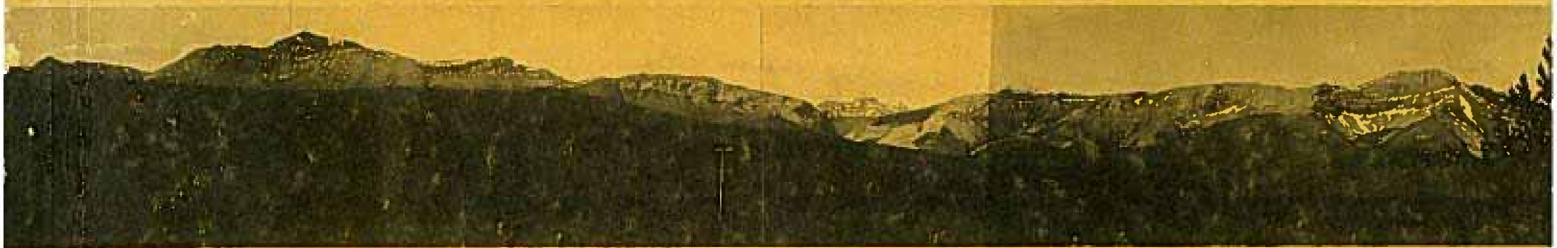

Edmonton Geological Society

EIGHTH ANNUAL
FIELD TRIP
GUIDEBOOK

Cadomin, Alta

August, 1966

Cover photo: Nikanassin Range and McLeod Gap from Highway 47 near Trapper Creek

EDMONTON GEOLOGICAL SOCIETY

Guidebook
Eighth Annual Field Trip

to

CADOMIN, ALBERTA
August, 1966

Edited by:
G. D. Williams
University of Alberta
Edmonton

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- Preface -

The Coal Branch region of the central Alberta Foothills provides a locale in which geologists can examine in outcrop virtually the entire stratigraphic section found beneath the adjacent Plains. Rocks of Palaeozoic and Mesozoic age which are the reservoirs in oil and gas fields of western Alberta, are exposed in the mountains of the Nikanassin and Front Ranges and surrounding Foothills, where their facies relationships may be studied in detail.

Cadomin was the site of the first field trip organized by the Edmonton Geological Society in 1959. The Society felt that a second visit was warranted after an absence of seven years. It is hoped that this Guidebook will provide a record of the geology of the area for the profession at large as well as for those who were able to participate in the actual field trip.

To those companies which helped in organizing the trip in so many diverse ways the Field Trip Committee and the Society in general express their sincere thanks and appreciation.

As Editor, I wish to record here my gratitude to the authors, who supplied manuscripts, often with very little notice, without the usual editorial arm-twisting. I also wish to acknowledge the facilities, and secretarial and drafting services provided by the Department of Geology, University of Alberta, Edmonton.

G. D. W.
July 27, 1966

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The following table is a listing of all the exploratory wells drilled for oil or natural gas in the Cadomin area to July 15, 1966.

Location	Well Name	Year Drilled	Total Depth	Formation Bottomed In	Status
5-36-47-22 W5M	Gulf et al. Mountain Park # 5-36	1955-56	11,200'	Banff ?	Capped Triassic gas well with an I. P. of 13 MMcf/d
12-30-46-18 W5M	British American et al. Lovett River #12-30	1957-58	12,500'	Luscar ?	Capped Mississippian gas well with a calculated I. P. of 24 MMcf/d
5-7-48-22 W5M	British American et al. Kaydee #5-7	1960	14,058'	Fernie	Abandoned
14-12-48-23 W5M	British American et al. Kaydee #14-12	1959	10,031'	Unknown - Logs incomplete	Abandoned with fish in hole
10-2-47-19 W5M	British American et al. Lovett River #10-2	1959-60	13,442'	Shunda	Abandoned
10-3-49-21 W5M	Imperial Coalspur #1	1944-45	12,955'	Mississippian	Abandoned
8-30-49-19 W5M	Southern Production Atlantic A-2-1	1954	8,385'	Cretaceous	Abandoned
10-31-44-19 W5M	Imperial et al. Chungo #10-31	1960	13,150'	Mississippian	Abandoned

RECOLLECTIONS OF THE ALBERTA COAL BRANCH

J. Roberts
Chapman Camp, B.C.

In the following pages I have tried to put down my recollections of the Alberta Coal Branch where I worked and resided in the village of Cadomin for something over thirty years. I went to the Coal Branch in the spring of 1921 and left after the Cadomin mine closed down in 1952.

The name "Coal Branch" refers to the branch line of the Canadian National Railways which left the main line at Bickerdike, seven miles west of Edson, and ran southward and westward into the Foothills to tap the rich coal reserves of that area. This branch line was first started in 1911 or 1912 and went as far as Coalspur, a distance of about 37 miles. From Coalspur the railway turned eastward and went as far as Lovett, a further distance of about 20 miles. Another branch ran from Coalspur to the west to the old Yellowhead Mine which was one of the first coal mines in the area. However, after having caught fire, this mine was closed down and the railroad pulled up by the time I arrived on the branch. The Mountain Park branch of the line was built about 1912 or 1913 and went as far as the village of Mountain Park, a distance from Coalspur of about 30 miles. I believe this part of the railroad was built by the Mountain Park Coal Company and then leased to the Canadian National Railways. When I arrived in Cadomin, the railroad was being built from Leyland Station to Luscar, 6 miles to the west.

Many mines were operated during the 45 to 50 year history of the Coal Branch. The branch railway to Lovett (named after A. H. Lovett of Montreal, President of the North American Coal Company) served other mines at Foothills, Coal Valley and Sterling. A kind of cooperative mine, the Balkan Collieries was operated at Robb mainly by people of Slavic decent. Later this mine was operated by the Lakeside Coal Company. Another mine west of this one was opened at Bryan for a short time.

The first mine from Coalspur on the Mountain Park branch was Mercoal. This mine, first known to us as Mile Five, derived its name from a compound portian of McLeod River Hard Coal Company, the company which operated it. Cadomin (Mile 22) got its name from a contraction of Canadian Dominion Mine. Mountain Park is purely a descriptive name. The town, for a time, had the distinction of having the highest railroad station in Canada at an elevation of about 6,000 feet above sea level. Luscar got its name from a town of the same name in Fifeshire, Scotland. Another mine was begun west of Luscar but was never as large or as important as the others in the area. It was first known as Gebo and later renamed Gregg River Collieries when it was bought out by the Cadomin Coal Company.

The mines in the inner Foothills-Mountain Park, Cadomin, Luscar and Gregg River-recovered coal from rocks of Lower Cretaceous age. Mercoal, Foothills, Lovett, Coalspur and other mines of the outer Foothills tapped beds of Upper Cretaceous age. Among mining people, the seams in all these mines were known as "steam coal" or "pitching seams" as distinct from the "flat lignite" or "domestic coal" seams on the Prairies. The miners who worked the flat seams would not move to work in the highly pitching coal seams of the Mountains. The same applied to the steam coal miners who would not move to the Prairies.

The people up the branch would probably average about the same in terms of various ethnic groups as in the other coal mining areas in the province. There is no doubt that any one group-say the Slavic group-would predominate at one particular mine. Perhaps the Latin group would predominate at another and the English, Scots and Welsh groups at others. There were, of course, among the miners restless people who would continually move from place to place with the result that the ethnic groups in a particular mining camp would change from time to time. There is one matter, however, that I would like to emphasize, and that is the close spirit of fraternity that existed among the mining people. Whether this closeness was because the people lived in isolated places or because of the common danger in which they shared, I would not wish to say, although, as one who has followed mining all my life, I would emphasize the latter. Even today with all our technical know-how, there is no such thing as a "safe" mine.

Living conditions in the coal camps in the early days left much to be desired. This was not the fault of the miners alone. Mostly they lived in closed camps where every house, shed and facility belonged to the mining company. All the houses were the same design, the same color (generally unpainted dirty grey, but even if they were painted, they were still either dirty grey or very dark chocolate in color) with no fences - a very depressing and monotonous scene. On the inside, however, some of these homes were kept so spic and span that if you wanted to, you could have eaten off the floor. As time went on, however, and the mining camps were thrown open, people could build their own homes, paint them in the colors they liked, have gardens, and even put in hot and cold water and indoor bathrooms.

Recreation in the camps was a do-it-yourself affair. In any new camp one of the first tasks for the men was the clearing of a sports field where baseball and football were played. Then an open-air hockey rink would be built, generally close to the river so it could be easily flooded with pails. Perhaps later a pump would be obtained to flood the rink more easily. Then a tennis court would be fixed up for the more refined folks of the camp. Picnic sites outside the village would be chosen and furnished with tables, swings and fireplaces so that in the summer people would have some place to go. The picnic areas were not too far from home because when the day ended and the children were tired there was the walk home.

Special sports days were held. Cadomin had the First of July, Mountain Park chose Labour Day and Luscar used to choose a random day sometime during the summer. A dance would be held the night before, and on the sports day, a special train would run from Edson, pick up the people all along the line in the morning and take them to the sports day, then return them to their homes at the end of the day.

As time went on and roads were built between Cadomin, Mountain Park, Luscar and later as far as Mercoal, trucks would be used to take people on Sunday picnics. These outings were enjoyed by all, particularly the women and children, as they broke the monotonous routine of camp life.

Each village had a small school. The first in Cadomin was held in a large room on the ground floor of a rooming house (known locally as the "black beetle" because of its being covered entirely with tar paper). As the camp grew larger and there were more children of school age, larger schools were built. A high school was opened in Cadomin just a few years before the mine closed down.

For two or three years Cadomin had no church of any kind. About 1922 or 1923 a church was built by voluntary labour for anyone who wished to use it. As I remember, it was not used very much and later was made into a dwelling. Still later, a Catholic Church, a United Church, and a Church of England were built.

Lack of church buildings did not mean that the early communities were neglected spiritually. The entire Coal Branch from Edson to Lovett, Mountain Park and Luscar was under the wing of the Reverend Louis Culerier, O.M.I. Father Louis was a familiar figure trudging along the railway track in all kinds of weather with his heavy pack strapped over his shoulders. He told me that during the early days of railroad construction, he used to walk along the right-of-way from Edson to Tete Jaune Cache and often as far as Prince George calling at all the camps, section houses and trapper's cabins wherever his services were needed.

In Cadomin he held Mass in various homes as there was no church. One evening on my return from the mine, the children were excited and told me about Father Louis who had called in to ask if he could hold Mass at our home. My son said that he liked Father Louis best when he played his whistle (he carried a small flute with him) as it was better than when he sang. He also said that Father Louis had on a long black nightgown. "Yes daddy," chimed in our little girl, "and it had beautiful lace curtains on the bottom." Father Louis was greatly amused when told of the children's comments.

On another occasion I was on my way home about 5:00 P.M. when I met Father Louis on the track with his heavy pack over his shoulders. It was snowing at the time with about 6 inches on the ground. Father Louis had walked from Mountain Park and was on his way to his little cabin on the river bottom close by. I invited him to have dinner with us and when he consented to come, I said, "Let me take your pack." I was a much younger man but when I lifted his two suitcases, one at each end of a heavy leather strap, I was shocked to find how heavy they were and to think of him packing them for miles. We had dinner and a smoke and talked for an hour or so. He was a wonderful conversationalist and could talk for hours on almost any subject. Then, thanking us, he said that he had better be going, so I offered to carry his pack to his cabin. He thanked me but said, "Now that I have wined and dined and I feel rested, I will continue my journey to Mercoal as I have service there in the morning." It was still snowing and cold and off into the night went the grand old man of the Cross.

Father Louis left the branch owing to ill health about 1927 or 28. He went to Edson, then Pincher Creek and finally to Montreal where he passed away at the age of 72.

One cannot leave Cadomin without talking about the wind. You may have heard the songs about the wayward wind and the wind that they called Maria but in my day I have heard the Cadomin wind called many names stronger than that. The worst time of the year was between November and January, but a wind storm could come up almost anytime. One that did the most damage occurred during the month of February. The Cadomin wind would blow for days on end. One bad spell, I remember, lasted for a week and blew steadily at about 45-50 miles per hour for the whole time. The strongest wind I ever measured was during the Cadomin fire, on December 3rd, 1923. The wind began to blow the night of the 2nd and kept it up for almost five days. On the afternoon of the fire, we clocked the wind at greater than 83 miles per hour. We used to say that it took someone from Cadomin about a month "outside" before he walked erect after being used to walking at about 45 degrees to the ground against the wind.

Speaking of the Cadomin fire, it started on December 3rd, 1923 on the hill above the tipple where some men were clearing brush. The wind came up and soon the brush fire was out of control with the result that in a very short time all the brush around the town was ablaze.

All the men were called out of the mine to fight the fire. Nearly all the buildings outside of the actual townsite went up in smoke. I personally lost everything.

We had just built a new bathhouse at the mine and all women and children were taken from the townsite together with bedding and food and put into this building which was heated by steam. There at least they would be warm, as the temperature outside was about zero. Men with buckets of water from the river were posted at the bathhouse, the cookhouses, and the hospital to put out embers as they fell on the buildings.

All the blasting powder from the powder magazine was dumped in the river to prevent a possible explosion. The only pump in town was at the powerhouse where it was hard pressed to save the tipple, the powerhouse and the wooden bridge from the mine to the tipple.

Two days after the fire started, a call came in from Leyland that Doctor Groff was needed to attend to a woman in labour. A healthy boy was safely delivered while men stood by with pails of water to put out embers on the roof which was held down by steel rails against the wind. Later, the boy, as a young man, worked in the mine and now lives in Edmonton with a family of his own. You may be sure that he is one native son whose birthday is always remembered.

Plate I

1. Cadomin Alberta about 1920. View southeast showing the old East Mine, tipple, power house and bridge over the McLeod River.

2. Cadomin during the 1940's. View southwest.

3. Gregg River Prospect, late 1940's. One of the tunnels on Sawmill Seam, Camp Creek.

Reminiscences come easily and I could go on to tell about how a group of youngsters found a bootlegger's cache one night when we were holding a dance during Prohibition; about some of the drifters that came and worked in the mines for short spells, or about the chap who arrived in camp accompanied by his two nieces (?) and a dancing bear. I could tell of the miners who lost their lives pursuing their dangerous occupation, of the bumps, the mine fires and the gas; of the long, cold, desolate winters and short, glorious summers.

Perhaps we should leave the Coal Branch as we came in - on the Blue Flea, the local train which carried freight and passengers between Edson and the towns of the Coal Branch in the days before the roads were built. After the highway was opened from Edson to Mountain Park and people had cars, the old spirit that pervaded the mining camps began to die out. Only the old folks remained in town on the weekends, and the playing fields, which in the early days swarmed like anthills, stood deserted to the occasional stray dog or horse. Now the towns are dead, abandoned to the wild flowers and to the ghosts of the past.

SOME ASPECTS OF THE NATURAL HISTORY OF THE CADOMIN AREA[1]

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INTRODUCTION

The area of the field trip lies mainly in the Foothills subprovince of western Alberta. Because of the elevation, latitude and climate of the region, the flora and fauna are typical of the Canadian Zone. On the lower mountain slopes in the western part of the area the Canadian Zone merges into the Hudsonian-Canadian (Sub-alpine) Zone. The upper edge of the Hudsonian-Canadian Zone defines the timberline.

FLORA

In the Cadomin area the flora of the Canadian Zone is characterized by white spruce, lodgepole pine, and aspen poplar on the uplands and by balsam poplar and a number of species of alders and willows along the more moist river and stream margins. Black spruce, larch and paper birch also occur within the area. In the higher elevations, in the Hudsonian-Canadian Zone, the Engleman spruce is the dominant tree along with scattered occurrences of alpine fir and white-bark pine.

Many species of wildflowers grow in both the Foothills and on the mountain slopes and no attempt will be made here to mention them in any detail, although the Indian paintbrush, tall lungwort, mountain phacelia, yellow columbine, ladies' tresses, various species of lupine along with the Provincial Flower, the wild rose, are particularly evident. At the present time the old townsite of Luscar is almost overgrown with a profusion of orange, yellow and white poppies.

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1 The author wishes to acknowledge the help of Mr. J. G. Stelfox, Western Parks Biologist, Canadian Wildlife Service, Edmonton, formerly Wildlife Biologist, Alberta Fish and Wildlife Division, Edmonton. Mr. Stelfox provided most of the data on game and fur-bearing animals, game birds and fish.

MAMMALS

Soper, in his "Mammals of Alberta" (Soper, 1964) lists fifty-one species of mammals as occuring or likely to occur in the Cadomin area. These range in size from the pygmy shrew that has a mean weight of 2.8 grams to the moose whose average weight is about 1000 pounds.

Five species of bats occur in the area. These are the little brown bat, the big brown bat, silver-haired bat, the big-eared bat, and the hoary bat. They are often seen at dusk and it is usually difficult to differentiate between the species. The little brown bat is probably the commonest species.

The varying hare or snowshoe rabbit is currently at the low point on its average 9.6 year cycle and consequently is very scarce. Its numbers will be increasing over the next few years.

Rodents are present in the area in considerable numbers. Species include the golden-mantled ground squirrel, the hoary marmot, (on the higher slopes), the little northern chipmunk and the Columbian ground squirrel. The red squirrel is presently quite common in the coniferous forests but its numbers are declining in areas where logging operations are in progress. Other small rodents present are the phenacomys vole, white-footed mouse, lemming vole, red-backed vole and flying squirrel.

The beaver is fairly common in the area wherever suitable habitats exist but the muskrat is very scarce in the Coal Branch area, as it is in most of the Foothills, due to a lack of small bodies of quiet water. Porcupine occur but are not numerous.

Many mammals were greatly reduced in numbers during the anti-rabies campaign conducted in Alberta from 1952 to 1956. Particularly affected were bears, cougars, coyotes and wolves, and although a reduction in their numbers was necessary at that time, the present increase in numbers should be viewed with satisfaction as predators play an important and necessary role in the ecology of a region; a role which has been often misunderstood in the past.

Black bears are fairly common and well distributed in the Coal Branch region. Their numbers have been increasing during the past few years. The grizzly bear is also common in the area and has possibly been increasing in numbers in the last decade. It is estimated that there is at least one grizzly bear per ten square miles at this latitude.

Cougars are quite plentiful throughout the Coal Branch region and their numbers have been increasing lately, probably as a result of the increase in the deer population during the last decade.

Coyotes occur throughout the area in considerable numbers. Wolves are common along the Drinnan, Gregg, Cardinal and McLeod Rivers and their numbers may be increasing after the rabies control campaign. A certain amount of necessary control of these animals is carried out during the winter months.

Lynx were plentiful in the area from 1958 to 1964. However, their principal food supply is the varying hare, and as the numbers of that animal are now very low the numbers of lynx are decreasing rapidly.

Both the fisher and the marten are relatively abundant in the coniferous forest but their numbers are expected to decline sharply in the wake of current logging operations. Mink are fairly abundant at the present time along the various streams.

The Cadomin area is well known for its herds of big game animals and several world record elk and bighorn sheep records come from this general area.

Both the mule deer and the white-tailed deer occur in the Cadomin area. The mule deer is not numerous at the present time but the white-tailed deer which moved into the area during the late 1950's is presently abundant. Their numbers reached a peak in 1961-62 but three severe winters subsequently have caused a reduction.

Moose are locally abundant along valley bottoms where deciduous vegetation is plentiful. In summer the large bulls move westward to higher ground and at that time can be found regularly near timberline.

Elk are presently common but not abundant in the Cadomin area, however, their numbers have seen great variations within the last half century. In 1916 it was estimated (Millar, 1916) that of the original elk herd in Alberta only five to fifteen individuals remained along the Brazeau River drainage southeast of Cadomin. Their numbers increased slowly until the 1930's when they invaded the headwaters of the Brazeau, Cardinal and McLeod Rivers. This movement was due to suitable graze becoming available as a result of an extensive fire in this area during the 1920's. Shortly after this, elk moved westward across the Coal Branch road and their numbers in this area increased to an estimated 900 animals by 1961. Several severe winters have since reduced this number. The particularly severe winter of 1964-65 caused a pronounced die-off in the Mountains, and the remaining animals moved east of the Coal Branch road.

Rocky Mountain sheep are presently more abundant than at any time since the mid 1930's. Heavy hunting of both sexes throughout the year during the days of mining activity kept their numbers reduced. The current sheep population in the Coal Branch region between the Brazeau and Athabaska rivers is estimated at between 465 and 525 animals (Stelfox, 1966, personal communication).

The Rocky Mountain goat was apparently plentiful in the Coal Branch region prior to the coal mining period. Since then goats have been very scarce in the area although a few may be present in the valleys of Whitehorse and Ruby Creeks and the Cardinal River. Current estimates of their numbers between the Athabasca and the Brazeau Rivers is from 75 to 100 animals (Stelfox, 1966, personal communication).

The annual harvest of big game animals in areas S436 and S438 (Brazeau River to Highway 16 and west of Forestry Trunk Road) for 1965 are as follows: Rocky Mountain sheep 40, Rocky Mountain goat 2, grizzly bear 5, black bear 15, moose 65, elk 45 and deer 20.

BIRDS

The bird life of the Cadomin area is rich and varied and includes species that utilize habitats ranging from the low moist river valleys to the upland coniferous forests and the high slopes near timberline. One hundred and thirty-six species are believed to nest in the area and many more pass through the area in migration.

Waterfowl are not particularly plentiful when compared to the Prairie to the east, however, mallards, green-winged teal and lesser scaup may be found on bodies of water in the Foothills. The colorful harlequin duck along with the Barrow's golden-eye is often seen along streams in the higher elevations, and the Canada goose nests wherever it can find suitable sites.

Eight species of hawks may be found in the Cadomin area. The goshawk, sharp-shinned hawk and Cooper's hawk are birds of the forest and are most often seen flying rapidly through and over the trees. In contrast the red-tailed hawk and osprey are usually seen soaring high in the air searching for small rodents and fish, respectively. Two small falcons, the merlin and the kestrel are regularly seen along roadsides and the edge of forest groves. The marsh hawk can be observed hunting over open fields and wetlands. The golden eagle occurs throughout the area and is often seen soaring high in the air especially in the more rugged parts of the area.

Six species of owls ranging in size from the pygmy owl with a length of six and one half inches to the scarce great grey owl which can be up to thirty-three inches in length are found in the area. The great horned owl, hawk owl, long-eared and boreal owl are also present. Owls are retiring birds and are best noted and identified by their calls. All hawks and owls are protected by law in Alberta.

A number of upland game birds are found in the area. The spruce grouse is very common in the spruce and pine forests and the blue grouse is fairly common in the Mountains primarily between 5,000 feet and 6,500 feet. The white-tailed ptarmigan is fairly common near Mountain Park and the headwaters of Whitehorse Creek. The ruffed grouse is somewhat local in its occurence. Populations of these grouse are present n the valleys of the McLeod and Embarras Rivers, but their numbers are cyclic and the species is at present at a low point in its cycle.

Shorebirds are not represented by many species but the familiar spotted sandpiper is a common sight along the edges of lakes and rivers in the region. Other shorebirds whose presence can be expected are the killdeer, Wilson's snipe, solitary sandpiper and the greater and lesser yellowlegs.

Hairy and downy woodpeckers and the yellow-shafted and red-shafted flickers are probably the commonest woodpeckers in the area. The black-backed three-toed woodpecker and the northern three-toed woodpecker are fairly abundant with the northern being the commoner of the two species. The large (crow-sized) pileated woodpecker is also often seen and heard.

A number of species of small flycatchers occur in the area but they are difficult if not impossible to identify except by an expert. An exception is the olive-sided flycatcher whose song, a loud "quick, three beers" identifies it as far as it can be heard.

Swallows are a common sight in the area. The commonest are probably the tree swallow and the bank swallow. The cliff swallow is also present in the area where it nests under bridges and on rock exposures on river banks. Barn swallows are currently making use of abandoned buildings at Cadomin and Mountain Park for nesting sites.

A number of species of thrush nest in the area and their musical flute-like singing is heard regularly in the late spring and summer. The commonest are the hermit thrush and the Swainson's thrush. The veery, while present, is somewhat local in distribution in the Cadomin area. The mountain bluebird occurs throughout the region but its numbers are diminishing rapidly due to the invasion of its habitat by English sparrows and starlings.

The large, colourful family of North American wood warblers are represented in the area by a number of species. The commonest are the Tennessee warbler, orange-crowned warbler, myrtle warbler, Audubon's warbler, MacGillivray's warbler, Wilson's warbler, redstart and yellowthroat.

The blackbirds are represented by the Brewer's blackbird, rusty blackbird, and the brown-headed cowbird. The cowbird is regularly seen in pastures feeding on the insects stirred up by livestock.

The song sparrow, savannah sparrow, vesper sparrow and clay-coloured sparrow are seen regularly in fields and along roadsides in the area. The white-crowned sparrow and the Brewer's sparrow are found in the higher elevations in the Foothills and Mountains. The chipping sparrow occurs commonly throughout the area.

FISH

The rivers and streams of the Mountains and Foothills of this area are well known for the good fishing they provide. The most common species are the rainbow and Dolly Varden trout and the Rocky Mountain whitefish. In addition, eastern brook trout, brown trout and Arctic grayling are found locally.

A considerable amount of restocking has been and is being done in the area. From the 1930's to the early 1950's miners back-packed fish of many species into almost all the streams and lakes within reach of settlement. In recent years numerous lakes and mine pits have been stocked, mostly with rainbow and eastern brook trout by the Alberta Fish and Wildlife Division. The eastern brook trout is particularly suitable for stocking mountain lakes that tend to remain frozen late in the spring. This species spawns in the fall and as a result it is in better condition in the spring than are the spring spawning species.

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THE CADOMIN LIMESTONE QUARRY

R. J. Gotts
Inland Cement Industries Ltd., Edmonton

Cadomin, located 70 miles southwest of Edson, Alberta, was once the centre of the coal mining industry for the Coal Branch area. At present no coal mines are in operation, most of them having closed down in the 1950's.

The limestone deposits presently being quarried are located about two miles south of the town on the east side of the McLeod River. The deposits are in the Palliser Formation of Upper Devonian age, which along with overlying beds of Carboniferous age makes up the Nikanassin Range. The limestone has been faulted over Jurassic and Cretaceous shales and sandstones of the Fernie and Nikanassin Formations by the Nikanassin thrust which strikes N60°W and dips at 45° to the southwest.

The Palliser Formation consists of limestone and is 500 to 700 feet thick. The general strike is N 80° W with a dip of from 23° to 35° to the south. The formation is composed of thick bedded, grey and blue, fine grained, high calcium limestone. Intercalated in the limestone are beds containing magnesium carbonate in the 10 to 20% Mg CO_3 range. Three of these beds are continuous through the deposit; one near the top, about one hundred feet below the shale contact, one in the centre and one near the base. These high-magnesium beds vary in thickness from 10 to 40 feet and are not usually distinguishable by eye from the high calcium beds. In outcrop, the high-magnesium beds have an irregular network on the weathered surface. Only occasional fossils have been found in the deposit and no large vugs have been encountered. Occasional large joints, resembling faults, about 4" wide with vertical dip and a south west strike occur through the deposit.

Movement along the sole fault between the Palliser and the Jurassic shales is of considerable magnitude, in the order of one mile of vertical displacement, yet there is very little brecciation, drag folding or disturbance in the Palliser

Formation. The fault crops out naturally along part of the north slope of the mountain and is exposed at the base of the mountain by mining. Fossils can be collected from the Jurassic shale a few inches below the thrust in the quarry.

One half mile south of the north deposit the Devonian limestone is repeated by another fault. The Palliser here overlies Mississippian limestone of the Rundle Group. The Palliser Formation is the same as in the north deposit except for a thicker high-magnesium band in the upper portion.

In the 1940's a small lime plant was operated by Mike Enico in what is now known as the north quarry in the first slice of the Palliser Formation. During 1953 and 1954 Inland Cement began detailed investigation of limestone deposits in the area. As a result of these investigations, it was ascertained that a large quantity of good quality limestone was available for cement manufacture. In 1955 a cement plant was built in Edmonton and operations begun in the north quarry. From 1960 to 1965 the south quarry was operated in the second slice of Palliser Formation, but this deposit has now been abandoned in favor of quarrying from the top of the north deposit.

The stone is blasted, then transported to a crushing plant at the base of the mountain by truck and gravity. Crushing reduces the rock to pieces less than 5 inches in diameter, and the crushed stone is then loaded aboard gondola cars for shipment to Edmonton.

Limestone used for cement manufacture averages 92% $CaCO_3$ and 4% $MgCO_3$, with a maximum limit of about 5% $MgCO_3$. Proven reserves in the Cadomin deposit are 22,000,000 tons. 470,000 tons were mined in 1965; and to date a total of 4,000,000 tons of limestone have been processed.

UPPER DEVONIAN STRATIGRAPHY IN THE VICINITY OF MOUNTAIN PARK, ALBERTA[1]

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Abstract

Upper Devonian carbonates and associated argillaceous strata that outcrop along the Front Ranges of the Rocky Mountains in the region south of Mountain Park form part of a large complex that continues for many miles to the southeast. Two formations, which in the Alberta subsurface contain oil- and gas-producing reservoirs, constitute the carbonate sequence. They are the Cairn Formation of dark brown dolomite, and overlying lighter coloured carbonates, the Southesk Formation. Both formations are replaced by laterally equivalent argillaceous beds. In this area some aspects of the transition and of stratigraphic relationships involved can be seen on the northeasterly-facing cliffs. Dolomites of the Cairn Formation change abruptly to laterally contiguous shales whereas the Southesk Formation transition is gradual and accompanied by intertonguing. The carbonate sequence and associated strata are bounded above by a disconformity.

INTRODUCTION

Upper Devonian and underlying Upper Cambrian strata outcrop along northeasterly-facing mountain slopes of the Front Range in the region south of Mountain Park (Fig. 1). A maintained gravel road, which runs south from the town[2] and along the north shore of the Cardinal River, provides access to the area and a series of vantage points from which to view some aspects of the regional geology. An early insight into the nature of Devonian stratigraphy in the Rocky Mountains was provided by McConnell (1886) and Dowling (1912). These two men described contrasting carbonate and argillaceous sequences of Devonian rocks in the mountains, and while their approximate stratigraphic equivalence was appreciated at the time, details of their mutual relationships were not resolved until some 40 years later (McLaren, 1956). Both facies occur in this area. The dominantly

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1 Published by permission of the Director, Geological Survey of Canada.

2 Mountain Park is an abandoned coal mining town. Little remains today of this once thriving community.

carbonate sequence occurs to the southeast and dark grey limestones and shales of the argillaceous province outcrop along the Front Ranges to the northwest. Rocky Pass, a local geographic feature, provides an approximate boundary between them.

