PROVINCE OF ALBERTA

Research Council of Alberta. *Report No.* 21.

University of Alberta, Edmonton, Alberta.

GEOLOGICAL SURVEY DIVISION

JOHN A. ALLAN, Director

Geology and Water Resources

IN PARTS OF

The Peace River and Grande Prairie Districts, Alberta

BY

RALPH L. RUTHERFORD

With Appendix by P. S. Warren

Printed by order of
THE LEGISLATIVE ASSEMBLY OF ALBERTA

EDMONTON:
PRINTED BY W. D. McLEAN, KING'S PRINTER
1930

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LETTER OF TRANSMITTAL.

HONOURABLE J. E. BROWNLEE,
Premier of Alberta,
Chairman, Research Council of Alberta,
Edmonton, Alberta.

SIR:

I have the honour to transmit herewith a report of the Geological Survey Division, entitled "*Geology and Water Resources in parts of the Peace River and Grande Prairie Districts, Alberta,*" prepared from field observations, by Dr. Ralph L. Rutherford in 1929. This is Report No. 21 of the Research Council of Alberta.

The area mapped geologically and discussed in the report is approximately 5,000 square miles, extending from Peace River, about 50 miles south, 75 miles west and 20 miles east. Accompanying this report is a geological map on a scale of one inch to four miles and printed in six colours.

An appendix to the report, prepared by Dr. P. S. Warren, contains the description of new species of fossils.

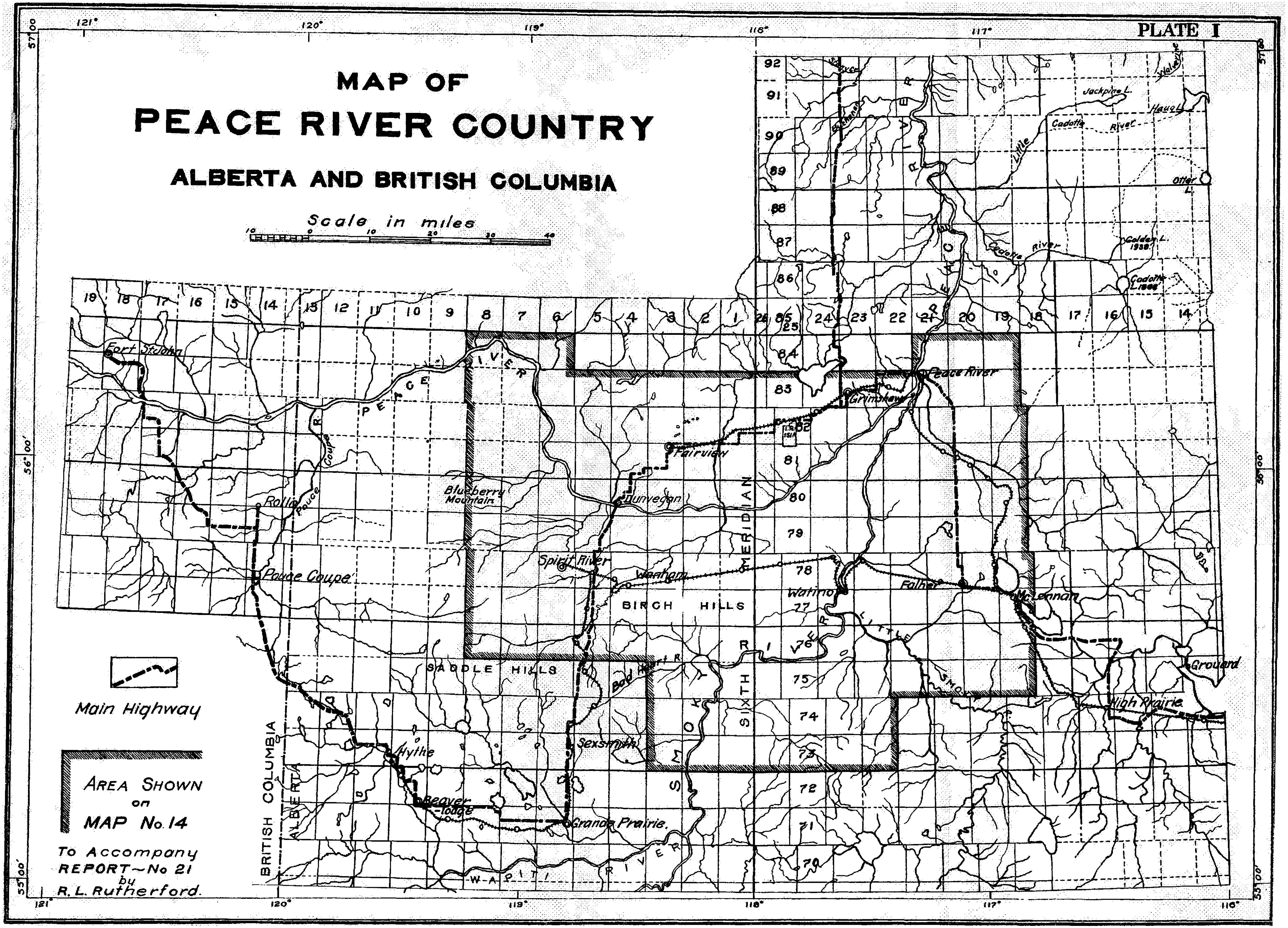
The object of this survey was primarily to obtain data on the possible underground water resources within the area surveyed.

All of which is respectfully submitted,

JOHN A. ALLAN,
Geologist.

Department of Geology,
University of Alberta,
Edmonton, Alberta,
June 14, 1930.

PLATE I


MAP OF
PEACE RIVER COUNTRY
ALBERTA AND BRITISH COLUMBIA
Scale in miles
Main Highway
Area Shown on MAP No. 14
To Accompany REPORT—No 21 by R. L. Rutherford.
Fort St. John
Peace River
Grimshaw
Fairview
Dunvegan
Blueberry Mountain
Rolla
Pouce Coupe
Spirit River
Wanham
Watino
Falher
McLennan
Grouard
High Prairie
BIRCH HILLS
SADDLE HILLS
Hythe
Beaverlodge
Sexsmith
Grande Prairie
Bad Heart R.
WAPITI RIVER
SMOKY RIVER
LITTLE SMOKY
SIXTH MERIDIAN
BRITISH COLUMBIA
ALBERTA
Pouce Coupe R.
Cadotte River
Little Cadotte River
Jackpine L.
Haig L.
Otter L.
Cadotte L.
Notikewin
Whitemud
PEACE RIVER

Geology and Water Resources

IN PARTS OF

The Peace River and Grande Prairie Districts, Alberta

By

RALPH L. RUTHERFORD.

INTRODUCTION

CHAPTER I.

General Statement.—The Peace River country, as it is commonly called, has received considerable publicity during the last few years on account of the fact that it contains relatively large unoccupied areas that are suitable for agricultural development. The existence of these areas was known for many years, but because of the long distance from transportation facilities, settlement within them was small until the construction of the Edmonton, Dunvegan and British Columbia railway and its branch lines (now known as the Northern Alberta Railways) made this country more accessible.[1] New settlement usually follows lines of least resistance and consequently the most open lands which require ~~the least effort in~~ preparation are settled first. Several areas of open land occur within the Peace River country and the thickest settled areas today are situated on these. Good soil free from stone is a consideration in selecting land, and most of these open lands satisfied this condition. The problem of an adequate supply of water suitable for domestic purposes has not as a rule been considered in new areas, since usually there are sufficient supplies obtainable from surface drainages and accumulations to supply the needs of the first settlers. With increased development, this supply is decreased through increase in consumption and decrease in supply due to clearing, cultivation and drainage of the land, and it becomes necessary to secure a supply of ground water. It is further essential to obtain water from such a source, since surface water in settled areas is more subject to pollution and contamination.

The Peace River country contains certain areas where it has been impossible to obtain a supply of water at shallow depths, and some of these areas are within the best settled districts. It should be realized, however, that there are some large districts within this general area of the Peace River where adequate supplies of ground water of excellent quality are available. The geographical distribution of these two types of districts as regards water supply is directly related to the geology of the country, as is shown in a later chapter.

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1 The railway reached McLennan in March, 1915, Peace River in December, 1915, and Spirit River in February, 1916.

In the districts where water has not been obtained at shallow depths, it was realized that relatively deep drilling or boring would be necessary. Since this procedure would be costly when depths to possible supplies were not known and possible results indefinite, requests were made to the Provincial Government for assistance in drilling and for information as to depths to water horizons. As a result of these requests, the Geological Survey Division of the Research Council of Alberta was assigned the problem of obtaining information as to the possible supplies of water at depth in those districts most in need of water at the present time. This investigation was made by the writer during the field season of 1929, and the following report is based largely on this field work.

Geographical Position and Accessibility. — The Peace River country as commonly referred to includes an area extending along the Peace river and its immediate tributaries in the western part of Alberta and north of the central line of the Province. It extends along the Peace river into the eastern part of British Columbia, where it is known as the Peace River block. Most of it lies between longitudes 116° and 121°, and between latitudes 55° and 55°30′. (Plate I.) The Northern Alberta Railways, which starts at Edmonton, enters the eastern parts of the Peace River country. Most of the settled areas are accessible by branch roads from what is known as the Peace River highway, which passes through most of the settled districts. The Peace river and its tributary, the Smoky, divide the Peace River country into separate districts. (Plate II.) The highway connects these by crossing the Peace river three times, namely, at Peace River and Dunvegan in Alberta, and near Fort St. John in British Columbia. Such a highway may appear somewhat indirect, but it serves to connect the sections of a new country where development has been interdependent to a certain extent.

For some time after the railway reached Peace river, this stream was the common route of travel by river steamer to the more distant areas. This service is still maintained along the Peace river, chiefly for some areas in British Columbia and for areas north of Peace River. This means of transportation is, however, giving way rapidly to motor transportation which has extended well beyond the terminus of the railway. The automobile highways within the Peace River country are on the whole as good as similar unsurfaced highways in other parts of the Province, and may be classed as good dry weather roads.

General maps showing the main districts within the Peace River country and their accessibility to railway and highway transportation are shown on Plates I and II.

Culture.—Farming constitutes the chief occupation of most of the settlers in the Peace River country. Mixed farming is carried on to a degree in some districts, but on the whole it is at present essentially a grain growing country. Some of the more isolated districts start with mixed farming, but as increased acreage is put under cultivation, grain growing supersedes the earlier mixed farming. This tendency to increase as rapidly as possible the acreage for grain growing is, in the opinion of the writer, an important factor which is already beginning to show its effect on the climate of the country, chiefly by removing brush and woods which induce precipitation and tend to act as a subduing factor against drying winds. This process has undoubtedly tended to reduce the supply of surface water.

The larger towns are situated within the more settled districts. Grande Prairie is the largest town in the Peace River country and is the main distributing center south of the Peace. Peace River, in the valley of the Peace, is the largest town in the northern part. Fairview, Spirit River, Sexsmith and Beaverlodge are the larger villages. The present size of some of these towns is perhaps influenced by their position as the present end of railway lines. The future development of railways will probably tend to follow a general east and west direction along the north and south sides respectively of the deep valley of the Peace, and unless some unsuspected development other than agriculture takes place, it will likely be a country of rural communities with villages at more central points.

The general aspect of the country is not without beauty, and many excellent views are available at numerous points along the valley sides of the Peace river. The settled areas may also be viewed to advantage from such well-known places as Holden's hill, near the village of Spirit River, and from Saskatoon hill, the flat-topped mesa near Beaverlodge.

Field Work and Preparation of Maps and Report.—This report is based largely on information obtained in the field during the months of June, July, August and the early part of September, 1929. The specific problem of the water supply in certain districts was assigned to the writer as the main object of investigation; consequently the greater part of the field season was spent within these districts. Map No. 14, accompanying this report, includes the areas to which most attention was given during the field work.

The nature of investigation was two-fold. First, information was obtained as to the present supply of water and as to the various tests for ground water that had been made. Samples of water from some of the wells were collected and have been analyzed. Since the present supply has proved inadequate and in many cases is of poor quality, it was necessary to obtain information on the character of the underlying bedrock formations, in order to determine the possibilities of a source of ground water from certain horizons. The examination of these formations as exposed along the main drainage channels constituted the second phase of the field work.

During the field work the writer was ably assisted by D. M. Phillpotts. W. G. Hole acted as cook and camp assistant. Most of the area was traversed by means of automobile, working from camps established at central points. The summer of 1929 was ideal for this mode of transportation, as it was an exceptionally dry season.

The area to which most attention was given is shown in map No. 14, accompanying this report. The base for map No. 14 has been compiled largely from the information given on the sectional sheets issued by the Topographical Survey of Canada. Map No. 14 includes parts of areas covered by the following sheets: No. 463, Smoky; No. 513, Shaftesbury; No. 462, Dunvegan; and No. 512, Montagneuse. The greater part of the area covered by these has been surveyed and contours on the sectional sheets show the approximate elevations in the surveyed areas. These contour lines represent general elevations rather than detailed topography, nevertheless, they show the major physiographical features and have been reproduced on map No. 14. The areal distribution of the geological formations is also shown on map No. 14. The boundaries of the formations are, in most places, projected from contacts exposed in river sections. Some exposures of key horizons within the inter-stream area were of assistance in determining the approximate position of these boundaries.

Although most of the season was spent within the area shown on map No. 14, some traverses were made into adjacent districts in order to obtain further information on some of the underlying formations. This was especially the case in obtaining data on the Dunvegan formation. As shown below, this formation is the uppermost one carrying sandstone beds that underlies several of the areas where the water problem is most acute. It has been hoped that this formation may prove a good water horizon and for that reason a brief examination of water conditions prevailing north of Rolla, British Columbia, was made. The Dunvegan formation is here at the surface. The Dunvegan beds were also examined where they come to the surface on Whitemud river north of Grimshaw. Some further examinations of the Wapiti formation and younger strata in the Grande Prairie district were made.

Previous Work.—The Peace river has been a historical trade route across this part of northwest Canada, and even today it is the route travelled to reach certain parts of British Columbia. Consequently, the earliest observations on the geology refer to features observed along this stream and its tributaries. The general open character of the country for comparatively long distances made it possible for earlier explorers to travel by pack train and some of the early reconnaissance surveys were made by overland route.

The earliest report containing some reference to the geology of these districts is that of Selwyn[2] in a general reconnaissance report of work done in northern British Columbia and adjacent areas to the east along the Peace river. A later survey, covering in part the same areas, was made by Dawson,[3] and his report contains more detail in respect to the Peace River country than is contained in Selwyn's report. Dawson subdivided the Cretaceous strata into formations, and some of the names that he assigned to these formations are still retained.

2 Selwyn, A. R. C., Explorations in British Columbia, Geol. Surv.. Can., Report of Progress for 1875-76, p. 29 et. seq.
3 Dawson, G. M., Geol. Surv., Can., Report of Progress, 1879-80, part B.

A more systematic survey and study of the Cretaceous formations exposed along the Peace and Smoky rivers has been made by McLearn.[4] He described the formations in some detail as to their lithological character, thickness and distribution, and made collections of fossils from these formations, which he has described in later publications.[5]

A general report on the geology of the Mackenzie river basin[6] contains a summary of the geology along the Peace and Smoky, as well as a correlation of the formations here with those in districts to the east along the Athabaska. This report also contains a map showing the areal distribution of the formations occurring along the major stream valleys in the Peace River country. The scale of this map is one inch to 50 miles and is too small to show detail, consequently the mapping of the formations is very general.

J. A. Allan examined the section along the Peace in 1921, and at some points along the Smoky river at a later date. The results of his observations appear in the Research Council of Alberta reports for 1921 and 1924.

ACKNOWLEDGMENTS.

The writer wishes here to acknowledge the assistance and courtesies given our party during the field work. Camping privileges and permission to use private supplies of water at various places were appreciated by us, since auto camps with the usual facilities have not been established in many of these districts. In this connection our party especially appreciated the courtesies extended by Mr. R. H. Macdonald of Fairview. Mr. R. H. Weaver, who has drilled several wells in the area, gave valuable information regarding results obtained.

Dr. P. S. Warren has identified the fossils collected during the summer, and has described several new species from our collections. These descriptions are included as an appendix to this report. Dr. J. A. Allan, under whose direction this survey was made, has spent considerable time in assisting with the preparation of this report and map. He has made traverses through parts of the Peace River country and his knowledge of the geological conditions there has been of considerable assistance in discussing various problems with the writer. Mr. J. A. Kelso, Provincial Analyst, has analyzed the water samples recorded in this report.

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4 McLearn, F. H., Peace River section, Alberta, Geol. Surv., Can., Summ. Rept. 1917, Pt. C., p. 14; Cretaceous, Lower Smoky river, Alberta, Geol. Surv., Can., Summ. Rept. 1918, Pt. C, p. 1; Little Smoky river, Alberta, Geol. Surv., Can., Summ. Rept. 1919, Pt. C, p. 13.

5 New species of Pelecypods from the Cretaceous of northern Alberta, Geol. Surv., Can., Museum Bull. No. 29, p. 9; Three new Pelecypods from the Coloradoan of the Peace and Smoky valleys, Alberta, Can. Field Naturalist, Vol. XXXIV, p. 53, 1920; New species from the Coloradoan of lower Smoky and lower Peace rivers, Alberta, Geol. Surv., Can., Bull. 42, p. 117, 1926.

6 Camsell, C., and Malcolm, Wyatt, Geol. Surv., Can., Memoir 108, 1919.

CHAPTER II.

GENERAL CHARACTER OF THE AREA.

Geological Succession.—The consolidated strata underlying the area shown on the accompanying map No. 14 are all of Cretaceous age. The various formations present are exposed chiefly along the valleys of the major streams. Some strata, probably of Tertiary age, occur at the surface in districts to the south near Beaverlodge, and some formations of Palaeozoic age are exposed to the north along the Peace. A mantle of superficial Pleistocene and Recent deposits covers some parts of the area. These deposits are thickest along stream valleys. The general character of the formations in this area and the names assigned to them are as follows:

TABLE OF FORMATIONS.

Quaternary.		Glacial, river and lake deposits of boulders, gravel, silts, clays.
Upper Cretaceous	MONTANA GROUP	*Wapiti formation* Upper part mostly light grey to brown clays with middle part massive sandstones, alternating with clay ironstone nodules and thin coal seams; clays and shales; lower part similar to upper part. Thickness over 1100 feet.
	MONTANA GROUP	*Smoky River formation* (Upper shale)—Dark to black shales of marine deposition, some ironstone concretion bands and some fine-grained thin beds of sandstone, especially in the upper part. Thickness 300 to 350 feet.
	COLORADO GROUP	(Bad Heart sandstone)—Sandstone, medium to coarse grained, brown weathering, fossiliferous marine. 10 to 25 feet thick. (Lower shale, Kaskapau)—Dark to black shales, thin bedded, of marine deposition, some sandstone beds in lower part in some districts. Approximate thickness 875 feet.
		Dunvegan formation Alternating sandstones and shales, brackish water deposition; some of the sandstone beds up to 50 feet thick. Thickness 450 to 550 feet.
?		*St. John formation* Dark grey to black shales with some clay ironstone bands and concretions. Similar in appearance to the shale member of the Smoky River formation. Approximate thickness 550 to 600 feet.
Lower Cretaceous		*Peace River formation* Only the upper part is exposed in this area. It consists of massive sandstones. Exposures along the Peace to the north show the lower part of this formation to consist of a shale member and a lower sandstone member.

In addition to the above, a still lower Cretaceous formation known as the Loon River formation, occurs at depth. It is composed mostly of marine deposited shales. The Wapiti formation is the uppermost representative of the Montana group in this area. It is possible that some still higher beds which have been eroded were of Upper Cretaceous age.

The above table shows the underlying stratigraphical succession in general to consist of an alternation between formations which are dominantly shale or sandstone. This is a significant feature in relation to the consideration of possible water horizons at depth. In general the strata dip to the south and the regional slope of the land is to the north. Thus the lower formations outcrop to the north and the younger to the south, as shown on map 14.

Physiography.—The area shown on the accompanying map is in general of low relief, although some physiographical features are pronounced. The general surface is composed of three elements, namely, uplands that are semi-continuous, broad areas with gentle slopes, and deeply incised valleys of the major streams. The greater part of the population lives on the broad, gently sloped areas between the river valleys and uplands. The structure profile sections accompanying the map illustrate these physiographical features to some extent, although the vertical scale on these sections has been exaggerated.

The maximum difference in elevation in this area between river bed and upland is approximately 2,000 feet, as for example between the Peace river level at Dunvegan and the top of the Saddle hills, about 30 miles to the south. In general the distance between high and low points is greater than this, and also the difference in elevation less.

Structurally and geologically this area occupies a position similar to the plains area of Alberta. The physiographical aspect is more like that in the southern plains of Alberta in the vicinity of Lethbridge than that of central Alberta in the Edmonton district. The depth and steepness of the river valleys and the gently sloped uplands, surrounded by flat areas, are the comparing feature of the Peace River country and the plains of southern Alberta, although the history of their development may be somewhat different in the two areas so widely separated.

The uplands and the deep valleys of the streams are the physiographic features which separate the country into districts with respect to settlement. For example, the Saddle hills separate the Spirit River and Grande Prairie districts; the Birch hills separate the Wanham and Heart valley districts; the Peace river valley separates the Waterhole-Fairview and Spirit River districts. Highways and railways cross these valleys and uplands, but not more often than is necessary to reach and serve the different districts.

The present surface is the result of erosion and deposition over a long period. Apparently there were three main stages in the development of the surface features. These may be referred to as, pre-glacial erosion, glacial erosion and deposition, and post-glacial erosion. The results of these stages of erosion and deposition and the character of the formations acted upon have an important bearing on the water problem in the districts referred to above.

The stage of pre-glacial erosion apparently was the longest of the three, although it has not been definitely determined when it began. There are some strata present in the Grande Prairie districts that are probably of lower Tertiary age, and east of this area lower Tertiary is represented in the strata present in Swan hills south of Lesser Slave lake.[7] Probably lower Tertiary beds were deposited over most of this area, but these and any later Tertiary strata that may have been deposited were removed in this first period of erosion. The general result of this erosion was to produce a surface of gentle slopes extending from the upland to the base of stream valleys. The stream valleys were not entrenched to their present depth, so that apparently the relief at the close of this period was not so marked as at present. The uplands resulted from a differential erosion on a series of formations alternating between those dominantly shale and those dominantly sandstone. The sandstone formations underly the uplands and the gentle dip to the south of the strata has tended towards the development of cuestas.[8] The elevation of the uplands ranges on the average from 2,500 to 3,000 feet above sea level. The lower slopes of these are at an elevation of 2,000 to 2,200 feet. The Saddle hills and the Birch hills in the southern part of the area are examples of these uplands.

