MEMOIR 89

WOOD MOUNTAIN-WILLOWBUNCH COAL AREA, SASKATCHEWAN

BY

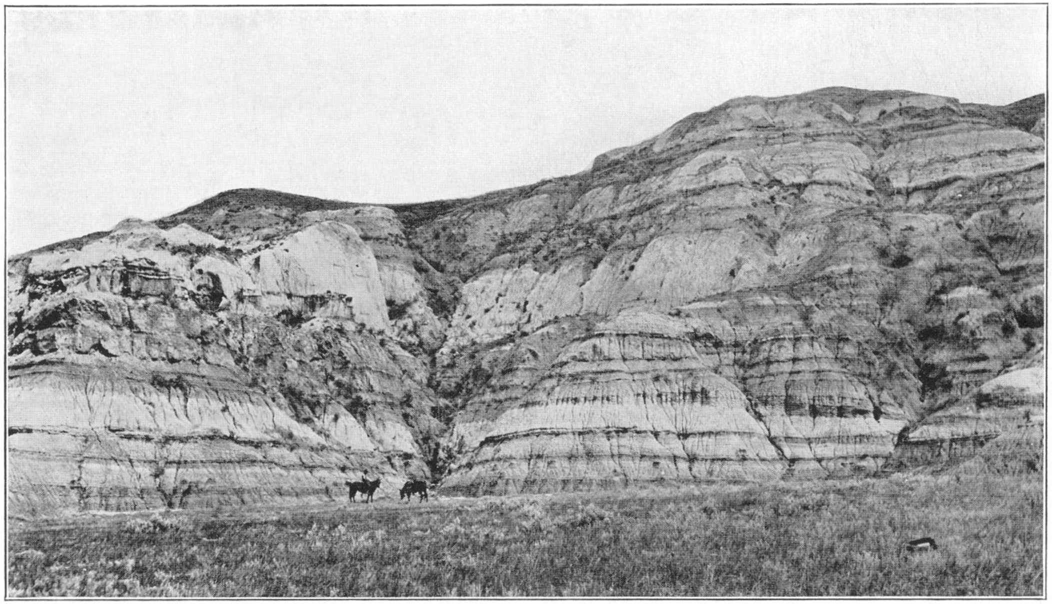
BRUCE ROSE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

OTTAWA

1916



Typical exposure of rocks of the Fort Union formation, Big Muddy valley.

CANADA
DEPARTMENT OF MINES
HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

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Bruce Rose

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CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

PAGE

CHAPTER IV.

ILLUSTRATIONS.

Wood Mountain-Willowbunch Coal Area, Saskatchewan.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

Recent development in southern Saskatchewan caused by the building of railways and the consequent influx of settlers, has made necessary an investigation of the coal measures and associated formations of that region. The investigation was carried out by the writer over an area about Willowbunch and Wood mountain (Figure 1) and shows that the area is abundantly supplied with lignite coal of good quality, and with clays suitable for the manufacture of a wide range of ceramic products, including common building brick, sewer-pipe, pottery, and fire-brick. The results of the investigation are set forth in this report.

FIELD WORK AND ACKNOWLEDGMENTS.

Two seasons of three months each during the summers of 1913 and 1914, were spent in the field. In 1913, the Willowbunch area east of the 3rd meridian was examined; and in 1914, the examination was extended to the Wood Mountain area west of the 3rd meridian.

On account of the large extent of territory covered, the work was necessarily of the reconnaissance type, and consisted largely of the measurement and sampling of coal and clay outcrops, the location of these on township plans, and the correlation of strata. The sectional maps of the Topographical Surveys Branch, Department of the Interior—No. 19, Willowbunch sheet, and No. 18, Wood Mountain sheet—on a scale of 3 miles to 1 inch, were used as base maps.

The analyses of the lignite coals were made by the Mines Branch, and the testing of the clays was done by J. Keele, of the Geological Survey.

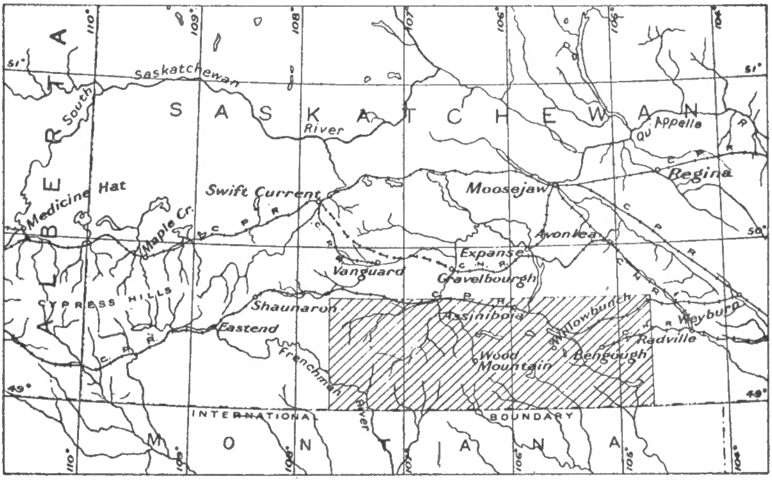

Figure 1. Location of Wood Mountain-Willowbunch coal area.

LOCATION AND AREA.

The Wood Mountain-Willowbunch coal area is located in south-central Saskatchewan, along the International Boundary. The Willowbunch division lies east and the Wood Mountain division west of the 3rd meridian (Figure 1). The Willowbunch division is comprised of townships 1 to 8 and ranges 21 to 30, west of the 2nd meridian; and the Wood Mountain division of townships 1 to 8 and ranges 1 to 13, west of the 3rd meridian. Together, they form a rectangle, 8 townships (48 miles) north and south by 23 ranges (138 miles) east and west, with an area of 6,624 square miles. This rectangle includes one row of townships on the north which were not included in the area described in the short reports on the Willowbunch coal area and the Wood Mountain coal area in the Summary Reports of the Geological Survey for the years 1913 and 1914.

A watershed cuts across the district from east to west. South of the watershed the drainage is to the Missouri river by numerous coulées, and north of it, by an irregular system of shallow-valleyed streams to an interior basin. The basin is small and really lies within the drainage area of the Saskatchewan river.

TRANSPORTATION AND COMMERCIAL POSSIBILITIES.

The open-plains nature of the topography makes all parts of the area easily accessible by wagon, and, until recently, this has been the only means of communication; but now the area is tapped by two railways. The Weyburn-Lethbridge branch of the Canadian Pacific railway cuts across the northern part of the area and the Radville branch of the Canadian Northern railway reaches as far as the town of Bengough in the eastern part.

The building of these railways has given a great impetus to grain growing and practically all the good farming land has been taken by homesteaders. The yield of grain is above the average yield for the prairie provinces, and the area promises to become a well populated and very thriving district in the near future. Much of it is, however, too far from railways for successful grain growing, particularly the part south of the main watershed. Here, numerous coulées with a north-south trend make railway construction difficult. This part is, however, admirably suited for ranching, for which close railway accommodation is not so necessary as for grain growing.

Several towns are growing up about railway stations and as development proceeds, will doubtless gradually become centres of manufacture and distribution. It is in connexion with this development that the coal and clay industries become important. The use of the coal for heating and power and of the clay for the manufacture of building bricks, sewer-pipes, and other ceramics will increase steadily. Development up to the present time has been confined to the mining of coal for local use at various localities. No brickyards are worked within the area, but some have been established in similar clays outside the area; and clay is being shipped by railway as far as Medicine Hat for the manufacture of sewer-pipe.

The coal is a lignite of good quality, and can be economically used for heating purposes locally, while tests show it to be a good gas producer.[1] It may, then, be counted as a power reserve for manufacturing.

The clays have a very wide range. Clays suitable for common brick, for sewer-pipe, and for pottery are common, while fireclays are less widely distributed.

The close association of the coal and clay is very fortunate since the two can be mined together in many localities. The coal can be used directly to burn clay products or as a gas producer, while the surplus can be sold. The combination of coal for fuel and power and of clay for the manufacture of brick is particularly advantageous, for there is practically no timber in the region and no water power.

With the opening up of the Canadian west and the increasing demand for fuel and building material, along with the increasing facilities for railway transportation, it is to be expected that the working of the associated lignites and clays of southern Saskatchewan will soon form a considerable industry.

One drawback to coal mining is that the lignites slack and crumble on exposure to air; thus it is necessary to have production just equal to consumption. Experiments are being made in briquetting the lignites and if these prove successful, the difficulty of storing will be overcome. Mining can then progress at a more steady rate and the briquettes can be stored until needed.

HISTORY.

General History.

The early explorers of the Great Plains did not visit the Wood Mountain-Willowbunch area. The valley of the Saskatchewan to the north and that of the Missouri to the south offered more easy routes to the regions that were sought farther west and so this area on the height of land between the two rivers

[1] Mines Branch, Dept. of Mines, Sum. Rept., 1912, p. 37.
Mines Branch, Report No. 83, "Investigation of the coals of Canada," vol. II, part VIII, table XXXVIII, p. 111.

was passed by. However, it was known to be a great buffalo country, and was a disputed hunting ground for the Cree Indians of the Saskatchewan and the Siouan tribes of the Dakotas and the Missouri. Each made yearly trips to the area on buffalo hunts and when they met, there were usually feuds and bloodshed. The Indians were incited to further efforts by the desire of the fur traders of the north and south (represented by the Hudson's Bay Company and the American traders of the Missouri, respectively), to obtain the buffalo skins from this area.

During this time half-breed settlements sprang up, whose members led much the same roving and hunting life as the Indians. In 1862, the wars between the Crees and Sioux ceased and a treaty of peace was made largely through the influence of the half-breed, Gabriel Dumont. After this the Crees and the Sioux mixed considerably and hunted together, making common cause against the Blackfoot Indians who threatened their hunting grounds in the Cypress Hills district farther west.

It was the custom of the fur companies to send traders to the winter quarters of the Indians, and in 1868, Mr. Isaac Cowie (chief factor of the Hudson's Bay Company, now retired and living in Winnipeg), was sent by the Hudson's Bay Company from Fort Qu'Appelle to Wood mountain to trade with the Indians there. A description of this trip and the conditions at that time may be found in his book "The Company of Adventurers."

The Indians were still, however, averse to white men coming among them except as fur traders, and, in the spring of 1873, Robert Bell of the Geological Survey was prevented from taking his survey party to Wood mountain. He made the trip alone, however, a few months later.

About this time individual traders began to come in. In 1870, George Fisher had a store 12 miles west of the present site of Willowbunch. In 1871, Mr. J. L. Légaré, at present postmaster at Willowbunch, built a store at Wood mountain. This he moved to a location 3 miles east of Wood mountain in 1873. Then, in 1876, the Indian chief Sitting Bull and his band of Teton Sioux to the number of 4,000, fled to Canada after the Custer massacre and located in this area. In the negotiations which followed for the return of these Indians to their own country, Mr. Légaré took a prominent part. Many of the Indians returned within the next few years, but a considerable portion, including the chiefs and their families, remained. In 1878, Leighton and Jordan, traders from the United States, built a stockaded trading post at Wood mountain in order to get the Indian trade. Soon buffalo became scarce and the fur traders interest in the district declined. In 1880, Mr. Légaré moved his store to Willowbunch where he has since remained. His store was the first building in the present small town of Willowbunch, which has gradually become the trading centre for a considerable tract of country. Subsequently Mr. Légaré bought out Leighton and Jordan's stock at Wood mountain and moved it to Willowbunch. In 1881, there were still about 500 Sioux Indians in Canada. On account of the scarcity of buffalo, conditions became so hard for them that they were in danger of starving and were in the habit of gathering about Mr. Légaré's store at Willowbunch daily to be fed. Finally, Sitting Bull was induced to return with his followers to the United States, and Mr. Légaré personally supervised the transportation of most of the Indians to the Missouri river.

A few of the Sioux still remained in Canada under the leadership of Whitecap, and were later placed on a small reserve near Wood mountain. This band, according to the latest report of the Department of Indian Affairs, now numbers about 70 persons.[1]

When the North West Territories were transferred to Canada in 1869, there were no permanent settlements in the Wood Mountain-Willowbunch area. Dr. G. M. Dawson, geologist on the British North American Boundary Commission of 1873–74, describes the Wood Mountain settlement of that time as "merely a base for a certain number of hunters and traders, who have found it convenient to erect wintering shanties there."[2]

When the Royal North West Mounted Police began to patrol the west in 1874, this area along the International Boun-

[1] Dom. of Canada, Dept. of Indian Affairs, Ann. Rept. for the year ending March 31, 1914, part II, p. 66.

[2] Dawson, G. M., "Geology and resources of the 49th parallel," Montreal, 1875, p. 249.

dary received their special care. Their attention was at first largely occupied in negotiations with the Indians, the settlement of their disputes and the placing of them on reserves. Later, they were kept busy with disputes between American and Canadian cattlemen over boundary grazing infringements and with cattle and horse thieves—troubles which continue to a less degree up to the present.

As late as 1882, the Indians were found showing open hostility when a party of thirty-two Crees took possession of Mr. Légaré's encampment at Willowbunch and he was forced to purchase his life and the lives of his men at the cost of his outfit. The miscreants were, however, arrested by the police.

With the building of the Canadian Pacific railway (1880–85) and the opening up of trading centres, surveyors and settlers began to spread over the country. The discontent which arose among the half-breeds was rife about Wood mountain and Willowbunch, and they were prevented from taking part in the rebellion of 1885 largely by the efforts of Mr. Légaré. He organized a corps of scouts to repel attacks of American sympathizers with the rebellion, and so selected his men that they represented practically all the half-breed families in that vicinity. They were distributed over the district at such a distance apart as to render them harmless if they became disaffected. The pay received went a long way to relieve the smouldering discontent and so a group of budding rebels was turned into supporters of the government.[1]

In the period of immigration, railway-building, and general development that followed the rebellion of 1885, the district lagged behind. It was too far from a railway to make grain-growing profitable, although for years farmers were accustomed to draw grain in winter to Moosejaw, a distance of from 50 to 100 miles. Ranching was for many years the principal occupation. The building of the Weyburn-Lethbridge branch of the Canadian Pacific railway and the Radville-Bengough branch of the Canadian Northern railway within the last five years, has brought to this section a great rush of homesteaders, and practically all the best agricultural land is now occupied.

[1] Black's History of Saskatchewan, p. 389.

The commercial possibilities of the district, in connexion with its agricultural development, the working of the coal, and the establishment of clay plants, are very bright, and it may be expected to make a rapid advance in material prosperity in the future.

Previous Work.

In 1857–8–9, James Hector, geologist on the Palliser expedition sent out by the British government for the exploration of British North America, travelled over a great deal of the Great Plains in Canada. Although he did not touch the Willowbunch-Wood Mountain area, his work in similar country to the east and north has a very direct bearing on this district. His reports are published in the journals and papers relative to Captain Palliser's exploration in British North America and are contained in the British Parliamentary papers for 1859–60, 1863, and 1865.

In 1857–8, H. Y. Hind led geological parties for the Canadian government on work very similar to that done by Hector. Like Hector's, his explorations did not reach this area. He travelled, *via* the Souris, Assiniboine, and Qu'Appelle rivers, as far as the elbow of the South Saskatchewan river. His reports are of particular value for their summation of the knowledge of the Cretaceous and Tertiary at that time. They are contained in the Legislative Assembly publications, Toronto, for the years 1858–9, and are also published separately in two volumes, "Narrative of the Canadian Red River exploring expedition of 1857" and "Assiniboine and Saskatchewan exploring expedition of 1858."

In 1873–4, G. M. Dawson was attached to the British North American Boundary Commission, as naturalist. He travelled directly across the area and his "Report on the geology and resources of the forty-ninth parallel from the Lake of the Woods to the Rocky mountains," is an exhaustive treatise on the physical geography and geology. This report formed the basis for future work on the geology and physiography of the Great Plains in Canada. It is interesting to find, from an historical as well as from a practical standpoint, that he concluded, after a thorough examination of the evidence for and against, that the lignite-bearing beds overlying the Foxhills-Cretaceous sandstone are of Tertiary age.

Soon after the North West Territories were transferred to Canada, the Geological Survey started exploratory work on the prairies and has continued it intermittently up to the present. The reports of these explorations may be found in the publications of the Survey for the various years in which they took place. In 1873, A. R. C. Selwyn crossed the prairies from Fort Garry (Winnipeg) to Rocky Mountain House. In the same year, Robert Bell travelled along the valley of the Qu'Appelle river westward to the elbow of the South Saskatchewan and back by way of the Dirt hills. He also made a hurried trip to Wood mountain on horseback, being prevented by Indians from taking his survey party. In 1875, R. W. Ells was in charge of boring operations in the west and travelled as far as Rocky Mountain House. In 1880, A. R. C. Selwyn was in charge of boring operations in the Souris valley. In 1883–4, R. G. McConnell examined the Cypress hills, Wood mountain, and adjacent country. His report, part C of the Annual Report, 1885, is the latest which deals directly with the area under discussion in this memoir. In 1902, D. B. Dowling examined and reported on the coal fields of Souris river, part F, Annual Report 1902–3. In 1905–6, R. Chalmers began an investigation of the surface geology of the prairie provinces and published summary reports of his work. Since 1910, H. Ries and J. Keele have been investigating the clays of the prairies and have published five memoirs on "The clays and shale deposits of the western provinces," Memoirs 24, 25, 47, 65, and 66.

Besides the work which has a direct bearing on the area under discussion, the Geological Survey has published important reports on neighbouring areas, including those of G. M. Dawson on the foothills country, those of J. B. Tyrrell, and D. B. Dowling on areas to the north and east, and reports by L. M. Lambe on the vertebrate fossils of the Cypress hills and Red Deer river. D. B. Dowling's report on "The coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia," Memoir 53, is the latest general report on the geology of the prairie provinces. It is to the work of G. M. Dawson, R. G. McConnell, D. B. Dowling, and J. B. Tyrrell chiefly that we owe our present knowledge of the structure and areal distribution of the formations of the prairie provinces.

During this time of geological exploration and survey in Canada, a great deal of work was done in neighbouring areas of the United States to the south, which has a direct bearing on the geology of the Wood Mountain-Willowbunch area, particularly in regard to the location of the Cretaceous-Eocene boundary. The quantity of work done and the volume of literature published are too large for anything but the briefest review. The work is chiefly that of government surveys and the records are to be found in government publications, in scientific journals and periodicals, and in the reports of various scientific societies and institutes.

Of first importance is the work of the Hayden, King, and Wheeler surveys between the years 1867 and 1879. It is to the work of the geologists on these surveys that is due the first delineation of the Cretaceous and Tertiary rocks of the central part of the continent; also it is due to the differences of opinion of these geologists that the Cretaceous-Eocene boundary controversy first arose. A complete catalogue and index of the publications of these surveys is given in Bulletin No. 222 of the United States Geological Survey. Since its organization in 1879, the United States Geological Survey has carried on this work and the reader is referred to the Survey's List of Publications for a concise catalogue and index. Beginning with the year 1900 the North Dakota Geological Survey has issued a series of biennial reports dealing largely with the clays and lignites of the state. These are of special interest on account of the nearness and similarity of the formations to those of the Wood Mountain-Willowbunch area.

No attempt is made to list reports published in journals and periodicals or in the transactions of societies and institutes; for these the reader is referred to the bibliography of North American geology in bulletins of the United States Geological Survey.

CHAPTER II.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

REGIONAL—THE GREAT PLAINS.

The Wood Mountain-Willowbunch area lies in the Great Plains province which, in Canada, slopes eastward from the foothills of the Rocky mountains to the Laurentian plateau. The following brief description of these plains applies particularly to the southern treeless areas of Alberta, Saskatchewan, and Manitoba.

The topography of the Great Plains is essentially that of a base-levelled surface. It is a plain developed on nearly flat-lying, soft strata—clays, shales, and friable sandstones—and over great areas the slope of the plain corresponds to the dip of the underlying strata; but, considered as a whole, the surface is seen to bevel the strata at small angles. It owes its flatness partly to the horizontality of the strata, but primarily to base-levelling by normal erosion. The origin of the plains is, then, in part structural and in part erosional. They were formed in pre-Glacial times and the surface has been modified by glacial scour and deposition. It is, in general, a region of rolling prairie, interrupted by ridges and valleys.

The evenness of the surface is in places made more complete by the filling of the hollows with superficial deposits and in places broken by the piling up of superficial deposits in ridges. The superficial deposits are almost wholly of glacial origin and were deposited during the retreat of the continental glaciers. The fillings are outwash and lake deposits as is shown by their sorted and stratified condition, and the ridges are morainal deposits. A veneer of boulder clay mantles the surface almost everywhere.

