp. 27, rge. 6, W5.

	BELLY RIVER FORMATION		
5	Sandstone, greenish grey, and shale, 25%	2	13.5
4	Shale, rubbly	1	11.5
3	Sandstone, fine-grained, greenish grey, carbonaceous; laminated	3.5	10.5
2	Shale, rubbly; thin sandstone at base	2	7
1	Sandstone, fine-grained, greenish grey, carbonaceous; massive in basal 3′, thinly bedded at top	5	5
	WAPIABI FORMATION		
	Nomad Member		
60	Shale; platy at top with thin siltstone bands; rubbly at base; light tan to rusty weathering	43	1,299
59	Shale, soft, greenish grey	5	1,256
58	Sandstone, argillaceous; buff weathering	1	1,251
57	Shale; blocky, brownish grey at top; more rubbly at base; concretionary bands	36	1,250
56	Dolomite, very argillaceous; buff weathering	2	1,214
55	Shale, rubbly	12	1,212

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Chungo Member		
54	Siltstone, argillaceous, with concretions; glauconite; scattered pebbles in upper 4′, more sandy in basal part	9	1,200
53	Mudstone, rubbly, few concretions	13	1,191
52	Dolomitic concretions, large	1	1,178
51	Mudstone, blocky to rubbly; rust weathering; concretions	29	1,177
50	Concretionary zone	1	1,148
49	Mudstone, blocky to rubbly, with concretions. GSC loc. 28054	34	1,147
	Small fault.		
	Hanson Member		
48	Mudstone, blocky; reddish-brown weathering concretions	8	1,113
47	Mudstone to shale, rubbly; some concretions	20	1,105
46	Mudstone; blocky at top, rubbly at base; concretions	27	1,085
45	Mudstone, blocky, dark grey; concretions and concretionary spots	55	1,058
44	Shale, rubbly, dark grey; concretions	33	1,003
43	Shale, rubbly; several bands of laminated sandstone; concretions	12	970
42	Mudstone, silty, blocky; very concretionary at top	8	958
41	Siltstone, argillaceous; to mudstone, somewhat bedded, with large concretions	13	950
40	Mudstone, blocky to rubbly; numerous concretions	22	937
39	Mudstone, rubbly, dark grey; numerous 4″×6″ concretions in rows	32	915
38	Mudstone, blocky; concretions	19	883
37	Mudstone, blocky, dark grey; concretions. GSC loc. 28072	15	864
36	Mudstone to siltstone, blocky; concretions	16	849
	Thistle Member		
35	Shale, platy, siltier at top	29	833
34	Shale, platy; thin siltstone bands, 30%	30	804
33	Siltstone and shale, 50%, platy	19	774
32	Shale, platy; thin bentonite at 17′ and 13′; lensy limestone band at 12′	37	755
31	Dolomitic band, argillaceous; tan weathering	1	718
30	Shale and siltstone, 50%, platy; dark grey bentonite at base	21	717
29	Shale, platy, dark grey	8	696
28	Siltstone, and shale, 40%, platy, dark grey; large limestone concretions; dolomitic band 2′ from top	22	688
27	Shale, platy to rubbly, siltier at top	30	666
26	Shale, and thin siltstone, 30%; few concretions; one large limestone concretion	32	636
25	Shale, platy to flaky; slightly rusty weathering	14	604
24	Dolomitic band; numerous shell fragments	1	590
23	Shale, platy, dark grey, slightly siltier at top	36	589
22	Siltstone, limy; yellow weathering; shale	2	553
21	Shale, platy, and thin siltstone, 25%; siltier at top	13	551
20	Siltstone, and shale, 40%; laminated bands as large as 3″; some fine-grained sandstone	14	538

Unit	Lithology	Thickness (feet)	Height above base (feet)
19	Shale, platy; few thin siltstone bands	10	524
18	Shale, and siltstone, 40%, platy	18	514
17	Siltstone, and shale, 60%, platy; grey weathering; 2″ soft bentonitic(?) shale at base	16	496
16	Shale, platy, dark grey; few thin siltstone beds; thin bentonite at 45.5′	47	480
15	Covered	17	433
14	Shale, platy, dark grey, silty; few thin siltstone beds	19	416
13	Siltstone, grey, laminated, 1″-2″ beds; and shale, 40%, platy	12	397
12	Shale, platy, dark grey. GSC loc. 28084	20	385
	Dowling Member		
11	Shale, rubbly; reddish brown weathering concretions	12	365
10	Covered interval	205	353
	Muskiki Member		
9	Shale, platy; thin siltstone beds; 2″ × 6″ reddish brown weathering concretions	22	148
8	Shale, rubbly; rusty weathering; some concretions	12	126
7	Shale, platy, dark grey; thin laminated siltstone bed at top	15	114
6	Mudstone, blocky, dark grey; reddish brown weathering concretions; bentonite at base	27	99
5	Shale to mudstone, blocky to rubbly; few thin siltstone lenses; bentonite at base	11	72
4	Shale, rubbly; rusty weathering; small dark concretions; bentonite at base	25	61
3	Shale, very rusty, flaky	8	36
2	Shale, to mudstone, rubbly; rusty weathering; few rare concretions; 2″ bentonite 1½″ from base	27.5	28
1	Pebble zone with 2″-3″ cemented conglomerate at top; pebbles as much as ¼″, chert	0.5	0.5

Section 6-22. Cardium formation; Bow River at Horseshoe Falls, Morley map-area, Alberta, tp. 25, rge. 8, W5.

	Sturrock Member		
40	Sandstone, argillaceous, brownish grey; tan weathering; massive; thin pebble zone at top, overlying sandstone	3	303.5
39	Covered. Appears to be siltstone	10	300.5
38	Sandstone, fine-grained; thinly bedded	1	290.5
37	Shale, platy, dark grey	1	289.5
36	Sandstone, fine-grained; thinly bedded	2	288.5
35	Sandstone, fine-grained, concretionary; rusty tan weathering; laminated, massive	3	286.5
34	Sandstone, fine-grained; laminated	2	283.5
33	Siltstone, sandy; laminated	2.5	281.5
32	Sandstone, fine-grained; brownish grey weathering; laminated	2	279

Unit	Lithology	Thickness (feet)	Height above base (feet)
31	Siltstone to thinly bedded sandstone	1	277
30	Sandstone, fine-grained; rusty weathering; thinly bedded	2	276
29	Covered. Siltstone to flaky shale	1	274
28	Sandstone, fine-grained; thinly bedded; *Cardium*	2.5	273
27	Covered. Siltstone, argillaceous	2.5	270.5
26	Sandstone, fine-grained, grey; tan weathering; laminated, thinly bedded, shows crossbedding; somewhat concretionary	11	268
	Leyland Member		
25	Siltstone, sandy, soft; concretionary lenses of sandstone	3	257
24	Siltstone, argillaceous, sandy; poorly bedded; few concretions near base	5	254
23	Partly covered. Silty shale with beds of sandstone	7	249
22	Sandstone, fine-grained; laminated; 4″ shale and thinly bedded sandstone at base	1	242
21	Shale, platy, sandy	2	241
20	Sandstone, fine-grained; laminated	1	239
19	Shale, silty; two beds of laminated sandstone	3	238
18	Shale, silty at top, rubbly at base; concretions	17	235
17	Inaccessible. Shale with sandstone beds; 1″ sandstone at base, eight 3″-8″ bands above	25	218
16	Inaccessible. Shale, dark grey	55	193
15	Siltstone, argillaceous; bedded; some concretions, chert pebbles at base	17	138
	Cardinal Member		
14	Sandstone, argillaceous, fine-grained, brownish grey; brownish grey weathering; massive	10	121
13	Sandstone to siltstone, argillaceous; bedded	6	111
12	Siltstone, grey, argillaceous; bedded	8	105
	Kiska Member		
11	Shale to siltstone, platy; concretions	9	97
10	Shale, platy to rubbly, dark grey; some concretions	12	88
9	Shale, rubbly, dark grey	29.5	76
8	Siltstone, argillaceous; wavy bedded; some concretions	5	46.5
	Ram Member		
7	Siltstone, argillaceous; 6″ chert-pebble conglomerate at top	2.5	41.5
6	Sandstone, fine-grained, brownish grey; brown weathering; crossbedded, laminated	4	39
5	Sandstone, silty, slightly concretionary; laminated, thinly and irregularly bedded; 1½′ massive sandstone at base	9	35
4	Siltstone, sandy, slightly concretionary, grey; wavy bedded; sharp lower boundary	10	26
3	Sandstone, fine-grained, grey; laminated, thickly bedded; some crossbedding at base, somewhat concretionary; few thinly bedded zones at base	16	16

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BLACKSTONE FORMATION		
2	Siltstone, argillaceous; laminated; shaly at base; some poorly developed concretions; few lensy sandstone beds	14	35
1	Shale, silty, with concretions	21	21
	End of exposure.		