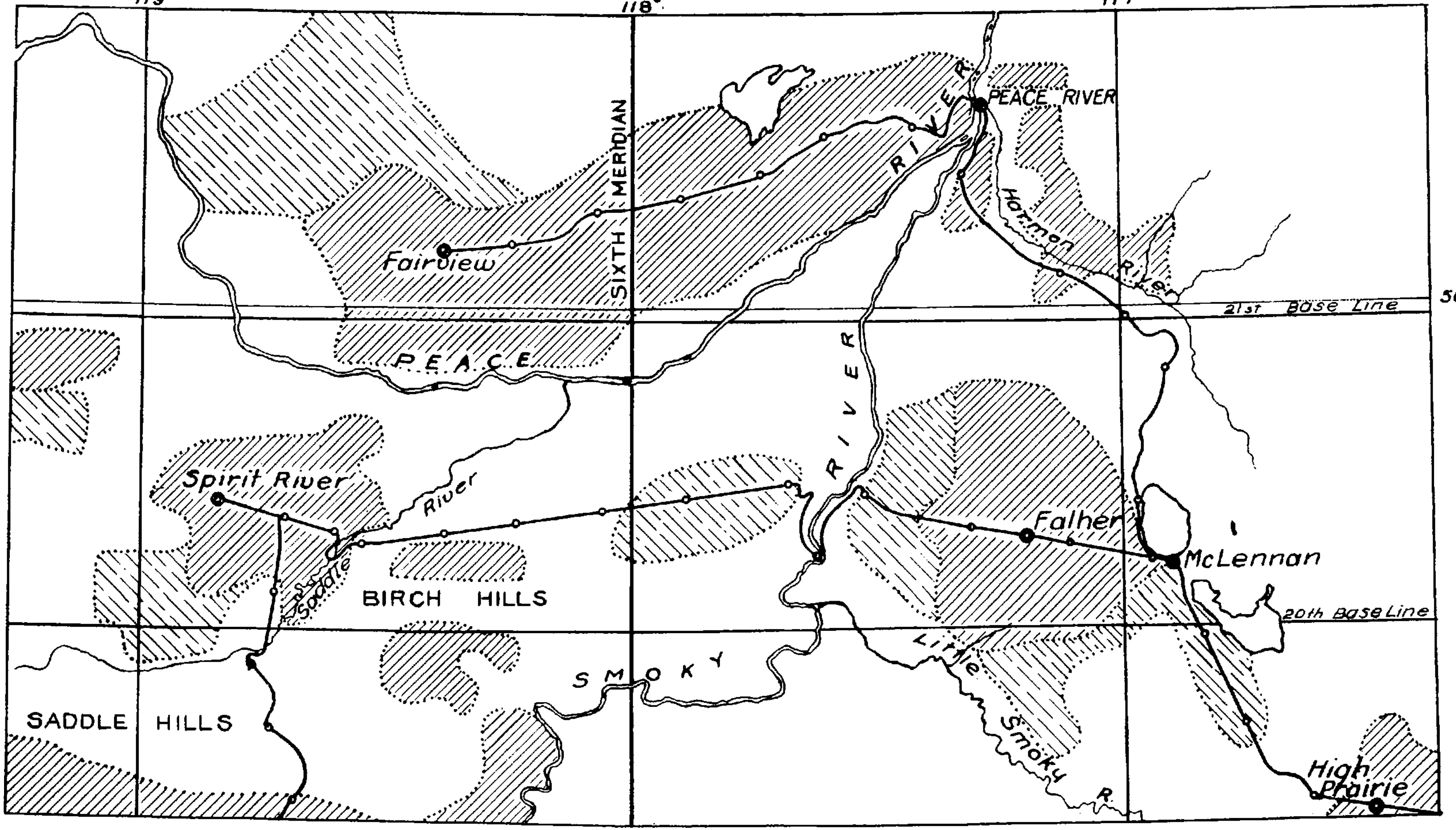
The second stage in development of the surface features was glacial erosion and deposition. From a consideration of water supply in certain districts, this is one of the most important stages, since the net result of this was to produce large areas with a relatively flat surface by filling in the lower areas left by pre-glacial erosion. The greater part of the agricultural settlements now occupy remnants of these broad flat areas, which are covered with these deposits. It is not possible to ascertain the extent of glacial erosion that resulted as a consequence of the covering of ice from the Keewatin center to the northeast during Pleistocene time. The more important results with reference to the present surface aspect were accomplished during the gradual retreat of the ice front, causing extensive laking in the lower areas. These lakes were gradually silted up, chiefly with clays and fine material derived in large part from the marine shale formations which form the underlying strata. It is difficult to ascertain the average thickness of these fine-grained deposits. The thickest exposures occur along the main river valleys, but they thin out in the direction of the uplands. The slope of the original surface on which they were deposited was in general steeper than the present surface. Some coarse material of glacial origin is also present in the form of gravel and boulders of Precambrian rocks. The boulders are more prevalent in the bottoms of deep valleys or fringing the uplands, the latter occurrence being due probably to the fact that the fine material has been washed out. The character and distribution of these glacial deposits and their relation to the water supply are discussed in a later chapter.

The third stage in development of the present surface is that of post-glacial erosion and deposition. The result of this has been

7 Allan, J. A., Geology of the Swan hills in Lesser Slake lake district, Geol. Surv., Can., Summ. Rept. 1917, Pt. C, p. 7.

8 A hill or ridge with one face steep and the opposite face gently sloping.

PLATE II



SHOWING (Approx.) SETTLED DISTRICTS ▨ AND PARTLY SETTLED DISTRICTS ▧

chiefly the dissection of the broad, nearly flat areas left after the deposition of the silts into the glacial lakes. This dissection has been deepest along the valleys of the major streams, where in addition to cutting through these comparatively soft glacial lake clays, the streams have deepened their channels into the underlying bedrock formations. The net result has been to produce relatively narrow, steep-sided, deep valleys along the main streams and the lower parts of their tributaries. The valley of the Peace, for example, is 600 to 700 feet on the average, measured from the top of the bank where it begins to slope gently to the north or south. The depth from the general level of the plain above is in most places 800 to 1,000 feet.

These deep valleys are also a factor of importance relative to the water supply, in that they furnish a means of rapid drainage of the interstream area during wet seasons. If this dissection were not so deep, it is probable that a larger amount of the seasonal precipitation would be retained as ground water.

The three stages outlined above have, to a large extent, produced the present surface. Recent erosion has tended to some extent to lower the upland levels, but only to a minor degree, since in many places the mantle of glacial debris has not been removed. The flat areas have been modified by stream dissection of comparatively recent date. The most pronounced form of erosion today is by landslide and slump along the steep sides of the deep valleys. This process conceals much of the bedrock that would normally be exposed along the valleys, and it also tends to produce an appreciable area of waste land, suitable only to a minor degree for grazing purposes. This slumping is developed to a very large scale along the Peace near Peace river, along the Smoky near Watino, and along tributary creeks in the Spirit River and Fairview districts.

Drainage.—The Peace river and its tributary, the Smoky, are the two main streams crossing this area. Very little of the volume of water carried by these streams is supplied from this area or those immediately adjacent to it. The greater part of the water in the Peace comes from its headwater stream in British Columbia, and the Smoky gathers most of its supply from the foothills and Rocky mountains to the southwest. The Little Smoky river is the largest tributary of the Smoky in this area, and it also obtains most of its supply from areas well removed from its mouth.

There are several small rivers and creeks rising within the area or crossing it, that are tributary to the main streams mentioned. These, with the names usually assigned to them, are shown on the accompanying map. Since water supply is a vital problem in certain districts, it might appear to one examining the drainage pattern of this map that an adequate supply should be available for most districts from these streams. It is obvious from an examination of the contours of these stream valleys, that even if the supply were sufficient, it would not be conveniently accessible to the settlers, who for the most part live on the flat areas above the top of the valleys. In places where the headwaters of these streams reach back into the settled areas, they are used as a local supply by a system of dams. The chief tributary streams in this area and some descriptive remarks about them are tabulated below:

Tributaries of Smoky and Little Smoky:

1. *Bad Heart river.* Derives most of its water from wooded slopes of Saddle hills; valley deep in settled area along lower part. In August a small flow of water, averaging 10 to 15 feet wide, running through gravel and sandy beds. Kakut creek draining Kakut lake, is the main tributary of the Bad Heart. Flowing very slowly in August.
2. *Peavine creek*, joining the Little Smoky. Drains areas around Falher and Donnelly. Flowing very slowly in June; most of the water in upper part is retained by dams for use by settlers.
3. *Racing creek*, joining the Smoky near Culp. Upper part drains settled area north of Falher and Girouxville. Upper waters retained by dams. Flowing very slowly through rocky bed in June.

Peace river tributaries:

1. *Harmon river* (often called the Heart or Hart river). Joins the Peace at Peace River. A permanent stream averaging about 50 feet in width and 6 to 12 inches deep in July. Most of its supply is obtained from muskeg and swampy unsettled areas east of Nampa. The valley is deep in the lower part. Is the main source of water for settlers east of Nampa.
   A number of creeks are shown joining the Peace between Peace River and the sixth meridian. Some of these, especially McAllister creek and Griffin creek, have a strong permanent flow, fed by springs coming from thick deposits of glacial gravels that form a well-pronounced ridge between Grimshaw and Whitelaw. Some of these are used for irrigating the low terraces along the Peace in the Shaftesbury settlement.
2. *Little Burnt river.* (Leith river on some maps.) Headwaters drain wooded unsettled area north of Bluesky. Flowing very slowly in July. Most of the water is retained by dams in the settled areas around Bluesky.
3. *Saddle river.* (Locally referred to as the Burnt river). Joins the Peace opposite Little Burnt river. This is the largest tributary stream in the area. Most of water is gathered from the wooded slopes of the Saddle hills, and a continual stream of water flows in the main branch throughout the summer. In August it was about 25 feet wide and 6 to 12 inches deep. The valley is deep where this stream crosses settled areas, and therefore is not used to any great extent as a water supply. The main tributary of the Saddle is the Spirit river. In August this stream was flowing very slowly on some days, and on others it was not flowing. There are some springs along its banks west of Roycroft. East of Roycroft the valley deepens rapidly.
4. *Dunvegan creek, Howard creek and the Ksituan river*, join the Peace near Dunvegan, all occupy deep valleys north of Spirit River. They were practically dry in August. The water in these is usually quite hard.
5. *Boucher creek*, on the north side of the Peace east of Dunvegan, is dry most of the summer.
6. *Hines river*, entering near Dunvegan, flows throughout the summer. Most of its supply is derived from wooded, unsettled areas north of Fairview; a small amount of water occurring in the tributary creeks from the east is largely retained by dams of the settlers. The valley is deep in the lower 15 miles. In August the stream was about 10 feet wide and flowing slowly through gravel and sand bars.
7. *Hamlin creek*, joining the Peace from the south, is similar to the Ksituan and Howard creeks. In August it was practically dry.

The above tabulation includes practically all the tributary streams which in part traverse the settled districts. From this it will be observed that all the streams rising within settled areas are intermittent, except those fed by springs. Since the summer of 1929 was a comparatively dry season following a light precipitation of snow in the winter of 1928-29, the average seasonal runoff in these tributaries is perhaps larger than in 1929, but on the whole the tendency is for this average to decrease through cultivation and clearing of the land and the gradual extending of the settled districts back into the more wooded areas.

The majority of the tributary streams meet the major streams at grade, consequently their individual gradients are usually steep. The present deep dissection of these valleys indicates that a much greater volume of water must have been drained from these districts in the past, since that now flowing in these streams would not be adequate to perform the erosion that has taken place. Further evidence of the existence of a much greater amount of surface water in times past is the presence of numerous old beaver dams. These are especially abundant along the tops of the deep valleys. Cultivation and clearing in many places have destroyed these, but in the wooded, unsettled parts along the top of the Smoky and other deep valleys, they still remain.

There are some lakes within the area mapped, although they are on the whole small and few, due perhaps to the general proximity of most parts to deep stream valleys. The lakes and smaller water bodies present are on the whole poorly drained.

The largest lakes are Kimiwan at McLennan and Cardinal lake north of Berwyn. Kimiwan lake (also known as Round lake) is surrounded by a marshy area and has no well defined outlet. Thus in dry seasons the water becomes stagnant and gives off a very unpleasant odor. Winagami lake (Stinking lake), which borders the area just east of McLennan, is similar in size and character to Kimiwan. The water in these is not fit for domestic purposes, although some ice is harvested from them in the winter. Magliore lake, surrounded by a swamp area, lies north of Falher and is drained into Racing creek. It also furnishes considerable ice in season.

Cardinal lake, locally known as Bear lake, north of Berwyn, has cleaner water than those near McLennan. It is not used extensively as a water supply, since good water is readily obtained from wells and springs in the settled areas to the south. A number of small ponds occur at intervals throughout a semi-wooded belt of country from Cardinal lake west to the Peace through townships 82 and 83. There are no lakes or even large ponds within the settled areas on the south side of the Peace west of the Smoky. Kakut lake, lying south of the Birch hills, is the only body of any size in the whole area south of the Peace. Consequently, in the whole area, local lakes cannot be looked upon as a possible source of water for any of the districts.

It is possible that the major drainage within the area has in times past followed a different general direction than at present. The possibility of such changes is of importance regarding the ground water conditions, since old drainage courses may exist beneath the mantle of recent deposits. Any major changes that may have occurred were probably directly or indirectly due to glaciation of this and adjacent areas.

The present topography and distribution of lakes to the east of this area suggest that some changes may have occurred. Lesser Slave lake, being about 30 miles to the east, is at present over 50 miles long, but in the past it is believed to have extended much further west, at least to include the lakes at McLennan. The flat area known as the High Prairie district occupies a silted-up old lake bottom which was a westward extension of Lesser Slave lake. Probably for a time part of this larger lake drained west *via* the Harmon into the Peace. It is also possible that during the retreat of the ice that the drainage from the Peace was to the east through Lesser Slave lake. Earlier drainages did not develop a system of valleys as deeply entrenched as the present valleys, and field evidence indicates that the pre-glacial drainage direction was essentially the same as that of the present. If a major change occurred it was temporary and took place during the ice retreat when the normal drainage to the north was blocked.

Forests and Woods.—The three elements of physiography as outlined above, namely, the upland, the flat areas, and the deep valleys, may be used as divisions with respect to the nature of forest growth. The uplands are, or have been, the most heavily wooded, chiefly with spruce and poplar. The growth has been of sufficient magnitude to sustain small lumber industries, and one company operates at present in the Saddle hills near Braeburn. In general the northern slopes possess the better stands of spruce. Lumbering and periodic forest fires are rapidly removing the forest growth, and this is affecting the water supply in the streams draining them, since the wooded areas induce precipitation and regulate the run-off.

The flat areas, which include most of the settled districts, are in part open and in part wooded, chiefly with poplar and shrubbery. This is gradually being removed from many districts through agricultural development. The earliest settlement was confined largely to the more open parts in which only small patches of brush occurred, as around Waterhole and Spirit River. Parts of the flat areas are fairly heavily wooded at present, chiefly with poplar and other deciduous trees and shrubs. The district from the Peace south to the railway and from the Smoky west to Wanham is mostly wooded in this manner. Similarly a heavy growth of poplar covers a belt from the Smoky east to Nampa. Periodic burning at suitable seasons, however, is gradually reducing the size of such wooded areas.

The deep valleys are wooded with spruce and in some places the growth has been sufficient to supply small sawmills. The south bank of the Peace is well wooded in this manner, and this growth extends above the valley top south for some distance along the flat area. The north bank is usually open and free from trees or shrubs.

CHAPTER III.

DESCRIPTIVE GEOLOGY.

Structure.—This area in general is situated on the east limb of what is generally known as the Alberta syncline. The late Cretaceous and early Tertiary formations occurring in Alberta are best developed in the southern half of the province where they occupy a broad basin with a general synclinal structure. The distribution of these formations as shown on the geological map of Alberta[9] indicates that the trend of the axis is to the northwest. Geological data obtained in the Peace River country indicate that this basin-like structure extends northwest and crosses the Peace near the west boundary of Alberta. In the Grande Prairie district the axis of the syncline lies southwest of the Wapiti river.

The inclination of the strata forming the east limb of this Alberta syncline is usually small throughout the province. This is also true of the strata in the area mapped, where the general attitude of the strata is that of small dips to the south or flat-lying. There are, in addition, some small differences in general structure in this area when different stratigraphical horizons are used to determine the structure.

In addition to the general structure, there are minor structures of lesser extent within the area. One noticeable feature is that the dip is usually greater in the ~~arenaceous formations~~ than in the shales, which may be due to some extent to a greater lensing in the sandstones. On the other hand, it may be fortuitous that the best exposures of these arenaceous beds occur on the steeper dipping parts of minor structures. As an example of this difference in dip, the exposures along the Smoky show steeper dips to the south in the Dunvegan and Wapiti beds than in the St. John and Smoky River shales.

The areal distribution of the formations as shown on map No. 14 indicates in general the dip and strike of the formations. The profile sections show in addition the minor structures somewhat exaggerated, as the vertical scale is about sixteen times as large as the horizontal.

The elevation of basal beds of the Wapiti formation taken at widely separated places, some of which are outside of this area, is a good key horizon for determining the general strike and dip. These basal beds occur in the north end of township 72, south of Lesser Slave Lake, and south of Slave Lake station they are at an elevation of approximately 1900 feet. They cross the Smoky at an elevation of approximately 1500 feet in the north end of township 73, and rise to 1900 feet elevation in the northern part of township 75, range 2, west of 6th meridian. If these two well-separated points are connected, the resulting strike direction is approximately north 83 degrees west. The angle of dip is relatively steep where these basal beds cross the Smoky, and they rise rapidly to the north to cap the

9 Map No. 10, Research Council of Alberta, 1925.

Birch hills and the uplands southwest of the town of Spirit River, known locally as White mountain. They cap 2700-foot hills in the west side of Alberta in townships 77 and 78. The dip to the south here would carry them to the 1900-foot level somewhere near the south boundary of township 77. Thus the general strike as determined from the basal Wapiti beds is north 80 to 85 degrees west.

The top of the Dunvegan formation occurs at approximately the same elevation at widely separated points in an east-west direction. For example, it is at about the same elevation in township 80 on the Smoky river as in township 80 on Pouce Coupe river at the west side of the province, thus making the strike in general east-west. Some minor undulations, however, occurring between these two points cause variations in the strike directions, so that in the area mapped the strike on the Dunvegan outcrops is on the average a few degrees to the north of west.

The dip direction is in general to the south, although at no place does it average more than 60 to 70 feet to the mile. The structure profile sections accompanying the map show the positions of steepest dip. McLearn[10] has recorded his observations along the Smoky river as follows:

"Mouth to 1 mile south of north boundary, Tp. 81	12 ft. per mile
Latter to south boundary, Tp. 81	Flat
Latter to middle, Tp. 79	25 ft. per mile
Latter to south of Smoky (Watino)	50 ft. per mile
Latter to south boundary, Tp. 77	20 ft. per mile
Latter to within 1 mile east boundary, R. 25	12 ft. per mile
Mouth of Bad Heart to Puskwaskau river	60 ft. per mile
Latter to horseshoe bend above Puskwaskau river	15 ft. per mile
Latter to 2 miles below Kleskun creek	30 ft. per mile
Latter to middle, Tp. 72	45 ft. per mile"

Our observations concur in general with those of McLearn, although it is difficult to obtain exact values on strata so nearly flat-lying. It is to be noted that the steeper dips occur where the Dunvegan and Wapiti beds cross the Smoky at river level.

Outcrops in districts removed from the larger stream valleys also show this general southerly dip. For example, the Bad Heart sandstone outcrops about a mile south of Wanham station at an approximate elevation of 2010 feet. It extends south beneath the Birch hills and outcrops in Kakut creek at about the 1700-foot level. Thus the dip between these two points averages 30 to 35 feet to the mile.

The regional dip of the Dunvegan beds is of special importance, since this may prove to be a water horizon. The dip to the south varies as shown in the tabulation given above, but the general average dip for the area mapped has been worked out to be approximately 20 feet to the mile. Approximate elevations at the top of this formation, taken at well-separated points, were used to determine this average, such as Dunvegan ferry, Watino, and an outcrop in section 29, township 86, range 23, on the highway to Battle River north of Grimshaw.

There are no faults evident from the exposures. It is not likely that such would be of any great magnitude, since deformation on

10 Geol. Surv., Can., Summ. Rept. 1918, p. 5C.

the whole has been slight. Processes of sinking of basins during sedimentation would be sufficient to account for some of the structure present. In fact, the difference in dip between the sandstone and shale formations suggests that such a sinking may be responsible for some of the structure.

STRATIGRAPHY.

General Statement.—The names assigned to the formations occurring within this area are tabulated in Chapter II. Most of these formations belong to the Upper Cretaceous. Some correlation of these formations with those in other areas has been made by McLearn, who has done work along the Athabaska to the east and the Peace to the west in British Columbia. They have not been correlated in detail with formations of the same age occurring in the foothills of Alberta to the south of Athabaska river, although some relations have been worked out on the basis of fossil remains.

Peace River Formation.—The lowest member of the Cretaceous system on Peace river is the Loon River formation, but this does not outcrop at the surface in the area mapped, and was not examined by the writer. It consists of a series of marine deposited shales which outcrop to the north along the Peace.

The lowest formation outcropping in this area is the Peace River formation, which has its greatest distribution north of the area mapped and only the upper part is exposed along the lower part of the Peace valley from Peace River town to the mouth of the Smoky. The area occupied is so small that it has not been shown in color on the map accompanying this report.

McLearn[11] has described the formation as consisting of three members, two of which are sandstone, separated by a shale member. The sandstone members show an appreciable thinning to the north. Part of the upper sandstone member is well exposed and forms steep banks along both sides of the Peace at Peace River and up the Harmon river. McLearn gives a thickness of 130 feet for this member in the vicinity of Peace River, but only 90 feet farther north, indicating a considerable thinning.

The exposures at Peace River consist of massive crossbedded sandstone, which grade upward into the marine shales of the succeeding St. John formation. The upper 25 to 30 feet of the Peace River formation is frequently composed of soft and somewhat argillaceous sandstones that are light grey in color and carry occasional thin bands of carbonaceous and coaly shale. The exposed beds below this are as a rule more indurated and usually weather out to vertical cliffs. The upper member of the Peace River formation appears to be of fresh water deposition.

McLearn gives a thickness of 30 feet for the middle shale member exposed on the Peace north of this area, and a thickness of 160 feet for the lower sandstone member. This latter member, however, thins to 20 feet in a northerly direction. The inference from such lateral changes in sedimentation as shown by the formation north of the area is that the Peace River formation probably

11 Geol. Surv., Can., Summ. Rept. 1917, p. 15C.

thickens to the south and west from Peace River town. Thus under most of the area mapped it is probably predominantly a sandstone formation and probably thicker than the total thickness determined from exposures along the river to the north. Furthermore, the strata occurring below the St. John shale along the Peace in British Columbia are all of fresh water deposition. This feature is of significance since it may be necessary in some areas to drill wells to the Peace River beds or their stratigraphical equivalents in order to obtain a water supply. The minimum total thickness of the Peace River formation at Peace River is probably about 350 feet, and is very likely much thicker under most of the area shown on map No. 14.

The writer did not collect or observe any fossils in the upper member of the Peace River formation, although McLearn[12] records a number of fossils from the Peace River formation. The inference from his earlier report[13] is that these occur chiefly in the lower member, and to the north of Peace River, although he later[14] described some species of pelecypods as coming from the Peace River formation at Peace River. McLearn assigns this formation to the lower Cretaceous and correlates it with the Grand Rapids formation exposed on the Athabaska river. No definite correlation has been made with lower Cretaceous formations of the upper Peace river, but it is apparently represented by beds of fresh water deposition.

St. John Formation (name derived from Fort. St. John, B.C.). —The St. John formation overlies the Peace River apparently conformably. The transition between the two formations is relatively abrupt, as may be seen in exposures along the river front of the Shaftesbury settlement, opposite the mouth of the Smoky.

The distribution of the St. John in this area is confined largely to the steep banks of the major stream valleys. The lower beds are exposed intermittently along the Peace from Peace River to near the mouth of the Smoky. The formation is shown to extend as far as the mouths of Little Burnt and Saddle rivers, although there are few if any exposures of St. John strata in place along the Peace between these rivers and Shaftesbury settlement. This is due largely to the fact that the St. John strata weather rapidly and are covered by slides of loose material from the overburden. The lower part of the St. John shale is well exposed at several places on the lower Smoky in township 82. In fact, this is the only place in the eastern part of the area where more than 50 feet of this formation are exposed. They extend up the Smoky, beneath the Dunvegan, and disappear below water level about the center of township 79.

The rise of the strata to the north brings the upper part of the St. John formation above river level along the Peace in the western part of the area in townships 82, 83 and 84. Allan[15] reports 300 feet of St. John shale in the banks of the Peace at the mouth of the Montagneuse river. McLearn[16] mentions the occurrence of St. John

[12] Geol. Surv., Can., Summ. Rept. 1918, p. 2.
[13] Geol. Surv., Can., Summ. Rept. 1917, p. 14C.
[14] Geol. Surv., Can., Museum Bull. No. 29, p. 9.
[15] Res. Coun. of Alta., Ann. Rept. for 1921, p. 37.
[16] Geol. Surv., Can., Summ. Rept. 1917, p. 17C.

shale along the lower valley of the Peace from the Montagneuse west into British Columbia. A greater thickness is exposed in township 84, ranges 7 and 8, near the Montagneuse, than at the western edge of Alberta in township 82 where the Dunvegan beds occur near water-level on the Peace. This is due to the dip of the strata, which brings the beds to higher levels where the Peace valley swings farthest north in township 84, ranges 7 and 8, west of 6th.