STRATIGRAPHY

Formation Terminology

The twofold system of formation terminology used to distinguish the lithologically contrasting carbonate and argillaceous facies has evolved from the work of a number of authors and dates from Sir James Hector's (1858) first published accounts of Devonian strata in the Rocky Mountains. A modern phase of exploration began when Raymond (1930) introduced formation names for distinctive rock units. Discovery of oil at Leduc in 1947 drew attention to the significance of stratigraphic relationships established in the mountains as a basis for study and reconstruction of the subsurface carbonate bodies. Significant papers by Belyea, McLaren, Hargreaves, Taylor and others have provided a comprehensive picture of Devonian stratigraphy in both the Mountains and Plains areas. Recent contributions by McLaren and Mountjoy (1962) and Mountjoy (1965) have further advanced our understanding of the nature of Devonian sedimentation and clarified stratigraphic relationships between the laterally equivalent carbonate and argillaceous formations, particularly in zones of transition between the two facies. For detailed lithologic descriptions of the rock units involved, the reader is referred to McLaren (1956) and the Appendix to this paper. Figure 2 is a stratigraphic chart showing the formation terminology used in this report.

Carbonate Facies

The carbonate sequence consists of the Cairn and overlying Southesk Formations, both with type sections on Mount Dalhousie about 20 miles to the southeast of the report area (McLaren, 1956). The formations and members have different areal distribution and thickness within the study area transition zone, as compared to the type locality, but lithologies are similar and the various units can be easily recognized.

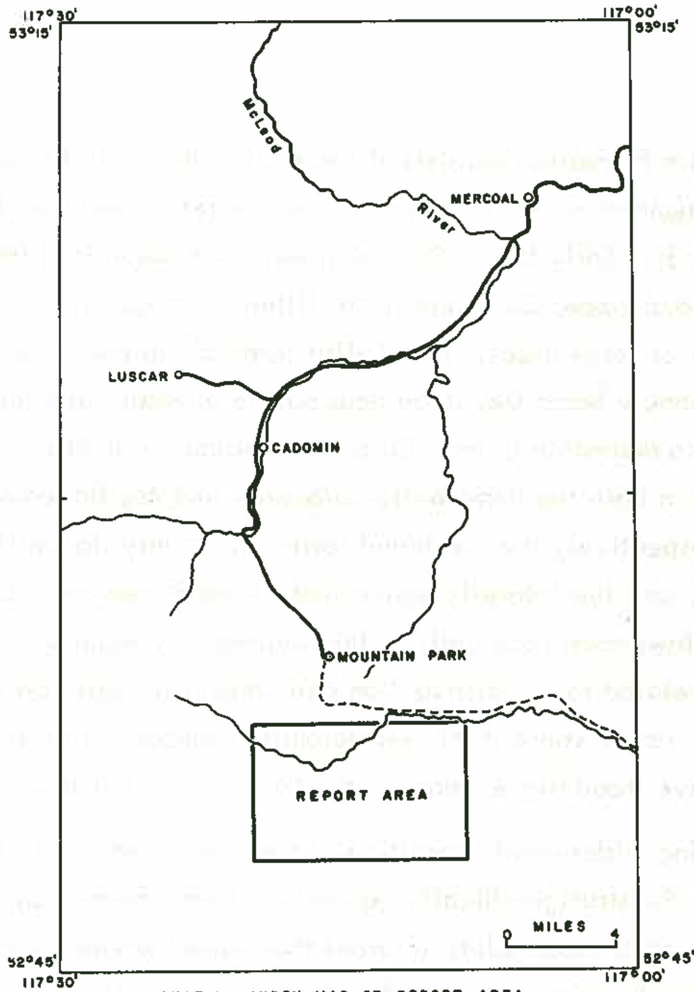


FIGURE I. INDEX MAP OF REPORT AREA

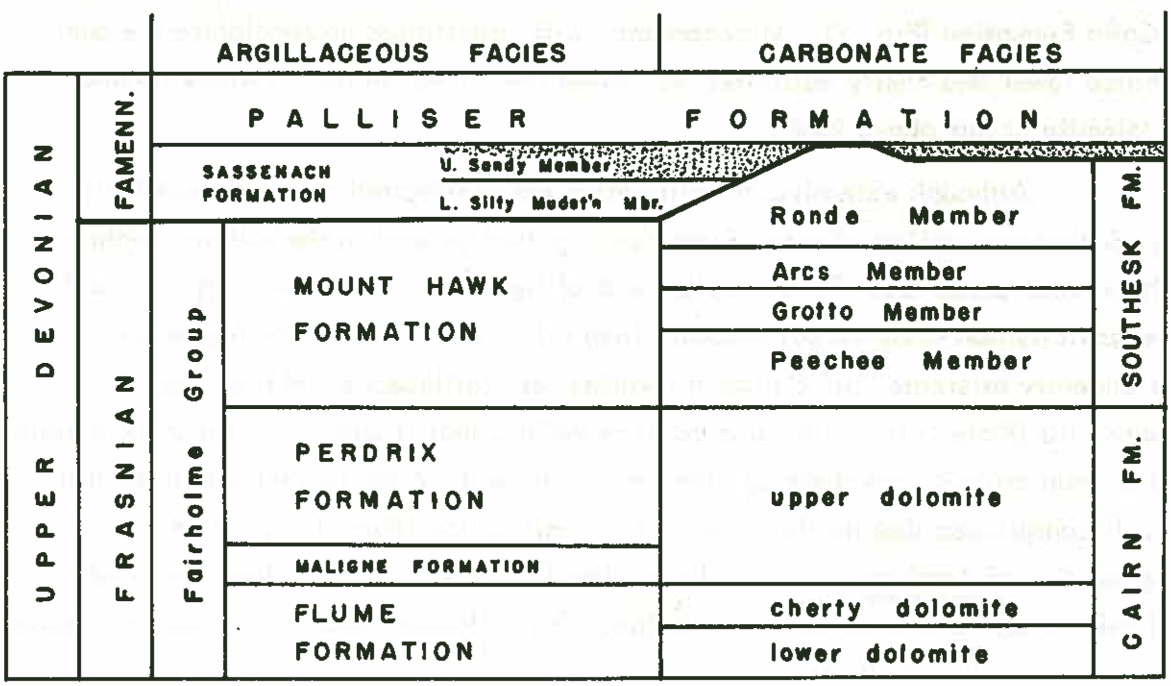


FIGURE 2. FORMATION TERMINOLOGY

Cairn Formation

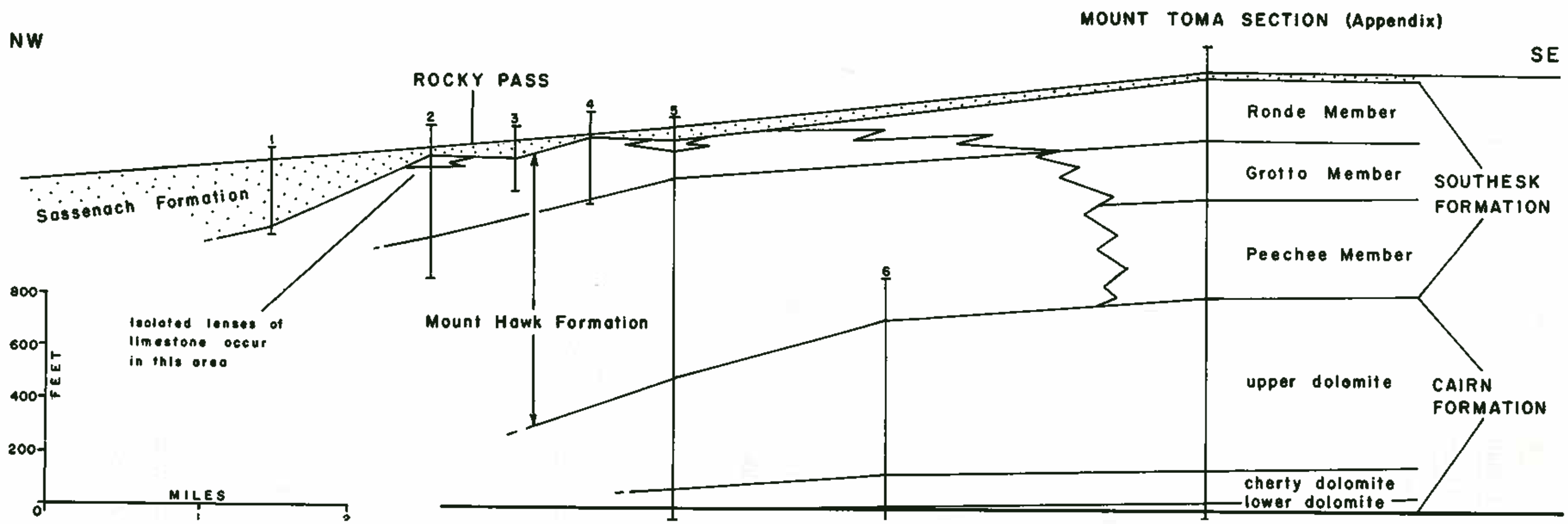
The Cairn Formation consists of informally designated lower, cherty, and upper dolomite members which in this area reach a total combined thickness of 785 feet (Figs. 2 and 3). Early Upper Devonian sediments deposited from seas transgressing over eroded Upper Cambrian strata filled in irregularities on the unconformity surface over large areas. Local silty intervals in the lower part of the sequence are probably basal Devonian beds but no attempt has been made here to separate them into mappable units. Carbonate sediments of this first phase of deposition occur in both the dominantly carbonate and argillaceous sites of deposition and constitute respectively the combined lower and cherty dolomite units of the Cairn Formation, and the laterally equivalent Flume Formation. Changes in thickness of the lowermost rock units of this sedimentary sequence are significant, for they can be related to the distribution and amount of relief on the sub-Devonian erosion surface. Areas where the lower dolomite member is thin or absent can be interpreted to have stood higher than areas where the unit is thick (Fig. 3).

Following widespread deposition of the lower and cherty dolomite units of the Cairn and the stratigraphically equivalent Flume Formation, carbonate sediments continued to accumulate in areas that were favourable to organic growth while argillaceous deposits were laid down in other parts of the basin (Fig. 4). The organic-rich carbonate sediments constitute the "upper dolomite member" of the Cairn Formation (Fig. 2). In accordance with established nomenclature the combined lower and cherty dolomites are called the Flume Formation where no upper dolomite occurs above them.

Although extensive dolomitization has obliterated most of the primary rock textures, relicts of some macro-features that existed in the original sediment have been preserved. For example, beds of light-coloured, relatively pure and essentially non-fossiliferous dolomite from a few inches to several feet thick, frequently alternate with similar thicknesses of argillaceous and fossiliferous dolomite (Plate I-1). Stromatoporoids of various shapes and sizes, which constitute the main organic rock-forming element in sediments of the Cairn Formation, are still conspicuous despite the effects of dolomitization (Plate I-2). With the exception of Amphipora and the large globular stromatoporoids, few identifiable fossils occur within the Cairn Formation. The following brachiopods were collected at a number of localities:

FIGURE 3. STRATIGRAPHIC CORRELATION BETWEEN UPPER DEVONIAN ARGILLACEOUS AND CARBONATE FACIES

Rocky Pass ——— Mount Toma



Atrypa cf. *A. multicostellata* Kottlowski
Eleutherokomma reidfordi Crickmay
Allanaria sp.
Atrypa sp.
Productella sp.

Southesk Formation

The Southesk Formation, in the report area, ranges in thickness from over 825 feet at Mount Toma in the southeast through a progressively thinning interval to remnants and isolated lenses, laterally equivalent to the uppermost part of the formation, on the northwest side of Rocky Pass (Plate I-3 and Fig. 3). Formally designated rock units, the Peechee, Grotto and uppermost Ronde Members (Belyea and McLaren, 1957, p. 171; McLaren and Mountjoy, 1962, p. 9) stand out clearly along the hillside between the east and west forks of Toma Creek (Plate I-4, Fig. 4).

The Peechee Member consists of about 380 feet of thickly bedded, coarsely crystalline light grey dolomite. In this area the Peechee is underlain by dark brown dolomite of the Cairn Formation across a sharp contact and changes abruptly upward to similar dark brown dolomite of the Grotto Member.

Corals and *Amphipora* are characteristic of the typically dark brown to almost black, slightly argillaceous Grotto Member. The unit, 219 feet thick at the Toma Creek section (Plate I-4, Fig. 3), is not present within the dominantly argillaceous facies on Mount MacKenzie about 2 miles to the northwest (Fig. 4). Both upper and lower contacts of the member where it is present are sharp and clearly defined.

The overlying Ronde Member is 227 feet thick in the Toma Creek area and consists of a sequence of fine-grained, relatively pure limestone and slightly argillaceous silty limestone. The silty beds typically occur in the lower part of the interval where they form a conspicuous recessive-weathering zone along the hillside (Plate I-4). Globular and encrusting stromatoporoids and stromatoporoid fragments are common in the upper part of the unit, particularly near the western margin of the carbonate facies (Plate I-5). In this area only a few feet of the uppermost beds are present (Plate I-6).

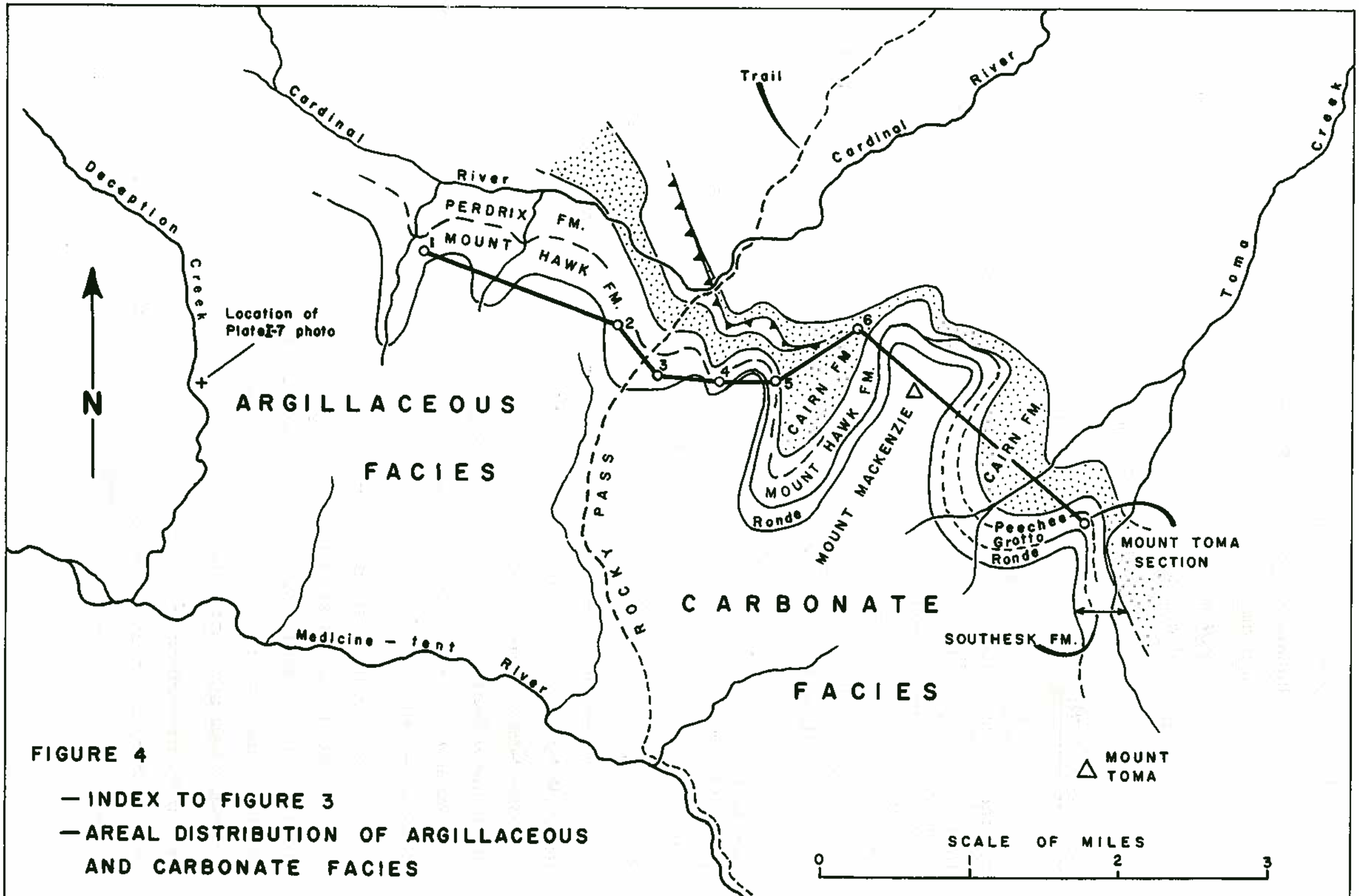


FIGURE 4

— INDEX TO FIGURE 3

— AREAL DISTRIBUTION OF ARGILLACEOUS AND CARBONATE FACIES

Marginal Facies

Where sediments of the Cairn Formation are involved, the change from carbonate to laterally equivalent argillaceous strata takes place abruptly, with little evidence of interfingering, along a contact that rises stratigraphically towards the carbonate facies. On the other hand, the change from carbonates of the overlying Southesk Formation to adjacent argillaceous beds is accompanied by intertonguing. The contact is gradational and rises across stratigraphic layering away from the areas of dominantly carbonate deposition.

Lateral relations of the Cairn Formation are well exposed on the east side of Deception Creek where dolomites of the Cairn form an irregular profile along the hillside (Plate I-7, Fig. 4). In this area, surrounding shales of the Perdrix Formation abut the moundlike dolomite developments on the top of the Cairn with little evidence of intertonguing or mutual contamination by the contiguous but lithologically different facies.

In contrast, stratigraphically higher beds of the Southesk Formation become progressively more widespread (Figs. 3, 4) and their transition to the laterally equivalent argillaceous sequence is accompanied by intertonguing. For example, stratigraphically lower members of the Southesk Formation that occur at Mount Toma are confined to smaller areas than the uppermost Ronde Member which is present on Mount MacKenzie about two miles away and persists as isolated limestone lenses as far as the west side of Rocky Pass (Plate I-3, Fig. 4). Northwestward from the area occupied by the carbonate facies, relatively pure, resistant limestones of the Ronde Member become more argillaceous near the transition zone, separate into tongues and as a consequence become less resistant to weathering. These beds, cliff-forming on Mount MacKenzie, are not conspicuous on the adjacent mountain spur to the northwest where laterally equivalent strata weather to a smooth profile (Plate I-8). Adjacent sediments of the argillaceous facies also are more calcareous near their transition from the carbonate sequence and in this area constitute a "reef[1]-margin facies". This lateral persistence of the lowermost and uppermost beds of the carbonate sequence along with a lithologically distinct near-reef argillaceous interval related to the Southesk Formation provides an indication of nearby carbonate sediments that constitute reservoirs for oil and gas

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1 "Reef", used here in accordance with common subsurface terminology of the Alberta Plains is applied to areas of relatively pure and predominantly autochthonous carbonate sedimentation.

in the subsurface.

Overlying Formations

Deposition of the Cairn and Southesk Formations and laterally equivalent argillaceous strata was followed by an accumulation of silty shales and carbonates, and relatively pure limestones of Famennian age, the Sassenach (McLaren and Mountjoy, 1962, p. 11) and Palliser Formations (Fig. 2). The boundary between the Sassenach and Palliser Formations is disconformable and represents an important depositional break that has been reported from widely separated areas of North America. It occurs, for example, in the Alberta subsurface (Belyea, 1955), in northwestern Montana (Hurley, 1963) and in Foothills and Mountain regions near Jasper, Alberta (McLaren and Mountjoy, 1962).

Within the report area, the Sassenach Formation, which is thicker overlying the argillaceous province, appears to onlap the area occupied by the carbonate sequence. In addition, relatively close spacing of short measured sections through the Formation on the east and west sides of Rocky Pass shows irregular thickening and thinning suggestive of deposition on an erosion surface with appreciable topographic relief. The formation is thin overlying the area of complete carbonate build-up southeast of Rocky Pass (32 feet at Mount Toma) and in some areas is absent. Where the beds are absent, for example about five miles south of Mount Toma, brecciated zones are common at the disconformity. The breccias consist of large angular fragments of dolomitic siltstone of the Sassenach Formation up to four feet in maximum dimension embedded in the underlying vaguely stratified and leached dolomites of the Southesk Formation. Appreciable relief is present on the erosion surface with dark grey argillaceous limestones of the Palliser Formation lying on the brecciated zones or on carbonates of the Southesk Formation.

Summary

Changes that take place within sediments where a dominantly carbonate facies is replaced by shales and argillaceous limestones are of value as an aid in locating potentially oil- or gas-bearing carbonate reservoir beds in the subsurface.

Within the report area the Cairn Formation and adjacent argillaceous strata have an abrupt contact with little evidence of mutual intermixing, although some intermixing probably does occur elsewhere. Mountjoy (1965, p. 42) stated that shales within a 2- to 4-mile zone surrounding the Miette Reef complex about 25 miles to the northwest contained more carbonate beds and were also more fossiliferous. In addition, the Cairn Formation itself thickens towards areas of carbonate deposition although perhaps in an irregular manner as illustrated by the dolomite mounds on the east side of Deception Creek.

A definite reef-margin facies occurs in argillaceous strata related to the overlying Southesk Formation. Increase in carbonate content and in the number of limestone tongues in these beds indicates proximity to a dominantly carbonate sequence. Thickening and thinning of formations overlying the disconformity can also be interpreted in terms of proximity to underlying carbonate strata.

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PLATE I

1. Interbedded light brown, non fossiliferous and dark brown stromatoporoid-bearing dolomite; note the light coloured spherical stromatoporoids that appear to be resting on the bed of light brown dolomite, Toma Creek Section, 703 feet above base of Cairn Formation.

2. Large globular stromatoporoids on a bedding plane surface, 20 feet above base of Cairn Formation.

3. Isolated lenses of light brown limestone in the upper part of the Mount Hawk Formation, north-facing cliff on west side of Rocky Pass. These limestone lenses are laterally equivalent to the Ronde Member of the Southesk Formation.

4. The Mount Toma section between the east and west forks of Toma Creek, looking north (Fig. 4).

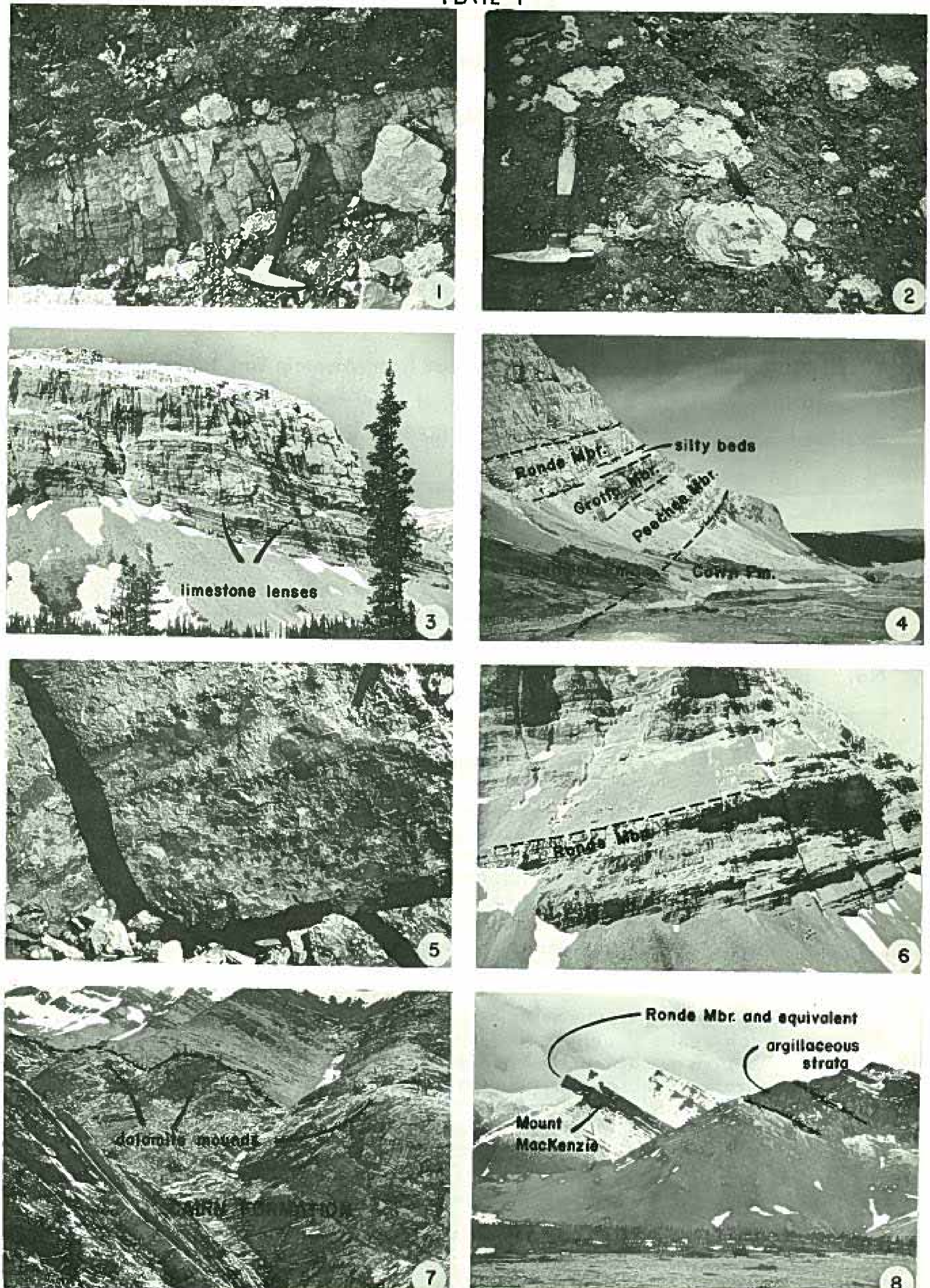
5. Stromatoporoid remains, 3 feet below the top of the Ronde Member, south-east (hidden) side of smooth-weathering ridge in Plate I-8.

6. Southeast (hidden) side of ridge in Plate I-8; thin bedded relatively pure stromatoporoid-bearing limestones underlie dolomitic siltstones (Sassenach Formation) here and can be correlated with the cliff-forming Ronde Member on Mount MacKenzie (Plate I-8).

7. An irregular upper profile and dolomite mounds in the Cairn Formation, east side of Deception Creek (Fig. 4).

8. Cliff-forming limestones of the Ronde Member on Mount MacKenzie become more argillaceous to the northwest and weather to a smooth profile on the ridge in the foreground.

PLATE I


1
2
silty beds
Ronde Mbr.
Peechee Mbr.
limestone lenses
3
4
Ronde Mbr.
5
6
dolomite mounds
7
Ronde Mbr. and equivalent
argillaceous strata
Mount MacKenzie
8

APPENDIX

= Mount Toma Section =

A spur extends from the peak of Mount Toma, trends northwest and then north-northeast to form a ridge between the east and west forks of Toma Creek. An Upper Devonian carbonate sequence consisting of the Cairn and Southesk Formations and overlying Sassenach and Palliser Formation beds is continuously exposed and easily accessible along the east side of the ridge. The principal lithologic units can be clearly seen from across the valley to the southeast (Plate I-4).

Access is via a maintained gravel road from Mountain Park to the junction of Cardinal River and Toma Creek, a distance of about seven miles; and thence an additional four miles on foot or horseback to the foot of the section.

