MEMOIR 259

GEOLOGY OF NORTHEASTERN BRITISH COLUMBIA

BY

F. H. McLEARN AND E. D. KINDLE

GEOLOGICAL SURVEY
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
OTTAWA
1950

A. East end of Hudson Hope, an old settlement at head of steamboat navigation on Peace River. Hall, porch of hotel, school, and cottage on left; Hudson's Bay store to right of centre and log Anglican church on extreme right (85386). (Page 3.)

B. Pioneer farm of James Beattie (Gold Bar post office), north side Peace River, about 35 miles west of Hudson Hope, in middle of Foothills (96665). (Pages 3, 14.)

CANADA

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PREFACE

The northeastern British Columbia of this report comprises an area of about 65,000 square miles. It is a region of plains, foothills, and mountains, underlain largely by sedimentary rocks, and has recently come into prominence with the construction of the Alaska Highway, which traverses it from southeast to northwest for a distance of 600 miles. Only limited parts of this great area have been geologically explored, but these have provided many items of scientific and economic interest. The Devonian succession bears much resemblance to that of Mackenzie River Valley, and is of special interest in relation to current explorations for oil in Western Canada. The Triassic section is unusually complete and rich in faunas, and bids fair to become a classic area for the system in North America. Important coal deposits are known, and their exploration has led to the opening of several small mines and a needed supply of coal for a growing population.

The present report, illustrated by a geological map, on a scale of 1 inch to 10 miles, and by numerous plates and figures, has been prepared by Drs. F. H. McLearn and E. D. Kindle of the Geological Survey, both of whom have investigated parts of the region involved. Their task has been to examine, co-ordinate, and organize all available published or unpublished geological data into a comprehensive and logically arranged account of what is known of this large region. It has included an historical summary of previous geological investigations dating back to the early seventies of last century; a description of the widely varying physical features of this extensive terrain; a description of the essential stratigraphic elements, compared where possible with those of better known, more southern regions; details of known structural features, such as may facilitate explorations for oil and gas; and information on features of economic interest, with particular attention to known coal deposits. Direct quotations from earlier reports, in part now out of print, are widely employed, and a full bibliography illustrates the abundant references consulted and the great variety of geological work that has been done in this, as yet, very incompletely mapped part of the province.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, February 23, 1950

GEOLOGY OF NORTHEASTERN BRITISH COLUMBIA

CHAPTER I

INTRODUCTION

SUMMARY

Northeastern British Columbia, as referred to in this report (*See* Figure 1), is a region of some 65,000 square miles lying north of latitude 55°30′ and mainly east of the Rocky Mountain Trench. The greater part

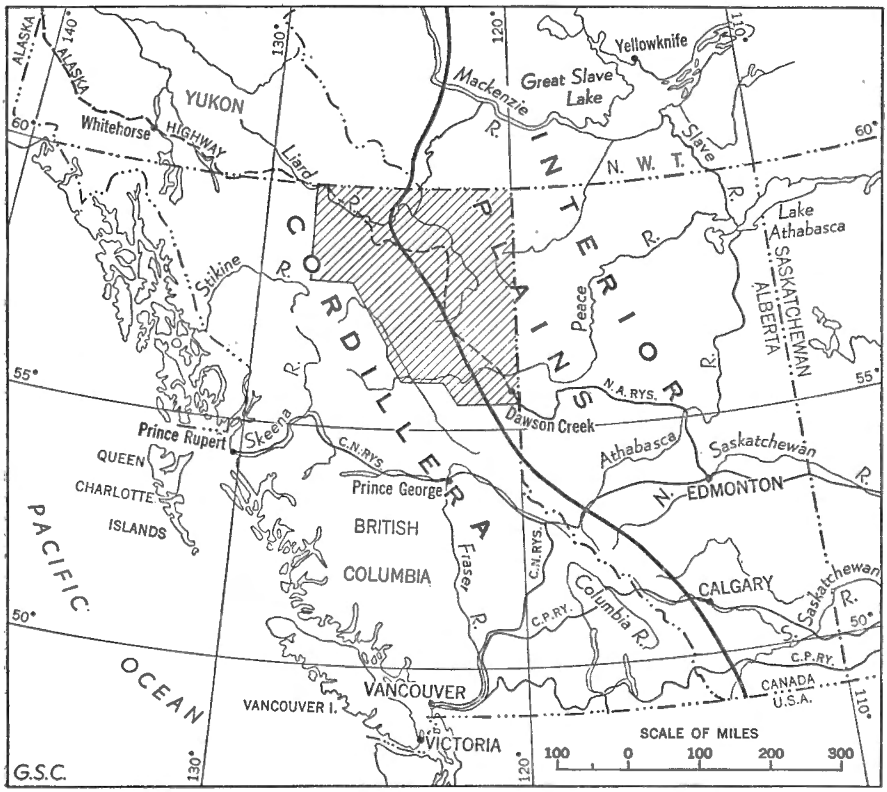

Figure 1. Index map showing area of northeastern British Columbia covered in this report, and the boundary between the Interior Plains and Cordillera in British Columbia and Alberta.

of this vast territory is unexplored, but geological investigations have been made along major streams and along the recently constructed Alaska Highway, so that the general stratigraphic succession has been well established.

The authors have here attempted to bring together and to summarize and co-ordinate all of the available geological information that has been published on this region. The senior author has written the chapters on stratigraphy, structure, and historical geology, and part of the chapter on economic geology; and E. D. Kindle has prepared the introductory chapter, the chapter on physical faetures, and part of the chapter on economic geology, and has compiled the accompanying geological map of the region.

The geological map of northeastern British Columbia has been compiled largely from geological maps and reports that have been published from time to time by the Geological Survey of Canada and the British Columbia Department of Mines. Several unpublished manuscripts have also been made available by the British Columbia Department of Mines, and some information supplied by oil company geologists has been incorporated in the map. The following geologists have contributed materially to the geological literature on this region: H. H. Beach, J. B. Bocock, L. D. Burling, B. J. Chronic, A. H. Cox, G. M. Dawson, V. Dolmage, J. A. Dresser, O. A. Erdman, C. F. J. Galloway, J. D. Galloway, A. J. Goodman, J. C. Gwillim, C. O. Hage, M. S. Hedley, S. S. Holland, G. S. Hume, E. J. W. Irish, F. Kidd, E. D. Kindle, L. R. Laudon, W. H. Mathews, R. G. McConnell, F. H. McLearn, W. F. Robertson, A. R. C. Selwyn, G. Shaw, E. M. Spieker, J. Spivak, C. R. Stelck, J. S. Stewart, P. K. Sutherland, J. A. Wallace, R. T. D. Wickenden, M. Y. Williams, T. B. Williams, and W. I. Wright. Much information has been obtained from the study of fossils collected by field geologists of companies exploring for oil and sent to Ottawa for study. Acknowledgment is made to the chief geologists of Gulf Research and Development Company, McColl-Frontenac Oil Company, Phillips Petroleum Company, Shell Oil Company, and Socony-Vacuum Oil Company for the opportunity of examining these collections.

The coal deposits of the Peace River district are the best known mineral resource of this part of British Columbia. The coal occurs in the upper part of the Bullhead group of Lower Cretaceous age. It is a high-grade bituminous coal, and there are plentiful reserves. An estimate by the Royal Commission on coal (MacKay, 1947)[1] places the reserves as 467,040,000 tons of probable mineable coal in this district, with 573,440,000 tons of possible additional mineable coal. Only four small coal mines are operating at present. The King Gething, Peace River, and Packwood Coal mines in Peace River Valley are more than 100 miles distant, by truck road, from railhead at Dawson Creek. The haul from the Hasler Creek coal mine south of Pine River is about 75 miles.

The broad belt of gently folded rocks that underlie the Foothills of the Rocky Mountains extends for more than 350 miles northwesterly from south of the Peace River Block north to Liard River. This belt contains many anticlinal and terrace structures, some of which may prove worth

[1] Names of authors and/or dates in parentheses are those of authors and dates of publication of reports listed in Bibliography, Chapter VII.

prospecting for petroleum. Only one attempt has been made so far at deep drilling for oil. In 1940–42 the British Columbia Government drilled a well to a depth of 6,940 feet on the Commotion Creek faulted anticline on Pine River, but failed to penetrate the Lower Cretaceous, Bullhead group to the more favourable Triassic and Palæozoic strata. No oil or gas was encountered. Further drilling by some of the large oil companies is anticipated now that the Alaska Highway has made this northerly Foothills belt more readily accessible.

Small amounts of fine placer gold have been recovered from time to time from gravel bars along Finlay, Parsnip, Peace, and Liard Rivers, but the yield has not encouraged extensive placer mining operations. No metallic mineral lode deposits of economic value have yet been found east of the Rocky Mountain Trench in this part of British Columbia, though the region retains some possibilities, as productive lead-zinc mines occur at Field, British Columbia, in the southern Rocky Mountains under very similar geological conditions.

ACCESSIBILITY

The Alaska Highway, reaching more than 1,500 miles northwest from Dawson Creek, British Columbia, to Fairbanks, Alaska, is the main artery for the flow of goods and services into northeastern British Columbia. Dawson Creek is accessible from Edmonton via the Northern Alberta railway (495 miles). The Pine Pass highway is also under construction to connect Dawson Creek with Prince George, and in dry weather it is possible to drive west from Fort St. John along the north side of Peace River by way of Hudson Hope (*See* Plate I A) to the Beattie farm (Gold Bar) in the middle of the Foothills (*See* Plate I B).

In the early days of the fur trade most travel through northeastern British Columbia was by boat or by horse, and in winter by dog sled. Liard River gave entry to the northern part of the province from the Mackenzie, but so many rapids and so much fast water were encountered above Hades (Hell) Gate that this route to the west was soon neglected. The Liard is, however, readily navigable for river boats to the mouth of Fort Nelson River and for 100 miles up the latter stream to Fort Nelson. Sikanni Chief River is said to be navigable by canoe, when the water is high, from the Highway crossing down to Fort Nelson River.

Peace River, navigable for 500 miles between Vermilion Chutes (150 miles up Peace River) and Hudson Hope, became the natural southern route into this region in the early history of the country, but has been superseded by good roads, and truck and railway transportation. West of Hudson Hope, water traffic is impeded by the necessity of portaging around the 18-mile long Peace River Canyon. Aside from this portage the river route may be continued west to the head of Peace River and up both of its great tributaries, Finlay and Parsnip Rivers. A good boat route also leads to the head of Peace River from Prince George via Summit Lake, Crooked River, McLeod Lake, and Pack and Parsnip Rivers.

Finlay River is navigable as far up as Fort Ware, the Hudson's Bay Company post at the junction of Kwadacha and Finlay Rivers. Deserters Canyon, half a mile long, is the only hazardous section on the Finlay, and is navigable only when the water is low. Fox River may be ascended with difficulty for 23 miles, in a straight line, from above a short portage near its mouth.

The Rocky Mountain Trench was followed by many of those entering the Yukon at the time of the Klondike gold rush in the late nineties, and a good trail was maintained at that time. According to Hedley and Holland (1941), this pack-horse trail is in fair condition from Fort Ware, on Finlay River, to Kechika River Crossing at Chee House, and thence to Lower Post on the Liard. It is 44 miles, northwesterly, from Fort Ware to Sifton Pass, and an additional 50 miles to the mouth of the Gataga, below which the Kechika is readily navigable. Boats may also be taken with difficulty up the Kechika to the mouth of Driftpile Creek.

A fair pack-horse trail leads east from Kechika Valley, at the mouth of Turnagain River, to the south end of Muncho Lake. Another trail extends westerly from the mouth of Turnagain River via Sand and Mosquito Creeks to the upper Turnagain and connects with the trail to Dease Lake. Another good trail follows the valley of Halfway River for 80 miles north from Peace River, then continues northwest, crossing the headwaters of Sikanni Chief, Besa, Prophet, and Muskwa Rivers. It follows the north side of Muskwa Valley in a westerly direction to Bedaux Pass, then down the valleys of Warneford and Kwadacha Rivers to Fort Ware.

An old winter tractor trail from Fort St. John to Fort Nelson lies 30 to 45 miles east of the Alaska Highway for much of the way, and should assist exploration in that direction.

The northern part of the Carbon Creek Basin coal area is 10 miles by river boat up Peace River from Gold Bar. A pack-trail extends southward up the west side of Carbon Creek from the Peace to the coal showings at Eleven (11-mile) Creek, and trappers' trails continue from this point not only up Carbon Creek but also up Eleven Creek and another tributary of Carbon Creek to Carbon (Indian) Lake. Another pack-trail leads from the head of Peace River Canyon, by way of Gething Creek and Wright Lake, to a point on Carbon Creek 15 miles from Peace River, where it joins the Carbon Creek trail.

Fort St. John, Fort Nelson, and Watson Lake may be reached by good air service, and stops can be arranged at intermediate emergency landing fields. Many lakes are suitable for hydroplane landings, which can also be made on most of the large rivers.

NATURAL RESOURCES

The prairies of the Peace River region are widely known for the high quality grains that are grown there. As on the plains farther south, the danger of harmful frosts is not lacking, but the district as a whole may be rated as first class for grain crops, and has also proved ideal for mixed farming and ranching. Evidence of possible successful agricultural enterprise on a large scale in the Fort Nelson area rests on the excellence of common garden produce, such as potatoes, cabbage, turnips, beans, peas, carrots, tomatoes, and beets that have been raised for many years at the Hudson's Bay Company posts at Fort Nelson and at Nelson Forks. Williams (1944) believes that, by proper land selection and drainage, small farming could be carried on for 50 miles westerly from Fort Nelson. Liard

Valley, from near Liard hot springs upstream to Watson Lake, includes many other areas of promising land for agricultural purposes, and flourishing gardens have long been grown at Lower Post.

The greater part of the region below an elevation of 4,500 feet is forest covered. Eight species of trees are abundant: white spruce, black spruce, alpine fir, balsam poplar, paper birch, trembling aspen, lodgepole pine, and northern larch. The most widespread forest community to be seen along the Alaska Highway is that of the white spruce, lodgepole pine, and aspen. A chart prepared by Raup (1945) shows that much of the area between Peace and Toad Rivers supports a forest cover of white spruce, alpine fir, black spruce, and lodgepole pine. Balsam poplar abounds and flourishes on the recent river flood plains and gravel bars. Larch is confined to the muskegs, and the paper birch, though never plentiful, is widespread in mixed stands. A few small areas of unsettled agricultural land in the Peace River area consist of coppice or park-like areas in which patches of open woods alternate with grassy, treeless tracts of varying extent.

Fur-bearing animals have been the source of important commerce in northeastern British Columbia for a century and a half. The annual take includes pelts of the bear (black, brown, and grizzly), coyote, wolf, wolverine, lynx, fox (red, cross, and silver), skunk, ermine or weasel, beaver, marten, otter, fisher, mink, and muskrat. Moose, caribou, mule deer, mountain sheep, and mountain goat occur in varying numbers in selected ranges of the region. Specific localities where big game is known to be abundant are outlined by A. L. Rand (1944). His report mentions the presence of Rocky Mountain elk in the Tuchodi Lake area.

Game birds that may be hunted in season include the Canada goose, ducks, snipe, prairie chicken, ruffed grouse, spruce grouse, and ptarmigan.

Many of the larger lakes contain abundant lake trout, whitefish, pickerel, pike, suckers, and ling. Peace River, because of its muddy waters, furnishes only a few fish, principally ling and goldeyes, but Dolly Varden and rainbow trout are plentiful in the clear, cold waters of its tributary mountain streams. Arctic grayling abound in the smaller tributary streams of the Liard, and inconnu, pickerel, and pike are occasionally caught in its larger tributaries.

Peace River Canyon offers a good site for future water-power development. The river flows through a canyon walled by high banks of sandstone and shale, for about 18 miles, and the fall in this distance is said to be 270 feet. Numerous possible dam sites may be found along the Grand Canyon of the Liard, but the distance to settled areas precludes their early utilization.

The mineral resources of the region are described in Chapter VI.

HISTORY OF EXPLORATION

Alexander MacKenzie (1801) was the first white man to enter British Columbia via the Peace River route. He established a fur-trading post at the mouth of Smoky River in the autumn of 1792, and in May 1793 ascended Peace River and then the Parsnip. He followed the Pack River, McLeod Lake, and Crooked River route south to Fraser River, then travelled westerly to the Pacific Coast by way of Westroad and Dean Rivers. In 1805, Simon Fraser established fur-trading posts at Fort St. John, Hudson Hope, and McLeod Lake, and from this time on the region was regularly visited by the agents and voyageurs of the fur-trading companies. Finlay River was ascended in 1824 by an officer of the North West Company, John Finlay, after whom the river is named. In 1828, Sir George Simpson (1872) travelled up Peace and Parsnip Rivers on a trip to the Pacific, and McLean (1849) tells of 25 years in the service of the Hudson's Bay Company in this region.

During the winter of 1872 and spring of 1873, W. F. Butler journeyed up Peace River en route from Winnipeg to Vancouver. His book (1874) relates a trip by dog sled from the forks of the Saskatchewan to Fort St. John and by canoe west from Peace River Canyon to Parsnip River. He ascended the Omineca, an easterly flowing tributary of the Parsnip, to reach the Germansen and Manson Creek placer fields, and then proceeded south on foot and by horse to Quesnel. He describes the Fort St. John of that day as consisting of a few ruined buildings on the south shore of Peace River, and Hudson's Hope as a solitary house (Hudson's Bay Company post) that marked where Peace River emerged from the canyon.

Sandford Fleming (1874), Engineer-in-Chief of Exploration and Surveys for the Canadian Pacific Railway, sent Messrs. Horetzky and Macoun on a trip to the Pacific Coast by way of Peace River Valley in 1873. They ascended the Parsnip to McLeod Lake, from where Horetzky proceeded west to the Pacific by way of Babine Lake and Skeena and Nass Rivers, and Macoun by the southern route via Quesnel and Fraser River.

Alfred R. C. Selwyn headed the first geological expedition into this region for the Geological Survey of Canada in 1875. He was accompanied by John Macoun, botanist. Selwyn entered the country via Quesnel and Parsnip River. He descended the Peace as far as Fort St. John, and explored Pine River Valley. Macoun continued alone down the Peace and returned to Winnipeg via Athabaska River and Ile-à-la-Crosse Lake.

George M. Dawson of the Geological Survey of Canada passed through the Peace River country in 1879 en route from Port Simpson on the Pacific to Edmonton. Dawson was assisted by R. G. McConnell, and they travelled a large part of the way in company with H. J. Cambie and H. A. F. MacLeod who were searching for a favourable railway route to the Pacific on behalf of the Canadian Pacific Railway.

R. G. McConnell re-visited the Peace River region in 1893. He descended the Parsnip and then Peace River as far as the Foothills, and after a hasty examination of the structure of the Rocky Mountains returned to the Parsnip at Finlay Forks. Finlay River was then ascended as far as Fishing Lakes, 30 miles north of Thutade Lake, and a side trip was made up Omineca River, with visits to the Germansen Creek, Manson Creek, and other placer mining camps, then nearly all abandoned.

In 1906, the Provincial Mineralogist for the British Columbia Department of Mines, W. Fleet Robertson (1907), made a trip overland from Hazelton to McLeod Lake, then by canoe down Parsnip and Peace Rivers. He made a trip south to Moberly Lake and to Pouce Coupé before going south via the Lesser Slave Lake route to Edmonton. In 1908, W. Fleet Robertson (1909) made an overland journey to Finlay River, investigating placer gold occurrences on McConnell Creek and Ingenika River en route.

He sent his horses back overland to Hazelton, and proceeded down the Finlay in a hastily constructed boat to Fort Grahame where he secured a canoe for the trip up Parsnip and Pack Rivers to McLeod Lake.

Liard River was used by officers of the Hudson's Bay Company about 1840 to gain access to northern British Columbia and the Yukon. In 1843, Robert Campbell ascended Liard and Frances Rivers to Frances Lake, then followed Finlayson Creek to Finlayson Lake and crossed over to the Pelly. During the next few years a line of trading posts was extended from Fort Simpson on the Mackenzie to Fort Selkirk at the junction of Lewes and Pelly Rivers, Yukon. But, following the pillaging of the Selkirk post in 1852 by a band of Coast Indians and because of the long and difficult route, most of the outlying posts were soon abandoned.

R. G. McConnell explored Liard River in 1887 for the Geological Survey of Canada. He entered the country with G. M. Dawson by way of Stikine and Dease Rivers, Dawson going north, following Campbell's route to the Pelly, while McConnell descended the Liard. His report (1891) states that a few prospectors and miners had entered the country by this route, the discoverers of the 'Cassiar gold fields', Messrs. McCullough and Thibert, having ascended it from Fort Simpson to the mouth of the Dease in 1871–72.

In 1884, the Legislature of British Columbia granted an area of 3,500,000 acres, known as the Peace River Block, to the Dominion Government for development and settlement. This block runs west from the Alberta boundary for 75½ miles and north for 72½ miles. Fort St. John lies near its centre. The fertile prairie land attracted settlers very slowly at first, and by 1911 a census showed a total population of less than 2,000 persons in the district, including settlers, traders, missionaries, and Indians. Following the penetration of the railway into the Peace River district in 1916 and its subsequent extension westerly to Dawson Creek, there was a rush of land seekers, as indicated by the census figures that follow: 9,100 in 1916, 18,600 in 1921, 16,600 in 1926, and 48,000 in 1931.

An investigation of the coal deposits near the south side of Peace River Canyon was made by C. F. J. Galloway for the British Columbia Department of Mines in 1912.

During the 1917 field season, F. H. McLearn examined the rocks along Peace River from Twelvemile Creek, above Peace River Canyon, down to Vermilion. His report (1918) mentions the discovery of oil that summer in the No. 2 well of the Peace River Oil Company about 15 miles below Peace River.

J. S. Stewart and J. C. Gwillim caried out geological explorations both north and south of Hudson Hope during the summer of 1919. They relate that several companies were drilling for oil during the years 1917–19 along the valley of Peace River near the town of Peace River, and that although some of the wells encountered small showings of gas and oil there was no production and results on the whole were disappointing.

In 1920, the British Columbia Department of Lands sent out John A. Dresser and Edmund Spieker to look for possible oil fields in the Peace River region. Dresser (1921) investigated an area north of Peace River and west of the Peace River Block, while Spieker worked south and southeast of Hudson Hope. Spieker's report (1921) includes a geological map that covers an area from Hudson Hope south to Pine River and southeast to Flatbed Creek. During the same summer, F. H. McLearn (1921) studied sections along the north side of Peace River, from the head of Peace River Canyon to 5 miles west of Schooler Creek.

From June 1921 to June 1922, the British Columbia Department of Lands bored five diamond drill-holes about a mile apart along Farrell Creek and tributary streams some 18 miles northwest of Hudson Hope. The holes penetrated Fort St. John shales and sandstones and entered the top of the Bullhead group. Some gas and water were encountered (Dresser, 1922). F. H. McLearn returned to this district in 1922 to study both the Triassic and the coal-bearing formations in the vicinity of Peace River Canyon. His report (1923) lists the presence of fifty coal seams in the Gething formation.

A winter road about 155 miles long was completed from Fort St. John on Peace River to Sikanni Chief River (at Whipsaw Creek) in 1922, and was followed in May of that year by G. S. Hume and M. Y. Williams of the Geological Survey on their way to Mackenzie River. They travelled by pack-train to Sikanni Chief River and by canoes from there down Fort Nelson and Liard Rivers to the Mackenzie. According to Williams (1923) the winter road followed an old trail used in part during the Klondike gold rush.

John D. Galloway visited the Peace River country for the British Columbia Department of Mines in 1923. His report (1924) describes the occurrence of coal on Carbon River; gives some notes on the coal deposits of Peace River Canyon; and describes briefly some placer mining operations on Peace River.

Victor Dolmage examined the Finlay River basin during the 1927 field season. His report (1928) and map describe the geology and some of the mineral deposits of the region. Dolmage relates that a trail leading up Finlay Valley was known as the 'Trail of 98'. It was built at the time of the Klondike gold rush to enable seekers to reach that district by an all Canadian overland route by way of Sifton Pass and Atlin. Dolmage made use of another famous old trail known as the 'Police trail', which extended from Fort St. John on Peace River to Fort Grahame and on to Hazelton, a distance of nearly 400 miles.

During the field season of 1930, C. M. Sternberg of the Geological Survey of Canada made a study of the dinosaur tracks that are so plentiful in the Gething coal-bearing beds of Peace River Canyon.

M. Y. Williams and J. B. Bocock were engaged in geological investigations for the Pacific Great Eastern Survey of Resources during the summers of 1929 and 1930 under the joint auspices of the province of British Columbia, the Canadian National Railways, and the Canadian Pacific Railway. They mapped the valley of Peace River from the mountains to the Alberta boundary, surveyed the entire valley of Pine River, and mapped the Peace River Block.

Douglas Lay ascended Finlay River in 1930 as far as Deserters Canyon and reported on the mineral occurrences of the district for the British Columbia Department of Mines.

In 1934, Charles E. Bedaux attempted a cross-country journey from Fort St. John to Telegraph Creek with four Citreon half-track motor cars of a type then used by the Swiss army. The cars (tractors) were abandoned due to track trouble, and a fresh start was made using horses. Two members of the expedition, C. E. Lemark and one of the guides, finally reached Telegraph Creek, but the others were forced to return when their horses developed hoof rot from standing in damp ground. Mr. Swannell, a member of the expedition, produced a topographic map of the region traversed, a copy of which is on file at Victoria

F. H. McLearn continued his studies of the stratigraphy of the Peace River Foothills during the 1937 and 1938 field seasons. This work resulted in the discovery of many new Triassic species, which McLearn later figured and described (*See* Bibliography).

Commencing in 1938, several geologists of the British Columbia Department of Mines visited the Peace River district in search of geological structures that might be worth testing for oil. A. H. Cox studied the geological structures of Kiskatinaw Valley and of the Hudson Hope area in 1938, and in the following season examined areas around Moberly Lake and in the neighbourhood of Coal Creek south of Peace River. M. Y. Williams examined structures along the valley of Pine River in 1938, and in 1939 studied the major folds between Pine River and Farrell Creek. C. R. Stelck carried out geological investigations in Red Willow, Pouce Coupé, Kiskatinaw, and Pine River areas during the summers of 1940 and 1941. His report to the Minister of Mines for British Columbia (unpublished manuscript) mentions a natural gas seepage 1½ miles south of the Monkman trail in direction south 50 degrees east from the south end of Lone Mountain, and in an area south of that herein described.

A test well was drilled at Commotion Creek during 1940 and 1941 by the British Columbia Government. Unexpectedly steep dips were encountered below a depth of 4,600 feet, and the well never reached Triassic beds. Drilling was suspended at a depth of 6,940 feet.

During the period 1939-41, the British Columbia Department of Lands and Forests mapped the Rocky Mountain Trench topographically from Finlay Forks to the northern boundry of the province, and a popular account of the project has been presented by Andrews (1942) in the Geographical Journal. M. S. Hedley and Stuart S. Holland (1941) penetrated the north part of the province with the land surveyors in 1940, and made a reconnaissance geological survey of the area drained by Kechika and Turnagain Rivers.

During the summer of 1942, H. H. Beach and J. Spivak made a geological survey of the Dunlevy-Portage Mountain map-area west of Hudson Hope, Peace River district, between latitudes 55°45′ and 56°15′ and longitudes 122° and 122°30′. In the same year Wickenden and Shaw geologically mapped a large part of the Mount Hulcross-Commotion Creek map-area in Pine River Valley.

In 1939, the Canadian Government commenced construction of the Northwest Staging Route, with plans for landing strips at Grand Prairie, Fort St. John, Fort Nelson, Watson Lake, and Whitehorse. In the winter of 1941, Canadian engineers built a preliminary road from Fort St. John to Fort Nelson.

A year later, as a result of war with Japan and the threat of an Alaskan invasion, United States Army engineers and contractors were given the task of building the Alaska Military Highway from the railhead at Dawson Creek, British Columbia, to Fairbanks, Alaska, a distance of 1,523 miles. The agreement between Canada and the United States was made on February 14, 1942, and within 2 years the highway was completed, at a total cost estimated at around $138,000,000.

The Geological Survey of Canada had seven geological field parties at work in northeastern British Columbia and contiguous areas in 1943. A geological reconnaissance was made along the newly built Alaska Highway between Fort St. John and Fort Nelson, British Columbia, by C. O. Hage (1944); from Fort Nelson to Watson Lake, Yukon, by M. Y. Williams (1944); and from Watson Lake to Teslin Lake, Yukon, by C. S. Lord (1944). E. D. Kindle (1944) traversed Fort Nelson River from Fort Nelson to Liard River and ascended the latter stream to Hades (Hell) Gate, and made a short trip up Beaver River into southeastern Yukon. The coal deposits in the vicinity of Hasler Creek, a tributary of Pine River in the Peace River district, were examined by J. Spivak (1944), and some detailed geological mapping was done; C. H. Crickmay (1944) mapped the Pouce Coupé-Peace River area, Alberta, bordering on the British Columbia boundary; and F. H. McLearn and E. J. W. Irish (1944) searched for workable coal seams in the Foothills on the north side of Peace River.

During the summer of 1944, a geological reconnaissance was made by C. O. Hage along Liard River from below the mouth of Fort Nelson River to Birch River, a distance of 200 miles, and traverses were run up its tributaries, Labiche, Kotaneelee, Petitot (Black), Muskeg, South Nahanni, Blackstone, and Birch Rivers. In addition, Hage spent 3 weeks around Trout Lake. A detailed study of Triassic stratigraphy was made the same year by F. H. McLearn in the Halfway, Sikanni Chief, and Tetsa basins. W. H. Mathews investigated the coal deposits and stratigraphy of the Carbon Creek-Mount Bickford map-area for the British Columbia Department of Mines in 1944 and 1945; his report (1947) includes a coloured geological map of the area.

During the summer of 1946, L. R. Laudon and B. J. Chronic (1947) made a study of the Mississippian rocks of Meramec age along the Alaska Highway from the Liard bridge on the northwest to mile 381 at Tetsa River on the southeast.

Commencing about 1943, some of the larger oil companies, such as the Socony-Vacuum Oil Company, Shell Oil Company, Imperial Oil Limited, and Phillips Petroleum Company, have been conducting geological exploration in the country made accessible by the Alaska Highway. The Geological Survey is indebted in a number of instances to officers of these companies for information given and for fossil collections supplied.

CHAPTER II

PHYSICAL FEATURES

PHYSIOGRAPHY

Northeastern British Columbia forms part of two, major, physiographic divisions (*See* Figure 2), the Interior Plains and the Canadian Cordillera. Within the Cordillera it embraces chiefly a part of the Rocky Mountains and Foothills, but to the west includes also parts of the Rocky Mountain

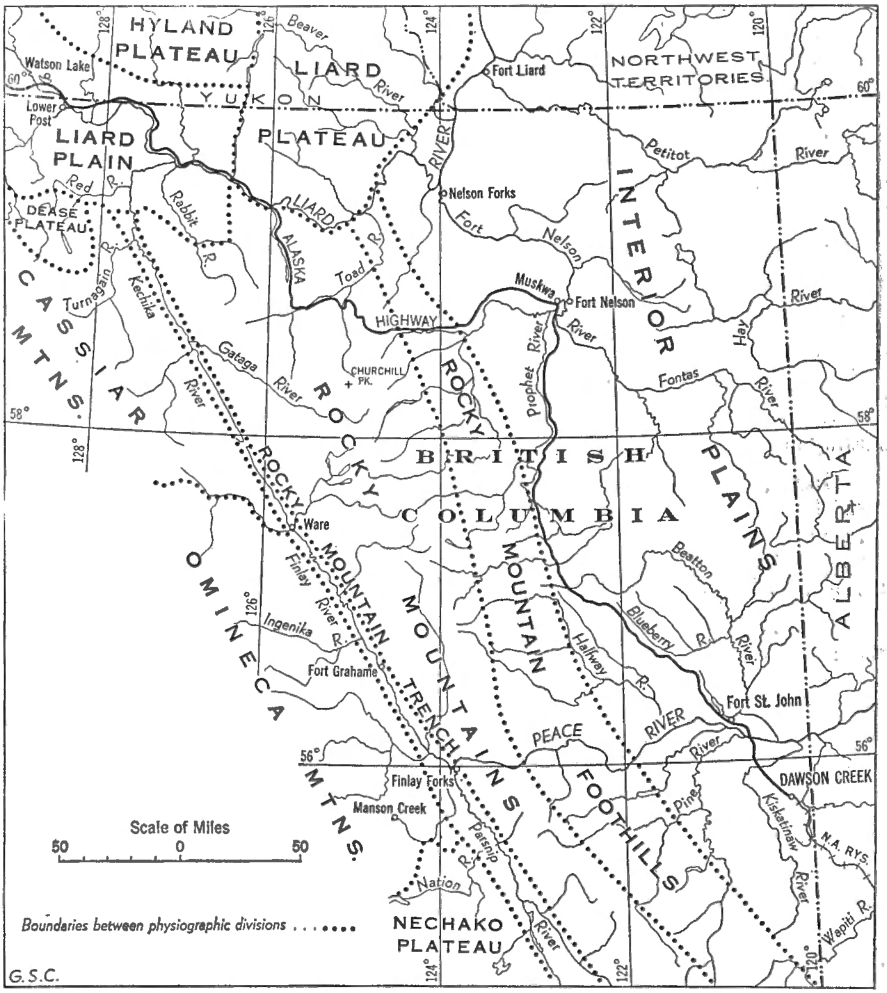

Figure 2. Northeastern British Columbia, showing chief physiographic divisions.

Trench and Cassiar Mountains and to the north parts of the Liard Plain and Liard Plateau (Bostock, 1948, Map 922A).

THE INTERIOR PLAINS

The Interior Plains of northeastern British Columbia comprise a relatively high, rolling or slightly undulating country that is generally underlain by flat-lying or gently folded beds of Upper Cretaceous age. The Plains display a relief of some 3,000 feet and drainage is controlled by a regional northeast slope. In the south, Peace River is incised below the 1,600-foot contour east of Hudson Hope and occupies a valley some 800 feet deep and 2 to 3 miles wide. Fort Nelson River, 200 miles north, is incised below the 900-foot contour, and occupies a wide valley some 300 to 400 feet deep. The smaller streams have also cut deep valleys, but on a lesser scale. Many of the headwater streams both east and west of the Alaska Highway rise in hilly country above an altitude of 4,000 feet. On the north side of Peace River, the Plains extend west as far as the Portage Mountain, Bullhead Mountain, and Butler Ridge line of folding; south of the river the Foothills belt swings more easterly to include the hills about Moberly Lake. The Alaska Highway traverses the Plains for roughly 350 miles northwesterly from Dawson Creek, to enter the Foothills belt 57 miles west of Fort Nelson. Williams (1944) describes the Plains west of Fort Nelson as follows:

"For about 57 miles west from Fort Nelson the Alaska Highway traverses a gently undulating plain, below which Muskwa River and its tributaries have carved valleys 200 to 400 feet deep. The plain varies in elevation from about 1,800 feet in the west to about 1,500 feet in the east. The Kledo branch of the Muskwa has a wide, flaring valley, whereas Muskwa Valley itself is deep, with steep sides. Near its mouth the river is nearly 400 feet below the adjoining upland. Fort Nelson River Valley at this locality is broad and well graded."

Hage (1944) states that the Alaska Highway trends northwesterly from Fort St. John for 97 miles, and follows the height of land between Cameron, Blueberry, and Beatton Rivers. The divide is formed of gently sloping, northerly trending ridges, and towards the north the elevation of the country rises about 1,000 feet in the first 95 miles from Fort St. John.

The Highway assumes a more northerly route near mile 146[1] and continues in this direction for 55 miles. For much of this distance it follows a high, west-facing scarp that parallels the mountains 12 to 18 miles to the west. The top of the scarp has a plateau-like appearance, and is dissected by east-flowing streams, including Beatton, Sikanni Chief, Buckinghorse, and Prophet Rivers. The height of land between the Peace and Fort Nelson drainage systems lies between Beatton and Sikanni Chief Rivers and near mile 157 on the road. The original army road in this area follows the top of the scarp across the divide and attains an elevation of nearly 4,200 feet a short distance north of mile-post 155, the highest point along this section of the road. From there the elevation drops to 2,662 feet above sea-level at Sikanni Chief bridge. North of Buckinghorse River, the scarp has an average elevation of 4,000 feet, and is about 1,000 feet above Minaker River to the west. At mile 201 the Highway leaves the

[1] Mile-posts referred to are numbered from Dawson Creek.

plateau, swings northeast for 30 miles, and then turns north along or adjacent to the east bank of Prophet River, which joins the Muskwa 3·5 miles west of the bridge at mile 302. The Muskwa River bridge is about 1,035 feet above sea-level. Adjacent to Prophet River, the Highway crosses numerous small streams entrenched in valleys several hundred feet deep. The plateau, which the Highway leaves at mile 201, may be seen several miles to the east of the Highway as far north as mile 244. The dissected part of the plateau, with its steeply dipping slopes, has a distinct mesa-like appearance. A large remnant of the plateau extends northward, west of Prophet River Valley. South of Trutch Creek the plateau rises 1,500 feet above the bed of the stream.

Pink Mountain, 10 miles west of the Highway in the Beatton River area, forms a prominent topographical feature that clearly marks the transition from Plains to Foothills. Its summit, about 5,900 feet above sea-level or 2,700 feet above Halfway River, is outlined by hard, resistant, quartzitic sandstone beds, whereas the adjacent, lower lying areas, with subdued topography, are underlain largely by shale.

ROCKY MOUNTAIN FOOTHILLS

The Rocky Mountain Foothills separate the Rocky Mountains on the west from the Interior Plains. They occupy a belt that in northeastern British Columbia ranges in width from 15 to 40 miles, and is composed entirely of sedimentary rocks, largely of Mesozoic age, with some Palæozoic and Tertiary formations. The eastern front of the Foothills is marked by the first zone of folding and faulting west of the Interior Plains. Along Peace River Valley the Foothills are well marked by the upfolding of erosion-resistant Bullhead sandstones and conglomerates. Near Sikanni Chief River the easternmost belt of close folding and the front ridge of hills disappear, so that the width of closely folded strata is narrowed from there northward, the place of the front ridge being taken by high plateaux and mesas of more gently dipping Cretaceous strata.

McLearn's (1940) description of the Peace River Foothills follows:

"The Foothill belt along Peace River in northeastern British Columbia is about 40 miles wide, from about longitude 122° 05′ to near longitude 123°10′, that is from Butler Ridge in the east to near Greene Mountain in the west. . .

"The scenery, although lacking the grandeur of the mountains, is on an imposing scale. The relief is high, from about 1,800 to nearly 5,000 feet above sea-level, and the surface is carved into bold and rugged outlines. Of particular interest is the variety of surface form. Beside the river and not more than 20 to 40 feet above it are broad flats, of which, for example, Branham Flat, triangular in outline, is about 2¾ miles long and nearly 1½ miles wide. Bordering and rising high above the flats are high terraces in various stages of preservation, some of which are broad and continuous for miles. They are only well preserved to a height of about 500 feet, although what appear to be remnants of older terraces have been found nearly 2,000 feet above river level. Extending high above the terraces are steep, high cliffs, long, narrow ridges, and high hills. The surface form is related to the lithology and structure of the underlying rock. The terraces are carved out of superficial sands, gravel, and boulder clay. The high hills that extend above them are carved partly out of the superficial deposits, but mainly out of the hard and resistant bedrock. The surface form also betrays the structure of the bedrock. The high, flat, or gently sloping hills with their buttress-like spurs are carved out of flat or gently sloping strata, whereas the high, narrow ridges are carved out of steeply dipping strata.

"The observer's impression of the scenery will vary with the location from which he views it. From the river or low river flat he is more impressed by the high and massive terraces and the steep slopes that front them than by the actually much bolder relief of the high ridges and the hills that tower above them. Should he, however, climb the steep terrace slope and the yet higher rocky ridges and view, in a different perspective, the valley from above, the bold features of the high hills will dwarf the terraces and flats below. Yet another variation in scenery is observed away from the main valley. There one is in the midst of the high steep ridges, the high but gently sloping or flat-topped hills, the long, steep-sided spurs, and the narrow ravines and gullies.

"Although most of the tributary streams are small, flow in narrow ravines, and, near their mouths, cut V-shaped notches through the terraces of the main valley, a few are larger. Thus Schooler and Carbon Creeks flow through fairly wide valleys and have long, high terraces, comparable with those of the main valley.

"Where some of the smaller tributary streams debouch on the low valley flats they have built up low alluvial fans. The Beattie farm buildings [*See* Plate I B] are erected on such a low, alluvial fan where Aylard Creek leaves the border of the high terraces on the north side of the valley and begins its course across Beattie Flat.

"The main valley is broad and deep, and is mostly out of proportion with the small tributary valleys, except those of Carbon and Schooler Creeks. It has much the appearance of a great trench across the Foothills.

"Within the Foothills and to the head of Peace River Canyon on the eastern border. . . . . Peace River is mostly a smoothly flowing navigable stream. The only exceptions to this are at Rapide-qui-ne-parle-pas, Little Parle Pas Rapids, and Black Rock Whirlpool, where projecting ledges give rise to some bad water. In contrast with the average quiet flow in the Foothills is the very rough and turbulent water in the canyon, the upper reaches of which no boat of any kind can navigate. The course of the river through the rocky walls of the canyon is clearly one of stream diversion. The river, as it approaches the eastern border of the Foothills, instead of following a previous, and probably preglacial, outlet through an old gap that now lies between the southern end of the Butler Ridge and Portage Mountain, and where it could easily have restored its preglacial course and grade by dissection of the unconsolidated morainal deposits there, turns abruptly south and southeast [*See* Plate II A] and spills over the rocky wall on the south side of the valley. Although this rock wall has been partly lowered by erosion in the canyon, it still acts as a dam, and maintains, inside the Foothills, a higher base level than if the river had flowed through the old gap and restored the preglacial level there. Because of this maintenance of the local base level, the river has developed a comparatively low gradient within the Foothills. Not only has this bedrock dam raised the base level within the Foothills, but it has also trapped a considerable amount of the sand and gravel 'fill' on the bottom of the valley and to a considerable depth. This is a fairly uniform material, on which the river can maintain a fairly even gradient. Were the 'fill' washed out of the valley the conditions would be very different; the river would flow on the bedrock floor of the valley, inequalities of the rocks in resistance to erosion would produce irregularities in gradient, and probably frequent rapids would result." (*See also* Beach and Spivak, 1943A.)

ROCKY MOUNTAINS

The Rocky Mountains north of Peace River are still largely unexplored, but H. S. Bostock has studied their physical features in great detail from air photographs, and has described them as follows (1948, p. 6).

"The Rocky Mountains stand between the Foothills and Rocky Mountain Trench, which marks their west boundary. They form a remarkably continuous wall of mountains traversed by only one stream, Peace River. On the east their boundary with the Foothills is well defined, as it follows the first chain of ranges of upfaulted, massive, Palæozoic limestone and quartzite, whose resistance to erosion has given the mountains their particularly rocky and rugged character [*See* Plate II B]. For the greater part, the mountains consist of ridges with a northwesterly alinement nearly parallel with that of the entire Rocky Mountain area. Their thick competent strata have broken and warped to form larger units than those comprised of Foothills strata. The ridges are separated by deep valleys cut along zones weakened by folds to erosion, fractures, and the presence of relatively soft strata. They are mainly formed of Palæozoic sediments, but include some of Late Precambrian age.

"The Rocky Mountains are approximately 50 miles wide from the Forty-ninth Parallel northward to Yellowhead Pass. Beyond this, they gradually narrow until they reach a minimum width of less than 25 miles at Peace River. Still farther north their west boundary continues northwesterly along the trench, but their east boundary swings to nearly north and, in consequence, they broaden in this direction to reach their greatest width of more than 85 miles.

"The Rocky Mountains form the continental divide from the Forty-ninth Parallel to about 150 miles north of Yellowhead Pass. Farther north the divide lies west of the Rockies, which are drained on that side by tributaries of Peace and Liard Rivers.

"South of Peace River, the Rocky Mountains are divisible into three parts. In the southern and central parts they are rugged, and the greater peaks, many more than 10,000 feet high, including Mount Robson (12,972 feet) the highest known peak of the Eastern system, form the continental divide. In the northern part, south of Peace River, the mountains narrow, their elevations decrease, no really great peaks are present, and they are characteristically less rugged.

"North of Peace River, where the Rocky Mountains are least known, they comprise a border zone surrounding a central area. The central area, 130 miles long and 30 miles wide, extends from about 210 miles southeast of Redfern Lake to 15 miles south of Muncho Lake, and is high and very rugged. It contains many peaks with elevations of more than 9,000 feet, according to present information, and is crowned by Churchill Peak, 10,500 feet high. Within it are many ice-fields and alpine glaciers, none more than a few miles in extent, the largest observed being those east of Quentine, Hamworth, and Chesterfield Lakes. This central area is largely composed of great thicknesses of massive strata, probably limestone, and the big peaks resemble those of the more southern areas. No intrusions have been reported in this northern part, but copper occurrences east of Fort Grahame suggest the presence of intrusions not far below the surface.

"The border zone surrounds the central area for a width of 15 miles or more. It consists of lower and less rugged mountains and contains no glaciers. In general the elevations of its summits decrease from the central area outwards. North of Sikanni Chief River, these summits in places retain remnants of an old erosion surface that truncates their tops. In the northern part of the zone, as the elevations decrease, areas in which the old erosion surface, here a rolling upland, remains, become more and more common as the boundary of the mountains is approached.

"At the north end of the border zone, the Rocky Mountains are cut off sharply by Liard Valley. Southwest, from nearly opposite the mouth of Smith River to Kechika River, the northern ends of the mountain ridges disappear more gradually, and the boundary between them and Liard Plain is less distinct, though viewed from a distance at an elevation of 20,000 feet a general belt is apparent where the ridges increase their elevation southward more rapidly to become mountains. Between Rabbit and Kechika Rivers the outer ridges of the mountains continue northwest along the side of the Rocky Mountain Trench, with summits at 4,000 to 5,000 feet or more, as far as the fifty-ninth parallel where they finally merge with Liard Plain. Terminus Mountain, 6,250 feet high, forms the northwest corner of the truly mountainous country.

"In the northern and northwestern parts of these border zone mountains the general parallelism of valleys and ridges is less marked. From Rabbit River a large valley extends obliquely to join that of Gataga River 25 miles above its mouth, and continues into the mountains as an outstanding valley feature that sends deep branches through the central area, joining with the valleys draining to Toad and Muskwa Rivers.

"Farther south the border zone adjacent to the Rocky Mountain Trench consists of parallel ridges and valleys. As the trench is approached, the elevations of the ridges decrease, and the intervening valleys become broader, that next to the trench being nearly as large as the trench itself.

"An area of less relief than usual lies in the border zone mountains around the head of Sikanni Chief River and south of the head of Graham River, and the boundary between it and the Foothills is indefinite. Farther south the boundary follows Nabesche River, but in this whole northern area the mountains of the border zone greatly resemble those of the Foothills."

LIARD PLATEAU

Liard Plateau is an area of broad, even-topped hills that rise in their higher parts to about 4,500 feet above sea-level and include a few ranges of mountainous character. In the central and southern parts of the plateau area the ranges are separated by wide, rolling valleys, most of which drain southeastward. The timbered higher benches of most of the valleys have elevations of about 3,000 feet, and the valley floors from 1,500 to 2,500 feet above sea-level. The plateau is underlain by the same Palæozoic and Mesozoic sedimentary formations as the Rocky Mountains and Foothills. The separate ranges show a general tendency to parallelism, as in the Rocky Mountains, but are more widely spaced. Folds trend northwest for some miles north of Liard River, then swing northeasterly, and west of Fort Liard they again strike north.

The east boundary of Liard Plateau trends northeastward and then north on the west side of Liard River from opposite the mouth of Toad River to South Nahanni River. Thus it continues the habit of the front of the Foothills in following the first distinct folds west of the Interior Plains. The west boundary of the plateau follows up Smith River through Toobally Lakes to Caribou River.

LIARD PLAIN

Liard Plain includes the greater part of Liard River Valley west of Smith River. It occupies a northwesterly trending area some 180 miles long and up to 65 miles wide; the greater part is less than 3,000 feet high, and much of the central part is at an elevation of only 2,200 feet (Bostock, 1948). The Plain is hemmed in by high plateaux and mountains in which the tributaries of the Liard arise, and both Liard River and its main tributaries are entrenched below its general level. Palæozoic sedimentary rocks and Tertiary strata are exposed along the rivers and in the hilly areas, but the greater part of the lower land is mantled by thick deposits of glacial drift.

ROCKY MOUNTAIN TRENCH

The Rocky Mountain Trench forms the west boundary of the Rocky Mountains. It has an overall length of more than 900 miles, from south of the Forty-ninth Parallel to Liard Plain. Except in the central part, between Tête Jaune Cache and Fort McLeod, the trench is bounded on one or both sides by steep slopes. The floor of the trench is nearly flat, and varies from 2 to 10 miles or more in width to where it is walled in by mountains. For most of its length it lies between 2,000 and 3,000 feet above sea-level, the highest point being at Sifton Pass, elevation 3,273 feet. Peace River leaves the trench at a little below 2,000 feet. At the north end of the Rocky Mountains the Cassiar Mountains recede from the western side of the trench, which opens out into Liard Plain, and its boundaries disappear. Some exceptionally fine views of the trench have been published by Andrews (1942).

Dolmage (1928) describes the trench in the Finlay River district, as follows:

"Finlay River occupies the Rocky Mountain Trench from Finlay Forks as far north as Fox River, a distance of 125 miles. Beyond this point the Fox occupies the trench for 41 miles to Sifton Pass, beyond which the Trench is drained to the north by a tributary of the Liard. The Finlay rises in Fishing Lakes 35 miles west of the Trench, and after flowing north for 25 miles bends east and then southeast, and enters the Trench at the mouth of the Fox.

"In Finlay River district, the Rocky Mountain Trench is from 4 to 8 miles wide and floored throughout by gravels and silts, usually well terraced. Only one rock canyon occurs in this section of the Trench. This is Deserters Canyon, situated 82 miles above the mouth of the Finlay and 30 miles above Fort Grahame. Here the river is a rushing torrent confined within a width of less than 100 feet, whereas, elsewhere, throughout its course through the Trench, it is from 100 to 300 yards wide and usually divided into a number of channels. The current of the river is swift, attaining a speed, during high water periods, of 12 miles an hour; it winds from side to side of its broad valley, rapidly cutting away the soft sandy or gravelly banks and felling into its stream large numbers of the trees from the dense forests covering the entire bottom of the valley. The meanders are rapidly cut through, forming new channels and many oxbow lakes or sloughs, through which the river flows only during the periods of high water. At such periods it is a maze of intricate channels very confusing to the inexperienced navigator."

OMINECA AND CASSIAR MOUNTAINS

Omineca and Cassiar Mountains form an almost continuous belt of mountains along the west side of the Rocky Mountain Trench and Liard Plain from the Interior Plateau to Yukon Plateau. The easterly trending valley of upper Finlay River, west of the Rocky Mountain Trench, forms a low, natural dividing line between Cassiar Mountains on the north and Omineca Mountains on the south. Finlay Ranges lying along the west side of the Rocky Mountain Trench constitute the most easterly division of Omineca Mountains and include Russel, Butler, and Wolverine Ranges. Finlay Ranges are described by Bostock (1948) as follows:

"Finlay Ranges are notable for the smooth profiles that characterize their slopes and most of their summits in contrast with the ruggedness of other parts of Omineca Mountains. The general plan of each of their main ranges shows a single backbone ridge approximately parallel with the Rocky Mountain Trench with spurs projecting normally from it. Except for a small granitic stock between Mesilinka and Swannell Rivers they are composed mainly of Precambrian and Palæozoic sedimentary rocks, with areas of Mesozoic strata along their west flank. The only glacier noted is near Swannell River, and as a whole the ranges show only little evidence of glacial erosion."

Cassiar Mountains comprise Stikine and Kechika Ranges and a fringe of plateau country; Dease Plateau is included with them. The Kechika Ranges are the northward extension of Finlay Ranges along the west side of the Rocky Mountain Trench; they consist of more or less parallel ridges, with moderately even summits, and are composed largely of Palæozoic sedimentary rocks.

GLACIAL DEPOSITS

Glacial deposits are to be found almost everywhere in northeastern British Columbia, and occupy all the larger river valleys. The wane of the Ice Age and melting of the valley glaciers resulted in the deposition of boulder clay, sand and gravel, and varved clays, and silts were laid down in the numerous temporary lakes that formed near the melting ice fronts.

Evidence presented by Armstrong and Tipper (1948) has indicated a great movement of glacial ice eastward across north-central British Columbia in Pleistocene time from gathering grounds in the Coast Mountains. On reaching the Rocky Mountain Trench some of this ice escaped easterly to the plains by way of Peace River and Liard River Valleys, and perhaps also by way of the low mountain passes, such as Pine Pass. Just where the continental and Cordilleran ice-sheets met and mingled in the Plains region has not been determined. Williams (1944) believes that the continental ice-sheet extended into the Foothills valleys for a time in the region west of Fort Nelson. He writes as follows regarding glaciation there:

"The valley system of the region is deeply entrenched below the old land surfaces. The pre-Glacial valleys were deeper and probably better graded than those of the present system although the immediate pre-Glacial uplift resulted in rapid down-cutting and stream adjustment. An excellent example may be seen in the Toad River-Muncho Lake-Trout River systems. The upper, laked valley of Toad River is continuous with the valley now followed northward to Liard River. Except for a short tributary of the Toad, the valley is occupied by the Muncho Lake-Trout River drainage, and is wide and of mature development. From the bend of the Toad, the river descends through a canyon of youthful character for 10 miles to the east before entering the wide, mature valley of Racing River. The canyon was filled with till and ill-sorted gravel, and is clearly pre-Glacial, but it was evidently developed during the period of maximum uplift and consequent drainage adjustment immediately preceding Pleistocene time.

"The Ice Age itself modified, rather than developed, the drainage system. Widened valleys, scarped spurs, hanging valleys, cirque formation, arrêtes, and other typical glacial forms resulted.

"The continental ice-sheet extended into the Foothills valleys almost to the mountain front, damming back the mountain glaciers with their loads of boulders, gravel, sand, and rock flour. The continental sheet retreated first, for remnants of mountain glaciers still remain south of the pass. At the close of the Ice Age, the whole land was probably 600 to 700 feet lower than at present, and the valleys were clogged with morainal and glaciofluviatile material to that depth. With the passing of the ice, the land gradually rose and re-excavation of valleys started. That process is still continuing rapidly, but at few places is the solid rock being attacked by stream erosion, as glacial debris covers most of the valley floors. Mountain streams are cutting gorges, and falls occur where they enter the main valley. Gorges and rapids occur in rivers where new channels have crossed rock spurs in old valleys, but in general post-Glacial erosion is closely controlled by the established pattern."

Bostock (1948) makes the following observation on areas of the Rocky Mountains that may have suffered little glaciation:

"During Pleistocene time the Rocky Mountains appear to have been an area of relatively light precipitation as they are today. In the south, valley glaciation was extensive and the level of the ice was high. Northward the effects of glaciation seem to have been less pronounced and in some areas north of Peace River no features attributable to glaciation can be detected in the air photographs. Exploring prospectors have reported that in travelling eastward into the mountains from the Rocky Mountain Trench, no evidence of glaciation could be seen on some of the higher levels, and the ice from the trench appeared to have pushed eastward up some of the valleys."

Williams (1944) makes the following comments on glaciation in the vicinity of Summit Lake on the pass between the drainage to Toad and to Fort Nelson Rivers. Summit Lake is the highest point on the Alaska Highway (altitude, 4,253 feet).

"The grey limestone mountains of the pass are similar in appearance to those at Jasper, but the valley itself is much narrower. Peaks to the north and south rise to heights of about 7,000 feet. A main peak to the north is named 'St. Paul' on the map and its companion of the south 'St. George'. Other peaks are nameless. About 15 to 20 miles south by east from the Highway, a group of peaks rises to conspicuous heights, and one of the mountains supports a hanging glacier. This is the highest group seen in the front range, some of the peaks probably rising to 9,000 feet above sea-level.

"Along the pass the peaks have rounded crests and are joined by long, gentle ridges. A peak south of mile 105 has conspicuous cirques on its west and north sides, and a terminal moraine occurs where the west facing glacier joined the ice-stream feeding north into MacDonald Creek Valley.

"Pronounced terraces of glacial till flank the sides of the pass to an elevation of about 700 feet above Summit Lake. These terraces may be traced for some miles to the east along Tetsa River and for some 20 miles to the northwest down MacDonald Creek. North of Summit Lake, local erosion has left well developed 'Hoodoos' of till standing on the mountain side. Similar terraces occur along Muncho Lake, and up a side valley hoodoos are present and others are being formed."

The glacial deposits that occur along the route of the Alaska Highway between Fort St. John and Fort Nelson have been described by C. O. Hage (1944) as follows:

"Deposits of glacial material of various types occur along almost the entire route of the Highway from Fort St. John to Fort Nelson. On the higher land the deposits are thin to absent, whereas on the lower slopes, especially in the valley bottoms, the deposits are thick. Glacial lake clays are found in most of the larger stream valleys, and boulder clay having the nature of ground moraine is the characteristic deposit elsewhere.

"Bedded clay deposits up to 50 feet thick are found in Beatton, Halfway, Minaker, and Prophet River Valleys. In most instances they are underlain and overlain by till. The underlying till differs from the overlying one in the composition of the contained pebbles. Along Halfway River, about 3 miles east of Pink Mountain, and along Minaker River north of mile 155, the underlying till contains pebbles of quartzite and sandstone. On a tributary stream flowing into the Minaker from the west a 20-foot gravel deposit underlies the glacial clay. The gravel is composed of well-rounded pebbles of sandstone of various kinds and of chert, limestone, light grey quartzite, and feldspar porphyry. Similar gravel deposits were observed along Prophet River east of Klingzut Mountain. The overlying till in all instances contains a large percentage of pebbles and boulders of igneous and metamorphic rocks, including various types of granite, schist, and gneiss. Along the banks of Prophet River this boulder clay deposit is several hundred feet thick. The lower till appears to have a source different from the overlying one and, as the pebbles and boulders contained in it are similar to the rocks outcropping in the immediate vicinity to the west, it seems reasonable to conclude that the glacier that deposited this material moved down the valleys from that direction. The source of the upper till containing the igneous and metamorphic pebbles and boulders may have been the Precambrian Shield to the northeast.

"The character of the surface till varies considerably at different localities. South of Sikanni Chief River granite boulders are present, but they are not numerous; north of the river igneous boulders are more numerous; and along Buckinghorse River and other streams farther north they are plentiful.

"The major stream valleys are pre-Glacial in age. In Prophet River Valley, for example, the present stream follows the old valley very closely, and it is only here and there that it has cut into the old river bank to expose outcroppings of the bedrock. Because of the thick deposit of glacial material in this old drainage channel, outcrops along the present stream are few."

Hage (1944) records a great thickness of glacial till in the vicinity of Fort Nelson as disclosed by the drilling of three deep water wells at the Fort Nelson Airport. The first well, Fort Nelson No. 1, reached a depth of 521 feet and was wholly in glacial drift; the second well encountered the base of the drift between 720 and 730 feet; and the third well apparently reached bedrock at a depth of about 700 feet. Another well drilled for water at mile 237 passed through 50 feet of glacial drift before entering dark grey shale.

When the Commotion Creek well was drilled in the valley of Pine River, the surface deposits were found to be 1,081 feet thick (Hume, 1944). A 100-foot test hole sunk on the sand plain about 5 miles due east of the north end of Bullhead Mountain is reported to have penetrated only sands and gravels without reaching bedrock (Beach and Spivak, 1943).

As pointed out in the first part of this chapter, the pre-Glacial gap between Portage and Bullhead Mountains was closed by a great terminal moraine during the wane of the Ice Age. With melting of the ice, waters of Peace River Valley flowed over the crest of a saddle on the west side of Portage Mountain and the diverted water ran south some 10 miles to join the Johnson Creek drainage. The latter, a northeasterly flowing stream, joined Peace River a few miles east of Portage Mountain in pre-Glacial time. The diverted waters of Peace River excavated a gorge some 700 feet deep, linking the course above the gap with the valley of Peace River east of Portage Mountain by way of this southern route. The slow cutting of Peace River Canyon necessitated concomitant slow erosion of the drift deposits occupying the valley upstream and made possible the production of a series of terraces along the valley of the Peace (*See* McLearn, 1940; Beach and Spivak, 1943A).

McLearn (1920) states that the main and tributary valleys of the Peace above the canyon are bordered with terraces carved in fluvioglacial gravel, sand, clay, and boulder clay.

CHAPTER III

STRATIGRAPHY

GENERAL STATEMENT

Information available on some parts of the geological column in northeastern British Columbia is much more complete than on others. That acquired on the Proterozoic and Palæozoic formations is, for example, based mainly on the section exposed along the Alaska Highway west of Fort Nelson and through the Rocky Mountains. Elsewhere little is known of these formations.

The Triassic, on the other hand, has been more thoroughly investigated than any other system in northeastern British Columbia and in places has been studied in great detail. The faunal zoning has been carried a long way toward completion.

The Jurassic, Fernie group has received little attention to date, whereas the upper part of the succeeding Bullhead group, because it contains coal seams of commercial value, has been carefully examined at some localities. The lower part of this group, however, should receive much more attention than it has from stratigraphers.

The formations and faunal zones of the Lower Cretaceous, Fort St. John group are now fairly well known, and are used by geologists engaged in mapping. More time could, nevertheless, be profitably devoted to acquiring additional information on the faunal zoning of this group.

The Upper Cretaceous, Dunvegan formation is now fairly well known and can be recognized with the aid of its characteristic fossils. The succeeding Smoky group can also be identified by its faunas in northeastern British Columbia, but it has not been studied at many localities and, in places, appears to contain more sandstone than in the type area farther east, in Smoky River Valley.

Some non-marine deposits of later Upper Cretaceous age, including those of the Wapiti group, apparently occur in the eastern part of the area covered by this report, but they have had little attention.

A few deposits of late Cretaceous or Paleocene age are known, including the Sifton formation in the Rocky Mountain Trench. Tertiary lignite occurs in the north. Little is known, however, of Tertiary beds later than the Paleocene. Possibly some have been misidentified and mapped as Late Cretaceous or Paleocene.

Rocks of the Cassiar batholith, the only intrusions of appreciable size in the area, occupy part of the northwest corner, west of the trench.

A generalized table of formations follows; more detailed tables will be presented at intervals through this chapter.

TABLE OF FORMATIONS

Era	Period or epoch	Formation or group (Thickness in feet)	Lithology
Cenozoic	Tertiary		Lignite, clay of Coal River
			Rhyolite flows, tuffs, and breccias; *west of Rocky Mountain Trench*
Mesozoic and Cenozoic	Upper Cretaceous and later	Sifton	Non-marine conglomerate, sandstone, shale, coal; *in Rocky Mountain Trench*
		Beds on Petitot River	Non-marine sandstones, shales, conglomerate with *Equisetum arcticum*
		Wapiti	Non-marine sandstone, shale, coal seams
		Smoky group 500± to 1,000±	Marine shale and sandstone
		Dunvegan 500± to 1,000±	Marine and non-marine sandstone and shale
Mesozoic	Lower Cretaceous	Fort St. John group 4,000 to 5,000	Mostly marine shale and sandstone
	Lower Cretaceous and earlier ?	Bullhead group 5,000±	Non-marine sandstone, shale, and coal above, and mostly marine sandstone and shale below
	Jurassic or Lower Cretaceous	Cassiar batholith	Granite, granodiorite, quartz diorite; *intrusive into formations west of Rocky Mountain Trench*
	Jurassic	Fernie group 1,100±	Marine shales, some sandstone
	Triassic	Pardonet beds 'Grey beds' 'Dark siltstone' 'Flagstones' Toad, Grayling 4,500± to 8,000	Marine, lithological units of dark siltstones, limestones, and shales, alternating with massive, grey, calcareous sandstones and grey limestones
Disconformity			
Palæozoic	Permian		Marine calcareous sandstone, near Stott Creek, Peace River Valley
	Carboniferous (?) and Permian		Marine chert, shale, sandstone, and limestone, on Mount Merrill

TABLE OF FORMATIONS—*Concluded*

Era	Period or epoch	Formation or group Thickness in feet	Lithology
Palæozoic	Pennsylvanian or Permian	(Kindle*)	Chert, on Alaska Highway, near mile 381
	Pennsylvanian		Marine limestone and shale, on Pine River between Callazon and Mountain Creeks
	Mississippian	400± (includes Kindle*)	Marine limestones, silty arenaceous limestone and shale of Alaska Highway; dark limestones of Fossil Point, Peace River; limestone, siliceous limestone, west of Mount Withrow, Sikanni Chief River
	Devonian	Fort Creek and Ramparts 1,800±	Marine limestone below; black fissile shale above, on Alaska Highway; black limestone on islet on Peace River above mouth of the Clearwater
	Devonian ?	(Muncho* and McConnell*) 1,800±	Unfossiliferous limestones, sandy limestones, and sandy siltstones
	Silurian	Ronning 1,200+	Marine, black, shaly limestone, dolomitic limestone, on Alaska Highway
	Ordovician		Limestones and dolomites on Halfway River
	Cambrian ?	(Macdougal*), Mount Selwyn, and unnamed beds 3,500± to 5,000±	Conglomerates and sandstones of Muncho Lake; massive quartzite and calcareous shale of Mount Selwyn; limestone of Finlay Valley

Angular unconformity

Proterozoic and (?) later		Misinchinka and unnamed beds	Quartzite, schist, argillite, slate, intruded by dykes on Alaska Highway; mica schist, gneiss (Misinchinka) of Peace and Finlay Valleys; includes Cambrian ?

*Named by Laudon and Chronic, 1947, 1949.

PROTEROZOIC AND (?) LATER

Peace River Valley

The oldest rocks recorded from Peace River Valley are the Misinchinka schists, first observed by Selwyn in 1875 and later named by Dawson (1881). They consist of finely laminated, pale, silvery mica schists, and are exposed in Peace River Valley from Andy Creek to Finlay Forks. They are unfossiliferous, and have been referred tentatively to the Precambrian (Williams and Bocock, 1932).

Finlay River Valley

Rocks resembling those of the Misinchinka schists and possibly continuous with them outcrop on both sides of Finlay River Valley. They consist of "mainly quartz-mica schist, mica quartzite, and acid gneiss, but there are also a few small bands of impure limestone and lenses of hornblende gneiss" (Dolmage, 1928). Some of these metamorphic rocks may prove to be of Cambrian age (*See* Roots, 1948).

Toad River Valley

The fossiliferous Silurian strata along the Alaska Highway in the Rocky Mountains are underlain unconformably by two rock groups, one more metamorphosed and more folded than the other (Williams, 1944; Laudon and Chronic, 1947). One has been referred, tentatively, to the Precambrian and the other, provisionally, to the Cambrian.

The older group is exposed on Toad River near the highway crossing and southeast of the bridge over McDonnell Creek. Williams states that it consists of metamorphosed, light-coloured quartzites, porcellaneous argillites, and slaty rocks with ripple-marks and mud-cracks. Laudon and Chronic (1949) record quartzite, schist, slate, and marble. These rocks are intruded by dykes of diabase and quartz gabbro, the only known igneous rocks in the region. Where they are in contact with Silurian strata Williams considers the relation to be that of an angular unconformity.

CAMBRIAN ?

Peace River Valley

Alfred R. C. Selwyn, during an exploratory traverse of Peace River, in 1875, ascended a conspicuous peak of the Rocky Mountains, on the south side of the river below Finlay Forks, which Macoun, who accompanied him, named Mount Selwyn. He observed massive quartzites on the lower ridges of this mountain. Williams and Bocock incorporate these beds into what they call the Mount Selwyn formation, which they state consists of about 3,500 feet of buff-coloured, massive quartzite and pink, calcareous shale. They compare the beds of this formation with Cambrian quartzites in the southern Rocky Mountains, and suggest that they may be of Cambrian age. They also note that this formation is present in the Murray Range at the summit of Pine Pass.

East of Finlay River Valley

Dolmage (1928) has mapped a wide band of white and grey, unfossiliferous limestone, partly pure, partly argillaceous or arenaceous, in the Rocky Mountains, east of Finlay Valley. He calls them "Cambrian (?) and possibly younger" because McConnell (1897) "considered them to be a part of the Castle Mountain group then known to contain members ranging in age from Middle Cambrian to Ordovician".

Dolmage also mapped similar beds west of Finlay River Valley. Armstrong and Roots (1948) have mapped Lower Cambrian limestone on the west side of Finlay River Valley on Mount Tsaydizkun.

TABLE I

Correlation Table—Proterozoic and Palæozoic of Northeastern British Columbia and Mackenzie River Valley, Northwest Territories

	Pine River	Peace River	Halfway River	Sikanni Chief River	Alaska Highway, Rocky Mts.	Liard Plateau	Lower Mackenzie Valley
Permian		Calcareous sandstone; limestone of Stott Creek			Chert (Kindle)*	Sandstone, chert, shale, limestone of Mount Merrill	
Penn.	Limestone, black shale; quartzite, between Callazon and Mountain Creeks				Chert (Kindle)*		
Miss.		Dark limestone of Fossil Point		Dark limestone, silty limestone, chert	Limestone, silty arenaceous limestone, chert (Kindle)*		
Devonian	Limestone of Murray Range	Dark limestone of island west of Point Creek			Black shale (Fort Creek)* Coralline limestone, dark limestone (Ramparts)* Grey, black, hard, silty limestone (Muncho)* Grey, black, hard limestone (McConnell)*		Imperial Fort Creek Ramparts
Silurian					Limestone, coralline limestone, dolomite, quartzite, shale (Ronning)*		Ronning

*Formation and group names used by Laudon and Chronic, 1947, 1949.