Section 6-23. Cardium formation, Kananaskis River, Morley map-area, Alberta, sec. 15, tp. 23, rge. 8, W5.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	WAPIABI FORMATION		
3	Shale, dark grey; concretions. Inaccessible		
2	Conglomerate; chert pebbles in sandy matrix, well cemented, concretionary at top	9	13
1	Shale to mudstone, blocky, dark grey; some scattered small chert pebbles; few small concretions	4	4
	CARDIUM FORMATION		
	Sturrock Member		
45	Sandstone, fine-grained, argillaceous, brownish grey; brownish grey weathering; slightly laminated, 4″-6″ beds; shows channel filling at base	4	353
44	Shale, somewhat soft, platy, dark grey, with poorly developed concretions. Partly covered at base	10	349
43	Sandstone, fine-grained, brownish grey; brownish grey weathering; laminated	0.5	339
42	Shale, platy, dark grey	6	338.5
41	Sandstone, fine-grained, argillaceous, dark grey; tan weathering; slightly laminated	2	332.5
40	Shale, platy, soft; 4″ sandstone at top and 6″ at base, fine-grained, somewhat clearer than above; laminated	2	330.5
39	Shale, platy; lensy sandstone, fine-grained; laminated	4	328.5
38	Sandstone, fine-grained, argillaceous, brownish grey; 4″ shale at base	2	324.5
37	Sandstone, fine-grained, grey, argillaceous; laminated	1	322.5
36	Poorly exposed. Shale	3.5	321.5
35	Sandstone, fine-grained, argillaceous, dark grey; laminated; poorly exposed in basal 3′	9	318
34	Sandstone, fine-grained, argillaceous, dark grey; laminated; poorly exposed in basal 1″	9	309
33	Sandstone, as above	5	300
	Leyland Member		
32	Covered	45	295
31	Shale, platy to slightly rubbly, dark grey; few concretions. GSC loc. 28216	18	250
30	Shale, platy; few concretions	7	232
29	Sandstone, fine-grained; laminated	0.5	225
28	Shale, platy, dark grey	11	224.5
27	Sandstone fine-grained; laminated	0.5	213.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
26	Shale, platy, dark grey; few concretions	13	213
25	Covered. Shale	65	200
	Cardinal Member		
24	Sandstone, fine-grained, silty, slightly platy; massive	5	135
23	Sandstone, fine-grained, silty, grey; brownish grey weathering; massive	7	130
22	Covered	3	123
21	Sandstone, argillaceous, fine-grained, dark grey; massive, irregularly bedded	10	120
20	Sandstone; thinly bedded; some shale	1	110
19	Sandstone, argillaceous, dark grey; bedded to wavy bedded, slightly laminated	4	109
18	Siltstone, sandy, argillaceous, dark grey; massive	4	105
	Kiska Member		
17	Inaccessible. Siltstone, blocky, argillaceous, dark grey; more bedded at base	15	101
16	Mudstone, blocky, dark grey; few concretions; large irregular concretions at base	14	86
15	Shale, rubbly, dark grey; rare concretions	19	72
14	Conglomerate; shale matrix in upper half, concretionary at base	1	53
13	Covered	4	52
	Ram Member		
12	Sandstone, fine-grained, grey; massive	1.5	48
11	Siltstone, sandy, argillaceous, dark grey; massive	6	46.5
10	Siltstone, shaly, argillaceous, dark grey	4	40.5
9	Sandstone, argillaceous; massive; more thinly and irregularly bedded at base; scattered pebbles on upper surface	3	36.5
8	Siltstone, argillaceous, dark grey; massive	2.5	33.5
7	Sandstone, silty, argillaceous, dark grey	1.5	31
6	Sandstone, very argillaceous, dark grey; some concretions; massive; more shaly at base; band of concretions	8	29.5
5	Sandstone, fine-grained, grey; laminated, massive; slightly concretionary upper 1′ separated by thin shale bed	6	21.5
4	Covered	4	15.5
3	Sandstone, fine-grained, grey; irregularly and thinly bedded	5.5	11.5
2	Sandstone, fine-grained, grey; laminated	2	6
1	Sandstone to siltstone, argillaceous; rusty weathering; irregular wavy bedding	4	4
	BLACKSTONE FORMATION		
	Inaccessible. Siltstone, argillaceous; rusty weathering; to silty shale at base; beds of reddish brown weathering concretions	25	25
	End of exposure.		

Section 6-25. Chungo member, Wapiabi formation; Oldfort Creek, Morley map-area, Alberta, tp. 25, rge. 8, W5.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BELLY RIVER FORMATION		
	Sandstone, medium- to coarse-grained, greenish grey; brownish grey weathering; massive, shows some crossbedding	11	11
	WAPIABI FORMATION		
	Nomad Member		
50	Covered	30	511
49	Shale, rubbly	20	481
48	Dolomite, very argillaceous, silty, dark grey, knobbly; tan to reddish brown weathering	1	461
47	Shale, silty, platy to somewhat blocky, dark grey; some dark grey concretions. GSC loc. 28203	23	460
46	Siltstone, platy, argillaceous, brownish grey; large argillaceous limestone concretion at top	6	437
45	Siltstone, argillaceous, platy, dark grey; laminated, bedded; concretionary band at 5′	11	431
	Chungo Member		
44	Sandstone, fine-grained, brownish grey; tan to brown weathering; laminated; very small chert pebbles on upper surface; massive, more bedded at base; appears to be channel fill at 5′; upper half very uneven, crossbedded	10	420
43	Sandstone, fine-grained, brownish grey; beds 4″-6″, crossbedded, laminated, massive	16	410
42	Sandstone, fine-grained; thinly bedded; few thin shale partings	2	394
41	Sandstone, fine-grained, brownish grey; laminated, beds 4″-8″, appears thinly bedded	10	392
40	Sandstone; very thinly bedded; shale	1	382
39	Sandstone, fine-grained, brownish grey; laminated, massive	3	381
38	Sandstone and shale; interbedded	1	378
37	Sandstone, fine-grained, grey; laminated, thinly bedded	7	377
36	Sandstone; very thinly bedded; 6″ shale at base, rubbly	1	370
35	Sandstone, fine-grained, brownish grey; laminated, thinly bedded	3	369
34	Shale, brownish grey, grey, rubbly	5	366
33	Sandstone, fine-grained, brownish grey; laminated; lenses out	1	361
32	Siltstone, knobbly, dark grey; concretionary spots	3.5	360
31	Sandstone, fine-grained, brownish grey; laminated, thinly bedded; thin shale at base	8	356.5
30	Sandstone, fine-grained; laminated; with shale, 40%, 6″ at top and base	3.5	348.5
29	Sandstone, fine-grained, brownish grey; rust to tan weathering; laminated, massive	3	345

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Siltstone, argillaceous, sandy; laminated	3	342
27	Sandstone, fine-grained; laminated, massive	5	339
26	Siltstone, knobbly, laminated; with shale	2	334
25	Sandstone, fine-grained; laminated, thinly bedded; with shale, 20%	8	332
24	Sandstone, and shale, 40%; beds 2″-6″; sandstone, grey; laminated	13	324
23	Inaccessible. Siltstone, argillaceous; beds of sandstone	15	311
22	Siltstone, sandy, argillaceous, dark grey; hard, well-cemented beds; few concretions. GSC loc. 28218	13	296
21	Sandstone, fine-grained; laminated 2″-6″ beds, silty; interbedded with argillaceous siltstone; few concretions	6	283
20	Siltstone, argillaceous, blocky, dark grey; large concretions	4	277
19	Mudstone, silty, blocky, dark grey; glauconitic at top, rubbly at base; some concretions; silty nodules near base	12	273
18	Siltstone, argillaceous, dark grey; 4″ laminated sandstone concretions	6	261
17	Sandstone, fine-grained; laminated; to bedded siltstone; more argillaceous siltstone at base; concretions	6	255
	Hanson Member		
16	Shale to mudstone, silty, blocky to rubbly; bedded appearance; few concretions	24	249
15	Mudstone, blocky to rubbly; concretions	12	225
14	Sandstone, 30%, fine-grained; laminated; and siltstone, argillaceous, blocky; becomes more shaly at base; some concretions	27	213
13	Siltstone, argillaceous, dark grey; concretions	7	186
12	Sandstone, fine-grained, grey; grey weathering; laminated, fairly massive; uneven base	4	179
11	Siltstone to shale, dark grey; concretions	4	175
10	Sandstone to siltstone; more argillaceous at base; bedded	8	171
9	Sandstone to siltstone; bedded and shaly at base; some concretions	25	163
8	Sandstone at top; grading into argillaceous siltstone and shale; concretions	13	138
7	Siltstone; massive to rubbly at base; concretions	7	125
6	Siltstone, argillaceous; concretions; massive	4	118
5	Inaccessible. Siltstone, sandy at top, argillaceous; bedded; concretions	17	114
4	Siltstone to silty mudstone, blocky; reddish brown weathering concretions	18	97
3	Sandstone to siltstone, argillaceous; thickly bedded; dark grey limy band at 4′; rare concretions	13	79
2	Siltstone to silty mudstone, brownish grey; blocky, bedded appearance; rare concretions. GSC loc. 28209	35	66

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Thistle Member		
1	Siltstone; laminated; and shale, dark to brownish grey; banded appearance	31	31

Section 6-32. Cardium formation; Sheep River, Dyson Creek map-area, Alberta, west flank of syncline, tp. 19, rge. 5, W5.