Unit No.	Description	Thickness in feet: Unit	Thickness in feet: Total from base
	UPPER DEVONIAN		
	Palliser Formation		
41	Limestone, argillaceous and dolomitic; dolomite shows as resistant-weathering brown-grey mottling on weathered surfaces and as mixed irregularly shaped grains and euhedral crystals about 150 microns maximum dimensions on etched surfaces; unit occurs in distinct beds from two to five feet thick, weathers light grey and is cliff-forming. Contact with underlying unit is abrupt	50	1758
	Limestone, slightly dolomitic, light brown; a coarse calcarenite of well rounded granules about 250 microns average maximum dimensions; recrystallization has blurred many grain boundaries; dolomite occurs in minor amounts as euhedral crystals and as irregularly shaped grains commonly confined within an interstitial sparry calcite cement. Unit consists of one resistant, light grey-weathering bed. Occasional large brachiopods occur throughout	4	1708

39	Limestone, argillaceous, strongly dolomitic, in part completely altered to dolomite, medium brown, medium crystalline with a little intercrystalline porosity; limestone is dark grey, microcrystalline and occurs in resistant beds from two to three feet thick	16	1704
38	Dolomite, calcareous, argillaceous, slightly silty, dark brown-grey; occurs in resistant grey-weathering beds from one and one half to two feet thick ..	12	1688

<u>Sassenach Formation</u>

37	Siltstone, dolomitic, fine, medium brown; fine resistant laminations on weathered surfaces show scour channels and cross-bedding; unit consists of thin flaggy beds from one to three inches thick, orange-weathering and recessive	32	1676

<u>Southesk Formation</u>

(Ronde Member)

36	Limestone, light brown, microcrystalline, in part shows vague, disturbed laminations about one eighth of an inch thick separated by clear sparry calcite. A few two to four inch beds of limestone breccia occur within the unit. The breccia is slightly argillaceous, medium brown and consists of fragments of light brown microcrystalline limestone in a matrix of dark grey micritic, argillaceous limestone; many thin laminae of light-brown limestone are only incompletely broken up; discrete fragments are angular and show a preferred orientation parallel to the bedding. Beds are from one to three feet thick, resistant and weather light grey	16	1644
35	Limestone, light brown, microcrystalline, a few scattered irregularly shaped eyes of sparry calcite; fair porosity in 1/4-inch diameter vugs; beds are from 1 to 3 feet thick, resistant, light grey-weathering.	12	1628
34	Intraformational conglomerate, well rounded fragments of medium grey, microcrystalline limestone, rounded composite granules of fine calcarenite and partially rounded elongate fragments of light brown microcrystalline limestone in a cement of clear sparry calcite. The fragments of medium grey microcrystalline limestone range from 1/8 to 1-inch maximum dimensions; the other constituents described are uniformly about 1/4 inch in diameter. Dolomitization has affected some of the interstitial sparry calcite cement	3	1616

33	Limestone, silty, slightly argillaceous, light yellow-brown; silt grains are about 80 microns average maximum dimensions, angular to subrounded and occur as thin laminations in a light brown, microcrystalline limestone. The silty laminations weather orange-yellow, are resistant and show fine cross-bedding on weathered surfaces. Unit is moderately resistant	3	1613
32	Limestone, light brown, microcrystalline, some vaguely calcarenitic areas, has a generally stirred up appearance, numerous large irregularly shaped areas of sparry calcite; occurs in resistant light grey-weathering beds from 1 to 4 feet thick	39	1610
31	Limestone, pink, completely recrystallized to crystals about 200 microns average maximum dimension; in HC1 leaves a light residue containing fine angular silt fragments; some areas of good porosity in small 1/8 to 1/4-inch vugs; occurs in resistant, light grey-weathering beds from 2 to 5 feet thick	39	1571
30	Limestone, microcrystalline, pink and medium grey-brown; in part dolomitic; individual beds change from limestone to dolomite along strike; occurs in distinct, resistant, light grey-weathering beds from 2 to 4 feet thick	41	1532
29	Limestone, slightly silty, argillaceous; silt grains about 40 microns average diameter have a frosted appearance under the microscope; beds are from 2 to 3 inches thick, resistant and grey-weathering ..	15	1491
28	Dolomite, argillaceous, medium brown, medium crystalline, with a little intercrystalline porosity; beds are from 6 inches to 2 feet thick, resistant and brown-grey-weathering	11	1476
27	Dolomite, silty, light brown, finely crystalline; silt occurs as angular grains about 25 microns average diameter; beds are recessive, yellow-weathering and from 2 to 8 inches thick	11	1465
26	Limestone, silty and slightly argillaceous, medium brown-grey, microcrystalline with areas of medium calcarenite; silt occurs almost entirely as authigenic quartz crystals with average dimensions of 25 x 75 microns; unit forms a horizontally persistant, light grey-weathering bed	2	1454
25	Dolomite, argillaceous and slightly silty, medium brown; medium crystalline, fair porosity scattered vugs up to 1 1/2 inches in diameter; occurs in recessive, brown-weathering beds from 1 to 2 feet thick	35	1452

(Grotto Member)

24	Dolomite, argillaceous, dark brown to almost black, fine and medium crystalline; a few broken coral colonies and some scattered gastropods; extensive sub-vertical fracturing throughout, recemented with white sparry dolomite; numerous elongate calcite lined vugs from 3 to 4 inches in maximum dimension; many small brecciated areas; a brecciated zone from 6 inches to 4 feet thick marks the base of the unit; bedding is indistinct; unit is moderately resistant and weathers dark brown	219	1417

(Peechee Member)

23	Dolomite, light and medium brown, coarsely crystalline; good intercrystalline and vuggy porosity, well bedded; occurs in cliff-forming, light grey-weathering beds from 1 to 3 feet thick	58	1198
22	Dolomite, light brown, coarsely crystalline; occurs in resistant beds from 2 to 4 feet thick	24	1140
21	Dolomite, light and medium brown, predominantly light brown, coarsely crystalline and with good intercrystalline porosity; occurs in distinct, resistant beds from 1 to 3 feet thick	77	1116
20	Dolomite, medium grey, coarsely crystalline, moderately well bedded, cliff-forming	73	1039
19	Dolomite, light brown, coarsely crystalline, with sucrose texture, in part friable, good intercrystalline porosity; contains occasional zones of intraformational conglomerate; medium grey coarsely crystalline fragments in a coarsely crystalline matrix; moderately well bedded in part but predominantly of indistinct, cavernous weathering strata	149	966

<u>Cairn Formation</u>

(upper dolomite)

18	Dolomite, argillaceous, medium and dark brown, medium crystalline; contains numerous unidentifiable fossil remains as well as thin beds of <u>Amphipora</u>; occurs in moderately resistant, brown, cavernous-weathering beds	40	817
17	Dolomite, argillaceous, dark brown, occurs in moderately resistant, dark brown-weathering beds from 2 to 4 inches thick	14	777

16	Dolomite, medium brown, medium crystalline, well bedded, occurs in brown-weathering, moderately recessive beds from 4 to 6 inches thick	10	763
15	Dolomite, argillaceous, dark brown to almost black, fine and medium crystalline; contains numerous light grey-weathering stromatoporoids from 2 to 6 inches in diameter; beds weather dark brown and moderately resistant	4	753
14	Dolomite, dark brown, medium and coarsely crystalline, good intercrystalline porosity; occurs in distinct but moderately recessive-weathering beds from 1 to 1 1/2 feet thick	8	749
13	Dolomite, light brown, medium and coarsely crystalline; occurs in vague, cavernous-weathering moderately resistant beds	6	741
12	Dolomite, Medium and dark brown, medium and coarsely crystalline, with numerous stromatoporoids and <u>Amphipora</u>, in beds from 2 to 8 feet thick alternating with beds of similar thickness, lighter in colour and containing no stromatoporoids or <u>Amphipora</u>, bedding contacts are commonly abrupt	169	735
11	Dolomite, argillaceous, medium and dark grey, fine and medium crystalline; contains numerous stromatoporoids and <u>Amphipora</u> throughout; bedding generally indistinct; weathers brown	66	566
10	Dolomite, medium and dark grey, medium and coarsely crystalline, in part has good intercrystalline porosity; contains numerous stromatoporoids and <u>Amphipora</u> throughout as well as other fossil remains, brachiopods and gastropods; occurs in resistant, brown-weathering beds	74	500
9	Dolomite, argillaceous and slightly silty, dark brown-grey, finely crystalline; contains a few nodular black chert lenses and numerous <u>Amphipora</u>, small solitary corals, brachiopods and gastropods; occurs in distinct, moderately resistant, brown-weathering beds from 4 inches to 1 foot thick	36	426
8	Limestone, argillaceous, dark grey, microcrystalline, with thin one half inch black chert lenses and nodules; scattered beds 2 to 4 inches thick contain numerous small brachiopods, imperfectly preserved but the fine shell outlines are conspicuous on weathered surfaces; shell valves are predominantly convex downwards; dolomitization has begun to affect the edges of valves; beds are moderately recessive, dark grey-weathering and from 2 to 4 inches thick	10	390

7	Dolomite, argillaceous, dark brown, fine and medium crystalline; contains numerous _Amphipora_ and numerous small 1/2-inch diameter vugs with white dolomite infilling, a few solitary corals, occurs in brown-weathering beds from 2 to 4 inches thick. . .	97	380
6	Dolomite, argillaceous, medium brown, fine to microcrystalline; occurs in moderately resistant, brown-weathering beds from six to eighteen inches thick . .	20	283
5	Limestone, argillaceous, trace of fine silt, dark grey, microcrystalline, contains scattered fine brachiopod remains throughout; shell fragments are fragile and largely broken; occurs in moderately resistant, light grey-weathering, 2 to 4-inch beds	37	263
4	Dolomite, argillaceous, dark brown, with thin beds containing numerous _Amphipora_; occurs in resistant, brown-weathering beds.	48	226
	(cherty dolomite)		
3	Dolomite, argillaceous, dark brown, fine and medium crystalline; contains numerous lenses and nodules of black chert; many calcite-infilled vugs about one half inch in diameter; occurs in distinct, brown-weathering beds from 12 to 18 inches thick.	104	178
2	Dolomite, argillaceous, dark brown to almost black, finely crystalline; contains numerous lenses and nudules of black chert; occurs in distinct, moderately resistant, brown-weathering beds 2 to 4 inches thick	16	74
	(lower dolomite)		
1	Dolomite, argillaceous, dark brown to almost black, finely crystalline, moderately recessive weathering; in distinct beds from 4 to 8 inches thick. . .	26	58
	UPPER CAMBRIAN		
0	Dolomite, silty, light brown-grey, fine to microcrystalline, dense uniform lithology; occurs in distinct, resistant, light yellow-grey weathering beds from 8 inches to 2 feet thick	32	32

MISSISSIPPIAN STRATIGRAPHY AND SEDIMENTOLOGY AT CADOMIN, ALBERTA[1]

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ABSTRACT

At Cadomin, Alberta, in the Rocky Mountain Foothills the Mississippian succession consists of the Exshaw (Devonian and/or Mississippian), Banff, Pekisko, Shunda, Turner Valley, and "Mount Head" Formations. The Banff Formation contains a lower shaly carbonate unit, a middle echinoderm limestone unit, and an upper, microcrystalline dolomite and micritic limestone unit. Pekisko lithologies are mainly echinoderm limestones which are partly dolomitized. The Shunda Formation is characterized by the presence of: (a) well-developed sedimentary cycles, and (b) at least ten solution breccias. Sucrosic, porous dolomite makes up most of the Turner Valley Formation, which is overlain by the dominantly microcrystalline dolomites of the "Mount Head" Formation.

A sedimentary environment model is presented which recognizes six main carbonate sediment environments ranging from offshore submarine areas to subaerial carbonate mud flats in which penecontemporaneous dolomitization of carbonate sediments took place. As applied to the Cadomin sequence, this model indicates three large cycles of sedimentation (Banff; Pekisko-Shunda; and Turner Valley-"Mount Head"). Each cycle begins with normal marine sediments and ends with microcrystalline dolomites of probable penecontemporaneous origin.

INTRODUCTION

Cadomin, Alberta is an extremely interesting area for studying ancient carbonate sediments. The Mississippian succession contains rocks which were deposited in environments ranging from offshore marine areas to subaerial mud-flats. In addition the Turner Valley Formation, which produces gas in the Edson field a short distance to the northeast, may be examined in surface outcrop.

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1 Published by permission of the Director, Geological Survey of Canada, Ottawa.

The first part of this paper discusses the structúral setting, formational subdivision and correlation of the Mississippian rocks of the Cadomin area; the second part, which is descriptive, outlines the stratigraphy and petrography of the sequence; the final, interpretive part is concerned with an analysis of sedimentary environments. Figure I gives a stratigraphic column of the Cadomin section, and an interpretation of the sedimentary environments represented.

LOCATION AND STRUCTURAL SETTING

Mississippian sedimentary rocks are exposed along the McLeod River Valley about one to three miles southwest of Cadomin townsite. The McLeod River has cut through the Nikanassin Range, exposing two Mississippian sections. The easterly, structurally lower (and incomplete) section is underlain by Devonian beds which are faulted over Jurassic rocks by the Nikanassin thrust at Cadomin (Mountjoy, 1959). The westerly, structurally higher section lies above a minor thrust fault which brings the Devonian Palliser Formation over Lower Rundle Group strata (upper beds of the Shunda Formation) of the lower section. Cadomin is located in the Foothills belt east of the McConnell (or Front Range) thrust of the Rocky Mountains, and the Mississippian section is thus similar in structural position to Mississippian sections to the south in the Brazeau and Bighorn Ranges near Nordegg (Brady, 1958), and at Moose Mountain (Illing, 1959).

FORMATIONAL NOMENCLATURE

On the basis of similarity in lithology and stratigraphic succession, the Mississippian sequence at Cadomin has been divided into six formations as at Nordegg (Brady, 1958) and Moose Mountain (Illing, 1959) to the south, and at Mount Greenock (Woodward, 1955; Moore, 1958) in the Rocky Mountains to the west. In ascending order these are the Exshaw and Banff Formations, and the Pekisko, Shunda, Turner Valley, and "Mount Head" Formations of the Rundle Group. It is important to note that stratigraphic relationships between the Cadomin area and the type sections of these formations, most of which are many miles to the south, have not yet been demonstrated. However it is significant that the Exshaw, Banff, Pekisko, Shunda, and Turner Valley Formations can be mapped in the subsurface from southern Alberta to the Edson area immediately east of Cadomin.[1]

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[1] Penner (1958) traced these formations in the subsurface of southern Alberta as far north as the Harmatton-Elkton area. H. L. Martin of the Geological Survey of Canada studied the area between Harmatton-Elkton and Edson.

At Mount Greenock Hawryszko and Hamilton (1964) used "Debolt (?) Formation" for beds which appear to be stratigraphically equivalent to strata identified in this paper as Turner Valley and "Mount Head" Formations. Mountjoy (1962) and Walasko, Lerbekmo, and Mountjoy (1964) gave a complete discussion of Mississippian nomenclature in the general Athabasca valley region.

Within the Rundle Group, the Pekisko, Shunda, and Turner Valley Formations at Cadomin are lithologically similar to the type sections of these formations to the south. The "Mount Head" Formation is very different from the type Mount Head, and the name is used for convenience only.

STRATIGRAPHY

Exshaw Formation

Two feet of rusty weathering, dark brown, fissile and non-calcareous shale tentatively assigned to the Exshaw Formation are exposed on the ridge to the northeast of the Whitehorse Creek campground. The contact with overlying yellowish weathering calcareous shale assigned to the Banff Formation is sharp and conformable. The yellowish-orange weathering silty dolomite or dolomitic siltstone which forms a prominent marker for the base of the Banff Formation in the Bow Valley, and as far north as Nordegg, appears to be absent at Cadomin.

Banff Formation

An informal subdivision of the Banff Formation into three units can be made at Cadomin. The lower, recessive-weathering unit, which is 352 feet thick, consists of dark brown papery to platy calcareous shales with minor interbedded shaly, micritic limestones at the base. Most of the upper half of the unit consists of a uniform sequence of rhythmically interbedded calcareous shales and micritic limestones, characteristic of this interval over much of the Athabasca valley area. The middle, resistant weathering unit is 63 feet thick, and consists of grey-weathering, micritic and echinoderm limestones, dolomitized in part, and separated into one inch to one to two foot beds by thin calcareous shale interbeds. Some beds have coarse-grained[1] echinoderm detritus, closely resembling the lithology of the overlying Pekisko Formation. A 100-foot sequence of prominent microcrystalline (silt size) to very fine crystalline yellowish-brown weathering silty dolomites with minor interbedded micritic limestones makes up the upper unit of the Banff. Some of the dolomites display fine lamination and current ripple marks. (Plate I-4)

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[1] Grain and crystal sizes given are in terms of the Wentworth grade scale as given by Pettijohn (1957, p. 18).

These informal units, which may be readily seen on the ridge to the northeast of the Whitehorse Creek campground, are similar to Mountjoy's (1962, p. 29) subdivisions of the Banff Formation in the Mount Robson map-area to the northwest of Cadomin. (Plate I-1)

Representatives of the "Platyrachella" rutherfordi fauna (Nelson, 1961) have been collected only from the middle and upper informal units of the Banff Formation at Cadomin. In the Rocky Mountains between Red Deer River and North Saskatchewan River this fauna occurs consistently in the upper part of the Banff Formation.

Pekisko Formation

Most of the Pekisko Formation is made up of massively bedded,[1] light grey weathering echinoderm limestones or their dolomitized equivalents. In the easterly stratigraphic section at Cadomin the yellowish-brown weathering dolomites of the upper Banff are overlain with sharp but apparently conformable contact by an 8 foot bed of medium grained ooliths set in a matrix of clear calcite which forms the base of the Pekisko. This bed passes gradationally upward into an echinoderm limestone, in part replaced by fine crystalline dolomite. Echinoderm limestones of the Pekisko are poorly sorted, with sizes ranging from very fine to very coarse grained. Some dark grey irregular chert bands are found near the top of the formation.

On the ridge to the northeast of Whitehorse Creek campground (westerly section) the Pekisko is 123 feet thick, and consists almost entirely of fine crystalline dolomite showing large-scale cross-bedding and traces of echinoderm detritus.

Shunda Formation

Almost continuous exposures of the Shunda Formation can be examined along the Cadomin-Mountain Park railway east of the Whitehorse Creek campground where it is 332 feet thick. Both upper and lower contacts are placed at lithologic-topographic changes which can be mapped. The lower contact has been discussed; the upper contact is marked by the first appearance of brown, massively bedded, resistant weathering, locally cavernous, fine to medium crystalline dolomite of the Turner Valley Formation. (Plate I-2)

There are four informal units in the Shunda Formation at Cadomin. The basal unit, which is 66 feet thick, is mainly composed of recessive weathering,

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[1] Bedding terms are: thin bedded, under 3"; medium bedded, 3"-1'; thick bedded, 1'-3'; massively bedded, over 3'.

thick bedded, generally fine crystalline dolomite with rare small vugs. Locally this dolomite contains traces of calcareous skeletal material which are readily seen when stained with alizarin red solution (Evamy, 1963). This unit is placed in the Shunda because it is recessive and brownish weathering, thick-bedded rather than massive, and is more finely crystalline than underlying Pekisko dolomites.

Excellent examples of sedimentary cycles are present in the overlying unit, which is 134 feet thick. A typical cycle is 3 to 5 feet in thickness (the thickest observed is 8 feet) and may be divided into two parts. The lower part, which may comprise up to half the total individual cycle thickness, consists of dense, micritic limestone usually with sub-angular intraclasts (see later section on petrography) up to one centimetre in diameter. Some intraclasts are surrounded by fine crystalline dolomite. Pellets, ooliths, pisoliths, and oncolites (algal nodules) occur in the micritic limestone portions of some cycles. The micritic limestones pass gradationally (in rare instances, sharply) upward into tan, brown weathering microcrystalline to very fine crystalline dolomite which is overlain with sharp contact by either another similar cycle, by non-cyclic shaly dolomite beds, or by fine crystalline dolomite. In some instances the basal micritic limestone grades upward into fine crystalline dolomite, which in turn grades to microcrystalline to very fine crystalline dolomite of the upper part of the cycle. Dolomites in the upper parts of the cycles sometimes show fine laminations which are even and regular in appearance or "crinkly" resembling small-scale ripple marks in cross-section. (Plate II-1)

The veritcal succession within the second unit of the Shunda comprises four groups of individual cycles separated by non-cyclic beds of either fine crystalline dolomite, or microcrystalline to very fine crystalline dolomite and shaly dolomite. At least 10 cycles are present in the entire unit.

A third unit, 38 feet thick, comprises a poorly exposed sequence of microcrystalline, brown weathering dolomite and recessive, shaly dolomite. The unit lacks micritic limestone, and is not obviously cyclic. Small thrust faults and local slight contortions are present in this unit, which is about one third covered in the section along the railway.

Sedimentary breccias, microcrystalline brown weathering dolomites (in part shaly), and grey weathering micritic limestones 94 feet thick constitute the upper part of the Shunda Formation. At least ten breccia zones are exposed along the railway. The breccias, which tend to be lenticular along strike, contain very angular fragments, mainly of microcrystalline dolomite and less commonly of micritic limestone. Although the fragments are up to one foot in size, most are in the one to five centimetre range. White vuggy calcite usually forms the matrix for these fragments. Thick breccias resemble calcareous tufa; they are porous and "crumbly" on the weathered surface, and tend to weather back. Some individual breccia zones are as much as three feet thick but most are six inches to one foot in thickness. No cyclic arrangement of microcrystalline dolomite, micritic limestone, and breccia is readily apparent. (Plate II-2)

No anhydrite or gypsum was found associated with these breccias, although Mountjoy (1962, p. 31) reported abundant anhydrite in his "Formation B" (probably Shunda equivalent) in the Solomon Creek well to the northeast of Cadomin.

The uppermost 10 to 15 feet of the formation is poorly exposed, but consists of very fine to fine crystalline dolomite unlike the typically microcrystalline dolomite of most of the Shunda.

The acid insoluble fraction of the Shunda consists mainly of fine silt to clay size material, much of which appears to be quartz.

Turner Valley Formation

Fine to medium crystalline, brown weathering, porous and resistant weathering dolomite makes up most of the Turner Valley Formation. Porosity is intercrystalline and fine vuggy, and is best developed in the lower half of the formation. Numerous colonies of the tabulate coral Syringopora occur in the lower part of the formation; lithostrotionid corals are also present near the base. Most of the colonies have been leached out, leaving only "ghosts" of the original corallites preventing precise identification. Traces of calcareous skeletal material confirm that the dolomite is a replaced echinoderm limestone, as has been suggested by many authors (Illing, 1959; Thomas and Glaister, 1959;).

Near the base of the formation several discontinous zones of brecciated fine to medium crystalline dolomite set in a white calcite matrix occur. Fragments are up to about 4 centimetres in diameter, and are very angular.

The formation is divided into upper and a lower porous zones (relationships of these porous zones with the "upper and lower porous" of the Turner Valley subsurface are not known) by a bed of very fine crystalline dolomite 18 feet thick located in the middle part of the formation. This unit is recessive weathering, and contains up to 20% black chert bands and cream coloured chert nodules. Silicified brachiopods are also present in the unit.

The upper part of the formation is generally fine crystalline, less porous than the lower part, and shows traces of large scale cross bedding. The uppermost 14 feet of the formation is recessive weathering and thick bedded rather than massive. The contact with the overlying "Mount Head" Formation is placed at the base of a deeply weathered, 7 foot zone of brecciated, microcrystalline dolomite.

"Mount Head" Formation

The Mount Head Formation has been the subject of extensive studies from the type area north to the Red Deer River (Macqueen, 1965). On the basis of these studies, usage of the term "Mount Head" Formation in the Cadomin area, although expedient, is a temporary measure. In the type area on Mount Head, and in the Front Range of the Rocky Mountains as far north as the head of Exshaw Creek in the Bow Valley, the formation can be divided into six members (Douglas, 1958; Macqueen, 1965). However, at Cadomin the sequence assigned to the "Mount Head" Formation consists of 200 feet of unfossiliferous, predominantly microcrystalline to fine crystalline dolomite with local interbeds of green dolomitic mudstone or shaly dolomite. Within the dolomites there are variations in crystal size, but these are not generally apparent on the weathered surface. Breccia zones of microcrystalline dolomite set in a calcite matrix are found at the base and top of the formation. Some beds show irregular, hummocky upper surfaces, and dessication cracks were found on the top of one bed. (Plate I-3 and II-3)

Work in progress by the author may clarify relationships between the sequence at Cadomin referred to the "Mount Head" Formation and the Mount Head Formation of the type area. At present the precise stratigraphic and biostratigraphic relationships of the Cadomin section are not known.

PETROGRAPHY

Introduction

A modified version of a carbonate classification scheme proposed originally by Leighton and Pendexter (1962) has been used successfully in studies of Mississippian sediments in the Mount Head - Moose Mountain - Banff area to the south of Cadomin. The sediment types outlined by this scheme facilitate comparison of Mississippian carbonate rocks with Recent carbonate sediments, and, an additional advantage is that there are no complex names to remember. All of the grain and matrix (textural) types described here are clearly visible with a hand lens, but are more easily seen with a binocular microscope on cut surfaces.

Limestone Grain Types

Limestone grains can be divided into skeletal and non-skeletal types (Illing, 1954). Skeletal types include the detritus of echinoderms (mainly crinoids, blastoids, and echinoids), bryozoans, brachiopods, gastropods, calcareous algae, foraminifera and calcispheres (small spherical bodies which may be the spore cases of some form of algae-(see Rich, 1965). Non-skeletal types include intraclasts (Folk, 1959), ooliths and pisoliths (Newell, et al., 1960), pellets and compound grains (Leighton and Pendexter, 1962).

Limestone Matrix Types

Two varieties of carbonate matrix types are recognized (Folk, 1959). Sparry calcite or spar is clear calcite originating for the most part as a pore-filling cement, which may be in optical continuity with skeletal grains such as echinoderm columnals. Micrite is calcite mud finer than .005 mm. Leighton and Pendexter (1962) suggested that a more satisfactory spar-micrite boundary is .030 mm, and this is the approximate boundary used here. Micrite may form a rock (the lime-mudstone or calcilutite of many authors), or may occupy interstitial space in cal-carenite.

Dolomites

Two varieties of dolomite are present at Cadomin. One type, which is similar to the "evaporitic dolomite" of Edie (1958), may exhibit the following features: 1. moderately uniform crystal size ranging from microcrystalline to very fine crystalline (.030 - .050 mm most common), 2. absence or rarity of invertebrate fossils, a primary feature, 3. association with evaporite minerals, or evidence of such association in the form of solution breccias or pseudomorphs after earlier evaporites, 4. light colour, especially pale yellowish orange, indicating low organic content, 5. association with micritic limestones, including vertical (and probably lateral) gradations to micritic limestones, 6. predominance of silt and clay sizes (mostly quartz) in insoluble residues, 7. frequent occurrence within well developed lithologic cycles.

The most important characteristics of the second type of dolomite are: 1. occurence as a replacement of limestone, with all gradations present from scattered euhedral dolomite rhombs in limestone to porous, sucrosic dolomite with relict skeletal grains, 2. crystal size is variable ranging on the average from .060

mm to .5 mm, 3. insoluble residue is consistent in amount and type with that of associated limestones, 4. silicified or dolomite-replaced fossils may be abundant.

Non-carbonate Constituents

No sandstones or siltstones occur in the Cadomin Mississippian, but insoluble residues of parts of the Banff and Shunda Formations show an abundance of silt and clay sized terrigenous material at some levels. Much of this appears to be quartz. The terms "shale" or "shaly" and "silt" or "silty" as used here imply the presence of appreciable amounts of clay or silt sized material, and may be added as modifiers to carbonate rocks types - e.g. silty dolomite, shaly micrite.

Chert is locally abundant, and some at least shows replacement relationships with the enclosing carbonate rocks.

Rock Types At Cadomin

Shallow water carbonate rocks of various kinds occur at Cadomin. Micrites and micritic-skeletal or skeletal-micritic limestones (dominant component last) are common in the Banff and Shunda Formations. Those of the lower part of the Banff are rich in terrigenous silt and clay sized material; skeletal fragments are mostly derived from echinoderms and brachiopods. Upper Banff and Shunda micritic limestones generally have lesser amounts of non-carbonate material. Micrites of the Shunda (especially those of the cyclic sequence) contain intraclasts, compound grains, and rare ooliths and pisoliths; calcispheres are locally very abundant. Pelleted "birdseye" micrites described by Illing (1959) occur locally in the Shunda.

Skeletal calcarenites dominantly of echinoderm and bryozoan detritus with sparry calcite matrix dominate the Pekisko in the easterly, slightly dolomitized fault slice. The middle unit of the Banff Formation contains echinoderm calcarenties with a micrite matrix.

Non-skeletal rock types are represented by oolitic calcarenites at the base of the Pekisko in the easterly stratigraphic section, and by the intraclastic and partly pelleted micrites of the Shunda Formation in the westerly section.

Of the two dolomite types described, microcrystalline to very fine crystalline dolomite dominates the upper part of the Banff Formation, the "Mount Head" Formation, and is an important constituent of the Shunda Formation. Fine to medium crystalline dolomite occurs in all formations except the Exshaw, and dominates the Pekisko and Turner Valley Formations east of the Whitehorse Creek campground. Intercrystalline and vuggy porosity is associated with this type of dolomite, especially in the Turner Valley Formation.

ANALYSIS OF MISSISSIPPIAN SEDIMENTATION AT CADOMIN

Environmental Model

Numerous authors (Douglas, 1958; Edie, 1958; Brady, 1958; Illing, 1959; Walpole and Carozzi, 1961) have classified Mississippian sediments in terms of the interpreted sedimentary environments represented. This type of analysis relates the orderly lateral and vertical succession of rock types to changes in depositional environments through time, and permits close comparison with Recent carbonate sediment environments.

Figure 1 presents a depositional environment classification based partly on work with the Mount Head Formation in the Banff-Mount Head area (Macqueen, 1965), and partly on the schemes cited above, especially that of Illing (1959). Six main carbonate sedimentary environments are recognized, which are thought to have formed a sequence of lateral environmental belts parallel to the shoreline at any given time during the Mississippian. Each environmental belt had a characteristic assemblage of sediments, (i.e. a characteristic facies) and some of these belts were probably tens of miles wide at any given time (e.g. the echinoderm-bryozoan banks of facies C).

Origin and Accumulation of Carbonate Sediment Types

Facies A, B, and C represent the transition from poorly aerated calcareous shales and limestones rich in terrigenous clastics of facies A into the bank-derived clastic-free echinoderm and bryozoan detritus of facies C. Decreasing water depth produced increasing turbulence, forming a complex assemblage of barrier bars, shoals and deltas in facies D, similar to those described by Kinsman (1964 a, b) in the Trucial Coast area of the Persian Gulf. Within this shallow-water zone of high energy, oolitic coatings were precipitated around skeletal and pellet nuclei.

Behind the bars and shoals of facies D, fine grained skeletal and pelleted micritic limestones of facies E accumulated in shallow lagoons. Occasional ooliths and pisoliths were washed in from the barrier bar and shoal complex, and some pisoliths may have been produced <u>in situ</u> in the lagoons by algal precipitation (blue-green algae?). Terrigenous clastics may have been contributed either by winds, or by stream-flow perhaps related to periodic heavy rainfall in adjacent land areas, or both. The pelleted carbonate muds of facies E formed by physico-

MISSISSIPPIAN STRATIGRAPHY AND SEDIMENTOLOGY CADOMIN, ALBERTA

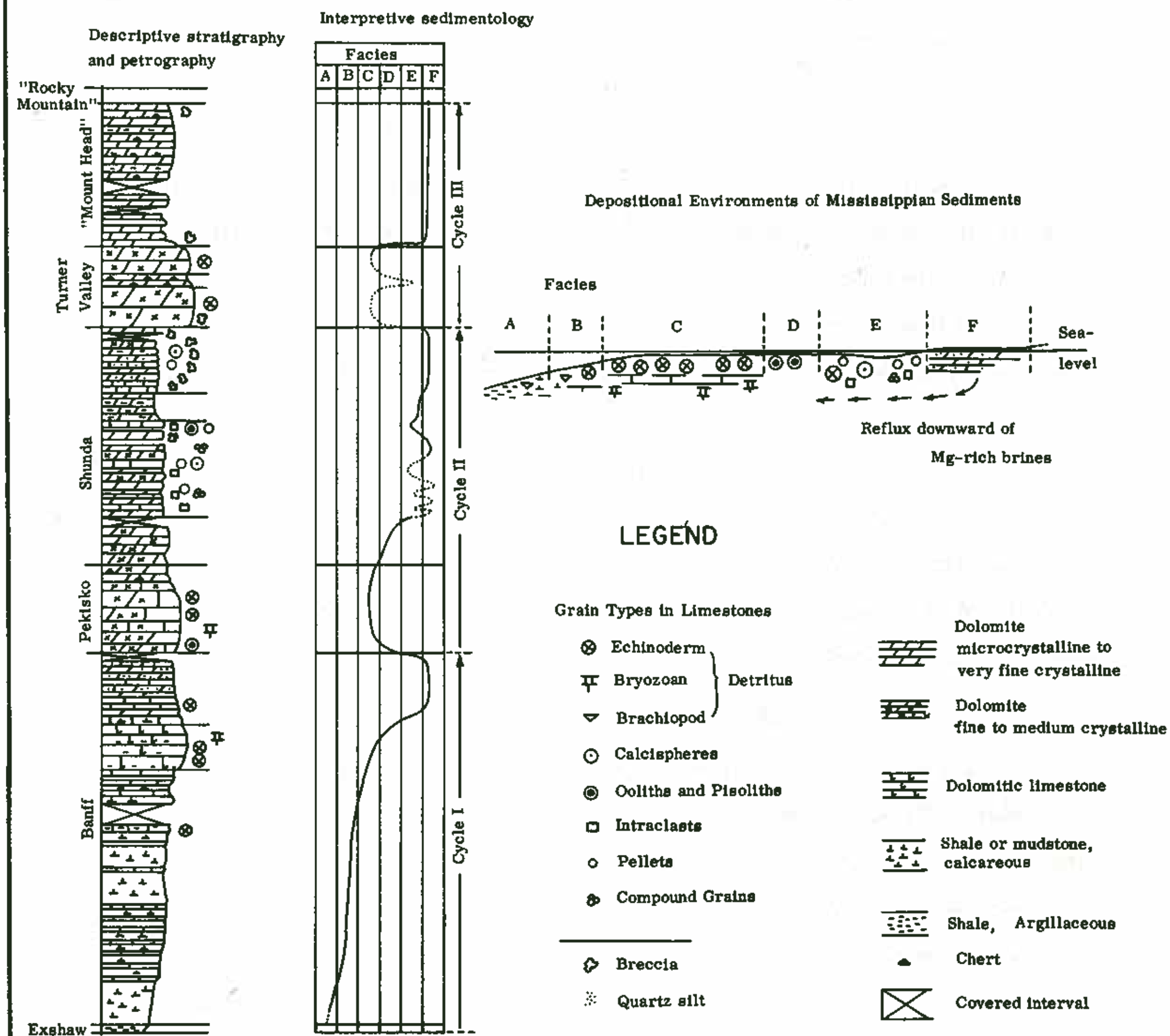

Figure 1. Mississippian stratigraphy and sedimentology at Cadomin, Alberta. Above left, columnar section (composite) of Mississippian formations at Cadomin, with interpretation of sedimentary environments. Above right, cross-section showing lateral sequence of Mississippian carbonate facies belts related to sea-level.

chemical precipitation in the shallow, supersaturated lagoons of this environmental belt, and accumulated in the lagoons and on marginal tidal flats, where they were pelleted by burrowing organisms.