The St. John is transitional into the Dunvegan, and the upper limit is less well defined than the contact with the Peace River formation below. The St. John is essentially a shale formation as exposed on the Smoky in the eastern part of the area. Dark to grey shales, mostly thin bedded, are the prevailing strata. Ironstone nodules and concretions are present in layers and isolated lensed bands at several horizons. It is of marine deposition and leached outcrops at certain seasons are incrusted with salts. The occurrence of these and similar deposits coming from the Smoky River shales above are dealt with more fully in Chapter V.

The thickness of the St. John is variable. McLearn estimates a thickness of 560 feet on the Smoky, but the gradual transition into the Dunvegan makes it difficult to establish an upper boundary to the formation, consequently the thickness will vary depending on where the upper boundary is placed. The Smoky valley near Judah exposes sandstones approximately 200 feet below the elevation of the station. These were taken as the basal Dunvegan beds, thus making the elevation of the top of the St. John here as approximately 1650 feet. The average river level of the Smoky at Judah is below the 1050-foot contour and the St. John shale extends to the river level here. This would make the thickness of the St. John 600 feet.

The whole of the St. John formation is not exposed on the Peace at the west side of Alberta, but in British Columbia McLearn[17] reports a greatly increased thickness. It is there present as three members, a lower shale of 800 feet and an upper shale of 1300 feet, separated by a sandstone member 50 to 80 feet thick. This increase from 600 feet on the Smoky to over 2100 feet in British Columbia occurs within an east-west distance of approximately 150 miles, giving an average increase of about 10 feet to the mile. If we assume that the increase is regular, which is a fair assumption since the strata are mostly marine shales, it would mean that the St. John would be on the average 100 feet thicker along the Peace in the western part of the area mapped than along the Smoky. It is not possible to determine the lateral changes to the south from Peace River except by drilling. Possibly an increase in thickness takes place, since such changes in a north-south direction are characteristic of the underlying Peace River formation.

The thickness of the St. John is important from a consideration of water supply, for if the Dunvegan beds do not prove productive, it may be advisable to test the Peace River sandstone below. This would necessitate drilling through the St. John, as it is very un-

[17] Geol. Surv., Can., Summ. Rept. 1917, p. 17C.

likely that it would carry a suitable water horizon. Furthermore, some districts on the uplands to the south and east of Peace River town may have to drill through the St. John to obtain water from the Peace River formation, if it should be proven productive by testing.

No fossils were observed in the St. John formation during our survey. The basal beds along the Peace in the Shaftesbury settlement and on Harmon river were searched for fossils without results. The thicker exposures on the Smoky were not, however, examined in detail for fossils. McLearn records the following forms from the St. John on the Peace:

Acanthoceras cornutum Whiteaves,
Nuculi dowlingi McLearn, and
Inoceramus sp.

The writer infers from his reports that these were all found in the British Columbia sections.

The age of the St. John is as yet not determined. McLearn, who has done the most work on this formation and examined it over a wide area, has at times placed it in the Colorado group of the upper Cretaceous, but in his latest publication dealing with these formations[18] he is uncertain as to whether it belongs to the Colorado or not. They are apparently the equivalent of the Pelican shale in the Athabaska river section.

Dunvegan Formation.—This formation is named after Dunvegan, an old trading center on the Peace where the highway crosses today. Special attention was given to this formation within the area mapped by our survey, because of the hope that it ultimately may prove to be a good water horizon. It is the highest formation carrying sandstone of appreciable thickness that underlies the flat, settled areas above the river valleys.

The distribution of this formation as shown on the accompanying map is confined largely to the valley sides of the major streams. Basal Dunvegan beds are exposed in the upper banks of the Smoky at Judah, and in the nose between the Smoky and Peace. They extend up the Smoky, and, dipping to the south, occur at successively lower levels in the banks. In township 79 these basal beds descend to river level, and at Watino where the railway crosses the Smoky, the top of the formation is at river level.

Intermittent exposures occur along the Peace, especially along the north bank, from Little Burnt river west beyond Dunvegan and on both sides in the steep-sided valley where the Peace flows in a southerly direction in ranges 6 and 7. Dunvegan beds extend farther up the lateral tributary valleys on the north than on the south side of the Peace, due to the southerly dip of the strata. There are practically no exposures along the Peace valley east of Little Burnt river, and the mapping here has been done by projecting contacts from observed exposures. Consequently the position of the formational boundaries as shown around Peace River are perhaps not as generally correct as in other parts. Furthermore, it was not possible to determine the thickness of overburden in this

18 Geol. Surv., Can., Bull. No. 42, p. 117, 1926.

district, and it is believed that pre-glacial erosion has removed the Dunvegan beds from a considerable part of the area shown to be underlain by these beds east of Peace River and along the Harmon river valley.

Some outcrops north of the area mapped were of use in determining the approximate position of the top of the Dunvegan in the district along the north side of the Peace east of Little Burnt river, where a thick mantle of glacial deposits conceals the formations. These outcrops of Dunvegan beds are on Whitemud river in section 9, township 86, range 23, west of 5th, and on the highway to Battle River (Notikewin) in section 29, township 85, range 23, about 14 miles north of Grimshaw. These were interpreted as middle Dunvegan beds and their position indicates that the Dunvegan underlies the surface in some of the districts to the north of the area mapped.

The Dunvegan strata consist of an alternating series of sandstones and shales, with all gradations between these two types of strata. Some of the beds are over 50 feet thick. Sandstones are more prevalent in the middle part of the formation, while shales predominate in the upper and lower parts. The sandstones are usually fine grained, crossbedded and massive, and light grey to buff in color, with varying hardness. The harder phases are usually confined to the thicker massive sandstones and are dark green in color on fresh surfaces. During the erosion of these sandstone along valley outcrops, the harder phases often weather out as large spherical masses up to 10 feet in diameter, a feature common to upper Cretaceous sandstones in many parts of the foothills of Alberta. These large blocks are not concretions, but appear to be centers which have undergone greater cementation. They are usually fine grained in texture.

The shale phases vary from arenaceous siltstones to thin bedded dark grey shales. These siltstones alternate with sandstone layers and usually represent gradations between the thicker sandstone members or sandstone and shale members. The thin bedded shales reach thicknesses in places of over 50 feet, especially in the upper part of the formation. Crystals of selenite (gypsum) occur frequently on the weathered surfaces of the shale outcrops.

The greater hardness of the Dunvegan strata, compared to that of the St. John shales below and the Smoky River shales above, causes them to stand out as cliffs in river banks. The lithological units are lenticular, consequently a section measured at one place cannot be readily correlated with one taken a few miles distant. A section exposing the upper part of the formation at Dunvegan ferry may be taken as typical of the Dunvegan strata.

SECTION ON NORTH SIDE OF THE PEACE AT DUNVEGAN FERRY.

Glacial and recent deposits:

1.	10 feet	—boulder clay.
	15 feet	—silt.
	1 to 5 feet	—gravel.

Dunvegan formation:

2.	50 feet	—shale, grey to dark grey, containing occasional hard, ironstone nodules, selenite crystals on the weathered surface; emits sulphurous odor when disturbed; somewhat arenaceous towards the base; contains fossils No. 5a.
3.	1 to 2 feet	—shale; weathers reddish brown; contains many small ironstone concretion-like pebbles.
4.	2 feet	—shale similar to 3.
5.	2 to 3 feet	—shale similar to 3; contains fossils No. 5.
6.	80 to 90 feet	—shales and arenaceous shales; weather easily; in part concealed; contain fossils No. 12, 25 feet above the base.
7.	60 feet	—sandstone, massive, light grey to buff, cross bedded; weathers to castellated forms. The upper part is in places interbedded with thin shale bands. The base is irregular. This is the uppermost well-defined sandstone in the Dunvegan in this vicinity. Some portions weather out to hard, spherical masses. Slow seepages of alkaline water emerge from the base of this sandstone and precipitate a white incrustation of salts on the beds below.
8.	60 feet	—concealed in part, but exposing occasionally soft argillaceous sandstones and sandy shales.
9.	3 feet	—sandstone, hard, crossbedded; forms a ledge.
10.	45 feet	—beds similar to No. 8, showing some bands of ironstone nodules.
11.	1 to 5 feet	—sandstone, lensed, hard, crossbedded; forms a ledge.
12.	55 feet	—mostly concealed; some soft shaly beds exposed.

The above section represents the upper 365 feet of Dunvegan beds. Lower beds are here concealed by outwash plain and river terrace deposits which extend up approximately 50 feet above river level.

The thick sandstones form the best key beds for tracing the distribution of the Dunvegan, since they frequently weather out to vertical cliffs. The rapid lateral variation in the strata is well shown by the exposures on Hines river near its mouth, which is within a mile of Dunvegan. A similar sequence of beds occurs as at Dunvegan ferry, but successive units of even approximately the same thickness cannot be recognized readily.

Upper Dunvegan beds are exposed at several points along the Smoky between Watino and the mouth of Racing creek and up this creek to a point east of Culp. Massive thick sandstone members are common in these upper beds. At Watino a massive sandstone is exposed near water level. The succeeding strata are not exposed, and whereas this sandstone has been taken as the top of the Dunvegan, there may be a few feet of upper Dunvegan concealed here.

The massive upper sandstone at Watino is capped by a coal seam averaging 4 to 6 inches in thickness. Coal occurrences are common at several points along the Peace valley. These are usually represented by blocks or chunks of coal in dislodged material. There is no evidence, from any exposures in place, of the occurrence of any seam over 6 inches thick in the Dunvegan beds in this area.

The Dunvegan formation is transitional to the underlying and overlying formations. This transition is represented by an increase in shale content downward into the typical marine St. John shales and upward in a similar manner into the Smoky River formation, consequently the boundaries between the Dunvegan and the formations embracing it are indefinite. In drilling water wells, by the usual method employed, the Dunvegan would not likely be recognized in the well records until the massive sandstones were encountered.

The thickness given for the Dunvegan is approximate, since the stratigraphical boundaries are indefinite. McLearn[19] estimates the thickness as 440 feet on the Smoky river and 530 feet on the Peace.[20] Our observations agree with these values, which indicate a slight thickening to the west. Apparently this formation also thins to the north and is perhaps less than 400 feet thick in the upper banks of the Peace near the town of Peace River. Further observations on the tributaries of the Peace to the north are necessary to verify this. This apparent northward thinning is due largely to a replacement of sandstone by shale.

The Dunvegan appears to be largely of brackish water deposition as exemplified by the type of lithology and assemblages of fossils. Some of the thick massive sandstones with associated thin coal bands may be of fresh water deposition, but the shales interbedded with these are not of the fresh water type.

The fossils listed below were collected from the Dunvegan beds at several places within the area. McLearn has recorded and described several forms from these beds. Dr. P. S. Warren has identified those in our collection and described some new forms. Fossils occur at various horizons throughout the formation, usually in lenses or discontinuous beds. Consequently, fossil horizons do not serve as key beds in the Dunvegan.

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19 Geol. Surv., Can., Summ. Rept. 1918, p. 3C.
20 Geol. Surv., Can., Summ. Rept. 1917, p. 18C.

DUNVEGAN FOSSILS.

Those marked with asterisk are new species described in the appendix to this report. The species named by McLearn have been described in the following publications: Geol. Surv., Can., Bull. No. 42, 1926; Geol. Surv., Can., Museum Bull. No. 29, 1919; Canadian Field Naturalist, Vol. 36, 1930, No. 3.

Field No.	Name.	Locality.	Approximate Horizon.
3	*Unio dowlingi* McLearn *Callista cf. orbiculata* (H. & M.)	Smoky river, S.E. ¼ Sec. 27, Tp. 78, R. 23, W. 5th.	Basal beds.
5 and 5*a*	*Exogyra suborbiculata* Lam.	North side of Peace at Dunvegan ferry.	Upper Dunvegan. Highest fossil horizon observed.
12	Same species as No. 5 occur at a lower horizon at same locality.		
6	**Ostrea dunveganensis* Warren *Anatina* sp. undet. *Brachydontes multilinigerus* Meek	Hines river, Sec. 18, Tp. 80, R. 4.	Upper Dunvegan.
7	**Ostrea dunveganensis* Warren *Brachydontes multilinigerus* Meek	Ksituan river, Sec. 14, Tp. 80, R. 5.	Upper Dunvegan.
13	**Ostrea dunveganensis* Warren *Callista* cf. *orbiculata* (H. & M.) *Mactra* cf. *emmonsi* Meek *Turritella* sp. undet.	Same locality as No. 6.	Upper Dunvegan, 30 feet higher than No. 6.
9	**Inoceramus mcconnelli* Warren	Dislodged, north bank of Peace in N.E. ¼ Sec. 3, Tp. 80, R. 3, W. 6th.	Horizon uncertain.
8	*Yoldia subelliptica* Stanton *Inoceramus* sp. undet. *Exogyra suborbiculata* Lam. *Unio dowlingi* McLearn *Brachydontes multilinigerus* Meek *Callista orbiculata* (H. & M.) *Tellina peaceriverensis* McLearn *Mactra emmonsi* Meek *Turritella* sp. undet.	Dislodged boulders, north bank of the Peace in S.E. ¼ Sec. 8, Tp. 80, R. 2, W. 6th.	Apparently from the lower part of the formation.

11	*Inoceramus* sp. undet.	Little Burnt (Leith) river near its mouth, W. ½ Sec. 18, Tp. 80, R. 1, W. 6th.	From a bed 2 to 3 feet thick in the lower part of the formation.
	Brachydontes multilinigerus Meek		
	Cyrena securis Meek?		
	Callista tenuis H. & M.?		
	Tellina whitei Stanton?		
	**Psammosolen dunveganensis* Warren		
	Corbula sp. undet.		
	Turritella sp. undet.		
	Fusus sp. undet.		
	Fish scale.		
10	*Nucula* aff. *n. coloradoensis* Stanton	Same locality as No. 11.	Horizon higher than No. 11.
a	*Corbula nematophora* Meek	Well dug in Sec. 30, Tp. 82, R. 24, W. 5th, near Berwyn.	Apparently in glacial drift.
b	*Inoceramus dunveganensis* McLearn	Racing creek.	Horizon uncertain.
	**Inoceramus tyrrelli* Warren		
c	**Inoceramus rutherfordi* Warren	Dislodged, Smoky River, near mouth of Racing creek.	Lower Dunvegan?

McLearn records the following forms not represented in our collections, although apparently present in the Dunvegan within this area.[21]

Rhytophorus? caurinus McLearn	Near the base of the formation on Smoky river.
Tellina dunveganensis McLearn	Lower part?, on Smoky river.
Barbatia micronema Meek	Middle part of the formation, west of Dunvegan.
Corbicula dowlingi McLearn	
Corbula pyriformis Meek	
Tellina dunveganensis McLearn	
Pachymelania? sp.	

In addition, the writer collected a few plant remains from the upper Dunvegan beds on Hines creek, but these have not been identified. Berry[22] refers to fossil plants from the Dunvegan, with respect to their age significance, in a general article on the age of certain geological formations in Western Canada.

McLearn has mentioned that the fossil remains in the Dunvegan are not represented elsewhere in the Cretaceous of Canada, although some of the forms have been found in the United States. Consequently it is not possible yet to definitely correlate the Dunvegan formation on the Peace with its equivalents in other parts of Alberta. It is probably early Coloradoan in age, and has been correlated with the Pelican sandstone in the Athabaska river section by McLearn. The Pelican sandstone is only 35 feet thick[23] on the Athabaska, and this represents a thinning of about 400 feet from the Smoky to the Athabaska in a distance of about 200 miles, or about 2 feet to the mile if the above correlation is correct. It is probable that this thinning to the east is more rapid in the western part of the area east of the Smoky than to the east in the vicinity of the Athabaska. There is some evidence for this in the records of drilling done at the east end of Lesser Slave Lake.

Smoky River Formation. The Smoky River formation overlies the Dunvegan apparently conformably. This formational name was first used by Dawson in 1879 for the shale strata exposed on Smoky river. McLearn in 1918 subdivided this formation into three members, namely the Upper shale, Bad Heart sandstone, and Lower shale, and on the basis of fossil remains he grouped the lower two members together[24]. In a later report[25], he assigned the name Kaskapau to the Lower shale member.

Lower Smoky River Shale (Kaskapau). In the area mapped the lower shale member has the greatest areal distribution at the surface. It occupies broad areas along both sides of the Peace and Smoky valleys, underlying many of the settled districts, and extends down to river level along the Smoky south and west of Watino.

The member consists essentially of thin-bedded, dark to black shales, with occasional ironstone and pyritic nodules, and is litho-

21 Geol. Surv., Can., Bull. No. 42, p. 118, 1926.
22 Berry, E. W., Trans. Roy. Soc. Can., Vol. XX, Sec. IV, p. 205, 1926.
23 Geol. Surv., Can., Memoir 108, p. 72, 1919.
24 Geol. Surv., Can., Summ. Rept. 1918, p. 4C.
25 Geol. Surv., Can., Bull. 42, p. 117, 1926.

logically similar to the St. John formation. There are some thin, fine grained sandstone beds present in the lower beds exposed in the western part of the area that apparently were not present in the exposure along the Smoky examined by McLearn. The lowest beds, resting upon cliffed exposures of the Dunvegan formation, are exposed along the Peace and Smoky and tributary streams. The upper beds of this member are best exposed along the Smoky river for some distance below the mouth of Bad Heart river. The thickest sections of lower beds occur in the deep valleys of the Ksituan and its tributaries north of Spirit River village. The Smoky River shales weather readily, and where they occur along steep valleys, slides and slumps prevail unless they are supported below by Dunvegan beds or capped above by the Bad Heart sandstone. Many of these slumped masses of shales are undecomposed, but often highly contorted and twisted, presenting an appearance similar to beds deformed by dynamic folding. Decomposition of the pyritic content of these slumped shales gives rise to vapors which condense at the surface, leaving crystalline salts as incrustations which are common along the Smoky near the mouth of the Little Smoky. These salts are discussed more fully in a later chapter.

The lower part of this member is well exposed on the Ksituan and its tributaries. The following succession may be taken as representative of this part of the formation in the western part of the area:

PART OF LOWER SMOKY, ON HOWARD CREEK, N.W. ¼ SEC. 13, Tp. 79, R. 6, W. 6th.

100 feet	Recent deposits and decomposed Smoky River shales.
110 feet	Shale,—fissile, dark grey, thin bedded; in places sulphur and gypsum veinlets along bedding planes; lower part very thinly bedded, weathers to vertical cliffs, presenting the appearance from a distance of a hard band. Contains fossils (No. 15) in the lower 20 feet. An additional 200 feet of these beds are exposed further up Howard creek in section 16, where a higher part of the succession is exposed.
30 feet	Shale, not so fissile as beds above, but very gypsiferous, especially around bands of nodules.
10 feet	Sandstone, in beds 1 to 3 feet thick, separated by thin beds of shale. Sandstones fine grained and hard. Fossils No. 16 at the base of these beds.
130 feet	Shale, in part concealed, but all exposures show shale which breaks into blocky fragments. Clay ironstone bands common. Fossils 16a near top. The lower 20 feet carry several beds of arenaceous shale.

The base of the exposure here at creek level is estimated to be about 125 to 150 feet above the top of the Dunvegan formation. The 10-foot sandstone member 130 feet above the creek level, at the above location, persists laterally up and down the valley of Howard creek and the Ksituan, and, locally at least, it is a good key horizon. Its position is 250 to 300 feet above the base of the Dunvegan. During a brief examination on Pouce Coupe river at the west side of Alberta, similar sandstone beds were observed in the lower Smoky River, but further work is necessary to determine the exact horizon. McLearn does not record sandstone beds in the lower members. The stratigraphical horizon of this sandstone should be represented in exposures along the Smoky somewhere between the mouth of the Bad Heart and the Little Smoky. This part of the area was not examined in detail by our survey.

There are some thin bands of arenaceous shale and sandstone, and clay ironstone, occurring in the upper part of this member. These become thicker and more numerous in the beds underlying the Bad Heart sandstone, and outcrops at the surface are difficult to differentiate from the Bad Heart. Such beds may be observed in the village of Spirit River, where bedrock comes practically to the surface under a very thin soil covering. In the village streets and garden plots one may observe rows of fragments of clay ironstone running east and west across the slope on which the village is built. Similar outcrops of these upper beds occur in some of the fields southwest of Roycroft.

The lower shale is the thickest member of the Smoky River formation. McLearn assigned a combined thickness of 550 feet for this member and the Bad Heart sandstone[26] as exposed along the Smoky river. We have assigned an approximate thickness of 850 to 875 feet to it. The contact with the Dunvegan is gradational, thus the thickness will vary depending on where the contact is placed, but this variation in position of contact would be within a range of less than 100 feet stratigraphically. It is difficult to obtain a thickness from the river sections, since it is several miles distance between the exposures of top and bottom of this member. The Bad Heart sandstone caps the lower Smoky river shale one-half mile south of Spirit River village, at an elevation of about 2200 feet, and Smoky River shales extend below the bottom of Howard creek, 7 miles to the north. The difference in elevation between these two points is over 775 feet. There is also a dip to the south in the 7 miles, of 10 to 15 feet to the mile. From this and calculations made at several other places in the area, the thickness given was determined.

This value, in the opinion of the writer, is more in keeping with the general character of the Cretaceous formations in this part of Alberta. The whole Smoky River formation has a thickness of about 1200 feet and has been correlated with the La Biche[27] shale on the Athabaska river, which has a thickness of 1100 feet. If the lower Smoky River were only 550 feet thick, then the Smoky River formation as a whole would show a thinning to the west, which is the reverse of the usual conditions.

Bad Heart Sandstone. McLearn assigned the name Bad Heart sandstone to a thin, continuous lithological unit separating the upper and lower shale members. It is best exposed along the Smoky and its tributaries in the vicinity of the mouth of the Bad Heart, and is reported to extend down the Smoky to near the mouth of the Little Smoky.[28] It varies in thickness from 15 to 25 feet, and consequently cannot be shown in separate color on a small scale map. This sandstone outcrops at a few places well

26 Geol. Surv., Can., Summ. Rept. 1918, p. 4C.
27 McLearn, opp. cit.
28 Geol. Surv., Can., Summ. Rept. 1918, p. 4C.

removed from the deep stream valleys, and such occurrences served as controls in mapping the upper and lower members of the Smoky River shale. It outcrops rather prominently a half mile south of the village of Spirit River, where it caps a flat-topped hill locally known as "Holden's hill," which has a steep east-facing scarp in settlement lot 32 and a similar north-facing feature in the S.W. ¼ of section 22, extending west across the center of sections 21 and 20 of township 78, range 6, west of 6th meridian.

Another inland exposure occurs about half a mile south of the village of Wanham. The Bad Heart here forms a small steep hill facing north, where it crosses the road between sections 3 and 4, township 78, range 3, west of 6th meridian. This ridge-like feature extends west for about 3 miles from the south road into Wanham village. A similar ridge formed by the Bad Heart occurs in sections 27 and 28, township 77, range 26, west of 5th meridian, southeast of Rahab. The east-west strike direction and southerly dip cause all these three occurrences to produce small ridge-like features, with a steep face to the north and a gentle slope to the south. The position of the areal boundaries of the upper and lower members of the Smoky River shale in the area between Spirit River village and the Smoky to the east, was determined largely from these three occurrences of the Bad Heart. Its approximate position east of the Smoky was determined by projection from the west side, since no outcrops of Bad Heart were observed to the east. A ridge 6 miles south of Donnelly may be due to the Bad Heart, but the mantle of glacial deposits conceals the bedrock here.

The Bad Heart consists of a medium to coarse grained, porous sandstone, which is dark red in all exposures observed. This coloration is apparently inherent and not due to recent weathering. The sandstone beds average 1 to 5 feet in thickness and are intercalated with thin arenaceous shale beds. Occasional bands of chert pebbles were observed and also old worm burrowings. The red coloration is one of the best guides where surface erosion or road cuts reveal the underlying bedrock.

The Bad Heart sandstone forms a water horizon at places where it is the surface rock and the overlying shales have been removed by erosion, as at Wanham. It apparently does not serve as a good ground water horizon at depth, since the surface area of its outcrop is not large enough at any place to provide a large enough intake area. Furthermore, the sandstone beds are lenticular and interbedded with shales, which interrupts a possible continuous porous horizon. Most of the settlement is in areas underlain by beds lower than the Bad Heart. Some settlers in the Peoria district south of the Birch hills have drilled wells through the upper Smoky River to the Bad Heart sandstone and obtained a small supply of hard water.