	CARDIUM FORMATION		
	Sturrock Member		
29	Siltstone, argillaceous, sandy; massive; concretionary at top	2.5	242
28	Siltstone, argillaceous, dark grey; reddish brown weathering, concretionary spots; massive	7	239.5
27	Shale, 60%, dark grey; platy and irregular beds of laminated fine-grained sandstone	7	232.5
26	Sandstone, fine-grained, grey, dirty; beds 4″-1′, laminated; slightly concretionary; few shaly intervals; somewhat more thinly bedded at base; *Cardium*	10.5	225.5
	Leyland Member		
25	Siltstone, argillaceous, dark grey; small reddish brown weathering concretions; massive to bedded; shaly in basal 1′; bentonite(?) at base	12.5	215
24	Siltstone, argillaceous; massive to bedded; shaly at 3′; grades into silty shale; small concretions. GSC loc. 28174	16	202.5
23	Shale, silty, platy to blocky; small reddish brown weathering concretions	13	186.5
22	Shale, silty, to mudstone; concretions; fragments of large pelecypods. GSC loc. 28059	19	173.5
21	Shale, rubbly to flaky, hard; rusty weathering; few concretions; bentonite(?) at 17′	22	154.5
20	Shale; rusty weathering; few thin laminated siltstone bands at top	10	132.5
19	Shale; rusty weathering; siltstone, 30%, platy	8	122.5
18	Siltstone, platy; laminated; to silty mudstone; bedded; reddish brown weathering concretionary spots; few concretions 4″ × 12″	20	114.5
17	Shale as above, with chert pebbles as large as 1½″ in diameter	1	94.5
	Cardinal Member		
16	Sandstone, fine-grained, argillaceous, dark grey; thin shale at base	1	93.5
15	Siltstone to sandstone, argillaceous, grey; massive; more shaly at base; concretions. GSC loc. 28063	7	92.5
14	Sandstone, fine-grained, grey; laminated; and shale, 30%; beds 4″-1′	7	85.5
13	Siltstone, argillaceous, dark grey, grading downward into shale; massive appearance; reddish brown weathering concretions	12	78.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Kiska Member		
12	Shale, rubbly, dark grey; 3" × 6" concretions; bentonite(?) at 8'	15	66.5
11	Talus covered. Shale, rubbly; rusty weathering	17	51.5
10	Shale; numerous chert pebbles up to 1" in diameter	3.5	34.5
9	Concretionary bed; reddish brown weathering; chert pebbles	1	31
	Ram Member		
8	Siltstone, argillaceous, sandy at top; massive to slightly bedded	5.5	30
7	Shale with chert pebbles	0.5	24.5
6	Siltstone; sandy at top, grading into shale at base; concretionary at top; bedded appearance	4	24
5	Siltstone, argillaceous; massive to slightly bedded; concretions	4.5	20
4	Siltstone, argillaceous, fairly well indurated; laminated	2	15.5
3	Sandstone, fine-grained; laminated, massive	1.5	13.5
2	Siltstone, argillaceous; massive	4	12
1	Siltstone; laminated bands and concretionary bands	8	8
	BLACKSTONE FORMATION		
5	Siltstone, argillaceous, to mudstone, blocky; rusty, weathering; slightly bedded appearance; concretions 4" × 8"	8	43
4	Talus covered. Shale, rubbly; rusty weathering; few small pebbles at base	18	35
3	Concretionary band; reddish brown weathering	1	17
2	Siltstone to shale, platy; rusty weathering; large concretions	7	16
1	Siltstone, argillaceous; rusty weathering; massive, slightly bedded	9	9

Section 6-33. Blackstone formation; Sheep River, Dyson Creek map-area, Alberta, west flank of syncline, tp. 19, rge. 5, W5.

	Opabin Member		
40	Siltstone, argillaceous; to mudstone, blocky; rusty weathering; slightly bedded appearance; concretions 4" × 8"	8	785
39	Talus covered. Shale, rubbly; rusty weathering; few small pebbles at base	18	777
38	Concretionary band; reddish brown weathering	1	759
37	Siltstone to shale, platy; rusty weathering; large concretions	7	758
36	Siltstone, argillaceous; rusty weathering; massive, slightly bedded	9	751
35	Mudstone, blocky to rubbly, dark grey; large round concretions	37	742
34	Shale, rubbly; blocky at top with row of concretions; scattered large concretions	23	705

Unit	Lithology	Thickness (feet)	Height above base (feet)
33	Shale, rubbly; rusty weathering; few scattered small concretions	41	682
	Haven Member		
32	Shale, platy to rubbly at base; rusty weathering; few concretions	13	641
31	Shale, and siltstone, 50%, platy; rusty weathering; rare concretions; siltstone beds as large as 2″	21	628
30	Shale, and siltstone, 25%; rusty weathering; few dark concretions	22	607
29	Shale, and siltstone, 30%; rubbly shale at base; rusty weathering; few concretions	20	585
28	Shale and siltstone, 50%; rusty weathering; beds as large as 2″; laminated; few concretions. GSC loc. 28188	27	565
27	Shale, platy; rusty weathering; flaky at base; some thin siltstone bands	37	538
26	Shale, platy, to rubbly at base; rusty weathering	22	501
	Vimy Member		
25	Shale, platy; slightly rusty weathering	9	479
24	Shale, platy, and siltstone, 40%; silver grey weathering; 2″-12″ limestone band at top	7	470
23	Shale, and siltstone, 30%, platy; silver grey weathering	33	463
22	Shale, and siltstone, 40%; beds as large as 2″; few large dolomitic concretions	17	430
21	Shale, platy; silver grey weathering	36	413
20	Shale, platy, dark grey; silver grey weathering	45.5	377
19	Dolomite, argillaceous, aphanitic, bluish grey	0.5	331.5
18	Shale, platy, dark grey; few argillaceous dolomitic bands	45	331
17	Dolomite, argillaceous, aphanitic; laminated	1	286
16	Shale, and siltstone, 30%, platy; silver grey weathering; large dolomitic concretions. GSC loc. 28213	33	285
15	Shale, platy; silver grey weathering; 2″ limy band at 16′	19.5	252
14	Dolomite, argillaceous, aphanitic. GSC loc. 28070	1.5	232.5
13	Shale, platy; some siltstone, with few limy bands. GSC loc. 28062	32	231
	Slight contortion.		
12	Shale, platy; silver grey weathering	48	199
	Contorted zone.		
	Sunkay Member		
11	Siltstone, 60%, and shale, platy; rubbly at base; rusty weathering	21	151
10	Siltstone, and shale, platy; rubbly at base; rusty weathering	27	130
9	Shale, rubbly; rusty weathering	14	103
8	Limestone band, dolomitic	1	89
7	Shale, rubbly; rusty weathering; limestone concretions	20	88
6	Shale, rubbly	10	68
5	Limestone zone, dolomitic	1	58
4	Shale and siltstone; rusty weathering	12	57

Unit	Lithology	Thickness (feet)	Height above base (feet)
3	Sandstone, coarse-grained, grey	1	45
2	Siltstone, argillaceous, blocky	15	44
1	Shale; platy at top, very rubbly at base; rusty weathering; limestone concretion; 3″ conglomerate at base	29	29
	Underlying beds of Blairmore formation, greenish and reddish shale.		

Section 6-34. Wapiabi formation; Sheep River, Dyson Creek map-area, Alberta, west flank of syncline, tp. 19, rge. 5, W5.

	Dowling Member (incomplete)		
21	Shale, rubbly, dark grey; few thin siltstone beds and concretions mainly in rows. GSC loc. 28082	82	433
20	Shale, platy to rubbly; few thin siltstone beds at top; 3″ × 6″ reddish brown weathering concretions	49	351
	Marshybank Member		
19	Shale, platy, and thin siltstone beds; some concretions	35	302
	Muskiki Member		
18	Mostly covered. Shale; platy at top to rubbly at base; some orange weathering concretions	45	267
17	Shale, platy; almost argillaceous siltstone at top; concretions	12	222
16	Partly covered. Shale, rubbly; concretions. GSC loc. 28092	24	210
15	Shale, platy; grading downward into rubbly shale	22	186
14	Shale, blocky to rubbly, dark grey; small reddish brown weathering concretions; becomes platy to massive siltstone at top, some concretions. GSC loc. 32861	25	164
13	Shale, rubbly, dark grey; reddish brown weathering concretions, 3″ × 6″	29	139
12	Shale, platy; dark concretions	20	110
11	Shale; platy at top, rubbly at base; small orange weathering concretions; (probably equivalent to unit 7). GSC loc. 28067	34	
10	Shale; rather platy at top with concretions and fragments of large pelecypods	18	
9	Shale, platy, dark grey	18	
8	Inaccessible. Shale, rubbly; 2″ bentonite at base	10	
	Fault		
7	Shale; with siltstone at top; platy in upper 7′, becomes rubbly at base; 2″ × 6″ reddish brown weathering concretions in lower half. GSC locs. 28068, 32882	32	90
6	Shale, platy; some thin laminated siltstone	20	58
5	Shale, rubbly, dark grey	10	38
4	Shale, slightly blocky to rubbly	5	28
3	Mostly covered. Shale, rubbly, dark grey	17	23
2	Sandstone, concretionary, coarse-grained	3	6

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Unit	Lithology	Thickness (feet)	Height above base (feet)
1	Shale, poorly exposed; pebbles	3	3
	For underlying beds see Section 56-32.		