Dolomitization of Sediments

One of the most important recent advances in the field of carbonate sedimentation has been the discovery of early diagenetic dolomite in Recent carbonate sediments of the Persian Gulf (Kinsman, 1964a; Illing et al., 1965), the Bahamas (Shinn and Ginsburg, 1965), and the island of Bonaire in the Caribbean (Deffeyes et al., 1965). Lagoonal and marginal tidal flat carbonate sediments (mostly aragonite) are dolomitized during early diagenesis by magnesium-rich brines produced by subaerial evaporation of pore waters on extensive carbonate mud flats. The mud flats or "sebkhas" owe their origin to seaward progradation of the shoreline by gentle uplift of the landmass, slight eustatic change in sea-level, or by sediment accumulation. In the Persian Gulf pelleted lime muds (micrites) of the lagoon pass shoreward through a zone of blue-green algal mats (which produce laminated sediment) into a mud flat or sebkha environment in which the dolomitization occurs. Dolomitization in the supratiaal environment produces a microcrystalline dolomite "mud", and is considered to be the most important mode of origin of the microcrystalline to very fine crystalline dolomites of facies F of the Mississippian at Cadomin.

On the island of Bonaire (Deffeyes et al., 1965) brines evolved through pore water evaporation on carbonate flats are also believed to produce "secondary" (fine to medium crystalline) dolomite by downward reflux. These authors believe that they have verified the reflux mechanism of dolomitization first proposed by Fischer (Newell et al., 1953) for the dolomitization of back reef limestones associated with the Capitan Reef of Permian age, a mechanism which was further discussed by Adams and Rhodes (1960). Some of the fine to medium crystalline Mississippian dolomites at Cadomin may have originated in this manner.

SEDIMENTATION OF THE CADOMIN SECTION

Banff Formation [1]

Deposition of the lower unit of the Banff Formation took place in

[1] Deposition of the Exshaw Formation is a problem related to the deposition of euxinic black shales in general (Pettijohn, 1957). Illing (1959) supposed that the Exshaw was deposited in vast lagoons of very restricted circulation. Banff sediments were considered by Illing (1959) to be of normal marine type.

an off shore , open marine environment, and was characterized by progressive shoaling, possibly in conjunction with fluctuations in the amount of fine terrigenous clastics supplied to the sea floor. Thus the record is one of alternating calcareous shales and shaly micritic limestones. Skeletal detritus increases in abundance upward in the section. Poorly sorted micritic echinoderm limestones of the middle part of the Banff indicate the local development of shoals of echinoderms, whose detritus was widely distributed beyond their actual area of growth. Red calcareous algae which grow in a narrow belt along the south shore of the Persian Gulf are similarly distributed in the modern environment. Upper Banff sediments at Cadomin indicate formation and accumulation in a lagoon - mud flat (sebkha) complex, with the microcrystalline dolomite of the assemblage having originated by penecontemporaneous dolomitization. This interpretation is strengthened by the dominance of microcrystalline to very fine crystalline dolomite showing such features as ripple marks and crinkly, "algal-mat" type lamination. Walasko (personal communication) arrived at a similar interpretation for Upper Banff sediments at Thornton Creek, near Mount Greenock.

Rundle Group

It is significant that a zone of oolitic calcarenite occurs at least locally at the base of the Pekisko Formation, as this zone marks the transition from the Upper Banff lagoon - mud flat complex to echinoderm-bryozoan banks which characterized Pekisko environments. Dolomitization of the Pekisko could have taken place by downward reflux of dense brines from lagoon - mud flat (sebkha) complexes of later Shunda time. Alternatively, Illing (1959) has suggested that upward flushing of magnesium-rich brines through porous sediments could lead to secondary dolomitization.

Shunda environments mark a return to the lagoon - mud flat complex of Upper Banff time. This interpretation is supported by the assemblage of micritic limestone (in part pelleted), microcrystalline to very fine crystalline dolomite, shaly dolomite, and micritic limestone - microcrystalline dolomite collapse or solution breccias. Sedimentary cycles in the micritic limestone - microcrystalline dolomite sequence are consistent with an alternation of lagoon (micritic limestone) and sebkha (replacement of pre-existing lime sediments) conditions. Most of the insoluble residue from the associated shaly dolomites and micrites is of silt and clay size, suggesting deposition of this material by wind transportation to the lagoon-sebkha complex. More data are needed on the nature and amounts of land derived material in the modern sebkhas. Evaporites in the Shunda, now indicated in the Cadomin section by extensive solution breccias, may have developed from sebkha brines during the dolomitization process. In the Persian Gulf, anhydrite beds up to one foot thick may form in the sebkha environment as a by-product of the dolomitization process (Kinsman, 1964a).

Dolomites of the Turner Valley Formation are of the "secondary" type, clearly replacing pre-existing echinoderm limestones. Data on the lateral and vertical distribution of facies within the Turner Valley and "Mount Head" Formations are needed before the relative importance of dolomitization by downward reflux or upward flushing can be assessed. Nevertheless downward reflux of dense sebkha brines from a "Mount Head" lagoon-sebkha complex, although not at present demonstrable, is an attractive hypothesis to account for dolomitization of the underlying Turner Valley Formation at Cadomin.

"Mount Head" time marks a third and final return to lagoon - mud flat conditions at Cadomin. However, the presence of tens of feet of microcrystalline to very fine crystalline dolomite without either interbedded micritic limestones or evidence of evaporites (except at the top and base of the formation) is anomalous, if the dolomite originated as a replacement of pre-existing carbonate sediments. Perhaps the dolomites of the "Mount Head" Formation at this locality mark the landward margin of vast sebkhas where dolomitization was most complete. If so, whatever evaporites were present must have been leached out at some pre-lithification stage, as solution breccias are conspicuously absent through most of the "Mount Head". Alternatively, some of the dolomite may be the product of very early carbonate diagenesis on mud flats analogous to those of the Coorong of southeast South Australia (Von der Borch, 1965). Such features as mud cracks, hummocky, channelled erosion (?) surfaces, and crinkly, "algal-mat" type lamination are consistent with a mud flat pene-depositional (diagenetic) environment.

The overlying sandstones and cherts of the "Rocky Mountain Formation" represent the closing phase of Palaeozoic sedimentation at Cadomin, and have been discussed at length by McGugan and Rapson (e.g. 1963).

CYCLIC SEDIMENTATION AT CADOMIN

Reference has been made in an earlier section to the 3 to 5 foot thick sedimentary cycles within the Shunda Formation which are interpreted as representing alternations between a lagoon and a mud flat or sebkha environment. On a larger scale, three gross sedimentary cycles can be recognized within the Mississippian at Cadomin (Fig. 1). The first cycle encompasses the entire Banff Formation (520 feet); the second, the Pekisko-Shunda sequence (455 feet); and the third, the Turner Valley - "Mount Head" succession (312 feet). If cycle thicknesses bear any direct relationship to rates of sedimentation, each successive gross cycle was of shorter duration than the previous one.

REGIONAL IMPLICATIONS

The Cadomin section has some interesting regional implications, provided the facies interpretations of Figure 1 are correct. If the Shunda Formation at Cadomin is the time equivalent of the upper Banff Formation of the type area along Bow River, the Shunda, which is in restricted environmental facies E and F at Cadomin, ought to pass laterally southward through a zone of clean sparry oolitic and echinoderm calcarenites of facies C and D, before changing to off-shore skeletal-micritic limestones and calcareous shales of facies A and B, which characterize upper Banff Formation of the type section. Such a facies change has not been demonstrated.

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Plate I

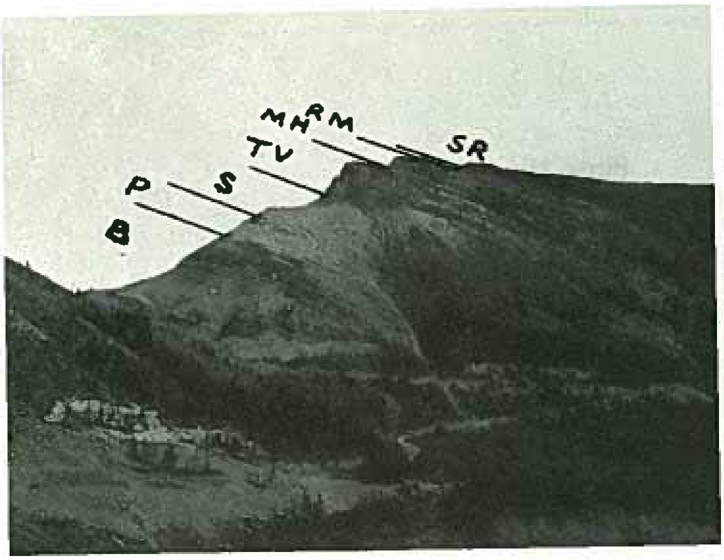
1. Mississippian section on ridge east of Whitehorse Creek campground. B=Banff Fm., P=Pekisko Fm., S=Shunda Fm., TV=Turner Valley Fm., MH="Mount Head" Fm., RM=Rocky Mountain Gp., SR=Spray River Fm. (Triassic)

2. Upper beds of Shunda Fm. (S), Turner Valley Fm. (TV), "Mount Head" Fm. (MH), Rocky Mountain Gp. (RM), and Spray River Fm. (SR) above the abandoned railway east of Whitehorse Creek campground.

3. "Mount Head" Fm. (MH), Rocky Mountain Gp. (RM) and Spray River Fm. (SR) as exposed along the abandoned Cadomin - Mountain Park railway.

4. Current ripple marks in microcrystalline dolomite of upper Banff Formation. 25 cent coin gives scale.

PLATE 1



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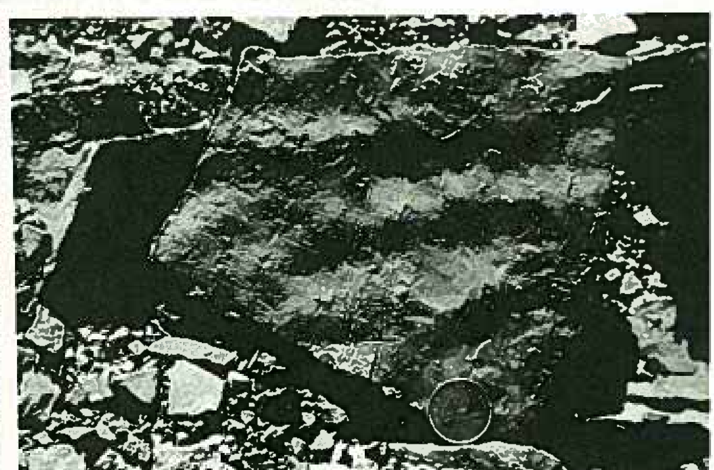

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Plate II

1. "Algal mat" type of lamination in micritic limestone and microcrystalline dolomite of the Shunda Fm. 25 cent coin gives scale.

2. Upper surface of bed of solution breccia in upper unit of the Shunda Fm. Micritic limestone fragments are embedded in white calcite. 50 cent coin gives scale.

3. Dessication cracks in microcrystalline dolomite of the "Mount Head" Fm.

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A NOTE ON THE TRIASSIC WHITEHORSE FORMATION OF THE TYPE SECTION

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INTRODUCTION

The age of the Whitehorse Formation in the area south of the Athabasca River has been in doubt for some time. Fossils are rare and poorly preserved and the relationship to the underlying Sulphur Mountain Formation is difficult to determine because of the usually poor Triassic exposures. No new data are given in this note - rather the information presented is a historical review of the age and relationships of the Whitehorse Formation.

STRATIGRAPHY

Kindle (1924) applied the term Spray River Formation to the Triassic of the Banff area. The faulted and incompletely exposed section in Spray River gorge near Banff was designated the type section.

Warren (1945) divided the Spray River Formation into the Lower Triassic Sulphur Mountain Member and the Middle Triassic Whitehorse Member. He designated Spray River gorge as the type section for the Sulphur Mountain Member but assigned no type section for the Whitehorse Member. No lithologic descriptions were given. Warren in 1927 had described the Spray River gorge section and in 1945 he referred to this section and amended the thickness from 3400 feet to 1853 feet.

Best (1958) designated the well exposed section at the junction of Whitehorse and Drummond Creeks as the type section of the Whitehorse Member. An informal division of dolomite-sandstone facies and red bed-evaporite facies was also made for the Whitehorse. In the paper no change was made in Warren's designation of Middle Triassic age for the Whitehorse. To the north of the Athabasca River, beds lithologically similar to the Whitehorse (Irish, 1954) had been established as Upper Triassic Karnian age. Best suggested that the Whitehorse was transgressive to explain the age discrepancy between the type area and the area to the north. Mountjoy (1960) revised the Whitehorse and Sulphur Mountain to formational status.

Subsequent work by Colquhoun (1960) and Manko (1960) firmly established the Triassic sequence in the area north of the Athabasca River and the age of beds lithologically similar to the Whitehorse as Upper Triassic.

Colquhoun (1960) suggested that Warren had used a basal contact for the Whitehorse below the contact established by Best (1958) in designating the type section. Warren (personal communication) indicated that his type section was approximately 300 feet thick and Shafiuddin (1960) in a thesis prepared under Warren's direction also obtained a thickness of 300 feet on remeasurement of Warren's type section. Best's thickness was 282 feet; therefore the designated type section for the Whitehorse is similar and probably the same as the one used by Warren (1945).

The only published paleontological data on the Whitehorse Formation south of the Athabasca River are those of Warren (1945). Discussions with Warren and re-examination of his material has determined that his fossils were collected from widely scattered localities and from localities that cannot be carefully established in the stratigraphic column. In addition much of his faunal evidence, for example, *Ceratites (Gymnotoceras) blakei*, came from north of the Wildhay River where an Upper Triassic age for the Whitehorse is well established. The validity of his Middle Triassic assignment for the type Whitehorse section is doubted (see Barss *et al.*, 1964).

Only Lower Triassic fossils have been collected from the Sulphur Mountain Member in the area south of the Athabasca River, but a considerable barren interval is present above the uppermost fossil horizon in the Sulphur Mountain and below the base of the Whitehorse. Physical correlation between Manko's subdivision in the Wildhay area and Best's divisions to the south, suggests that Manko's Black Shale Member and Upper Siltstone Member (Anisian and Ladinian in age) are equivalent to Best's Upper Siltstone unit. The presence of black radioactive shales in the interval 6147-6230' in the Triad McDermott Cline River 9-17-38-17- W5 well below the Whitehorse Formation tends to reinforce this correlation as radioactive shales are characteristic of Manko's Black Shale Member. In the more easterly sections, the Whitehorse is disconformable on the Sulphur Mountain although the contact may be gradational in the western sections. Precise faunal evidence of the age of the Whitehorse is lacking. Identifiable fossils have been obtained from the formation only north of the Athabasca River. The preponderance of evidence is that the base of the Whitehorse is no older than Ladinian and that the top, at least north of the Athabasca River, is Karnian in age.

LITHOLOGY

The type Whitehorse section at the junction of Whitehorse and Drummond Creeks in Township 45, Range 24, W5th Meridian was described by Best (1958) as follows:

"In the area the Whitehorse member forms a characteristic white weathering resistant unit. The contact with the Fernie is sharp." The section in descending order follows.

FERNIE FORMATION

Nordegg Member

	Thickness
Limestone, argillaceous, slightly sandy, dark grey, cherty, blocky, a few shale interbeds..............................	5' 4"
Shale, calcareous, slightly sandy, black, rather flaky, partly covered..	5' 8"
Total Nordegg measured..	11'0"

SPRAY RIVER FORMATION

Whitehorse Member - This member is whitish-grey weathering unless otherwise stated.

Quartzite, dolomitic and siliceous cement, light grey, medium grained, well sorted and rounded, uniform, minor carbonaceous flecks, blocky light grey weathering........	17' 5"
Dolomite, slightly argillaceous, light grey, very fine grained, dense in 1' beds with 3" shaly sandstone interbeds (20%)...	4'11"
Dolomite, argillaceous, sandstone streaks, (10%), light	

	Thickness
bluish grey, very fine grained, dense, tends to nodular weathering..	1' 8"
Dolomite, some fine sand, medium bluish grey, very fine grained, dense, hard uniform.............................	8"
Dolomite, argillaceous, medium bluish grey, very fine grained, dense, slightly nodular and blocky weathering..............	1' 6"
Dolomite, light brown, sublithographic, uniform, dense..........	2' 6"
Dolomite, sandstone (30%), light grey, very fine grained, dense, irregular wavy streaks of medium grained sandstone, some floating sand grains, in 2' even beds.......................	5' 2"
Dolomite, light grey, very fine grained, dense, uniform, evenly bedded...	4' 5"
Dolomite, sandy (5%), light grey, very fine grained, chalky, dense, streaks and bands of fine grained sandstone...........	9'10"
Sandstone, very dolomitic, fine to medium grained, in rusty weathering thin wavy beds..............................	11"
Dolomite, light grey, very fine grained, chalky, dense, in 1' even beds..	21' 3"
Dolomite, light brown, very fine grained to sublithographic, dense, hard, banded, in slightly irregular wavy beds.........	3' 6"
Dolomite, 20% sandy bands, light grey, very fine grained, dense uniform, massive..................................	2' 4"
Dolomite, as above with no sand..............................	3' 5"
Dolomite, likely calcareous, light brown, fine grained, crystalline banded, in one massive light brown weathering bed...	2' 6"
Dolomite, slightly sandy, light grey, very fine grained dense, soft, banded, in three even beds..........................	3' 6"
Dolomite, greyish white, very fine grained, chalky, dense in 1' even beds..	3' 8"
Dolomite, slightly calcareous, light greyish brown, fine grained, crystalline, sometimes chalky, in part recrystallized, abundant 1" vugs, in a very massive light to medium grey weathering bed. The upper part becomes very fine grained, earthy and with fewer vugs.........................	19' 7"
Dolomite, slightly calcareous, greyish white, very fine grained, chalky, soft, slightly banded, in 1" beds.............	1'10"

	Thickness
Dolomite, calcareous, light brown and grey banded, fine grained, crystalline, friable, intergranular and some vugular porosity, wavy banded, bed partly brecciated and at times completely brecciated, in massive irregular beds which tend to break into smaller wavy beds..............	31' 1"
Covered..	106' 2"
Dolomite, medium bluish grey, very fine grained, dense, light brown weathering, thinly bedded at the top.............	14' 4"
Covered..	17' 5"
Dolomite, as above in 14' 4"..................................	2' 0"
Total Whitehorse member......................................	281' 7"

Sulphur Mountain Member

Sandstone, slightly dolomitic, medium bluish grey, very fine grained, hard massive, dense.

A measureable section of the Sulphur Mountain is absent at this locality but a section is present along structural strike where Mackenzie Creek passes through the Nikanassin Range. At this locality the Sulphur Mountain is 526 feet thick. As this is slightly thicker than expected, minor faulting is probably present.

COMMENTS

The Triassic sections exposed in the Foothills and Front Ranges in the area south of the Athabasca River are more sandy and silty than the stratigraphically equivalent fossiliferous sections described north of the Athabasca River. If more westerly, probably shaly and fossiliferous sections could be studied, or the 150 foot interval immediately below the Whitehorse could be carefully examined for black shale beds in the covered intervals, the author feels that Middle Triassic faunas similar to those to the north would be found in the Sulphur Mountain and that more direct evidence of the probable Upper Triassic age of the Whitehorse would result.

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LOWER CRETACEOUS SECTION, CADOMIN AREA, ALBERTA

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ABSTRACT

Lower Cretaceous strata of the Cadomin area and adjacent parts of the central Alberta Foothills form a succession of interbedded conglomerate, sandstone, silty shale, and coal between three and four thousand feet thick. Divisible into three major depositional units (Nikanassin Formation, Cadomin plus lower Luscar Formations, and upper Luscar plus Mountain Park Formations) the succession is especially useful in establishing a province wide correlation of Lower Cretaceous rock units, exhibiting facies aspects characteristic of both the nonmarine Lower Cretaceous succession of the southern Alberta Foothills and equivalent partly marine strata of the northern Foothills and Plains.

INTRODUCTION AND TERMINOLOGY

Lower Cretaceous strata of the Cadomin area have been the subject of various investigations since the beginning of the century owing to their extensive high-grade coal deposits, which were mined on a commercial scale until 1957 when the last (Luscar) mine closed down.

The formational names currently in use for these rocks were proposed by MacKay (1929a), appearing on map legends of the Cadomin and adjacent Mountain Park sheets. The units were subsequently defined by MacKay (1930) as follows, arranged here in ascending order:

Nikanassin Formation (1900 feet): grey sandstone and dark grey shale with thin shaly coal beds;

Cadomin Formation (35 feet): resistant chert and quartz pebble conglomerate;

Luscar Formation (1700 feet): soft grey sandstone and dark grey shale with commercial coal beds in the upper part;

Mountain Park Formation (400 feet): coarse, green, ridge-forming sandstone and green shale with lenses of chert pebble conglomerate.

Previous workers (Malloch, 1911; Allan and Rutherford, 1924) had mapped the coal bearing beds -- including the Nikanassin, Cadomin, and Luscar Formations -- as "Kootenay", on the basis of an implied correlation with the coal bearing Kootenay Formation of the southern Foothills. However, MacKay (1930) correctly pointed out that although the Nikanassin flora is similar to the Kootenay flora of the southern Foothills, the flora of the overlying Luscar coal measures is similar to the non-dicotyledonous flora found in the lower part of the Blairmore Group, which overlies the Kootenay Formation in the southern Foothills. The Cadomin Formation, being correlative with the basal Blairmore conglomerate of the southern Foothills was used in the absence of other criteria, to differentiate the Nikanassin and Luscar Formations.

The Mountain Park Formation, lying between the Luscar coal measures below and the marine Alberta Group shales above, was originally described under a variety of names, now obsolete: "Dakota Formation" (Malloch, 1911; MacVicar, 1920), "Sunset Sandstone" (MacVicar, 1924), and "MacLeod Member" (Allan and Rutherford, 1924). Few fossil remains have been collected from this unit, and its relationship to the underlying Luscar Formation and to the Blairmore Group of the southern Foothills has remained somewhat obscure (Bell, 1956). MacKay (1929b) himself was unable to distinguish between the Luscar and Mountain Park Formations in the Brule coal basin north of Cadomin, and subsequent investigators in adjacent parts of the central and northern Foothills, with the notable exception of Douglas (1955, 1958), generally have not recognized the Mountain Park Formation as a distinct lithologic unit, including correlative strata with the underlying Luscar Formation for mapping purposes.

DESCRIPTION OF FORMATIONS

Nikanassin Formation

The Nikanassin Formation of the Cadomin area has been described in some detail by Kryczka (1959), who measured four sections along or adjacent to the McLeod River, south of Cadomin townsite, and on MacKenzie Creek to the southeast. Kryczka assigned a thickness of approximately 1400 feet to the Nikanassin Formation in this region, although the most complete and best exposed

Table 1. Correlation of Foothills Lower Cretaceous strata.

AGE	SOUTHERN FOOTHILLS	CADOMIN	NORTHEASTERN BRITISH COLUMBIA
Upper Cret.	BLACKSTONE FM	BLACKSTONE FM	CRUISER GOODRICH HASLER FMS
Lower Cretaceous			
	Crowsnest Mbr		
	UPPER BLAIRMORE		
	MIDDLE BLAIRMORE	MOUNTAIN PARK FM	COMMOTION FM
		LUSCAR FM	MOOSEBAR FM
		marine tongue	
	"calcareous" mbr		GETHING FM
	LOWER BLAIRMORE		
		CADOMIN CGL	CADOMIN CGL
?	KOOTENAY FM	NIKANASSIN FM	NIKANASSIN FM
Jura.	FERNIE FM	FERNIE FM	FERNIE FM

of his sections, on MacKenzie Creek, is terminated by a fault 1265 feet below the top of the formation.

The Nikanassin Formation comprises a rather monotonous succession of thin bedded, dark grey, fine grained sandstone and dark grey to black laminated siltstone and silty shale interbedded on a scale ranging from a few inches to tens of feet in thickness. The contact with the underlying, predominantly shaly beds of the Fernie Formation is gradational over an interval of about 50 feet ("passage beds"), above which thin siltstone and sandstone beds form a significant part of the section.

Representative portions of the lower part of the formation, including the basal "passage beds", are exposed at intervals in railway and stream cuts along the valley of the McLeod River between Cadomin and Mountain Park. The arenaceous units range up to 25 feet thick, consisting of dark grey, dominantly fine grained, microcrossbedded sandstone in thin, ripple marked beds separated by numerous dark grey silty or shaly partings. The shaly intervals, also widely variable in thickness, contain a high proportion of siltstone or silty sandstone interbedded on a very fine scale with true shale.

The Nikanassin sandstones are tough, siliceous rocks composed mainly of detrital quartz with minor amounts of chert, argillaceous rock fragments, and clastic carbonates. Small amounts of plagioclase feldspars also are present, serving to distinguish the sandstones from the siliceous sandstones in the overlying lower beds of the Luscar Formation, which they otherwise resemble. The predominant cement is quartz, as overgrowths on detrital grains, associated with minor authigenic carbonates.

The upper 200 feet or so of Nikanassin strata are well exposed in railway cuts at Cadomin townsite, the beds being overturned and dipping steeply to the west under the projected fault plane at the base of the Nikanassin Range. The strata appear to be more arenaceous than those described above but also exhibit much complex interbedding of fine grained, dark grey sandstone, siltstone, and silty shale. The rocks contain abundant carbonaceous matter, and three thin coal seams with an aggregate thickness of about 5 feet are found in the upper 100 feet of section (Kryczka, 1959). The contact with the overlying Cadomin Conglomerate is sharp and probably marks the locus of a regional disconformity.

The Nikanassin Formation of the Cadomin area has yielded few

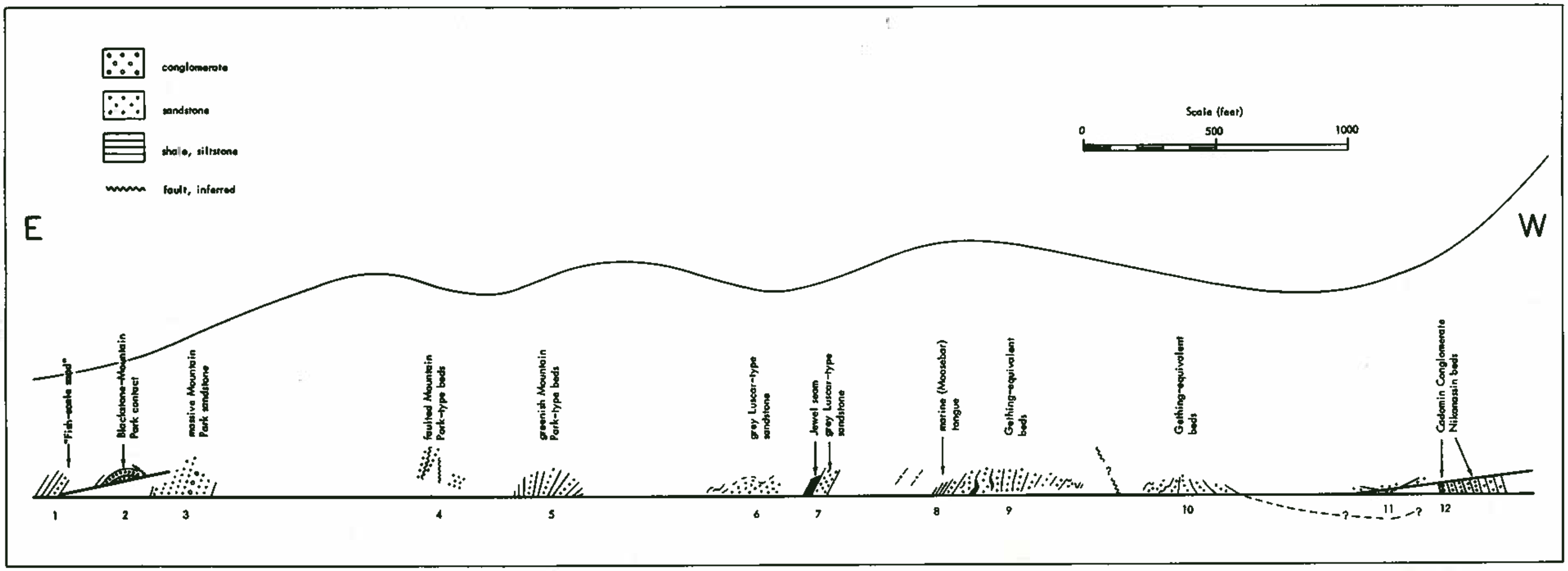

Figure I. Sketch showing the distribution and bedding attitudes of exposed Lower Cretaceous strata along the railway track at Cadomin, Alberta.

identifiable fossil remains. A few leaf impressions have been collected from the uppermost beds exposed along the McLeod River, to which Bell (1956) has assigned a Kootenay age. Kryczka (1959) reported the presence of poorly preserved agglutinated foraminifera in the basal beds on Prospect Creek, near its junction with McLeod River, but these have no value for correlation purposes. Kryczka also has described poorly preserved specimens of Buchia (Aucella) from exposures on Drystone and Morris Creeks, northwest of Cadomin, but does not give their location in the section. Other marine invertebrates, including species of Buchia and Belemnites, have been found in the lower portion of the Nikanassin Formation in the Foothills north of the Athabasca River (Irish, 1965); these indicate a Jurassic rather than a Cretaceous age for at least part of the Nikanassin Formation.