The underlying rock formations of the Great Plains are for the most part of Cretaceous age, but here and there plateaus of Tertiary rock stand above the general level. These are remnants of much more widely distributed Tertiary deposits, the greater part of which has been denuded away during the base-levelling process. The rise from the plains to the plateaus is usually abrupt. The boundaries of the plateaus are commonly marked by clay bluffs, particularly on the south and west sides. The north and east slopes are, as a rule, covered with a mantle of boulder clay. The plateau surfaces are, like the plains surfaces, rolling prairies and the question arises as to whether they owe their flatness to the original, horizontal position of the strata, or represent the remnants of a previous, base-levelled surface like that of the Great Plains. This question will be referred to in a separate treatment of the plateau topography.

The valleys cut below the level of the plains detract very little from the apparent evenness of the general plains surface. They are noticeable only when the observer is in their immediate vicinity and are lost to view from the broad interstream areas. The valleys are of two types. Streams such as the Saskatchewan with headwaters in the Rocky mountains and with a perennial flow have cut canyon-like valleys in the soft strata, while streams with headwaters on the plains and an intermittent flow usually have shallow valleys. Streams of the latter type have their sources in an intricate system of ramifying and inosculating coulées especially when they head in the rocks of the Tertiary plateaus, mentioned above.

A second and earlier system of stream courses, in part coinciding with the present system, is marked by valleys which are now abandoned or in which the present streams are so small as to be wholly inadequate to account for their excavation. These valleys were excavated at a time when the climate was much more humid and the precipitation consequently much greater than at present, probably during the retreat of the continental glaciers. The abandoned valleys are commonly occupied at intervals along their courses by shallow saline lakes, or for short distances by intermittent streams.

Over considerable areas, the evaporation is equal to the precipitation and there is an almost absolute lack of running water. In some areas the surface water is concentrated in lakes with no outlets, giving, locally, an interior basin drainage.

The southern part of the Great Plains in Canada is divided into three steppes by two eastward facing escarpments. The first steppe or lowest prairie level is that of the Red River valley, the Winnipeg system of lakes and the flat land surrounding them. This plain is developed on Palæozoic rocks, and in that respect differs from the more typical Great Plains to the west, which are developed on the soft Cretaceous rocks. It was occupied on the retreat of the continental glacier by a great lake—glacial Lake Agassiz—and the surface is deeply mantled with boulder clay and with alluvium deposited in the lake. It has an average elevation of about 800 feet above the sea and drains to Hudson bay by way of the Nelson river.

The passage from the first to the second steppe is over a rise or eastward facing escarpment of Cretaceous rocks, known as the Manitoba escarpment. The drainage channels from the second to the first steppe are wide and divide the escarpment into several prominent groups of hills known as the Pembina, Riding, Duck, Porcupine, and Pasquia hills. The summits of these hills rise from 500 to 1,000 feet, in places more, above the level of the first steppe.

West of the Manitoba escarpment the Cretaceous plains stretch away to the foothills of the Rocky mountains. The elevation above the sea increases gradually from less than 1,500 feet to more than 4,000 feet. This is the area occupied by the second and third steppes. The second steppe lies between the Manitoba escarpment and the Missouri coteau, an eastward facing escarpment of Tertiary rocks. This escarpment is the eastern boundary of the Wood Mountain plateau, one of the Tertiary remnants mentioned above. The eastern boundary and a northwesterly trending arm from it form a steplike rise of from 200 to 500 feet; but since there is an equal drop on the western side of the Tertiary remnant the Missouri coteau does not mark a rise from one prairie level to another as the Manitoba escarpment does. It forms, however, a convenient dividing line on the plains. East of it, the boulder clay deposit is thicker than to the west and the front of the escarpment is almost everywhere deeply covered with the boulder clay. It seems probable that the coteau acted as a barrier to ice advancement at certain stages of the glacial period and that the greater thickness of glacial accumulations along the front of it and to the east are to be accounted for in this way.

The third steppe reaches from the Missouri coteau to the foothills. It is in general like the second steppe but the superficial deposits covering it are thinner; and, while there is only one Tertiary plateau on the second steppe (Turtle mountain, along the boundary between Manitoba and North Dakota), there are a number of such residuals on the third steppe. Chief among these is the Wood Mountain plateau, which is more fully discussed under local topography, and the Cypress Hills plateau.

This threefold division of the Great Plains is chiefly useful for descriptive purposes. The actual decrease of elevation in passing from one steppe to the next lower is small in comparison to the decrease due to the general eastward slope of the plains. Despite minor irregularities—plateaus, valleys, and escarpments—they preserve their character as plains throughout and stand as one of the best examples known of an uplifted and base-levelled surface. The region is often described as a "rolling prairie," a general term that is aptly applied to the whole extent of the plains.

LOCAL TOPOGRAPHY.

The location of the map-area on the Great Plains is near the eastern border of the third steppe, just west of the Coteau du Missouri. The watershed between the Missouri river and streams flowing north cuts across it in an east-west direction. This divide is part of the Missouri-Saskatchewan watershed, but in this particular area none of the streams flowing north reach the Saskatchewan. They are caught in an interior basin in which lie Lakes Johnston and Chaplin.

In the Wood Mountain division a remnant of Tertiary rocks, known as the Wood Mountain plateau, forms the watershed. This plateau in the western part of the sheet is very narrow. It is merely a ridge which for a distance of 40 miles is in few places more than 5 miles wide and in several places has been nearly cut through by the headward working of the streams. To the west of the area the plateau has been completely cut away but reappears in the Tertiary plateau of the Cypress hills. To the north and south of this plateau plains stretch away to the areas beyond the map-area. The plateau broadens towards the east and occupies the full width of the Wood Mountain area. Its northern boundary extends to the north-east to join the ridge of the Coteau du Missouri near Lake Johnston, and its southern boundarv crosses into Montana. It extends eastward to the Coteau du Missouri so that its eastern border corresponds with the eastern border of the third steppe. Thus, the Willowbunch map-area lies on the eastward extension of this plateau, although Wood Mountain plateau, as defined by McConnell, lies wholly to the west of the 3rd principal meridian.[1]

The break from the plateau to the surrounding plains is marked by an escarpment from 200 to 300 feet in height. In the Wood Mountain division, where the plateau is narrow, this break is a very striking feature, but in the Willowbunch division the plateau character predominates.

In detail, several special phases of topography are exhibited and will be discussed under separate headings.

Plateau Topography.

The plateau topography is essentially the same as the plains topography. The Wood Mountain plateau is a plain developed on flat-lying strata of Tertiary age. It rises gradually from 2,000 feet above sea-level, along the Coteau du Missouri in the northeast corner of the area, to more than 3,300 feet along the narrow watershed in the western part of the Wood Mountain division. Its surface, particularly in the southern and western parts, is very irregular. It is cut by an intricate system of coulées tributary to the Missouri river (Plate IIA). The coulées have a general north-south trend and so make road and railway building in an east-west direction very difficult. The main

[1] McConnell, R. G., "Report on the Cypress hills, Wood mountain, and adjacent country." Geol. Surv., Can., Ann. Rept., vol. I, 1885, p. 13 C.

coulées are wide and deep, but since they are now grass-covered and carry very little water, they must have been excavated at a time of much more humid climate than the present. The plateau surface where it is not cut by coulées is rolling prairie.

The mode of origin of Wood Mountain plateau is in doubt and cannot be determined from the data collected in the area itself. It must be considered in connexion with the physiography of the Great Plains in general, and more particularly in connexion with that of the Cypress Hills area to the west. Two hypotheses present themselves: Wood Mountain plateau is either a remnant of Tertiary rocks, which, on account of its location on a watershed, has escaped denudation and so owes its flatness to the original horizontality of the strata, or it is part of an old base-levelled surface the greater part of which has been destroyed during the period of denudation to which the surrounding Great Plains are due. The latter hypothesis is here accepted for the following reasons:

(1). Although the rocks are so nearly flat-lying and the plateau so nearly level, yet in passing from east to west successively higher series of strata are met. Hence the plateau surface truncates the strata at a small angle and so is a true erosion surface.

(2). The same condition exists in the Cypress hills, a Tertiary remnant farther west on the Great Plains; but, while the top formation in the Wood Mountain plateau is of Eocene age, the top strata of the Cypress hills are of Oligocene age. This difference, however, helps to confirm the belief that a general base-level of erosion was developed over a large area, and is then not confined to the Wood Mountain plateau.

(3). Oligocene sediments overlie the Fort Union-Eocene formation on the top of the Cypress hills, also to the east, in western North Dakota,[1] in an area which is directly connected with the Wood Mountain-Willowbunch area. It is probable then that Oligocene sediments were present in the area under consideration but have been denuded by the base-levelling process.

[1] Leonard, A. G., "The geological map of North Dakota," Quart. Jour., Univ. of North Dakota, vol. IV, No. 1, Oct., 1913, p. 11.

(4). The sudden break from the plains to the plateau, marked by the escarpment at the edge of the plateau, proves that the plateau must have developed during an earlier cycle of erosion. At the present time, erosion is gradually destroying the plateau; the escarpment bounding the plateau is being pushed back and eventually the Tertiary rocks will all be removed, leaving an unbroken Cretaceous plain.

Plains Topography and Interior Basin Drainage.

To the north and south of Wood Mountain plateau, where erosion has exposed the Pierre-Cretaceous shales, flat plains with meandering water channels have developed. These are the typical prairie plains which have already been described in the general account of the Great Plains.

A very marked change is noted in the character of the streams as they emerge from the plateau to the plains. In the plateau they are confined in deep coulées, but on the plains their channels are so shallow as to be almost negligible. This is most noticeable north of the Wood Mountain plateau.

The plains area to the south of the plateau is cut in two by a through-flowing stream, Frenchman river. This stream heads in the Cypress hills to the west and has cut a canyon-like valley across this part of the plain. Its tributaries join it at grade so that they also have cut deep valleys near the main stream and so differ from the majority of the small plains streams. The valley of the Frenchman river is a plain from 1 to 2 miles wide, cut from 200 to 300 feet below the general plains level. The valley bottom is a silt plain through which the stream meanders in a very crooked course. This large valley is thought to have been excavated at a time of greater humidity than the present and its broad flat bottom is due to the silting up of the stream following the change to the drier climate.

North of the plateau the streams all concentrate to form Wood river. This stream meanders across the plains in a very shallow valley and about 40 miles north of the map-area empties into the basin of Lakes Johnston and Chaplin, two large saline lakes connected by a channel. The water entering these lakes either evaporates or soaks into the underlying strata.

There is here then interior basin drainage. Such local interior basins are characteristic of the Great Plains in southern Saskatchewan and Alberta, but they are so interspersed with through-flowing streams that they do not form striking topographic features. They owe their existence to the disorganization of the drainage following a change from wet to dry climate, as mentioned in the preceding paragraph. Old drainage channels became silted up and the present run-off is so small that it evaporates as fast as it accumulates.

Abandoned River Valleys.

The presence of coulées too large to have been excavated by the present streams, the silting up of rivers like Frenchman river, and the existence of local interior basin drainage have been mentioned and explained as due to a change of climate from wet to dry. It is thought that the climate was at one time much more humid than at present, the run-off was large, and a well organized system of drainage, not corresponding to the present system, existed. Another and most striking proof of this is the presence of abandoned river valleys.

There are in the area large coulées or valleys which at first sight seem to mark the courses of large rivers, but which contain no through-flowing streams. These old channels can be traced for many miles and a former drainage system worked out. The bottoms of the valleys have become silted up and are now occupied by scattered saline lakes, by streams of greatly diminished size, or for short distances by local streams from nearby springs. The water of these streams and springs sinks into the silt or empties into the saline lakes and evaporates.

A good example of one of these old valleys is Big Muddy valley. It is tributary to the Missouri river and in its lower course carries a small stream, Big Muddy creek. The head of this creek barely reaches the International Boundary, but the large valley can be traced for 100 miles farther. It is cut to an average depth of 250 feet below the prairie level and has a width varying from 1 to 1½ miles. A line of terraces about 200 feet above the valley bottom marks a break between a mature upper valley and a main younger valley and indicates that there were at least two stages in its development. The valley crosses into Canada in tp. 1, range 22, W. 2nd mer. Springs in that vicinity form the headwaters of Big Muddy creek. After crossing a slight divide, the first of a series of saline lakes, Big Muddy lake is met. This lake occupies the old valley bottom for a distance of 19 miles and for 15 miles is less than 1 mile wide. In tp. 4, range 25, W. 2nd mer., Big Muddy valley divides into two branches of about equal size. The north branch is occupied along its course by Willowbunch lake, 21 miles long, and by Lake of the Rivers, 25 miles long. It heads in the flat country about Lakes Johnston and Chaplin, and doubtless at one time drained that area. The south branch passes close to the town of Willowbunch, along a number of small saline lakes, and finally through Twelvemile lake, a lake over 15 miles long, but in few places more than one mile wide. It heads in the country immediately north of Wood Mountain plateau which is now occupied by the headwaters of Wood river.

The period during which this large valley, the large valley of Frenchman river, and the large coulées of the area were excavated, is here assigned to late Tertiary and Glacial times, or more particularly, to the time of retreat of the continental glacier. The water supply was much more plentiful during this period and the ice blocked the drainage to the north and east, so that the drainage to the south and west was large. The Missouri river without doubt received the drainage from this area. Since the retreat of the ice the Missouri has silted up its flood-plains to a depth of more than 80 feet.[1] During the glacial retreat the ice front seems to have remained stationary at the Missouri coteau for a great length of time, for the coteau is deeply covered with morainal gravels and boulder clay. A melting ice-sheet so close would supply the great amount of water required to excavate the deep valleys in the Wood Mountain-Willowbunch area.

These abandoned or almost dry valleys are very common over the Great Plains. A very noticeable thing on looking at a map of southern Saskatchewan and Alberta, is the number of

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[1] Leonard, A. G., "Bismark Folio, N.D.," No. 181 of the Geologic Atlas of the United States, U.S.G.S., p. 6.

long, narrow lakes. These lakes lie along the old river valleys. One of the best examples of an abandoned valley is the old river course connecting the headwaters of the Qu'Appelle river with the South Saskatchewan river at Elbow. At one stage the waters of the South Saskatchewan flowed along this course and out by way of the Qu'Appelle valley. The small stream and the number of long narrow lakes in the upper course of the Qu'-Appelle are features that are characteristic of these abandoned valleys. Last Mountain lake on one of the tributaries of the Qu'Appelle is 55 miles long. Examples of abandoned valleys could be multiplied almost indefinitely, proving that the conditions that caused their formation were not confined to Wood-Mountain-Willowbunch area but were general over the Great Plains.

The readjustment of the drainage systems was accompanied by and probably partly caused by elevations and depressions of certain parts of the Great Plains relative to one another. The basin of Lakes Johnston and Chaplin, which at one time drained through Big Muddy valley, stands to-day at a lower elevation than parts of the abandoned valley. Again, this valley after leaving the basin of Lakes Johnston and Chaplin cuts across Wood Mountain plateau, where it stands 200 to 300 feet higher than the basin, so that the plateau must have been elevated or the basin depressed to that extent since the stream flowed through Big Muddy valley. Such adjustments can only be measured relatively. It cannot be told whether the change was brought about by an elevation in one area or by a depression in the neighbouring area. They were in no sense diastrophic movements. No faulting or folding of the strata can be noted. They were simply broad flexures extending over large areas and in most cases the movement was so slow that the streams were able to adjust themselves to the changing conditions, so that the abandoned valleys are not pointed to as proofs of changes in elevation. They stand rather as a proof of change of climate, from the humidity which characterized the glacial period to the semi-arid conditions which prevail over the southern part of the Great Plains in Canada at present.

Lake and Slough Country of the Coteau du Missouri.

Cutting across the northeast corner of the area is the band of hilly country known as the Coteau du Missouri. The coteau forms the eastern boundary of the third steppe and also the eastern edge of the Wood Mountain plateau. The escarpment forming this boundary lies just outside the area mapped. This escarpment formed a barrier to the ice at certain stages in the Glacial period and considerable morainic gravel and boulder clay were stranded along it. In the Willowbunch area this accumulation of material is distributed over a belt about 20 miles in width running in the general northwest-southeast direction of the coteau. The gravel and boulder clay are very irregularly distributed in ridges and hills, and the intervening hollows are commonly occupied by small lakes and sloughs. These basins have no outlets and there is an absolute lack of any connected drainage. The lakes and sloughs are, like the hills, irregular in shape. They conform in outline to the surrounding hills and many of them are long and narrow, filling the hollows between morainic ridges.

Beyond this hilly country to the west, there is a considerable area covered with outwash and lake deposits formed in front of the glaciers. The town of Bengough is situated on one of these flats. Such flats are confined to the country north and east of Willowbunch and Big Muddy lakes. To the south and west there is the typical plateau topography.

Although very irregularly distributed, there is some parallelism to the morainic ridges in an east and west direction. Furthermore, they occur in zones. A zone of hilly country several miles in width is followed by a depression of corresponding width. It is suggested that the ridges mark the seasonal retreat of the ice and that there was a cyclic change of climate as well as the seasonal change. The depressed zones with little morainic material may represent times of rapid retreat of the ice. These are followed in each case by a zone of morainic ridges marking several years of regular retreat. The depressions may, however, be valleys cut by Glacial or pre-Glacial streams, but no evidence of fluvial action remains. The railways and main roads follow the depressions. The examination on which these observations on the topography of the coteau are based were not confined to the area mapped, but extend from the main line of the Canadian Pacific railway near Moosejaw south to the International Boundary.

Coulée and Badland Topography.

As previously noted the Wood Mountain plateau forms a watershed between streams flowing north to Johnston and Chaplin lakes and streams flowing south to the Missouri river, and the headwaters of these streams are made up of numerous coulées extending well into the plateau. The coulées at the border of the plateau are wide and deep, but towards the centre divide into an intricate system of ramifying and inosculating tributaries which are in many cases partly wooded (Plate II A).

Where the coulées are deep, especially towards the edge of the plateau, and along those coulées tributary to Big Muddy valley, the sides are steep and there is a very scanty vegetation. The alternating layers of clay, sand, and lignite of which the strata are composed, are easily eroded and weather into gullies and bluffs giving a semi-badland topography. A small area along Rock creek southwest of Wood mountain is characterized by very rugged and desolate clay buttes and deep gullies which G. M. Dawson has described as badlands,[1] and it is thought that this small area is composed of beds of the Lance formation which are particularly apt to weather into badlands.

The weathering in such areas takes place under peculiar conditions. Erosion occurs mainly in the spring months when the snow melts and the precipitation is greatest. The clays become water-soaked and slump into the gullies and valleys leaving bluffs and hills with no vegetation. During the rest of the year there is very little precipitation and the clays dry and crack. Then, with the return of the rains the cracks form slumping planes. This alternate wetting and drying of interbanded clays and sands, in a region where the total precipitation is not great enough or sufficiently distributed throughout the

[1] Dawson, G. M., "Geology and resources of the 49th parallel," Montreal, 1875, p. 103.

year to support a flourishing vegetation, but is concentrated in a short period so that erosion is vigorous for a time, leads to the formation of badlands. Some very peculiar topographic forms are developed. Gullies commonly inosculate and leave steep isolated hills or buttes (Plate IIB). Water channels form underground along cracks in the clays. These gradually develop into gullies and the overhanging clays slump into them; but in some cases the clay is strong enough to support itself and as the gully works back a natural bridge of clay is left over its lower course (Plate III).

The badland and coulées topography makes a great part of the area difficult of access. This is especially true of the south side of the Wood Mountain plateau where travelling is made almost impossible by the great number of deep coulées running to the south. The building of railways through this part will be very difficult and it is likely to remain a grazing country, for which it is much better adapted than for farming.

Lakes.

The lakes are classified by R. G. McConnell as follows:[1]

(1). Lakes occupying portions of the abandoned channels of ancient streams.

(2). Lakes occupying depressions in the drift which have become the receptacles for the drainage of the adjoining higher land.

(3). Lakes partaking of the character of springs.

The lakes of the first class have been mentioned in the description of abandoned river valleys. In this area, they are confined to the Big Muddy valley and its tributaries, and include Big muddy, Twelvemile, and Willowbunch lakes, Lake of the Rivers, and several smaller lakes. Lake of the Rivers extends 20 miles beyond the north boundary of the area mapped. The lakes occupy depressions along the old river valleys and conform in shape to them and so are all long and narrow. They are all saline and most of them have no outlets and are gradually becoming more saline. The inflowing streams are small and local

[1] McConnell, R. G., "Report on the Cypress hills, Wood mountain, and adjacent country." Geol. Surv., Can., Ann. Rept., vol. I, 1885, p. 21 C.

and the water is lost by evaporation. Twelvemile lake receives the water of a considerable stream from Wood Mountain plateau; but since this stream enters near the west end where there is also an outlet connecting it to Wood river, only the western part of the lake is freshened, the rest remaining quite saline.