TABLE I—*Concluded*

	Pine River	Peace River	Halfway River	Sikanni Chief River	Alaska Highway, Rocky Mts.	Liard Plateau	Lower Mackenzie Valley
Ordovician			Limestone and dolomite				Argillites
Cambrian		Mt. Selwyn formation			Conglomerate and sandstone (Macdougal)*		Macdougal
Proterozoic		Misinchinka schists			Quartzites, argillites, schists, basic dykes		Katherine

*Formation and group names used by Laudon and Chronic, 1947, 1949.

Muncho Lake

The younger group of pre-Silurian rocks along the Alaska Highway, mentioned in a preceding paragraph, is less folded than the older group exposed there. It lies unconformably below the Silurian, but unlike the older group shows no discordance with it (Williams, 1944; Laudon and Chronic, 1947). It outcrops along the west side of Muncho Lake and in the valley of Trout River, and consists of about 5,000 feet of coarse, red conglomerate and grey sandstone, with possibly some limestone (Williams, 1944). Laudon and Chronic describe nearly flat-lying unmetamorphosed limestone in the McDonnell Creek section. Williams compares this younger group of unfossiliferous rocks with the Cambrian beds of Gravel (Keele) River and Franklin Mountains on the basis of similar stratigraphic position and similar lithology. Laudon and Chronic (1947, 1949) compare it with the Cambrian, Macdougal group of the Mackenzie Mountains and adopt the name Macdougal for the Alaska Highway beds.

ORDOVICIAN

Very little is yet known of the Ordovician in northeastern British Columbia. As exploration proceeds, however, more occurrences will doubtless be found.

Recently the geologist of an oil company has found limestones and dolomites with Upper Ordovician fossils on Halfway River, west of Mount Wright.

SILURIAN

Alaska Highway

Beds, mostly limestones, of Middle Silurian age outcrop in several places along the Alaska Highway, between Summit Lake and Trout River. They have been described by Williams (1944) and by Laudon and Chronic (1947, 1949).

They are included in Williams' 'Silurian and Devonian' unit, and comprise about 50 feet of limy shale, with worm burrows, below, and coral reef limestone, above, on the west side of Muncho Lake; brown weathering fine-grained quartzite, overlain by interbedded blue limestone and quartzite and a 50-foot coral-reef limestone, on McDonnell Creek; and limestone, partly coralline, and sandstones, a few to 70 feet thick, on Mount St. Paul and west of this mountain.

Laudon and Chronic place these Middle Silurian strata in the Ronning formation, on the assumption that this formation of the lower Mackenzie River Valley extends this far south. They state that it consists of more than 1,200 feet of massive, grey, dolomitic limestone, thin-bedded, black, shaly limestone, and some chert. The Middle Silurian age is based on corals in the coralline limestones.

UNFOSSILIFEROUS DEVONIAN (?) LIMESTONES

Alaska Highway

Williams (1944) notes that light grey limestone, apparently unfossiliferous, lies between the coral-reef limestones of Middle Silurian and Middle Devonian age, on the Alaska Highway. Laudon and Chronic (1947, 1949) recognize three, unfossiliferous, lithological units between the Middle Silurian and Middle Devonian coralline limestones. The lowest unit, called the McConnell formation, consists of about 680 feet of grey and black, hard limestone and some shale, and has disconformable relations with beds above and below. Above this hard limestone they record a second unit, called the Muncho formation, consisting of about 600 feet of grey and black, hard, laminated, silty, shaly limestone, and massive limestone with, in places, a thin conglomerate at the base. Each of these unfossiliferous units is included in the Devonian. A third unfossiliferous unit is recognized by Laudon and Chronic, and is assigned by them to the Ramparts formation of lower Mackenzie River Valley. It consists of about 500 feet of thin-bedded, yellow to tan siltstones and silty and sandy limestones. It rests unconformably on the beds of the second unfossiliferous unit, noted above, and is conformable with the overlying Middle Devonian, fossiliferous limestones, also included by Laudon and Chronic in the Ramparts formation.

DEVONIAN

Peace River Valley

Black limestone occurs on a small, rocky island in the channel of Peace River, about 3 miles above the mouth of Clearwater Creek. Fossils include corals, brachiopods, and gastropods of late Middle Devonian age (Williams and Bocock, 1932).

Rocks similar to the above are found on the north bank of Peace River, 1 mile below the mouth of Wicked River. Massive, white limestones on the east slope of Wicked River Valley are also thought by Williams and Bocock to be of Devonian age.

Pine River Valley

Williams and Bocock describe Devonian beds from Pine River Valley, where possibly as much as 2,000 feet of limestones outcrop on the west slope of Murray Range. The lowest beds are hard, flinty, light bluish grey, unfossiliferous, massive limestones, weathering to a peculiar honeycomb texture. These are overlain by thin-bedded, bluish grey, hard, compact, cryptocrystalline limestone, with inclusions of black chert. Layers of hard, flinty, limy shale, dense black limestones, and arenaceous limestones are also present. Williams and Bocock found only fragments of fossils, but note that Dawson obtained what was possibly a small *Athyris*. On this basis, Williams suggests a Devonian age for these beds in Pine River Valley, and that they are the same as those outcropping high on the east slope of Wicked River Valley.

Alaska Highway, West of Summit Lake

It has been stated in a preceding paragraph that the lower part of the beds assigned by Laudon and Chronic to the Ramparts formation is unfossiliferous and hence only provisionally included in the Devonian. The upper part, however, is fossiliferous and of definite Devonian age; it comprises more than 1,000 feet of limestone, including coral-reef limestone. Williams (1944) placed these fossiliferous limestones in the upper part of his Silurian and Devonian unit and noted that they are well exposed in the bed of a small mountain creek that crosses the Alaska Highway 6 miles west of the summit. "About 200 to 300 feet below the top, the limestone is thin-bedded and mud-cracked into irregular polygons.... The upper limestone is dark grey and includes coral reefs from which" corals, brachiopods, and trilobites have been collected. Another fossiliferous zone, in dark grey limestone, was found near a temporary bridge over Racing River, in which some corals, brachiopods, and a trilobite were discovered.

Williams states that the fauna collected by him from these fossiliferous limestones "in a general way . . . suggests Middle Devonian faunas of Mackenzie River". Laudon and Chronic correlate these Devonian coralline limestones with the Middle Devonian Ramparts formation of that valley.

The Middle Devonian fossiliferous limestones are overlain disconformably by more than 800 feet of soft, black, fissile, pyritic shales, weathering yellow-brown. These black shales were included by Williams in the lower part of his 'Devonian and Mississippian' unit and by Laudon and Chronic in the Fort Creek formation, on the assumption that this formation of Mackenzie River Valley extends this far south. They outcrop in the vicinity of McDonnell Creek and at other places farther west. Near the base and a few inches above the Middle Devonian limestone, Williams found *Tentaculites spiculus* Hall. He proposes a correlation with the Upper Devonian Chemung formation of New York and with the Minnewanka formation of the southern (Canadian) Rocky Mountains.

MISSISSIPPIAN

Peace River Valley

The presence of Carboniferous rocks at 'Fossil Point' on the north bank of Peace River, about 3 miles above Rapide-qui-ne-parle-pas, has been known since Selwyn's exploration of Peace River in 1875. Williams and Bocock describe black, well-crystallized limestone with streaks of calcite at this locality, and list a small fauna, including brachiopods and corals of Mississippian age.

Sikanni Chief Valley

About 900 feet of light and dark grey, mostly crystalline, partly crinoidal and dense limestone, interbedded with chert and siliceous limestone are described by Hage (1944) in Sikanni Chief Valley (*See* Figure 3). These beds outcrop along the crest of an anticline crossing Sikanni Chief River about 2 miles west of Mount Withrow. Corals, brachiopods, a gastropod, and a trilobite of Mississippian age, identified by Alice E. Wilson, are recorded by Hage (1944).

Alaska Highway

Williams (1944) has described the Mississippian beds of the Alaska Highway under two headings 'Devonian and Mississippian' and 'Mississippian and later?'. Fossiliferous rocks of Mississippian age in the upper part of his 'Devonian and Mississippian' section include: "hard, black, cherty rock" in a road-cut, and limy sandstone and shale on the mountain to the east, near the highway along McDonnell Creek, all with brachiopods of probable Mississippian age; sandstone and shale, with brachiopods of Mississippian age in a road-cut on the east bank of Racing River, above the mouth of McDonnell Creek; and "very dark grey, calcareous argillite" with *Productus* and other brachiopods of Mississippian (Kinderhook) age and correlated "rather closely with the Banff shale of the Jasper Park area", on the north side of Liard River just west of the suspension bridge over the Liard.

Some unfossiliferous shales and sandstones outcropping along the Alaska Highway between McDonnell Creek and the Liard River bridge are described by Williams under the heading of 'Devonian and Mississippian'. They include slaty beds and hard sandstone in the valley of McDonnell Creek; hard, black shale in a road-cut in the valley of Trout River; and "soft, hackly mudstone, with soft sandy beds discoloured with iron rust" in another road-cut and on an island in Trout River.

Other unfossiliferous rocks, mostly shales, argillites, and sandstones, outcrop in places along the Alaska Highway west of the Liard River bridge, and include brown weathering argillite, sandstone, and chert, on the north side of Liard River, just west of the bridge; black, rusty weathering shale on the highway, east of Smith River; grey-blue sandstone on the north bank of Liard River west of Whirlpool Canyon; shales and sandstones west and north of a series of limestone ridges east of Irons Creek; and soft, banded shale and black, hackly shale near Hyland River. Williams considers whether these unfossiliferous beds should be placed in his 'Devonian and Mississippian' unit or whether they are more akin to the Ordovician graptolite-bearing shales on Dease River, described many years ago by McConnell (1891). He concludes that the "shales along the lower Dease and upper Liard Rivers . . . . do not suggest graptolite shales to the author, and their rather close resemblance to the more easterly outcrops makes it seem desirable to include them tentatively with the Devonian-Mississippian series".

Williams' 'Mississippian and later' strata overlie his 'Devonian and Mississippian' section and include more limestones and calcareous rocks. They underlie only a small area and are part of a narrow band of late Palæozoic rocks crossing the Alaska Highway from mile 380 to 382·5.

A section recorded by Williams and exposed in the valley of a short tributary of Tetsa River near mile 381·5 is, in descending order, as follows:

Sandstone, limy, alternating with black shale; *Spirifer* and *Syringothyris* near top
Sandstone, fine, limy, argillaceous; with *Productus*
Sandstone, shaly, limy

Productus crawfordsvillensis Weller (?) and *Spirifer floydensis* Weller were collected at the base of this section; *Productus inflatus* McChesney (?), *Productus burlingtonensis* Hall, *Productus jasperensis* Warren, *Productus* (other species), and *Spirifer floydensis* Weller from near the top; and *Spirifer floydensis* Weller(?) and *Syringothyris subcuspidata* Hall (?) at the top. One-half mile east, Williams records vertical beds of highly crinoidal limestone, with bryozoa, *Productus*, *Chonetes chesterensis* Weller (?), *Dielasma* sp., and *Euomphalus*. Along the Alaska Highway, west of the short tributary of Tetsa River mentioned above, "fossiliferous limestone and overlying limy sandstone contain a wealth of fossil brachiopods and pelecypods and some trilobites". A limestone block carries *Brachythyris suborbicularis* (Hall) and other fossils. "The adjoining hillside is composed of about 100 feet of dark grey, limy sandstone, which loses its lime cement through weathering and appears as a brown, fine-grained sandstone.

"There are probably about 200 feet of these beds exposed westward along the hillside, where they rise in a small anticline and are overlain by chert beds of the succeeding formation.

"Six hundred and fifty feet up the hillside above mile 382·5, *Dielasma* sp. occurs in brown calcareous sandstone".

Williams recognizes "two distinct faunas in these 'Mississippian' strata, the lower one characterized by various productids and the upper one by spiriferoids. Neither of these faunas has much in common with faunas so far described from the Banff, Moose Mountain, Jasper, Peace River, or Liard River sections. Warren has listed *Productus jasperensis*, *P. burlingtonensis*, *Dielasma chouteauensis*, and two species of *Brachythyris* (but not *suborbicularis*) from the Banff shale at Jasper". Compared with "the Illinois section, it is clear that both faunas are dominantly Osage (Burlington and Keokuk). Chester affinities are suggested by *Chonetes chesterensis* and *Productus inflatus*". He notes that the "spiriferoid fauna is higher stratigraphically. Its correlation would be with the Rundle or younger limestones of more southern sections, although the two faunas represent different facies, and have little in common".

The Mississippian beds in the Rocky Mountains, along the Alaska Highway, have also been studied by Laudon and Chronic (1947, 1949), who have placed them in one unit, the 'Kindle' formation, which is said to rest unconformably on dark shales of Upper Devonian age (Fort Creek) and to attain a thickness of about 400 feet. The section examined outcrops in the valley of a short tributary of Testa River near mile 381·5;

on the south side of Toad River; at mile 418, beneath the Liard River bridge; and on the west side of McDonnell Creek. It comprises the following:

	Thickness Feet
Limestone, thin-bedded, grey, silty, with thin shale partings; on weathered surface has appearance of dark green to black chert	100
Limestone, grey, silty; interbedded with shale, dark green to black, mottled, sandy.................................. Limestone, hard, irregularly bedded, grey to light tan, sandy, with calcite veins; fossiliferous..........................	70
Unconformity	
Limestone, massive, grey, silty; shale, soft, thin-bedded, silty, grey to black; fossiliferous..............................	165

The upper 100 feet of this section is described by Williams as a thick zone of chert, and is regarded by him as Pennsylvanian or Permian (*See* below). The massive limestone in the lower (165 feet) part is said to increase in proportion to the shale from the base, upward. The contact between these basal beds and the intermediate 70 feet of the section is recorded as somewhat irregular, abrupt lithologically, and marked by local, thin, conglomerate beds at the bottom. Like Williams, Laudon and Chronic collected a fauna in the lower 165 feet of the section, and their list includes species of *Productella*, *Dictyostylus*, *Leiorhynchus*, *Spirifer*, other brachiopods, and *Deltopecten*. They note that some of these species occur in the Calico Bluff formation, of early Meramec age, near Eagle on Yukon River, Alaska, and also in the Moorefield formation of the Ozark area, which is of post-Osage age. A fauna, similar to that collected in the lower beds, was found in the intermediate beds, below the upper (100 feet) beds. The combined section of the lower (165 feet) and middle (70 feet) beds was thought to have a stratigraphic position between the Kinderhook (Banff) and Rundle formations of the Banff and Jasper areas. The authors assume, of course, that the Banff-Rundle contact is disconformable, and they describe the cyclic sedimentation in the 'Kindle' formation as they have in other formations of the Alaska Highway section.

PENNSYLVANIAN

Pine River Valley

Williams and Bocock (1932) describe strata of Pennsylvanian age on Pine River between Callazon and Mountain Creeks. The sequence, because of the disturbance of the rocks, is difficult to determine. Williams and Bocock consider the section to be somewhat as follows, only parts of the section being measured:

Top of Section	Thickness Feet
Limestone, a thick bed	
Limestone, very fossiliferous	
Limestone, siliceous; with bands of quartzite up to 2 feet thick	
Limestone, hard, very pure, well crystallized, fossiliferous.......	20+
Limestone, hard, flinty, with inclusions containing crinoid stems	
Limestone, black, with *Productus*	
Concealed	
Shale, glossy, black, with minute stringers of quartz (several hundred feet)	
Slate, black..	20
Quartzite, massive, hard, flinty............................	30±
Limestone, dense, black, cherty, fossiliferous; with streaks of calcite (several hundred feet)	
Limestone, platy, thin-bedded, dark grey	

Williams and Bocock (1932) record species of *Seminula, Camarotoechia, Spirifer, Chonetes, Zaphrentis, Menophyllum, Diphyphyllum,* bryozoa, and crinoid columns from the above section.

PENNSYLVANIAN OR PERMIAN

Alaska Highway

Near miles 381 and 382, Alaska Highway, an exposure of 200 to 300 feet of black, hackly chert, weathering grey or brown, is described by Williams. Its contact with the underlying Mississippian beds is said to be abrupt, and the relationship disconformable. The upper contact is missing, and no higher Palaeozoic beds are known on the highway. The beds are unfossiliferous, but Williams notes that similar chert beds are present in the upper part of the Rocky Mountain quartzite in Jasper Park.

These beds were included by Laudon and Chronic in the upper part of their Mississippian 'Kindle' formation. They were described as thin-bedded, grey, silty limestones with thin shale partings, having the appearance of chert on weathered surfaces (*See also* page 32).

CARBONIFEROUS(?) AND PERMIAN

Mount Merrill

On Mount Merrill[1], 38 miles above the mouth of Beaver River (*See* Plate III A), a tributary of the Liard, a section of late Palæozoic rocks described by Kindle (1944) is as follows, in descending order:

	Thickness Feet
Sandstone, calcareous	30
Chert, massive, roughly laminated, 1 foot to 10 feet thick, separated by layers of shale, 1 inch to 3 inches thick	150+
Sandstone, grey to yellow, with some shaly beds and some limestone	?

Several collections from the lower, grey to yellow sandstones were identified and dated Permian, or possibly Upper Carboniferous, by Alice E. Wilson. One collection, taken at 420 feet above the river, contains *Pustula* sp., *Dictyoclostus* sp., *Leiorhynchus* sp., *Athyris* sp., and *Dielasma*, and was said to be of "Upper Carboniferous or Permian age, probably Permian" by Miss Wilson. A second collection, from the grey to yellow sandstones, collected 280 feet higher up the slope, includes *Buxtonia* sp., *Allorisma* sp., and *Aviculopecten* sp., and was dated, probably Permian. Another collection from the same sandstones 200 feet vertically below the peak of Merrill Mountain, includes *Echinoconchus* sp., *Pugnoides* sp., *Dielasma* sp., and *Martiniopsis* sp. A fourth collection from these sandstones, near the last locality, yielded *Productus* sp., close to *P. uralicus* Tschernyschew, *Marginifera* sp., close to *M. jisuensis* Chao, and other fossils, and was considered by Miss Wilson to be "almost certainly of Permian age".

The calcareous sandstone, above the chert, has yielded bryozoa, *Productus* sp. close to *P. uralicus, Spirifer* sp., *Marginifera* sp. close to *M. jisuensis,* and cf. *Sphenotus* sp. This collection is similar to one from the lower sandstones, below the chert, and like it has been dated almost certainly Permian by Alice E. Wilson.

[1] Mount Merrill is north of the map-area, east of Beavercrow Mountain.

PERMIAN

Peace River Valley

Permian beds are mapped by Beach and Spivak (1944) on the south side of Peace River Valley at the west boundary of the Dunlevy-Portage Mountain map-area. A section measured in a canyon just west of Stott Creek is as follows:

Top of Section	Thickness Feet
Sandstone, fine, grey-buff, with carbonate cement	275
Sandstone, soft, very light grey, calcareous, fossiliferous	50
Limestone, dark grey, arenaceous	25
Limestone, black, phosphatic, thin-bedded	10
Sandstone, fine, with calcareous cement	55
Total thickness	415

The uppermost sandstone contains vugs filled with quartz, calcite, and small amounts of pyrobitumen. The upper contact is unknown, but these beds rest on dark grey limestone.

Alice E. Wilson has identified the following fossils from Beach and Spivak's collection: *Dielasma, Spirifer, Notothyris, Edmondia, Solemya, Shizodus, Aviculopecten,* Pteriidae, Pernidae, *Allorisma, Aviculopinna,* and *Myalina.* This fauna is tentively dated Permian by Miss Wilson.

TRIASSIC

GENERAL STATEMENT

Triassic rocks have long been known in northeastern British Columbia. As early as 1875, Alfred R. C. Selwyn of the Geological Survey of Canada found them on upper Peace River, in the western part of the Foothills. Four years later, G. M. Dawson discovered Triassic beds in Pine River Valley. In 1887, R. G. McConnell, while making his hazardous descent of Liard River, recognized Triassic strata in ledges and in walls of the canyon from the Rapids of the Drowned to Hades (Hell) Gate. Later, and for more than a quarter of a century, beginning in 1917, the Geological Survey has, from time to time, given special attention to the Triassic stratigraphy of northeastern British Columbia, and in particular to that of the Peace River Foothills. Field parties of the Pacific and Great Eastern Railway Survey, in 1929 and 1930, included the Triassic in their program of field studies, as have also geologists of the British Columbia Department of Mines and of various private companies exploring for petroleum.

The formational classification of the Triassic of northeastern British Columbia is not yet completed. A few formation names have been proposed, but pending more experience in mapping, and as a precautionary measure, temporary lithological units have been segregated and given mere lithological names, for example, 'Grey beds' and 'Dark siltstones'. When these, or more satisfactory lithological units, are established as good mapping units they can be recognized as formations and given the usual geographic names.

It is doubtful if Schooler Creek, proposed by McLearn in 1921, will survive either as a formation or group name. It was given to beds in the

Peace River Foothills now comprising the tentative lithological units of 'Dark siltstones', 'Grey beds', and Pardonet beds.

Triassic formations, lithological units, and faunal zones are recorded in the following table:

TABLE OF TRIASSIC FORMATIONS AND LITHOLOGICAL UNITS

		Formation		Lithology	Faunal zones
Triassic	Upper	(Thickness in feet) Pardonet beds 250-2,000+		Dark calcareous siltstones and shales; some dark limestone	*Monotis subcircularis* *Himavatites* *Cyrtopleurites* cf. *bicrenatus* *'Styrites' ireneanus* *Tropites* *Stikinoceras*
Triassic	Upper / Middle	'Grey beds' 2,500±	Liard (lower part)	Grey, massive, thick-bedded, calcareous sandstone; grey limestone	*Lima? poyana* Mahaffy cliffs faunal zone
Triassic	Middle	'Dark siltstones' 75-430+	Liard	Thin-bedded calcareous siltstones; dark limestone	*Nathorstites*
Triassic	Middle	'Flagstones' 235-380±	Liard	Thin-bedded siltstones, flagstones, some massive grey sandstone and limestone	
Triassic	Middle / Lower	Toad 800-1,800		Dark, calcareous siltstone, shales, and dark limestone	*Beyrichites–Gymnotoceras* *Wasatchites*
Triassic	Lower	Grayling 600-1,000		Dark shale	cf. *Claraia stachei*

GRAYLING FORMATION

Definition

The Grayling formation, named and described by E. D. Kindle in 1944, consists of marine, dark grey shale and some layers of sandstone. It lies conformably below the Toad formation and probably disconformably above the highest Palæozoic rocks in the region.

Liard River Valley

In Liard River Valley, Kindle (1944) describes 600 to 1,000 feet of soft, laminated, friable, grey shale, with in places layers of hard, ripple-marked sandstone, 1 inch to 10 feet thick, but commonly not exceeding 1 foot. The formation is exposed in cliffs, 300 feet high, on the lower part of Grayling River, and this is the type locality. It is also exposed on the Liard, east and west of the mouth of Grayling River (*See* Figure 4). It is probably present in the Tetsa and more southern valleys, but has not yet been recognized there.

Age and Correlation

(*See* Figure 5)

Fossils are rare in the Grayling formation, but Kindle collected cf. *Claraia stachei* Bittner on Grayling River, a mile north of the Liard. The specimens are imperfect, but are probably of, or close to, this species. *Claraia stachei* in Greenland ranges through both the Otoceratan and Gyronitan, the first two ages of early Lower Triassic time in the chronological nomenclature of Spath (1934).

Warren (1945) records the presence of *Claraia stachei* in the lower part of the Sulphur Mountain member of the Spray River formation in the central Canadian Rockies.

In Nevada, *Claraia stachei* occurs about 150 feet above the base of the Candelaria formation (Muller and Ferguson, 1939). This species is also recorded in the Woodside formation in southeastern Idaho and in the Dinwoody of Wyoming (Newell and Kummel, 1941).

TOAD FORMATION

Definition

The Toad formation, named and described by Kindle in 1944 and redefined by him in 1946, consists of marine, dark grey, brown, or black, platy shales; dark, shaly, thin-bedded, calcareous siltstones; some hard, massive siltstones; and thin, lenticular layers of dark limestone. The thickness varies from 800 to 1,800 feet, and the type locality is on Liard and Toad Rivers, near the mouth of the Toad (*See* Figure 4).

The Toad is conformable with the underlying Grayling formation, and in most places conformable with the overlying Liard formation or with the 'Flagstones'. Locally, where a fine sediment is overlain by a coarse sediment, minor disconformities have been observed.

Halfway River Valley

The Toad formation has been definitely located at one place in Halfway River Valley, namely, in the Fourth Gully on Mount Wright (*See* Plate III B). It is overlain, conformably, by the 'Flagstones'. The formation consists of shaly, calcareous siltstones. Poor fossil specimens, identified as *Beyrichites* or *Gymnotoceras*, record the fauna of the upper part of the Toad formation. It is quite probable that this formation will be recognized in other parts of Halfway Valley.

If the beds of this formation extend south as far as the Peace River Foothills, they are deeply buried there beneath Triassic formations of later age.

Sikanni Chief River Valley

The Toad formation outcrops in Sikanni Chief Valley, and is best known on the west slope of Mount Hage (*See* Plate IV A), where it is exposed on Hage and McTaggart Creeks (*See* Figure 6). The lowest beds are far up McTaggart Creek, and the highest are on Hage Creek, above the junction of these two creeks, where they are overlain by the 'Flagstones'. In this section are dark, somewhat shaly, calcareous siltstones with some harder and more massive layers of calcareous siltstones and some dark

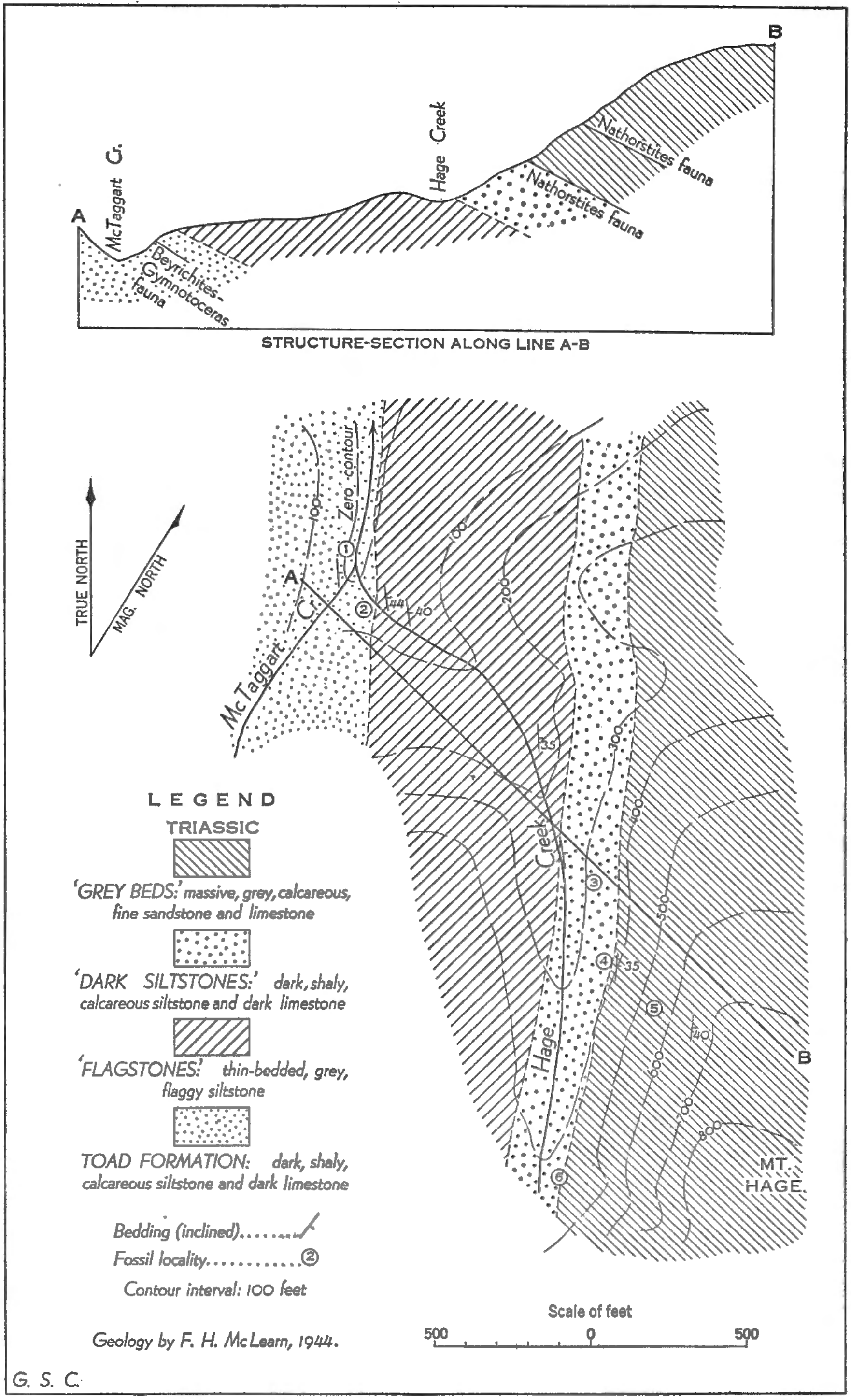

Figure 6. Triassic formations on Hage and McTaggart Creeks on west slope of Mount Hage, south side of Sikanni Chief Valley.

limestone. They carry the *Beyrichites-Gymnotoceras* fauna (McLearn, 1948), which identifies the upper part of the Toad formation. The lower part of the Toad is concealed below the level of McTaggart Creek.

It is inferred that the Toad formation also outcrops on Mount Withrow, west of Mount Hage, and on the north side of Sikanni Chief Valley, for specimens of the *Beyrichites-Gymnotoceras* fauna, typical of the upper part of the Toad formation, were collected there by Hage (1944). No description of the lithology has been given.

Muskwa River Basin

The Toad formation is known to underlie a large area in the basin of Muskwa River. No details of lithology or occurrence have yet been published, but many collections of the *Beyrichites-Gymnotoceras* fauna forwarded to the Geological Survey for identification bear witness to its presence in this part of northeastern British Columbia.

Tetsa River Valley

The Toad formation outcrops in Tetsa Valley, where the upper part is well exposed in low cliffs or ledges along the Alaska Highway from mile 374 to about mile 378, and in ledges on the southern slopes of Cameron, Smith, and Shaw Hills (*See* Figure 7). The Triassic beds outcrop on the axes of the anticlines, and the overlying dark shales of Jurassic or Cretaceous age outcrop in the synclines. The lower beds of the formation are concealed below river level and so do not outcrop in this part of the valley.

First observed by Williams (1944), this section was later studied by McLearn (1946, 1948). The exposed beds consist of about 500 feet of dark grey, partly carbonaceous, thin-bedded, calcareous shales, shaly calcareous siltstones, and thin lenticular beds of dark limestone. Near the top the beds become coarser and more massive, and, at the top of the section, some thick-bedded, grey, calcareous, fine sandstones and grey limestones, with a few brachiopods, may belong to the basal part of the Liard formation or may be considered beds transitional into that formation.

Marine fossils are common in the lower part of the 500-foot section outcropping in this part of Tetsa River Valley, and have been collected along the highway on the axes of the Smith and Shaw anticlines and east of the axis of the Cameron anticline and on the south slope of Cameron Hill (*See* Figure 7). They are all of the *Beyrichites-Gymnotoceras* fauna, and include species of the ammonoid genera *Parapopanoceras*, *Longobardites*, *Beyrichites*, and *Gymnotoceras* (McLearn, 1946, 1948).

The Toad formation may also be exposed in a low ledge, beside the Highway near mile 383, where dark calcareous siltstones contain poorly preserved shells, possibly of the *Beyrichites-Gymnotoceras* fauna.

Liard River Valley

At the type locality on Liard River (*See* Figure 4) at and near the mouth of Toad River, the Toad formation consists of about 800 feet of "brown and black, platy shales, and grey to brown and yellowish, thin-bedded siltstone, with a few thin, lenticular beds of grey to black, fossiliferous limestone. These strata are particularly well exposed in steep,

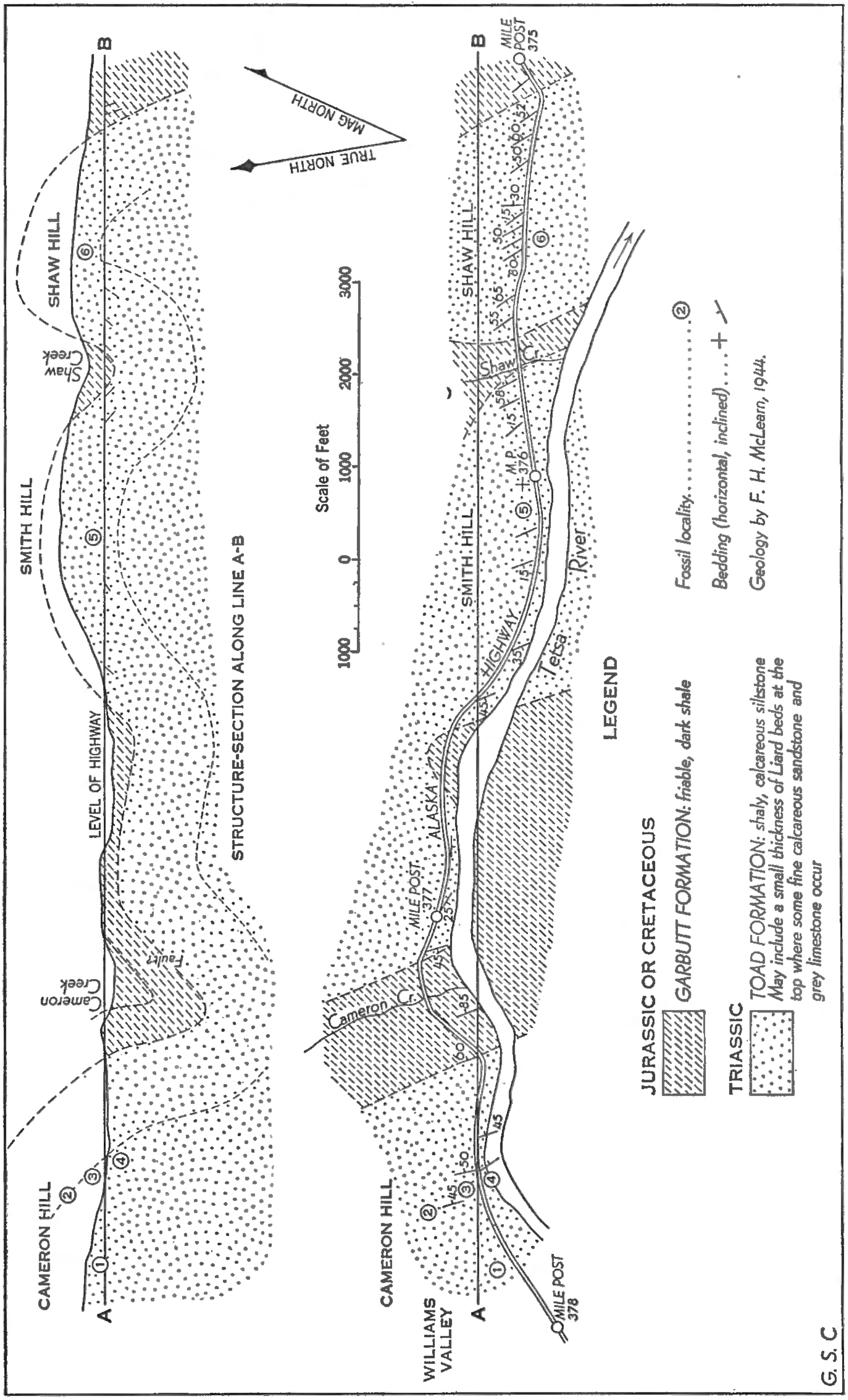

Figure 7. Geology along Alaska Highway, in part of Tetsa River Valley.

400-foot rock bluffs on the north side of Liard River between 1 mile and 2 miles downstream from the mouth of the Toad, where the Liard cuts easterly across the formation" (Kindle, 1948). They rest conformably on beds of the underlying Grayling formation, and are overlain disconformably by the basal Jurassic or Lower Cretaceous shales of the Garbutt formation. A 6-inch bed of limestone in this type section of the Toad formation, 400 feet above its base and exposed "on the north bank of the Liard, about 2 miles below the mouth of the Toad", is highly fossiliferous, and carries specimens of the *Wasatchites* fauna. The same fauna occurs in a thin limestone band on the northeast bank of Toad River, 2 miles above the mouth of the Toad. ". . . . 1,000 feet downstream from the 6-inch *Wasatchites* bed [referred to] above, on the south bank of the Liard and 300 feet higher in the section, or 80 feet below the top of the formation, are several narrow beds of black limestone associated with dark, argillaceous shales. Both limestone and shale contain abundant fossils within a [20-foot zone] . . . and concretions found in the shales are also fossiliferous" (Kindle, 1948). These fossils include species of the *Beyrichites-Gymnotoceras* fauna, although *Beyrichites* and *Gymnotoceras* are not among the genera represented.

Farther up Liard River, 8 miles southwest of the mouth of the Toad, the formation is 1,800 feet thick, much thicker than at the mouth. Here, on the north bank of the river are thin-bedded shales, sandstones, and siltstones. "The shales range from brown to black, and are interbedded with narrow grey and brown sandstone and siltstone beds. Towards the upper part of the formation the sandstone beds are calcareous and contain a few fossils. A 40-foot band of black, sandy limestone that occurs 150 feet below massive calcareous sandstones of the overlying formation (Liard) is highly fossiliferous. It is underlain by 35 feet of black, platy [fossiliferous] shale" (Kindle, 1948). From the limestone band, Kindle collected the *Beyrichites-Gymnotoceras* fauna.

Age and Correlation

(*See* Figure 5)

The Toad formation represents a fairly long range of geological time, as it contains a Lower Triassic fauna, the *Wasatchites*, near the middle of the formation and a Middle Triassic fauna, the *Beyrichites-Gymnotoceras*, near the top.

The *Wasatchites* fauna has not been found elsewhere in Canada and is not known in Alaska.

In the Fort Douglas area, Utah, the Lower Triassic comprises the Woodside and Pinecrest formations. It was in the Pinecrest, between the zones of *Meekoceras* and *Tirolites* of Upper Owenitan age, that A. A. L. Mathews (1929) recognized and described the ammonoid genus *Wasatchites*. With it he recorded species of *Xenoceltites*, *Hemiprionites*, *Gurleyites*, *Anasibirites*, and other genera. With this *Wasatchites* fauna of Utah, the *Wasachites* fauna of Liard River shows considerable resemblance: *Wasatchites canadensis* is close to the coarsely ribbed *Wasatchites perrini* Mathews and *W. magnus* Mathews; a Liard River specimen is close to *W. meeki* Mathews; and some Liard River specimens resemble *Xenoceltites hannai* Mathews (McLearn, 1945A).

In Idaho, the Dinwoody and Woodside formations and the Thaynes group and Timothy formation are of Lower Triassic age (J. P. Smith, 1932; Newell and Kummel, 1941; Kummel, 1943). The *Wasatchites* fauna is not known there, but beds of *Wasatchites* age may occur in the Thaynes group between the *Meekoceras* and *Tirolites* limestones.

Wasachites has not been reported from either California or Nevada. Possibly equivalent beds may lie in the upper part of the Candelaria formation of Nevada (Muller and Ferguson, 1939).

Spath (1934) has described a species of *Wasatchites* from the *Posidonomya* beds of Spitsbergen, but suggests that these beds may be a little younger than the *Wasatchites* beds of Utah. The same author has described a species of *Wasatchites* from the *Anasibirites* beds of the island of Timor in the Netherlands East Indies.

In Spath's (1934) system of chronology *Wasatchites* is of late Owenitan to Columbitan? (late Lower Triassic) age.

The age and correlation of the *Beyrichites-Gymnotoceras* fauna, high in the Toad formation, have been discussed recently (McLearn, 1948). Correlation is with the late Anisian, probably Paraceratitan (Spath's system of chronology), that is, early, but not the earliest, Middle Triassic fauna of the American Pacific coast, Arctic, Mediterranean, Indian, and other regions.

Very little is known in Canada of this fauna, outside of northeastern British Columbia. A fauna containing *Gymnotoceras*, however, has been reported by Warren (1945) from the upper or Whitehorse member of the Spray River formation in the central Canadian Rockies. It is doubtful if any part of the Nicola group of southern British Columbia is of Middle Triassic age. Indeed, most, if not all, of the Triassic of central and western British Columbia is of Upper Triassic age.

The *Beyrichites-Gymnotoceras* fauna resembles closely the early Middle Triassic Anisian fauna, containing *Anolcites*, *Nevadites*, *Paraceratites*, and other ammonoid genera, that occurs in the lower part of the Star Peak formation of the West Humboldt Range of Nevada. A collection from Forest Hill in the American Canyon, West Humboldt Range (J. P. Smith, 1914), contains species similar to species in the Canadian fauna. *Longobardites nevadanus* Hyatt and Smith and *Longobardites intornatus* McLearn occur in both faunas and, indeed, in a broad sense, the latter may be only a variety of the former. The Canadian specimens of *Beyrichites* cf. *falciformis* are close to *B. falciformis* Smith; specimens of *Beyrichites* aff. *tenuis* are very close to *B. tenuis* Smith; and *Sphaera* cf. *whitneyi* recalls *S. whitneyi* Gabb. *Paraceratites*, common in the *Nevadites* fauna, is extremely rare in the Canadian fauna, only one poor specimen being known. *Epigymnites* is unknown in the Canadian fauna. *Anolcites*, *Nevadites*, and *Protrachyceras*, represented by so many species in Nevada, have not yet been found in Canada in beds correlated with the Anisian.

The fauna of the Pit shale in Shasta county, California, with *Nevadites*, is a small one, and has nothing in common with the Canadian *Beyrichites-Gymnotoceras* fauna. It may, however, be of the same age, or nearly, and possibly, if better known, would show considerable resemblance to the Canadian fauna.

The slates of Brooks Mountain, Seward Peninsula, Alaska, are said to carry *Daonella* cf. *lommeli* Wismann and *Gymnotoceras* sp. (Martin, 1926). If this is so, they are probably of the same age as the Canadian beds carrying the *Beyrichites-Gymnotoceras* fauna.

Species of *Gymnotoceras* and *Parapopanoceras* have been described from the island of Spitzbergen in the Arctic Ocean (Mojsisovics, 1886). *Parapopanoceras tetsa* McLearn and its varieties are close to the Spitzbergen *Parapopanoceras malmgreni* (Lindstrom) and *P. verneuili* (Mojsisovics). The Canadian species *Gymnotoceras columbianum* McLearn, *G. wrighti* McLearn, and *G. helle* McLearn recall Spitzbergen species like *G. nathorsti* Mojsisovics and *G. geminatum* (Mojsisovics) (McLearn, 1948).

Kiparisova (1937) has recently described a Triassic fauna from the mouth of Olenek River and other localities in northern Siberia. This fauna contains some species, such as *Hungarites grumulus* Kiparisova, which resemble the inner whorls of *Longobardites intornatus* in the Canadian *Beyrichites-Gymnotoceras* fauna.

Gymnites hagi in the Canadian fauna resembles *Gymnites subclausus* var. as figured by Salopek (1911) in a fauna from Od Drenini, near Spizza in southern Dalmatia. This Dalmatian fauna is said to contain *Paraceratites trinodosus,* and so is of Anisian and Paraceratitan age.

Anagymnites lamarcki Oppel occurs in the Muschelkalk of the Himalayan Mountains, and is presumably of Paraceratitan age. It resembles *A.* cf. *lamarcki* found in the Canadian *Beyrichites-Gymnotoceras* fauna (McLearn, 1948).

LIARD FORMATION

Definition

The beds of the Liard formation were first included by Kindle (1944) in his Toad formation. Later, however, he separated the higher, more massive and coarser grained strata from the lower, more thin-bedded and more finely grained beds, giving the name of Liard to the former and retaining the name of Toad for the latter (Kindle, 1946). The Liard, so defined, lies between the Toad and the Lower Cretaceous, possibly partly Jurassic, Garbutt formation, and consists of more than 600 feet of marine, grey, mostly light grey weathering, thick, massive beds of fine, calcareous sandstone, arenaceous limestone, limestone, and minor amounts of siltstone and shale.

The contact with the underlying Toad formation is mostly conformable, although in places it may be slightly disconformable. The contact with the overlying Garbutt formation is disconformable, all of the Upper Triassic and possibly the Jurassic and part of the Lower Cretaceous being absent.

The type locality is near Hades (Hell) Gate, along Liard River.

Liard River Valley

At the type locality, on an island and on the south bank of Liard River near Hades (Hell) Gate (*See* Figure 4 and Plate IV B), Kindle (1946) measured a section of the upper part of the Liard formation:

	Thickness Feet (Approximate)
Overlying dark shales of Garbutt formation	
Sandstone, calcareous; and limestone........................	200
Sandstone, hard, calcareous; and limestone; with *Nathorstites* fauna..	50

The contact with the overlying, Lower Cretaceous, possibly partly Jurassic, Garbutt shales is structurally conformable.

A better section is exposed in the belt of Triassic strata that crosses Liard River east of Hades (Hell) Gate, between Brimstone and Crusty Creeks (*See* Figure 4). Here, Kindle (1946) measured more than 600 feet of mostly massive, thick-bedded, occasionally thinly laminated, calcareous sandstone, grey limestone, arenaceous limestone, and some shale. Near the top of this section is a bed with numerous shells of the brachiopod *'Coenothyris'*. In a flat-lying vein near river level at this locality, crystals of quartz about 4 inches long have been collected. The contact with the underlying Toad formation is concealed.

Farther east, at the mouth of Toad River, the Liard formation is missing in the section, and the shales of the Garbutt formation rest directly on the Toad formation (Kindle, 1946).

The Liard formation is exposed upstream for many miles above Hades (Hell) Gate, for McConnell (1891) collected species of the *Nathorstites* fauna at the lower end of the canyon west of Hades (Hell) Gate and at the Rapids of the Drowned.

Tetsa River Valley

The Liard formation is recognized in Tetsa Valley, along the Alaska Highway, and, as on Liard River, is thick in the west and thins rapidly to the east (McLearn, 1947A).

On the east slope of Cameron Hill and on Smith and Shaw Hills, between miles 378 and 375 on the Alaska Highway (*See* Figure 7), a thin section only of massive, fine sandstone and limestone, overlying beds typical of the Toad, can be referred to the Liard formation. On the axis and on the west limb of the Williams Valley anticline near and west of mile 378, the Liard thickens rapidly and is exposed on a high and abandoned Highway location north of the present roadway. There it consists of massive, thick beds of fine sandstone and grey limestone, fossiliferous in places and containing specimens of the brachiopod genus *'Coenothyris'* and of the pelecypod genera *Pecten, Ostrea,* and *Pinna.* Although no ammonoids have been found, the brachiopods and pelecypods are of the *Nathorstites* fauna, which is represented in the Liard formation on Liard River. These beds on the north side of the Alaska Highway extend nearly 2 miles to the west on a long ridge where they conceal the underlying beds of the Toad formation.

The Liard formation is also represented in the second and broad belt of Triassic that crosses the Highway approximately between miles 382·5 and 389. In 1943, Williams collected fossils of the *Nathorstites* fauna on the top of a high hill north of mile 383·2 and just west of the bridge over Tetsa River. He also collected specimens of this fauna in a road-cut at about mile 387 on the Highway and at higher elevations in that vicinity.

Age and Correlation

The age and correlation of the Liard formation will be discussed subsequently, when dealing with the 'Grey beds', where also the age of the *Nathorstites* fauna will be considered.

'FLAGSTONES'

Definition

'Flagstones' is a provisional name assigned by McLearn (1947A) to a well-defined unit between the Toad formation and the 'Dark siltstones' in Halfway and Sikanni Chief Valleys, and in other parts of northeastern British Columbia. The unit consists of 235 to 380 feet of grey, flaggy, thin-bedded, calcareous siltstones, and in places fine, massive, calcareous sandstones and limestones. It lies, apparently conformably, between the Toad formation and the 'Dark siltstones'.

Halfway River Valley

A good section of the 'Flagstones' is exposed on the Fourth Gully of Mount Wright, on the north side of Halfway Valley (*See* Plate III B). About 200 feet of flaggy, calcareous siltstone and fine sandstone are overlain by 180 feet of massive, grey, thick-bedded, calcareous, fine sandstone and limestone containing *'Coenothyris'* (McLearn 1947A, 1948).

The structure is almost flat, and the 'Flagstones' are underlain down the gully by the Toad formation and up the gully by the 'Dark siltstones'.

Sikanni Chief River Valley

The 'Flagstones' are exposed on Hage Creek (*See* Figure 6) on the west slope of Mount Hage, on the south side of the Sikanni Chief River Valley (McLearn, 1947A). They consist of about 235 feet of unfossiliferous, thin-bedded, flaggy and massive siltstone. The grey, massive, thick-bedded, fine, calcareous sandstone and limestone of the Mount Wright section do not appear to be present on Hage Creek.

The 'Flagstones' probably occur in other parts of northeastern British Columbia but have not yet been recognized.

Age and Correlation

It is probable that the 'Flagstones' of Halfway and Sikanni Chief River Valleys are equal to some lower part of the Liard formation in Tetsa and Liard Valleys. They lie between beds of the Middle Triassic, Anisian, Toad formation and those of the Middle Triassic, Ladinian 'Dark siltstones'.

The species of *'Coenothyris'* in the upper part of the 'Flagstones' of Mount Wright resemble species of the same genus in the 'Dark siltstones', and suggest an age nearer to that of the 'Dark siltstones' than to the Toad formation.

'DARK SILTSTONES'

Definition

The provisional name 'Dark siltstones' was assigned by McLearn (1947A) to a well-defined lithological unit lying between the 'Flagstones' below and the 'Grey beds' above. This unit is probably identical with Hage's (1944) 'shale member' of the Schooler Creek formation, the 'upper shale' of some field geologists. It consists of from about 75 feet to more than 450 feet of marine, dark, calcareous shale, dark, calcareous siltstone, and dark, lenticular limestone. It encloses the *Nathorstites* fauna, which, however, is not confined to it, but passes upward into the lower part of the 'Grey beds'.

Peace River Valley

A good section, although not complete, of the 'Dark siltstones' is exposed at the east end of the Beattie ledge, between Adams and Aylard Creeks, on the north bank of Peace River (*See* Figure 8). It is overlain conformably by the 'Grey beds'. The lower part of the 'Dark siltstones' is concealed below river level at this locality. A section measured by McLearn (1947A) is as follows, in descending order:

	Thickness Feet (Approximate)
Overlying 'Grey beds'	
Siltstone, dark grey and brownish grey, somewhat carbonaceous, shaly, and slabby....................................	300
Siltstone, dark, somewhat carbonaceous, fissile; and shaly and lenticular dark limestone; with the *Nathorstites* fauna......	30
Siltstone, dark grey, brownish grey, somewhat carbonaceous, calcareous, shaly; and some limestone....................	100+

Far up Folded Hill Creek (*See* Figure 8), between Brown and Folded Hills on the north side of Peace River, are exposures of shales and dark calcareous siltstones. They are overlain by the 'Grey beds' but their lower limit is unknown. They carry poor fossils, including *Daonella* sp., and are probably part of the 'Dark siltstones'.

Halfway River Valley

In the Fourth Gully on Mount Wright (*See* Plate III B), the Triassic beds are almost flat-lying, and higher and higher strata are met with as the gully is traversed toward its source. In this gully, between the top of the 'Flagstones' unit below and the base of the 'Grey beds' above, are about 300 feet of dark, shaly siltstone, limestone, and shale with the *Nathorstites* fauna. To the west, these beds extend along the cliff on the north slope of Mount Wright, and there, changing to a steep west dip, extend down the Third Gully of Mount Wright, where they are well exposed and have the same lithology as in the Fourth Gully and carry the same *Nathorstites* fauna.

The beds of this unit have also been observed on the south side of Halfway Valley west of Mount Wright.

Sikanni Chief River Valley

The strata of the 'Dark siltstones' are well exposed in the bottom, and on the lower part of the east side, of the valley of Hage Creek, which drains the west slope of Mount Hage on the south side of Sikanni Chief River

Valley (*See* Figure 6). Here, they consist of about 75 feet of dark, calcareous siltstone and dark shale, separated from the underlying 'Flagstones' by a concealed interval equivalent to 30 feet of strata and immediately overlain by massive, calcareous, fine sandstone of the 'Grey beds'. At about 40 feet above the exposed base and near the top they carry the *Nathorstites* fauna (McLearn, 1947A).

In Sikanni Chief River Valley, west of Mount Withrow, the geologists of an oil company have discovered dark siltstones, carrying species of the *Nathorstites* fauna.

Prophet River Drainage Basin

Collections of the *Nathorstites* fauna have been made by geologists of oil companies in the valley of Prophet River and near Kluachesi Lake. Details of sections are not available, but some of the collections were obtained from 'shale' and are probably from the 'Dark siltstones' lithological unit. This unit has not been recognized to the north, neither in the northern part of the basin of Muskwa River nor in Laird River Valley.

Age and Correlation

The 'Dark siltstones' carry the *Nathorstites* fauna, and, therefore, can be correlated with a part of the Liard formation. Their age and that of other units carrying this fauna will be dealt with in discussing the succeeding 'Grey beds'.

'GREY BEDS'

Definition

'Grey beds' is a provisional name assigned by McLearn (1940) to a thick lithological unit lying between the 'Dark siltstones' and the Pardonet beds. Like the Liard formation, this unit consists of massive, thick-bedded, grey, calcareous, fine sandstones and grey limestones, with a small proportion of calcareous siltstone and shale. Its thickness is about 2,500 feet. The 'Grey beds' appear to constitute a good mappable unit, and may prove to have the status of a formation. The unit is left unnamed at present, however, pending further experience in the mapping of the Triassic of northeastern British Columbia.

The 'Grey beds' contain three, fairly well-defined faunas: the *Nathorstites* fauna in the lower part; the Mahaffy Cliffs or Red Rock Spur fauna near the middle; and the *Lima? poyana* fauna near the top (McLearn, 1940). The fossiliferous zones are separated by barren strata or strata with only rare or poorly preserved fossils.

Pine River Foothills

The 'Grey beds' have as yet been little studied in the Pine River Foothills. The upper part of these beds, however, is exposed near the mouth of Mountain Creek, for Williams and Bocock (1932) obtained species of the *Lima? poyana* fauna there.

Peace River Foothills

The 'Grey beds' are well exposed in the Peace River Foothills. A lower part is represented on Beattie Hill, between Aylard and Adams

Creeks, on the north side of Peace River (*See* Figure 8). It overlies the 'Dark siltstones' exposed at the east end of the Beattie ledge. A section has been measured by McLearn (1940A) and, in descending order, is as follows:

	Thickness Feet (Approximate)
Sandstone, very fine, calcareous; siltstone; and impure, shelly limestone; dark grey, light grey weathering, massive and mostly thick-bedded; carries *Lingula*....................	800
Similar beds with *Lingula*, and brachiopods and pelecypods of the *Nathorstites* fauna....................................	200
Similar beds with *Nathorstites;* other ammonoids and brachiopods and pelecypods of the *Nathorstites* fauna.................	200

Upward, the brachiopods and pelecypods of the *Nathorstites* fauna extend higher than the *Nathorstites* and other ammonoids; *Lingula* appears with the brachiopods and pelecypods and finally only *Lingula* is recorded. The 'Grey beds', with a lithology similar to that of the beds on Beattie Hill and with the *Nathorstites* fauna, are exposed on the high hill on the north side of Peace River Valley, east of Aylard Creek and north of the Beattie ranch.

A section of part of the 'Grey beds' is exposed between Red Rock Spur and McLay Spur on the north side of Peace River Valley about 5 miles west of Beattie Hill (*See* Figure 8). This section does not include the lowest part of the 'Grey beds', that with the *Nathorstites* fauna, for being below river level the *Nathorstites* zone does not outcrop. The higher part of the 'Grey beds', however, from the Red Rock Spur faunal zone to the contact with the overlying Pardonet beds can be studied, and is roughly 1,300 feet thick. The following is the general sequence, but detailed measurements are not available:

Pardonet beds

Limestone, grey, partly dark grey, crystalline, shelly, and crinoidal; sandstone, grey, fine, calcareous; siltstone, calcareous; all interbedded in many layers and with rare fossils.

Sandstone, massive, grey, fine, calcareous; limestone, grey, partly crinoidal; limestone, impure, silty; siltstone, calcareous; limestone, the 'coquina'; all interbedded in thick layers and with species of *Lima ? poyana* fauna.

Sandstone, fine, calcareous, with *Lingula.*

Sandstone, grey, massive, calcareous; limestone, grey; siltstone; all in thick layers and mostly barren.

Sandstone, grey, fine, calcareous; limestone, grey, impure; siltstone, grey, calcareous; all in thick layers, weathering grey, yellowish, and reddish, with the Red Rock Spur fauna of pelecypods.

West of McLay Spur, the west dip carries the 'Grey beds' below river level. The 'coquina' limestone is a prominent and readily identified bed and consists of 5 feet of limestone composed mainly of comminuted shells and a few entire shells (McLearn, 1941B).

The higher part of the 'Grey beds', with the *poyana* zone, reappears west of the Jewitt fault, and is exposed on the lower slopes at the southern ends of Jewitt Spur and Schooler Hill and on the Dry Canyon shoulder (*See* Figure 8). The 'coquina' limestone can be traced along these slopes, where it is very useful in determining structure. It outcrops in the long ledge just west of the Jewitt fault, above a terrace, and above the pack-trail. Below it are grey limestones and calcareous siltstones with *Pecten? dishinni*, and above it are grey limestones and calcareous, very fine sandstone with the diagnostic *'Terebratula'* cf. *julica* Bittner and *Lima ? poyana* of the *poyana* faunal zone. Higher, are mostly barren grey limestone, calcareous siltstones, and calcareous, fine sandstones at the top of the 'Grey beds'. These pass gradually into the dark, more carbonaceous, and finer strata of the Pardonet beds (McLearn, 1941B).

The *Lima? poyana* zone of the higher part of the 'Grey beds' is exposed on the steep, southern slopes of the Dry Canyon shoulder. McLearn (1941B) records grey, calcareous, fine sandstone with *Lingula*, overlain by grey limestone and calcareous siltstone with species of the *L.? poyana* fauna. These are in turn suceeded by the 'coquina' limestone, grey limestone, grey, calcareous siltstone, and grey, calcareous sandstone, with species of *Myophoria* and *Pecten* typical of the *L.? poyana* fauna.

A section of the 'Grey beds' has been studied on the north side of Peace River Valley, west of Schooler Creek. It is not all exposed, however, and only parts of it can be observed and described. The lowest exposed beds are seen on Mahaffy Creek, a small stream that crosses the low flat between Mahaffy Cliffs and the bank of Peace River (*See* Figure 8). Here are low exposures of grey, calcareous, fine sandstone and grey limestone with shells of the *Nathorstites* fauna. Higher, both in elevation and stratigraphically, in the steep ledges of the Mahaffy Cliffs, are fine, calcareous sandstone, calcareous siltstone, grey, greenish grey, buff, and yellowish weathering, impure limestone, and very rare, calcareous, coarse sandstone, all containing specimens of pelecypods belonging to what has been called the Mahaffy Cliffs fauna (McLearn, 1941B). Towards Kerr Spur and the mouth of Schooler Creek, the southeast dip carries the beds with the Mahaffy cliffs fauna below river level, and higher beds of the *poyana* zone are exposed on the south slopes of Kerr Spur (*See* Figure 8). Here are ledges of fine, calcareous, grey sandstone, calcareous siltstone, and grey limestone, with a few fossils characteristic of the *L.? poyana* zone (McLearn, 1941B).

Farther west, the 'Grey beds' are well exposed on Brown Hill (*See* Plate V A), on part of the west spur and on all of the east spur (*See* Figure 8). A section studied by McLearn is, in descending order, as follows:

	Thickness Feet (Estimated)
Overlying Pardonet beds on west spur	
Limestone, grey; sandstone, fine, calcareous; siltstone, calcareous; with a few fossils, apparently of the *L.? poyana* zone; measurement includes some concealed beds	200
Sandstone, coarse, massive, barren	200
Sandstone, calcareous, fine; siltstone, calcareous; grey limestone; measurement includes concealed beds	450
Sandstone, fine, calcareous; limestone, grey; siltstone, calcareous; with brachiopods	400
Sandstone, fine, calcareous; limestone, grey; some siltstone, calcareous; with brachiopods, pelecypods, and ammonoids of the *Nathorstites* fauna	500
Similar beds, with fewer fossils	400+
Underlying "Dark siltstones" of Folded Hill Creek	

East and West Glacier Spurs (not on map), on the south side of Peace River, are on the line of strike of the strata of the east and west spurs of Brown Hill, respectively (*See* Figure 8). The East Glacier Spur, like the east Brown Spur, is underlain by massive, calcareous sandstone and limestone with the *Nathorstites* fauna. All strata are concealed between East and West Glacier Spurs. On the eastern slope of the west spur, however, are good exposures of the uppermost part of the 'Grey beds', including grey, massive limestone and grey, fine, calcareous sandstone.

The upper part of the 'Grey beds', including the *Lima? poyana* zone, is well exposed at the east end of Pardonet Hill (*See* Plate V B) in an area drained by Laurence Creek (*See* Figure 9). The section has been measured by McLearn (1947) and, in descending order, is as follows:

	Thickness Feet (Approximate)
Sandstone, thick-bedded, massive, fine and very fine, grey, calcareous; limestone, shelly or finely crystalline, partly crinoidal, grey; siltstone, grey, calcareous; with the *Lima? poyana* fauna	520
Sandstone, massive, calcareous; mostly barren, but with rare fossils, including *Myophoria* and *'Orbiculoidea'*	280

Aylard Summit and Hackney Hills

H. H. Beach (field notes) has collected specimens of the *Nathorstites* fauna on Aylard Summit[1], about 10 miles north of the mouth of Aylard Creek. There the lower part of the 'Grey beds' is evidently present. Beach has also found the lower part of the 'Grey beds' on the east side of the Hackney Hills, 1½ miles north of Graham River, where he has collected specimens of the *Nathorstites* fauna.

Halfway River Valley

The 'Grey beds' are known to occur at several localities in Halfway River Valley, but very little information concerning them is available.

Calcareous sandstones and grey limestones are exposed north of the pack-trail on the north side of Halfway River, 7 or 8 miles west of Quarter Creek. They contain a few pelecypods, and appear to belong to the lower part of the 'Grey beds'.

The 'Grey beds' are well exposed on Mount Wright on the north side of Halfway River (*See* Plate III B). They overlie the 'Dark siltstones' in the upper part of the Fourth Gully where they consist of grey, massive, fine, calcareous sandstone and grey limestone. They also overlie the 'Dark siltstones' between Second and Third Gullies, where they are exposed at intervals in protruding ledges, dipping steeply to the west, and consist of massive, thick-bedded, grey, fine, calcareous sandstones and grey limestones with rare fossils. Higher beds at Second Gully include thick-bedded, grey, calcareous, fine sandstone, siltstone, and some limestone. Higher beds of this unit are concealed on the lower slopes of Mount Wright between First and Second Gullies (McLearn, 1946A).

[1] Aylard Summit has not been located on any map. It lies, however, about 10 miles north of Gold Bar or north of mouth of Aylard Creek.

Sikanni Chief River Valley

A section of the 'Grey beds', but with long concealed intervals, can be studied on the west slope of Mount Hage (*See* Figure 6 and Plate IV A). The lowest strata are exposed on the east slope of Hage Creek Valley, where they overlie the 'Dark siltstones' and comprise 50 feet of hard, massive, thick-bedded, grey, calcareous, fine sandstone with species of the *Nathorstites* fauna. These are overlain, on the higher eastern slope of this creek valley, by massive, calcareous, fine sandstone with a 10-foot bed of grey limestone at the top. Above this, across a nearly flat area, a concealed interval extends to where ledges of massive, calcareous, fine sandstone with pelecypods are exposed. From these ledges, up the steep slope of the mountain, the beds, amounting to hundreds of feet in thickness, are concealed. Above are ledges of massive, grey, fine sandstone and fine-grained limestone. Near the top of the slope these beds are overlain by the darker and finer grained strata of the Pardonet beds (McLearn, 1946A).

Not far from where Hage Creek issues on the flat bordering the main river, are exposures of fine, calcareous sandstones and shaly siltstones carrying species of the *Nathorstites* fauna. They evidently belong to the lower part of the 'Grey beds'.

Hage (1944) obtained fossils from the lower part of the 'Grey beds' on Mount Withrow, but did not describe the section.

On the crest of the anticline crossing Sikanni Chief River east of the mouth of Chicken Creek, the Pardonet beds are underlain by grey limestone with *Gryphaea* and other fossils. It is probable that this limestone lies at the top of the 'Grey beds'.

Prophet River Drainage Basin

'Grey beds' with the *Nathorstites* fauna have been observed along Prophet River. No particulars of lithology or succession are available.

Age and Correlation

(*See* Figure 5)

In the upper part of the 'Grey beds', a massive, mostly barren sandstone occurs in the sections on both Brown and Pardonet Hills, just below the *Lima? poyana* zone. It is doubtful, however, if this lithological correlation can be carried very far.

The relation of the 'Flagstones', 'Dark siltstones', and lower part of the 'Grey beds' to the Liard formation is a problem of local correlation. The *Nathorstites* fauna ranges throughout the Liard formation. It is also present in the lower part of the 'Grey beds' and in the 'Dark siltstones'. The 'Flagstones' are mostly unfossiliferous; however, in the section on Fourth Gully, Mount Wright, the massive beds at the top of the 'Flagstones' carry brachiopods similar to, if not identical with, brachiopods in the *Nathorstites* fauna and in the 'Dark siltstones' and lower part of the 'Grey beds'. If this means that the 'Flagstones' do carry representatives of the *Nathorstites* fauna, then the 'Flagstones', 'Dark siltstones', and lower part of the 'Grey beds' of the section on Halfway and Sikanni Chief Rivers are to be correlated with the Liard formation on Liard River on the basis of their common fauna.

The 'Grey beds' contain the *Nathorstites* fauna below, the Mahaffy Cliffs and Red Rock Spur faunas near the middle, and the *Lima? poyana* fauna at the top. A study of these faunas should furnish evidence of the age of this unit.

The age and correlation of the *Nathorstites* fauna have been recently discussed (McLearn, 1947A). Two species of this fauna in British Columbia, *Spiriferina borealis* Whiteaves and *Dawsonites canadensis* Whiteaves, have been listed from float on Hamilton Bay, Kupreanof Island, Alaska (Martin, 1926). This occurrence is not recorded by Smith (1927).

Nathorstites alaskanus has been described by Smith (1947) from limestone a mile above the mouth of Nation River, Alaska. This species shows very little resemblance to any of the typical *Nathorstites* species of northeastern British Columbia.

The *Nathorstites* fauna has been reported from three localities within the Arctic Circle; on the island of Spitzbergen, on Bear Island, and on Kotelny Island. *Nathorstites*-bearing beds are present in the central and eastern parts of West Spitzbergen Island and on the nearby Barents Islands. They lie between the *Daonella* beds below and Rhaetic plant-bearing beds above (Stolley, 1911; Frebold, 1935), and are said to contain several species of *Nathorstites* of which one is in common with the *Nathorstites*-bearing beds of northeastern British Columbia. On the east coast of Bear Island, grey sandstone and dark shale with clay-ironstone concretions carry a fauna with *Nathorstites* (Boehm, 1903). They are the youngest known strata on the island, and are underlain by barren sandstone. The fauna of these beds includes *Nathorstites mcconnelli* var. *lenticularis* Whiteaves and *Dawsonites canadensis* Whiteaves, in common with the *Nathorstites* fauna of northeastern British Columbia. *Nathorstites* has also been reported from Kotelny, one of the New Siberian Islands (Diener, 1916).

The *Nathorstites*-bearing beds of northeastern British Columbia may also be correlated with the European and southern Asiatic Triassic succession, particularly in the Mediterranean and Himalayan realms, on the site of the ancient Tethys seaway. Such a correlation has been briefly considered by McLearn (1947A) and will be more fully treated in a later publication on the Triassic.

Although the fossil evidence does not appear to afford decisive evidence for either a Ladinian or Karnian age of the *Nathorstites* fauna in northeastern British Columbia, it does somewhat favour the former age. The possibility, however, of an early Karnian age or an age intermediate between Ladinian *P. archelaus* and Karnian *Trachyceras* time is not ruled out. It is evident that some of the uncertainty arises from the similarity of the *P. archelaus* and *Trachyceras* faunas, a similarity that has been noted by Spath (1934).

The age of the *Nathorstites* fauna of Spitzbergen and Bear Island is not necessarily the same as that of the *Nathorstites*-bearing fauna of northeastern British Columbia. Indeed, the recorded occurrence of *Halobia* rather weights the evidence in favour of a Karnian and Upper Triassic age of the fauna preserved at these northern localities.

The Mahaffy Cliffs fauna includes numerous species of pelecypods, among them being *Lima* cf. *striata* var. *lineata* Schlotheim, *Myophoria*

(*Tropiphora*) cf. *laevigata* Zeithen, and *Myophoria* (*Tropiphora*) cf. *ovata* Goldfuss. These species recall the German Triassic and suggest an age not later than Middle Triassic. The somewhat similar Red Rock Spur fauna contains, among other pelecypods, *Myophoria* (*Tropiphora*) cf. *laevigata* Zeithen, *M.* (*Tropiphora*) cf. *laevigata* var. *elongata* Philippi, and *Lima* cf. *striata* var. *lineata* Schlotheim, also suggesting the German Triassic and an age not later than Middle Triassic. These two faunas are not known outside of Peace River Valley in northeastern British Columbia.