Section 6-35. Belly River and Wapiabi formations; Sheep River, Dyson Creek map-area, Alberta.

	BELLY RIVER FORMATION		
28	Sandstone, medium- to coarse-grained, greyish green, carbonaceous; greyish green weathering, some weathers platy; homogeneous to laminated, thickly bedded, some crossbedding; few shaly intervals, one near base	33	445
27	Sandstone, as above, not as thickly bedded	14	412
26	Mostly covered. Shale	7	398
25	Sandstone, medium- to fine-grained, greyish green; laminated	4	391
24	Mostly covered. Shale	10	387
23	Sandstone, as above	4	377
22	Shale, rubbly, greyish brown to green; few sandy beds	23	373
21	Sandstone, medium- to coarse-grained, greyish green, carbonaceous; thickly bedded, with thinly bedded and shaly intervals	19	350
20	Sandstone and shale, greyish green, carbonaceous	18	331
19	Shale, rubbly, green to brown	6	313
18	Sandstone, medium-grained, greyish green, carbonaceous; thickly bedded; 3′ at base is channel fill in coaly shale	8	307
17	Shale, rubbly, greyish black; coaly at top	9	299
16	Sandstone, medium-grained, greenish grey; very carbonaceous; laminated, crossbedded, massive appearance	12	290
	Nomad Member		
15	Shale, rubbly to blocky, dark grey to greyish black; rusty weathering	19	278
14	Sandstone, fine-grained, carbonaceous; laminated	1	259
13	Shale, as unit is above; 2″-3″ zone of small pebbles at base; extremely large concretions about 10 feet from base; selenite crystals. GSC loc. 32867	33	258
12	Siltstone, argillaceous, blocky, dark grey; massive to bedded; limonitic spots; fucoid markings; pebbles at base	12	225
	Chungo Member		
11	Mostly covered. Some green rubbly shale and brownish carbonaceous sandstone	25	213
10	Sandstone, medium-grained, greenish grey, slightly carbonaceous; weathers brown; laminated, somewhat crossbedded, thickly bedded to massive; platy at base	15	188
9	Shaly interval, partly covered. Some coaly shale and greenish brown sandstone	23	173

Unit	Lithology	Thickness (feet)	Height above base (feet)
8	Sandstone, clean, medium grey; weathering grey to brownish grey; laminated, crossbedded, massive to thickly bedded; few scattered pebbles especially in basal beds	20	150
7	Conglomerate, mainly chert pebbles ⅛″-1½″, rounded, in coarse-grained matrix	3	130
6	Sandstone, as unit 8 above	4	127
5	Conglomerate, as above; with cobbles up to 3″	2	123
	Highwood Sandstone		
4	Sandstone, medium-grained, grey; weathers brownish grey; thinly bedded; partly covered, curved fractures	10	121
3	Sandstone, medium-grained, clean, grey; brownish grey weathering; thickly to wavy bedded	17	111
2	Sandstone; thinly bedded	1	94
1	Sandstone, fine- to medium-grained, slightly greenish grey, carbonaceous; brownish grey weathering; homogeneous to laminated, thickly bedded; somewhat coarse-grained in centre	93	93
	WAPIABI FORMATION		
	Hanson Member		
17	Sandstone, fine-grained, brownish grey; laminated; and shale; thinly interbedded	11	352
16	Sandstone, fine-grained, grey; laminated; and shale, 40%; carbonaceous fragments on bedding surfaces; brownish grey weathering; 2″-6″ beds	11	341
15	Sandstone and shale as above, grading downward into more rubbly shale, dark grey	23	330
14	Siltstone, argillaceous, to mudstone; massive concretionary spots and few concretions; becomes more shaly at base. GSC loc. 28215	11	307
13	Mudstone to siltstone, argillaceous, platy, dark grey; few beds of carbonaceous sandstone and rare concretions; bedded appearance	30	296
12	Sandstone, and shale interbedded with lensy limestone, dense, argillaceous at top	5	266
11	Sandstone, fine-grained, carbonaceous; buff weathering; laminated; and shale, 60%; limy zone at 21′ and at base	39	261
10	Siltstone, very argillaceous; to mudstone, blocky, dark grey; grading downward into more rubbly mudstone; rare concretions. GSC loc. 28210	30	222
9	Shale, blocky to rubbly at base, dark grey; bedded appearance	36	192
	Thistle Member		
8	Shale, platy; some thin siltstone beds	14	156
7	Shale, platy, dark grey	13	142
6	Shale, and siltstone, 25%, platy; few large limestone concretions	12	129
5	Shale, platy	13	117
4	Shale, rubbly, dark grey; finely bedded. GSC loc. 28069	51	104

Unit	Lithology	Thickness (feet)	Height above base (feet)
3	Dolomite, argillaceous, aphanitic, bluish grey; yellow weathering	1	53
2	Shale, platy to rubbly; some thin siltstone	50	52
1	Dolomite, argillaceous, aphanitic	2	2
	Remainder of section inaccessible.		

Section 6-39. Blackstone formation; Sheep River, Turner Valley map-area, Alberta, sec. 19, tp. 19, rge. 3, W5.

	WAPIABI FORMATION		
	Shale, and thin siltstone, 20%; rusty weathering; bentonite at 25′. GSC loc. 28053	26	38
	Shale, rubbly to flaky; rows of 2″ × 4″ concretions; 2″ bentonite at 9′; few small pebbles at base	12	12
	CARDIUM FORMATION		
	Sturrock Member		
16	Siltstone, very argillaceous, platy; becoming more shaly at base; large concretions	3	229
15	Shale, silty, dark grey; bedded appearance; 3″ × 6″ reddish brown weathering concretions	6	226
14	Siltstone, very argillaceous; concretions	3	220
13	Siltstone, argillaceous; bedded concretions	6	217
	Leyland Member		
12	Shale, silty, rubbly at base, dark grey; 3″ × 6″ concretions	14	211
11	Shale; some siltstone at top, rubbly at base; concretions	23	197
10	Shale, silty; few thin siltstone beds; few concretions; bentonite at 9′	21	174
9	Shale, flaky; rusty weathering	7	153
8	Covered	115	146
	Ram Member		
7	Siltstone, sandy, argillaceous; bedded; few concretions	7	31
6	Sandstone, fine-grained; laminated	1	24
5	Siltstone, sandy at top, argillaceous at base	4	23
4	Sandstone, fine-grained; laminated	1	19
3	Siltstone, argillaceous, dark grey; bedded; shaly at base; few concretions	7.5	18
2	Sandstone, fine-grained; laminated, 2″-4″ beds	2.5	10.5
1	Siltstone, argillaceous, dark grey; bedded; shaly at base	8	8
	BLACKSTONE FORMATION		
	Opabin Member		
35	Mudstone to shale; rusty weathering; becomes more rubbly at base; large reddish brown weathering concretions	116	614

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Haven Member		
34	Shale, flaky to rubbly, dark grey; rusty weathering	6	498
33	Shale, and siltstone, 20%, platy; rusty weathering; large limestone concretions	16	492
32	Shale, flaky to rubbly; rusty weathering; few concretions at base. GSC loc. 28071	36	476
31	Shale, and siltstone, 30%, platy; rusty weathering	5	440
30	Shale, flaky to rubbly; rusty weathering	36	435
29	Shale, few thin siltstone bands; rusty weathering	13	399
28	Shale, flaky to rubbly; 2″-3″ bentonite at 8′, thin bed at 20′	22	386
	Vimy Member		
27	Shale, silty, platy, dark grey; silver grey weathering	27	364
26	Shale, platy to flaky, dark grey; silver grey weathering; 3″ limestone at 9′ and 16′; thin bentonite at base	29	337
25	Shale, fissile to flaky; few thin bentonite layers at top	19	308
24	Shale, flaky to platy, dark grey; silver grey weathering	21	289
23	Limestone, very argillaceous, platy. GSC loc. 28211	1	268
22	Shale, platy to flaky, dark grey; silver grey weathering	17.5	267
21	Limestone, argillaceous	1	249.5
20	Shale, platy	2	248.5
19	Limestone, argillaceous	0.5	246.5
18	Shale and siltstone, 50%; beds as thick as 3″; large limestone concretion at base	7	246
17	Shale, platy, silty; some siltstone; 3″ sandstone at 8′; few limestone concretions; fish scales	18	239
16	Shale, platy to flaky; few thin limy beds towards base	52	221
15	Shale, flaky, with thin limy beds; platy appearance; thin bentonite layers from 46′	52.5	169
14	Bentonite, white	0.5	116.5
13	Shale, platy, dark grey	6	116
	Sunkay Member		
12	Shale, and thin siltstone, 30%, becoming more rubbly at base; rusty weathering; few concretions	18	110
11	Shale, and siltstone, 30%; rusty weathering; rubbly in basal 2′	7	92
10	Shale, and siltstone, 30%; rusty weathering	7	85
9	Shale, platy; some thin siltstone; rusty weathering; few concretions	16	78
8	Shale, rubbly; rusty weathering	5	62
7	Shale, and siltstone, 40%, platy; rusty weathering	14	57
6	Shale, rubbly; rusty weathering	3	43
5	Shale, and siltstone, 30%; rubbly at base; bentonite at 1′ and 7′	29	40
4	Grit, platy, 25%, and shale; rusty weathering	2	11
3	Grit, with thin shale partings	3	9
2	Shale, and laminated siltstone, platy, gritty	2	6
1	Grit, 2″-6″; yellow staining	4	4
	BLAIRMORE FORMATION		
4	Shale, sheared, green, bentonitic(?)	1	10
3	Sandstone, silty, greenish grey; and shale, 40%	5	9
2	Shale, rubbly, greenish grey	2	4
1	Sandstone, fine-grained, silty, greenish grey	2	2