The lakes of the second class are numerous in the lake and slough country of the Coteau du Missouri. They are also scattered here and there over the plateau but are mostly quite small. The smaller ones grade into sloughs which are simply marshy lakes depending on the drainage from their immediate vicinity for a water-supply; and in a dry season they may contain no water. One of the larger lakes classed with this group, is Fife lake. It receives the drainage from Hay Meadow creek.

The lakes of the third class, those partaking of the nature of springs, cannot be separated from those of the second class. Both classes depend on the water-supply from their immediate vicinities, and it is impossible to tell whether this supply is from springs or from neighbouring drainage.

CLIMATE AND AGRICULTURE.

The climate is very similar to that of the open treeless prairie in general. It may be described as a typical steppe climate. It is characterized by hot summers, cold winters, high winds, and a meagre precipitation.

The precipitation is about 14 inches per year, of which about 8 inches fall during the months of May, June, and July, when it is most beneficial to the growing crops. Winds and the scarcity of moisture prevent the growth of trees except along stream courses, in the protected hollows of the larger coulées, and along the border of the plateau. The vegetation consists mostly of grasses which grow abundantly during a wet spring season and cure to a natural hay during the late summer, thus making the district a good grazing country. The winters are cold and the summers hot. The range of temperature is large, from 40 degrees below zero F. in winter to 90 degrees F. in summer, with an approximate average of 10 degrees for the months from November to March and of 52 degrees for the months from April to October.

The yield of grains is above the average for the prairies and since the coming of the railway into the northern part of the area within the last five years there has been an inrush of settlers so that now practically all the best agricultural land is occupied.

The broken coulée areas which are too rough for grain growing are admirably suited for grazing. Numerous springs supply abundant good water.

CHAPTER III.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

The rocks of the Wood Mountain-Willowbunch area consist of sedimentary deposits of Cretaceous and Tertiary age, and superficial deposits of Quaternary age. The Cretaceous and Tertiary rocks are a conformable series of flat-lying shales, clay-shales, clays, sands, sandstones, and lignites. The lignites are confined to the Tertiary members of the series. The superficial deposits are the Pleistocene glacial accumulations and Recent alluvium which mantle the surface.

Table of Formations.

Quaternary	Pleistocene and Recent	Superficial deposits.
Tertiary	Eocene	Fort Union formation.
Tertiary (?)	Eocene (?)	Lance formation.
Cretaceous	Upper Cretaceous	Fox Hills sandstone.
		Pierre shale.

The Cretaceous-Tertiary boundary is tentatively placed at the top of the Fox Hills sandstone, following the usage of the United States Geological Survey for the areas to the south. The old name "Laramie" which, according to the practice of the Canadian Geological Survey, has been used to include all the stratigraphically conformable formations from the top of the Pierre-Fox Hills to the unconformity below the Oligocene, is replaced by the names, "Lance formation" and "Fort Union formation" for this area.

CRETACEOUS SYSTEM.

Pierre Shale.

The Pierre is the dominant formation of the Great Plains in southern Canada from the Manitoba escarpment westward, but in the Wood Mountain-Willowbunch area the Tertiary rocks of Wood Mountain plateau occupy the greater part of the space. The Pierre is confined to the typical Great Plains area north and south of the plateau. The rocks of the Pierre formation, however, underlie the whole district and are part of the general expanse of the Pierre of the Great Plains.

The formation consists of a monotonous succession of fine-grained, dark grey and greenish grey fissile and jointed shales. The strata are approximately flat-lying and so nearly alike in texture and colour that they can in many places be distinguished from one another only by slight lines of darker muds which mark perhaps a time of slow deposition. Exposure to the air causes the shales to become very friable and they weather to crumbling banks of earthy appearance. It is thus very easy to distinguish the Pierre formation from the overlying ones which have a tendency to stand in bluffs or form badlands.

The fine-grained texture and the dark grey to greenish grey colour of the shales along with the marine fossil fauna which they contain, indicate that they were uniformly deposited as muds under pelagic conditions. There are, however, towards the top of the formation, beds containing calcareous concretions and beds showing yellowish iron stains, while gypsum crystals occur between certain strata. One bed at its outcrop along Frenchman river was covered with white crystals of salts which were deposited as the water oozing out of this bed evaporated. These conditions seem to indicate that towards the end of the period of the Pierre sea there were fluctuations in the depth of the sea with a tendency to shallowing. This shallowing was simply a forerunner of the shallow water conditions which obtained during the deposition of the succeeding Fox Hills sandstone.

The best exposures of the Pierre shales are found in the area south of the Wood Mountain plateau, along Frenchman river, and in the coulées running from the plateau to the river. To the north of the plateau, along Wood river and its tributaries, there are few exposures; the streams run in very shallow valleys and the banks are, in most places, grass covered. Exposures are found only where freshets have undermined the banks at sharp bends in the meandering streams and, as the shales soon crumble and slump the cutting has to be very recent to give a good exposure.

The thickness of Pierre shale in this area is approximately 500 feet. No sections of this extent are exposed. This figure is obtained by taking the difference in elevation between the valley of Frenchman river and the surrounding plains. The exposed sections along the Frenchman river are from 200 to 300 feet in thickness. There are no drillings in the district to show to what depth the shale extends but its thickness is probably considerably over 1,000 feet. Its estimated thickness in the Belle Fourche quadrangle, South Dakota,[1] is 1,400 feet.

The Pierre shales from this area are not well adapted for the manufacture of clay products. They require a large amount of water for tempering, generally 30 to 35 per cent. Their working qualities are not good as they are exceedingly stiff and sticky in the wet state. They dry slowly with cracking, warping, and excessive shrinkage. There is a further shrinkage in burning and the colours of the burned body are various shades of light red which are not very pleasing to the eye.

Fox Hills Sandstone.

The Pierre shale is succeeded in ascending order by a sandstone formation, the Fox Hills sandstone. This overlies the Pierre shales conformably and represents the deposits of a shallowing Pierre sea. It is the most recent of the marine formations of the Great Plains province in Canada. After its deposition the sea receded southward and never again extended as far north as this area although its recurrence in areas to the south is evinced by the Cannonball marine member of the Lance formation in southern North Dakota.[2]

The rock is a fine-grained, friable sandstone or unconsolidated sand. On the weathered surfaces of outcrops it is stained yellow or brown by iron oxides formed by the decomposition of the ferromagnesian silicates. When freshly broken and unweathered it is light grey in colour. The color is controlled by

[1] Belle Fourche folio, No. 164, Geol. Atlas of U.S., U.S.G.S.

[2] Lloyd, E. R., "The Cannonball River lignite field, North Dakota," Bull. 541-G, U.S. Geol. Surv., p. 9.

the mineral composition in which grains of vitreous quartz predominate with dark green and black grains, which are probably pyroxenes and amphiboles next in amount, and grains of feldspars and both light and dark micas in smaller quantity. The dark micas are mostly decomposed and in their places are rusty stains. The rock is calcareous and effervesces freely with hydrochloric acid. Whether the calcium carbonate is present as an original lime cement or as a decomposition product is hard to tell in so friable a rock. Cross-bedding is common and the alternation of hard and soft layers causes the rock to weather in bands, the soft layers receding more quickly than the hard. The hard layers are made so by an iron cement which collects along certain bands and causes them to become indurated. The iron also collects in concretions and nodules and some beds are composed almost completely of these with a small amount of grey sand matrix. The sandstone weathers to bluffs and cliffs and this feature along with its yellow colour makes it easily distinguishable from the crumbling grey Pierre shales beneath it. The passage from the underlying beds is in most places abrupt, the ferruginous sandstone of the Fox Hills lying directly on the argillaceous shale of the Pierre; but in a few places alternating bands of shale and sandstone mark a transition and no definite line can be drawn.

The Fox Hills sandstone outcrops along the border of the Wood Mountain plateau capping the top of the Pierre where it disappears under the Tertiary rocks of the plateau. Its thickness is nowhere greater than 75 feet and in most places is much less. Since it is so thin and outcrops on the steep face of the bluff or escarpment bounding the plateau, its areal extent is not great. Its outcrop can be followed along a sinuous course at the base of the plateau but its width is not great enough to allow of its being indicated by a separate colour on the accompanying map. Hence it is mapped along with the Pierre as Cretaceous and its location is marked by the line dividing the Cretaceous from the Tertiary.

The Fox Hills sandstone is a marine deposit and is thought to represent the shallow water deposits of the retreating Pierre sea which, in this area, mark the close of the Cretaceous. The facts which support this conclusion are: (1) the Fox Hills sandstone overlies the Pierre shale conformably and in places thin beds of the two are intercalated, indicating the continued presence of the sea with no erosion interval, but with enough fluctuation in the depth of the water at times to change the nature of the deposition from mud to sand and resulting finally in the shallow Fox Hills sea; (2) the sandstone composition of the Fox Hills indicates shallow water off-shore deposits and the cross-bedding indicates current action; (3) the wide distribution and the thinness of the sandstone formation along with its fine-grained character show uniform conditions of deposition which in a marine deposit extending over a wide area is best accounted for by a retreating shore-line; (4) the presence of a marine fauna is proof of marine conditions and the close relation of this fauna to that of the Pierre indicates that no great time interval elapsed between the two and that the Fox Hills sea had free communication with the retreating Pierre sea, otherwise one would expect to find a fauna in the shallow water sand deposits quite different from that found in the deep water mud deposits.

The Fox Hills sandstone is well exposed at the Cretaceous-Tertiary boundary along Twelvemile lake, where the formation is approximately 75 feet thick. A massive layer near the top protects the under strata and the formation stands in bluffs along the shore. This feature is particularly noticeable along the south side of the lake in tp. 6, range 2, W. 3rd mer. The rocks dip to the east about 10 feet per mile and the sandstone gradually disappears beneath the level of the lake. It is overlain by a massive, white, sandy clay, the lowest Tertiary member. This white sandy layer has a tendency to stand in bluffs also, so that the junction of the yellow Fox Hills with it is clearly marked. Towards the west end of the lake, the passage of the Fox Hills downward to the Pierre is marked by an intercalation of yellow sand and grey shale layers.

The best exposures of the Fox Hills are those on the north side of Wood Mountain plateau along Twelvemile lake. From there westward, there is an occasional outcrop along the base of the escarpment marking the plateau border. These outcrops are small and a large part of the northern escarpment is covered with boulder clay and grassed so that the base of the escarpment has been taken as the Cretaceous-Tertiary boundary for most of the distance.

South of the plateau the best exposures of Fox Hills sandstone are found along Rock creek. The thickness of the formation is about the same here as along Twelvemile lake. It is probably not greater than 75 feet, but in most places is much less. It rests on typical Pierre shale and is succeeded by fresh-water Tertiary deposits which weather to badlands and are tentatively placed in the Lance formation. From Rock creek westward along the south border of Wood Mountain plateau the Fox Hills sandstone outcrops in most of the coulées. The outcrops are in many places 10 feet or less in thickness but this is enough to show the persistence of the formation. From range 12, westward, no outcrops were found. The west end of Wood Mountain plateau is deeply covered with boulder clay and the location of the Cretaceous-Tertiary boundary in that area is only approximate.

Yellow ferruginous sands, referable to the Fox Hills formation are also reported by Dawson on both sides of the Frenchman river along the International Boundary.[1] This locality was not visited by the writer and since the Fox Hills and Pierre are represented by the same colour on the geological map, its location cannot be shown.

The thickness of the Fox Hills is, as already mentioned, not over 75 feet in this area and over the greater part it is much less, 10 feet and less being common in exposures. McConnell places its maximum thickness for the Cypress Hills area to the west as 150 feet,[2] and it is known to be a thin formation where it outcrops in Montana, North Dakota, and South Dakota. In the Belle Fourche quadrangle it is estimated at 140 feet.[3] Farther south in the central Great Plains it is usually less than 300 feet thick, although in the Denver region it attains a thickness of 1,000 feet.[4] Over most of the area where it is present it is a thin

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[1] Dawson, G. M., "Geology and resources of the 49th parallel," Montreal, 1875, p. 109.
[2] McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. I, 1885, p. 25 C.
[3] Belle Fourche Folio, No. 164, Geologic Atlas, U.S.G.S., p. 9.
[4] Darton, N. H., "Geology and underground water resources of the central Great Plains." P. P. No. 32, U.S.G.S., p. 169.

formation and represents the off-shore deposits of the retreating Pierre sea.

The Fox Hills sandstone is not abundantly supplied with fossils in this area and the Pierre shale was not examined with a view to finding fossils. These two formations have usually been considered as one and the following list of invertebrate fossils is taken from McConnell's report on the Pierre and Fox Hills formations of the Cypress Hills-Wood Mountain area.[1]

Lingula nitida Meek and Hayden.
Ostrea patina Meek and Hayden.
Chlamys nebrascensis Meek and Hayden.
Pteria linguiformis Evans and Shumard.
Pteria (Oxytoma) nebrascana Evans and Shumard.
Inoceramus altus Meek.
Inoceramus barabini Morton.
Inoceramus sagensis var. *nebrascensis*, Owen.
Inoceramus tenuilineatus Hall and Meek.
Gervilla recta Meek and Hayden.
Gervilla recta, var. *borealis* Whiteaves.
Modiola attenuata Meek and Hayden.
Yoldia scitula Meek and Hayden.
Yoldia evansi Meek and Hayden.
Lucina occidentalis Morton.
Cyprina ovata Meek and Hayden.
Protocardia subquadrata Evans and Shumard.
Protocardia borealis Whiteaves.
Callista (Dosiniopsis) deweyi Meek and Hayden.
Mactra (Cymbophora) warrenana Meek and Hayden.
Mactra (Cymbophora)gracilis Meek and Hayden.
Liopistha (Cymella) undata Meek and Hayden.
Neæra morecauensis Meek and Hayden.
Haminea occidentalis Meek and Hayden.
Actæon attenuatus Meek and Hayden.
Cinulia concinna Meek and Hayden.
Anisomyon alveolus Meek and Hayden.
Anisomyon centrale Meek.
Lunatia concinna Hall and Meek (sp.).
Auchura americana Evans and Shumard (sp.).
Vanikoropsis tuomeyana Meek and Hayden (sp.).
Baculites compressus Say.
Baculites grandis Hall and Meek.

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[1] McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. I, 1885, p. 66 C.

Scaphites abyssinus Morton (sp.).
Scaphites nicolletii Morton.
Scaphites nodosus Owen.
Scaphites subglobosus Whiteaves.
Placenticeras planceta DeKay (sp.).

TERTIARY (?) SYSTEM.

Lance Formation.

The Lance formation lies at the boundary between the Cretaceous and Tertiary systems of rocks and there has long been controversy as to whether it should be included with the Cretaceous or with the Tertiary. This controversy over the location of the Cretaceous-Tertiary boundary in North America has occupied the attention of geologists since the Hayden explorations and surveys of the Territories in the fifties and sixties of last century. Although a great deal has been written and said concerning the Laramie question, as it has been called, there is still disagreement. Briefly stated the present position in regard to the question at issue is this: the beds overlying the marine Fox Hills sandstone are freshwater deposits and contain an Eocene fossil flora so that palæobotanists place them in the Tertiary system, but the same beds contain dinosaurian fossils of pronounced Mesozoic types so that palæozoologists place them in the Cretaceous system. The chief exponent of the palæobotanists is Dr. F. H. Knowlton and of the palæozoologists, Dr. T. W. Stanton, both of the United States Geological Survey. Their views are summed up in papers presented before the Palæontological Society and published in the Bulletin of the Geological Society of America, vol. 25, No. 3, September, 1914. Although there is still disagreement the United States Geological Survey has decided to classify the Lance formation, including its marine member, as Tertiary (?), and this classification is tentatively accepted here.

The Lance formation consists as a rule of sombre-coloured clays and sands with a few small beds of lignite and carbonaceous shale and bands of clay-ironstone nodules. The beds, where exposed, have a tendency to weather to a badland topography.

The formation overlies the marine, Fox Hills sandstone, conformably, is itself a freshwater formation, as shown by its fossil flora, and is overlain conformably by the Fort Union, a typical freshwater, Eocene-Tertiary formation. It is in many places so similar, lithologically, to the overlying Fort Union that it cannot be separated from it. It contains, however, dinosaurian fossils and this is the distinguishing mark which separates the Lance formation from the Fort Union formation. The name "Lance formation" has been then adopted for the non-marine dinosaur-bearing formation overlying the Fox Hills sandstone. It replaces the terms "Ceratops beds," "Lower Fort Union," "Laramie," "Hell Creek beds," and "Somber beds," which have been used by different geologists to denote this formation. It is taken from the term "Lance Creek beds" applied by J. D. Hatcher to the beds where they are represented in Converse county, Wyoming.[1]

It has been the practice in the older reports of the Geological Survey of Canada to include under the term "Laramie" all the stratigraphically conformable formations from the top of the Pierre-Fox Hills to the unconformity below the Oligocene. In the Wood Mountain-Willowbunch area this interval includes the Lance and the Fort Union formations. It has been generally recognized that what was mapped as Laramie in southern Saskatchewan belongs largely to the Fort Union formation, but the presence of the Lance formation there had not been recognized before the present investigation was made, although both Dawson and McConnell recognized a lower division of the Fort Union beds, as will be shown later, and Dowling mentions the probability of the presence of the Lance formation in Saskatchewan.[2]

In his earlier writings Dawson referred to the lignite-bearing formations overlying the Fox Hills sandstone as the Lignite Tertiary.

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[1] Hatcher, J. D., "Relative age of the Lance Creek (Ceratops) beds of Converse county, Wyoming, the Judith River beds of Montana, and the Belly River beds of Canada," American Geologist, vol. 31, pp. 369–375, 1903.

[2] Dowling, D. B., "Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia," Geol. Surv., Can., Mem. 53, 1914, p. 59.

The recognition of the Lance formation in the area under consideration depends on the following observations. The rocks overlying the Fox Hills sandstone along the south of Wood Mountain plateau, and particularly in the vicinity of Rock creek, are grey and white clay and sand with a few small lignite seams and carbonaceous shale beds. They have in general a more sombre colour than the clays and sands overlying the Fox Hills sandstone in other localities, especially when viewed from a distance, and they have weathered to a rugged badland topography. Dawson in 1874 collected dinosaurian fossils from these beds. These facts are all suggestive of the presence of the Lance formation and, taken in connexion with the location of the beds just where one would expect to find the Lance, and the recognition of similar beds as Lance to the south in Montana, Wyoming, and the Dakotas, seem to prove its presence here. Its upper limit cannot be set as it grades into the Fort Union; and, as it occurs along the escarpment of the Wood Mountain plateau and is a thin formation, its areal extent is small.

The following description of a section in the badlands of Rock creek is taken from Dawson.[1]

"The most instructive section, however, in the Wood Mountain region, lies twenty miles south of the settlement of that name, on the forty-ninth parallel near the 425 mile point from Red river; here beds undoubtedly belonging to the Lignite Tertiary formation—which east of this locality has covered so great an area of country—are found clearly superposed on indubitable Cretaceous rocks. The exposures are numerous, and are produced by the streams flowing from the southern escarpment of the watershed plateau above referred to, which has here been gashed by their action into most rugged *Bad Lands*.

"The general section at this place which though not exposed as a whole at any one spot, is remarkably clear; is naturally divided into four parts.

"Taking first the highest bed seen, the order is as follows:

α. Yellowish sand and arenaceous clay, sometimes indurated in certain layers and forming a soft sandstone. It forms the flat plateau-like top of the highest hills seen. *About 50 feet.*

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[1] Dawson, G. M., "Geology and resources of the 49th parallel", Montreal, 1875, p. 103 et. seq.

β. Clays and arenaceous clays, with a general purplish-grey colour when viewed from a distance. *About 150 feet.*

γ. Yellowish and rusty sands, in some places approaching arenaceous clays, often nodular. *About 80 feet.*

δ. Greyish-black clays, rather hard and very homogeneous, breaking into small angular fragments on weathering, and forming earthy banks. *About 40 feet seen.*

"The whole of the beds appear to be conformable, and disregarding minor irregularities, are quite horizontal to the eye.