Cadomin, Luscar, and Mountain Park Formations

The Cadomin, Luscar, and Mountain Park Formations form a succession of interbedded conglomerate, sandstone, silty shale, and coal between 1500 and 2500 feet thick. The units form two narrow northwesterly trending belts of strata separated by older rocks of the south plunging, faulted Nikanassin Range. Displacement or repetition of beds by numerous local folds and faults and the general lack of good exposures, except for the thicker arenaceous units, make it difficult to determine formation thicknesses and lithologic details. The section described below is exposes in railway cuts along the south side of the McLeod River at Cadomin townsite and contains at least partial sections of each of the rock units under discussion. A sketch showing the location of outcrops, bedding attitudes, and stratigraphic marker beds is given in Figure 1.

The Luscar Formation at Cadomin is divisible into two parts on the basis of differences in gross lithology and sandstone composition (cf. Douglas, 1955). The lower part (in which the writer would include the Cadomin Conglomerate as the basal member) extends from the top of the underlying Nikanassin beds (12, Fig. 1) to the base of a thin tongue of dark grey marine shale (8, Fig. 1), forming a series of scattered outcrops along the railway tracks for a distance of about 2000 feet.

The Cadomin Conglomerate is about 35 feet thick, consisting of well rounded white, pink, grey, and, black quartzite, chert, and siliceous argillite pebbles up to 6 inches in diameter in a grey silica cemented sandstone matrix. The proportion of pebbles decreases in the upper 10 feet of beds, which consist of interbedded pebbly sandstone and medium grained cherty sandstone. Both upper and lower contacts appear sharp.

The overlying portion of the lower Luscar succession consists of dark grey silty shale, laminated siltstone, and thin bedded, fine grained, dark grey sandstone with scattered coal seams from 1 to 2 feet thick. Plant remains are abundant, and molluscs and ostracodes are found in some of the shaly intervals. The best exposures are found in a railway cut about 500 feet in length, consisting of about 300 feet of steeply dipping beds in the upper part of the succession, beneath the marine tongue (9, Fig. 1). Beds similar in lithology, but contorted and probably faulted, crop out at two localities to the west of the upper exposures (10, 11, Fig. 1), their exact position in the succession being uncertain.

The dominant lithology of the lower Luscar beds is dark grey fine grained sandstone and laminated siltstone in intervals up to 25 feet thick, separated by black silty shale and shaly coal beds from 1 to 5 feet thick. The sandstones tend to be thin bedded owing to scattered siltstone and shale partings, generally becoming more silty towards the base of a unit. The thin bedding and silty nature of the lower Luscar sandstones are comparable with similar properties of the arenaceous units in the older Nikanassin Formation but are sufficient to distinguish them from the thick homogeneous sandstones in the upper part of the Luscar Formation.

The sandstones themselves are tough, fine grained, siliceous rocks composed of quartz, chert, siliceous rock fragments, and carbonates. Volcanic detritus, (including feldspars), present in the underlying Nikanassin sandstones and abundant in the upper Luscar and Mountain Park sandstones, is absent or extremely rare.

The upper 10 feet of lower Luscar beds consist of dark grey, laminated, silty shale carrying abundant ostracode remains and are correlative in stratigraphic position with the ostracode bearing "calcareous" member found at the top of the lower Blairmore succession in the southern Alberta Foothills. The boundary with the overlying marine shales is sharp but conformable, and there is no evidence for a break in deposition at the contact, the ostracode bearing beds probably marking a phase of deposition transitional from the coastal coal swamps in which the underlying plant bearing beds were deposited to the distinctly marine environment associated with overlying foraminifera bearing shales.

The marine tongue at Cadomin (8, Fig. 1), which marks the base of the upper Luscar succession, comprises about 20 feet of dark grey non-silty shale with scattered thin ironstone nodules or beds. The lower contact is sharp, being marked by a thin ironstone bed containing abundant crushed pelecypod shells. The shales carry abundant agglutinated foraminifera in addition to rare calcareous forms found in the Moosebar, Loon River, and Clearwater Formations of northeastern British Columbia and Alberta (Mellon and Wall, 1963), and thus provide a reliable marker bed for correlation purposes. The upper boundary of the unit is covered, and only a few "grass roots" outcrops consisting of dark grey, carbonaceous, laminated siltstone and shale are exposed between this level in the section and the overlying grey Luscar type sandstone beneath the Jewel Seam.

The uppermost exposures of the Luscar Formation comprise two thick grey sandstones separated by a lateral interval of about 100 feet (6, 7, Fig. 1). The coal seam formerly mined at Cadomin (Jewel Seam) directly overlies the lower sandstone, being 28 feet thick (MacKay, 1930). MacKay also mentioned the presence of a 4-foot thick coal seam, about 75 feet below the Jewel Seam, the lower coal being covered at this locality.

The two sandstones above and below the Jewel seam are grey, medium grained, crossbedded, relatively homogeneous units, the lower being 50 feet thick and the upper of uncertain thickness owing to local folding. The lower sandstone contains small amounts of feldspars and volcanic rock fragments, and the upper contains abundant amounts. Kaolinite and quartz are the dominant cements in both sandstones, and small reddish brown siderite pellets 1-2 millimeters in size are present in the upper sandstone, a common characteristic of upper Luscar and correlative sandstones through the central Foothills and Plains.

The upper sandstone grades up into laminated, dark grey, silty and shaly beds several feet thick, but the nature of the contact with the overlying Mountain Park beds is obscured by a covered interval that extends for about 500 feet along the railway track. In sections south of Cadomin, between Ram and North Saskatchewan Rivers, the Luscar-Mountain Park contact is gradational over an interval of 50 to several hundred feet, depending on the criteria used to define it.

The Mountain Park Formation comprises several hundred feet of detrital strata exposed only in scattered intervals along the railway track between the overlying Alberta Group shales to the east (1, Fig. 1) and the grey Luscar type sandstone above the Jewel Seam (6, Fig. 1). The lower exposures (4,5, Fig. 1) consist mainly of greenish grey weathering silty and shaly strata with thin fine grained sandstone interbeds. The beds are steeply dipping and in places folded and probably faulted (4, Fig. 1).

The most prominent exposure is towards the eastern end of the section (3, Fig. 1), where a thick, steeply dipping, ridge forming sandstone unit crops out, beneath the folded contact with the overlying Alberta Group shales. The unit is about 165 feet thick and is divisible into two sandstone intervals, separated by a thin dark grey silty shale bed 40-45 feet above the base. The sandstones are dark green in color, well sorted and crossbedded, ranging from fine to coarse grained, with lenses of pebbly sandstone at the base of the upper interval. Scattered dark grey mudstone pebbles are present in the lower beds of the upper sandstone, possibly caused by reworking of the underlying silty shale bed along strike. The upper beds grade into fine grained dark green silty sandstone and shale, folded and faulted at the contact with the overlying Alberta Group.

The predominant feature of the Mountain Park sandstones is their greenish color, which can be attributed largely to abundant authigenic chlorite cement. The sandstones also contain abundant feldspars and volcanic rock fragments, a compositional feature of considerable value in tracing correlative beds in the Foothills south of Cadomin. Other cements are illite and quartz and abundant but erratically distributed authigenic calcite (Mellon, 1964).

The uppermost beds of the Mountain Park Formation consist of 35 feet of interbedded dark greenish grey shale and siltstone in sharp but confomable contact with dark grey silty shales of the Alberta Group. Shaly beds 20 feet below the contact contain a flora composed of the following species (identified by C. R. Stelck):

<u>Cladophlebis munda</u>
<u>Cladophlebis parva</u>
<u>Sphenopteris goepperti</u>
<u>Sphenopteris</u> sp. cf. <u>S. mclearni</u>
<u>Pityophyllum nordenskjoldi</u>
<u>Pseudocycas</u> sp. cf. <u>P. unjiga</u>
<u>Athrotaxites berryi</u>

The flora is similar to that found in the underlying Luscar beds, forming part of Bell's (1956) "lower Blairmore" flora, which ranges through the lower and middle parts of the Blairmore Group in the southern Alberta Foothills.

The Mountain Park-Alberta Group contact is about 75-100 feet below a 20-foot interval of thin bedded, dark grey, silty shale and siltstone carrying abundant fish scales (1, Fig. 1). Microfaunal evidence indicates that these beds are correlative with the "Fish Scale Marker" bed of the Alberta Plains (Wall, in press).

AGE AND CORRELATION

The stratigraphic relationship of the Lower Cretaceous section at Cadomin with correlative strata in the Foothills of southern Alberta and northeastern British Columbia is summarized in Table 1.

The Nikanassin Formation is correlative on the basis of stratigraphic position and floral content with the coal bearing Kootenay Formation of southern Alberta, which is at least partly Jurassic in age (Frebold, 1957). There is also some faunal evidence in the north central and northern Alberta Foothills to indicate a partly Jurassic age for the Nikanassin Formation, which from a comparison of lithologies and fossil content is undoubtedly a partly marine facies of the coal bearing Kootenay Formation to the south.

The overlying Cadomin, Luscar, and Mountain Park Formations are correlative with the lower and middle parts of the Blairmore Group in the southern Foothills, the Luscar and Mountain Park successions both containing elements of Bell's (1956) non-dicotyledonous "lower Blairmore" flora. The marine tongue in the middle of the Luscar succession apparently thickens to the north at the expense of the overlying coal bearing beds to form the Moosebar Formation of the northern Foothills, the underlying lower part of the Luscar Formation being correlative with the Gething Formation of that area. South of Cadomin, in the region of the North Saskatchewan River, the marine tongue is replaced by shoreline or nonmarine beds, which in the south central and southern Alberta Foothills lie on fossiliferous calcareous shales and freshwater limestones ("calcareous" member) at the top of the lower Blairmore succession. The marine (Moosebar) tongue itself can be dated as middle Albian from the associated microfauna (Mellon and Wall, 1963), but the precise age of the underlying lower Luscar (lower Blairmore) succession is still debatable.

The coal bearing upper Luscar beds can be traced as far south as Ram River, apparently grading laterally to the south into Mountain Park type beds in the lower part of the middle Blairmore succession. North of the Athabasca River the Mountain Park Formation generally has not been recognized as a distinct lithologic

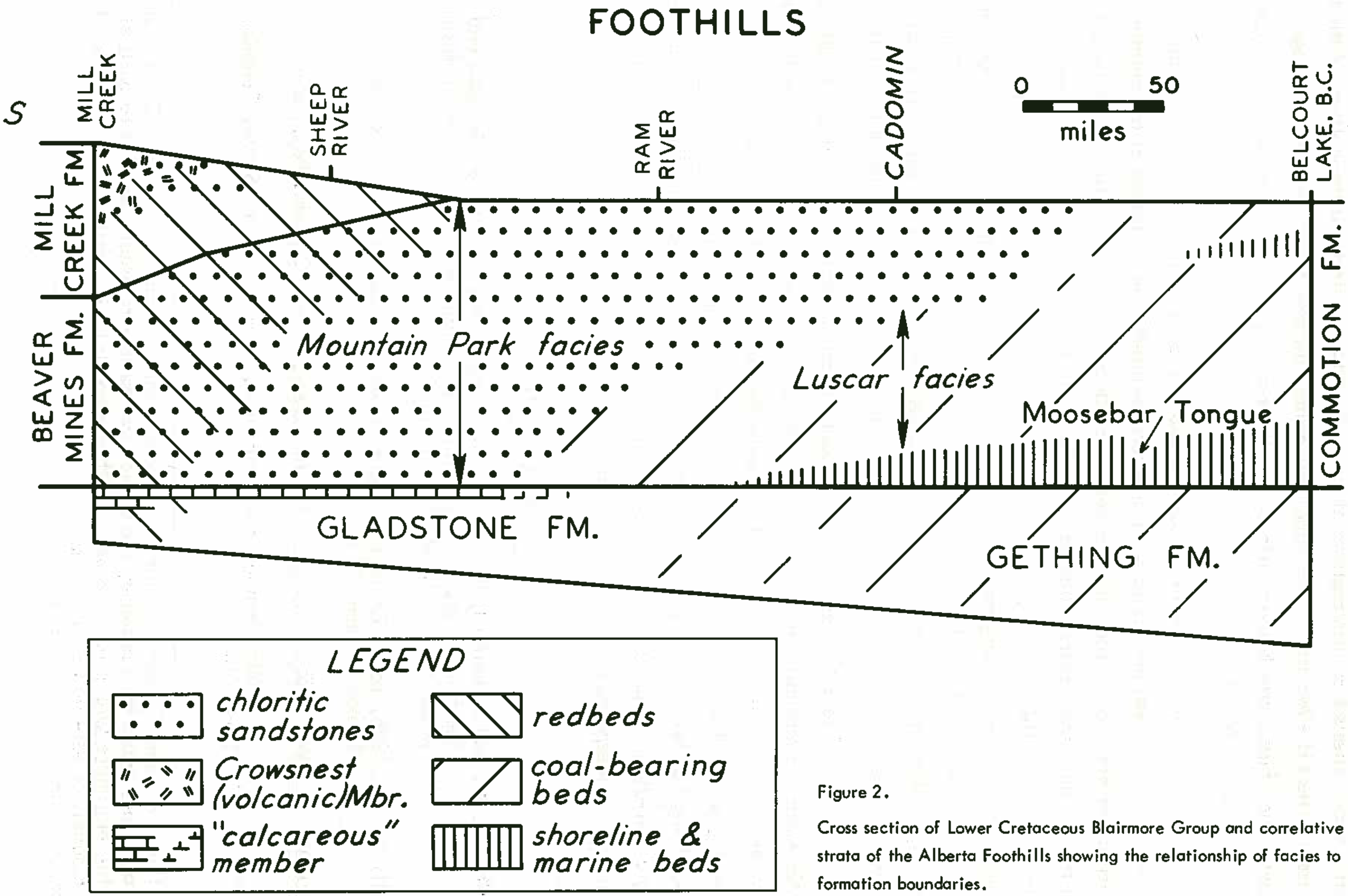

Figure 2.

Cross section of Lower Cretaceous Blairmore Group and correlative strata of the Alberta Foothills showing the relationship of facies to formation boundaries.

unit, and it seems from descriptions of Lower Cretaceous strata in the northern Alberta Foothills that the Mountain Park type beds grade laterally there into coal bearing Luscar type beds, which are contiguous with the partly marine Commotion Formation of northeastern British Columbia (Stott, 1960).

This relationship is summarized in Figure 2, in which the Mountain Park and Luscar beds are interpreted as laterally interfingering facies of the middle part of the Blairmore Group (designated as the Beaver Mines Formation in Figure 2*) in the southern and central Alberta Foothills. The Mountain Park facies represents the nonmarine, fluviatile deposits to the south, whereas the Luscar facies represents coastal plain deposits marginal to the shoreline and marine Commotion and Moosebar beds to the north. A similar facies distribution exists in the underlying lower Blairmore (Gladstone Formation) - lower Luscar beds, which take on a "less continental" aspect as they are traced from the southern into the north central Alberta Foothills.

The dicotyledon bearing upper Blairmore beds of the southern Foothills (Mill Creek Formation) are absent in the north central Alberta Foothills either through non-deposition or erosion. Thus, at Cadomin the basal beds of the Alberta Group, carrying a pre-"Fish Scale", post-Viking microfauna (Miliammina manitobensis microfauna) of late Albian age, rest directly on nonmarine Mountain Park beds carrying a non-dicotyledonous flora of middle Albian age, the contact of the two units marking a widespread break in sedimentation during Albian time.

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CRETACEOUS ALBERTA GROUP IN THE REGION OF McLEOD RIVER, ALBERTA[1]

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Abstract

The Upper Cretaceous Alberta Group consists of a sequence of shales and sandstones, predominantly of marine origin. Lithology, age relationships, and depositional environments of the Blackstone, Cardium, and Wapiabi Formations in the McLeod region are reviewed briefly. Two diagrams depict the relationships of non-marine and marine strata within the Cardium Formation in the region between Athabasca and North Saskatchewan Rivers.

INTRODUCTION

Cretaceous rocks in the McLeod region were investigated first by Rutherford (1925) and MacKay (1929a, 1929b), who included the Blackstone, Cardium (Bighorn), and Wapiabi Formations in the Colorado Group. The name Alberta Group, originally defined by Hume (1930), was applied in the region between Crowsnest Pass and Brazeau River by Webb and Hertlein (1934) who also devided the formations into minor lithologic units (see Fig. 1). The Alberta Group in the Brazeau region was intensively studied by Hake et al. (1942) and Scott (1951) during the course of their investigations of folded faults. Areas immediately adjacent to the Cadomin and Mountain Park map-areas were mapped by MacKay (1940a, 1940b) and more recently revised by R. J. W. Douglas (manuscript). In conjunction with the latter, the present writer (Stott, 1963, in press) made a regional study of Upper Cretaceous marine rocks, giving considerable emphasis to the Alberta Group in the Brazeau region. Structure, isopach, and facies maps of equivalent beds in subsurface between Pembina River (latitude 53°) and Peace River (latitude 56°) were presented by Burk (1963). The Cardium Formation beneath the Plains southeast of the McLeod region was described by Michaelis (1957).

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STRATIGRAPHY

Introduction

The Alberta Group in the Foothills near McLeod River comprises a thick succession of Upper Cretaceous marine shales separated into two parts by a sandstone sequence; the formations are, in ascending order, Blackstone (shale), Cardium (sandstone), and Wapiabi (shale) respectively. The type sections of these formations are south of McLeod River in the adjacent Brazeau-Bighorn region. To the north beyond Athabasca River, a prominent sandstone, the Dunvegan Formation, develops within beds equivalent to the lower part of the Blackstone and in that region the overlying marine succession is included in the Smoky Group. In addition, a marked change occurs within the Cardium Formation between Cardinal and Athabasca Rivers. The succession in the vicinity of McLeod River contains elements of both the northern and southern sequences and is transitional between them.

This succession of Upper Cretaceous rocks reveals a lateral and vertical succession of marine shale, littoral and epineritic sandstones, and lagoonal to deltaic sediments. The intertonguing of these deposits records the shifting depositional environments related to rapid westward transgression of marine water and the succeeding slow eastward progradation of the shorelines. The general succession is similar to that found along the modern Gulf Coast. Marine shales grade upward into fine-grained, massive sandstone. A transition zone from shale through interbedded shale and thin-bedded sandstone which resembles the transition zones of barrier islands and epineritic bars is almost always present at the base of the overlying sandstones. Above the sandstones is a succession of greenish to brownish, clay mudstones with thin beds of carbonaceous siltstone, sandstone, and coal believed to represent lagoonal and marsh deposits. Repetition of parts or all of this succession record several oscillations of the shoreline.

Sandstones of the Alberta Group are known to hold substantial reserves and are currently major producers of petroleum and natural gas at Pembina and other fields east of the McLeod region. Most of the sandstones in the Foothills lack good porosity because of siliceous cementation and compaction; those beneath the Plains, having undergone much less compaction and being less well cemented, constitute a more favourable reservoir rock. The lenticular sand bodies are enveloped by impermeable shale, forming good stratigraphic hydrocarbon traps.

SOUTHERN AND CENTRAL REGION

HECTOR (WHITEAVES 1895)	DAWSON 1884	CAIRNES 1907		MALLOCH 1911	ROSE 1920		SLIPPER 1921		RUTHERFORD 1927		HUME 1930		WEBB & HERTLEIN 1934			HAKE, WILLIS, & ADDISON 1942			SCOTT 1951			STOTT 1957		
			BELLY RIVER	BRAZEAU		ALLISON		BELLY RIVER		BELLY RIVER		BELLY RIVER			BELLY RIVER						BRAZEAU			BELLY RIVER
															Transition			Transition			Transition			Nomad
															Upper concretionary shale			Blocky			Siltstone			Chungo
																		Upper conc. shale			Upper conc. shale			Hanson
			Claggett formation	Wapiabi formation						Upper Benton formation		Upper		Wapiabi formation	Platy shale		Wapiabi formation	Platy shale		Wapiabi formation	Platy shale		Wapiabi formation	Thistle
																		Lower concretionary shale						Dowling
															Lower concretionary shale						Lower concretionary shale			Marshybank
																		Striped						Muskiki
															Upper member			Upper sandstone			Upper sandstone			Sturrock
																		Upper shale						Leyland
"Cardium" shales and also "Ostrea" shales	Dark shales		Cardium sandstone	Bighorn formation	Benton formation	Cardium sandstone	Benton formation	Lineham member	COLORADO GROUP	Cardium formation	Alberta shale	Cardium bands	ALBERTA GROUP	Cardium formation	Middle member	ALBERTA GROUP	Bighorn formation	Middle sandstone	ALBERTA GROUP	Cardium formation	Middle shaly member	ALBERTA GROUP	Cardium formation	Cardinal
																		Lower shale						Kiska
		Niobrara-Benton formation																						Moosehound
															Lower member			Lower sandstone			Basal sandstone			Ram
															Transition			Transition			Transition			Opabin
															Rusty shale			Hydrogen sulphide			Rusty shale			Haven
				Blackstone formation						Lower Benton formation		Lower		Blackstone formation	"I. labiatus"		Blackstone formation	"I. labiatus"		Blackstone formation	"I. labiatus"		Blackstone formation	Vimy
															Barren			Barren			Barren			Sunkay
			"Dakota" fm.	"Dakota" fm.		"Dakota" fm.		"Dakota" fm.		Blairmore fm.		Blairmore fm.			Blairmore fm			Mtn Park fm.			Blairmore fm.			Blairmore fm.

GSC

Figure 1. Nomenclature of Alberta Group, Alberta foothills (from Stott, 1963, Table I)

Blackstone Formation

The Blackstone Formation, originally named by Malloch (1911), contains four members which are, in ascending order, Sunkay, Vimy, Haven, and Opabin (Stott, 1961, 1963). The formation consists mainly of dark marine shale and siltstone with minor beds of argillaceous limestone, sandstone, bentonite, and some ironstone concretions. In general, the Blackstone contains more silt in sections along the western Foothills. The thickness of a composite section on Thistle Creek near Brazeau River is 1,411 feet (Stott, 1963) although a maximum of over 1,700 feet was measured on Bighorn River.

In the McLeod region, the Blackstone overlies beds designated as Mountain Park Formation or Blairmore Group. The contact, as seen in the railroad cut at Cadomin, is abrupt with rusty weathering shale lying above soft greenish clay and sandstone. A few pebbles and some gritty shale are present within the basal 2 to 3 inches of shale. The base of the formation is diachronous, ranging from late Albian in the central Foothills to as young as late Cenomanian to Turonian in the Crowsnest Pass region.

The Sunkay Member, comprising the basal, rusty weathering shale and siltstone, has a maximum thickness of 631 feet in the type section on Bighorn River. The lower part of the member is commonly much siltier than the upper and generally contains large reddish brown weathering concretions. It is well exposed at Cadomin where a prominent unit of siltstone and shale, about 80 feet above the base, contains abundant fish scales and fragments. The strata probably represent the "Fish Scale" marker bed that is considered to coincide with the Albian-Cenomanian boundary (Stelck *et al.*, 1958) and that is shown by Burk (1963) to be present eastward in subsurface. The presence of the Pouce Coupe Sandstone at Cadomin was reported by Stelck and Wall (1955, p. 25). On McLeod River upstream from Mountain Park, a 15-foot unit of argillaceous fine grained sandstone occurs within the rusty weathering shales considered to be part of the Sunkay Member. That unit lies about 25 feet below another resistant unit of dark argillaceous siltstone. These beds may be equivalent in part to the Pouce Coupe Sandstone or to the Dunvegan Formation, known to be present north of Athabasca River. The Sunkay sediments were deposited under mildly oxidizing conditions during a major advance of the Cretaceous sea in late Albian and early Cenomanian time. The *Dunveganoceras* zones of Cenomanian age are the only megafaunal zones definitely recognized in the member. *Dunveganoceras* parvum Cobban and D. conditum Haas were reported by Warren and Stelck (1955) from Blackstone shales at Cadomin and D. clowi Warren and Stelck, from Luscar Creek. On the basis of lithologic correlation, the writer (Stott, 1963) suggested that beds of late Albian age are present in the Sunkay of the central Foothills. That inference was later confirmed by the discovery by Wall and Germundson (1963) of the late Albian Miliammina manitobensis - Verneuilina canadensis microfauna in Sunkay beds south of Nordegg. Stratigraphic relationships and the presence of the Fish Scale beds in lower Sunkay strata at Cadomin suggest that the basal beds there may be also of Albian age.

Silvery grey weathering calcareous shales lying above the rusty Sunkay beds were included in the Vimy Member (Stott, 1961, 1963) which is in the order of 600 feet thick in the Brazeau region. The base of the member is in many places approximated by a persistent bed of bentonite. However, at Cadomin the member is in fault contact with Sunkay strata. Higher beds of the Vimy are almost flat-lying east of Cadomin and a large part of the member is not exposed. The Vimy shales record one of the most widespread Cretaceous inundations. The calcareous shales and thin beds of dense argillaceous dolomitic limestone represent a mid-basin environment lying farther offshore than the underlying sideritic facies, the sediments having been deposited below wave base in a reducing environment. The Vimy Member lies within two well established Turonian megafossil zones. The well known Inoceramus labiatus Schlotheim fauna characterizes the lower beds and Prionocyclus woollgari Mantell occurs in the uppermost beds. The Vimy Member, considered equivalent to the lower or second white-speckled shale of the Colorado Group of the Plains, contains a pelagic microfauna (Wall and Germundson, 1963). The "White specks" of the Plains either do not occur in outcrop within the Foothills or are obscured by the increased silt content, although the marker horizon is recognized by Burk (1963) in wells northeast of Cadomin.

The Haven Member contains dark grey, rusty weathering shales with thin beds of siltstone and a few large calcareous to dolomitic concretions. A yellowish efflorescence and fetid odour commonly characterize this member. Haven shales are not completely exposed in this region but upper beds outcrop near the junction of Luscar Creek and McLeod River. The thickness is probably in the order of 250 to 300 feet. That facies apparently represents a highly reducing stagnant environment in a restricted mid-basin environment. The Haven Member lies within the Prionocyclus woollgari zone which, according to J. A. Jeletzky (pers. com.), is of early late

Turonian age. Scaphites cf. S. patulus Cobban and Prionocyclus sp. indet. were collected 100 feet below the top of the member in the eastern fault slice above the mouth of Luscar Creek.

Concretionary beds lying above the rusty weathering Haven Member and below the thick-bedded Cardium Sandstone are included in the Opabin Member. A thickness of 156 feet was measured on the second or middle fault slice at the mouth of Luscar Creek. The sediments range from blocky to rubbly shale through siltstone to fine grained, platy sandstone. Large reddish brown weathering concretions occur sporadically or in layers throughout the member. Lamination and bedding are commonly poorly developed and may be absent. The silty shales, containing siderite and glauconite, were deposited in a neritic environment and resemble pro-delta and offshore clays of the Gulf of Mexico. The beds are transitional from the mid-basin facies of the older Blackstone shales to the epineritic Cardium sandstones and mark the beginning of a major regression. Ammonites referable to or comparable with Prionocyclus woollgari Mantell were collected from the Opabin Member in its type region.

Cardium Formation

The Cardium Formation (Hector, in Whiteaves, 1895; Cairnes, 1907; Rutherford, 1927) of the McLeod region is transitional between the northern (in large part non-marine) and southern (dominantly marine) facies. To the south in the type region, six members are recognized (Stott, 1961; 1963); in ascending order, they are Ram, Moosehound, Kiska, Cardinal, Leyland, and Sturrock. The lateral variations in the McLeod region are recorded in the sections on McLeod and Pembina Rivers, Maskuta, Sphinx, and Mackenzie Creeks (Figs. 2 and 3).

The Cardium sandstones are somewhat discontinuous along strike (Fig. 3), although they occur at approximately the same stratigraphic level. Several en echelon, linear bodies are probably present, as has been demonstrated from well data east of McLeod region (Burk, 1963). Marine shales flank their eastern sides and coal bearing beds lie on their western sides (Fig. 4). The areal pattern of the sandstones suggests the linear, gently curving trends and distribution of environments found along the Gulf and Atlantic coasts. The vertical succession repeats the horizontal sequence (Fig. 3).