Section 6-40. Cardium formation; McPhail Creek, first section west of Highwood River, just off Mount Head map-area, Alberta.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	WAPIABI FORMATION		
11	Shale to argillaceous siltstone; scattered chert pebbles at base	2	154
10	Sandstone, fine-grained, brownish grey; brown weathering; laminated, beds 2"-6"; becomes slightly argillaceous and irregularly bedded at base; *Cardium*. GSC loc. 28190	12	152
9	Siltstone, argillaceous, grey; rusty weathering; laminated at top, becoming shaly at base; somewhat slightly concretionary	9	140
8	Covered. Probably shale	67	131
7	Sandstone; silty in upper 1' and lower 6"; centre bed is fine-grained, rusty weathering, laminated, somewhat concretionary	3	64
6	Siltstone, sandy, argillaceous; bedded; reddish brown weathering concretions	6	61
5	Siltstone, argillaceous, becoming shaly at base, grey; reddish brown weathering concretions	8	55
4	Shale; silty at top, rubbly at base; few reddish brown weathering concretions	26	47
3	Shale, platy, silty; some laminated siltstone at top; rusty weathering	15	21
2	Shale, silty with chert pebbles as large as ½"; concretionary near top	4	6
1	Shale, blocky; rusty weathering; 6" concretionary band 6" from base	2	2
	CARDIUM FORMATION		
	Sturrock Member		
36	Sandstone, fine-grained, grey; rusty tan weathering; laminated, beds 2"-6", crossbedding; shale pebbles on some bedding surfaces; few shale intervals; channel filling; *Cardium*	20	282
35	Sandstone, fine-grained; laminated; 8" silty shale at top, and shale intervals; numerous shell fragments. GSC loc. 28184	3.5	262
34	Sandstone, silty; laminated to poorly bedded, thinly bedded; 'bolster' structure at base; concretionary spots	9	258.5
33	Siltstone, very argillaceous, blocky, grey	2.5	249.5
32	Sandstone, silty; laminated, beds 2"-12"; rather knobby; shale intervals	8	247
31	Siltstone, very argillaceous, blocky, with 30% laminated sandstone bands; banded appearance; weathers black; 6" rubbly dark grey shale at base	10.5	239
30	Sandstone, fine-grained, grey; rusty tan weathering; laminated; thinly bedded at base; shaly zone at 4' with channel filling and crossbedded sandstone	5.5	228.5
29	Siltstone, argillaceous, blocky; 2" shale at base, 6" laminated sandstone above shale	2.5	223

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Sandstone, fine-grained, lensy; laminated, suggestion of crossbedding, thinly bedded	1.5	220.5
27	Siltstone, argillaceous, blocky; and sandstone, 50%, fine-grained; laminated, beds 4″-6″	5.5	219
26	Sandstone, fine-grained, grey; rusty tan weathering; laminated, massive; suggestion of crossbedding at base	3	213.5
25	Siltstone, argillaceous, blocky; grades into shale (*below*)	5	210.5
24	Shale, silty, dark grey; not well exposed at base	7	205.5
23	Siltstone to sandstone, argillaceous, dark grey; brownish grey weathering; massive; bedded at base; few concretions	7.5	198.5
22	Covered. Probably shale	6	191
21	Siltstone, sandy, argillaceous, dark grey; somewhat bedded; small reddish brown weathering concretions	4	185
20	Covered	3	181
19	Sandstone, fine-grained, grey; rusty tan weathering; laminated, massive	2	178
18	Covered	3	176
17	Sandstone, fine-grained; laminated; bedded in upper half, argillaceous and massive towards base; knobby at base; few concretions	12	173
	Leyland Member		
16	Siltstone, argillaceous, knobby, dark grey; bedded; concretionary	7	161
15	Mostly covered. Silty shale with concretions at top; rubbly shale with 3″ pebble zone at base	49	154
	Cardinal Member		
14	Sandstone, fine-grained, grey; tan weathering; laminated, beds 4″-6″; tracks and trails	4	105
13	Sandstone, fine-grained, knobby, slightly carbonaceous; grey; thinly bedded; some concretions; grades into sandstone and shale (*below*)	6	101
12	Sandstone, and shale, 20%; banded appearance; concretions; grades into sandstone and shale (*below*)	8	95
11	Sandstone, fine-grained; laminated; and shale, 40%	6	87
	Kiska Member		
10	Shale, and sandstone, 25%; rusty weathering	8.5	81
9	Siltstone, somewhat sandy, argillaceous, dark grey; massive; few round chert pebbles embedded in upper surface; break at 9′	16	72.5
8	Shale, blocky; rusty weathering	5	56.5
7	Siltstone, argillaceous, dark grey; massive; few chert pebbles embedded in upper surface	7.5	51.5
6	Siltstone, argillaceous; becoming more bedded	8	44
5	Covered. Probably shale	10.5	36
	Ram Member		
4	Siltstone to sandstone, argillaceous, dark grey; reddish brown weathering; massive	6.5	25.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
3	Siltstone, to sandstone, argillaceous, brownish grey; more bedded than above; becoming very argillaceous at base; some concretions	7	19
2	Covered. Probably shale	7	12
1	Siltstone, argillaceous; reddish brown weathering; massive	5	5
	BLACKSTONE FORMATION		
	Opabin Member		
4	Siltstone, argillaceous; blocky at top, grading downward into more rubbly shale with few orange weathering concretions	27	114
3	Shale, blocky; rusty weathering; orange weathering concretions	64	87
2	Shale; thin siltstone; few concretions	8	23
1	Siltstone and shale, 50%, platy; rare concretions	15	15

Section 6-44. Highwood sandstone, Wapiabi formation; Highwood River, Turner Valley map-area, Alberta, sec. 30, tp. 18, rge. 2, W5.

	Transition zone below Belly River formation is mostly covered, with some indication of faults. Interval is large—over 200′ estimated.		
	Highwood Sandstone		
12	Sandstone, fine-grained, dirty brownish grey; brown weathering; laminated; thinly bedded and crossbedded in centre; pebbles on upper surface	20	159
11	Sandstone, fine-grained; laminated, 4″-6″ beds; interbedded shale, 30%	21	139
10	Sandstone, fine-grained, brownish grey; laminated, thinly bedded; more massive appearance	5	118
9	Sandstone; very irregularly bedded; bumpy rounded structures	8	113
8	Sandstone, fine-grained; laminated, thinly bedded	8	105
7	Siltstone, argillaceous and sandy, platy; laminated; small orange weathering concretions	15	97
6	Covered	9	82
5	Siltstone to shale, brown; few concretions	11	73
4	Mostly covered. Mainly shale with some thin beds of sandstone towards base	15	62
3	Sandstone, and shale, 40%; sandstone in 4″-6″ beds, brown; laminated	15	47
2	Siltstone and shale, brownish grey; interbedded; banded appearance	18	32
1	Shale, rubbly; few silty bands; few concretions	14	14
	End of exposure. Thistle member exposed across river.		