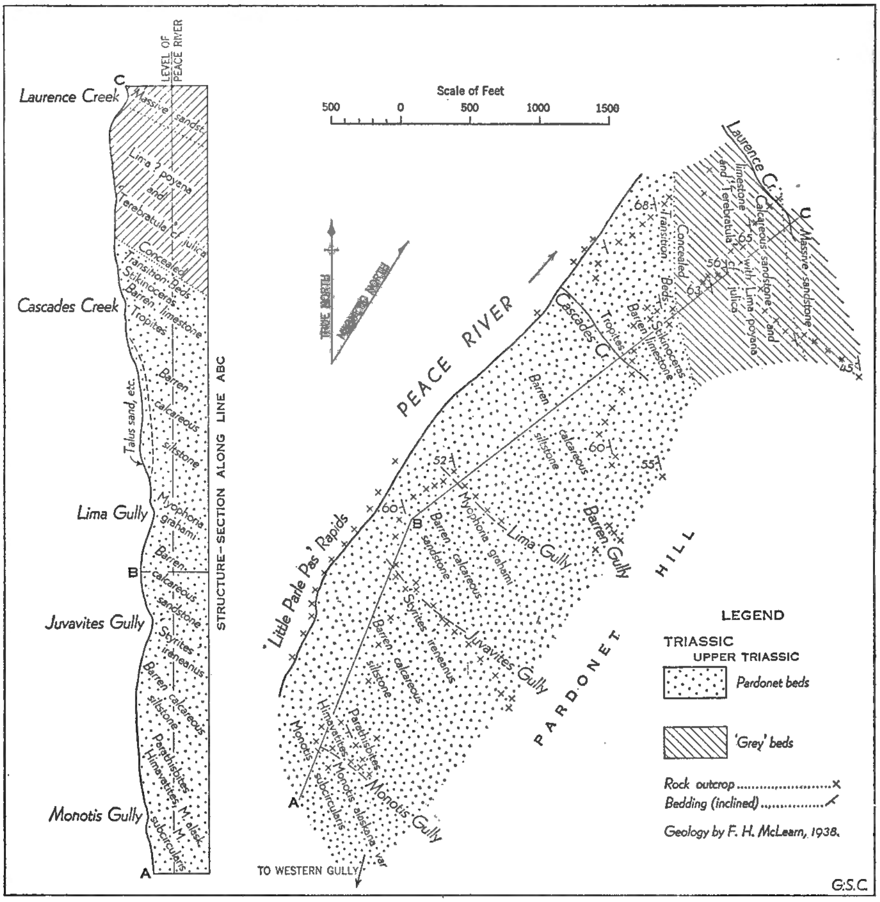

Figure 9. Geology of Pardonet Hill, Peace River Foothills, showing faunal and lithological zones.

The *Lima? poyana* fauna comprises a brachiopod, several pelecypods, and probably a single species of an ammonoid. The brachiopod, '*Terebratula*' cf. *julica* Bittner suggests a Karnian age, as does also the ammonoid *Sirenites* sp. Specimens apparently close to *Myoconcha curionii* Gemmellaro also suggests a Karnian age. A tentative correlation with the early Karnian of Europe has, therefore, been proposed (McLearn 1940). '*Terebratula*' *julica* has been listed from the Lewes River group of the Yukon

(Lees, 1934) and from the Luning formation of Nevada (Muller and Ferguson, 1939).

PARDONET BEDS

Definition

The name 'Pardonet' has been proposed by McLearn (1940) for the higher, finer, and darker beds of the Schooler Creek formation. Experience in recent years has shown that these beds constitute a good, practical mapping unit from at least Sikanni Chief River to Pine River, and they will probably be treated in the future as a formation.

The Pardonet beds comprise dark, calcareous shales, dark, calcareous siltstones, with small proportions of dark limestones, and, rarely, fine, calcareous sandstones. A characteristic layer, in places, is a fissile, dark, calcareous siltstone, which owes its 'cleavage' to closely packed and flattened shells of *Halobia*. The thickness varies from about 250 feet to possibly more than 2,000 feet, the greatest thicknesses being found in the more western sections. The contact with the underlying 'Grey beds' is conformable, and in most places gradational, so that it is difficult to choose the exact plane of demarcation. The contact with the overlying Jurassic beds of the Fernie group is disconformable.

Pine River Foothills

Very little is known of the Pardonet beds in Pine River Valley. *Monotis subcircularis* Gabb and '*Monotis*' n.sp. from near the mouth of Mountain Creek, collected by Williams and Bocock, record the presence of the upper part of the Pardonet beds. Other collections from Pine River Valley contain *Monotis alaskana* var.

Peace River Foothills

A section of the Pardonet beds has been studied by McLearn (1947) on Pardonet Hill (*See* Plate V B), on the south side of Peace River, east of the mouth of Nabesche River (*See* Figure 9), and, in descending order, is as follows:

	Thickness Feet (Approximate)
Siltstone, dark, calcareous; limestone; with *Monotis subcircularis* Gabb	90+
Siltstone, dark, calcareous; limestone, argillaceous; limestone, *Halobia*-bearing and shelly; *Himavatites* fauna	80
Siltstone, dark, calcareous; limestone, impure; *Parathisbites oineus* McLearn	90
Siltstone, dark, calcareous, unfossiliferous	250
Siltstone, dark, calcareous; limestone; '*Styrites*' *ireneanus* fauna	100
Sandstone, dark, somewhat calcareous, fine; unfossiliferous	360
Siltstone, dark, calcareous; shelly limestone; *Halobia* and brachiopods	35
Siltstone, dark, calcareous; unfossiliferous	30
Limestone, dark grey, partly shelly, partly crystalline, partly impure; *Myophoria grahami* McLearn	25
Siltstone, dark, calcareous; two lenses of limestone with *Spiriferina*	1,010
Limestone, grey, shelly; *Tropites*	10
Limestone, dark grey, argillaceous, crystalline	160
Limestone, grey, impure; limestone, *Halobia*-bearing, fissile; *Stikinoceras kerri*	70

	Thickness Feet (Approximate)
Sandstone, grey, calcareous; siltstone, dark grey, calcareous; limestone, partly crystalline, partly shelly; in places small shells, in places crinoid stems; transitional from 'Grey beds' to Pardonet beds	185

On the north side of the valley and on the strike of the rocks of Pardonet Hill is Black Bear Ridge [1]. Only a part of the section on this ridge has been studied. Dark limestones and siltstones with *Monotis subcircularis* Gabb outcrop on the west slope of the ridge, and are underlain farther up the slope by similar limestones and siltstones with *Monotis alaskana* Smith var. These beds are underlain near the crest of the ridge by dark siltstones and limestones with the *Himavatites* fauna. At a yet lower horizon down the south slope are beds with *Juvavites biornatus* (McLearn, 1947).

A section of the Pardonet beds has been measured by McLearn (1941) in a shallow gully on the west slope of the west spur of Brown Hill on the north side of Peace River, about 10 miles east of Pardonet Hill (*See* Figure 8). In descending order, it is as follows:

	Thickness Feet (Approximate)
Limestone, dark, shelly; siltstone, calcareous; *Monotis subcircularis* Gabb	60
Limestone, dark, shelly; siltstone, calcareous; *Monotis alaskana* Smith var.	20
Siltstone, calcareous; limestone, dark; *M. alaskana* Smith var. and *Himavatites*	20
Siltstone, dark, calcareous; limestone, dark; *Cyrtopleurites* sp.	20
Siltstone, dark, calcareous; limestone, dark; *Cyrtopleurites* cf. *bicrenatus* (Hauer), *Drepanites rutherfordi* McLearn, *Halobia* cf. *dilatata* Kittl	15
Siltstone, calcareous; limestone, dark, fissile; *Juvavites biornatus*.	15
Siltstone, dark, calcareous; limestone, dark; *Juvavites (Gonionotites) belli* McLearn, *Juvavites* (*Malayites*) sp.	15
Concealed	20
Limestone, dark grey; siltstone, calcareous; *Halobia* in some beds	20
Concealed	5
Siltstone, calcareous; limestone, grey	15
Concealed	15
Limestone, dark, shelly; siltstone, calcareous; *Stikinoceras kerri*	5
Concealed	10
Limestone, dark; siltstone, calcareous; *'Buchites' dawsoni*	10
Limestone, grey; siltstone, dark, calcareous; small pelecypods; transitional to 'Grey beds'.	

Compared with the section on Pardonet Hill, that on the west spur of Brown Hill is, first of all, much thinner. Thick zones of barren siltstones and fine sandstones are missing. Moreover, the succession of faunas is not quite the same. However, three faunas are common to both sections: the *Stikinoceras kerri*, *Himavatites* or *Monotis alaskana* var., and the *Monotis subcircularis* faunas. Other faunas occur in one section and not in the other. The faunal successions of the two sections are, however, probably complementary, and McLearn (1947) has inferred that the faunal succession

[1] This ridge is too small to show on the map. It lies north of Pardonet Hill and east of Nabesche River.

in the Pardonet beds in the Peace River Foothills is as follows, in descending order:

Monotis subcircularis Gabb
Himavatites, Monotis alaskana Smith var. *(Parathisbites oineus* McLearn)
Cyrtopleurites cf. *bicrenatus* Hauer, *Drepanites, Halobia* cf. *dilatata* Kittl
  (Juvavites biornatus McLearn)
'Styrites' ireneanus McLearn
Tropites sp.
Stikinoceras kerri McLearn

Typical dark, calcareous siltstones and dark limestones of the Pardonet beds overlie grey, calcareous sandstones and limestone of the 'Grey beds' on West Glacier Spur [1]. Pelecypods, confined to the Pardonet beds, have been collected in the lower part of these dark siltstones and limestones, and, at a little higher horizon (McLearn, 1941B), *Juvavites biornatus.*

Farther east in the Peace River Foothills, the Pardonet beds underlie the higher parts of Stelck Ridge, Schooler Hill, and Jewitt Spur, Childerhose Coulée, and the higher parts of McLay and Bell Spurs (*See* Figure 8). Here the Pardonet beds consist of the typical, dark, calcareous siltstones and the dark limestones. The contact with the underlying 'Grey beds' is transitional, and in places is difficult to locate, the coarse, massive, grey beds passing gradually upward into the finer, less massive, and darker Pardonet beds. Stelck Ridge (*See* Figure 8) is capped by strata of the lower part of the Pardonet beds. The southern ends of Schooler Hill and Jewitt Spur carry beds low in the Pardonet. Higher strata are encountered in ascending Schooler Hill to the north, and at the northern end are beds of the *Monotis alaskana* zone almost at the top of the Pardonet. The highest beds of this unit, however, those with *Monotis subcircularis,* appear to be eroded from Schooler Hill and Jewitt Spur, west of the Jewitt fault. East of the Jewitt fault, beds high in the Pardonet are exposed above the pack-trail, and carry numerous pelecypods. They are also exposed in a ledge on the bank of the river. In the ravine in the lower part of Childerhose Coulée (*See* Figure 8) are dark calcareous siltstones and limestones with numerous pelecypods. Higher in the same coulée are exposures of the highest Pardonet beds—shelly limestones and calcareous siltstones, with *Monotis subcircularis* Gabb. The lower part of the Pardonet beds, including dark, calcareous siltstones and dark limestones with ammonoids and pelecypods, is exposed at the south end of McLay Spur. The siltstones and limestones of the Pardonet beds also occur on the higher parts of Bell Spur and on the narrow ridge just east of Horseshoe Creek (*See* Figure 8).

West of Pardonet Hill, dark calcareous siltstones at the mouth of Nabesche Creek carry fossil remains of the marine reptile *Ichthyosaurus* (Williams and Bocock, 1932). The highest Pardonet beds, calcareous siltstones and impure limestones, with *Monotis subcircularis* Gabb, are exposed at Rapide-qui-ne-parle-pas, first observed by Selwyn in 1875. They are overlain disconformably by Jurassic beds of the Fernie group.

On the outer border of the Rocky Mountains, the *Monotis subcircularis* beds are exposed on Clearwater Creek. Ledges of dark, calcareous siltstone and limestone, on the north bank of Peace River west of the mouth of Point Creek, bear specimens of *Discotropites sandlingensis* Hauer, indicative of a late Karnian or early upper Triassic *Tropites* zone.

[1] West Glacier Spur is on the south side of Peace River and in alinement with the west spur of Brown Spur.

Aylard Summit

H. H. Beach and J. Spivak (field notes) have collected typical fossils of the Pardonet beds at Aylard Summit.

Halfway River Valley

A section of the Pardonet beds has been studied in the first gully at the west end of Mount Wright (*See* Plate III B) on the north side of Halfway River (McLearn, 1946A); in descending order it is as follows:

	Thickness Feet (Approximate)
Limestone, dark grey; *Monotis subcircularis* Gabb	30
Limestone, dark grey; *Monotis alaskana* var.	40
Limestone, dark, fissile, with *Halobia;* siltstone, calcareous	100
Siltstone, calcareous; limestone, dark, shelly and crinoidal, fossiliferous	200
Siltstone, calcareous, dark; sandstone, fine, dark, calcareous; fossiliferous	110
Siltstone, dark, calcareous; limestone, dark, argillaceous; sandstone, fine, dark, calcareous	110

The lowest 110 feet of this section may be transitional to the underlying 'Grey beds'. The three succeeding zones, although fossiliferous, contain long-ranging species, and their place in the zonal arrangement of the Pardonet beds is unknown. The 40 feet of limestone represent the *Himavatites* zone and the top 30 feet obviously belong to the *Monotis subcircularis* zone.

The Pardonet beds have also been recognized on the trail just west of Grave Creek, on the north side of the river.

The Triassic beds mapped by Hage (1944) at 'the Notch' on Pink Mountain and also in Pink Mountain Pass include beds of the high *Monotis alaskana* var. zone, but possibly not the highest zone of the Pardonet beds, for *Monotis subcircularis* is not present in any collections from Pink Mountain. Lower parts of the Pardonet beds may occur here, but have not been recorded.

Sikanni Chief River Valley

A good Triassic section was found by Hage (1944) on Sikanni Chief River, below the mouth of Chicken Creek. It comprises apparently all of the Pardonet beds and the highest of the 'Grey beds'. It has been studied in detail by McLearn (1946A), and, in descending order, is as follows:

	Thickness Feet (Approximate)
Siltstone, dark grey, carbonaceous, shaly, calcareous; *Monotis alaskana* var	12
Siltstone, massive, dark grey, calcareous; siltstone, shaly, calcareous; *Monotis alaskana* Smith var., *Himavatites columbianus* McLearn	13
Siltstone, shaly to fissile, dark, calcareous; limestone with 'knobs' of *Halobia*-bearing limestone; *Monotis alaskana* Smith var.	7
Limestone, hard, somewhat fissile; siltstone, calcareous; 'knobs' bearing *Halobia* shells and marine reptilian bones	9

	Thickness Feet (Approximate)
Siltstone, shaly to massive, calcareous; *Monotis alaskana* Smith var., *Himavatites*	10
Limestone, dark grey; limestone, shelly with abundant *Halobia;* siltstone, shaly, calcareous; *Halobia* cf. *dilatata* Kittl	7
Siltstone, hard, massive to shaly, dark, calcareous; 'knobs' of shelly limestone with small brachiopods; pelecypods	15
Limestone, massive to shaly; siltstone, calcareous; *Halobia*	4
Siltstone, calcareous, and limestone, massive to shaly, dark; limestone, shelly; *Halobia*	25
Siltstone, dark, shaly, calcareous; *Halobia*	30
Siltstone, dark, shaly, calcareous; *Gryphaea*	35
Siltstone, shaly, calcareous	40
Grey limestone, top of 'Grey beds'?	

If the grey limestone on the axis of the anticline at this locality is the top of the 'Grey beds', the thickness of the Pardonet beds here is about 160 feet. The top beds, the *Monotis subcircularis* beds, appear to be absent here as on Pink Mountain. The highest five zones in the above section, comprising 51 feet, are evidently of the *Himavatites-Monotis alaskana* var. zone. The sixth zone from the top, the 7 feet of limestone and siltstone, appears to be of the *H.* cf. *dilatata* or *Cyrtopleurites* cf. *bicrenatus* zone, which underlies the *Himavatites* zone in the section on the west spur of Brown Hill in the Peace River Foothills. The remaining and lower part of the section below Chicken Creek probably belongs somewhere between the *Stikinoceras kerri* and *'Styrites' ireneanus* zones on Pardonet Hill, or embraces them all; no zonal fossils are present, however.

The Pardonet beds can also be recognized about 10 miles farther west on the south side of Sikanni Chief Valley, high on the west slope of Mount Hage (*See* Plate IV A). The section is thicker and has fewer fossils than below Chicken Creek. It has been measured by McLearn (1946A) and, in descending order, is as follows:

	Thickness Feet (Approximate)
Limestone, dark, shaly; limestone, shelly; *Monotis subcircularis* Gabb	15
Limestone, dark, shaly; siltstone, calcareous; *Monotis alaskana* Smith var.	25
Concealed	170
Limestone, dark grey	150
Concealed	10
Shale, black, fissile; siltstone, dark, calcareous; very small shells of *Halobia*	30
Concealed	40
Limestone and calcareous sandstone of 'Grey beds'?	

The thickness of the Pardonet beds here is about 400 feet, a considerable increase over the thickness in the more eastern section below Chicken Creek. The uppermost 15 feet is of the *Monotis subcircularis* zone, apparently absent below Chicken Creek. The 25-foot section below the *M. subcircularis* beds is a part at least of the *M. alaskana* var. or *Himavatites* zone, although *Himavatites* is not present here. Other and lower zones cannot be identified in this section.

Hage has collected fossils characteristic of the Pardonet beds at two localities between Mount Hage and Chicken Creek, namely, on Sikanni Chief River $4\frac{1}{2}$ miles west of the lower trail crossing, and about 1 mile west of the same crossing. No particulars of the rocks at these places have been published.

Geologists of an oil company have collected fossils from near the top of the Pardonet beds in Sikanni Chief River Valley, about 6 miles west of Mount Withrow.

Prophet River Drainage Basin

The Pardonet beds are known to occur as far north as Klingzut Mountain where they have been observed by Dr. S. S. Holland of the British Columbia Department of Mines and by geologists of oil companies.

The Pardonet beds disappear to the north. They do not seem to be present in the Muskwa River drainage basin and certainly do not occur in Tetsa and Liard River Valleys. They also seem to disappear to the east, for at least the higher parts of the Pardonet beds have not been recognized on Pocketknife Ridge.

Age and Correlation

(*See* Figure 5)

Very little is yet known of the Upper Triassic series south of Pine River Valley. Dark, fissile siltstones with *Halobia* outcrop near Wapiti Lake and can be correlated with some part at least of the Pardonet beds.

Farther south, on Vine Creek, a tributary of Athabasca River in the Rocky Mountains, Parajaz (1931) has collected *Monotis* cf. *subcircularis* Gabb. The beds containing this species can be correlated with the highest of the Pardonet beds.

In southern British Columbia, in the Chilko Lake area, volcanic rocks and other beds described by Dolmage (1925) contain Triassic, probably Upper Triassic, fossils and may in part be of the same age as the Pardonet beds. In the Tyaughton Lake area (Cairnes, 1943) the Noel and Pioneer formations and the Hurley group have been referred to the Triassic and the Tyaughton group to the Upper Triassic. The Tyaughton group is equivalent in part at least to the Pardonet beds. The strata with *Monotis subcircularis* can be correlated directly with the highest of the Pardonet beds; the part of the group with *Cassianella* and *Myophoria* can probably also be correlated with some upper part of the Pardonet beds, but not necessarily the uppermost part. The Nicola group of the Princeton map-area (Rice, 1947) is of Upper Triassic age equivalent to the lower, if not as well higher, Pardonet beds. The fossils collected by Crickmay (1930) and by Duffell from the Nicola group in the Ashcroft area also suggest a correlation with the lower part of the Pardonet beds.

In central British Columbia the Triassic part of the Takla group in the Takla map-area (Armstrong, 1945) is probably in part equal to the Pardonet beds. In the Pinchi Lake Mercury belt (Armstrong, 1942) the limestone on the north shore of Pinchi Lake containing *Monotis subcircularis* is equivalent to the highest of the Pardonet beds; and the argillite on Halobia Creek may be the equivalent of some lower part of the Pardonet beds.

In northern British Columbia, in the Stikine map-area, Upper Triassic fossils have been collected from the sedimentary group of the Triassic series (Kerr, 1948). Fossiliferous strata on Kirk Mountain can be correlated with the highest Pardonet beds, and north and west of Flag Creek can probably be correlated with some of the lowest Pardonet beds. The Thibert group in the Dease Lake area (Kerr, 1926) may be equivalent in age to some part of the Pardonet beds.

Triassic beds are known in parts of the Yukon. The *Monotis subcircularis* and *Monotis alaskana* var. zones of the Pardonet beds occur in a section near the forks of Rakla River (Keele, 1906). Lees (1934) has recognized beds of Upper Triassic age in the Lewes River group of the Teslin-Quiet Lake map-area, Yukon. That part of the group with *Monotis subcircularis* can be correlated with the highest Pardonet beds; the part with *Juvavites subinterruptus* Mojsisovics can be correlated with much lower Pardonet beds.

Upper Triassic strata are present in southeastern Alaska in Chitina Valley (Smith, 1927). The Chitistone formation carries *Tropites*, which is also present in the lower part of the Pardonet beds. The Nizina limestone is unfossiliferous, and the higher McCarthy formation carries *Monotis subcircularis* and so can be correlated with the highest Pardonet beds. The fossiliferous strata on Stelna Creek, from which Smith (1927) has recorded *Halobia dilatata* Kittl, may be equivalent to some middle part of the Pardonet beds.

On Vancouver Island the Sutton limestone in the Vancouver group carries Upper Triassic fossils in the Cowichan Lake area (Clapp and Shimer, 1911). These fossils have nothing in common with those of the Pardonet beds, but may be close in age to high, but not the highest, Pardonet beds. The fossiliferous beds of the Bonanza group in the Nimpkish area (Gunning, 1932), with *Monotis subcircularis*, are of the same age as the highest Pardonet beds. Strata of this age are present in the upper part of the Parson Bay formation on Harbledown Island (Crickmay, 1928). Fossiliferous beds with *Tropites* and other fossil species collected by Gunning on Quadra Island are to be correlated with the lower part of the Pardonet beds.

In Houston Stewart Channel, Queen Charlotte Islands, argillites and limestones with *Monotis subcircularis* are equivalent to the highest Pardonet beds, and fossiliferous strata on Frederick Island are of the same age (MacKenzie, 1916).

The Triassic of the Hawthorne and Tonopah quadrangles, Nevada, has been described by Muller and Ferguson (1939). Comparison of the zones of the Pardonet beds with this Nevadan section has been attempted by McLearn (1947). The *Tropites* zone of the Pardonet beds can be correlated with the late Karnian *Tropites subbullatus* zone of the Luning formation. The *Stikinoceras* fauna has no exact counterpart in the Luning, but may be only a local, Peace River, phase of a part of the *Tropites* fauna. The same may be true of the '*Styrites*' *ireneanus* fauna. The *Himavatites* fauna has no exact counterpart in Nevada. Possibly it is in part equivalent to the early Norian (Haloritan) *Sagenites* cf. *giebeli* fauna of the Gabbs formation, or may represent an horizon in barren strata above the level of *S.* cf. *giebeli* in the Gabbs. *M. alaskana* does not appear to extend as far south as Nevada. *Monotis subcircularis* is not recorded from the Hawthorne-Tonopah quadrangles; Muller and Ferguson (1939), however, consider that the late Norian zone of *Pinacoceras* is equivalent to that of *Monotis subcircularis.* The Rhaetic zone of *Choristoceras marshi* Hauer and *Pteria* aff. *contorta* Portlock, present in the Gabbs formation, is not known in the Peace River Foothills, nor anywhere else in North America.

The lower part of the Pardonet beds, with *Tropites*, is correlated with the lower part of the Hosselkus limestone of California. The upper part, with *Monotis subcircularis*, is correlated with the Brock shale of California.

Correlation with Europe and Asia has been attempted by McLearn (1947) and will receive more attention in a forthcoming report on the Triassic of northeastern British Columbia. It is probable that the *Stikinoceras*, *Tropites*, and '*Styrites*' *ireneanus* faunas are of late Karnian, or Tropitan age in Spath's chronology. The *Cyrtopleurites* cf. *bicrenatus* or *Drepanites* tauna, including *Juvavites biornatus* and *Pterotoceras caurinum*, and the *Himavatites* fauna are of Norian age. The *Monotis subcircularis* fauna may be of late Norian time. No evidence of Rhaetic age has been found. Thus in terms of European nomenclature the Pardonet beds may range in time from late Karnian to late Norian or fairly early to fairly late Upper Triassic.

JURASSIC

The Jurassic system has not been thoroughly studied in northeastern British Columbia. Beds comparable with those of the Fernie group of the central and southern Foothills of Alberta have been observed, and it is possible that a lower part of the Bullhead group is of Jurassic age.

FERNIE GROUP

Definition

Spieker (1921) evidently intended that the formational name 'Pine River' should apply to the Jurassic shales lying between the Triassic beds below and the sandstone of the Bullhead group above, in Pine River Valley and, presumably also, in all of northeastern British Columbia. Wickenden and Shaw (1943), however, have pointed out that the shales of the Pine River formation at the type locality are not of Jurassic but of Lower Cretaceous age, and comparable with the Moosebar shales of the Peace River section. As a result, Hage (1944) has recommended that the name 'Fernie', long used for Jurassic strata in the southern and central Foothills, be applied to the Jurassic shales in northeastern British Columbia.

Pine River Valley

Spieker (1921) and Williams and Bocock (1932) record Jurassic shales in several parts of Pine River Valley. Stelck (1941) describes 835 feet of shale, siltstone, and some fine sandstone on Le Moray Mountain, on the upper part of Pine River. He also collected Jurassic fossils from Gold Creek.

Peace River Foothills

Dark shales, with sandy and clay ironstone layers at some horizons, outcrop on the southern slope of Branham Ridge west of Adams Creek (*See* Figure 8). They are mostly concealed and disturbed by landslides, but are exposed in a small creek draining the south slope of this ridge, and also on the north bank of Peace River, downstream from Branham Flat. At the latter locality the Fernie is at a much lower level than its actual outcrop, having moved downhill in a landslide. Only a few pelecypods have been collected at this place, and the thickness of the group is unknown.

Farther west, on the north side of Peace River between Tepee Rocks Spur and the west spur of Brown Hill, the depression called Tepee Rocks Coulée is excavated out of the easily eroded rocks of the Fernie group (*See* Figure 8). These rocks consist of about 700 feet of dark, partly carbonaceous shale; rare greenish, probably glauconitic shale; and some layers of impure limestone and very fine sandstone. The contact with the overlying beds of the Bullhead group is gradational and apparently conformable.

The valley of Black Bear Creek[1] on the north side of Peace River, north of Pardonet Hill, is carved out of the soft weathering beds of the Fernie. A section, measured by Beach and Spivak (1944), is as follows, in descending order:

	Thickness Feet (Approximate)
Shale, black, hackly, fissile; sandstone, dark grey, fine; clay ironstone, in many thin beds	125
Shale, black; sandstone, carbonaceous, dark brown, crossbedded; in thin beds	50
Shale, black, fissile; concealed intervals	925
Total	1,100

The contact with the overlying Bullhead is gradational; that with the underlying Triassic, disconformable.

Shales of the Fernie group also outcrop on Nabesche River, about 2 miles above its confluence with the Peace (Beach and Spivak, 1944). A section, 300 feet thick, consisting of beds of shale, 4 feet thick, and thin beds of limestone, is exposed in high cut banks (Williams and Bocock, 1932). This, of course, is only part of the group.

On the south side of Peace River, Beach and Spivak have seen shales of the Fernie in the vicinity of Stott Creek. Mathews (1947) has recorded 350+ feet of shaly beds on Indian Head and 500 feet of similar beds on the eastern slope of Carbon Peak.

Halfway River Valley to Sikanni Chief River Valley

Jurassic rocks have been reported from the west slope of Pink Mountain, about 3½ miles north of Halfway River, by Hage (1944). They comprise about 130 feet of dark grey to black, calcareous shale, with several beds of dark grey limestone and a 2-foot layer of argillaceous limestone at the base. The section contains marine fossils.

Below Chicken Creek, on Sikanni Chief River, Hage (1944) observed about 30 feet of Jurassic shale, but 11 miles to the west on the same river he measured 240 feet. Farther north, on a tributary of Minaker River, the Fernie shales are only 18 feet thick.

[1] A short creek on the north side of Peace River, immediately west of Black Bear Ridge and north of Pardonet Hill.

No Jurassic strata have been recognized in Tetsa River and Liard River Valleys. Either they have thinned out in that direction or are included in basal shales of the Garbutt formation.

Age

Very little is known of the age of the Fernie group in northeastern British Columbia, as few fossils of diagnostic value have been collected. The fossiliferous strata on Pink Mountain, recorded by Hage, and the basal beds of the Fernie on Black Bear Creek are of Lower Jurassic age.

LATE JURASSIC OR EARLY CRETACEOUS

CASSIAR BATHOLITH

The description of the Cassiar batholith is included at this point because of its generally inferred late Jurassic or early Lower Cretaceous age, and not because of any direct contact with the Fernie or Bullhead groups. Indeed, neither diastrophism nor intrusion, but a gradational sequence, marked the passage from the Fernie to the Bullhead in the Foothills of the Rocky Mountains in the eastern system of the Cordilleran region. The Cassiar batholith outcrops in a very different part of northeastern British Columbia, in the Cassiar Mountains of the Interior system of the Cordilleran region.

The Cassiar batholith has recently been described by Hedley and Holland (1941). It underlies a large area in the Cassiar Mountains, west of the Rocky Mountain Trench, that is, west of the valley of Kechika River and Sifton Pass.

"The rock is all quartz-bearing and light in colour, with a small amount of dark-coloured minerals, chiefly biotite. The dominant type is granite, but there is also granodiorite and some quartz diorite. Perhaps the commonest rock type is a pink granite or porphyritic granite, of rather coarse grain, which, when prominently porphyritic, contains orthoclase phenocrysts up to 2 inches in length. Another type, probably a border phase, is a medium to fine-grained, grey, speckled mica-granite. A third type, one occurring in the southern part, is a grey to white porphyry, quartz-bearing and with little or no pink orthoclase."

Hedley and Holland note a roof pendant between the head of Mosquito Creek and the mouth of Three Forks Creek, "and at least one other was seen several miles to the northwest". They describe outlying bodies of diorite and quartz diorite near the head of Wheaton Creek and rare dykes of porphyry, andesite porphyry, diorite, and lamprophyre at several localities. They note also the abundance of pegmatite in the southern part of the region. With all of this detail they furnish little information concerning what formations are intruded, and offer little or no evidence on the age of the intrusion.

Farther south, in the Aiken Lake map-area, Roots (1948) is able to prove that the similar intrusions of the Omineca batholith are of Upper Jurassic or early Lower Cretaceous age (*See also* Armstrong, 1945).

LOWER CRETACEOUS AND ? EARLIER

BULLHEAD GROUP

Definition

Bullhead Mountain was proposed as a formation name by McLearn, in 1918, to comprise a succession of shales, sandstones, conglomerates, and coal seams lying between the Triassic strata and the late Lower Cretaceous Fort St. John group in the Peace River Foothills. Although it is now known that both the shales of the Fernie group and the sandstones, shales, and other beds of the Bullhead group lie between the late Triassic Pardonet beds and the late Lower Cretaceous Fort St. John group, it is evident from the 1918 description that it was not the intention to include the shales of the Fernie group in the Bullhead, and, indeed, their occurrence in the section was unknown at the time. In the original description, the formation was divided into lower and upper parts, and subsequently the name of Gething was given to the upper part (McLearn, 1923). In 1943, Wickenden and Shaw proposed that the name Bullhead Mountain be shortened to Bullhead, and that it be recognized as a group name. In 1944, Beach and Spivak gave the name of Dunlevy to the lower Bullhead in the Peace River Foothills, raised both Dunlevy and Gething to the rank of formations, and united them in the Bullhead group. The areas studied by Beach and Spivak, by Wickenden and Shaw, and by McLearn were in the eastern Peace and Pine River Foothills, and it is to the Bullhead group of this part of the Foothills that the Dunlevy-Gething classification has been applied.

Recently, Mathews (1947), working in the western part of the Foothills and particularly in the Carbon Creek basin, has questioned the Dunlevy-Gething classification, at least in so far as it can be applied to the section in the western Foothills. He has devised a new classification, one that he has used in the mapping of the Carbon Creek-Mount Bickford map-area:

Bullhead group
    Non-marine Bullhead (coal measures)
    Marine Bullhead: Monach formation
        Beattie Peaks formation
        Monteith formation

The Monteith, Beattie Peaks, and Monach formations of this classification are together about equal to that part of the Dunlevy formation that lies below the upper, conglomerate- and coal-bearing part. The 'non-marine Bullhead' corresponds roughly with the upper, conglomerate- and coal-bearing part of the Dunlevy plus all of the Gething formation. It is difficult to reconcile this dual nomenclature within the Bullhead group or evaluate the relative merits of the two classifications. Much depends on the results of future field work, but it may be that the western and eastern lithological successions are different and call for two, independent classifications. The Bullhead group has not been divided north of Peace River Valley.

Pine River and Peace River Foothills

Table of Eastern Formations

Group	Formation	Thickness	Lithology
		Feet	
Bullhead	Gething	1,400+	Non-marine sandstone and shale; coal seams
	Dunlevy	3,000 to 3,200	Non-marine conglomerate, sandstone, and shale; thin coal seams above; partly marine?, massive, thick-bedded sandstone; some shale below.

Dunlevy Formation

The Dunlevy formation is well exposed in the eastern part of the Peace River Foothills, on Portage Mountain, on Butler Ridge, in the upper part of Peace River Canyon (*See* Plate VI A), on the lower slopes of Mount Gething, on Branham Ridge, and in the ridges and cliffs of Rainbow Rocks. For the purpose of description it may be divided into two parts, a lower and an upper.

A section of the lower part was measured by Beach and Spivak (1944) on the lower slopes of Mount Gething, where it consists of 2,440 feet of mostly thick-bedded, very hard, fine-grained, quartzitic sandstone interbedded with dark, carbonaceous shale. Some sandstones are massive, others are bedded, and some are crossbedded. Some are brown and somewhat carbonaceous. The sandstone beds are from 10 to more than 100 feet thick. The shale beds are thinner, and vary from very thin to beds more than 25 feet thick; an exception, however, is a bed or zone of shale 143 feet thick, about 700 feet above the base of this section. Beach and Spivak note that at least 200 feet should be added to the thickness of this part of the formation at this locality to account for concealed beds between the top of the section described and the base of the upper and conglomerate-bearing part of this formation. The contact with the underlying Fernie group is gradational.

The upper part of the Dunlevy formation differs from the lower part in the presence of conglomerates and thin coal seams. Beach and Spivak (1944) record 400 to 600 feet of "massive, crossbedded, coarse-grained, grey to reddish weathering, conglomeratic sandstones and grits, in beds 5 to 20 feet thick, interbedded with 6-inch to 2-foot beds of buff weathering, fine-grained sandstones, carbonaceous shales, and thin coal seams. Some beds consist entirely of conglomerate with pebbles up to 2 inches in diameter and averaging ½ inch. The pebbles are angular to subrounded, and consist of green and black chert, white quartz, and quartzite. Individual conglomerate beds are commonly lenticular and wedge out rapidly along the strike of the beds". Beach and Spivak measured 400 feet of the conglomerate member on Mount Gething and at least 600 feet on Butler Ridge. McLearn and Irish (1944) record conglomerates, fine sandstones, siltstones, dark shales, and thin coal seams. Some of the fine sandstones and siltstones in this upper part are ripple-marked, and carry fossil wood fragments and fine plant debris. The toal thickness of the Dunlevy formation is estimated by Beach and Spivak to range from about 3,000 to 3,200 feet.

The upper and conglomerate bearing part, with thin coal seams, is of non-marine origin. The lower part may be of marine origin, like the Monteith, Beattie Peaks, and Monach formations in the western sections of the Foothills, but no definite evidence of origin is yet available.

Gething Formation

The Gething formation, in the eastern Peace River Foothills, has received considerable attention from geologists because of its coal seams. It has been studied by Galloway (1913), McLearn (1923), Williams and Bocock (1932), Beach and Spivak (1944), and McLearn and Irish (1944). It is particularly well exposed in Peace River Canyon (*See* Plate VI B), where it has been studied in detail. It also occurs on the east slope of Portage Mountain, the east side of Butler Ridge, in Dunlevy Valley, and on Mount Gething.

The Gething overlies the Dunlevy formation conformably, the plane of demarcation being drawn where conglomerates and coarse sandstones become rare or disappear, and fine sandstone, shale, and coal seams become more common; this change may not everywhere take place at the same stratigraphic horizon. In Peace River Canyon, the Gething formation has been estimated to be more than 1,400 feet thick.

Many different kinds of sedimentary rocks comprise the section of this formation exposed in Peace River Canyon (McLearn, 1923). The shale beds are 2 inches to 10 feet thick; some are grey to black and have a shaly structure; others are black and carbonaceous and are fissile; still others are arenaceous. Clay ironstone occurs both as concretions and as thin or thick continuous layers in the shales. Thick zones of thin-bedded siltstones or very fine sandstones (flagstones) form layers 1 inch to 5 inches thick, and, here and there, are interbedded with dark grey shales; the latter occur as very thin beds and may show well-defined mud-cracks. Many of the flagstones show symmetrical ripple-marks. Beds of sandstone, from about 1 foot to 12 feet thick, vary from fine to coarse, and from massive to banded; some are crossbedded on a large scale; some are argillaceous, some carbonaceous or micaceous; the colours are white, cream, pale yellowish, yellowish grey, dark grey, and brown. Thicker beds or zones of sandstone, from 15 to 25 feet thick, in the lower part of the Gething formation persist for more than 2 miles in the upper part of Peace River Canyon and have been mapped as members (McLearn and Irish, 1944; and Figure 10). They include several kinds of sandstones—massive, evenly bedded, crossbedded, coarse to fine grained, and here and there may carry lenses of conglomerate. Commonly they rest with slight erosional unconformity on subjacent beds due to the removal of a foot or more of sediment prior to the accumulation of the sand.

Various plant remains are found in the Gething of the Peace River Canyon section: fronds, stems, fine woody fragments, large pieces of wood, 'drift wood', tree trunks lying prostrate along the bedding, vertical rootlets, and, rarely, upright 'stumps'. The coarser remains are in the sandstones. Identifiable plant remains are those of ferns, cycads, conifers, and a single seed, apparently allied to that of the living gum or *Nyassa* (Bell, 1944).

Shells, probably non-marine, are rare. They are poorly preserved and indeterminate.

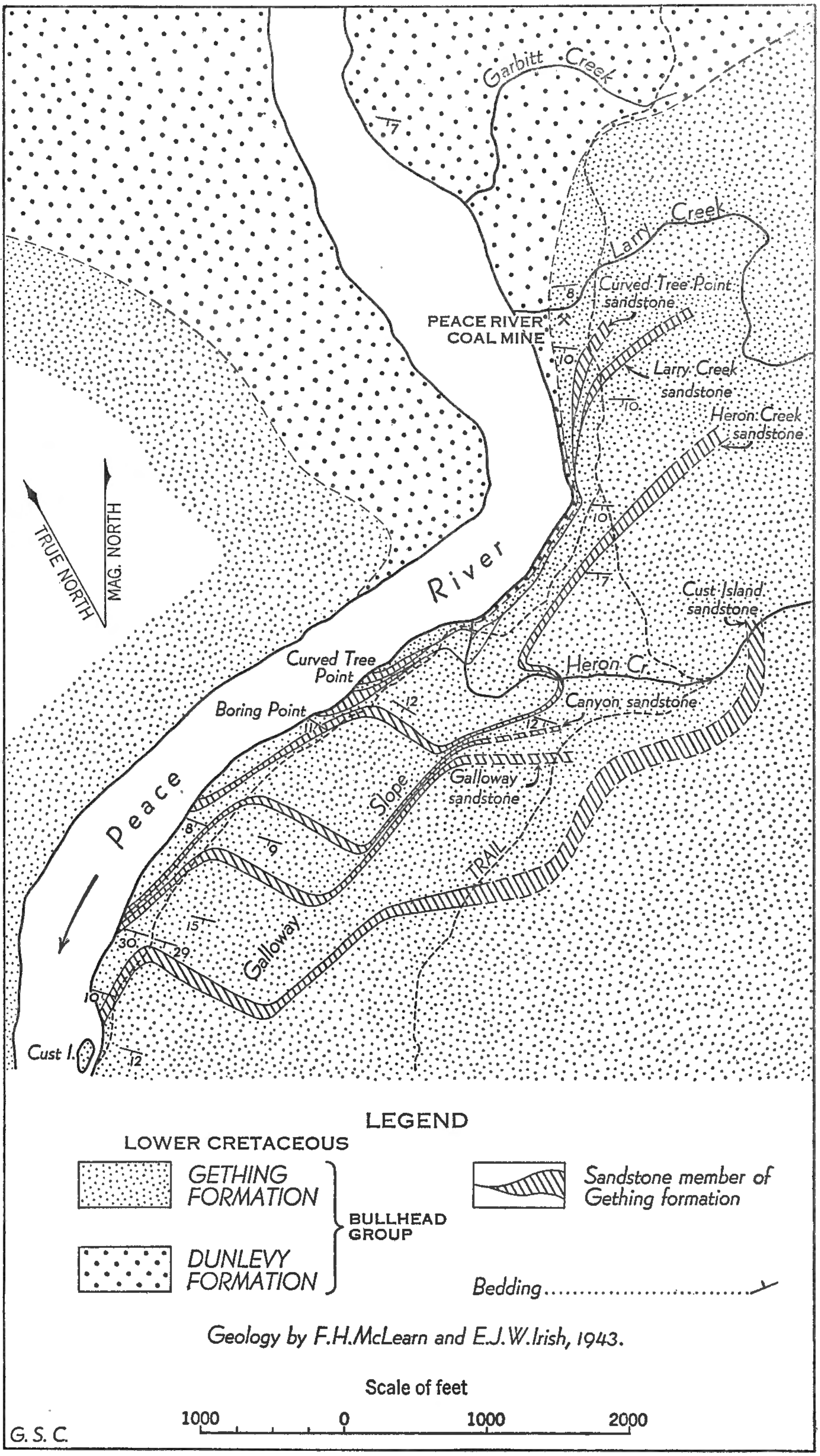

Figure 10. Geology of upper part of Peace River Canyon.

Footprints of dinosaurs, first discovered by McLearn (1923), have been later collected and described by Sternberg (1932). They occur mostly in trackways on the surfaces of the thin-bedded siltstones and fine sandstones or flagstones, but also on layers of clay ironstone. These footprints have been found in Peace River Canyon from near Grant Flat upstream to Ferro Point (*See* Figure 11). Both carnivorous and herbiverous dinosaurs, including, possibly, horned dinosaurs, are represented. Sternberg (1932) has referred them to six genera and eight species. No bones of these reptiles have been discovered.

In the section of Dunlevy Creek, sandstone, shale, and thin coal seams have been recorded by Williams and Bocock (1932). A section on Hasler Creek in Pine Valley, about 550 feet thick and representing only a part of the formation, has been described by Spivak (1944). It consists of shales, siltstones, sandstones, and coal. The shales, in 6-inch to 16-foot beds, comprise black, fissile types with concretionary bands or irregular nodules; grey, black, hackly shale; brown weathering carbonaceous shale, with coal seamlets; and arenaceous shale. The siltstones, in 16-inch to 8-foot beds, are dark grey, buff weathering and laminated and some have ironstone concretions. Sandstones range from 4 inches to 18 feet thick, and are massive or thin bedded, and grey, cream, or buff weathering; some are micaceous and some are ripple-marked. The section also includes many coal beds.

These beds of the Gething formation are mostly or entirely non-marine. This is attested by the abundance of plant remains, absence of marine fossils (so far as known), by many rootlets, by lack of boring mollusks in the fossil wood, and by the tracks of land animals (McLearn, 1923). Many kinds of subaerial, plain environment are recorded by the sediments, but only a special study would permit their complete restoration. The fossil stumps and tree trunks record forest growth, and the coal seams indicate swamps of great extent. The thick, massive sandstones are probably the result of great floods from the Cretaceous mountains. The ripple-marked, thin-bedded siltstones and fine sandstones, with thin layers of shales, accumulated in shallow ponds or in shallow, temporary flood-plain 'lakes'. The mud-cracks in the shale record stages when, in the dry seasons, the ponds or 'lakes' dried up and left broad mud flats. It was across these flats that the dinosaurs walked and left their trackways (McLearn, 1931A; McLearn, in Sternberg, 1932). Brackish water or marine habitats have not yet been recorded.

Table of Western Formations

In the Carbon Creek-Mount Bickford map-area, in the western part of the Foothills between Pine River and Peace River Valleys, Mathews (1947) has divided the Bullhead group into the following formations:

Group		Formations	Lithology
		Thickness in feet	
Bullhead		Non-marine Bullhead 4,000-4,500	Non-marine sandstone, shale, and conglomerate; coal seams
Bullhead	Marine Bullhead	Monach 300-400	Marine sandstone; some shaly beds
Bullhead	Marine Bullhead	Beattie Peaks 600-1,200	Marine shale
Bullhead	Marine Bullhead	Monteith 1,000-1,750	Marine sandstone; some shaly beds

Monteith Formation

'Monteith' was proposed as a formational name by Mathews (1947) to embrace a thick succession of sandstones lying between the underlying Fernie shales and the overlying Beattie Peaks formation. It is said to be well exposed on the north face of Mount Monteith, and this, presumably, is the type locality of the formation.

The Monteith formation has a wide distribution in the Carbon Creek-Mount Bickford map-area, extending around all of the Carbon Creek basin from Mount Monteith north to the valley of Peace River and extending also south to the headwaters of Beaudette Creek, a tributary of Pine River. Mathews states that the formation is 1,750 feet thick on the western slope of Beattie Peaks, but does not exceed 1,000 feet in the north at Indian Head.

The lower and greater part consists of "dark grey arkosic sandstone, massive to flaggy, and in places showing crossbedding and ripple-marks. This sandstone occurs in beds usually from 10 to 30 feet thick, each separated by a few feet of shale or shaly sandstone". The upper part consists of 500 feet "of white quartzite, commonly stylolitic and locally vuggy" (Mathews, 1947). The contact with the underlying Fernie is said to be conformable.

Mathews favours a marine origin. "No terrestrial fossils, plant fragments, or coaly beds have been found." Marine fossils are present in talus from either the upper part of the Monteith or lower part of the Beattie Peaks formation. Mathews notes that crossbedding and ripple-marks suggest "that the sediments were deposited in shallow water".

Beattie Peaks Formation

The Beattie Peaks formation was established by Mathews for a lithological unit, mainly of shale, lying between the coarser sediments of the Monteith formation below and of the Monach formation above. It is well exposed on the western slopes of Beattie Peaks, the type locality.

Like the Monteith formation, the Beattie Peaks extends as a rim around the Carbon Creek basin. It is about 1,200 feet thick on Beattie Peaks, about 750 feet at Indian Head, and 600 to 700 feet on Beaudette Creek (Mathews, 1947). It consists of shales, shaly sandstone, sandstone, and, in a few localities, quartzite. "A few beds of clay ironstone, rarely more than 4 feet thick, are present." Marine shells were collected. Plant fragments, "but no other fossils of continental origin were seen. The formation is probably marine".

Monach Formation

The Monach formation, established by Mathews (1947), contains marine, massive sandstones lying between the dominant shales of the Beattie Peaks below and the non-marine Bullhead group above. It is well exposed on The Monach and on Beattie Peaks, and extends around the border of the Carbon Creek basin and south to Beaudette Creek. It is from 300 to 400 feet thick.

"The Monach formation consists of several thick sandstone members, each separated by a few feet of shaly beds. Much of the sandstone occurs in coarse crossbedded layers which weather into stacks of plates, each about one half to 1 inch in thickness and 1 foot or more across." The Monach rests conformably on the underlying Beattie Peaks formation. Marine shells have been found in it by Mathews, who includes it in his marine Bullhead.

Non-marine Bullhead

The upper and non-marine part of the Bullhead group, overlying the marine Monach formation in the Carbon Creek-Mount Bickford map-area, is not subdivided by Mathews, but is left in one unit, called 'Non-marine Bullhead' or 'Coal Measures'. It is approximately equivalent to, but is thicker than, the upper and conglomeratic, coal-bearing part of the Dunlevy plus all of the Gething of the eastern section of the Bullhead. Mathews records a thickness of 4,000 to 4,500 feet. It underlies a large area in Carbon Creek Valley and a smaller area in Fisher Creek Valley. It also outcrops on Beaudette Creek and east of Falling Creek.

The 'Non-marine Bullhead' consists principally of alternating beds of sandstone and shale, ranging from a few feet to 30 feet in thickness. Some sandstones and siltstones have symmetrical ripple-marks. Carbonaceous shales are recorded, and conglomerate occurs with sandstone in thick zones. A 20-foot bed of conglomerate was observed "at the base of the coal-measures on the Beattie Peaks and 2 miles west of Mount Monteith, but is elsewhere apparently absent . . . . Massive sandstone and conglomerate, 30 feet in thickness occur about 1,100 feet above the base of the coal-measures on Mount Bickford". Mathews also records that a "lenticular conglomerate zone, 20 to 50 feet thick, possibly 1,500 feet above the base of the coal-measures, marks a distinct erosional unconformity" . . . at "two localities on the hill 4 miles west of Mount Monteith; at one locality it rests upon beds about 30 feet stratigraphically higher than at the second locality 100 yards away. Fossils below this unconformity, however, are similar in age to those at higher horizons in the coal-measures". A thick sandstone member, 55 feet thick, includes some conglomerate and outcrops "near the mouth of Ten (10 Mile) Creek and at least 3,500 feet above the base of the non-marine beds . . . Conglomeratic bands, one about 8 feet thick and another about 25 feet thick, outcrop on Eleven (11 Mile) Creek between 3,500 and 4,500 feet above the base of the continental beds".

Coal seams are found in various parts of the 'Non-marine Bullhead', "but thick seams are most common in the upper part of the coal-measures" (Mathews, 1947). Fossil plants include a liverwort, ferns, cycads, and conifers.

Halfway River to Pocketknife River

Undivided Bullhead Group

The Bullhead group has not been subdivided north of the Peace River Foothills. Although it must have a wide distribution there, it has only been examined and mapped in a few places and only studied in detail at one locality. No record has been made of the nature and distribution of this group in Graham, Chowade, and Cypress Valleys.

Not much is known of the distribution of the Bullhead on Halfway River. Massive sandstones are exposed on a high ridge on the north side of the river about 5 or 6 miles west of the mouth of Quarter Creek. Sandstones, thin-bedded siltstones, and grey and black, carbonaceous shale, with fossil plant fragments, outcrop in the lower part of Grave Creek. Thick sandstone ledges also appear on the west side of this valley and extend up on a high hill where the rocks are folded into an anticline and syncline. The basal sandstones of the Bullhead group are exposed also on the west slope of Mount Wright.

The Bullhead outcrops on Pink Mountain, where it occupies most of the top of the hill and all of the flanks. It has been described by Hage (1944). At the base is a coal seam, more than 5 feet thick, which is "overlain by 140 feet of fine-grained, dark grey sandstone interbedded with dark grey and carbonaceous shale". Hage notes that these "beds resemble the Kootenay formation in the Foothills of southern Alberta, and are overlain by coarse-grained, quartzitic sandstone beds with conglomerate and scattered pebbles of chert, quartzite, limestone, altered ironstone, and porphyry in the basal part. Minor amounts of dark grey, carbonaceous shale are interbedded with the sandstone".

The Bullhead is exposed in two good sections on Sikanni Chief River, both of which are north of Pink Mountain. It is also present at the upper waterfalls and on the top of Mount Hage. One of the two good sections has been studied in detail by Hage (1944). It extends from near the mouth of Chicken Creek upstream for about a mile. This section comprises 835 feet of Bullhead strata, consisting of beds of sandstone 0·8 foot to 46 feet thick, and beds of shale 0·5 foot to 9 feet thick, but including much more sandstone than shale. The sandstones are light to dark grey, are mostly fine grained, and are either massive or bedded. Some layers are ripple-marked. The sandstones are in part hard and quartzitic, and conglomeratic types, that is, sandstones with layers or lenses of conglomerate, appear in parts of the section. Thin coal seams range throughout the exposed parts. Hage suggests that the basal sandstones and shales of the section on Pink Mountain are missing on Sikanni Chief River, but notes that the lowest bed of this Sikanni Chief section is "within 200 feet of the base of the group", implying that the basal beds are concealed and not included in the measured section. Farther west, at the upper falls on this river, the Bullhead is 1,620 feet thick (Hage, 1944), indicating an increase in thickness from east to west.

Sandstones of the Bullhead group cap the summit of Mount Hage, and large blocks cover the higher slopes of this mountain.

West of Minaker River, the outcrop of the Bullhead forms a narrow band or rim around an anticlinal ridge. Hage notes that on "a tributary stream of Minaker River . . . the base of the group is marked by a 3-inch conglomerate bed composed of pebbles of quartzite, chert, porphyry, and vitreous quartz, and is overlain by a 12-inch bed of coarse, sugary, quartz sand and dark grey, coarse- to medium-grained, quartzitic sandstone. Only the basal part of the formation is exposed in the area, and the total thickness of the group there is believed to be less than on Sikanni Chief River".

Somewhere between Pocketknife and Tetsa Rivers, the Bullhead group disappears from the geological column, for it has not been found in Tetsa and Liard Valleys.

Sufficient study has not yet been made of the Bullhead group between Halfway and Pocketknife Rivers to establish its origin definitely. Coal seams suggest non-marine deposition of at least a part of the group.

Age and Correlation

(*See* Figure 12)

The sandstones and shales of the Bullhead group, as now defined, were correlated by Dawson (1881) with the Dunvegan formation. Referring to the lower sandstones and shales, to which he gave the formational name of Dunvegan, Dawson stated that they "may further, I believe, be regarded as probably including the sandstones of the Canon of the Mountain of Rocks above Hudson's Hope". Galloway (1913) placed the sandstones and shales exposed in the Peace River Canyon, or Canyon of the Mountain of Rocks, in the Dunvegan formation, following Dawson. Six years later McLearn (1918) showed that these sandstones and shales were older than the Dunvegan, and a new formation was proposed for them, to which the name of Bullhead Mountain was given. As already noted, it was divided into two members. No fossils were at that time found in the lower member, but "a few cycads, conifers, etc., and a single specimen of a dicotyledon" were collected from the upper member. It was noted that "the plant association of this flora suggests that of the lower part of the Blairmore formation of the Crowsnest district" (McLearn, 1918). The entire formation was placed in the Lower Cretaceous. The flora collected from the upper member was later examined by E. W. Berry and correlated by him with the Kootenay of the southern Foothills (*See* McLearn, 1921). The dicotyledon was lost, and did not appear in the collection submitted to Professor Berry; moreover, he was at that time unacquainted with the floras of the Blairmore formation. Later, Berry (1926) revised his correlation of 1921 and compared the flora of the upper member, by that time named Gething, with the flora of the lower part of the Blairmore formation of the southern Foothills. This lower Blairmore flora, found in 1916 by McLearn in the lower part of the Blairmore formation in southwestern Alberta, was dated "uppermost Comanchean" – using Comanchean in the sense of Lower Cretaceous – by McLearn (1916); "later part of Aptian time and all of Albian time", by Berry (1929); "about Aptian", by McLearn (1929); and "as old as Aptian" by McLearn (1932). For many years W. A. Bell has consistently dated this flora "Aptian" in reports on collections made by field officers of the Geological Survey of Canada, and has recently discussed its age at some length (Bell, 1946). He has also correlated the Luscar with the Lower Blairmore and Gething floras, considering them all to be of one age, that is Aptian (the second last stage of the Lower Cretaceous).

The age of the lower part of the Bullhead group has not been determined as satisfactorily as that of the upper part. Mathews (1947) has proposed a late Upper Jurassic or early Lower Cretaceous age for the lower part of the Bullhead group, that is, for the Monteith, Beattie Peaks, and Monach formations. J. A. Jeletzky (personal communication) tentatively suggests a late Upper Jurassic or earliest Lower Cretaceous age for the *Aucella* found by Mathews in talus from the upper part of the Monteith or lower part of the Beattie Peaks formation. He also tentatively proposes an early Lower Createceous age for fossils collected, in place, by Mathews from the Beattie Peaks and Monach formations.

No diagnostic fossils have yet been collected from the undivided Bullhead. No fossils have been collected from the Bullhead group in the Halfway, Sikanni Chief, and adjacent valleys, and it is not known whether it represents a part or all of the same group in Peace River and Pine River Valleys. Nor is it known whether, in disappearing to the north, on Tetsa and Liard Rivers, this lithological group is replaced there by shale in the lower part of the Garbutt formation, or whether it thins out and is unrepresented there by strata of equivalent age.

To the south, in the central Foothills, the Luscar formation, as already noted, contains the same flora as the Gething, and so is correlative with it. The lower and marine part of the Bullhead group may be equivalent to some part of the Nikanassin formation, but no actual evidence exists upon which to base a correlation. In the southern Foothills, the Gething is compared with the lower part of the Blairmore on the basis of sharing the same fossil flora. The typical flora of the Kootenay formation, however, has not been recognized in the non-marine part of the Bullhead; indeed little is known of the Kootenay north of Athabasca River. If no beds equivalent to the Kootenay occur in the Bullhead group, the non-marine Bullhead may rest disconformably on the marine Monach formation, and strata of both the Hauterivian and Barremian (mid-Lower Cretaceous) stages may be missing.

A tentative correlation of the upper part of the Bullhead group, containing the Gething flora, has been made with the sandstone at the base of the Cretaceous section in deep wells in lower Peace River Valley (McLearn, 1945) and with the McMurray formation on lower Athabasca River (Stelck, 1941; McLearn, 1945). It may be, too, that the unfossiliferous lower part of the Loon River formation on lower Peace River could be of very early Albian or even of Aptian age and equivalent to part of the Bullhead, for the Albian (latest Lower Cretaceous) fauna of the Loon River is confined to the upper part of the formation. These correlations of the upper part of the Bullhead with beds of more eastern localities, however, are based mainly on similar lithology, and have not the validity of those based on similar faunas.

LOWER CRETACEOUS

FORT ST. JOHN GROUP

Definition

The late Lower Cretaceous (Albian) formations of the northern Foothills and Plains, lying between the Bullhead group below and the Dunvegan formation above, are incorporated in the Fort St. John group. Because the lithological succession varies from place to place it is not possible to use one, uniform classification of the strata for all of northeastern British Columbia. Local classifications are required. Thus in the Pine and Peace River Foothills the Fort St. John group embraces five formations: Cruiser (top), Goodrich, Hasler, Gates or Commotion, and Moosebar; farther north, in Sikanni Chief and Buckinghorse River Valleys, the group comprises two formations: Sikanni (top) and Buckinghorse; and in Liard River Valley, it consists of three formations: Lépine (top), Scatter, and Garbutt. The Garbutt may extend lower stratigraphically than either the Moosebar or the Buckinghorse formation; that is, it may possibly include beds of pre-Albian (pre-latest Lower Cretaceous) age.

The name Fort St. John has been used in more than one sense. It was originally given by Dawson (1881) to the 'Lower dark shales' of Peace and Pine River Valleys. The upper limit was clearly defined, at the base of the 'Lower sandstones and shales', that is at the base of the Dunvegan formation. The lower limit was not so definitely established. It was stated, however, that the 'Lower dark shales' extend from about 6 miles below Hudson Hope to a little below the mouth of Pine River North, now called Beatton River. The shales, thus located, do have a fairly well defined range, namely, from the top of what is now called the Gates formation up to the base of the Dunvegan; but Dawson was merely describing the distribution of the shales, was indeed quoting from Selwyn's field notes, and, moreover, knew nothing about the Gates formation. It cannot be said, therefore, that Dawson set any lower limit to the 'Lower dark shales' or Fort St. John group.

In 1893, R. G. McConnell used the name Fort St. John for shales on the lower Peace River, between the Peace River and Dunvegan formations.

In 1918, McLearn placed all strata between the Bullhead group and the Dunvegan formation in the Fort St. John formation. In 1932, he gave Fort St. John a shorter range, to embrace all beds between the Gates and Dunvegan formations. Later, in 1943, Wickenden and Shaw reverted to McLearn's usage of 1918, including all strata between Bullhead and Dunvegan. They also recognized Fort St. John as a group name.

Peace and Pine River Foothills

The Fort St. John group of Pine River Valley has been studied by Spieker (1921, 1922), M. Y. Williams (1939, 1940), Williams and Bocock (1932), C. R. Stelck (1941), Wickenden and Shaw (1943), and others. The same group on Peace River has been studied by McLearn (1918, 1923, 1932, 1945), Williams and Bocock (1930, 1932), and Beach and Spivak (1944).

Table of Formations

		Formation		Lithology	Faunal zones
Lower Cretaceous	Fort St. John group	(Thickness in feet)			
		Cruiser 800-900		Marine shale	
		Goodrich 500-600		Marine sandstone and shale	*Neogastroplites* and *Posidonomya nahwisi*
		Hasler 1,100-1,200	Commotion 1,300-1,500	Marine shale	*Gastroplites*
		Gates 250-400		Marine sandstone and shale	*Lemuroceras* and *Beudanticeras affine*
		Moosebar 1,100-1,200		Marine shale	

Moosebar Formation

The Moosebar is the lowest formation of the Fort St. John group in Pine and Peace River Valleys, and lies between the Gething formation of the Bullhead group below and the Gates or Commotion formation of the Fort St. John group above. It consists of 1,000 to 1,200 feet of marine, dark shale, with, in places, thin layers of clay ironstone and, particularly in the upper part, some beds of sandstone. The type section is that exposed in the central part of Peace River Canyon, and in valleys of streams entering the canyon from the south and southwest.

The name was first used by McLearn (1923), and applied as a formation name to what had previously been called the lower shale member of the Fort St. John formation (McLearn, 1918). The beds on Crassier Creek, to which Spieker (1921) gave the name of Pine River formation, are interpreted by Wickenden and Shaw to be equivalent to the Moosebar on Peace River; Spieker, on the other hand, thought that he was naming Jurassic beds underlying, not overlying, the Bullhead group. If the identity of the Pine River with the Moosebar can be proved, the question arises as to the priority of the name Pine River over Moosebar. It must be remembered, however, that the name Moosebar is now established in the literature, that it has been retained by Wickenden and Shaw, and that, if changed to Pine River, the change will lead to confusion.

In Pine River Valley, the Moosebar formation is exposed on Hasler Creek and underlies a fairly large area south of Pine River, from Hasler Creek to and beyond Falls (Falling) Mountain. Wickenden and Shaw (1943) state definitely that the shales of this formation overlie the Bullhead on Hasler Creek. They also measured a section of this formation on Crassier Creek, a northern tributary of Pine River, consisting of 540 feet of dark grey, calcareous shale, with scattered brown weathering concretions, a thin seam of bentonite, and some beds of sandstone. Farther west, Mathews (1947) has mapped an area of Moosebar in the valleys of Fisher and Falls (Falling) Creeks, tributaries of Pine River. Within this area, on Beaudette Creek, he has recorded exposures of "several hundred feet of shales with some shaly sandstones". He also has noted a "persistent conglomerate bed 10 to 20 feet thick" at the base of the formation.

The Moosebar formation is better known in Peace River Valley, where Beach and Spivak have mapped it in the type area southwest and south of the canyon (*See* Figure 11). The outcrop extends across Gething, 'Aylard', Moosebar, and Johnson Creeks; curves around the 'nose' of the southward plunging Portage-Butler structural zone; and, extending north, crosses the canyon west of Steamboat Island. In this part of the area Beach and Spivak measured the following section, in descending order, of the Moosebar on the south fork of Gething Creek:

	Thickness Feet
Sandstone, thin-bedded, grey, medium-grained	54
Sandstone, dark grey, thin-bedded, argillaceous	45
Shales, grey, sandy	10
Shale, black, hackly	20
Sandstone, massive, carbonaceous; wood fragments	5
Shale, black, sandy	15
Sandstone	2
Concealed	15
Sandstone, grey weathering, shaly	33
Concealed	2
Sandstone, grey, rubbly, shaly	21
Shale	5
Sandstone	2
Shale	4
Sandstone, massive	3
Concealed	20
Shale, ironstone nodules	10
Shale, black, sandy, thin-bedded, buff weathering	26
Sandstone, black, massive	4
Shale, sandy	12
Sandstone, hard, shaly	4
Shale, dark grey, thin-bedded	15
Sandstone, hard, argillaceous	3
Shale, dark grey, hackly; ironstone bands	28
Shale, rectangular columnar jointing; ironstone bands	72
Shale, dark grey	90
Shales; a few marcasite concretions	60
Shales, dark grey; seventeen ironstone bands	94
Shales, dark grey; numerous concretionary bands near top	180
Shales, dark grey; clay ironstone nodules	200
Shales, grey, hackly; some concretionary bands; 4-inch bentonite bed near top	120
Shales, dark grey, hackly; eight ironstone bands	60
Shales, thin-bedded; 6-inch limy bands at 6-foot intervals near base	50
Shales, thin-bedded, hackly, dark grey; ironstone bands 6 inches thick about 3 feet apart	50
Conglomerate, chert pebbles	2
Total	1,336

Underlying beds—Gething formation

Beach and Spivak note that the upper part of this section "contains several sandstone members and probably includes strata of the overlying Gates formation". Farther east they note that on "Coalbed Creek, near its junction with Johnson Creek [*See* Figure 11] the Moosebar has a conglomerate bed at the base", 2 feet thick, which contains "well-rounded, black, chert pebbles up to 2 inches in diameter embedded in a black, argillaceous cement. The conglomerate fills small channels and depressions in the underlying Gething sandstone, indicating an interval of erosion before deposition of the Moosebar". In the upper part of the Moosebar shale on Johnson Creek, Beach and Spivak collected *Beudanticeras* sp. about ½ mile above the junction with Coalbed Creek, and *Lemuroceras?* sp. below the junction with the same creek.

A few marine fossils, including *Lemuroceras irenense* from near the top of the formation, have been found west of Steamboat Island in the canyon (*See* Figure 11). They are from the 800-foot section of the Moosebar measured by McLearn in 1918.

It is not known how far north of Peace River Valley the Moosebar preserves its entity as a formation. Shales of equivalent age have been observed, however, east of Butler Ridge; they include 1,000 feet or more of shale and sandstone penetrated in bore-holes on Farrell Creek; beds on a creek north of Chinaman Lake, with *Beudanticeras affine* Whiteaves; and fossiliferous beds on the upper part of Lynx Creek, recorded by Beach and Spivak. Conglomerate lies between the Moosebar and Gething formations in this area east of Butler Ridge. Dresser (1922) described conglomerate at the base of the section penetrated by wells on Farrell Creek, and Beach and Spivak measured 35 feet of conglomerate on Ruddy Creek. Marine fossils and lack of any evidence of non-marine deposition show that the Moosebar formation is of marine origin.

McLearn's estimate of 800 feet for the thickness of this formation is probably low. Beach and Spivak believe that the correct figure is more nearly 1,000 to 1,200 feet.

Gates Formation

The Gates overlies the Moosebar formation in Peace River Canyon and in Peace River Valley at least as far east as 'The Gates' and possibly far out on the Plains. It consists of from 245 to more than 400 feet of marine, massive, partly crossbedded, thick beds of sandstone and some thick beds of shale. The type locality is at 'The Gates' on Peace River.

The Gates formation was first called the middle sandstone member of the St. John formation (McLearn, 1918) and later given its present name (McLearn, 1923). Only the upper part of the formation may outcrop at 'The Gates' (*See* Plate VII A). At this locality, crossbedded sandstones with fossil stem and wood impressions form steep-sided islands and low cliffs. Marine shells have been found by a geologist of an oil company in sandstone at this locality, including *Astarte portana* in place and *Beudanticeras*? in talus.

West of Hudson Hope, sandstones of the Gates formation outcrop in the steep walls of small islands and in cliffs on the banks of Peace River. Beach and Spivak (1944) state that the formation here consists of two sandstones, each 75 to 100 feet thick, separated by about 200 feet of shale. In the shale between the two sandstones *Lemuroceras?* and other marine shells have been collected.

Still farther west, in the lower part of Peace River Canyon, the Gates disappears below river level, so that at the mouth of Starfish Creek only the overlying shales of the Hasler formation outcrop. However, not much farther west, at Steamboat Island (*See* Figure 11), it reappears in easterly dipping ledges above river level, and outcrops on the island, on the river bank, and on the valley slopes. Here Beach and Spivak measured the following section:

	Thickness Feet
Sandstone, crossbedded, platy; plant fragments	75
Shale, black	60
Sandstone, massive, quartzitic	30
Shale	75
Sandstone	5
Total	245

From the uppermost sandstone of this section the geologist of an oil company collected specimens of marine pelecypods, including species of *Ostrea, Pecten (Entolium)*, and *Arctica?*.

On Johnson Creek, Beach and Spivak (1944) measured 430 feet of sandstone and shale in the Gates formation. On Coalbed Creek, a tributary of Johnson Creek, they collected *Beudanticeras* sp. and other fossils from the Gates or basal Hasler formation.

Little is known of the extension of the Gates formation north of Peace River. Dresser (1921, 1922) describes exposures of sandstone on Farrell Creek, near the forks. These overlie the thick section of shale and sandstone penetrated in bore-holes at that locality previously referred to in describing the Moosebar formation. Although no proof of identity, based on fossils, exists, it is possible that this sandstone is a northern continuation of the Gates. This formation does not appear to extend as far north as Sikanni Chief Valley; at least it has not been recognized by Hage (1944).

Although some evidence of non-marine origin has been noted (McLearn, 1918), it is evident, from the entombed marine fossils, that most of the Gates formation is of marine origin.