Upper Smoky River Shale. The upper Smoky River shale member overlies the Bad Heart sandstone and is the uppermost marine shale member of the Cretaceous succession in this part of Alberta. So far as is known, there were no other marine shales deposited during any later time in this area.

This member occupies an east-west belt across the southern part of the area, as shown on the accompanying map. Since its thickness is less than half of the lower shale member, it does not occupy as large areas where it underlies the surface. The increased width of the surface area of upper Smoky River south of Falher is due to a more gentle slope of the surface than is present south of Spirit river where the width is much less.

Lithologically the upper Smoky River shale is similar to the lower shale member, being essentially dark colored, thin bedded marine shales. Clay ironstone nodules are more common in the lower shale and they are quite prevalent in some exposures of the uppermost beds, which also carry thin sandstone beds.

The thickness of the upper Smoky River averages between 300 and 350 feet. Along the Smoky near the Bad Heart and at points east it is about 300 feet, but in the district south of Spirit River, 350 feet appears to be a more nearly correct thickness.

This member grades up rather abruptly into the Wapiti formation which is a fresh water deposit, and some erosion of the upper Smoky River may have preceded the deposition of the basal Wapiti. This would tend to produce an irregular surface on the upper Smoky River and result in a variable thickness for it.

Palaeontology. Fossils were collected from various localities and horizons in the three members of the Smoky River formation. P. S. Warren has identified the following, among which are several new species described in the appendix to this report. The species named by McLearn are described in the same publications given for the Dunvegan formation.

McLearn records some forms from the lower Smoky River not represented in our collections. He mentions Cyprina from a lower horizon than our No. 2. *Prionotropis* cf. *woolgari* Mantell and *Acanthoceras* cf. *coloradoensis* Henderson are recorded from a locality apparently the same as our No. 2. *Watinoceras reesidei*, described in the appendix, is probably the same form as the *Prionotropis* cf. *woolgari*. *Prionotropis* are said to recur also at a higher horizon above the mouth of Little Smoky. This horizon would be lower than No. 1 and probably lower than 16, if McLearn's estimate of 200 feet from the base is correct. *Inoceramus umbonatus* (M. & H.) and *I. albertensis* McLearn are reported from the upper beds within 50 feet of the Bad Heart sandstone. This is a higher horizon than any represented in our collections.

FOSSILS FROM THE LOWER SMOKY RIVER SHALE (KASKAPAU)

*New species described in the appendix.

Arranged in descending order, stratigraphically.

Field No.	Name.	Locality.	Horizon.
1	*Nucula* sp. undet. *Baculites asper* Morton *Baculites codyensis* Reeside **Baculites albertensis* Warren **Baculites borealis* Warren **Baculites trifidalobatus* Warren *Scaphites* sp. undet.	Little Smoky river, N.W. ¼ Sec. 24, Tp. 75, R. 22, W. 5th.	Estimated 500 to 600 feet above the base.
17	*Inoceramus labiatus* Schlotheim **Inoceramus tyrrelli* Warren **Inoceramus tenuiumbonatus* Warren *Scaphites* sp. undet.	Howard creek, Sec. 16, Tp. 79, R. 6, W. 6th.	Same horizon as No. 15.
15	*Inoceramus labiatus* Schlotheim	Howard creek, Sec. 13, Tp. 79, R. 6, W. 6th.	40 to 50 feet above 16 and 16a.
16	*Cyrena* sp. undet. *Arctica* sp. undet.	Howard creek, Sec. 13, Tp. 79, R. 6, W. 6th.	16a, a few feet lower than 16.
16a	**Inoceramus allani* Warren	See section on previous page.	About 250 to 300 feet above the base.
2	*Inoceramus labiatus* Schlotheim *Inoceramus corpulentus* McLearn **Watinoceras reesidei* Warren **Scaphites delicatulus* Warren	South side Smoky river near Watino, N.W. ¼ Sec. 21, Tp. 77, R. 24, W. 5th.	Within the lower 50 to 60 feet of this member.

Prionotropis borealis, a new species being described elsewhere by P. S. Warren, was collected from basal Smoky River beds in a well at Grimshaw.

FOSSILS FROM THE BAD HEART SANDSTONE.

Field No.	Name.	Locality.
14	*Inoceramus coulthardi* McLearn *Inoceramus pontoni* McLearn	Hilltop ½ mile south of village of Spirit River.
19a	**Pteria linguiformis var borealis* Warren *Inoceramus selwyni* McLearn *Ostrea* sp. *Scaphites ventricosus* M. & H. *Pinna*—internal mould.	½ mile south of Wanham village, L.S. 1, Sec. 4, Tp. 78, R. 3, W. 6th.
21	*Inoceramus coulthardi* McLearn *Inoceramus* aff. *I. barabini* Morton *Inoceramus fragilis* H. & M. *Goniomya* cf. *americana* H. & M. *Protocardia subquadrata* E. & S. *Lunatia obliquata* E. & S. *Scaphites ventricosus* M. & H. *Scaphites vermiformis* M. & H.	Kakut creek, south of Peoria, S.W. ¼ Sec. 19, Tp. 76, R. 2, W. 6th.

The Bad Heart is only 15 to 25 feet thick, so that all the fossils listed may be said to come from the same horizon. McLearn records in addition the following not represented in our collections: *Baculites* cf. *asper* Morton; *Inoceramus erectus* Meek; *Nucula*; *Oxytoma nebrascana* E. & S.; *Pecten silentiensis* McLearn; *Gervillia stantoni* McLearn.

FOSSILS FROM THE UPPER SMOKY RIVER SHALE.

FIELD NO.	NAME.	LOCALITY.	HORIZON.
20	*Baculites ovatus* Say *Baculites compressus* Say? *Desmoscaphites bassleri* Reeside	Kakut creek, Sec. 22, Tp. 76, R. 3, W. 6th.	Middle part.
19	The same forms as 20, including a shark tooth.	Bad Heart river, Sec. 19, Tp. 76, R. 2, W. 6th.	Uppermost beds.

On the basis of fossil evidence, the lower Smoky River member and the Bad Heart sandstone are assigned to the Colorado, whereas the upper Smoky River member, on the same basis, is at least in part Montanan in age. The lithological succession of the upper Colorado and lower Montanan sequences here is similar to that existing throughout the foothills of Alberta from the Athabaska river to the Bow. That is, marine conditions of Colorado time extended into the Montanan time, and are usually represented by 200 to 300 feet of marine deposited shales carrying fossils of Montana age. Fossils from the lowest horizon in the lower Smoky River also represent as low a horizon as any occurring in the Colorado of the Alberta foothills. Thus the entire marine Colorado sequence of these foothills, which in places is over 3,000 feet thick, is apparently represented here by less than 1,000 feet of beds.

Wapiti Formation. The Wapiti is the uppermost formation in this area and the lower part of it occupies an east-west belt across the southern part. It is best exposed along the Smoky valley south from the Bad Heart and in the tributary valleys along this part of the river. It underlies uplands such as the Saddle and Birch hills, and its lithological character is believed to be in part responsible for these physiographical features. The uplands underlain by Wapiti usually present a steeper slope to the north than to the south, since the beds dip to the south. The Saddle hills are a somewhat dissected upland separating the Spirit River district from the Sexsmith district to the south. Basal and lower Wapiti beds are exposed on the north slope of these hills at a few places. The lowest beds exposed are on a small hill near the highway, in the southwest quarter of section 16, township 76, range 5, west of 6th meridian. This exposure is of special interest, in that it shows a badland type of erosion. The Saddle river valley extends west along the north face of the Saddle hills, and an upland to the north, locally known as "White mountain", is capped by basal Wapiti beds. Badland type of erosion exposes these lower beds on the south and east-facing slopes of this upland in section 21, township 77, range 7, west of 6th meridian.

The Birch hills south of Wanham are capped by lower Wapiti beds. This upland has a steep face to the north and a gentle south slope. Its wooded character and altitude have been against settlement, thus it divides the Wanham and Peoria-Heart valley districts. Occasional exposures of lower Wapiti beds occur along the north face of the Birch hills.

Lithologically the Wapiti formation consists of sandstones and shales of fresh-water deposition. The units vary in thickness from a few inches up to as much as 50 feet, the average thickness being more often 10 to 20 feet. All phases of gradation between sandstone and shale are common. The more massive sandstones are frequently crossbedded and concretionary masses are common in eroded faces. Light grey to buff are the prevailing colors, and on the whole fine grained textures are most common. The shales are poorly stratified, a characteristic common to shales of fresh-water deposition.

It is not possible to divide the Wapiti into definite lithological units from data obtained thus far. The lower 150 to 200 feet are predominantly argillaceous, consisting of compact, poorly stratified clay shales that weather to variegated colors. Thin bands of clay ironstone nodules are common in these, and a thin coal seam ranging from a few inches up to 2 feet in thickness occurs wherever these lower beds are exposed. This seam has been prospected at several places, but has not proven of sufficient thickness to be commercial. McLearn reports another coal seam, 3 to 4 inches thick, occurring 580 feet above the base. Some seams of commercial thickness occur at a still higher horizon on the Red Willow river south of Beaverlodge[29], but the stratigraphical horizon of these seams is higher than represented by the Wapiti in the area mapped.

The upper Wapiti beds have been removed from this area by erosion, but in adjacent districts the Wapiti is at least 1100 feet thick. Water of good quality is readily obtained in relatively shallow wells in the settled districts underlain by Wapiti beds. This is the condition in the part of the Heart Valley settlement south of Wanham. The Wapiti beds carry good water-bearing horizons at depths up to 500 feet in almost the entire settled districts south of the Saddle hills.

No invertebrate fossils were collected from the Wapiti beds. It is of interest to note that a few fragmentary vertebrate bones, probably dinosaurian, were found in the lower Wapiti in section 16, township 76, range 5, west of 6th. This is the most northerly reported occurrence of such in upper Cretaceous beds. The writer previously reported a similar occurrence in the Whitecourt district on the Athabaska river.[30]

The Wapiti formation, at least the lower part, is considered the stratigraphical equivalent of the Belly River formation in the plains and foothills of the southern half of Alberta, and is Montanan in age. It is of interest to note that the Wapiti formation in the Peace River district is underlain by about the same thickness of shales of Montana age as is the Belly River and its equiva-

[29] Res. Coun., Alta., 8th Ann. Rept. No. 22, p. 40, 1927.
[30] Res. Coun., Alta., Rept. No. 19, p. 23, 1928.

lents throughout the foothills of Alberta south of the Athabaska. Thus the stratigraphical horizon of the base of the Wapiti is almost the same as that of the base of the Belly River formation.

Younger Formations. With the exception of Pleistocene and Recent deposits, there are no other strata younger than the Wapiti represented in this area. Observations made in areas to the south in 1929, and on a previous occasion in 1927 with J. A. Allan, seem to indicate the presence of younger beds in the Grande Prairie district. Some tentative deductions and conclusions based on these observations are included here.

The Swan hills, 25 to 30 miles south of Lesser Slave lake, rising to elevations of over 4,000 feet, form an upland underlain by the youngest strata in Alberta. The geological succession here has been described by Allan[31], who records the presence of Paskapoo formation of Tertiary age in the upper strata. Beneath this is Edmonton formation, which, although Cretaceous, is younger than the lower Wapiti. Thus the Swan hills succession contains the equivalents, at least in part, of the Edmonton and Paskapoo formations of south central Alberta. So far no equivalents of these formations have been recorded northwest of the Swan hills.

In the Grande Prairie district a small upland known as the Kleskun hills occurs in the central part of township 72, range 4, west of 6th meridian. The strata underlying this upland are well exposed at the east end, where they are weathered out into badlands. Lithologically they are very similar to the typical Edmonton formation, and are composed essentially of bentonitic clays, thin sandy phases and thin coal seams. These strata have been estimated to be about 1100 feet above the base of the Wapiti formation. There are at least 250 feet of these Edmonton-like beds exposed in the Kleskun hills. Exposures of similar beds occur near the village of Beaverlodge at about the same stratigraphical horizon as those in the Kleskun hills.

A relatively high, flat topped mesa occurs in the central part of township 72, range 8, west of 6th meridian, a few miles east of Beaverlodge. This is known as "Saskatoon hill", which rises about 600 feet above the surrounding gentle sloped areas at the base. The shape of this hill is mesa-like and about 150 feet of the underlying strata near the top are exposed in steep cliffs. These beds, consisting of coarse crossbedded sandstones and sandy shales, are very similar in appearance to the Paskapoo formation as developed elsewhere in Alberta.

From these observations the writer is inclined at present to consider that the Edmonton and Paskapoo are represented in the Grande Prairie district and that the Belly River of central Alberta is represented by about 1100 feet of beds assigned to the Wapiti formation.

Pleistocene and Recent Deposits. Some reference to these deposits has already been made in the discussion on physiography. Pleistocene deposits, including those formed immediately following

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31 Allan, J. A., Geology of the Swan hills, etc., Geol. Surv., Can., Summ. Rept. 1917 p. 7C.

glaciation, are prevalent throughout much of the area. The recent deposits, consisting chiefly of river gravels and sands, are of no special significance, being present chiefly as bars and low river terraces along the drainage channels. The deposits due to glaciation are chiefly derived from areas to the northeast, since ice from the Keewatin center covered the area. Some material from the Cordilleran ice sheet deposits may be present in the recent river deposits, having been transported by streams in post-glacial time, and intermixed with other material.

The Pleistocene deposits are of two main types, namely, unassorted materials derived from melted ice, consisting chiefly of boulder clays and gravels, and semi-stratified glacio-lacustrine deposits composed chiefly of fine material. The first type is more prevalent in areas considerably removed from the major stream valleys. Perhaps the original distribution was not so restricted, but later deposition of the finer material may have buried much of these coarser materials that may have been deposited in the low areas.

Boulder clays and gravels are more extensive along the north side of the Peace than the south in this area. The most pronounced deposit of this type is one which extends from the Peace valley east of Grimshaw, west to Fairview. The eastern part of this deposit is in places mostly gravel, whereas to the west there is a larger percentage of boulder clay. The railway and highway follow approximately along the south edge of this deposit almost all the way from Grimshaw to Fairview. It is from the coarser material in the eastern part of this deposit that good supplies of water are obtained at Berwyn, Brownvale and Whitelaw. From Whitelaw west it becomes increasingly more difficult to obtain water from wells drilled or bored into these, and at Fairview no water was found to depths of 130 feet in these glacial deposits. This long ridge is perhaps a terminal moraine. Its exact thickness is not known and perhaps it varies considerably from one place to another. It is at least 130 feet thick at Fairview and over 100 feet thick at Berwyn. It thins to the north and becomes a thin mantle of boulders, sand and clay, with bedrock projecting through at a few places such as along the highway 15 miles north of Grimshaw.

A mantle of unassorted glacial deposits covers the Saddle hills and the Birch hills. Fringes of boulders and smaller pieces of gneisses and schists frequently surround small uplands that rise above the general plains level. Unassorted deposits of boulders, gravel and sand cover a ridge about 6 miles south of Donnelly and similar deposits occur in a wooded belt crossing the highway about half way between Donnelly and Nampa. Frequently the lower parts of deep valleys of tributary streams are paved with glacial boulders.

The above are the chief occurrences within the area of the first class of deposits, which are for the most part unassorted. There is some indication of sorting along the southern edge of the morainal ridge along the north side of the Peace.

The second type of glacial deposits, namely the semi-stratified silts and clays, is a pronounced feature especially in the flat areas bordering the deep valleys of the main streams. These have been interpreted as glacio-lacustrine deposits, because of their lateral continuity and relatively level surface. In the discussion on physiography, three divisions of physical features were made, namely, the uplands, the bordering relatively flat areas, and the deep river valleys. It is probable that prior to glaciation the slope from river level to upland was more regular than at present, and the surface contour at such a time would not have shown such a marked three-fold division of physical features. Two causes have contributed to this change of surface, namely, a filling of the depressions with glacial lake deposits and a subsequent development of deeper river valleys. The filling was composed largely of muds and fine silts, in part of glacial origin, but also derived in part from erosion of the relatively soft shale formations occurring at the surface. This fine material apparently was deposited in long lakes occupying the valleys or depressions, the lakes being due to damming during the ice retreat. These water bodies, although probably fluctuating in level as the ice barrier gradually withdrew, were of sufficient duration to permit the accumulation of upwards of 200 feet in places of fine textured muds. These are best exposed in steep cliffs along the valleys, although only a small percentage of the banks expose these beds in place, since they disintegrate readily and are one of the contributory causes of so much slumping and sliding along the valleys.

An additional feature, noticeable at numerous places, is the presence of a thin layer of gravel, usually up to 5 feet thick, lying immediately beneath these fine textured deposits and covering the bedrock. This feature was observed along the Peace, the Ksituan and its tributaries, the Bad Heart and its tributaries, and appears to be too general to be considered as river gravels in old pre-glacial valleys. These gravels have been interpreted to be glacial in origin.

The fine textured and argillaceous composition of the glacial lake deposits render them in most places impermeable to ground water migration, so that in most places where wells have penetrated them the results are unsatisfactory. Occasionally arenaceous phases occur, especially in proximity to an upland underlain by sandstones. In such cases the erosion of the upland has contributed sufficient sandy material to render porous horizons, and water is obtained from these. The Spirit river valley west of Roycroft is a good illustration of this feature. A few shallow wells along this valley obtain a fair supply from sandy layers in these deposits.

It is difficult to obtain data on the thickness of these glacial lake deposits in flat areas well removed from deep valleys, as for example in the Falher district. Well drillings often bring up small pebbles of glacial origin from depths up to 200 feet, but these may have been worked down during the process of drilling. Their maximum thickness is probably between 200 and 300 feet. They thin out from a maximum along river valleys, to a few feet at the foot of the present slope to the uplands. From field evidence, it is believed that these deposits attain their maximum distribution along the upper part of the Peace valley in the general vicinity of Peace River town, where no bedrock is exposed in the upper 500 feet of the valley or its tributaries such as the Harmon river.

CHAPTER IV.

WATER SUPPLY.

General Statement. One of the chief objects of investigation in this area was to obtain data on the present water supply and determine the possibility of obtaining a more adequate supply from underground sources in those areas where the need of such is becoming increasingly important. Data were obtained on the results of dug, bored and drilled wells in the various districts, and samples of water from several places were taken for analyses. The present water supply for the settled and partly settled districts, as shown on Plate II, is derived from the following sources, namely,—reserves of surface water, streams, springs, shallow wells and deep wells. Surface water is by far the most common supply for most of the settled districts, and since these reserves have tended to diminish considerably within the past few years, due in part to cultivation and clearing, an increased effort has been put forth in an attempt to obtain good water. Furthermore, in several instances where a reasonably good supply has been obtained in shallow wells, the quality has not been very good.

It should be emphasized that the water problem does not apply to all the districts of the Peace River country, or even all of the areas shown on the accompanying map No. 14. Districts underlain by the Wapiti formation, such as Grande Prairie, are, on the whole, adequately supplied with good water from drilled wells. Drilling depths to good water horizons in the Wapiti range up to 500 feet, and in some places, as at Hythe, flowing wells occur. There is no general water problem here as in those areas underlain by Smoky River or St. John shales.

The deep valleys divide the area under consideration into districts, and the water conditions in each are discussed separately, although such conditions are often continuous from one to the other. For this purpose, the area has been divided into five districts, namely:

Falher-McLennan,
Spirit River-Wanham,
Waterhole-Fairview,
Whitelaw-Grimshaw,
Harmon River district.

The first four are underlain by Smoky River shales, whereas St. John shales underly the fifth.

Falher-McLennan District. This district extends from the east bank of the Smoky to McLennan, and from the Little Smoky north to township 80. Falher and Donnelly are situated about the center of the more settled part, while newer settlement is extending to the south along the Little Smoky, to the west and north up to the banks of the Smoky, and to the southeast from McLennan along the railway.

The water supply for most of this district has been derived from individual reserves of surface water, supplemented by rain water and ice, the latter being used almost exclusively for cooking and drinking. A few shallow wells occur at separated points, and within the last year and a half some wells over 600 feet deep have been drilled at McLennan and Falher.

The individual reserves are retained mostly in shallow open depressions or "dugouts" as they are frequently called. These are often located along some original depression or drainage course by constructing a small earth dam across the low area. The object is to retain as much water as possible from the melting snow in the spring and the wetter seasons of the year. The size of these dugouts varies with the individual demand, and frequently they are arranged in tandem along an old creek bed. The chief loss of water from these is by evaporation, since the surface subsoil, being largely clay, is quite impervious. During the early part of the summer season these supplies are of better quality than later, when, due to evaporation and a certain amount of leaching, the salinity increases and they become very hard. It is obvious that such accumulations of water are not the best as regards health conditions, as in many cases they are drained from fields and pastures. Small sloughs or ponds are utilized to considerable extent, especially for ice harvesting.

Surface accumulations of water have tended to decrease in recent years, and numerous attempts have been made to obtain water from either dug, bored or drilled wells. The drilled wells have reached greater depths and given better results than the others. Most of the dug wells have been to depths of less than 50 feet and have yielded a supply of very hard water, or no water at all. In some cases these wells are used as storage basins where water is hauled to them and withdrawn as required. Some shallow dug wells produce good water where they have penetrated superficial coarse glacial deposits or peat beds. Such deposits, however, are not common to the more thickly settled parts of the district. No generalization can be made as to results obtained in dug wells that penetrate shales or clays which underly most of the settled area. Some get a supply of hard water, others get none.

The character of water obtained from surface gravel and sand deposits is shown in analysis No. 1. This well is about 15 feet deep, 8 feet square, on the north slope of a ridge south of Donnelly (legal subdivision 12, section 6, township 77, range 20, west of 5th meridian). This is much softer than the average from shallow wells. Unfortunately it is not situated very close to many settlers, although some haul water from it for distances of 10 to 15 miles at certain seasons. It does not appear to be capable of supplying a very large volume, but the ridge on which it is situated covers several sections to the south and east, and it is possible that other productive wells could be dug on it.

The shallow wells dug in peaty material occur chiefly in a part of the district about 5 miles north of Donnelly, where a belt of small muskegs extend across from Kimiwan lake to Magliore lake. These are gradually drying up as fields are cleared around them, but small patches of 2 or 3 acres in size will often hold sufficient water to supply a farmer, who digs a well at the edge or within the muskeg. The water in these wells is usually quite soft, but highly colored with organic material from the peat. There is a tendency for many farmers to reduce the size of these small muskegs by burning them out to increase their cultivated acreage. It seems advisable that at least a certain acreage of muskeg should be preserved as a water reservoir.

The bored wells, on the average, have met with about the same results as the dug wells. These are usually less than 100 feet deep and 2 feet in diameter. Most of them have penetrated shales and clays. Two of these south of Donnelly are of interest in that the water rises to the surface and flows over. These two are at less than a quarter of a mile apart, one 48 feet deep in legal subdivision 8, section 30, and the other 60 feet deep in legal subdivision 16, section 19, township 77, range 20, west of 5th meridian. The water is quite hard, as may be judged from analysis No. 2 of a sample of water from the 48-foot well. The flow is not strong at any time, but is said to be continuous. In June, 1929, it was overflowing very slowly. The owner of the 48-foot well says the water was much softer in 1920 when the well was bored than it is at present.

Other bored wells have given differing results. Some have reached depths of 80 feet with no water, whereas others produce very hard water.

Most of the drilled wells have been situated within the villages, since the cost of such to the average individual farmer has been prohibitive when results are uncertain. It has been possible to reach greater depths by drilling, and although some of the shallow wells give a sufficient supply for individual farmers or householders, the supply does not prove sufficient for towns, villages, hotels, convents, and similar institutions.

Prior to 1929 several attempts had been made to obtain water by drilling at McLennan and Falher. None of these, however, proved productive until early in 1929 when R. H. Weaver completed a well for the Giroux Brothers' Hotel at McLennan. According to information supplied by Mr. Leon Giroux, this well was drilled to a depth of 682 feet in shales. The water rises 600 feet in the well, which is cased with 3½-inch pipe. The supply is sufficient to the needs of the hotel, which pumps from a depth of 240 feet. Analyses No. 3 and No. 4 were made from two samples from this well, taken at about a year's interval. No. 3 was made soon after its completion, and No. 4 was made to see if there was any appreciable change in the salinity during this period. A noticeable chemical feature of the water is the high total solids content and low hardness, as compared with waters from higher horizons such as that from the flowing well south of Donnelly (shown in No. 2). The water may be classed as soft, but the high percentage of salts make it unsuitable for drinking or household purposes other than washing. Another objectionable feature is the high percentage of suspended matter in the form of colloidal-like clay. The water is very murky when pumped, owing to this clay, and has to be allowed to stand in tanks to permit settling. The settling is only partly complete after many hours of standing, and slight agitation causes much of the finer material to rise and mix with the water. Mr. J. A. Kelso made tests on some of this water with alum compound used in sedimentation basins, and finds that this will precipitate the fine clay material readily. There does not appear to be any practical method for removing or reducing the high content of salts in solution.