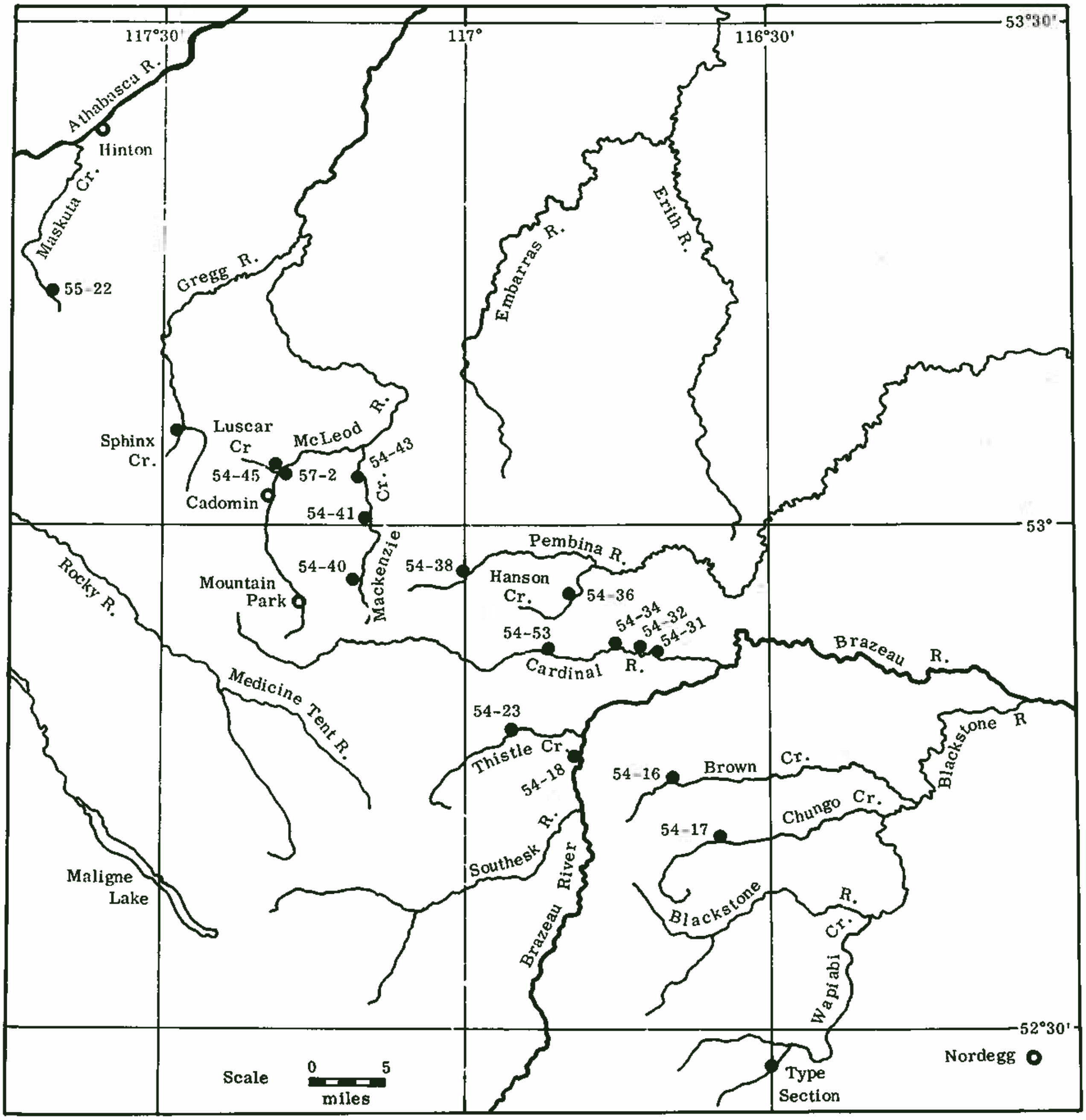

Figure 2. Location of illustrated outcrop sections of Cardium Formation, central Foothills, Alberta

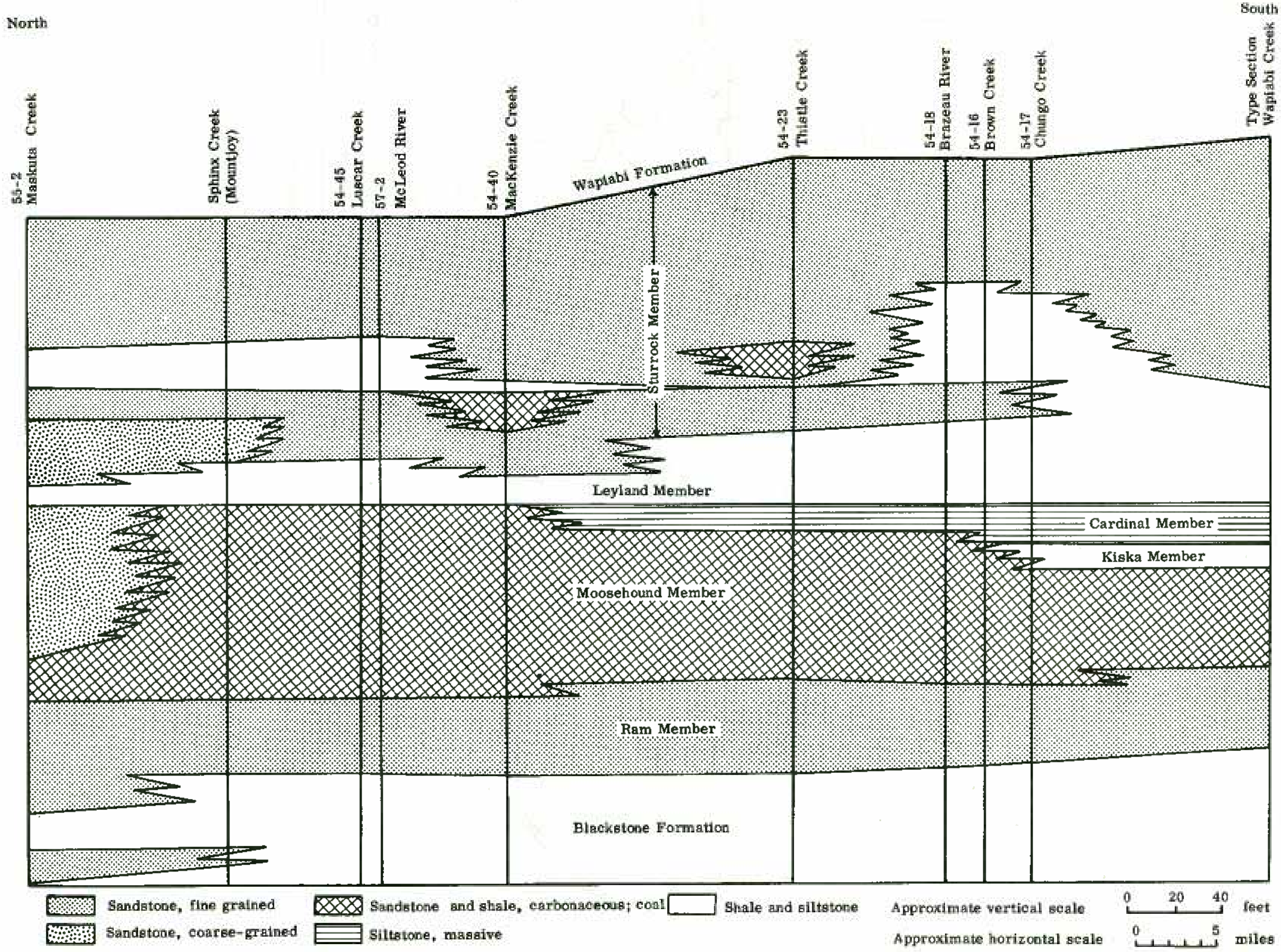

Figure 3. Schematic diagram illustrating thicknesses and variation in lithology of Cardium Formation along Western Foothills between Maskuta Creek and Wapiabi Creek

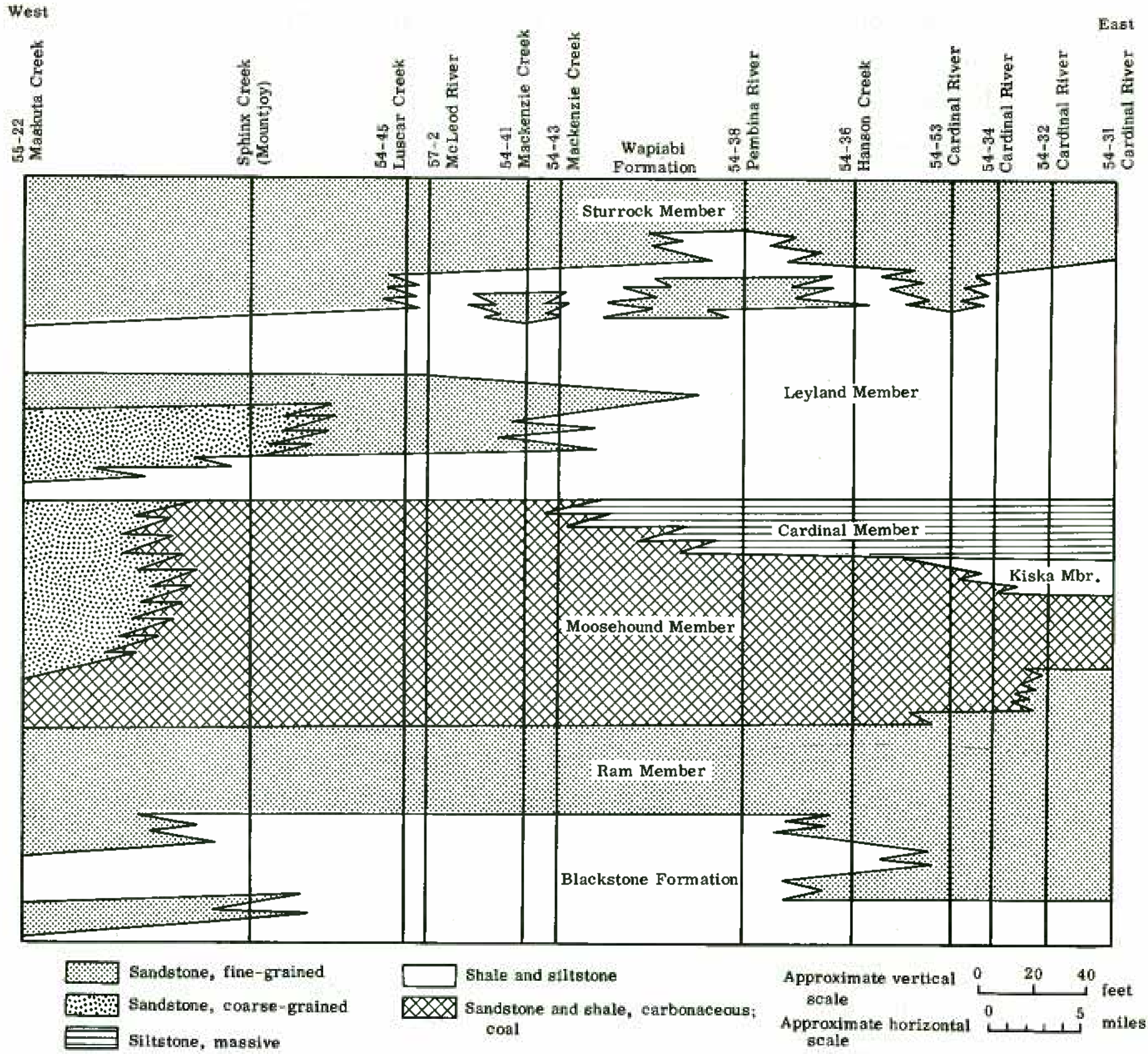

Figure 4. Schematic diagram illustrating thicknesses and variation in lithology of Cardium Formation in an easterly direction between Maskuta Creek and Cardinal River

Fine clay shales of the mid-basin grade into sandy silt and silty shale which in turn grade into interbedded silty shale and thinly bedded sandstone, then into well sorted, thick bedded sandstone of the epineritic and littoral environments. Those sandstones are overlain by carbonaceous mudstones and silty sandstones.

The Cardium Formation in the central Foothills is dated mainly by its position above beds containing fauna of the late Turonian Prionocyclus woollgari zone and below beds containing fauna of the late Turonian (?) to earliest Coniacian zone of Scaphites preventricosus and Inoceramus deformis.

The Ram Member, averaging about 30 feet thick in the McLeod region and comprising fine grained, thick bedded sandstone, formed as elongate littoral to epineritic sand bars. The sandstones consist of quartz, chert and lithic fragments. Such shallow water features as mottling, ripple marks, burrows, tracks and trails of organisms are commonly present. The member contains marine fossils such as Inoceramus fragilis Hall and Meek, I. ex gr. I. lamarcki (Parkinson) and Cardium pauperculum Meek.

Carbonaceous mudstones and argillaceous sandstones of the Moosehound Member were laid down as lagoonal and marsh deposits. These beds, 75 to 100 feet thick in the McLeod region, contain abundant plant debris, thin coal beds, and an assemblage of brackish water fossils. Some of the sandstones are coarser than those of the epineritic sediments and may be channel deposits. The various types of sediments are thinly interbedded and show many repetitions throughout the succession, indicating frequent changes of the environmental setting. Beds are lenticular without much lateral extent. Beds equivalent to Moosehound sediments apparently grade laterally eastward into marine shale and siltstone included in the Kiska and Cardinal Members respectively (Fig. 4). The latter marine beds do not appear to be represented in the outcrops along McLeod River. The gradual regression of the sea over gently sloping basin sediments resulted in the development of a low energy environment of marginal lagoons and tidal marshes separated from the open epicontinental basin by beaches of high energy sedimentation. The lagoonal and barrier deposits migrated basinward with accompanying offlap of earlier deposits as the coastline continued to slowly prograde during an approximately constant position of sea-level relative to land.

The Leyland Member, comprising dark grey sideritic marine shales, is only 25 to 30 feet thick in the western Foothills but increases to more than 100 feet in eastern exposures.

The Sturrock Member includes all the fine grained, thick bedded sandstone of the upper Cardium Formation. Between Athabasca River and Mackenzie Creek, where the member is about 95 feet thick, two main sandstone tongues are separated by a thin unit of silty marine shale (Fig. 4). The lower tongue includes very coarse grained to conglomeratic sandstone at Maskuta Creek, finer sandstone at McLeod River, and some carbonaceous shales and coal on upper Mackenzie Creek. The upper tongue is dominantly fine grained, thin bedded sandstone with intercalated silty shale.

Wapiabi Formation

The Wapiabi Formation (Malloch, 1911) includes all the beds between the underlying Cardium Formation and the coarse grained, greenish grey sandstones of the Brazeau Formation. The shales of the lower and upper thirds of the Wapiabi vary from fissile to blocky, are sideritic and include reddish brown weathering sideritic concretions. The middle shales are calcareous to dolomitic. Sandstone near the top is fine grained and thick bedded. The formation is 2,100 feet thick at the type section on Thistle Creek and is reported by Mountjoy (in press) to be 1,786 feet on Sphinx Creek, a tributary of Gregg River. Only the upper part of the formation is well exposed on McLeod River.

The Wapiabi Formation overlies the Cardium Formation with possibly some slight disconformity. Concretionary, coarse grained sandstone and sandy shale with small chert pebbles occur at the base of the formation in the McLeod region, being 6 to 9 feet thick at Luscar Creek and 24 feet thick on Mackenzie Creek.

In the central Foothills, the formation contains seven members; in ascending order, Muskiki, Marshybank, Dowling, Thistle, Hanson, Chungo, and Nomad (Stott, 1961, 1963).

The succession, similar in many respects to the combined Blackstone and Cardium, forms a major rhythmic sequence, containing transgressive and regressive phases separated by an inundative phase. The transgressive phase includes the concretionary beds of the lower three members. The calcareous Thistle shales, similar to those of the Vimy Member, form the inundative phase. The regressive phase is represented by the Hanson and Chungo Members.

The Muskiki Member, having a maximum thickness of 325 feet on Thistle Creek, consists mainly of alternating beds of rubbly and flaky sideritic shales which give it a banded or striped appearance. Basal beds, in most sections, lie within the latest Turonian (?) to Coniacian zone of Scaphites preventricosus Cobban and Inoceramus deformis Meek. The remainder of the member lies within the Coniacian zone of Scaphites ventricosus Meek and Hayden and Inoceramus involutus.

The Marshybank Member includes about 90 feet of massive argillaceous siltstone occurring 200 to 250 feet above the base of the Wapiabi. The lower beds are gradational into the underlying Muskiki but the upper contact is abrupt and marked by a thin layer of pebbles. Farther north beyond Athabasca River, fine grained sandstone, occurring in an equivalent stratigraphic position is included in the Bad Heart Formation. The member contains Scaphites comparable with or referable to Scaphites depressus Reeside, dated by Jeletzky (pers. com.) as early Santonian.

The Dowling Member, comprises concretionary, sideritic shales lying between the Marshybank siltstones and calcareous shales in the middle of the Wapiabi Formation. The member ranges in thickness from 100 feet in the eastern Foothills to as much as 350 feet in the western Foothills. The Dowling Member lies within the upper part of the Scaphites depressus zone and the Scaphites vermiformis zone, dated by Jeletzky (pers. com.) as early Santonian.

Calcareous shales in the middle of the Wapiabi Formation are included in the Thistle Member. The succession is 734 feet thick in the type section on Thistle Creek. The shales are fissile to platy, dark grey to black, and weather grey. Large lenticular, concretionary masses of argillaceous dolomite, occurring in many sections, weather greyish yellow. The lower two thirds of the member contains fauna of the zone of Scaphites montanensis Cobban, considered by Jeletzky (pers. com.) to be of middle to early late Santonian. In the southern Foothills, the upper beds of the Thistle lie within the Santonian zone of Desmoscaphites erdmanni Cobban. It is probable that the upper Thistle beds in the central Foothills are about the same age. The top of the Thistle Member is approximately equivalent to the First White Specks Marker Horizon that is recognized by Burk (1963) in wells east of the outcrop belt.

The Hanson Member, 160 feet thick on Cardinal River, includes those concretionary shales lying above the platy calcareous shales of the Thistle Member. The Hanson shales are blocky to rubbly, sideritic, and weather rusty. The Hanson Member contains a characteristic fauna of Inoceramus ex gr. I. lobatus-cardissoides-steenstrupi and Baculites ovatus var. haresi Reeside, placed by Jeletzky (pers. com.) in the Santonian to early Campanian generalized zone of B. ovatus and I. lobatus. Rare collections of Desmoscaphites bassleri of Santonian age, reported by Warren and Rutherford (1928), Warren (1933), and Gleddie (1954), were obtained from upper Wapiabi (presumably Hanson) shale.

The Chungo Member on McLeod River and Mackenzie Creek contains more than 250 feet of dark grey massive glauconitic siltstone and fine grained, brown weathering sandstone. The member includes beds previously referred to as Solomon Sandstone (Lang, 1946), Highwood Sandstone (Webb and Hertlein, 1934), and Chinook Sandstone (Gleddie, 1949, 1954). Facies changes within the Chungo Member are similar to those found in the Cardium Formation although the Chungo sandstone is thicker and the non-marine beds are not so well developed. Again, the vertical sequence repeats from bottom to top the sequence of sediments from mid-basin toward shore. In the western Foothills, as on McLeod River and Mackenzie Creek, the upper part of the member is dominantly sandstone but farther east grades laterally into argillaceous siltstone and finally into silty shale. Greyish green shales with some thin coal beds occur within the member in the area west of the Bighorn Range. The Chungo Member contains Baculites ovatus var. haresi Reeside and Inoceramus lobatus Goldfuss. As diagnostic fossils of early Campanian age are lacking, Jeletzky favours a late Santonian date for the collections (pers. com.). However, the writer considers the Chungo Member to be stratigraphically equivalent to the Milk River sandstone, which in turn is equated with the Eagle Sandstone of Campanian age (Cobban and Reeside, 1952).

Recessive beds lying between the fine grained, brown weathering sandstone of the Chungo Member and coarse grained, green weathering sandstone of the Brazeau Formation, are included in the Nomad Member. The base of the member is marked by concretionary, conglomeratic sandstone and mudstone, ranging in thickness from 6 feet on McLeod River and Mackenzie Creek to 18 feet on Pembina River. A bed of dense, argillaceous, dolomitic limestone, 4 feet thick, occurs a few feet above the conglomerate on Mackenzie Creek and extends many miles southward into the Bighorn region. Dark grey, rusty weathering shales in the lower part of the member grade upward into olive brown to greenish brown shales, argillaceous siltstone, and sandstone. Plant debris becomes increasingly abundant toward the top. The thickness ranges from 90 to 130 feet throughout most of the Foothills, increasing to as much as 170 feet in eastern sections where basal Brazeau sandstones have graded into shale. A calcareous foraminiferal assemblage was reported from Nomad beds in the central Foothills by Wall and Germundson (1963). They suggested that the assemblage was indicative of a neritic environment. No diagnostic megafossils have been obtained from the member. The writer considers the Nomad to be equivalent to the Pakowki Formation and, therefore, to be of Campanian age.

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THE BRAZEAU FORMATION IN THE CENTRAL FOOTHILLS

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INTRODUCTION

In the general area of the present field trip, many problems still exist in the stratigraphy of the uppermost Cretaceous and Tertiary strata. In the central Alberta Foothills, it is the author's opinion that for general mapping purposes, the Belly River, Edmonton and Paskapoo Formations cannot be differentiated in the field and should be "lumped" under one name the Brazeau Formation.

TERMINOLOGY

Brazeau Formation

Malloch (1911) first applied the name Brazeau to some 1700 feet of nonmarine beds overlying the Wapiabi Formation in the Bighorn Coal Basin west of Rocky Mountain House. Unfortunately, however, he did not mention an upper contact and the problem of how much section he intended to include in the formation has never been resolved. Opinions differ as to whether beds equivalent to the Paskapoo Formation of the Alberta Plains should be included in the Brazeau or kept separate. MacKay (1943) traced the Brazeau Formation from the Bighorn basin to the Coalspur area, where he found that it did, in fact, contain Paleocene strata. Stratigraphic relationships of the Brazeau and adjacent beds are summarized in Figures 1 and 2.

Belly River Formation

The name Belly River was applied by Dawson (1883) to include the strata between the Colorado and Bearpaw Shales. The Belly River is predominantly a sandy unit, but contains shale and thin coaly beds towards the top.

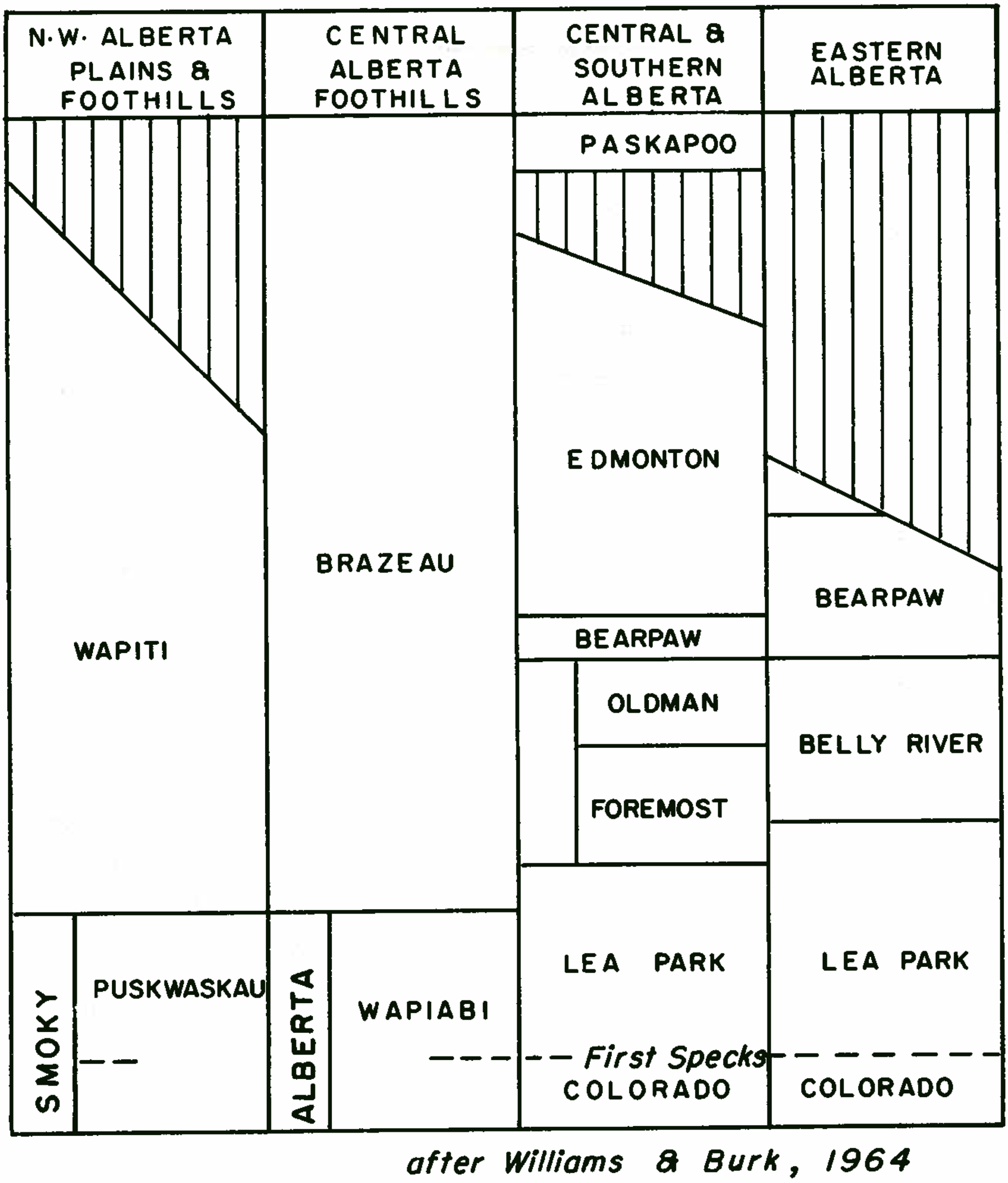

Figure 1. Correlation table of the Brazeau Formation and equivalent strata.

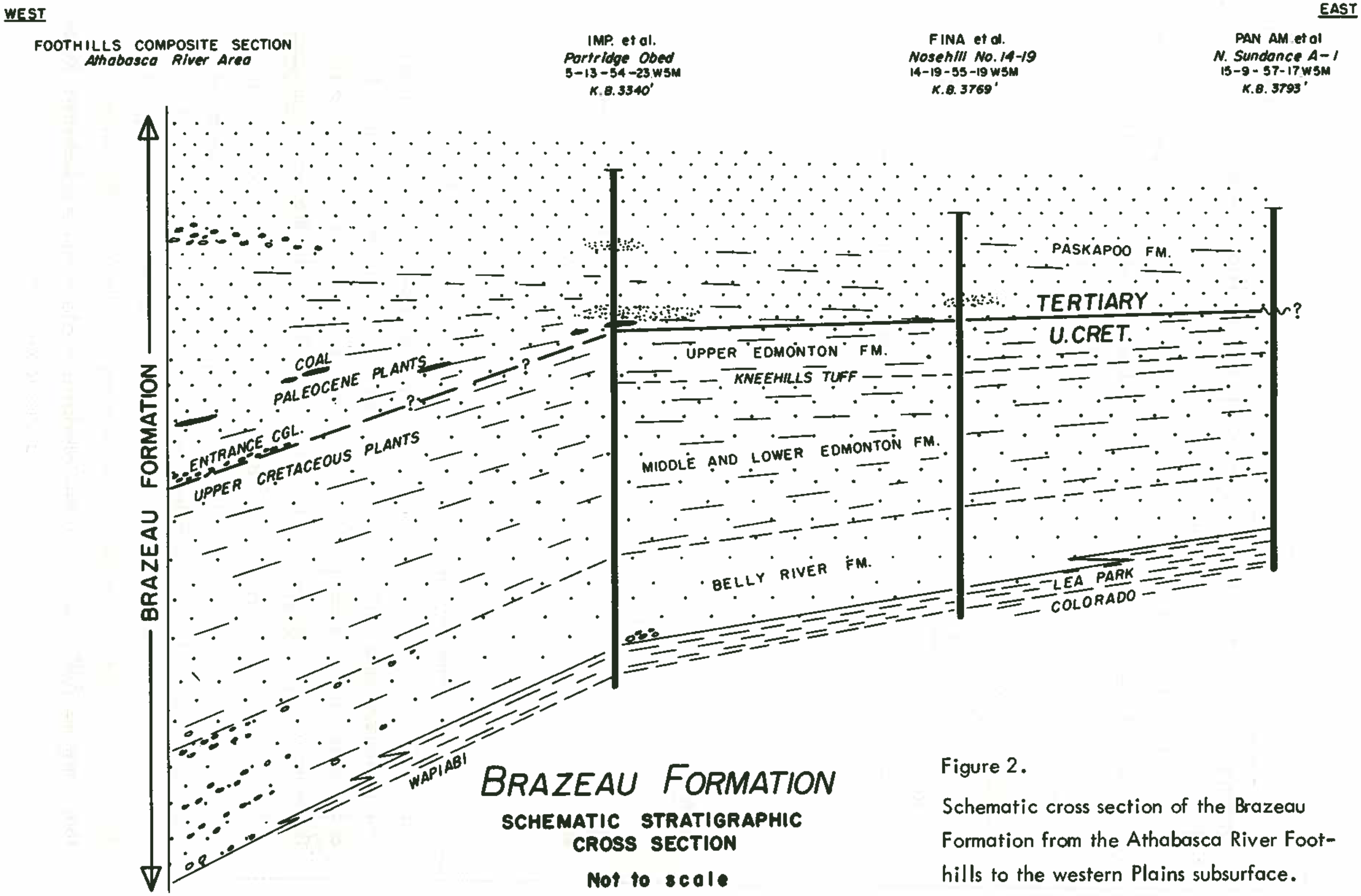

Figure 2.

Schematic cross section of the Brazeau Formation from the Athabasca River Foothills to the western Plains subsurface.

Bearpaw Formation

The Bearpaw Formation is a tongue of black marine shale which separates the predominantly nonmarine strata of the Belly River from another nonmarine sequence (the Edmonton Formation) above. The Bearpaw is recognized as far northwest as Fort Assiniboine on the Athabasca River, but does not extend much west of the Fifth Meridian or north of about Township 60. North and west of the Bearpaw edge, the Belly River and Edmonton Formations are in mutual contact.

Edmonton Formation

The Edmonton Formation was defined by Tyrrell (1887) along the Red Deer and Saskatchewan Rivers as the rocks that included all the dinosaur-rich, nonmarine beds lying above the marine Bearpaw shale and below the Ardley coal seam. Subsequently the upper contact has been placed at the base of a massive, brown to olive weathering sandstone at the base of the Paskapoo Formation, which lies disconformably on the light grey weathering shales, fine sandstones and coaly beds of the Edmonton.

Paskapoo Formation

Tyrrell's (1887) original definition was "... all Laramie rocks above the Edmonton series". Most subsequent writers recognize the nonmarine Paskapoo sandstones and shales to be of early Tertiary (Paleocene) age.

DESCRIPTION AND CORRELATION

The base of the Brazeau Formation in the Coal Branch area lies about 100 feet above a prominent hard, grey green, buff to orange weathering, fine grained marine sandstone approximately 100 feet thick, the Chungo Member of the Wapiabi Formation (Stott, 1963). This sandstone was originally called the Solomon Sandstone by Lang (1945) and included in the Brazeau Formation.

In a section measured by the writer along the Blackstone River approximately 40 miles south-southeast of Mountain Park, the thickness of the Brazeau Formation (including Paleocene beds) is more than 5000 feet thick. In the Hinton area, the Brazeau is apparently 11,000 feet thick (Lang, 1947), 5000 feet of which is considered to be Tertiary. Rutherford (1925) estimated that there was 5300 feet of Brazeau between the Athabasca and Embarras Rivers.

The lower part of the Brazeau, which MacKay correlated with the Belly River Formation of the Plains, consists of nonmarine, grey, buff weathering rock-fragment sandstone and grey green shales. In thin section the rock fragments constitute 55-60% of the total rock and consist of volcanic rocks and chert particles. Feldspar and quartz are the other main constituents.

The base of the Edmonton Formation which in the Plains can be recognized by the change from marine Bearpaw shale to nonmarine grey green shale and light grey sandstone, is indistinguishable in the Foothills because the Bearpaw is not present and there is little color difference. In the Foothills the Edmonton equivalent of the Brazeau is megascopically similar to the Belly River equivalent. It consists of grey green nonmarine shales, buff colored rock fragment sandstones and coals. Thin sections show that an average of 55% of the total rock consists of rock fragments, mainly chert and volcanics. MacKay (1943), in the central Foothills, arbitrarily placed the top of the Belly River at a conglomerate 900 feet below the lowest coal seam, making the Edmonton part of the Brazeau Formation 3000 feet thick.

