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MEMOIR 239

MESOZOIC STRATIGRAPHY OF THE EASTERN PLAINS, MANITOBA AND SASKATCHEWAN

BY

R. T. D. Wickenden

OTTAWA
EDMOND CLOUTIER
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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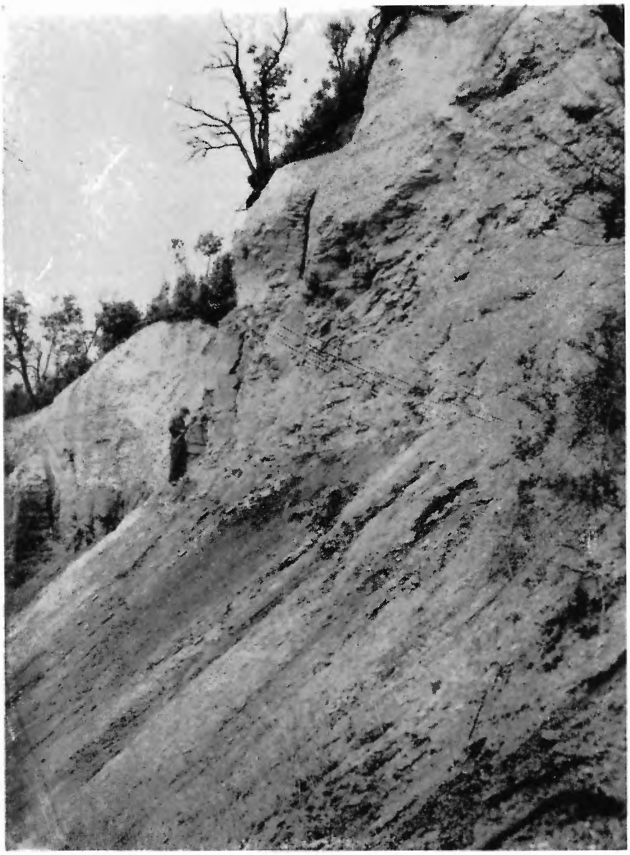

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Exposure of Boyne beds, Vermilion River formation, on north side of Pembina Valley, showing massive calcareous shale or impure limestone near top of the member. (Page 35.)

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CHAPTER VI

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CHAPTER I

INTRODUCTION

GENERAL STATEMENT

This report deals with an area of 36,700 square miles underlain by Mesozoic formations. The area (*See* Figure 1) lies mainly east of the Second meridian, or longitude 102 degrees, in western Manitoba and eastern Saskatchewan, and extends as far north as latitude 53 degrees. North of latitude 52 degrees the western boundary lies one degree west of the Second meridian. The eastern boundary of the area mapped runs northwesterly from the International Boundary, a few miles west of Emerson, Manitoba, to near where Red Deer River crosses the interprovincial boundary. The geology of this area is shown on the accompanying Assiniboine, Mafeking, and Etomami River maps (in pocket).

The field work on which this report is based was done by several members of the Geological Survey. In 1928, 1929, and 1930 the late S. R. Kirk studied and mapped the area between the International Boundary and latitude 52 degrees. In 1935, F. H. McLearn and R. T. D. Wickenden mapped the area in the vicinity of Hudson Bay Junction, and in the following year McLearn included the area that lies between Minitonas and Mafeking. The area west of Mafeking to near Hudson Bay Junction was mapped, in 1937, by R. W. Landes. The later work indicated that more information was needed on the southern part of the area and, accordingly, further work was done there, in 1938, by R. T. D. Wickenden, and, in 1939, by R. A. C. Brown. All investigations since 1930 were made in more detail than those of earlier years, and accurate elevations and locations were determined by stadia-alidade surveys.

The opinions expressed in this report are essentially those held by the author, partly as a result of his own field studies and partly from reference to the field notes of others who have worked in the area. All information provided by other workers, such as descriptions of some of the stratigraphic sections, is duly acknowledged, and the writer wishes to make it clear that whatever merit the report may possess is largely due to the efforts of these geologists. All identifications of macro-fossils were made by F. H. McLearn of the Geological Survey.

Acknowledgment is also made of the co-operation of the many persons who provided information in the course of field work, and to the students who assisted on the field parties. Thanks are due to Messrs. George Cole and Frank D. Shepherd of the Mines Branch, Department of Mines and Natural Resources, Manitoba, and to Mr. E. Swain, Supervisor of Mines, Department of Natural Resources, Saskatchewan, who furnished samples from deep wells and, also, information on developments in the area.

EARLY GEOLOGICAL WORK

The bedrock geology of the region had been investigated by few persons prior to 1928. The outstanding piece of work was that by Tyrrell during the years 1887 to 1890. The area underlain by Mesozoic formations forms only a part of Tyrrell's report, which was published in 1892. Much useful information about outcrops and general geology is contained in this report, but correlations of some of the formations are somewhat confusing. His Millwood formation

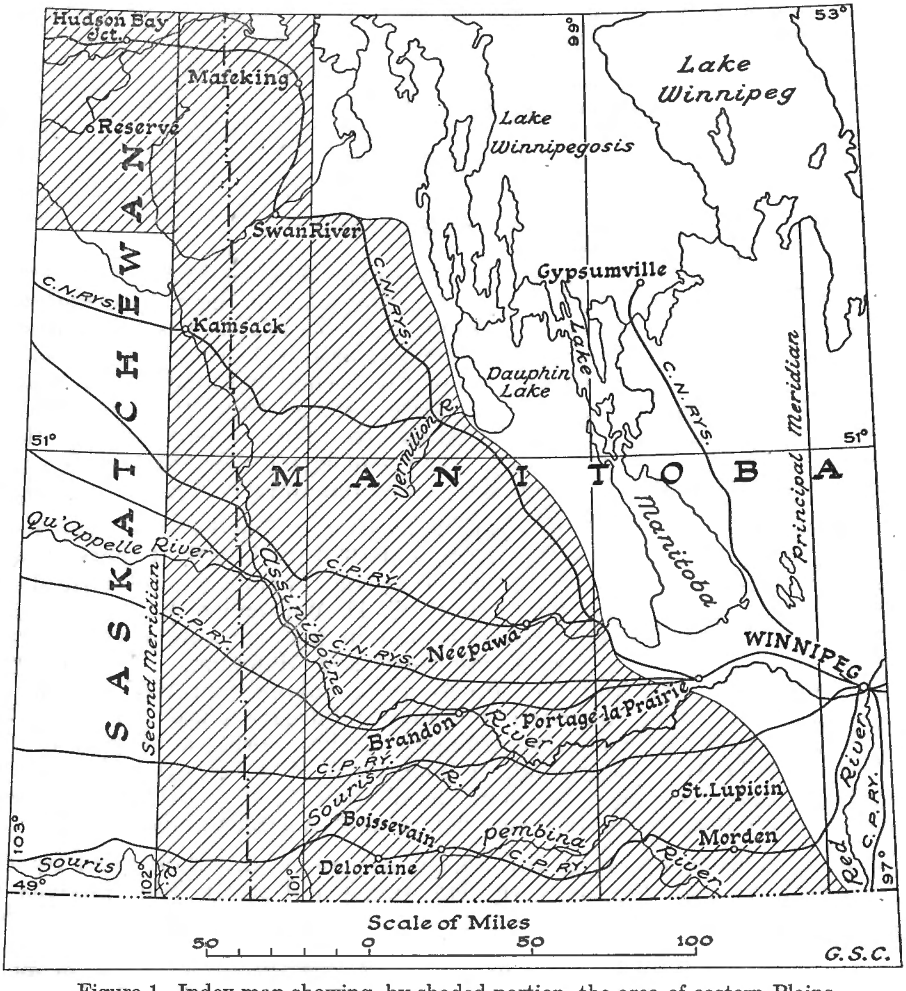

Figure 1. Index map showing, by shaded portion, the area of eastern Plains covered in this report.

contains, in part, the present Riding Mountain formation, and, in part, the Pembina and Morden members of the Vermilion River formation. What is now known as the Favel formation was then called Niobrara, because of its calcareous composition, although a better understanding of the fauna now indicates that the formation is older than the Niobrara. In most localities Tyrrell used the name Benton for what is now called the Ashville formation. More recent studies indicate that the upper part of the Ashville, the Favel, and possibly part of the Vermilion River formations are equivalent to the Benton, and the Boyne member of the Vermilion River formation is the equivalent of the Niobrara. Later reports continued to use the terms Niobrara and Benton in some localities in the sense that Tyrrell had used them; in other localities the same terms were given a more accurate interpretation. As a result, it is not always possible to be certain what strata were being described.

The extreme southern part of the area was examined by G. M. Dawson in 1874 as part of his work on the geology of the Forty-ninth parallel. Dawson observed exposures of the Boyne and other members of the Vermilion River formation along the Pembina escarpment, and correctly compared the cream-coloured calcareous (Boyne member) beds to the Niobrara of the United States. His chief basis for comparison was the foraminiferal fauna. Unfortunately his descriptions and illustrations of species were rather generalized, so that it is not possible to identify them. It is probable that his description of the calcareous shale of the Boyne member was the basis for Tyrrell's correlation of what is now known as the Favel formation with the Niobrara.

More recently, in 1914 and 1915, A. MacLean studied the geology of the southern part of the area and recognized the relationships of the various formations. His results, however, were only published in summary form, and formations were not named. Dowling referred to McLean's unpublished results in a paper on the coal resources of the Prairies (1921).

The coal-bearing beds of the Turtle Mountain formation were studied by Dowling in 1902. He recorded most of the known exposures of this formation, as well as reports of coal in water wells dug in this part of the area. Dowling also described these occurrences in a paper referred to in the bibliography (1921).

In 1930, Kirk published some of his results and established the proper relationship of the various Upper Cretaceous shale members.

The Pleistocene geology for most of the area was described by W. A. Johnston in a memoir published in 1934.

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CHAPTER II

PHYSIOGRAPHY[1]

The area underlain by deposits of Mesozoic age occupies part of the Manitoba lowland and the first prairie step. The change in level is directly related to the presence of the Mesozoic formations. These strata dip gently to the west and southwest, and, as they consist of soft beds overlain by harder beds, an escarpment has formed. The Jurassic and, in part, the Lower Cretaceous formations consist of soft, easily eroded shale and loose, poorly cemented sandstones. Overlying Upper Cretaceous shales are somewhat tougher and resist erosion better than the older formations. The high land formed by these beds is known as the Manitoba escarpment. That part of it lying south of Assiniboine River is referred to as Pembina Mountain. A broad, flat area extending from near the Assiniboine to a little north of Neepawa is in part related to the delta deposited by the river during the existence of glacial Lake Agassiz. This flat area is covered by a thick mantle of drift. A very wide gap in the escarpment may have existed in this part of the area in preglacial times. Such a broad valley or gap may in some way be related to the structure of the underlying bedrock. Although the attitude of the strata may ordinarily be considered flat, as they dip only 6 to 10 feet to the mile, any increase or decrease in dip over a fairly wide area might have a noticeable effect on the topography. In the area between Neepawa and the Assiniboine a slight decrease in dip may have resulted in the formation of a broad, structural saddle, thereby permitting the development of a wide valley instead of an escarpment. It is also possible that the Assiniboine drained most of the country west of Pembina and Riding Mountains and that it developed a much broader valley than other streams that cut across the structure.

North of Neepawa to Valley and Wilson Rivers, west of Dauphin, the high land of the Manitoba escarpment is known as the Riding Mountains. Farther north, to Swan River, is Duck Mountain, which includes the highest part of the escarpment with elevations to 2,500 feet or more above sea-level. These heights may be due in part to a moraine that coincides with the highland area in this region. Between Swan River and Red Deer River Valleys the highland area comprises Porcupine Mountain.

In preglacial times the escarpment, particularly the southern part, was much more pronounced in relation to the lowland to the east, but glacial deposits, and probably to a great extent those of glacial Lake Agassiz, have buried the lowlands and hidden the Jurassic, Lower Cretaceous, and part of the Upper Cretaceous formations in the southern part of the area. The results obtained in the drilling of water wells in this part of the area indicate an abrupt drop in the bedrock surface east of the easternmost occurrence of the Favel formation beneath the surface deposits. The Favel and Ashville formations are the oldest formations that help form the scarp in the northern part of the areas mapped.

South of Swan River Valley the country west of the escarpment is drained mostly by the Assiniboine and its tributary the Souris. Swan River drains the west slope of Porcupine Mountain. Other streams that cross the escarpment do not drain territory far west of the crest. It is probable that the Pembina

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[1]*See also* Johnston, W. A.: Geol. Surv., Canada, Mem. 174, pp. 1-6.

carried most of the present Souris drainage during late glacial or even in preglacial time, but its valley has since been cut by a tributary of the Assiniboine. At present, Pembina Valley is steep sided, 300 to 400 feet deep, with a small misfit stream in the bottom.

West of the Manitoba escarpment the land surface slopes almost imperceptibly to the southwest into the valleys of the principal streams that drain the area, such as Assiniboine and Swan Rivers. Farther southwest the area rises gently towards the high country underlain, in southeastern Saskatchewan, by the younger Cretaceous and Tertiary formations. Turtle Mountain, which forms an outstanding feature along the International Boundary, is formed by an outlier of the late Cretaceous and early Tertiary formations and by a moraine of the continental glacier. Elsewhere in the area mapped, the hills are formed of glacial moraines rather than of bedrock, except for numerous small hills or knobs formed by erosional remnants of the Odanah phase of the Riding Mountain formation. Pilot Mound is a well known example of this type of hill in the Pembina Mountain region.

The area is in a youthful stage of the erosion cycle as a result of the setback given to the development of the drainage by the deposition of an irregular mantle of till and glacial lake deposits. It is probable that the entire region was fairly well in slope in preglacial times and that erosion had then reached a stage of late youth or early maturity.

CHAPTER III

STRATIGRAPHY

GENERAL STATEMENT

The post-Palæozoic formations in the mapped area range in age from Jurassic to Paleocene. Both top and bottom of this stratigraphic section are poorly exposed, and most of the information concerning them has been obtained from well samples and drill records.

The following table lists the formations present and their thicknesses in various parts of the map-area.

TABLE OF FORMATIONS

Era	Period	Epoch	Formation	Southern or Pembina Mt. Thickness, feet	Middle or Riding Mt. Thickness, feet	Northern or Porcupine Mt. Thickness, feet
Cenozoic	Tertiary	Paleocene	Turtle Mt. Ravenscrag[1]	300–400 300–500	Missing	Missing
Mesozoic and Cenozoic	Tertiary? and Cretaceous		Boissevain	100		
Mesozoic	Cretaceous	Upper Cretaceous	Riding Mt.	1,000+	500+	315+
			Vermilion River: Pembina member	80±	40–50	30±
			Vermilion River: Boyne member	140±	80±	40±
			Vermilion River: Morden member	190±	115±	60+
			Favel	150±	115±	60–100
		Upper Cretaceous and Lower Cretaceous	Ashville	40+	130±	100–350
	Jurassic	Lower Cretaceous	Swan River[2]	50+ 380±	75± −280	300+ ?
Erosional Unconformity?						
Palæozoic or Mesozoic	Jurassic or earlier		Amaranth	220	150–240	Probably missing
Erosional Unconformity						
Palæozoic	Devonian Silurian Ordovician					

[1]Ravenscrag may include some Cretaceous beds equivalent to the Frenchman formation.

[2]The Swan River group and formations of Jurassic age are shown as a unit under "Jurassic and Cretaceous" on the Assiniboine map, and the Swan River group is the "Lower Cretaceous" of the Mafeking map.

PALÆOZOIC-MESOZOIC RELATIONS

The contact between Palæozoic and Mesozoic formations appears to be unconformable. The Mesozoic strata dip at about 5 or 6 feet to the mile over most of the area, whereas the Palæozoic beds dip from 12 to 16 feet to the mile. Also, in different parts of the area, different Palæozoic formations underlie the Mesozoic rocks (*See* Figure 2). Furthermore, Devonian beds comprise the youngest Palæozoic rocks identified in the area, and Jurassic beds the oldest known Mesozoic strata. Between them lies an assemblage of red shale, gypsiferous beds, and calcareous rocks that have previously been considered Devonian, but as they are unconformable on the known Devonian beds and may or may not be conformable with the Jurassic strata, it is uncertain to what period they belong. The name Amaranth is suggested for this formation.

AMARANTH FORMATION

Although the Amaranth formation is exposed east of the area mapped, and, therefore, in an area underlain presumably by Palæozoic formations, there is a possibility that it may be of Mesozoic age. It will, consequently, be given brief consideration in this report. The name was suggested by Kirk, on his manuscript map, for the gypsum-bearing beds in the vicinity of Amaranth. The most complete information on the sequence of these beds is obtained from well samples, and the lithological succession is contained in the logs of the Commonwealth Manitou No. 2 and Neepawa Salt Company No. 2 wells, given in Chapter VI of this report. The formation was also drilled in the Dauphin well, but distribution north of this point is not known. Probably the formation extends fairly far to the east in the southern part of the area mapped, as thick beds of red shale have been noted in a water well at Rosenfeld and other localities. Similar red shales and gypsum beds have been drilled in deep wells in south-central Saskatchewan, and it is probable that further drilling will, in time, indicate that the formation is continuous throughout the southern part of the area.

The Amaranth, like the overlying Jurassic beds, appears to thin toward the north. In the Commonwealth Manitou No. 2 well it is about 200 to 220 feet thick; in the Neepawa Salt well it has a thickness of about 240 feet; but in the Dauphin well the beds are only about 140 feet thick (*See* Figure 2).

Correlation. As the Amaranth consists of red beds and gypsum it is not apt to carry many fossils, and no diagnostic types have yet been found in it. The lithology is similar to that of beds of the Spearfish formation of Triassic age intersected in the California Kamp well in North Dakota[1], and, in Manitoba, the distribution of the beds seems to be more closely parallel with the Jurassic than with the Devonian formations.

There is a possibility, however, that the Amaranth is of Carboniferous or even of Devonian age. A considerable erosional interval was noted between the known Devonian and the Amaranth beds in the Commonwealth Manitou No. 2 well, where nearly 300 feet of Devonian is missing as compared with the section at the Neepawa Salt well. The relationship of the Devonian of Manitoba to the Upper Devonian marine red beds found in the Simpson well in Saskatchewan[2] is not known. Although no unconformity is recognized within the Devonian of southern Manitoba, the possibility of such must not be overlooked.

The possibility of a Carboniferous age for the Amaranth must also be considered, as red beds and gypsum were observed in samples of Carboniferous

[1]Seager, O. A.: Stratigraphy of North Dakota; Am. Assoc. of Pet. Geol. Bull., vol. 28, p. 1418 (1942).

[2]Wickenden, R. T. D.: Notes on Some Deep Wells in Saskatchewan; Trans. Roy. Soc., Canada, vol. XXVI, sec. IV, 1932, p. 188.

rocks from wells in the Moose Jaw basin in Saskatchewan. Further, the distribution of Carboniferous strata in the southern part of Saskatchewan indicates a stratigraphic relationship somewhat similar to that of the Amaranth formation.

JURASSIC

The formations of Jurassic age in southern Manitoba and Saskatchewan have not been found exposed, and our knowledge of the strata of this age is based only on information gained from a study of samples obtained in drilling a few deep wells.

Three localities have yielded well samples containing Jurassic fossils. These are: on Pembina River about 6 miles south of Manitou; at Neepawa; and on Vermilion River about 9 miles southwest of Dauphin. No well north of the Dauphin well has yielded fossils or other means of determining the age of beds that occur at about the same horizon as the Jurassic of the more southern areas, but it is possible that some of these northern beds are of Jurassic age.

The southernmost wells, the Commonwealth Manitou No. 1 and No. 2, passed through beds of Jurassic age and, as No. 2 well is the deeper and samples from it are the less contaminated, the section represented by the samples from it may be accepted as typical of this part of the area. The complete log of the samples is given in Chapter VI of this report; the following is a general discussion of the Jurassic section with some reference to underlying strata.

Between the Amaranth beds and the calcareous shales of known Jurassic age lies a series of white or light grey, sandy limestones that appears to have been derived, by erosion, from the older formation. These beds contain no fossils and their age is uncertain, but as they seem to grade into overlying Jurassic shale, they may be regarded, tentatively, as basal Jurassic beds.

The oldest beds of known Jurassic age encountered in the Commonwealth Manitou No. 2 well consist of grey, calcareous shales with a little sand. They contain a few foraminifera and ostracods. Above them is about 20 feet of grey and red or reddish brown shale that contains foraminifera and fragments of marine macro-fossils such as brachiopods and echinoderms. This zone seems to represent a transition from the more calcareous shales below to less calcareous grey shales above. The latter form a section 10 feet thick and contain marine micro-fossils and fragments of macro-fossils similar to those in the underlying beds.

The above marine beds are overlain by a series of variegated shales that contain smooth ostracods and chara fruit and are evidently of non-marine origin. Similar ostracods[1] and chara[2] fruit have been described from the Morrison formation in the United States.

The non-marine beds are overlain by 70 feet of grey shale containing foraminifera and fragments of other marine fossils. This shale represents the highest beds in the Commonwealth Manitou No. 2 well, which contain Jurassic fossils, and the overlying sand and shale are considered to be of Cretaceous age.

Other wells in this district have been drilled to the Palæozoic, but none has furnished as complete or as clean a set of samples. The other samples indicate, however, that the section of Jurassic beds described is representative of the district.

Farther north, the nearest wells to pass through Jurassic formations are at Neepawa. The first of the wells was drilled between 1910 and 1914 and appar-

[1]Harper, Frances, and Sutton, A. H.: Ostracods of the Morrison Formation from the Black Hills, South Dakota; Jour. of Pal., vol. 9, pp. 623-628 (1935).

[2]Peck, Raymond, E.: Morrison Charophta from Wyoming; Jour. of Pal., vol. XI, pp. 83-90 (1937).

ently no samples were kept. In listing the probable formations, based on a driller's log, Dowling suggested that some of the beds were of Jurassic age, but there was no proof of this and the presence of Jurassic at this locality was not established until more recently. In 1935 the Neepawa Salt Company drilled a new well about 1,000 feet from the old well and good samples of the formations were kept. Part of the section contains Jurassic fossils and the following is a log of this part[1]:

Depth Feet	Lithology and Remarks	Thickness Feet
412–470	Shale, medium to dark grey, some sand; probably Lower Cretaceous	58
	Jurassic	
470–520	Shale, medium grey, much pyrite at 500 to 520 feet; Jurassic foraminifera and fragments of dentaliums, echinoderms, and other marine fossils in samples from 500 to 520 feet	58
520–540	Shale, medium grey to slightly brownish; some calcareous sandstone; limestone and numerous smooth, rusty yellow grains of probably limonite; some fragments of fossils of marine origin	10
540–570	Shale, medium to light grey; much calcareous sandstone and cream-coloured limestone; few fossil fragments; many smooth ostracods and chara fruit at 560 feet	30
570–580	Shale, buff-grey; some fragments of brownish red shale	10
580–610	Shale, medium grey; some cream-coloured limestone; some calcareous sandstone; foraminifera and many fragments of marine fossils at 600 feet	30
610–620	Shale, buff; a little white limestone	10
620–630	Shale, brownish red and grey; probably mottled or variegated.	10
630–640	Shale, yellowish brown	10
640–650	Shale, grey and brownish red; a few foraminifera that may have come from cavings	10
650–660	Shale, light brown	10
660–680	Shale, grey and light brown	20
680–690	Shale, light brown and brownish red; sample contains many fragments of rock from surface	10
690–720	Shale, greyish buff	30
720–730	Shale, medium grey; a little very light buff platy limestone; suggesting algal origin	10
730–750	Limestone, light grey with streaks and specks of black, carbonaceous material	20
	Jurassic or Palæozoic	
750–760	Limestone and calcareous sandstone, light grey; much grey chert	10

The preceding section resembles the one in the Commonwealth Manitou No. 2 well in that it contains marine Jurassic at the top with a probable non-marine member, containing smooth ostracods and chara fruit, below, and another marine member below that. Whether the beds below 610 feet to 750 feet are all Jurassic is uncertain as they contain no fossils, but they appear to be composed of rocks related to the overlying types, that is, soft shales and calcareous sandstones. They do, however, include some limestone, a rock type usually associated with the Palæozoic formations, but, judging from the samples examined, occurring here only as narrow bands in the shale.

The contact between the Jurassic strata and the Amaranth formation is placed, in the well sections, where there is a more definite change in lithology

[1]For complete log, *See* Chapter VI.

to hard limestone, as at a depth of about 730 feet in the Commonwealth Manitou No. 2 well. The presence of sandstone and chert fragments in the samples from 750 feet down may be evidence of an erosional unconformity.

About 65 miles northwest of Neepawa, Jurassic beds were drilled in the Dauphin well, located in the SE. ¼ sec. 14, tp. 24, rge. 20, W. 1st mer. The following log comprises that part of the well section that is interpreted as Jurassic:

Depth Feet	
0–160	Beds of Upper and Lower Cretaceous age.
	Jurassic
160–170	Shale, light grey; some sand.
170–200	Shale, light grey; much calcareous sandstone; some shell fragments; smooth ostracods and chara fruit.
200–210	Shale, brownish red.
210–220	Shale, light grey; some red shale.
220–230	Shale, light grey.
230–240	Shale, red.
240–270	Shale, light to medium grey.
270–310	Shale. These samples contain mostly shale, which, at this locality, is only found in the glacial drift, indicating contamination.
310–330	Shale, medium grey; glauconite and numerous shell fragments.
	Jurassic (?)
330–380	Limestone, light grey with much chert; probably weathered zone at Palæozoic-Jurassic contact—Amaranth (?).

Samples from the Dauphin well indicate a somewhat different section from that encountered in the Neepawa Salt Company well in that no marine fossils were observed in the grey shale in the upper part of the section. This may mean that part of the marine zone is missing. The smooth ostracods and chara fruit from between 170 and 200 feet appear to be the same as those from 560 feet in the Neepawa well. The lithology of these two fossiliferous zones is also much the same, so that it is probable that they represent the same horizon in both wells. If this is true, there is about 100 feet of marine Jurassic missing in the Dauphin area that is present at Neepawa. The lower beds, 330 to 380 feet, in the Dauphin well only correlate in a general way with strata occupying the same position in the Neepawa well.

The extent of the Jurassic north from Dauphin is not known. The wells at Mafeking are the nearest of those that reached the Palæozoic, but they encountered no marine Jurassic, the only type of deposits that contain guide fossils. A well drilled on Thunder Hill, west of Swan River, did not reach the Palæozoic, but bottomed in beds that were probably not far above. As some of the lower samples from this well contained glauconite, it seems probable that some marine Jurassic is represented this far north; but it is doubtful if it extends much farther.