Mr. Weaver also drilled a well at the new hospital site in McLennan, and an adequate supply was obtained at a depth of 652 feet. This well is a short distance from the hotel, but it was not in use for several months after completion until the construction of the hospital was started in the summer of 1929. The hospital was opened after our return from the field and subsequently a sample of water was submitted for analysis. It is similar chemically to the water from the hotel well, as shown by analysis No. 5, and it is also murky when freshly pumped, due to fine clay material held in suspension.

Mr. Weaver drilled a well for the convent at Donnelly early in 1929. This was not in use during the summer of 1929. It has been drilled to a depth of about 400 feet and the water is said to be very hard.

Unsuccessful drilling tests have been made in Falher village at different times. This is the largest village within the district and the water supply there is entirely inadequate. A large convent and six elevators make it a central place, and a supply of good water is its chief need. Several drilling tests have been made during the last few years, and each time deeper horizons were reached, but without satisfactory rssults. The Woodland Dairy, Limited, attempted to get water a few years ago to use in a creamery. One well was drilled to 525 feet, without results, and an old well about 225 feet was deepened to about 385 feet, where a small supply (said to be about 10 barrels a day) was obtained. This 385-foot horizon was met with in the first well and is probably the same horizon drilled to at the convent in Donnelly.

Mr. Weaver, who drilled the deep wells at McLennan and Donnelly, moved his drilling outfit to the convent at Falher and was drilling here while we examined the area. The first well was drilled to a depth of 630 feet, but had to be abandoned on account of accidental loss of tools in the hole. A second was drilled a few feet from the first. It was put down to 612 feet. The driller claims considerable water was struck, but it was very hard. This well has been abandoned, at least temporarily, and so far as known, no use is being made of the water in it. A third well was started in hopes of reaching a hard water horizon said to occur at a depth of 280 to 300 feet. This well was not completed.

Mr. Weaver later drilled another well a few miles south of Falher in the northeast quarter, section 21, township 77, range 21, west of 5th meridian. According to information supplied by Mr. Dupuis, who submitted a sample for analysis, the well was drilled to a depth of 612 feet and water rises 450 feet. The supply is sufficient for his needs, which are 12 to 15 barrels per day. The chemical character is shown by analysis No. 6, and it may be classed as soft water, although the salinity is high. It is very similar to the water from the McLennan wells, but the sample submitted does not carry so high a content of suspended clay as those from McLennan.

Thus, from tests made to date, water supplies of sufficient quantity cannot in general be obtained under depths of less than 600 feet in the Falher-McLennan district, and whereas supplies obtained from depths between 600 and 700 feet are adequate and of considerable value, the quality of water is not all that may be desired. This is a new and expanding district and in most places deep drilling will be necessary.

All the deeper drilling has passed through surficial deposits and the lower Smoky River shales. At Falher and McLennan the depth to the base of the Smoky River shales is approximately 600 feet. The upper part of the Dunvegan formation is in part shale, so that similar drilling conditions prevail to depths of approximately 650 feet. The variation in surface elevation will change these depth figures slightly from one place to another. Furthermore, the underlying strata have a dip to the south which is as much as 50 feet to the mile in places, consequently shallower drilling depths to a certain horizon will obtain north of the railway than to the south. From information available it is believed that the deeper wells at McLennan and Falher have reached the upper Dunvegan beds, but have not penetrated them to a sufficient depth to test the possibilities of the whole formation.

Spirit River-Wanham District. The area lying to the north and east of Spirit River village constitutes the oldest settled part of this district. Settlement extends from this village north to the deep valleys of the Ksituan and its tributaries and east along the tributaries of Spirit and Saddle rivers. The Wanham portion is comprised of a narrow settled belt extending along the south side of the railway from the Saddle river east to Belloy. In addition there is some settlement south of the Birch hills known as the Heart valley or Peoria districts. New settlement is taking place in many parts adjacent to the Spirit River and Wanham districts. The Whitburn and Blueberry Mountain districts west of Spirit River, and the valley of the Saddle river west of the highway, are areas of new settlement. The Peoria district is extending east towards the Smoky. There are still, however, large sections unsettled lying between Wanham and the Peace (Plate II). This is due largely to the wooded character of the surface and the deep valleys of the Saddle river and its tributaries as they near the Peace valley.

Water conditions in this district are similar in many respects to those in the Falher-McLennan district. Surface water stored in private dams and a few wells constitute the main supply. Some unsuccessful attempts have been made to obtain a better supply by boring and drilling.

There is some difference between the surface aspect of the Spirit River-Wanham district and that in the Falher-McLennan area.

The former is, on the whole, closer to both upland and deep valleys, and the water run-off is in general more rapid. The general drainage slope is to the north, or opposite to the dip direction of the underlying strata.

Some of the shallow dug wells in this district are worthy of note, since they are the chief source of water for their respective localities. A large part of the water used for household purposes in Spirit River is hauled from a well 14 feet deep in legal subdivision 4, section 24, township 78, range 6, west of 6th meridian, about a mile and a half from the village. This well is 14 feet deep, in fine grained silts. Several producing shallow wells occur along the Spirit river in the old Spirit River settlement west of Roycroft. These are dug wells, 14 to 20 feet deep and usually located on an old river terrace within a few yards of the river. These are all on the north side of the stream between settlement lots 8 and 15. The existence of this water horizon is due to the occurrence of sandy beds in the recent deposits along the Spirit river valley. This stream rises in the uplands to the southwest, which are underlain by Wapiti beds, and erosion of these has contributed the sands that form the present water-bearing horizon. Such horizons have not been found along the Spirit river valley near Roycroft or eastwards.

Spirit River village is underlain almost to the immediate surface by undecomposed bedrock constituting the lower Smoky River shales. Several wells less than 50 feet deep have been dug or bored within the village, and most of these carry some water, which is very hard and unfit for domestic purposes.

The Bad Heart sandstone caps a small flat-topped hill a half miles south of the village. This sandstone is a good water horizon, but the surface area of it here is not of sufficient size to permit a large accumulation of water. It is eroded to steep-faced cliffs on three sides at this locality, and such accumulation of water that it may obtain in wet seasons is readily drained out.

Several wells have been bored or drilled in the flat areas north of the village, but without satisfactory results. For example, two wells, 90 and 110 feet deep, that were drilled in section 6, township 79, range 6. The deepest test was made at Spirit River village about three years ago. According to information supplied by the Municipal Secretary, this well was drilled to a depth of 575 feet. Water was struck at 535 feet but it disappeared over night, and drilling was continued to 575 feet where sandstone is reported to have been encountered.

This well was drilled in lower Smoky River shales, and was not deep enough to reach the Dunvegan sandstones, since it started within 150 feet of the base of the Bad Heart sandstone, and the lower Smoky River is here about 875 feet thick. The sandstone reported at 575 feet is probably that recorded in the section of lower Smoky River on Howard creek, described in a previous chapter. Thus far the possibilities of even the upper Dunvegan beds have not been tested at or in the vicinity of Spirit River.

At Roycroft and the immediately surrounding district conditions are similar to those at Spirit River. Some deep tests have been made, but the records of these are very indefinite. One well is said to have been drilled to a depth of 500 to 700 feet, and another well 315 feet deep had water in it up to within 95 feet of the top. Neither of these are in use now. A well 100 feet deep has some water in it now, but not enough to supply the hamlet of Roycroft.

The newer districts adjacent to Spirit River and Roycroft are using surface water, since in such places the supplies in small sloughs are usually sufficient until continued clearing of the land reduces their number. Such conditions prevail in the Blueberry Mountain and Whitburn districts west of Spirit River.

At Wanham and vicinity conditions are much the same as at Roycroft. Two shallow wells on a ridge capped by Bad Heart sandstone, about a half mile from the village, constitute the supply, and a few farmers situated on this same ridge to the west have good shallow wells. The average depth of these wells is 12 to 16 feet, and the occurrence of Bad Heart sandstone at the surface is the only reason why the wells so situated carry good water. It is a porous horizon and occurs at the surface along a small wooded ridge paralleling the road to Roycroft. It has been eroded off to the north and dips to the south under overlying shales of the upper Smoky River formation.

Wells of various depths have been put down within the village of Wanham, but no satisfactory results obtained. One well, 48 feet deep, has very hard alkaline water, unfit for almost any purpose except perhaps fire fighting. The deepest test made was a drilled well 300 feet deep which struck a small amount of hard water at depths of 37 and 62 feet, but nothing at deeper horizons.

The drilling depths to the top of the Dunvegan sandstone at Wanham will be approximately 800 feet, since the Bad Heart sandstone is here only 70 feet above the village level. There is no settlement as yet north of the railway at Wanham. In this direction drilling depths to the Dunvegan should decrease, as the strata rise to the north and the slope of the land is in the same direction. A narrow strip of settlement situated along the foot of the north slope of the Birch hills also has water trouble. The underlying strata here are the upper Smoky River shales. It is possible that wells to a depth varying up to 400 feet may obtain water from the Bad Heart sandstone. A small supply is obtained from springs along the north slope of the Birch hills. These springs are not strong flowing, but are largely surface seepages through the mantle of soil and recent deposits.

Water conditions in the Peoria and Heart valley districts are variable, depending on the position one is located with respect to geological boundaries. Those living south of Kakut creek and also at a position where at least a few feet of Wapiti beds occur, usually get good wells at shallow depth. Those situated on places underlain by upper Smoky River shales have the same trouble as in other areas underlain by shales. On the north side of Kakut creek conditions are similar except that the mantle of recent deposits is in places arenaceous, due to erosion of the Wapiti sandstones in the Birch hills. Consequently shallow wells are more numerous here than on the south side of Kakut creek.

Some deeper wells have been drilled at Peoria. One in section 30, township 76, range 2, west of 6th meridian, was drilled to a depth of 260 feet and gave a good supply prior to caving. It is believed that this well reached the Bad Heart sandstone, which should occur at about this depth here.

A relatively large area, sparsely settled in a few spots only, situated between Belloy and the Smoky river, was not examined in detail, but water conditions are believed to be the same here as in the adjoining areas to the east and west. It extends north from the railway to the Peace and south to the Smoky around the east end of the Birch hills. At present it is heavily wooded in places and new settlers around Tangent and Eaglesham are using surface water. But here, as in other districts, such supplies will automatically diminish and prove insufficient to the needs as settlement increases.

Waterhole-Fairview District. The settled area north of the Peace, as shown on Plate II, forms a continuous belt from Hines river east beyond Grimshaw. This has been divided into two parts, for purposes of consideration of water supply, namely the Waterhole-Fairview and Whitelaw-Grimshaw districts.

The Waterhole-Fairview district extends from the Peace north beyond Fairview, and from Hines river east beyond the Little Burnt river to about the sixth meridian. In general, water conditions are similar to those outlined for the other areas, the main supply being obtained from individual reserves of surface water. Several wells have been drilled or bored, but only a few of these have been productive. One of these productive deeper wells is located on Mr. Caspar's farm in legal subdivision 5, section 27, township 81, range 3, west of 6th meridian, about a mile south of Fairview. This well was drilled about 10 years ago. It is 380 feet deep and water rises about 60 feet. The supply is adequate for his needs, but would not be sufficient for a village the size of Fairview. The water is hard, as shown by analysis No. 7. It is believed that this well at 380 feet is in the upper Dunvegan beds at approximately the same horizon as the 600 to 675-foot wells in the Falher-McLennan district. In 1925 a well over 400 feet deep was drilled at Waterhole in section 16, township 81, range 3. It is said to have passed through over 225 feet of surface deposits, and although some water was obtained, pumping trouble prevented its general use. Waterhole was a rural trading center prior to the construction of the railway west from Whitelaw to where Fairview is now situated. Most of the business establishments moved from Waterhole to Fairview, and no recent attempts have been made to obtain water from this well.

A 400-foot well at Waterhole would not reach quite as low a horizon as the 380-foot well at Mr. Caspar's, since the dip of the strata to the south is greater than the slope of the surface between these two points.

Several other wells have been bored or drilled to depths ranging up to 200 feet. Some obtained a small supply of hard water, others were dry. In the description of glacial deposits it was noted that a morainal-like ridge extends across the northern part of this district, parallel to the railway and highway. Fairview is situated near the west end of this ridge, which is composed largely of boulder clays and other glacial materials. Water is derived from several wells in these glacial deposits around Bluesky, but at and near Fairview similar wells are not productive. A bored well 135 feet deep at Fairview reached a gravel bed after passing through boulder clay, but no water occurred in this lower porous horizon, which is 15 to 20 feet thick. Another dry well 150 feet deep was drilled in section 19, township 82, range 3, west of 5th meridian. A dug well 150 feet without water is situated in section 36, township 82, range 3, west of 5th meridian, near Fairview. In fact, practically all the wells along the ridge and close to Fairview have been non-productive, but to the east near Bluesky there is usually some water obtained from wells which penetrate these glacial deposits. The depth of these varies, as shown by the following:

Bored well in L.S. 13, Sec. 33, Tp. 81, R. 2, W. 6th, 120 feet deep, 12 years old, has 70 feet of water, hard.

Bored well in L.S. 13, Sec. 4, Tp. 82, R. 2, W. 6th, 58 feet deep, very hard water, in gravel.

Bored well in L.S. 9, Sec. 1, Tp. 82, R. 2, W. 6th, 132 feet deep, water rises 100 feet, very hard.

East of Bluesky water horizons become more numerous as the gravel content increases, and water is available at almost any point along the ridge east of Little Burnt river.

The absence of water in this ridge near Fairview is attributed to the fact that the deposits forming it are too argillaceous to permit ground water sinking to any appreciable depth. There is a possibility, however, of obtaining some water similar to that near Bluesky, if wells were put down on the north slope of the ridge about 2 miles north of Fairview. This has been an Indian reserve until recently, consequently no tests have been made.

A further attempt to secure water for the village of Fairview was made in the fall of 1929 after we left the district. Mr. R. H. Weaver, who drilled at Falher and McLennan, moved an outfit to Fairview and commenced drilling. In October, 1929, it was reported that a good flow of water was struck at a depth of 272 feet. No. 8 is an analysis of this water. Apparently this was only a temporary supply, as the well was readily pumped dry and drilling proceeded to a depth of approximately 380 feet. No further water supply was obtained and the hole was abandoned on account of some drilling difficulties. A second well was drilled to about the same depth, but so far as is known this is not producing. These wells at depths of 380 feet have not reached as deep a horizon as that in the Caspar well a mile south of Fairview, since the wells at Fairview start at an elevation about 50 feet higher and the rise in strata in this distance would be about 25 feet. They have, however, probably reached the upper Dunvegan beds at depths of 350 to 400 feet. Deeper drilling is necessary to test the possibilities of the Dunvegan beds in this district.

Whitelaw-Grimshaw District. Although this adjoins the Waterhole-Fairview district and is continuous with it as respect settlement, water is more readily obtained here than in any of the other districts referred to. This is due chiefly to the fact that the ridge of glacial deposits referred to above, contains more gravel to the east than to the west, and a larger proportion of settlement is located along the ridge than to the west around Fairview. There is, however, a narrow belt between the Peace and this ridge where water conditions are the same as at Waterhole.

Good supplies of water are obtained from dug or bored wells to depths averaging around 100 feet, at Whitelaw, Berwyn and Brownvale. Strong springs emerge from the south slope of the ridge at several places. Three of the best of these are located as follows:

1. L.S. 13, Sec. 35, Tp. 81, R. 1, W. 6th, south of Whitelaw.
2. About the center of the Indian reserve southeast of Brownvale, feeding Griffin creek.
3. N.E. ¼ Sec. 14, Tp. 82, R. 24, W. 5th, southeast of Berwyn.

A fourth near Grimshaw is the chief source of water supply for this village. Several flowing wells occur east of Griffin creek and near the Indian reserve. These are within a small area, about 2 miles square, occupying parts of sections 35 and 36, township 81; sections 1, 2 and 3, township 82, range 25, west of 5th meridian. Most of these are drilled wells and range in depth from 175 to 325 feet. The flow is not strong in any, and the water is usually hard. Analysis No. 9 is from a sample of water from a flowing well 176 feet deep, in the southwest quarter of section 2, township 82, range 25, west of 5th meridian. Although some of these flowing wells are deep and probably have gone through the glacial deposits into bedrock, the water in them may be coming from a higher horizon than that reached at the bottom of the wells.

Although water is available in most of the Whitelaw-Grimshaw district, there is a part of it parallelling and bordering the valley of the Peace, where water conditions are similar to those at Waterhole. This part is physiographically an eastward extension of the same type of country as around Waterhole, and its relative narrowness is due to the fact that the Peace valley and the ridge of glacial deposits to the north are much nearer each other than at Fairview. Wells of various types and depths in this part of the district have given different results. The water obtained is usually very hard, as shown by analysis No. 10 from a 90-foot well in legal subdivision 16, section 7, township 82, range 24, west of 5th meridian.

Three deep dry wells in township 81, range 25, west of 5th meridian are of interest because of their proximity to flowing wells within a mile to the north. The location and depths of these wells are:

382 feet deep in L.S. 5, Sec. 35,
350 feet deep in L.S. 5, Sec. 25,
380 feet deep in S.W. ¼, Sec. 26.

One is less than a quarter mile from a flowing well. These conditions seem to indicate that the water in the flowing wells near Griffin creek are from a higher horizon than the depths of the wells indicate. The dry deep wells are of further importance since they have very probably penetrated upwards of 200 feet of Dunvegan beds, since they are close to where the approximate boundary between the Smoky river and Dunvegan occurs. Glacial deposits may rest directly upon Dunvegan beds here, but these are not thought to be over 150 feet thick. If such an interpretation is correct, it would appear that the upper 200 feet of Dunvegan formation is not a water-bearing horizon here.

Harmon River District. This district includes several small somewhat separated areas adjacent to the Harmon river. One part lies between the Peace and the Harmon, and is usually referred to as the Judah district. This is only partly settled along the flat areas between the two deep stream valleys. Several partly settled areas lie east of the Harmon river from Peace River south to Nampa. These include what is known as the Little Prairie district, situated within the north half of township 81 and the south half of township 82, range 19 and 20, west of 5th meridian, northeast of Nampa and Reno.

Some difficulty in obtaining water has been experienced in parts of this district. Many of the wells around Judah are dry or contain very hard water. Most of the supply in this part of the district is obtained from accumulations of surface water. Similarly, surface water is used in partly settled areas between the highway and the east side of the Harmon.

The Harmon river banks are shallower east of the highway, and most of the settlers whose land adjoins the stream use river water. One flowing well, 172 feet deep, is situated in legal subdivision 4, section 4, township 82, range 20, west of 5th meridian. The analysis of this water is No. 11, and shows it to be very hard. The deepest test made in this district was a well drilled to a depth of 352 feet in legal subdivision 1, section 1, township 82, range 21, near the Harmon river. No water was obtained.

Although water conditions in the Harmon River district are somewhat similar to those in others already discussed, the underlying bedrock conditions are somewhat different. Most of it is shown on the accompanying geological map to be underlain by Dunvegan beds, but the average thickness of recent deposits here is not known. It is believed that the Dunvegan beds were removed from a large part of this district by pre-glacial erosion, so that the glacial and recent deposits lie upon the St. John shales. Consequently, drilled wells are likely to reach this formation, which is similar to the Smoky River formation and about 700 feet thick. The Peace River sandstone below the St. John may be a water horizon, but no wells have been drilled to sufficient depth to test this horizon.

ANALYSES OF WATER SAMPLES
MADE BY J. A. KELSO, PROVINCIAL ANALYST
Parts per Million

Analysis No.	1	2	3	4	5	6	7	8	9	10	11
Total solids	155	1360	1780	1982	2172	2172	2340	1870	1335	1919	1890
Magnesium carbonate	20	167	10	15 }	30	15	353	52	117	239	257
Calcium carbonate	78	140	15	20 {		15	71	59	366	86	446
Sodium carbonate		....	875	1211	1030	1817	....	518	....	....	....
Sodium sulphate	....	365	....	100	....	nil	1513	1055	750	685	625
Sodium chloride	6	43	850	544	1015	239	16	115	23	33	78
Silica	9	14	....	18	....	10	10	10	12	14	11
Vegetable matter	32	76	20	58	54	63	30	50	17	52	47
Calcium sulphate	....	498					340		....	787	364
Iron oxide and alumina	4	28					nil		30	trace	50
Total hardness	102	705		38	30	33	741	121	505	948	1020
Carbonate hardness	102	339		38	30	33	491	121	505	370	752
Non-carbonate hardness	nil	366		nil		nil	250	nil	nil	578	268
Suspended matter	....	....	....	210	....	15					
Grains per Gallon											
Total solids	10.9	95.2	124.6	138.7	152.04	152.0	163.8	130.9	93.5	134.1	132.3
Magnesium carbonate	1.4	11.7	.7	1.1 }	2.10	1.1	34.7	3.64	8.2	16.7	18.0
Calcium carbonate	5.5	9.8	1.05	1.4 {		1.1	5.0	4.13	25.6	6.0	31.2
Sodium carbonate		....	61.25	84.8	72.10	127.2	....	36.28	....	....	....
Sodium sulphate	....	25.6	....	7.0	....	....	105.9	73.85	52.5	48.0	43.8
Sodium chloride	.4	3.0	59.50	38.1	71.05	16.7	1.1	8.05	1.6	2.3	5.5
Silica	.6	1.0	....	1.3	....	.7	.7	.7	.8	1.0	.8
Vegetable matter	2.2	5.3	1.4	4.1	3.78	4.4	2.1	3.5	1.2	3.6	3.3
Calcium sulphate	....	34.9					23.8		....	55.1	25.5
Iron oxide and alumina	.3	2.0							2.1	trace	3.5
Total hardness	7.1	49.4	1.93	2.7	2.10	2.3	51.9	8.48	35.4	66.4	71.4
Carbonate hardness	7.1	23.7		2.7	2.10	2.3	34.4	8.48	35.4	25.9	52.6
Non-carbonate hardness	nil	25.6		nil	nil	nil	17.5	nil	nil	40.5	18.8
Suspended matter	....	....	....	14.7	....	1.1					

LOCALITIES FROM WHICH WATER SAMPLES WERE TAKEN.

No. 1 Dug well on gravel ridge south of Donnelly, L.S. 12, Sec. 6, Tp. 77, R. 20, W. 5th.
No. 2 Bored well, flowing, south of Donnelly, L.S. 8, Sec. 30, Tp. 77, R. 20, W. 5th.
No. 3 Drilled well, hotel at McLennan.
No. 4 Same as No. 3, taken after well was in use several months.
No. 5 Drilled well, hospital at McLennan.
No. 6 Drilled well south of Falher, N.E. ¼ Sec. 21, Tp. 77, R. 21, W. 5th.
No. 7 Drilled well, Caspar farm, south of Fairview, L.S. 5, Sec. 27, Tp. 81, R. 3, W. 6th.
No. 8 Drilled well, village of Fairview.
No. 9 Drilled well, flowing, south of Berwyn, L.S. 4, Sec. 2, Tp. 82, R. 25, W. 5th.
No. 10 Dug well, south of Berwyn, L.S. 16, Sec. 7, Tp. 82, R. 24, W. 5th.
No. 11 Drilled well, flowing, Little Prairie, L.S. 4, Sec. 4, Tp. 82, R. 20, W. 5th.

NOTE: The Saskatchewan river water at Edmonton ranges from 9 to 20 total hardness in grains per gallon. Those shown in the above table with a total hardness of over 30 may be said to be very hard waters. It is noteworthy that some of the waters carrying a high percentage of dissolved salts are soft, due to the fact that sodium carbonate is the chief salt in solution.