The Kneehills Tuff marker bed, common on the Plains is not recognized in the Foothills. The loss of this unit could be due to increased sedimentation diluting the volcanic ash in the Foothills area and destroying the discrete characteristics of the marker. A number of bentonites are present in the Brazeau Formation.

In the Entrance area, the Entrance Conglomerate, a quartzite and chert congolomerate 20 feet thick marks the boundary between the Upper Cretaceous and Tertiary portions of the Brazeau (Lang, 1947; Bell, 1949). Above the conglomerates, are 5000 feet of nonmarine sandstones, conglomerates, shales and coals equivalent to the coal measures at Coalspur which Lang correlated with the Paskapoo of the Plains. Taylor et al. (1964) placed the Entrance Conglomerate in the uppermost Cretaceous part of the Brazeau.

Where the Entrance Conglomerate is not present, it is virtually impossible to distinguish between Cretaceous and Tertiary beds in the Brazeau Formation.

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SURFICIAL GEOLOGY BETWEEN EDMONTON AND CADOMIN
NEAR HIGHWAYS 16 AND 47

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Abstract

From the western outskirts of Edmonton west to the junction of Highway 47, a distance of about 128 miles, Highway 16 traverses Pleistocene deposits of till, lacustrine and deltaic clays and silts, and fluvial sands and gravels. Bedrock, comprising sandstones of the Tertiary Paskapoo Formation and sandstones, shales, carbonaceous shales and coals of the Upper Cretaceous Edmonton Formation is exposed beneath the surficial deposits in stream and river valleys, road cuts, borrow pits and strip mines.

Highway 47, from its junction with Highway 16, 6 1/2 miles west of Edson, south to Cadomin crosses surficial deposits of recent alluvium, Pleistocene till, lacustrine clays and silts, and Pleistocene or post-Pleistocene sand dunes. Mesozoic to Tertiary conglomerates, sandstones, siltstones, shales and coals are exposed beneath surface materials in road cuts, river and stream valleys and foothill ridges.

On the Plains east of Edson, relief is mostly a function of the type of Pleistocene deposits found at the surface. West and south of Edson, the topography was formed mainly by Tertiary fluvial erosion. The Foothills were overridden by glaciers during the Pleistocene, but the higher peaks of the Mountains stood as nunataks above the ice.

Laurentian and Cordilleran ice sheets merged near Edson producing a zone five to twenty miles wide of till with characteristics of both continental and mountain tills. West of Edson only Cordilleran till is found and east of the mixed till zone only continental glacial deposits are present.

INTRODUCTION

The surface deposits and present topography of the Plains, Foothills and eastern Rocky Mountains for approximately 185 highway miles between Edmonton and Cadomin, have been formed by a combination of pre-glacial, glacial and post-glacial processes depositing different materials. Under the Plains, the bedrock is uppermost Cretaceous to Tertiary in age. Palaeozoic and Mesozoic rocks crop out in the disturbed belt of the Foothills and Mountains to the west.

Bedrock surfaces are mainly of pre-glacial origin, but have been modified somewhat by ice action. Surface topography on the Plains depends predominantly on the types of glacial deposits present in the area, but in places the effects of post-glacial fluvial and aeolian processes may be seen.

PRE-GLACIAL DEPOSITS

Bedrock

The bedrock beneath the Plains, from Edmonton to about 30 miles southwest of Edson, is composed of flat-lying strata of the Edmonton and Paskapoo Formations of Upper Cretaceous and Tertiary age respectively. As the Foothills are approached it becomes progressively more difficult to recognize individual formations which are distinctive farther east, and the Paskapoo and Edmonton Formations are grouped with underlying beds of similar lithology as the Brazeau Formation.

The Edmonton Formation consists of greyish sandstone, shale, coaly shale, and coal. In the past, soft bituminous coal was mined from seams in the Formation around the city of Edmonton and at Evansburg. Presently, strip mining operations north of Lake Wabamun provide coal for fuel for the Calgary Power Ltd. generating station near the eastern end of the lake. In this area reserves amenable to stripping total over 70 million tons. Large reserves suitable for strip mining are also present near Genesee on the north Saskatchewan River, 10 to 15 miles south of Lake Wabamun.

The Paskapoo Formation of early Tertiary age, lies disconformably above the Edmonton on the Plains, but in the Foothills and western Plains no erosional break between the two formations can be recognized. The Paskapoo is composed mainly of massive, brown weathering, medium to coarse grained "salt and pepper" sandstone.

The Brazeau Formation of the westernmost Plains and Foothills consists of grey, greenish grey and yellowish grey sandstones, siltstones, shales and coal seams. Coal, mined from the Formation at Robb, Coalspur, Mercoal, Foothills, Coal Valley and Sterco, may be either Upper Cretaceous or Tertiary in age.

Sands and Gravels

Western Canada was glaciated only during the Wisconsin or latest stage of the Pleistocene. Consequently Nebraskan, Kansan and Illinoisan glacial deposits are not present, and that part of Pleistocene time represented by these deposits is considered pre-glacial in this area (Bayrock, in press).

Fluvial erosion of the Rocky Mountains subsequent to their formation early in the Tertiary, ultimately produced, after several erosional cycles essentially the present Mountain, Foothill and Plains topography. Large rivers flowed eastward from the mountains across the Plains and drained into the Arctic Ocean, Hudson Bay or the Gulf of Mexico through wide mature valleys (Gravenor and Bayrock, 1961; Barton et al., 1964). One of these rivers was the pre-glacial North Saskatchewan, which flowed northeasterly across central Alberta near Edmonton. The valley of this pre-glacial river is expressed at the surface by a prominent topographic low extending from a few miles north of Stony Plain, approximately parallel to Highway 16, through St. Albert to Clover Bar where it is joined by the present North Saskatchewan River. Part of this valley is occupied by Atim Creek and Big Lake. A tributary stream from the south entered the old river valley at Edmonton, and another larger tributary entered from the west near Wabamun. Parts of this latter tributary, which is also expressed at the surface as a topographic low, are occupied by Lake Wabamun and Chip Lake.

Sediments in the pre-glacial river valleys, carried eastward from the Cordillera, consist of medium to coarse grained sand and quartzite pebble to cobble gravel. These are known as the Saskatchewan Sands and Gravels and are exposed in many places in Alberta. They may be seen in the banks of the North Saskatchewan River at Clover Bar, at the Big Bend south of the Edmonton Golf and Country Club, and near Whitemud Creek in Edmonton. Along Highway 16 west of the city, the gravel phase is well exposed in road cuts, gravel pits, and the strip mine north of Lake Wabamun as far west as the junction with Highway 57 to Drayton Valley.

For many years, the age of the Saskatchewan Sands and Gravels was in doubt. Recent finds of vertebrate fossils in the unit, particularly *Bison*, *Equus*, *Mammuthus*, and *Camelops* (Bayrock, in press; Westgate, 1965) have established a late Pleistocene, perhaps earliest Wisconsin age for these sediments.

The Saskatchewan Sands and Gravels were deposited mainly by aggrading rivers as a consequence of their being blocked by the advancing Wisconsin ice in their downstream (northeastern) reaches.

GLACIAL DEPOSITS

Contorted Bedrock

The surface layers of the soft Edmonton, Paskapoo and Brazeau Formations, when they were overridden by glacier ice a mile or more in thickness, deformed into numerous gentle folds and occasional small thrust faults. Such contorted bedrock is very common along Highway 16 from Lake Wabamun west, well exposed in road cuts and in the strip mine. Contorted bedrock, although very common in the western Canadian Plains, is relatively rare in other parts of the world.

Till

Till is that material which is deposited directly from glacier ice. Moraine is composed of till and associated reworked fluvial and lacustrine deposits, such as sand, silt, and clay lenses. Often these lenses contain fossil shellfish or ostracods which lived in the meltwater ponds on or adjacent to the ice.

Till surfaces may be arbitrarily classified into three types on the basis of local relief (Gravenor and Kupsch, 1959).

(a) ground moraine (local relief 0-10')
(b) intermediate moraine (local relief 10-25')
(c) hummocky-dead-ice moraine or hummocky moraine
(local relief greater than 25')

Often intermediate moraine is not mapped separately, and, the boundary between ground and hummocky moraine is then taken where the local relief is about 15 feet.

All three types of moraine were formed in the same manner in Alberta by the melting of stagnant or non-moving ice sheets (Bayrock and Hughes, 1962). Melting of the stagnant ice at its upper surface produced a concentration of material on top of the ice. This water-saturated till slumped or flowed into any depressions or along any slopes on top of the ice. Hummocks or knobs on the present till surface were formed by this material accumulating in depressions on the ice. Hollows or kettles on the till surface are the result of melting of blocks of ice which were surrounded or buried by the super-glacial till.

Relief on the till surface is related to the thickness of till present. In central Alberta, the thickness of till in any area is approximately five times the local surface relief. For example, in intermediate moraine with local relief of about 20 feet, the till will be approximately 100 feet thick.

The composition of till reflects the origin of the ice sheet from which it was deposited, and the local bedrock over which the ice flowed. A southwest-flowing sheet of Laurentian ice from a centre west of Hudson Bay extended more than a hundred miles west of Edmonton. Till deposited from this ice contains a high proportion of Precambrian igneous and high grade metamorphic rocks from the Canadian Shield. Ice from Cordilleran centres flowed eastward across the Foothills and western Plains, merged with the Laurentian ice across a zone five to twenty miles wide and then flowed southeasterly along the eastern front of the Foothills. Till deposited from Cordilleran ice contains abundant stones composed of dark coloured limestone, dolomite, chert and other sedimentary rocks which are found in the Rocky Mountains. A mixed till with characteristics of both Laurentian and Cordilleran tills marks the zone of merging of Laurentian and Cordilleran ice. Along Highway 16 this zone of mixed till is about 10 to 15 miles wide, extending approximately from just west of Edson east to Wolf Creek. Because of lacustrine sediments overlying the till, the limits of the zone are difficult to place precisely.

Lacustrine Deposits

After the melting of the glaciers and the deposition of till in central Alberta, the pre-glacial northeasterly drainage was still blocked by ice farther to the north. As a result of this blocked drainage, meltwater ponded in front of the ice, producing rather extensive ice-marginal lakes.

One of these lakes was Lake Edmonton (Bayrock and Hughes, 1962). The western and northern margin of Lake Edmonton lay against the ice sheet, while the southern margin stretched in an arcuate line from about Fort Saskatchewan to Leduc to Drayton Valley and thence in a northwesterly direction towards Edson. A lobe of ice extended into the lake from the north in the vicinity of Lake Wabamun, giving Lake Edmonton a somewhat semi-circular shape. The area occupied by this ice lobe extends from the junction of Highway 43 west along Highway 16 to the railway over-pass at Magnolia, a distance of approximately 23 miles. Lacustrine sediments do not occur in this area, and till of the Duffield moraine forms the surface. The exact dimensions of Lake Edmonton are not known at the present time, because much of the area has not been mapped.

The lake was deepest (200 to 250 feet) in an area stretching from northwest Edmonton to Big Lake. In this area, varved and stratified clays up to 100 feet thick were deposited above the till. From varve counts where the lake sediments are thickest, it has been deduced that Lake Edmonton probably existed for about 40 years. Because of the short duration of the lake, beach deposits did not develop along the shorelines.

From Winterburn Corner, west along Highway 16 to the junction of Highway 43, surface deposits consist of silt and very fine grained sand with generally rough topography. This area is known as the Lake Edmonton Pitted Delta. The Pitted Delta is a composite delta formed by many streams flowing off a lobe of the glacier which occupied a position to the west of Highway 43. These deltas were built into Lake Edmonton, and were deposited partly over and partly around large ice blocks standing in the water around the margin of the lake. As the front of the glacier receded, the deltas were built in different places near the edge of the glacier. Subsequent melting of the ice blocks produced the characteristic pits and kettles of the delta.

In places the deltaic silts and sands contain numerous small ice-rafted stones and lenses of till-like material which probably slumped off the stranded blocks of ice. Because of the rough topography and the peculiar sediment type, this deposit was originally called "silt till". Later with the advent of aerial photographs and as roads were built through the area and sediments exposed in road cuts, it became clear from sedimentary structures such as varves, and from remains of shell fish in the sediments that the deposits were of lacustrine and deltaic origin.

Meltwater filled the Lake Edmonton basin until an outlet was found. At least four outlets or spillways were active in draining the lake water towards the south. The major outlet was the Gwynne outlet just east of Nisku. Lake water apparently escaped through the Gwynne outlet with considerable velocity as evidenced by incision of the outlet of 100 to 150 feet.

Deposits from a second ice-marginal lake are crossed by Highway 16 near Edson. This lake has been called Lake Edson, and differed from Lake Edmonton in that it had one shoreline against the continental ice sheet to the east and the other against the Cordilleran ice to the west (M. Roed, Univ. of Alberta, Ph.D. thesis, in preparation). Lake sediments are thus a mixture of materials from the Canadian Shield and the Cordillera. The extent of Lake Edson is relatively unknown at the present time, but the deposits may be continuous with lake sediments traversed by

Highway 47 for about 15 miles beginning 5 miles south of the junction with Highway 16. The deposits of Lake Edson for the most part obscure the underlying till, so that the zone of mixed Cordilleran and Laurentian till cannot be accurately mapped.

POST-GLACIAL DEPOSITS

Aeolian deposits

Wind-blown sand occurs south of Highway 16 along Highway 60 in the Devon-Woodbend area southeast of Stony Plain (Bayrock and Hughes, 1962). Dune sands are also encountered for about 3 miles along Highway 47 beginning about 4 miles south of the junction with Highway 16. The dunes consist mainly of fine grained, well sorted sand with very little clay.

In both of these areas, the dunes are mainly of the parabolic and U-shaped varieties and developed under semi-arid conditions (Odynsky, 1958). Sand was blown out of deflation basins by the wind and piled up on the downwind side of the resulting depressions. The dunes are U-shaped in plan view with the "horns" pointing upwind. This is in contrast to the classical barchans or crescentic dunes of arid regions which in plan view have "horns" pointing downwind.

The sand making up the dunes was derived from lacustrine or fluvial deposits adjacent to or underlying the dune fields.

The time of dune formation remains problematical. The dunes could have developed immediately following recession of the ice and draining of the lakes, or later during the Altithermal Interval. The former is the most probable time, as it is thought that during the Altithermal the countryside was vegetated although less densely than at present. In all cases in Alberta, the dunes were formed by westerly to northwesterly winds (Odynsky, 1958).

At the present, the dunes along Highway 47 are completely stabilized by forest vegetation, and the deflation basins are occupied by muskeg. The fact that the typical muskeg plant community is a subarctic one argues for an early period of dune formation, when the climate was cold, the water, table lower and vegetation sparse.

Fluvial deposits

Nearly all the streams and rivers in western Alberta have incised their beds below the level of the general surface, with resultant development of floodplains and terraces. These landforms are well exhibited in the valleys of the Pembina River at Entwistle, the McLeod River at the highway bridge 5 miles east of Edson and to the south of the highway between the bridge and Edson. Highway 47 is built upon terrace deposits of the McLeod and Embarras Rivers for various portions of its length. Fluvial deposits in the valley of the McLeod River at Cadomin are probably over 100 feet thick where they fill the bottom of a glacial U-shaped valley.

Fluvial deposits are mainly gravel; cobble and boulder-sized material in the Mountains, becoming finer towards the east.

Other deposits

A wide variety of other materials forms a very small proportion of the surficial deposits. Organic muck is present in most of the sloughs and water-filled depressions; colluviation and slope wash have been active on steeper slopes, partly obscuring the materials beneath, but having little effect on the overall topography.

De-levelling

Following the melting of the Pleistocene ice sheets, and continuing up to the present time, there has been a more-or-less continuous uplift of the Rocky Mountains (Bayrock, 1964). This movement, which has probably been of a diastrophic (epeirogenic) nature, has resulted in uplift in the mountains of the order of 2000 feet relative to Edmonton over the past 5000 to 10,000 years. As a result, the Plains in western Alberta have been tilted towards the northeast at about 10 feet per mile since glacial times.

Evidence for the de-levelling may be obtained from measurements of the elevations of river terraces and lacustrine deposits. For example, the shorelines of Lake Edmonton in the vicinity of the railway overpass at Magnolia are presently found at elevations approximately 600 feet higher than shorelines near Fort Saskatchewan or Sherwood Park.

Further evidence may be found in the reversal of flow direction in old glacial spillways. The Gwynne outlet for example, drained the waters of Lake Edmonton towards the southeast. It is now occupied by Blackmud Creek which flows northwest.

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APPENDIX

ROAD LOG OF HIGHWAYS 16 AND 47 BETWEEN EDMONTON AND CADOMIN

Note: This road log and the preceding paper are designed to supplement each other. Comments on the log will be more meaningful if the paper is read first.

Mileage	
0.0	Intersection of 107 Avenue and Highway 16 near the western outskirts of Edmonton. Surficial deposits are composed of clayey sediments of glacial lake Edmonton. In this part of the city, they are about 100 feet thick.
2.9	Passing through a sedge grass bog or swamp. The pumping oil well about 200 yards north of the highway produces from the Ellerslie Member of the McMurray Formation of Lower Cretaceous age.
3.8	Winterburn Corner. West of this point the highway crosses the Lake Edmonton pitted delta.
5.3 to 6.4	Crossing the Acheson Devonian oilfield. Production is obtained from the Nisku and Leduc Formations of the Upper Devonian Winterburn Group.
6.9	Junction of Highway 60 to Devon to the south.
9.9	Overpass over the main line Canadian National Railways. The topographic low marking the bedrock channel of the pre-glacial North Saskatchewan River may be seen to the north where it is occupied by Big Lake.
12.9	Spruce Grove Railway Station. The north-south trending ridge on the horizon to the west is the highest point of the Lake Edmonton pitted delta. The elevation of this ridge is more than 300 feet higher than the elevation of the city of Edmonton.
14.5	Historical Point of Interest sign commemmorating a band of Iroquois Indians which was brought by the old North West Company from Montreal during the days of the fur trade.

19.1 Entering the main part of the pitted delta. Looking eastward one can get an appreciation of the large build up of sediments in the delta. Note that the kettle holes do not normally contain water due to the high permeability of the lake silt.

20.7 Junction with Highway 29 to Edmonton Beach.

21.2 Stop No. 1 - side road entering Highway 16 from the north. The first road cut on the west side of the road is composed of lenses of till-like material, fine sand, silt and beds of clay. This mixture is typical of sediments deposited near stagnant or rafted ice blocks in a lacustrine environment. One of these blocks probably occupied the kettle hole immediately east of the road. A second road cut about 100 yards north on the east side of the road exposes only fine sand and silt with occasional shells of fresh water molluscs. This heterogeneity of sediment type is characteristic of a pitted lacustrine delta.

23.5 Highest point of the pitted delta on Highway 16. This area has the most rugged topography of any part of the pitted delta. Deltaic sediments here are over 300 feet thick.

26.7 Junction of Highway 43 to Whitecourt and Valleyview. This point marks the western edge of the Lake Edmonton pitted delta. The topographic depression approximately 1/4 mile to the west is a small glacial spillway which drained meltwater towards the southwest at the close of Lake Edmonton time. The western bank of the spillway is a hummocky-dead-ice moraine.

28.0 Stop No. 2 - side road entering Highway 16 from the north. Road cuts along the road close to the highway expose a brown clayey till which is slightly more stony than is usual for central Alberta. Small pockets or lenses of sand or gravel are common mixed with the till. The area of till which we are entering is known as the Duffield moraine.

Note the soil which is exposed in the road cuts. This is a typical grey wooded soil which has developed on the till under forest belt vegetation. These poorly productive soils contrast with the rich black and degraded black chernozem soils found under the parkland vegetation in the Edmonton area.

Forest belt vegetation here includes as the main types of trees trembling aspen (white poplar), balsam poplar (black poplar) and spruce (mainly black spruce). The muskegs common in this area are holdovers from glacial times when they formed under a climate which was much more severe than the present climate. No new muskegs are forming at the present time. However, the ecology of the muskeg plant community is such that once it is established no other vegetation will encroach upon it.

35.1 Junction with Highway 30 to Kapasiwin to the south. Kapasiwin is a Cree Indian word which means camping ground. For the next several miles Lake Wabamun may be seen to the south of the highway. The depression occupied by Lake Wabamun is a bedrock channel tributary to the pre-glacial North Saskatchewan River. The channel is about 200 feet deep beneath Lake Wabamun. For the next 10-15 miles Highway 16 follows the northern flank of this valley or cuts across it. Glacial deposits in this area are underlain by Saskatchewan Gravel. Saskatchewan Gravel beneath the till may be seen in road cuts and small outcrops along the highway for the next several miles.

37.2 Road cut showing contorted bedrock of the Edmonton Formation overlain by till.

38.6 Wabamun strip coal mine. The coal mined here from the Edmonton Formation provides fuel for the Calgary Power Ltd. generating station which may be seen to the south on the lake shore. (This plant was originally designed to use natural gas from the Alexander Field of Lower Cretaceous age north of St. Albert). Overburden above the coal consists of sandstone and shale of the Edmonton Formation, Saskatchewan Gravel, and till, and is removed by one of the two largest electric power shovels in western Canada.

44.2 Junction with road to Fallis to the south.

45.9 Entering the upper reaches of the Lake Wabamun pre-glacial bedrock valley. Outcrops of brown bedded sandstone in the road cuts and ditch to the south of the highway may be either Paskapoo Formation or Edmonton Formation.

48.3 Junction with Highway 31 to Seeba Beach to the south and Lake Isle to the north. Saskatchewan Gravel may be seen in the road cuts around the junction and coaly beds of the Edmonton Formation are present beneath the overpass on the north side.

50.8 Railway overpass at Magnolia. At this point the highway passes out of the pre-glacial Lake Wabamun bedrock valley, the main part of which lies about 2 miles north of the railway overpass. For the next several miles the highway passes close to a former shoreline of glacial Lake Edmonton, and some road cuts show till covered by a few feet of lake clay whereas others show only till forming the surface. The lake sediments in this region are thin, generally less than 5 feet in thickness and lie over hummocky-dead-ice moraine. The rough topography is the actual topography of the former lake bottom.

57.8 Stop No. 3 - gravel pit about 100 yards south of Highway 16 and between 0.4 and 0.5 miles east of Highway 57. The gravel pit is approximately 35-40 feet deep and the section exposed in the sides of the pit is as follows:

5 feet - lacustrine silt and clay
10 feet - till, normal dark brown in colour, much more stony than till in the Edmonton area
15-20 feet - Saskatchewan Gravel
5 feet - Saskatchewan Sand in the bottom of the gravel pit, base not exposed.

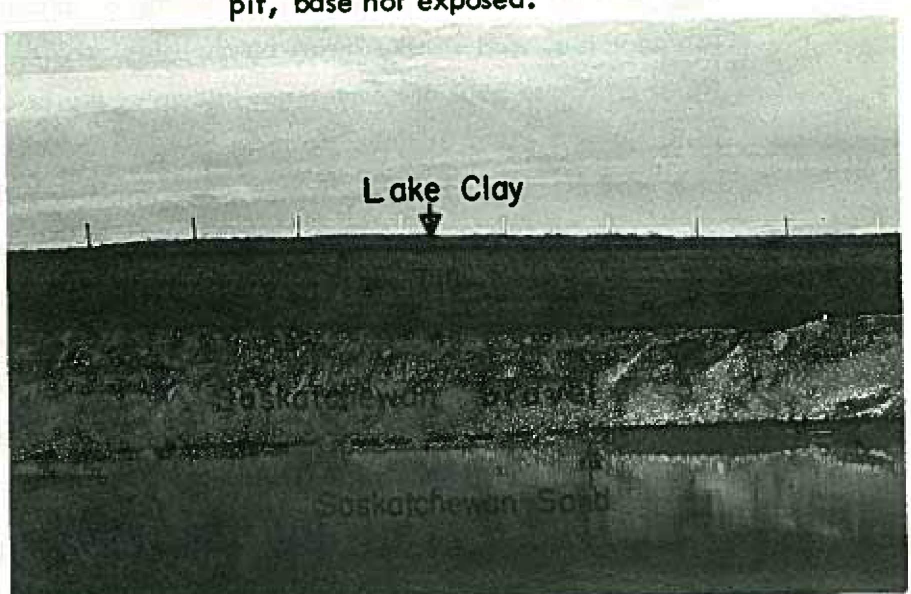


Photo 1. Stratigraphic section exposed in gravel pit near junction of Highways 16 and 57 (Mileage 57.8)

59.1 Junction with Highway 57 to Drayton Valley to the south.

59.9 Bridge over the Pembina River at Entwistle. Looking south from the bridge at the entrenched meanders of the Pembina River, the following section may be seen in the undercut slope in the east bank of the valley:

10-15 feet - till
15-30 feet - thinly bedded, soft silty sandstone
25-30 feet - massive, brown weathering sandstone. The Edmonton-Paskapoo contact has been placed at the base of this massive unit. However, recent work suggest that the actual Cretaceous-Tertiary Boundary does not lie exactly at the base of the sandstone.
150 feet - dark greyish or brownish grey shale, sandstone, and coaly shale extending down to the water level.

Note to fishermen: The largest pickerel ever caught in Alberta, weighing over 20 lbs was taken from the river here beneath the bridge.

62.4 Road cuts exposing 4-6 feet of dark lacustrine clay lying over light brown till.

63.8 A factory for processing peat moss is located north of the highway near the railway track. For the next several miles the highway passes through extensive muskegs or sphagnum bogs. The sphagnum bogs contains a plant community consisting of sphagnum moss, labrador tea, kini-kinik, dwarf birch, black spruce and tamarack (larch). These bogs are sometimes known as dry bogs because there is no water present at the surface in contrast to the wet sedge grass bogs which contain standing water. Sphagnum is able to grow upwards upon its own remains as a substrate, and because of this, sphagnum bogs are often elevated a foot or more above the level of the surrounding countryside. Sphagnum is an excellent insulating medium and sporadic organic permafrost may often be found as far south as this latitude at depths of 1-3 feet below the surface of these sphagnum bogs.

66.1 Junction with Highway 16A to the north to Evansburg.

71.2 Eastern end of Chip Lake to the right. The lake was originally called Buffalo Dung Lake. This name offended the sensitivity of some of the later settlers who changed the name to Dirt Lake. Later it became known as Buffalo Chip Lake and still later this was shortened to Chip Lake.

76.5 Road cuts for the next 2 miles show contorted bedrock overlain by continental till ranging from 5-15 feet in thickness which in turn is overlain by dark brown to very dark brown lacustrine clays 2-6 feet thick.

78.7 Chip Lake Railway Station to the right.

88.0 A sedge grass muskeg or bog may be seen to the south of the highway. The plant community in this type of bog consists of sedge grass, willow, dwarf birch and rarely black spruce. The bog is often called a wet bog because of standing water at the surface.

92.0 Bridge over the Lobstick River. Soils in this region are either grey-wooded or peat organic types. The peat organic soils are very poor in comparison to the grey wooded types. These in turn are poor in contrast to the black soils of the Edmonton region. Peat soils have very low productivity because they contain insufficient quantities of micronutrients such as zinc, cobalt and copper. In addition such soils are deficient in nitrogen because, it is taken up by bacteria which decompose the organic material.

93.4 A sphagnum bog to the south of the highway. On June 13, 1966 permafrost was encountered approximately 18 inches below the upper surface of the sphagnum.

97.1 Bridge over Carrot Creek.

98.4 Outcrops of continental till in road cuts. The gentle subdued topography of this area is typical of ground moraine in Alberta.

101.5 Junction with Highway 32 to the north to Peers and Whitecourt.

103.5 Lake deposits exposed in road cuts for the next mile.

105.9 Till exposed in road cuts for approximately the next 7-8 miles. The till is a typical continental till containing large numbers of pebbles from the Canadian Shield.

115.4 Bridge over Wolf Creek. Bedrock is exposed in the steep undercut creek bank immediately north of the bridge. The section consists of a lower shaly, bentonitic, impermeable portion overlain by an upper sandy, permeable portion. The contact between the shaly and sandy material is marked by a line of contact springs. Approximately 200 yards west of the bridge a borrow pit on the north side of the highway exposes till containing material derived from the Canadian Shield in addition to abundant pebbles of black limestone and sandstone which were brought from the Cordillera. This till is characteristic of the zone of mixed Cordilleran and Laurentian tills.

116.7 Till overlain by lake deposits of glacial Lake Edson.

117.5 Large flat topped hills may be seen on the horizon to the north. These are erosion remnants of Tertiary high plains, correlative approximately to the Cypress Hills and Hand Hills to the south. These hills have Tertiary gravels on top and were overridden by the glaciers as indicated by erratics found on top of them.

117.7 Bridge over the McLeod River. Road cuts north and south of the highway on the west bank of the river expose an excellent stratigraphic section as follows (See photo below):

22 feet	-	lake silt and clay deposited in glacial Lake Edson.
15-20 feet	-	Mixed continental and Cordilleran till.
100 feet	-	Paskapoo Sandstone at Highway level and extending to the river below.

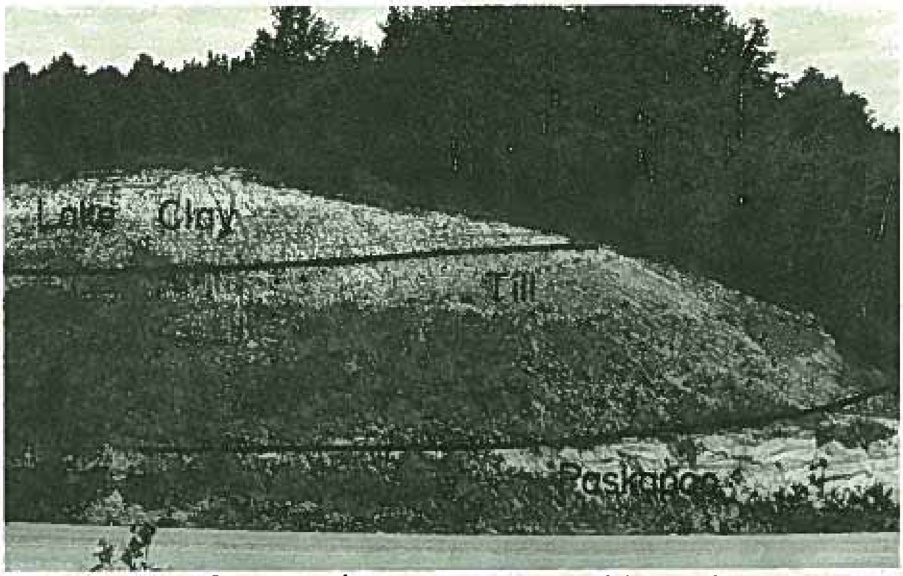


Photo 2. Stratigraphic section exposed in road cut north of Highway 16 at west end of McLeod River Bridge (Mileage 117.7)

The till here is stonier than tills to the east but less stony than a typical Cordilleran till. From a cursory examination of pebbles in the road cuts, perhaps 90% of the material came from the Cordillera with only about 10% of the material coming from the Shield.