"The clays and arenaceous clays of the upper part of division β are very regularly bedded, and include a lignite bearing zone. Three lignite beds of from one to two feet each in thickness were observed, but they are separated from each other by rather wide clay partings, and are not pure or of good quality. A bed rich in the remains of plants, immediately overlies the upper lignite. It is composed of a very fine, and nearly white indurated clay, in which the most delicate structures are perfectly preserved. From its soft and crumbling character, it is almost impossible to obtain or keep good specimens; but in the fragments which were preserved, a few very interesting plants appear. Of these, some are characteristic of the Fort Union group, and identical with those of Porcupine Creek. The association of remains is that of a fresh-water pond or lake, and a fine new species of *Lemna* occurs abundantly.

"In the lower portion of this division, the beds are more sombre in tint, and little differentiated by colour, which elsewhere often renders the stratification apparent. They contain some layers of sand and sandstone, which show much false-bedding and current structure, and sometimes terminate suddenly with abrupt undulations. In some places, sufficient calcareous cement has been introduced among the grains to form hard sandstone, but their thickness is never great, nor do they extend far. Much ironstone occurs in thin nodular layers, and some selenite. About one-third from the base of this division a bed was found, in which curious fruits have been preserved, referable to a new species of *Æsculus*.

"The most interesting feature of this part of the section, however, is the occurrence of the remains of vertebrate animals.

They are found exclusively in the lower portion of this division, and most of them below the fruit-bed just mentioned. They are generally closely connected with the ironstone layers, and are often themselves impregnated with that substance. They are also, unfortunately, apt to be attached to the ironstone nodules, or incorporated with them, and traversed by crack-lines, in such a way as to render it difficult to obtain good specimens. A more prolonged search among these hills, than I was able to make, would, however, no doubt result in the discovery of localities where the remains are more abundant and in better preservation.

"Professor Cope has kindly examined the vertebrate fossils obtained in connection with the expedition. Those from this place include fragments of several, species of turtles, scales of a gar-pike, and broken bones of dinosaurian reptiles. Of the turtles, two are new species, to which Professor Cope has given the names —*Plastomenus costatus* and *P. coalescens*—and there are portions of species of *Trionyx* and *Compsemys*. The gar-pike belongs to the genus *Clastes*, and of the dinosaurian remains though mostly too fragmentary for determination a caudal vertebrate resembles that of *Hadrosaurus*.

"Division γ, the lower series of yellow sands and arenaceous clays, is a much better defined member of the section than Division α. It is exposed chiefly in the banks of the smaller ravines, but also in the upper parts of those of the main brooks. The nodules which it contains, are large and irregular, but often approach more or less closely to a spherical form. They are arranged in horizontal lines in the exposures. No fossils were found in this part of the section.

"The line of separation between divisions γ and δ, is quite well-marked by the change in colour. The latter shows scarcely a trace of stratification lines. I was very anxious to obtain fossils from it but succeeded only in collecting a few small fragments. They, however, indicate purely marine conditions: and one of them is referable to the genus *Leda* or *Yolida*. The identification of the horizon of this bed does not, however, depend on such slight grounds as these, as it was afterwards traced westward, and found to be continuous with well-marked fossiliferous Cretaceous rocks.

"Division α and β of this section, clearly belong to the Lignite Tertiary. They probably represent, however, merely the lower layers and differ somewhat in lithological character and arrangement, from those seen at Porcupine Creek, thirty miles east of this place, and at other localities still further eastward. These beds, no doubt, belong to a lower part of the series than is exposed in any of the sections examined between this locality and the Missouri Coteau, and are probably also older than any of those found in the Souris valley. The beds described as occurring on the trail south of Wood Mountain, belong to about the same horizon, and it is probable that those seen on some places on the Trader's Road, may not be much higher up in the series. It would appear that the conditions most favourable to the formation of the deposits of lignite, did not occur frequently or continue long in the earlier stages of the formation in this locality.

"Division δ being certainly Cretaceous it only remains to classify division γ, which is so markedly different in character from the beds above and below it. This bed, I believe represents group No. 5, of the Cretaceous, or the Fox Hill group of Meek and Hayden."

From Dawson's description it is quite clear that division δ of the section is the top of the Pierre formation, division γ is the Fox Hills sandstone and divisions α and β, which he calls the Lignite Tertiary, belong to what has been mapped as Laramie, and is here divided into the Lance and Fort Union formations.

Whether the whole of division β of the section should be classed as Lance or not is questionable. Since the Lance cannot be distinguished from the Fort Union lithologically in many places, and in this section division β grades into division α, it is impossible to mark an exact division line. The Lance certainly includes that part of division β up to the location of the vertebrate remains which according to Dawson's diagram is about 30 feet from the bottom. It will be noted that Dawson says that in the lower part of this division the beds are more sombre in tint and this is also a characteristic of the Lance. The writer examined this section in the field but found no vertebrate remains. The sombre tints of the beds immediately overlying the Fox Hills sandstone were noted, however, and the upper part of division β was found to be lithologically like the Fort Union. Holding then to the definition of the Lance as the non-marine, dinosaur-bearing beds of sombre colours which overlie the Fox Hills sandstone, the thickness of the formation along Rock creek is placed at $50\pm$ feet.

There is, however, a lower division of the beds that are classed with the Fort Union formation and the probability of these belonging to the Lance is here noted. In discussing the Laramie of Cypress hills and Wood mountain, McConnell says: "The Laramie may be separated lithologically over most of the district into two distinct divisions. The lower one, which succeeds the Fox Hill conformably wherever the contact plane of the two formations was observed, bears a strong resemblance to the upper part of the Belly River series, and consists of about 150 feet of feebly coherent, greyish, and pure white clays, sandy clays, and sands, with occasional beds of carbonaceous shales and lignite. A small bed of black clay was also found to be pretty widely distributed. The beds of pure white sands and clays form the most distinctive feature of this band, and were observed with few exceptions, wherever the base of the formation was exposed. In the badlands south of Wood mountain this division consists almost exclusively of clay. The upper division is more arenaceous and is predominately yellowish in colour. It has a maximum thickness in the district of 750 feet, and is composed of sands passing into soft sandstone, silts, and clays, and also holds a few beds of hard sandstone, part of which is of nodular character, together with some carbonaceous shales and lignite."[1] This lower division is very noticeable both north and south of the Wood Mountain plateau on account of the white colour of its beds, which distinguishes it from the yellow beds of the upper division. It is very striking where it overlies the Fox Hills sandstone along Twelvemile lake and outcrops to the east along Big Muddy valley for a distance of 50 miles. It was also

[1] McConnell, R. G., "Report on the Cypress hills, Wood mountain, and adjacent country," Geol. Surv., Can., Ann. Rept., vol. I, 1885, pp. 67–68 C.

noted in the bottom of the branch of Big Muddy valley now occupied by Willowbunch lake and Lake of the Rivers; so that, should it be classed as Lance, that formation would have a wide distribution in southern Saskatchewan. But as no dinosaurian remains have been found in these white beds and as they differ lithologically so much from the typical sombre coloured beds of the Lance, it is preferable to include them as a lower division of the Fort Union. However, it is probable that the lower 150 feet of the lignite-bearing beds throughout the area may be referred to the Lance formation.

From the information at hand and set forth in the preceding paragraphs, it appears, then, that rocks referable to the Lance formation outcrop in the badlands area, in the vicinity of Rock creek south of Wood mountain. The location of the outcrops is along the southern escarpment of the Wood Mountain plateau just above the Cretaceous-Tertiary boundary line. The areal distribution of these beds in Canada is small. They are confined to the area of Rock creek and its small tributary coulées in tps. 1 and 2, ranges 4 and 5, W. 3rd mer.

No fossils were collected from the Lance formation; but those cited above as collected by Dawson, the presence of lignite and carbonaceous layers, and the fact that the beds grade upward to the Fort Union beds indicate that it is a freshwater formation. This is further attested by the arenaceous character of some of the beds which show false-bedding and ripple-marks and by the presence of ironstone nodules and selenite.

The evidence collected in this area is of interest also in its bearing on the Cretaceous-Tertiary boundary problem. The period was one of transition; sedimentation proceeded quietly and more or less continuously from the marine Cretaceous of the Pierre and Fox Hills through the freshwater Lance formation, with its Tertiary flora and Cretaceous dinosaurs, to the typical, freshwater Eocene-Cretaceous of the Fort Union formation. Deep sea conditions are represented by the shale deposits of the Pierre. A change to shallow water conditions gradually took place as the Pierre sea retreated southward, and the marine Fox Hills sands were deposited. At the same time a Tertiary flora developed on land and when the Cretaceous sea finally withdrew, at the end of the Fox Hills epoch, its place was taken by freshwater lakes and swamps in which the clays, sands, and lignite of the Lance were deposited. However, this gradual change from the marine Pierre-Fox Hills to the freshwater Lance, with its Tertiary flora, was not accompanied by the extinction of the Cretaceous fauna. The marine forms in the sea which had retreated southward, were still of Cretaceous types and in the lakes and swamps of the Lance, Cretaceous reptiles still persisted, as is evinced by the remains of turtles and dinosaurs. The final extinction of the reptiles marks the end of the Lance, and was followed by the deposition of the typical freshwater Tertiary deposits of the Fort Union formation.

Throughout this transition period there were many fluctuations in the shore-lines of both the marine and freshwater bodies; but the general tendency was toward a shallowing and southward retreat of the Cretaceous seas with a concurrent southward advance of the Tertiary freshwater bodies. The final retreat of the sea from the area is marked by the division between the Fox Hills sandstone and the Lance formation. There was, however, a recurrence of the sea farther south. E. R. Lloyd describes the Lance formation in the Cannonball River lignite field, North Dakota, where 400 to 500 feet of freshwater beds are overlain by 250 to 300 feet of marine beds which he calls the Cannonball marine member and which has a modified Fox Hills fauna.[1] The same occurrence is described by T. W. Stanton in an attempt to prove the Cretaceous age of all beds up to and including this member.[2]

The recurrence of a Cretaceous fauna at this horizon further verifies the above conclusion that the passage from Cretaceous to Tertiary was a transition period. It must be thought of as a time when a flourishing Tertiary flora had developed on land while a Cretaceous fauna still existed in the seas and the Cretaceous life gave way very slowly before the advancing Tertiary forms.

[1] Lloyd, E. R., "The Cannonball River lignite field, North Dakota," U.S. Geol. Surv., Bull. 541 G, pp. 8–10.

[2] Stanton, T. W., "Boundary between Cretaceous and Tertiary in North America as indicated by stratigraphy and invertebrate faunas": B.G.S.A., vol. 25, No. 3, Sept., 1914, pp. 348–354.

No definite horizon can be fixed upon as the dividing line between the Cretaceous and Tertiary.

TERTIARY SYSTEM.

Fort Union Formation.

The dominant formation of the Wood Mountain-Willowbunch area is the Fort Union. It forms Wood Mountain plateau and occupies all the higher parts of the area, although in places hidden by superficial deposits of Pleistocene and Glacial age. It is a continuation of the rocks described under the Lance formation. It overlies the Lance conformably or grades upward from it; and where the Lance is not present it rests on the Fox Hills with apparent conformity.

The Fort Union is a freshwater formation made up of a succession of almost horizontal strata of clays, clay shales, sands, and lignites with a small amount of sandstone (Plate I). In general, it is quite uniform in appearance. The colours of the clays, shales, and sands range from yellowish-grey through drab and grey almost to white. None of the members are greatly indurated except the sandstone, and it forms a very small part of any section and is not continuous for any great distance.

Sandstone and clay-limestone concretions are common in the beds. The sandstone concretions are commonly elongated in form as if formed along underground water-courses. They resist weathering and in many places are left on the surface like long broken columns after the surrounding material has all been washed away (Plate IV). In other places the nodules are joined together or considerable portions of sand layers have become indurated and hoodoo-like forms are left after the less indurated parts have been carried away (Plate V). In still other places a mortar-bed structure has developed in the sands and these layers, on account of their resistance to weathering being greater than that of the surrounding sands and clays, are left capping hills or standing out prominently along the edges of coulées. The clay-ironstone concretions are most plentiful along certain strata and in places form an almost continuous band from 1 to 3 inches in thickness. Gypsum in the form of selenite occurs in many places as a parting between strata.

The succession of strata varies greatly from place to place, and although a particular member may in places be traced for several miles, the sections are so different at different points that no correlation of individual beds can be made. The deposits really consist of a series of broad, thin, interfingering lenses of clays, sands, and lignites and the variations in the succession are due to changing conditions of deposition. The beds are a series of shallow water, lake deposits. This is evinced by the variability in character of the lens-shaped beds, the thin bedding, the cross-bedding particularly in the sands, the generally arenaceous character of the deposits, the occurrence of gypsum between strata, the lignite beds, and a continental fossil flora and fauna.

A conspicuous feature of the Fort Union is the presence of red beds and clinkers produced by the burning of lignite beds. The beds above the burned seams show the most marked effects and are commonly baked and changed in colour, some to cream and buff colours, but most conspicuous are those changed to pink and red. In places considerable slag having the appearance of lava or scoriae has been produced by the fusion of the overlying beds. The red layers are most noticeable in the badlands or semi-badlands. Along Big Muddy valley south of Harptree where a seam of coal has burned and left a layer of clinkers, the overlying clay was melted and ran down the slopes and is now to be found in the bottom of the neighbouring coulées or strewn over the coulée sides. The same seam is represented less than one mile away by an 18-foot seam of lignite.

It has been stated in the description of the Lance formation that the lower 150 feet of the beds that have been classed as Fort Union, have a much lighter colour than the rest of the formation. These beds outcrop to the north and south of Wood Mountain plateau and in the abandoned stream channel of Big Muddy valley. They are so light in colour that they are commonly spoken of as the white beds. They consist of greyish and pure white clays, sandy clays, and sands, with occasional beds of carbonaceous shale and lignite. The lignite seams in this division are not important; the thickest noted is only 2 feet.

It is in this division, however, that the most refractory clays of the area are found.

Above the lower 150 feet of white beds the colours are predominately grey and yellow. This upper division has a general yellowish tint which distinguishes it from the lower white beds. In it, all the important lignite beds of the area are found and many good red and buff-burning clays and sands. Exposed sections of this division in the main coulées are in places 150 to 200 or more feet in thickness, and the total thickness of the formation in the area is placed at 700± feet. The figure for the latter thickness is obtained by calculations made from barometer elevations taken at various points.

The following section exposed on the south side of Big Muddy lake in sec. 26, tp. 2, range 22, W. 2nd mer., illustrates the character and variability of the strata. The bottom of this section is probably not more than 50 feet above the white beds of the lower division.

Beginning at the top, at the prairie level.

	Feet	Inches
Blue-grey clay with clay-ironstone band	11	0
Grey sand	5	0
Shaly blue clay	0	6
Lignite	0	9
Grey clay	5	6
Lignite	1	0
Grey clay	10	0
Dark grey shale	1	6
Blue-grey clay with clay-ironstone bands	21	0
Lignite—very small.		
Grey clay	3	0
Lignite	0	6
Grey clay	6	0
Lignite	1	0
Sandy grey clay	10	0
Shaly and woody clay	0	6
Sandy grey clay	24	0
Clay and lignite	0	9
Lignite	1	6
Woody clay with gypsum	0	6
Lignite	1	0
Yellow-grey sand	2	0

	Feet	Inches
Lignite	2	0
Shaly grey-white clay	2	0
Lignite	2	0
Grey clay	10	6
Lignite (worked for local use by farmers)	6	6
Sandy grey clay with sandstone concretions	7	0
Yellow-grey shale with fossil leaves	1	0
Sandy yellow-grey clay	5	6
Lignite	2	0
Sandy grey clay	34	0
Lignite	0	4
Grey clay	2	0
Lignite	1	3
Grey clay	1	9
Lignite	1	0
Sandy grey clay	17	0
Lignite at water's edge		
	203	4

The Fort Union is early Eocene in age and contains a fossil flora of nearly 400 species, and a fossil fauna of both invertebrates and vertebrates. The following plants were collected by G. M. Dawson from this area and are described by Sir William Dawson.[1]

Onoclea sensibilis Linnaeus.
Davallia (*Stenoloma*) *tenuifolia* Swartz.
Equisetum sp.
Physagenia parlatorii Heer.
Glyptostrobus europaeus Heer.
Sequoia langsdorfii Brongniart.
Thuja interrupta Newberry.
Lemna (*spirodela*) *scutata* Dawson.
Phragmites ? sp.
Scirpus sp.
Populus Richardsoni Heer.
Salix Raeana? Heer.
Corylus rostrata Aiton.
Corylus americana Walten.
Platanus heterophyllus Newberry.
Diospyros sp.

[1] Dawson, G. M., "Geology and resources of thè 49th parallel," Montreal, 1875, Appendix A, pp. 327–331.

Sapindus affinis Newberry.
Rhamnus concinnus Newberry.
Rhamnus sp.
Carya antiquorum Newberry.
Juglans cinerea?
Viburnum pubescens Pursh.
Aesculus antiquus Dawson.
Trapa borealis? Heer.
Carpolithes sp.

A considerable quantity of fossil wood was also collected, most of it the wood of conifers, but some of it referable to the genus *Populus*, a genus which is also largely represented among the fossil leaves.

A list of fossils from the Fort Union of southern Saskatchewan is given by D. B. Dowling[1] as follows:

Unio priscus.
Corbula mactriformis.
Thaumastus limnaeiformis.
Goniobasis nebrascensis.
G. tenuicarinata.
Campeloma productum.
C. multilineatum.
Viviparus trochiformis.
V. leai.
V. conradi.

And the following plants: *Platanus heterophyllus, P. nobilis, Sassafras selwyni, Quercus* sp., *Taxites olriki, T. occidentalis.*

Characteristic fossils of the Fort Union formation, and also of the other formations described here, are given by A. G. Leonard for neighbouring areas in North Dakota and Montana.[2]

QUATERNARY SYSTEM.

Superficial Deposits.

The rocks discussed under the Cretaceous and Tertiary systems are quite different from later deposits. The Cretaceous and Tertiary rocks are alike in that they are all flat-lying sedi-

[1] Geol. Surv., Can., Mem. 53, "Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia," p. 31.

[2] "The Cretaceous and Tertiary formations of western North Dakota and eastern Montana." Jour. Geol., vol. XIX, 1911, pp. 507–547.

ments; and they form a conformable series ranging through the marine deposits of the Pierre and Fox Hills to the freshwater Lance and Fort Union beds. Before any further deposition took place in the area there were long periods of erosion and the Cretaceous and Tertiary rocks were eroded to about their present topography. Then came the great continental glaciers of the Pleistocene era. The glaciers, left behind the boulders, boulder clays, sands, silts, and gravels, which mantle the surface everywhere except on the steep sides of coulées or along stream courses.

Glacial boulders are scattered, here and there, over the surface of the area and are included in the boulder clay. They are for the most part granite and gneissic rocks from the Pre-Cambrian shield, and limestone boulders from the Palæozoic rocks of Manitoba and indicate that the glaciers came from the northeast. They are particularly thick in the portion of the area occupied by the Coteau du Missouri. Westward from the Coteau belt they are more scattered but are more numerous on the northern slope of Wood Mountain plateau than over the rest of the area.

Boulders from 1 to 3 feet in diameter are very thickly strewn in places along the banks of the abandoned valley in which the Frenchman river now runs. They occur in lines along the banks at certain heights and seem to have been dropped from stranded ice. This seems quite likely when we consider that the origin of the abandoned valleys is attributed partly to the action of large streams during the retreat of the continental glaciers. Hence the presence of floating ice at this time is not surprising.

Horizontal bands of boulders of somewhat similar appearance but of different origin have been noted along stream courses at other points on the Great Plains. McInnes in his description of the Saskatchewan says,[1] "The river from above the forks, flows between high scarped banks of clay, 80 feet or more in height, with here and there short stretches, the sites, probably, of old landslides, where the high land lies 15 or 20 chains back and the immediate banks are not more than 10 feet above the water. The section exposed by the scarped banks shows occa-

[1] McInnes, W., "The Basins of the Nelson and Churchill rivers," Geol. Surv., Can., Mem. 30, p. 101.

sional boulders scattered through the sandy clay and, for many miles, a very persistent, horizontal band, formed of flattened pebbles or boulders lying at intervals of a few feet from one another, stands out prominently along its face at a height, near the forks, of about 40 feet above the water; 30 feet or more of light yellow sandy clay overlies the boulder band. The even distribution of these boulders gives the impression that they were dropped by floating ice." Hind noticed very similar conditions on the South Saskatchewan, below the Elbow.[1] "Two tiers of boulders, separated by an interval of 20 feet, are visible in the clay cliffs lower down the river. Where first noticed, they were about 15 feet above the water. As we descended the river they were seen to rise above its level, preserving evidently a nearly horizontal position. The lower tier consists of very large fragments of water-worn limestone, granite and gneissoid boulders; above this is an indurated sand, containing pebbles; this is superimposed by an extremely fine, stratified clay, breaking up into excessively thin layers, which envelop detached particles of sand, small pebbles, and aggregations of particles of sand. Above the fine, stratified clay, yellow clay and stratified sand occur. The fine clay must have been deposited in very quiet waters; a microscopic examination, subsequently made, failed to reveal any diatomaceae."