Northern Royalties No. 3 well, drilled near Kamsack, Saskatchewan, yielded no samples that could be identified as Jurassic. The samples were, however, very unsatisfactory as they indicated considerable mixing of materials from the surface and upper parts of the hole, so that the evidence cannot be taken as conclusive.

The eastward extent of the Jurassic is indicated by 300 feet of beds, in the Neepawa Salt well, and 100 feet in a well drilled at Morden. Possibly in some parts of southern Manitoba the Jurassic sea may have extended to near the present Precambrian-Palæozoic boundary.

In the southern part of the area mapped the Jurassic beds extend westward into Saskatchewan, as indicated by the presence of a similar sequence of Jurassic beds in a well drilled near Regina and another near Avonlea.

The age of the Jurassic of Manitoba is indicated by the correlation of the micro-fossils in the wells described with those in the Avonlea well. Cores from this well contained fragments of ammonites of late Middle or early Upper Jurassic age[1]. They were derived from the same upper marine zone as that encountered in the Neepawa Salt and Commonwealth Manitou No. 2 wells. It is probable, therefore, that the Jurassic in Manitoba is of the same age.

There are numerous fragments of macro-fossils in samples from the Jurassic beds penetrated in Commonwealth Manitou No. 2 and Neepawa Salt wells. These fragments are from brachiopods, oysters, other pelecypods, and belemnites, but no specimen is large enough to identify the species.

The micro-fossils are well preserved, and foraminifera and ostracods are fairly common. Of these the ostracods are less numerous; are probably not diagnostic; and no attempt has been made to identify them. The foraminifera are fairly numerous in certain beds, and include species that are easily recognized and that seem to be diagnostic of the formation on the Plains.

SWAN RIVER GROUP

Overlying the beds identified as Jurassic and underlying the Ashville formation, in the southern part of the area mapped, are shales, sands, and sandstones collectively referred to as the Swan River group. North of Swan River and, possibly, to a little south of the river, where no marine Jurassic has been identified, the Swan River beds occupy the interval between Devonian strata and beds of the Ashville formation. In the south these intervening beds are probably all of Lower Cretaceous age, but in the north they may include non-marine equivalents of the Jurassic of the south. For convenience in description this assemblage of strata, which varies both in age and lithology, will be referred to as the Swan River group, from their typical occurrence in Swan River Valley. The name does not appear on the accompanying maps, on which the strata are referred to by age only as the oldest of the exposed Mesozoic formations.

In most previous publications the Swan River group is referred to as the Dakota sands. The Dakota is, however, of Upper Cretaceous age and should not be confused with the Swan River. In Kirk's report (1930) the Swan River beds were called the basal beds. The term Swan River was used by Johnston (1934, page 12) to conform with Kirk, who intended to use the name on his map. The Swan River group underlies nearly the entire map-area, but is exposed in only a few places north of Vermilion River. In the southern part of the area the presence of glauconite and fragments of shells of marine mollusca indicate that the group is, in part, of marine origin. Coal occurs at several places and indications are that the group is entirely of non-marine origin in the northern part of the area.

The thickness of the Swan River varies from a few to possibly 400 feet, the latter being the thickness as intersected in a well drilled on Thunder Hill.

In the south, knowledge of the Swan River beds is based on the study of samples from deep wells. Several of these wells have penetrated Lower Cretaceous beds, but samples are generally poor. The Commonwealth Manitou No. 2 well provided a suite of samples that seem to be in good order, although

[1]Geol. Surv., Canada, Mem. 176, p. 12.

they differ appreciably from samples obtained from well No. 1, drilled by the same company a little over 1½ miles away. Samples from well No. 1 show some contamination from the sands that lie immediately below the Ashville formation, and it is probable that they are not typical.

In Commonwealth Manitou No. 2 well the samples between 705 and 755 feet are assigned to the Swan River. Down to 738 feet they consist of fairly pure quartz sand with smooth, well-worn grains; from 738 feet to 755 feet the rock is all a medium to dark grey shale. There is some sand with the shale, but the amount is less at depth and was probably derived through cavings from the loose sand beds above.

The beds between 755 and 900 feet were formerly considered Lower Cretaceous, but reconsideration of the evidence, especially a comparison with the material drilled in the Neepawa well, seems to indicate that this part of the section is more closely related to the Jurassic.

In the Neepawa well the section is very similar to that of the Commonwealth Manitou No. 2 well. Samples from 385 to 412 feet are sand and from 412 to 470 feet medium to dark grey shale. The sand and sandstone in this part of the section carries water. The Swan River beds are easily recognized and have been drilled in several other wells in southern Manitoba. The Deloraine well in SE. ¼ sec. 10, tp. 3, rge. 23, W. Principal mer., obtained salt water in these beds at a depth of 1,800 feet. This is the most southern and westerly place in Manitoba where the beds have been drilled.

The most southern exposure of the Swan River beds is on Wilson River about 6 miles northwest of Dauphin, in NE. ¼ sec. 27, tp. 25, rge. 20, W. Principal mer. It comprises a few feet of greenish grey sandstone and underlies beds of the Ashville formation. On the same river three other low exposures of sandstone outcrop in SE. ¼ sec. 35, tp. 25, rge. 20, W. Principal mer.

Along Valley River, near the mouth of Drifting River, are numerous angular blocks of white or light grey sandstone that seem to be very nearly in place.

On Pine River, in sec. 7, tp. 34, rge. 20, W. Principal mer., is an exposure of white sandstone about 8 feet high and 30 feet long. A shaft was sunk there in search for coal, but apparently encountered only a small pocket of low-grade coal in a carbonaceous shale.

Exposures in the Swan River district are somewhat better, and a diamond drill well on Thunder Hill has penetrated most of the Swan River beds. Information from the well indicates that the sands and sandy beds beneath the Ashville are much thicker than the section assigned to the Swan River in the southern part of the area. This difference may be due, partly, to the occurrence in the north of predominantly non-marine, and, therefore, coarser, sediments in Lower Cretaceous time in contrast with the partly marine sediments in the south. It is also possible that part of the predominantly arenaceous beds that lie between the Ashville and formations of Palæozoic age may include near shore or even continental Jurassic deposits. As no fossils have been found, there is no way of differentiating these beds from the Lower Cretaceous.

The beds beneath the Ashville and above the Devonian formations in the Swan River district and north to the limits of the area mapped are composed predominantly of unconsolidated sand and soft sandstone with a few, harder, indurated layers. Grey shale, plastic clay, green sand, and carbonaceous shale and coal constitute a smaller part of the formation.

Outcrops of Swan River beds from Swan River north are few and only expose a small proportion of the beds. Along Swan River, between the eastern edge of sec. 6 and the northwest corner of sec. 3, tp. 37, rge. 26, W. Principal mer., a number of outcrops expose the contact of the Ashville formation with about 40 feet of the underlying beds. McLearn records the following sections on the north bank of the river in this locality. The highest exposure is on the north side of Swan River, 200 feet west of the boundary between sections 5 and 6.

Top of section	Thickness Feet
Shale, black	1·2
Sand, white, with thin beds dark clay and green layers	1·0
Clay, black	0·48
Sand, white	0·84
Sand, green and white, thin-bedded	0·58
Clay, black, with beds of white silt	0·32
Sand, white and green, thin-bedded	0·20
Sand, white, partly cemented; some greenish beds	1·10
Black clay and white silt in beds ½ to 1 inch thick; some green sand	8·9
Concealed to river level	2·40
Total	16·02

The black shale at the top of this section is probably the base of the Ashville formation. Foraminifera found in a sample of this shale are the same as those found in the shale at the base of the Ashville in well sections.

Downstream from the foregoing exposure are many hard sandstone ledges containing specimens of *Lingula* in places. These ledges are the cemented parts of beds that are probably represented by soft, unconsolidated sands in other parts of the section.

The next exposure, showing a section a few feet thick of Swan River beds, is about a mile down the river in the extreme southeast corner of sec. 8, tp. 37, rge. 26, W. Principal mer., just south of the house on Fraser's ranch. McLearn's measurements of this section are as follows:

	Thickness Feet
Sand, white and light grey, with numerous thin beds of silt, glauconite, and black shale	2·03
Sandstone, hard, grey weathering, with brown and green stains	0·65
Sand, grey and white, loose, with few bands of green sand and black clay	5·9
Sandstone, white, hard; some carbonized fragments of wood; green layers near base	3·0
Total	11·58

Near this outcrop and at a slightly lower elevation the following section is exposed and was measured by McLearn.

	Thickness Feet
Clay, black; very thin beds of white and green sand	3·00
Sand, green (glauconite)	0·40
Clay, dark grey; some thin beds of sand	1·70
Sandstone, hard, calcareous, contains fossil Ostrea, *Brachydontes tenuisculpta*, *Gervillia?*, and *Nucula?*	3·3
Sand, grey, fine-grained; black shale in thin beds	2·0
Total	10·4

There are other low exposures along the river bed for a short distance down stream. These are mostly of sandstone with fragments of carbonized wood and in places lenses of pyrite.

Still lower in the section, light grey plastic clay with thin beds of silt occur below dark grey clay. These beds are exposed about a mile downstream from Fraser's ranch, and McLearn measured the following section on the north bank of the river in the NW. ¼ sec. 3, tp. 37, rge. 26, W. Principal mer.:

	Thickness Feet
Clay, black, with thin beds of silt	2·6
Clay, brown	2·0
Clay, light grey, with some thin white silt lenses and rare concretions	5·0
Clay, grey, with very thin white silt lenses and concretions with fragments of fossil plant remains	3·5
Total	13·1

Some of these clays have refractory properties that are discussed in another part of this report. So far as is known they are peculiar to this locality; certainly they are not exposed elsewhere in the area.

The well drilled by Canadian Industries, Limited, on top of Thunder Hill, about 10 miles west of the exposures on Swan River, gives some idea of the total thickness and sequence of the beds below the Ashville formation. The well was drilled with a diamond drill and almost no core was recovered from the loose sands. The only record is of the shale and clay beds and the sandstone members. Details of the section can be found in the log of the well in Chapter VI of this report. In this log the samples between 820 and 1,152 feet were identified as from below the Ashville. The well was drilled to 1,232 feet without reaching Palæozoic rocks. This indicates that there are at least 400 feet of beds between the Ashville and the Palæozoic. No fossils were seen in the cores from this part of the well, but sludge below 1,100 feet contained a little glauconite, and it is probable, therefore, that some of the lower beds are of marine origin.

In the Swan River district there are a few exposures of white sandstone on Roaring River, and Tyrrell mentions the occurrence of white sandstone on Kettle Hill near Swan Lake. It is not known where these scattered exposures fit into the section.

The upper part of the Swan River beds is exposed on Steeprock River, in l.s. 4, sec. 23, tp. 43, rge. 26, W. Principal mer., and the following section was measured by Landes:

	Thickness Feet
Sandstone, light greenish grey; calcareous cement, weathering reddish brown, with nodular surface	1·7
Glauconite and quartz sand	1·7
Clay, green, sandy, plastic	1·2
Sand, clayey, green	0·6
Total	5·2

In the river bed, below this outcrop, are numerous slabs of hard, calcareous sandstone in which *Lingula* is abundant.

The highest exposure on Red Deer River is also of the upper part of beds and comprises much the same type of rocks as another, measured by Landes, in the north bank of the river in sec. 15, tp. 46, rge. 31, W. Principal mer.

	Thickness Feet
Sand, glauconitic	1·0
Sandstone, hard, calcareous, light grey, weathering brown, with *Lingula* and *Brachydontes*	1·0
Total	2·0

Lower down Red Deer River are several outcrops of the unconsolidated quartzose sands that form the bulk of the formation. Below the glauconitic phase are beds that resemble the sand and dark clays of the Swan River section. In this part of the section indurated layers of red weathering sandstone with ripple-marked surfaces are fairly common, and one such layer paves the bed of the river for several hundred square feet. Below this the fine-grained quartzose sands appear in several good outcrops, one of which, located on the northeast bank where the river makes a fairly sharp turn, in sec. 24, tp. 46, rge. 31, W. Principal mer., gives the following section:

	Feet
Unconsolidated, white, quartzose sand with a few thin streaks of dark shale	20
Crossbedded, buff-weathering sandstone	10
Total	30

Below this again is found uniform, unconsolidated, fine-grained, quartzose, white sand exposed in a cliff about 30 feet high and 600 feet long.

The lowest exposure of the sandstone on Red Deer River was on the south side in sec. 20, tp. 46, rge. 30, W. Principal mer., and Landes records this as follows:

	Feet
Sandstone, fine- and medium-grained, light grey, with a few streaks of shale and a few beds with small fragments of lignite; some coarse, reddish brown sand	25
Covered	20
Clay, dark green, plastic	4
Covered	6
Sandstone, hard, red weathered	1
Total	56

The Trail Blazer well, the log of which is given in Chapter VI of this report, passed through all beds between the Ashville formation and strata of Palæozoic age. Samples from the well indicate that sand and sandstone are the principal components of these intervening beds. Except for those immediately below the Ashville there is no evidence that any of them are of marine origin. An occurrence of dolomite in the samples at about 350 feet is anomalous, and may have originated from loose material at the surface. The presence also of numerous fragments of igneous rock in the same samples as those containing the dolomite suggests a similar origin.

Limestone at 520 to 540 feet is probably in place, and the presence of sand and chert with it suggests that it may be related to the limestone assigned to the top of the Palæozoic in the other wells.

The occurrence of lignite in samples from 450 to 460 feet in the Trail Blazer well may indicate a fair deposit in the vicinity. If so, some coal should be found in the drift farther east near where these beds come to the surface. In his traverse of Red Deer River, Landes, however, did not observe any such coal, and it seems doubtful if the deposits are extensive.

Farther west, in the northern part of the area, the Northern Royalties (sec. 25, tp. 40, rge. 5, W. 2nd mer.) and the Coalgate (NW. ¼ sec. 34, tp. 39, rge. 5, W. 2nd mer.) wells both passed through a considerable part of the Swan River beds, and samples indicate more shale and fine sand in this part of the area than in the vicinity of the Trail Blazer well. The contact between the Ashville and underlying beds is here more gradational, and it is probable that beds included in the Ashville are equivalent to some placed below this formation in the eastern part of the area.

In the northern part of the area the thickness of the Swan River beds is variable. The Trail Blazer well passed through about 340 feet of such beds, including the sandstone that occurs below the probable ledge of limestone at 520 feet. In the Mafeking area the same beds appear to be 218 feet thick. The Coalgate well farther west penetrates 350 feet of these beds without reaching the Palæozoic and, as already mentioned, a well at Thunder Hill drilled over 400 feet of beds below the Ashville without reaching the Palæozoic. On the other hand, wells in the Kamsack area encountered only about 100 feet of these beds. It is probable, therefore, that the area around Swan River north to near Hudson Bay Junction is a relatively local basin in which fairly thick deposits were laid down during Lower Cretaceous and, possibly, part of Jurassic time.

The only locality where macro-fossils have been found is that already referred to in the description of beds on Swan River. These fossils have no special age significance. The few micro-fossils found in beds definitely below the Ashville are poorly preserved foraminifera that resemble types found only in beds farther west of probable Lower Cretaceous age.

ASHVILLE FORMATION

The Ashville formation lies between beds of Lower Cretaceous age, already described, and the Upper Cretaceous, Favel formation. Its name was originally suggested by S. R. Kirk[1] for beds exposed on Wilson River near the village of Ashville, in tp. 23, rges. 20 and 21, W. Principal mer. As these beds have proved to be extensive and form a mappable unit, they properly represent a formation. The Ashville is the "Benton" shale of Tyrrell's[2] report.

The Ashville is made up of dark grey to black shales associated in part of the area with some silt and sand beds. Two types of shale are recognized. One, in the upper part of the formation, is a greasy black rock that weathers brown or pinkish brown and breaks into numerous flakes or flat chips. The lower shale is dark grey and has a more clayey texture. It breaks into chunky fragments. The lower part of the Ashville contains some glauconite with the shale, and the contact with the sandy beds of underlying, Lower Cretaceous strata is essentially transitional. A silt or sand member occurs between the two shales in the northern part of the area.

Distribution. Exposures of Ashville are found in stream valleys from near McCreary to near Hudson Bay Junction. South of McCreary, where deposits of glacial Lake Agassiz cover the foot of the escarpment formed by Cretaceous formations, the Ashville is not exposed.

Some wells drilled in the southern part of Manitoba penetrated this formation and samples from these give a fair idea of the Ashville.

In the Commonwealth Manitou No. 2 well, beds between 600 and 700 feet are mostly of non-calcareous, dark grey shale, but, due to material that has fallen into the well from beds of the overlying Favel formation, it is difficult to identify the position of the upper, Ashville contact. It is evident, however, that the Ashville comprises at least 150 feet of beds. Commonwealth Manitou No. 1 well, about $1\frac{1}{2}$ miles away, yielded poorer samples, but these indicate that the non-calcareous shale, which is assumed to be Ashville, is about 100 feet thick. Samples from just above the sandy zone in this well contain foraminifera that resemble those from the Lower Cretaceous in wells farther west.

Samples from 1,585 to 1,830 feet in the Deloraine well appear to be Ashville, although the lower 40 feet includes some glauconite and a little fine sand or silt.

[1] Kirk, S. R.: Cretaceous Stratigraphy of the Manitoba Escarpment; Geol. Surv., Canada, Sum. Rept. 1929, pt. B, p. 117 (1930).

[2] Tyrrell, J. B.: Report on NorthwesternManitoba; Geol. Surv., Canada, Ann. Rept., vol. V, pt. E, p. 210 (1892).

This contains the same foraminifera as those found in the lower part of the Ashville in the Commonwealth Manitou No. 1 well.

It is evident that the Ashville thickens a little to the southwest and that measurements taken along the Manitoba escarpment are not reliable indications of the thickness of this formation in the western parts of the area.

Several other wells have drilled through the Ashville formation in the southern part of Manitoba, but samples from them show considerable contamination and are, therefore, unreliable.

The brine well, drilled by Canadian Industries, Limited, at Neepawa, in 1935, penetrated the entire Ashville formation between depths of 290 and 390 feet. The upper part of the formation here contains some sand and silt beds as well as thin beds of limestone. These beds probably represent a phase similar to that exposed near Kelwood, Norgate, and McCreary, as referred to by Kirk (1930, page 118). This rather sandy phase appears to be developed only in this part of the area. Samples from the lower part of the Ashville, in the Neepawa well, do not show the more clayey shale and foraminifera found in wells in the more southern parts of the province, as already described. Apparently, however, this fossil zone is not thick and may or may not be represented in well samples.

The most southerly exposures of Ashville that have been observed are in road-side ditches 2 to 3 miles south of Kelwood. These show only a foot or two of the calcareous sandstone and limestone that lies near the top of the Ashville in this part of the area. Kirk (1930, page 118) mentions two bands of impure limestone, about 14 feet apart, in the vicinity of Kelwood, Norgate, and McCreary. Judging from samples from the Neepawa salt well, there are probably several other bands of calcareous rocks, but these seem to disappear towards the north and south.

Nowhere is a complete section of the Ashville exposed. On Vermilion River, southwest of Dauphin, the formation outcrops at several places, but only the upper part can be observed. The contact between Ashville and the overlying Favel is exposed in various places in secs. 1, 2, and 12, tp. 24, rge. 20, W. Principal mer. At two of these places a bed of white or light grey, bentonitic clay is exposed (*See* Plate II A), and associated with it are beds of impure dark grey or black marl. These are probably the beds referred to by Kirk as occurring 35 feet below the base of the Favel (Keld). Apparently there is a slight structure in this part of the area, as a result of which the bentonitic shale and impure limestone are a little lower in the section than Kirk estimated. This outcrop is on the southeast side of the river in a bend in the south-central part of the NW. $\frac{1}{4}$ sec. 1, tp. 24, rge. 20, W. Principal mer. Farther downstream some more of the bentonitic and calcareous beds were observed, but these are slumped.

Intermittent outcrops of Ashville are found along Wilson River between the middle of the E. $\frac{1}{2}$ sec. 15, tp. 25, rge. 21, W. Principal mer., and the NE. $\frac{1}{4}$ sec. 27, tp. 25, rge. 20, W. Principal mer., a distance of about 5 miles.

Outcrops along the Wilson do not give a complete section of the Ashville, although the top and bottom of the formation are exposed. The outcrops indicate that the formation consists mainly of dark grey to black, non-calcareous shale. The difference in elevation between the top and bottom of the formation on Wilson River is about 154 feet, but the outcrops used in determining this difference are about 6 miles apart and there is no evidence to indicate what the attitude of the beds is in this interval. A slight dip to the southeast between these two points would result in an increase in thickness to over 154 feet, or to about 170 feet, as estimated by Kirk for the Vermilion River area. The contact between the Ashville and the overlying Favel is seen at several places along Vermilion River and at one locality on Wilson River, but as these all show more of the overlying Favel formation than they do of the Ashville they are given in detail in discussing the Favel.

Kirk suggested that the hard limestone exposed on the east side of Valley River in l.s. 2, sec. 11, tp. 26, rge. 21, W. Principal mer., was the same as the limestone found on Vermilion River (*See* Plate II A) and, farther north, on Favel River. These limestone outcrops may occupy much the same position in the section, but it is doubtful if they are the same beds. As already stated, there are apparently several limestones in the Ashville farther south, and in view of the fact that no complete or even nearly complete section of the formation has been observed in the vicinity of Vermilion or Valley Rivers it is impossible to correlate the limestone horizons.

North of Valley River to Swan River there are few exposures of the Ashville, and as no distinctive horizons have been observed in the formation it is impossible to trace its features for any distance.

In the Swan River district, the Ashville is exposed on the west branch of Favel River and on Roaring River. On the former only the upper 35 to 40 feet of the formation is exposed, and on Roaring River, only beds from somewhere in the middle of the formation. About 10 feet of dark grey Ashville shale can be seen at the base of the formation on Swan River in the eastern part of sec. 7, tp. 37, rge. 26, W. Principal mer.

An approximate thickness of the Ashville for this district is indicated by the difference in elevation between exposures showing the top of the formation on the west branch of Favel River and the bottom of the formation on Swan River. This difference amounts to about 225 feet. The two exposures are, however, 9 miles apart, and, though there is no evidence between to suggest other than horizontal beds, even a slight dip, no more than 3 feet to the mile, would reduce this estimated thickness to about 200 feet on Swan River.

The Ashville is also exposed on the east end of Thunder Hill. Two of the diamond drill holes there passed through about 420 and 480 feet, respectively, of Ashville beds. The cores show that the beds dip from 10 to 60 degrees. It is evident that the excessive thickness is due to irregularities in structure.

Dark grey, nearly black, shale makes up most of the Ashville formation as seen in exposures in the Swan River district. A few bands of silt, bentonite, and gypsum were observed in places, but it has not been possible to use them for positive correlations.

On Roaring River, in secs. 11, 14, and 15, tp. 35, rge. 27, W. Principal mer., several exposures of Ashville together represent the upper 100 feet of the formation. One exposure, near the contact with the Favel formation, contains a 2-foot zone of silty shale. About a mile south another exposure at the Favel contact shows two beds of bentonite about 5 feet apart just below the contact, but no silt beds. Similar beds of bentonite were observed in exposures of the Ashville below the contact on Favel River, but in other outcrops the bentonite was not seen. These features indicate that there are no reliable horizon markers in the upper part of the Ashville in the Swan River district. Two of the holes drilled on Thunder Hill show the presence of a well-defined silt or sandy zone at a drilling depth of about 200 feet from the top of the formation. As the formation has a total drilled thickness of over 400 feet, it seems probable that this zone lies about midway of the formation. Probably the outcrops on Roaring River do not expose enought of the formation to reach beds equivalent to the silt and sandy zone encountered in the two holes.

Along the east side of Porcupine Mountain the Ashville is poorly exposed, but on the south side of Red Deer Valley good outcrops again appear and, although the formation consists predominantly of dark grey shale, silty and sandy horizons are more prominent than farther south. The best exposures in this northern part of the area are on Little Woody River, Camp Seven Creek, Armit River, and Little Armit River. The succession on Little Woody River may be accepted as typical. The lowest exposure of Ashville on this river is in the NE. ¼ sec. 22, tp. 22, rge. 29, W. Principal mer., just below the main forks of the stream. This outcrop probably represents the middle part of the formation. The section, measured by Landes, is as follows:

Top of section	Thickness Feet.
Shale, dark grey, fissile	4·0
Sand, light grey, fine-grained; silt, crossbedded in 2- to 3-inch layers.	1·1
Shale and fine-grained sand alternating in thin beds	1·0
Shale and silt in equal proportions	0.8
Shale, dark grey, with streaks of fine-grained sand and silt	2·6
Total	9·5

Upstream from this outcrop are numerous large exposures, consisting predominantly of dark grey fissile shale. In these are occasional thin beds of hard, medium grey, silty shale, with small inclusions of darker shale. Farther upstream, on the east branch of the river, in NW. ¼ sec. 14, tp. 44, rge. 29, W. Principal mer., a second pronounced silty and sandy zone is exposed. It lies about 75 feet above the first and is 25 feet below the base of the Favel formation. The section, measured by Landes, is as follows:

Top of section	Feet
Shale, dark grey, weathered	3
Shale, dark grey, fissile	10
Shale, dark grey, alternating with thin beds of fine-grained sand and silt; some sandy beds cemented with calcite	5
Bentonite	0·5
Shale, dark grey, with many thin beds of fine-grained sand and silt in which fragments of fish remains are abundant	4·4
Shale, dark grey, with many thin beds of silt	6·0
Total	28·9

As the top 13 feet of this section is all dark grey shale, and as farther upstream 15 feet of dark grey shale was found underlying the medium grey, speckled shale of the Favel formation, it is evident that the 25 feet of section between the top of the silt and the base of the Favel is all dark grey shale. The section of the Ashville on Little Woody River may be compiled as follows:

	Feet
Favel	
Shale, medium grey, with fine white specks	
Ashville	
Shale, dark grey	25
Shale, dark grey, with many beds of fine-grained sand and silt	16
Shale, dark grey, with a few thin beds of hard, silty shale	75
Shale, dark grey, and fine-grained sand	5
Shale, dark grey	?
Total	121+

Farther west, on Camp Seven Creek, in secs. 16 and 21, tp. 44, rge. 29, the dark grey shale below the Favel, the upper sandy horizon, and the underlying dark grey shale are all well exposed, but the middle sandy horizon does not outcrop. The upper sandy horizon on this creek is fossiliferous and the harder sandy layers yield *Ostrea* and *Inoceramus* shells. Similar fossils occur in a sandy horizon at the top of the Ashville on Red Deer River. On Armit River the Ashville is exposed in large but discontinuous outcrops, from the Lower Cretaceous sand and Ashville contact, in section 25, to the contact of the Ashville and the Favel, in sec. 12, tp. 44; rge. 30, W. Principal mer. Except for a thin silty shale bed in the top of a large outcrop in the centre of section 24, all of the Ashville beds exposed along this river consist of dark grey shale. The lack of silt and sand beds is believed to be due to accidents of exposure rather than to absence of sand in the succession, for sandy and silty beds again appear in Ashville beds exposed along Little Armit River 4 miles to the west, in sec. 17, tp. 44, rge. 30, W. Principal mer. The character of the Ashville in the north-western part of the area is shown in samples from the Trail Blazer well and by surface exposures of the upper part of the formation along Red Deer River. The Trail Blazer well, in l.s. 1, sec. 31, tp. 44, rge. 2, W. 2nd mer., passed through 50 feet of glacial drift, or surface deposits, before reaching bedrock. The highest bedrock horizon in this well is part of the Ashville, about 30 to 40 feet below the top of the formation. The following section of Ashville was drilled in this well:

	Feet
Shale, medium grey, with some silt near the top	125
Sand, white, medium- to coarse-grained	20
Shale, medium grey	75
Total	220

It seems probable that the sand in the middle of the Ashville in this well is at the same horizon as the silt and sand bed in the middle of the Ashville in the wells drilled on Thunder Hill.