General Summary of Water Supply. The data given above regarding depths of wells are believed to be in general approximately correct, as obtained from various people interviewed. The geological conditions prevailing indicate that a good supply of water cannot be obtained from the upper strata in these districts. The Dunvegan formation has possibilities, since it is composed in part of sandstone beds which may be water horizons. The upper Dunvegan beds have been reached at Falher and McLennan by wells to depths of over 600 feet, which have obtained an adequate supply of soft water, which has, however, a high salinity. Some of the deeper wells at Fairview have yielded water at depths of 380 to 400 feet, apparently also from the upper Dunvegan beds. The deeper drilled wells south of Berwyn are believed to have penetrated the upper 200 feet of Dunvegan, without obtaining water. An additional 350 to 400 feet of drilling at these places would test the whole of the Dunvegan formation as to water possibilities.

There is no place within the area where shallow wells are known definitely to be producing water from Dunvegan beds. A brief visit was made to Rolla district in British Columbia near the west boundary of Alberta, as it was anticipated that Dunvegan beds would underly the surface in part of this district. From a brief survey it appears that water is obtained only at places where massive sandstones of the Dunvegan occur near the surface.

The possibility of the Dunvegan formation containing artesian aquifers has also been considered. This formation rises to the surface to the north of the area mapped, and should have a relatively large areal distribution at the surface, since the dip angle is small. Such areas may be covered too deeply with glacial deposits to permit much water reaching the Dunvegan beds, but there is a possibility of a down-the-dip migration of water to positions underlying parts of the area along the Peace and Smoky. The Dunvegan beds or their stratigraphical equivalents rise to the surface in British Columbia. It is possible that some water entering the Dunvegan here may migrate north-eastwards if porosity conditions are favorable.

If there were any appreciable movement of water from either of the sources suggested, there would undoubtedly be numerous springs occurring along the Peace at such places as Dunvegan, where the Peace valley has cut almost through the Dunvegan formation. Springs from the Dunvegan beds are scarce along the Peace and Smoky, where almost the whole of the formation is exposed, consequently it is concluded that the Dunvegan formation does not carry a large amount of migrating water. The lenticular character of the lithological units may be in part responsible for this, and a large part of the Dunvegan formation is shale which is impervious. Thus the Dunvegan formation does not hold very good prospects of becoming a general water supply horizon, nevertheless it seems advisable that it should be thoroughly tested as to its possibilities at some points removed from the major stream valleys.

Should such tests prove unsuccessful, there is the possibility of drilling still deeper to the Peace River formation, which occurs below the St. John formation. It would require an additional 600 to 700 feet of drilling to reach this formation, and it is not possible to predict what the quality of the water would be if found in the Peace River formation. There is always the possibility of such deep horizons carrying water too salty to be of use. Drilling to reach the Peace River sandstone is not a practical proposition when, for example, at Fairview, it would mean a depth of at least 1,600 to 1,700 feet, and at Spirit River approximately 2,000 feet. Such depths are prohibitive from a standpoint of costs to the individual farmer, and in most cases to the villages also.

There does not appear to be any alternative solution to this water problem other than drilling in search of water horizons. It would be impractical to attempt any scheme of obtaining water from the major streams which occupy the deep valleys. Most of the smaller streams do not carry a sufficient supply throughout the year to warrant any comprehensive plan of storage and distribution. There has been some suggestion made lately regarding a diversion or control of some of the water flowing through the High Prairie district into the west end of Lesser Slave lake. Some streams here overflow periodically and cause considerable damage to parts of the High Prairie district. Most of the water causing this damage comes from the uplands to the south of High Prairie, but one stream, namely the Heart river, flows from the north. In a part of its course in townships 76 and 77, ranges 17 and 18, west of the 5th meridian, it flows close to Winagami lake, from which it is separated by relatively low land in places. It may be practical and possible to divert at least a part of the Heart river water into this lake, which in turn could be connected to Kimiwan lake at McLennan. This water would tend to freshen these lakes, which are stagnant most of the year. It might also be feasible to construct an outlet from these lakes through the Donnelly district.

Such a scheme is here put forward as a suggestion. The practicability of it would depend on results of an investigation by engineers familiar with such projects.

The writer would recommend that deeper drilling tests be made at central points within the districts where the water problem is most serious. Falher appears to be the logical place to make one of these deeper tests. A well 1200 feet deep would prove the possibilities of the Dunvegan formation in this district. A well 900 feet deep at Fairview would test the same horizon for that district, and since this is a central point, it is recommended that one be drilled here. A third test should be made on the south side of the Peace, at either Spirit River or Roycroft. Drilling depths to test the same horizons may be about 100 feet greater than at Falher.

In conclusion the writer feels that the public should be warned against acting on the advice of numerous so-called water-finders. Many wells have been dug, bored or drilled on the advice of these individuals, and needless to say, the results have been chiefly wasted effort. It is not desirous to here belittle the scientific methods of geophysical prospecting, but merely to point out that the ordinary methods of so-called "water witching" or "divining" have been proven to be fallacies.

CHAPTER V.

ECONOMIC GEOLOGY.

Salt Incrustations. The occurrence of salts, as white incrustations upon the shale banks, have been noted by several observers at various times in this area. The origin and chemical composition of the salts have attracted interest, since they resemble alums, and some occurrences have been investigated in the hope of discovery of a compound high in potash.

The salts occur along the steep slumped banks where the St. John or Smoky River shale formations form the consolidated bedrock. This displaced material is usually composed of partly disintegrated bedrock mixed with soil and other debris. The Smoky River and St. John shales often contain iron sulphide nodules. When the shale becomes loosened by slumping and sliding, oxidation of the iron sulphide takes place, causing spontaneous combustion, and water seeping through the loose material is vaporized and rises from the beds in a heated condition. The salts are apparently precipitated from vapors emanating from these beds.

Selwyn reported the occurrence of these as "smokes" or *bocannes*,[32] and they have also been referred to as "fires." He observed them on the lower part of the Smoky river about 14 miles above its mouth, where they occurred in slides of St. John shales.

The banks of the Smoky near the mouth of the Little Smoky, south of Watino, is the best known locality for these occurrences of salts. Dawson records one of the *bocannes* here in 1879[33] and states that this was the only one in action on the Smoky at that time.

Samples of these salts have been sent to the University of Alberta at various times, and the analyses of some of these samples are recorded in the geological sections of the Annual Reports of the Research Council of Alberta.[34] There is considerable uncertainty as to the exact location from which most of these samples came.

In 1929 the writer was directed to one of the best of these salt occurrences by Mr. S. Thomson of Watino. This is located on the east bank of the Smoky just above the mouth of the Little Smoky. The "fires" were in action during our visit to a steep slumped bank of Smoky River shale. The vapors arising from these heated shales are visible only at close range on dry, warm summer days, but on cool winter days they form clouds that are visible for considerable distance. It is said that under certain winter atmospheric conditions they do not rise above the valley, and the accumulation of the vapors make it almost impossible to travel along the ice-covered river. These vapors rise through cracks and openings in the shales, and temperatures near the surface are often too high for handling the material with bare hands. The shale fragments are frequently baked to a red brick-like material.

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32 Geol. Surv., Can., Rept. of Progress for 1875–76, pp. 56, 58 and 73
33 Geol. Surv., Can., Rept. of Progress for 1879–80, pp. 47B, 123.
34 Allan, J. A., Annual Report 1920, p. 126; and 1921, p. 39.

The salts precipitate at or near the surface. They are very soluble in water and are readily washed away by rain or melting snow, thus the best material is available during dry seasons. We collected some in June, the largest piece available being about a foot cube. Most of it was in thin veins up to 4 inches thick. It is a soft white crystalline material, readily soluble in water, to which it gives a bitter taste and a somewhat astringent character. Analysis No. 1 was made from some of this material. The crystals are too small to determine their system, but under the microscope they are birefringent, and appear to be monoclinic in system. It is similar both in crystal habit and chemical composition to pickeringite, a member of the halotrichites, which are related to the alums.[35] Pickeringite has been reported to occur in a manner similar to the material on the Smoky; that is, an efflorescence on shale due to decomposing pyrite. The relatively high percentage of magnesium is the chief chemical similarity of pickeringite and this mineral. An analysis of pickeringite, as given in Dana, is included for comparison.

The purest material on the Smoky river banks is white, but often it is light yellow or light red in color. The red coloration is due to iron staining, while the yellow is in some cases due to native sulphur and in others is probably due to iron oxide.

During our examination of this part of the Smoky there was only one large "fire" in action at the locality given. Others are said to have been active within recent years on the east bank of the Little Smoky at its mouth. A smaller one was observed on the west bank of the Smoky in section 21, township 77, range 24, west of the 5th meridian.

Apparently these "fires" are only temporary and cease to act after a time, due perhaps to excessive slumping, wetting or completion of oxidation of the material available. It appears that certain conditions are essential to their activity. First, a certain amount of iron sulphide or similar material must be present. The stratified bedrock must be disturbed to some extent and rendered more porous to permit air and water to enter. This is accomplished by slumping or sliding.

The size of the deposits is too small to be of commercial importance if there were a market for the mineral. Furthermore, it is usually intermixed with clay and shale to such an extent that it requires hand picking to secure even a small amount of pure material.

The fact that such salts are derived from the shales has a bearing on the nature of water supply that may be derived from some horizons in these marine shales. These salts indicate a high sulphate content, which is also shown in several analyses of water obtained from horizons within the Smoky River shales.

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[35]Dana, A System of Mineralogy, p. 953, New York, 1911.

ANALYSES OF SALT INCRUSTATIONS.

	1	2	3	4	5	6
SiO_2	.53					
Al_2O_3	11.90	10.64	11.9	16.21	10.04	12.90
Fe_2O_3	.40			6.19	4.16	.70
FeO		.58				
CaO						
MgO	6.32	4.79	4.7	8.24	9.74	.02
SO_3	39.92	36.33	37.3	67.18	73.56	39.92
H_2O, etc.	41.35	46.06	46.1			45.41
Insoluble in water..........				4.75	3.02	.68
K_2O				2.06	2.32	

(1) From Smoky river at mouth of Little Smoky, collected by R. L. Rutherford, analysis by J. A. Kelso.

(2) From Newport, Nova Scotia, analysis given in Dana's "System of Mineralogy." This material occurs on shale due to decomposing pyrite.

(3) Calculated percentage of pickeringite, $MgSO_4.Al_2(SO_4)_3+22\ H_2O$, as given in Dana's "System of Mineralogy."

(4) Said to have come from upper Peace river in the vicinity of Spirit and River. Analyses by J. A. Kelso. Reported by J. A. Allan in Res.

(5) Coun., Alta., Second Ann. Rept. 1920, p. 126, 1921; Fifth Ann. Rept. 1924, p. 42, 1925.

The percentage of water present was not determined in material represented by analyses Nos. 4 and 5, consequently the soluble solids show a higher per cent. The proportion of the various soluble constituents of Nos. 4 and 5 are similar to those of No. 1, except that they show a much higher percentage of iron oxide and also a small amount of K_2O. The common property of Nos. 1, 4 and 5 is the relatively high per cent. of MgO, indicating a magnesian alum. The writer observed some thin surface coverings of salts on the banks of Howard creek north of Spirit River, but none were of sufficient thickness to permit collection for analysis.

(6) Allan, in the 1921 report, records this analysis of a specimen said to have come from the Smoky river near its mouth. This does not show the usual high magnesium content. No. 6 is from the St. John shales if the location given is correct, whereas Nos. 1, 4 and 5 are from the Smoky River shales.

Selwyn collected some similar material from the bank of the lower part of the Smoky river. This was analyzed by Hoffman[36] who classed it as sal ammoniac and sulphur. It is not tabulated above since it is not given in a manner that lends itself to ready comparison. Hoffman records only a trace of magnesium and in this respect it is similar to No. 6. It is probable that at times these incrustations are composed of more than one compound.

Gypsum Crystals. The water analyses from shale horizons usually show a high sulphate content, and gypsum crystals occur very commonly on exposures of the shales. They are more prevalent on slumped exposures of recent silts occurring along the steep banks of deep valleys. Crystals of the transparent variety, selenite, are most common, although occasional thin bands of the fibrous variety were observed in the Smoky River shales. The crystal faces are often well developed, and individual crystals up to 4 inches in length are not uncommon. Small mounds of earth removed in excavations and left on the surface often become clustered with

[36] Geol. Surv., Can., Report of Progress for 1875–76, p. 420.

small, well-formed gypsum crystals, and well borings in the dark grey boulder clays contain numerous spherical masses of radiating groups of gypsum crystals.

Road Surfacing Material. The occurrence and accessibility of material for road surfacing is an important economic consideration in most of the agricultural areas of Alberta. Trunk highways and subsidiary roads are being constructed in many parts of this area, as in other parts of the province, and ultimately it will be necessary to surface some of these.

There are two chief sources from which gravel for roads may be obtained, namely, the river terraces and flood plain deposits along the stream valleys, and the glacial deposits that occur on the plains adjacent to the deep valleys. Some gravel occurs along the major stream valley bottoms, but silt and clay frequently compose the low flood plains and terraces. Gravel deposits occur in places where these large streams make rather marked changes in the general direction of the course, such as the Smoky at Watino. The gravel deposits at such places are related to earlier river levels.

River valley gravels are not readily accessible to the highways because of the usual steepness and depth of the valleys, and deposits of glacial material on the plains above the valleys are a more desirable source, if such are available. Such deposits are best developed and most accessible north of the Peace. Gravel is available at many places along the main highway from Grimshaw to Fairview, and part of this road is already fairly well surfaced by reason of the gravelly nature of the surface through which the road passes.

Glacial deposits of gravel and coarse material are not so plentiful in the settled districts south of the Peace. In the Falher-McLennan district there are some deposits about 6 miles south of Donnelly and perhaps some may occur in the wooded areas about 10 miles to the north of Donnelly. No coarse surface material was observed between Nampa and Peace River.

The Spirit River district is also lacking in coarse material suitable for road surfacing. Some gravel is available in the valley of the Saddle river, but its recovery on a large scale would necessitate a handling of considerable unsuitable material.

Thus in general road surfacing material is apparently not readily available within most of the settled districts in this area south of the Peace. A more systematic search, however, may reveal the presence of such deposits which are at present concealed by other material.

Oil and Gas Possibilities. The chief object of the field investigation was to obtain geological information relative to the possibility of obtaining a water supply for certain districts. Areas adjacent to and in part included by that shown on the accompanying map have at times been considered as having oil and gas possibilities, consequently it seems appropriate to make a few statements relative thereto in this report.

Many of the inhabitants hold the belief that valuable reserves of oil occur in the Peace River country. It is evident that such beliefs held here as elsewhere are founded on hope rather than on definite evidence. Lithologically some of the underlying formations are suitable for the accumulation of oil, and in fact, the sequence of strata may be said to be ideal in this respect. Structural conditions appear to be favorable in places, but as in other areas that have been tested, all that is needed is the oil. This area has not been tested as to its oil and gas possibilities, although tests have been made in areas somewhat removed where lithological and structural conditions are the same or similar.

Two wells have been drilled near the north edge of the area, at the town of Peace River. Drilling commenced near the top of the Peace River formation and passed through the underlying Lower Cretaceous formations into the Palaeozoic formations below. Several other wells have been drilled along the valley of the Peace. These are distributed at varying intervals, over a distance of 30 to 40 miles north from Peace River.[37] One of the wells at Peace River, known as Victory Oil No. 1, is situated at the west end of the railway bridge, and is reported to have reached a depth of 1807 feet. At present a small quantity of gas and a strong flow of sulphurous salt water are escaping from the hole. Another well on the east side of the river just north of the town is reported to have reached a depth of 1162 feet.

Heavy oil was encountered in some wells drilled north of this area, but none proved commercially productive. In some of these wells oil-bearing sands were struck in the basal portion of the Loon River formation, which is in part a marine shale formation underlying the Peace River formation.[38] The structure along the Peace north of Peace River is not pronounced, but is in general anticlinal.

To date only the lower part of the Lower Cretaceous formations have been tested in an area to the north of Peace River. There are more pronounced dips to the strata at several places within the area mapped than along the Peace to the north where the drilling has been done. The structure of the area is described in detail in a previous chapter. The maximum dip to the south is 50 to 60 feet to the mile and occurs within an east-west belt across the southern part of the area mapped. The structures evident in Upper Cretaceous beds at the surface are not necessarily superimposed on similar structures at depth, yet it is likely that the maximum dips at depth are to a certain extent coincident in position with similar conditions at the surface.

It is not the purpose here to indicate favorable drilling sites or to recommend drilling, but in time there will likely be more tests for oil and gas made in this general area. If such are to be made, the writer feels that the more favorable structural conditions prevail south of the Peace between Watino and Spirit River.

There has been some drilling done in other areas somewhat removed from this, where a greater thickness of Cretaceous has

37 Hume, G. S., Oil and gas in western Canada, Geol. Surv., Can., Econ. Geol. Series, No. 5, Fig. 12, p. 102, 1928.
38 McLearn, F. H., Geol. Surv., Can., Summ. Rept. 1917, p. 17C.

been drilled through than by the wells at Peace River and to the north. A well was drilled at High Prairie to a reported depth of 2205 feet. It commenced drilling in the upper part of the Smoky River shales. Two wells have been drilled near the northeast corner of Lesser Slave lake. These started to drill in the upper part of the Smoky River shales. The deepest of these, International Oils No. 2, was drilled to a depth of 3105 feet. Both have been abandoned without obtaining satisfactory results.

Two wells have been drilled in the valley of Pouce Coupe river north and east of Rolla, British Columbia. One was drilled in section 26, township 80, range 13, west of 6th meridian, by the Imperial Oil Company. According to Hume[39] this well was drilled to a depth of 3057 feet and commenced in the St. John shales. A strong gas flow, estimated at 10,000,000 cubic feet per day, was struck at 1675 feet, and other flows were encountered at greater depths. A second well was drilled further south in the Pouce Coupe valley. Its location is the northwest quarter of section 19, township 79, range 13, west of 6th meridian, at the mouth of Saskatoon creek. The writer has not been able to obtain any definite information as to its depth. It started near the base of the Smoky River shales or in the upper part of the Dunvegan formation, and at present is a flowing water well.

Thus, none of the tests made in the Peace River country have proven commercially productive, although oil and gas have been struck in some wells. Most of the wells north of Peace River were drilled with a view to testing the Paleozoic formations at depth. The lower Cretaceous have been penetrated on the Pouce Coupe river at the west side of Alberta, and similar horizons have been drilled through at High Prairie and at the east end of Lesser Slave lake. The results of such drilling do not give very favorable indications as to possibilities within the area mapped, yet it is the writer's opinion that more favorable structural conditions prevail in parts of this area than in those already tested.

It is not recommended that further expenditures be made at present to test the oil possibilities within this area or those adjacent, but since such expenditures are frequently made irrespective of recommendations, it is felt that the above considerations may direct any such action to locations that appear to the writer to be the more favorable.

39 Hume, G. S., opp. cit., p. 110.

APPENDIX.

PALAEONTOLOGY.

NEW SPECIES OF FOSSILS FROM SMOKY RIVER AND DUNVEGAN FORMATIONS, ALBERTA.

BY P. S. WARREN.

INTRODUCTION.

The specimens described below form part of a collection of Cretaceous fossils obtained by Dr. R. L. Rutherford from the Smoky River shale and Dunvegan sandstone in the vicinity of Peace and Smoky rivers in north-central Alberta. These formations correspond, in part at least, to the Colorado shale as developed in the foothills region of Alberta. The collections proved interesting on account of the large number of new species which appear, and which, in many cases, dominate the fauna. Although new species in themselves may be of little value to science, the initiation of so many new forms in this area points to a considerable change in the character of the fauna of the Colorado group of formations in its extension through northern Alberta. This change in the character of the fauna may be more apparent than real and further collections may show closer affinities between the faunas of the two areas; nevertheless, sufficient collections have now been obtained from these areas to demonstrate the major features of both faunas, and additional collections appear to accentuate their differences rather than their similarities.

Although many new species are introduced in the formations on the Peace and Smoky rivers, the main zone fossils of the Colorado shale of the foothills[40] are present. *Inoceramus labiatus* Schlotheim occurs in the collections from the lower member of the Smoky River shale, though not in any great abundance. Species of *Prionotropis* occur sparingly in the lower part of the Smoky River shale, but it is doubtful, from our present knowledge of its distribution, if the genus will be of much value as a zone fossil. The main types of the Niobrara fauna *Scaphites vermiformis* M. & H., *Scaphites ventricosus* M. & H., and *Baculites* of the *asper* type are well represented in the upper part of the lower member of the Smoky River shale and in the Bad Heart sandstone. *Baculites ovatus* Say, the typical form in the upper beds of the Colorado shale group of the foothills, is present in the upper member of the Smoky River shale. The occurrence of these zone fossils in both areas makes the correlation of the two groups of formations comparatively simple.

40 Warren, P. S., and Rutherford, R. L., Fossil zones in the Colorado shale of Alberta, A.J.S., Vol. XVI, pp. 129–136, 1928.

McLearn[41] initiated the study of the Coloradoan faunas in the Peace and Smoky River area in listing and describing many species and correlating the formations with the Colorado group in other areas. The fauna described below supplements McLearn's list and produces additional evidence of the change in character of the fauna in the northern extension of the Colorado formations. Further evidence is submitted, also, regarding the extension of various fossil zones as defined in the Colorado shale of the foothills of Alberta in Chapter III.

The uppermost zone of the Colorado group as defined in the Great Plains region of United States is marked by such forms as *Scaphites vermiformis* M. & H., *Scaphites ventricosus* M. & H., *Inoceramus umbonatus* M. & H., and *Baculites* of the *asper* type. The horizon producing this fauna in the foothills of Alberta has been termed the *Scaphites* zone[42] and has been correlated with the Niobrara of the Great Plains region and the Coniacian of European stratigraphers. In the Peace and Smoky River area this zone is contained in the Bad Heart sandstone and extends downward at least 200 feet into the lower, or Kaskapau, member of the Smoky River shale.

The upper member of the Smoky River shale contains a Montana fauna exemplified in our collections by *Desmoscaphites bassleri* Reeside, and *Baculites ovatus* Say. This fauna is contained in the uppermost beds of the Colorado shale group in the foothills, and the horizon is known as the *Baculites ovatus* zone, on account of the prominence of that species. *Desmoscaphites bassleri* serves to correlate this fauna with the lowest Montana faunas in the western interior of the United States. The occurrence of *Desmoscaphites bassleri* and *Baculites ovatus* in the upper member of the Smoky River shale leads to a correlation of the overlying Wapiti formation with the lower part of the Saunders formation of the foothills which there immediately overlies the Colorado shale beds containing a similar fauna.

In the lower part of the Smoky River shale a fauna is obtained which differs conspicuously from those occurring at higher horizons. The well known pelecypod *Inoceramus labiatus* Schlotheim is present, permitting a correlation with the lower portion of the Colorado shale of the foothills, the Greenhorn limestone of the Great Plains region of the United States, and the Turonian of European stratigraphers. The present known range of *Inoceramus labiatus* in the Smoky River shale is in the lower 350 feet of the formation. It is accompanied by such forms as *Acanthoceras albertense* Warren, *Scaphites delicatulus* Warren, *Watinoceras reesidei Warren*, the genus *Prionotropis* and other *Inocerami*. It should be noted here that all the ammonites were collected from the base of the formation.

In the foothills region, the genus *Prionotropis* occurs most abundantly just above the *Inoceramus labiatus* zone, and has also been collected there just below the main *I. labiatus* zone. Such

41 McLearn, F. H., New species from the Coloradoan of lower Smoky and lower Peace rivers, Alberta, Geol. Surv., Can., Bull. 42, pp. 117–126, pl. 20–23, 1926.

42 Warren, P. S., and Rutherford, R. L., loc. cit.

distribution of the genus does not apply in the Peace and Smoky area so far as is shown in our present collections.

The Dunvegan sandstone, underlying the Smoky River shale, contains a varied fauna, a greater part of which is not known outside of this area. Species of diagnostic value are lacking and no exact correlation can be attempted at present. The typical Turonian form, *Inoceramus labiatus*, is not present in the collections from the formation, and it is possible that a lower horizon than the Turonian is represented.

The fauna collected by Dr. Rutherford from the Dunvegan sandstone is listed in Chapter III.

DESCRIPTION OF NEW SPECIES.

Inoceramus rutherfordi sp. nov.

Plate VII, figs. 1, 2 and 3.