From these descriptions it is evident that the horizontal bands of boulders along the Saskatchewan occur in stratified glacial deposits and have been exposed by the river cutting its valley through these deposits; whereas the lines of boulders along the valley of the Frenchman river are not in stratified deposits but were deposited by floating ice after the main valley had been excavated and are confined to the immediate slopes or banks of the abandoned valley.

Boulder clay forms a veneer over most of the area. In places, it is not more than a foot or two thick, but on the north slope of Wood Mountain plateau and along the Coteau du Missouri, it is much thicker. The rise of the Coteau and the north slope of the plateau doubltess formed barriers to the advance

[1] Hind, H. Y., "Canadian Red River and Assiniboine and Saskatchewan expedition." London, 1860.

of the ice and hence more morainic material was deposited on them than elsewhere. These deposits are very thick on the Coteau where they are the controlling features of the topography over a belt approximately 30 miles in width which constitutes the lake and slough country previously described. The morainic deposits are rather heterogeneously massed in mounds and ridges, the hollows are occupied by small lakes and sloughs, and there is a lack of any connected drainage system. The boulders and pebbles in the clay, like those on the surface, are mostly granite, gneiss, and limestone, but west of the coteau there is an increasing number of quartzite pebbles.

The source of the quartzite pebbles is in the Rocky mountains to the west so that they could not have been carried by the glaciers which brought the granite gneiss and limestone pebbles from the east. This was at one time used as evidence that much of the boulder clay is of sub-aqueous origin, and a float-ice theory to account for the mixed character of the boulders and pebbles was advocated.

This view is, however, no longer held. The fact which seems to prove that the floating-ice theory is wrong, is that the southern limit of the glacial deposits in Montana and the Dakotas is marked by a line of terminal moraines along a course which could never have been the boundary of a large body of water. A body of water which would have permitted the deposition of boulder clay along this line of moraines would have extended southward into the Mississippi basin, and under such circumstances one would not expect to find the glacial deposits confined to a certain line as they are. This line of moraines across Montana and the Dakotas then marks the southern limit of continental glaciation.

Sands, silts, and gravels, also referable to the Glacial period, occur here and there over the area. These are mostly stratified and represent outwash deposits formed at the front of the glacier. They are commonly found filling hollows of the pre-Glacial surface. Large areas of level prairie, such as that about Bengough where the soil is uniformly fine with occasional knolls and small ridges of gravel, represent outwash lake deposits.

Recent deposits are so small that they are almost negligible. The silting up of the abandoned valley channels with silts, sands, and gravels, and the filling in of sloughs with plant remains and blown material is assigned to the Recent period. The silting up of stream courses is believed to have gone on concurrently with a change of climate from wet to dry, and this is associated with the retreat of the continental glaciers. As the glaciers retreated the climate became warmer and less humid. Streams of considerable magnitude had their water supply cut off and began to aggrade their channels. Stratified gravels, sands, and clays were deposited to considerable depths. Streams like that in Big Muddy valley finally disappeared altogether and the valley bottom is now occupied by shallow lakes and short intermittent streams. The aggradation of the valley is still proceeding; the spring freshets bring alluvium from the side coulées and numerous springs supply a small amount through the year. The later deposits are all very fine, however, so that the valley bottom is covered with fine clay or silts to a depth of several feet. Valleys like that of the Frenchman still have through-flowing streams, but these meander through the recent alluvium and are doubtless at present aggrading more than they degrade. Borings in the valley of the Missouri in the Bismark quadrangle, North Dakota, show the alluvium to be 80 feet deep.[1]

STRUCTURE.

The structure of the rocks in the Wood Mountain-Willowbunch area is extremely simple. As has been explained, the Cretaceous and Tertiary deposits are conformable series of sediments that have been very little disturbed since deposition and are still essentially a flat-lying series of horizontal strata. However, since no one stratum can be traced for any great distance (this is particularly true of the Tertiary members) and the strata are seen to peter out in places, they may be thought of rather as a series of broad and thin overlapping and interfingering lenses. On the whole the beds have a slight easterly or northeasterly dip that is in no place greater than 10 feet per mile. Dawson calculated the dip by taking levels on the Fox Hills sandstone 30 miles apart and found it to be 8 feet to the mile.[2] Locally,

[1] Leonard, A. G., Bismark folio, No. 181, United States Geologic Atlas, U.S.G.S., pp. 5–6.

[2] Dawson, G. M., "Geology and resources of the 49th parallel," Montreal, 1875, p. 111.

dips to the west and south were noted and these are thought to be due to irregularities in deposition. Owing to the lack of easily recognizable beds that can be followed for a distance it is impossible to say just how uniform the easterly and northeasterly dip is. There may be minor undulations and broad anticlines and synclines, but no evidence of faulting or folding was noted in any place. The only deformation the beds have undergone since deposition, is that which accompanied the continental uplift which brought this part of the continent above the sea at the beginning of the Tertiary age. Any minor elevations or depressions which may have taken place since are not marked in this area.

GEOLOGICAL HISTORY.

The history of the Wood Mountain-Willowbunch area is essentially the same as that of the Great Plains of which it forms an integral part. No attempt is made to interpret its Pre-Cambrian history but throughout the Palæozoic and Mesozoic eras it was an area of alternate elevations and depressions. Several of the depressions admitted the sea, and great series of sediments were deposited. The evidence for this is not to be found in the map-area as the oldest rocks there present, the Pierre shales, are Upper Cretaceous; but in passing westward from the Pre-Cambrian shield across the Great Plains a series of Palæozoic and Mesozoic sediments, with gentle westward dips, are met with and drill holes at various points show that these extend westward under the areas now occupied by the Upper Cretaceous and Tertiary sediments.

None of the elevations or depressions were accompanied by mountain building in the Great Plains area. They were of an epeirogenic rather than of an orogenic nature. The sediments have remained approximately flat-lying and no faulting or folding occurred other than broad, gentle flexures, which accompanied the continental elevations and depressions. Even the periods of erosion, which are marked by the intervals in the succession of the strata when the area must have been above sea-level, did not leave any great unconformities between the strata of different ages.

The Palæozoic era is represented by Ordovician, Silurian, and Devonian sediments and the Mesozoic era by Cretaceous sediments of the Dakota, Colorada, and Montana stages. Of these, only the Dakota sediments are of continental origin; the rest are all marine deposits. This brief summary brings the geological history up to the Upper Cretaceous, which is the first period represented by sediments in the map-area. The Pierre shale and the Fox Hills sandstone belong to the Montana stage and from that time on the history can be more definitely traced.

During the Montana stage of the Upper Cretaceous, then, this area, along with the whole interior of the continent, was depressed and was occupied by the sea. A great thickness of shale was deposited, the top of which is represented by the Pierre shale of the map-area. Towards the latter part of the period of the Pierre sea there were fluctuations in the depth of the water, with a tendency to shallowing. This is indicated by the presence of gypsum, iron stains, and calcareous concretions in the upper layers. This state of fluctuation gradually gave place to the shallow water conditions which prevailed during the deposition of the succeeding Fox Hills sandstone. The Fox Hills is a cross-bedded marine sandstone and must have been deposited in a shallow sea with current action. It is an off-shore deposit formed during the retreat of the Pierre sea. After the deposition of the Fox Hills sandstone, the sea withdrew finally from this area and its place was taken by freshwater lakes and swamps in which the sands, clays, lignites, and carbonaceous shales of the Lance and Fort Union formations were deposited. The change from marine to freshwater conditions marks the end of the Mesozoic era and the beginning of the Tertiary. This change was very gradual. A Tertiary flora had developed on land while the sea life was still Cretaceous in character and many land reptiles of Mesozoic types still lived. Of these, the dinosaurs were very abundant. The final disappearance of the dinosaurs marks the end of the deposition of the Lance formation. The Lance formation is then a transitional formation between the Mesozoic and Tertiary eras but is here tentatively classed with the Tertiary. The overlying Fort Union, which is a continuation of the Lance without the reptile remains, marks a period of typical, freshwater, Tertiary deposition. It contains a fossil flora of approximately 400 species which is definitely Eocene in age. The conditions at this time were particularly favourable for the formation of lignite and the deposition of high grade clays.

No Oligocene sediments are found in the map-area, but deposits of this age occur in the Cypress Hills area to the west, and in North Dakota to the southeast. Those in the Cypress Hills area are coarse conglomerates whose deposition is thought to have been concurrent with the upheaval of the Rocky mountains, whence the sediments came. Those in North Dakota are sands and clays and may represent a finer state of the same sediments as the Cypress Hills conglomerate. If any of the Oligocene sediments were deposited in the map-area they have been removed by erosion.

Following the Oligocene deposition there was a period of erosion during which the Great Plains area was base-levelled. This is marked by the plateau surfaces on the tops of the Cypress Hills and Wood Mountain plateau. Then, following an uplift of the whole region, another period of erosion set in which destroyed to a great extent the evidence of the first period. During this time the present drainage system was largely developed over the Great Plains and most of the Tertiary deposits were eroded away. A few remnants, such as the Wood Mountain plateau and the Cypress hills, remain. This period of erosion may be assigned largely to the Pliocene; but there is nothing to indicate the time limits of events between the deposition of the Oligocene sediments and the end of the Pliocene, because the whole period is represented only by the effects of erosion. The topography at the end of the Pliocene was much the same as it is to-day. The Great Plains, which were then developed, stand as one of the best examples known of an uplifted and base-levelled surface.

Calhoun advances the hypothesis of another uplift in the Rocky mountains during Pliocene times in order to account for the occurrence of quartzite pebbles which are found mixed with later glacial deposits. He assumes that the pebbles were spread over the plains during the period of uplift and they were later reworked by the Keewatin glaciers and mixed with its boulder clay.[1] Whether this explanation must be inserted in the geological history of the area or not to account for quartzite pebbles there, cannot be decided. The pebbles may have been carried by glaciers.

The close of the Tertiary era was marked by a change of climate from temperate to frigid and during the Pleistocene the area was overridden by a continental glacier. This changed the surface features very little. On the retreat of the glacier a veneer of boulder clay was left which is in places not over one foot thick. Along the Coteau du Missouri in the northeast part of the area the boulder clay is piled up to great depths. This escarpment doubtless formed a barrier to ice advance for some time and so a great deal of morainic material accumulated there. In front of the glacier as it retreated, were deposited gravels, sands, and silts. These fill hollows and are of local distribution only. The most marked effect of the glaciation was the disorganization of the drainage. The ice came from the northeast and blocked the Tertiary drainage channels. The supply of water from the ice-sheet was very large and new drainage channels were developed or old ones leading south and east to the Missouri river were greatly increased in size. Then on the retreat of the ice, drainage to the north and east was resumed, the water-supply was much smaller, and many of the glacial drainage channels were abandoned. Big Muddy valley is the best example in the map-area of such an abandoned valley. Other valleys are now occupied by streams of greatly diminished size, like the Frenchman river which runs in one of the old glacial channels.

From the retreat of the continental glacier until the present time there has been very little change. The valleys which carried the large glacial streams have been silted up and are now occupied by intermittent streams and saline lakes or by streams of greatly diminished size. At present precipitation is almost balanced by evaporation and absorption by the soil, so that the run off from the area is very small. Over most of the area there is interior basin drainage, and, in the area of the Coteau du Mis-

[1] Calhoun, F. H. H., "The Montana Lobe of the Keewatin ice-sheet," U.S. Geol. Surv., Prof. Paper No. 50, p. 51.

souri, where the morainic material is heaped up and the surface water is restricted to sloughs and small lakes, there is a lack of any drainage system. In the vicinity of the abandoned valleys the drainage is to the saline lakes which lie in the old channels and north of Wood Mountain plateau, it is to Johnston and Chaplin lakes which lie some distance beyond the map-area. South of the plateau there is through drainage to the Missouri river, but the run off is mostly during the spring freshets. The history of the Recent epoch is, then, largely one of silting up of stream courses with only a slight rearrangement of the rock within the district.

CHAPTER IV.

ECONOMIC GEOLOGY.

The mineral products of economic importance in the Wood Mountain-Willowbunch area are described under the following headings: coal, clay, gravel and sand, soil, and surface and underground waters.

COAL.

Occurrence and Distribution.

The coal is all lignite and is found only in the Lance and Fort Union formations of the Tertiary. The coal of economic importance is confined to the Fort Union as the beds in the Lance are too small to be mined.

The lignite occurs in flat-lying beds interstratified with clays, sands, and shales. The beds vary in thickness from one inch and less to more than 20 feet. Outcrops are found along the sides of coulées and abandoned river channels (Plate I). It is not possible to trace the beds for any great distance as they are in most places covered with soil and grass and, owing to the mode of their deposition in shallow lakes and swamps, form with the clays, sands, and shales a series of interfingering lens-shaped deposits.

However, it was noted that the same succession of strata (lignite, followed upwards by clay with fossil plants and then fine grey sand) occurs at various localities throughout the area examined and that the thickness of the lignite is in each case greater than the average thickness for lignite seams in southern Saskatchewan. It is concluded that they are all contemporaneous deposits and while there is not a co-extensive seam, the various outcrops are at least at the same horizon. The following are a few of the localities where this seam outcrops.

Sec.	Tp.	Range	W. 2nd mer.	Thickness feet
12	2	23	" " "	9
35	2	24	" " "	3½
30	2	25	" " "	11
16	2	26	" " "	16
28	3	26	" " "	22
29	3	26	" " "	21
32	3	26	" " "	18
32	1	28	" " "	11
13	5	28	" " "	14
4	1	29	" " "	8
17	4	1	" 3rd "	5
16	4	4	" " "	11
24	4	6	" " "	6

Also south of the International Boundary, reported by G. M. Dawson[1], thickness 18 feet.

This seam then is recognized over a distance of 78 miles in an east and west direction. Its north and south extension is not known. It doubtless represents deposition in several small basins rather than in one large basin, the similarity in the succession of strata being due to the prevalence of similar physical conditions throughout the area during the time of deposition.

The following section exposed in sec. 2, tp. 4, range 23, W. 2nd. mer., illustrates the character of the strata and the number of lignite seams which occur in one section. While the number of lignite seams occurring in this section is representative, the aggregate thickness is higher than the average in sections throughout the area. The coal in this section forms more than one-tenth of the total thickness.

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[1] Dawson, G. M., "Geology and resources of the Forty-ninth parallel," Montreal, 1875.

	Feet	Inches
Sandy clay	40	0
Lignite	2	0
Grey clay	9	0
Shaly sandstone	9	0
Yellowish grey clay—sandy streaks	17	0
Lignite	4	6
Grey clay	7	0
Lignite	0	6
Sand	0	6
Blue clay	1	0
Lignite	1	0
Blue clay	4	0
Lignite	0	6
Blue clay	1	0
Sandy yellow-grey clay	10	0
Lignite	0	4
Sand	3	0
Banded clay and lignite	11	0
Selenite crystals		
Sandy grey clay with concretions	15	6
Lignite—with bands of clay and sand	6	0
Grey sand, grading to clay at bottom	25	0
Lignite	3	9
Compact, yellow-grey, limy sand—contains bands of clay-ironstone and sandstone concretions	20	6
Lignite—upper part shaly	4	0
Limy sand with clay-ironstone concretions	15	0
Clay shale	2	0
Lignite—2-inch clay parting, 16 inches from the top, this seam is mined—see analysis No. 2, page 61	6	0
Clay shale	3	0
Lignite—reported from boring	5	0
From here to bottom of coulée is clay with some lignite indications, mostly grass covered	50	0
	277	7

Since the lignite is confined to the Tertiary formations, it outcrops only in the Wood Mountain plateau. The boundary of the plateau marks the line between the Tertiary and Cretaceous formations and the limit of possible coal outcrops (see geological map, in pocket). No outcrops appear in the northeast part of the area which is occupied by the morainic boulder clay of the Coteau du Missouri. The lignite formation extends beneath the boulder clay, however, and has been encountered in well-borings. The greatest number of outcrops occur along Big Muddy valley and in the coulées which head in the Wood Mountain plateau in the vicinity and west of Wood Mountain post-office. Outcrops are fewer west of range 6, W. 3rd mer., and from ranges 10 to 13 there is probably no workable lignite.

Mining.

Lignite has been mined for local use at a few localities. The mines or pits are in all cases located on the sides of coulées where coal outcrops occur and no development work or prospecting has been done outside the coulée area.

The open pit method of mining is commonly used by the farmers, who go to the nearest coal outcrop, strip off the overlying strata, and dig out the lignite (Plate VI). Mining by this method cannot extend far. The sides of the coulées are usually so steep that after digging a few feet into the bank the thickness of the overburden becomes so great that the expense of removing it is greater than the value of the coal.

In a few localities underground mining is carried on (Plate VII). Timbering is used for a main tunnel and the lignite is extracted by the room and pillar system. The scarcity of trees on the prairie and the consequent high cost of timber must be taken into account in the consideration of any mining operations.

Physical and Chemical Characters.

The colour of the coal is very black for lignite and the streak is black to brown. Most of the fresh lignite has a dull lustre, but bright streaks and lenses are common. The texture is commonly dense though in places it is woody and flattened stems and tree trunks are recognizable in the beds. When freshly dug, the lignite is compact and breaks with a hackly fracture into massive lumps; but on exposure to the air, a great deal of the moisture evaporates and it slacks almost to a powder. It is advisable then to mine the coal only as needed or to keep it sheltered in tightly packed piles. Attempts have been made to overcome this difficulty and experiments on briquetting the lignite are being made which, if successful, will solve the problem of storing.

The proximate chemical analyses of the coal show it to be a true lignite. The following analyses are from samples collected across seams where fresh openings could be found, and are thought to be representative. The analyses were made in the laboratories of the Mines Branch, Department of Mines, Ottawa.

Samples Nos. 1 to 9 were collected in the season of 1913, and Nos. 10 to 17 during the season of 1914 and the marked difference in the percentages of moisture is due to the more thorough drying of the 1913 samples. The moisture in the freshly mined lignite is very high, commonly running from 30 to 40 per cent and it is the rapid loss of this water by evaporation that causes the coal to slack on exposure to the air.

The analyses show considerably smaller percentages of moisture and higher percentages of ash than are given in most of the published analyses of the lignite of southern Saskatchewan. The small percentages of moisture are accounted for by more thorough air drying before analysing. The percentages of ash are thought to be representative. Care was taken in sampling to get average samples across the seams from freshly opened workings, while it seems probable that many of the published analyses are from picked samples.

The following summary of analyses, boiler tests, and gas-producer tests, made by the Mines Branch, Department of Mines, on lignite coal from the Souris coal-field, may be taken as representative of the lignite from the Wood Mountain-Willowbunch area since the coal in the Souris field is from similar flat-lying Fort Union beds and the two fields are continuous with one another. On account of the lack of railway accommodation, it has not been found practicable to ship sufficient quantities of the lignite for testing from the actual area dealt with.

Analyses of Lignite.

No.	Locality				Moisture	Volatile matter	Fixed carbon	Ash
	Sec.	Tp.	Range	W. mer.				
1	17	3	21	2nd	9·1	41·2	32·7	17·0
2	2	4	23	"	8·1	38·2	42·3	11·4
3	3	5	23	"	8·8	39·6	38·8	12·8
4	28	1	24	"	8·1	36·9	39·8	15·2
5	30	2	25	"	8·1	40·8	39·1	12·0
6	32	3	26	"	8·5	39·5	35·4	16·6
7	35	5	26	"	7·4	34·6	34·3	23·7
8	27	7	27	"	8·2	40·6	35·6	15·6
9	11	3	19	"	7·3	38·4	36·2	18·1
10	28	10	28	"	10·3	37·4	39·9	12·4
11	17	4	1	3rd	12·9	40·9	36·8	9·4
12	13	5	1	"	12·8	35·9	34·1	17·2
13	21	6	1	"	13·1	35·9	34·6	16·4
14	8	1	2	"	13·8	38·3	37·3	10·6
15	1	6	2	"	12·7	41·3	32·6	13·4
16	10	5	4	"	12·0	33·5	29·2	25·2
17	24	4	6	"	13·5	36·9	35·8	13·8

Analyses of Souris Coal.