Commotion Formation

South of Peace River Valley, the Commotion formation is partly the equivalent of the Gates, but appears to include higher beds; it contains beds of coarser texture than the Gates, and consists of about 1,300 to 1,500 feet of marine and non-marine sandstone, conglomerate, and shale, with rare, very thin coal (Wickenden and Shaw, 1943). It lies conformably between the shales of the Moosebar below and the shales of the Hasler formation above.

In early reports on the Pine River and adjacent areas, the beds of the Commotion formation were placed in the Bullhead group, and the thick conglomerate exposed in the lower part of Commotion Creek was called the Boulder Creek Conglomerate member (Spieker, 1921). Later, however, it was realized by geologists studying the Fort St. John group that they were not only distinct from any part of the Bullhead, but actually overlay the Moosebar formation (Williams, 1940; Stelck, 1941; Wickenden and Shaw, 1943). It was realized also that their stratigraphic position was much like that of the Gates formation of Peace River Valley, but because of their greater stratigraphic range and somewhat different texture, it was inferred that they could not be placed in the Gates, but must be incorporated in a new formation to which Wickenden and Shaw (1943) gave the name of Commotion.

On the north side of Pine River Valley this formation is exposed between Fred Nelson and Crassier Creeks, on Alvin Creek, and on the lower part of Commotion Creek. On the south side of the valley it outcrops on Falls Mountain, in a long, narrow band from nearly opposite the mouth of Fred Nelson Creek to Hasler Creek and east of the mouth of Goodrich Creek.

Wickenden and Shaw (1943) state that no complete exposures of the Commotion formation are known. However, they measured a part of the formation as exposed on Hasler Creek, and the section, in descending order, is as follows:

	Thickness Feet (Approximate)
Chert-pebble conglomerate	100
Sandstone	200
Dark grey shale	250
Sandstone	500-600
Base of section concealed	

They also note that 180 feet of sandstone, shale, and coal overlie conglomerate on Commotion Creek, and observed two bands of conglomerate near Goodrich Creek. They collected some marine fossils: *Inoceramus* cf. *altifluminis*, from about 145 feet below the conglomerate on the west bank of Commotion Creek about 500 feet below the falls; and species of marine pelecypods from shale below the conglomerate on Hasler Creek, about ½ mile below the coal mine (*See* Figure 13). Stelck (1941) has reported *Gastroplites* from the upper part of the formation. Fossil plant fragments have been found in beds above the conglomerate on Commotion Creek.

Wickenden and Shaw estimate that the thickness of the Commotion formation in Pine River Valley is at least 1,300 to 1,500 feet, depending "on where the contact with the Moosebar is placed".

Farther west, between Pine and Peace River Valleys, southeast of Mount McAllister, Mathews (1947) has mapped an area of steeply dipping conglomerate as the Commotion formation. He has also mapped sandstones of this formation near Carbon (Indian) Lake. Mathews describes an exposure of the lower part of the formation "on the south fork of Gething Creek, 3 miles northeast of Mount McAllister . . . Here the formation possesses a gradational contact with the underlying shales and consists chiefly of sandstones, in part ripple-marked, and at least one thin conglomerate bed".

The coal seams and plant remains record a non-marine origin for some of the upper layers of the Commotion formation. Marine shells, however, indicate that a large part of the formation is of marine origin.

Hasler Formation

The Hasler formation lies between the Commotion and Goodrich formations in Pine River Valley, where it consists of 1,100 to 1,200 feet of shale, with, here and there, thin beds of siltstones and fine sandstone, and in at least one place a band of conglomeratic sandstone has been observed. In Peace River Valley it lies between the Gates and Goodrich formations, and, consequently, includes lower beds than on Pine River.

On the south side of Pine River, the Hasler outcrops from Young to Browns Creeks and on Hasler and Johnsen Creeks[1]. From Johnsen Creek the outcrop extends in a narrow band to Pine River, which it reaches west

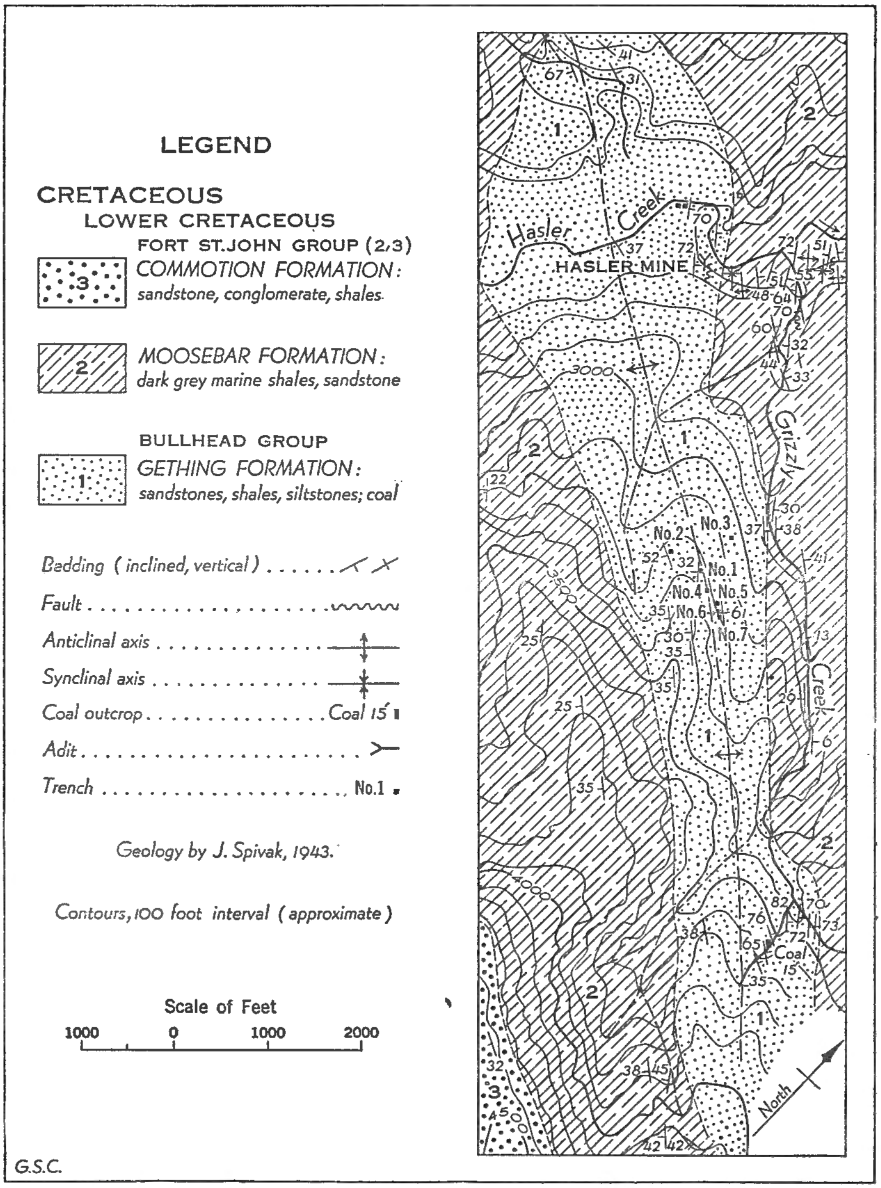

Figure 13. Southeast part of Hasler Creek coal area, British Columbia.

[1] The west branch of Hasler Creek, south of Pine River, not to be confused with Johnson Creek, which flows into Peace River Canyon.

of Browns Creek. The formation also underlies a triangular area north of Falls Mountain. North of Pine River it outcrops from Submarine Mountain westward to nearly opposite the mouth of Browns Creek. It also outcrops on Commotion, Walton, Hulcross, and Alvin Creeks (Wickenden and Shaw, 1943).

In spite of the fairly large area of outcrop, no completely exposed section of the formation is known. The lower part, including the contact with the underlying Commotion formation, is exposed on the east bank of Commotion Creek, about ¾ mile above the falls. There the rocks show a transition from light and medium grey sandstone upward to dark grey, non-calcareous shale. The lower part of the shale includes a bed about 6 inches thick of chert-pebble conglomerate. A short distance downstream from this exposure, a heavy band of hard, dense sandstone is regarded as the top of the Commotion formation (Wickenden and Shaw, 1943). The upper part of the Hasler formation is well exposed on the east bank of Hasler Creek, 3 miles south of Pine River, and the section, in descending order, is as follows:

	Thickness Feet
Goodrich formation	
Concealed	100 ±
Shale, dark grey, with numerous, thin bands of fine-grained sandstone or siltstone	112
Sandstone, conglomeratic	3
Shale, dark grey; with thin beds of fine-grained sandstone, becoming more numerous near the top	255
Total thickness	370

A few worm trails or burrows and fish scales have been observed in this formation (Wickenden and Shaw, 1943).

In the Peace River Foothills, the Hasler formation has been recognized by Beach and Spivak (1944). In the lower part of Peace River Canyon, at the mouth of Starfish Creek (*See* Figure 11) and exposed on both sides of the canyon, are "700 feet . . . of fine, dark grey, thin-bedded, marine shales with thin, interbedded, sandstone members. About 600 feet above the base, some shaly sandstone beds contain the *Gastroplites* ammonoid fauna" (Beach and Spivak, 1944). From talus at this locality McLearn (1944B, 1945) has illustrated the following species: *Lopidiaster silentiensis, L.* cf. *silentiensis, Inoceramus altifluminis,* and *Gastroplites kingi.* Near the top of the formation on Burnt Trail Creek, Beach and Spivak measured 200 feet of shale, siltstone, and thin-bedded, grey weathering sandstone.

Shales exposed in cliffs along Peace River below 'The Gates' are probably of the Hasler formation. Here, 1 mile below and on the north bank of the river, the geologist of an oil company collected *Gastroplites canadensis* var. and *Inoceramus cadottensis.* He also collected *Gastroplites* on Maurice Creek, south of Hudson Hope. No details are available. If, however, on Maurice Creek, this diagnostic genus occurs in shale, it is probably in the Hasler; if in sandstone, from the Commotion formation. If in the Commotion, it must be inferred that this formation here extends north to Peace River Valley. As already stated, however, the shorter ranging Gates formation mostly supplants the Commotion from south to north, that is, from the Pine to Peace River Valley.

Southeast of Mount McAllister, Mathews (1947) has mapped a small area of the Hasler formation, and has measured 350 feet of shale with several beds of sandstone, 4 to 15 feet thick. Fragments of a dicotyledonous leaf were found in sandstone.

Goodrich Formation

The Goodrich formation lies conformably between the Hasler, below, and the Cruiser formation, above, and consists of 550 to 600 feet of marine sandstone and some shale. In early reports on Pine River Valley, the strata of the Goodrich formation were included in the Dunvegan. During the drilling of the Commotion well the question was raised as to whether a fault occurs between Submarine and Cruiser Mountains. This focused attention not only on the structure of this part of the Pine River Foothills, but on the stratigraphy as well. As investigation proceeded it soon became evident that two sandstone units of formational rank were represented, a lower one on Submarine and a higher unit on Cruiser Mountain. Which was the Dunvegan? The first field interpretation was to identify the lower as Dunvegan and the upper unit as a sandstone formation in the Upper Cretaceous Smoky group. Fossils collected by Wickenden and Shaw, however, showed that the higher sandstone carried fossils typical of the Dunvegan and the lower one shells related to a fauna in the upper part of the Fort St. John group on Peace River. Consequently, the lower sandstone could only be regarded as a formation hitherto unknown and unnamed in the Fort St. John group. For this new formation the name Goodrich was proposed by Wickenden and Shaw (1943).

In the southern part of the Pine River Foothills, the Goodrich formation outcrops south of Young Creek; from Goodrich west to Hasler Creek; and on high uplands from Hasler Creek west to beyond Browns Creek. In the northern part of the same foothills, it underlies a large area between Commotion and Hulcross Creeks; a long, narrow area north of Submarine Mountain; and a narrow area from near the mouth of Commotion Creek west to almost opposite the mouth of Browns Creek.

Wickenden and Shaw measured only one section in the Mount Hulcross-Commotion Creek map-area, that exposed on the first eastern tributary of Bowlder Creek; it comprises only a little more than the lower half of the formation and is as follows, in descending order:

	Thickness Feet
Sandstone, light grey, fairly thin-bedded, little crossbedding	33
Grey sandstone, thin-bedded, becoming shaly at base	24
Shaly sandstone, medium to dark grey	29
Sandstone, greenish grey, medium-grained, rather massive	10
Sandstone, grey, rubbly, fine-grained	3
Concealed	20 ±
Sandstone, grey, thin-bedded	9
Sandstone, grey, massive	26
Sandstone, grey, somewhat rubbly, fine-grained	8
Concealed	11
Sandstone, grey, fairly massive	37
Sandstone, shaly, medium grey	0·8-1
Shale, medium to dark grey	16
Sandstone, grey	16
Shaly sandstone and sandy shale, medium grey	19
Total thickness	262 ±
Hasler formation, dark grey shale	

Wickenden and Shaw note that "although this section indicates that the Goodrich consists chiefly of sandstone, exposures elsewhere in the area point to the presence of several fairly thick shale bands", for example "on Hulcross Creek, 2 and 4 miles above the forks of Alvin Creek, and on Walton Creek, 4 miles above the forks . . . on Walton Creek they are about 60 feet thick and occupy a position approximately 300 feet above the base of the formation".

The contact of the Goodrich with the underlying Hasler formation is fairly sharp on Hulcross and Walton Creeks, marked by "a change from dark grey shale below to hard, massive sandstone above; at the remaining localities the contact is transitional through several beds of alternating sandstone and shale".

Wickenden and Shaw found it difficult to measure this formation because in few sections are both the upper and lower contacts exposed. Such a section, however, was found on Bowlder Creek, where a thickness of 550 to 600 feet was measured.

Fossils are abundant in the Goodrich formation at some localities in Pine River Valley. All are marine. Shells of the genus *Oxytoma* are common, and indeed the Goodrich could be called the *Oxytoma* sandstone. A variety of *Posidonomya nahwisi* is a very characteristic fossil, and has been collected on the north side of Pine River Valley 2 miles west of Bowlder Creek; on the west side of Hulcross Creek Valley, north of the west branch; from a shaly member 1 mile above Alvin's cabin on Hulcross Creek; in a gully west of Johnsen Creek; and elsewhere. *Oxytoma pinan'a* and *Pleuromya kissoumi* were collected on a mountain east of the east branch of Commotion Creek. *Tancredia stelcki* is from the north side of Pine River Valley, 2 miles west of Bowlder Creek. *Pleuromya wickendeni* and *Lucina? goodrichensis*, collected by C. R. Stelck, are from the south valley wall east of Young Creek.

The Goodrich formation does not outcrop on the banks of Peace River near the canyon; it has evidently been removed by erosion, even from the synclines. It does, however, outcrop on high uplands south of the canyon and in the valley of Moberly River. Beach and Spivak (1944) state that the "Goodrich formation is exposed on the south side of Peace River, on Tworidge Mountain, and near Pete Lake in the Moberly River region. Its thickness is estimated to be 550 feet", and it comprises "a series of interstratified, buff to light grey, medium- to coarse-grained sandstones, and black, sandy shales. On Burnt Trail Creek, the lowermost 50 feet of the Goodrich includes 20 feet of coarse conglomerate containing variegated chert pebbles $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches in diameter. Underlying beds are of medium- to coarse-grained, grey, crossbedded sandstone, with some clay ironstone bands".

Beach and Spivak measured a section near the base of the formation on a creek north of Tworidge Mountain; in descending order it is as follows:

	Thickness Feet
Sandstone, fine-grained, greenish grey	122
Sandstone, thin-bedded, grey; thin shale beds	21
Shale, black, fissile; ironstone concretionary bands	42
Sandstone, grey, fine-grained, partly micaceous	41
Sandstone, grey-green; some concretionary bands	29
Sandstone, quartzitic, grey-green	11
Shale, black, sandy; carbonaceous fragments; fossils	6
Total thickness	272

Beach and Spivak collected the marine pelecypods, *Posidonomya nahwisi* var. *goodrichensis* and *P. nahwisi* var. *moberliensis* in this formation on an east branch of Coalbed Creek, southeast of Moosecall Lake (*See* Figure 11); and on the central branch of Coalbed Creek.

Much farther west, between Pine and Peace River Valleys, on the northeast spur of Mount McAllister, 1 mile east of Wright Lake, Mathews (1947) has mapped the rocks of a small area as Goodrich. The beds consist of sandstone with minor amounts of conglomerate. Northward from Peace River Valley the sandstones of this formation are continuous with those in the lower part of the Sikanni formation.

Cruiser Formation

The Cruiser formation lies conformably between the Goodrich and Dunvegan formations, and is the highest formation of the Fort St. John group in the Pine and Peace River Foothills. It consists of 800 to 900 feet of dark shales, with some beds of sandstone. It was first named by Wickenden and Shaw (1943), and first applied by them to beds in the Pine River Foothills. The formation is said to be well exposed on Cruiser Mountain, which is the type locality of the formation.

Wickenden and Shaw describe the lower contact of the Cruiser formation, as exposed on Bowlder Creek between 400 and 700 feet below the forks. "The contact shows a change from heavy massive sandstone in the Goodrich to dark grey shale and sandy shale of the Cruiser through several alternating beds of sandstone and shale". About 60 to 70 feet of the lower part of the Cruiser are exposed.

More than 700 feet of the uppermost part of the Cruiser is exposed on a small tributary on the south side of Pine River, $\frac{3}{4}$ to 1 mile east of Young Creek. Wickenden and Shaw measured a section there:

Top of Section	Thickness Feet
Dunvegan formation	
Shale and sandstone, dark and medium grey	30
Shale, dark grey to black; a few sandstone bands	154
Shale, dark grey, with many thin sandstone bands	257
Shale, dark grey to black, with a few thin sandstone bands	188
Shale, dark grey, with many thin sandstone bands	84
Total thickness	713

Another section of the uppermost part of the formation was measured by Wickenden and Shaw on the east side of the east branch of Bowlder Creek; it may include beds of the overlying Dunvegan formation:

Top of Section	Thickness Feet
Sandstone, grey, with shale parting	22·3
Shale, dark grey, blocky, with thin sandstone beds	33·0
Conglomeratic sandstone, grey; pebbles $\frac{1}{4}$ to $\frac{1}{2}$ inch; a few small ironstone concretions	3·7
Shale, dark grey, with many beds of sandstone; contains many fragments of fossil plants	10·2
Sandstone, coarse-grained, conglomeratic; pebbles $\frac{1}{8}$ to $\frac{1}{4}$ inch	1·0
Shale, dark grey, with many thin sandstone beds	5·0
Total thickness	75·2

Wickenden and Shaw estimate that the Cruiser formation has a total thickness of 800 feet on the north side of Pine River Valley, about 3 miles west of Commotion Creek. Farther north, on Moberly River near the east boundary of the Dunlevy-Portage Mountain map-area, Beach and Spivak (1944) measureed a section of the upper part of the Cruiser formation:

Top of Section	Thickness Feet
Dunvegan formation	
Shale, sandy, with 4-inch sandstone beds	40
Shale, dark grey	120
Shale, dark grey; 1-inch, fine-grained sandstone beds	20
Bentonite	0·25
Shales, dark grey	40
Shales, sandy; finely crossbedded, thin sandstones; concretionary bands	90
Total thickness	310

Still farther north, on the north slope of Tworidge Mountain, Beach and Spivak record the presence of more than 400 feet of folded and faulted beds of the Cruiser formation. On the west side of the mountain the beds are not so disturbed, and Beach and Spivak estimate a total thickness of 800 to 900 feet. The exposed part of this section consists "of grey-black, fissile shales with interbedded, thin, white, finely crossbedded sandstones and black, micaceous sandstone beds".

Farther west, between Pine and Peace River Valleys, on the northeastern spur of Mount McAllister, Mathews (1947) has mapped about 1,000 feet of shale as Cruiser. This shale overlies sandstones mapped by the same author as Goodrich.

No diagnostic fossils have been found in the Cruiser formation.

Halfway, Sikanni Chief, and Buckinghorse River Valleys

Table of Formations

		Formation	Thickness	Lithology	Faunas
Lower Cretaceous	Fort St. John group	Sikanni	Feet 980	Marine sandstones and shales	
					Neogastroplites, *Posidonomya nahwisi* and varieties
		Buckinghorse	3,300 to 3,600	Marine dark shales	
					Lemuroceras

Buckinghorse Formation

The Buckinghorse formation consists of 3,300 to 3,600 feet of marine, dark grey, "bedded and chunky" shale with minor amounts of "fine-grained, thin sandstone and sandy shale beds and varying amounts of brown weathering ironstone concretions. Thin bentonite beds are present in the basal part" (Hage, 1944). The section on Buckinghorse River, west of the Alaska Highway, is well exposed, and is, presumably, the type section. The name was first used by Hage (1944).

The formation underlies a large part of the Foothills belt, west of the Alaska Highway. It occupies, mostly, an area of low relief, for the shales of the Buckinghorse formation yield readily to erosion. Good exposures occur where the larger streams, such as the Halfway, Sikanni Chief, and Buckinghorse, cross this low-lying area.

Hage (1944) measured a section of the greater part of the formation, as exposed along Buckinghorse River, west of the Alaska Highway:

Top of Section	Thickness Feet
Overlying beds—Sikanni formation	
Bedded and semi-bedded, dark grey shale, with a few ironstone concretions and some interbedded thin sandstone beds	1,000
Fine-grained, dark grey sandstone, sandy shale, and shale	50
Dark grey, chunky shale with sparse ironstone concretions	375
Dark grey, fissile shale and thin sandstone beds with a few concretions	75
Dark grey, fissile shale containing large, limy, light buff weathering concretions	100
Bedded, fissile shale, with ironstone beds containing a few scattered ellipsoidal concretions	825
Dark grey, chunky shale; with numerous ironstone concretions	375
Shale containing three bentonite beds 1 inch to 6 inches thick	25
Dark grey, chunky shale; with numerous ironstone concretions	475
Total thickness	3,300

The beds of this formation are conformable with those of the underlying Bullhead group, the contact being marked by a transitional zone of variable thickness. This zone consists of interbedded sandstone and shale and is abnormally thick as exposed on Sikanni Chief River, 14 miles west of the Highway.

Top of Transition Zone	Thickness Feet
Sandstone, grey, hard, fine-grained; a few chert pebbles	4·6
Shale, dark grey, thinly bedded	1·2
Sandstone, dark grey, fine-grained; ripple-marks	1·0
Shale, dark grey; interbedded with siltstone in beds 1 inch thick	5·0
Sandstone, brownish grey, medium-grained	2·7
Shale, dark grey, thinly bedded	1·4
Sandstone, dark grey, medium-grained; with small concretions	1·0
Shale, dark grey, thinly bedded	1·0
Sandstone, brownish grey, medium-grained	6·0
Conglomerate with black, bean-size chert pebbles	0·5
Sandstone, brownish grey, medium-grained	37·0
Shale, dark grey, thinly bedded	2·0
Sandstone, brownish grey, thinly bedded	2·5
Shale, dark grey; interbedded with dark grey sandstone	8·0
Sandstone, brownish grey, medium-grained, bedded	18·5
Shale, sandy, dark grey	5·0
Sandstone, dark grey, fine-grained	2·0
Shale, dark grey; with ironstone concretions at top	7·0
Sandstone, brown, fine-grained, hard	2·5
Shale, dark grey, fissile; interbedded with fine sandstone	7·0
Sandstone, dark grey, medium-grained	5·0
Shale, dark grey, fissile; interbedded with fine-grained sandstone	11·5
Sandstone, grey, medium-grained	4·5
Shale, dark grey, fissile	1·5
Sandstone, brownish grey, medium-grained	6·0
Shale, dark grey, fissile; interbedded with siltstone	3·0
Sandstone, dark grey, medium-grained	7·0
Shale, dark grey; interbedded with some sandstone	15·0

	Thickness Feet
Sandstone, dark grey, fine-grained	1·5
Shale, dark grey, fissile	11·0
Sandstone, dark grey, fine-grained, hard	3·4
Shale, dark grey, fissile; ironstone concretions	17·0
Sandstone, dark grey; interbedded with dark grey siltstone	30·0
Total thickness of zone	232·3

The section on Sikanni Chief River above this transition zone is estimated to have a thickness of 3,300 feet.

Fossils are rare and poorly preserved. All are marine. From the basal part of the formation, near a "branching seaweed layer", about 8½ miles west of the Alaska Highway bridge on the left bank of Sikanni Chief River, the geologist of an oil company collected *Aucellina*? *dowlingi* (=*Aucellina gryphaeoides* Sowerby?) and *Lemuroceras*? sp. The same geologist collected *Lemuroceras* cf. *indicum* Spath from the lower part of the formation on Sikanni Chief River, 10 miles west of the Alaska Highway bridge. At a much higher horizon, at the sharp bend in Sikanni Chief River, about 7½ miles west of the Alaska Highway and below a large island, flattened specimens of an ammonoid were collected. Similar crushed ammonoids were collected on Mason Creek, about 3 miles above its confluence with Sikanni Chief River.

Sikanni Formation

The Sikanni formation, as named and defined by Hage (1944), consists of about 980 feet of marine sandstone and shale. It comprises two members. The lower, about 380 feet thick, is composed of four, thick sandstones separated by thick, dark shales. The upper member, about 600 feet thick and nowhere well exposed, consists of dark shale. The type locality is Sikanni Chief River at and east of the Alaska Highway bridge.

The Sikanni formation outcrops along the western border or scarp of the Plains physiographic province. Good exposures were found by Hage where Sikanni Chief and Buckinghorse Rivers cut across this scarp on and east of the Alaska Highway from near Buckinghorse River to Trutch Creek, and on Halfway River at, and below, the 'Elbow'.

Hage (1944) measured the following section of the lower member, exposed on Sikanni Chief River, 2 miles east of the Alaska Highway bridge:

Top of Section	Thickness Feet
Shale, dark grey	?
Fourth sandstone member: fine-grained, grey, bedded and banded; small carbonaceous fragments along bedding	47
Shale, dark grey, bedded; with a few scattered ironstone concretions	44
Third sandstone member: fine-grained, grey, banded; interbedded with minor amount of shale	46
Shale, dark grey and sandy; a few ironstone concretions	71
Conglomerate; black chert pebbles	0·5
Second sandstone member: fine- to medium-grained, grey, bedded and banded	72
Shale, dark grey, banded and poorly bedded; contains ironstone concretions	65
First sandstone member: fine-grained, grey, crossbedded, banded	35
Total	380.5

"The banded and bedded character of the sandstone is characteristic of the various members. The thin, chert-pebble conglomerate on top of the second sandstone member was observed at mile 152 and at several places along Sikanni Chief River, and is a useful horizon marker. The lower part of the formation is of uniform character for a distance of 60 miles from the 'Elbow' on Halfway River east of Pink Mountain to Prophet River."

Marine fossils have been collected from the lowest sandstone member by Hage (1944), by geologists of oil companies, and by others. They include *Oxytoma pinania, Solecurtus? (Azor?)* sp., and *Neogastroplites* cf. *cornutus* Whiteaves, on the crest of the Kobe anticline on the left bank of Halfway River a few miles below the mouth of Graham River; and *Posidonomya nahwisi* var. *goodrichensis* on Halfway River, 1 mile south of the confluence of Cypress Creek and Halfway River. The following were collected from the second sandstone member: *Neogastroplites* sp. and *Pteria via-media*, on the left bank of Halfway River at the confluence of Cypress Creek and Halfway River; *Posidonomya nahwisi* var. *goodrichensis* and *Pecten burlingi*, from talus on creek entering the right bank of Sikanni Chief River, 3 miles east of the Highway bridge; *Corbicula?* sp. and *Oxytoma* sp. on Buckinghorse River 2 miles east of the Highway bridge; and *Thracia stelcki* from talus on Buckinghorse River, east of the Highway bridge. The following were collected from the third sandstone member: *Oxytoma* sp., *Pleuromya sikanni, Modiolus via-alaska, Thracia yarwoodi*, and *Pinna hagi*, on south bank of Sikanni Chief River near the bridge. The following are from the fourth sandstone member: *Pharus* sp., *Oxytoma* sp., and *Neogastroplites?* sp., from talus on the bank of a creek entering the right bank of Sikanni Chief River 3 miles east of the Highway bridge, and *Tancredia stelcki* on Buckinghorse River 5 miles east of the Highway bridge.

Tetsa River Valley

No formational subdivision of the Fort St. John group has yet been attempted in the section exposed along the Alaska Highway west of Fort Nelson and in Tetsa River Valley. In this region, however, the Fort St. John group consists of a lower unit principally of shale, a middle unit of sandstone and shale, and an upper shale unit (Williams, 1944):

Top of Section	Thickness Feet
Shale	250
Sandstone and shale with *Posidonomya nahwisi* var. *goodrichensis* and *P. nahwisi* var. *moberliensis;* poorly preserved plant remains	600
Shale and sandstone	500+

As Williams points out, the estimate of 500 feet for thickness of the lower shale and sandstone is probably very low.

The lower shale is underlain disconformably by beds of Middle Triassic age. The magnitude of the disconformity is not known, for the lower shale has so far proved to be unfossiliferous. The upper shale is overlain, apparently conformably, by the sandstones and conglomerates of the Fort Nelson formation.

The middle unit of sandstone and shale contains a thin coal seam, and may be partly non-marine, though marine shells have been found in it. Williams (1944) has furnished the following information on the Fort St. John group of Tetsa River Valley:

"The wide plains area extending 57 miles westward from Fort Nelson is underlain by soft, sandy, dark brown or black shale. Because of its softness it is rarely exposed along the Highway.

"A small stream [8 miles west of Fort Nelson] flows southward from a hill that rises 200 to 300 feet above the plain. The hill consists of black, sandy shale, with small concretions in some of the beds. A bore-hole, drilled for water, had penetrated to a depth of 208 feet in this shale. The formation here is nearly horizontal. [Twenty-seven miles west of Fort Nelson] black shale occurs in a road-cut", and to the southwest a shale outcrop occurs on Kledo River.

"The Highway enters the Foothills [50 miles west of Fort Nelson], there consisting of horizontal dark shale. About 200 feet of shale is exposed and is overlain by sandstone. The shale is nodular, commonly rusty weathering, with sheared vertical surfaces, striking south 50 degrees west. At the forks of Tetsa and Muskwa Rivers . . . . exposures of dark shale show in the banks. Along the old road [54 miles west of Fort Nelson], a 500-foot section is in part exposed. This consists of several ledges of thin-bedded, grey-blue sandstone weathering buff, with covered intervals above and below strongly suggestive of shale interbeds. At the top of the section sandstone occurs interbedded with shale. Worm burrows are numerous on some slabs . . . . . [At about 53 miles and at about 54 miles west of Fort Nelson] on the new location of the road *Posidonomya nahwisi* var. *moberliensis* and *P. nahwisi* var. *goodrichensis* were found. Just below these fossiliferous beds poorly preserved plant remains and a 3-inch coal seam occur in the sandstone . . . . .

"To the west, the sandstone beds dip downward to a syncline, beyond which they rise gently into Tepee Mountain. This somewhat round-topped hill is situated [55 to 58 miles west of Fort Nelson] on the new road . . . The strike of the strata varies from north to northwest, the dip being easterly at from $5\frac{1}{2}$ to 10 degrees. Pepper and salt sandstone outcrops along the road on the south side of the mountain, soft sandstone and shale beds continuing upward. About 1,100 feet up, pepper and salt sandstones outcrop on the north side and continue upward, being more massive near the base of cliff-forming, massive, Upper Cretaceous conglomerate at 1,400 feet. This conglomerate continues to the top of Tepee Mountain at an elevation of about 4,500 feet, or 1,800 feet above the outcrops on the Highway" about 60 miles west of Fort Nelson.

"A more complete section occurs on the east flank of Steamboat Mountain and the ridge to the south . . . The section appears to start in shale in the creek bottom at an elevation of about 2,600 feet above sea-level. Five hundred feet higher, concretionary shale outcrops, and a sandstone ledge outcrops at 600 feet. In talus below this ledge, a fragment of '*Inoceramus*' was found that resembled *Posidonomya nahwisi* var. *goodrichensis*. Ledges of sandstone outcrop at elevations of 3,450 to 3,500 and at 3,600 feet, with some 60 feet of intervening shale. Those beds form a decided cliff. The upper beds carry numerous worm casts. Ledges of sandstone outcrop at 3,800, 4,000, and 4,300 feet. Firm nodular shale occurs between the upper beds of sandstone. From about 4,300 feet, coarse sandstone rises as a cliff 50 feet high to the base of massive, Upper Cretaceous conglomerate that forms an overhanging cliff on the east face of Steamboat Mountain. This conglomerate, with interbedded sandstone and lenses of sandstone, rises sheer for 500 feet. Massive upper beds overhang as much as 50 feet. Cones of huge conglomerate blocks piled up in front of the cliff record the cliff recession."

Liard River Valley

Kindle (1944) has established three formations in the Liard River section, and considers them to be the equivalent of the Fort St. John group:

Table of Formations

		Formation	Lithology	Faunas
Lower Cretaceous	Fort St. John group	Lépine	2,000 feet of marine shale; some sandstone lenses and concretions	*'P.' liardense*
		Scatter	750 feet of marine sandstone, with some shale and concretions	*Gastroplites*, *Inoceramus cadottensis*
		Garbutt	2,000 feet of marine shale, with some sandy shale and concretions	

Garbutt Formation

The Garbutt formation, first named and described by Kindle (1944), "consists of about 2,000 feet of dark, friable shales that weather into small, rust-flecked particles" and that include scattered, rusty argillite beds 3 or 4 inches thick. Concretions are common at some horizons, are rust stained, and may have a core of fine pyrite (Kindle, 1944). The type locality is on Garbutt Creek, where the formation is well exposed.

The Garbutt outcrops in several narrow bands in the Nelson Forks map-area (Kindle, 1944). These cross Liard River near Hades (Hell) Gate, at Brimstone Creek, and at Garbutt Creek; another band crosses Beaver River east of Mount Merrill.

The shales of the Garbutt formation are underlain by "5 feet of coarse, brown, impure sandstone that contains carbonized wood fragments". Kindle suggests that this sandstone is of Jurassic age. Immediately below this sandstone are "thin-bedded, well sorted Triassic sandstones".

No fossils have yet been found in the Garbutt formation.

Scatter Formation

The Scatter formation consists of about 750 feet of sandstone and shale. Kindle (1944) briefly summarizes the succession as follows:

Top of Section	Thickness Feet
Sandstone and shale	100
Black shale	200
Sandstone and shale	250
Shale	125
Sandstone	75

The type section is on Scatter River, and the formational name was first used by Kindle in 1944.

Exposures extend along Scatter River for more than 10 miles, beginning 1½ miles west of Liard River (*See* Plate VII B). They are seen in the walls of a "rock canyon, whose walls rise abruptly to from 400 to 500 feet above the valley bottom". The section in this canyon has been measured by Kindle (1944):

Top of Section	Thickness Feet
Sandstone (strike north 15 degrees east, dip 17 degrees southeast)	3
Shale, grey, sandy, with concretions	10
Sandstone, fine-grained; with rusty concretions	3
Shale, grey, sandy, bedded; with rusty concretions	5
Sandstone, grey, hard; with rusty concretions	5
Shale, grey, bedded; with rusty concretions	10
Sandstone, clean, hard, bedded; with concretions	30
Shale, grey, bedded, sandy; with concretions	4
Sandstone, bedded, fine; with rusty concretions	3
Shale, grey; with rusty concretions	5
Sandstone, bedded; with concretions containing *Inoceramus cadottensis*	15
Shale, fine-grained, black to dark grey, sandy; with concretions containing *Inoceramus cadottensis*	200
Sandstone, bedded; with concretions	2
Shale, black to dark grey; with concretions	20
Sandstone, hard, bedded; with concretions	15
Shale, dark grey, bedded; with concretions	25
Sandstone, bedded; with concretions	2
Shale, dark grey; with concretions	25
Sandstone, bedded; with concretions	2
Shale, dark grey; with concretions	4
Sandstone, bedded; with concretions	3
Shale, dark grey; with concretions	10
Sandstone, fine-grained, bedded; with concretions	15
Shale, dark; with concretions	3
Sandstone, bedded; with concretions	2
Shale, dark grey; with concretions	6
Sandstone, clean, bedded; with concretions	100
Shale, sandy, bedded; with concretions	25
Shale, black, friable; with many concretions	125
Sandstone; with thin shale layers and concretions	75
Total thickness	752

The marine fossils are in the upper 300 feet of the formation and include the pelecypod *Inoceramus cadottensis* var.

Lépine Formation

The Lépine formation overlies the Scatter, and consists of about 2,000 feet of grey and black, marine shales, with some sandstone and concretions at some horizons. Presumably the type section is the one on Liard River opposite the mouth of Lépine River, although a more complete section is exposed on the Liard, opposite the mouth of Scatter River. The name was first used by Kindle (1944) and applied to beds on Liard River.

The formation outcrops along Liard River from 12 miles northeast to 15 miles southwest of the mouth of Scatter River. The section exposed on the east bank of the Liard, opposite the mouth of Scatter River, was measured by Kindle (1944):

Top of Section	Thickness Feet
Shale, dark; with rusty concretions	30
Sandstone, straw coloured; with rusty concretions	10
Shale, dark; with rusty concretions	30
Sandstone, straw coloured; with rusty concretions	10
Shale, dark, friable; with rusty concretions	110
Shale, dark, firm; with concretions	90
Shale, friable, grey, breaking in thin flakes; with concretions	330
Sandstone and shale; with a few concretions	10
Shale, friable; with rust-stained concretions	15
Sandstone and shale in alternating beds; with concretions	4
Shale, soft, crumbly; with concretions	10
Sandstone in 2- to 6-inch bands; with thin shale partings	10
Shale, friable; with concretions	18
Sandstone, impure, shaly; with concretions	2
Shale, dark; with 1- to 2-inch rusty argillite beds at 10- to 20-foot intervals	160
Sandstone and fine conglomerate	1
Shale, dark, rust-flecked, crumbly; with scattered iron-stained concretions and a few 1- to 2-inch beds of argillite	820
Shale, concealed beneath Liard River and drift at mouth of Scatter River, at least	340
Total thickness	2,000

Marine fossils collected by Kindle (1944) from 200 feet above river level, on the east bank of Liard River opposite the mouth of Lépine Creek, include: *Gastroplites* cf. *kingi*, *Inoceramus cadottensis* var., and *I. altifluminis*. At or near the same locality, but at elevations of 300 to 800 feet above river level, are exposures of thin-bedded, friable, grey to black, flaky shales; in the lower part of these shales are large flat concretions with '*Placenticeras*' *liardense* Whiteaves.

Clay ironstone concretions are very common in the Fort St. John group, particularly in the shales. This is emphasized more in the descriptions of some authors than of others.

Petitot River

Hage (1945) records the presence of Lower Cretaceous strata on La Biche and Petitot Rivers, tributaries of the lower part of Liard River. On Petitot River the Lower Cretaceous section includes:

Top of Section	Thickness Feet
Fissile shale	1,625 ±
Sandstone	625 ±

The lower half of the fissile shale contains *Neogastroplites cornutus* (Whiteaves)? and *Arctica* sp., the upper half, *Beudanticeras* sp.

Peace River, Cache Creek to Alces River

In Peace River Valley, at the mouth of Cache Creek and eastward, the Upper Cretaceous Dunvegan formation appears at a high elevation on the steep north side of the valley, and is underlain by dark shales that extend down to river level. These shales, referred to as the 'Shaftesbury' shales in a previous report (McLearn, 1944), belong to the upper part of the Fort St. John group. It was from them that Selwyn in 1875 collected *Neogastroplites cornutus* (Whiteaves). Other species from the same beds are *Neogastroplites selwyni, Nucula dowlingi,* and *Posidonomya nahwisi* (McLearn, 1944). These are characteristic fossils of the Goodrich formation. As they occur in shale, however, and no sandstone has been recorded from the section in the cliffs east of Cache Creek, it is apparent that the Goodrich formation does not extend this far east.

It is not known how far below river level these 'Shaftesbury' shales extend. It is probable, however, that they are underlain by the Gates and Moosebar formations. These formations, as already noted, are known in the western sections. If they, as Allan and Stelck (1940) claim, can be recognized as far east as the Guardian No. 1 well at Bonanza, Alberta, it can be reasonably inferred that they occur in an intervening area, between Cache Creek and Alces River, even if below river level.

Age and Correlation

(*See* Figure 12)

Local Correlation

The first serious attempt to co-ordinate stratigraphic information on the Lower Cretaceous of the western interior of Canada was by McLearn in 1932. By this time the study of the Canadian Lower Cretaceous faunas had progressed sufficiently to undertake correlations based on fossils, and to permit some interpretation of the palæogeography. The work of L. F. Spath of the British Museum of Natural History on the ammonoid family Hoplitidae and some Lower Cretaceous ammonoidea from India, appearing at about this time, was also a contributing factor to an understanding of the Canadian faunas. Later, correlations and palæogeography were revised and extended after revision by Spath (1942) of the age of the *Lemuroceras* fauna of India and Madagascar; Wickenden and Shaw's (1943) study of the section on Pine River; Beach and Spivak's (1944) study of the section in the Peace River Foothills; Hage's (1944) examination of the sections in Halfway, Sikanni Chief, and Buckinghorse Valleys; Williams' (1944) study of the section on the Alaska Highway, west of Fort Nelson; Kindle's (1944) examination of the section on Liard River; Hage's (1945) study of the section on the Lower Liard; Feniak's (1944) work in the 'Athabaska-Barrhead map-area'; and studies by geologists in the employ of oil exploration companies. Information was also obtained from an unpublished report by C. R. Stelck (1941) and from a recent paper by Wickenden (1948) on the Lloydminster area of Alberta and Saskatchewan.

Local correlations of Lower Cretaceous formations of northeastern British Columbia have been considered in recent reports by McLearn (1944B, 1945). In them the evidence furnished by marine invertebrates, on the one hand, and by similar lithology and stratigraphic position, on the other, was found to apply. For convenience these sources will be referred to as the faunal and lithological evidence respectively. The first is the only reliable source of long distance correlation. The second can commonly be applied to short distance correlation, in which marker horizons are traced from one locality to another. It has been the experience of Canadian geologists studying the Mesozoic that many correlations based on lithological resemblances alone have been unreliable, and that they have been revised when faunal evidence has become available.

Three and possibly four macrofaunas are known, and furnish faunal evidence for correlation. The three well-defined faunas are, in descending order:

Neogastroplites fauna
Gastroplites fauna
Lemuroceras or *Beudanticeras affine* fauna

The *Lemuroceras* fauna, as recorded in previous paragraphs, carries species of the genus *Lemuroceras*, and *Beudanticeras affine* (Whiteaves), and some pelecypods. The *Gastroplites* fauna includes species of *Gastroplites* and *Inoceramus*, and some starfish. The *Neogastroplites* fauna has species of *Neogastroplites*, *Posidonomya*, and *Oxytoma*. It is possible, but far from proved, that a fourth ammonoid zone lies between the *Gastroplites* and *Neogastroplites* zones. It contains crushed specimens of an ammonoid difficult to identify generically. Specimens collected by McConnell on Liard River were described by Whiteaves (1892) and given the name of *Placenticeras liardense*, and may represent a younger ammonoid genus than *Gastroplites*.

The *Lemuroceras* fauna is found in the Moosebar and Gates formations on Peace River, and permits a faunal correlation of these strata with a lower part of the Buckinghorse formation on Sikanni Chief River. The *Gastroplites* fauna has been reported from the upper part of the Commotion formation on Pine River, and makes possible a correlation of that part with a lower part of the Hasler formation on Peace River and an upper part of the Scatter formation and lower part of the Lépine on Liard River. The *Neogastroplites* or *Posidonomya nahwisi* fauna in the Goodrich formation on Pine and Peace Rivers correlates that formation with the lower and sandstone-bearing part of the Sikanni formation on Sikanni Chief River; the middle sandstone in Tetsa River Valley; a part of the 'fissile shale' on Petitot River; and shales high in the 'Shaftesbury' formation east of Cache Creek on Peace River.

The correlations, considered in the foregoing paragraph and based on faunal evidence, afford a strong supporting framework for the remaining correlations, which, unfortunately, must rest on the weaker lithological evidence. Because of similar lithology and similar stratigraphic position the Moosebar shale on Pine River is correlated with the Moosebar on Peace River. The claim made by students of the Pine River section that the Commotion formation on Pine River is equivalent to the Gates plus a lower part of the Hasler formation on Peace River is a reasonable one, for it has already been demonstrated that faunal evidence supports a correlation of the upper part of the Commotion with the lower part of the Hasler formation, and the evidence of similar lithology supports a correlation of the lower part of the Commotion formation with the Gates.

On lithological evidence, Allan and Stelck (1940) compare the Moosebar shales and Gates sandstone with similar shales and sandstones in the No. 1 Guardian well near Bonanza, Alberta, just east of the area included in this report.

The *Gastroplites* zone has not been identified in the Cretaceous section on either Sikanni Chief or Buckinghorse Rivers. If, however, no hiatus occurs, some upper part of the Buckinghorse formation may include beds of *Gastroplites* age, and so be of the same age as the upper part of the Commotion formation on Pine River plus the lower part of the Hasler in Peace River Valley. On the basis of lithological and stratigraphic evidence, the uppermost part of the Buckinghorse can be correlated with the uppermost part of the Hasler formation in Pine and Peace River Valleys. The *Gastroplites* fauna has not been found in the Cretaceous section on Tetsa River, but some upper part of the 'lower shale' may include beds of *Gastroplites* time. On Petitot River, Hage (1945) suggests that the unfossiliferous sandstone, the lower lithological unit of the section described by him, is of the same age as the Scatter formation on the upper Liard and so of *Gastroplites* time.

Some uncertainty exists as to the age of the lower part of the 'lower shale' of Tetsa River Valley and the basal shales of the Garbutt formation on Liard River. Northward the sandstones of the Bullhead group disappear from the geological column; are absent in Tetsa and Liard Valleys; and no longer set a downward limit to the overlying shales as they do to the south in the Pine, Peace, and other valleys. The basal shales may be of the same age as the Bullhead group and represent a replacement of sandstone by shale in the north; they may be a northward continuation of the shales of the Jurassic Fernie group; or they may be of post-Bullhead age.

The *Neogastroplites* fauna has not been found on Liard River in the area studied by Kindle (1944). Some beds high in the Lépine formation may, however, be of *Neogastroplites* time. The uppermost strata of the Fort St. John group, above the zone of *Neogastroplites*, in northeastern British Columbia are everywhere lacking in diagnostic fossils. Because of similar stratigraphic position, however, a tentative correlation can be made of the Cruiser formation on Pine and Peace Rivers with the upper shale member of the Sikanni formation on Sikanni Chief and neighbouring rivers; with the 'upper shale' on Tetsa River; with the top of the Lépine on Liard River; with the upper part of the 'fissile shale' on Petitot River; and with the top of the 'Shaftesbury' shale on Peace River, east of Cache Creek.

External Correlation

Correlations have been attempted of the Fort St. John group in northeastern British Columbia with Lower Cretaceous formations in other parts of the western interior of Canada (McLearn, 1932, 1944B, 1945). Some difficulties, however, have been encountered. Faunal studies to date have been confined mostly to the macrofaunas, which unfortunately have a limited distribution: the *Neogastroplites* fauna is little known outside of northeastern British Columbia; the *Gastroplites* fauna is known as far east as the lower part of Peace River, but has not been found on the lower Athabasca River, on the Manitoba escarpment, or in the southern Foothills and Plains; the *Beudanticeras* or *Lemuroceras* fauna has a wider distribution in the north than either the *Gastroplites* or *Neogastroplites* fauna and is known as far east as the lower part of Athabasca River, but it has not been obtained from the Manitoba escarpment or from the southern Foothills and Plains. Evidence from the study of microfaunas is needed; and indeed is now becoming available, but not yet in sufficient amount to settle the many unsolved problems of correlation. In the past where faunal evidence has been lacking recourse has been made to the criteria of similar lithology and similar stratigraphic position, but not always with success. Undoubtedly some current correlations will require revision when more faunal, and particularly microfaunal, evidence is obtained.

The Moosebar plus the Gates formation in northeastern British Columbia is correlated with the upper and fossiliferous part of the Loon River formation plus the basal beds of the Lower sandstone member of the Peace River formation on lower Peace River, on the basis of the *Beudanticeras affine* or *Lemuroceras* fauna. The lower part of the Hasler formation, containing *Gastroplites* on Peace River, and probably the upper part of the Commotion on Pine River, are of the same age as the Cadotte member of the Peace River formation (*See* Stelck, 1941; McLearn, 1932, 1944B, 1945). The upper part of the Hasler formation, in addition to the Goodrich and Cruiser formations, is correlated with the Shaftesbury formation, on the basis of similar stratigraphic position (*See* Figure 12).

The Moosebar and Gates are correlated with the Clearwater formation in the lower Athabasca River Valley, on the evidence of the *Beudanticeras* or *Lemuroceras* fauna; it is possible that a part of the Grand Rapids formation, which overlies the Clearwater, should be included in this correlation. The equivalent of the beds carrying the *Gastroplites* fauna, that is the lower part of the Hasler on Peace River and the upper part of the Commotion formation on Pine River, has not yet been determined in the section on the lower part of Athabasca River, as the *Gastroplites* fauna has not been found there; it probably lies somewhere in the section embraced by the upper part of the Grand Rapids and the lower part of the Joli Fou formations. The equivalent of the Goodrich and Cruiser formations may lie somewhere within the range of the Joli Fou and Pelican formations (*See* Figure 12). Foraminiferal studies now being conducted by R. T. D. Wickenden may lead to more exact correlations.

In the central Foothills of Alberta, the Mountain Park formation plus a basal part of the Blackstone formation may, like the Fort St. John group, be of late Lower Cretaceous age. In the southern Foothills of Alberta, the upper part of the Blairmore, with the Albian flora, is of late Lower Cretaceous age and is correlated with at least a part of the Fort St. John of the north. It is at present unknown whether a basal part of the Blackstone in the southern Foothills should be correlated with the Fort St. John.

In the deeply buried early Cretaceous beds of southern Saskatchewan, it is possible that the section that comprises the upper part of the 'Varicoloured beds', together with the grey shales with *Haplophragmoides gigas*, and the grey sandstone and shale with coal (*See* Fraser *et al.*, 1936), is equivalent, in whole or in part, to the Fort St. John group. In southern Alberta, the equivalent strata of this group fall somewhere within the section that embraces the upper part of the 'Varicoloured beds', together with the shale and sandstone with *H. gigas*, and the Bow Island chert.

On the Manitoba escarpment, a part of the Ashville formation has been correlated with the Shaftesbury formation (Wickenden, 1945) and so with the upper part of the Fort St. John group on Peace River. Some part of the Swan River group, which underlies the Ashville, may be equivalent to some part of the Fort St. John group, but no faunal evidence has been obtained to substantiate this correlation.

The Sans Sault formation in Mackenzie River Valley contains fossils of marine origin, including the diagnostic ammonoid genera *Gastroplites* and *Lemuroceras* (Link and Hume, 1945; Warren, 1947). It is correlated with the lower part of the Fort St. John group in Peace River Valley—that is, with the Moosebar, Gates, and Hasler formations.

The Haida formation in the Queen Charlotte Islands is like the Fort St. John group of Albian age, although its exact age within the Albian has not yet been established. The faunas, however, have nothing in common.

Gastroplites has recently been discovered on Sabine Island, East Greenland (Spath, 1946), in "clay-ironstone concretions from the *Inoceramus* beds".

On the island of Madagascar, the ammonoids with which *Lemuroceras* is associated are of the *mammillatum* zone of the Albian stage (Spath, 1942). In the Gault formation of Folkstone, England, *Gastroplites* occurs in the *cristatum* zone of the Albian stage, and, therefore, is of somewhat later Albian age than *Lemuroceras*.

Unfortunately, *Neogastroplites* has so far only been found in northeastern British Columbia, and, therefore, affords no evidence for intercontinental correlation. It is dated late Albian because it is closely related to the Albian genus *Gastroplites*, but the possibility of an early Cenomanian (early Upper Cretaceous) date cannot be entirely eliminated.

UPPER CRETACEOUS

DUNVEGAN FORMATION

Definition

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 non-marine, light grey, massive, crossbedded sandstones, flat ironstone concretions, thick shales, thin-bedded sandstone and shale, rare calcareous layers, and rare, thin coal seams.

The name was first used by Dawson (1881), and applied to what he called the 'Lower Sandstones and Shales' of Pine and Peace River Valleys. Among the sections described by him was that exposed in the cliffs on the north side of Peace River, west of the old Hudson's Bay Company trading post at Dunvegan on Peace River; this, presumably, is the type locality.

Pine River Valley

The Dunvegan formation has been mapped in the Mount Hulcross-Commotion Creek map-area by Wickenden and Shaw (1943). It outcrops in an area between Hulcross and Bowlder Creeks; in the vicinity of Cruiser Mountain; and on the south side of Pine River, east of Young Creek. The formation is more than 1,200 feet thick, and consists mostly of sandstone, with some conglomerate. "The beds near the base are usually fine-grained sandstone, and at many localities conglomerate or conglomeratic sandstone occurs about 100 feet above the base. Cross-bedding is prevalent throughout most of the formation." *Unio dowlingi* has been collected about 50 feet above the base at localities east and west of Commotion Creek, and fossil plant fragments were found on Cruiser Mountain.

The Dunvegan formation in Pine River Canyon was described by Dawson in 1881. It was said to consist of "flaggy sandstones, often brownish grey in colour, and false-bedded or ripple-marked, greenish grey, fine-grained sandstones and black, soft argillaceous sandstones and shales holding plant impressions.....In the valley of a small stream which cuts the bank on the south side of the canyon, not far above the river level, Mr. Selwyn, in 1875, found, in alternating strata of sandstones and shales, four thin seams of coal, which in descending order are—six inches, eight inches, two feet and eight inches thick". The Dunvegan was also recorded by Dawson at the lower forks of Pine River, on Coal (Coldstream) Brook, and on Murray River (east branch of Pine River). In addition, fossils of the Dunvegan formation have been collected on Flat (Rhubarb) Creek.

The Dunvegan formation is exposed in the valley of Kiskatinaw River (Williams and Bocock, 1932) from its mouth to range 18.

South of Pine River Valley, Spieker (1921) recognized an upper member of the Dunvegan to which he gave the geographical name of Sukunka. It was said to comprise green shale, hardened calcareous mudstone, grey, platy, crossbedded, lenticular sandstone, with flat nodules of black shale, and some thin seams of carbonaceous material and low-grade coal.

Moberly and Peace River Valleys

In the Dunlevy-Portage Mountain map-area, the Dunvegan formation is said to be best exposed on Tworidge Mountain and in Moberly River Valley. It "consists of massive, coarse- to fine-grained, buff to reddish weathering sandstones. Narrow lenses and thin beds of conglomerate occur near the base of the formation. Higher strata consist of medium-grained, greenish weathering, micaceous sandstones, and interbedded greenish brown, sandy shales. Large scale crossbedding is common" (Beach and Spivak, 1944).

A section of the lower part of the formation, measured by Beach and Spivak on Moberly River, near the eastern boundary of the area, is as follows:

Top of Section	Thickness Feet
Sandstone, green, shaly, fine-grained, rubbly	20
Sandstone, grey, medium-grained	10
Sandstone, green, shaly; with interbedded sandy shale	200
Shale, green, sandy	30
Concealed	100
Sandstone, massive, medium-grained	1
Sandstone, crossbedded, fine-grained	70
Conglomerate, fossiliferous	0·5
Sandstone, crossbedded, grey, micaceous	30
Total	461·5
Underlying beds—Cruiser formation	

Unio dowlingi occurs in the lower part of the formation in this area. Beach and Spivak (1944) estimate a total thickness of more than 1,100 feet.

Far to the west, in the Foothills between Pine and Peace River Valleys, Mathews (1947) has mapped a small area of Dunvegan northeast of Mount McAllister. About 200 feet of sandstone and conglomerate are exposed. No fossils were found.

Peace River Valley, Cache Creek to Alces River

On the north side of Peace River, at the mouth, and east, of Cache Creek, the Dunvegan formation is exposed in the higher parts of the cliffs where it overlies dark shales at the top of the Fort St. John group. A short distance downstream the outcrop of the Dunvegan recedes from the cliffs overlooking the river, and only the Fort St. John shales are exposed. It reappears in high banks and hills on the north side of the river near the mouth of Alces River, and to the east rapidly descends on the valley sides and forms low sandstone cliffs near river level.

The Dunvegan formation, southeast of Alces River and in the Pouce Coupé Valley has been described in several reports. In the latest, that of Gleddie (1949), it is said to be about 650 feet thick and to consist of sandstone and shale with a little coal, mostly of non-marine, but partly also of brackish water and marine, origin. Overlying sandstone and shale, including the Doe Creek and Pouce Coupé sandstones, are placed in the Kaskapau formation.

Fort St. John to Indian Creek

Hage (1944) has studied the Dunvegan formation from Fort St. John to Indian Creek, along the Alaska Highway (*See* Plate VIII A). Here are "fine- to coarse-grained, grey, brown-weathering, crossbedded sandstones interbedded with grey, brown-weathering shale. Thin coal seams are present, and small fragments of carbonaceous material are common along bedding planes. Lenses and beds of pebble-conglomerate are commonly associated with the coarser sandstone beds".

Along the east side of Charlie Lake, massive, medium- to coarse-grained, feldspathic sandstone, in beds up to 20 feet thick and containing ironstone concretions up to 4 inches in diameter, is exposed in cliffs 75 feet high. Hage (1944) states:

"A section about 350 feet thick exposed south of Trutch Creek and 5 miles east of the Highway is composed of four thick sandstone beds separated by interbedded shale and sandstone. The upper sandstone bed is overlain by 50 feet of pebble-conglomerate.

"Another section, east of Indian Creek . . . . . is quite similar to that south of Trutch Creek. A section, 82 feet thick, of medium- to coarse-grained sandstone containing a few thin beds of pebble-conglomerate, is also exposed . . . . . along the scarp [2 miles south of Suicide Hill]. On Suicide Hill . . . . . a 100-foot section exposed by the road-cut consists of medium-grained sandstone beds interbedded with sandy shale that contains a 3-inch seam of coal. This section underlies the thick coarse-grained sandstone [2 miles south of this hill]. Along the Highway northwest from Charlie Lake and at elevations higher than the outcrops east of the lake, are outcrops of dark grey and light grey shale interbedded with fine-grained, soft sandstone beds. Most of the shale has specks of carbonaceous material. No fossils were found in any of these outcrops. They are believed to represent parts of the Dunvegan formation but may be younger".

Age and Correlation

(*See* Figure 12)

The age of the Dunvegan, proposed by various authors, has varied from earliest Upper Cretaceous (Cenomanian) to Belly River (Campanian). It was dated Niobrara or late Coloradoan by Dawson (1881); Belly River by McConnell (1893); Belly River by Dowling (1915); Coloradoan by McLearn (1918); probably early Coloradoan by McLearn (1926); Upper Cretaceous, about Cenomanian, by McLearn (1932); late Cenomanian or rather early Turonian by Williams and Bocock (1932), on the advice of W. A. Bell; Cenomanian or very early Turonian by McLearn (1937); Cenomanian by Warren and Stelck (1940); and probably Cenomanian (early Upper Cretaceous) by Hage (1944), on the advice of W. A. Bell. The correlation by W. A. Bell is based on a study of the flora. The invertebrate evidence for international correlation is not strong, as most of the species are local. Varieties of *Inoceramus dunveganensis*, however, with fairly well-developed concentric ornament closely resemble *Inoceramus crippsi* Mantell from the Upper Greensand, Chalk Marl, and Lower Chalk of England, that is, from the early Upper Cretaceous Cenomanian stage. Warren and Stelck (1940) record the presence of two fragments of an ammonoid "undoubtedly referable to" the genus *Dunveganoceras* Warren and from 200 feet below the top of the Dunvegan formation. As will be noted later, this genus is probably of Upper Cenomanian age and is at the very latest of early Turonian. Other species in this fauna are confined to northeastern British Columbia or afford no comparison with foreign strata whose age has been established. Today, however, all students of Canadian Cretaceous faunas will accept an early Upper Cretaceous age for the Dunvegan formation and, tentatively at least, a Cenomanian date in terms of European chronology.

An interesting contribution, mostly by geologists of oil companies, has been the tracing of the Dunvegan formation southward along the Foothills, almost to Athabasca River. South of this river, as noted on a previous page, it appears to pass into shales, fairly low in the Blackstone formation.

The Dunvegan formation extends eastward across the Plains to Dunvegan on lower Peace River and to exposures on lower Smoky River. In Athabasca River Valley, the Pelican sandstone has been correlated with the Dunvegan formation (McLearn, 1932) on the basis of lithological resemblance. The Pelican, however, may be a little older than the Dunvegan. The small fauna with '*Acanthoceras*' sp. and *Inoceramus athabaskensis*, which is probably of the same age as the Dunvegan fauna, occurs (Wickenden, 1949) about 200 feet above the top of the Pelican sandstone.

It has been proposed that beds at the top of the Ashville formation on the Manitoba escarpment may be the equivalent of the Dunvegan formation (McLearn, 1937; Wickenden, 1945). However, the fossils in the Ashville that suggest this correlation are too fragmentary for exact determination.

The equivalent of the Dunvegan in southwestern Alberta has yet to be recognized. It is not to be found in the upper beds of the Blairmore, as Warren and Stelck (1940) have claimed, for the upper part of the Blairmore formation is of Albian (late Lower Cretaceous) and not of Cenomanian (early Upper Cretaceous) age. The equivalent beds, possibly, are to be found in some very low part of the Blackstone formation.

Correlation with the early Coloradoan of the United States interior has been proposed in a previous paragraph. The No. 1 zone of Coalville, Utah; the coal-bearing beds of Kannara and Cedar City, Utah; the Woodbine of Texas; and the Bear River formation of Texas are possible correlatives. It is interesting to note that the beds of definite Cenomanian age, with the diagnostic genus *Acanthoceras*, have been found in the United States interior, in the Graneros shale of south-central Colorado, and in the so-called Dakota of mid-western Colorado (Reeside, 1927).

FORT NELSON FORMATION

Definition

The Fort Nelson formation consists of more than 600 feet of massive, thick-bedded conglomerate and sandstone, and some shale beds. The name was first used by Kindle (1944), and applied to beds in the valleys of Liard River and of streams tributary to it. The type locality is along the east side of Liard River Valley, from near the mouth of Toad River almost to the mouth of the Beaver.

Tetsa River Valley

The massive conglomerate and sandstone capping Tepee, Steamboat, and Table Mountains, east of Mill Creek, are described by Williams (1944) and referred to the Fort Nelson formation:

"On Table Mountain, the heavy conglomerate series is 550 feet thick. The conglomerates rest on soft clay shale interbedded with soft sandstone with a bed of coal 1 foot thick near the top. The slumping and weathering of this formation have caused the recession of the plateaux, marked by the cliff fronts and the cones and piles of huge conglomerate blocks that occur at intervals from Table to Steamboat Mountains. Glacial moraines are interlocked with these boulder piles, showing that glacial ice has played an important rôle in the removal of surplus debris and in arranging what remains.

"On the top of Table Mountain, near the eastern face, one huge cubic block of conglomerate appears to rest on one corner, forming a landmark visible from the Highway near Mill Creek.

"The surface of Table Mountain conforms to the surface of the conglomerate, which dips about 6 degrees north by east. The conglomerate is cut into huge joint blocks, which, near the western precipice, have opened widely, leaving trenches 8 to 10 feet deep and 10 to 15 feet wide.

"The conglomerate on Tepee Mountain includes pebbles up to 2 inches in diameter. These consist of black chert, bleached yellow chert, white sugary quartzite, and opaque white quartz. One pebble of coarse-grained granodiorite was seen. Upward in the formation sandstone occurs.

"The upper 500 to 600 feet of Steamboat Mountain is composed of massive sandstone and conglomerate. The basal beds are of hard, cream weathering sandstone, 50 feet thick, and the upper beds consist of massive conglomerate. The formation is cliff-forming, as may be seen in the east face of Steamboat Mountain. The upper massive conglomerate overhangs as much as 50 feet and the precipice is over 500 feet high.

"Other flat-topped hills to the north and northeast appear to be capped by the same conglomerate. The complete thickness of the formation is not represented at any locality visited, and must have been considerably more than 600 feet."

Liard River Valley

The Fort Nelson formation outcrops in two parts of the Nelson Forks map-area (Kindle, 1944). A long band lies east of Toad River, continues along the east side of Toad and Liard River Valleys, and extends beyond Beaver River. A section was measured by Kindle on the east side of Liard River, opposite the mouth of Scatter River. "The bottom of the section is 1,660 feet above the river, where the Fort Nelson formation conformably overlies the Lower Cretaceous shales of the Lépine formation." This section is as follows:

Top of Section	Thickness Feet
Conglomerate; clean, well-washed beds	325
Sandstone, clean, coarse, yellow	15
Shale, dark	20
Sandstone and shale, interbedded	40
Conglomerate, massive	30
Sandstone, coarse, yellow, crossbedded	15
Sandstone and shale, interbedded	25
Conglomerate, massive, mostly grit size	20
Sandstone, coarse, yellow	40
Total thickness	530

A second area of outcrop is that along the valley of Fort Nelson River from Patry Lake nearly to Nelson Forks. Kindle notes that the "first outcrops to be seen from Fort Nelson River below Fort Nelson are flat-topped bluffs of conglomerate, grit, and sandstone. They rise to 1,000 feet above the river at distances of 2 or 3 miles north and south of the stream and, roughly, 35 miles southeast of Nelson Forks. A few miles farther downstream the bluffs are close to the river, and they form its east bank for 12 miles. They decrease gradually in height toward the northwest and disappear beneath the drift 10 miles south of Nelson Forks. The conglomerate beds strike northeast and dip from 2 to 3 degrees northwest, thus accounting for the gradual topographic slope to the northwest. The lower slopes below the nearly vertical cliffs of conglomerate that face the river are littered by a talus of huge conglomerate blocks that conceal the underlying shale formation. The bluffs were climbed in two places, 3 miles apart, and at each place were found to comprise about 400 feet of conglomerate with minor beds of sandstone. The conglomerate forms both thin and thick massive beds, and in places shows well-defined crossbedding. Much of the conglomerate is of grit size, with a scattering of larger pebbles; in other beds the pebbles are close packed and range from 1 to 3 inches in diameter. The pebbles are of quartz, chert, slate, argillite, quartzite, chalcedony, jasper, and minor calcite or limestone".

Petitot River

An outcrop of the Fort Nelson formation is mapped by Hage (1945) on the lower part of Petitot River and crossing the Liard above Fort Liard, and is estimated to have a thickness of 500 to 800 feet. It is described by Hage as follows:

"Overlying the dark grey, fissile, marine shales of Lower Cretaceous age on Petitot River are grey, banded sandstones and interbedded, dark grey, chunky shale transitional from the marine shale to the overlying medium-grained, grey, buff weathering sandstone. Thirty feet of the transitional beds are exposed at this locality. Above them the section is only partly exposed to where the uppermost 250 feet of conglomerate and coarse, grey, crossbedded sandstone form continuous outcrops along the banks for 4 miles through the canyon. A section in the partly exposed interval shows 130 feet of beds composed of dark grey shale interbedded with medium- to fine-grained sandstone overlain by medium- to coarse-grained sandstone beds and a 15-foot bed of loosely cemented pebble-conglomerate. Carbonaceous fragments were observed along some of the bedding planes. The upper conglomerate member contains pebbles of quartz, quartzite, grey, green, and black chert, and grey and black argillites. These are as much as an inch in diameter, and are fairly well sorted. The sandstone associated with the conglomerate is coarse grained and cross-bedded."

Age and Correlation

The only fossils yet found in the Fort Nelson are a few leaves collected by Kindle from the upper part of the formation on Liard River, and they are not diagnostic. Williams (1944), Kindle (1944), and Hage (1945) all propose a correlation with the Dunvegan formation of which they consider the Fort Nelson to be a northern extension.

SMOKY GROUP

Definition

The Smoky group embraces all strata between the Dunvegan formation below and the Wapiti group above. In northeastern British Columbia it contains considerable sandstone, but in most places is predominantly shale. On the Plains, it consists mostly of shale, with the exception of a sandstone near the middle. The group is entirely of marine origin.

'Smoky River' was first used as **a** formation name by Dawson in 1881, for the 'Upper shales', "well seen" by him on Coal Creek and the lower part of Smoky River. On Smoky River, two thick shales are separated by the Bad Heart, or in the broad sense, Bighorn sandstone. The lower shale unit has been called Kaskapau member (McLearn, 1919). The upper shale has not been named, and can probably be called Wapiabi (Gleddie, 1949). 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, 1943; Crickmay, 1944; Gleddie, 1949). The Smoky has a shorter downward range than the Alberta group.

Very little has been published on the Smoky group of northeastern British Columbia, and few sections have been examined carefully.

Kiskatinaw River

Williams and Bocock (1932) have recorded the following section of the Smoky group on Kiskatinaw River, about 3 miles above its mouth:

	Thickness Feet
Shale, black	20
Sandstone; shale, arenaceous	10
Shale, dark grey to black	90
Dunvegan formation	

Clay ironstone concretions and selenite crystals occur in these basal beds of the Smoky group.

Tuskoola and Wartenbe Mountains

About 800 feet of sandstone and shale of the Smoky group have been described by Williams and Bocock (1932) on Tuskoola Mountain. These authors list the diagnostic *Watinoceras* cf. *coloradoense* Henderson and *Inoceramus labiatus* Schlotheim from the upper 675 feet of this section. They also have suggested that "1,000 feet or so of mixed sandstones and shales belong to the Smoky River" on Wartenbe (Table) Mountain.

Pouce Coupé River

In Pouce Coupé River Valley, at the eastern border and east of the region under consideration in this report, the lower part of the Smoky group has been described by Warren and Stelck (1940). They acknowledge that it is difficult to draw a boundary between the Dunvegan and the Smoky, but do place it at the top of what they call the Doe Creek sandstone. The Pouce Coupé sandstone member, about 100 feet stratigraphically above the Doe Creek sandstone, is included in the Smoky. This sandstone and the overlying shales contain the *Dunveganoceras* fauna, and, not far above it, the Turonian fauna, with *Watinoceras* and other genera, appears.