The Paskapoo Sandstone near the highway on the west side of the bridge, shows a mottled brown and grey coloration. The brown colour is an oxidation phenomenon and is only present in the vicinity of joints and bedding planes in the rock.

A similar oxidation phenomenon affects glacial till and in many places accounts for the difference in colour observed in till. Brown colour indicates that the material has been oxidized, whereas grey colour indicates lack of oxidation. Colour, therefore, cannot be used to differentiate between tills or as evidence for multiple tills or to assign age relationships to tills.

119.4 Crossing the Edson Mississippian Oilfield.

122.8 Traffic lights at intersection of Highway 16 and Edson main street.

127.4 Road cuts to the north of the Highway expose Cordilleran till with no overlying lacustrine deposits.

129.1 Contorted bedrock overlain by till in road cut.

129.7 Junction with Highway 47 to the south to Robb, Coalspur, Cadomin and Nordegg. Turn left onto Highway 47.

131.2 Outcrop of contorted bedrock on road cut to the left. Local relief is mainly a reflection of bedrock topography although surficial deposits are till. The till is thicker in the valleys and thinner on top of the ridges.

Photo 3. Contorted bedrock. Highway 47 (Mileage 131.2)

131.7 Railway overpass.

133.9 Aeolian sand exposed in road cut on side road approximately 50-100 yards west of the highway. For the next three miles the highway passes through a dune field composed of U-shaped and parabolic dunes and deflation basins. Winds which formed the dunes blew from a west-northwest to northwest direction. The sand originated in glacial lake and outwash deposits to the west. The deflation basins are presently occupied by muskegs.

138.1 Bridge over McLeod River. The McLeod River is actively downcutting forming incised meanders and leaving gravel bars and terraces above water level.

140.4 Road cuts in gully expose lacustrine silt. For approximately the next 10 miles the highway passes through lake deposits of clay, silt and very fine grained sand. The coarser lake deposits have been reworked by wind into sand dunes but where the lake deposits were mainly silt or clay they have not been modified by wind action.

147.9 Outcrop of till and lacustrine materials in road cut to the right. The Embarras River is directly against the road grade on the left exposing Brazeau Formation in the undercut river bank. The Brazeau consists of medium to coarse grained, cross bedded sandstone, the uppermost 3-5 feet of which has been contorted by glacial action. For the next 3/4 mile the road is built upon a terrace of the river.

148.7 To the left road cut exposing fine aeolian sand.

150.0 Railway crossing.

150.7 Road cut exposing Cordilleran till.

154.0 View point towards the southwest. The first range of mountains beyond the Foothills is the Nikanassin Range. Beyond the Nikanassin Range, the higher peaks of the Rocky Mountains may be seen. The fault bounding the Front Range of the Rocky Mountains marks the boundary between the Foothills and Rocky Mountains. The Coalspur anticline which is probably faulted against the flat lying rocks of the Plains is considered to be the easternmost structure of the Foothills belt.

159.6 Railway crossing. For the past several miles road cuts have exposed Cordilleran till which makes up the surficial deposits.

163.6 Railway crossing and Forestry Road junction at Robb. Approximately 2.2 miles to the right along the Forestry Road to Hinton is the abandoned Bryan Mountain coal strip mine. Coal was mined from several seams of either Tertiary or Uppermost Cretaceous age in the Brazeau Formation. The beds dip toward the northeast at approximately 40 degrees. Flattened carbonized tree trunks ranging from about 15-20 feet in length and up to about 1 foot in width may be seen on the bedding planes in the coal.

163.9 Bryan Hotel on the right.

164.0 Road cut on the right exposes glacial sand overlain by outwash gravel.

164.4 To the left across the valley may be seen another abandoned strip mine.

165.7 Brazeau Formation is exposed in road cuts along the highway for the next several miles.

166.4 Passing over the axis of the Coalspur anticline.

167.7 Outcrops of Brazeau sandstone to the right on the banks of Embarras River. The beds strike approximately north 50° west and dip southwest at about 62°. A thin quartzite cobble conglomerate is exposed at the base of a small fall or rapids in the river immediately to the right of the highway. This conglomerate is considered to be correlative to the Entrance Conglomerate near the Tertiary-Cretaceous contact.

168.0 Bridge over Embarras River. Abandoned mine workings may be seen to the left across the valley.

168.4 Railway crossing.

168.5 Bridge over small creek. The abandoned Coalspur strip mine may be seen directly in front on top of the hill. Estimated reserves 3,600 million tons of bituminous high-volatile, non-coking coal.

169.5 Road junction. Foothills,Sterco and Nordegg to the left, Mercoal, Luscar, Cadomin and Mountain Park to the right.

172.4 Brazeau Formation exposed in road cuts on left for approximately the next 1/2 mile.

172.9 View of the Nikanassin Range, Luscar Mountain to left, Mount Gregg to right, showing shaly facies of Devonian Fairholme Group (Palliser, Sassenach, Mount Hawk and Perdrix Formations) thrust over Mississippian rocks which are exposed in an anticline overturned to the northeast. Banff shales form the core of the structure. The Mississippian in turn lies mainly on Jurassic to Triassic beds below the Nikanassin Thrust.

174.2	Entrance to Mercoal to the right. Mercoal was the last mining town to be abandoned in the coal branch. The workings were closed in 1959.
174.5	Road cut on left at corner in the highway exposes conglomeratic beds dipping towards the east. These beds are thought to be correlative with the conglomerate at mileage 167.7 and the Entrance Conglomerate near the Tertiary-Cretaceous boundary.
175.6	Railway overpass.
176.1	Brazeau Formation exposed in the river bank and road cuts to the right of the road for approximately 1/4 mile.
176.2	Bridge across McLeod River.
176.7	Alberta Forestry Service Air Strip to the right.
181.2	View of the Nikanassin Range. The flat topped mountain to the left is Leyland Mountain with Luscar Mountain in the centre.
182.3	Bridge over McLeod River. Outcrops of Brazeau Formation to the right in the river bank.
182.8	Cardium Formation exposed in bend of the river to the right, not visible from the road. The section exposed is approximately as follows from the base:

20 feet - Opabin Member or transition zone of the uppermost Blackstone Formation.
30 feet - Ram Member of the Cardium Formation consisting of fine grained ripple marked sandstone.
100 feet - Moosehound Member of the Cardium Formation consisting of shale, mudstone and minor sandstone.
50-60 feet - Leyland Member of the Cardium Formation consisting of concretionary shale and siltstone.
30 feet - Sturrock Member of the Cardium Formation consisting of fine grained sandstone.

Basal beds of the Wapiabi Formation do not outcrop in the creek, but may be exposed between the highway and the railway over the next 1/2 to 3/4 mile.

184.4	Outcrops across the valley to the right may be Cardium or Brazeau Formation. Beds exposed in Watson Creek immediately to the right of the road are probably Brazeau Formation.

185.9 Bridge over McLeod River. Brazeau Formation exposed at the bridge and for about 1/4 mile downstream to the right. These beds are equivalent to the lower Belly River Formation in the Plains.

186.3 Road into abandoned saw mill site to the left. Stop No. 4 to examine contact relationships between the Wapiabi and Brazeau Formations at Hells Gate. Trail to the river begins to the right of old wooden stairway at the far side of the clearing.

Hells Gate is formed by a massive conglomerate in the lower part of the Brazeau. The beds are overturned towards the northeast and dip southwest at about 80°. Across the river 200-300 feet of greenish silty shales and sandstones are exposed below the conglomerate. The contact between the Brazeau and underlying Wapiabi is exposed on the near side of the river approximately 200 yards upstream to the right. The resistant orange weathering sandstone extending as a promontory into the edge of the river was originally named the Solomon Sandstone by Rutherford. The sandstone plus the underlying sandy and silty concretionary and glauconitic shale

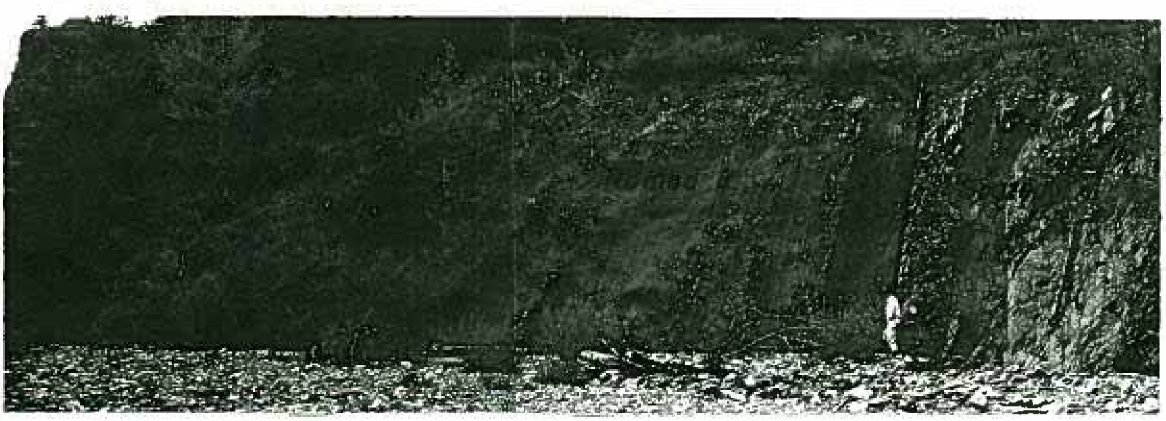


Photo 4. Contact relationships between Wapiabi and Brazeau Formations, north bank of McLeod River, just above Hell's Gate (Mileage 186.3)

were renamed the Chungo Member of the Wapiabi Formation by Stott. Above the Chungo Member is 100 feet of black shale, concretionary beds and thin silty stringers which Stott has called the Nomad Member. The Brazeau Formation lies conformably on top of the Nomad Member. Marine pelecypods have been collected from the Chungo Member and the shales of the Nomad Member contain a marine microfauna.

187.1 Bridge over Luscar Creek.

187.5 Contact relationships between the Blackstone and Cardium Formations are exposed in the slope to the right. This section was measured and described in detail by D. F. Stott in G.S.C. Memoir 317 on the Alberta Group.

Photo 5. Contact relationships between Blackstone and Cardium Formations, north side of Highway 47 near Luscar Creek (Mileage 187.5)

187.8 To the right the uppermost Blackstone and Cardium Formations are repeated by thrust faulting.

187.9 Junction with road to Luscar to the right.

189.2 The Vimy Member of the Blackstone Formation may be seen to the left across the railway track at Leyland Railway Station. The Vimy Member is equivalent to the Second White Specks Marker in subsurface terminology.

189.7 Cadomin Post Office on right. Continuous outcrops of Blackstone Formation may be seen along the railway track across the river to the left.

190.0 A small anticlinal fold may be seen along the railway track across the river. The contact between the shales of the Blackstone Formation to the left and the sandstones of the Mountain Park Formation to the right occurs immediately to the right of the fold. The Sunkay Member of the Blackstone Formation is well exposed immediately above the Mountain Park Formation. The Sunkay Member contains within it an interval of thin bedded sandstone and shale with abundant fish scales equivalent to the Fish Scale Zone of the Plains. A thin sandstone containing Dunveganoceras is present a few feet above the zone of fish scales and may be equivalent to the Dunvegan Formation of the Peace River area.

190.2 Road cuts to the right expose greenish weathering sandstones of the Mountain Park Formation.

190.6 Abandoned mine entrance tunnel to the right.

190.7 Across the river to the left may be seen structurally deformed thin sandstones, shales, coaly shales and coals of the Luscar Formation. The main coal seam may be seen lying above (to the left of) a massive sandstone bed approximately 30 feet thick. Below the sandstone, shaly beds include a thin marine tongue equivalent to the Clearwater and Moosebar Formations of the Athabasca River and Peace River regions, and a calcareous fossiliferous shale equivalent to the "Ostracod Zone" or "Calcareous Member" of the Blairmore and Mannville Formations to the south and east.

191.5 Road to the left to the Inland Cement Co. Quarry.

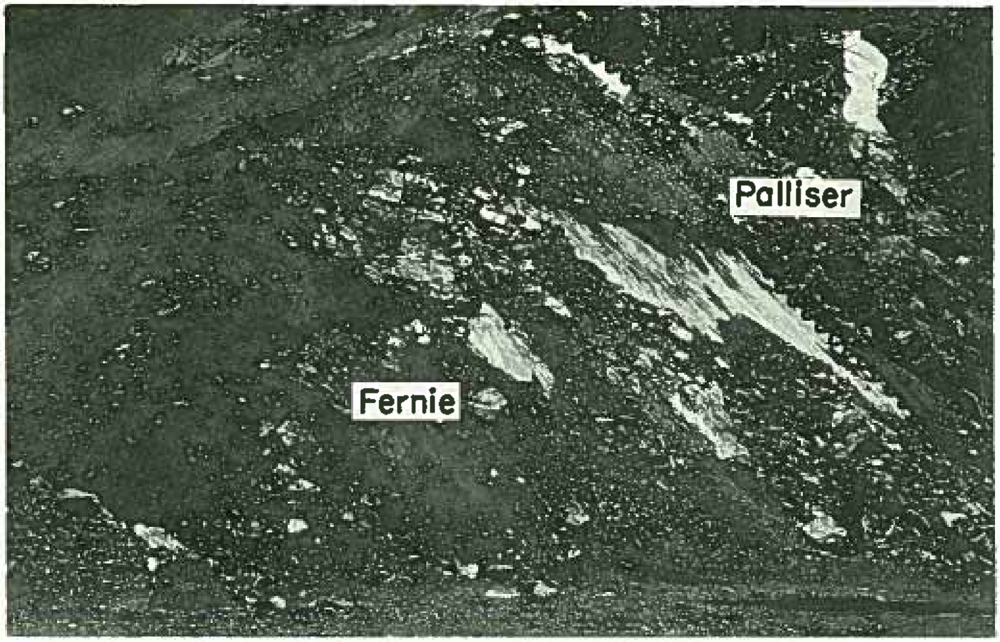


Photo 6. Exposure of the Nikanassin thrust in the Inland Cement Co. north quarry. Devonian Palliser Formation faulted over Jurassic Fernie Formation. Man at lower right gives scale.

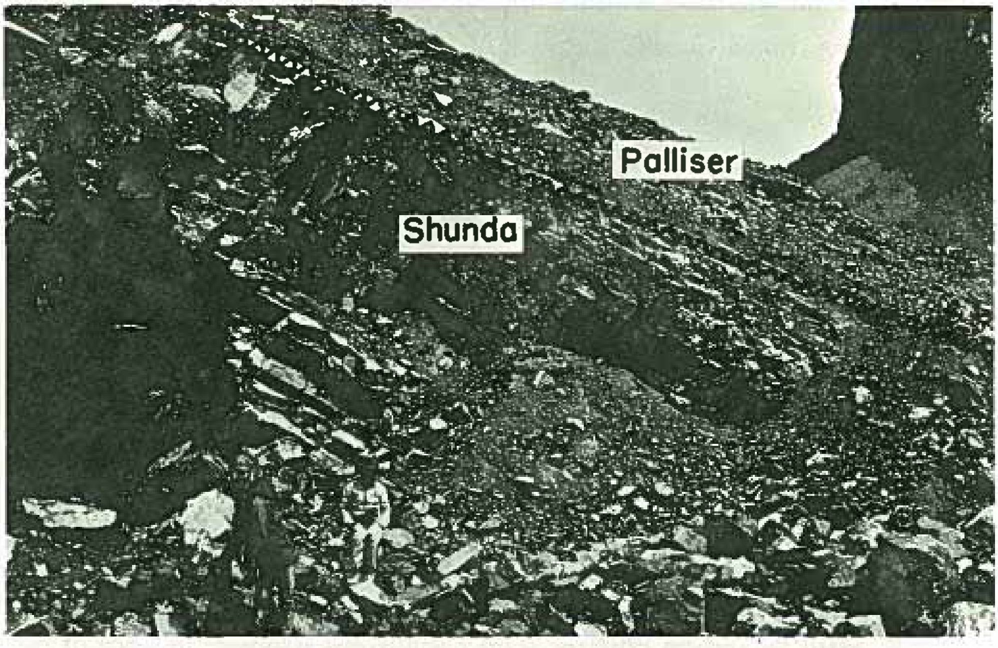


Photo 7. Exposure of thrust fault in the Inland Cement Co. south quarry. Devonian Palliser Formation faulted over Mississippian Shunda Formation. Men at lower left give scale.

192.2 The Palaeozoic formations making up the Nikanassin Range are well exposed in both sides of the valley. To the left (southeast), the Nikanassin thrust faults grey, cliff forming Palliser Formation over soft, black Jurassic shale of the Fernie Formation. The fault plane is exposed in several places in the quarry. Banff Formation is exposed in the switch backs of the road to the upper quarry workings and along the ridge top in the saddle to the right of the Palliser, where the Banff/Rundle relationships may also be seen. The lower road to the right exposes Shunda Formation and the fault contact between the Shunda and the overlying Palliser in the creek at the left of the abandoned quarry about 1/4 mile south of the main quarry. Along strike to the northwest, the Palliser Formation above the Nikanassin thrust plunges out in the core of an overturned anticline beneath Leyland Mountain. The second (southwestern) slice of Palliser caps Leyland Mountain and the smaller ridge immediately north of the road. A small cave visible from the road near the lower left end of this ridge marks the Shunda/Palliser fault contact. Above the Palliser, a normal Mississippian sequence is exposed as high as the Turner Valley Formation which caps the next ridge immediately north of Whitehorse Creek.

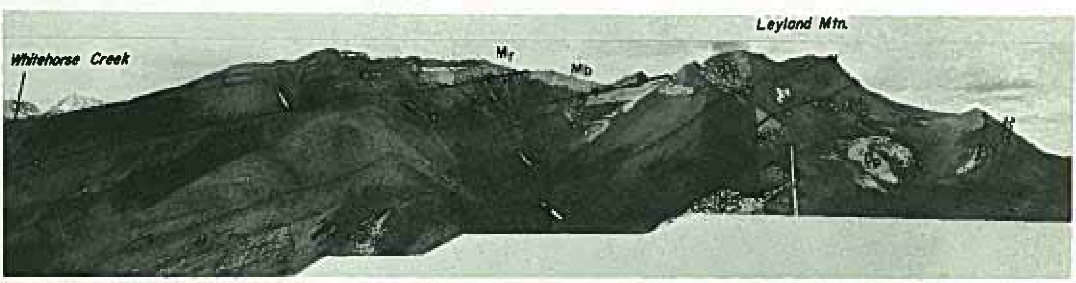


Photo 8. Panoramic view northwest from top level of the Inland Cement Co. north quarry along strike of the Nikanassin Range. Nikanassin thrust at right with Mississippian Rundle Group (Mr) faulted over Cretaceous Luscar Formation (Kl). Mississippian Banff (Mb) Devonian Palliser (Dp) Formations exposed in core of overturned anticline above the thrust. Palliser faulted over Rundle caps Leyland Mountain and the small peak in the left foreground. Turner Valley Formation of the Rundle Group caps the skyline ridge north of Whitehorse Creek.

192.9 View eastward towards the Nikanassin Range. The Palliser Formation forms the ridge to the left with shales of the Exshaw and Banff Formations exposed in the saddle immediately in front. The first cliff on the right of the saddle is composed of micritic dolomite (penecontemporaneous?) of the uppermost Banff. The slope above the first cliff is composed of light grey weathering Pekisko Formation overlain by slightly darker grey weathering shaly carbonates of the Shunda Formation. The second and third cliffs are composed of Turner Valley Formation which is overlain by the Mount Head Formation making up the fourth and fifth cliffs and the intervening slopes. The Mount Head is overlain by 15-20 feet of Rocky Mountain Group and at the top of the mountain the Triassic Spray River Formation makes up the last two knobs.

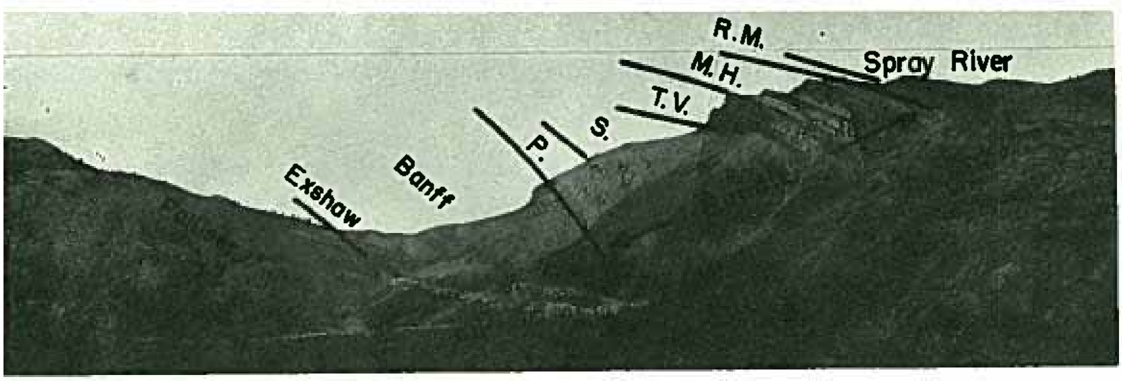


Photo 9. Panoramic view eastward towards the Nikanassin Range from Mileage 192.9. Palliser, Exshaw, Banff, Pekisko (P), Shunda (S), Turner Valley (T.V.), Mount Head (M.H.) Rocky Mountain (R.M.) and Spray River Formations exposed along the ridge in normal sequence.

193.1 Bridge over Whitehorse Creek. On the right immediately south of the bridge are outcrops exposing approximately 25-30 feet of Shunda Formation. The Shunda here consists of grey weathering micritic limestone, in part pelleted and containing scattered oolites, pisolites, oncolites and intraclasts. Well exposed in the outcrop are three prominent buff weathering, microcrystalline dolomite beds which can be interpreted as being penecontemporaneous. Across the river along the railway, channelling and mud cracks are associated with these dolomite beds, suggesting that they were deposited in shallow water, perhaps on sebkha type mud flats. The contact with the overlying Turner Valley Formation is probably near the top of this outcrop, perhaps in the trees at the base of the overlying covered interval.

193.4 Mount Head Formation outcrops in road cuts to the right. For the next 1/4 mile road cuts give almost continuous exposures of Mount Head, Rocky Mountain, and Spray River strata. To the left across the valley the extensive rubbly scree slope is developed on the Sulphur Mountain Member of the Spray River Formation of Triassic age.

193.8 Bridge over small creek.

193.9 Across the valley to the left, the very light grey weathering material is the Whitehorse Member of the Spray River Formation.

194.6 Black shale and orange weathering siltstone bands of the Fernie Formation in road cut to the right.

194.7 Bridge over Prospect Creek. Road to the right up Prospect Creek is normally passable by car. Exposures of Fernie, Nikanassin and Cadomin Formations occur along the creek for approximately 1 mile upstream.

194.8 Fernie Formation exposed in road cut on right.

194.9 Sandstones and shales of the lower Nikanassin Formation exposed in road cut to the right.

195.1 View to the left across the river shows structurally deformed beds of the Nikanassin Formation. Northwards across the unnamed creek entering the river from the right the contact between the Sulphur Mountain and Whitehorse Members of the Spray River Formation are distinctly seen on the back slope of the ridge. The lower part of the contact may be a fault as the distinct colour change appears to cut across the bedding (See photo below).

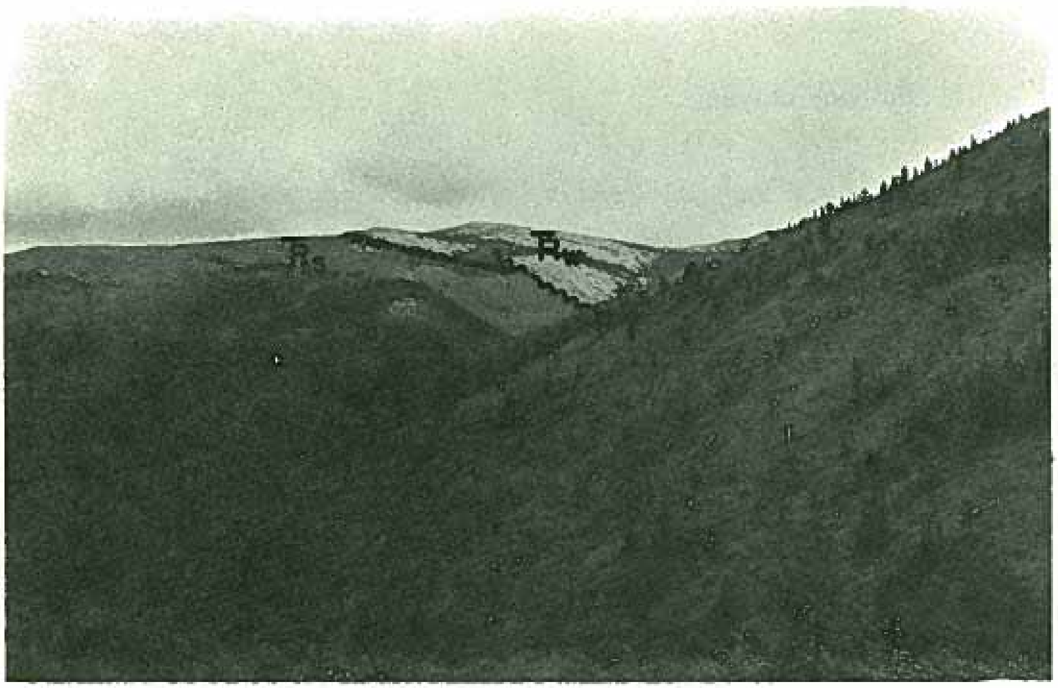


Photo 10. Triassic Sulphur Mountain (Trs) and Whitehorse (Trw) Members exposed on back slope of ridge. View northward from Mileage 195.1.

195.6 Nikanassin Formation outcrops along the road for approximately the next 1 mile.

196.1 Railway crossing.

196.8 Massive conglomerates of the Cadomin Formation outcrop on the left across the McLeod River and on the right in the banks of a small creek across the railway track.

197.0 Outcrops of Luscar Formation to the right.

197.1 Cadomin conglomerate exposed to the left across the river. This area is cut by a number of small thrust faults which repeat the Cadomin Formation.

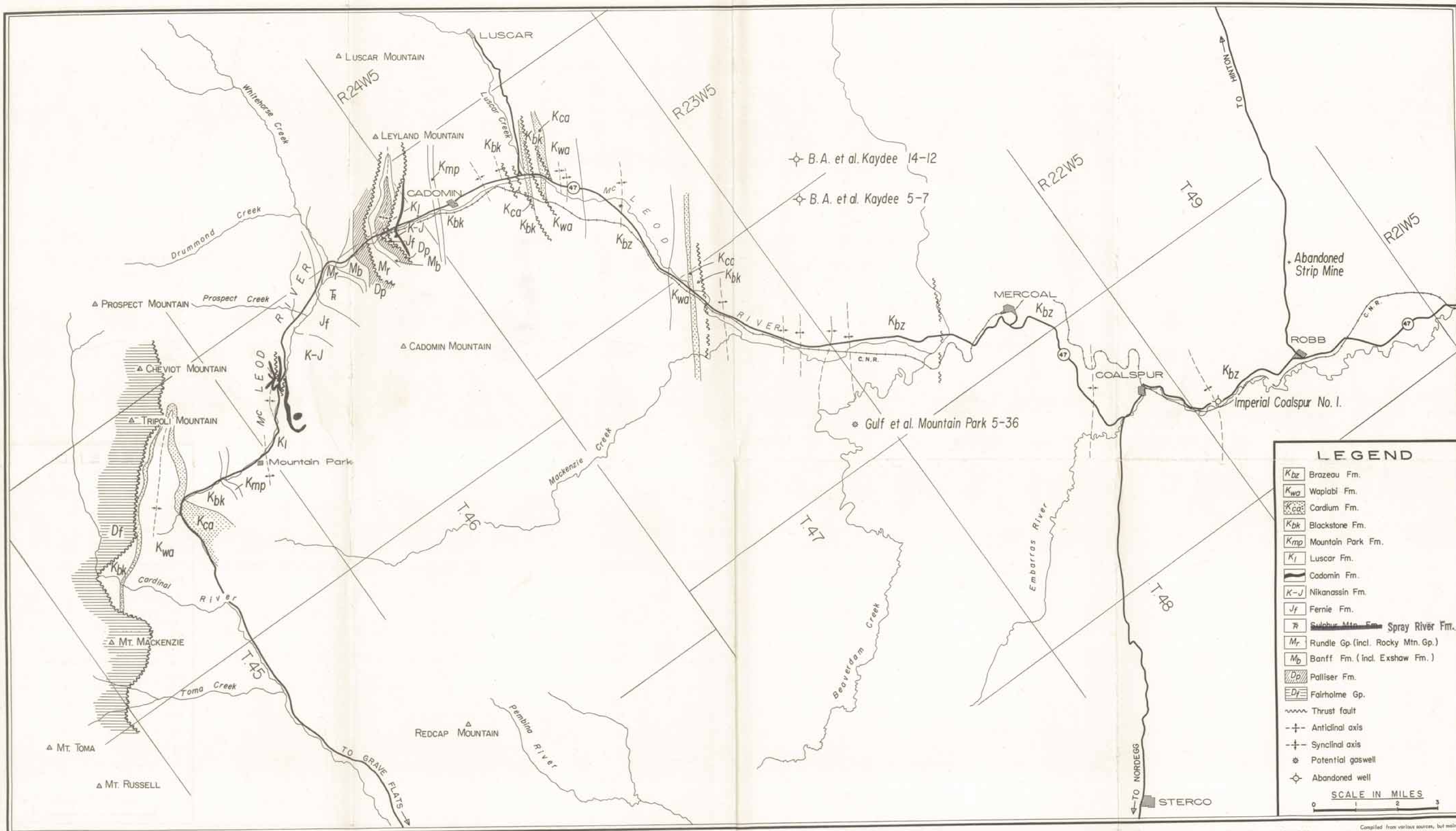
197.5 To the left, carbonaceous shales, coaly shales and sandstones of the Luscar Formation exposed for the next .2 miles.

197.8 Bridge over McLeod River.

198.1 Railway crossing.

198.9 Mountain Park Railway Station (abandoned) on left.

Photo 11. Panoramic view of the Front Range of the Rocky Mountains to the southwest of Mountain Park railway station. Devonian Fairholme Group thrust over Cretaceous shales of the Alberta Group.



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Compiled from various sources, but mainly from Maps 208A – Mountain Park sheet and 209A – Cadomin sheet of the Geological Survey of Canada, by B.R. MacKay, 1929.

GEOLOGICAL MAP OF HIGHWAY 47 FROM ROBB TO MOUNTAIN PARK