Locality.	Moisture.		Proximate analysis of dry coal.			Ultimate analysis of dry coal.					
	Mine. %	Air-dried %	Vol. %	F. C. %	Ash. %	C. %	H. %	S. %	N. %	O. %	B.T.U. dry coal.
Taylorton..........	28·6	18·0	42·9	49·0	8·1	59·8	4·8	0·6	1·0	25·7	10,690
Estevan	30·9	18·2	40·0	43·2	16·8	57·7	4·3	0·5	1·0	19·7	9,650

Boiler Test of Souris Coal.

Source of coal.	Cal. value of coal per lb. as fired. B.T.U.	Moisture in coal as fired. %	Ash and clinker for dry coal. %	Equivalent evaporation per lb. as fired.
Western Dominion colliery, Taylorton........................	7,520	29·7	8·24	3·91

Gas Producer Tests of Souris Coal.

	1	2
Volatile matter, per cent	32·8	43·3
Ash	7·2	11·1
Moisture, per cent	23·3	13·4
Cal. value of coal as charged B.T.U	8,300	9,374
Cal. value of gas (lower) per cu. ft. B.T.U	112·7	117·4
Producer efficiency	0·578	0·488
Coal per B.H.P. per hr., lbs	2·28	2·48
Coking of coal	None	None
Average interval between poking	5 hours	6 hours
Clinker	Very slight	None
Tar	None	Gas washer not used, no tar.
Uniformity in gas quality	Very uniform	Very uniform
Amount of steam used	Very little	None
Combustible in refuse	Not analysed	Moderate
Remarks	Very suitable fuel for producer, easily worked.	Very suitable for producer, easy to work, no trouble.

1 and 2. Lignite from Western Dominion Collieries, Ltd., Taylorton, Sask.

Descriptions by Locality.

In the following pages those lignite occurrences are briefly described from which the samples were taken for the analyses given on page 61. These outcrops are representative ones and it is thought that a brief description of them will give a good idea of the general conditions. The numbers used in the descriptions are those used in the table of analyses, in which the localities are more exactly defined. The reader is referred to the general geological map for the location of other outcrops which are not described here.

Sample No. 1 is from a small mine operated by Mr. Richard Appleby at Roanmine, Saskatchewan, on the west side of Roan Mare coulée. At this locality 7 feet of workable lignite is overlain by 1 foot of bituminous clay shale, which makes a good roof. Above the shale lies 3 feet of clean building sand and above the sand a succession of clays, shales, and small lignite seams. The coulée sides are quite grass covered and the seam has consequently not been traced, but it is thought to be of considerable extent. The mine, located as it is well up a side coulée, has easy drainage and the seam is horizontal so that mining is carried on at small cost. At the time the property was visited only one tunnel had been driven.

The mine is situated on one of the coulées running to Big Muddy lake and the conditions there are typical of those in the area around the lake and southward about Big Muddy post-office where several pits and tunnels have been opened by farmers who depend on the lignite for a fuel supply.

Sample No. 2 is from an open pit operated by Mr. W. H. Treleaven, Waniska, Saskatchewan. The pit is in a steep-walled coulée or amphitheatre on the east side of Bender coulée at the foot of a bold hill called Eagle butte (Plate VI). The strata are well exposed in the neighbourhood and a section measured there is given on page 58. The section shows a number of coal seams of workable size, but the demand for the product is so limited that only one seam is worked.

Sample No. 3 is from an abandoned mine at Coal Mine lake, 6 miles southeast of Bengough, where a 5-foot seam has been exposed by trenching for a quarter of a mile along the east side of the lake and has been worked by tunnels at three points. The tunnels have caved in and at the time the mine was visited, it was possible to examine only one of the tunnels, for 50 feet from the entrance, and at this point the sample analysed was collected. The mine was abandoned owing to lack of demand for the product, in competition with the soft coal shipped by rail from Alberta to Bengough.

Sample No. 4 is from an open pit worked by the farmers of the district. It is situated in tp. 1, range 24, W. 2nd mer., in a district devoid of trees and a long distance from a railway. A seam from 4 to 5 feet thick is exposed on an open hillside, and is both overlain and underlain by clay. The slope of the hill is gentle and open-pit mining by stripping the clay overburden can be economically carried on for a number of years if the lignite is used only for local use.

A number of similar coal pits are located in the district about Paisley Brook, Eddyside, and Pretty Valley post-offices.

Sample No. 5 is from a mine operated by Mr. Olaf H. Person, at Eddyside, Saskatchewan. There is an 11-foot seam with a clay parting at 3 feet from the bottom and the upper 2 feet is banded with clay. Above is a bed of clay shale with fossil leaves, followed by fine yellow-grey sand.

The bottom 6 feet of lignite is worked by undercutting on the clay parting at 3 feet, picking down the upper 3 feet and then raising the lower 3 feet. The mine is well located on the side of a coulée where the coal can be dumped into wagons at the tunnel entrance. It is worked by the room and pillar system.

Sample No. 6 is from a mine operated by Mr. C. H. Waldon, at Hart, Saskatchewan. The lower 7 feet of lignite of an 18-foot seam is worked. The succession of strata here is the same as that at the mine operated by Mr. Person in sec. 30, tp. 2, range 25 (No. 5), and is thought to represent the same horizon. The clay parting is thicker and is located above the worked portion so that there are really two seams. An old tunnel on the upper part was driven 75 feet, while the tunnel on the lower part at present worked, had been driven 80 feet at the time the mine was visited.

Samples Nos. 5 and 6 are both from the seam which, as described under the section on "Occurrence and Distribution," was correlated over a distance of 78 miles. This seam outcrops in several places in the Fife Lake and Poplar River district, but no samples for analysis were collected from that region. An open pit mine on this seam is operated in sec. 32, tp. 1, range 28, W. 2nd mer.

Sample No. 7 is from a mine at Willowbunch lake south of the town of Viceroy. A tunnel is in more than 200 feet on a seam 5 to 6 feet thick. The quality of the coal is uniform throughout. It is overlain by a bed of clay-shale which is used as a roof. The seam outcrops at several points along the sides of the old valley channel in which Willowbunch lake lies, but owing to the grass covering no section was obtained.

Sample No. 8 is from a mine operated by Mr. A. Caillet, Readlyn, Saskatchewan. The lignite is interbanded with clay as follows:

Clay..................................	
Lignite................................	2 feet
Clay with fossil plants..................	6 "
Lignite................................	1 foot
Clay..................................	6 inches
Lignite................................	2 feet

The thicknesses of the individual beds vary. The bands of clay are in places one foot thick and in places pinch to nearly nothing with a corresponding increase in the thickness of the coal.

Just across a coulée to the north from this mine and at a lower level are the caved workings of another mine.

Sample No. 9 is from a mine operated by Eidsness Brothers, at Gladmar, Saskatchewan (Plate VII). The seam lies to the east of the map-area but is correlated with the seam at Roanmine (No. 1). In this case a 7-foot seam of lignite is overlain by clean building sand similar to that at Roanmine and, as at Roanmine, the upper part of the seam is a bituminous clay. The lower 4½ feet of the seam is worked, leaving a roof of the bituminous clay to support the sand. A 2-inch clay parting about 2 feet from the bottom is picked out in mining. A main tunnel has been run on the coal seam and running from it are branch tunnels. It is the intention of the operators to work by the room and pillar system. A shaft to the surface provides ventilation (Plate VII).

A second mine on the same seam also in sec. 11, tp. 3, range 9, is operated by Mr. Bungard.

Sample No. 10 is from a seam outside the map-area on the property of the Consumers Coal Company near the north end of Lake of the Rivers. The seam outcrops along the old valley in which the lake lies, in sec. 28, tp. 10, range 28, W. 2nd mer. At the time the property was visited the seam had been exposed by stripping and it is now being mined. The seam is approximately 5 feet thick.

On the east side of the same lake in sec. 36, tp. 10, range 28, W. of 2nd mer., the Consumers Coal Company have carried on mining operations on a 7-foot seam and several hundred tons of the lignite have been mined and used locally. A fault was encountered and mining ceased. Borings have since proved the seam on the other side of the fault. The faulted portion is only a block which has slumped into the coulée and mining was carried on in the slumped portion.

A 10-ton lot of lignite from this mine was tested at the fuel testing plant of the Mines Branch, Department of Mines, Ottawa, and was pronounced to be an excellent fuel for the production of power, when utilized in a gas-producer plant.[1]

Sample No. 11 is from an open pit on Mr. Frank's ranch along Hay Meadow creek. The seam is 5 feet thick, and is correlated with outcrops as far east as Big Muddy lake and as far west as Lidgett post-office.

Sample No. 12 is from a 2-foot seam near the home of Mr. Vikers in sec. 13, tp. 5, range 1, W. 3rd mer. The lignite outcrops near the bottom of a coulée running towards Twelvemile lake and has been worked for local use, though not thick enough to pay for extensive mining. It is typical of the numerous outcrops in the townships to the south of Twelvemile lake. Num-

[1] Mines Branch, Dept. of Mines, Sum. Rept., 1912, p. 37.

bers of open-cuts have been made in this district and considerable lignite dug for local use, but beds thick enough to make tunnelling profitable have not been found.

Sample No. 13 is from a well in sec. 21, tp. 6, range 1, W. 3rd mer. The region north of Twelvemile lake is all grassed, and coulées are few, so that there are no outcrops. However, in digging a well, coal was found at about 10 feet from the surface and measured 6½ feet in thickness with some small clay partings. Since it is situated in an area where coal is scarce the seam will probably pay to work. At the time the locality was visited, the owner of the well had started an incline from the surface to the lignite. The sample for analysis was taken from the heap of coal which had been excavated in digging the well.

Sample No. 14 is from an open pit south of Willowbunch post-office. The lignite seam is 5 feet thick and the overburden at the point where the seam is worked, is approximately 15 feet. This consists of banded sand and clay with minute seams of lignite. The slope of the coulée is small and it will be possible to work the seam over a considerable area by stripping and the open pit method. This is the only workable seam found in the mine townships comprised by tps. 1 to 3 and ranges 1 to 3, W. 3rd mer., and this district is so far from any railway that it is difficult to obtain other fuel. It is worked for local use by the farmers of the district.

Sample No. 15 is from a 2-foot lignite seam in sec. 1, tp. 6, range 2, W. 3rd mer. This seam is representative of a number of outcrops along the coulées running to Twelvemile lake. There are no big pits nor mines in this neighbourhood, but numerous small pits have been opened along the coulées from which the farmers have dug out a few wagon-loads of coal.

Sample No. 16 is from a mine operated by Mr. Sturgeon in sec. 10, tp. 4, range 6, W. 3rd mer. A tunnel has been driven 150 feet and is being worked by the room and pillar system. The lignite seam is 5 to 6 feet thick and has a clay parting 1½ feet from the bottom. This working is near the northern boundary of the coal formation and is favourably situated for supplying lignite to the farming country north of it.

Sample No. 17 is from a large open pit operated by Mr. Blood. There is a 6-foot lignite seam with a 6-inch clay band 2½ feet from the bottom. The lignite outcrops on the north slope of the Wood Mountain plateau and from here east to Wood Mountain post-office outcrops are numerous. The workings on these seams are mostly small and are all open pits. Similar pits are opened on outcrops to the south on the southern slope of the plateau, and this district is particularly well supplied with coal which can be easily mined.

From range 6, westward, outcrops become fewer. Two seams of 2½ feet thickness each and separated by 1 foot of clay are worked by an open pit in sec. 2, tp. 3, range 8, W. 3rd mer. A seam of 3 to 4 feet in thickness occurs in sec. 11, tp. 5, range 10, W. 3rd mer., but the overlying clay had caved in at the time of visiting and the coal could not be sampled. From here to the western edge of the map-area there are few outcrops. Grass covers the surface everywhere and the only coal reported, is a few small seams in clay from a well in the north of tp. 6, range 13.

The lignite area described in this report forms only a part of a much larger field. That the mining of lignite of this character may be a profitable industry is shown by the production of the mines in the same formation in the Souris coal field to the east and in North Dakota and Montana to the south.

CLAY.

Occurrence and Distribution.

Clays, clay-shales, shales, and sands suitable for the manufacture of clay products, are widely distributed in the area. They occur in all the formations except the Fox Hills sandstone. Owing to the abundance of good clay in the older formations the superficial deposits were not sampled nor tested as to their suitability for clay products, although probably some of the finer of the Pleistocene clays and some of the Recent silts of the valley-fillings could be used to make common brick.

The dark grey clay-shales of the Pierre formation are not well adapted for brick-making as they are stiff and sticky in the wet state and dry slowly with cracking, warping, and excessive shrinkage. The Fox Hills being a sandstone formation need not be considered. The clays and shales of the Lance formation were not sampled, since the area in which they occur is small and lies far from a railway.

Most of the workable clays in the area are found in the Fort Union formation. They occur in the flat-lying beds of this formation interbedded with sands and lignites and outcrop on the sides of coulées and old river channels (Plate I). Their distribution is the same as that of the lignite and is roughly confined to the area of the Wood Mountain plateau.

The close association of the clays and lignite is very fortunate since the lignite forms the only fuel supply of the area which can be used to burn the clays. In places, the two can be mined together and where the working of the coal or the clay separately might not be profitable, the combined working of the two is to be considered.

Samples of clay were collected from the most promising beds at various localities and sent to J. Keele of the Geological Survey, for physical tests. The results show that while some of the clays have serious defects, most of them are suitable for the manufacture of common brick, many are semi-refractory, and some may be classed as fireclays. Of the two divisions of the Fort Union, it may be said that the lower white beds supply the more refractory clays. The yellow clays of the upper division make good ordinary brick and the white clays are high grade. They are of the stoneware type, used for pottery, stoneware, or sewer-pipe.

A large proportion of the strata consists of clay and it has not been possible to test a sufficient number of samples to convey a right conception of their real importance. This is especially true of the more refractory clays. Fireclays are known and worked in the same formation in North Dakota and in the Dirt Hills area south of Moosejaw, Saskatchewan, where the Saskatchewan Clay Products Company, Limited, have recently opened a plant.

Physical Tests of the Clays.

The following descriptions are taken largely from Mr. Keele's report of the physical tests, and the section on page 82, "Summary of tests and general remarks on clays," was written by Mr. Keele. The clays are listed and described under the laboratory number assigned to each. The list gives these numbers and the location of each.

List of Clays Tested.

Lab. No.	Location			
	Sec.	Tp.	Range	W. mer.
170	30	6	18	2nd
171	9	1	22	"
172	31	3	24	"
173	12	6	30	"
174	6	6	29	"
175	28	7	27	"
176	5	7	27	"
176B	31	3	24	"
176A	31	3	24	"
177	35	5	26	"
178	14	11	28	"
179	3	5	23	"
179A	3	5	23	"
179B	3	5	23	"
282	1	8	29	"
284	15	5	4	3rd
286	8 or 9	6	1	"
289	36	6	22	"
291	36	6	22	"
292	36	6	22	"
293	36	6	22	"
a[1]	36	6	22	"
b	28	10	28	2nd
c	10	5	4	3rd
d	20	4	3	"
e	20	6	5	"
f	20	1	8	"

[1] a–f did not have laboratory number assigned.

Lab. No. 170. Sample is from a 2-foot seam of greyish-white clay shale which outcrops in a coulée at Brooking. When tempered with 21 per cent of water, this clay forms a very plastic good working body. Its drying shrinkage is 5 per cent and it will probably dry intact when made into full-sized wares. This clay burns to a cream-coloured body at all temperatures up to cone 5 (1230° C.), and the body remains porous and open, behaving so far like a fireclay. The body is grey in colour and vitrified at cone 10 (1330° C.), but numerous dark, fused spots appear on the surfaces. It fuses at cone 20 (1530° C.), so that it is not a fireclay [fireclay is required to stand up to cone 27 (1670° C.)]. Although this is nota refractory material it is nevertheless a valuable, high grade clay. It can be used for a high class face brick, and, if mixed with good red-burning clay, for sewer-pipe and fireproofing.

Lab. No. 171. Sample is from a 4-foot bed of hard, grey clay shale lying above a 3-foot seam near Big Muddy post-office. The material requires 31 per cent of water for tempering and is very plastic, smooth, and sticky. Its drying shrinkage is 8 per cent. The small test pieces did not crack, but it is probable that full-sized bricks made from it would check in drying.

It burns to a light red colour at cone 06, the fire shrinkage is 1 per cent, and the absorption is rather high. It fuses to a slag at cone 3. The drying qualities of this clay should be tested on a large scale. If it dries intact it might be used for common brick, but the high shrinkage would have to be reduced by the addition of sand.

Lab. No. 172. Sample is from a grey-white gritty clay that outcrops for several miles along Big Muddy valley in a bed that is in places over 20 feet thick. The bed is easily recognized on account of its being much lighter in colour than any other bed in the vicinity. It is one of the white clays from the lower division of the Fort Union beds.

It requires 24 per cent of water for tempering and is very plastic, stiff, and pasty in the wet state. It dries slowly and exudes soluble salts. The test pieces did not crack in drying and the shrinkage was 7 per cent. This clay burns to a pink colour at all temperatures up to cone 5 (1230°C.). The body is vitrified, develops fused iron spots, and becomes slightly vesicular at cone 10 (1330° C.). It fuses at cone 20 and, therefore, is not a fireclay; but, like No. 170, it may be classed as a semi-refractory or bastard fireclay, suitable for high class face brick, sewer-pipe, and fire-proofing. A sample, dry-pressed bricklet is light buff in colour at cone 03 and its absorption is 12 per cent. It would probably give good results for face brick if burned harder.

Lab. No. 173. Sample is from a light yellow-grey silty clay occurring in a 10-foot bed, above a coal seam. This is one of the few clays in the region which has a noticeable lime content. It requires 25 per cent of water for tempering and is fairly plastic, but rather flabby, owing to its silty character. It will stand fast drying with artificial heat. The drying shrinkage is 5·5 per cent. It burns to a porous, pale red, or salmon colour at cone 06, and fuses to a slag at cone 5. It is suitable for the manufacture of common building brick.

Lab. No. 174. Sample is from a dark grey, clay shale lying above a coal seam. This shale requires the extraordinary amount of 44 per cent of water for tempering and forms a highly plastic, stiff, pasty mass which is very hard to work. Its drying shrinkage is 10 per cent, which is excessive. It burns to a red body, hard and dense at cone 06, with a fire shrinkage of 3 per cent. This clay has several serious defects, including excessive shrinkage, cracking in drying, and bad working qualities. It also contains carbonaceous matter in sufficient amount to cause swelling in burning, unless it is fired very slowly. It is not well adapted, therefore, for the manufacture of clay products.

Lab. No. 175. Sample is from a grey clay shale overlying a coal seam. This shale is very similar to No. 174, both in appearance and in the behaviour under treatment. It is, therefore, not considered suitable for manufacturing purposes.

Lab. No. 176. Sample is from a 15-foot bed of grey, sandy, clay shale exposed along the Canadian Pacific railway, west of Verwood. When tempered with 44 per cent of water this clay forms a highly plastic, stiff, and sticky mass which is exceedingly hard to work. It is rather soapy to the touch and evidently contains considerable colloidal matter. It cracks so badly in drying that even the small test pieces could not be dried safely in the room-temperature of 65°F. It burns to a hard, red body at cone 06 and fuses at cone 5. It is useless for the manufacture of clay products.

Lab. No. 176 B. Sample is from a grey clay shale containing bands of clay-ironstone concretions in a 43-foot bed overlying the bed represented by No. 172. This material makes a stiff, sticky paste when tempered with 30 per cent of water. The test pieces cracked so badly in drying that they could not be tested further. The clay appears to be useless in the raw state, but might be rendered workable by the preheating treatment if the greater expenditure were warranted by economic conditions. The addition of sand will not overcome the defects of this clay.

Lab. No. 176 A. Sample is from a grey sandy clay which occurs in a 34-foot bed overlying Nos. 172 and 176B. When mixed with 30 per cent of water it becomes fairly plastic and rather sticky, but the small test pieces moulded from it cracked in drying and were not thoroughly dry in six days. It burns to a rather porous, weak body at cone 06, and is useless for the manufacture of clay products.

Lab. No. 177. Sample is from a massive, grey, clay shale overlying the coal seam exposed along Willowbunch lake, south of the town of Viceroy. It requires 36 per cent of water for tempering and works into a very plastic, sticky mass. Although the small test pieces did not crack in drying this clay would probably crack if made up into wares of large size. Its drying shrinkage is 9·5 per cent. It burns to a steel-hard, light-red body at cone 06 with a fire shrinkage of 2 per cent; the absorption is 15 per cent. The clay is vitrified at cone 3, but the shrinkage at that temperature is abnormal, being 10 per cent. The total shrinkage is 19·5 per cent. When made up by the dry-pressed process this clay burns to a fair, red colour, and hard body at cone 06, and the shrinkage is within practical limits. If burned to cone 03 the dry-pressed body is almost impervious; but the shrinkage is too great; otherwise it is one of the best red-burning clays of the series.