The fact that the micro-fossils above and below the sand horizon in this well are much the same as those above and below the silty, sandy horizon in the wells near Thunder Hill indicates that the sand horizon in the middle of the Ashville extends from the vicinity of Red Deer River to at least as far as the Swan River district.

The upper silty horizon is also well developed on Red Deer River, as shown in the following section, measured by McLearn, in sec. 24, tp. 44, rge. 3, W. 2nd mer.:

	Feet
Favel	
Shale, medium grey, calcareous	7·5
Ashville	
Shale, dark grey	5·4
Bentonite	0·24
Shale, dark grey	10·00
Shale, brown, hard	0·24
Bentonite	0·12
Shale, dark grey	12·0
Shale, dark grey, with beds of silt and fine-grained sand	5·5
Total	40·8

The information about the lower 13 feet of this section was obtained by drilling with a soil auger. The sandy horizon at the base is probably the same as the one at the top of the Ashville on Little Woody River. It is probable that this horizon is part of the silt zone that occurs in the upper part of the Trail Blazer well.

About 25 to 30 miles south and west of the Trail Blazer well and the sections on Red Deer River, wells drilled in the vicinity of Bertwell and Reserve passed through part or all of the Ashville. Samples from these wells indicate some changes in the thickness and lithology of the formation. The Ashville may be divided into three members, as in the other parts of the map-area, namely, two shale members separated by a sand member. In the Kakwa No. 5 well of the Petroleum Engineering Company, drilled near Bertwell, only the upper shale member and the middle sand member were penetrated. Judging from samples the upper shale member is thinner here, but there is some sand and shale in the samples just above the pure sand of the middle sand member, and probably these beds are all represented by shale in sections near the Trail Blazer well.

The Northern Royalties No. 1 well, near Reserve, passed through 133 feet of shale above the white sand member, but the lowest 33 feet of this contained some sand. The middle sand member in this well is 42 feet thick, and below this is 130 feet of shale, some of which contains foraminifera similar to those found in the lower part of the Ashville in the Trail Blazer well. These last two members are about twice as thick in this well as in the Trail Blazer well. Evidently the lower part of the Ashville thickens to the west in this part of the area.

Palæontology and Correlations. Macro-fossils are scarce in the Ashville and no good specimens of diagnostic fossils have been found. In the east half of sec. 24, tp. 44, rge. 3, W. 2nd mer., McLearn found poorly preserved specimens of *Inoceramus*, which he[1] compares with *Inoceramus dunveganensis* and *Inoceramus mcconnelli* Warren. He suggests that this may indicate possible correlation with the Dunvegan formation. This would mean that these beds belong to the earliest Upper Cretaceous in the Plains of Canada. These fossils were found near the top of the Ashville above a silt zone, in beds that may be related to either the Favel or the Ashville.

Fragments of oysters and *Inoceramus* have been found at other localities, but are less complete. The Ashville also contains fragments of fish remains, but none of these has proved of value in establishing correlations.

Micro-fossils include species of foraminifera and radiolaria. The latter have not been studied sufficiently to identify the various species, but they are useful for local correlation because they are confined to the upper shale member of the formation. Foraminifera occur in upper and lower shale members, and the assemblage of species is somewhat different in these members. All species found so far have arenaceous tests, and nearly all specimens are crushed or deformed. Because of this, identification is somewhat difficult where the species belong to long range, somewhat variable genera, as *Haplophragmoides* and *Ammobaculites*, and specific identification of some of the species is not made here. The following species have been found in the Ashville:

Upper shale member
- *Haplophragmoides* sp.?
- *Ammobaculites* sp.?
- *Tritaxia manitobensis* Wickenden
- *Gaudryina* sp.?
- *Miliammina manitobensis* Wickenden
- *Trochammina* sp.?

Lower shale member
- *Haplophragmoides* sp. A
- *Haplophragmoides* sp. B
- *Ammobaculites* sp. A.
- *Gaudryina* sp.?

All the species listed from the lower member are different from those of the upper shale member. The *Haplophragmoides* and *Ammobaculites* are the same as some that occur in the Fort St. John group in the Peace River district.

[1]McLearn, F. H.: Trans. Roy. Soc., Canada, 3rd ser., vol. 31, sec. IV, p. 113 (1937).

The correlation of the Ashville is problematic because of the lack of macro-fossils. Kirk (1930, page 117) suggested that the formation might be the equivalent of the Graneros formation of the Benton shales in the United States. As already mentioned, the few macro-fossils found by McLearn suggest that the top part of the formation may be the equivalent of the Dunvegan or the oldest Upper Cretaceous that we know in the Plains and Foothills. This does not conflict materially with the correlation suggested by Kirk. It is probable that these correlations apply only to the upper part of the formation, because, as already pointed out, the micro-faunas of the two shale members are different and the lower seems to be more closely related to the Shaftesbury formation in the Peace River district. It seems probable that the Ashville includes beds of both Upper and Lower Cretaceous age.

FAVEL FORMATION

The name Favel is proposed for the formation that overlies the Ashville and underlies the Vermilion River formations. Kirk originally called this part of the section Assiniboine and Keld beds, but more recent, extensive studies indicate that the two sets of beds are members of one formation. The name Favel has been chosen because of some excellent sections exposed on the east and west branches of Favel River, a tributary of the Swan, near Minitonas, Manitoba. The type sections of the Keld and Assiniboine beds are, however, on Vermilion River, and these may also be considered the type sections of the Favel formation.

The formation varies in thickness from 60 or 80 feet in the northern part of the area to 170 feet in the southern part. Grey shale speckled with white, calcareous material constitutes most of the Favel. Bands of limestone are found near the top of the formation throughout the area and, in the north, some impure grey limestone occurs near the middle of the formation. These bands mark the top of the Keld beds at the type locality. A few bands of bentonite occur in the Favel, but none is of much use as an horizon marker.

No exposures of the formation were found south of Assiniboine River and our knowledge of the formation there is based on the study of well samples. The Deloraine well passed through 120 feet of this formation between depths of 1,455 and 1,575 feet. Some of the samples near 1,480 feet contain a few fragments of impure limestone, indicating one or more thin limestone bands near the top of the formation in this part of the area.

The Commonwealth Manitou No. 2 well, in l.s. 8, sec. 26, tp. 2, rge. 9, W. Principal mer., also furnished samples of the Favel formation. The beds between 410 and 580 feet are of grey shale with specks of white, calcareous material. Samples from 450 to 460 feet contain much limestone and probably were derived from one of the limestone bands exposed farther north near the top of the formation. In the well samples the impure limestones, which mark off the Assiniboine from the Keld in exposed sections, cannot be distinguished from calcareous shale. This makes it impossible to separate the Favel in well sections into the Assiniboine and Keld members.

Some low exposures of the Favel occur along Assiniboine River in sec. 36, tp. 8, rge. 11, W. Principal mer., and sec. 6, tp. 9, rge. 10, W. Principal mer. These are the beds that underlie the upper limestone beds of the formation. Farther downstream, near the Ladysmith ferry in the south half of sec. 16, tp. 9, rge. 11, W. Principal mer., a low exposure of grey speckled shale underlies a band of grey impure limestone or calcareous shale. Judging by its fossils, this exposure represents beds that lie about midway of the formation, or at the top of the Keld member.

The nearest exposure of the Favel north of Assiniboine River is about 70 miles away in a roadside cut a mile north of Kelwood. This and other nearby exposures do not show more than a few feet of the formation, but the fossils indicate that a part of the Keld member is exposed here.

The first fairly thick sections of the Favel are exposed on Ochre River about 8½ miles south of the town of Ochre River, in SW. ¼ sec. 32, tp. 22, rge. 17, W. Principal mer. Kirk (1929, page 121) gives the following as a summary of the section of the Favel formation exposed there:

	Feet
Base of Vermilion River	
Shale, grey, non-calcareous	
Favel (Assiniboine member)	
Limestone, hard, grey, buff weathering; highly fossiliferous	5.0
Shale, grey, specked, calcareous	18·0
Limestone, hard, grey, fossiliferous	0·66
Shale, grey, speckled, calcareous	43·0
Shale and limestone (top of Keld member)	5·0
Total	71·66

Farther north and west good exposures are also found on Edwards Creek, but the formation is best exposed on Vermilion River where Kirk studied the type sections of Keld and Assiniboine beds. These sections were re-studied and re-measured in 1938 by the writer, and the results, which differ a little from those published by Kirk, are given here. The exposure, in l.s. 8, sec. 2, tp. 24, rge. 20, W. Principal mer., on the west bank of Vermilion River (*See* Plate II B), contains a section of the lower part of the Favel formation as follows:

	Thickness Feet
Glacial drift	5–10
FAVEL FORMATION	
Assiniboine member	
Shale, medium to dark grey, speckled, calcareous	8·0
Bentonite, light grey to white	0·2
Shale, medium to dark grey, speckled, calcareous	6·0
Bentonite, light grey to white	0·2
Shale, dark grey	1·0
Keld Member	
Limestone, soft, impure, medium grey, weathers buff; some shale partings at base, contains *ammonites*	0·8
Shale, medium to dark grey, speckled, calcareous	7·0
Limestone, impure, soft, medium grey, speckled	0·1
Shale, medium to dark grey, speckled	0·1
Bentonite parting	0·05
Shale, medium to dark grey, speckled, calcareous	2·5
Bentonite parting	0·02
Shale, medium to dark grey, speckled, calcareous	1·0
Bentonite, white to light grey	0·1
Shale, dark grey	0·1
Limestone, medium grey, speckled	0·5
Shale, medium to dark grey, speckled, calcareous; *Inoceramus labiatus* common	4·0
Limestone, medium grey, impure, soft, speckled	0·5
Shale, medium to dark grey, speckled, calcareous	6·4
Bentonite, white, weathers yellowish grey	0·3
Shale, dark grey, partly speckled	4·1
Bentonite, white, weathers yellowish grey	0·3
Shale, dark grey, speckled, slightly calcareous	5·7
Bentonite parting	0·05

Keld Member—Concluded	Thickness Feet
Shale, medium to dark grey, speckled, slightly calcareous	19·0
Bentonite, light grey to white	0·2
Shale, dark grey, speckled	1·8
Bentonite, light grey to white	0·3
ASHVILLE FORMATION	
Shale, dark grey, non-calcareous	3·6
Bentonite, white to cream	0·1
Shale, dark grey, non-calcareous	21·7
Total thickness of bedrock section	95·72

The preceding section is apparently the one Kirk used in his description of the Keld on Vermilion River, but it must be noted that although all of the speckled shale is included in the Keld this section measures only 53 to 54 feet, whereas Kirk's published section showed 65 feet. A check of Kirk's field notebooks failed to discover any section for this locality that compares with the one that was published, whereas there is one given for the SE. ¼ sec. 2, tp. 24, rge. 20, W. Principal mer., that agrees in nearly all details with the one measured by the writer. When the section was measured in 1938 it was realized that the results did not agree with those that had been published, and measurements were checked by determining the elevation of various key beds by stadia and alidade as well as by hand-level and rod.

A section of the lower part of the Keld member and the top of the Ashville, which outcrops in the NE. ¼ sec. 12, tp. 24, rge. 20, W. Principal mer., was studied carefully and the results indicate that the formation has about the same thickness as in the section given above, but that bands of impure limestone do not always occur at exactly the same horizons. The comparison of these two sections and the fact that the elevations of the limestone bands vary a great deal suggest that these beds are rather lenticular, although they may occur in much the same part of the formation in the various outcrops.

The upper part of the Favel formation is well exposed in l.s. 5, sec. 35, tp. 23, rge. 20, W. Principal mer., where Kirk measured the type section of Assiniboine beds. At this locality (*See* Plate III A) the measured details, in 1938, differ from those obtained by Kirk, and were checked by employing two methods used in measuring the lower part of the formation. The section, as measured in 1938, is as follows:

Lithology	Thickness Feet
Glacial drift	10–20
Dark grey, non-calcareous shale	8
FAVEL FORMATION	
Assiniboine Beds	
Shale, speckled and non-speckled, with calcareous and limestone bands 1 to 2 inches thick; many fossils, mostly pelecypods	18·0
Limestone, grey, weathers brown; with *Inoceramus*, oysters, belemnites, etc	4·0
Shale, dark grey, speckled, calcareous	6·0
Bentonite	0·2
Shale, dark grey, speckled	18·2
Bentonite, light grey to white, weathers brownish	0·2
Shale, dark grey	3·5
Bentonite	0·1
Shale, dark grey, speckled	3·2
Bentonite	0·1
Shale, dark grey, speckled	1·0

FAVEL FORMATION

Keld Beds	Thickness Feet
Limestone, impure, medium grey, speckled	0·8
Shale, medium to dark grey, speckled	7·0
Total thickness of bedrock exposure	70·1

The foregoing measurements indicate that the Assiniboine beds are 54 to 55 feet thick at this locality. They also give a total thickness for the Favel formation of about 110 feet.

Although in many places there is a bed of limestone near the top of of the Favel, the position may vary and here, in contrast with the exposure described on Ochre River, a lower limestone is better developed (*See* Plate III A). Although it is possible that the absence of the limestone at the top of the formation might be considered evidence of an unconformity, it seems more probable, in view of the fact that the bed varies in thickness from place to place, that the beds are lenticular. The presence of several small bands of limestone in the beds overlying the 4-foot limestone indicates that even thicker beds of limestone may have been deposited in places at or near the top of the Favel formation.

Continuity of the individual beds in the Favel formation is a difficult thing to prove, and it is probable that although certain zones in the formation may contain similar strata in different localities it is very doubtful if many or any of the beds are continuous. Comparison of the sections on Vermilion River with sections exposed on Wilson and Valley Rivers only a few miles away reveal the variability of the beds.

The lower part of the Favel formation and the contact with the Ashville is exposed on the west side of Wilson River in l.s. 9, sec. 15, tp. 25, rge. 21. At this locality R. A. C. Brown measured the following section:

	Thickness Feet
Boulder clay	15·6
FAVEL FORMATION	
Keld Member	
Shale, dark grey	2·0
Bentonite parting	0·05
Limestone and shale, blocky	2·0
Bentonite parting	0·02
Shale, calcareous, almost limestone, blocky	4·2
Bentonite parting	0·05
Shale, calcareous	2·5
Bentonite parting	0·02
Shale, calcareous, speckled	2·5
Bentonite parting	0·02
Shale, calcareous, fissile, speckled	5·1
Bentonite	0·15
Shale, calcareous, speckled	1·9
Bentonite parting	0·05
Shale, calcareous	0·6
Bentonite	0·1
ASHVILLE FORMATION	
Shale, black, petroliferous; unweathered pieces are hard and flat; possibly some very fine silt bands	3·4
Bentonite	0·15
Hard, dark, petroliferous shale	8·8
Total thickness of rock	33·61

Comparison of this section with that measured in l.s. 8, sec. 2, tp. 24, rge. 20, W. Principal mer., on Vermilion River, shows that the bentonite beds and partings do not match, and even the limestone bands do not correspond. It is evident that the amount of lime and the occurrence of bentonite vary considerably in this part of the Favel formation.

A section showing most of the upper part of the Favel was measured by R. A. C. Brown on the south bank of Valley River a short distance west of the middle of sec. 30, tp. 25, rge. 21, W. Principal mer., and is as follows:

	Thickness Feet
Boulder clay	11·0
FAVEL FORMATION	
Assiniboine Beds	
Shale, dark, bituminous, with several hard crystalline limestone bands and numerous fragments of a large *Inoceramus*	6·5
Limestone, grey, somewhat crystalline, tending to break into thin slabs; contains oysters and large *Inoceramus* fragments	2·2
Bentonite and speckled shale	0·3
Limestone, weathered buff, similar to 2·2-foot bed	0·5
Bentonite and speckled shale	0·3
Limestone, similar to above	0·1
Shale, grey, speckled, calcareous	15·7
Bentonite	0·1
Shale, grey, speckled	3·5
Bentonite parting	0·02
Shale, grey, speckled	3·5
Keld Beds	
Limestone, grey, blocky	0·4
Shale, grey, speckled, calcareous	6·2
Bentonite parting	0·05
Shale, hard, speckled; includes small limestone band	4·5
Bentonite parting	0·05
Shale, grey, speckled, hard; includes small limestone band	3·8
Total section of rock	47·72

Apparently the limestone band that formed a bed 4 feet thick in the section measured on Vermilion River is somewhat more broken in this section. The beds between the lowest crystalline limestone bed and the top of the Keld, in the Valley River section, are about 23 feet thick as compared with 33 feet thick in the section on Vermilion River. The sequence of beds just above the Keld in the two sections is much the same, though it is evident that the bentonite beds do not always correspond in the different sections.

On Sclater River, R. A. C. Brown observed several fairly good exposures of parts of the Favel formation. Upper and lower contacts are not exposed, but it is evident that most of the formation is represented. A section of part of the formation near the contact with the Ashville is exposed in the most easterly outcrop in l.s. 14, sec. 15, tp. 34, rge. 23, W. Principal mer., on the north bank of the river. This section, measured by Brown, is as follows:

Top of section	Thickness Feet
Limestone, in thin slabs and containing *Inoceramus*	2·7
Shale, grey, calcareous, speckled	0·7
Limestone, buff weathering, impure, crystalline; contains *Inoceramus labiatus*	1·9
Shale, grey, calcareous, speckled	9·2
Bentonite parting	0·02
Shale, calcareous, speckled	1·2

	Thickness Feet
Bentonite parting	0·005
Shale, grey, calcareous, speckled	1·8
Shale, calcareous, speckled; many thin bands of limestone containing *Inoceramus* sp.?	8·0
Total	22·125

About three-tenths of a mile downstream from the exposure just described is an outcrop of black, non-calcareous shale resembling the Ashville formation. It is assumed, therefore, that the above section of Favel is very near the base of the formation. The occurrence of crystalline limestones in this part of the formation indicates a considerable variation in the texture of the beds that make up the formation.

The occurrence of a crystalline limestone band in the lower part of the Favel is also shown in a section on Sclater River about one-quarter mile west of the section just described. The exposure is on the northwest bank of the river in l.s. 13, sec. 15, tp. 34, rge. 23, W. Principal mer. Brown measured the following section at this locality:

Top of section	Thickness Feet
Mixture of shale and boulder clay	8·0
FAVEL FORMATION	
Limestone, soft, friable, grey	0·1
Bentonite parting	0·02
Shale, calcareous, speckled	3·0
Bentonite parting	
Shale, calcareous, speckled	1·3
Bentonite parting	
Shale, calcareous, speckled	7·2
Bentonite parting	
Shale, calcareous, speckled, platy, blue-grey weathering	19·6
Limestone, grey, with fish scales	0·2–0·1
Shale, calcareous, speckled	1·0
Bentonite parting	
Shale, calcareous, speckled	2·0
Bentonite parting	
Shale, calcareous, speckled	0·8
Limestone, soft, fissile	0·2
Shale, calcareous, speckled	0·3
Bentonite parting	
Shale, calcareous, speckled	0·2
Limestone, hard, partly crystalline, with *Inoceramus labiatus*	6·9
Total bedrock section exposed	42·75

The relationship of this to the previous section is uncertain. If the limestone at the base of this section is the same as the limestone at the top of the other, the part of the formation equivalent to the Keld beds on Vermilion River is much thinner here. On the basis of the interpretation that the top of the Keld occurs at the thin limestone band above the *Inoceramus labiatus* zone, the top of the Keld beds in this locality might be placed about 7½ feet above the base of this outcrop. Brown does not mention the occurrence of the ammonite zone in this locality, but, at what appears to be the same horizon at a locality a little upstream just east of the highway, ammonites have been found in a thin band of soft limestone. In this case the bed is near the same zone as the top of the Keld member in the sections on Vermilion River.

The exposures on Pine River a little north of the Sclater show similar limestone bands in the beds that contain *Inoceramus labiatus*. It is not possible to estimate the thickness of the Favel formation on Sclater and Pine Rivers because, apparently, some of the beds have a slight dip or else there is some faulting. On Pine River the difference in elevation between the limestone near the top of the Ashville and the top of the Favel formation is only about 70 feet. Elsewhere the limestone in the Ashville is about 20 to 30 feet below the contact with the Favel. If the difference between the Ashville limestone and the top of the Favel represents the thickness of the Favel plus at least 20 feet of Ashville, there is only room for about 50 feet of Favel. As there is no indication that any beds are missing, the small difference in elevation must be due to structure rather than to thinning of the formation.

Although there are small exposures on some of the intermediate streams, the nearest good outcrops to the above sections are on the east and west branches of Favel River. The lower contact with the Ashville is well exposed on the west branch in the NE. ¼ sec. 26, tp. 35, rge. 26, W. Principal mer., where McLearn measured the following section:

Top of section

FAVEL FORMATION

Keld Member	Thickness Feet
Shale, medium grey, with white, calcareous specks; thin beds of impure limestone	8·0
Bentonite	0·03
Shale, medium grey, with white, calcareous specks; thin beds of hard, very calcareous shale; bed with *Inoceramus labiatus* present	6·2
Shale, medium grey, with white, calcareous specks; poorly preserved *Inoceramus labiatus*	9·0
Bentonite (?), weathers gritty	0·1
Shale, medium grey, with white, calcareous specks and many large *Inoceramus*	2·2
Bentonite	0·05
Shale, medium grey, with white, calcareous specks	4·7
Bentonite	0·3
ASHVILLE FORMATION	
Shale, dark grey	0·9
Bentonite	0·03
Shale, dark grey	2·6
Total rock section exposed	34·11

Farther upstream a section that overlaps the one just described was measured by McLearn on the east bank of the west branch of the Favel in SE. ¼ sec. 26, tp. 35, rge. 26, W. Principal mer. This section is as follows:

FAVEL FORMATION

Keld Member	Thickness Feet
Shale, medium grey, calcareous, speckled	1·0
Bentonite	0·05
Shale, medium grey, calcareous, speckled	0·8
Bentonite	0·1
Shale, medium grey, calcareous, speckled	0·4
Bentonite	0·1
Shale, medium grey, calcareous, speckled; *Inoceramus labiatus*	6·8
Bentonite	0·1
Shale, medium grey, calcareous, speckled; thin limestone beds; *Inoceramus labiatus*	5·4
Bentonite	0·1
Shale, medium grey, calcareous, speckled; limestone in thin beds; *Inoceramus labiatus*	3·9
Bentonite	0·05

Keld Member—Continued	Thickness Feet
Shale, medium grey, calcareous, speckled, very hard; *Inoceramus labiatus*	4·0
Bentonite	0·2
Shale, medium grey, calcareous, speckled; some thin, hard, limy layers	3·0
Bentonite	0·1
Shale, dark grey, with white, calcareous specks	0·9
Bentonite	0·2
(*Inoceramus labiatus* uncommon below this level)	
Shale, medium grey, with white specks; occasional *Inoceramus labiatus*	11·5
Bentonite	0·02
Shale, medium grey, calcareous, with white specks	2·5
Bentonite	0·02
Shale, medium grey, calcareous, with white specks	0·5
Bentonite (?), weathers gritty	0·2
Shale, medium grey, calcareous, with white specks; large species of *Inoceramus* common	3·3
Total	45·06

The gritty layer near the base of the two sections is the principal horizon on which the sections are correlated. The first bentonite bed above the grit is apparently the same bed in both sections. Some of the other bentonite beds do not correlate very well.

Although the last section described does not seem to include all of the Keld beds described on Vermilion River, the thickness suggests that the top of the section is not far below the contact of the Keld and Assiniboine members.

Most of the Assiniboine member is not exposed in this part of the area and the best outcrop of this part of the formation is one exposing about 20 feet of the very top of the formation. This is located on the east branch of Favel River about $1\frac{1}{4}$ miles east of the last exposure described. At this locality, on the southwest side of the river in SW. $\frac{1}{4}$ sec. 30, tp. 35, rge. 26, W. Principal mer., McLearn measured the following section:

VERMILION RIVER FORMATION	Thickness Feet
Shale, dark	5.0
FAVEL FORMATION	
Assiniboine Beds	
Limestone, hard, buff-grey	0·9
Limestone, fairly hard, grey; some shale	2·0
Grey, gritty layer with bentonite in the middle	0·3
Limestone, buff-grey, hard	1·8

The above part of the section was measured at the south end of the exposure, where the contact with the Vermilion River formation can be seen. The part of the section that follows was measured at the north end of the outcrop where the beds below the limestone are better exposed:

	Feet
Shale, dark grey	1·0
Bentonite	0·2
Shale, dark grey; many crushed *Inoceramus* shells	1·6
Shale, dark grey, some speckled shale; *Inoceramus*	1·5
Dark shale, many crushed *Inoceramus* shells	0·8
Bentonite	0·05
Shale, dark grey, with crushed *Inoceramus* shells	0·3
Bentonite	0·05
Shale, dark grey, speckled	2·5
Grey, gritty, weathered layer	0·2
Bentonite	0·03
Shale, dark grey, speckled	5·5
Total	23·72

This section differs a little from those described on Ochre and Vermilion Rivers. It resembles the one on Ochre River in that it has a limestone bed at the top of the formation, but the occurrence of dark grey shale instead of speckled shale is unusual.