Description.—Shell equivalve, irregular and variable in shape, strongly convex, higher than long. Beaks anterior, incurved, curved slightly forward and produced a little beyond the hingeline. Anterior part of shell sharply truncate and slightly concave. Post-umbonal slope prominent, irregularly rounded and marked on the posterior portion by a strongly defined but irregular sulcus extending nearly to the beaks. Posterior part of shell strongly compressed, rather alate and sharply separated from the post-umbonal slope by a prominent ridge bounding the posterior border of the sulcus. Surface ornamented by rather strong but irregular concentric undulations. Dimensions of a nearly perfect left valve: height 70 mm., length 60 mm., convexity 25 mm.

Remarks.—This species has been described from two left valves and one right one, none of which is complete. The variability in shape is a conspicuous feature, being especially noticeable in the compressed posterior portion and the lower margin. The convexity also varies greatly, the figure given in the description being the lowest for the three specimens.

This shell bears a close relationship to *I. cordiformis* Sow. It differs especially in its less prominent umbones and more prominent sulcus on the post-umbonal slope.

The species is named for Dr. R. L. Rutherford of the Geological Department, University of Alberta.

Catalogue Nos. of cotypes, Ct. 410-412, Geol. Mus., Univ. of Alta.

Location and horizon.—The specimens were obtained in talus blocks from the basal beds of the Dunvegan formation on Smoky river near the mouth of Racing creek.

Inoceramus mcconnelli sp. nov.

Plate IV, figs. 1, 2 and 3.

Description.—Shell equivalve, of medium size, thin, sub-quadrate to sub-ovate in outline, moderately convex, higher than long. Beaks at the anterior end of the hingeline, sharp, slightly incurved and curved slightly forward, rising considerably above the hingeline. Post-umbonal slope conspicuous and rather narrowly rounded in most specimens, inclining sharply to the anterior margin and more gently to the posterior margin. Anterior margin rounded, extending considerably forward beyond the beaks. Lower margin regularly rounded (as shown by the concentric ornamentation). Posterior margin nearly straight. Postero-dorsal area flat. Ornamentation consisting of irregular, poorly defined, concentric undulations, hardly noticeable on the upper part of the shell, but more strongly expressed on the lower part. Dimensions of an incomplete valve: height 55 mm., length 40 mm., convexity 15 mm.

Remarks.—Several specimens of this shell have been examined, none of which are complete. There seems to be a considerable variation in the convexity of the post-umbonal slope, some being more sharply rounded than others. The margin of the shell is imperfect in all the specimens, but the configuration of the outline may be inferred from the concentric ornamentation.

This form may be compared quite favorably with McLearn's species *I. selwyni.* It differs chiefly in being a smaller form, much less convex, with a thinner shell and less conspicuous ornamentation. The shell is larger and lacks the strong corrugations of *I. costellatus* Woods, from the chalk of England.

The species is named for Mr. R. G. McConnell, one of the original geological explorers in this area.

Catalogue Nos. of cotypes, Ct. 417-418, Geol. Mus., Univ. of Alta.

Horizon and locality.—In drift, north bank of Peace, section 3, township 80, range 3. Dunvegan beds, horizon uncertain.

Inoceramus tyrrelli sp. nov.

Plate VI, fig. 1.

Description.—Shell equivalve, of medium size, thin, sub-rhombic in outline, moderately convex, longer than high. Beaks anterior, protruding beyond the anterior margin, slightly incurved and curved slightly forward, rising slightly above the hingeline. Hingeline long. Anterior part sharply truncated and straight on the upper part, concave beneath the umbones, rounding to the ventral margin. Post-umbonal slope gently rounded, with a tendency to flatten in the medial portion. Posterior part declining gently from the post-umbonal region to a depressed postero-dorsal area. Surface ornamented by rather sharply defined irregular undulations, becoming indistinct in the lower part of the shell and becoming subdivided there into finer corrugations. Dimensions of a nearly perfect left valve: height 65 mm., length 75 mm., convexity 15 mm.

Remarks.—The ornamentation seems to vary on different specimens, but this is rather a characteristic feature of the genus *Inoceramus.* Of the specimens examined, the sculpture varies in strength rather than in kind, one specimen being nearly smooth. The ornamentation is reminiscent of that of *I. labiatus* Schlotheim, and the shape of the shell, especially in an imperfect condition, may be compared rather favorably with that species. It differs, however, from Schlotheim's form in the greater length of the shell, the more prominent truncated anterior portion, and in the shape of the lower margin which in *I. labiatus* is generally quite regularly rounded.

The species is named for Dr. J. B. Tyrrell, geologist and explorer.

Catalogue Nos. of cotypes, Ct. 415-416, Geol. Mus., Univ. of Alta.

Horizon and locality.—Smoky River shale on Howard creek, north of Spirit River in N.E. ¼ section 16, township 79, range 6, west of 6th meridian; stratigraphical horizon approximately 300 to 350 feet above the base of the Smoky shales. Loc. 17.

Inoceramus tenuiumbonatus sp. nov.

Plate VI, figs. 2 and 3.

Description.—Shell of medium size, thin, subovate in outline, erect, moderately convex, higher than long. Beaks anterior, strongly incurved and curved forward, rising considerably above the hingeline. Hingeline short. Umbones narrow, attenuate. Anterior part curving sharply to the front margin, being concave beneath the umbones. Post-umbonal slope regularly rounded. Posterior part curving less abruptly than the anterior part to the margin; a small compressed area behind the beaks. Surface ornamented by wide, rather ill-defined, concentric^corrugations; faint traces of longitudinal striations present on the internal mold. Dimensions of a nearly perfect left valve: height 110 mm., length about 70 mm., convexity, 25 mm.

Remarks.—This species is not liable to be confused with other Cretaceous Inocerami of North America, the distinctive features being the erect attitude, the attenuated umbones and the character of the ornamentation. It bears a considerable resemblance to a large specimen of *I. concentricus* Parkinson from the Gault of England, but differs in its less prominent umbones and its ornament.

Catalogue No. of holotype, Ct. 414, Geol. Mus., Univ. of Alta.

Horizon and locality.—Smoky River shale, north of Spirit River in N.E. ¼ section 16, township 79, range 6, west of 6th meridian; stratigraphical horizon approximately 300 to 350 feet above the base of the Smoky River shales. Loc. 17.

^ **undulations on which are superimposed finer concentric**

Inoceramus allani sp. nov.

Plate III, fig. 1.

Description.—Shell large, thin, sub-ovate to sub-quadrate in outline, moderately convex, higher than long. Beaks anterior, not incurved, projecting slightly forward and above the hingeline. Anterior part of shell sharply truncate and strongly concave in outline. Post-umbonal slope well rounded, expanding and flattening toward the bottom, the line of greatest convexity down the slope curving in conformity with the anterior outline. Posterior part of shell compressed, the division between the post-umbonal slope and the depressed area being quite sharply defined. Bottom and posterior margins rounded. Surface ornamented by wide, ill-defined, concentric undulations, on which are superimposed finer corrugations. Dimensions of a nearly perfect right valve: height 130 mm., length about 120 mm., convexity 40 mm.

Remarks.—This species compares very favorably with some forms of the variable species *I. fragilis* H. & M. It compares most favorably with the smaller specimens, the larger specimens attaining a much different outline. The points of difference that may be mentioned are the much larger size of our specimen, the more strongly concave anterior outline, the large compressed anterior area and the finer corrugations on the surface. The anterior margin forms an angle of about 100 degrees with the hingeline, rather than 90 degrees as in *I. fragilis*, and by reason of this greater deflection of the anterior margin, the lower anterior portion of the shell extends considerably in front of the beaks.

In respect to its general shape, this species resembles *I. pictus* Sowerby from the chalk of England. It is, however, a larger and wider shell than Sowerby's species and the ornament is entirely different.

The species is named for Dr. J. A. Allan, Professor of Geology, University of Alberta.

Catalogue No. of holotype, Ct. 413, Geol. Mus., Univ. of Alta.

Horizon and locality.—Loc. 16a, Smoky River shale on Howard creek, section 13, township 79, range 6, west of 6th meridian; stratigraphical horizon 250 to 300 feet above the base of the formation.

Ostrea dunveganensis sp. nov.

Plate VII, figs. 4-8.

Description.—Shell variable in size, usually small, thin, sub-ovate in outline but often distorted. Lower (left) valve convex, usually uneven and distorted by the attachment scar. Upper (right) valve flat and usually showing little distortion. Surface, where well preserved, marked by imbricating lamellae.

Remarks.—The variations expressed in a collection of these shells leads to a suspicion that more than one species is represented, but an attempt to divide the various specimens into definite groups proved a failure. Some specimens are very regular, in others the beak is twisted to the side, while certain ones are badly distorted by the attachment scar which may occupy nearly half the valve. With a larger collection, definite varieties may be delimited.

The species may be distinguished from *O. congesta* Conrad, with which it may be confused, by its larger size. It has also a different configuration, being more ovate than Conrad's species. It differs from *O. anomioides* Meek chiefly in its much more prominent beak and in the character of the ornamentation.

Catalogue Nos. of cotypes, Ct. 427-441, Geol. Mus., Univ. of Alta.

Horizon and locality.—Dunvegan sandstone, Loc. 13 and 6. Within the upper 300 feet of the Dunvegan sandstones on Hines river, in N.W. ¼ section 13, township 80, range 5, west of 6th meridian.

Genus Psammosolen Risso.

Psammosolen dunveganensis sp. nov.

Plate IV, fig. 6.

Description.—Shell thin, twice as long as high, sub-ovate in outline, moderately convex, gaping at both ends. Beaks small, central in position, curved slightly forward and rising moderately above the hingeline. Cardinal margin nearly straight, being slightly elevated behind the beaks. Nymphs apparently present. Anterior end regularly rounded; lower margin nearly straight and parallel to the cardinal margin; posterior end slightly truncate. Shell slightly flattened medially. Surface marked by distinct concentric furrows. Dimensions of a left valve: height 17 mm., length 34 mm., convexity 5 mm.

Remarks.—The reference of this shell to Risso's genus is attended with some doubt, as the typical ornamentation of that genus cannot be made out on our specimen, which is badly exfoliated. The fine, oblique lines, typical of the genus *Psammosolen* would only be shown on well preserved specimens. The teeth of our specimen are also obscured, but the general character of the shell seems to make the reference to Risso's genus most likely.

The only other shell in the Alberta Cretaceous described to this genus is *P. taylori* Warren, from the Birch Lake sandstone.[43]. These two forms may be readily distinguished by the general shape of the shell, though the dimensions of the two species are quite similar.

Catalogue No. of holotype, Ct. 442, Geol. Mus., Univ. of Alta.

Horizon and locality.—Dunvegan sandstone, Loc. 11. Basal beds on Little Burnt (Leith) river, legal subdivision 5, section 16, township 80, range 1, west of 6th meridian.

43 A marine fauna in the Birch Lake sandstone, Alberta, Trans. Roy. Soc. Can., 3rd Ser., Vol. XX, Sec. IV, 1926, p. 13.

Pteria linguiformis var. *borealis* var. nov.

Plate IV, figs. 4 and 5.

This variety bears a close resemblance to Meek's variety *subgibbosa*.[44] It differs in its less sinuous outline, and consequently less conspicuous auriculations, and its narrower base.

Pteria linguiformis (E. & S.) in its typical development in the Bearpaw of Alberta shows considerable variation in size and minor features of outline. Well developed auriculations are, however, generally present. Specimens approaching the form of the variety *subgibbosa* have been observed, but on account of the variability of the species, have not been designated by the varietal name by the writer. The reason for this attitude is that there seemed to be no clear-cut division between the various forms, and they appeared also to have no stratigraphic significance. The present variety, however, occurs at a lower horizon, in conjunction with a typical Niobrara fauna, so it seems preferable for the present to regard these specimens as distinct from the Bearpaw forms.

Catalogue Nos. of cotypes, Ct. 422-425, Geol. Mus., Univ. of Alta.

Horizon and locality.—Bad Heart sandstone, Loc. 19a, one mile south of Wanham station, legal subdivision 8, section 4, township 78, range 3, west of 6th meridian.

Genus Baculites Lamarck.

The genus *Baculites* is well represented in the collections from the lower part of the Smoky River shales. The genus proved troublesome in making specific determinations, as variations in the suture as well as minor features in shape and ornament are multitude. Most of the specimens are ascribed to new species, only one specimen of *Baculites asper* Morton and three of *B. codyensis* Reeside being identified.

In determining the authenticity of each of the new species erected to receive this variable collection of forms, it seemed advisable to combine some definite character of the suture with some definite external feature. This proved satisfactory for most of the forms in the collection and three well-marked species were separated. A larger collection may show forms intermediate between any two of these species, but it seems preferable for the present to regard the three specified groups as distinct.

Baculites albertensis sp. nov.

Plate V, figs. 5-8, 10 and 13.

Description.—Shell gradually tapering, sub-ovate in section, with the flanks of the siphonal side slightly more compressed laterally. Ornament consisting of regular, well-developed, arcuate nodes on the antisiphonal flanks, produced diagonally upwards on

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44 U.S.G.S. Terr., Vol. IX, p. 33, Pl. 28, fig. 12.

the siphonal flanks as inconspicuous ribs. Suture especially characterized by a strong anti-siphonal lobe and a small bifid lobe on the siphon. Dimensions of a section of a septate specimen 14 mm.×11 mm.

Remarks.—The forms ascribed to this species bear a considerable resemblance to *B. codyensis* Reeside. The ornament does not differ essentially, but the shell is larger and stouter than Reeside's species, and the suture differs especially in the character of the small lobe on the siphon.

Catalogue Nos. of cotypes, Ct. 446, 458-461, Geol. Mus., Univ. of Alta.

Horizon and locality.—Smoky River shale, Loc. 1. Estimated to be 500 to 600 feet above the base of the Smoky River shales, Little Smoky river, legal subdivision 13, section 24, township 75, range 22, west of 5th meridian.

Baculites borealis sp. nov.

Plate V, figs. 3, 4, 9 and 14.

Description.—Shell gradually tapering, sub-ovate in section with the flanks of the siphonal side slightly more compressed laterally. Ornament consisting of strong, regular, close-set, arcuate nodes on the flanks, produced diagonally upwards on the siphonal side as conspicuous ribs. Suture especially characterized by a long, anti-siphonal lobe and a prominent bifid lobe bisecting the saddle of the siphonal lobe. Dimensions of a section of a septate speciment, 16 mm.×13 mm.

Remarks.—This species differs from *B. albertensis* in its stouter form and more closely set nodes. The nodes differ also in extending over nearly the whole flank of the shell and in being more nearly semi-circular. The suture differs especially in its narrower lobes, the long anti-siphonal lobe and the strong bifid lobe on the siphon.

Catalogue Nos. of cotypes, Ct. 465-466, Geol. Mus., Univ. of Alta.

Horizon and locality.—Smoky River shale, Loc. 1. Estimated to be 500 to 600 feet above the base of the Smoky shale, Little Smoky river, legal subdivision 13, section 21, township 75, range 22, west of 5th meridian.

Baculites trifidolobatus sp. nov.

Plate V, figs. 1, 2, 11 and 12.

Description.—Shell gradually tapering, sub-ovate in section, siphonal side more compressed laterally. Ornament consisting of rather distinct arcuate nodes on the anti-siphonal flanks produced upwards as inconspicuous ribs on the siphonal flanks. Suture especially characterized by the small trifid lobe bisecting the saddle of the siphonal lobe and the trifid character of the terminals of the other lobes. Dimensions of a section of a septate specimen, 14 mm.×11 mm.

Remarks.—This species is characterized by the smoother character of the shell, especially in the older stages. Young specimens have fairly well developed nodes, but in the upper portion of the shell the nodes are farther apart and indistinct. The trifid character of the lobes is a distinctive feature.

Catalogue Nos. of cotypes, Ct. 462, 463, 464, Geol. Mus., Univ. of Alta.

Horizon and locality.—Smoky River shales, Loc. 1. Estimated to be 500 to 600 feet above the base of the Smoky shales, Little Smoky river, legal subdivision 13, section 24, township 75, range 22, west of 5th meridian.

Scaphites delicatulus sp. nov.

Plate III, fig. 3; Plate IV, figs. 7 and 8.

Description.—Shell small, elliptical, stout. Whorls depressed, broadly rounded on the venter, sharply rounded on the flanks. Living chamber, commencing at the point of straightening, subquadrangular in outline, a notable swelling on the flanks at its base; aperature contracted. Ornament consisting of primary ribs on the umbilical area terminating in a strong, sharp node on the mid-line of the flank; thence dividing into two or three secondary ribs with one or two intercalated ribs, all crossing the venter evenly. Number of primary ribs on the last whorl of the septate portion about 13. Suture of the normal scaphite type, the elements becoming progressively smaller toward the umbilical border.

Remarks.—This little form is characterized by the fine but sharply defined sculpture, especially on the septate portion. On the living chamber the primary ribs disappear and the secondary ribs and nodes become less distinct toward the aperature. The species may be compared quite favorably with Reeside's *S. stantoni.* It differs, however, in the more compressed form of whorl, the more delicate ornamentation and the character of the swelling on the living chamber.

Catalogue Nos. of cotypes, Ct. 417-421, Geol. Mus., Univ. of Alta.

Horizon and locality.—Lower part of Smoky River shale, Loc. 2. Within the lower 50 feet of Smoky shales on Smoky river, N.W. ¼ section 21, township 77, range 24, west of 5th meridian.

Family *Mantelliceratidae* Hyatt.

Genus *Watinoceras* gen nov.

Discoidal forms, slightly involute and laterally compressed. Costae generally alternating in length, not crossing the venter, developing two rows of nodes on each side of the venter and occasional nodes on the umbilical border in gerontic stages.

The genus has been erected to receive one species which is described below.

Watinoceras reesidei sp. nov.

Plate III, fig. 2; Plate IV, figs. 9-12.

Description.—Shell discoidal, slightly involute, laterally compressed. Whorls of at least five volutions, gradually enlarging, higher than wide. Dimensions of a whorl at the base of the living chamber: height 6 mm., width 5 mm. Sides of whorl rather flattened, rounding gently to the venter and more abruptly to the umbilicus. Umbilicus wide, representing about one-half the diameter of the shell. Depressed area representing not more than one-sixth the height of the whorl. Costae sharply defined, generally alternating in length, sometimes bifurcating especially on the younger whorls. Primary costae extending over the umbilical shoulder; secondary costae usually not reaching the umbilicus. No costae crossing the venter, but developing two rows of nodes on each side of the smooth venter. Inner rows (nearest the siphon) more conspicuous than the outer rows. Umbilical nodes also present on some primary septae on the living chamber of larger forms. Total number of costae on ultimate whorl of hototype, 42, of which about 24 reach the umbilicus. All costae inclined forward and slightly sigmoidal. Suture simple, with wide saddles and narrow lobes. First lateral saddle over twice as wide as the siphonal or first lateral lobe and nearly twice as wide as the second lateral saddle. At least two adventitious lobes.

Remarks.—It seems appropriate to erect a new genus for the reception of this little ammonite. It undoubtedly belongs to the family Mantelliceratidae of Hyatt and in some points compares quite favorably with the genus *Mantelliceras* Hyatt. This genus has been variously construed by different authors, but in comparison with types of the genus *Ammonites mantelli* from the Chalk in England, our genus has essentially a much wider umbilicus and differs also in points of ornament. Our form has a closer affiliation with *Acanthoceras coloradoense* Henderson[45] from the same horizon in Colorado. It differs essentially in its smaller size, alternation of costae and minor details of ornament. It seems evident, however, from an examination of plaster casts of Henderson's species, kindly provided by Dr. J. B. Reeside Jr., of the United States Geological Survey, that the inner whorls of *A. coloradoense* more closely approximate those of our species. The two forms, however, must be considered generically distinct for the present.

The species is named for Dr. J. B. Reeside Jr. of the United States Geological Survey, whose generous assistance in the determination of various Cretaceous ammonites is much appreciated by the writer.

45 Henderson, J., New species of Cretaceous invertebrates from northern Colorado, Proc. U.S. Nat. Mus., Vol. XXXIV, p. 259, pl. XIII, figs. 10, 11, 1908.

Catalogue Nos. of types: holotype, Ct. 478; paratypes, Ct. 479-481, Geol. Mus., Univ. of Alta.

Horizon and locality.—Lower 50 feet of the Smoky River shale, on Smoky river near Watino, Alberta, N.W. ¼ section 21, township 77, range 24, west of 5th meridian.

EXPLANATION OF PLATE III.

(All figures are natural size except where stated otherwise. The numbering of the specimens is according to the catalogue of the geological museum, University of Alberta.)

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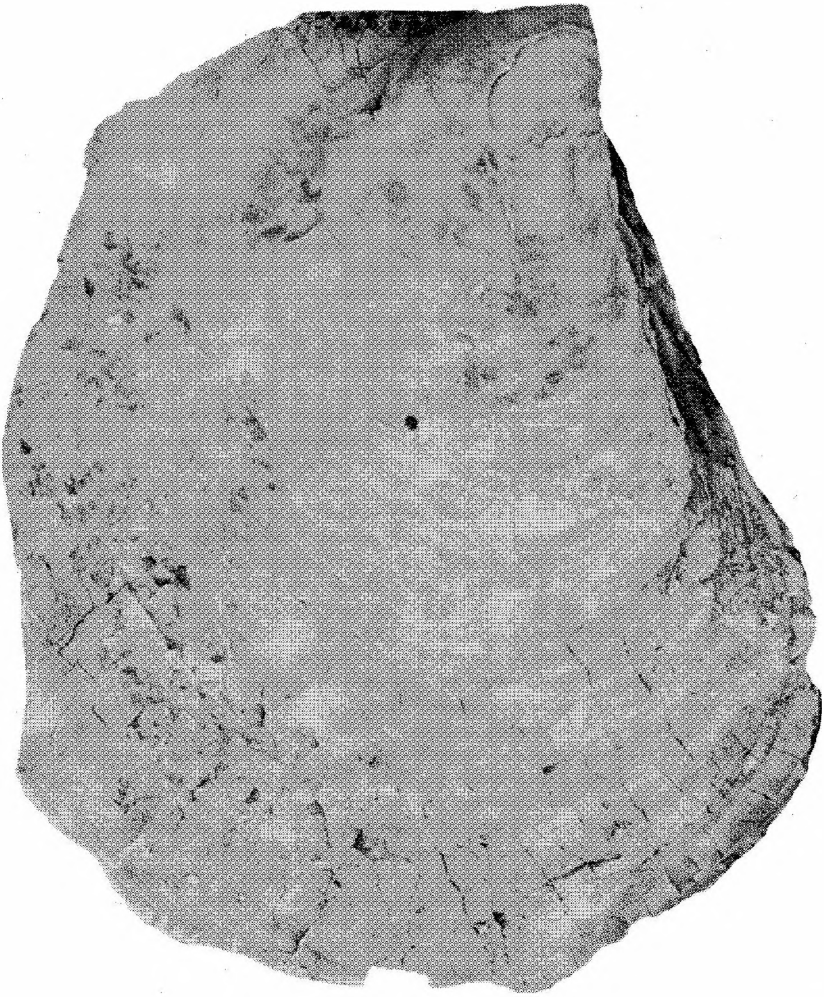
Inoceramus allani Warren	62
Fig. 1. View of holotype. No. Ct. 413.	
Watinoceras reesidei Warren	67
Fig. 2. View of suture line. x 4.	
Scaphites delicatulus Warren	66
Fig. 3. View of suture line. x 4.	



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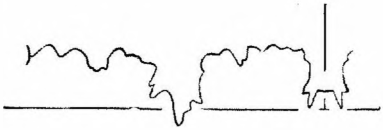

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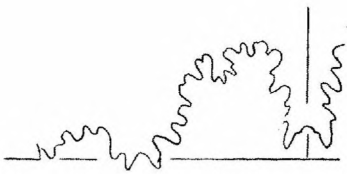

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PLATE III.

EXPLANATION OF PLATE IV.

PAGE.

Inoceramus mcconnelli Warren 60

Fig. 1. View of imperfect left valve. Cotype. No. Ct. 418.

Fig. 2. View of imperfect right valve. Cotype. No. Ct. 417.

Fig. 3. Anterior view of cotype. No. Ct. 418.

Pteria linguiformis var *borealis* Warren 64

Figs. 4 & 5. Views of imperfect right valves. Cotypes. Nos. Ct. 425 and 422.

Psammosolen dunveganensis Warren 63

Fig. 6. View of the holotype. Ct. 442.