Crickmay (1944) has described the Smoky group in the vicinity of Pouce Coupé. He states that it "overlies the Dunvegan with obvious conformity. It consists mainly of shale with a few prominent beds of sandstone. One of these, 22 feet thick, lies 270 to 285 feet above the base of the formation in the Pouce Coupé section".

Near Pouce Coupé, Gleddie (1949) estimates a thickness of 1,550 feet of the Kaskapau and a thickness of 650 feet of the Wapiabi formation. In the same area he assumes a thickness of 100 feet of the Bighorn or 'Cardium' formation. He includes the Doe Creek and Pouce Coupé sandstones in the lower part of the Kaskapau.

It is probable that sediments of the Smoky group underlie a large area on the Plains, east of the Alaska Highway, that is, east of outcrops of the Dunvegan formation. Very little is known, or at least very little has been published, on the geology of this part of northeastern British Columbia.

KOTANEELEE FORMATION

Liard River Valley

The Kotaneelee formation consists of 500 to 1,000 feet of marine shale, sandstone, and rare conglomerate. It lies between the Fort Nelson formation below and an unnamed group of non-marine sandstones and shales, probably the equivalent of the Wapiti group, above, and has about the same stratigraphic range as the Smoky group.

The name Kotaneelee was first used by Hage (1945), and was applied to strata in the valleys of Kotaneelee and Petitot Rivers, tributaries of the Liard. The area of outcrop is large, extending over the lower part of the Dunedin River Valley, the valley of the Liard from near the mouth of Beaver River to the mouth of Kotaneelee River, and the lower part of the valley of Petitot River.

Coarse and fine sandstone and dark shale, with a few thin beds of hard, rusty shale and some scattered fossiliferous concretions, are exposed in banks up to 300 feet high on the east side of Beaver River, from 4 to 12 miles north of the Liard. In places also are exposures 100 feet high of soft grey, laminated clay shale, with rusty, fossil-bearing concretions (Kindle, 1944). Six miles north of the Liard and east of Beaver River, Kindle collected *Inoceramus pontoni ?* and *Scaphites ventricosus* Meek and Hayden, diagnostic of the Coniacian, Lower Wapiabi fauna.

About 200 feet of sandstone, shale, and thin conglomerate are exposed on the north side of Liard River, 9 miles northwest of Nelson Forks. Exposures of the Kotaneelee formation have also been observed on the south bank of the Liard west of the mouth of Dunedin Creek (Kindle, 1944).

Beds higher in the formation, consisting of sandstone and shale, are exposed on a hill on the east side of Liard River, about 12 miles below the mouth of the Fort Nelson. Here, in 1922, Hume collected *Inoceramus* cf. *tuberculatus* Woods?. In this vicinity also, at Pretty Hill, Hage (1945) collected *Inoceramus* in shale and thin beds of sandstone, from 300 to 500 feet above the river. Hage measured a section of this formation, on the east bank of Liard River, about 4 miles farther downstream.

Top of Section	Thickness Feet
Loose blocks of grey sandstone	
Shale, dark grey, chunky; with ironstone concretions; *Inoceramus*	100
Pebble layer of black chert	0·2
Sandstone, grey, interbedded with grey shale; *Protocardium*	15
Shale, dark grey, chunky; ironstone concretions	100
Total thickness	215·2

Fossils collected from the talus below the outcrop comprise *Inoceramus* (cf. *tuberculatus* Woods and cf. *steenstrupi* Loriol) and *Baculites.*

Hage (1945) measured a section of the Kotaneelee formation on Kotaneelee River about 7 miles above its mouth; neither the top nor basal beds of the formation are exposed at this locality.

Top of Section	Thickness Feet
Shale, dark grey; with concretions	150
Sandstone, bedded, medium-grained	8
Shale, sandy	20
Shale, grey, chunky, brown; with ironstone concretions	150
River level	
Total thickness	328

Fossils collected from the lower 200 feet are: *Oxytoma nebrascana, Inoceramus lobatus* Goldfuss, in broad sense (cf. var. *lundbreckensis* McLearn; cf. also *I. patootensis* Loriol), *Anomia* cf. *subquadrata*, and *Baculites ovatus.*

The following section of the Kotaneelee formation in the lower end of the canyon on Petitot River was measured by Hage (1945):

Top of Section	Thickness Feet
Shale, dark grey	5
Sandstone, medium-grained; *Inoceramus*	10
Shale, grey, soft, chunky; few concretions; *Inoceramus pontoni?*	175
Sandstone, brown weathering, fine	10
Conglomerate, unconsolidated; pebbles in sandy shale	5
Shale, sandy; and fine-grained sandstone	20
Concealed	100
Shale, bedded, grey	20
Contact, Fort Nelson formation	
Total thickness	345

Kindle (1944) suggests a possible thickness of 1,000 feet for the Kotaneelee formation in the Nelson Forks map-area. Hage (1945) states that it is in excess of 500 feet in Kotaneelee Valley in the Lower Liard River map-area.

The presence of marine fossils indicates a marine origin for the Kotaneelee formation and for all the Smoky group in northeastern British Columbia.

Age and Correlation

(*See* Figure 12)

Five faunal zones of the Smoky group have been recognized in the northern Plains and Foothills. In descending order they are:

Inoceramus (of the *lobatus* species group)
Scaphites ventricosus
Prionotropis
(*Watinoceras*)
Dunveganoceras

Although fragments of *Dunveganoceras* are said to occur in the Dunvegan (Warren and Stelck, 1940), good specimens of this genus occur in the overlying and basal beds of the Kaskapau formation (Rutherford, 1930; Warren, 1930; McLearn, 1937; Warren and Stelck, 1940; Gleddie, 1949). Unfortunately, *Dunveganoceras* is only known in Alberta, northeastern British Columbia, and Wyoming. It does, however, show some resemblance to the upper Cenomanian ammonoid genus *Acanthoceras* Neumayr and the early Turonian *Mammites* Laube and Bruder. Typical Cenomanian genera like *Acanthoceras* Neumayr, *Mantelliceras* Hyatt, and *Schloenbachia* Neumayr are absent. Most geologists, however, will accept a tentative Cenomanian and possibly late Cenomanian age for this *Dunveganoceras* fauna.

A zone of *Watinoceras,* distinct from and underlying the zone of *Prionotropis,* has been proposed (McLearn, 1937), but is not yet established by field work. Indeed Gleddie (1949) suggests that *Watinoceras* ranges up into the zone of *Prionotropis.* If *Watinoceras* is a lower and a distinct zone it affords a correlation of the sandstone of Tuskoola Mountain with shales low in the Kaskapau formation on Smoky River, and is of early Turonian age. A lower part of the Favel formation (Wickenden, 1945) on the Manitoba escarpment and at least a part of Division C (Hume and Link, 1945), the Little Bear formation (Stewart, 1945) of Mackenzie River Valley, may be of this time.

The late *Turonian* zone of *Prionotropis* has not yet been recognized in northeastern British Columbia on the basis of faunal evidence. Unfossiliferous beds of this age, may, however, occur in the Upper Cretaceous succession in British Columbia, as, for example, in the higher part of the section on Tuskoola Mountain and vicinity; in the Smoky group, east of the Alaska Highway, on Sikanni Chief and other rivers; and in the lower part of the Kotaneelee formation in the basin of Liard River. In the central Great Plains of the United States interior, the *Prionotropis* fauna occurs in the Carlile shale.

In northeastern British Columbia the *Scaphites ventricosus* fauna has been found in the Kotaneelee formation only in the basin of Liard River, and allows a correlation of a middle part of this formation with the uppermost part of the Blackstone and all of the Bad Heart formation on Smoky River; with the upper part of the Bighorn formation and with the lower part of the Wapiabi formation in the central and southern Foothills; and with the lower part of the Boyne member, and possibly all or part of the Morden member of the Vermilion formation on the Manitoba escarpment. In the United States interior, this fauna occurs in the upper part of the Colorado shale of northern Montana and in the Niobrara formation of Wyoming and of the Great Plains (Reeside, 1923). This fauna is correlated with the Coniacian stage of the Upper Cretaceous of Europe.

The fauna, with *Inoceramus* of the *lobatus* species group, is known in northeastern British Columbia as yet only from the upper beds of the Kotaneelee formation. It permits a correlation of these beds with the upper part of the Wapiabi formation of the Alberta group of the central and southern Foothills; with the upper part of the Boyne member on the Manitoba escarpment; with the Telegraph Creek formation of Montana; and with part of the Cody shale of northern Wyoming (Reeside, 1923). It is of Santonian and perhaps early Campanian age, in the European chronology, based chiefly on the close resemblance, or even identity, of the *Inoceramus* to species of the *I. lobatus-steenstrupi-cardissoides* group.

WAPITI GROUP

Definition

The Wapiti conformably overlies the Smoky group and consists mostly of non-marine, thick-bedded sandstones, flaggy, shaly sandstones, shales, and clays. Coal seams occur at some horizons, and plant remains and non-marine shells have been collected. A thin, basal zone of marine strata has been reported. Dawson gave the name in 1881 to the beds he called the 'Upper sandstones and shales' of Pine River and Peace River Valleys. The group was first described on Wapiti River and on the lower part of Smoky River, but its total thickness is unknown.

Plains, South of Peace River

Very little is known of the Wapiti group south of Peace River in the region described in this report. Williams and Bocock (1932) placed massive sandstones with lenses of coarse grit, on Bear Mountain, south of the Dawson Creek-East Pine Road, in the Wapiti group. They also mapped several small areas of the group in the vicinity of Dawson Creek and Pouce Coupé.

Liard River Valley

"Overlying the Kotaneelee formation at several localities are medium-grained grey sandstone and fine pebble-conglomerate beds. On Pretty Hill, 720 feet above the river, are 25 feet of medium-grained, banded sandstone and pebble-conglomerate. Along the east bank of Liard River, 2 miles above the mouth of Kotaneelee River, a sandstone bed at least 25 feet thick occurs 400 feet above river level. The sandstone is banded, medium to coarse grained, feldspathic, buff weathering, calcareous, and both massive and thinly bedded. It is overlain by a seam of low-grade coal 15 inches thick. Coal of better quality was observed in a slump block 20 inches thick, close to river level and below the other seam. The slumped coal is believed to have come from the concealed interval below the sandstone outcrop. No fossils were found in the upper sandstone beds, but a non-marine origin is indicated by the coal and carbonaceous material present. The stratigraphic position of this non-marine assemblage above the marine Kotaneelee formation indicates that it is correlative with the Wapiti group" (Hage, 1945).

Age and Correlation

(*See* Figure 12)

The upper stratigraphic range of the Smoky group is about the same as that of the Alberta group. The overlying Wapiti beds, therefore, begin at an horizon similar to that of the Belly River of the central and southern Foothills. How high stratigraphically this thick freshwater group extends is not known; it may, in some areas, extend as high stratigraphically as the Paskapoo formation of the central Foothills and Plains of Alberta, but probably not so high in northeastern British Columbia. In terms of European chronology, it begins in about late Santonian or early Campanian time and ends in some areas in Paleocene time.

UPPER CRETACEOUS AND (OR) PALEOCENE

SIFTON FORMATION

Definition

Many years ago McConnell (1896) mapped and described some coarse sedimentary rocks, chiefly conglomerates, in the Rocky Mountain Trench, extending from near the mouth of Ingenika River to beyond Sifton Pass. Much later, in 1941, Hedley and Holland (1941) placed these beds in a formation to which they gave the name of Sifton.

Finlay River Valley

An area of outcrop of the Sifton formation, about 3 miles long and ½ mile wide in the Rocky Mountain Trench, appears on the Aiken Lake map (Armstrong and Roots, 1948).

The conglomerate of the Sifton formation is described by Roots (1948). It consists "of subangular to rounded pebbles, averaging about 1½ inches in diameter, of limestone, sandstone, schist, slate, and quartz, in an impure silty matrix. Water-worn, subangular pebbles and boulders up to 8 inches in diameter of blue-grey or buff-coloured limestone, mostly well-bedded, comprise about 70 per cent of the rock. About 15 per cent is composed of pebbles of brownish grey to buff-coloured, medium- to fine-grained, well-bedded, calcareous sandstone. Minor constituents include pebbles of white quartz, blue-grey chert, or highly silicified limestone, and a bright red, soft, sheared rock that may be a ferruginous limestone or slate or a weathered volcanic rock. The matrix of the conglomerate is shaly to silty, highly calcareous, and locally ferruginous.

"The conglomerate is roughly sorted, but only local evidences of bedding could be obtained .... [It] outcrops on a long, low ridge that trends parallel with the trench. No estimate of the thickness of the conglomerate was obtained."

Sifton Pass

The Sifton formation has been described by Hedley and Holland (1941). It extends along the Rocky Mountain Trench for 10 or 15 miles north and south of Sifton Pass, and "locally to elevations of about 5,000 feet, or 2,000 feet above the valley floor".

Conglomerate is the most abundant sediment, but "local, minor beds of sandstone and shale" are present. Fragmentary plant remains are common in the sandy beds and coal seams are recorded. A non-marine origin is inferred.

"The sands and shales, locally strongly carbonaceous, are for the most part weakly coherent.

"The conglomerate is strongly cemented and is a hard, resistant rock, but on weathering tends to break down so as to free the constituent pebbles." The size of the well-rounded pebbles is commonly "between that of a hazel-nut and an egg. The matrix is finely conglomeratic or sandy. Constituent materials are all sedimentary, among which limestone is always present and predominates locally; in some of the exposures, the proportion of limestone is 8 to 1 and the matrix is calcareous. Other pebbles are shales, sandstones, argillites, quartzites, and cherts; some black chert pebbles, commonly rather small, are everywhere present. No igneous pebbles are found, and none of schists or rocks metamorphosed beyond the grade of phyllite". Hedley and Holland do not discuss the source of these sediments, but they note that the "beds are clearly unconformable with the underlying rocks". The relation of this formation to the Cassiar batholith is not stated and is probably unknown.

Age and Correlation

(*See* Figure 12)

Plant fossils collected by McConnell suggested an Upper Laramie age to Sir William Dawson. They were restudied by W. A. Bell of the Geological Survey, who proposed an Upper Cretaceous or Paleocene age.

Bell also examined a collection made by Hedley and Holland. He states that "several fragments of dicotyledonous leaves are present, and none is sufficiently complete for identification. The best is seemingly a *Viburnum* .... There is a single, small, poorly preserved fragment of a fern, again not certainly identifiable although comparable to *Asplenium? coloradoense* Knowlton or to *Asplenium? magnum* Knowlton. The bulk of the collection consists of twigs of a *Sequoia*, probably belonging to the same species as one recorded by Hollick from the Upper Cretaceous Chignik formation of Alaska .... the best that may be stated is 'Upper Cretaceous?' A Paleocene or Eocene age is a possibility" (*See* Hedley and Holland, 1941).

Roots (1948) suggests that the Sifton formation may be "regarded as a part, probably an upper part, of the Sustut group of areas to the West". The formation is of some interest in view of its composition, age, position on the floor of the trench, and its structural relations to adjacent formations. Its study may provide important evidence bearing on the history and origin of the trench.

BEDS WITH EQUISETUM ARTICUM

Hage (1945) has suggested that some sandstones, shales, and conglomerates on Petitot River, about 5 miles above the canyon, are of Tertiary age. They are not, however, mapped separately on the Lower Liard River map nor on the map accompanying the present report, but are included with the Upper Cretaceous formations.

Hage measured the following Petitot River section:

Top of Section	Thickness Feet
Shale, interbedded with fine-grained sandstone; contains plant remains	5·0
Conglomerate; chert and quartzite pebbles and coarse sandstone	25·0
Shale, dark grey, and sandy shale; beds 10 to 12 inches thick	21·0
Sandstone, medium-grained	2·0
Shale, dark grey	1·0
Sandstone, feldspathic, medium-grained	7·0
Shale, light grey	1·0
Sandstone, fine-grained, thinly bedded	3·0
Bentonite, and streaks of carbonaceous matter	0·1
Shale, light and dark grey	6·3
Shale, sandy	1·0
Shale, fissile, dark grey	10·0
Bentonite	0·05
Sandstone	1·0
Total thickness	83·45

Fossils from the top of this section were identified by W. A. Bell as tuberous rhizomes of *Equisetum arcticum* Heer. Bell noted "that the species occurs in Arctic Paleocene, and if the beds containing it on Petitot River are actually Upper Cretaceous the range of the species must be extended" (*from* Hage, 1945).

Hage states that these "beds are assigned tentatively to the Tertiary, but, as definite proof of age is lacking and as field observations were limited to a single outcrop, they have not been mapped separately from the late Upper Cretaceous on the accompanying map.

"Criteria favouring a possible Tertiary age are:

(1) The strata contain *Equisetum arcticum* Heer, previously recorded from the Paleocene.
(2) The presence nearby of pre-Glacial gravels overlying the Fort Nelson formation.
(3) Bentonite was not observed in the Fort Nelson formation elsewhere, but is present in Tertiary strata at Fort Norman."

TERTIARY

RHYOLITE

Member 1 of Hedley and Holland's (1941) section of the Turnagain and Upper Kechika Rivers area, "consists of white, flesh pink, and grey rhyolite flows, and rhyolite tuffs and breccias. The dominant rock appears to be a flesh-coloured, highly-quartzose breccia, whose constituent feldspars are kaolinized but whose quartz is clear and glassy. The rocks outcrop in an elongated area about 8 miles long and 1½ miles wide on the south fork of Mosquito Creek near the divide between it and Turnagain River.

"This member appears to occupy part of a trough in the older Member 7 [mostly limestone of unknown age], and though some of the volcanics dip westward their general structure is unknown. The general appearance and similarity to Tertiary volcanics elsewhere in the province suggest that these rocks may be Tertiary in age."

COAL RIVER TERTIARY

Lignite is exposed on Coal River, about 6 miles directly north of the Alaska Highway and north of the big bend in that river. It is mostly covered with outwash gravel, but at one place is overlain, apparently conformably, by ashy grey clay. Upstream the gravel has been removed from the surface of the coal, which "is burning over an area 150 yards along the stream and for 50 yards in width . . . Nodules of clay have been vitrified". Near the "Highway large masses of brown lignite and slabs of lignitized wood lie scattered over the river bars" (Williams, 1944). These masses of lignite, as noted by Williams, were also seen by McConnell (1891).

On the west bank of Coal River and downstream 1½ to 2 miles below the Highway, Williams records exposures of white clay in places in banks 15 feet high and overlain by gravel.

"The relationship of the coal and clay deposits has not been determined, but they clearly belong to the same Tertiary basin. This is evidently several square miles in area, occupying Coal River Valley from its mouth for 8 to 10 miles upstream. Its width may be estimated as from 2 to 4 miles" (Williams, 1944).

Williams recalls that McConnell (1891) observed the presence of sandstone, clay, and lignite in the lower part of a stream entering the Liard from the south about 7 miles beyond Hyland River. Williams infers that several basins of Tertiary age may be present in this vicinity.

No basal contact is visible, but it is evident that these Tertiary deposits rest unconformably on Palæozoic formations. No fossils have been found in them.

CHAPTER IV

STRUCTURAL GEOLOGY

GENERAL STATEMENT

Folds and faults of variable intensity have disturbed the strata in the several physiographic regions of northeastern British Columbia. On the Plains, late Lower and Upper Cretaceous terrains are gently sloping or flat lying or, near their western margins, are gently folded. In the Foothills, Triassic, Jurassic, and early Lower Cretaceous strata are disturbed by open folds and faults. In the Rocky Mountains, as yet little studied, Proterozoic, Palæozoic, and in places Triassic, formations have been subjected to overthrust faulting and some folding. At the southern end of the Liard Plateau, late Palæozoic, Mesozoic, and Paleocene beds are folded and faulted. In the Rocky Mountain Trench, late Cretaceous or early Tertiary beds are folded and may be downfaulted. In the Cordillera, west of the Trench, late Proterozoic, Palæozoic, and Mesozoic strata, including both volcanic and sedimentary rocks, are intensely folded and faulted on a large scale, and are intruded by igneous bodies of batholithic dimensions.

The regional structural trend in the Rocky Mountains and Foothills of northeastern British Columbia varies, but averages about north 20 to 30 degrees west. The direction of the Trench is about north 30 degrees west, so that the folded and faulted belt between the Trench and the Plains widens from southeast to northwest.

In some parts of the region the structures of the Foothills decrease in intensity so uniformly and pass so gradually into those of the Plains that it is difficult, on a structural basis, to know where to draw a boundary. Even where this can be determined, it has been found convenient, in describing some sections, to include structures on the Plains along with those of the Foothills; otherwise some that are closely connected would be isolated from one another in the text.

The structures of the Foothills have been more carefully and intensively studied than those of other physiographic divisions of the region, and more has been published concerning them.

INTERIOR PLAINS

PINE AND PEACE RIVER VALLEYS

The structure of the Plains in the vicinity of Pine and Peace River Valleys has been studied by Gwillim, Spieker, Dresser, Williams, Bocock, Stelck, and others. Although valuable work has been done, the structural study of this area is not complete. Moreover, most of the recent investigations have been recorded only in manuscript, which, not having been prepared for publication, can only be quoted with reserve. Some anticlinal axes between Moberly Lake and Kiskatinaw River and between Hudson

Hope and 'The Gates' are plotted on the map accompanying this report; they have been taken from a manuscript map complied by M. Y. Williams and J. B. Bocock and included by them with manuscript reports of the Survey of Resources, Pacific Great Eastern Railway Lands.

In 1921 and 1922, Spieker described the Moberly Lake anticline near the west end of Moberly Lake, with dips of about 9 degrees on the east limb and about 5 degrees on the west limb. He suggested that it is continuous with a low anticline on Wartenbe (Table) Mountain. In an unpublished report, Williams and Bocock (1930) have stated that the Moberly Lake anticline extends northwest by north and that it has dips of 3½ to 8 degrees on the southwest limb and 2½ to 10 degrees on the northeast limb. Spieker described a broad, low structure on the west slope of Wartenbe (Table) Mountain, to which he gave the name of Table Mountain anticline. He considered it to be continuous with the Moberly Lake anticline. Williams and Bocock (1930), however, have suggested that this structure passes through hills near the east end of Moberly Lake. Later, Williams (1939), Stelck (1941), and others have proposed that faulting rather than folding is the principal feature of the Wartenbe (Table) Mountain structure.

Williams (1939) and Stelck (1941) record faulting near the Little Prairie settlement.

Williams and Bocock (1930) have described the Graveyard anticline, whose axis extends northwesterly across Graveyard Creek, between Moberly Lake and Pine River. It is a wide, low, and as yet not well understood structure. A low, northeast dip (about 1 degree) was observed near the mouth of Stewart River, and a southwest dip of about 3 to 8 degrees on the southwest limb.

Dresser (1921) and Spieker (1921, 1922) have described the Hudson Hope anticline. It is said to be a small fold, with dips of about 2 degrees near the axis. About 1½ miles west of the axis, however, is a structural terrace, which is said to have a maximum southwest dip of about 15 degrees. It is claimed to be continuous with a structure on the west fork of Maurice Creek. Williams (1939) has recorded some thrust faulting on the southwest limb.

Dresser (1921) refers to a "sharp" fold on Lynx Creek, with a southwesterly dip of 45 degrees on one limb. In an unpublished report, Williams and Bocock (1930) observe that the Gates anticline, at 'The Gates' on Peace River, has a dip of about 1 degree on the northeast limb and 2 to 3 degrees on the southwest limb.

Far to the east, on Pouce Coupé River, Crickmay (1944) records a gentle southeasterly dip, and just over the border, in Alberta, he has described an interesting, probably a domed, structure.

FARRELL CREEK

Dresser (1921, 1922) has described an anticline on Farrell Creek (Red River), north of Chinaman Lake and northwest of Hudson Hope. In the 1921 report, a broad anticline, with its axis crossing near where the trail from Hudson Hope passes through Farrell Creek, was inferred from the attitude of exposed strata. In the 1922 report, this was thought to be a dome-like structure, from the elevations of a bed of conglomerate penetrated in several bore-holes drilled in 1921.

HALFWAY RIVER TO STEAMBOAT MOUNTAIN

The structure in Halfway River Valley, where this river flows across the Plains, has not been recorded in any publication. Possibly some gentle folds are to be found there.

In Sikanni Chief and Buckinghorse Valleys, adjacent to, and west of, the Highway, small folds have been noted. They are recorded under 'Foothills', page 121 (*See also* Figure 3).

On the western border of the Plains, on and east of Minaker River, several small folds have been observed and carefully studied. On Minaker River, east of the Pocketknife anticline, Hage (1944) has indicated a small anticline or 'roll'. A few miles to the northeast is the Minaker River anticline.

The axis of the Minaker River anticline, trending about north 14 degrees west, crosses the Alaska Highway at latitude 57°45′ and Minaker River less than 2 miles west of the Highway (Hage, 1944). Dips vary from 3 to 15 degrees. Hage notes that, because exposures are few, this structure is not fully understood. On the same river, below the mouth of Beaver Creek, several minor folds were observed on the east limb of this anticline; these small folds, however, were not seen in exposures along the Highway (Hage, 1944).

East of the Alaska Highway and not far from the mouth of Bear Creek, near the western border of the Plains, the shales of the Buckinghorse formation are folded into the Bear Creek anticline (Hage, 1944). The dips are low, 5 to 6 degrees. The extent of this structure is unknown. Hage, however, notes that a "few outcrops on the creek above and below the Highway bridge (about a mile south of Indian Creek) . . . are suggestive of an anticline that may be a continuation of the one on Bear Creek".

Williams (1944) has described the structure of the Plains along the Alaska Highway west of Fort Nelson. For more than 50 miles, the Lower Cretaceous sandstones and shales are flat-lying or have a gentle east dip. The crest of a low, asymmetric anticline is situated about 51 miles west of Fort Nelson. Farther west is a broad syncline, the axis of which lies about on Tepee Mountain. Dips on the northeast limb are said to vary from 5 to 8½ degrees southwest, and those on the southwest limb 5½ to 10 degrees northeast. No other structure has been reported between Tepee Mountain and the Foothills, where the Triassic is brought to the surface on the axes of several anticlines.

Nothing is yet known of the structure on the Plains east of the Alaska Highway between Fort St. John and Fort Nelson.

FOOTHILLS

PINE AND PEACE RIVER FOOTHILLS

Portage-Butler Structural Zone

(*See* Figure 11)

The Portage-Butler structural zone on the eastern border of the Peace River Foothills trends from north to northwest, and is described as an 'anticlinorium' by Beach and Spivak (1944). The resistant conglomerates and quartzitic sandstones of the Dunlevy formation outcrop on the anticlinal axes of this structure, and are responsible for the high elevations of Butler Ridge and Portage Mountain.

The eastern component of this 'anticlinorium' is the Bullhead anticline. On Portage Mountain, the west limb is broken by a west-dipping thrust fault, close to the axis. To the north, on Butler Ridge, the trend changes from north to about north 5 to 20 degrees west, and the fold is nearly symmetrical, with dips of from 50 to 60 degrees. Locally, however, Beach and Spivak have observed attitudes as high as 75 degrees or even vertical on the east limb, and some faulting has been noted. The anticline is said to have "a closure of about 500 feet at the top of the Dunlevy formation" and to continue northwestward for 9 miles to where the closure decreases and the fold ends along the northeast slope of Butler Ridge.

The Bullhead syncline, west of the Bullhead anticline, lies between the Bullhead and Butler anticlines. It is faulted locally, and has steep flanks on Butler Ridge (Beach and Spivak, 1944).

The Butler anticline, west of the Bullhead syncline, is broken by a high-angle fault on the east limb, on Portage Mountain—the same fault that on Butler Ridge disturbs the centre of the Bullhead syncline. The west limb, as recorded by Beach and Spivak, has dips of 60 to 75 degrees, and the northeast limb, on Butler Ridge, is moderately steep. Near the headwaters of Brenot Creek, a gentle, synclinal fold is said to form on the crest of this anticline, and yet farther north the Butler anticline loses its identity in a fault zone (Beach and Spivak, 1944).

The Danish Creek anticline, lying southwest of the Butler anticline on Butler Ridge, is symmetrical, and appears to plunge rapidly to the southeast. To the northwest this fold is also lost in a fault zone (Beach and Spivak, 1944).

A small anticline and a fault have been mapped by Beach and Spivak on the lower part of Cust Creek, on the west flank of the Portage-Butler structural zone.

To the south and near Mount Johnson, the folds of the Portage-Butler structure plunge steeply to the south, so that progressively younger formations, the Gething, Moosebar, Gates, Hasler, and Goodrich, outcrop along the crestal area, south of Coalbed Creek (Beach and Spivak, 1944).

Dunlevy Syncline

A broad, shallow syncline west of the Portage-Butler structural zone crosses Peace River Valley between Butler Ridge and Stott Creek, and has been mapped by Beach and Spivak (1944). The Gething formation outcrops along the axis of this structure, in the valley of Dunlevy Creek and on the northern and eastern slopes of Mount Gething.

Gething-Stott Structural Zone

The Gething-Stott structural zone lies west of the Dunlevy syncline, and trends north 20 degrees west from Gaylard Creek, through Mount Gething, to the upper part of Stott Creek, south of Peace River. It may be the eastern or northeastern part of a wide, folded and faulted zone. It has been studied by Beach and Spivak (1944).

On Mount Gething, the major features of this structural zone are a flat-topped or 'box' anticline and a thrust fault. On the southwest limb of the anticline, lower beds of the Dunlevy formation dip 45 to 60 degrees to the southwest; on the crest of the same anticline, which is about 1 mile wide, the same beds are flat or gently arched; on the northeast limb the beds dip steeply to the northeast or are overturned. Along the thrust, on the northeast side of the anticline, the lower beds of the Dunlevy are thrust over on the upper or conglomerate-bearing part of the same formation (Beach and Spivak, 1944).

A little farther northwest, on and near Stott Creek and at a lower elevation than on Mount Gething, the anticline is more closely folded than on that mountain, and lower strata are exposed on the crest, successively, of Jurassic, Triassic, and Permian age. The displacement along the fault is greater than on Mount Gething, and several subsiduary folds occur east of the fault (Beach and Spivak, 1944). It may be added that although Beach and Spivak mention only one fault in the text, they show two on Mount Gething on the Dunlevy-Portage Mountain map-sheet. They record only one, however, to the north near Stott Creek, on the same map-sheet, where the two faults coalesce. It may be that the Gething-Stott structural zone is a northern continuation of the Commotion-Hulcross structural zone. The latter will be described on a subsequent page.

Beattie Hill Structure

(*See* Figure 8)

Across Peace River to the northwest, the Gething-Stott structural zone passes into a wide belt of disturbed rocks, both folded and faulted, west of Rainbow Rocks. Little is known of the structure, except at the westernmost end of this disturbed zone, on Beattie Hill.

West of Aylard Creek and in the eastern part of Beattie Hill, the Triassic 'Dark siltstones' and overlying 'Grey beds' are flat-lying. On the west end of the same hill these Triassic strata dip steeply to the west (McLearn, 1940A). The structure may be a 'flat-topped' anticline, of which the east limb is concealed, or it may be a monoclinal structure bounded on the east by a fault.

Branham Ridge Syncline

(See Figure 8)

A broad, shallow syncline lies between the Beattie Hill and Horseshoe Hill structures (McLearn, 1940, Figure 1; Beach and Spivak, 1944). Strata ranging from the 'Grey beds' to the Dunlevy formation are involved in this structure on Branham Ridge. The resistant rocks of the Dunlevy are exposed in high cliffs on the top of the ridge and in large rock slides on its higher slopes. The Fernie group is exposed in creek bottoms. The 'Grey beds' and Pardonet beds are concealed below rock slides and boulder clay on the lower slopes of the ridge, but their occurrence is inferred. This syncline plunges to the southeast, for on the south side of the river the Dunlevy formation is at a much lower elevation than on Branham Ridge.

The Branham Ridge syncline extends southeastward, and may be continuous with the Pine River syncline in Pine River Valley. More field work must be done in the hills between Pine and Peace River Valleys, however, to establish this correlation.

Horseshoe Hill Structure

(*See* Figure 8)

The structure on Horseshoe Hill and along the valley of Horseshoe Creek is interpreted as a sharply crested anticline, faulted along its axis (McLearn, 1940). On the southwest limb are southwest-dipping 'Grey beds' and Pardonet beds, and on the northeast limb are east-dipping 'Grey beds', Pardonet beds, shales of the Fernie group, and sandstones, shales, and conglomerates of the Bullhead group. Two high-angle faults have been observed on the crest of the structure in the upper part of Horseshoe Hill Valley; it is probable, however, that only one fault continues to the southeast. The structure in the lower part of Horseshoe Hill Creek has not been studied in detail.

Mathews (1947) has shown that a similar structure occurs on the northeast side of the Carbon Creek basin and in line with the Horseshoe Hill structure. He records only one overthrust fault, the plane of which has a high southwest dip.

Schooler Creek Syncline

(*See* Figure 8)

West of the Horseshoe Hill and east of the Folded Hill structure, the Triassic 'Grey beds' and Pardonet beds are folded into a wide, shallow syncline plunging southeast (McLearn, 1941B). It is the northwest end of the Carbon Creek synclinal basin to be described in a later paragraph.

On Red Rock Spur, the southwesterly dips of the southwest limb of the Horseshoe Hill structure and northeast limb of the Schooler Creek syncline are high. They become much lower and almost flatten on the east side of Jewitt Spur and adjacent to the Jewitt fault. On this high-angle fault the 'Grey beds' are thrust over the Pardonet beds. West of this fault is a low, subsidiary arch on the Dry Canyon shoulder. West of Schooler Creek, on Kerr Spur and on Mahaffy Cliffs, and near the northwest end of the synclinal basin, are low, southeasterly dips (McLearn, 1941B).

Folded Hill Structure

(*See* Figure 8)

On Folded Hill, on the north side of Peace River, between Mahaffy Cliffs and Brown Hill, the 'Grey beds' are folded into two anticlines and two synclines. This composite structure is probably bounded on both the east and west sides by high-angle overthrusts, and is probably continuous to the southeast with folds on the southwestern margin of the Carbon Creek basin.

Brown Hill Structure

The Brown Hill structure lies at the end of the 10-mile section on the north side of Peace River, from Tepee Rocks Spur to Beattie Hill, studied by McLearn. West of Folded Hill and continuing west to Tepee Rocks Spur, Triassic, Jurassic, and early Lower Cretaceous rocks dip steeply to the west (McLearn, 1941). As the section immediately west of the Tepee Rocks has not been studied, it is not known what the structure is there.

Pardonet Anticline

(*See* Figure 9)

On Pardonet Hill, the Triassic 'Grey beds' and Pardonet beds dip steeply to the west. On a low ridge east of Pardonet Hill, the beds flatten and then dip east at a low angle. The resultant fold crosses Peace River, and appears in cliffs on the north side of the valley north of the Wallace Ranch (McLearn, 1947).

Carbon Creek Basin

The Carbon Creek basin has been described and mapped by Mathews (1947). It trends about north 22 degrees west, and extends more than 25 miles from Schooler Creek, north of the Peace, to the headwaters of McAllister Creek. It is about 9 miles wide, from Mount Rochfort to Battle (Saddle) Mountain. It is a shallow structure in the northwest, but deepens southeastward, reaching a maximum depth near Eleven Mile Creek. From there it shallows to the southeast, and finally ends, passing into a highly folded structure near the head of McAllister Creek. The middle and greater part of the basin is filled with 'Non-marine Bullhead' beds, which are rimmed on all sides by outcropping bands of the Monteith, Beattie Peaks, and Monach formations of the marine and lower part of the Bullhead group (Mathews, 1947).

As already stated, a southeastward continuation of the Horseshoe Hill structure marks the northeastern border of the basin. Mathews shows it to be a faulted anticline, with, near Carbon Peak, low southwest dips on the southwest limb of the structure and steeper dips on the northeast side. A single thrust fault, dipping southwest, is shown on his cross-sections. The movement on this thrust fault is estimated by Mathews to be 3,000 feet in the northwest, near Peace River, and 10,000 feet in the southeast, near Wright Lake.

The basin is limited on the southwest by an anticlinal belt, thought to be continuous with the Folded Hill structure on Peace River. On Mount Barr and Mount Wrigley this structure consists of a single anticline; on The Monach it comprises several folds (Mathews, 1947).

Fisher Creek Structural Zone

The highly folded structure that forms the southeastern limit of the Carbon Creek basin at the headwaters of McAllister Creek, extends almost to Moberly River. Beyond this, the beds plunge to the southeast and what may be called the Fisher Creek structural zone, in alinement with the Carbon Creek basin, appears. South of Moberly River, this structural zone, as mapped by Mathews (1947), comprises a deep syncline with small, subsidiary folds. Farther southeast, in Pine River Valley, this structure is more complex; near the axis of the syncline are several small, subsidiary folds and a thrust fault. The Moosebar formation outcrops in the central part of this structure and the Non-marine Bullhead on the flanks (Mathews, 1947).

An anticlinal structure borders the southwest side of the Fisher Creek structural zone, just as a similar structure lies southwest of the Carbon Creek basin. The Monteith, Beattie Peaks, and Monach formations are folded into an anticline, with a minor fold on one limb. Southeast of Pine River, the same formations are folded into an anticline faulted close to the axis (Mathews, 1947).

Pine River Anticline

Northeast of the Fisher Creek structural zone and south of Moberly River is an anticline. It rises in a complex and not yet thoroughly understood structure near the upper part of McAllister Creek, a structure that may be continuous, more or less, with the faulted anticline northeast of the Carbon Creek basin and probably continuous with the Horseshoe Hill structure north of Peace River, described in a foregoing paragraph. This anticline crosses Pine River west of Crassier Creek (Mathews, 1947) and extends to and beyond Hasler Creek, where it has been mapped by Spieker (1921, 1922), Wickenden and Shaw (1943), and Spivak (1944). South of the Pine it trends about north 45 degrees west.

Near Falls Mountain this anticline is broad, and has some minor folds on the northeast limb and a small fault on the southwest limb near the axis. In Pine River Valley, Bullhead and Moosebar beds outcrop on the axis of this anticline and Moosebar and Commotion beds on the flanks (Wickenden and Shaw, 1943; Spivak, 1944).

Pine River Syncline

A broad syncline lies between the Pine River anticline in the southwest and the Commotion-Hulcross structural zone in the northeast. It has been mapped by Wickenden and Shaw (1943). It is a broad, shallow syncline, widening to the northwest, and is possibly continuous with the Branham Ridge syncline in Peace River Valley.

The Dunvegan outcrops at high elevations and the Cruiser and Goodrich formations at lower elevations, on the axis of this syncline.

Commotion-Hulcross Structural Zone

The Commotion-Hulcross structural zone has been described by Wickenden and Shaw (1943). It comprises three anticlines, all lying northeast of the Pine River syncline.

The Commotion Creek anticline trends a little west of north and extends along Goodrich and Commotion Creeks to about 6 miles north of Peace River. The axial plane dips about 45 degrees west and the plunge north of Pine River is northerly at about 35 feet per mile. The dip on the west limb is about 5 degrees and on the east limb is low for about ¾ mile east of the crest, where it steepens to 50 or 60 degrees; at one place, on Young Creek, the attitude is vertical and faulting occurs. The high dips on the east limb are said to continue to about 3 miles north of the forks of Commotion Creek. Wickenden and Shaw believe that the high dips met with in the Pine River No. 1 (Commotion) well, near the mouth of Commotion Creek, record a continuation below the surface of this high-dipping structure. They also advance the opinion that the high dips are in a west-dipping rupture or zone of faulting on the eastern flank of the Commotion Creek anticline. They consider that a mere overthrust will not entirely explain this structure, as "horizons east of this fault, on South Cruiser Mountain, are at higher elevations than corresponding beds west of the fault on Submarine Mountain". Wickenden and Shaw interpret this to mean that "the ruptured beds occur along a narrow, compressed syncline that trends between the two mountains parallel to the anticline". A thrust displacement of 200 feet was observed east of Young Creek. The Commotion, Hasler, and Goodrich formations outcrop on the axis of this anticline. The Goodrich is overthrust on the Cruiser formation along the fault on the eastern limb (Wickenden and Shaw, 1943).

Three miles north of the forks on Commotion Creek, this anticline passes into a northeasterly dipping monoclinal fold. The assumed syncline in the fault zone, east of the anticline, south of the forks can be observed here, but is merely a minor flexure.

Beyond an area of poor exposures and northwest of the site of the Commotion Creek anticline, on Alvin Creek, is the Hulcross anticline. It trends northwest and is not considered by Wickenden and Shaw to be continuous with the Commotion Creek anticline. Strata of the Commotion, Hasler, and Goodrich formations outcrop along the crest of this fold. The dips on the southwest limb are low and those on the northeast limb are much higher. The fold pitches southeast, and Wickenden and Shaw infer that a thrust fault underlies the northeast limb.

A third, the Moberly anticline, is described by Wickenden and Shaw. It lies north of the Hasler anticline, and is said to trend north 60 degrees west and to plunge easterly.

Comments

Many structures in Peace River Valley appear to be continuous with structures in Pine River Valley. The folded structure of Folded Hill on Peace River can be followed southeast through one or more anticlines along the southwest border of the Carbon Creek basin and the southwest border of the Fisher Hill structure to Pine River Valley. The Schooler Creek syncline can be traced southeast through the Carbon Creek basin, where it is cut off by a complexly folded structure at the headwaters of McAllister Creek, and is in alinement with the synclinal Fisher Creek structure in Pine River Valley. The faulted anticline of the Horseshoe Hill structure can be traced southeastward along the northeast border of the Carbon Creek basin; is involved in a complex structure near the headwaters of McAllister Creek; and is in structural alinement with the Pine River anticline. The Branham Ridge syncline is probably continuous with the Pine River syncline in Pine River Valley. The folded and faulted structural zone between Beattie Hill and Rainbow Rocks is in part continuous with the Gething-Stott structure on the south side of Peace River, and may be in structural alinement with the Commotion-Hulcross structural zone in Pine River Valley. The Dunlevy syncline and the Portage-Butler structural zone seem to disappear to the southeast. Some of the structures show a south or southeast plunge, for example, the Branham Ridge syncline and the Portage-Butler structural zone. Some changes in regional trend in Pine and Peace River Valleys have been recorded.

It has been observed that the concentration of high dips in narrow belts separated by wide belts of gently folded strata is a characteristic feature of the Peace River Foothills (McLearn, 1940). "The major structural features of the Peace River Foothills are narrow zones of anticlinal folds commonly broken by high-angle thrust faults, separated by broad synclinal basins of gently folded strata" (Beach and Spivak, 1944). Mathews (1947) has made similar statements.

Another feature of the structure in the Peace and Pine River Foothills is the 'flat-topped' or 'box' anticline (Beach and Spivak, 1944; Mathews, 1947). Thus, on some anticlines, the dip near the crest is low and on the flanks is high. The same authors note that on such anticlines much of the folding is concentric rather than similar, and Beach and Spivak infer that "such folds are more superficial than folds of similar size in the southern Foothills".

HALFWAY RIVER TO PROPHET RIVER

Pink Mountain Structure

(*See* Figure 3)

Although it is difficult, on a structural basis, to draw a line between Foothills and Plains in the area extending from the Halfway to Prophet River, the Pink Mountain can without doubt be included among the Foothills structures. It has been described by Hage (1944).

On Pink Mountain the Triassic Pardonet beds, the Jurassic Fernie group, and the Jurassic? and Lower Cretaceous Bullhead beds are folded into a long, narrow anticline, with a southwest-dipping thrust fault on the northeast limb. The crest of the fold is broad and low-dipping and the "limbs have dips averaging from 50 to 60 degrees. Some of the beds along the northeast limb north of Halfway River are overturned". The south closure is about 500 feet and the north closure near the Gap is more than 1,000 feet (Hage, 1944).

Halfway River Valley

The structure along Halfway River, west of Pink Moutain, has been little studied, but a few folds have been noted. About 5 miles west of Quarter Creek, the 'Grey beds' are folded into an anticline. Still farther west, the axis of a syncline in the Bullhead group centres on Grave Creek. The beds of this group outcrop and rise to the southwest on the southwest limb of the Grave Creek syncline and northeast limb of an anticline, the crest of which is on Grave Ridge. Other folds were noted in the high hills west of Grave Ridge. East of Grave Creek, beds of the Bullhead rise on the southwest limb of an anticline that exposes Triassic beds on hills east of this Creek.

Farther west, Triassic formations are nearly flat at the east end of Mount Wright in the Fourth Gully (*See* Plate III B). Triassic 'Dark, siltstones', 'Grey beds', Pardonet beds, Jurassic Fernie shales, and Jurassic? and Lower Cretaceous Bullhead strata dip at a high angle at the west end of this mountain.

Structures in Sikanni Chief Valley

(*See* Figure 3)

The section on Sikanni Chief River has been described by Hage (1944). The cross-section plotted by him extends from the Alaska Highway nearly, but not quite, to the Rocky Mountain front.

The anticline crossing Sikanni Chief River below the mouth of Chicken Creek is a northward continuation of the Pink Mountain structure, and trends about north 20 degrees west. On the axis of this anticline, at and near river level, the Pardonet beds and 'Grey beds' outcrop and are surrounded by outcrops of the Fernie and Bullhead groups. A southwest-dipping fault on the northeast limb of this anticline thrusts lower beds of the Bullhead group over upper beds of the same group, with a displacement of 1,000 feet (Hage, 1944). The southwest limb of the Chicken Creek anticline is modified by a low roll and a southwest-dipping thrust fault, interpreted by Hage (*See* Figure 3) to be a branch of the fault on the northeast limb of this anticline. The two faults are thought by Hage to join at depth. Farther west is a deep syncline with southwest-dipping axis and faulted on the southwest limb. This structure lies near the crossing of the lower trail, that is, the trail from Quarter Creek. West of this structure to the Rocky Mountain front, Triassic rocks are folded into numerous, open folds. In the western part of his section, only one fault is recorded by Hage, a thrust fault near the axis of a deep, narrow syncline (*See* Figure 3).

East of the Chicken Creek anticline, Hage has mapped four anticlines in a distance of 4 miles, all of which show closure. He has mapped one fault in this part of the area, the plane of which he considers to have an easterly dip. Beds of the Bullhead group and Buckinghorse formation are involved in these structures.

Buckinghorse River Valley Structures

(*See* Figure 3)

On both branches of Buckinghorse River, Hage (1944) has recorded three anticlines in the Buckinghorse formation, with dips of from 5 to 55 degrees. Farther west he has mapped two anticlines in Triassic, Jurassic, and Lower Cretaceous formations, with dips of from 15 to 70 degrees.

Pocketknife Anticline

The Pocketknife anticline occurs on about the eastern border of the Foothills, between Klingzut Mountain and Minaker River. It trends north 25 degrees west, is long and narrow, and has dips as high as 50 degrees on the flanks. Triassic beds outcrop along the axis, and the Jurassic Fernie group, Jurassic? and Lower Cretaceous Bullhead group, and Lower Cretaceous Buckinghorse formation on the flanks of the structure. Apparently the anticline shows both northwest and southeast as well as northeast and southwest closure (Hage, 1944). It is not known whether the northeast limb is modified by a thrust fault.

TETSA RIVER FOOTHILLS

Eastern Triassic Belt

(*See* Figure 7)

Williams (1944) has mapped two Triassic belts, separated by a fault block of Palæozoic rocks, in the Foothills along the Alaska Highway in Tetsa River Valley. In the eastern belt of Triassic rocks, McLearn (1946) has described three anticlines west of mile 375 on the Highway, and other anticlines, possibly two, occur east of mile 375.

Of the three anticlines studied by McLearn (*See* Figure 7), the Cameron Hill and Smith Hill are broad, open, almost symmetrical folds. The Shaw Hill anticline is narrower, and dips are steeper than on the other two. Triassic beds outcrop on the anticlines, and the Jurassic or Cretaceous shales outcrop in narrow bands along the axes of the synclines.

Palæozoic Fault Block

West of mile 381, Alaska Highway, Upper Palæozoic rocks have a nearly vertical attitude and are in faulted contact with Triassic strata. At the western end of this fault block, Upper Palæozoic beds are folded and in faulted contact with beds of the western Triassic belt (Williams, 1944). This fault block is also recorded in Laudon and Chronic's (1949) structure-section, but dips are lower than shown by Williams.

Western Triassic Belt

In the eastern part of the western Triassic belt "black limestones and limy sandstones . . . have dominant westerly dips varying from 30 to 68 degrees" and are part of the east limb of a syncline (Williams, 1944). Farther west, shales and dark sandy limestones dip easterly at angles of from 13 to 48 degrees, but "the structure is locally confused by crushing, as indicated by vertical and reversed dips". Williams states that near the Rocky Mountain front black shale with some hard chert and quartzose beds has an average dip of 40 to 50 degrees northeast; crumpling and reversed dips were noted by him.

On Laudon and Chronic's (1949) structure profile, the dips are lower, and the folds broader and more open than on Williams' structure-section.

FOOTHILLS AND LIARD PLATEAU

LIARD RIVER BASIN

In the basin of Liard River, the structures of the Foothills of the Rocky Mountains continue into the Liard Plateau; some continue without change; others disappear and new structures appear. In this passage from the one structural region to the other, the trend changes from northwest to north and northeast. The structure of this drainage basin has been studied by Kindle (1944).

Liard Syncline

The Liard syncline, a major structural feature, has been traced along its axis for more than 60 miles from the Foothills of the Rockies to the Mackenzie Mountains. At its southern end, where it crosses Dunedin Creek, it trends northwest; dips on the northeast limb are 2 to 3 degrees, and on the southwest limb generally from 10 to 30 degrees. The latter limb is marked on the surface by a high escarpment of the Lower Cretaceous Scatter and Lépine formations and the Upper Cretaceous Fort Nelson formation. The centre or trough of the syncline is occupied by the Upper Cretaceous Kotaneelee formation. On the northeast limb is a wide outcrop of the Fort Nelson formation extending along Fort Nelson River (Kindle, 1944).

Near latitude 59°30′ the axis of this syncline swings north and then northeast down Liard River Valley, where it follows close to the river. At its northern end it "is joined by other structures and passes into the Liard Range" of the Mackenzie Mountains (Hage, 1945).

Toad Anticline

(*See* Figure 4)

West of the Liard syncline the Triassic Grayling and Toad formations and the Jurassic(?) and Lower Cretaceous Garbutt formation are folded into a broad arch, the axis of which crosses Liard River about a mile east of the mouth of Grayling River (Kindle, 1944). It trends northwest. The dips on the northeast limb of this anticline are from 10 to 30 degrees and on the southwest limb from 40 to 75 degrees. Many small folds are superimposed on this structure. Kindle states that this anticline closes "about 20 miles northwest of the Liard, where other anticlinal structures swing northeast across its path". The topography suggests to Kindle that the anticline may "close 12 to 15 miles south of the mouth of Toad River".

A folded structure with two faults is mapped by Kindle in Liard Valley between Brimstone Creek and Hades (Hell) Gate.

Scatter River Monocline

(*See* Figure 4)

A terrace structure is found west of Liard River in and near Scatter River Valley. Near Liard River, the beds of the Lépine formation are said to dip 10 to 20 degrees east. Farther west the underlying Scatter formation comes to the surface and the dip decreases; from about 2 to 8 miles west of the Liard the beds of the Scatter formation are flat-lying (Kindle, 1944).

Beaver River Anticline

About 12 miles north of the mouth of Beaver River, an asymmetrical anticline trends northeastward. On the southeast limb, beds of the Scatter, Lépine, and Fort Nelson formations dip 15 to 35 degrees and on the northwest limb beds of the Scatter formation dip 3 to 7 degrees northwest.

Structures Recorded on Air Photographs

Kindle (1944) has observed an escarpment, thought to be a fault scarp, on air photographs, northwest of Liard River. From a point on Crow River, more than 20 miles west of its mouth, the escarpment trends northeast almost to Beaver River and is only a little out of alinement with the Dickie Mountain anticline, north of the map-area.

Kindle (1944 map) has also observed that Dickie Mountain, north of the map-area, northeast of Beaver River and northeast of Beavercrow Mountain, is the site of the southeast limb of the Dickie Mountain anticline. This anticline trends northeast and dips on both limbs appear, on air photographs, to be from 15 to 25 degrees. The axis, Kindle notes, extends southwest almost as far as Beaver River and northeast to La Biche River. As Merrill Mountain, lying well out on the southeast limb of the Dickie Mountain anticline, is underlain by Carboniferous and Permian strata, Kindle assumes that Carboniferous or older rocks underlie Dickie Mountain.

The southeast limb of the Beavercrow Mountain anticline rests on Beavercrow Mountain, at the northern border of the map-area. Study of air photographs suggests to Kindle (1944 map) that this structure trends northeast; that the dips on the southeast limb are from 10 to 30 degrees; that dips on the northwest limb are from 35 to 85 degrees; and that the axial plane has a pronounced southeast dip.

Kindle (1944) has recorded a major anticline, the West Grayling anticline, 27 miles northwest of the mouth of Grayling River and extending from Grayling River to and beyond Crow River and to 1 mile or 2 miles west of Larsen Lake. It lies partly on and partly north of the map-area and trends northerly. The low-dipping, resistant rocks of the east limb underlie a high plateau between Crow and Grayling Rivers. The beds of the west limb appear to dip from 25 to 85 degrees west.

Southeast of the above structure is the symmetric East Grayling anticline, trending south for 12 miles between Scatter and Grayling Rivers. Kindle (1944) has observed that the strata on both limbs of this fold dip about 10 degrees, near Scatter River. Farther southwest, toward Grayling River, they steepen and appear to reach, or even exceed, 45 degrees.

La Biche Anticline

The crest of La Biche Range, north of the map-area and west of Kotaneelee River, is the crest of an anticline that trends northerly, north of La Biche River, and northeastward, south of that river. Hage (1945) records a dip of 40 degrees on the east limb and 35 degrees on the west limb. Mississippian rocks outcrop on the crest and Mississippian, or Pennsylvanian, and Lower Cretaceous beds on the flanks. This structure plunges to the southwest, where Cretaceous rocks outcrop along the axis of the fold. It may pass into the Beaver Creek anticline and possibly into the Scatter River monocline.

Liard Range Structure

The Liard Range, north of the map-area, occupies the southwestern part of Northwest Territories. Hage (1945) records the presence of two or more anticlines, the easternmost of which is bounded by a west-dipping fault. The Pointed Mountain anticline at the southern end of this range trends north 30 degrees east and plunges to the southwest (Hage, 1945).

Petitot River Syncline

The Petitot River syncline, north of the map-area, is separated from the Liard syncline by a thrust fault near Fort Liard. It trends northward and crosses Petitot River about 20 miles above its mouth. Hage states that the Liard thrust passes into a fold farther south (Hage, 1945).

ROCKY MOUNTAINS

PINE RIVER TO MUSKWA RIVER

In 1881, Dawson stated that the attitude of the rocks on some of the mountains in Pine River Valley is nearly flat. He also noted that strata, mostly limestones, in mountains west of the Upper Fork of Pine River have chiefly southwesterly dips. Beds on the eastern border of the 'limestone ranges' are said to be much disturbed. Later, Bocock (1929) stated that beds near and west of the summit in the mountains along Pine River occur in thrust blocks; for example, the Misinchinka shales are said to be overthrust on Devonian limestones.

It is remarkable that the section exposed along Peace River, in the Rocky Mountains, so easily accessible by canoe or small boat, has not yet been studied systematically. Selwyn (1877), in his report on a reconnaissance examination of Peace River Valley in 1875, merely noted that the beds on Mount Selwyn have a high southwest dip. Later, McConnell (1896) observed west and southwesterly dipping strata, reverse faults, and subordinate folds. He also noticed that the age of the rocks outcropping along this river, in the mountains, increases from east to west; Precambrian and probably Cambrian strata outcrop in the west, and Devonian, Mississippian, and Triassic beds have been located in the eastern part of the section. It is inferred that overthrusting in the west is more intense than in the east, and, consequently, older rocks have been brought nearer the surface in the west than in the east.

The structure of the mountains between Peace River in the south and the Alaska Highway in the north has not been recorded in any publication.

SUMMIT LAKE TO MUNCHO LAKE

The structure of the eastern half of the Rocky Mountains along the Alaska Highway, between Summit and Muncho Lakes, has been studied in detail by Laudon and Chronic (1949), who have published a structure profile. Some notes on the structure have also been provided by Williams (1944).

Williams states that the structure is similar to that in the south, and that compression from the west has produced overturned folds and thrust faults. The mountain front lies just east of Summit Lake, and is said to be marked by a major thrust, where grey limestone, presumably of Silurian age, is faulted against Triassic shale. The mountain front is said to be straight and well defined for miles to the northwest and southeast of Summit Lake.

The same mountain front is displayed in Laudon and Chronic's structure-profile. In what they call the Stone Range, Precambrian (pre-Silurian), Silurian, and Devonian formations dip west or southwest at a low angle. The eastern front of this range is defined by a west-dipping fault where Precambrian beds are thrust upon Devonian shales. Farther west, in Racing Creek Valley, Devonian, Mississippian, and possibly Triassic terrains are folded into several low, broad anticlines and one narrow anticline.

West of Racing River Valley and in the high Sentinal Range, Precambrian to Devonian formations occur in several large thrust blocks, separated by west- or southwest-dipping thrust faults. Within the thrust blocks, dips are low to moderately steep. These structures extend to Muncho lake (Laudon and Chronic, 1949).

A prominent feature of Laudon and Chronic's structure-section is the angular unconformity between the Precambrian (pre-Silurian) strata and the Silurian limestones. The undulating, well-folded structure below the unconfromity is in marked contrast with the little folded structure above it. This angular unconformity was also observed by Williams (1944).

MUNCHO LAKE TO LIARD RIVER BRIDGE

Very little is known of the structure along the Alaska Highway northwest of Muncho Lake. In or near Liard River Valley, not far from the Liard River bridge, Williams has observed some east-west faults, which he considers are connected with the abrupt, northern termination ot the eastern Rocky Mountains.

EAST OF SIFTON PASS

Hedley and Holland (1941) state that slates, argillites, limestones, siltstones, and rare volcanic rocks occur in the Rocky Mountains immediately east of Sifton Pass. Sufficient field work was not done to determine the structure, but steep dips suggested close folds.

LIARD PLAIN

Limestone outcropping on the west bank of Coal River above the Highway bridge (over Coal River) is said by Williams to have, on the average, a northwest strike. The dips suggest to Williams a series of sharp anticlines and synclines. Limestone beds west of Coal River are said to have high dips and variable strikes.

ROCKY MOUNTAIN TRENCH

The northern part of the Rocky Mountain Trench separates the northern Rocky Mountains on the east from the Omineca and Cassiar Mountains on the west. It is probably a surface manifestation of a structural zone in which faulting is an important feature. This zone is narrow, long, almost straight, and trends northwest.

Hedley and Holland (1941) state that some of the faulting in the Trench may be as recent as late Tertiary. The Sifton formation in the Trench is said to be strongly deformed, showing high dips, drag-folds, and shear zones and faults. The direction of the Trench is said to be at an angle of about 10 degrees with the trend of the Rocky Mountains structures.

EASTERN PART OF OMINECA AND CASSIAR MOUNTAINS

West of the Rocky Mountain Trench, in the eastern part of the Omineca Mountains, rocks of the Ruby (Proterozoic) and Ingenika (Lower Cambrian) groups are folded into two, northwesterly trending anticlinoria on which open subsidiary folds are superimposed (Roots, 1948).

Farther north, in the eastern part of the Cassiar Mountains, between the Cassiar batholith and the Trench, sedimentary rocks of probable Palæozoic age are folded into anticlines and synclines. Hedley and Holland (1941) state that this folding is not so uniform as in the RockyMountains east of the Trench. Individual folds are interrupted by cross flexures and complicated by drag-folds and thrust faults.

CHAPTER V

HISTORICAL GEOLOGY

GENERAL STATEMENT

Not enough is known at present to write an unqualified account of the geological history of northeastern British Columbia. It seems worth while, however, to treat the subject briefly and make the best of the evidence now available. The account given should be considered merely as a working hypothesis, subject to revision as new evidence is acquired. It is hoped that the attempt will stimulate interest in the geology of this part of British Columbia, will draw attention to some of the more outstanding features of the geology, will show how the local history is related to the history of the western interior of Canada, as a whole, and that it will focus attention on some of the unsolved problems of the geology of northeastern British Columbia.

AN OLD, PROTEROZOIC(?) BASEMENT

The most important feature of the lower part of the geological column in northeastern British Columbia, as described by Williams, and by Laudon and Chronic (*See* Chapter III), is the angular unconformity between two rock groups of pre-Silurian age, that is, between the quartzites, argillites, and slates of Toad River, below, and the Macdougal conglomerates and sandstones of Muncho Lake, above. After deposition, probably in Proterozoic time, in an old geosynclinal basin, the beds of the older group were deeply buried, metamorphosed to argillites, intruded by basic dykes, uplifted to form ancient mountains, and deeply eroded. The occurrence of igneous rock on the site of the Rocky Mountains is most unusual. It may be recalled, however, that diorite sills and basaltic flows have been found in the Proterozoic, Purcell group, far to the south in the Clark Range of the Rocky Mountains. The flows, of course, appeared during the geosynclinal phase, and the intrusions, either then or in some early phase of the succeeding orogeny.

The original sands and muds, now metamorphosed as the older and lower part of the Misinchinka schists in the western part of the mountains, along Peace River, may have accumulated in seas of Proterozoic age and in some old geosyncline, the limits of which are unknown.

PALÆOZOIC SEAS

The Cambrian history ot the region is, as yet, obscure. Sands and gravels of the Macdougal group were laid down on the old Proterozoic(?) basement, in a sea possibly of Cambrian age. This and other Cambrian seas may have spread over a wide area, even to the west of the present Trench where beds of Cambrian age have been definitely recognized (Roots, 1948).

Very little is at present known of the Ordovician history of northeastern British Columbia. A boreal sea of this time is recorded by limestones on Halfway River, west of Mount Wright (*See* Chapter III), and it doubtless spread over a wide area on the site of the Rocky Mountains and Foothills and perhaps even over a part of the Plains. Other Ordovician seas may have inundated this part of the continent, but their recognition awaits further exploration.

The Silurian history is fragmentary. A sea with coral reefs and of definite Middle Silurian age is known to have occupied the site of the Rocky Mountains along the Alaska Highway. It appears to have been a northern sea, connected with the Arctic Ocean across what is now Mackenzie River Valley. Its southern and eastern extensions are not known, and westward it may not have reached beyond the Trench. Armstrong (1946) and Roots (1948) have recorded no Silurian or Devonian beds in the Aiken Lake map-area, nor in any other area west of the Trench from Omineca River to the Cariboo district. The region west of the Trench was land (Armstrong, 1946) during Silurian and Devonian times, unless deposits of these ages have been overlooked there or have been removed prior to the Carboniferous period.

The Devonian history is only a little better known than the Silurian. At times sedimentation was interrupted (*See* Chapter III), due, possibly, to temporary emergence above the sea. During a part of Middle Devonian time, a sea with coral reefs lay on the site of the northern Canadian Rockies, and, like the mid-Silurian coral sea, may have been connected with the Arctic Ocean across the site of Mackenzie River Valley. Like the Silurian coral sea, also, it may not have extended west of the Trench. Later, during part of Upper Devonian time, black muds accumulated in a sea that extended northward across the site of Mackenzie River Valley and southward an undetermined distance.

Mid-Palæozoic sedimentation was not disturbed by vulcanism. No flows, tuffs, or breccias are interbedded with the sediments.

In contrast with the inferred restriction of the mid-Palæozoic seas to areas east of the site of the Trench, the later Palæozoic seas appear to have extended far to the west beyond the Trench, for sediments of the late Palæozoic, Cache Creek group have been recorded from the Aiken Lake map-area by Roots (1948). The sea bottom of this time was not disturbed by vulcanism east of the site of the Trench, but west of the Trench, Roots (1948) records altered flows, tuffs, and agglomerates interbedded with the sediments of the Cache Creek group.

The Palæozoic-Mesozoic contact and the nature of the latest Palæozoic and earliest Mesozoic sediments have not yet been sufficiently studied to infer all of what happened during the passage from one era into the other. It was not marked by orogeny east of the Trench; the interruption of marine aggradation was not prolonged there, for beds of Permian age are preserved in places and fairly early Lower Triassic beds have been recognized. Some uplift and erosion, of course, may have taken place.

RESTRICTED LOWER AND MIDDLE TRIASSIC SEAS

Unless beds of Lower and Middle Triassic age west of the Trench have been overlooked or were present and were removed by erosion before Upper Triassic time, no Lower and Middle Triassic seas extended westward into the Aiken Lake or adjoining areas, or occupied any part of northern British Columbia west of the site of the Trench (Armstrong, 1946). They were confined to the east, and may have extended in that direction at least as far as the Pouce Coupé area. To the north, they did not inundate the site of the present La Biche and Liard Mountains.

Some seas[1] of this time may have extended far to the south or southeast; others less so. The Lower Triassic *Wasatchites* sea may have continued south of the International Boundary; at least there was some direct communication with the *Wasatchites* sea of Utah. The *Beyrichites-Gymnotoceras* sea probably extended at least as far south as the central Canadian Rockies, and perhaps to Nevada and California. The *Nathorstites* sea has not yet been recorded south of Peace River Valley.

Although a few at least of the Lower and Middle Triassic seas had direct connection with the Arctic Ocean, the path followed by these inundations of the northwestern part of the continent is unknown. Unless Triassic beds were removed in pre-Cretaceous time, this path lay west of the site of Mackenzie River Valley and west and southwest of La Biche and Liard Mountains. No Lower Triassic beds have yet been reported from Alaska, and neither Lower nor Middle Triassic, as yet, from the Yukon. *Wasatchites* occurs in the Arctic, but no evidence has yet been found of any seaway between the Arctic and northeastern British Columbia. The *Beyrichites-Gymnotoceras* sea may have been connected with the Arctic Ocean across Alaska; if across the Yukon, no evidence of it has yet been found. The *Nathorstites* sea may have extended across Yukon or Alaska, or across both.

The sea floors of Lower and Middle Triassic time in northeastern British Columbia were not disturbed by igneous activity. No flows, tuffs, or agglomerates are interbedded with the sediments.

UPPER TRIASSIC MARINE EXPANSION

Unless their deposits were removed by uplift and erosion in pre-Cretaceous time, the Upper Triassic seas did not extend as far to the north as the earlier Triassic seas and perhaps not as far east; at least no record of the Upper Triassic has been found in the Muskwa and Liard River basins. However, some at least of the Upper Triassic seas extended far to the west, beyond the site of the Trench, and spread widely over the northwestern part of the continent. Present information does not justify any attempt to delineate the shores of these seas.

Late Karnian seas, of about *Tropites* time, may have flooded extensive areas far west of the Trench in Stikine River Valley, in the Yukon and Alaska, and even in central, southern, and coastal British Columbia, but may have had little expansion in the Arctic regions. Little is known of

[1] It is not known whether the Triassic faunas of northeastern British Columbia record several, separate inundations of the continental interior, one for each fauna, or whether the faunas succeeded one another in one, continuous sea.

the extension of these seas, or sea, southward along the site of the Rocky Mountains. The Norian *Monotis alaskana* or *Himavatites* sea inundated not only most of northeastern British Columbia, but parts of the Yukon and Alaska as well; although this sea occupied a large area in northwestern North America, the fauna included species remarkably close to some in a fauna of similar age in the East Indies. The late Norian and northern *Monotis subcircularis* sea extended south along the Rockies at least to Athabasca River Valley (Vine Creek) and northwest and west over large areas in British Columbia, the Yukon, and Alaska.

The red, gypsiferous beds in the Guardian well, near the eastern border of the present map-area, and in the Mowitch Range far to the south (Allan, 1933), may record a shallow sea, possibly near the eastern shore, with excessive evaporation. Not much is known, however, of this phase of the Triassic.

LATE TRIASSIC EMERGENCE

No beds of Rhaetic, that is late Upper Triassic, age have yet been found in British Columbia or Alberta. The northern part of the continent may have been completely emergent at this time.

JURASSIC SEAS

Early in Lower Jurassic time northeastern British Columbia was again flooded by the sea. Details are lacking, but the Jurassic seas, or sea, are known to have covered western and southern Alberta, large areas in British Columbia, and parts of Yukon and Alaska.

AUCELLA SEAS

The marine phases of the Nikanassin formation in Alberta, and the lower part of the Bullhead group in northeastern British Columbia, record a sea or several successive seas on the site of the Foothills. They may have spread south as far as Athabasca River Valley, and may have been invasions from the Arctic Sea following a path somewhere west of Mackenzie River Valley. The later of these *Aucella* seas is probably of early Lower Cretaceous age and the earliest is possibly of very late Jurassic or very early Lower Cretaceous age (*See* Chapter III).

CRETACEOUS LANDS AND SEAS

The alluvial plains and swamps recorded by the Kootenay formation of the southern Foothills and Mountains may or may not have been deposited marginal to a sea. Those recorded by the Gething, Luscar, and lower Blairmore beds may have been deposited marginal to a sea, but to what sea is at present uncertain. All of the late Lower Cretaceous and all of the Upper Cretaceous alluvial plains are marginal to a sea, and were built out into them as deltas. These deltas formed in shallow seas in a subsiding basin, and not in a deep body of water with stationary floor. They were of the Mississippi type of delta rather that that of Lake Bonneville (Barrell, 1912; Storm, 1945), and may be called marginal alluvial plains or deltas.

All non-marine Cretaceous formations of the Canadian western interior, like those of the United States interior (Bartram, 1937; Pike, 1947;

Spieker, 1949) include a large proportion of sandstone. The marginal, alluvial or delta plains were formed when sediment of sand grade was being supplied from the Cretaceous highlands. A fairly large proportion of finer sediments, now preserved as shale, was also retained on the plains.