Elsewhere in Swan River Valley and along the east side of Porcupine Mountain there are several exposures of the Favel, but most of them do not show much of the formation and there is no particular change in the lithology from that of exposures already described. An exception to the general lithological succession seems to occur farther north and is exemplified in an exposure examined by Landes on Barrows Creek, in sec. 22, tp. 44, rge. 28, W. Principal mer. At this locality Landes measured the section as follows:

	Thickness Feet
Limestone, with interleaved black shale	7·0
Shale, medium to dark grey, with white, calcareous specks; weathering into irregular large fragments	10·0
Bentonite	0·1
Shale, dark grey, speckled with white; coarsely friable	1·7
Bentonite	0·05
Shale, medium grey, speckled white, hard and platy; *Inoceramus labiatus*	4·0
Total	22·85

According to Landes' notes and his manuscript report on the area he considers that the limestone at the top of this section is at the top of the Favel formation. Another outcrop a short distance away on the same stream shows 5 feet of dark grey, non-calcareous shale overlying the limestone. This shale is thought, by Landes, to represent the Vermilion River formation. If this exposure shows the top of the Favel formation the occurrence of *Inoceramus labiatus* only 12 feet below the base of the limestone is very different from all occurrences of this part of the formation observed farther south. As has been shown by the sections described on Sclater River, limestone can occur in the Favel formation very near the *Inoceramus labiatus* zone, and the section described from the east branch of Favel River shows some dark grey shale in the Assiniboine member of the formation. If these conditions exist on Barrows Creek the exposure may be lower in the formation than Landes considered, and the dark grey shale that overlies the limestone may be part of the Favel rather than of the Vermilion River formation.

Other exposures of the Favel formation were observed by Landes on some of the streams on the north side of Porcupine Mountain, but most of these are low outcrops and not much information on the sequence of beds in the formation in this part of the area can be gained from them. The most northerly exposure in the area is one on Red Deer River where the contact of the Favel and Ashville formations is exposed. This outcrop shows only 15 feet of speckled shale assigned to the Favel formation.

Study of the samples from wells drilled in the area indicate the thickness and general relationship of the Favel formation, although it is impossible to recognize the details that can be obtained from the study of outcrops. The thickness of the formation in the northern part of the area seems to be 60 to 80 feet. This is considerably thinner than that shown by the exposures on Vermilion River, and although some beds must disappear towards the north the imperfect knowledge gained from the study of outcrops and well samples fails to reveal which these are.

The logs of the Coalgate No. 1, Northern Royalties No. 1, and Kakwa No. 5 wells give an idea of the type of material and the thickness of the Favel formation in the northern part of the area.

The Favel formation was also penetrated in wells in the vicinity of Kamsack, but unfortunately some uncertainty exists as to the reliability of the samples. What appears to be the most dependable set of samples was obtained from Ventures, Limited, No. 7 well, the log of which is given in Chapter VI of this report. This well reached the top of the Favel, at a drilling depth of 340 feet, and the top of the Ashville at 440 feet. Apparently the Favel has about the same thickness here as shown on Vermilion River.

Palæontology and Correlations. Although the Favel includes beds that contain many fossils, there are few species in the fauna. The following is a list of species of macro-fossils found in the formation:

Inoceramus labiatus Schlotheim
Inoceramus n.sp. var. A
Inoceramus n.sp. var. B
Inoceramus capulus Shumard
Ostrea congesta Conrad
Loricula canadensis Whiteaves
"*Metoicoceras*"? sp.
Serpula cf. *semicoalita* Whiteaves
Belemnitelle manitobensis Whiteaves
Anomia sp.

Inoceramus is the most useful of these fossils, as its species occur at different zones and seem to be confined to those parts of the formation. The species referred to as *Inoceramus* n.sp. var. A is a large flat form that occurs in the upper beds of the Favel formation. No complete specimens of this species have been found, although some fragments nearly 2 feet long have been observed (*See* Plate III). The species had a fairly thin shell considering its size, most of the shell being not more than one-eighth to one-quarter inch thick.

Inoceramus capulus has been found only in impure limestone beds that occur in the middle of the formation, that is, at the top of the Keld member. This species has been observed only in the area between Swan and Vermilion Rivers. On Favel River and farther north no exposure has been identified as representing this part of the formation, and it is possible that the species has not been observed because the zone in which it occurs is not exposed or is missing from the formation.

Inoceramus labiatus is confined to a zone in the lower part of the formation, the Keld member. It is very abundant in about 20 feet of the formation below the *Inoceramus capulus* zone. Landes, however, observed it only 12 feet below a limestone band that he thought was at the top of the Favel formation on Barrows Creek. As already mentioned, there is some uncertainty about the significance of this occurrence.

The species designated as *Inoceramus* n.sp. var. B occurs below the *Inoceramus labiatus* zone and extends to near the base of the formation. This species has a fairly flat, thin shell roughly circular and usually about 6 inches across, and no specimens have been observed that are as large as those of variety A. It has been found in exposures at least as far north as Swan River Valley.

The ammonite designated as "*Metoicoceras*"*?* sp. has been found in the same impure limestones in the Keld member as *Inoceramus capulus* at localities from Assiniboine to Sclater Rivers. Unfortunately, although several specimens have been found at different localities, none is well enough preserved to show details of the venter or the sutures in any specimens collected. Under these circumstances the ammonite cannot be identified with any degree of certainty.

The other fossils on the list have no particular stratigraphic significance.

The micro-fossils occur under much the same conditions as the macro-fossils. There are few species, but specimens are abundant in the beds where they occur. Only the five species listed below have been found in the Favel formation:

Gumbelina globulosa (Ehrenberg)
Gumbelina globifera (Reuss)
Gumbelitria cretacea Cushman
Ventilabrella eggeri Cushman
Globigerina cretacea d'Orbigny

Of these species only those of *Gumbelina* and *Globigerina* are common; the others are fairly rare. Some beds contain a great many specimens of foraminifera, and, in fact, these fossils may make up a great part of the more calcareous strata.

On the basis of fossils the Favel can be correlated with the Greenhorn limestone and Carlyle shale in the United States and part of the Lower Alberta formation in the southern Foothills, the Blackstone formation in the northern Foothills of Alberta, and the Kaskapau of the northern Alberta Plains. As already pointed out by the author, shales of the same type seem to occupy a similar position in well sections at least as far as the Alberta-Saskatchewan boundary. The speckled type of shale that occurs in Manitoba and Saskatchewan disappears near the Foothills.

VERMILION RIVER FORMATION

Overlying the Favel is a formation of dark grey and black shale that Kirk named the Vermilion River. The formation appears as a distinctive lithological unit in the Cretaceous succession from the International Boundary north to beyond Hudson Bay Junction. In the south the formation includes three assemblages of strata that Kirk named the Morden, Boyne, and Pembina beds. These are now considered members of the Vermilion River formation. Although this threefold division exists throughout the mapped area, the boundaries of the members merge, and it is possible that contacts are not always marked by the same beds.

The Vermilion River formation varies in thickness from about 450 feet in the southern part of the area mapped to about 100 feet in the northern part, and is probably thickest in the southwest. The lowest, or Morden, member is about 200 feet thick in the south and only 20 to 30 feet thick near Hudson Bay Junction, in the north; the Boyne member varies from about 140 feet in the south to 30 to 40 feet in the north; and the uppermost or Pembina beds thin from about 70 feet in the south to 30 feet in the north.

The Vermilion River formation is composed of various types of grey shale. The Morden member consists mostly of dark grey, non-calcareous shale. The succeeding Boyne member is composed mainly of medium grey, calcareous, speckled shale with some non-calcareous, dark grey shale, most of the calcareous beds lying at the top of the member. These two members contain a little bentonite, but the most prominent series of bentonite beds is at the base of the uppermost or Pembina member, and is a characteristic of that member wherever exposed. It is difficult, however, to recognize the bentonite in well samples, as it tends to wash out or cave and, consequently, is found in many samples that come from other horizons.

MORDEN MEMBER

The Morden member is exposed in the southern part of the area, in valleys that cut into the Manitoba escarpment. A few feet of the top is exposed below the Boyne member on the south side of Pembina Valley near the International Boundary in SW. $\frac{1}{4}$ sec. 5, tp. 1, rge. 6, W. Principal mer. The upper 15 feet is here all calcareous, speckled shale, whereas the underlying 20 feet of the exposure is made up of dark grey to black, non-calcareous, blocky shale with some thin partings of white sand.

Outcrops expose a somewhat different phase of this member in a valley about 1½ miles southwest of Morden, in NE. ¼ sec. 36, tp. 2, rge. 6, W. Principal mer. They are composed of fairly soft, somewhat fissile, dark grey, non-calcareous shale that contains large, ellipsoidal, septarian concretions. Kirk reports that the largest concretion he saw was 8 feet in diameter. Other low exposures of the Morden member were observed in some of the valleys between Morden and Miami, but none gives much information on the various beds that make up the member. Near Leary station a few feet of the top of the Morden is exposed in an excavation that was made to obtain material for making bricks. The lowest Morden beds exposed in the southern part of the area are on Cypress River near its junction with the Assiniboine and consist of 5 to 10 feet of blue-grey, non-calcareous clay shale. The shale contains some of the same microfossils that are found in the Morden beds near Morden. About 3 miles east of this outcrop the top of the Favel is exposed along the Assiniboine, so that the Morden exposures examined are probably not more than 50 feet above this formation.

The delimitation of beds of the Morden member in sections exposed along Vermilion River and other localities farther north is uncertain due to changes in thickness and the less than normal calcareous character of the overlying Boyne beds. Large septarian concretions occur in the bed of Vermilion River near where the lower part of the Morden member should be found if exposures were good. A short distance below the ford, in SW. ¼ sec. 26, tp. 23, rge. 20, W. Principal mer., some low exposures in the west bank of the river are probably of Morden beds that lie just above the concretionary zone. As these exposures rest about 35 feet above the limestone that occurs near the top of the Favel formation about a mile north of this point, and as beds to the north and south dip no more than 2 or 3 feet to the mile, it seems doubtful if there are 20 feet of beds between the exposures mentioned and the top of the underlying Favel formation. The fact that there was 18 feet of calcareous shale with limestone bands above the heavy 4-foot limestone bed, where a section was measured, suggests that the beds exposed near the ford are not more than 20 feet above the top of the Favel. Kirk placed 70 feet of Morden beds, reported from the old Vermilion River bore-hole, below those exposed near the ford. Unless, however, some unusual structure intervenes, it is improbable that there is anything like such a thickness of beds at this place. It is more probable that the position of the Vermilion River bore-hole, referred to by Tyrrell, was not where assumed by Kirk. The well may have been located on ground a little higher than was supposed by Kirk, or the crossing referred to by Tyrrell was the one about 4 miles upstream.

About 2,000 feet upstream from the ford a section exposed on the east bank of Vermilion River, almost on the boundary between the NE. ¼ and NW. ¼ sec. 23, tp. 23, rge. 20, W. Principal mer., shows 52 feet of dark grey shale, the lower part of which may be the equivalent of the upper part of the Morden member. This section is described under the discussion of the Boyne member.

Farther north are other incomplete exposures of Morden beds along streams that drain the east side of Duck and Porcupine Mountains. On the east branch of Favel River a series of exposures show dark grey, non-calcareous shale above limestone at the top of the Favel formation. These exposures are in SW. ¼ sec. 30, and NW. ¼ sec. 19, tp. 35, rge. 26, W. Principal mer. Here the speckled shale of the Boyne beds is poorly developed and the contact between Boyne and Morden beds is uncertain. Septarian concretions characteristic of part of the Morden member near Morden and on Vermilion River were not observed on the Favel. Exposures on the Favel are discontinuous, but it is improbable that the Morden is more than 30 feet thick at this locality.

The Morden member is poorly exposed in the Porcupine Mountain region and along Red Deer River and its tributaries. Southwest of Hudson Bay Junction wells drilled near Bertwell showed about 30 feet of non-calcareous shale above the Favel formation and below the speckled shale of the Vermilion River, Boyne member.

In the vicinity of Kamsack some wells have penetrated the entire Vermilion River formation and samples obtained from Ventures Kamsack No. 7 show about 30 feet of non-calcareous shale immediately above the Favel formation. It is possible that some of the shale above this zone should also be included in the Morden.

No identifiable macro-fossils have been found in the Morden member in the northern part of the area. Near Morden and near the junction of Cypress and Assiniboine Rivers the member contains some foraminifera.

BOYNE MEMBER

The Boyne member of the Vermilion River formation is composed of calcareous shale with a few beds of bentonite and some dark grey, non-calcareous shale. The amount of lime in the rocks is greater in the south than in the north. In places, as on Vermilion River, the Boyne shale is only slightly calcareous and is difficult to differentiate from that of the non-calcareous members above and below. The calcareous shales are somewhat petroliferous in most localities.

There are many exposures of the Boyne member south of Assiniboine River along the front of the escarpment. The most complete section observed is on the north side of Pembina Valley near the International Boundary, in SW. ¼ sec. 4, tp. 1, rge. 6, W. Principal mer. (*See* Plates I and IV A). There the following section of the Boyne was measured, commencing at the base of a series of bentonite beds at the bottom of the overlying Pembina member:

Top of section *Boyne Member*	Thickness Feet
Shale, medium grey, speckled white, calcareous; this part of the section is partly covered with glacial drift that has slumped from above	30
Shale, or impure limestone, medium grey, weathering white or cream, rather massive (*See* Plate I)	40
Shale, dark grey to black, non-calcareous	15
Shale, dark grey, speckled white; contains fragments of ammonites, *Baculites*, and *Inoceramus*	7
Bentonite, light grey	0·05
Shale, dark grey, speckled white	5
Bentonite, light grey	0·10
Shale, dark grey, speckled white	8
Bentonite, light grey	0·1
Shale, dark grey, speckled white	2·75
Bentonite, light grey	0·15
Shale, dark grey, speckled white	0·5
Bentonite, light grey	0·1
Shale, dark grey, speckled white	6·5
Bentonite, light grey	0·5
Shale, dark grey, non-calcareous, much yellow stain	12·0
Shale, medium grey, speckled white, calcareous; weathers into thin layers (paper shale) (*See* Plate IV A)	15·0
(Section below this is from hole bored at this site)	
Shale, medium to dark grey, speckled white, calcareous	5·0

Morden Member	Thickness Feet
Shale, black, non-calcareous	4·5
Shale, medium grey, a little silt	2·0
Shale, medium grey, with white silt layers	4·2
Total	158·45

This is the most complete section of the Boyne that was seen in the area. In measuring it, that part above the 6-inch bentonite bed, in the middle of the section, was studied in the eastern part of the exposure and the part below this bed in the western part of the exposure. There are several other exposures of the Boyne in Pembina Valley, and it was observed that the lithological divisions used in describing the above section were typical for the various parts of the Boyne wherever they were seen in this valley.

It is a little uncertain that the actual top of the formation was observed in this section, as some of the overlying Pembina beds may have slumped a little on the very slippery bentonite layers, but in any case it is doubtful if the contact, as determined here, is far out, as the elevation agreed closely with that obtained for the same contact at nearby points. In view of this, it is probable that the thickness of the Boyne member is 145 to 150 feet in this part of the area. Although there are numerous exposures of part of the Boyne in many of the valleys along the front of the Pembina escarpment, no other fairly complete section can be seen except in the valley of the south branch of Morris River near St. Lupicin (Babcock) station on the Canadian National Railway line west of Carman. There a nearly complete section of the Boyne can be constructed by studying sections at two localities. The highest beds outcrop about a mile west of the station in a cut bank along the railway track on the south side of the valley. The bentonite series of the Pembina member is exposed there at the top of the bank, and about 40 feet of the top of the Boyne member can be seen but is poorly exposed because of slumping from the top of the bank. To verify the conclusion about the upper part of the Boyne a bore-hole was made with a soil auger commencing in the lower part of the Pembina member. The section of Boyne beds consists of 18 feet of medium grey speckled shale overlying a bed about a foot thick of light grey, gritty bentonite. Below the bentonite, to the base of the outcrop, is 15 feet of medium grey speckled shale. There may be some minor beds of bentonite in the section, but details were not obtained. This part of the section was partly covered in the exposure described from Pembina Valley and may account for the fact that the thick band of bentonite was not seen there. It is more probable, however, that this band is a local development because it was not seen in an exposure showing the upper part of the Boyne beds in a creek valley about 16 miles south in SE. ¼ sec. 36, tp. 3, rge. 7, W. Principal mer.

The base of the section studied along the tracks west of St. Lupicin (Babcock) is about 10 feet higher, in elevation, than the top of the next section well exposed down the valley. The latter is located on the north side of the creek about one-half mile northwest of St. Lupicin station in SE. ¼ sec. 15, tp. 6, rge. 8, W. Principal mer., and measured as follows:

Glacial drift	Thickness Feet
Boyne Member	
Shale, medium grey, weathers cream to white, very calcareous; grades down into dark shale	26
Bentonite	0·20
Shale, medium grey, speckled with white	6
Bentonite parting	?
Shale, medium grey, speckled with white	0·50
Bentonite parting	?

Boyne Member—Continued	Thickness Feet
Shale, medium to dark grey, speckled with white	3
Bentonite parting	?
Shale, medium to dark grey, speckled with white; somewhat papery cleavage	11
Bentonite, light grey to white	0·05
Shale, medium to dark grey, some white specks	6
Bentonite, light grey, weathers yellow	0·2
Shale, medium to dark grey; fissile "paper shale"	13·3
Shale, dark grey, many "worm burrows"	3
Shale, medium to dark grey, speckled, hard	0·5
Total thickness	69·75

The elevation of the bottom of the Boyne beds as determined here is within 5 feet of that of the beds taken as the base of the Boyne in an exposure about half a mile west of Leary. As the shale at the base of this section contained a foraminiferal fauna similar to that found just above the base of the Boyne, about 1¼ miles east, near Leary, a hole was bored at the base of the St. Lupicin section to determine the contact. This hole passed through 8 feet of dark grey speckled shale and 15 feet of sandy or silty, dark grey, non-calcareous shale. The base of the Boyne is apparently about 8 feet below the bottom of the section, where the calcareous shales end. The elevations indicate that there is very little dip in the beds between the exposures near Leary and those northwest of St. Lupicin (Babcock) station. As the exposure showing the top of the Boyne along the railway west of St. Lupicin is almost in line with the other exposures it is safe to assume that at most no more than 10 feet of beds are missing in the gap between the top of the section just described and the base of the section along the track west of St. Lupicin. It seems correct to assume that the Boyne beds are about 115 feet thick in this part of the area.

Apparently the Boyne member is a little thinner in Morris Valley than in Pembina Valley. Just how this thinning takes place is uncertain. Except for the top and the bottom of the member there are no beds distinctive enough to correlate. Bentonite beds in the two sections do not match, and it is probable that they are of local occurrence. Even the abundant zone of micro-fossils near the base of the Boyne in Morris Valley was not recognized in samples collected in Pembina Valley. It is possible, however, that sampling may have missed the fossil bed in the exposures in Pembina Valley, although it was believed at the time that they represented a continuous section. This fossil zone is represented in samples from 150 to 160 feet below the surface in the Commonwealth Manitou No. 2 well, about 25 miles south-southwest of the sections near St. Lupicin station, indicating that the fossil zone is fairly widespread.

The top of the Boyne member is not well exposed in the St. Lupicin section and, although there appears to be some variation in detail, the section observed on the north side of a valley in SE. ½ sec. 36, tp. 3, rge. 7, W. Principal mer., gives a fair example of the type of material that can be found in the top of the Boyne member. This section is as follows:

Top of section	Thickness Feet
Black shale, alternating with cream bentonite	5
Boyne Member	
Shale, medium grey, speckled, weathers to buff, calcareous	3·6
Bentonite, grey, much iron-stained	0·1
Shale, medium grey, speckled, weathers to buff, calcareous	10·5
Bentonite, white, much iron-stained	0·6
Shale, medium grey, weathers buff, calcareous	0·8

Boyne Member—Continued	Thicknes Feet
Bentonite, cream, weathers to brown	0·15
Shale, medium to dark grey	1·0
Bentonite	0·05
Shale, medium to dark grey, weathers to light grey	1·1
Bentonite, cream, stained brown	0·1
Shale, dark grey, somewhat fissile	2·8
Bentonite	0·05
Shale, dark grey to black	0·25
Bentonite, white to grey	0·2
Shale, dark grey	1·0
Bentonite, white to grey	0·2
Shale, dark grey	1·0
Bentonite, white to light grey	0·2
Shale, dark grey	0·6
Bentonite, light grey	0·2
Total thickness	29·5

It is probable that some one or group of bentonite bands in the above section is the same as the thick band observed along the railway track west of St. Lupicin station, although none is as thick.

No other good section of the Boyne member was studied south of Vermilion River, but some information about the characteristics of this member may be had from the study of well samples obtained in the drilling of the Commonwealth Manitou No. 2 well and the well at Deloraine. Some other wells have been drilled into this member in the southern part of Manitoba, but the samples are all very poor.

As can be seen in the log of the Commonwealth No. 2 well, the upper part of the Boyne is missing and the first sample from bedrock at a depth of 140 feet is fairly well down in the member. The occurrence at a depth of 150 to 160 feet in this well of a fauna similar to that found near the base of the Boyne in sections near St. Lupicin (Babcock) suggests that this must be near the base of the member. Also the fact that foraminifera are scarcer and belong to species found in the Morden beds is an indication that this must be the equivalent of the Boyne-Morden contact. Due either to contamination or a change in the composition of the member the shale continues to be calcareous to a depth of 290 feet, so that this criterion cannot be used to separate the two members in this well.

The Boyne member is also present in the Deloraine well, but samples are not good enough to permit the separation of the various members of the Vermilion River formation.

North of Assiniboine River the first good exposures of the Boyne member are found on Vermilion River. In this part of the area the calcareous character of the member has almost disappeared and the contact with the underlying Morden member is difficult to recognize.

On the east bank of Vermilion River about one-quarter mile south of the ford, where the road between secs. 23 and 26, tp. 23, rge. 2, W. Principal mer., crosses the river, is an exposure of shale that probably includes the contact between the Boyne and Morden members. At this place the following section was measured:

	Thickness Feet
Shale, dark grey, non-calcareous; a few concretions	15·0
Bentonite, white	0·2
Shale, dark grey, non-calcareous	2·4
Bentonite, white	0·1
Shale, dark grey, non-calcareous; with concretions	10·3
Shale, medium to dark grey (lighter than above)	2.0
Shale, dark grey to black, non-calcareous; thick concretions	22·0
Total thickness	52·0

Judging from the elevation and general relationship of this section to those farther upstream it is probable that the upper part includes Boyne beds. It must be admitted, however, that the characteristics of the shale in this section are those of the Morden, in so far as they are non-calcareous.

About three-quarters of a mile south of the section just described an exposure showing 80 feet of beds occurs on the east bank of the river in SW. ¼ sec. 23, tp. 23, rge. 20, W. Principal mer. There R. M. Sternberg, who assisted the author in the field, measured most of the following section below the glacial drift:

	Thickness Feet
Pembina Member	
Shale, black, non-calcareous	25·0
Bentonite bands alternating with shale	7·5
Boyne Member	
Shale, dark grey, non-calcareous, massive; with a little selenite	5·0
Shale, dark grey, less massive; some weathered melanterite on bedding planes; many small crystals of selenite	10·0
Shale, dark grey, more massive, grading up into more friable shale	2·1
Bentonite, grey, much iron stained	0·05
Shale, dark grey, in alternating massive and papery bands	1·6
Bentonite parting	0·02
Shale, dark grey, with a few white specks, papery	1·3
Shale, dark grey, soft, friable; many small selenite crystals; some melanterite, iron stained	4·7
Shale, dark grey, not so friable; irregularly spaced patches of speckled shale	2·4
Shale, dark grey, dries light grey, finely speckled in part; fragments of ammonites and baculites	1·0
Shale, dark grey; many concretions, some selenite	3·8
Shale, dark grey, finely speckled, tough, massive	1·0
Shale, dark grey, friable, becoming massive at base	1·8
Bentonite, greenish yellow	0·4
Shale, dark grey, very friable, streaked with melanterite	1·3
Shale, dark grey, with a few white specks, non-friable	0·6
Bentonite, greenish yellow	0·3
Shale, dark grey, somewhat massive, non-calcareous	3·8
Shale, brownish black, irregular fracture	4·6
Ironstone concretions, grey to brown	0·2
Shale, brownish black	8·2
Shale, with bentonite bands; partly covered with talus	17·0
Total thickness of exposed section	104·4

This section overlaps part of the previously described section. The bentonite beds near the base are probably the same as those about 15 feet below the top of the previous section, their elevations at the two localities being within 2 feet of each other. The beds of bentonite were also observed in other outcrops that occur along the valley between the described sections.

The lack of speckled shale in previous sections, and the irregular occurrence of such shale in the east section, show how poorly this phase of the Boyne beds is developed in Vermilion River district. The foraminifera found in this east section indicate a correlation with the Boyne beds in southern Manitoba.

Between Vermilion and Swan Rivers no sections show much of the Boyne member. Those that were observed indicate that the speckled shale is not well developed. It is probable that the member is more calcareous farther west, as wells near Kamsack show a fairly good section of this type of shale, as do also some low exposures on Swan River north of Pelly.

The east branch of Favel River provides many exposures of the Boyne member, but none is over 20 feet thick and only in one was any speckled shale observed. Some speckled Boyne shale was seen along Birch River, on the east side of Porcupine Mountain, and on a few other streams in this region.