Section 6-45. Blackstone formation; Highwood River, Turner Valley map-area, Alberta.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	CARDIUM FORMATION		
12	Shale, rubbly; rusty weathering; some concretions. GSC loc. 28179	17	131.5
11	Shale, platy; rubbly at base; rusty weathering; orange weathering concretions	28	114.5
10	Shale, platy; few concretions	7.5	86.5
9	Conglomerate, sandstone, and grit, with chert pebbles	1	79
8	Siltstone, argillaceous; scattered small chert pebbles	11	78
7	Shale, rubbly	6	67
6	Siltstone, flaggy; shaly at base; orange weathering concretions	22	61
5	Shale, rubbly; rusty weathering; concretions	4.5	39
4	Shale, rubbly with 2" conglomerate at top	3.5	34.5
3	Conglomerate and concretionary band	1	31
2	Siltstone, argillaceous; rusty weathering; shaly at base	15	30
1	Inaccessible. Siltstone, argillaceous; to mudstone, blocky; reddish brown weathering concretionary bands	15	15
	BLACKSTONE FORMATION		
	Opabin Member		
42	Siltstone to shale, blocky, dark grey	10	705
41	Shale, rubbly; rusty weathering; large reddish brown weathering concretions	24	695
40	Concretionary bed; reddish brown weathering	1	671
39	Shale, rubbly; rusty weathering; large reddish brown weathering concretions in rows; some septarian concretions towards base	73	670
	Haven Member		
38	Shale, platy; rusty weathering; rare small reddish brown weathering concretions	19	597
37	Shale, and siltstone, 35%, platy; rusty weathering. GSC loc. 28172	16	578
36	Shale, rubbly; rusty weathering; few silty beds at top	22	562
35	Shale, platy; few thin siltstone bands and concretions. GSC loc. 28187	18	540
34	Shale, rubbly; rusty weathering; some platy bands	43	522
33	Shale, platy to flaky; rusty weathering; rare limestone concretions	34	479
	Vimy Member		
32	Shale, platy, and siltstone, 20%, platy; silver grey weathering; rare long thin lensy band; bentonite at 15′ and 20′	27.5	445
31	Dolomite, lensy, dark grey; yellow weathering; laminated	0.5	417.5
30	Shale, platy; silver grey weathering; some lensy siltstone bands	15	417
29	Dolomite, lensy; yellow weathering	0.5	402

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Shale, flaky to fissile; few limy siltstone lenses	11.5	401.5
27	Shale, platy to flaky; more fissile towards base; silver grey weathering	24	390
26	Shale, platy to flaky; bentonite at 1′, 15′, and 23′	28	366
25	Dolomite, lensy; fish scales	1	338
24	Shale, platy, dark grey; silver grey weathering; bentonite at 27′	28	337
23	Dolomite, dense, argillaceous, platy; yellow weathering	3	309
22	Shale, platy, dark grey; silver grey weathering; limy siltstone beds, 30%; 6″ limestone at 3½′, and limestone concretions at top; bentonite at 9′; break at 23′	39	306
	Shear.		
21	Shale, platy to flaky; limy siltstone beds; quite banded appearance	29	267
20	Shale, fissile, dark grey; silvery grey weathering; limy siltstone beds	22	238
19	Shale, flaky, dark grey; silvery grey weathering; bentonite at 12½′ and 15′	17	216
18	Bentonite, white	1	199
17	Shale, platy, and limy siltstone beds; slightly rusty weathering; very rubbly at base	14	198
	Sunkay Member		
16	Shale, rubbly; rusty weathering; yellow staining; limestone concretions	7	184
15	Shale, and siltstone, 15%; limestone concretions; becomes very rubbly at base	20	177
14	Shale, and siltstone, 20%; rusty weathering; few limestone concretions	30	157
13	Shale, and siltstone, 30%; rubbly 4′-6′ beds; large limestone concretion at top	25	127
12	Shale, platy to rubbly; 1′ lensy limestone at top	12	102
11	Shale, and siltstone, 30%; rusty weathering	9	90
	Shear.		
10	Shale, and siltstone, 10%; rusty weathering	10	81
9	Shale, and siltstone, 35%, platy; rusty weathering	12	71
	Contorted zone.		
8	Limestone, argillaceous, platy	1	59
7	Shale, rubbly; rusty weathering	10	58
6	Shale, platy to rubbly; rusty weathering	28	48
5	Shale, with gritty lenses	1	20
4	Shale, rubbly	4	19
3	Sandstone, coarse-grained, dark grey	1.5	15
2	Siltstone, sandy, platy; and shale	2.5	13.5
1	Sandstone, coarse-grained, dark grey; rusty to greenish weathering; 2″-4″ beds	11	11
	BLAIRMORE FORMATION		
4	Shale, silty, green, somewhat greyish at top	13	22
3	Shale, blocky, green	3	9
2	Sandstone, greenish grey; massive	1	6
1	Shale, rubbly, greenish grey	5	5

Section 6-46. Belly River and Wapiabi formations; Highwood River, Turner Valley map-area.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BELLY RIVER FORMATION		
34	Sandstone, medium-grained, greenish grey, carbonaceous; weathering dark greyish green, some weathers platy; laminated, thickly to massive bedded; fucoid markings	34	409
	Nomad Member		
33	Shale and siltstone interbedded; shale is dark to brownish grey or green, carbonaceous; siltstone is greyish green, 1″-2″ bands	13	375
32	Sandstone, fine-grained, greyish green, carbonaceous; laminated, shows some crossbedding	1	362
31	Sandstone and shale as above, interbedded	3	361
30	Sandstone, fine-grained, greyish green, slightly carbonaceous; weathers flaggy; laminated, thickly bedded; limonitic spots	8	358
29	Sandstone and shale as above	2	350
28	Sandstone and shale interbedded; more sandstone at top, flaggy; thinly bedded	9	348
27	Shale, rubbly to blocky, greyish black; rust weathering; some silty beds	55	339
26	Sandstone, coarse-grained, pebbly, dark grey, concretionary; weathers rust to brown	3	284
25	Siltstone and shale, sandy; lenses of coarse-grained sandstone; limonitic spots	6	281
24	Siltstone, argillaceous, platy, sandy, dark grey; wavy bedded; limonitic spots; traces of *Baculites*	19	275
	Chungo Member		
23	Sandstone, fine-grained, brownish grey; laminated, thinly bedded; pebbles at base	2	256
22	Sandstone, fine- to medium-grained, brownish grey, slightly carbonaceous; laminated, massive at top, flaggy towards base, some crossbedding; pebbles embedded in upper surface	15	254
21	Mostly covered. Appears to be sandstone as above	18	239
20	Sandstone, fine-grained, brownish grey, slightly carbonaceous; thinly and wavy bedded	15	221
19	Shale, flaky, black, somewhat coaly; rust weathering; 1′ greenish shale at top overlying thin sandstone	7	206
18	Shale, rubbly, greenish grey; plant fragments	1.5	199
17	Shale, silty, concretionary	0.5	197.5
16	Shale, rubbly, dark brown, carbonaceous	7	197
15	Sandstone, medium-grained, greyish green, carbonaceous; thinly to thickly bedded; some shaly intervals	24	190
14	Sandstone, medium-grained, brownish grey; massive; pebbles on upper surface	2	166
13	Conglomerate; chert pebbles ¼″-1″	0.5	164
12	Sandstone, medium-grained, brownish grey; some disseminated pebbles; thinly bedded at top	3.5	163.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
11	Conglomerate; chert pebbles ¼"-1"; very well defined basal contact	2	160
	Highwood Sandstone		
10	Sandstone, fine- to medium-grained, grey; weathering grey to brownish grey; thickly bedded, slightly laminated; pebbles on bedding surfaces at intervals of 6" or more	15	158
9	Sandstone, as above; few scattered pebbles; massive to thickly bedded	14	143
8	Sandstone and platy shale interbedded	3	129
7	Sandstone, medium-grained, greyish green, carbonaceous; brownish weathering; pebbles on upper surface; laminated, crossbedded, thickly bedded; massive appearance	19	126
6	Partly covered	17	107
5	Sandstone, medium-grained, brownish grey, carbonaceous; laminated, thickly bedded; massive appearance; 1' thinly bedded sandstone at base	19	90
4	Sandstone as above; finely and evenly laminated	10	71
3	Sandstone, as above; massive, some crossbedding; 1½' of thinly bedded sandstone at base	18	61
2	Sandstone as above; massive; shaly interval at base	35	43
1	Sandstone, as above, brownish grey	8	8
	WAPIABI FORMATION		
	Hanson Member		
60	Sandstone, fine-grained, brownish grey; laminated; and shale interbedded	2	1,055
59	Sandstone, fine-grained, brownish grey; laminated, 6"-2' beds; and shale, 40%	13	1,053
58	Partly covered. Sandstone and shale, 50%; interbedded in 2"-6" beds	13	1,040
57	Sandstone, and shale, 60%, platy, brownish grey	9	1,027
56	Siltstone and sandstone bands with shale, 40%, dark grey; bedded; shaly at base	31	1,018
55	Siltstone, argillaceous, to mudstone; bedded; rare small reddish brown weathering concretions; shaly at base	16	987
54	Shale, rubbly, with 2"-3" beds of laminated sandstone; brownish weathering; striped appearance	14	971
53	Shale, brownish grey, with 2"-4" beds of laminated sandstone, 50%; brown weathering; 2' lensy argillaceous limestone at top	15	957
52	Shale, blocky to rubbly, dark grey; few concretions. GSC loc. 28178	45	942
	Thistle Member		
51	Shale, and siltstone, 30%, platy, dark grey	13	897
50	Shale, platy; few siltstone beds	27	884
49	Dolomite lenses; yellow weathering; laminated	1	857
48	Shale, platy to flaky, dark grey	22	856
47	Shale, more platy than above; limy at base	23	834
46	Limy bed, very shaly, platy; yellow weathering	1	811
45	Shale, platy, and some siltstone, dark grey; bentonite at 11½'	33	810