Scaphites delicatulus Warren........ 66

Figs. 7 & 8. Views of a nearly perfect specimen. Cotype No. Ct. 419.

Watinoceras reesidei Warren 67

Fig. 9. View of a nearly perfect specimen. Holotype. No. Ct. 478.

Figs. 10, 11, 12. Views of imperfect specimens. Paratypes. Nos. Ct. 479, 480, 481.

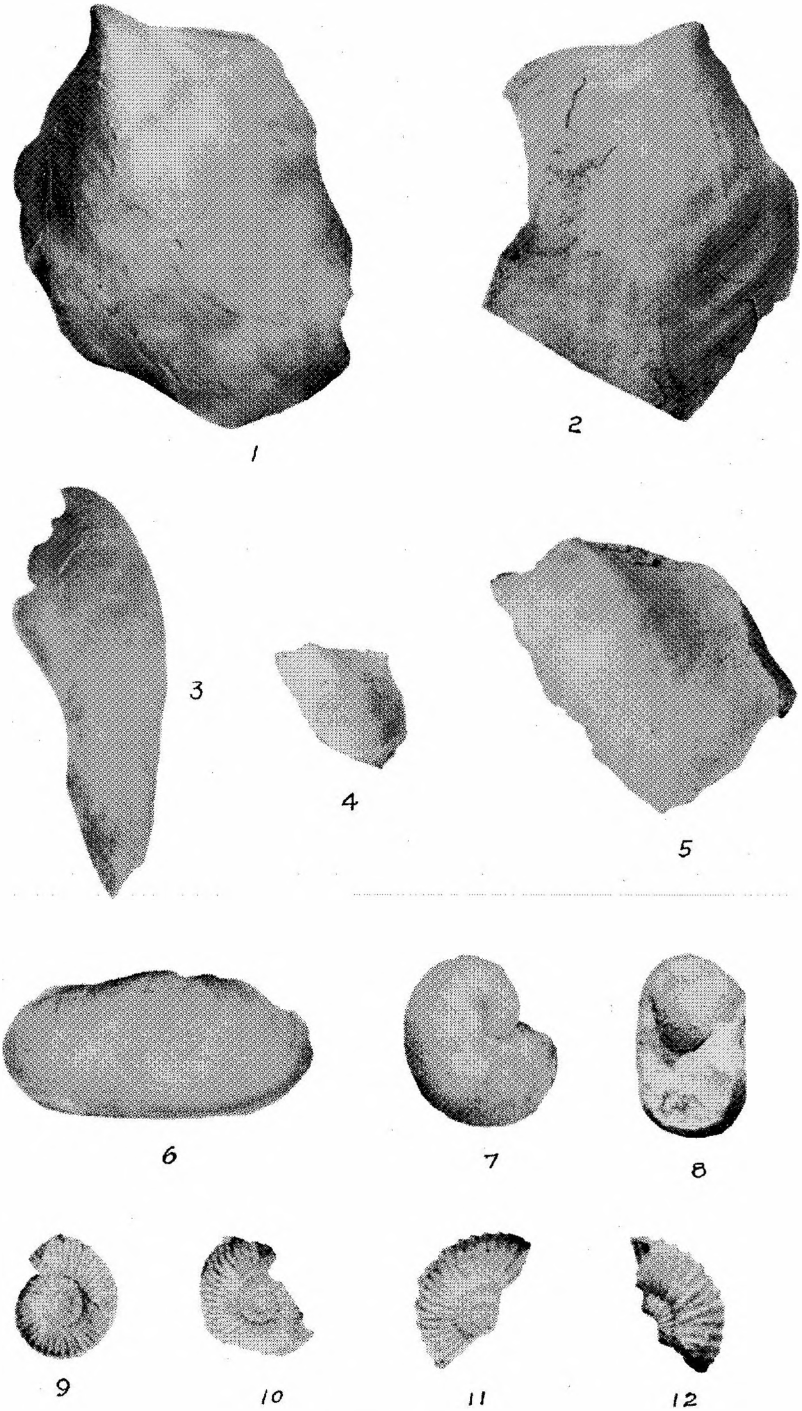


PLATE IV.

EXPLANATION OF PLATE V.

PAGE.

Baculites trifidolobatus Warren — 65

Fig. 1. Side view of cotype. No. Ct. 462.

Fig. 2. Antisiphonal view of the same specimen.

Fig. 11. Outline of cross-section of a septate portion of the same specimen.

Fig. 12. The suture of the same specimen. x 2.

Baculites borealis Warren — 65

Figs. 3 and 4. Side and antisiphonal view of a septate portion of a cotype. No. Ct. 465.

Fig. 9. Outline of a cross-section of the same specimen.
Fig. 14. The suture of the same specimen. x 2.

Baculites albertensis Warren — 64

Figs. 7 and 8. Side and antisiphonal view of a septate portion of a cotype. No. Ct. 458.

Figs. 5 & 6. Antisiphonal and side views of a living chamber. Cotype. No. Ct. 446.

Fig. 10. Outline of cross-section of a septate portion of a cotype. No. Ct. 458.

Fig. 13. The suture of the same specimen. x 2.

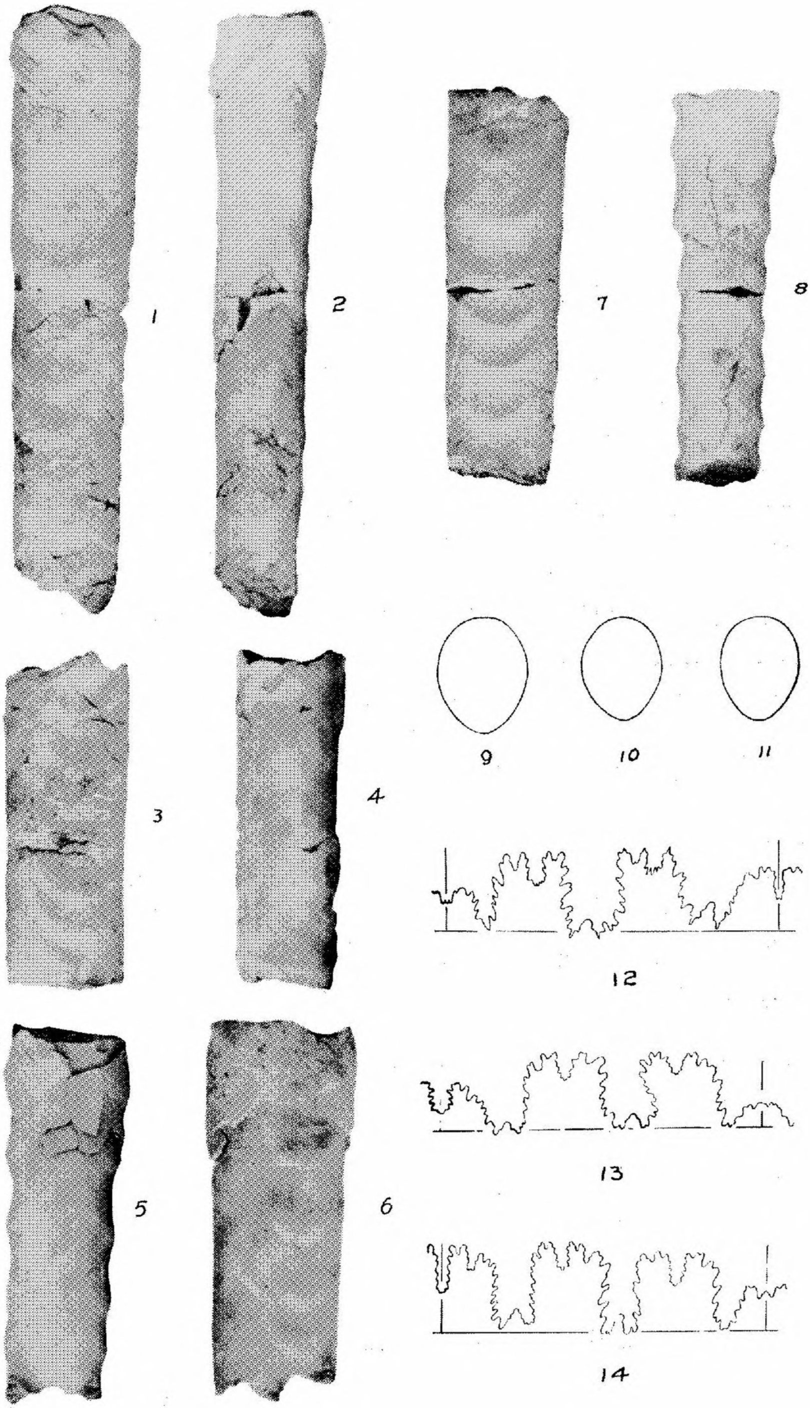


PLATE V.

EXPLANATION OF PLATE VI.

PAGE.

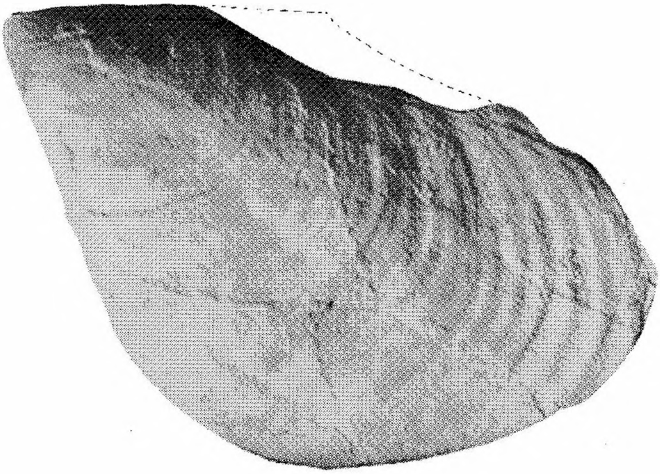
Inoceramus tyrrelli Warren 60

Fig. 1. View of a cotype. No. Ct. 416.

Inoceramus tenuiumbonatus Warren 61

Fig. 2. View of holotype. No. Ct. 414. The position and attitude of the hingeline is shown by the dotted line, but the extent and character of the posterior part is not known.

Fig. 3. Anterior view of the holotype, showing the incurving of the beak.



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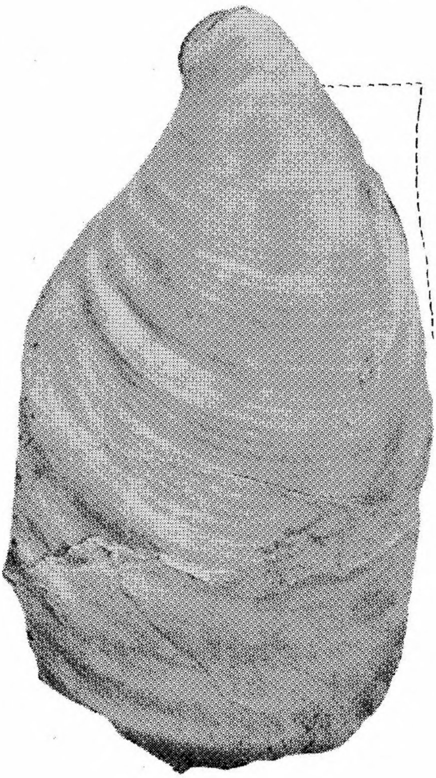

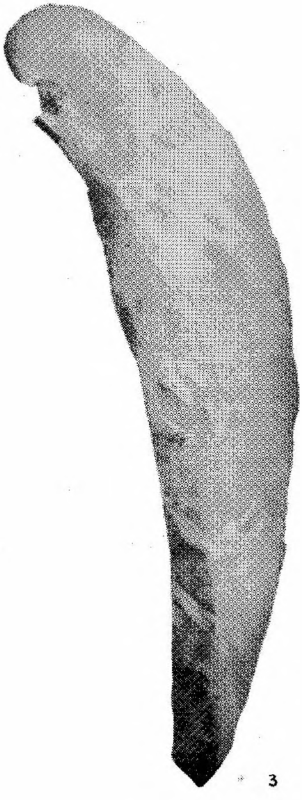

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PLATE VI.

EXPLANATION OF PLATE VII.

PAGE.

Inoceramus rutherfordi Warren 59

Fig. 1. Imperfect specimen of left valve. Cotype. No. Ct. 411.

Fig. 2. Imperfect specimen of right valve. Cotype. No. Ct. 412.

Fig. 3. Anterior view of cotype, No. Ct. 411, showing small pointed beak.

Ostrea dunveganensis Warren 62

Figs. 4 & 7. View of two upper valves showing variation in size and shape. Cotypes. Nos. Ct. 427 and 438.

Figs. 5, 6 & 8. View of lower valves showing variation in size and shape. Fig. 8 shows the attachment scar. Cotypes. Nos. Ct. 435, 434 and 431.

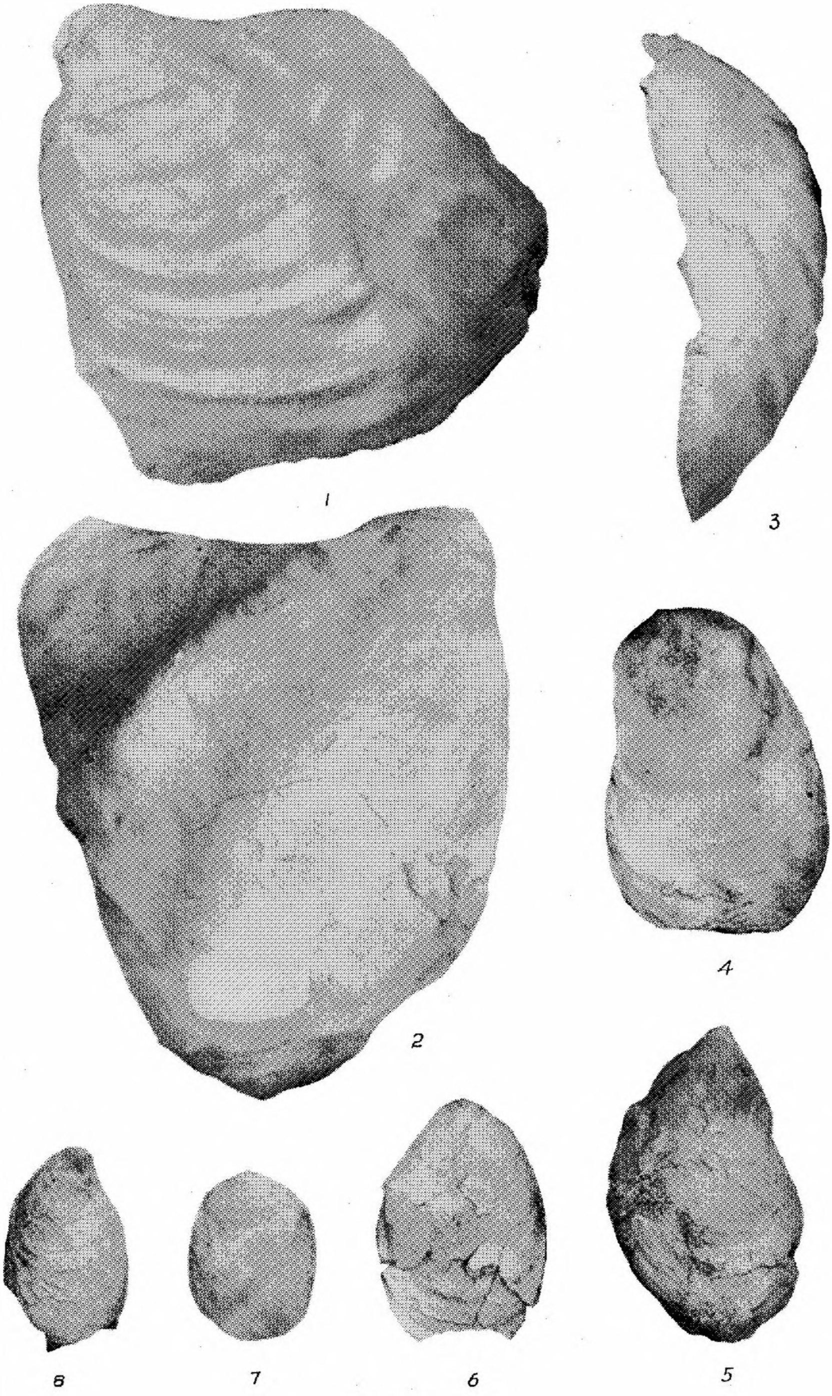

PLATE VII.

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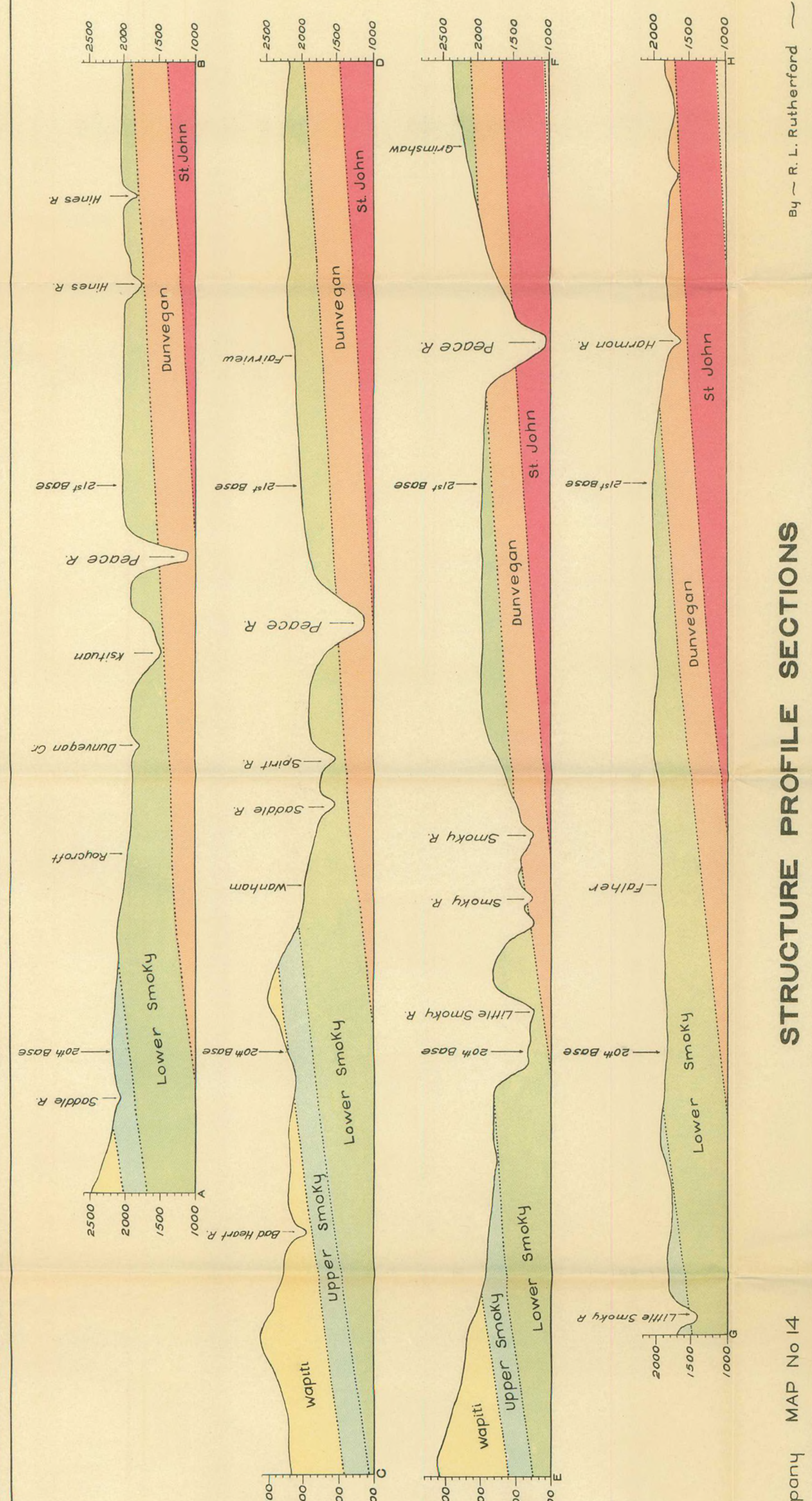
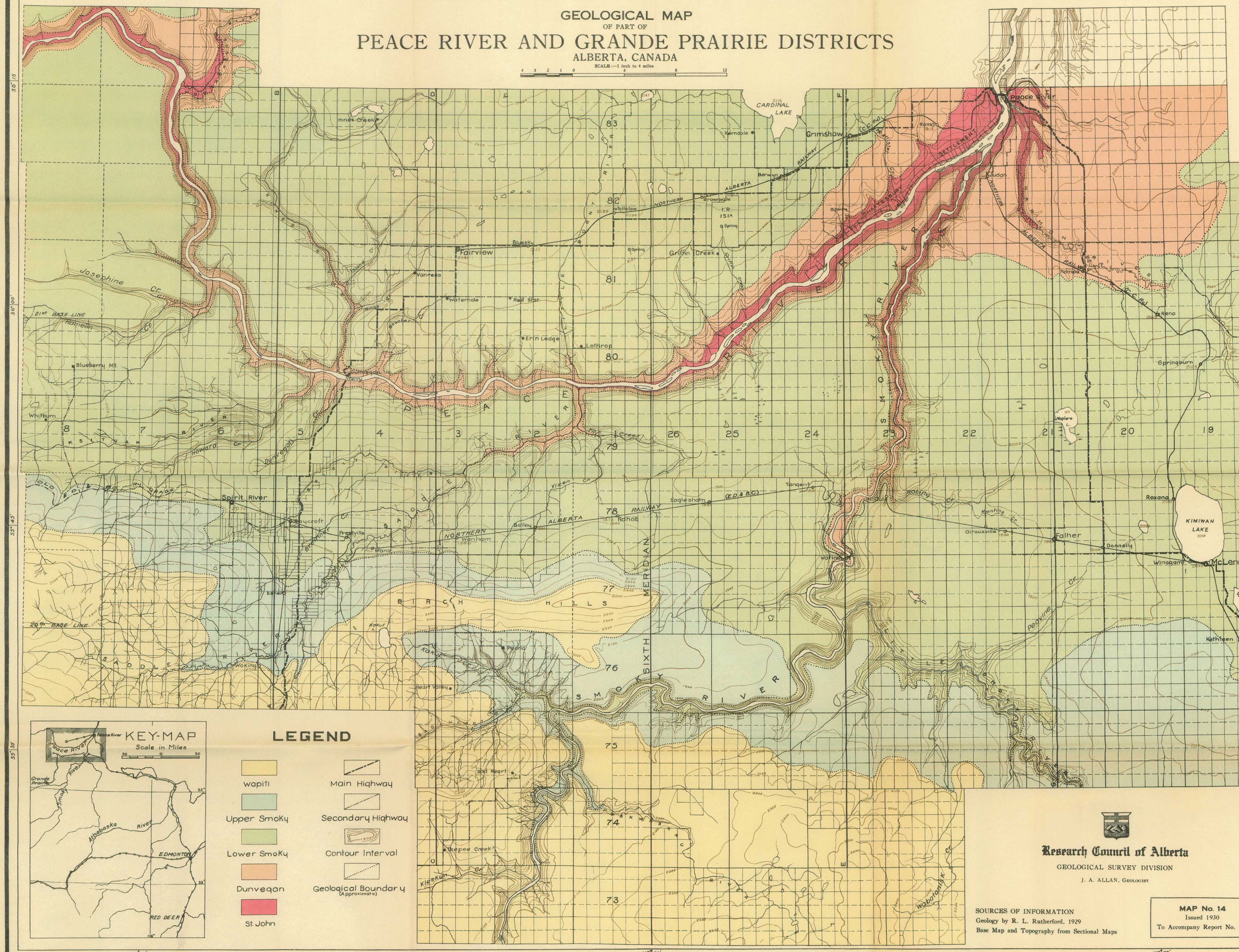


GEOLOGICAL MAP OF PART OF PEACE RIVER AND GRANDE PRAIRIE DISTRICTS

ALBERTA, CANADA

SCALE :—1 inch to 4 miles



Research Council of Alberta

GEOLOGICAL SURVEY DIVISION

J. A. ALLAN, GEOLOGIST

SOURCES OF INFORMATION

Geology by R. L. Rutherford, 1929

Base Map and Topography from Sectional Maps

MAP No. 14

Issued 1930

To Accompany Report No. 21