According to the logs of wells drilled near Bertwell (Kakwa), the Boyne is about 40 feet thick in that part of the area. Most of the member is exposed in a number of low outcrops along the valley of Etomami River in sec. 22, tp. 42, rge. 4, W. 2nd mer., to sec. 15, tp. 43, rge. 3, W. Principal mer. Here McLearn measured three sections that together probably represent most of the Boyne beds. Some of the lowest beds of the member are exposed on the east side in a sharp bend of the river, in NW. ¼ sec. 3, tp. 43, rge. 3, W. 2nd mer. The beds dip slightly and are offset by a fault, but the three measured sections give the sequence of beds for this part of the Boyne member. At the north end of the exposure the following section was measured:

	Thickness Feet
Shale, black, weathers friable to fissile	1
Shale, grey, much weathered; may be partly calcareous	1·75
Shale, dark grey, hard, calcareous, slabby	1·90
Bentonite	0·05
Shale, dark grey, hard, calcareous	0·85
Bentonite	0·04

The lower part of this section contains *Inoceramus pontoni* and *Scaphites ventricosus.*

Farther south a trench exposed the following section underlying the lower bentonite of the previous section:

	Thickness Feet
Bentonite	0·05
Shale, dark grey, calcareous, hard	3·85
Bentonite	0·06
Shale, dark grey to black, calcareous?	1·30
Bentonite	0·12

The preceding two sections are on the downthrown side of a small, normal, easterly trending fault. Just south of the fault the following section was measured, commencing with the bentonite bed at the base of the previous section:

	Thickness Feet
Bentonite	0·10
Shale, dark grey (weathered)	1·30
Shale, black, non-calcareous	0·65
Bentonite	0·03
Shale, black; some melanterite	1·25
Total	14·15

It is possible that some of the beds exposed in the last and lowest section may be part of the underlying Morden member, although, as already pointed out, some non-calcareous shale does occur in the Boyne member in the north. An example of this is seen in the occurrence of an 8-foot section of non-calcareous shale in an exposure in NW. ¼ sec. 33, tp. 42, rge. 3, W. 2nd mer. This exposure comprises beds that are probably higher than those in the sections just described.

The top of the Boyne and part of the overlying Pembina beds are well exposed in a section on the northwest bank of Etomami River near the centre of sec. 32, tp. 42, rge. 3, W. 2nd mer., which McLearn measured as follows:

Pembina Member	Thickness Feet
Shale, black	0·33
Bentonite	0·05
Shale, black	0·18
Bentonite	0·50
Shale, black	2·42
Bentonite	0·25
Shale, black	0·35
Bentonite	0·23
Shale, black	0·44
Bentonite	0·05
Shale, black	0·45
Bentonite	0·23
Shale, black	0·15
Concretionary layer	0·10
Shale, black	0·55
Bentonite	0·16
Shale, black; with scattered pyrite	0·30
Bentonite	0·03
Shale, dark grey	0·13
Pyrite layer	0·10
Bentonite	0·06
Shale, black	0·24
Bentonite	0·11
Shale, black	0·18
Bentonite	0·21
Boyne Member	
Shale, dark grey to black, fissile; some beds of speckled shale near base	3·05
Bentonite	0·10
Shale, black, fissile; some speckled shale	0·50
Bentonite	0·18
Shale, dark grey, speckled with white	1·30
Bentonite	0·03
Shale, grey, speckled with white, calcareous	0·50
Bentonite	0·03
Shale, grey, speckled with white, hard, calcareous	1·30
Bentonite	0·03
Shale, grey, speckled with white	0·40
Bentonite	0·03
Shale, dark grey, speckled with white, hard, calcareous; *Ostrea* bed about middle of section	3·45
Bentonite	0·03
Shale, dark grey, speckled with white; *Ostrea* zone at top	1·55
Bentonite	0·17
Shale, dark grey, speckled with white, hard, calcareous	2·30
Covered to river level	2
Total thickness	25·02

The top of the Boyne is placed at the base of that part of the section that carries much bentonite, because in the south, where the formation is better developed, the change from beds that contain much bentonite to beds that are calcareous marks the contact of the two members. The fact that some of the beds in the Boyne are not of speckled shale is not unusual, as the beds on Vermilion River also show much non-calcareous shale.

These sections are representative of the most northerly development of the Boyne in this area. Other small exposures in this vicinity and farther east along the escarpment show essentially the same type of lithology.

Palæontology and Correlations. The Boyne is the only member of the Vermilion River formation that contains diagnostic fossils. In sections along the Etomami, McLearn identified the following:

Ostrea congesta Conrad
Inoceramus cf. *lundbreckensis* McLearn
Inoceramus pontoni McLearn
Oxytoma nebrascana Evans and Shumard
Scaphites ventricosus Meek and Hayden
Baculites cf. *codyensis* Reeside

Outcrops in the speckled shale zone along Vermilion River yielded a few fragments of ammonites that resemble *Scaphites ventricosus* and some fragments of a species of *Baculites*. In the higher beds, near the contact with the overlying Pembina, on Vermilion River, some small *Scaphites* and *Baculites* were found. The identification of these has not been revised, and although Kirk thought that they resembled *Scaphites nicolleti* it seems doubtful in view of the proximity of the *ventricosus* fauna. McLearn has been unable to identify any specimens from this locality as *Scaphites nicolleti*. A specimen found at this locality by McLearn resembles *Baculites ovatus*.

No diagnostic macro-fossils were found in outcrops in Morris Valley. In Pembina Valley some fragments of *Scaphites ventricosus* and *Inoceramus pontoni* were found in the speckled shale zone of the Boyne beds on both the north and south sides of the valley. In the southern exposures *Ostrea congesta* is fairly common at several localities.

The occurrence of *Scaphites ventricosus* indicates correlation with the Niobrara of the United States and with the lower part of the Wapiabi formation of the Foothills in Alberta. *Inoceramus pontoni* indicates the same relationship with the Alberta beds, but *Inoceramus lundbreckensis* is believed to be confined to the upper part of the Wapiabi formation, and its occurrence in the upper part of the Boyne member, at localities collected by McLearn on Etomami River, suggests a correlation with the upper beds of the Wapiabi.

Micro-fossils are fairly common in the Boyne member, but the fauna varied somewhat with local conditions at the time of deposition. In the vicinity of Leary and St. Lupicin is an abundant fauna with some variation similar to that described by Leotterele[1]. Many of the species have been found nowhere else in the area. The common species found in the Boyne are:

Gaudryina rugosa d'Orbigny
Lenticulina macrodiscus (Reuss)
Heterohelix americana (Ehrenberg)
Gumbelina globulosa (Ehrenberg)
Gumbelina striata (Ehrenberg) or *plummerae* Leotterele
Gumbelina globifera (Reuss)
Ventilabrella eggeri Cushman
Neobulimina sp.?
Loxostoma plaita (Carsey)
Loxostoma tegulata (Reuss)
Globigerina cretacea d'Orbigny
Globigerinella aspera (Ehrenberg)
Gyroidina nitida (Reuss)
Gyroidina cf. *depressa* Alth
Planulina kansasensis Morrow

PEMBINA MEMBER

The upper part of the Vermilion River formation consists of a series of dark grey to black, non-calcareous shales with numerous bands of bentonite

[1] Leotterele, G.J.: The Micropalaeontology of the Niobrara Formation in Kansas, Nebraska, and South Dakota; Nebraska Geol. Surv., Bull. 12, 2nd ser., 1937.

near the base in all parts of the area. The name Pembina beds was given by Kirk to this part of the formation in the southern part of the area. More recent work has shown that the member persists throughout the area mapped, although showing some variation in composition and arrangement of beds in different localities. The member was included in Tyrrell's Millwood formation, and in other parts of the plains may have been included with the Benton, Alberta, or Lea Park formations.

In the southern part of the area many outcrops include the beds that contain numerous bentonite bands near the base of the member. On the other hand, owing to the fact that the lower beds of the overlying Riding Mountain formation slump very easily, the upper part of the Pembina is rarely exposed. Only one outcrop showing this part of the formation was observed in the southern part of the area mapped.

The best section of Pembina beds observed in the southern part of the area occurs on the north bank of Pembina River just east of the bridge, in SW. $\frac{1}{4}$ sec. 27, tp. 1, rge. 8, W. Principal mer. The top of the section is very near the contact with the Riding Mountain formation, but weathering of the Pembina shale and slumping from above the measured section made it impossible to determine the exact position of the contact. Some Riding Mountain beds are exposed a short distance up the road from the section. The section was measured in two parts, the upper part at the west end of the exposure and the lower part (*See* Plate IV B), and the bore-hole showing the contact with the underlying Boyne beds, near the eastern end of the exposure. The complete section is as follows:

Top of section	Thickness Feet
Shale, much weathered, brownish	5·0
Shale, dark grey; some fish remains	11·0
Bentonite, cream coloured	0·3
Shale, dark grey to black	6·5
Bentonite, cream coloured	0·1
Shale, dark grey to black	3·9
Bentonite parting	
Shale, dark grey	1·7
Bentonite, cream coloured	0·05
Shale, dark grey	4·8
Bentonite, cream coloured	0·07
Shale, dark grey to black	14·8

Below this the section was taken from the east end of the outcrop. It continues as follows:

	Thickness Feet
Bentonite, cream coloured	0·1
Shale, black	1·0
Bentonite, cream coloured	0·05
Shale, black	5·3
Bentonite, cream coloured	0·05
Shale, black	0·3
Bentonite, cream coloured	0·05
Shale, black	2·4
Bentonite	0·25
Shale, black	1·7
Bentonite, cream coloured	0·05
Shale, black	0·8
Bentonite, cream coloured	0·5
Shale, black; with bentonite parting near top	0·5
Bentonite, cream coloured	0·8
Shale, black	0·3
Bentonite, cream coloured	0·25
Shale, black	0·3

	Thickness feet
Bentonite, cream coloured	0·3
Shale, black	0·7
Bentonite, cream coloured	0·15
Shale, black	0·2
Bentonite, cream coloured	0·1
Shale, black	0·15
Bentonite, cream coloured	0·4
Shale, black	1·0

Below this point a hole was made with a soil auger to a depth of a little over 11 feet. The section penetrated is as follows:

	Thickness Feet
Shale, black	3·9
Bentonite, greyish	0·5
Shale, black	0·6
Bentonite, grey to white	0·1
Shale, black	0·2
Bentonite, grey	0·5
Shale, black	0·1
Bentonite, grey	0·1
Shale, black	0·5
Bentonite, grey	0·1
Shale, black	0·4
Bentonite, grey	0·3
Hard, calcareous or sandy rock, grey	0·05
Shale, black	0·25
Bentonite, grey	0·3
Shale, black	0·7
Bentonite, grey	0·05
Shale, black to dark grey	1·75
Bentonite	0·1
Boyne Member	
Shale, medium grey, calcareous, speckled	0·7

The total thickness of Pembina beds in this exposure and bore-hole is 76·4 feet, and the total thickness of the Pembina at this locality is probably a little over 80 feet.

The bentonite beds in the Pembina vary in thickness from place to place and may not be continuous. In the vicinity of Thornhill they include several fairly thick beds with little shale between, and bentonite has been produced commercially. Along the track west of St. Lupicin (Babcock) none of the beds is more than 3 or 4 inches thick and the sequence is somewhat different.

No outcrop of Pembina beds was observed between Morris River and Vermilion River districts southwest of Dauphin.

A nearly complete section of the Pembina member is exposed on the north-west bank of Vermilion River in SW. ¼ sec. 22, tp. 23, rge. 20, W. Principal mer. This section was not studied in as much detail as the others, but in general is as follows:

	Thickness Feet
Shale, dark grey, weathering brownish; with yellow iron encrustation like melanterite and some clay ironstone concretions near top	62·0
Bentonite, yellowish to white	0·2
Shale, dark grey, non-calcareous	6·0
Bentonite band	0·3
Shale, dark grey	5·0
Series of alternating shale and bentonite bands, including six or seven of the latter not over 3 inches thick	7·0
Boyne Member	
Shale, dark grey; with hard layer of concretions near top	19·0

This section contains fewer bentonite bands than were seen in this member in other parts of the area. But the position of these beds above the Boyne was proved at another exposure downstream from here and the relationship to the overlying Riding Mountain beds was established by tracing the beds upstream to where the contact of the Riding Mountain formation and the Pembina beds was observed. The top of this exposure is probably within a few feet of this contact. The Pembina beds at this locality are about 85 feet thick. The contact between the Pembina and the overlying shale of the Riding Mountain formation was observed farther upstream in SW. ¼ sec. 16, tp. 23, rge. 20, W. Principal mer. At this locality Kirk measured the following section:

RIDING MOUNTAIN FORMATION	Thickness Feet
Shale, greenish grey, soft; ironstone band at base	11·0
VERMILION RIVER FORMATION	
Pembina Member	
Shale, dark grey	10·0
Bentonite	0·2
Shale, dark grey	3·5
Bentonite	0·2
Shale, dark grey, with band of concretions	3·0
Bentonite	0·2
Shale, dark grey, with ferruginous bands	15·0
Bentonite	0·2
Shale, dark grey, ironstone concretion near top	16·0
Total thickness	59·3

The beds placed at the top of the Pembina member in this section have the softness of the Riding Mountain beds and the dark grey colour of Vermilion River beds. They have been placed tentatively in the Vermilion River formation.

The characteristics of the Pembina change from east to west as well as from north to south. In the vicinity of Kamsack wells have drilled 30 to 40 feet of non-calcareous black shale above the speckled shale of the Boyne. The total thickness of the beds assigned to the Vermilion River formation at Kamsack is 190 feet and compares favourably with 175 feet estimated along Vermilion River. Differences in the thickness of the Pembina member may be due to an unconformable contact with the Riding Mountain formation, thickening of the Boyne and Morden members, or else conditions responsible for the deposition of calcareous speckled shale may have lasted longer in the Kamsack district.

No outcrops of Pembina beds were observed north of Vermilion River for about 70 miles along the escarpment, that is, to approximately between Renwer and Cowan. West from there, along the re-entrant in Swan River Valley and north along the escarpment to the northern limit of the area mapped, intermittent exposures of these beds are found. Most of the exposures are small and not much is known about the formation. At several places between Birch River and Barrows what appeared to be fair exposures of Pembina beds were observed, but at each place evidence of slumping indicated that the information was not reliable. Beyond the north end of the area of slump the upper part of the Pembina can be seen in place, and Landes measured the following section on Barrows Creek near the north side of sec. 16, tp. 44, rge. 28, W. Principal mer.:

RIDING MOUNTAIN FORMATION	Thickness Feet
Shale, greenish grey, friable	1·0
VERMILION RIVER FORMATION	
Pembina Member	
Bentonite	0·04
Shale, dark grey, friable	0·2
Bentonite	0·04
Shale, dark grey, friable	0·2
Bentonite	0·04
Shale, dark grey, friable	0·8
Bentonite	0·04
Shale, dark grey, friable	0·6
Bentonite	0·04
Shale, dark grey, friable	1·0
Bentonite	0·06
Shale, dark grey, friable	1·00
Total thickness	5·06

Even near this locality Landes observed slumping, and it is possible that some of the beds are not in place.

On Sawmill Creek, in sec. 22, tp. 44, rge. 28, W. Principal mer., Landes measured the following section, which he considered as near the middle of the Pembina member:

	Thickness Feet
Bentonite	0·3
Shale, dark grey	1·0
Bentonite	0·05
Shale, dark grey, friable	0·3
Bentonite	0·4
Shale, dark grey, friable	0·3
Bentonite	0·3
Shale, dark grey, friable	0·3
Bentonite	0·3
Shale, dark grey, friable	0·6
Bentonite	0·3
Shale, dark grey, friable	0·2
Bentonite	0·2
Shale, dark grey, friable	0·1
Bentonite	0·3
Shale, dark grey, friable	0·9
Bentonite	0·05
Shale, dark grey, friable	0·35
Bentonite	0·4
Total thickness	6·6

On the same creek another exposure shows what Landes considered to be the lower part of the Pembina member, and the following section was measured:

	Thickness Feet
Bentonite	0·1
Shale, dark grey	0·2
Bentonite	0·1
Shale, dark grey	0·6
Bentonite	0·1
Shale, dark grey	0·3
Bentonite	0·1
Shale, dark grey	0·7
Bentonite	0·1
Shale, dark grey	0·3

	Thickness Feet
Bentonite	0·1
Shale, dark grey	0·8
Bentonite	0·2
Shale, dark grey	1·0
Bentonite	0·15
Shale, dark grey	0·4
Bentonite	0·1
Shale, dark grey	0·5
Bentonite	0·1
Shale, dark grey	0·3
Bentonite	0·2
Shale	1·6
Bentonite	0·05
Total thickness	8·0

These three sections show a total of over 17 feet of the Pembina member. None of the sections overlaps, and the nature of the missing beds is not known. Landes observed small slump blocks consisting mostly of non-bentonitic beds, and he considered that the missing parts were made up mostly of this type of shale. Farther west most of the Pembina is exposed along Etomami River. The lower part of the member has already been described with the section including the upper part of the Boyne member.

A section showing the upper part of the Pembina, within a foot or two of the top, was measured by McLearn on the south side of Etomami River a little west of the centre of sec. 15, tp. 42, rge. 4, W. 2nd mer.:

Top of section	Thickness Feet
Shale, dark grey to black, friable, soft	5·80
Bentonite	0·14
Shale, dark grey to black, friable, soft	3·33
Bentonite	0·05
Shale, dark grey to black, friable	0·80
Bentonite	0·18
Shale, dark grey to black, friable, soft	1·20
Bentonite	0·20
Shale, dark grey to black, friable	3·40
Bentonite	0·05
Shale, dark grey to black, friable	0·10
Bentonite	0·05
Shale, dark grey to black, more fissile	0·90
Bentonite	0·04
Shale, dark grey to black, hard	0·25
Bentonite	0·03
Shale, dark grey to black, hard, fissile	0·20
Bentonite	0·03
Shale, dark grey to black, hard, fissile	0·05
Bentonite	0·11
Shale, dark grey to black, hard, fissile, some selenite crystals	1·61
Total thickness	18·52

This section apparently includes beds a little above the top of the section shown on page 41. As the total thickness of the Pembina wells at Bertwell (Kakwa) is between 30 and 40 feet, probably the gap between the two sections is not over 5 feet.

RIDING MOUNTAIN FORMATION

The name Riding Mountain was used by Kirk (1930) to designate the soft, greenish grey clay beds that overlie the Vermilion River formation. Kirk considered these beds to be 80 to 250 feet thick. Overlying the soft shales in many parts of the area are medium to light grey, hard, siliceous shales that had been called the Odanah by Tyrrell. Kirk noted that the contact of the Odanah and the Riding Mountain did not appear to be stratigraphic. More recent work indicates this to be true, and it seems probable that the Odanah is merely a peculiar lithologic phase of Riding Mountain beds. For this reason the name Riding Mountain is retained in this report for the entire formation and the term Odanah is employed only in referring to the hard type of shale within it.

The total thickness of the Riding Mountain formation is, roughly, 1,100 feet or more. No well has penetrated it completely nor as yet has it been possible to compile the necessary information from outcrops. Although several wells have been drilled through nearly complete sections of the formation, in nearly all instances samples have either not been kept or were so carelessly taken that they are useless. The estimate of the thickness is based on results obtained in drilling the Deloraine water well in 1888 to 1890. Although very few samples were kept the thickness can be estimated because the well was located only about 3 miles north of where Boissevain sandstone is exposed at an elevation of about 100 to 150 feet higher. A sample from a depth of 1,000 feet in this well is of brownish, non-calcareous shale that much resembles the shale near the top of the Vermilion River formation.

The Fleming well, sec. 14, tp. 12, rge. 30, W. Principal mer., drilled through most of the Riding Mountain formation. Although the samples contain but few fragments of concretions, and although all of them include some material from glacial deposits, the changes that occur in the micro-faunas at progressively greater depths in the well indicate that the samples represent a fairly complete section. The contact of the Riding Mountain and Vermilion River formations in this well is at a depth of 1,060 to 1,080 feet. As the upper 80 feet of the well is in glacial deposits the total thickness of Riding Mountain beds must be more nearly 1,100 feet.

In the northern part of the area much of the upper part of the Riding Mountain formation is missing.

The basal part of the Riding Mountain is composed of clay shale that is slippery and tends to slump very easily. Under such conditions exposures showing an undisturbed contact between the Pembina member and the Riding Mountain formation are rare. Kirk (1930) mentions that there are probably 80 feet or more of soft shales at the base of the formation in the southern part of the area. In contrast with this the Fleming well shows over 500 feet of soft shales below the hard Odanah type of shale. This may indicate, in part at least, that the contact between the hard and soft shales is quite irregular, or it may indicate that part of the section seen along the escarpment to the east has slumped out. Apparently the hard shale alternates with layers of soft shale, near the base at least, and this condition may exist fairly high in the section.

A section showing some of the softer shale grading into the overlying hard shale is exposed near Wawanesa on the east bank of Souris River, near the centre of sec. 23, tp. 7, rge. 17, W. Principal mer. At this locality Kirk measured the following section, in descending order:

	Thickness Feet
Shale, medium to light grey, in bands 2 to 6 inches thick alternating with soft greenish grey shale	10·0
Shale, greenish grey; with two bentonite bands	1·0
Shale, alternating hard and soft as above	14·0
Shale, soft, greenish grey; some layers of concretions with fossils, including *Baculites*, *Inoceramus*, and *Dentalium*	48·0

The southernmost exposure showing an undisturbed contact of the Vermilion River and Riding Mountain formations is on Vermilion River and has already been described. At this place the contact seems to be gradational from black shale to greenish grey shale. Several outcrops farther north expose what appear to be lower Riding Mountain beds, although there is generally much uncertainty about their position due to probable slumping. On Etomami River some of the lower beds are exposed, and these consist only of greenish grey clay shale with ironstone concretions. One exposure in NW. ¼ sec. 15, tp. 42, rge. 4, W. 2nd mer., shows a gradational contact from black shale below into greenish grey shale above.

In all localities along the escarpment and in localities west of the escarpment from Kamsack north the exposures of Riding Mountain beds are either of the hard siliceous shale or of a very soft, greasy, greenish grey shale. Along Assiniboine River in the vicinity of Millwood and Harrowby about 100 feet of sandy shale is exposed. No other outcrops of this phase of the Riding Mountain beds were observed. In view of the fact that most of the exposures along the front of the escarpment, those not composed of the hard, siliceous shale of the Odanah phase, have slumped, it is possible that beds exposed near Millwood are covered over in other places. If the well near Fleming passed through a normal section of the formation there is plenty of room below the hard shales for beds that have not been observed in exposures.

Palæontology and Correlations. The Riding Mountain formation comprises beds that appear to be equivalent in age to formations from Lea Park to Bearpaw, inclusive, in the northern part of the Plains of Alberta and western Saskatchewan, and probably from Milk River to Bearpaw in the southern plains of Alberta. It is probably the equivalent of the Pierre shale of the northern part of the Plain in the United States.

Sufficient fossils have not been identified from the Riding Mountain formation to ascertain if it can be zoned. The changes in species of foraminifera in the Fleming well suggest, however, that zoning is possible and that at present these fossils afford the best chance of correlating sections and wells.

Along Assiniboine Valley between Millwood and Harrowby several exposures of Riding Mountain beds have yielded fossils, collected by various geologists. The following macro-fossils have been identified:

Inoceramus barabini Morton
Inoceramus barabini n. var.
Inoceramus tenuilineatus Hall and Meek
Lucina occidentalis Meek and Hayden
Pteria notukuensis Warren
Thyasira n.sp.
Scaphites nodosus var. *brevis* Meek
Scaphites ncdosus close var.
Scaphites sp.
Baculites compressus Say

Elsewhere very few fossils have been collected from the Riding Mountain formation. Some were found about half a mile north of Dand in concretions in roadside exposures of the hard, siliceous shale. These fossils were identified as follows:

Oxytoma nebrascana Evans and Shumard
Scaphites (Discoscaphites?) sp.
Baculites compressus Say

Some of the *Baculites* at this locality are small specimens that show the initial coil.

Near Wawanesa specimens of *Ostrea* and *Serpula* were found in beds that appear to lie at the base of the hard Odanah phase of the Riding Mountain formation.

The micro-fossils of the Riding Mountain formation have not been studied in much detail. The foraminifera give indications of varying in different parts of the formation. In the lower part *Glomospira charoides* (Jones and Park) var. *corona* Cushman and Jarvis and *Ammodiscus cretacea* (d'Orbigny) are fairly common. In the northern part of the area *Bigenerina hastata* Cushman occurs in some of the lower beds.

Near the base of the Odanah phase an occurrence of *Silicosigmoilina californica* Cushman and Church may prove to be a good horizon marker.

Several other species have been found in samples from the upper part of the Fleming well, as well as a few species from outcrops along the Assiniboine near Millwood.

The occurrence of numerous radiolaria in the lower beds in the northern part of the area is also characteristic of the Riding Mountain formation. Some of these were described by D. Rust from material collected by Tyrrell.

BOISSEVAIN FORMATION

A sandstone and sand formation overlies Riding Mountain beds along the base of Turtle Mountain. Only a few exposures of the formation have been observed (*See* Plate V) and its boundaries are but little known. In some localities the sandstone is solid enough to serve as a building stone, and it is described as Boissevain sandstone by Parks in his "Building Stones of Canada." Neither the upper nor lower contact is exposed, although beds very near the top of the formation were observed south of Whitewater, in sec. 3, tp. 2, rge. 21, W. Principal mer. Some fairly high beds in the formation can also be seen about 2 miles south of Boissevain, near SW. $\frac{1}{4}$ sec. 13, tp. 3, rge. 20, W. Principal mer. The lowest exposure of Boissevain was seen in a roadside cut in the SW. $\frac{1}{4}$ sec. 18, tp. 3, rge. 19, W. Principal mer. The various exposures indicate that the Boissevain is made up of greenish grey sandstone that weathers a yellowish, somewhat rusty colour. Some parts of the sandstone have been cemented into a hard rock that occurs as lenses in the formation. These hard lenses furnished the building stone used in many buildings in Boissevain. Judging by the elevations of the highest and lowest beds seen, it is assumed that the Boissevain is about 100 feet thick.

There is no fossil evidence for the age of the Boissevain. Its position just above the Riding Mountain shale suggests that it may be the equivalent of some or all of the arenaceous formations that overlie the Bearpaw in Saskatchewan. It does contain white clay as the Whitemud formation does, but it is possible that this far east conditions did not favour the formation of such deposits. The few fragments of carbonized plant fossils found in the Boissevain indicate that the formation is of continental or freshwater origin. Some fragments of plants from a concretion were collected by Kirk, and W. A. Bell has identified them as a seaweed-like plant like *Fucus lignitum* Lesquereux, and a number of fragments of *Trapa? microphylla* Lesquereux.

TURTLE MOUNTAIN FORMATION

A series of shale and sandstone and some lignite-bearing beds rests on the Boissevain formation on Turtle Mountain. The name Turtle Mountain formation was given these beds by Kirk in his manuscript map, and Johnston (1934) used the name in a brief account of formations in his report on the glacial deposits of Manitoba.

The thickness of the Turtle Mountain formation is not known because there are only a few scattered outcrops. Water-well records indicate that members of the formation occur up to an elevation of 2,000 feet. As the lowest exposures are at an elevation of about 1,800 feet, it is probable that the formation is 200 feet thick.