Lab. No. 178. Sample is from a white, sandy clay, collected at a point outside the map-area on the west arm of Lake of the Rivers, south of Expanse. It is a soft clay consisting essentially of fine quartz grains in a matrix of white, plastic clay. It requires 20 per cent of water for tempering, and its plasticity is good. Its drying shrinkage is 5 per cent and fast drying of full-sized wares moulded from it can probably be accomplished with safety. It burns to an open, cream-coloured body at all temperatures up to cone 5 (1230° C.). When burned to cone 10 the body is grey in colour and contains small black specks. The fire shrinkage at this temperature is 2 per cent and the absorption is 6·4 per cent. The clay softens at cone 27 (1670° C.), so that it falls slightly short of the requirements of a fireclay. It may, however, be classed as a second-class fireclay and can be used for many purposes where refractoriness up to a certain point is essential.

Lab. No. 179. Sample is from a sandy clay or yellowish coloured silt underlying 179A. When tempered with 25 per cent of water, it forms a body of rather low plasticity, which is short in texture. The drying shrinkage is 6 per cent and it probably dries without cracking. Burning tests, cone, 06: percentage of fire shrinkage, 0; percentage absorption, 19·0; colour, light red. This clay appears to be suitable for the manufacture of common brick, although the drying qualities would have to be further tested, on a large scale.

Lab. No. 179A. Sample is from a grey shaly clay which occurs in a 2-foot seam below the coal at Coal Mine lake. This clay forms a highly plastic, stiff, and sticky mass when wet and will probably crack on drying. It burns to a hard red body at cone 06, with a total shrinkage of 12 per cent, which is excessive. The burned body is badly scummed. This clay is of little value and is not recommended for brick-making purposes.

Lab. No. 179 B. Sample is made up of a mixture of equal parts of 179A and 179 by the dry-pressed process. The sample burned to a light red, very porous, and rather weak body at cone 06, but will give a better product at cone 03.

Lab. No. 282. Sample is from an open pit worked by the Alberta Clay Products Company of Medicine Hat, Alberta. The clay is shipped by rail from Willows station, via Weyburn and Moosejaw, to Medicine Hat, where it is used in the manufacture of sewer-pipe. The mixture consists of mixed lumps of dark grey and whitish clay of sandy texture. It requires 30 per cent of water to bring it to the best working consistency. The working qualities are excellent and the plasticity good. The drying shrinkage is 6·5 per cent and the drying qualities are good. The results obtained on burning were as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	6	15	white
3	6	14	"
5	6	13	"
9	7·5	10	grey
20 to 26	softens		

The clay is taken from two different beds, one being more refractory than the other. Both are high grade clays and are not vitrified at the softening point of cone 9 (1310°C.) as the above tests on the mixture indicate. The clays are used for the manufacture of sewer-pipe but can also be used for a second grade fire-brick.

Lab. No. 284. Sample is from one of the prominent white beds on the north escarpment of the Wood Mountain plateau. The sample was taken across a 7-foot seam. The material consists of a sandy clay of good plasticity and working qualities. It can be dried safely without checking after moulding, the shrinkage on drying being 5·5 per cent. The results obtained in burning are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	2·6	15	white
3	3	15	"
5	3	13	grey
9	3	12	"
14	softens		

This is a semi-refractory clay which could be used for the manufacture of sewer-pipe, conduits for electric wires, or other similar products. If mixed with a good red-burning clay, a hard-burned, fireproofing, or face brick of high grade could be manufactured from it. It is not a fireclay, but could be used for the manufacture of stove linings, or for other purposes where it would not have to stand very high temperatures.

Lab. No. 286. Sample is from the north shore of Twelve-mile lake taken at the level of the water. This material is a white clay of sandy texture, resembling No. 284, but is not quite so sandy. This is another of the white clays from the lower division of the Fort Union formation. It requires 27 per cent of water to bring it to the best working consistency. The shrinkage in drying is 6·5 per cent. This clay will have to be dried slowly to avoid cracking. The results obtained in burning are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	2·3	10·9	white
3	3	9	
5	3	8·7	grey
9	3·4	7·4	"
13	softens		

This clay burns to a dense body but is not quite vitrified at cone 9. It is adapted to uses similar to those given for 284, which it resembles.

Lab. No. 289. This sample and Nos. 291, 292, 293, and sample *a*, were collected because of their favourable appearance and their location close to the railway. Nos. 289, 291, 292, and 293 are from white beds occurring at the base of the Fort Union formation along Frenchman river south of the Cypress hills and so are a good distance away from the Wood Mountain-Willowbunch area; but on account of their similarity to the white clays of that region they are included here. The clays outcrop for miles along the steep walls of the Frenchman River valley south of the Cypress hills and at East End village, where the samples were collected, are particularly favourably situated, close to water supply and to railway transportation. A spur from the railway could be run to the foot of the bluffs where the outcrops occur.

Sample No. 289 is a white clay from a pit west of East End village, sec. 36, tp. 6, range 22, W. 3rd mer. This clay requires 24 per cent of water for tempering; the wet body has the qualities of stoneware clay, being very smooth and plastic. The drying shrinkage is 5 per cent and the drying qualities are good. The results obtained on burning are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	1	13	white
3	1·4	12	"
5	2	12	"
9	3·3	6	grey
24	softens		

This material is excellent in many respects; its working, drying, and burning qualities are good and the shrinkages are low. It can be shaped into various utensils for domestic use, and fitted with proper glazes. The temperature of burning would be rather high, as a dense body is not obtained below cone 9 or 10. It would give better results for stoneware products if mixed with clay No. 291 or No. 292, which occur in the vicinity, as the temperature of burning such a mixture could be reduced to cone 5. This clay is useful to mix with a good red-burning clay for the manufacture of vitrified structural products.

Lab. No. 291. This is an average sample taken across 20 feet in thickness of a bed of white clay at East End. It varies from white fine-grained clay to light grey clay with sandy texture. It has good plasticity and working qualities, when tempered with 22 per cent of water. The shrinkage on drying is 6·5 per cent. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	3	4·5	buff
3	4·3	3·7	"
5	5·3	2·5	grey
7	vitrified		
21	softened		

This clay burns to a fairly dense body at cone 1 and is almost vitrified at cone 5. It differs considerably from any of the other samples in its vicinity in its behaviour during burning; none of the others were vitrified even at cone 9. This clay is of the stoneware type, but is also suitable for the manufacture of vitrified structural clay products.

Lab. No. 292. This is an average sample taken from the same bed as No. 291, at a distance of about 1,000 feet from that sample. The sample submitted is a light grey, nearly white, hard clay, having a conchoidal fracture. It differs in this respect from all other samples, which are soft clays. It is very smooth and plastic when tempered with water and is more like a typical stoneware clay than any of the others from the vicinity. Its drying shrinkage is 7 per cent. No test was made of the drying qualities but it probably can be dried slowly without cracking. The burning tests are as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	4·7	6	buff
3	7·3	2·5	grey
5	9	vitrified	"
20	softened		

This clay matures into a vitrified body at a lower temperature than 291. The shrinkages are too high for commercial purposes, but a mixture of this clay with 289, the shrinkages of which are quite low, would probably give good results in practice. In addition to stoneware and vitrified goods this clay could be profitably used for the manufacture of fireproofing or hollow building blocks as it burns to a hard strong body at as low a temperature as cone 03 (about 2000°F.), but for this purpose about 25 per cent of sand would have to be added in order to improve its drying qualities and reduce the shrinkage.

Lab. No. 293. Sample is from the strata overlying No. 292. The sample contained some surface soil and at the time of collecting it was not thought to be as good a clay as No. 292, but was taken because it would have to be stripped in order to work No. 292, and it was thought advisable to test it to see if it could be profitably worked along with the underlying strata. The tests show it to be one of the most refractory clays collected. It is a light grey clay, very sandy in texture, but has fairly good plasticity and working qualities. Its drying shrinkage is 6 per cent and the drying qualities are probably good. Its behaviour in burning is as follows:

Cone	Fire shrinkage %	Absorption %	Colour
1	1·7	11	white
3	2·3	11	"
5	2·4	10	"
9	3·6	6·8	grey
27	begins to soften		

This material is almost refractory enough to be a fireclay, and bricks made from it will probably give good satisfaction in many places where firebricks are called for but where the highest refractory qualities are not essential. This sample resembles 289 but is not nearly so smooth in texture.

Sample *a*. This sample represents the surface clay and soil overlying No. 289 at East End, Saskatchewan. It is a yellowish, non-calcareous, silty clay containing small, rounded pebbles and might be used for the manufacture of common brick if the drying can be accomplished safely. It burns to a hard strong red body at 1850°F. If there are not too many pebbles in the deposit, it might be mixed with the white sandy fireclays of the vicinity for the manufacture of sewer-pipe or fireproofing.

Samples *b* and *c*. Sample *b* was collected from a clay bed overlying the coal seam in sec. 28, tp. 10, range 28, W. 2nd mer. This is the seam which was mined by the Consumers Coal Company of Moosejaw. Above the coal is from 3 to 4 feet of blue clay, then 6 to 8 inches of coal, and above this 3 to 4 feet of blue clay from which the sample was taken. It is a fine blue clay and it was thought from its appearance it might make a good brick.

Sample *c* is from a 6-foot layer of blue clay overlying the coal worked by Mr. Sturgeon in sec. 20, tp. 4, range 3, W. 3rd mer. The clay is similar to clay *b* and they behaved the same in the physical tests. These clays require a large amount of water for tempering, generally 30 to 35 per cent. Their working qualities are poor. They are exceedingly stiff and sticky in the wet state. They dry slowly with cracking, warping, and excessive shrinkage. There is a further considerable shrinkage in burning. The colours of the burned body are various shades of red. Neither of these materials is recommended for the manufacture of clay products.

Sample *d*. This material is from a yellow calcareous clay of sandy texture occurring in the Fort Union beds at Wood Mountain post-office. This clay is used as a wall plaster by the people in the vicinity. For this purpose it is simply mixed with enough water to bring it to the proper consistency for spreading. The clay is suitable for the manufacture of common brick. It burns to a cream-coloured, hard body at cone 03 (about 2000°F.) with shrinkages within working limits. The clay can be dried without cracking if the process is not hurried.

Samples *e* and *f*. These two samples were collected from the Pierre shale, one to the north and the other to the south of

Wood Mountain plateau. The physical tests show that these shales are not well suited for the manufacture of clay products, especially since the good clays of the Fort Union formation in the Wood Mountain plateau are close at hand. They are dark grey clay shales. They require a large amount of water for tempering, are stiff and sticky in the wet state, and dry slowly with cracking, warping, and excessive shrinkage. They burn to a red body and there is further shrinkage in burning. They are not recommended for the manufacture of clay products.

Summary of Tests and General Remarks on Clays—by J. Keele.

The white or light grey clays described from the Wood Mountain-Willowbunch area and East End, are typical of clays that occur at a similar geological horizon over a large part of southern Saskatchewan between the eastern slopes of Dirt hills and the Alberta boundary. They are the best clays of the region; in many localities they are true fireclays, not softening under a temperature of cone 27 (3038°F.); but even at their lowest estimate where their fusing point drops to cone 12 (2500°F.) they are still valuable clays.

There is not a great demand for firebricks in the province of Saskatchewan, hence high refractoriness of itself is not such an important property in clays. The clay products that are in greatest demand are building brick, hollow ware, sewer-pipe, and paving brick. The white clays or mixtures of these with suitable red burning clays should produce very good products of these kinds.

The white clays appear to be so widespread in this region that they cannot be monopolized, nor can they be exhausted. They are better situated with regard to transportation facilities and ease of working, at some points than at others, and these considerations are the only ones which render clay lands more valuable than the ordinary farm lands of the district.

While the white clays have certain characteristics in common, they vary widely in certain of their properties, such as texture, shrinkage, and behaviour in burning. The series of tests on the East End clays show these differences very clearly.

It is, therefore, highly important that careful field investigation and sampling should be done, particularly in cases where manufacturers contemplate utilizing the clays for pottery or stoneware articles.

For the manufacture of the rougher clay products, it may be only necessary to obtain a large enough deposit conveniently situated and without an excessive overburden; in other words, for this purpose quantity and not fine distinctions in quality is to be looked for.

Associated with the white clays are immense beds of materials, many of which are quite worthless as far as the manufacture of clay products is concerned. Attention has been directed to the defects of these clays in a former report[1] and in the present report certain of the samples collected by B. Rose are condemned as unfit.

The principal defect is cracking on drying, and this is generally accompanied by excessive shrinkages. Mild cases of cracking may be overcome by the addition of small percentages of quicklime, but there does not seem to be any remedy for extreme cases. A few of the samples of low grade clays show by the tests that they would be suitable for the manufacture of common brick.

GRAVEL AND SAND.

Superficial deposits of gravel and sand are scattered here and there over the area. These are lake and outwash deposits left during the retreat of the continental glaciers. There is also gravel in the terraces along the abandoned river channels. No special study of the gravel and sand was made in the field, so that little can be said of their extent or distribution other than that they are plentiful throughout the area.

There is an abundance of gravel and sand for building purposes and of gravel for road metal and railway ballast. Some of the gravel is very coarse. Coarse gravel from a pit near Ponteix, Saskatchewan, just north of the map-area, was used

[1] "Clay and shale deposits of the western provinces," Geol. Surv., Can., Part II, Mem. 25.

for ballast in the construction of the Canadian Pacific railway for over 100 miles.

There are sands in the Fort Union formation which are suitable for any purposes for which surface sands are suitable. There is a probability that some of the clean sands from the Fort Union would prove suitable for the manufacture of glass. A sample of very white, clean sand from the Fort Union beds near East End, Saskatchewan, which was tested for this purpose, did not give a clear glass and its fusing point is too low for refractory purposes.

SOIL.

The soil of the Wood Mountain-Willowbunch area is largely composed of glacial deposits. As previously pointed out boulder clay mantles almost the entire surface of the area. It is very deep in the region of the Coteau du Missouri but thins out to the west and is in many places not more than one foot thick. The boulder clay is mixed with residual soil from the underlying rocks and carbonaceous matter from the decomposition of plants. The result is a humus which is very fertile.

There are flat areas, such as that about the town of Bengough, in which the soil is a silt, deposited doubtless in lakes in front of the retreating continental glacier. In places also glacial sands or gravels form the bulk of the soil.

The bottoms of Big Muddy and Frenchman River valleys and of some of the larger coulées are filled with alluvium of recent origin. This soil is in places very fertile but a large part of the bottoms is near the level of the saline lakes and is saturated with saline water. The vegetation is scanty in such places and in the hot summers the soil dries and cracks.

There is very little purely residual soil in the area. In areas such as the badlands along Rock creek, and the bluffs along coulées and old valleys, where there is no capping of boulder clay, the slopes are so steep that the rock is carried away before it, weathers, and decomposes enough to make soil.

In summation then it may be said that the area is well provided with fertile soil. As pointed out in the section on climate and agriculture the region is an excellent grazing district and the yield of grains is above the average for the prairies. The precipitation is, however, only about 14 inches per year so that it requires careful farming with the practice of dry farming methods to get the best returns from the soil.

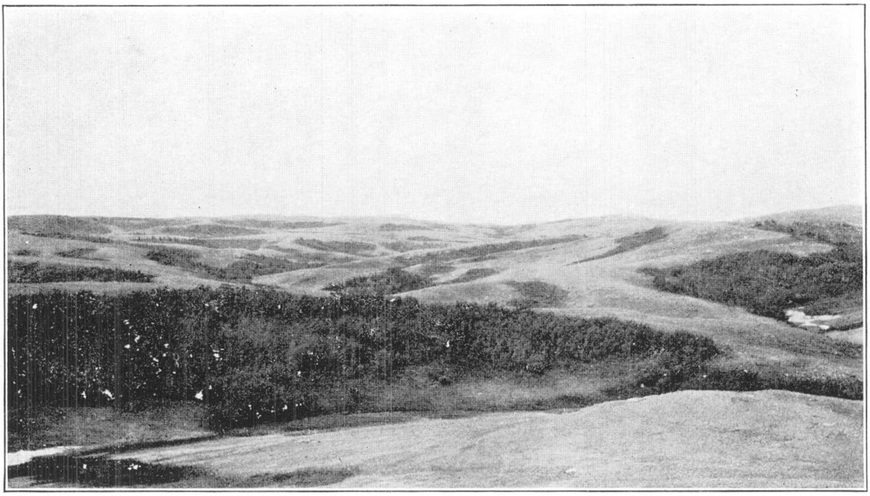
SURFACE AND UNDERGROUND WATER.

The supply of running water in the area is small, much of the area has interior basin drainage and the streams are short and intermittent. Frenchman river is a through-flowing stream and the headwaters of Wood river flowing north from Wood Mountain plateau contain fresh running water, also some of the coulées draining south to the Missouri contain water. But over most of the area there is no run off. The precipitation soaks into the soil and underlying rocks. There are, however, many small lakes and sloughs which draw a supply of water from the soil soakage. These are very abundant in the area of the Coteau du Missouri. A second class of lakes are those which lie along the old valley bottoms, including Willowbunch, Twelvemile, and Big Muddy lakes. These are so saline that their water is not potable and is little used even for stock.

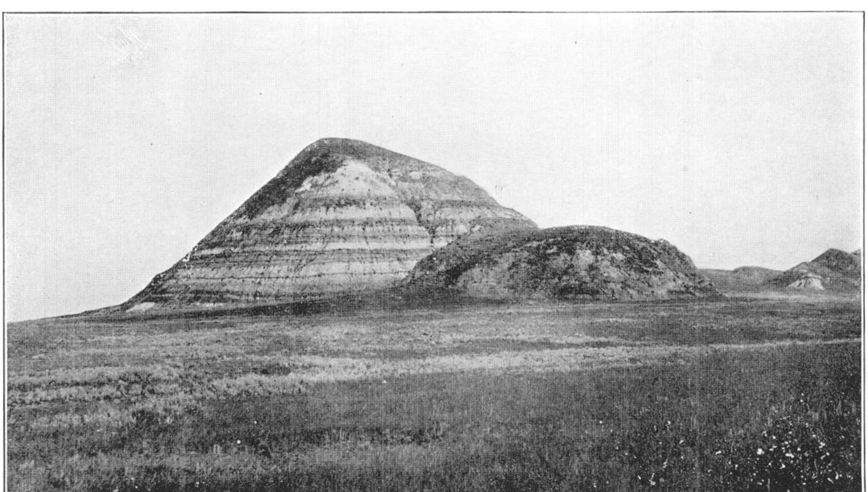
The only other supply of surface water comes from springs and may be classed with the underground water. Springs are numerous at the heads of coulées and along the sides of the abandoned valleys. The water from the springs is excellent for drinking. Most of it soaks into the alluvium in the valley bottoms but some finds its way to the running streams.

On account of the recent settlement of the area, the underground water-supply has not been thoroughly prospected since most of the farmers have found water in shallow wells. The water is for the most part good, but in cases very hard and in some cases quite alkaline. Many of the farmers depend on springs for a supply of water and some have dug wells close to lakes or sloughs in order to utilize the seepage from them. In these cases, however, a water-supply could be had on higher ground, away from the lakes and sloughs, by digging deeper wells. Wells sunk in the superficial deposits are fairly sure of a good water-supply, but in many places the wells are in the underlying Tertiary and Cretaceous rocks where the water seepage is slow, particularly in the shale beds. A few tubular wells have been sunk in the area and good water has in most cases been obtained, although a well of this kind at Verwood has a flow of strongly alkaline water of a brownish colour. There are a few localities where shallow wells have failed to supply a sufficient amount of water; but in these cases deep borings will probably give a good supply, because the gentle eastward slope of the strata over the whole area is favourable for the catching and storing of a supply.

PLATE II.