All of the sand was not held, however. Much of it passed beyond and into the bordering brackish and marine waters, where it formed deposits of mostly marine, but partly brackish, sandstones. These fringing sandstones are probably the "littoral sandstones" of Spieker's (1949) classification, but some may have been deposited far from the shore or delta front and will be referred to here as fringing sands or sandstones. Some marine sandstones of the Canadian interior have no visible contact with deposits of the marginal alluvial plains, and cover large areas. There is some reason to believe, however, that if traced west across the Rocky Mountains, which unfortunately is not possible, it might be found that they would pass into marginal alluvial plain deposits.

The greater part of the fine sediments, now preserved as shale, passed into the sea, where it was deposited beyond the fringing sands. All thick sections of shale, where fossiliferous, contain the remains of marine animals.

VARIABLE GEOGRAPHIC OUTLINES OF LOWER CRETACEOUS TIME

General Statement

In spite of the great mass of information gathered by geologists, it is not yet possible to produce accurate palæogeographic maps of the western interior of Canada in Lower Cretaceous time. An attempt to draw such maps was made by McLearn in 1932. Twelve years later a revision was necessary (McLearn, 1944). Another is now called for, but it will be useless to attempt it until some important problems of correlation are settled and more is known of the subsurface stratigraphy of the Lower Cretaceous of the interior regions of Canada.

Amid all the revisions, however, several features of the palæogeography have remained unchanged. One is the greater variety of geographic outline in the Lower than in the Upper Cretaceous; that is, more distinctive kinds of outlines throughout Lower Cretaceous time. Another is the boreal origin of the Fort St. John seas. Another is the peculiar lineaments of sea and marginal alluvial plain in middle Fort St. John time; however, it is admitted that the palæogeographic maps of this time must be drastically revised.

Much of the evidence of Cretaceous history has been destroyed. To the west, rocks of this age have been removed from the Rocky Mountains; to the north they have suffered denudation in the Mackenzie Mountains.

Possible Emergence in Middle Lower Cretaceous Time

No beds of middle Lower Cretaceous age have yet been recognized in the Bullhead group of northeastern British Columbia, and the possibility of a break in the succession between the non-marine and upper part and the marine and lower part of this group has been considered (*See* page 72). If, in the course of investigation, substantial proof of this break is obtained, emergence above the sea in middle Lower Cretaceous time in northeastern British Columbia must be inferred.

Gething Alluvial Plain

Deposition was resumed in Gething time, following the supposed Kootenay emergence, and a wide alluvial plain, with, at times, coal swamps and temporary ponds or 'playas', occupied the site of the Rocky Mountains, Foothills, and Plains as far north as Pocketknife River in northeastern British Columbia and far to the east into Alberta. It was coextensive with the Luscar alluvial plain, with its coal swamps, in the central Canadian Foothills, with the Lower Blairmore alluvial plain of southwestern Alberta, and, perhaps, with the 'Varicoloured' alluvial plain in southern Alberta. It is not known whether the Gething plain continued into eastern Alberta. In 1932, McLearn mapped this plain as marginal to an early stage of the Clearwater or *Lemuroceras* sea. In 1944, it was mapped as coextensive with the McMurray alluvial plain. More exact correlation of the Peace River with the Athabasca River section is required before this palæogeographic problem can be settled.

Luscar Sea

No marine fossils have yet been found in the Gething formation in the Foothills. Farther east, however, in the Pouce Coupé area, beds encountered in the section of the Guardian well, and correlated by Allan and Stelck with the Gething, contain not only coal and plant remains, but glauconite, thus recording marine or brackish water as well as non-marine environments. McLearn (1944) has shown that evidence of marine or brackish water habitat is recorded in places by the Luscar formation and its correlatives, and that a sea at this time lay somewhere in the interior Yen (1949) considers that the Lower Blairmore and Luscar formations are partly of marine or estuarine origin. This sea may have been of Aptian or very early Albian (late Lower Cretaceous) age and perhaps older than the *Lemuroceras* or Clearwater sea.

Marine Invasions from the North

The seas recorded by the marine beds of the late Lower Cretaceous (Albian) Fort St. John group spread not only over the Foothills and Plains of northeastern British Columbia, but over large areas on the site of northern and central Alberta as well, and at times may have extended far to the south, even into southern Alberta and Saskatchewan.

They were northern seas, inundations from the Arctic Ocean (McLearn, 1932, 1944) southward across the site of Mackenzie River Valley. They did not extend west of the Trench, being separated from the Pacific Ocean by a land barrier. Nor did they extend far enough south to join the late Lower Cretaceous seas that spread northward from the Gulf of Mexico.

These Fort St. John seas included the *Lemuroceras*, *Gastroplites*, (*Haplophragmoides gigas*), and *Neogastroplites* inundations. The exact age of the *H. gigas* sea, named for a species of foraminifera, is not known, but may be later than the *Gastroplites* sea. It appears to have had the maximum southern expansion to the International Boundary in Saskatchewan, where it has been recorded by Wickenden (1932). The *Lemuroceras* fauna has not yet been recorded south of Athabasca River, nor the *Gastroplites* fauna south of the Pine, at least not in print.

Outlines of Deltas in Middle Fort St. John Time

The outlines of delta or alluvial plains shown on palæogeographic maps in 1932 by McLearn were revised in 1944 by the same author. Whatever further drastic revisions may be necessary as new stratigraphic data and new correlations become available, it does appear that some unusual outlines were traced by the fronts of these deltas. North-south replacement of marine by non-marine strata, and of shale by sandstone, noted by McLearn (1932, 1944), Wickenden and Shaw (1943), Nauss (1945A), and Wickenden (1948), call for somewhat unorthodox palæogeography. McLearn has inferred that some of the delta fronts extended in an approximately east-west direction. The deltas advanced and retreated in a more or less north-south or southwest-northeast direction. Apparently a delicate balance was maintained at times between sea, on the one hand, and coastal swamp and alluvial plain on the other, so that marine and non-marine beds are, in places, intimately related in some formations.

In northeastern British Columbia, the marine sand bottoms and alluvial plain or coastal swamps of middle Fort St. John time are recorded by the Commotion and Gates formations. The non-marine beds included, along with marine beds, in the Commotion on Pine River, disappear to the north on Peace River, as already noted, and point to an old coastal swamp or delta front between the sites of these two rivers.

An important event in late Lower Cretaceous or Albian history was the appearance in abundance of dicotyledons, or plants with leaves, productive of a marked change in the forest landscape of the delta plains. They are recorded in northeastern British Columbia by the flora of the Commotion formation.

Late Fort St. John Marine Sands

A widespread sandy sea floor is recorded by beds of the Goodrich formation and its correlatives. This floor covered the site of the western part of the Plains, at least from Pine River north to Steamboat Mountain, but may not have extended very far out on the Plains. As knowledge of the stratigraphy increases, it will be interesting to determine to what extent the outline and location of this sand bottom differed from the outlines of the deltas in middle Fort St. John time, and to what extent they were prophetic of the outline and the localities of the later Dunvegan delta or marginal alluvial plain.

This sand covered a large area for a littoral marine sand. It may indeed have had an even wider extent than the known outcrops of sandstones of the Goodrich and Sikanni formations indicate; for it may have spread west or southwest across the site of the Rocky Mountains to the western shore of the Goodrich or *Neogastroplites* sea. It may, however, not have extended so far west or southwest and have lain, as a wide, fringing, sandy sea floor, on the site of the Foothills and western part of the Plains, in front and east or northeast of a marginal alluvial plain, on the site of the Rocky Mountains. In either case the unusually large area of marine sand floor requires an explanation: subsidence of the sea floor may have been too rapid to permit growth of a delta or marginal alluvial plain, which so commonly formed when sediment of sand grade was being carried into the interior Cretaceous sea; or subsidence was rapid enough to impede advance of the alluvial plain and restrict it to a narrow area to the west or southwest on the site of the Rocky Mountains and leave a wide belt of fringing marine sand to the east or northeast.

UPPER CRETACEOUS GEOGRAPHIC OUTLINES

General Statement

The geographic lineaments varied less in Upper Cretaceous than in Lower Cretaceous time; that is, there were fewer styles of outlines. The marginal alluvial plains or deltas advanced and retreated, mainly in an east-west direction and with a more or less north-south or northwest-southeast direction of the delta front. There appears also to have been a tendency for the deltas to advance a little farther eastward in the northern than in the southern part of the Canadian interior.

All seas now extended south into the United States interior and probably to the Gulf of Mexico. Many, perhaps all, extended to the Arctic, so that the continent was divided into two by a great interior sea stretching from the Arctic to the Gulf. Palæogeographic maps of later Upper Cretaceous time have been prepared by Russell (1939).

Marginal Alluvial Plain in the Northwest

In very early Upper Cretaceous, probably Cenomanian, time, a great marginal alluvial plain or delta occupied a large part of what is now northeastern British Columbia and northwestern Alberta, an area that had previously been flooded by the Fort St. John seas (McLearn, 1932). It is recorded by sediments of the Dunvegan and Fort Nelson formations. It extended southeast along the Foothills almost to Athabasca River, northwest at least as far as the Liard, and eastward at least as far as Dunvegan, but probably not to Athabasca River, as inferred by McLearn (1932) in an earlier paper. Its western extension is not known, but may have been to or even beyond the site of the Trench.

Over most of this area, the sediments record a marginal alluvial or delta plain with scattered coal swamps, at times inundated by the sea. If the Fort Nelson formation is a northern extension of the Dunvegan, it records an environment closer to the Piedmont slopes of that time than the sediments of the Dunvegan formation.

Except where it flooded the Dunvegan delta and there left traces of its fauna, little is known of the sea of this time. It may be recorded by shales low in the Blackstone formation in the central Canadian Foothills (*See* Chapter III). It may also be recorded by beds near the base of the speckled shale zone, with *Inoceramus athabaskensis*, on Lower Athabasca River (*See* Chapter III), and possibly by beds near the top of the Ashville formation on the Manitoba escarpment (McLearn, 1937; Wickenden, 1945). However, it must have inundated parts of the southern Canadian interior, for it certainly was connected with early Cretaceous seas in Utah and Colorado; it was the first of the Cretaceous seas of the Canadian interior to connect with seas of the southern interior of the continent (McLearn, 1932, 1937). The northern distribution of this sea is not known. No record of it has yet been found in Mackenzie River Valley.

Middle Upper Cretaceous Marine Expansion

The Dunvegan marginal alluvial plain retreated and the seas spread over most of the site of the Foothills and Plains and may even have inundated the site or the present Rocky Mountains. Most, or all, of them extended from the Gulf to the Arctic Ocean, dividing the continent, but only, of course, by a shallow sea. The palæogeography of this time is commonly illustrated in current textbooks on Historical Geology. Mostly fine-grained sediments were deposited on the sea bottom, and are now preserved as shale. Finer sediments, speckled calcareous shale, and even some limestone formed in places, particularly in the east. Some sand accumulated in the extreme west. Little, if any, evidence of delta building is preserved. The sandstones, however, may have fringed, that is, lain out in front of, marginal alluvial plains on the site of the Rocky Mountains, but any evidence of such plains was destroyed during the deep erosion that the Canadian Rockies have undergone.

The *Dunveganoceras* sea is recorded by shale and sandstone near the base of the Kaskapau formation on Pouce Coupé River, near the eastern border of the map-area, by shale at the base of the Kaskapau at Dunvegan, by shales low in the Blackstone formation in southwestern Alberta, and by beds of the same age in Wyoming (Haas, 1949). It, doubtless, had a much wider distribution than the fossil record shows, and spread some distance into northeastern British Columbia.

The *Watinoceras* and *Prionotropis* seas inundated the interior of the continent, and records of them are preserved from Mackenzie River Valley to Texas. In northeastern British Columbia, sand was deposited in the vicinity of Pine River Valley, where *Watinoceras* has been collected on Tuskoola Mountain. Finer sediment was laid down farther east, in the Pouce Coupé area.

In *Scaphites ventricosus* time both fine and coarse sediment accumulated in the sea, and some of the sand was carried to the site of lower Smoky River, far beyond the east border of British Columbia. The question might well be asked whether alluvial plains existed at this time to the west on the site of the Rocky Mountains. Like the *Prionotropis* and *Watinoceras* seas the *Scaphites ventricosus* sea has left its mark on the interior of the continent from the Arctic to the Gulf.

The later sea, recorded by *Inoceramus* of the *lobatus* species group, had a wide and probably a similar distribution to that of *Scaphites ventricosus* time. Fine sediments accumulated in this sea, mostly now preserved as shale, but calcareous deposits formed in the eastern part, particularly on the Manitoba escarpment. A little sand enters in the extreme western sections. This sea is recorded in northeastern British Columbia by sandstone and shale near the top of the Kotaneelee formation on lower Liard River. It may well have spread widely over northeastern British Columbia and Jeletzky (1950) suggests an extension to the Arctic.

Eastern Advance of the Delta Plains

In northeastern British Columbia the last middle Upper Cretaceous sea was expelled by the advance of a delta or marginal alluvial plain, which covered all of this part of the continent. This was in early Belly River, possibly about late Santonian or early Campanian time. Here the advance was final and complete. In the south, on the site of southern Alberta and Saskatchewan, it was otherwise. There the deltas retreated to admit of two incursions of the sea, in both Pakowki and Bearpaw time, before the final advance of the delta plains in the late Upper Cretaceous (Russell, 1939). As in southern Alberta and Saskatchewan, the alluvial plains may have persisted into Paleocene time.

The advance of the alluvial plains in northeastern British Columbia is recorded by the non-marine strata of the Wapiti group and by the non-marine beds on Petitot River, correlated with it. Possibly this plain extended to the west and to the Trench, where beds of the Sifton formation may be of similar age.

It is not impossible that seas may have persisted into late Upper Cretaceous time far to the east, but if so their deposits have been removed by erosion (Jeletzky, 1950).

SOURCE OF CRETACEOUS SEDIMENTS

Since 1887, all geologists interested in palæogeography have agreed with Tyrrell that the bulk of the Cretaceous sediments of the western interior of Canada have come from the west and beyond the Rocky Mountains. It is only natural, therefore, to look for the source of the Cretaceous sediments of northeastern British Columbia to the west of the Trench, in the Omineca and Cassiar Mountains and adjacent areas.

Too little effort has been made in previous studies to co-ordinate the history of folding, elevation, and other geological events gained by a study of the source area itself with the history inferred from the nature of the sediments in the area of deposition. Diastrophism in the one should be reflected in the sediments of the other.

After folding and intrusion of the Omineca and Cassiar batholiths at the end of Jurassic or beginning of Lower Cretaceous time (Roots, 1948; Armstrong, 1949) mountains rose on the site of the present Omineca and Cassiar Mountains. Their denudation would produce a large amount of sediment, some of which would be of sand grade, particularly if the mountains formed by folding and uplift were high. The erosion was sufficient to expose the top of the batholith, but not sufficient to erode it deeply nor to remove all of the Jurassic strata, even some that may have been deposited at a late stage before the uplift. Armstrong (1949) believes that the sediment so derived may have been a main source of the Lower Cretaceous rocks. It may well be that the coarse sediments of the Bullhead group have come from these old mountains west of the Trench.

Some features of sedimentation in Bullhead time require explanation. Although these explanations, with our current knowledge, cannot be complete, they are worth considering.

(1) The question can be asked, why did marine conditions prevail in earlier Bullhead and non-marine conditions in later Bullhead time. As one hypothesis, it may be assumed that although a large quantity of coarse sediment was being delivered to the sea at both times, subsidence of the sea

bottom was too rapid to permit delta building during deposition of the lower Bullhead, whereas later, slower subsidence made delta building possible.

(2) The disappearance of the Bullhead group to the north also requires explanation. It is to be assumed that uplift west of the Trench was less, for example, in the old pre-Cassiar Mountains in the north than in the old pre-Omineca Mountains in the south.

The sediments of the Fort St. John group are mostly fine grained. Sand entered into the deposition of the Commotion and Gates formations, and sand passed into mud and non-marine into marine conditions from south to north. Some of this sediment may have come from the west in a late phase of the denudation of the ancient pre-Omineca and pre-Cassiar Mountains. Some, however, may have come from the southwest or south, from a northern extension oi the pre-Selkirk Mountains. McLearn (1932, 1935) has proposed that much of the late Lower Cretaceous sediment came from the pre-Selkirk Mountains and spread out northeastward onto the site of the Plains.

The main reason, generally accepted since Tyrrell's original observation, for the exclusion of the site of the Rocky Mountains as a source of Cretaceous sediment is its inability to supply feldspar to the sands and igneous boulders to the conglomerates. It must be admitted, however, that not much is known of the petrography of either the sandstones or conglomerates of the Cretaceous of northeastern British Columbia.

The source of the Upper Cretaceous and Paleocene sediments of northeastern British Columbia is a greater problem than that ot the Lower Cretaceous sediments in the same region. In particular, large quantities of coarse sediments are required to fill in the sea and build out the early Upper Cretaceous Fort Nelson-Dunvegan and late Upper Cretaceous and Paleocene Wapiti marginal alluvial plains. It has been noted that elevation and erosion of the late Jurassic of early Lower Cretaceous pre-Omineca and pre-Cassiar Mountains may well have furnished the coarse sediments of the Bullhead group. The evidence is not so strong that these old mountains were the chief source of the Upper Cretaceous sediments. It is true that some sediment may have come from this source, because some increase is shown in size of grain of sediment from east to west. An examination, however, of the Aiken Lake, McConnell, and adjoining map-sheets will show that the Sustut group covers a large area west of the Trench, and that only a comparatively narrow strip of terrain is left between the easternmost outcrops of the Sustut group and the Trench to serve as an elevated and source area. The question is: would the denudation of an area this wide, even if highly uplifted, supply all of the sediment required to build up the Upper Cretaceous formations that accumulated on the site of the Rocky Mountains, Foothills, and Plains of northeastern British Columbia and northwestern Alberta. Moreover, if the Sifton formation in the Trench is a part of the Sustut group (Roots, 1948) and were once continuous with it, an hypothesis that cannot be entirely rejected, the site of the Omineca

Mountains may have been the site of aggradation, not denudation, during late Cretaceous or Paleocene time.

If future research should eliminate the site of the Omineca and Cassiar Mountains as the area of source of the Upper Cretaceous sediments in northeastern British Columbia, other regions of uplift and erosion at this time must be sought. Far to the west or southwest, beyond the outcrops of the Sustut group, is a long way to seek for the sediments of the Dunvegan, Fort Nelson, and other Upper Cretaceous formations of northeastern British Columbia. Other possible regions of Upper Cretaceous uplift can be considered—north or northwest of the Cassiar Mountains, and north of Liard River, for example, in the Liard Plain, Hyland Plateau, and Logan Mountains, or even farther to the north or northwest. It is probable that when the origin of the sediments of the Sustut group is known, that of the Upper Cretaceous beds of northeastern British Columbia, now outcropping in the Foothills and Plains, will also be known.

ROCKY MOUNTAIN REVOLUTION

The great mass of sediment that had accumulated in the Rocky Mountain geosyncline was finally folded, faulted, and elevated to form the Rocky Mountains. It is difficult to date this revolution accurately in northeastern British Columbia. In the central and southern Foothills, where beds of Paleocene age have been accurately identified, the folding of the Paleocene with the Cretaceous strata and the lack of an angular unconformity between them indicate that the Rocky Mountain orogeny did not affect the beds on the site of the Foothills until post-Paleocene time. No direct evidence of the date of the earliest movements in the Rocky Mountains can be obtained, because of the removal by erosion of all Upper Cretaceous deposits from there. Russell and Wickenden (1933) have shown that the first gravels derived from the erosion of the Rockies appeared on the Plains of southwestern Saskatchewan in Upper Eocene time.

No igneous intrusions were associated with this revolution in northeastern British Columbia, east of the Trench, nothing even comparable with the Ice River complex in the Field area of the central Canadian Rockies. Little volcanic material is interbedded with the Cretaceous sediments. The Crowsnest volcanic formation of southwestern Alberta and occasional bentonite beds are the only possible manifestations of igneous activity during deposition of the Cretaceous in the western interior of Canada (Williams, 1947).

TERTIARY

DENUDATION

Since their first uplift, the Rocky Mountains of northeastern British Columbia have been deeply eroded. From the site of these mountains all Cretaceous and Jurassic and, indeed, most of the Triassic sediments have been removed, and most of the Cretaceous has also been removed from the Foothills. On the Plains, however, strata as late as Upper Cretaceous and Paleocene have been retained.

DEPOSITION

Of the great amount of sediment removed from the Rocky Mountain area little remains on the continent. Much of it may have been carried north to the Arctic Sea, along some old Tertiary drainage route. The lignite and clay of Coal River record swamps and advanced weathering of sediments, and deposition on alluvial plains on the site of the Liard Plain. This may have been when the mountains were reduced to a low level after the first uplift; doubtless one or more uplifts have followed.

Remnants of Tertiary gravels, like the Cypress Hills and Wood Mountain gravels of southern Saskatchewan, may yet be preserved in the Plains of northeastern British Columbia, but as yet they have not been discovered.

CHAPTER VI

ECONOMIC GEOLOGY

INTRODUCTORY STATEMENT

Placer gold has been found in many gravel deposits along Parsnip, Finlay, and Peace Rivers, and in places is associated with a little placer platinum. The gold is generally in very fine particles or 'colours', and in part may be classified as 'flour gold'. The fine gold obtained from the bars along Peace River is not thought to have been derived from a local source, that is from the underlying Schooler Creek or Bullhead formations, but to have come from schists and other older rocks within the mountains to the west. It was transported by glacial action in Pleistocene time and by normal fluviatile agencies in both Pleistocene and Recent times. Sorting and concentration of the fine gold are continually in progress along the larger streams, particularly during stages of flood, when the sand, gravel, and boulder clay deposits of the stream beds are under most active attack. The gold generally tends to concentrate at or near the surface of the flats and bars, but may be found anywhere throughout the reworked sand and gravel deposits where there has been a momentary slowing of the water.

On Peace River, placer gold is known to occur as far downstream as the mouth of Battle River. McConnell (1893) tested a mile-long gravel bar 3 miles above the mouth of Battle River, and obtained fifteen to twenty colours of fine gold by washing a few handfuls of the mixed gravel and sand in an ordinary frying pan. Twelve miles farther up the river, another bar yielded from twenty to forty colours to the pan. McConnell believed that the presence of fine gold in some quantity in these bars was due to the diminution in the strength of the Peace River current, which takes place here, and its consequent loss of transporting power. This fact is shown in the gradual substitution of sand bars for gravel bars.

Colours of gold occur in the gravel bars along the Liard all the way down to its mouth, but no deposits of economic value are known below the Devil's Portage (McConnell, 1891). A number of bars were worked between this portage and the mouth of Dease River for several years after the discovery of gold on the Liard, by Messrs. McCulloch and Thibert in 1872, but no records of the quality of gold recovered are available. There was some successful 'sniping' for placer gold along the Liard in the vicinity of construction camps when the Alaska Highway was being built.

The Annual Report of the Minister of Mines of British Columbia for 1947 gives the total production of placer gold for Peace River division during the period 1900 to 1947 as 4,116 ounces, valued at $94,977.

Lode deposits are not known to occur in the Rocky Mountain Foothills, and so far as known are rare in the Rocky Mountains. The Foothills and

Rocky Mountain Ranges are composed very largely of Palæozoic and Mesozoic strata and include no known intrusive rocks, conditions that are generally considered unfavourable for the occurrence of lode deposits. Profound faulting along the course of the Rocky Mountain Trench may have opened fissures along which minerals were deposited, but if so they will be difficult to find because of the heavy drift cover. The occurrence of copper minerals on Pesika Creek, 25 miles northeast of Fort Grahame, is, however, proof that lode deposits are to be found, if only rarely, along subsidiary faults, in the Rocky Mountains immediately east of the Trench.

Highly folded quartzite, argillite, and slaty rocks that outcrop south of the Alaska Highway along the valleys of Toad River and McDonnell Creek, and that are thought to be of Precambrian age, are probably worth prospecting. These rocks are intruded by gabbro dykes, some of which are 50 feet wide, near the Highway. Williams (1944) has noted the presence of quartz veins, showing brown and yellow stains, in the quartzites 1½ miles south of the Highway up McDonnell Creek. He also records an occurrence of purple fluorite in the overlying limestone near mile 399. Small quantities of fluorite were also seen in the limestone near the south end of Muncho Lake.

High-grade bituminous coal seams of Lower Cretaceous age constitute the most valuable mineral resource found to date in northeast British Columbia. The coal is found in the upper part of the Bullhead group, which is widely exposed in the Foothills along the valleys of Peace and Pine Rivers, and along Carbon and Fisher Creeks. The formation extends north to beyond Sikanni Chief River, but thins in that direction and is unknown north and west of Fort Nelson.

Coal leases were acquired in the Peace River Canyon coal area as early as 1908, by Neil Gething and associates. The Grant seam at the west end of Grant Flat on the north side of Peace River, 15 miles west of Hudson Hope, was the first seam to be actively worked. It was recorded by F. H. McLearn of the Geological Survey in 1918, and by 1922 was opened by an adit 360 feet long. During the summer of 1926, Peace Canyon Mining and Transportation Company Limited shipped some coal down the Peace by barge from Grant Flat, but this method of transportation was found to be too hazardous and the property was closed down.

The building of the Alaska Highway gave a new impetus to coal mining, and resulted in the opening of four new mines, namely, Peace River mine on Larry Creek, on the west slope of Portage Mountain; King Gething mine, on the east slope of Portage Mountain, 1½ miles north of Peace River and 12 miles west of Hudson Hope; Packwood mine, on a southern spur of Butler Range, 22 miles west of Hudson Hope; and the Hasler mine on Hasler Creek 8 miles south of its junction with Pine River about 95 miles west of Dawson Creek. The following table shows the annual production of these mines during the period 1942 to 1947. The figures represent tons of coal mined and sold as reported in the Annual Reports of the Minister of Mines of British Columbia.

Year	Peace River mine	King Gething mine	Packwood mine	Hasler mine
1940	....	40	....	....
1941	....	5	....	....
1942	....	206	40	....
1943	....	1,400	1,511	....
1944	748	566	2,700	777
1945	2,542	831	831	3,156
1946	1,333	300	670	....
1947	3,312	460	1,548	....
Totals	7,935	3,808	7,300	3,933

Grand total—22,976 tons.

An additional 1,000 tons of coal was produced at the Grant Flat mine prior to 1940, but not all of this was shipped.

Petroleum possibilities in northeast British Columbia have not been tested as yet by deep drilling. There is hope that the thick assemblage of limestones, siltstones, sandstones, and shales of Palæozoic and Triassic age may contain productive strata. Shallow test holes drilled into the Cretaceous formations have encountered gas and minor showings of oil in the strata of the Fort St. John group. The Commotion Creek well in Pine River Valley was drilled with the view of penetrating Triassic and older strata. It was drilled to a depth of 6,940 feet, but did not reach the base of the Bullhead group.

PLACER DEPOSITS

According to McConnell (1896), the first discovery of placer gold in the Peace River country was made on Parsnip River, about 20 miles above its mouth, by Bill Cust, in 1861. The following year a Cornish miner, Pete Toy, discovered some exceptionally rich gravel bars on Finlay River below its junction with the Omineca, some of which was said to yield "one dollar to the bucket". Pete Toy was still working this ground when W. F. Butler ascended Finlay and Omineca Rivers, in 1873.

Selwyn (1877) reported that Daniel Williams ("Nigger Dan"), whom he met at Fort St. John, had been some 12 to 14 years on the Parsnip, and had lived more or less by gold washing. According to Nigger Dan, the gold "was in or immediately beneath the upper layer of silt left by the spring flood level of the river along the outer margin of the bushes".

McConnell (1896) found fine gold throughout the length of Finlay River, but not in what he considered workable amounts except at Pete Toy's bar. In ascending the river he found gold, mostly fine, at the mouths of Ingenika, Kwadacha, and Fox Rivers, also on two of the smaller western tributaries, one of which enters the Finlay 8 miles below the mouth of Paul River and the other 6 miles above the Fox. With the exception of Kwadacha, no 'colours' were found by McConnell on the eastern, or Rocky Mountain, streams above Deserters Canyon.

W. Fleet Robertson, in the Annual Report of the British Columbia Minister of Mines for 1908, states that sufficient gold occurs in the wide low gravel benches that form the north shore of Finlay River for several miles downstream from the mouth of Bower Creek to justify serious investigation. He reports that although the gravels are scarcely rich enough to permit of being worked by hand, in so remote a district, they present distinct possibilities for dredging, or steam shovel work, when, at some future time, the district becomes more accessible.

W. Fleet Robertson (1909) describes Pete Toy's bar on Finlay River as not properly a 'bar' at all, but a low gravel bench on the right side of the river, some 6 or 8 feet above high water. It showed evidence (1908) of having been extensively worked by shallow workings not more than about 5 feet deep.

Douglas Lay, in the Annual Report of the British Columbia Minister of Mines for 1928, states that Finlay River Mining Company Limited employed five men to test Pete Toy's bar during the summer of 1928. About 8 inches of the upper part of the bar gravels were shovelled into the sluice flume, and the material caught by the riffles was tabled and the black sand concentrate saved; 971 pounds of black sand concentrates shipped to Goldsmith Bros. Smelting and Refining Company, Chicago, contained 21·362 ounces gold and 0·971 ounce platinum.

The Peace River Gold Dredging Company was engaged in testing Branham Flat, 26 miles above the head of Peace River Canyon, in 1923. J. D. Galloway (1924) describes this flat as extending about 2 miles back from the river for a length of 2 miles. Fine gold and platinum were found in the first 25 feet from the surface, but no testing had been done below that depth. It was reported that a large area of gravels on the flat would run about 50 cents a cubic yard. In 1922, the Company tested various bars on Peace River near the site of Old Fort St. John, with a single-bucket type of dredge. It is reported that the work done was not particularly successful.

The January number of the 'B.C. Miner' for 1934 states that during the previous summer thirty individual and group placer operations were in progress along stretches of both Parsnip and Peace Rivers, and that most of these were "making wages". The difficulties of saving the fine gold has discouraged placer mining along these streams in recent years, but there is generally, nevertheless, a small annual production.

The region west of Finlay River produced placer gold in some quantity for many years, but as it is beyond the scope of this report to deal with mineral occurrences lying west of the Rocky Mountain Trench, it will be sufficient only to mention that gold was discovered on Silver, Vital, and Germansen Creeks, tributaries of the Omineca, in 1868, 1869, and 1870, respectively; on Manson and Slate Creeks, tributaries of Manson River, in 1871; and on Tom Creek, tributary of the Omineca, in 1889. These creeks have produced gold valued at nearly $1,500,000. Much of this was mined before 1890, but the district has been productive each year since. Memoir 252 by J. E. Armstrong (1949) includes a description of the geology and mineral resources of the greater part of that region, and descriptions of the mineral occurrences in the more northerly Aiken Lake area are contained in Paper 48-5 by J. E. Armstrong and E. F. Roots (1948).

LODE DEPOSITS

Little prospecting has been done in the Rocky Mountains east of Parsnip and Finlay Rivers, and so far only minor gold and copper deposits have been reported. Ores of silver-lead-zinc, copper, barite, and gold, and deposits of mica have been found in the district west of the Rocky Mountain Trench (Dolmage, 1928; Roots, 1948; and Armstrong, 1949), but only descriptions of those properties lying east of the Trench are within the scope of this report.

MOUNT SELWYN GOLD QUARTZ

Mineral claims were staked as early as 1899 on some of the quartzite bands that together with schist and limestone form the bulk of Mount Selwyn on the south side of Peace River 8 miles east of Finlay Forks. The quartzite was said to contain a little gold. In 1922 and 1923, Peace River Mining and Milling Company carried out some surface work on nine Crown-granted mineral claims on this mountain. A small test mill was erected, and 12 tons of rock were treated, but according to the owners the plant developed mechanical difficulties and did not yield satisfactory results.

J. D. Galloway visited these claims in 1923, and his report (1924) states that quartz occurs in small stringers and veinlets throughout the quartzite, and, in the aggregate, forms a negligible percentage of the whole. The owners, however, claimed that gold to the value of from $2 to $4 a ton occurred generally throughout the quartzite bands without relation to the quartz.

Douglas Lay visited the property for the British Columbia Department of Mines in 1928. Five samples collected by him yielded not even a trace of gold. The property was under option to Gold Mountain Mines Syndicate in 1933, at which time additional sampling was done by J. G. MacGregor. Consolidated Mining and Smelting Company did some sampling in 1935. Rejects from some three hundred and fifteen samples collected by the Company were sent to the Department of Mines at Victoria. The Provincial Assayer quartered these samples and prepared a 70-pound bulk sample, representative of the rejects, which he sent to the Department of Mines at Ottawa. An amalgamation test showed that it contained only a faint trace of gold.

COPPER EAST OF FINLAY RIVER

A copper occurrence east of Finlay River and about 20 miles north of Fort Grahame has been described by Dolmage (1928). The deposit is above timber-line on the steep side of a high limestone mountain, and consists of a mass of enargite several feet long enclosed in unaltered limestone. Below the enargite the limestones are stained with malachite, giving the deposit, when viewed from a distance, the appearance of being much larger than it is. Efforts to find more extensive deposits have been unsuccessful.

"About 15 miles northwest of this deposit and at the same distance east of Finlay River, a large body of disseminated pyrite and marcasite enclosed in limestone and associated with veins of siderite was examined. No other minerals however, are present, and assays of samples taken show only traces of gold. Along a line joining these two deposits and extending far beyond to the northwest, rusty outcrops of siderite and pyritized limestone occur at intervals. Many of these have been examined by prospectors, but none has been found to carry any ore" (Dolmage, 1928).

COPPER ON PESIKA CREEK

The Wedge and Protection group of claims on Pesika Creek about 25 miles east of Finlay River were visited by Douglas Lay in 1930, and his description of the claims as recorded in the Annual Report of the Minister of Mines, 1930, is given below. The claims were owned at that time by Mort Tease, D. Miner, J. Blanchard, L. Smaastet, and associates of Prince George.

"The Wedge and Protection groups adjoin and are reached by a good trail constructed by the owners with the aid of the Department of Mines (British Columbia). This trail leaves the Finlay River at the lower end of Deserters canyon, joins 'The Trail of 98', and follows that trail for a mile or so; then swings off it up Pesika Creek, following the left bank of the latter at first, and crossing the creek by a good bridge about 10 miles from the starting point. Thereafter the right bank is followed to the property, which is situated between a tributary and the main creek on the north side of the latter.

"The mode of mineral occurrence exhibited is a large quartz vein, mineralized with chalcopyrite, sparingly. The vein reaches a width of 134 feet at one point and is exposed on the surface for several thousand feet. Its strike is about N. 10°W. (true), with steep westerly dip. The enclosing country rock is limestone. Exposures, which are by natural agencies and by an extensive system of trenching, lie between elevations of 4,760 and 5,440 feet. Mineralization consists of chalcopyrite, pyrite, and copper stain. This is a shear-zone fissure and the filling consists of brecciated country rock cemented with quartz. It is evident that after the fissure was first formed it was reopened and again filled; mineralization with chalcopyrite took place on both occasions.

"Mineralization is generally somewhat sparse, or appears so on the surface, but in some places open cuts show a width of 6 feet quite well mineralized. A sample across a width of 6 feet at one such point assayed: gold, trace; silver, trace; copper, 2·9 per cent. A sample of selected ore from this cut assayed 6·9 per cent copper and showed traces only of gold and silver. These samples were taken at the north end of the property, at which end depth can only be gained by sinking or long crosscuts. At the south end, on the other hand, where the vein is exposed on the main valley of Pesika Creek, depth can be gained by drifting. Further, at this point the best natural exposure was observed. Here a width of 23 feet is sparsely mineralized. A sample across this width assayed: gold, 0·02 oz. to the ton; silver, 0·20; copper, 0·3 per cent. It will be noted that this sample disclosed a very much higher ratio of precious metal to the unit of base metal than is disclosed by samples taken at the north end of the property.

"This vein, like some other quartz veins observed, appears to be bleached white on the surface presumably by reason of the fact that surface waters in some localities carry reducing solutions. In such cases the true criterion of surface mineralization is not at the actual surface but a few feet below it. The immense size of the vein, the favourable topography from the standpoint of mining, and the fact that mineralization, although sparse, occurs at points several thousand feet apart horizontally and several hundred feet apart vertically are all favourable features which justify some further work. The geographic position of the property is interesting. No granitic intrusive was seen in the vicinity."

BOG IRON DEPOSITS

CAMERON RIVER BOG IRON

Spring deposits of bog iron ore are situated at intervals along the valley of Cameron River (north fork of Halfway River) from its head to its junction with Halfway River. Several of these deposits some 10 miles up Cameron River were visited by J. D. Galloway in 1923, and the following information is taken from his report (1924).

The deposits consist of isolated, small, circular masses of bog iron, which is relatively pure near the centre of each mass, but grades into iron-stained gravels and clays on the outside. Each deposit has had its origin from a central spring, the water of which contained iron in solution, which was precipitated as iron oxide after reaching the surface. In many instances the springs forming the deposits have ceased to flow, and the bog iron has lost its water content and hardened. The pure iron oxide deposited near the mouths of the springs is good-grade ore, but where it is mixed with surface gravels and clay it is too low in iron content to be of any possible value as iron ore. The iron deposits are nowhere continuous for any appreciable distance, and for the most part are too mixed with clay and gravel to be of value.

BEATTON RIVER BOG IRON

The occurrence of bog iron along Beatton River has been recorded by C. O. Hage (1944) as follows:

"Along Beatton River west of the Alaska Highway are several deposits of bog iron. One of these is 2 miles upstream from the Beatton River bridge and ¼ mile south of the river. Another is 5 miles above the bridge on the north side of the river and on the pack trail to Lily Lake. Both deposits cover areas of several hundred square feet. The depth of the deposits was not determined except to note that it is more than 10 inches. No glacial material was found on top of the iron deposits and they can, therefore, be considered as of post-Glacial age. They are believed to have been precipitated from spring waters issuing from shales of the Fort St. John group."

The following are analyses of samples collected by C. O. Hage and analysed in the laboratory of the Mineralogical Section, Geological Survey of Canada, Ottawa:

——	2 miles west of Beatton River bridge	5 miles west of Beatton River bridge
	Per cent	Per cent
Fe_2O_3	79·70	78·10
MnO	Trace	None
H_2O	15·11	19·38
Insol.	3·50	Not weighed
Total	98·31	97·48

In addition to the above, the samples contained a small quantity of organic matter, probable traces of lime and magnesium, and a little carbon dioxide.

OCHRE

According to Williams (1934), iron hydroxide in the form generally known as ochre occurs in considerable quantity near Thorson's Landing, about 4 miles above Fort St. John. There are two deposits, each about 100 feet in diameter and with an estimated depth of 10 feet.

MINERAL SPRINGS

LIARD RIVER HOT SPRINGS

Mineral springs are known in several places in the region drained by Liard River. The hot springs about a mile northwest of the north end of the Liard River suspension bridge are best known. Their presence and the luxuriant vegetation in this part of Liard Valley induced early trappers in the district to refer to the area as the "Tropical Valley". The hot springs have been described by Williams (1944) as follows:

"North of a large beaver pond on the west flank of a hill, several springs occur. The upper ones are quite cool, but have built up small basins and terraces of calcareous tufa. Just below these, a very hot spring issues from the ground. Alongside it the ill-fated Tom Smith built his cabin, and lived with his daughter Jane. The old cabin was torn down by United States Army engineers and two frame buildings were constructed, one over a small pool through which the water flows and one alongside for a dressing room. The water in this spring is said to have a temperature of about 121°F. To the north, and approached by a steep path, is a large open pool about 100 yards by 50 yards in dimensions. A tufa dam on its northwest side rises 60 feet from a beautiful valley. This pool has a soft mud bottom from which sulphur water bubbles. The temperature is reported as 110°F. Rough plank benches have been constructed alongside, and plank floats have been extended into the water for bathers. This pool is greatly appreciated by truck drivers and in fact by all who work along this part of the Highway.

"Gallon samples were collected from each of the hot springs and are reported on by the Department of Mines, Victoria, B.C., as follows:

Submitter's Mark	*Laboratory Report*		
Lower Hot	CaO	29·2	milligrams per 100 c.c. of sample
Spring No. 1	SrO	1·3	"
Temp. 125°	MgO	6·8	"
Mi. 213 Alcan rd.	Na_2O	3·3	"
(Alaska Highway)	SiO_2	5·7	"
—½ mile north of	Cl	2·3	"
highway from	CO_2	2·6	"
Tropical Valley	SO_3	50·5	"

Traces of: B, Mn, Pb, Fe, Al, Cu, Ag, Ni, Cr, Ba, Ti, K
Total solids on 100 cc. sample dried at 103°C......119·5 milligrams
Total solids on 100 c.c. sample dried at 180°C.....115·6 milligrams
Total solids on 100 c.c. sample ignited at 400°C....100·9 milligrams
Probable combination of major constituents:

$CaSO_4$	62·9	milligrams per 100 c.c. sample
$CaCO_3$	5·9	"
$SrSO_4$	2·3	"
$MgSO_4$	18·8	"

Submitter's Mark		*Laboratory Report*
Upper Hot	CaO	25·9 milligrams per 100 c.c. sample
Spring No. 2	SrO	1·3 "
Temp. 90°	MgO	6·5 "
Mi. 213 on Alcan	Na_2O	2·9 "
(Alaska) rd. ½ mi.	SiO_2	6·5 "
north of road from	Cl	1·8 "
Tropical Valley	CO_2	2·3 "
	SO_3	44·6 "

Traces of: B, Mn, Pb, Fe, Al, Cu, Ag, Ni, Cr, Ba, Ti, K
Total solids on 100 c.c. sample dried at 103°C.....105·5 milligrams
Total solids on 100 c.c. sample dried at 180°C.....101·4 milligrams
Total solids on 100 c.c. sample ignited at 400°C.... 92·0 milligrams
Probable combination of major constituents:

$CaSO_4$	55·8 milligrams per 100 c.c. sample
$CaCO_3$	5·2 "
$SrSO_4$	2·3 "
$MgSO_4$	16·2 "

(Signed) G. Cave-Browne-Cave,
Chief Analyst and Assayer."

Small warm springs are also reported on the north bank of Liard River about 2 miles below the mouth of Coal River. There are no available descriptions of these.

Sulphurous fumes and water escape from small crevices in the sedimentary rocks on both Lépine and Crusty Creeks. The springs occur along the tops of small anticlinal folds about a mile from the confluence of the creeks with Liard River. Boulders in the stream beds below the springs are sulphur coated. Gas escaping from a spring a few feet from the east bank of Brimstone Creek, 3 miles north of the Liard, is believed to be composed mostly of carbon dioxide and sulphur dioxide. It could not be ignited, and has a strong sulphur odour.

TOAD RIVER HOT SPRINGS

Toad River Hot Springs are reported to be about 8 miles from the Alaska Highway. Rand (1944) states that they are situated in the valley bottom on a shelf about 20 yards north of Toad River, and about 1½ miles above the junction of Toad and Racing Rivers. "There are about fifteen of them, varying in size from tiny pools to one big enough for five men to swim in at once" (Rand, 1944). The easiest way to reach them is down the right bank of Racing River, across the ford at the junction of Racing and Toad Rivers, and then up the left bank of Toad River. An Indian burying ground on a hill north of the junction suggests that the springs have long been known and used by the natives of this region.

PROPHET RIVER HOT SPRINGS

P. K. Sutherland of Phillips Petroleum Company reports (personal communication) the presence of a hot spring on the south bank of Prophet River some 35 miles west of the Alaska Highway. The position of the spring is marked by tufa deposits.

PEACE RIVER TUFA

Williams (1934) states that large deposits of calcareous tufa are exposed along the north bank of Peace River at Hudson Hope. One of these deposits is about 30 feet high, and extends some 1,500 feet along the river bank. The tufa is deposited from the spring waters that emerge from the calcareous sandstones of the area. It is good material for the manufacture of quicklime.

STRUCTURAL MATERIALS

LIMESTONE, ETC.

The mountainous areas afford an abundant supply of Triassic and Palæozoic limestones that might be suitable for building purposes. The Triassic limestones are nearest to areas of settlement in the Peace River district. Some of the quartzitic sandstones of the Bullhead group should make an excellent building stone, and some of the harder beds of the Dunvegan sandstone might also be used for that purpose.

M. Y. Williams (1934) has pointed out that raw materials and fuel for the manufacture of Portland cement are available in close proximity in the Peace River district. Suitable shale occurs 2 miles up Nabesche (Ottertail) River; limestone may be obtained 15 miles up Peace River above the mouth of the Nabesche; and coal is available on Carbon River within a distance of 12 miles of the Nabesche. On Pine River, a plant situated between the mouths of Le Moray and Mountain Creeks would have a large selection of limestone within a radius of 10 miles, shale within 1 mile, and coal on Pyramid Mountain, within 3 miles.

GRAVEL AND STONE

Plentiful supplies of gravel are available along the river benches and bars of the larger streams for road building purposes. Where the haul from stream channels is too great, the Dunvegan sandstones have been quarried and crushed for road metal in a few places along the Alaska Highway. Terminal moraines and eskers furnish large deposits of gravel in a few localities.

MARL

The occurrence of freshwater marl of excellent quality at Swan Lake south of Pouce Coupé has been noted by Williams (1934). The deposits are said to be about a foot thick and to cover the lake bottom where the water is shallow.

Marls composed mainly of calcium carbonate can be burned locally for quicklime. They make a valuable land dressing, and are used as an ingredient of cement.

CLAY AND SHALE

The following description of an occurrence of Tertiary pottery clay on Coal River is taken from William's 1944 report:

"Fifteen feet of greyish white clay outcrops below a gravel cover in the west bank of Coal River, from 1½ to 2 miles above the Highway. In all probability the area underlain is of considerable extent, as each clay outcrop is about 100 yards in length and the two outcrops are about 200 yards apart. The Tertiary basin is part of that in which the lignite occurs.

"A 2-pound sample of the clay was submitted to the Bureau of Mines, Department of Mines and Resources, Ottawa, and the following report was received:

Nature of material—a buff-coloured, smooth clay that was found to be non-calcareous by the dilute hydrochloric acid test.
Water required to temper to stiff plastic state—27 per cent.
Working properties—plastic, works well.
Drying behaviour—satisfactory.
Average drying shrinkage—6 per cent.

Firing Behaviour

Cone	Fire shrinkage	Absorption	Colour	Remarks
	%	%		
2(2075°F.)	6·7	4·0	Cream	Very hard
12 (2390°F.)	5·4	0·0	Grey	Vitrified (over-fired and bloated)

Softening point (Pyrometric Cone Equivalent) —17.
Approximate temperature—2669°F.

"*Economic Considerations.* From the limited amount of testing that could be carried out on the size of sample submitted, this clay is considered as having good possibilities for the production of such ceramic products as: sewer-pipe, pottery, stoneware jugs, bowls, etc., acid-proot brick, buff-coloured tace brick, and other products for which a stoneware clay is required. Its refractoriness is too low for it to be of any value as a fireclay.

"The close proximity of clay and fuel in the form of lignite is to be noted in making an appraisal of the possibilities of either of these materials."

C. O. Hage (1944) reports that:

"Beds of glacial-lake clays are found along Halfway, Beatton, Minaker, and Prophet Rivers. The deposit on Halfway River is 3 miles east of Pink Mountain, is 5·0 feet thick, and is varved in beds ranging from 3 to 24 inches in thickness. No samples were analysed, but the clay should be suitable for making bricks."

There is an unlimited supply of Cretaceous shales in the Foothills that might be used in the manufacture of bricks and tile.

COAL DEPOSITS

GENERAL STATEMENT

Large deposits of good quality bituminous coal occur in northeastern British Columbia in the Gething formation of Lower Cretaceous age. The deposits are found in the following localities: Peace River Canyon coal area, Dunlevy Creek-Cust Creek-Butler Ridge area, Carbon Creek coal basin area, Fisher Creek-Pine River area, Hasler Creek coal area, and Halfway-Sikanni Chief Rivers area. The Peace River Canyon coalfield is the best known of these; several small mines have been worked from time to time during the past 25 years, and the coal transported to Dawson Creek and Fort St. John for domestic use. The King Gething mine on King Creek (King seam), on the east slope of Portage Mountain, and the Peace River coal mine on Larry Creek (Murray seam), on the west slope of Portage Mountain, are presently active. Coal is also mined at the Packwood mine (No. 1 seam) on a southern spur of Butler Ridge, and at the Hasler Creek mine on Hasler Creek (Discovery seam). The combined coal resources of the six areas have been estimated by the Royal Commission on Coal (MacKay, 1947) as 467,040,000 tons of probable mineable coal with 573,440,000 tons of possible additional mineable coal (*See* Table II). It is obvious from these figures that the coal deposits of northeastern British Columbia form an important reserve, and there is no doubt that more and more use will be made of them as transportation improves and as population grows in that region.

Descriptions of the geology and structure of the individual coal areas are given under separate headings in pages that follow.

A few additional coal seams are found in the Dunvegan sandstones of Upper Cretaceous age, but these are too small to be commercially important, although some of them have been worked on a small scale for local domestic use. According to M. Y. Williams (1934), a 30-inch seam is exposed on Doig River and a 12-inch seam outcrops here and there for 10 miles above its mouth. A 20-inch seam is exposed about 3 miles above the mouth of Kiskatinaw River, and a similar seam outcrops on the same river at the west boundary of tp. 80, rge. 17. A 1-foot seam in the valley of Coal Creek and a 2-foot seam in the north bank of Pine River near the Forks (East Pine) have both been worked. Small seams also occur at the mouth of Coldstream Creek southeast of the Forks. Williams (1944) also reports a 1-foot seam of coal on Table Mountain west of Fort Nelson at the base of the Fort Nelson formation, which is the equivalent of the Dunvegan formation. C. O. Hage (1945) found a 15-inch seam of low-grade coal in late Upper Cretaceous sandstone beds that cap the Kotaneelee formation on the east bank of the Liard 2 miles above the mouth of Kotaneelee River.

An occurrence of brown lignite on Coal River 6 miles north of mile 533, Alaska Highway, is an added coal resource. Large masses of drift lignite collected from the river bars were used in heating camp buildings when the road was under construction. The amount of lignite accessible has not yet been determined, but Williams (1944) notes that it is at least 15 feet thick and outcrops for some 600 yards along the river bank for the width of the river flats, or about 300 yards.

In the following pages, coal is referred to as of a certain 'rank' based on the fixed carbon percentage and the calorific value of the coal calculated on a mineral-matter-free basis. Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis are classified according to fixed carbon, regardless of their calorific value, whereas lower rank coal containing less than 69 per cent fixed carbon is classified according to B.t.u. per pound on the moist mineral-matter-free basis. When lower rank coals are marginal between bituminous and sub-bituminous, those that show a "weathering index" of less than 50 per cent, and thus are considered non-weathering, and/or tend to cake or agglomerate on burning

Table II

Coal Reserves of Northeastern British Columbia, Based on Seams Not Less Than 3 feet in Thickness to a Maximum Depth of 2,500 feet[1]

(Thousands of net tons)

District and area	Coal-bearing formation	Area underlain by coal formation (sq. miles)		Coal seams			Mineable						Recoverable	
							Probable			Possible (additional)				
		Total	Area used	No.	Aggregate thickness (feet)	Thickness used (feet)	Thickness used (feet)	Area (sq. miles)	Tonnage	Thickness used (feet)	Area (sq. miles)	Tonnage	Probable	Possible (additional)
Peace River Canyon—														
Gething-Johnson Creek and Ext.	Gething	8	8	8	28	20	20	6	134,400	20	2	44,800	67,200	22,400
Moosecall Lake North........	Lower Cretaceous	6	6	4	15	10	10	3	33,600	10	3	33,600	16,800	16,800
Butler Ridge—														
Packwood North Extension...	"	25	15	7	24	20	20	5	112,000	20	10	224,000	56,000	112,000
East Flank..................	"	20	15	4	15	10	10	5	56,000	10	10	112,000	28,000	56,000
Carbon River.................	"	10	10	5	15	10	10	6	67,200	10	4	44,800	33,600	22,400
Falls Creek..................	"	10	5	2	10	10	10	3	33,600	10	2	22,400	16,800	11,200
Hasler Creek-Willow Creek.....	"	18	7	2	25	12	12	1	13,440	12	6	80,640	6,720	40,320
Halfway-Sikanni Chief Rivers..	"	10	5	1	5	5	5	3	16,800	5	2	11,200	8,400	5,600
Minaker River................		Insufficient data as to thickness												
Total..................	....	......	....	.....	....	....	....	......	467,040	....	......	573,440	233,520	286,720

[1] From Coal Reserves of Canada by B. R. MacKay, 1947.

are raised in this classification to bituminous rank. Coals of higher rank, that are marginal between bituminous and semi-anthracite, are delimited according to their agglomerating properties. Coals that have the other properties of semi-anthracite but show agglomerating properties are lowered in classification to low volatile bituminous coal, the highest group of the bituminous class. Full particulars of this system appear in a report on "The A.S.T.M. [American Society Testing Materials] Standard Specifications for Classification of Coals by Rank and by Grade and their Application to Canadian Coals", issued by the National Research Council as N.R.C. (National Research Council) Report No. 814 (1939). The classes and groups and their delimiting factors according to the A.S.T.M. system of classification by rank are indicated in Table III. Under this system, the rank of all coal seams in the Gething formation in the Peace River Foothills falls into either the low volatile bituminous or the medium volatile bituminous group.

TABLE III

Classification of Coals by Rank[1]

(A.S.T.M. Designation: D.388-38)-1937

Class	Group	Limits of fixed carbon or B.t.u. mineral-matter-free basis	Requisite physical properties
Anthracite	Meta-anthracite	Dry F.C., 98 per cent or more.	Non-agglomerate[2]
	Anthracite	Dry F.C., 92 per cent or more and less than 98 per cent.	
	Semi-anthracite	Dry F.C., 86 per cent or more and less than 92 per cent.	
Bituminous[4]	Low volatile bituminous coal	Dry F.C., 78 per cent or more and less than 86 per cent.	Either agglomerate or non-weathering[6]
	Medium volatile bituminous coal	Dry F.C., 69 per cent or more and less than 78 per cent.	
	High volatile A bituminous coal	Dry F.C., less than 69 per cent and moist[3] B.t.u. 14,000[5] or more.	
	High volatile B bituminous coal	Moist[3] B.t.u. 13,000 or more and less than 14,000.	
	High volatile C bituminous coal	Moist B.t.u. 11,000 or more and less than 13,000.[5]	
Sub-bituminous	Sub-bituminous A coal	Moist B.t.u. 11,000 or more and less than 13,000.[5]	Both weathering and non-agglomerate[6]
	Sub-bituminous B coal	Moist B.t.u. 9,500 or more and less than 11,000.[5]	
	Sub-bituminous C coal	Moist B.t.u. 8,300 or more and less than 9,500.[5]	

TABLE III—*Concluded*

Classification of Coals by Rank—Concluded

Class	Group	Limits of fixed carbon or B.t.u. mineral-matter-free basis	Requisite physical properties
Lignitic	Lignite	Moist B.t.u. less than 8,300.	Consolidated
	Brown coal	Moist B.t.u. less than 8,300.	Unconsolidated

The fixed carbon and heat value on the above basis may be calculated by using the following formulæ:

$$\text{Dry, mm.-free F.C.} = \frac{\text{F.C.}}{100-(M + 1\cdot 1A + 0\cdot 1S)} \times 100$$

$$\text{Moist, mm.-free B.t.u.} = \frac{\text{B.t.u.}}{100-(1\cdot 1A + 0\cdot 1S)} \times 100$$

where:

mm. = mineral matter
B.t.u. = British thermal units
F.C. = percentage of fixed carbon
M = percentage of moisture
A = percentage of ash
S = percentage of sulphur

Moist refers to the natural bed moisture of the coal, but doesn't include visible water on the surface of the coal.

[1] From National Research Council, Report No. 814 (1939).

[2] If agglomerate, classify in low-volatile group of the bituminous class.

[3] Moist B.t.u. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[4] It is recognized that there may be non-caking varieties in each group of the bituminous class.

[5] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of B.t.u.

[6] There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerate and non-weathering; Variety 2, agglomerate and weathering; Variety 3, non-agglomerate and non-weathering.

PEACE RIVER CANYON COAL AREA

Peace River Canyon coal area extends from the foot of Peace River Canyon to the head of the canyon, and includes all neighbouring ground underlain by the Bullhead group along Gething, Aylard, Mogul, Moosebar, and Johnson Creeks, to the south and west of the river, as well as the long slopes of Portage Mountain to the north and east of the canyon (*See* Figure 11).

The presence of coal along the walls of the canyon was first noted by Alexander MacKenzie in 1793. Leases were acquired in the area by Neil Gething and associates as long ago as 1908, and in 1912, C. F. J. Galloway reported on the Canyon coalfields for the British Columbia Department of Mines. F. H. McLearn examined the area during the 1922 field season, and his report (1923) describes the coal occurrences in great detail. Further investigations of the coal resources were made by F. H. McLearn and E. J. W. Irish in 1943.

The coal seams occur in the Bullhead group of Lower Cretaceous age, and most of the coal is found in the Gething formation, which comprises the upper, non-marine part of the group. The Gething formation has a thickness here of 1,400 feet, and consists of sandstone, shale, clay ironstone, and coal seams. The lower part of the Bullhead group (Dunlevy formation) exceeds 3,000 feet in thickness, but only the upper part is exposed along the canyon. This part consists of conglomerates, grits, and coarse sandstones, together with smaller amounts of medium to fine sandstones and shales, with only a few thin coal seams.

In measuring a section from Grant Flat to Ferro Point and Aylard Creek[1], McLearn (1923) located and measured fifty coal seams in the Gething formation, and estimated that the total number would exceed sixty. Of the measured fifty, nineteen are 11 inches thick or less, fifteen vary from 1 foot to 1 foot 11 inches, four vary from 2 feet to 2 feet 6 inches, eleven are from 2 feet 7 inches to 4 feet, and one is more than 4 feet thick; three of the eleven seams expand to more than 4 feet in at least one other section studied. Ten of these seams were named and described by McLearn (1923), the Superior, Trojan, Titan, Falls, Little Mogul, Mogul, Castle Point, Milligan, Grant, and Riverside. In addition, several seams from the unmeasured Johnson and Gething Creek sections, which have not been correlated with the ten above, were also described. Two of the ten better seams are well down in the lower half of the Gething formation and the remaining eight are in the upper half. It is worth noting that some of the seams are paired in position; thus, the Titan and the Falls, the Little Mogul and the Mogul, the Castle Point and the Milligan, and the Grant and the Riverside. The coal seams in the upper part of the canyon have been measured and described by McLearn and Irish (1944). Of these the Murray, Boring, Twin, and Knight seams are worth description.

The accompanying diagram of columnar sections (Figure 14) gives the thickness and stratigraphic positions of the seams exposed in the walls of Peace River Canyon, including all the thin seams.

The following descriptions of coal seams are taken from McLearn (1923) and McLearn and Irish (1944). All coal analyses have been made in the Division of Fuels and Fuel Testing, Bureau of Mines, Ottawa.

Superior Seam

"The Superior seam is from 23 to 26 feet below the Moosebar contact. On Aylard creek it is exposed at the upper falls, where it is 2 feet thick. On Moosebar creek it is exposed at the upper falls, where the creek forks, and is 3 feet 8 inches thick there. A third known exposure is at Contact point where the Superior seam is present in a low cliff at the river side; the thickness is 2 feet 8 inches. At each of these localities it consists of clean-looking coal, but no samples were taken . . . . On main Gething creek, if present, it is in the high cliff at the upper falls; unfortunately, the position at which this seam would lie in this cliff is inaccessible, but the size of talus blocks in front of the cliff indicates that a seam at least 2 feet 6 inches thick is present. This may be the Superior seam. It should also be sought in the higher cliffs of Island creek and near the top of the high cliff opposite Fossil-tree point. The highest cliffs on, and east and west of, Mogul creek

[1] This Aylard Creek flows into Peace River Canyon. It is not the Aylard Creek near Gold Bar.

should be examined and, if the contact with the Moosebar shale can be located, this seam may be just below it. In the eastern part of the area, it should be prospected for on the north shore northeast of Contact point.

Trojan Seam

"In the central and western part of the area the Trojan is from 115 to 130 feet below the Moosebar contact and in the east, at Contact point, is 93 feet below. It is exposed on the north branch of Gething creek, some distance above the forks; a short tunnel or drift, about 35 feet long, has been driven along the coal in the cliff on the north bank. On main Gething creek it is exposed above the forks between the third and upper falls. The outcrop runs to the northeast and exposures should be sought in the higher cliffs of Island creek and near the top of the high cliff opposite Fossil-tree point. On Aylard creek[1] this seam is exposed between the small third falls and the upper falls. From Aylard creek the outcrop is estimated to have a southeasterly course to Moosebar creek, where there is an exposure a short distance below the upper falls. No intervening exposures are at present known, but the highest cliffs about Mogul creek should be examined, and particular attention be given to any exposures a little over 100 feet below the Moosebar contact, if the latter can be located. The exact course of the outcrop to Johnson and Coal creeks is difficult to estimate, but the Trojan seam is exposed on the east bank of Coal creek some distance above its junction with Johnson creek; a tunnel about 35 feet long has been driven to the coal, and a drift about 65 feet long has been driven on the coal. In the east this seam is exposed at Contact point on the south bank of the river.

"In the tunnel on the north branch of Gething creek this seam has the following section, including 5 feet 6 inches of coal and two partings aggregating 6 inches:

	Feet	Inches
Coal	2	1
Sandstone	0	2
Coal	2	1
Sandstone	0	4
Coal	1	4

"On main Gething creek one-third mile to the south the Trojan has the following section and includes 8 feet 4 inches of coal and four partings of sandstone, aggregating 10 inches:

	Feet	Inches
Shale	–	–
Coal	0	5
Sandstone	0	2
Coal	0	7
Sandstone	0	2
Coal	3	3
Sandstone	0	3
Coal	2	5
Sandstone	0	3
Coal	1	8
Shale	–	–

"Comparing the above two sections, it is probable that on north Gething creek the two thin top benches and a part of the third bench from the

[1] A small creek entering the canyon below Gething Creek. It is not the Aylard Creek near Gold Bar.

top of the seam in the main Gething Creek section are gone. To the southeast, 2·1 miles, on Aylard Creek, the section is as follows, and includes only 3 feet 8 inches of clean coal, 4 inches of bone coal, and two partings aggregating 8 inches.

	Feet	Inches
Shale	–	–
Coal	0	3
Shaly sandstone	0	2
Coal	1	11
Shale	0	6
Coal	1	6
Bone coal	0	4
Black carbonaceous shale	–	–

"On Moosebar Creek, 2·5 miles to the southeast, there is 3 feet 7 inches of coal and a 4-inch parting.

	Feet	Inches
Shale	–	–
Coal	2	1
Sandstone	0	4
Coal	1	6
Carbonaceous shale	–	–

Two feet six inches above, and separated by shale and sandstone, is a 6-inch layer of coal. This coal may be equivalent to the higher coal of this seam in other localities and the intervening clastic sediments may be lateral replacements or widening of partings or both. On Coal Creek, a branch of Johnson Creek, and 2·1 miles southeast from the Moosebar Creek exposure, the section is as follows, including 6 feet 8 inches of coal and two partings aggregating 6 inches of [argillaceous sandstone]:

	Feet	Inches
Canneloid coal	0	4½
Coal	1	7½
White argillaceous sandstone	0	2
Coal	2	2
White argillaceous sandstone	0	4
Coal	2	6

"The section here is more comparable with those of main Gething and north Gething creeks. At Contact point, 3 miles to the northeast, there is 3 feet 6 inches of coal, but a little above it there is another bed of coal; both beds may be equivalent to the whole seam in the west and the intervening sediments may be due to the widening of a parting. The section is as follows:

	Feet	Inches
Coal	2	8
Arenaceous shale and sandstone bands	4	6
Coal	3	6

The lower coal has two very thin sandstone partings. White sandstone partings are typical of this seam. The sections described above show that this seam is thickest in the vicinity of Gething Creek and also on Coal Creek. On Aylard and Moosebar creeks it is much thinner . . . The thickness of coal between main and north Gething creeks—a distance of about one-half mile—changes only from 8 feet 3 inches to 5 feet 6 inches."

Analyses of samples from the Trojan seam are as follows:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property[1]	Colour ash	S	B.t.u.
Upper half seam, Contact Point	0·7	16·1	24·8	58·4	Agglomerate[2]	Grey		
Lower half seam, Contact Point	0·6	11·2	26·7	61·5	Good	Cream		
Coal Creek, top 4½ feet	1·1	21·5	18·8	58·6	Non-agglomerate	White		
Coal Creek, middle benches, 1 foot 7 inches and 2 feet 2 inches	1·2	10·6	24·1	64·1	Poor	Flesh		
Coal Creek, lowest bench, upper 1 foot 3 inches	0·7	6·1	28·6	64·6	Good	Flesh		
Main Gething Creek	1·6	8·4	26·0	64·0	Non-agglomerate	Light brown	0·5	13,350
North branch Gething Creek	1·0	8·6	24·5	65·9	Non-agglomerate	Grey	0·7	13,820

These coal samples are of medium volatile bituminous rank.[1]

[1] Caking property and rank, originally recorded in McLearn (1923), are revised in accordance with modern usage and the A.S.T.M. (American Society of Testing Materials) designation, and checked by E. Swartzman, Fuel Testing Division, Bureau of Mines.

[2] Agglomerate is synonymous with very weakly caking. Non-agglomerate is equivalent to non-caking. Caking or agglomerating properties are judged from the residue after conducting a standard volatile matter test in a platinum crucible. A good caking coal, as evaluated by this test, does not necessarily indicate a coal that will make a good coke for industrial use. Coking properties are best evaluated by large scale tests (personal communication, E. Swartzman, Bureau of Mines).

Titan Seam

"The Titan seam, in the western part of the area, is from 200 to 255 feet below the Moosebar contact and, in the east, at Contact point, is about 160 feet below. The type locality is on Aylard Creek, where the seam is exposed in the creek just above the small third falls. Northwestward the outcrop is estimated to run towards the river and to be in the cliff on the south bank above Earle narrows, where it should be looked for. About one-quarter mile above Earle narrows and high in the cliff on the south bank is a seam locally known as the 'ladder seam'; this may be the Titan. In the high cliff opposite Fossil-tree point this seam should be near the middle of the section there exposed. It should also be sought in the cliffs on Island Creek. From there the outcrop is estimated roughly to run south from the main canyon towards the lower forks of Gething Creek, for on main Gething Creek above the third falls there is a thick seam exposed which is correlated with the Titan.

"Southeasterly from the type exposure on Aylard Creek it is estimated that the outcrop runs a little back from the river. In the vicinity of upper Mogul Creek, exposures should be sought in the higher, but not the highest, cliffs. On Moosebar Creek a seam exposed some distance above the Big or third falls is correlated with the Titan. The exact course of the outcrop southeast of Moosebar Creek is difficult to estimate, and not sufficient work has been done on Johnson Creek to locate this seam there. In the east, a seam exposed on the south bank above Contact point is correlated with the Titan.

"On main Gething Creek the seam correlated with the Titan is 5 feet thick, but includes a layer of thick concretions, over 1 foot thick, near the base. To the southeast 2·1 miles, at the type exposure on Aylard Creek, the section is as follows:

	Feet	Inches
Bedded 5-inch layers of fine sandstone and 2-inch layers of shale	–	–
Coal	4	0
Concealed	2	0
Bedded 5-inch layers of fine sandstone and 2-inch layers of shale	–	–

"To the southeast 2·5 miles, on Moosebar Creek, the seam correlated with the Titan contains 4 feet 1 inch of coal and two partings aggregating 11 inches:

	Feet	Inches
Dark shale	–	–
Coal	2	11
Shale and argillaceous sandstone	0	9
Coal	0	7
Sandstone	0	2
Coal	0	7
Shale, having jet bands	–	–

"Three miles to the east, at Contact point, the seam correlated with the Titan contains 5 feet 2 inches of coal and a 1-foot parting:

	Feet	Inches
Shale	–	–
Coal	2	8
Clay ironstone	1	0
Coal	2	6
Sandstone	–	–

One foot below is a 2-inch band of jet coal.

"As regards thickness, this seam is best on Aylard Creek, not so good on Gething Creek and at Contact point, and poorest on Moosebar Creek... In future exploration its extension northwest and southeast from Aylard Creek should, in particular, be examined; the localities favourable for exposures are indicated above. Unfortunately neither the rank nor grade of the coal in this seam is known; the only sample taken was lost in transit.

Falls Seam

"The Falls seam is about 250 feet below the Moosebar contact and 40 feet below the Titan seam. The type exposure is on Aylard Creek at the small third falls. From there the outcrop runs northwestward to the canyon and to the cliffs above Earle narrows; about one-third to one-half mile above Earle narrows on the south bank, a seam exposed in the cliff comes nearly to river level and may be the Falls seam. Westward the exposure of this seam rises in the cliff, and in the high cliff opposite Fossil-tree point should be at about the middle of the section there revealed. This seam, also, should be sought in the cliffs up Island Creek. Westward, the outcrop is estimated to run back from the river and to the third falls on Gething, where a seam exposed is correlated with the Falls seam. From the type exposure on Aylard Creek the outcrop is estimated to run southeasterly in the cliffs a little back from the river, and exposures should be sought in the higher, but not the highest, cliffs up Mogul Creek and neighbouring gullies. Continuing, the outcrop probably runs southeasterly back from the river, but no exposures are at present known for 2 miles; the next exposure is on Moosebar Creek, where a seam between the third and upper falls is correlated with the Falls seam. It is not at present possible to estimate where this seam would come on Johnson creek.