The outcrops found are all in an area south and a little east of Goodlands. No outcrop shows more than about 10 feet of beds, so that the sequence could not be determined. The outcrops observed consist mostly of fine-grained, white or yellowish sand or sandstone with occasional fossil plant remains. Some shaly bands are present and also a few thin concretionary layers, and beds of lignite.

A few fossil plants were collected from these beds by Mr. Frank Shepherd of the Manitoba Department of Mines. These fossils were identified by W. A. Bell of the Geological Survey as: *Sequoia nordenskiöldi* Heer, *Taxodium occidentale* Newberry, and *Cladophlebis* sp. They indicate a probable Paleocene age, probably equivalent to the upper part of the Ravenscrag.

RAVENSCRAG FORMATION

The southwest corner of the Assiniboine map-area is represented as underlain by the Ravenscrag formation. There are no outcrops, but records of water wells show that some coal-bearing sandy beds occur here. These beds are assumed to belong to the Ravenscrag formation, as do the Estevan coal-bearing beds. Possibly some late Upper Cretaceous formations also underlie this area, but there is no evidence for differentiating them.

CHAPTER IV

STRUCTURE

Throughout most of the area included in this report the strata are nearly flat-lying, the regional dip being to the southwest at about 5 to 10 feet to the mile. The beds exposed along the Manitoba escarpment show minor structures in places, but over most of the area suitable key beds were not found or there were no exposures. Samples from the Fleming well, however, indicate that the Riding Mountain formation may contain identifiable micro-fossil zones that with further study would facilitate structural interpretations. If so, minor structures may be disclosed in the southwestern part of the mapped area. Some indication of the apparent gentleness of the regional structure is gained by noting elevations obtained at the top of the Boyne beds in those parts of the area where observations could be made. The following table supplies this data:

Location	Elevation	Type of occurrence and remarks
	Feet	
SW. ¼ sec. 4, tp. 1, rge. 6, W. Principal mer......	1,281 ± alidade	Outcrop
SE. ¼ sec. 20, tp. 1, rge. 5, W. Principal mer.....	1,301 ± bar	Outcrop and bore-hole
NE. ¼ sec. 20, tp. 2, rge. 6, W. Principal mer.....	1,293 ± bar	Outcrop and bore-hole
SW. ¼ sec. 4, tp. 1, rge. 5, W. Principal mer......	1,278 bar	Outcrop and bore-hole
NW. ¼ sec. 29, tp. 3, rge. 6, W. Principal mer....	1,272 bar	Outcrop and bore-hole
Centre sec. 15, tp. 6, rge. 8, W. Principal mer....	1,306 alidade	Outcrop and bore-hole
SW. ¼ sec. 27, tp. 1, rge. 8, W. Principal mer.....	1,174 bar	Outcrop and bore-hole
Sec. 23, tp. 2, rge. 9, W. Principal mer..........	1,200 ±; 1,210 bar	
Deloraine well..............................	565 ± contour	
Fitzsimmon or Fleming well, SE. ¼ sec. 14, tp. 12, rge. 30, W. Principal mer..................	600 ± contour	
On Vermilion River, SE. ¼ sec. 22, tp. 12, rge. 30, W. Principal mer..........................	1,320 −	Approximate contact
Kamsack..................................	1,250 −	Well
Bertwell..................................	1,220 −	Well

The elevations of the horizon give an idea of local variations in the structure and of the general west or southwest regional dip. The value of the elevations on this horizon is less obvious in the north because the information is more scattered. The variations in thickness of the members of the Vermilion River referred to in the description of the formation must be taken into consideration in determining dips over long distances. The members may vary in thickness from place to place, so that the dip at a particular contact at one place may differ from the dip obtained on the same contact at another place.

The upper part of the Favel formation represents a fairly consistent zone, and elevations on this indicate the local as well as the regional structure, particularly in the northern part of the area. The following table gives the elevation of the top of the Favel at various localities:

Location	Elevation	Remarks
	Feet	
Commonwealth Manitou No. 2 well, sec. 23, tp. 2, rge. 9, W. Principal mer.	810	Contact at 450 ft. in well; ground elevation by stadia traverse, 1,256 ft.
Deloraine well	190	Contact at 1,450 ft. depth; surface assumed as 1,640 ft.
Fitzsimmon or Fleming well	440	Surface elevation of well assumed as 1,800 ft., according to contours.
Ochre River, probably in sec. 30, tp. 22, rge. 17, W. Principal mer.	1,194	Elevation on upper limestone traverse by Kirk; not a closed traverse.
Vermilion River, NW. corner l.s. 14, sec. 35, tp. 23, rge. 20, W. Principal mer.	1,250	Outcrop stadia traverse.
Vermilion River, east bank of river near NW. of l.s. 10, sec. 35, tp. 23, rge. 20, W. Principal mer.	1,243	Outcrop.
Vermilion River, east bank of river near centre sec. 35, tp. 23, rge. 20, W. Principal mer.	1,234	
Vermilion River, near centre l.s. 5, sec. 35, tp. 23, rge. 20, W. Principal mer.	1,232	
Vermilion River, near NW. corner l.s. 3, sec. 35, tp. 23, rge. 20, W. Principal mer.	1,230	
Vermilion River	1,225	Other part of same outcrop.
Vermilion River; average of elevations	1,238	
Pine River, SW. ¼ sec. 1, tp. 33, rge. 23, W. Principal mer.	1,271	Stadia by R. A. C. Brown.
East branch, Favel River, SW. ¼ sec. 30, tp. 35, rge. 25, W. Principal mer.	1,320	Stadia traverse by F. H. McLearn.
Swan River north of Benito, north bank of River near centre sec. 3, tp. 35, rge. 29, W. Principal mer.	1,255	
Swan River north of Benito, south bank of river near NE. corner SE. ¼ sec. 31, tp. 34, rge. 29, W. Principal mer.	1,265	
Kamsack	1,083	Oil Ventures No. 7 well; depth 340 ft.; surface elevation 1,423 ft.; barometric survey by Prof. F. H. Edmunds.
Birch River, NW. sec. 32, tp. 39, rge. 26, W. Principal mer.	1,318	Stadia traverse by F. H. McLearn.
Bertwell (Kakwa No. 5 well), l.s. 14, sec. 31, tp. 41, rge. 4, W. 2nd mer.	1,150	Depth 200 ft. below surface; elevation from stadia traverse by F. H. McLearn.
Reserve Northern Royalties No. 1, sec. 27, tp. 40, rge. 5, W. 2nd mer.	1,109	Depth 434 ft.; elevation from stadia traverse by R. W. Landes.
Piwei Hill Coalgate No. 1, l.s. 15, sec. 34, tp. 39, rge. 5, W. 2nd mer.	1,105	Depth 730 ft.; elevation from stadia traverse by R. W. Landes.

Several structural interpretations may be made from the above elevations of this horizon. The regional strike changes in different parts of the area: in the south the trend seems to be northwest-southeast; between Vermilion River and Kamsack it is a little more northerly; and from the vicinity of Pine River and Swan River north it seems to be almost due north. The Piwei Hill and Reserve wells are apparently just about on strike, which would be only a few degrees west of north. The regional dip seems to be mostly west or southwest at the rate of 6 to 10 feet a mile.

Although little information could be obtained on local structures over most of the area, a few indications of the nature and magnitude of such structures were observed along the Manitoba escarpment.

In the general vicinity of the escarpment south of Assiniboine River there are some indications of a gentle rise of the top of the Boyne beds to the north-northwest from the International Boundary south of Morden to St. Lupicin. From this point a slight drop is indicated to 1½ miles west-southwest of Treherne. The beds near Treherne are at least 25 feet lower than near St. Lupicin. This may indicate a more northerly trend of the strike or it may indicate a slight warping of the beds, with the high point in the vicinity of St. Lupicin.

A small local high in Pembina Valley south of Manitou indicates that other such structures may occur in the southern part of the area. This high shows a small patch of the Vermilion River surrounded by the Riding Mountain formation. The beds at this locality are about 35 feet higher than near the Mowbray bridge in sec. 27, tp. 1, rge. 8, W. Principal mer. Wells drilled near Pilot Mound and near Purves indicate that the beds dip to the west and northwest. Three wells were drilled on this structure and small quantities of gas were obtained in the beds of the Swan River group. Unfortunately the samples obtained from the wells near Purves and Pilot Mound were so poor that the dip could not be determined very accurately.

The formations drilled in the Deloraine well, SE. ¼ sec. 10, tp. 3, rge. 23, W. Principal mer., may be interpreted as evidence of a local low structure. The top of the Favel formation in this well is 620± feet lower than in the Commonwealth Manitou No. 2 well and 250± feet lower than in the Fleming well. The presence of late Cretaceous and early Tertiary deposits in the Turtle Mountain area may be interpreted as an indication of a minor basin of deposition similar to that in which Whitemud and Ravenscrag occur in south-central Saskatchewan. The difference in elevation between these beds in the Commonwealth and Deloraine wells amounts to only about 6 feet to the mile. Possibly the higher elevation of the beds in the Fleming well may indicate a high structure. The strike of the beds between Deloraine and Fleming is more westerly than indicated by formations farther east along the escarpment. The apparent variation in strike may be due to local structures. In the southern part of the area there are probably other structures similar to the one in Pembina Valley south of Manitou.

The area north of Assiniboine River to the vicinity of Birnie and Kelwood exposes no outcrops. Evidently this is an area where there has been much erosion of the bedrock. Water wells in this area are 100 to 300 feet deep in unconsolidated deposits. It is possible that these conditions are related to structure. A flattening of the dip or a change in strike might induce more lateral erosion to take place in the development of the valley in this part of the area.

Along most of the escarpment in the Riding Mountain region the information obtained was insufficient to determine any local structures. Vermilion River Valley was the only part of this region where some indication of local structure was obtained. As can be seen from the table of elevations of the top of the Favel formation in sec. 35, tp. 23, rge. 20, W. Principal mer., the strata drop 20 to 25 feet to the south. In contrast with this the elevation of a bentonite bed in the Vermilion River formation in secs. 15 and 23 of the same township does not vary more than 3 feet in a southwesterly direction in a distance of about $1\frac{1}{2}$ miles.

In the vicinity of Swan River Valley there are indications of local structures. On the west branch of Favel River the contact of the Ashville and Favel formations is at an elevation of about 1,220 feet. About $3\frac{1}{2}$ miles west and southwest on Roaring River, the same contact appears to have an elevation of between 1,275 and 1,300 feet. West of Roaring River, on Swan River north of Benito, the same contact is estimated to have an elevation of between 1,150 and 1,175 feet. With outcrops scattered as they are it is impossible to be certain whether these variations in elevation are due to folding or to faulting.

Another locality in the vicinity of Swan River where a local structure is indicated is Thunder Hill. Tyrrell (1892, page 109E) noticed that the formation (Favel) in this locality was much higher than in the surrounding area. He accounted for this anomaly by assuming that the underlying Cretaceous sandstones had thickened or that the beds exposed on the hill were part of the "Pierre." Kirk (1930, page 134) recognized that the beds exposed on the hill were part of the Favel formation, and, as no indication of marked change in the thickness of the lower beds was noted in the surrounding areas, he assumed that the hill is the site of some high structure due to a local uplift, possibly to doming of the underlying Devonian beds.

Since that time three diamond drill holes have been sunk in this locality and further geological information has been obtained. One hole, Thunder Hill No. 1 (Canadian Industries, Limited) well (*See* logs in Chapter VI), located on top of the hill, passed through the Favel formation and layers of boulders down to 340 feet. At 340 feet the Ashville was entered and the well continued in this formation to 820 feet where Lower Cretaceous sands were reached. The well continued in sands of Lower Cretaceous or Jurassic age to 1,232 feet when drilling was stopped. The beds had appreciable dips down to 957 feet. Below this depth they appeared to be flat. The other two holes, located about a mile east and west, respectively, of the Thunder Hill No. 1, reached the formation contacts at lower elevations. Judging from the dips shown in this well, whatever force disturbed these formations was more effective near the surface than at depth, and this has suggested that the folding was caused by continental glaciers. The depth to which folding takes place in the well is at least 300 feet below the valley of Swan River and 100 feet lower than where the Lower Cretaceous sands are exposed on the river 20 miles to the northeast. No other locality along the escarpment exhibits similar folding, although there are many other localities where the bedrock could obstruct the ice mass as effectively. In drilling the Thunder Hill No. 1 well no gas nor water was reported by the driller; in fact, drilling water was absorbed by the sand in the lower parts of the well. This would suggest that the sand is cut off from water-bearing sources such as the Lower Cretaceous beds along Swan River 20 miles to the northeast.

In consideration of the facts revealed by the wells it seems probable that the structure in the vicinity of Thunder Hill is the result of the modification of a preglacial structure by the action of glaciers. Possibly the centre of the structure lies to the northeast and was in part carried away or pushed west by the glacier, after which the area denuded was covered by glacial drift and lake deposits.

North of Swan River Valley to Red Deer River outcrops are too scattered to determine what local structures may exist. Part of this area includes a tract that has been left blank on the Mafeking map because of extensive landslides. In the landslide area, which has been studied carefully by McLearn and Landes, beds down to the Ashville formation have been disturbed, and apparent outcrops have slid from place to much lower altitudes. The beds of these disturbed masses of shales often show high dips and such occurrences may be mistaken for structures. The landslide area is 3 miles wide in many places.

Structure in the vicinity of Red Deer and Etomami Rivers has been discussed in another publication (McLearn and Wickenden, 1936). Apparently there are small irregular changes in the attitude of the beds although the regional dip is about west-southwest. Beds in a series of outcrops along Red Deer River in the eastern part of tp. 44, rge. 3, and in tp. 44, rge. 2, W. 2nd mer., show a slight east and northeast dip to the vicinity of the Trail Blazer well in l.s. 1, sec. 31, tp. 44, rge. 2, W. 2nd mer. The beds apparently rise again to the east or northeast downstream from the well. It is possible that the structure may, in part, be due to faulting. Farther west, on Etomami River, the beds show a gentle southwest dip, except in places in the eastern part of tp. 42, rge. 4, W. 2nd mer., where the apparent dip is about 10 feet to the mile to the northeast. A small normal fault observed at one locality has a downthrow to the east. This fault displaces the beds about 10 feet. A few other faults of about the same magnitude could easily account for the apparent dip in the structure northwest of the Trail Blazer well.

It is probable that other minor structures exist in the area, but there is no available means of determining them, other than by test holes, unless some method of correlating beds in the Riding Mountain formation is devised.

CHAPTER V

ECONOMIC GEOLOGY

OIL AND GAS

Although small quantities of gas have been found in many parts of the area, oil in quantities approaching that required for commercial development has not been found. Drilling has been done in many parts of the area, but there are still many places where further investigation is warranted. The following outline of work that has been done may, however, be of some value in planning operations in the future.

PEMBINA VALLEY

As already mentioned, a small high structure is indicated by outcrops of upper Vermilion River beds south of Manitou. Three wells have been drilled in the immediate vicinity of this structure. One, drilled in 1915 or 1916, encountered a little gas at a depth above 925 feet. In 1930 and 1931 the Commonwealth Oil Company drilled a well at almost the same locality and had a slight show of gas in the Favel formation and Swan River beds. The well was continued to 1,120 feet and was abandoned in beds of Jurassic age. Salt water was also encountered in Lower Cretaceous and Jurassic sands. Another well was drilled by the same company about a mile farther north. This was sunk to the Precambrian at a depth of 2,626 feet, but, so far as is known, encountered no appreciable quantities of oil or gas. Two other deep wells have been drilled in this general district: one is near Purves, and one about 2 miles northwest of Pilot Mound. There are no indications of structure near Purves and no commercial shows of gas or oil were found. The samples were very carelessly taken in drilling this well and no satisfactory correlations could be made with wells to the northeast on Pembina River. The indications are that the formations are at a little lower elevation here than those in Pembina Valley. Small shows of gas and oil were reported by the driller.

The Pilot Mound well was located apparently on the assumption that the hill that gives the place its name was the surface expression of an anticline. Samples supplied from this well were very poor and taken at irregular intervals. They indicate that the formations penetrated are at least 100 feet lower than in the Commonwealth Manitou No. 2 well in Pembina Valley. Although the operators reported shows of gas and oil no oil stains were observed on the samples submitted.

DELORAINE

A well drilled by the town of Deloraine for water in 1891-92 reached the Swan River beds at a depth of about 1,800 feet, where sulphur water was encountered. This is the horizon that carried salt water in the Commonwealth Manitou No. 2 well. As mentioned in the chapter on structure it is possible that the well is on the site of a small basin.

FLEMING

The Fleming well (*See* Chapter VI) drilled south of the town of Fleming, Saskatchewan, is reported to have reached a depth of 1,800 feet, although the deepest sample received by the Geological Survey came from a depth of 1,500 feet. A small show of gas occurred at about 400 feet in the well in beds of the Riding Mountain formation.

WASKADA AND OTHER SOUTHERN DISTRICTS

Wells drilled to depths of 250 feet have obtained enough gas for domestic use in this district. Wallace (1927, page 38) reports the average pressure as 14 pounds. It is probable that the gas originates in the Riding Mountain formation and escapes through fractures in the hard beds in this formation.

In the vicinity of Treherne the wells have obtained small supplies of gas at a depth of 150 feet. The source for this gas is probably in the Vermilion River or Favel formations.

At Rapid City, in tp. 13, rges. 19 and 20, W. Principal mer., two wells were drilled for gas. Records, however, do not contain any mention of gas, oil, or water and no samples of the formations drilled are available. Although one well reached a depth of 704 feet there is no means of correlating the formations encountered in other wells or in outcrops.

On Ochre River, in tp. 23, rge. 20, W. Principal mer., two holes have been drilled. Small shows of gas were reported in one of these, which went to a depth of 540 feet. The other well is 1,487 feet deep, but it is not known whether any gas or oil was encountered. There is no evidence of a definite structure in this vicinity.

Vermilion River Valley has been the site of several holes, but no commercial shows of oil or gas were obtained. One hole was drilled to what appears to be the top of the Silurian at a depth of 1,256 feet.

KAMSACK GAS FIELD

In the vicinity of Kamsack, gas has been found in many wells at depths of a little over 200 feet. The gas occurs in the Boyne beds of the Vermilion River formation. Apparently the reservoir is due to some peculiar condition in the speckled shale as no sand has been found in the samples. Elevations of the contact of the Riding Mountain and Vermilion River formations show that the beds have a southwest dip of about 10 feet to the mile, but there is no indication of a structural trap for the gas. The highest well, structurally, obtained no gas. Evidently the permeability of the beds is fairly extensive because the drop in pressure has been general throughout the field. Mr. E. Swain gauged the pressure on several wells in 1940 and it was about 33 pounds a square inch. In 1943, Professor Edmunds made a survey of the field and found that the pressure had dropped to 23 pounds. At this rate it seems unlikely that the supply available at this shallow depth will last long. The amount of gas in the wells varies from small shows to 170,000 cubic feet a day. Very few of the wells have obtained more than 50,000 cubic feet. A pipe-line has been laid to supply gas to some buildings in the town.

One hole at Kamsack was drilled into the Devonian formations, but, unfortunately, little information was obtained. The hole was made with a rotary rig and the samples obtained are so poor that it is impossible to recognize the contact between Mesozoic and Palæozoic formations. No occurrences of gas were observed at deeper horizons in this well. Owing to the manner in which the well was drilled there is some possibility that low pressure gas shows may have been shut off by the mud used in drilling.

MAFEKING AREA

In the vicinity of Mafeking eight wells were drilled in the early 1920's. The deepest well reached formations of Ordovician age and several penetrated the Devonian. Only a few small shows or pockets of gas were encountered. There is no indication of a structure suitable to trap oil or gas in this vicinity, though there is danger that some of the slumped ground may be mistaken for worthwhile structures.

HUDSON BAY JUNCTION AREA

The Hudson Bay Junction area is defined here as including the various localities that have been drilled along the lower part of Red Deer and Etomami Rivers and at Bertwell and Reserve. The well nearest to Hudson Bay Junction was drilled on the north side of Red Deer River in sec. 31, tp. 44, rge. 2, W. 2nd mer. This well, known as the Trail Blazer, was drilled in 1932 to a depth of 900 feet. It commenced in the lower part of the Ashville formation and stopped in beds that appear to lie well down in the Devonian. A show of heavy asphaltic oil was encountered in a sand that appears to fill a cave under a ledge of Palæozoic rock. The oil was too heavy to permit pumping.

In the vicinity of Bertwell (Kakwa) eight wells were drilled during 1934 to 1936. The deepest of these, Kakwa No. 5, was 430 feet; the others were between 200 and 300 feet. A little gas was found in the Favel formation between 200 and 300 feet in two of the wells, and Kakwa No. 5 had a small show at 332 feet. None of the wells produced gas in commercial quantities. There is no evidence of structure in this vicinity and the gas probably occurs where local conditions have developed a porous zone in the calcareous shales and limestones of the Favel formation.

Near Reserve a well was drilled to a depth of 1,158 feet, and no good shows of oil or gas were reported. Another well was drilled about 4 miles south of Reserve without encountering oil or gas. There are no outcrops in this vicinity and no indication of local structure other than the southwest regional dip.

CONCLUSIONS

Though results of past drilling in the areas mapped are not encouraging, certain conditions appear to warrant further investigation for oil and gas. Some essential features, such as possible source beds and reservoir beds, are represented in the area. The Favel and Vermilion River formations contain shales that yield 2 to 8 gallons of oil a ton (Ells, 1923). Marine Jurassic beds are present in most of the southern part of the area, and beds of this type and age are associated with the occurrence of oil and gas in southern Alberta. It is also probable that some of the younger Palæozoic formations occur at drilling depths unconformably beneath the Mesozoic strata in southwestern Manitoba and southeastern Saskatchewan. Such conditions might provide stratigraphic traps in beds that are nowhere exposed at the surface. The sandy Lower Cretaceous and Jurassic beds would certainly provide reservoirs where structures are favourable for trapping the oil or gas.

Most of the drilling has been near the Manitoba escarpment or in areas where there is no indication of structure. The occurrence of small structures near the escarpment may be an indication that structures exist farther west where the formations are more deeply buried.

The haphazard type of drilling such as has been done cannot be expected to yield any better results if continued. Bedrock in most of the western part of the area is covered with drift and the only means of determining structure there is by drilling test holes and correlating the formations by means of microfossils and lithology. This work may appear expensive, but in the long run it has a better chance of success than the hit-or-miss methods previously employed. If further drilling is attempted a more serious effort should be made to obtain good samples of the material drilled and to see that these samples and the records of the drilling are retained for future reference. It is possible that adequate information from non-commercial holes may lead eventually to the discovery of oil or gas in some part or parts of the area.

BRINE

The Neepawa salt well, drilled about 1910 to 1914, tapped a flow of brine in what appears to be Silurian rocks. A few years ago Canadian Industries, Limited, took over the well and commenced production of salt by evaporating the brine. In 1934 it was decided to drill another well in order to ensure a continuous supply of brine. Samples of the material drilled in this well were kept, and a log will be found in Chapter VI of this report. The brine is about 68 per cent saturated and contains only a small proportion of calcium and magnesium salts.

The formation in which the brine occurs was not drilled in wells in the southern part of Manitoba, but was probably present in a well on Vermilion River near Dauphin. Samples from the deep well at Kamsack were so poor that it was impossible to determine if these beds are also present there. It is probable that the brine horizon may extend some distance north and to the west of Neepawa, but drilling will have to be deeper to reach it.

BENTONITE

The bentonite at the base of the Pembina beds has been quarried near Thornhill, Manitoba. Some difficulty has been experienced in getting rid of the black shale between the bentonite beds. The thickness of the beds varies from place to place, and other occurrences may be developed only where there is little overburden and where the bentonite beds are thick. Such occurrences are not known to be common.

CLAY

Some brick clay has been obtained from lake deposits in parts of the area. Attempts have been made to use various beds from the Riding Mountain formation. Most of the bedrock clays shrink too much and tend to crack in drying and firing.

In the vicinity of Swan River, McLearn collected samples of beds that looked promising for fireclays. These were tested at the Mines Branch in Ottawa. Although they have a fairly high fusion point, other properties render them unfit for commercial development. The results of the tests are shown in the following table:

Ceramic Tests

Supervised by J. G. Phillips.

Locality: Swan River, Manitoba, NE. ¼ sec. 4, tp. 37, rge. 26, W. 1st mer.

Thickness	Field No.	Nature of material	Tempering water	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness	Remarks
Feet			%				%		%	%			
3·5	500A	Clay, colloidal, grey, soft, smooth	22	Veryplastic; works well	15	Cracks badly	6	06	0·6	10·4	Salmon	Hard	This sample contains an excessive amount of colloidal material, which causes it to crack badly in drying. Also, due to its colloidal nature, together with its content of carbonaceous matter, it exhibited a decided tendency to bloat during the firing process. In addition, the sample was found to fire to an unfavourable colour. This clay possesses a moderately high fusion point (P.C.E.), but due to the unfavourable properties mentioned, it is not considered a desirable raw material for the production of clay products.
								03	2·7	6·0	Salmon	Very hard	
								2	3·0	6·0	Salmon	Very hard	
								6	3·7	4·0	Brown	Very hard	
5·0	500B	Clay, highly colloidal, grey, soft, smooth	23	Veryplastic; works well; somewhat tough	18	Cracks badly	7	06	1·0	9·6	Salmon	Hard; badly scummed	This sample exhibited properties similar to 500A and the same comments on its industrial possibilities apply.
								03	3·0	5·8	Salmon-buff	Very hard; badly scummed	
								2	3·0	5·6	Dark buff	Very hard; badly scummed	
								6	3·9	3·6	Dark buff	Very hard; badly scummed	
2·0	500C	Clay, highly colloidal, grey, soft, smooth	24	Veryplastic; works well	18½	Cracks badly; moderately scummed	8	06	1·0	10·4	Salmon	Hard; badly scummed	This sample exhibited properties similar to 500A and the same comments on its industrial possibilities apply.
								03	3·2	6·7	Dark buff	Very hard; badly scummed	
								2	3·2	6·5	Dark buff	Very hard; badly scummed	
								6	4·6	3·6	Dark buff	Very hard; badly scummed	
2·6	500 D-H	Clay, dark grey, colloidal; thin silt beds	29	Veryplastic; tough; works well	16	Cracks badly	8	06	2·0	13·5	Salmon	Considerable scum	This sample exhibited properties similar to 500A and the same comments on its industrial possibilities apply.
								03	5·5	5·8	Brown	Considerable scum	
								2	5·2	3·2	Brown	Badly bloated	
5·4	501A	Clay, grey, fairly smooth; rare concretions	22	Veryplastic; works well	17	Cracks badly; slightly scummed	7·2	06	0·9	10·2	Salmon	Hard; badly scummed	This sample exhibited a decided tendency to crack during drying, and fired to unfavourable colour. It is not considered a desirable raw material for the production of clay products. However, if its tendency to crack during drying were corrected, it could probably be used for the production of common brick or tile and possibly buff face-brick.
								03	2·6	5·9	Salmon	Hard; badly scummed	
								2	3·0	5·3	Salmon	Very hard; badly scummed	
								6	3·9	3·4	Dark salmon	Very hard; badly scummed	

Ceramic Tests—Concluded

Locality: Swan River, Manitoba, SE. $\frac{1}{4}$ sec. 8, tp. 37, rge. 26, W. 1st mer.