Unit	Lithology	Thickness (feet)	Height above base (feet)
44	Dolomite, argillaceous, lenses; yellow weathering; large *Inocerami* and other pelecypods	2	777
43	Shale, platy, and some thin siltstone; bentonite at 11′, 14½′ and 24′	31	775
42	Shale, with limestone lenses	1	744
41	Shale, platy, dark grey	8	743
	Shear.		
40	Shale, platy; some thin limy beds	44	735
39	Dolomite zone with 1′ platy shale in centre	2	691
38	Shale, platy, and siltstone, 20%, dark grey; limy laminated siltstone beds; some limestone	23	689
37	Dolomite, argillaceous, lenses	1	666
36	Shale, platy, and some siltstone	8	665
35	Shale, and siltstone, 20%; limy lenses at base	18	657
34	Shale, platy; some limy crossbedded siltstone beds; bentonite at 26′	34	639
33	Shale, and siltstone, 25%, platy	8	605
32	Dolomite beds	1	597
31	Shale, platy, dark grey	31	596
30	Shale, platy, with siltstone, 30%; crossbedded siltstone beds	33	565
29	Shale, platy, dark grey	11	532
	Shear.		
28	Shale, platy	8	521
	Dowling Member		
27	Shale, platy, rubbly at base; 4″ × 18″ laminated reddish brown weathering concretions; thin bentonite at base	29	513
26	Shale, platy; 3″ × 6″ reddish brown weathering concretions	14	484
25	Shale, platy, with some siltstone; reddish brown weathering concretions in rows	33	470
24	Shale, platy; rusty weathering; rubbly toward base; rare concretions	54	437
23	Shale; rusty weathering; some concretions	27	383
22	Covered. Rubbly shale at base	23	356
	Marshybank Member		
21	Shale, platy; few reddish brown weathering concretions	46	333
	Muskiki Member		
20	Shale, rubbly to blocky; 4″ × 1′ concretions	21	287
19	Shale, rubbly; slightly rusty weathering; concretions in rows	12	266
18	Shale, and thin siltstone, 10%; concretions; rubbly at base	36	254
17	Shale, and siltstone, 25%; 2″ beds at top; reddish brown weathering concretions	25	218
16	Shale, rubbly; few siltstone beds; few reddish brown weathering concretions	16	193
15	Shale, and siltstone, 15%, platy; rubbly at base; concretions; large 2′ concretions at base	26	177

Unit	Lithology	Thickness (feet)	Height above base (feet)
14	Shale, rubbly to slightly blocky; small reddish brown weathering concretions	34	151
13	Shale, slightly platy to flaky; few concretions	55	117
12	Shale, rubbly to flaky; some concretions; bentonite at base	59	62
11	Conglomerate, concretionary; reddish brown weathering; some shale	3	3
	Fault.		
	(22′ rubbly shale lies above 1′ concretionary conglomerate.)		
	CARDIUM FORMATION		
10	Sandstone, fine-grained, with siltstone ,50%; 6″-1′ beds	8	177
9	Siltstone, sandy; bedded; concretions	12	169
8	Siltstone argillaceous, sandy at top; rusty weathering	16	157
7	Shale, blocky to rubbly; rusty weathering; large concretions	7	141
6	Shale, blocky to rubbly; rusty weathering; concretions	44	134
5	Partly covered. Shale, as above; with concretions	26	90
4	Shale, rubbly; rusty weathering; concretions	20	64
3	Siltstone, argillaceous, platy	7	44
2	Shale, platy to rubbly; rusty weathering; few siltstone bands	13	37
1	Shale, platy; rusty weathering; few concretions	24	24
	End of exposure.		
	Across Creek, section is faulted onto overturned Wapiabi shales.		

Section 6-49. Cardium formation; Lynx Creek, just below George Creek, Carbondale map-area, Alberta, sec. 12, tp. 6, rge. 4, W5.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Immediately overlying beds of Wapiabi not exposed.		
	Top beds of Cardium appear slightly crumpled.		
12	Siltstone, argillaceous, dark grey; slightly bedded to massive; few reddish brown weathering concretions. Possibility of fault at base	12	153.5
11	Siltstone, argillaceous, platy; rusty weathering; bedded; reddish brown weathering concretions, 3″ × 6″; sharp base—shear	13	141.5
10	Shale, platy to rubbly; rusty weathering; rare concretions. GSC locs. 28177, 28217	27	128.5
9	Shale, as above; slightly more rubbly; rusty weathering. GSC loc. 28214	16	101.5
8	Shale, platy to rubbly, dark grey; rusty weathering; large reddish brown weathering concretions at base with few chert pebbles	17	85.5
7	Siltstone, argillaceous; bedded; chert pebbles on upper surface; some large reddish brown weathering concretions; shaly at base	16	68.5
6	Shale, very silty, to siltstone, dark grey; bedded; few concretions	26.5	52.5

Unit	Lithology	Thickness (feet)	Height above base (feet)
5	Siltstone, argillaceous; massive; some concretions; scattered chert pebbles at base	7	26
4	Shale, very silty; bedded	1	19
3	Sandstone, fine-grained, knobbly, slightly argillaceous; rusty weathering; massive	5.5	18
2	Siltstone, argillaceous, dark grey; massive	7	12.5
1	Siltstone; more bedded; few reddish brown weathering concretions; bentonite at base	5.5	5.5
	BLACKSTONE FORMATION		
4	Mudstone to siltstone; bedded; reddish brown weathering concretions; fairly massive at top	8.5	33.5
3	Mudstone, blocky; rusty weathering; some concretions	11	25
2	Shale, platy to blocky; rusty weathering	7	14
1	Not well exposed. Shale, platy, dark grey; reddish brown weathering concretions	7	7
	End of exposure.		

Section 6-51. Blackstone formation; Lynx Creek, Carbondale map-area, Alberta, sec. 11, tp. 6, rge. 4.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Overlying beds of Cardium formation.		
	Opabin Member		
20	Siltstone, argillaceous; rusty weathering; bedded	8	262
19	Shale, blocky; rusty weathering. Partly covered	18	254
18	Covered	8	236
17	Shale, blocky; rusty weathering	25	228
	Haven Member		
16	Shale; rusty weathering; some concretions	8	203
15	Shale; rusty weathering; some siltstone; rare concretion; very silty 8′ from top	20	195
	Shear.		
14	Shale, blocky to rubbly; slightly rusty weathering; rare concretion	14	175
	Vimy Member		
13	Shale, dark grey	9	161
	Shear.		
12	Shale, and siltstone, 35%, platy; beds of laminated siltstone to sandstone; increases to almost 50% siltstone at top	19	152
	Shear.		
11	Shale, and siltstone, 20%, platy	13	133
	Shear.		
10	Shale, platy; silver grey weathering	10	120
9	Shale, and siltstone, 25%, platy; silver grey weathering; some limy concretions	23	110
8	Shale, and siltstone, 15%, platy; silver grey weathering; few limy concretions	13	87

Unit	Lithology	Thickness (feet)	Height above base (feet)
7	Shale, platy, dark grey; silver grey weathering	42.5	74
6	Shale, platy, dark grey; silver grey weathering; bentonite at 6′ and 9′; 4″ bentonite at base; *Inoceramus labiatus*	17.5	31.5
	Shear.		
5	Shale, rubbly to blocky; rusty weathering	3	14
4	Bentonite, greenish white; clayey at base, blocky at top	4.5	11
	Sunkay Member		
3	Shale, flaky; rusty weathering; very hard at top	3	6.5
2	Shale, with lenses of pebbles	2	3.5
1	Chert pebbles as large as 2″, in shale matrix	1.5	1.5
	Siltstone, 0.5′, limy, argillaceous; massive; numerous pelecypods.		
	Crownest agglomerate, green.		

Section 6-53. Sunkay member, Blackstone formation; Castle River, Carbondale map-area, Alberta.

6	Shale, platy; silver grey weathering	26	41.5
5	Bentonite	0.5	15.5
4	Shale, platy; silver grey weathering	1	15
	Sunkay Member		
3	Shale, platy to rubbly; rusty weathering	9.5	14
2	Conglomerate; chert and quartzite pebbles up to 2″; gritty matrix; massive; upper surface covered with cobbles up to 3″	1.5	4.5
1	Shale, platy; rusty weathering; with chert pebbles up to 1′	3	3
	Crowsnest agglomerate.		

Section 6-54. Cardium formation; Drywood River, Pincher Creek map-area, Alberta.

	Overlying shale is similar and no real break in lithology occurs.		
8	Shale, platy to rubbly; rusty weathering; 2″-3″ pebble-conglomerate at top	42	74
7	Concretionary band	1	32
6	Shale; rusty weathering	7	31
5	Sandstone, fine-grained; tan weathering; massive; coarse-grained at top	3.5	24
4	Sandstone, fine-grained; tan weathering; 4″-1′ beds; shale partings	7	20.5
3	Siltstone to shale; bedded	10	13.5
2	Sandstone, fine-grained, concretionary; shaly break in centre; upper half very coarse grained, gritty	2.5	3.5
1	Concretionary bed with some shale	1	1

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BLACKSTONE FORMATION		
2	Shale, silty, blocky, dark grey	3.5	15.5
1	Shale, blocky to platy, dark grey; rare concretions; reddish concretionary zone at top	12	12

Section 7-1. Cardium formation; south side of McLeod River near junction of Cadomin-Luscar road.