"At the type exposure on Aylard Creek the Falls seam has the following section, including 2 feet 7 inches of coal and 1 foot of canneloid coal:

	Feet	Inches
Massive sandstone	–	–
Coal	0	8
Canneloid coal	1	0
Coal	1	11
	3	7

Sandstone and shale in 1- to 5-inch bands.

"About one mile to the northwest on the cliff wall above Earle narrows the seam correlated with the Falls seam is 3 feet thick, but this measurement includes large concretions near the base. The upper part is of canneloid coal.

"About 1·2 miles to the west, the seam on Gething creek correlated with the Falls has the following section and includes 1 foot 11 inches of coal and 11 inches of canneloid coal:

	Feet	Inches
Coal	0	8
Canneloid coal	0	11
Coal	1	3

The bottom 1½ inches consists of jet coal. To the southeast, 2·5 miles from the type exposure, the Moosebar Creek seam, correlated with the Falls, contains about 1 foot 8 inches of coal and has the following section:

	Feet	Inches
Clay ironstone	—	—
Coal	0	8
Shale	0	2
Coal and clay ironstone concretions 1 foot thick	1	4
Canneloid coal	0	8

The presence of canneloid coal is a characteristic of this seam.

"Only the exposure on Gething Creek was sampled:

	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash
Top 8 inches	1·1	5·5	24·0	69·4	Poor	Light brown
Middle 11 inches	1·0	3·3	23·8	71·9	Non-agglomerate	Grey
Bottom 15 inches	0·9	2·3	25·9	70·9	Poor	Light brown

The rank [is medium volatile]... in all three benches. The middle canneloid coal should be classified as lean cannel and is non-agglomerate. It is to be noted that the canneloid coal has lost a little more volatile matter than the jet coal. The coal of the uppermost and bottom benches is poor caking. The grade depreciates upward, the percentage of ash increasing progressively from the bottom to the top bench.

"Although this seam is depreciated by the presence of large concretions in the exposures on Moosebar Creek and above Earle narrows, and is in these localities below the set standard, it is described on account of its thickness on Aylard Creek, its quality on Gething Creek, its nearness to the Titan seam, and the possibility that it may be of workable thickness and grade in exposures not yet explored. It should be looked for in all the localities suggested above from Moosebar to Gething creeks.

Little Mogul Seam

"The Little Mogul is a small seam, of only local importance, but is described on account of its proximity to the Mogul seam. It lies about 460 feet below the Moosebar contact and 10 feet above the Mogul seam. The type exposure is on Aylard creek a little above its mouth. From there the outcrop rises eastwardly and the seam is exposed in a draw west of Mogul creek, just above the trail on the west side. It is also exposed on Mogul creek above the trail. Its extension to Moosebar creek is problematical, although a seam there has been tentatively correlated with it. Northwestward from the type exposure on Aylard creek, a small seam on the south bank at Earle narrows is without doubt the Little Mogul.

"On Aylard creek this seam is 3 feet thick, but includes a 3-inch concretion. About 0·28 mile to the northwest, at Earle narrows, this seam is only 8 inches thick . . . It holds its thickness better to the southeast; 0·35 mile in that direction, in a draw west of Mogul creek, it contains 3 feet 3 inches of coal. On Mogul creek, 0·06 mile to the southeast, it contains 2 feet 8 inches of coal. The seam tentatively correlated with it on Moosebar creek is 11 inches thick. . . For a distance of about 0·4 mile, between Aylard and Mogul creeks, this seam appears to maintain a thickness of from 2 feet 8 inches to 3 feet 3 inches, and may maintain this thickness over a large area, but is known to depreciate toward Earle narrows, in which direction not much can be expected of it. . . .

"A sample was taken from the exposure on Mogul creek.

Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash
2·7	10·5	24·3	62·5	Non-agglomerate	Fawn

The rank is [medium volatile] bituminous and the grade is low, for 10·5 per cent ash is high for this area.

Mogul Seam

"The Mogul seam lies about 475 feet below the Moosebar contact, and is separated from the overlying Little Mogul by about 10 feet of strata. The type exposure is on the south bank near river level at Earle narrows. From there the outcrop runs a little back from the shore to Aylard creek where there is an exposure in the bank on the east side a little above the mouth of the creek. Continuing, the outcrop rises somewhat and the next known exposure is in a draw west of Mogul creek, above the trail and on the west side. On Mogul creek there is an exposure above the trail. From Mogul creek the outcrop is estimated to run southeasterly back from the river, and just above the third or high falls on Moosebar creek a seam exposed is correlated with the Mogul. West of the type exposure at Earle narrows the outcrop is estimated to run northwesterly below the river channel and either to the low cliffs at Fossil-tree point, or to below river level in front of Fossil-tree point.

"At the type exposure on the south bank at Earle narrows there are 4 feet 8 inches of coal and a couple of small concretions. The bottom 5 inches is of jet coal. To the southeast 0·28 mile, on Aylard creek, the section is as follows and includes 3 feet 6 inches of coal:

	Feet	Inches
Coal	0	2
Concretion	0	4
Coal	3	4

The concretion appears to be local. In the draw west of Mogul creek 0·35 mile distant, there is 4 feet 4 inches of coal. On Mogul creek 0·06 mile distant, there is 3 feet 2 inches of coal:

	Feet	Inches
Coal	0	6
Concretion	1	2
Coal	2	8

"To the southwest 2·1 miles, on Moosebar creek, the seam correlated with the Mogul has 3 feet 4 inches of coal. Thus, between Mogul creek and Earle narrows, a distance of about three-quarters of a mile, this seam is known in four places and maintains a thickness of from 3 feet 2 inches to 4 feet 8 inches. . . . . Whether this thickness is maintained all the way to Moosebar creek cannot be said, for it is not known to be exposed in that interval.

"Samples were taken at two localities:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
Mogul creek	1·2	4·6	22·9	71·3	Non-agglomerate	Dark grey		
Earle narrows	1·4	4·2	22·7	71·7	Non-agglomerate	Flesh	0·9	14,220

The rank in both samples is [medium volatile] bituminous.

Castle Point Seam

"The Castle Point seam is about 585 feet below the Moosebar contact. It is exposed on the north side of the river at Milligan point near the bottom of the cliff. From there the outcrop runs inland and comes to the river again on the north bank at Earle narrows, but there is no exposure there, the seam being concealed on the axis of the roll. From there the outcrop runs southeasterly and crosses the river to Aylard creek; there is an exposure just east of Aylard creek on the south bank. Downstream the outcrop rises in the high cliff on the south side of the canyon. In this cliff the exposure is for the most part inaccessible, but there is an exposure, easily reached at the top of the cliff at the mouth of Mogul creek. From there the outcrop runs southeasterly back from the river and on Moosebar creek a seam below the third or high falls is tentatively correlated with the Castle Point.

"At Milligan point the section of the seam is as follows, including 2 feet 1 inch of coal and two partings aggregating 2 feet:

	Feet	Inches
Sheeted carbonaceous shale	–	–
Coal	0	8
Clay ironstone	1	0
Coal	1	0
Shale	1	0
Coal	0	5
	4	1

"At the mouth of Aylard creek, 1·3 miles distant, the seam contains 3 feet 5 inches of coal and a concretionary band 4 inches thick, or 3 feet 9 inches in all; the foot-wall is black carbonaceous shale. To the southeast 0·41 mile, at the mouth of Mogul creek, there is 3 feet 2 inches of coal. Two miles southeast, the seam on Moosebar creek correlated with the Castle Point has 2 feet 3 inches of coal and partings aggregating 2 feet 1 inch:

	Feet	Inches
Shale	–	–
Coal	0	6
Clay ironstone	1	0
Coal	0	6
Shale	0	6
Coal	0	10
Shale	0	7
Coal	0	5
	4	4

"This seam has been described on account of its fair thickness in the Aylard-Mogul Creeks locality and on account of its proximity to the Milligan seam. . . The rank and grade of the Castle Point coal seam are not known, no samples having been taken.

Milligan Seam

"The Milligan seam is about 605 feet below the Moosebar contact and 28 feet below the Castle Point seam. It is exposed at Milligan point on the north shore near the base of the cliff. From there the outcrop runs inland and comes to the river again on the north shore a little below Earle narrows, where the seam is exposed. The outcrop crosses the river, and the seam is exposed on the south bank near river level just below the mouth of Aylard creek. Downstream, the outcrop rises gently in the cliff, and near the mouth of Mogul creek is exposed about halfway up the cliff. From there the outcrop runs inland back from the river, and a seam on Moosebar creek below the third or high falls is correlated with the Milligan.

"At Milligan point this seam is 2 feet 6 inches thick and consists of coal and large concretions. One mile southeast, just below Earle narrows, on the north bank this seam is 2 feet 9 inches thick, and has small scattered concretions. To the south 0·29 mile, on the south shore at the mouth of Aylard creek, it is 2 feet 10 inches thick. To the southeast 2·52 miles, on Moosebar creek, below the third or high falls, the seam correlated with the Milligan is 2 feet 5 inches thick. In the west the large concretions are objectionable.... but in the Earle Narrows-Mogul Creek part of the area the concretions, where present, are much smaller....

"Samples were taken in two localities:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash
North bank at Earle narrows	2·0	3·5	21·8	72·7	Non-agglomerate	Brown
Moosebar creek	2·3	3·5	21·2	73·0	Non-agglomerate	Brown

[These samples are on the border between low volatile bituminous and medium volatile bituminous coal.]

Grant Seam

"The Grant seam is about 1,215 feet below the Moosebar contact. It is [exposed for a distance of about 680 feet] just above river level in a low cliff on the north bank at the west end of Grant flat." Its occurrence there was first recorded by McLearn (1918), and by 1922 an adit 360 feet long had been driven on this seam. Later, considerable development work was done at this locality and some coal was shipped down Peace River by scow. There are no records of activity at this mine in recent years.

North of the canyon the Grant seam outcrops above river level and extends "up the west slope of Grant mountain and thence northwesterly to the upper part of the canyon far beyond Milligan point . . . To the southeast of the exposure at the west end of Grant flat the outcrop is estimated to cross the river and extend to the lower part of Johnson creek, where unfortunately there are no exposures. In the creeks from Moosebar creek west this seam is below creek level and, up the creeks, lies at increasing depths. In most of the area the dip of this seam is estimated to be from 7 to 15 degrees, but on the west slope of Grant mountain and on Johnson creek dips up to 45 degrees may be anticipated.

"In the 680-foot exposure in the river bank at Grant Flat, the seam, where measured, varies in thickness from 5 feet 5 inches to 5 feet 9 inches. In the tunnel at Grant Flat[1] the thickness, where measured, varied from 5 feet 3 inches to 5 feet 9 inches. This seam consists of three benches of coal: the lowest varies from 9 to 11 inches in thickness, the middle from 1 foot 9 inches to 1 foot 11 inches, and the uppermost from 2 feet 8 inches to 3 feet 2 inches. The lowest bench is made up of a bright friable jet which with little handling is reduced to small fragments; the coal of this bench is mined separately and sold locally as a blacksmith coal. The upper two benches consist of grey, greasy, dull or matte coal with bands of jet."

Analyses are as follows:

[1] This working is known as the Grant Flat mine, and has also been referred to as the Aylard mine (*See* Figure 15).

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.	A.S.T.M. classification[1]
Cliff 300 feet west of W. crosscut. Bottom 9 inches	0·6	3·4	23·6	72·4	Good	Flesh			Med. vol. bitum.
Cliff 300 feet west of W. crosscut. Middle and top 5 feet	0·8	3·4	20·4	75·4	Poor	Flesh			Low vol. bitum.
Cliff entrance to W. crosscut. Bottom 11 inches	0·7	2·1	24·6	72·6	Good	Flesh			Med. vol. bitum.
Cliff entrance to W. crosscut. Middle and top 4 feet 6 inches	0·6	2·6	18·7	78·1	Non-agglomerate	Flesh			Low vol. bitum.
Tunnel 35 feet from portal. Bottom 8 inches	0·7	6·5	22·0	70·8	Good	Cream	0·7	14,440	Med. vol. bitum.
Tunnel 35 feet from portal. Middle 1 foot 11 inches	0·6	2·9	19·5	77·0	Non-agglomerate	Brown	0·7	14,940	Low vol. bitum.
Tunnel 35 feet from portal. Top 3 feet 2 inches	0·7	5·3	19·6	74·4	Non-agglomerate	Brick	0·7	14,420	Low vol. bitum.
Tunnel at E. crosscut. Bottom 9 inches..	0·7	2·4	22·9	74·0	Good	Flesh	0·7	15,130	Med. vol. bitum.
Tunnel at E. crosscut. Middle 1 foot 9 inches	0·8	2·6	19·3	77·3	Agglomerate	Flesh	0·7	14,960	Low vol. bitum.
Tunnel at E. crosscut. Top 3 feet........	0·7	6·1	18·7	74·5	Non-agglomerate	Cream	0·6	14,300	Low vol. bitum.
Face tunnel Sept. 26, 1923. Bottom 9 inches	0·6	2·4	24·8	72·2	Good	Flesh			Med. vol. bitum.
Face tunnel Sept. 26, 1923. Middle 1 foot 10 inches	0·6	2·6	19·5	77·3	Non-agglomerate	Cream			Low vol. bitum.
Face tunnel Sept. 26, 1923. Top 2 feet 8 inches	0·6	4·1	20·1	75·2	Non-agglomerate	Grey			Low vol. bitum.

[1] *See* Table III.

Riverside Seam

"The Riverside is 1,250 feet below the Moosebar contact and 35 feet below the Grant seam. It is exposed at low water on the north bank a little below No. 1 Prospect tunnel at the west end of Grant flat. The seam is so close stratigraphically to the Grant coal that the statements regarding the outcrop and attitude of the Grant apply also to the Riverside.

"In the known exposure the thickness of this seam is 2 feet 10 inches. At the bottom is friable jet coal and above there is dark grey, shiny, but not brilliant, coal. The presence of a layer of friable, brilliant jet coal at the base of a seam is a common occurrence in this coal area. A sample gave the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
0·7	5·6	18·8	74·9	Agglomerate	Grey	0·8	14,400

The rank is [low volatile] bituminous.

"In addition to the above seams there are a few on Gething and Johnson creeks worthy of description, which have not been correlated with seams in other localities and may or may not be the equivalent of seams already described.

Gething Seam

"At the junction of main Gething creek and its north branch there is a seam containing 2 feet 4 inches of coal and a 1-inch parting:

	Feet	Inches
Coal	0	6
Shale	0	1
Coal	1	10
	2	5

It lies below the seam correlated with the Falls seam. [An analysis is as follows:]

Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash
1·0	3·5	25·2	70·3	Non-agglomerate	Light brown

The rank is [medium volatile] bituminous.

Galloway Seam

"The Galloway lies at some depth below the Gething and outcrops at the first or Galloway falls on Gething creek below the forks. It disappears below river level upstream above the falls, but downstream can be followed high in the cliffs almost to the mouth of Gething creek. It contains at the falls:

	Feet	Inches
Canneloid coal	1	6
Coal	2	6
	4	0

"The thickness at this locality varies from 3 feet 7 inches to 4 feet 2 inches, but there is an almost continuous line of large concretions near the base at the falls. However, downstream these concretions become small or entirely disappear, for, in the cliffs below, the coal looks clean. The top is a canneloid coal with characteristic fracture and has a banding expressed by layers of finer and coarser granular texture. Analyses are as follows:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	S	B.t.u.
Upper bench...	0·8	3·7	18·9	76·6	Non-agglomerate	0·8	14,590
Lower bench...	0·9	3·7	19·3	76·1	Non-agglomerate	0·9	14,550

The rank is [low volatile] bituminous on both benches.

Seams on Johnson Creek

"A seam on Johnson creek a little above where the first exposures begin is 2 feet 10 inches to 3 feet in thickness and includes a 2-inch parting of shale. The bottom 5 inches is of jet coal. The hanging-wall consists of 6 inches of shale followed by arenaceous shale above. The foot-wall is arenaceous shale. A sample gives the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash
0·6	4·1	19·0	76·3	Non-agglomerate	Light brown

The rank is [low volatile] bituminous.

"Higher in the Johnson Creek section is a seam containing 4 feet 1 inch of coal. There is friable shale on the hanging-wall and 1 foot of carbonaceous shale on the foot-wall. A sample taken gives the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
0·8	7·4	20·7	71·1	Non-agglomerate	Dark brown	0·07	13,820

The rank is [low volatile] bituminous.

Canneloid Seam on Moosebar Creek

"A small seam on Moosebar just below the second falls . . . . [is thin], but is described on account of its canneloid character. It is 10 inches thick and consists entirely of canneloid coal with the characteristic texture and fracture. A sample gave the following analysis:

Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash
1·0	10·5	17·7	70·8	Non-agglomerate	Cream"

It ranks as low volatile bituminous coal.

Murray Seam

The Murray seam, in the upper part of the Canyon, is at about the same horizon as the Grant seam in the middle part of the Canyon; that is, near the base of the Gething formation. It occurs in a thick, black shale zone, about 30 feet below the Curved Tree Point sandstone member (*See* Figure 10), and was uncovered in 1943 in a trench excavated on the edge of the high, east Canyon wall, just south of Larry Creek (McLearn and Irish, 1944). The seam is 5 feet thick in the discovery trench and has an 0·5-foot bed of clay ironstone near the middle. A sample from this trench, possibly weathered, yields the following analysis:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
As received	13·1	13·7	22·0	51·2	Non-agglom-erate	Light rose	0·4	9,750
Dry		15·8	25·3	58·9	Non-agglom-erate	Light rose	0·4	11,210

Softening temperature of ash is 2,050°F.
The rank, indicated by the analysis, is medium volatile bituminous.

In 1944, Peace River Coal Mines Limited (Lloyd Gething, Manager) commenced coal mining operations near the discovery trench at the mouth of Larry Creek. That year 748 tons were mined, and by the end of 1947 total production stood at 7,935 tons of coal mined and sold. A slope (*See* Plate VIII B) has been driven down the dip, and drifts have been run off each side of the slope. The coal is shipped by truck to Fort St. John.

The latest development in this mine is described in the Report of the Minister of Mines, British Columbia, for 1948. A new and more central portal is being planned. The seam is said to be 7 feet 2½ inches thick with a 6-inch and a 4½-inch band of clay-ironstone and to dip 3½ degrees southwest.

Downstream this seam outcrops in the high canyon wall and is inaccessible. It gradually descends toward the mouth of Heron Creek, near which it reaches river level and, crossing the river, is apparently continuous with a seam worked by Neil Gething many years ago called the '7-foot' seam.

Boring Seam

The Boring seam is 12 feet above the Larry Creek sandstone member (*See* Figure 10) in the lower part of the Gething formation. It outcrops at river level in ledges on the south side of the canyon, at Boring Point, and consists of:

	Feet	Inches
Coal, canneloid....................................	1	6
Coal, shiny and dull................................	0	2
Shale, black..	0	9
Coal, shiny...	1	0

Analyses of the upper 1·5 feet and the bottom 1 foot are as follows:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
Upper 1·5 feet As received.	2.2	11·5	19·5	66·8	Agglomerate	Pinky white	0·7	13,060
Dry.......		11·7	20·0	66·3	"	"	0·7	13,360
Basal 1 foot As received.	4.3	5·2	21·6	68·5	Good	Pale pink	0·8	14,070
Dry.......		5·5	22·5	72·0			0·9	14,690

The first analysis indicates a low volatile bituminous coal and the second is of medium volatile bituminous rank.

The outcrop of this seam can be seen in the high wall of the canyon to the east of Boring Point. It rises to the depression cut by Heron Creek in the cliff. It then extends into the lower part of the valley of Heron Creek, but it is concealed there. It may also continue to rise up the canyon wall northwest of Heron Creek and come to the surface south of Larry Creek.

Twin Seams

The Twin seams lie immediately above the Heron Creek sandstone member (*See* Figure 10) in ledges at river level, about 1,100 feet downstream from, and west of, Boring Point. The lower of the Twin seams is 2·3 feet thick and the upper 2 feet. Between them is 7 feet of siltstone, dark shale, and some very thin coaly layers. Analyses are as follows:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
Upper seam As received.	3·5	5·8	20·3	70·4	Agglomerate	Light mauvey white	0·6	13,810
Dry.......		6·0	21·1	72·9			0·7	14,310
Lower seam As received.	2·3	8·2	20·5	69·0	Agglomerate	Light pinky white	0·8	13,510
Dry.......		8·4	21·0	70·6			0·8	13,830

Both seams are of low volatile bituminous rank.

The Twin seams pass below river level not far west of their exposure on the shore of the river. Eastward they rise in the high canyon cliff, reaching the top near Boring Point where they are concealed. It is inferred that they extend across a high bench to the Galloway slope, up that slope, and into Heron Creek Valley. These seams can be found anywhere by opening a trench just above (that is on the down-dip side of) the outcrop of the Heron Creek sandstone.

Knight Seam

The Knight seam immediately overlies the Canyon sandstone. Indeed the line at the top of the outcrop of this sandstone in Figure 10 can be taken as the outcrop of this seam. It is exposed at river level on the northeast of Cust Island. There it consists of 3 feet of coal of low volatile bituminous rank. The outcrop can be followed up the canyon wall, across an old back channel excavated at an early stage of canyon development, and up the Galloway slope. It is only exposed, however, on the shore of the river and in the canyon wall. It was opened in a trench excavated just above the outcrop of the Canyon sandstone at the top of the Galloway slope. At this place the seam had increased to 3·9 feet in thickness. Both on the shore and in the trench on the Galloway slope the coal is of medium volatile bituminous rank. Analyses are as follows:

—	Moisture	Ash	Volatile matter	Fixed carbon	Caking property	Colour ash	S	B.t.u.
No. 1 As received.	2·6	9·1	20·7	67·6	Poor	Light rose	0·8	13,510
Dry.......		9·4	21·2	69·4			0·8	13,870
No. 2 As received.	11·0	14·9	21·7	52·4	Non-agglomerate	Light pink	0·6	9,980
Dry.......		16·8	24·4	58·8			0·7	11,210
No. 3 As received	11·0	9·3	22·2	57·5	Non-agglomerate	Mauve	0·7	11,870
Dry.......		10·4	25·0	64·6			0·8	12,780

Softening temperature of ash for each sample as received were: No. 1, 2,290°F., No. 2, 2,140°F., and No. 3, 2,140°F.

No. 1 is sample of 3 feet of coal on shore of river. Nos. 2 and 3 are samples from trench on Galloway slope; No. 2 is of entire 3·9-foot seam and No. 3 is of the lower 1·5 feet.

Variations in Seams in Peace River Canyon

In some coal sections, where samples have been taken from separate benches, the ash is found to increase progressively upward in successive benches. Examples are the Trojan seam on Coal Creek and at Contact Point, the Falls seam on Gething Creek, and some of the sections sampled of the Grant seam. Other coal sections show about equal ash content in the upper and lower benches. Examples are: one of the Grant coal sections at the west end of Grant Flat and the Galloway seam at Galloway Falls on Gething Creek. One of the sections of the Grant seam examined has the highest ash in the bottom bench. The amount of ash may also vary laterally, but, in most of the examples noted, less than vertically. The percentage of ash in the bottom bench of the Grant seam varies from 2·1 to 3·4 in four sections, and is 6·1 in a fifth section sampled. The middle bench varies, in three sections, from 2·6 to 2·9, and the top bench, in three sections, varies from 4·1 to 6·1. At three localities the Trojan seam varies from 8·4 to 10·6 in percentage of ash, omitting the 6·1 ash content of the lowest bench on Coal Creek. At Contact Point this seam is very high in ash. The Trojan shows the highest lateral variation at present known for any coal seam in this area. The following seams have a percentage of ash below 5: Grant, Milligan, Mogul, Gething, Galloway, the 3-foot seam on Johnson Creek, and the lower and middle benches of the Falls seam on Gething Creek. The following seams vary in ash percentage from 5·5 to 7·4: the top bench of the Falls seam on Gething Creek, Riverside, lowest bench of the Trojan seam on Coal Creek, and the 4-foot seam on Johnson Creek. The following vary in ash from 8·4 to 11·2 per cent: Trojan seam on main Gething Creek and on the north branch of Gething Creek, Little Mogul, upper benches of the Trojan seam on Coal Creek, and the lower part of the Trojan seam at Contact Point. The upper part of the Trojan seam at Contact Point and the topmost 4½-inch bench of canneloid coal in the Trojan seam on Johnson Creek vary from 16·1 to 21·5 per cent ash.

The Peace River Canyon coals vary in rank from medium to low volatile bituminous. The variation does not appear to be related to geographic position in the area nor to proximity to rolls or other structural features. Rather, the variation is with the seam and with the bench within the seam.

Most of the coal in Peace River Canyon is non-agglomerate, or just agglomerate, with very few samples showing good caking qualities. No entire seam studied is caking throughout. This quality is confined to a bench within a seam, and, in all places so far studied in this area, to a lower bench. The lowest 8- to 11-inch bench of the Grant seam is good caking. On Coal Creek, the part of the lowest bench of the Trojan seam sampled is also good caking. At Contact Point the lower part of the Trojan seam is good caking, and the upper part agglomerates. In the west, on Gething Creek and on the north branch of Gething Creek, the Trojan seam is non-agglomerate.

The canneloid coal, cannel-like in grain and fracture but not in chemical character, varies in percentage of ash from 3·3 to 21·5. In all samples it is non-caking. The fuel ratio of the canneloid coals sampled have a smaller range than the ordinary coals, varying between 3·0 and 4·05. Where it forms a bench in a seam, the rank of the canneloid coal is as high as, or a little higher than, that of the ordinary coal in other benches. The canneloid coal occurs as thin seams or as benches in thicker seams.

Variations in thickness have been referred to in describing each seam and suggestions have been given for further exploration.

As compared with coals of similar age in the Kootenay and Luscar formations of the south, those of the middle and lower part of the Peace River Canyon are comparatively thin; eight of the ten seams described attain a thickness of from 2 feet 6 inches to 4 feet 8 inches in parts of the area; one seam varies from 5 feet 5 inches to 5 feet 9 inches, and another, known over a larger area, varies in thickness of coal from 3 feet 7 inches to 8 feet 4 inches. Against the comparative thinness of the seams must be balanced low ash content of some of them.

EAST SLOPE OF PORTAGE MOUNTAIN

Some coal seams have been examined on Knight, King, and Irish Creeks (*See* Figure 15), on the east slope of Portage Mountain (McLearn and Irish, 1944). Structurally these seams have an east dip, 13 to 35 degrees, on the east limb of the Bullhead anticline of the Portage-Butler structural zone.

"Near the crest of the [Bullhead] anticline, . . . a fault has thrust Dunlevy beds over the Gething formation. A small anticlinal fold shows in the Gething strata just east of the fault. The lower part of the Gething, although not the actual base, is exposed east of the fault in the upper reaches of Knight, King, and Irish Creeks. Beds in the middle of the formation are concealed in the central part of the map-area, but a few exposures of beds high in the formation were observed near the mouth of King Creek, and also east of King Creek, on the north side of the canyon..."

King Seam

The 'King' is the thickest seam known on the east slope of Portage Mountain. It is in the lower part of the Gething formation, although the exact distance above the base is not known. The seam is exposed in the upper part of King Creek and is worked in the King Gething mine. It can be traced northwest up the hill about 600 feet from the mine by means of a ledge of siltstone that immediately overlies the coal. It could not, however, be traced farther toward Irish Creek without digging deep trenches. It was not found on Irish Creek, but is probably present somewhere between the group of exposures near the head of the creek and another group farther downstream. It could not be traced south from the mine, in which direction bedrock is heavily drift covered, nor is it exposed on Knight Creek, though it probably lies east of the exposures on this creek.

"Where measured at the King Gething mine, the King seam is 5·2 feet thick, including a 0·3-foot shale parting. The section from top to bottom is as follows:

	Feet
Dull coal	0·7
Dull and bright coal	1·6
Shale	0·3
Bright and dull coal	2·0
Bright coal	0·6
Total	5·2

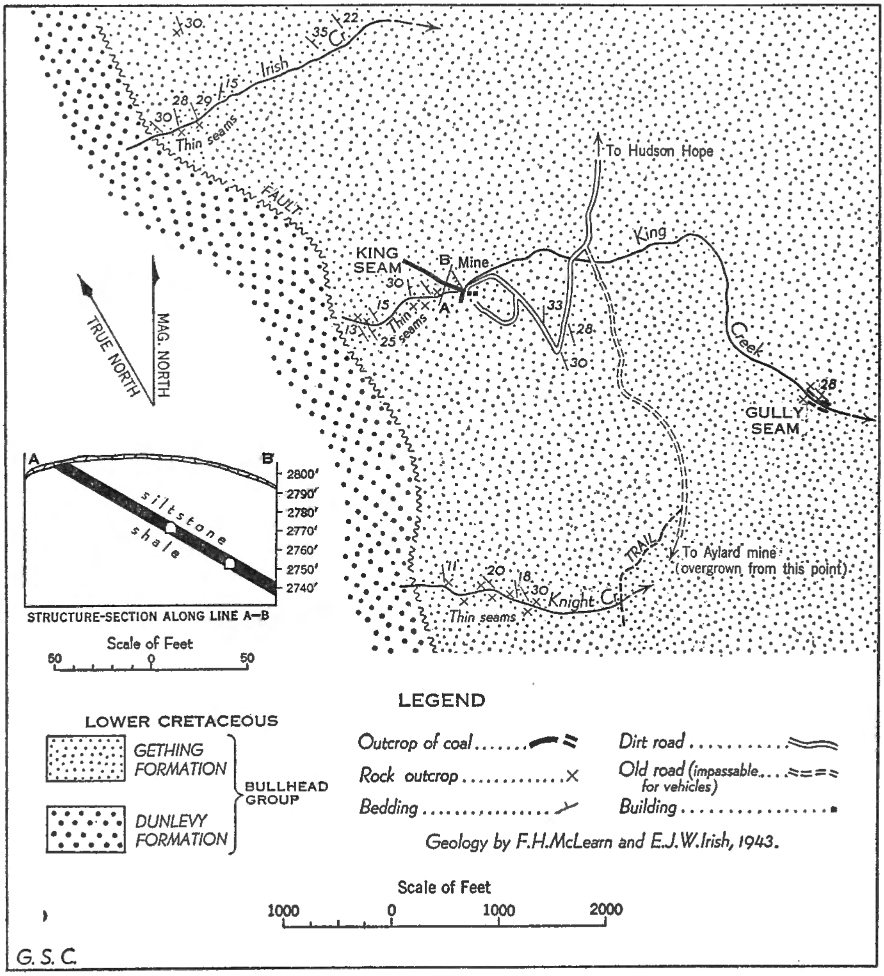

Figure 15. Geology in the vicinity of King Gething mine, east side of Portage Mountain.

"In the upper part of the seam are large lenses of clay ironstone. Where present, they do not replace the coal, which maintains its thickness. Analyses by benches, are given in a table that follows. In all benches, the coal is of medium volatile bituminous rank. In the basal, 0·6-foot bench the coal has good caking properties."

Analyses of coal samples from the King seam in the King Gething mine are as follows:

—	0·7-foot bench		1·6-foot bench		2·0-foot bench		0·6-foot bench	
Moisture condition	As rec'd	Dry	As rec'd	Dry	As rec'd	Dry	As rec'd	Dry
Proximate analysis								
Moisture..........%	3·8		5·9		5·7		4·5	
Ash...............%	10·5	10·9	16·1	17·1	3·3	3·4	1·3	1·4
Volatile matter....%	22·1	23·0	26·8	28·5	21·4	22·7	26·2	27·4
Fixed carbon (by difference).......%	63·6	66·1	51·2	54·4	69·1	73·9	68·0	71·2
Ultimate analysis								
Sulphur............%	1·8	1·8	0·8	0·9	0·8	0·9	0·9	0·9
Calorific value								
B.t.u. per lb. gross...	12,900	13,420	11,080	11,770	13,840	14,680	14,480	15,170
Caking properties	Agglomerate		Agglomerate		Agglomerate		Good	
Softening temperature of ash.............	2,050°F.		2,300°F.		2,710°F.		2,680°F.	
Colour of ash..........	Light mauve		Light brown		Very light pink		Light salmon-pink	

These coals are all of medium volatile bituminous rank.

"On King Creek several thin seams lie stratigraphically below the King seam. One has a thickness of 2 feet, including 0·2 foot of shale. Below this, and farther west upstream on the crest of an anticline, is a coal seam 0·9 foot thick. Other seams exposed by trenching measured 3 inches or less.

"Seams are also present below the horizon of the King seam on Knight Creek. They vary from 0·3 to 0·8 foot in thickness.

"Other seams, probably below the King seam, occur at the headwaters of Irish Creek. On the crest of the anticline, just east of the fault, is a seam 1·2 feet thick. Adjacent seams vary from 2 to 8 inches in thickness.

"A seam above the King is exposed in a small trench northwest of the King Gething mine. It is 2·6 feet thick."

Quentin and Gully Seams

Still higher stratigraphically, and about 320 feet above the King seam, is the Quentin seam. It is 2·3 feet thick where measured on King Creek, and 2·7 feet thick where measured beside the mine road. It consists of bright and dull coal, and, where sampled on the road, gave the following analysis:

—	—	—
Moisture condition	As received	Dry
Proximate analysis		
Moisture..........%	24·1	—
Ash...............%	12·9	17·0
Volatile matter.........%	23·0	30·3
Fixed carbon (by difference).........%	40·0	52·7
Ultimate analysis		
Sulphur...........%	0·6	0·7
Calorific value		
B.t.u. per lb. gross..........	7,720	10,180
Caking properties	Non-agglomerate	
Colour of ash..........	Pinkish white	

This sample was too weathered to permit a proper classification as to rank.

"Very high in the Gething formation is the Gully seam. It is exposed in the bottom of King Creek about a mile below the mine. Its total thickness, including 0·1- and 0·05-foot shale partings, and some clay ironstone concretions near the base, is about 2·9 feet.

"Other possibly good seams may occur in the upper part of the formation above the Gully seam, but, if present, are deeply buried beneath superficial deposits.

King Gething Mine

"The Gething property is on the east slope of Portage Mountain, 12 miles by road west of Hudson Hope. [King Gething is owner and operator.] The mine is on King Creek at an elevation of 2,750 feet, and is 1,200 feet above river level. At this point the stream flows in a deep gully, into the east bank of which the entries have been driven.

"At the end of June 1943, underground workings consisted of two entries along the strike of the seam and connected by two raises at 70 and 110 feet, respectively, from the portal. The lower, or main, entry was 200 feet long. No. 1 raise, nearest the portal, extended 70 feet up the dip and joined the upper entry. No. 2 raise had been driven 60 feet up the dip and a small room opened at the upper end. No. 3 raise, 150 feet from the portal, had been driven up about 30 feet.

"The upper entry, 18 feet higher than the main entry, was 120 feet long and did not connect with No. 3 raise.

"On September 13, when [E. J. W. Irish] again visited the mine, the main entry had been driven an additional 30 feet, the face then being 230 feet from the portal. Work was in progress on the upper entry, which was then 190 feet long. No. 1 and No. 2 raises had been filled in, and a room was being opened from No. 3 raise.

"It is planned this winter to drive each entry to a length of 310 feet. Two new raises are expected to be worked at 230 feet and 310 feet, respectively from the main portal.

"Both shale partings and ironstone concretions cause difficulties in mining the King seam. The shale must be cleaned from the coal, and the large concretions are hard to remove without shattering the coal. Further, the 30-degree dip of the seam is not steep enough for the coal to slide down the chutes, and is too great to allow the cars to be pushed up to the face. It is necessary, therefore, to shovel the coal from the chutes into the cars. All drilling is done with a coal auger.

"Production in the past has been on an extremely small scale and very irregular. Recent government assistance has, however, been very helpful and it it expected that production this winter will be between 12 and 20 tons a day." During the 5-year period ending December 1947, 3,357 tons of coal were mined and sold.

"The main problem, common to the district, is the long haul by truck to the Alaska Highway and Fort St. John. Production depends to a considerable extent on the condition of this road, which at times is impassable for trucks."

The 1946 Annual Report of the Minister of Mines for British Columbia states that the main entry is in about 540 feet, and that because of a fault and flow of water at the face, preparations were under way to reach the seam at a lower elevation. The 1947 report states that a slope was started on the west bank of King Creek to open up the seam previously marked in the east bank of the creek.

DUNLEVY CREEK-CUST CREEK AREA

The Dunlevy Creek-Cust Creek area includes the west side of Butler Ridge and the southern parts of the valleys of Dunlevy, Gravel Hill, and Cust Creeks. A reconnaissance examination of this area was made by F. H. McLearn and E. J. W. Irish in 1943, and the following information is from their report (1944):

"Butler Ridge is underlain by the Dunlevy formation, and the lower parts of Dunlevy and Gravel Hill Valleys by the Gething formation. Both formations are exposed in the Cust Valley. The structure includes the steep west limb of a flat-topped anticline on the west side of Butler Ridge, and the more gentle slopes of the same limb in Dunlevy and Gravel Hill Valleys. Dips on Butler Ridge are from 40 to 70 degrees southwest, and in Dunlevy Valley from 2 to 5 degrees southwest. The structure on Cust Creek is faulted and dips are less regular.

Coal Seams

"No seams thick enough to mine are exposed in the canyon of Dunlevy Creek, or in the canyon or upper reaches of the east fork of Dunlevy Creek and its tributaries. Only thin seams were found on Gravel Hill and Cust Creeks.

"At and near the Packwood mine, at the south end of a spur from Butler Ridge, two thin seams occur in the upper conglomerate-bearing part of the Dunlevy formation.

"The No. 1 seam, worked in the mine, has an average thickness of 30 inches in the upper level and 20 inches in the lower level. The lower 10 inches of the seam is finely crushed, and movement is also indicated by slickensides on both walls. The foot-wall rock is silty shale and the hanging-wall consists of hard, massive sandstone. The seam was sampled at the face in both levels. Analyses are as follows:

—	Upper level		Lower level	
Moisture condition	As rec'd	Dry	As rec'd	Dry
Proximate analysis				
Moisture %	5·0		4·5	
Ash %	6·1	6·4	4·7	4·9
Volatile matter %	18·9	19·9	19·1	20·0
Fixed carbon (by difference) %	70·0	73·7	71·7	75·1
Ultimate analysis				
Sulphur %	0·6	0·6	0,6	0·6
Calorific value				
B.t.u. per lb. gross	13,220	13,920	13,580	14,230
Caking properties	Agglomerate		Agglomerate	
Colour of ash	Very light pink		Very light pink	

"This is a low volatile bituminous coal.

"The No. 2 seam is 15·5 feet above the No. 1 seam and is 30 inches thick where exposed in a pit. It is underlain by 3·5 feet of fine siltstone that grades downward into the hard, coarse sandstone that forms the hanging-wall of No. 1 seam.

Packwood Mine

"Packwood coal mine is 22 miles west of Hudson Hope. It is situated on the steep, southern end of a south-trending spur of Butler Ridge, 1 mile north of the river by road and about 480 feet above river level.

"The property was acquired by Mr. George Packwood in 1940. During the same year the mine was opened and 125 tons of coal taken out. There was no production in 1941, but during the following winter the mine was reopened and approximately 104 tons of coal were trucked to Fort St. John. Hauling was stopped in the spring of 1943 due to the bad condition of the road, although 100 tons of coal remained to be transported. During the summer of 1943 the remaining 100 tons were removed." About 7,260 tons of coal were mined during the 5-year period ending December 31, 1947.

"Underground workings consist of two entries along the strike of the seam: one at an elevation of 2,500 feet, and the other at an elevation of 2,380 feet. Prior to February 1943, only the upper entry existed, but work is now confined to the new, lower entry.

"The upper entry is 230·6 feet long, in which distance four raises, each about 30 feet high, have been put up. No. 1 raise is connected by a crosscut to No. 2 raise, and extends to the surface as an air shaft. The seam on this level is 3·1 feet thick at the portal, but thins to 2·6 feet at the face. It contains no partings or concretionary bodies, and consists mainly of bright coal.

"By September 7, 1943, the lower entry had been driven 150 feet. On this level the seam measures 2 feet at the portal and 1·6 feet at the face. A large, lens-like projection of sandstone from the hanging-wall starts 66 feet from the portal and persists for 30 feet. This 'cut-out' locally pinches the seam to less than 1·8 inches.

"Coal removed from the upper entry had to be lowered by cable down a steeply inclined track to an old bunker at the foot of the hill, a vertical distance of nearly 200 feet. This required a hoist at the portal. The new entry is 120 feet lower, and coal is now trammed a short distance on a trestle and emptied into a newly constructed, 2-compartment bunker having a capacity of 2,400 cubic feet, or about 65 tons. This bunker is provided with a screen that separates most of the slack.

"Work planned for this winter (1943-44) included completing the lower entry as far in as the present face of the upper entry, and then driving raises between the two entries. No large amount of coal will be removed until work in the lower entry is complete.

"Removal of coal from the raises is facilitated by the high dip of the seam, which is 54 degrees to the southwest. This allows the coal to slide into the cars from the chutes. Mining is hampered by the necessity of removing considerable rock with the coal. For this reason a compressed air drill is used in the drift, whereas coal augers are used in the raises.

"No partings are present in the seam, but some wall-rock must be removed.

"The coal is hauled by truck to Fort St. John over a poor road, a distance of about 83 miles."

The Annual Report of the Minister of Mines for British Columbia (1946, p. 248) states that new mine workings have been opened on what appears to be the same seam ½ mile north of the old workings and dipping at an angle of about 43 degrees. The seam is here described as 5 feet thick, with two rock bands, each about 1 inch thick, in the top 6 inches. This mine is now operated by Reschke Coal, Limited.

BUTLER RIDGE, EAST SIDE

A few narrow coal seams were observed by Beach and Spivak (1944) on creeks east of Butler Ridge. One such seam, 1½ to 2 feet thick, dipping 18 degrees east, could be traced for 1,200 feet along the middle branch of Ruddy Creek.

CARBON CREEK COAL BASIN

The Carbon Creek coal basin lies about 20 miles west of the Peace River Canyon coal area. The coal-bearing and older marine beds (Mathews, 1947) of the Bullhead group are downfolded to form a northwesterly trending synclinal basin, measuring about 20 miles long and 9 miles wide and extending from Peace River on the north almost to Moberly River on the southeast. Carbon Creek flows northwesterly to the Peace, along the axis of the synclinal basin, and most of the coal seams are exposed along this stream or at no great distance up its tributaries. As most of the coal seams occur in the upper parts of the coal-bearing strata, near the axis of the syncline, they are thought to be within a thousand feet of the surface in most places and thus favourably situated for future exploration and development.

Coal was first discovered on Carbon Creek in 1911, when Messrs. Cowper Rockfort, David Barr, and George McAllister traced coal float from the mouth of Carbon Creek to its source upstream. In 1923, J. D. Galloway spent 2 days in examining outcrops of coal along Carbon Creek and some of its tributaries, and his report (1924) was the first to record the high quality of the coal beds. W. H. Mathews spent a part of the 1944 and 1945 field seasons in geological mapping of the Carbon Creek basin and Fisher Creek syncline for the British Columbia Department of Mines, and his published report and map (1947) give the first comprehensive description of the nature and extent of this coalfield.

At least ten seams in the Carbon Creek coal basin are more than 4 feet thick, and at least five others range between 3 and 4 feet in thickness. Very little is known as yet of the variability in thickness of individual coal seams, as many are known at only one locality and cannot be correlated with other, nearby exposures. In the Eleven Creek area in the central part of the Carbon Creek basin, one seam exposed at three points within a third of a mile ranges from 4 feet to 4 feet 4 inches or possibly 5 feet in thickness. Another seam varies between 5 feet 7 inches and 6 feet 3 inches for ¾ mile, and an adjacent seam, including shale partings, from 10 feet 4 inches to 17 feet, but this variation may be due in part to thickening of the seam at the crest of a fold. Two other seams, each slightly more than 4 feet thick in one exposure, appear to correspond to two seams, each 1 foot thick, only 1,000 feet away, but their correlation remains uncertain, due to the possibility of a fault in this locality.

W. H. Mathews (1947) collected a large number of samples of coal from the Carbon Creek coal basin and he arranged the analyses of these samples into two convenient tables, which are reproduced here (*See* Tables IV, V). The following excerpts describe the localities from which the samples listed in Table IV were collected, and Figure 16 is a reproduction from Mathews' report to show the localities from which the samples listed in Table V were collected.

"The lowest of the thicker coal-seams known to occur in the northern part of the Carbon Creek basin is exposed on a small creek which enters Carbon Creek from the west, 5 miles above the Peace River. This seam lies about a quarter of a mile west of Carbon Creek and is about 1,000 feet above the base of the coal-measures. Its thickness is 2 feet 11 inches. An analysis (No. 1) of a sample from this exposure is given in Table 1 [IV].

"Four seams are believed to be present near the junction of Carbon Creek and Seven Creek. The lowest of these seams, about 5 feet in thickness, is exposed on Seven Creek 2·2 miles from its mouth, and apparently also on a creek joining Carbon Creek from the east a few hundred yards above Seven Creek. This seam may also correspond to the one described by Galloway as occurring on Carbon Creek itself about half a mile below Seven Creek, but which could not be found by the writer. Analyses (Nos. 2, 3, and 4 respectively) of samples from these exposures are given in Table 1 [IV]. This seam lies about 2,000 feet above the base of the coal-measures. The second seam, some 3 feet in thickness, lying approximately 25 feet above the first, is exposed on Seven Creek about 1·5 miles above its mouth, and apparently also on Carbon Creek opposite the mouth of Seven Creek (Analyses 5 and 6, Table 1 [IV]). The third seam, 2 feet 4 inches thick, about 150 feet above the second, and a fourth seam, 2 feet 2 inches thick, 20 feet above the third, are exposed on Seven Creek 1·5 miles from its mouth (Analyses 7 and 8, Table 1[IV]).

"No other seams are known to occur in the northern part of the basin between these four seams and the seam 3,000 to 4,000 feet above the base of the coal-measures, exposed on Nine Creek 1·2 miles from its mouth. The latter seam is described by J. D. Galloway as being 5 feet 4 inches thick, exclusive of a 2-inch shale parting 10 inches from the base of the seam (Analysis 9, Table 1 [IV]). In 1944 and 1945 the lower part of this seam was inaccessible, and only the upper 4 feet 2 inches could be sampled (Analysis 10, Table 1 [IV]). This seam may correspond to the lowest seam, about 6 feet thick, exposed in the canyons of Eleven Creek.

"A seam 2 feet 7 inches thick, probably less than 1,000 feet above the base of the coal-measures, exposed in the western part of the basin on Eleven Creek 5 miles from its mouth (Analysis 11, Table 1 [IV]) cannot be correlated certainly with any of those described above.

"Several seams in the lower part of the coal-measures in the southern part of the basin outcrop on McAllister Creek and on a tributary entering it 2·8 miles above its junction with Carbon Creek. An exposure of one seam on the latter tributary 1 mile above McAllister Creek, possibly 1,000 feet above the base of the coal-measures, is 8 feet 9 inches thick, but has probably

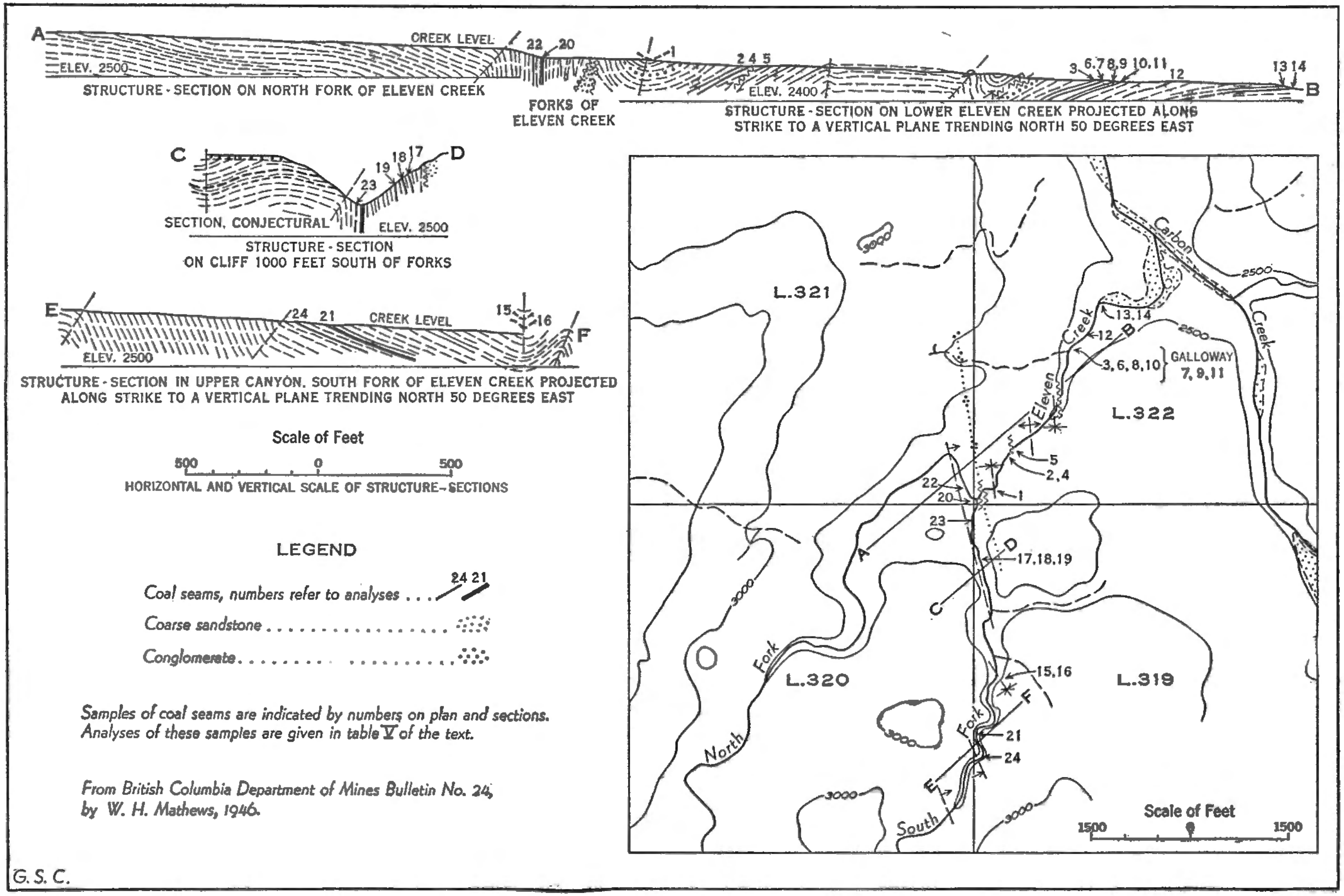

Figure 16. Plan and sections along Eleven Creek, showing points at which coal samples listed in Table V were collected.

here been markedly thickened at the crest of a fold (Analysis 12, Table 1 [IV]). A second seam 2 feet 6 inches thick exposed on McAllister Creek 2·2 miles above its junction with Carbon Creek lies perhaps 2,500 feet above the base of the coal-measures (Analysis 13, Table 1 [IV]). A third seam, 2 feet 9 inches to 3 feet thick, exposed on McAllister Creek 1 mile above its junction with Carbon Creek, is perhaps 3,000 feet above the base of the coal-measures (Analysis 14, Table 1 [IV]). The stratigraphic position of these three seams is difficult to determine because of the complexity of folding in this part of the basin.

"The majority of the seams in the Carbon Creek field are exposed in the central part of the basin between the mouths of Ten Creek and McAllister Creek, at horizons probably at least 3,500 feet and possibly 4,500 feet above the base of the coal-measures. Nine seams locally exceeding 4 feet in thickness are present in about 650 feet of strata within this area. Most of the seams are exposed in the canyons of lower Eleven Creek and its southern fork, but in spite of the almost continuous exposures of the coal-measures found along these creeks, the existence of several faults renders the correlation of several seams and the determination of the intervals between them impossible on existing evidence. The succession of these seams, spacing where known, thicknesses, and analyses are given in Table 2 [V]. The position where the samples, listed in Table 2 [V], were taken are indicated in the plan and structure sections, Eleven Creek Area, Carbon Creek Coal-basin [*See* Figure 16].

"One seam 34 inches thick, and apparently corresponding with one of the lower seams on the Eleven Creek section, is exposed on Ten Creek about 0·5 mile from its mouth (Analysis 15, Table 1 [IV]). A pair of seams, the lower 5 feet 7 inches thick (Analysis 16, Table 1 [IV]) and the second about 16 feet higher in the succession, 2 feet 6 inches to 6 feet thick (the latter figure reported by Stines) (no sample), outcrop on Carbon Creek 0·7 mile above the mouth of Eleven Creek. Their relationship to the seams on Eleven Creek is concealed by drift. They may correspond to the two lowest seams on Eleven Creek, since the lower seams in each case are of comparable thickness and the spacing between the seams is similar. The upper seam on Carbon Creek is, however, much thinner than the upper of the two seams on Eleven Creek. Two other seams, the lower 5 to 6 feet thick, the upper 3 feet 5 inches thick, separated by 18 feet of shale and sandstone, are exposed on Carbon Creek 3 miles above Eleven Creek. The lower seam outcrops in the creek, and only the uppermost 2 feet 6 inches could be sampled (Analysis 17, Table 1 [IV]). The upper seam is exposed on the banks of the creek, and the full width could be sampled (Analysis 18, Table 1 [IV]).

"Other seams less than 3 feet thick are known, but have not been sampled. A seam (No. 13, Table 2 [V]) 4 feet 9 inches thick, including a 1-inch and a 2-inch shale parting, first disclosed by stripping on lower Eleven Creek in 1945, has not been sampled by the writer.

"At several localities in the Carbon Creek basin, coal seams have been partly burned. The shales and sandstones in their vicinity have commonly been baked to a brick-red colour, and in one place, on the south fork of Eleven Creek 0·2 mile from its junction with the main stream, the shales overlying one burned seam have been fused into a scoriaceous clinker, mottled in shades of red, yellow, brown, and green. In this locality contact of burned and unburned areas is exposed on the post-glacial canyon walls and nearly parallels the present surface. The burning has, therefore, taken place in post-glacial times, but in no place within the basin are the fires known to be still smouldering. The overlying beds have slumped down to occupy the position formerly occupied by the burned coal, and except on very continuous exposures the position of a burned coal-seam may not be detected. Comparison of an analysis of a sample taken only 1 foot from a burned area with the analysis of a sample from the same seam much farther from the burned area indicates that the coal close to the old fire was not materially affected by the heat."

TABLE IV

Analyses of Coals[1]

Northern Part of Carbon Creek Basin

Analysis No.	Distance above base of coal-measures	Thickness sampled	H_2O	Vol. comb.	Fixed carbon	Ash	Sulphur	B.t.u.
	Feet	Ft. Ins.						
1	1,000	2 11	3·3	21·6	70·1	5·0	0·49	13,590
2	2,000	5 0	5·8	24·3	64·7	5·2	0·52	12,800
3	2,000	5 4	5·2	20·4	59·2	15·2	0·47	11,410
4	2,000	4 6†	2·1	22·0	69·4	6·5	....	......
5	2,250	3 0	2·6	17·9	49·8	29·7	0·54	9,580
6	2,250	3 5	2·7	18·3	57·6	21·4	0·71	11,410
7	2,400	2 4	2·8	24·2	64·0	9·0	0·65	13,320
8	2,420	2 2	4·2	21·4	61·0	13·4	0·58	12,040
9	3,500	5 4‡	5·5	24·8	61·5	8·2	....	......
10	3,500	4 10§	2·8	25·8	63·9	7·5	0·67	12,930

Western Part of Carbon Creek Basin

Analysis No.	Distance above base of coal-measures	Thickness sampled	H_2O	Vol. comb.	Fixed carbon	Ash	Sulphur	B.t.u.
11	1,000	2 7	5·0	19·5	72·1	3·4	0·46	13,320

Southern Part of Carbon Creek Basin

Analysis No.	Distance above base of coal-measures	Thickness sampled	H_2O	Vol. comb.	Fixed carbon	Ash	Sulphur	B.t.u.
12	1,000	8 9‖	4·5	15·6	66·9	13·0	0·36	12,090
13	2,500	2 6	2·5	16·4	77·5	3·6	0·50	14,180
14	3,000	2 10	2·0	20·0	69·7	8·3	0·76	13,470

Central Part of Carbon Creek Basin

(Except Eleven Creek, *See* Table V)

Analysis No.	Distance above base of coal-measures	Thickness sampled	H_2O	Vol. comb.	Fixed carbon	Ash	Sulphur	B.t.u.
15	3,500—4,000	2 10	4·4	25·6	65·4	4·6	0·57	12,850
16	3,500—4,000	5 7	7·3	22·7	55·4	14·6	0·48	10,620
17	3,500—4,000	2 6¶	1·8	21·5	75·6	1·1	0·52	14,620
18	3,500—4,000	3 5	1·5	30·2	64·3	4·0	0·78	13,980

† Taken by J. D. Galloway—full width of seam, but excluding 5 inches of bone.

‡ Taken by J. D. Galloway—full width of seam, excluding 2 inches of shale parting.

§ Base of seam not accessible.

‖ Probably thickened locally at crest of a fold.

¶ Five- to six-foot seam, base not accessible.

[1] From Mathews (1947).

TABLE V

Analyses of Coals—Eleven Creek, Carbon Creek Basin[1]

Interval between seams	No.	Thickness sampled Ft. Ins.	H_2O	Vol. comb.	Fixed carbon	Ash	Sulphur	B.t.u.
120 feet	*1	3 6	3·4	30·4	52·7	13·5	0·56	11,830
	2	1 9	3·4	29·2	61·0	6·4	0·85	12,670
	3	1 8	4·5	29·8	60·3	5·4	0·73	12,730
10 feet	4	4 1	3·3	27·0	66·3	3·4	0·57	13,150
	5	4 3	1·9	27·2	68·6	2·3	0·77	13,980
	6	4 4	3·5	26·1	67·3	3·1	0·49	13,620
	7	5 0‡	4·6	25·2	66·6	3·6	....	......
15 feet	8	1 4	2·7	24·9	56·8	15·6	0·70	12,000
	9	1 4‡	2·9	23·7	56·2	17·2	....	......
3 feet 6 inches	10	2 2	2·7	27·7	66·9	2·7	0·67	13,650
	11	2 1‡	3·4	26·2	67·7	2·7	....	......
45 feet (±)	12	4 9	....	....	....	....	....	......
80 feet (±)	13	1 1	2·2	29·4	65·9	2·5	0·79	13,750
4 feet 9 inches	14	2 10	3·4	24·5	68·4	3.7	0·70	13,150
(?)	15	4 0§	3·0	19·5	46·1	31·4	0·44	9,140
25 feet	16	6 0	3·3	23·3	70·7	2·7	0·59	13,650
100 feet (?)	17	4 4‖	7·2	25·3	57·2	10·3	0·59	10,950
18 feet	18	4 5‖	9·6	20·5	54·9	15·0	0·47	10,360
25 feet	19	4 3‖	5·5	25·1	67·7	1·7	0·53	12,700
125 feet	20	17 0‖	2·2	25·1	58·1	14·6	0·62	11,840
	21	9 2¶	2·9	23·6	57·9	15·6	0·50	11,740
15-20 feet	22	6 0	2·6	25·5	69·2	2·7	0·61	13,970
	†23	6 3	7·2	25·6	64·0	3·2	0·48	12,230
	24	5 7	3·6	23·9	70·1	2·4	0·61	13,580

* Highest known seam.
† Lowest known mineable seam in Eleven Creek area.
‡ Sampled by J. D. Galloway.
§ Only upper 3 feet 4 inches sampled.
‖ Thickness may be abnormally great.
¶ Excluding 14-inch shale parting.
[1] From Mathews (1947).

"Analyses of coal samples from the map-area indicate that several of the seams contain less than 5 per cent ash and, in this respect, compare very favourably with coals from other North American fields. The calorific value is high, being more than 13,000 B.T.U.'s per pound for many seams, even in surface samples, and the calorific value of nearly all coal samples computed on an ash-free moisture-free basis exceeds 14,000 B.T.U.'s per pound. The carbon ratio, that is the ratio of the content of fixed carbon to volatile combustible matter, ranges from 1·7 to 4·7 and averages about 2·5. Most of the coal can be considered as medium-volatile bituminous according to the classification by rank as proposed by a committee of the

American Society of Testing Materials (*See* Stansfield, 1937, p. 6). The marked variations in the carbon ratio may be attributed in part to weathering of coal samples, although there is a tendency to higher carbon ratios in the lower seams and in the more closely folded areas. With one exception, all samples were found to be of non-caking coal. Some of the seams have been crushed and would produce only friable coal or slack, but many of the seams are of relatively strong coal which would withstand a considerable amount of handling.

"Experience of householders in the Peace River district indicates that the similar coals from the Hasler Creek and Hudson Hope areas produce an extremely hot fire in ordinary stoves and heaters. If Peace River coals were to be marketed on the Pacific Coast for domestic use, provision should be made for special adjustments and fire-brick walls for stoves and furnaces, or for blending the Peace River coal with some other coal having a higher content of volatile combustible matter. As steam-coal for use in larger installations, the cleaner Peace River coals are probably unexcelled."

FISHER CREEK-PINE RIVER COAL AREA

The Fisher Creek-Pine River coal area lies southeast of the Carbon Creek area on the same synclinal belt. Non-marine coal-bearing beds of the Bullhead group outcrop adjacent to Pine River for more than 3½ miles downstream from the mouth of Fisher Creek and 2 miles upstream. For a few miles up Fisher Creek the favourable upper beds of the Bullhead group are concealed by the Moosebar formation as a result of the synclinal structure, and the latter formation also extends southeasterly up Falling Creek. An anticlinal fold, known as Pine River anticline, trends northwesterly across Pine River 3 miles downstream from the mouth of Fisher Creek, and Crassier Creek, which flows southeasterly to enter the Pine a mile farther down, follows very closely the contact of the Bullhead group and overlying Moosebar formation. Coal seams of mineable thickness may well occur in the eastern limb of the Pine River anticline near Crassier Creek, but bedrock is almost entirely drift covered there, so that no mineable seams have been discovered. The known seams of mineable thickness all occur on the southwest limb of the Fisher Creek syncline.

According to Mathews (1947), seven seams in the area are known to be more than 3 feet thick. The following description of these seams is from his report:

"One seam 3 feet 2 inches thick occurs 0·5 mile northeast of Bickford lake only about 300 feet from the base of the coal-measures (Analysis 1, Table 3 [VI]). A second seam 4 feet thick is exposed 0·3 mile farther east and about 1,000 feet higher in the succession (Analysis 2, Table 3 [VI]).

"Five exposures of coal were found on Beaudette Creek, but may represent only three seams. Two of the seams are exposed on the eastern limb, and three on the western limb of a closely folded minor anticline in the uppermost part of the coal measures. Although no faulting is apparent the successions on opposite limbs of this fold do not correspond closely and the correlation of seams remains uncertain. The coal in all but one of the exposures is badly crushed and the seams lenticular. The first seam encountered on ascending Beaudette Creek is 2 miles from its mouth and a few hundred feet southwest of the fault separating the Moosebar formation from the coal measures, varies from 5 to 15 feet thick and is 8 feet 5 inches thick where sampled (Analysis 3, Table 3 [VI]). The second seam, 4 feet 4 inches thick and not badly crushed, lies about 150 feet stratigraphically lower in the succession than the first and about 200 feet upstream from it (Analysis 4, Table 3 [VI]). The third seam, exposed on the western limb of the anticline a few hundred feet upstream from the second, is 2 feet 11 inches thick (Analysis 5, Table 3 [VI]). The fourth exposure, a seam which may correspond to the second is 4 feet 2 inches thick and about 50 feet stratigraphically above the third. The fifth and last exposure, a seam which may correspond to the first encountered, is crushed and lenticular, varies up to 10 feet thick and is 9 feet where sampled (Analysis 7, Table 3 [VI])."

TABLE VI

Analyses of Coals—Fisher Creek Syncline[1]

No. and locality	Thickness sampled		H_2O	Vol. matter	Fixed carbon	Ash	B.t.u.'s.
	Ft.	Ins.					
1. Northeast of Bickford Lake	3	2	2·6	16·2	77·2	4·0	14,240
2. Northeast of Bickford Lake	4	0	1·7	17·5	63·2	17·6	12,140
3. Beaudette Creek	8	5	1·7	18·1	36·3	43·9	8,100
4. Beaudette Creek	4	4	1·5	25·4	58·7	14·4	12,390
5. Beaudette Creek	2	9	1·6	22·9	59·6	15·9	12,630
6. Beaudette Creek	4	2	2·2	21·5	65·1	11·2	12,850
7. Beaudette Creek	9	0	2·2	18·8	46·1	32·9	9,630

[1] From Mathews (1947).

HASLER CREEK COAL AREA

During the summer of 1943, J. Spivak mapped geologically and in detail a belt 2 to 4 miles wide and 15 miles long in the Hasler Creek coal area, some 65 miles west of Dawson Creek. The following descriptions and map (Figure 13) are from his report (1944).

"The Hasler Creek Coal Company was incorporated in British Columbia in December 1943 to develop the Discovery seam on Hasler Creek. This seam was discovered in 1934 by Mr. G. Goodrich, after unusually high water had removed the overburden along the east bank of Hasler Creek near the coal outcrop. No work was undertaken until the winter of 1940–41, when the seam was opened up by an adit about 15 feet above creek level and extending into the coal for 56 feet. In addition, coal was mined, by means of open-cut benches, to a height of about 50 feet above the adit. Six hundred tons were delivered to the drilling contractors at Pine River Well No. 1 at Commotion Creek. During the winter of 1942 the adit was cleaned out in preparation for mining underground, but no production was attempted. In December 1943 a tipple and camp buildings were erected and a daily production of 35 tons was reached." During 1944, 777 tons of coal were mined and sold, and during 1945 the amount was 3,156 tons. There was no production during 1946 or 1947.

"The Discovery seam lies about 200 feet south of the Moosebar-Gething contact, on the east side of Hasler Creek. It is 159 feet, stratigraphically, below the top of the Gething formation at this locality. The coal section includes:

	Thickness Feet	Inches
Coal, Discovery seam, hard, bright, with 2-inch sandstone parting near base	7	4
Coal, sheared and foliated	1	4
Shale, carbonaceous, brown weathering, contains ¼-inch coal seamlets	4	2
Coal, sheared, with ½-inch shale partings	5	2
Total thickness of coal with shale partings	18	0

"About 300 feet south of the adit, or 261 feet stratigraphically below the Discovery seam, a coal section, designated as the Point seam, includes the following beds:

"Point seam	Thickness Feet	Inches
Coal, somewhat sheared	2	7
Shale, carbonaceous, with thin coal seamlets	1	6
Coal, bright	2	6
Total thickness of coal and shale parting	6	7

"Between the two sections there are at least five individual seams varying from 6 inches to 2½ feet in thickness. None of these is considered thick enough to warrant development work under existing conditions.

"The coal consists of alternating bright and dull bands, is black, and has a black streak. The bright bands are commonly lenticular, and vary from ⅛ to ¼ inch in thickness. Dull bands are of similar thickness and usually predominate over the bright bands. Analyses of five samples from the Discovery and Point seams are given below:

Number and form of analyses	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value B.t.u.	Caking proper-ties	Ash softening temp.
1—A[1]	5·1	18·7	72·1	4·1	0·7	14,120	Good	2,780°F.
—B[2]		19·7	76·0	4·3	0·7	14,880	Good	2,780°F.
2—A	5·1	18·9	70·1	5·9	0·7	13,880	Good	2,530°F.
—B		19·9	73·9	6·2	0·7	14,620	Good	2,530°F.
3—A	4·4	15·2	44·5	35·9	0·3	8,970	Fair to	2,250°F.
—B		15·9	46·5	37·6	0·3	9,380	good	2,250°F.
4—B	9·5	17·1	47·7	35·2	0·5	8,590	Non-agglomerate	2,800°F.
5—B	13·7	21·3	59·8	18·9	0·5	10,630	Non-agglomerate	2,850°F.

[1] A—As received. [2] B—Air dried.

Location of samples

1. Discovery seam, from adit face, 7 feet 4 inches.
2. Discovery seam, duplicate sample taken 1 foot above 1.
3. Bench below Discovery seam, in adit face and crosscut, 6 feet 2 inches.
4. Point seam, upper bench, 2 feet 7 inches.
5. Point seam, lower bench, 2 feet 6 inches.

"Coal from the Discovery seam is of low volatile, bituminous rank. The ash content is low and coking properties are good. The section underlying the Discovery seam was sampled to determine whether it could be included in the commercial coal, but the analyses indicated a low calorific value and high ash content.

"The Point seam is inferior in rank, grade, and thickness to the Discovery seam. The samples are from two benches separated by 15 inches of carbonaceous shale. The coal is weathered and it is probable that the analyses given above are not indicative of the true grade and rank. The Point seam may, however, furnish additional tonnage if a mining plant is installed to work the Discovery seam.

"The map shows the detail of the southeasterly part of the area near Hasler Creek. The contact between Moosebar and Gething formations was used as an horizon marker in prospecting and trenching for coal exposures.

"Two localities were found in which comparatively shallow trenches revealed coal: one is about 3,250 feet southeast of the adit and 700 feet above creek level; the other is 7,500 feet southeast and about 900 feet above Hasler Creek. At the first locality, seven pits and test holes revealed coal. The coal in Pit No. 1 is about 18 feet thick and apparently occurs at the crest of an anticline. Overlying beds strike south 45 degrees east and dip 32 degrees southwest; about 30 feet below the pit, and apparently underlying the coal, sandstones and shale strike south 60 degrees east and dip 20 degrees northeast. Overlying beds near the ridge top, south of Pit No. 1, dip about 32 degrees southwest. A section of sandstone and shale in Pit No. 7 strikes south 45 degrees east and dips 61 degrees northeast. The overburden was too thick to permit determination of the thickness of the coal seams in the other pits. The thickness of the coal in Pit No. 1, its stratigraphic position, and the structural data, indicate that the coal probably represents the Discovery seam. At the second locality, a 15-foot seam of sheared coal occurs about 500 feet south of the Moosebar-Gething contact. The strata between the contact and the coal outcrop dip steeply and exhibit isoclinal folding with minor faulting. Additional prospecting and trenching along the creek section are necessary before it is possible to determine whether this coal section is the continuation of the Discovery seam.