Thickness	Field No.	Nature of material	Tempering water	Working properties	P.C.E.	Drying behaviour	Drying shrinkage	Cone	Fire shrinkage	Absorption	Colour	Hardness	Remarks
Feet			%				%		%	%			
0·6	507A	Clay, grey, soft, silty	22	Fairly plastic; somewhat flabby	17	Satisfactory	7	03	0·6	11·2	Buff	Hard; scummed	This clay is rather silty, and somewhat lacking in plasticity. It is not considered a good grade of clay for the manufacture of clay products, but could probably be used for the production of common brick or tile and possibly buff face-brick.
								2	1·2	10·3	Buff	Very hard; scummed	
2·0	507B	Clay, grey, soft, colloidal	27	Very plastic and tough; works well	20	Cracks badly; slightly scummed	7	03	5·6	2·2	Dark buff	Very hard; considerable scum; bloated	This sample exhibits properties similar to 500A and the same comments on its industrial possibilities apply.
								2	4·2	2·0	Dark buff	Very hard; considerable scum; bloated	
								6	4·0	2·0	Dark buff	Very hard; considerable scum; bloated	
1·8	507C	Clay, dark grey, highly colloidal; some silt	29	Plastic; works well	19	Cracks badly; slightly scummed	8	06	1·7	13·4	Buff	Hard; badly scummed	This sample exhibits properties similar to 500A and the same comments on its industrial possibilities apply.
								03	5·3	7·1	Dark buff	Very hard; badly scummed	
								2	5·5	2·9	Dark buff	Very hard; badly scummed	
								6		0·0	Dark buff	Very hard; badly scummed	
2·3	507D	Clay, dark grey	26	Very plastic; works well	16	Possesses a tendency to crack during drying	7	06	1·0	15·1	Buff	Hard; considerable scum	Providing the tendency of this clay to crack in drying could be corrected, it would be suitable for the manufacture of buff face-brick. Also in veiw of its long firing range, it is considered as having possibilities as a stoneware clay.
								3	3·7	10·0	Dark buff	Very hard; considerable scum	
								2	3·2	9·6	Dark buff	Very hard; considerable scum	
								6	6·2	4·2	Dark buff	Very hard; considerable scum	
1·1	507E	Clay, grey, very silty	24	Short and flabby	18½	Satisfactory	5	06	exp.	18·8	Buff	Soft; moderately scummed	This sample is a very silty clay that exhibited poor working properties. In the firing behaviour tests it maintained a high absorption even when fired to cone 6. This clay is considered unsuitable for the manufacture of clay products.
								03	0·0	17·3	Buff	Soft; moderately scummed	
								2	0·0	18·0	Buff	Soft; moderately scummed	
								6	1·3	14·0	Buff	Hard; moderately scummed	

GLASS SAND

Sand suitable for the manufacture of glass was examined by W. G. Worcester (1943) in deposits on Red Deer River north of Armit, tp. 46, rge. 30, W. Principal mer. The deposits are in beds of the Swan River group. According to Worcester the sand after washing is of a suitable grade for various types of glass, including plate glass.

Similar sands occur in Swan River beds in other parts of the area. One of the most accessible places is along Swan River, below the town of Swan River, and on Roaring River. The Swan River locality was examined by W. A. Johnston and the results can be found in Part D of the Summary Report of the Geological Survey for 1917.

COAL

The lignite deposits in the Turtle Mountain formation southeast of Goodlands have been mined for local use for many years. The seams vary in thickness from 1 to 5 feet. The presence of water and the unconsolidated character of the formations have made mining difficult.

Small lenses of coal have been found in various localities in the north in Lower Cretaceous beds, but no seam has been found to extend far. Samples from some of the wells in the Hudson Bay Junction region contained a fair amount of coal, but there was no way to determine if the seams are thick and if they are extensive enough to be worth mining.

CEMENT

The calcareous shale of the Boyne member in the vicinity of St. Lupicin (Babcock) was used for a short time for making natural cement. The composition of the beds varied a great deal and there was too much overburden to permit extensive quarrying. Under these circumstances the venture was abandoned as unprofitable.

MANGANESE

Several attempts have been made to mine manganese from deposits of calcareous tufa around mineral springs. More recently some attempts have been made to develop deposits found associated with concretions in the Riding Mountain beds. None of these deposits has proved to contain sufficient material of high enough quality to be commercially valuable.

CHAPTER VI

WELL RECORDS

The well logs that follow are those the author considers most representative of the section of the Mesozoic formation within the areas mapped. The variations of these formations have already been discussed, so that little further information is required in this report. However, as the underlying Palæozoic formations have not been described in this report, some comments will be made and attention drawn to possible correlations, but no attempt will be made to deal with these older formations in detail.

Logs of some of the wells have been published previously by the writer, but the present details are the result of complete re-examination of the samples from these wells and differ in many details from the earlier records.

The wells are logged in order from south to north following the same sequence as that employed in the descriptions of formations.

Log of Commonwealth Manitou No. 2 Well

Location: l.s. 8, sec. 26, tp. 2, rge. 9, W. Principal mer.

Elevation: ground 1,256 feet. (The derrick floor was probably about 5 feet higher.)

Well drilled in 1931-1932 with cable tool rig.

Depth	Lithology
Feet	
0–100	Intermittent samples all containing much glacial drift.
100–140	Missing.
	VERMILION RIVER FORMATION
	Boyne Member
140–160	Shale, medium grey; some white, calcareous specks; some fine white silt; foraminifera.
160–180	Shale, medium grey; few, white, calcareous specks.
180–200	Missing.
200–290	Shale, medium grey; few, white, calcareous specks.
	Morden Member
290–300	Shale, medium to dark grey.
300–320	Missing.
320–410	Shale, medium to dark grey, non-calcareous.
	FAVEL FORMATION
410–420	Shale, medium to dark grey; speckled with white, calcareous material; some *Inoceramus* prisms.
420–430	Shale, medium to dark grey; speckled as above; some fine-grained, calcareous sandstone; many *Inoceramus* prisms.
430–440	Shale, dark grey, slightly calcareous; few white specks.
440–450	Shale, dark grey, calcareous; a little silt or sand.
450–460	Limestone, grey, impure; many foraminifera.
460–580	Shale, dark grey; with specks as above; some bentonite at 560–570 feet.

Log of Commonwealth Manitou No. 2 Well—Continued

Depth	Lithology
Feet	
	ASHVILLE FORMATION
580–630	Shale, dark grey, non-calcareous.
630–640	Shale, dark grey, non-calcareous; much bentonite; a little impure limestone.
640–670	Shale, dark grey.
670–700	Missing.
700–705	Shale, dark grey; a little quartz sand.
	SWAN RIVER GROUP
705–735	Sand, white, quartz, medium- to coarse-grained; fairly well rounded at top, but becoming more angular toward base.
735–755	Shale, dark grey; a little sand and some granular pyrite.
755–765	Shale, light grey; some fine silt.
765–780	Shale, light grey and reddish brown; some silt.
780–790	Shale, light grey; some white granular limestone or calcite.
790–800	Shale, light grey and dull brick-red.
	JURASSIC
800–830	Shale, light grey, calcareous.
830–855	Shale, medium grey; much contamination with red, cintre-like material.
855–870	Shale, grey and pink; some fine white sand and silt.
870–880	Shale, brick-red; some pink granular limestone.
880–895	Shale, light and medium grey; some pink and white calcareous sandstone.
895–900	Sand, white, quartz, fine-grained.
900–970	Shale, medium and light grey; some fragments of grey and white limestone; fragments of echinoderms, brachiopods, and other fossils; Jurassic foraminifera; some yellowish brown, roughly oval pellets of calcareous material at 950 feet.
970–1,060	Shale, calcareous, or impure limestone, variegated brick-red, light grey, greenish, and yellow; a little white gypsum; a little silt and fine sand; numerous smooth ostracods and chara from 1,000 feet down; probably non-marine deposits.
1,060–1,070	Shale, medium grey, slightly calcareous; some red and light grey shale; some fossils; probably marine.
1,070–1,080	Shale, light grey and dull brick-red; some variegated; marine fossils; some white limestone.
1,080–1,090	Shale, light grey and variegated; slightly calcareous mixture of marine and non-marine fossils.
1,090–1,110	Limestone and shale, light grey; some white gypsum; some sand.
1,100–1,180	Limestone, light buff, fine-grained; much gypsum; few ostracods in several samples; fairly numerous at 1,140 to 1,150 feet.
	AMARANTH FORMATION
1,180–1,200	Limestone, light grey; some gypsum.
1,200–1,210	Missing.
1,210–1,220	Gypsum, white to cream.
1,220–1,230	Shale, brownish red; some white gypsum.
1,230–1,240	Missing.
1,240–1,260	Gypsum, white, and shale, brownish red; a few grains of anhydrite; a little green shale.
1,260–1,290	Shale, brownish red and greyish green; some white gypsum.
1,290–1,300	Shale, brownish red; little greenish shale and gypsum.
1,300–1,330	Missing.
1,330–1,380	Shale, reddish brown; some grey shale; white gypsum; many fragments of steel; some brick-red sandstone with frosted sand grains.
1,380–1,400	Sand and sandstone, brick-red; some brownish red shale and white gypsum; sand grains well rounded, frosted, and medium-grained.

Log of Commonwealth Manitou No. 2 Well—Continued

Depth	Lithology
Feet	
	DEVONIAN
1,400–1,410	Limestone, buff and pinkish, somewhat granular; a little sandstone; few fossil fragments.
1,410–1,430	Limestone, light buff and pink; some red shale; numerous fossil fragments of brachiopods and other shells; few ostracods, including *Octonaria* sp.?
1,430–1,450	Limestone, light buff; few shell fragments; a little pink limestone.
	SILURIAN
1,450–1,470	Dolomite, rose to light buff.
1,470–1,490	Shale, brick-red; some white gypsum.
1,490–1,500	Dolomite, pink, granular.
1,500–1,510	Limestone, pink, amorphous texture; a little dolomite.
1,510–1,520	Limestone, light buff; a little dolomite.
1,520–1,530	Dolomite and limestone, pink and buff; dolomite, granular.
1,530–1,550	Dolomite, pink and white, very finely granular.
1,550–1,570	Dolomite, bright pink to rose.
1,570–1,580	Limestone, cream to white.
1,580–1,600	Dolomite, pink and white, granular.
1,600–1,620	Limestone, white; some pink dolomite.
1,620–1,640	Dolomite, pink, granular.
1,640–1,660	Dolomite, white to cream, very fine-grained.
1,660–1,670	Dolomite, pink and white, very fine-grained; a little gypsum.
1,670–1,685	Dolomite, buff and pink, amorphous.
1,685–1,700	Dolomite, cream and pink; many irregularly shaped smooth grains similar to oolites or fossils.
1,700–1,780	Dolomite, cream to white, very finely granular, almost amorphous.
1,780–1,790	Dolomite, light buff to pink.
1,790–1,800	Shale, brick-red, sandy, sand grains well rounded and frosted; a little pink dolomite and green shale.
1,800–1,810	Sandstone, light rose, fine-grained, a little brownish red shale.
1,810–1,820	Sandstone, very fine-grained, light pink, dolomitic; much cream-coloured dolomite, fine-grained.
1,820–1,850	Dolomite, cream and light pink, fine-grained; some sand grains in lowest sample.
	ORDOVICIAN
	Stony Mountain Formation
1,850–1,870	Sandstone, fine-grained, rose to brown; and dolomite, pink and cream, fine-grained; many grains of well-rounded, frosted sand may be from cavings.
1,870–1,910	Limestone, grey and reddish brown; many fragments of fossils; much fine sand; round, frosted grains may be from cavings.
1,910–1,925	Missing.
1,925–1,933	Limestone, medium and light grey.
1,933–1,935	Sand, light grey, well rounded, frosted grains may be from cavings.
1,935–1,950	Missing.
	Red River Formation
1,950–1,980	Dolomite, light buff.
1,980–2,000	Limestone, light buff; much sand and grey limestone may be partly from cavings.
2,000–2,017	Dolomite, light buff.
2,017–2,030	Missing.
2,030–2,045	Dolomite, cream; some medium grey shale.
2,045–2,055	Dolomite, light buff.
2,055–2,060	Limestone, cream; some white chert.
2,060–2,070	Limestone, cream, granular.
2,070–2,080	Limestone and dolomite, cream; some fine sand grains and some fragments.
2,080–2,105	Limestone, white, finely mottled with very light buff or cream-coloured limestone; some fragments of fossils.
2,105–2,120	Missing.

Log of Commonwealth Manitou No. 2 Well—Concluded

Depth	Lithology and Remarks
Feet	
	Red River Formation—Concluded
2,120–2,130	Limestone, cream colour; some fragments of fossils.
2,130–2,145	Missing.
2,145–2,172	Limestone, cream colour; some fragments of fossils.
2,172–2,290	Limestone, white, crystalline.
2,290–2,300	Limestone, cream; some fragments appear to have caved from higher horizons.
2,300–2,330	Limestone and dolomite, cream to white; some grey shell fragments and rounded sand grains, probably mostly from cavings; samples appear poor.
2,330–2,430	Limestone, cream; some fossil fragments.
2,430–2,480	Samples poor, calcareous mud, may be in part shale.
	Winnipeg Formation
2,480–2,490	Shale, greyish green; some brown dolomite and fossil fragments; much pyrite.
2,490–2,520	Shale, greyish green; some pyrite; some well-rounded, frosted sand grains and sandstone with pyrite cement.
2,520–2,570	Shale, greyish green; little pyrite.
2,570–2,600	Shale, brownish and greyish green; little pyrite; few fragments have sand grains in shale.
2,600–2,610	Sand, well rounded and frosted, medium-grained.
	PRECAMBRIAN
2,610–2,612	Mixture of red feldspar, shale, and sand (arkose?).
2,612–2,639	Igneous and metamorphosed rock; mostly quartzose samples, all very rusty.

Restudy of the samples from this well has resulted in changes in the description of samples as well as in placing the contacts of the formations. Attention is drawn particularly to changes made in the contacts of the Palæozoic formations. The discovery of an *Octonaria,* which closely resembles those associated with Devonian brachiopods in the Dauphin well, suggests that the beds from 1,400 to 1,450 feet are of this age. The red shale and dolomite beds that underlie this fossil-bearing member suggest a Silurian age for the underlying beds.

There seems to be good evidence of a marked unconformity between the Devonian and the overlying Amaranth. Beds from 1,400 to 1,480 feet in the Commonwealth Manitou No. 2 well compare with samples at 1,250 to 1,280 feet in the Neepawa salt well. Comparison of samples below this zone in the two wells also indicates that Devonian beds are missing. This condition suggests a marked difference in the distribution of areas of deposition of Devonian rocks from those of Silurian rocks, and also may be interpreted as pointing to an unconformity. The Silurian-Ordovician contact in this well is placed at almost the same horizon as it was in the previous publication of this log by the writer.

The sandstone of the Winnipeg formation exposed in the narrows between Lake Manitoba and Lake Winnipeg contains *Whitella* sp., a fossil indicative of Upper Ordovician age[1]. Probably the beds assigned to this formation in the Commonwealth Manitou No. 2 well are of the same age.

[1]Wilson, Alice E.: Geol. Surv., Canada. Personal communication.

Log of Fleming Well

Location: sec. 14, tp. 12, rge. 30, W. Principal mer.
Elevation: about 1,800 feet, according to contour map.
Drilled by: Fitzsimmon Gas Company prior to 1920.
Log: from examination of samples by R. T. D. Wickenden, 1944.

Depth	Lithology and remarks
Feet	
0–70	Glacial drift; some shale mixed in from 60 to 70 feet.
	RIDING MOUNTAIN FORMATION
70–120	Shale, medium and light grey, slightly sandy; few very small grains of carbonaceous material.
120–310	Shale, medium to light grey, fairly hard.
310–350	Shale, medium to light grey, fairly hard, somewhat sandy.
350–380	Shale, medium to light grey, fairly hard; many fragments of brown concretions.
380–430	Shale, medium to light grey, fairly hard; few concretions and sandy shale fragments.
430–540	Shale, medium to light grey, fairly hard.
540–560	Mixed shale and fragments of limestone and sand from glacial drift; shale apparently softer than above.
560–1,060	Shale, grey, soft; some pyrite; bentonite in a few samples and a few concretion fragments.
	VERMILION RIVER FORMATION
	Pembina Member?
1,060–1,160	Shale, medium grey, with a few fragments of dark grey, non-calcareous shale; dark grey shale is probably contaminated from cavings from Riding Mountain formation above.
	Boyne and Morden Members
1,160–1,260	Shale, medium to dark grey; samples contain some glacial drift and much material from the Riding Mountain beds and a few fragments of speckled shale.
1,260–1,280	Shale, dark grey, speckled with white.
1,280–1,340	Shale, dark grey; some speckled shale.
	FAVEL FORMATION?
1,340–1,500	Shale, dark grey, with white specks; many *Inoceramus* prisms and specimens of *Globigerina cretacea.*

Many of the samples from this well are made up of a mixture of various beds, especially those from below 1,000 feet. The interpretation given here takes into consideration the fact that the lower part of the Riding Mountain formation is very soft and tends to cave. Undoubtedly the contacts are not accurately placed, but they give an approximate idea of the depths at which the formations occur in this part of the area. It is of some interest to note that the hard Odanah type of shale is about 500 feet thick, and that below it is more than 500 feet of the softer shale. The fact that there are changes in the microfauna indicates that there is little mixing of the samples in the upper part of the well.

Log of Neepawa Salt Company Well

Location: l.s. 9, sec. 33, tp. 14, rge. 15, W. Principal mer.
Elevation: 1,242 feet; elevation at Neepawa station well may be a little lower.
Drilled with cable tool rig in 1935 and 1936.
Log from examination of samples by R. T. D. Wickenden, 1944.

Depth	Lithology
Feet	
0–150	Missing.
150–160	Glacial drift.
160–230	Missing.
	FAVEL FORMATION
230–260	Shale, medium to dark grey, with white, calcareous specks; many foraminifera, mostly *Globigerina cretacea;* many *Inoceramus* prisms.
	ASHVILLE FORMATION
260–280	Sandstone, grey, fine-grained; some glauconite and fossil fish bones; some grey shale.
280–290	Limestone, medium grey.
290–320	Shale, medium to dark grey.
320–330	Sandstone, fine-grained, grey; fossil fish fragments.
330–350	Shale, dark grey, some sandstone as above.
350–395	Shale, dark grey.
	SWAN RIVER GROUP
395–412	Sand, light grey, all quartz.
412–470	Shale, medium to dark grey; some sand.
	JURASSIC
470–520	Shale, medium grey, much pyrite at 500 to 520 feet; Jurassic foraminifera and fragments of dentaliums, echinoderms, and other marine fossils in samples from 490 to 520 feet.
520–530	Shale, medium grey, much light grey, calcareous sandstone.
530–540	Shale, medium grey, slightly brownish; some calcareous sandstone, limestone, and numerous smooth grains of rusty yellow material, probably limonite; some fragments of fossils of marine origin.
540–570	Shale, medium to light grey, and much calcareous sandstone and cream-coloured limestone; few fossils; many smooth ostracods and chara fruit at 560 feet.
570–580	Shale, buff-grey; some fragments of brownish red shale.
580–610	Shale, medium grey; some cream-coloured limestone; some calcareous sandstone; foraminifera and many fragments of marine fossils at 600 feet.
610–620	Shale, buff; a little white limestone.
620–630	Shale, brownish red and grey; probably mottled or variegated if found in situ.
630–640	Shale, yellowish brown.
640–650	Shale, grey and brownish red; few foraminifera, but may not be in place.
650–660	Shale, light brown.
660–680	Shale, grey and light brown.
680–690	Shale, light brown and brownish red; sample contains many fragments of rock from surface.
690–720	Shale, greyish buff.
720–730	Shale, medium grey, a little very light buff platy limestone, suggests algal origin.
730–750	Limestone, light grey, with streaks and specks of black, carbonaceous material.

Log of Neepawa Salt Company Well—Concluded

Depth	Lithology
Feet	
	AMARANTH FORMATION
750–760	Limestone and calcareous sandstone, light grey; much grey chert.
760–770	Dolomite, buff; much contamination from overlying formations.
770–790	Gypsum, white.
790–820	Gypsum and anhydrite, white; some buff dolomite.
820–850	Anhydrite, white; some white gypsum; some reddish brown shale at 840–850 feet.
850–860	Shale, brick-red, slightly sandy; some pinkish or buff-red shale; some gypsum and anhydrite.
860–890	Shale, brick-red and light grey, sandy; some white gypsum.
890–900	Shale, red and grey; much sand, medium grain, well rounded, with frosted surface; some gypsum and anhydrite.
900–930	Shale, brick-red and light grey; much gypsum and some anhydrite.
930–940	Shale and gypsum, dull red and white.
940–950	Limestone, light grey, porous; some gypsum and red shale inclusions.
950–960	Dolomite, light buff, with thin streaks of gypsum.
960–970	Gypsum, white and pink.
970–980	Dolomite, light buff; some streaks of gypsum.
980–990	Sand, white, medium-grained, well rounded; some polished and some frosted grains.
	DEVONIAN
990–1,010	Dolomite, light buff with reddish streaks; a little fine-grained sandstone.
1,010–1,020	Dolomite, light buff; many fragments show gypsum mixed with dolomite.
1,020–1,040	Anhydrite, light buff to cream; a little gypsum and dolomite.
1,040–1,050	Dolomite, light buff; some gypsum and anhydrite.
1,050–1,060	Dolomite, light buff, granular, fine-grained; some rose or purplish, fine-grained sandstone.
1,060–1,070	Dolomite, light buff, and rose purplish shale with streaks of light greenish grey shale.
1,070–1,080	Dolomite sandstone; light grey and buff dolomite; some rose shale and gypsum.
1,080–1,090	Dolomite, buff, fine-grained; some anhydrite.
1,090–1,130	Dolomite, light buff, chalky; anhydrite, white.
1,130–1,160	Dolomite, pink and white, granular.
1,160–1,170	Dolomite, buff, granular; some anhydrite.
1,170–1,192	Dolomite, buff, very fine-grained; some anhydrite.
1,192–1,197	Shale, greyish brown; some buff dolomite.
1,197–1,210	Dolomite, buff, granular.
1,210–1,240	Limestone, buff; fossil fragments and ostracods.
1,240–1,250	Dolomite, light buff, granular.
1,250–1,280	Limestone, buff and pinkish, somewhat granular; some fragments of fossils and ostracods, including a species of *Octonaria*.
1,280–1,300	Sand, fine-grained, white; grains mostly subangular.
1,300–1,310	Limestone, white; fine sand.
1,310–1,320	Limestone, cream; a little white sand.
1,320–1,330	Limestone, greyish buff, finely granular.
1,330–1,340	Limestone, cream, slightly granular.
1,340–1,350	Dolomite, buff, amorphous, and limestone, buff, granular.
1,350–1,360	Missing.
	SILURIAN ?
1,360–1,370	Shale, reddish buff; some light buff dolomite.
1,370–1,380	Dolomite, pink, granular (crystalline).
1,380–1,400	Dolomite, light buff, very finely granular; some gypsum; some fine sand may be from cavings.
1,400–1,420	Dolomite, cream to white, granular.
1,420–1,490	Dolomite, light buff, granular.

Comparison of the Amaranth-Devonian contact in this well with the same contact in the Commonwealth Manitou No. 2 well has already been discussed. Restudy of the Dauphin well has resulted in some uncertainty as to the occurrence of Silurian beds in the Neepawa well. The limestone at 1,250 to 1,280 feet resembles a limestone at 540 to 550 feet in the Dauphin well. If these two limestone beds are the same, it seems probable that there is much more Devonian at Neepawa than at Dauphin, or there may be an unconformity within the Devonian.

Although there is a red shale bed at 1,360 to 1,370 feet in the Neepawa well, it is not certain that this shale and the beds below it are of Silurian age. The pinkish buff shales at 760 to 780 feet in the Dauphin well may correspond with the reddish shale in the Neepawa well. If so, the beds below 1,360 feet in the Neepawa well are of Devonian age, as below that zone in the Dauphin well fragments of brachiopods resembling *Atrypa reticularis* were found with other fossils that suggest the Devonian.

Log of Dauphin Well

Location: SE. ¼ sec. 14, tp. 24, rge. 20, W. Principal mer.
Elevation: about 1,100 feet.
Drilled with cable tool rig, 1929-30.
Log from examination of samples by R. T. D. Wickenden, 1944.

Depth	Lithology
Feet	
0–10	Glacial drift.
10–20	Shale, medium to dark grey.
20–30	Mostly glacial drift.
30–110	Shale, medium to dark grey. (Ashville?)
110–160	Shale, medium grey; some glauconite. (Ashville or Swan River?)
160–190	Sandstone, white, calcareous; much cream limestone; some smooth ostracods. (Jurassic?)
190–200	Limestone, cream-coloured; some light grey shale.
200–210	Shale, light grey and brick-red. (Jurassic.)
210–220	Shale, light grey and brick-red; some pink and yellow limestone; some chara fruit. (Jurrassic.)
220–230	Sandstone and limestone, same as at 160 to 190 feet.
230–240	Shale, brick-red; some pink, white, and yellow limestone; many fossil chara fruit. (Jurrassic.)
240–250	Limestone; cream and white sandstone.
250–300	Contaminated samples; material looks like weathered shale from Favel formation.
300–310	Shale and limestone, grey.
310–320	Shale, medium to light grey; some glauconite and fragments of shells.
320–330	Shale, brownish grey.
	AMARANTH FORMATION
330–350	Limestone, cream to white; much light grey banded chert or chalcedony apparently filling vugs in limestone.
350–360	Gypsum and anhydrite, white.
360–370	Gypsum and anhydrite, white; some reddish brown shale and buff dolomite.
370–380	Missing.
380–390	Dolomite, buff; some white gypsum and clear, crystalline quartz.
390–410	Shale, reddish buff.
410–430	Shale, brick-red; a little gypsum.
430–495	Shale, sandy, dull brick-red; sand grains very fine; some white gypsum; a little light grey and greenish grey shale; some samples show more gypsum than others.
495–510	Dolomite, light buff; a little gypsum.
510–520	Sandstone, rose, fine-grained, calcareous.
520–530	Missing.