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Contact of the Cardium formation with the Wapiabi formation is not exposed.		
	Sturrock Member		
19	Sandstone, fine-grained, grey; weathering grey to brownish grey; thickly bedded; 6" shaly break at 8'	16	251
18	Sandstone, and shale, 25%; 6"-1' beds	11	235
17	Sandstone as above; thickly bedded; more thinly bedded at base	8	224
	Leyland Member		
16	Shale to mudstone, silty, dark grey; more silty at top with few thin bands of sandstone; concretions and concretionary beds	37	216
15	Sandstone, fine-grained, grey; thinly bedded, 6"-12", with 1"-2" shale beds; concretions and concretionary beds; pebbles at top	19	179
14	Sandstone, fine-grained; light brown weathering; massive	5	160
13	Shale to mudstone, silty; banded appearance; more rubbly with concretions at base	27	155
	Moosehound Member		
12	Sandstone, greyish brown, carbonaceous; laminated; concretionary at top; 1' silty shale in middle	4	128
11	Sandstone, soft, silty, greenish grey; poorly bedded	4	124
10	Shale to mudstone, rubbly, soft, light greenish grey	6	120
9	Sandstone, as unit 9 above	1	114
8	Shale, soft, greyish brown; few concretions	10	113
7	Sandstone, brown, carbonaceous; upper and lower 1' are thinly bedded, middle beds are thickly bedded	5	103
6	Mudstone, with coaly shale at base	5	98
5	Covered	20	93
4	Mudstone, silty, greenish grey	5	73
3	Sandstone, silty, carbonaceous; laminated; shaly in middle	7	68
2	Covered	31	61
	Ram Member		
1	Sandstone, clean; tends to weather platy; laminated, beds 1'-2', more massive at base (shear in middle)	30	30

Unit	Lithology	Thickness (feet)	Height above base (feet)
	BLACKSTONE FORMATION		
	Opabin Member		
11	Shale and siltstone; banded appearance	7	205
10	Sandstone	2	198
9	Sandstone and shale	5	196
8	Shale, silty; concretionary beds	16	191
7	Siltstone; sandy at top, shale at base; concretionary	14	175
6	Sandstone; laminated; shaly intervals	4	161
5	Siltstone; sandy at top, shaly at base; concretions	17	157
4	Sandstone, fine-grained; laminated	5	140
3	Siltstone, grading into shale at base; concretions	29	135
2	Siltstone to mudstone, banded; concretionary beds; grading into rubbly shale at base	46	106
1	Siltstone and shale, grading downward into rubbly shale; concretionary beds	60	60
	Section below is slightly folded but Haven member is immediately below.		

Section 7-3. Belly River and Wapiabi formations; Sheep River, Turner Valley map-area, Alberta, sec. 19, tp. 19, rge. 3W.

	BELLY RIVER FORMATION		
37	Sandstone, medium-grained, greyish green, carbonaceous; brownish green weathering; thickly bedded	3	675
36	Covered	19	672
35	Shale, rubbly, greyish green, carbonaceous	2	653
34	Covered	22	651
33	Sandstone, fine-grained, greyish green, carbonaceous; laminated	2	629
32	Shale, as above	33	627
31	Sandstone, fine-grained, greenish grey	1	594
30	Shale, silty, greenish grey	11	593
29	Sandstone, fine-grained, silty, greenish grey; limy concretions	2	582
28	Shale, rubbly, greenish grey	7	580
27	Sandstone, as unit 29 above	1	573
26	Covered. Some shale	13	572
25	Sandstone, as unit 27 above; shale interval in centre	10	559
24	Covered	22	549
23	Sandstone, fine-grained, micaceous, greyish green; homogeneous, thickly bedded	15	527
	WAPIABI FORMATION		
	Nomad Member		
22	Mostly covered. Some interbedded sandstone and shale as above	14	512
21	Sandstone, fine-grained, greyish green; homogeneous, thickly to thinly bedded	19	498
20	Covered	41	479

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Chungo Member		
19	Sandstone, fine- to medium-grained, greyish green; homogeneous, massive to thickly bedded. GSC loc. 32864	9	438
18	Covered	46	429
17	Siltstone, argillaceous, sandy, dark grey; massive; few concretions; platy at base	15	383
16	Mudstone; very silty at top, platy towards base; limonitic spots; few concretions	18	368
15	Siltstone, argillaceous, sandy; bedded appearance	17	350
	Highwood Sandstone		
14	Sandstone, fine- to medium-grained, greyish green to brown; thickly bedded; laminated 2″-3″ conglomerate at top	5	333
13	Partly covered. Sandstone, much as above	40	328
12	Sandstone and shale interbedded; shaly at base	62	288
11	Sandstone at top, interbedded with shale below	17	226
10	Sandstone, fine-grained, brownish grey; interbedded with silty shale	21	209
9	Siltstone and shale interbedded; more shale at base; concretions	35	188
	Hanson Member		
8	Shale, very silty, blocky; few concretions	20	153
7	Siltstone and shale interbedded	15	133
6	Sandstone, fine-grained, argillaceous; laminated, thinly bedded	2	118
5	Siltstone and shale	7	116
4	Siltstone to mudstone, dark grey, blocky; few concretions and hard silty bands	40	109
3	Mudstone; some concretions	11	69
	Thistle Member		
2	Mudstone; with sandy beds at top, shaly at base	18	58
1	Siltstone and shale interbedded, platy; banded appearance	40	40

Section 7-6. Belly River and Wapiabi formations; Oldman River, Alberta

	Belly River Formation		
	Overlying beds not exposed.		
34	Sandstone, fine- to medium-grained, greyish green, carbonaceous; weathers greyish green; homogeneous, thickly to massive bedded; some cross-bedding	24	522
	Nomad Member		
33	Sandstone and shale interbedded, 50%; sandstone is fine-grained, greyish green, carbonaceous, platy; shale is greyish green, rubbly	15	498

Unit	Lithology	Thickness (feet)	Height above base (feet)
32	Shale, and sandstone, 25%, as above	6	483
31	Sandstone, and shale, 20%, as above	4	477
30	Shale, rubbly, brownish grey; few sandstone beds	6	473
29	Sandstone, fine-grained, platy; laminated; with shaly intervals, 30%	4	467
28	Shale, rubbly, brownish grey to greenish grey; few silty bands	30	463
27	Shale, rubbly, dark grey; rusty weathering	7	433
26	Mudstone to shale, rubbly, dark grey; grey weathering; gritty lenses; few concretions at top; some scattered pebbles in upper 1" and in basal 1'. GSC loc. 32866	10	426
	Chungo Member		
25	Sandstone, medium-grained, grey to brownish grey, slightly carbonaceous; laminated, thickly to massive bedded; shale pebbles	8	416
24	Covered	59	408
23	Sandstone, fine- to medium-grained, platy; wavy bedded	3	349
22	Covered	27	346
21	Sandstone, fine-grained, platy, soft, greyish green	2	319
20	Sandstone, medium-grained, soft, greyish green to greyish brown; laminated, crossbedded; massive appearance	9	317
19	Siltstone, greyish green, with 6" sandstone near base	5	308
18	Sandstone, medium-grained, grey, brownish grey; laminated, massive to thickly bedded; limonitic spots	14	303
17	Covered	25	289
16	Shale, soft, flaky, greyish brown	6	264
15	Mudstone, greyish green; rubbly, with silty concretions at top	5	258
14	Sandstone, brownish grey; laminated; shaly at base	2	253
13	Shale, rubbly, brownish grey	3	251
12	Sandstone, fine- to medium-grained, brownish to greenish grey; carbonaceous; laminated, crossbedded, massive to thickly bedded; some weathers platy	25	248
11	Sandstone, as above; shaly break at base	10	223
10	Sandstone, much as above; laminated, crossbedded	20	213
9	Sandstone, as above; poorly bedded in part	60	193
8	Sandstone, fine-grained, brownish grey, thinly bedded; some shaly intervals	39	133
7	Siltstone, sandy, medium grey; grey to brownish weathering; thinly bedded; some sandstone beds	15	94
6	Sandstone, and shale, 30%, interbedded	11	79
5	Siltstone, argillaceous, dark grey, more shaly at base	10	68
4	Sandstone, fine-grained, brownish to greyish green; thinly bedded	31	58
3	Covered	8	27
2	Sandstone, as above	1	19
1	Sandstone and shale interbedded; thinly bedded to platy	18	18

Unit	Lithology	Thickness (feet)	Height above base (feet)
	WAPIABI FORMATION		
	Thistle Member		
11	Sandstone; thinly bedded, to flaggy as above	10	362
10	Covered	15	352
9	Shale, silty, blocky to rubbly, dark grey	7	337
8	Covered	31	330
7	Shale, platy, dark grey; not well exposed	122	299
6	Siltstone, and shale, 40%, interbedded, dark grey, platy, slightly calcareous; laminated; dolomitic bed at 5′	22	177
5	Shale, and some silt, 20%	40	155
4	Shale, platy, dark grey, slightly calcareous; dolomitic bed at 10′; large concretion at 40′. GSC loc. 32860	48	115
3	Siltstone and shale, 50%, platy; dolomitic limestone bed at top and base. GSC loc. 32865	36	67
2	Shale, platy, with some siltstone	23	31
1	Shale and silt	8	8
	Fault.		

INDEX