"Insufficient development work has as yet been done to permit definite correlation of coal seams and the calculation of tonnages throughout the area. Local faults and changes in physical character of the coal in the folded zone might reduce estimates of mineable coal considerably. An approximation of the tonnage of coal in the Discovery seam on the east limb of the anticlinal structure has been made, assuming continuity between the adit and Pit No. 1. This region contains 400,000 tons of coal above Hasler Creek level, using a 7-foot mineable section as the average thickness. If the Discovery seam is continuous to the second locality on Grizzly Creek, the available tonnage on the east limb would be 1,200,000 tons. Further prospecting should reveal the Discovery seam on the west limb of the anticline, from which additional tonnage would be available."

WILLOW AND JOHNSEN CREEKS

"Coal outcrops were observed at several localities in the Willow Creek[1] area. The overburden there is too thick to permit tracing seams for any distance, and in most instances insufficient data are available to determine the stratigraphic position of the seams. On a westerly branch of Johnsen[1] Creek, a coal outcrop more than 7 feet thick occurs near the top of the Gething formation. Several 2- to 3-foot seams outcrop on Willow Creek, above the first falls, near the base of the Gething. South of Pine River a 3-foot seam and a 5-foot seam occur in the upper part of the formation, but their exact stratigraphic position could not be determined.

"Prospecting for coal in this area should be confined mainly to a relatively narrow belt near the contact between the Gething and Moosebar formations. This is the stratigraphic horizon in which the thickest coal seam is known to occur on Hasler and Johnsen Creeks. The most accessible region for prospecting and development is east of Willow Creek on the south side of Pine River and just west of Crassier Creek on the north side of the river."

HALFWAY-SIKANNI CHIEF RIVER COAL AREA

Coal-bearing strata of the Bullhead group are exposed by a major anticlinal fold on Sikanni Chief River, Pink Mountain, and Halfway River from 8 to 10 miles west of the Alaska Highway (west and northwest of mile 150). This structure has been named the Pink Mountain anticline by Hage (1944). It has a length of about 17 miles between Sikanni and Halfway Rivers, but as the topographic expression of the fold continues south of Halfway River almost to Cypress Creek, the total length of the anticline may approach 30 miles.

A section of the Bullhead group exposed about a mile above the waterfalls north of Pink Mountain has a thickness, calculated by Hage (1944), of 900 feet, but as the strata are broken by an east-dipping fault of undetermined displacement, the true thickness is not apparent. Another section exposed 9 miles farther west has a calculated thickness of 1,620 feet. As the Bullhead group in the Peace River district is more than 5,000 feet thick, there is evidently a marked thinning of the strata in a northerly direction.

Little prospecting has yet been done in this area, so that the economic possibilities of its coal measures are unknown. The following notes on the known occurrences are from C. O. Hage's 1944 report.

"On Sikanni Chief River the Bullhead group contains at least ten coal seams, none of which is more than a foot thick. The seams are more common to the upper part of the group, which in this respect is similar to the Gething formation of the Peace River area. The coal is good grade bituminous, but the seams where observed are too thin to be worth mining.

"At the base of the Bullhead group on Pink Mountain, immediately north of Halfway River and close to the crest of the anticline, is a seam of

[1] Willow Creek flows northwest to enter Pine River near the mouth of Crassier Creek. Johnsen Creek (not to be confused with Johnson Creek south of Peace River Canyon) is the west branch of Hasler Creek.

good-grade coal more than 5 feet thick. On the east side of the mountain this seam has been burnt out. Along the west side, however, pieces of float coal were observed for 3½ miles north of Halfway River. Any prospecting for this seam should be done on Pink Mountain adjacent to Halfway River."

An analysis of a sample taken by Hage near the surface, at base of the Bullhead group, Pink Mountain, is as follows:

—	As received	Dry
	Per cent	Per cent
Moisture	5·6	
Ash	4·4	4·6
Volatile matter	12·5	13·3
Fixed carbon (by difference)	77·5	82·1
Sulphur	6·0	6·3
B.t.u. per lb.	12,670	13,420
	Non-caking	

Softening temperature of ash 2,600°F.
This is low volatile bituminous coal.

The following is an analysis of a sample taken from a seam close to the top of the Bullhead group at the north end of Pink Mountain:

—	As received	Dry
	Per cent	Per cent
Moisture	0·6	
Ash	13·4	13·5
Volatile matter	25·9	26·1
Fixed carbon (by difference)	60·1	60·4
Sulphur	3·8	3·9
B.t.u. per lb.	13,270	13,350

Caking properties good.
Softening temperature of ash, above 2,850°F.
This is a medium volatile bituminous coal.

COAL RIVER LIGNITE

(By M. Y. Williams, 1944)

"At Coal River, mile 533, Alaska Highway, large masses of brown lignite and slabs of lignitized wood lie scattered over the river bars. These were reported by McConnell, who failed to reach their source in the time at his disposal. The outcrop occurs north of the big bend in Coal River, and about 6 miles in a direct line from the Highway. The distance is much longer by the river, possibly 10 miles.

"The coal seam forms a rapid across the river, which is over 200 yards wide, and outcrops for about 300 yards along the river bank. In the west bank, 15 feet of lignite is well exposed, dipping 6 degrees to the northwest. The lignite weathers brown; some of it is very friable and some is tough and woody, containing large, well-preserved sections of logs. Ashy grey overclay shows in one place, but basal beds were not seen. In general the coal is overlain by a thick mass of outwash gravel.

"Upstream, where the gravel cover has been removed by the river, the coal is burning over an area 150 yards along the stream and for 50 yards in width. Smoke and fumes are issuing freely from the surface, and trees and shrubs show all stages of death and destruction. Nodules of clay have been vitrified, and slumped overburden indicates subsurface collapse.

"Coal is said to extend upstream as far as the 'falls', but what distance that is can only be estimated. Hills could be seen [on] approaching the river, some 2 miles upstream from the coal outcrops.

"Downstream about 1½ to 2 miles from the road, white clay outcrops in the west bank of the river at two localities. It extends upward from the river to a height of about 15 feet and is overlain by heavy gravel deposits. The exposures are about 200 yards apart and are each about 100 yards long. Evidently a considerable area is underlain by clay.

"The relationship of the coal and clay deposits has not been determined, but they clearly belong to the same Tertiary basin. This is evidently several square miles in area, occupying Coal River Valley from its mouth for 8 or 10 miles upstream. Its width may be estimated as from 2 to 4 miles.

"The age of the coal and clay deposits is certainly Tertiary, but to which division they belong is not known.

"McConnell reported sandstone, clay, and lignite in the lower valley of a stream entering Liard River from the south about 7 miles below Hyland River. This locality was not visited by the writer. It is probable that several basins of Tertiary age may occur in this vicinity."

A test of a sample of Coal River lignite gave the following results:

—	As received	Dry
	Per cent	Per cent
Moisture	15·4	
Ash	6·2	7·4
Volatile matter	45·6	53·9
Fixed carbon	32·6	38·7
Sulphur	0·3	0·3
B.t.u. per lb. gross	8,970	10,600
Non-agglomerate		
Softening temperature of ash, 2,490°F.		
Fuel ratio—0·72		

OIL AND GAS

PEACE AND PINE RIVER VALLEYS

Williams (1934) has noted that the late Palæozoic limestones, including those of the Carboniferous, and the Triassic and Jurassic sandstones, limestones, and shales are the most likely to contain oil. He does not consider the non-marine Cretaceous promising, and has little hope of production from the Fort St. John. The older formations are the more promising, but have not been tested. He has also noted the great variety of structure between "the highly folded and faulted mountain structures . . . and the almost imperceptible undulations of the plains". Between may be structures favourable for production of oil or gas.

In the Dunlevy-Portage Mountain map-area, in the eastern part of the Foothills, Beach and Spivak (1944) suggest that tests for oil be confined to Triassic and older formations, as all later strata reach the surface. They note that both the Triassic and Permian beds are marine, but the Triassic has little porosity and the Permian beds are less consolidated and contain numerous vugs, some of which are filled with pyrobitumen. They warn that although the Bullhead anticline is the most favourable in the area for a test, the east limb is steep and may be faulted. They call attention to the difficulty of drilling through the hard sandstone and conglomerate of the Dunlevy formation and state that this might be avoided by drilling in the preglacial river channel between Portage Mountain and Butler Ridge.

East of the Foothills and north of Peace River, in the vicinity of Farrell Creek, six holes were drilled in 1922 on the Farrell Creek anticline or dome (Dresser, 1921, 1922). Beach and Spivak (1944) note that these holes penetrated the Hasler, Gates, and Moosebar formations, and 800 feet of the Gething. At a depth of 2,273 feet, apparently in the upper part of the Gething, 2 feet of tar clay was encountered. Dresser (1922) reported an oil concentration of 80 gallons a ton. It may be observed that these holes were not carried through to the Triassic and Palæozoic and so afforded no test of the oil possibilities of these older beds. Other structures in Peace River Valley east of the Foothills have not been tested.

Wickenden and Shaw (1943) do not discuss the oil possibilities of the Mount Hulcross-Commotion Creek map-area, which includes a part of Pine River Valley. Spivak (1944), however, recommends that drilling tests be confined to beds below the Gething. He regrets the lack of information concerning porosity. Indeed too little attention has been given to the study of porosity of the rocks in northeastern British Columbia.

The Commotion Creek well was carried to a depth of 6,940 feet without obtaining oil or gas (Hage, 1944). The hole ended in the Bullhead beds, and appears to have entered a fault zone.

In a search for oil and gas in the Plains, drained by Pine and Peace Rivers, the comparatively gently undulating structures described by Spieker, Dresser, Williams and Bocock, and others (*See* Chapter IV) should be considered. It may be noted that some of the interpretations of structure made on the basis of earlier work have been revised in later investigations; some faulting has been recorded where before only folding had been recognized.

PEACE RIVER TO MUSKWA RIVER

Hage (1944) has briefly discussed the oil and gas possibilities in the Foothills and Plains between Peace and Muskwa Rivers. He considers that the presence of porous and permeable reservoir beds is important. They may occur at erosional unconformities, especially where limestone has been subjected to erosion. He does not know whether such beds are in the Palæozoic group, and suggests that a search be made for them in future investigations. He calls attention to medium- to fine-grained sandstone in the Triassic system. No porosity tests, however, were made by him.

Indeed many of the Triassic sandstones and limestones appear to be very tight and impermeable; possibly some of the Palæozoic and Triassic shell limestones have porosity suitable for a reservoir. Hage notes the induration of many of the sandstones of the Bullhead group, but suggests that this may decrease eastward. It may be further noted that the Bullhead group entirely disappears north of Prophet River, where it need not be considered when drilling is planned.

Hage (1944) states that structures with closure have been mapped. "Several have been outlined sufficiently to show their extent and type" (*See* Chapter IV).

A well drilled for water for a construction camp near Indian Creek was carried to a depth of 410 feet. It passed through 50 feet of glacial drift and 360 feet of dark grey shale. A small flow of gas occurred at 190 feet. "The gas burned with a flare about 4 feet long as it escaped from a 1-inch pipe. It was under very little pressure" (Hage, 1944).

FORT NELSON TO VALLEY OF TETSA RIVER

No special investigation of porosity or permeability of the rocks exposed along the Alaska Highway west of Fort Nelson has been made. Williams (1944), however, notes "that the Mississippian formations include argillaceous and arenaceous limestones of a type commonly petroliferous. Overlying chert beds . . . are suitable as cover rocks. The thick Triassic arenaceous limestones also suggest porosity".

So far as known, and subject to confirmation as future investigation proceeds, the structure of the eastern Triassic block (*See* Chapter IV) does not include faults and is one of folds only. Williams considers that the wide, gentle structures near Steamboat Mountain deserve attention. He concludes that the "main hope for petroleum production lies in the thick assemblage of marine, calcareous and arenaceous beds of upper Palæozoic and Triassic ages. . . . . A variety of structures is available, but a test location should be made only after careful field investigation".

Hage (1944) has described three wells drilled for water at the Fort Nelson airport. No. 1 well "reached a depth of 521 feet and was wholly in glacial drift. It encountered a pocket of gas and was abandoned". No. 2 well reached a depth of 1,451 feet, passed from drift into bedrock between 720 and 730 feet and encountered a flow of gas at 1,010 feet in fine-grained sandstone. A supply of water was found in coarse gravel at the base of the drift, and rose to within 250 feet of the surface. An analysis of the gas is as follows:

	Per cent by volume
Methane	98·41
Ethane	0·18
Propane	Nil
Butanes	Nil
Pentanes	0·10
Carbon dioxide	0·28
Oxygen	0·91
Nitrogen	0·12
Helium	Trace
Total	100·00

Specific gravity (Air = 1·000) 0·575
Heating value at 760 mm. and 60°F.
B.t.u. per cu. ft. = 999

No. 3 well was located near No. 2, and was drilled to a depth of 706 feet, not deep enough to reach the gas encountered in No. 2 well.

None of these wells was carried deep enough to afford a test of the oil and gas possibilities of this area.

LIARD RIVER VALLEY

Oil possibilities of the Liard River Valley have been discussed by Kindle (1944). As possible source beds, he mentions Palæozoic limestones, shales, and sandstones, Triassic black, marine shales and impure limestones, and Lower Cretaceous shales. He notes that on Beaver River the Permian sandstones are comparatively porous and are overlain by shale. Impure sandstones of the Triassic Toad formation are also suggested as possible reservoir rocks. Sandstones of the Scatter formation are considered by him to be more porous than sandstones in older formations. Sandstones and grit conglomerates of the Fort Nelson formation are also included by him among the more porous beds.

No oil seepages are recorded by Kindle. Gas is escaping from a spring near the east bank of Brimstone Creek, 3 miles above its mouth. He considers that it is probably sulphurous. Similar fumes are escaping from beds along the axes of anticlines of Lépine and Crusty Creeks.

Kindle concludes that "the area is situated favourably with respect to possible source rocks and structures that aid accumulation of oil, but the actual presence or absence of oil in the area has not been established and can only be determined by future work".

DAWSON CREEK–POUCE COUPÉ GAS FIELD

Gas has been produced from the Triassic in a well drilled in sec. 11, tp. 81, rge. 17, W. 6th mer., about 20 miles northwest of Dawson Creek. Preliminary tests give a flow of 416,000 cubic feet a day. Gas has also been obtained from the Lower Cretaceous in other wells in this part of British Columbia, but nearer the Alberta border.

East of Pouce Coupé, in Alberta, a gas area is indicated (Hume and Ignatieff, 1948). Five wells have been drilled. In one the gas flow is small, but in the others it ranges from 5,000 Mcf. to 32,000 Mcf. Hume and Ignatieff estimate a "probable" gas area of nearly 10 square miles. Production is from the Lower Cretaceous Fort St. John group and from a depth of about 2,100 to 2,200 feet. A small showing of oil was obtained from the Triassic strata in one well, the Guardian No. 1, at a depth of about 4,774 feet.

CHAPTER VII

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APPENDIX[1]

PEACE RIVER CANYON COAL AREA

DETAILS OF COLUMNAR SECTIONS[2]

"Thick" refers in general to layers over 6 inches thick; thin to those under 6 inches. "Shale" refers to fine-grained argillaceous beds, having the structure of shale, i.e., breaking in layers that have curved surfaces; these layers further break down into irregular and angular fragments. "Fissile shales" as so designated here are those that break into smooth sheets or plates parallel to bedding. "Flag", "flaggy," and "flagstone" refer to the nature of the bedding and not to the grain and composition of the rock; the rock weathers into layers parallel to the bedding, each layer being a natural stratum.

North Shore, Fossil-tree Point to Milligan Point (B 1 to B 2)[3]

	Feet	Inches
Coal	1	3
Shale, carbonaceous, jet seamlets	0	5
Sandstone, argillaceous, some jet	0	8
Sandstone, fine grained, massive	1	1
Shale, arenaceous	1	6
Clay ironstone, prostrate plants	6	8
Shale, carbonaceous, somewhat fissile, prostrate plants	2	0
Sandstone, medium grain, ripple-marked	1	0
Coal	0	7
Shale, grey, friable	1	3
Coal	0	7
Sandstone, carbonaceous, with jet	0	3
Coal	0	3
Shale, grey, arenaceous	0	6
Sandstone and shale in irregular 8-inch beds	2	0
Coal	0	4
Shale, carbonaceous, with jet	0	10
Coal	0	7
Shale, somewhat fissile	1	0
Clay ironstone	0	6
Sandstone, light grey, medium grain, in ripple-marked flags, brown weathering	3	6
Sandstone, light grey, coarse grained, massive	3	4
Sandstone, films black shale	1	5
Shale, dark	1	11
Coal, 4-inch jet on bottom	1	6
Jet coal and irregular clay ironstone concretions	0	5
Shale, carbonaceous, micaceous	0	6
Sandstone, carbonaceous, micaceous	1	3
Sandstone, yellow and banded above, coarse and massive below	20	3
Coal, having 8-inch concretions in places	1	10
Shale, arenaceous	0	7
Sandstone, light grey, massive	1	10
Sandstone, massive	1	2
Sandstone, fine, yellow weathering	1	4
Sandstone, light grey, medium grain, fine lined; peculiar unsolved plant remains?	4	0
Sandstone, white, coarse; peculiar unsolved plant remains?	5	3
Sandstone, ripple-marked	2	3

[1] Reprinted from report by F. H. McLearn, 1923.
[2] All sections read from highest beds downward.
[3] For locations *See* Figure 11.

North Shore, Fossil-tree Point to Milligan Point (B 1 to B 2)—Continued

	Feet	Inches
Shale	0	3
Coal	0	2
Sandstone, fine, argillaceous	1	4
Sandstone, fine, in ripple-marked beds	5	6
Sandstone, fine, argillaceous in ripple-marked flags	12	6
Sandstone, argillaceous, micaceous, fine lined	4	10
Jet coal	0	3
Shale	0	7
Coal	0	7
Shale, prostrate plants	1	0
Sandstone, medium grain, light grey	0	11
Sandstone, medium grain, weathers yellow	1	6
Sandstone, grey, some ripple-marked surfaces	2	9
Shale, having thin beds of clay ironstone	10	0
Sandstone, fine, some ripple-marked surfaces	8	0
Shale, grey	0	8
Coal	0	4
Shale, carbonaceous, fissile	2	0
Coal	0	8
Clay ironstone	1	0
Coal	1	0
Shale	1	0
Coal	0	5
Shale, black	2	0
Shale, black, carbonaceous	2	0
Shale, black, having bands of jet	1	8
Shale, grey, friable	2	0
Sandstone, banded with shale	2	8
Sandstone, grey, massive	2	3
Shale, dark, somewhat fissile	0	8
Coal—Milligan seam	2	6
Shale, black, carbonaceous, micaceous	0	2
Banded dark shale, light sandstone, and clay ironstone in about 12-inch bands	10	0
Sandstone, light grey, ripple-marked	2	0
Sandstone, light grey, hard, ripple-marked	1	6
Shale, having sandstone lenses	1	6
Shale, fine discontinuous band of white sandstone	5	10
Coal	1	2
Shale, somewhat friable	0	2
Sandstone, medium grain	0	8
Shale, dark, carbonaceous, jet bands	1	4
Clay ironstone	2	0
Shale, carbonaceous, plant remains	0	3
Coal, 3-inch jet on bottom	2	0
Shale, somewhat fissile, having jet bands	1	8

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)

Coal and clay ironstone concretions	0	9
Shale, arenaceous	1	0
Shale, arenaceous, clay ironstone	1	3
Clay ironstone	2	0
Shale, somewhat fissile, jet bands	0	3
Sandstone	1	0
Shale, clay ironstone nodules	1	6
Shale, carbonaceous, somewhat fissile, jet bands	0	6
Shale, fissile	0	6
Coal	0	7
Shale, carbonaceous	0	6
Shale	0	3
Sandstone, carbonaceous, medium grain	1	0
Clay ironstone	2	0
Sandstone, ripple-marked	0	10
Sandstone, coarse, massive	2	8
Sandstone, medium grain, micaceous	2	0
Shale	2	0
Coal	1	6
Clay ironstone	0	1

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Coal	0	4
Shale, coaly	0	5
Sandstone, dark, fine, a few ripple-marked layers, includes 4-inch clay ironstone band	6	0
Sandstone, fine, some ripple-marked layers	3	0
Sandstone, medium grain, massive, unsolved plant remains; good horizon marker	5	0
Shale	0	3
Coal	2	0
Shale, carbonaceous	0	3
Sandstone, medium grain, argillaceous, rootlets	6	0
Sandstone, coarse, white, in ripple-marked, thick-bedded, unsolved plant remains; good horizon marker	6	6
Sandstone, coarse, in flags, arenaceous shale beds	1	2
Coal	0	3
Sandstone, argillaceous, rootlets	1	8
Shale, arenaceous in thin beds	1	8
Sandstone, ripple-marked, in flags	4	0
Sandstone, fine, in ripple-marked flags, separated by very thin, sun-cracked, arenaceous shale; clay ironstone bands	8	6
Coal	0	8
Shale, coaly, and bands of coal	1	0
Shale, dark	2	4
Sandstone in ripple-marked flags 6 inches to 12 inches	2	5
Sandstone flags, weathering brown	2	5
Shale, arenaceous	3	0
Shale, dark	2	0
Sandstone, finely crossbedded	3	6
Sandstone, dark, argillaceous	0	3
Coal	0	3
Concealed	25	0
Sandstone, fine, brown weathering	8	0
Milligan seam—		
Coal +2 inches concretion .... 2 feet 1 inch		
Coal, jet .... 8 inches	2	9
Shale, black, micaceous	0	7
Sandstone, massive, ripple-marked	4	0
Sandstone, light grey, very fine dark bands	3	0
Shale, dark	1	0
Sandstone, argillaceous, massive	0	9
Sandstone, massive, argillaceous, clay ironstone	5	6
Shale, grey	4	4
Coal	1	0
Shale, dark, somewhat fissile	1	6
Sandstone in thin flags	3	6
Concealed	10	0
Sandstone, light grey, fine, in ripple-marked flags, roots	5	0
Coal .... 0 foot 8 inches		
Shale .... 0 foot ½ inch		
Coal and irregular concretions 7 inches thick .... 1 foot 11½ inches		
Coal, jet .... 0 foot 8 inches	3	4
Shale, grey	0	6
Sandstone, dark, fine	2	0
Sandstone, banded, argillaceous, in ripple-marked layers	7	0
Shale, grey	3	9
Shale, fissile, having jet bands	0	3
Shale, grey, having jet bands	1	0
Sandstone, banded	2	8
Shale, dark	2	3
Sandstone, massive	2	0
Clay ironstone	1	6
Sandstone, rather coarse, massive	12	0
Shale, black	1	8
Shale, black, having very thin sandstone lenses	3	6
Shale, black	1	8
Coal and many clay ironstone concretions	0	8
Shale, fissile, having plant remains and jet bands	0	3
Shale, grey, arenaceous	1	0
Shale, carbonaceous, fissile	0	6
Shale, arenaceous, friable	0	6
Shale, carbonaceous, fissile	0	5

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Shale, grey	0	3
Sandstone, fine	0	11
Shale, grey, having ironstone concretions	2	2
Sandstone, fine lined	1	0
Shale, arenaceous, some clay ironstone	0	2
Sandstone, fine	1	0
Shale, grey	0	6
Shale, fissile	0	6
Coal, canneloid	0	10
Shale, grey, somewhat fissile	0	8
Coal, canneloid	0	1½
Shale	0	4
Coal, jet	0	4
Shale, coaly	0	4
Coal, jet	0	2
Shale, dark, carbonaceous, somewhat fissile	3	6
Sandstone, fine grained, argillaceous	1	0
Sandstone in ripple-marked layers, a few bands arenaceous shale	2	6
Sandstone, fine, weathering brown	2	0
Shale, grey, arenaceous	0	6
Coal, irregular concretions 1 foot from bottom, bottom 12 inches chiefly jet	3	1
Shale, somewhat fissile, carbonaceous, seam jet	0	8
Sandstone, argillaceous	0	6
Shale, grey, arenaceous, friable	1	0
Sandstone, medium grain, fine crossbedding	6	8
Sandstone, fine, finely banded	1	3
Shale, arenaceous, having bands of fine sandstone	6	0
Shale, friable	3	0
Coal, Ferro Point seam	2	2
Shale, carbonaceous, friable, jet seamlets	1	6
Coal, jet	0	3
Shale, dark, fissile, jet	0	5
Shale, arenaceous	0	11
Sandstone, finely banded	1	0
Sandstone, medium grain, ripple-marked, yellow weathering	3	0
Sandstone, fine grained, argillaceous, fine lined, in 6-inch beds	5	4
Sandstone, very thinly banded with dark shale	2	6
Shale, grey, arenaceous, 3-inch clay ironstone band	2	0
Shale, fissile, jet bands	0	6
Shale, dark, arenaceous	0	8
Sandstone, finely lined, banded with shale	3	8
Sandstone, dark, argillaceous	1	2
Shale, dark grey, arenaceous	2	0
Shale, carbonaceous, fissile	0	5
Clay ironstone	0	9
Sandstone, medium grain, poorly sorted in flags, some layers ripple-marked	12	0
Shale, arenaceous	2	3
Coal, jet	0	4
Shale, dark, carbonaceous	0	8
Sandstone, dark, fine lined	1	2
Sandstone, medium grain, interbedded with friable shale; clay ironstone bands above; middle beds are ripple-marked layers of sandstone with thin beds sun-cracked shale; thin coal seam above ripple-marked layers	40	0
Shale, dark, somewhat fissile, jet bands	1	0
Concealed	8	0
Shale, arenaceous, clay ironstone concretions	1	0
Shale, friable, one jet band	0	7
Sandstone, fine, argillaceous in ripple-marked layers	5	0
Sandstone, coarse, massive, rare ripple-marked surfaces	35	0
Shale, grey, prostrate plants; narrow bands clay ironstone	4	0
Shale, carbonaceous, fissile, jet bands, prostrate stems	0	11
Coal, 1-inch parting 4 inches from top, 1-inch parting 1 inch from bottom	2	4
Sandstone, argillaceous, poorly sorted, upright stems	2	8
Shale, grey	2	0
Clay ironstone, banded with shale	1	8
Sandstone, argillaceous, burrows?	2	8
Shale, dark, friable	1	3

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Sandstone, fine, in ripple-marked layers, separated by thin shale bands	2	6
Clay ironstone, three thin bands friable shale	4	3
Shale, grey, friable; thin bands clay ironstone, fine wood debris	1	9
Sandstone, fine banded, and clay ironstone	1	0
Shale, dark, friable	2	0
Coal, jet	1	0
Shale, carbonaceous, fissile, prostrate fronds	0	3
Sandstone, fine, grey, in ½-inch layers, ripple-marked, thin shale layers sun-cracked, Dinosaur tracks	2	6
Shale, dark	0	8
Sandstone, fine, massive	0	6
Shale, black, somewhat fissile	0	10
Coal	0	3
Shale, arenaceous, fine, friable	0	7
Sandstone, fine, argillaceous, flaggy	0	7
Sandstone, medium grain, grey, in ripple-marked layers 1 inch to 4 inches thick, some thin shale bands and films, a few clay ironstone bands 1 inch to 3 inches	10	0
Shale, dark grey, arenaceous, friable, many 2-inch clay ironstone bands	11	0
Sandstone in ripple-marked layers	1	0
Sandstone, dark grey, poorly sorted, mottled, some vertical roots, stems, prostrate wood fragments	3	0
Sandstone, flaggy, much driftwood	2	0
Sandstone, light grey, in thick ripple-marked layers	3	9
Sandstone, fine, thin, ripple-marked layers, thin, dark shale bands	3	3
Sandstone, fine, in flags	3	0
Shale, arenaceous, in very thin flags, ripple-marked, thin bands, films black shale, sun-cracked, burrows, trails, some 2-inch clay ironstone bands	5	8
Shale, grey	0	8
Coal	0	7
Shale, carbonaceous, micaceous, jet	0	6
Sandstone, medium grained, light grey in 4-inch to 6-inch ripple-marked layers	8	0
Concealed	20	0
Shale, arenaceous, prostrate plants	0	9
Sandstone, fine, in ripple-marked layers; weathers brown, a few Dinosaur tracks	3	0
Shale, black, carbonaceous, fissile	0	8
Shale	1	0
Sandstone, fine, dark lined, irregularly platy	2	0
Shale, carbonaceous, fissile, fronds	1	0
Coal	0	8
Shale, friable	3	0
Clay ironstone and thin layers of friable shale	4	0
Shale, friable, beds of clay ironstone 2 feet thick	8	0
Shale, friable, ½-inch clay ironstone bands	4	6
Coal, jet	0	2
Shale and jet	2	0
Carbonaceous, somewhat fissile shale, jet	0	7
Shale, dark, finely friable	4	8
Sandstone, medium grain, finely crossbedded	0	4
Sandstone, with arenaceous shale	1	0
Sandstone, coarse, massive	2	2
Shale, friable, clay ironstone bands	3	10
Sandstone, medium grain, massive	1	6
Shale, arenaceous, friable	0	5
Sandstone, medium grain, massive	0	9
Shale, friable, clay ironstone bands	6	6
Coal	1	0
Shale	0	7
Coal	0	3
Shale, friable	0	11
Coal	0	3
Shale, dark, friable	0	5
Sandstone, fine grained, shale bands	2	6
Shale, friable, clay ironstone concretions	4	0
Clay ironstone	1	3
Shale, friable, clay ironstone concretions	3	3

North Shore, Fossil-tree Point to Grant Flat (C 1— C 2)—Continued

		Feet	Inches
Sandstone, fine, thin banded		2	3
Shale, friable		0	7
Sandstone, fine, thin bands shale near bottom		1	1
Shale, dark grey		1	0
Shale, black, friable		1	6
Sandstone, fine, argillaceous, erect stems		1	2
Shale, friable		1	6
Coal		0	9
Shale		0	3
Sandstone, fine, vertical stems?		2	0
Shale, arenaceous, friable, clay ironstone nodules, vertical stems?		3	6
Coal, 4 inches jet at base		1	0
Shale, friable, many roots and stems		2	6
Sandstone, massive, weathers yellow		2	0
Shale, a few rootlets, etc		0	6
Sandstone, massive, weathers yellow		0	5
Sandstone, fine, dark grey, ironstone concretions		2	4
Shale, grey, friable		1	2
Sandstone, fine, dark grey		1	3
Shale, finely friable		0	8
Clay ironstone		0	2
Shale, grey		1	2
Clay ironstone		0	3
Sandstone, fine, ripple-marked on some surfaces, weathers brown		1	0
Sandstone, fine, argillaceous		2	8
Shale, grey		1	9
Shale, carbonaceous, much jet, plant remains		1	1
Coal, having thin parting		1	7
Shale, carbonaceous, fissile		0	3
Sandstone, coarse, grey		4	6
Concealed		30	0
Sandstone, fine, uneven fracture and in 1-inch to 2-inch bands		6	0
Sandstone, coarse		1	2
Sandstone, fine, slightly argillaceous		1	4
Sandstone, coarse, massive		1	8
Index seam—	Inches		
Coal	5		
Shale	6		
Coal (3-inch jet on bottom)	11	1	10
Shale		3	0
Sandstone		2	6
Shale		6	0
Sandstone		1	6
Shale, friable		5	0
Sandstone, coarse, grey		10	0
Shale		1	6
Shale, carbonaceous, and coal		0	8
Shale		0	6
Sandstone, coarse		0	6
Shale, arenaceous		2	0
Shale		2	0
Shale, arenaceous, erect stems?, clay ironstone		4	0
Sandstone, coarse, massive, thick bedded		4	6
Coal		0	4
Shale		0	4
Coal		1	2
Shale and clay ironstone		2	0
Sandstone		4	0
Shale, carbonaceous, and coal		1	0
Sandstone		3	0
Clay ironstone		0	6
Sandstone, crossbedded on large scale, one or two ripple-marked layers		3	6
Clay ironstone		1	0
Sandstone, coarse, massive		5	0
Shale		5	0
Sandstone		1	6
Clay ironstone		1	0
Coal—Grant seam		5	8

North Shore, Fossil-tree Point to Grant Flat (C 1—C 2)—Continued

	Feet	Inches
Concealed	30	0
Clay ironstone	1	0
Shale	1	0
Coal—Riverside seam	2	10

Aylard Creek Section (E 1—E 3)

	Ft.	In.	Feet	Inches
Shale of Moosebar formation				
Concealed			5	0
Sandstone, massive			15	0
Shale			1	6
Sandstone, massive			4	0
Shale, arenaceous			2	5
Coal—Superior seam			2	0
Shale, fissile, with jet bands			0	2
Sandstone, coarse, massive			2	3
Shale			0	5
Sandstone, fine, massive			2	4
Shale, dark, fissile, many jet bands			2	8
Shale, arenaceous			2	0
Concealed			3	0
Shale, arenaceous			1	0
Sandstone, fine, thin, irregular bands and films of shale			3	0
Shale			0	10
Coal, irregular 3-inch parting			1	3
Shale, friable			2	0
Concealed			60	0
Sandstone, massive			0	6
Shale			4	0
Trojan seam—	Ft.	In.		
Coal	0	3		
Sandstone	0	2		
Coal	1	11		
Shale	0	6		
Coal	1	6		
Bone coal	0	4	4	8
Shale, black, carbonaceous, fissile			0	6
Shale, dark			0	9
Sandstone, fine			1	0
Shale			1	0
Concealed			82	0
Sandstone, brown weathering, fine, in 5-inch beds separated by 2-inch shale beds			4	0
Coal, Titan seam			4	0
Concealed			2	0
Sandstone, brown weathering, fine, in 5-inch beds separated by 2-inch shale beds			3	8
Shale, jet above			2	10
Clay ironstone and carbonaceous shale			1	6
Shale, arenaceous, clay ironstone concretions			1	6
Clay ironstone			1	3
Shale, arenaceous			0	3
Clay ironstone			3	0
Concealed			5	0
Shale			3	4
Shale, black, carbonaceous, fissile			1	6
Shale, arenaceous			1	0
Shale			0	8
Shale, carbonaceous			0	8
Shale			2	6
Sandstone, medium grain, massive			4	7
Falls seam—	Ft.	In.		
Coal	0	8		
Canneloid coal	1	0		
Coal	1	11	3	7
Sandstone and shale in 1-inch to 5-inch beds			5	0
Clay ironstone			0	5
Shale			0	4
Shale, dark, carbonaceous			0	5
Coal			0	2

Aylard Creek Section (E 1—E 3)—Continued

	Feet	Inches
Shale, dark, carbonaceous	1	0
Concealed	3	0
Sandstone, fine grained	3	0
Sandstone, massive, argillaceous, in part altered to arenaceous clay ironstone	3	2
Sandstone	1	9
Shale, arenaceous	5	0
Shale, dark	10	0
Sandstone, fine grained	3	6
Shale, arenaceous	4	8
Shale, clay ironstone bands	13	0
Clay ironstone	3	3
Shale	1	10
Coal, large concretions, and 1 foot 3 inches canneloid coal	2	8
Sandstone, fine, massive, thick layered	10	6
Sandstone in thin flags, films of shale	3	8
Sandstone, fine, massive	1	2
Shale, dark	3	2
Shale, arenaceous	1	2
Shale, dark	2	0
Coal	0	2
Shale	0	9
Clay ironstone	2	8
Shale	1	4
Clay ironstone	0	10
Sandstone, coarse	1	0
Shale	3	6
Sandstone, massive	1	3
Coal, pyrites in bottom bench	2	0
Concealed	9	0
Sandstone, massive	2	6
Shale, arenaceous	0	3
Sandstone, fine, massive	3	0
Shale, friable, jet bands	1	11
Coal, jet	1	11
Shale, carbonaceous, above, plant remains	2	2
Sandstone and shale, banded	2	0
Shale, arenaceous	7	6
Shale, black, carbonaceous	0	4
Coal	0	5
Bone coal, granular	0	3
Coal	0	6
Shale, fissile, and coal	0	6
Shale	3	3
Sandstone, fine, massive	0	7
Shale, friable	2	4
Coal	0	6
Shale, carbonaceous, fissile	0	8
Sandstone, fine, with bands of shale	3	0
Sandstone, medium grain	2	10
Shale	9	0
Coal	9	0
Shale	0	2
Coal, jet	0	2
Shale	1	6
Sandstone, fine, having thin shale films	3	9
Shale, grey	0	9
Coal	0	6
Shale, fissile, prostrate fronds	0	5
Coal	0	6
Sandstone, very fine, argillaceous	0	8
Sandstone, medium grain	3	0
Shale, dark, micaceous, two thin bands jet at top	1	9
Sandstone, medium grained, in thick ripple-marked layers	3	0
Sandstone, fine, argillaceous, very thin bands and films shale	7	9
Shale, black, finely friable, some jet bands	0	10
Coal	0	8
Sandstone, medium grain	0	2
Shale, dark, friable, some plant remains	1	3
Sandstone, medium grain in poor flags; several ripple-marked surfaces	7	0

Aylard Creek Section (E 1—E 3)—Continued

	Feet	Inches
Sandstone, fine, argillaceous, coarsely friable in fracture	4	6
Shale, grey, friable	1	9
Clay ironstone, massive	5	0
Sandstone, medium grain, massive	8	0
Sandstone, fine, argillaceous, friable; plant remains; thin clay ironstone bands	1	6
Shale, carbonaceous, fissile, many fine jet bands	1	5
Sandstone, fine, argillaceous, massive	2	3
Coal, small concretions near top; Little Mogul seam	3	0
Shale, black, arenaceous	0	2
Sandstone, fine, argillaceous, ripple-marked on some surfaces. Thin films shale	10	0
Coal, scattered large (4 inches) concretions near top; Mogul seam	3	10
Sandstone, medium grain, dark, argillaceous, micaceous	1	6
Sandstone, grey, medium	9	0
Sandstone, medium, massive, brown weathering	5	0
Shale	2	3
Shale, carbonaceous, sheeted; jet bands	0	4
Coal	0	7
Shale	0	7
Coal	0	5
Shale with pyrites	0	6
Coal	0	4
Sandstone, fine, micaceous	0	6
Sandstone, fine, ripple-marked in thick to medium flags	5	8
Clay ironstone, massive	0	9
Sandstone, coarse, weathering in knobs and ill-defined layers	2	0
Sandstone, medium grain, in 2-inch flags	1	0
Sandstone, coarse, massive, unsolved plant remains	1	0
Sandstone, coarse, thick layered	2	2
Sandstone, coarse, massive, unsolved plant remains; good horizon marker	2	6
Sandstone, fine, ripple-marked flags	0	10
Coal, concretions near bottom	1	8
Sandstone, fine, dark, carbonaceous	0	3
Sandstone, medium grain, brown weathering, massive	3	0
Sandstone, fine, in ripple-marked flags	4	0
Sandstone, coarse, thickly irregularly layered, unsolved plant remains; good horizon marker	3	3
Sandstone, ripple-marked, thin beds films shale, thin flags below, thick flags above	3	2
Coal	0	5
Shale, dark, carbonaceous	1	3
Sandstone, thick, irregularly bedded, some vertical roots or stems.	1	8
Sandstone, fine, in thin ripple-marked flags	12	8
Shale, dark, some thin sandstone bands	9	3
Coal	0	9
Sandstone, fine, ripple-marked flags; thin shale bands and films; sun-cracks	10	6
Sandstone, fine	1	6
Shale, grey	1	8
Shale, dark, fissile, jet bands	0	10
Coal, having two thin partings	0	8
Sandstone, thickly layered, clay ironstone	3	0
Sandstone, fine, grey, argillaceous, prostrate plant remains	10	6
Shale, dark	0	6
Coal, irregular, small concretions up to 4 inches. Castle Point seam	3	9
Shale, black, carbonaceous, fissile, plant remains	1	6
Sandstone, medium grain, tree trunks prostrate	1	6
Shale, arenaceous, irregular lenses clay ironstone	4	6
Sandstone, fine, argillaceous	3	0
Sandstone, fine, in thin ripple-marked flags	4	8
Shale, dark, somewhat fissile	0	7
Coal, Milligan seam	2	10
Shale, black, micaceous	0	5
Sandstone, fine, ripple-marked, in flags; thin bands films dark shale; flags 2 inches to 3 inches above, very thin below	7	4
Shale, black, carbonaceous, jet bands	1	4
Sandstone, fine, dark	3	6
Sandstone, fine lined, brown weathering, in flags above	10	0
Shale, arenaceous, friable	3	11

Aylard Creek Section (E 1—E 3)—Concluded

	Feet	Inches
Coal, small irregular parting	1	0
Sandstone, fine, thin layers, dark shale; 100 feet to west changes to shale with fine sandstone bands, i.e., proportion shale greater than sandstone	8	0
Sandstone, fine, mottled, poorly sorted, finely friable	2	0
Sandstone, massive, inclined beds lower strata on either side; estimated	10	0
Sandstone, in thick layers, a few thin beds shale	8	0
Coal, jet	0	3
Sandstone, dark, argillaceous	0	6
Sandstone, white, fine grain, thin flags; roots	4	0
Sandstone in ripple-marked thin flags; also films and very thin bands black shale	1	10
Coal, including concretions up to 2 feet 6 inches, 8 inches jet coal on bottom	3	11
Shale, arenaceous	0	8
Sandstone, medium grain, thick bedded; some ripple-marks	8	9
Shale, arenaceous	4	0
Sandstone, dark, jet bands	0	6
Sandstone, medium grain, massive	4	0
Coal, 4-inch parting in middle	0	9
Shale, sandstone, fine banded and lens-like	4	6
Shale, dark, somewhat fissile	1	4
Coal and 2-inch parting	0	7
Shale, dark, jet	0	1
Sandstone, fine, argillaceous, a few vertical roots or stems	3	6
Shale, grey	0	10
Sandstone, massive, weathering yellowish	5	0
Sandstone, massive, +clay ironstone	8	9
Shale, black	0	6
Coal, canneloid	0	10
Shale, black, clay ironstone band	2	0
Coal, jet	0	3
Shale, black	1	0
Shale, dark, thin sandstone bands	1	0
Coal, including in middle large concretions up to 2 feet	3	0
Shale, dark, thin sandstone bands	3	0
Sandstone in thick flags, some ripple-marked surfaces; weathers brown	4	10
Sandstone, fine, in ripple-marked flags	3	9
Sandstone, fine, argillaceous, thin bands of clay ironstone	2	0
Shale, arenaceous	1	5
Shale, grey	2	1
Coal, small concretions, Ferro Point seam	2	2
Shale, grey, some jet; prostrate plant remains	1	10
Sandstone, films of shale	1	4
Sandstone, fine, films shale, weathers yellowish	3	8

Section in Draw West of Mogul Creek (F)

Coal, Little Mogul seam	3	3
Shale, arenaceous	10	0
Coal, Mogul seam	4	4

Sections on Mogul Creek (G 1—G 2)

Coal	2	4
Shale	1	0
Sandstone, fine, argillaceous	10	0
Concealed	8	0
Shale, arenaceous, friable	6	0
Sandstone, fine, hard	6	9
Coal	1	0
Shale, dark	2	11
Shale, arenaceous	3	9
Shale, carbonaceous	0	3
Coal	0	4
Sandstone, medium grained	5	6
Sandstone, massive, medium grained, coarse	3	9

Sections on Mogul Creek (G 1—G 2)—Concluded

	Feet	Inches
Coal	0	3
Shale	1	6
Coal	1	10
Shale, carbonaceous	1	0
Sandstone	5	0
Shale	1	6
Coal, canneloid above	1	9
Shale, dark	2	7
Sandstone, fine	1	2
Shale, arenaceous	1	6
Coal	0	4
Shale, carbonaceous, jet bands	0	9
Shale, arenaceous	1	1
Sandstone, medium grain	1	11
Shale	1	9
Sandstone, medium grain	2	2
Shale, dark	3	0
Concealed	6	0
Sandstone, massive	8	0
Coal	0	7
Shale	0	3
Concealed	2	0
Sandstone	6	8
Sandstone, fine, films dark shale	11	0
Coal	1	0
Concealed	1	0
Sandstone, fine	10	0
Shale, arenaceous	3	6
Shale, dark	3	2
Clay ironstone	4	3
Shale, arenaceous	1	7
Sandstone, fine, thin, flaggy	2	0
Shale, dark	1	10
Coal, Little Mogul seam	2	8
Shale	2	0
Sandstone, fine	9	0
Mogul seam— Ft. In.		
Coal 0 6		
Concretion 1 2		
Coal 2 8	4	2
Sandstone, fine	4	0
Shale, dark	0	9
Coal	0	6
Sandstone, fine	2	3
Coal	0	7
Shale, carbonaceous, fissile	0	5
Coal	0	3
Shale, dark	0	3
Coal	0	7
Shale, dark	1	5
Sandstone	4	0
Sandstone, massive	3	6
Shale	2	6
Coal	0	1
Shale	4	6
Sandstone, fine	3	1
Coal	0	5
Shale, dark, carbonaceous	0	4
Concealed	1	0
Sandstone, massive	6	0

Moosebar Creek Section (H 1—H 2)

Shale of Moosebar formation		
Sandstone having scattered pebbles	1	6
Sandstone, thick bedded, estimated	9	0
Shale, arenaceous, estimated	1	6
Sandstone, grey, fine, estimated	8	0
Shale, dark, arenaceous	1	0
Shale, black, blocky	1	6

Moosebar Creek Section (H 1—H 2)—Continued

	Ft.	In.	Feet	Inches
Shale, dark, somewhat fissile			0	3
Coal, Superior seam			3	8
Sandstone, argillaceous, in thick beds (1 foot to 2 feet), surfaces of some beds ripple-marked			15	0
Sandstone, fine, argillaceous, thin bedded			2	8
Shale, arenaceous, somewhat fissile			0	6
Coal			0	7
Shale, carbonaceous, fissile			0	5
Shale, shaly 3-inch clay ironstone band near base			7	6
Coal			0	8
Shale, carbonaceous, fissile			0	4
Sandstone, medium grain, massive			3	2
Sandstone, fine			3	3
Shale, arenaceous, 3-inch clay ironstone band at top			2	5
Shale, carbonaceous, fissile			0	8
Coal			0	3
Shale, fissile			0	3
Coal			0	3
Shale, arenaceous			4	0
Sandstone, massive			11	0
Sandstone, fine			2	0
Coal, 1-inch parting 4 inches from top, ½-inch parting 4 inches from bottom			1	5
Shale, carbonaceous, arenaceous			0	10
Sandstone and thin bands of arenaceous shale			9	6
Shale, dark, a few clay ironstone bands			13	0
Coal			1	0
Sandstone			0	4
Coal			0	6
Sandstone			0	3
Coal			0	5
Shale, carbonaceous, fissile, jet bands, prostrate fronds			3	0
Sandstone, fine, argillaceous, rootlets			2	0
Shale, dark, some clay ironstone			6	6
Sandstone, fine, massive, weathering brown			1	6
Coal			0	8
Shale			0	3
Sandstone, argillaceous			0	9
Sandstone, massive, weathering brown			1	0
Shale			0	6
Trojan seam—				
Coal	2	1		
Sandstone	0	4		
Coal	1	6	3	11
Shale, black, carbonaceous, some jet, fissile			0	9
Sandstone, fine			2	6
Shale, dark			6	0
Sandstone, fine, massive, brown weathering			2	6
Shale			6	0
Sandstone, fine, massive, brown weathering			1	4
Shale, arenaceous			5	6
Sandstone, massive			0	9
Shale			2	0
Sandstone, massive, weathering brown			7	6
Shale			0	5
Shale, carbonaceous, fissile			1	0
Coal			1	8
Clay ironstone			3	9
Shale			1	6
Shale, hard			1	8
Shale, arenaceous			1	10
Shale, hard, carbonaceous			0	8
Coal			0	3
Shale			2	3
Shale, hard			2	0
Shale			1	8
Clay ironstone			4	3
Coal, 1-inch parting in middle			0	7
Shale			1	10
Coal			0	5
Shale, somewhat fissile				2

Moosebar Creek Section (H 1—H 2)—Continued

	Feet	Inches
Sandstone, fine, in thin flags, shale films	3	4
Shale, dark	1	0
Shale, somewhat fissile, two jet bands	1	2
Sandstone, fine, massive	3	6
Shale	1	0
Coal	0	4
Sandstone, fine, shale lenses	1	7
Shale and clay ironstone	4	0
Coal	0	7
Shale, some coal and canneloid coal	1	8
Sandstone, hard, argillaceous	0	8
Shale	0	8
Clay ironstone	1	4
Shale	1	0
Coal, canneloid	0	10
Shale	0	6
Sandstone, massive	1	3
Coal	0	5
Shale	0	10
Clay ironstone	1	1
Shale and thick beds clay ironstone	6	0
Shale, carbonaceous, somewhat fissile; has jet bands	1	0
Coal	0	4
Shale, somewhat fissile, and having jet bands	1	0
Clay ironstone	3	0
Shale, jet bands	0	11
Clay ironstone	1	3
Shale	0	2
Clay ironstone	1	3
Shale	6	6
Clay ironstone	0	6
Shale	1	10
Clay ironstone	1	0
Shale	1	10
Coal	0	2
Shale	1	0
Shale and thin clay ironstone bands	2	8
Clay ironstone	3	3
Shale, dark	0	8
Titan seam, correlated with— Ft. In.		
Coal 2 11		
Shale and argillaceous sandstone 0 9		
Coal 0 7		
Sandstone 0 2		
Coal 0 7	5	0
Shale, some jet	1	7
Sandstone, fine grained, argillaceous, altered in places to arenaceous clay ironstone	9	6
Shale	1	6
Coal	0	7
Shale, arenaceous	1	2
Clay ironstone	1	5
Sandstone, fine grained, thin beds of shale	2	0
Shale, arenaceous	2	0
Sandstone, fine grained	1	7
Shale, arenaceous	3	6
Shale	4	0
Coal	0	3
Clay ironstone	6	0
Coal, 2-inch parting 8 inches from top, 8 inches dull coal on bottom; large concretions; correlated with Falls seam	2	10
Shale, coaly	0	5
Clay ironstone and shale	3	4
Shale	2	0
Coal, canneloid	0	10
Shale, arenaceous	1	0
Clay ironstone	1	2
Shale	1	8
Clay ironstone	0	8
Shale, somewhat fissile, jet bands	1	5
Shale, and a few clay ironstone bands	19	4

Moosebar Creek Section (II 1—II 2)—Continued

	Feet	Inches
Clay ironstone	4	0
Shale, dark	1	0
Shale, dark, a few jet bands	0	8
Coal	1	0
Shale, fissile	0	4
Shale, dark	0	3
Clay ironstone	4	9
Shale	0	7
Shale, dark, fissile	0	4
Coal	0	3
Shale	1	9
Canneloid coal	1	0
Coal	1	0
Shale, carbonaceous, jet bands	1	0
Sandstone, fine, argillaceous	1	5
Clay ironstone	0	4
Shale, dark, somewhat fissile	1	8
Sandstone, fine grained	2	10
Sandstone, ripple-marked in thin layers; very thin beds and films dark shale	2	2
Sandstone and shale, very thin bedded	0	9
Coal	0	2
Shale, dark	2	0
Coal and 4-inch parting coaly shale	1	0
Shale, coaly	0	5
Shale, fissile	0	8
Coal	0	5
Shale	2	0
Sandstone, argillaceous, brown weathering	1	2
Shale	1	8
Sandstone, argillaceous, brown weathering	2	0
Shale	8	0
Sandstone, argillaceous	1	0
Clay ironstone	0	9
Sandstone, argillaceous	1	8
Coal, large concretions	1	4
Shale, jet bands	0	5
Sandstone, fine grained and lined	1	5
Shale and jet bands	9	0
Shale, dark, carbonaceous	0	3
Coal, canneloid above	0	6
Shale	1	6
Sandstone, fine grained	3	8
Shale	6	0
Concealed	4	0
Shale	3	0
Sandstone, fine grained	17	0
Shale	1	0
Coal	0	11
Shale	0	8
Concealed	4	0
Sandstone in thin layers separated by thin shale bands	6	6
Shale	2	6
Coal	3	4
Shale	0	8
Sandstone	2	8
Shale and large clay ironstone concretions	7	0
Coal	0	4
Shale	0	6
Coal	1	1
Sandstone, fine grained, massive	7	0
Inaccessible at high third falls, estimated	44	0
Coal inaccessible, estimated	2	0
Inaccessible, estimated	16	0
Coal inaccessible, estimated	1	0
Inaccessible, estimated	26	0
Shale, carbonaceous, somewhat fissile, jet bands	0	6
Shale, arenaceous, carbonaceous, somewhat fissile	0	6
Sandstone, argillaceous, massive, prostrate plant remains	0	10
Shale, arenaceous, partly altered to arenaceous clay ironstone	2	11

Moosebar Creek Section (H 1—H 2)—Continued

	Ft.	In.	Feet	Inches
Shale			1	0
Castle Point seam, correlated with—				
Coal	0	6		
Clay ironstone	1	0		
Coal	0	6		
Shale	0	6		
Coal	0	10		
Shale	0	7		
Coal	0	5	4	4
Shale, carbonaceous, fissile, jet bands			0	9
Shale and clay ironstone			4	6
Concealed			5	0
Sandstone, fairly coarse, massive			10	0
Shale			0	6
Coal, correlated with Milligan seam			2	5
Sandstone, argillaceous, fine, thin bedded or layered			8	0
Shale			1	11
Sandstone, massive			7	6
Shale, arenaceous			2	10
Shale			0	10
Coal			0	10
Sandstone and thin films black shale			3	0
Sandstone, fine, thick banded			3	0
Sandstone, thin layered			2	6
Shale, arenaceous, bedded; some clay ironstone and upright tree trunks			10	0
Concealed			10	0
Sandstone, massive			3	0
Sandstone			8	0
Shale			2	6
Coal			1	1
Shale, arenaceous			5	10
Coal, canneloid			0	2
Coal, jet			0	5
Shale, arenaceous, prostrate leaves			1	7
Shale, jet			0	6
Sandstone, medium grain, massive			5	5
Shale			0	9
Shale, black, carbonaceous			0	6
Coal, canneloid			0	10
Shale, black			0	7
Coal, canneloid			0	2
Shale			0	3
Sandstone, fine, argillaceous			1	4
Shale			0	3
Coal			0	4
Shale, carbonaceous, prostrate plants			1	0
Sandstone, fine, argillaceous, thin layered			1	1
Shale, dark			0	8
Coal			1	6
Coal and shale			0	7
Coal			0	8
Shale, black			0	11
Sandstone, fine, argillaceous, prostrate plants			4	0
Shale, arenaceous			5	0
Shale, dark			1	9
Coal and 1-inch parting			1	2
Shale, dark			1	0
Shale, arenaceous			2	2
Shale, carbonaceous, somewhat fissile, jet			1	5
Sandstone, fine, massive, prostrate fronds			0	8
Sandstone, fine, massive			7	6
Shale and clay ironstone			2	6
Shale, dark, jet bands			2	0
Sandstone, medium grain			9	0

Moosebar Creek Section (H 1—H 2)—Concluded

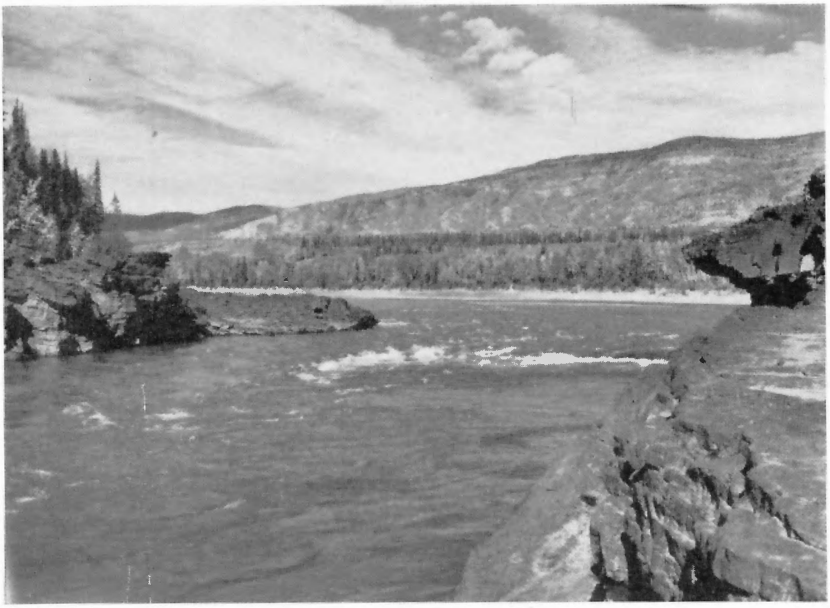
	Feet	Inches
Shale, arenaceous	1	0
Sandstone, medium grain, massive	13	0
Shale	2	0
Coal	1	1
Shale	5	3
Shale, arenaceous	2	0
Sandstone, fine, massive, irregular bands of shale	4	0

South Bank of Peace River at Contact Point (J 1—J 2)

Shale of the Moosebar formation		
Sandstone, having scattered small pebbles up to 3 inches	1	6
Sandstone, very fine, argillaceous, and thin bands of sandstone	11	0
Shale	6	6
Clay ironstone	3	6
Sandstone, and shale, very thin banded	2	0
Shale	0	10
Coal, Superior seam	2	8
Shale, black, carbonaceous	0	7
Sandstone and shale in thick bands	2	8
Sandstone and shale, thin banded	1	6
Coal	0	11
Shale	1	5
Shale and sandstone in thin, discontinuous bands	2	3
Coal and irregular parting	0	9
Shale, fissile	0	2
Shale	0	6
Sandstone, fine, carbonaceous, micaceous, argillaceous	1	10
Sandstone, thin bedded above, thick below, ripple-marked, thin shale bands	5	4
Shale, clay ironstone bands	2	3
Shale, fissile	0	7
Shale, somewhat fissile	0	6
Coal	0	1
Shale	1	2
Sandstone, fine, in thin layers; films of shale	4	0
Sandstone, fine, in thin ripple-marked layers; films of shale	4	8
Sandstone, fine, argillaceous	0	6
Coal	1	3
Shale, dark, carbonaceous, fissile, jet bands	0	6
Sandstone, thick layered, a few ripple-marked surfaces	3	10
Sandstone, thick layered, thin shale bands	3	0
Sandstone, fine, argillaceous, and shale, thin banded	3	9
Shale, arenaceous, clay ironstone bands	3	6
Concealed	3	0
Shale and 6-inch clay ironstone bands	4	0
Coal	2	8
Shale, arenaceous, and sandstone bands	4	6
Coal, Trojan seam	3	6
Shale, dark, carbonaceous, many jet bands	0	9
Shale, grey	1	0
Concealed	9	6
Sandstone and bands of arenaceous shale	10	0
Coal	0	7
Shale	0	4
Coal	0	9
Shale, carbonaceous, fissile, jet bands, prostrate plants	2	8
Clay ironstone	4	0
Shale, carbonaceous, fissile	1	0
Sandstone, very fine, argillaceous, layered	1	7
Shale, carbonaceous, jet bands	0	3
Sandstone, argillaceous	1	8
Shale, arenaceous	1	10
Sandstone, fine, argillaceous	0	10
Shale, dark	1	6
Coal	0	5
Shale	0	2
Shale, dark, arenaceous	2	0
Coal	1	9
Shale, dark, clay ironstone concretions	2	8

South Bank of Peace River at Contact Point (J 1—J 2)—Concluded

			Feet	Inches
Coal			1	8
Shale, clay ironstone bands			3	8
Sandstone, fine, argillaceous, massive above, having shale bands below			3	6
Shale, dark, arenaceous, fine bands of sandstone			1	6
Coal, canneloid			0	2
Coal			0	5
Sandstone			0	4
Shale			0	2
Sandstone, fine, massive, argillaceous			1	3
Shale, plant remains			1	6
Shale, arenaceous, plant remains			0	6
Shale			1	6
Shale, dark			1	0
Titan seam, correlated with—	Ft.	In.		
Coal	2	8		
Clay ironstone	1	0		
Coal	2	6	6	2
Sandstone, fine			1	0
Coal, jet			0	2
Shale, dark grey			1	0

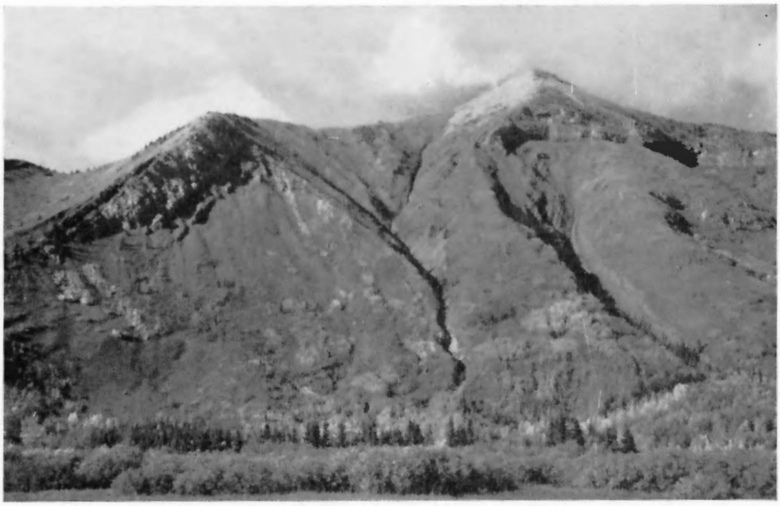


A. Entrance to Peace River Canyon. High terraces on far side of river. Butler Range in background (93500). (Page 14.)

B. Rocky Mountain front from lower slopes of Pardonet Hill (85364). (Page 15.)

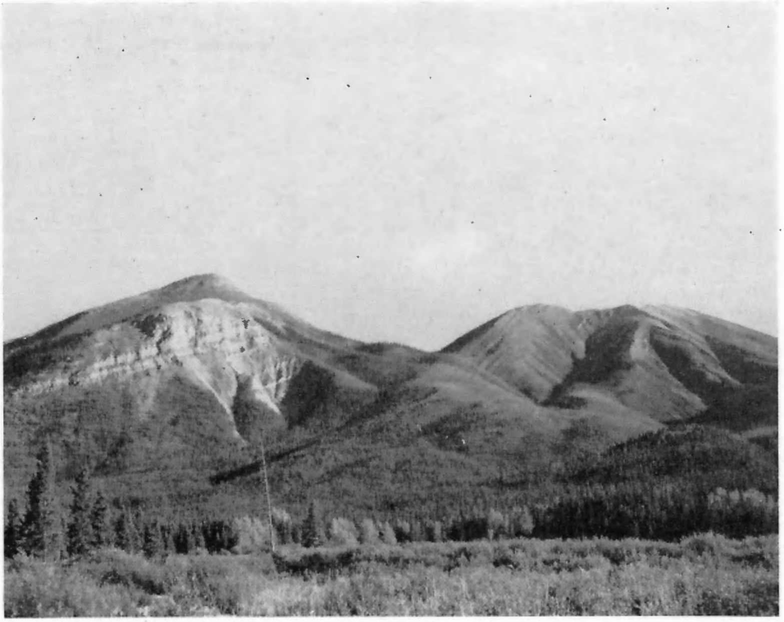
PLATE III

A. Permian chert, north side Beaver River, 38 miles north of Liard River (93455). (Page 33.)



B. Mount Wright, north side Halfway River. First Gully a little to left of plate; Second Gully near centre; Third Gully to right of Second Gully; and Fourth Gully a little to right of plate (96689). (Pages 44, 45, 49, 56, 120.)

PLATE IV



A. Mount Hage, south side Sikanni Chief River. Hage Creek to right of centre. McTaggart Creek, right side of plate (96678). (Pages 36, 50, 57.)

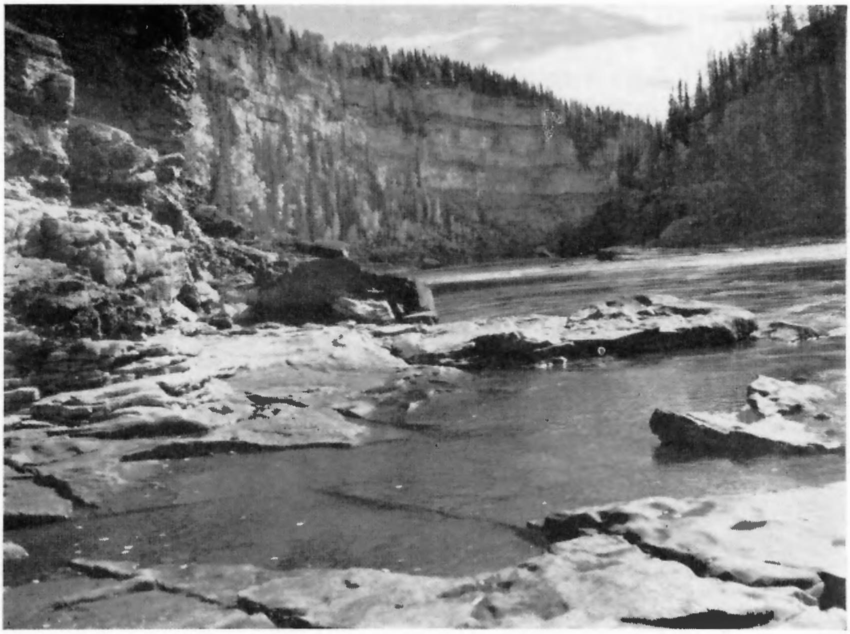
B. Exposures of Liard formation, 3 miles east of Hades (Hell) Gate (93469). (Page 43.)

PLATE V

A. From left, base of Bullhead group on Tepee Rocks Spur; Fernie and Pardonet beds in Tepee Rocks Coulée; "Grey beds" on Brown Hill, centre, and in Folded Hill Valley at right (85390). (Page 48.)

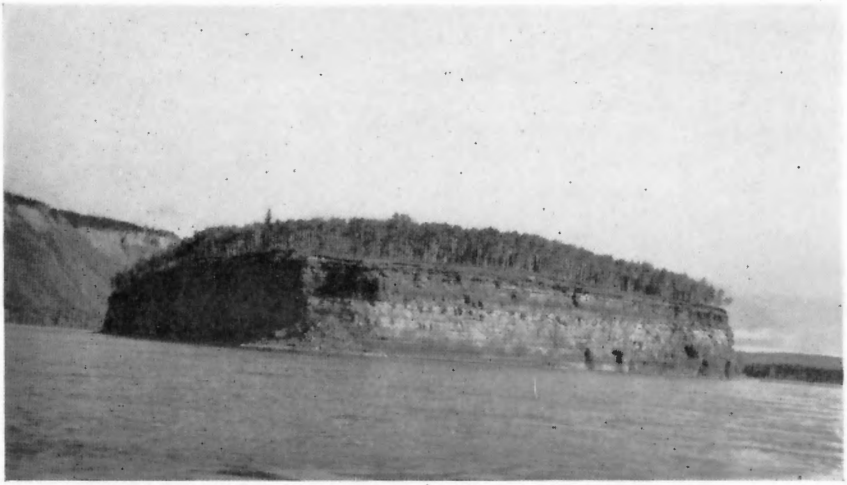
B. Pardonet Hill (85370). (Pages 49, 53.)

PLATE VI

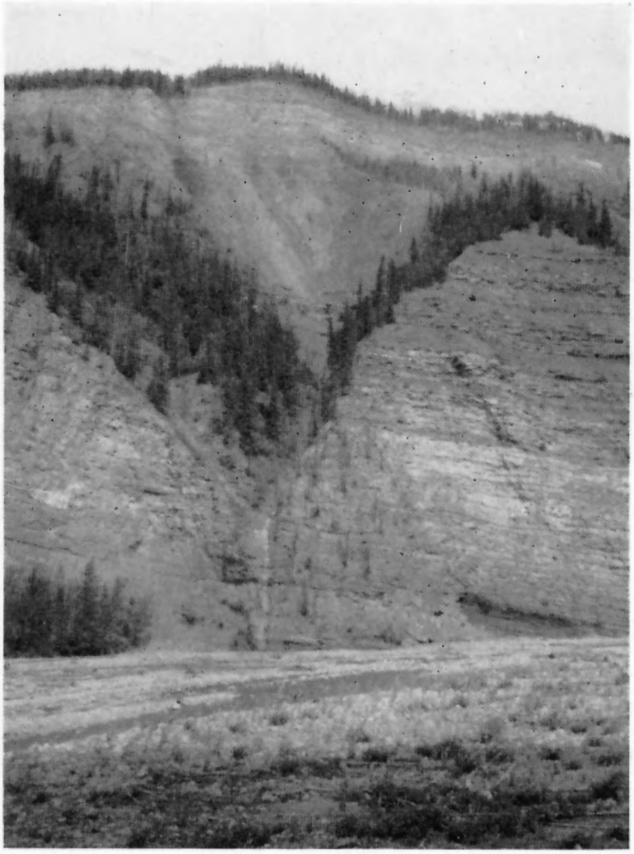


A. Upper part Dunlevy formation (lower part of non-marine Bullhead) near head of Peace River Canyon (93501). (Page 64.)

B. Peace River Canyon above mouth of Gething Creek; upper part Dunlevy formation (lower part of non-marine Bullhead) in foreground; Gething formation or upper part of non-marine Bullhead in background (93517). (Page 65.)



A. Gates formation at "The Gates", Peace River (82869). (Page 76.)



B. Scatter formation, north side Scatter River, 1½ miles west of the Liard (93466). (Page 90.)

A. Quarry in Dunvegan formation, Alaska Highway, about 20 miles north of Fort St. John (93294). Photo by C. O. Hage, Geological Survey. (Page 98.)

B. Entry Peace River mine, near Larry Creek (96669). (Page 168.)

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