Log of Dauphin Well—Concluded

Depth	Lithology
Feet	
	DEVONIAN
530–540	Dolomite, rose-buff; a little gypsum.
540–550	Limestone, light rose to pink; some sandy fragments; fossil shell fragments (looks like that at 1,400 feet in Commonwealth Manitou No. 2 and at 1,250 to 1,280 feet in Neepawa salt wells).
550–570	Dolomite, light buff, granular, fine-grained; some inclusions of gypsum.
570–580	Limestone and dolomite, light buff; some gypsum.
580–590	Dolomite, light buff, granular, medium-grained; a little gypsum.
590–610	Limestone, rose, granular; a little buff dolomite.
610–630	Dolomite, light buff, and gypsum, white.
630–640	Gypsum, white.
640–650	Missing.
650–680	Limestone, light grey, finely granular; few fragments of fossils.
680–690	Missing.
690–710	Limestone, light grey and light buff.
710–720	Anhydrite and gypsum, bluish and white.
720–730	Missing.
730–740	Anhydrite and gypsum; bluish and white.
740–760	Dolomite, light buff; a little gypsum.
760–780	Dolomite, cream to white; much anhydrite; a little pinkish buff shale.
780–790	Limestone, white and pink.
790–800	Limestone or dolomite, rose.
800–820	Dolomite, cream and pink.
820–830	Limestone, cream and white.
830–870	Dolomite, cream, somewhat crystalline; a little white gypsum at 860 feet.
870–880	Missing.
880–890	Poor sample; powdered calcareous material.
890–910	Missing.
910–920	Mixture of gypsum, anhydrite, limestone, and dolomite.
920–940	Limestone, greyish brown, granular.
940–950	Limestone, greyish brown, granular, light grey, fine-grained.
950–990	Limestone, light grey; many fragments of fossils; ostracods include a species of *Octonaria*, a few attached species of foraminifera.
990–1,030	Limestone, light buff.
1,030–1,050	Limestone, light grey.
1,050–1,060	Missing.
	SILURIAN ?
1,060–1,070	Shale, red and light greenish grey, slightly calcareous.
1,070–1,090	Missing.
1,090–1,130	Anhydrite, white.
1,130–1,140	Gypsum, white, with numerous fine streaks of brown lime.
1,140–1,150	Limestone, brown, with much gypsum and anhydrite.
1,150–1,170	Limestone (magnesian?), buff, with dark brown streaks (bitumen?).
1,170–1,180	Limestone? badly stained with rust from bit.
1,180–1,230	Dolomite, light buff to cream, somewhat crystalline.
1,230–1,240	Dolomite, white and pink, probably mottled.
1,240–1,256	Shale, buff-red; some dolomite as in previous sample.

The samples from parts of this well appear to have been carelessly taken, but on the whole the well gives a fairly complete section of the formations, particularly below the Jurassic. The part of the section assigned to the Devonian differs from the Neepawa section and from the section in wells farther north. Apparently the sequence of beds in the Devonian varies a great deal, and, because of this and the limited information obtained from the well, it is impossible to subdivide the well section into formations.

The contact of the Devonian and Silurian is probably nearly correct, and, in the prevalence of anhydrite and dolomite beneath a red shale, compares favourably with the description of this contact as seen in exposures.

Log of Ventures Kamsack No. 7 Well

Location: l.s. 14, sec. 23, tp. 29, rge. 32, W. Principal mer.
Elevation: 1,423 ± feet (barometer, courtesy of Prof. F. H. Edmunds).
Drilling method: standard.
Samples at Department of Geology, University of Saskatchewan.

Depth	Lithology
Feet	
0–150	No samples.
	VERMILION RIVER FORMATION
	Pembina Member
150–184	Shale, dark grey; some white clay (?) with much pyrite at 165 feet.
	Boyne Member
184–225	Shale, medium grey, with white specks.
225–255	Shale, medium grey; some fish bones.
255–275	Shale, medium grey, with white specks; some non-speckled grey shale.
275–290	Shale, dark; light grey bentonite.
290–300	Shale, dark grey, with white specks; probably shell fragments.
	Boyne or Morden Member
300–310	Shale, medium grey, some speckled with white; some shell fragments.
	Morden Member
310–340	Shale, dark grey, few fish bones.
	FAVEL FORMATION
340–350	Shale, medium grey with few white specks; many *Inoceramus* prisms.
350–360	Shale, dark grey, with white specks; many *Inoceramus* prisms.
360–365	Shale, medium to dark grey, with white specks; some grey limestone.
365–370	Shale, medium to dark grey, with white specks; some bentonite.
370–390	Shale, medium to dark grey, with white specks; many globigerina.
390–420	Shale, medium to dark grey, with white specks; some bentonite in 390–400; pieces of grey limestone 400–410; a little non-speckled shale.
420–440	Shale, grey; sample rather muddy; some *Inoceramus* prisms, but looks mostly non-speckled shale.
	ASHVILLE FORMATION ?
440–450	Bentonite and grey shale; many *Inoceramus* prisms.

In drilling this well great care was taken not to have more water than necessary in the hole at any time, and the water was placed in the hole with a bai'er. As a result the samples are particularly free from contamination and give a very good section of the Vermilion River and Favel formations.

Log of Thunder Hill No. 1 (Canadian Industries, Limited) Well

Location: l.s. 1, sec. 25, tp. 35, rge. 30, W. Principal mer.
Elevation: 1,850 ± feet.
Drilling method: diamond drill.
From an examination of the core samples by R. T. D. Wickenden and F. J. Fraser, 1938.

Depth	Lithology
Feet	
0–50	Samples missing.
	ASHVILLE FORMATION
50–53·5	Shale, medium grey.
53·5–59·5	Missing.
59·5–117	Shale, medium grey; some glauconite and foraminifera in part of samples—dip varies from 0 to 40 degrees; a little light grey sand in lower samples.
117–118·5	Missing.
118·5–123	Shale, medium grey; foraminifera and a little light grey sand.
123–124·5	Sand, green, mostly glauconite; a little shale.
124·5–135	Shale, dark grey, with beds of green sand.
135–150·5	Shale, dark grey, with thin beds of white and green sand at partings.
150·5–160	Green sand; only about one-half of core recovered.
160–165	Sandstone, light grey; only 1 foot of core recovered.
165–167	Missing.
167–185	Shale, dark grey; only about one-half of core recovered, rest probably sand; samples show some glauconite and sand partings.
185–193	Sand and shale; some glauconite.
193–205·25	Shale, dark grey; pockets of sand and glauconite; some marcasite; dip varies from 10 to 40 degrees.
205·25–218	Shale, black; marcasite; parting of light grey to white sand; dip varies from 10 to 60 degrees.
	GLACIAL DRIFT
218–225	Shale, dark grey, speckled; granite and limestone or dolomite pebbles.
225–262	Missing.
	FAVEL FORMATION
262–291	Shale, dark grey with white specks; shell fragments; dip varies 20 to 40 degrees.
	GLACIAL DRIFT
291–305	Missing; drift pebbles only; driller reports stones encountered at 302 feet; probably mostly drift.
305–319	Missing.
319–323	Mostly granite and dolomite pebbles.
323–331	Mostly dark grey shale; only 1 ft. 8 in. of core recovered.
331–340	Shale, dark grey, some glacial material.
	ASHVILLE FORMATION
340–371	Shale, dark grey; dip varies from 10 to 30 degrees; shows slickensides; beds are probably contorted.
371–375	Shale, dark grey; 14 in. band of grey "bentonite"; some calcareous bands with shales near base; dip 50 degrees.

Log of Thunder Hill No. 1 (Canadian Industries, Limited) Well—Concluded

Depth	Lithology
Feet	
	ASHVILLE FORMATION—*Concluded*
375–386	Shale, dark grey; some limestone bands; dip varies from flat to nearly vertical.
386–436	Shale, dark grey; parts of core not recovered; dip from 0 to 60 degrees.
436–439	Missing.
439–446	Shale, dark grey; dips 10 to 40 degrees.
447–550·5	Shale, dark grey; white sand partings; dip varies from 0 degrees to nearly vertical.
550·5–560·5	Shale, dark grey; 4-in bed of grey "bentonite" at 556 feet.
560·5–703	Shale, dark to medium grey; dip varies from 10 to 40 degrees; some marcasite and sand partings.
703–713	Missing.
713–820	Shale, medium to dark grey; some white sand and glauconite; some marcasite; dip varies from 0 to 60 degrees.
	SWAN RIVER GROUP
820–855·5	Shale, dark grey; some bands of sand and glauconite; dip 10 to 40 degrees. Part of core missing; probably sand beds; some marcasite.
855·5–908	Missing, probably nearly all sand.
908–912	Shale, dark grey, somewhat sandy; marcasite; foraminifera.
912–922	Shale, medium grey; some white sand with glauconite; foraminifera; dip 40 degrees.
922–932	Sandy shale; only 4 feet of core recovered; some sandstone; low dip.
932–940	Missing.
940–950	Shale, medium grey; only 3 feet of core recovered; rest probably sand; foraminifera and glauconite; dips 40 degrees; 3 ft. 4-in. core recovered.
950–957	Sandy shale, medium grey; fine, hard-grained sandstone; carbonized plants; sandy shale; 7 in. thin sandstone; dips about 20 degrees.
957–962	Shale, dark grey; some sandstone layers; carbonized plant remains; calcareous concretions.
962–968	Shale and sandstone, dark grey; calcareous concretions; 11-in core recovered.
968–973	Missing.
973–979	Sandy shale, medium grey; 9-in. core recovered.
979–985	Sandy shale, medium grey; 2-in. core recovered; pyrite or marcasite concretion; carbonized plant remains.
985–990	Shale and sandstone, grey and white; marcasite; 10-in. core recovered.
990–995	Sandstone, medium grey; 1 ft. 2-in. core recovered.
996–999	Sandy shale, medium grey, grading to sandstone; 11-in. core recovered.
999–1,004	Missing.
1,004–1,009	Sandy shale and sandstone, medium grey; 4-in. core recovered.
1,009–1,014	Sandstone, brown, iron carbonate stained.
1,014–1,026	Missing.
1,026–1,030	Marcasite; 1-in. core recovered.
1,030–1,037	Shale, light grey, sandy; dip zero; 1 ft. 8-in. core recovered.
1,037–1,047	Shale, light grey, sandy; dip zero; 1 ft. 6-in. core recovered.
1,047–1,057	Shale, light grey, sandy; dip zero; 1-ft. core recovered.
1,057–1,078	Missing
1,078–1,086	Shale, medium grey; 3-in. core recovered; marcasite nodules.
1,086–1,096	Shale, light grey; 4-in. core recovered.
1,096–1,106	Shale, light grey; 1 ft. 2-in. core recovered; ironstone nodule at top.
1,106–1,116	Shale, light grey; 10-in. core recovered; ironstone nodule at top.
1,116–1,139	Missing.
1,139–1,142	Marcasite; 8-in. core recovered.
1,142–1,152	Shale, light grey; 1 ft. 4-in. core recovered.

Evidently the hill in which this well was drilled is made up, in part, of large masses of shale belonging to the Ashville and Favel formations that were picked up by glaciers and deposited on this site. During transportation the shales were crumpled and folded to some extent, but the sequence from top to bottom seems to be normal. Below 340 feet the beds appear to be in place and in normal sequence. Folding has affected the beds down to 957 feet and the thickness of the Ashville and the upper part of the Swan River is much greater in the well than it is in undisturbed sections elsewhere. The folding apparently dies out at depth, and where cores were recovered the beds below 975 feet do not appear to be folded. It is probable that the folding was caused by some force exerted near the surface, such as the continental glaciers.

Log of Trail Blazer Oil and Gas Company No. 1 Well

Location: l.s. 1, sec. 31, tp. 44, rge. 2, W. 2nd mer.

Elevation: 1,150 feet.

Drilling method: standard; drilled 1934-1935.

From an examination of the well samples by R. T. D. Wickenden, 1944.

Depth	Lithology
Feet	
	DRIFT
0–25	Missing.
25–60	Drift, light grey.
	ASHVILLE FORMATION
60–170	Shale, medium to dark grey.
170–175	Shale, medium to dark grey; some fine white sand.
175–195	Sandstone, white.
195–200	Shale, medium grey.
200–220	Shale, medium grey.
220–230	Shale, medium grey; sandy concretions.
230–265	Shale; sandy concretions; foraminifera.
265–270	Shale, medium grey.
	SWAN RIVER GROUP
275–280	Sand, light grey, fine- to medium-grained; glauconite.
280–290	Sand, white; glauconite.
290–295	Sand, cream, medium- to coarse-grained.
295–300	Sand, brownish, coarse-grained, reddish brown; pyrite; concretionary material?
300–320	Shale, medium grey.
320–330	Sand, very light buff.
330–340	Sand, cream.
340–350	Sand, very light grey.
350–352	Dolomite, cream; probably from surface.
352–380	Sandstone, light and medium grey, shaly, fine-grained; coal.
380–400	Shale, medium grey; coal.
400–430	Sandstone, light grey, fine-grained; trace of coal.
430–450	Shale, light grey.
450–460	Sand, dark grey; and coal.
460–480	Sandstone, medium grey.
480–500	Shale, medium grey.
500–505	Sandstone, light grey.
505–510	Shale, light grey; some dolomite.
	MESOZOIC OR PALAEOZOIC ?
510–540	Dolomite, cream.
540–610	Sandstone, cream; thick bituminous material at 590 feet.

Log of Trail Blazer Oil and Gas Company No. 1 Well—Concluded

Depth	Lithology
Feet	
	DEVONIAN
610–640	Limestone, light buff and cream; some fragments of fossils.
640–650	Sand, white, fine-grained quartz; some buff oil-stained dolomite; this sample may be mostly from cavings.
650–680	Limestone, light buff; much quartz sand.
680–740	Limestone, light buff and light grey.
740–780	Limestone, light buff to cream.
780–800	Limestone, light grey.
800–810	Limestone, light buff.
810–820	Limestone, light grey; some light buff limestone.
820–890	Limestone, light buff, somewhat granular; much buff chert; some black, carbonaceous streaks.
890–900	Limestone, light grey; very fossiliferous.
900–910	Limestone, light greyish buff; few fossil fragments.
910–965	Limestone, light buff.
965–975	Shale, brick-red.
975–990	Limestone, light buff, somewhat crystalline.
990–1,010	Limestone, light buff; some reddish buff and brick-red shale.
1,010–1,020	Shale, brick-red and reddish buff, calcareous; some light buff limestone.
1,020–1,030	Shale, buff, calcareous.
1,030–1,085	Limestone; light buff and brick-red and buff shale.

The Devonian section in this well does not agree with that found in the other wells referred to in this report. The red shale in the lowest samples is included with the Devonian because there is still some limestone rather than dolomite below the shale. It is probable that the Silurian contact is not far below the bottom of the well.

Log of Piwei No. 1 Well (Reserve Drilling Company and Coalgate Oil and Gas Company)

Location: sec. 34, tp. 39, rge. 5, W. 2nd mer.
Elevation: 1,835 feet (Landes stadia-alidade traverse).
Drilling method: standard; drilled 1936.
Samples with Geological Survey, Ottawa.

Depth	Lithology
Feet	
0–45	Missing.
45–360	Glacial drift.
360–380	Glacial drift and grey shale (bedrock?).
	RIDING MOUNTAIN FORMATION
380–570	Shale, medium grey, greenish when wet.
570–580	Shale, same as above, with bentonite.
580–620	Shale, same as above.
	VERMILION RIVER FORMATION
	Pembina Member
620–650	Shale, dark grey, with bentonite.

Log of Piwei No. 1 Well (Reserve Drilling Company and Coalgate Oil and Gas Company)—Concluded

Depth	Lithology
Feet	
	VERMILION RIVER FORMATION—*Concluded*
	Boyne and Morden Members
650–720	Shale, medium to dark grey, with white, calcareous specks.
720–730	Shale, dark grey.
	FAVEL FORMATION
730–840	Shale, medium to dark grey, with white, calcareous specks; some *Inoceramus* prisms and pyrite.
840–860	Shale, dark grey; some light grey silt.
	ASHVILLE FORMATION
860–940	Shale, dark grey.
940–960	Sand, white; some concretionary pyrite.
960–970	Shale, sandy, medium grey.
970–1,010	Shale, medium grey, some white sandstone.
1,010–1,090	Shale, medium grey; some glauconite and foraminifera.
	SWAN RIVER GROUP
1,090–1,110	Missing.
1,110–1,130	Shale, sandy, medium grey.
1,130–1,180	Sand, white; a little grey shale and pyrite.
1,180–1,190	Sandstone, grey; a little dark grey shale and white sand.
1,190–1,200	Sand, white; a little grey shale and brown, spherical concretions.
1,200–1,210	Sand, white; some buff sandstone.
1,210–1,240	Sand, white; a little grey shale.
1,240–1,250	Shale, medium grey; a little white sand.

The location of the well in a moraine accounts for the great thickness of glacial drift. The Cretaceous formations are normal in thickness and composition. The foraminifera at 1,040 feet appear to be the same species as are found at 235 to 265 feet in the Trail Blazer well.

Log of Northern Royalties No. 1 Well

Location: sec. 27, tp. 40, rge. 5, W. 2nd mer.
Elevation: 1,543 feet (Landes stadia-alidade traverse).
Drilling method: standard rig.
Samples with Geological Survey, Ottawa.

Depth	Lithology Samples taken at irregular intervals from 10 to 30 feet
Feet 0–10	Missing.
	RIDING MOUNTAIN FORMATION
10–20	Shale, medium grey.
20–30	Missing.
30–345	Shale, medium grey; samples at irregular intervals of 20 to 30 feet.

Log of Northern Royalties No. 1 Well—Concluded

Depth	Lithology
Feet	
	VERMILION RIVER FORMATION
345–375	Shale, dark grey.
375–395	Shale, dark grey; some bentonite.
395–405	Shale, dark grey.
405–420	Shale, dark grey; some bentonite.
	FAVEL FORMATION
420–495	Shale, medium to dark grey, with white, calcareous specks.
	ASHVILLE FORMATION
495–633	Shale, dark grey.
633–634	Sand, white, subangular, medium-grained.
634–675	Sand, white; some shale.
675–685	Sand, white; much shale.
685–695	Sand, white.
695–703	Missing.
703–707	Dolomite, cream, probably caving from surface.
707–750	Shale, medium grey; some sand.
750–760	Shale, brownish grey.
760–762	Dolomite, buff and white; probably from caving.
762–770	Shale, medium grey; some glauconite and foraminifera.
770–780	Shale, medium grey; much sand and pyrite; bentonite.
780–790	Shale, medium grey; much sand and pyrite.
790–805	Shale, medium grey, some glauconite and foraminifera.
	SWAN RIVER GROUP
805–845	Sand, light grey, fine-grained; a little shale and pyrite.
845–855	Shale, dark grey; some white sand; traces of carbonized plants.
855–875	Sand, white; some grey shale and bentonite.
875–880	Shale, dark grey; some bentonite; a little white sand and some hard, light grey shale.
880–895	Sand, white; some medium grey shale.
895–925	Shale, medium grey; some white sand.
925–975	Sand, white, very fine-grained; some small, spherical, brown, concretionary particles.
975–1,005	Shale, light grey; a little white sand.
1,005–1,040	Shale, sandy, medium grey; some brown particles as above.

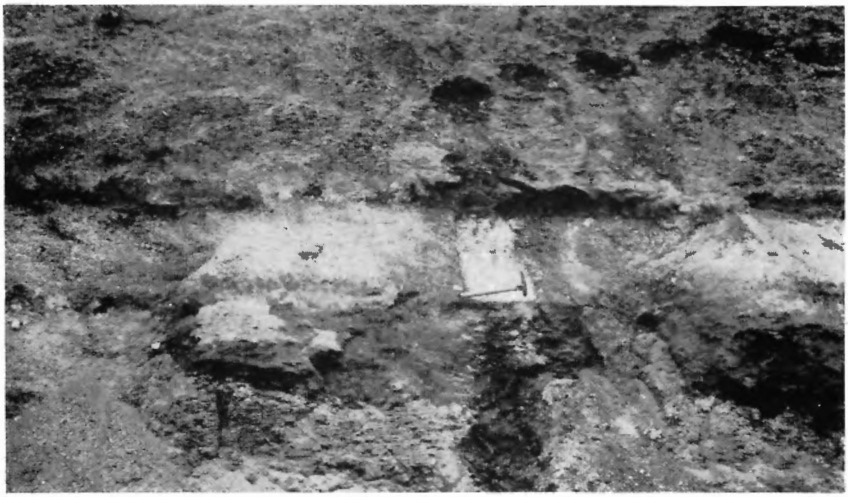
The irregular and great intervals at which these samples were taken renders them unreliable for judging the thicknesses of the formations. Although the Upper Cretaceous formations agree in lithology and thickness with those determined in this part of the map-area, the thickness and lithology of the Swan River beds appears very different. This may in part be due to careless sampling, but it may also indicate marked changes in the character of this group west of the escarpment.

Log of Kakwa No. 5 (Petroleum Engineering Company) Well

Location: l.s. 14, sec. 31, tp. 41, rge. 4, W. 2nd mer.
Elevation: 1,350 feet (McLearn stadia-alidade survey).
Drilling method: standard.
Samples with Geological Survey, Ottawa.

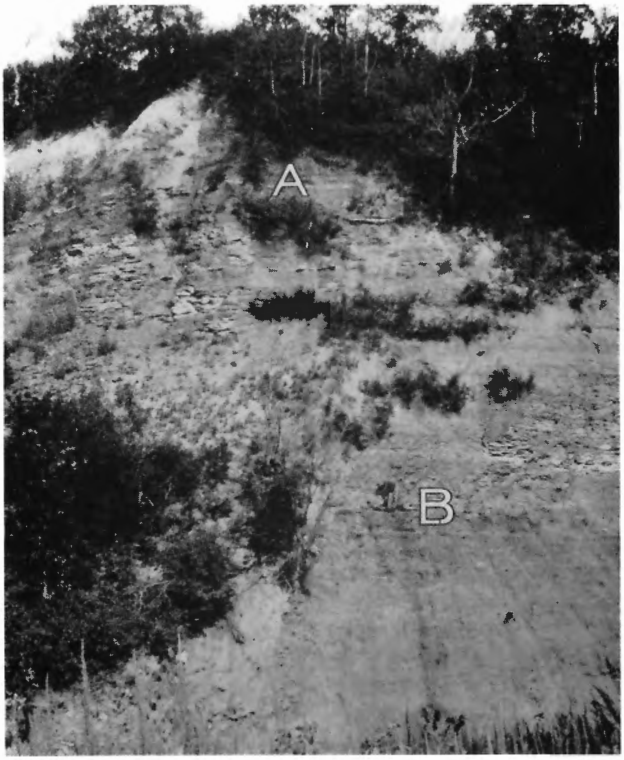
Depth	Lithology
Feet	
0–10	Glacial drift.
	RIDING MOUNTAIN FORMATION
10–80	Shale, medium to greenish grey; some bentonite.
	VERMILION RIVER FORMATION
	Pembina Member
80–130	Shale, dark grey, with bentonite.
	Boyne and Morden Members
130–160	Shale, dark to medium grey, speckled with white, calcareous material.
160–200	Shale, speckled and not speckled.
	FAVEL FORMATION
200–250	Shale, calcareous, medium grey, speckled with white, calcareous material; many *Inoceramus* prisms.
	ASHVILLE FORMATION
250–280	Shale, dark grey; a little grey silt and some limestone.
280–300	Shale, dark grey; and fine, medium grey silt.
300–320	Shale, dark grey.
320–390	Sand, white; dark grey shale.
390–430	Sand, white, medium grain, subangular.

PLATE II



84823

A. Thick bentonite bed near top of Ashville formation, Vermilion River. (Page 18.)



84825

B. Type section Keld member, Favel formation, on Vermilion River. Light-coloured band at A is impure limestone at top of the Keld. Man near B is standing on Ashville-Keld contact. (Page 24.)

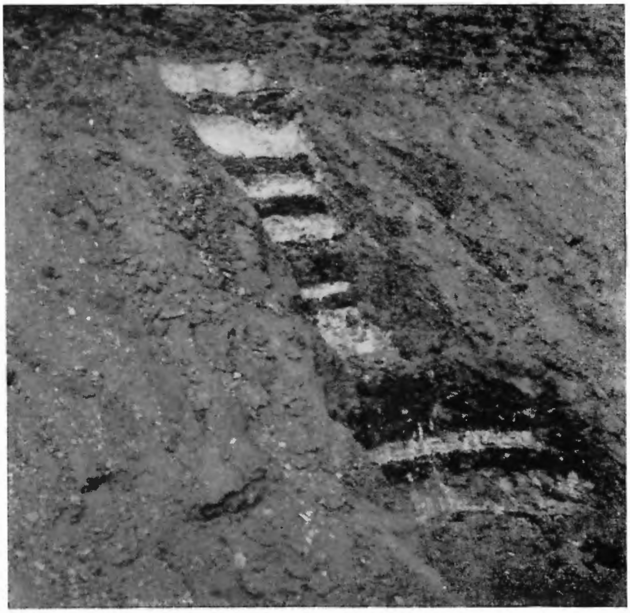
84822

A. Type section of Assiniboine member Favel formation, on Vermilion River. The contact with the overlying Vermilion River formation is shown at A; a 4-foot limestone bed can be seen at point B; and at point C impure limestone is in contact with the underlying Keld member of the Favel formation. (Page 25.)

84826

B. Fragment of *Inoceramus* n.sp., var. A, from top of Assiniboine member, Favel formation. (Page 32.)

84814
A. Papery shale, from near base of Boyne member, Vermilion River formation, on north side of Pembina River. (Page 35.)



84815
B. Series of bentonite beds near base of Pembina member, Vermilion River formation, exposed on Pembina River east of Mowbray bridge. (Page 43.)

PLATE V

84821
Boissevain sandstone, south of Boissevain. Beds exposed in upper left part of picture are composed of hard, well-cemented sandstone, such as has been used for building stone; remainder of exposure consists of loosely cemented sandstone. (Page 50.)

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