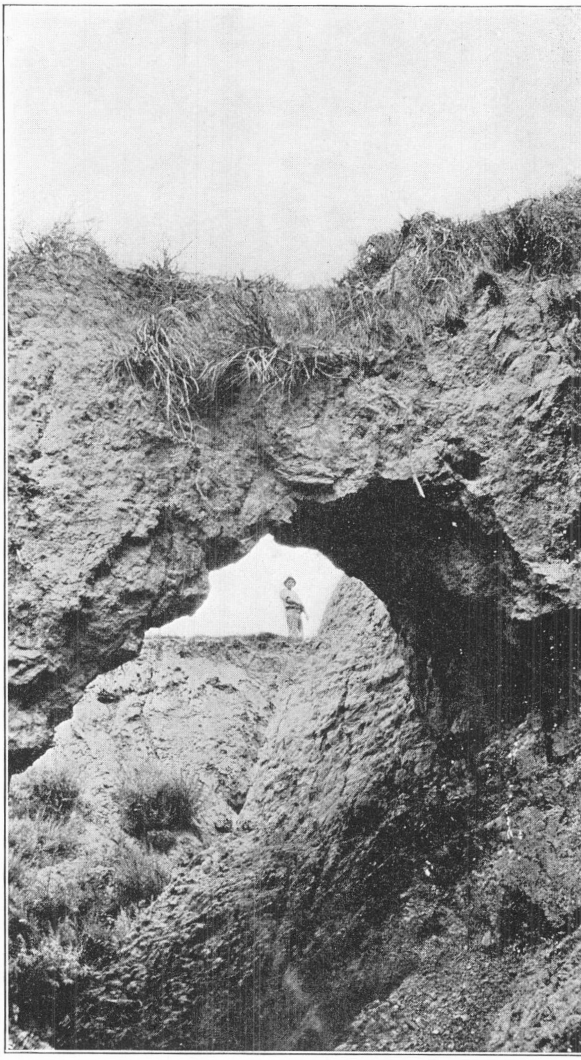


A. Plateau topography, Wood Mountain plateau.



B. Butte, Fort Union formation, Big Muddy valley.

PLATE III.

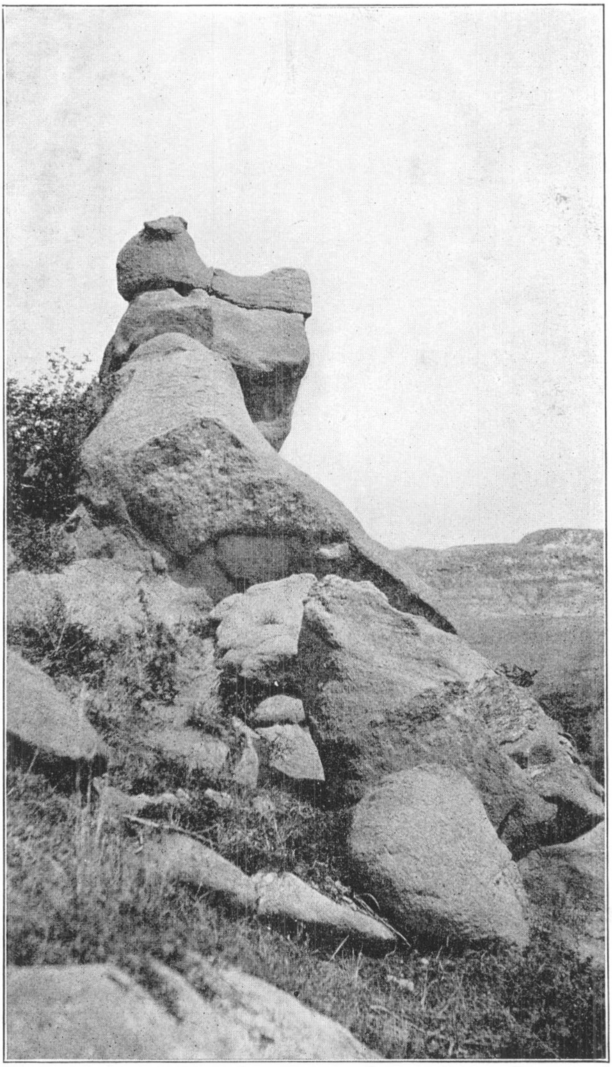


Natural bridge in Fort Union clay.

PLATE IV.

Elongated sandstone concretion left on the surface by the weathering away of the surrounding sand. Fort Union formation.

PLATE V.

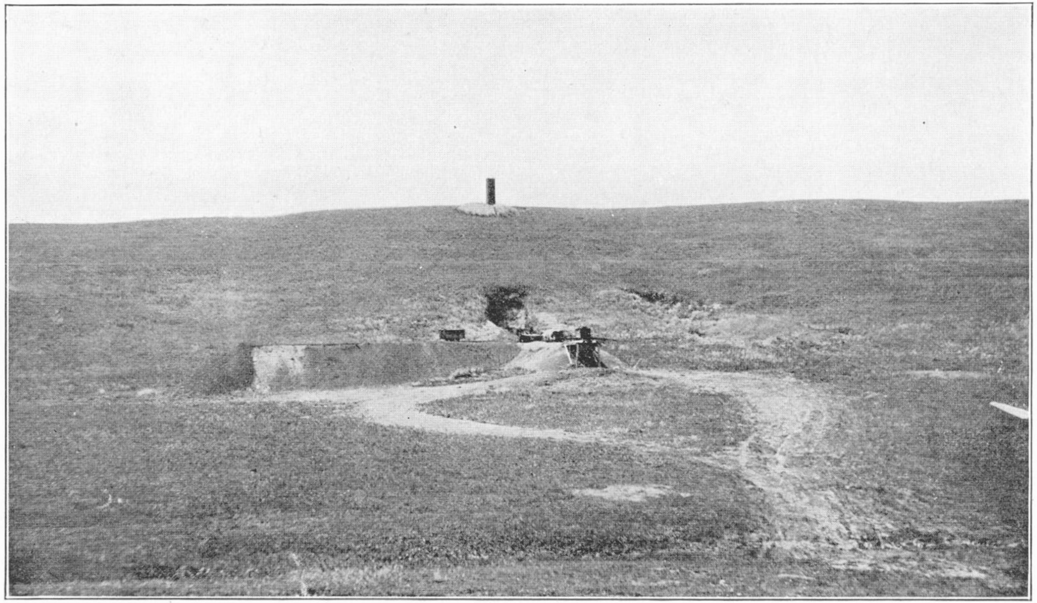


Hoodoo of concretionary sandstone, Fort Union formation.

PLATE VI.

Mine at Waniska, Sask., illustrating the open-pit method of mining.

PLATE VII.



Mine at Gladmar, Sask., illustrating the tunnelling method of mining.

INDEX.

A.

B.

C.

D.

E.

F.

G.

N.

O.

P.

Q.

R.

S.

PUBLICATIONS OF THE GEOLOGICAL SURVEY.

The Geological Survey was established in 1842 and "Reports of Progress" were issued, generally in annual volumes, from that date to 1885, the first report being that for the year 1843 published in 1845. Beginning with the year 1885, "Annual Reports" (new series) were published in volumes until 1905, the last being Vol. XVI, 1904. Many of the individual reports and maps published before 1905 were issued separately and from 1905 to the present, all have been published as separates and no annual volume has been issued. Since 1910, the reports have been issued as Memoirs and Museum Bulletins, each subdivided into series, thus:—

Memoir 41, *Geological Series 38.*
Memoir 54, *Biological Series 2.*
Museum Bulletin 5, *Geological Series 21.*
Museum Bulletin 6, *Anthropological Series 3.*

In addition to the publications specified above, a Summary Report is issued annually; and miscellaneous publications of various kinds including Reports of Explorations, Guide Books, etc., have been issued from time to time.

Publications Issued 1910-1915 Inclusive.

MEMOIRS.

MEMOIR 1. *Geological Series 1.* Geology of the Nipigon basin, Ontario, 1910—by Alfred W. G. Wilson.

MEMOIR 2. *Geological Series 2.* Geology and ore deposits of Hedley mining district, British Columbia, 1910—by Charles Camsell.

MEMOIR 3. *Geological Series 3.* Palæoniscid fishes from the Albert shales of New Brunswick, 1910—by Lawrence M. Lambe.

MEMOIR 4. *Geological Series 7.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec, 1911—by W. J. Wilson.

MEMOIR 5. *Geological Series 4.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory, 1910—by D. D. Cairnes.

MEMOIR 6. *Geological Series 5.* Geology of the Haliburton and Bancroft areas, Province of Ontario, 1910—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *Geological Series 6.* Geology of St. Bruno mountain, Province of Quebec, 1910—by John A. Dresser.

MEMOIR 8. *Geological Series 8.* The Edmonton coal field, Alberta, 1911—by D. B. Dowling.

MEMOIR 9. *Geological Series 9.* Bighorn coal basin, Alberta, 1911—by G. S. Malloch.

MEMOIR 10. *Geological Series 10.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in south-western Ontario, 1911—by J. W. Goldthwait.

MEMOIR 11. *Topographical Series 1.* Triangulation and spirit levelling of Vancouver island, B.C., 1909, issued 1910—by R. H. Chapman.

MEMOIR 12. *Geological Series 11.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906, issued 1911—by Anton Handlirsch.

MEMOIR 13. *Geological Series 14.* Southern Vancouver island, 1912—by Charles H. Clapp.

MEMOIR 14. *Biological Series 1.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia, 1911—by William H. Dall and Paul Bartsch.

MEMOIR 15. *Geological Series 12.* On a Trenton Echinoderm fauna at Kirkfield, Ontario, 1911—by Frank Springer.

MEMOIR 16. *Geological Series 13.* The clay and shale deposits of Nova Scotia and portions of New Brunswick, 1911—by Heinrich Ries assisted by Joseph Keele.

MEMOIR 17. *Geological Series 28.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., 1913—by Morley E. Wilson.

MEMOIR 18. *Geological Series 19.* Bathurst district, New Brunswick, 1913—by G. A. Young.

MEMOIR 19. *Geological Series 26.* Geology of Mother Lode and Sunset mines, Boundary district, B.C., 1914—by O. E. LeRoy.

MEMOIR 20. *Geological Series 41.* Gold fields of Nova Scotia, 1914—by W. Malcolm.

MEMOIR 21. *Geological Series 15.* The geology and ore deposits of Phoenix Boundary district, British Columbia, 1912—by O. E. LeRoy.

MEMOIR 22. *Geological Series 27.* Preliminary report on the serpentines and associated rocks in southern Quebec,, 1914—by J. A. Dresser.

MEMOIR 23. *Geological Series 23.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C., 1914—by J. Austen Bancroft.

MEMOIR 24. *Geological Series 16.* Preliminary report on the clay and shale. deposits of the western provinces, 1912—by Heinrich Ries and Joseph Keele.

MEMOIR 25. *Geological Series 21.* Report on the clay and shale deposits of the western provinces, Part II, 1914—by Heinrich Ries and Joseph Keele.

MEMOIR 26. *Geological Series 34.* Geology and mineral deposits of the Tulameen district, B.C., 1913—by C. Camsell.

MEMOIR 27. *Geological Series 17.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911, issued 1912.

MEMOIR 28. *Geological Series 18.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario, 1912—by Charles D. Walcott.

MEMOIR 29. *Geological Series 32.* Oil and gas prospects of the northwest provinces of Canada, 1913—by W. Malcolm.

MEMOIR 30. *Geological Series 40.* The basins of Nelson and Churchill rivers, 1914—by William McInnes.

MEMOIR 31. *Geological Series 20.* Wheaton district, Yukon Territory, 1913—by D. D. Cairnes.

MEMOIR 32. *Geological Series 25.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C., 1914—by R. G. McConnell.

MEMOIR 33. *Geological Series 30.* The geology of Gowganda Mining Division, 1913—by W. H. Collins.

MEMOIR 34. *Geological Series 63.* The Devonian of southwestern Ontario, 1915—by C. R. Stauffer.

MEMOIR 35. *Geological Series 29.* Reconnaissance along the National Transcontinental railway in southern Quebec, 1913—John A. Dresser.

MEMOIR 36. *Geological Series 33.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C., 1914—by C. H. Clapp.

MEMOIR 37. *Geological Series 22.* Portions of Atlin district, B.C., 1913—by D. D. Cairnes.

MEMOIR 38. *Geological Series 31.* Geology of the North American Cordillera at the forty-ninth parallel, Parts 1 and II, 1913—by Reginald Aldworth Daly.

MEMOIR 39. *Geological Series 35.* Kewagama Lake map-area, Quebec, 1914—by M. E. Wilson.

MEMOIR 40. *Geological Series 24.* The Archæan geology of Rainy Lake, 1914—by Andrew C. Lawson.

MEMOIR 41. *Geological Series 38.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick, 1914—by Marie C. Stopes.

MEMOIR 42. *Anthropological Series 1.* The double-curve motive in northeastern Algonkian art, 1914—by Frank G. Speck.

MEMOIR 43. *Geological Series 36.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec, 1914—by J. J. O'Neill.

MEMOIR 44. *Geological Series 37.* Clay and shale deposits of New Brunswick, 1914—by J. Keele.

MEMOIR 45. *Anthropological Series 3.* The inviting-in feast of the Alaska Eskimo, 1914—by E. W. Hawkes.

MEMOIR 72. *Geological Series 60.* The artesian wells of Montreal, 1915—by C. L. Cumming.

MEMOIR 73. *Geological Series 58.* The Pleistocene and Recent deposits of the, island of Montreal, 1915—by J. Stansfield.

MEMOIR 74. *Geological Series 61.* A list of Canadian mineral occurrences, 1915—by R. A. A. Johnston.

MEMOIR 75. *Anthropological Series 10.* Decorative art of Indian tribes of Connecticut, 1915—by Frank G. Speck.

MEMOIR 76. *Geological Series 62.* Geology of the Cranbrook map-area, 1915—by S. J. Schofield.

MEMOIR 77. *Geological Series 64.* Geology and ore deposits of Rossland, B.C., 1915—by C. W. Drysdale.

MEMOIR 78. *Geological Series 66.* Wabana iron ore of Newfoundland, 1915—by A. O. Hayes.

MEMOIR 79. *Geological Series 65.* Ore deposits of the Beaverdell map-area, 1915—by L. Reinecke.

MEMOIR 80. *Anthropological Series 11.* Huron and Wyandot mythology, 1915—by C. M. Barbeau.

MEMOIR 81. *Geological Series 67.* Oil and gas fields of Ontario and Quebec, 1915—by Wyatt Malcolm.

MEMOIR 82. *Geological Series 68.* Rainy River district, Ontario. Surficial geology and soils, 1915—by W. A. Johnston.

MUSEUM BULLETINS.

The Museum Bulletins, published by the Geological Survey, are numbered consecutively and are given a series number in addition, thus: Geological Series No. 1, 2, 3, etc.; Biological Series No. 1, 2, 3, etc.; Anthropological Series No. 1, 2, 3, etc.

In the case of Bulletins 1 and 2, which contain articles on various subjects, each article has been assigned a separate series number.

The first Bulletin was entitled *Victoria Memorial Museum Bulletin;* subsequent issues have been called *Museum Bulletins.*

MUS. BULL. 1. (*Issued* 1913). *Geological Series 1.* The Trenton crinoid, Ottawacrinus, W. R. Billings—by F. A. Bather.

Geological Series 2. Note on Merocrinus, Walcott—by F. A. Bather.

Geological Series 3. The occurrence of Helodont teeth at Roche Miette and vicinity, Alberta—by L. M. Lambe.

Geological Series 4. Notes on Cyclocystoides—by P. E. Raymond.

Geological Series 5. Notes on some new and old Trilobites in the Victoria Memorial Museum—by P. E. Raymond.

Geological Series 6. Description of some new Asaphidae—by P. E. Raymond.

Geological Series 7. Two new species of Tetradium—by P. E. Raymond.

Geological Series 8. Revision of the species which have been referred to the genus Bathyurus (preliminary report)—by P. E. Raymond.

Geological Series 9. A new Brachiopod from the base of the Utica—by A. E. Wilson.

Geological Series 10. A new genus of dicotyledonous plant from the Tertiary of Kettle river, British Columbia—by W. J. Wilson.

Geological Series 11. A new species of Lepidostrobus—by W. J. Wilson.

Geological Series 12. Prehnite from Adams sound, Admiralty inlet, Baffin island, Franklin—by R. A. A. Johnston.

Biological Series 1. The marine algæ of Vancouver island—by F. S. Collins.

Biological Series 2. New species of mollusks from the Atlantic and Pacific coasts of Canada—by W. H. Dall and P. Bartsch.

Biological Series 3. Hydroids from Vancouver island and Nova Scotia—by C. McLean Fraser.

Anthropological Series 1. The archæology of Blandford township, Oxford county, Ontario—by W. J. Wintemberg.

MUS. BULL. 2. (Issued 1914). *Geological Series 13.* The origin of granite (micropegmatite) in the Purcell sills—by S. J. Schofield.

Geological Series 14. Columnar structure in limestone—by E. M. Kindle.

Geological Series 15. Supposed evidences of subsidence of the coast of New Brunswick within modern time—by J. W. Goldthwait.

Geological Series 16. The Pre-Cambrian (Beltian) rocks of southeastern British Columbia and their correlation by S. J. Schofield.

Geological Series 17. Early Cambrian stratigraphy in the North American Cordillera, with discussion of Albertella and related faunas—by L. D. Burling.

Geological Series 18. A preliminary study of the variations of the plications of Parastrophia hemiplicata, Hall—by A. E. Wilson.

Anthropological Series 2. Some aspects of puberty fasting among the Ojibwa—by Paul Radin.

MUS. BULL. 3. *Geological Series 19.* The Anticosti Island faunas, 1914—by W. H. Twenhofel.

MUS. BULL. 4. *Geological Series 20.* The Crowsnest volcanics, 1914—by J. D. MacKenzie.

MUS. BULL. 5 *Geological Series 21.* A Beatricea-like organism from the middle Ordovician, 1914—by P. E. Raymond.

MUS. BULL. 6. *Anthropological Series 3.* Prehistoric and present commerce among the Arctic Coast Eskimo, 1915—by V. Stefansson.

MUS. BULL. 7. *Biological Series 4.* A new species of Dendragapus (Dendragapus Obscurus Flemingi) from southern Yukon Territory, 1914—by P. A. Taverner.

MUS. BULL. 8. *Geological Series 22.* The Huronian formations of Timiskaming region, Canada, 1914—by W. H. Collins.

MUS. BULL. 9. *Anthropological Series 4.* The Glenoid Fossa in the skull of the Eskimo, 1915—by F. H. S. Knowles.

MUS. BULL. 10. *Anthropological Series 5.* The social organization of the Winnebago Indians, an interpretation, 1915—by P. Radin.

MUS. BULL. 11. *Geological Series 23.* Physiography of the Beaverdell map-area and the southern part of the Interior plateaus of British Columbia, 1915—by L. Reinecke.

MUS. BULL. 12. *Geological Series 24.* On Eoceratops Canadensis, gen. nov., with remarks on other genera of Cretaceous horned dinosaurs, 1915—by L. M. Lambe.

MUS. BULL. 13. *Biological Series 5.* The double-crested Cormorant (Phalacrocorax Auritus) and its relation to the salmon industries on the Gulf of St. Lawrence, 1915—by P. A. Taverner.

MUS. BULL. 14. *Geological Series 25.* The occurrence of glacial drift on the Magdalen islands, 1915—by J. W. Goldthwait.

Mus. Bull. 15. *Geological Series 26.* Gay Gulch and Skookum meteorites 1915—by R. A. A. Johnston.

Mus. Bull. 16. *Anthropological Series 6.* Literary aspects of North American mythology, 1915—by P. Radin.

Mus. Bull. 17. *Geological Series 27.* The Ordovician rocks of Lake Timiskaming, 1915—by M. Y. Williams.

Mus. Bull. 18. *Geological Series 28.* Structural relations of the Pre-Cambrian and Palæozoic rocks north of the Ottawa and St. Lawrence valleys, 1915—by E. M. Kindle and L. D. Burling.

Mus. Bull. 19. *Anthropological Series 7.* A sketch of the social organization of the Nass River Indians, 1915—by E. Sapir.

Mus. Bull. 20. *Geological Series 29.* An Eurypterid horizon in the Niagara formation of Ontario, 1915—by M. Y. Williams.

Mus. Bull. 21. *Geological Series 30.* Notes on the geology and palæontology of the lower Saskatchewan River valley, 1915—by E. M. Kindle.

UNCLASSIFIED.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont., 1910—by W. H. Collins.

Report on the geological position and characteristics of the oil-shale deposits of Canada, 1910—by R. W. Ells.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories, 1910—by Joseph Keele.

Summary Report for the calendar year 1909, issued 1910.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902, issued 1911—by Alfred W. G. Wilson.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers, 1911—by W. McInnes.

Report on the geology of an area adjoining the east side of Lake Timiskaming, 1911—by Morley E. Wilson.

Summary Report for the calendar year 1910, issued 1911.

Summary Report for the calendar year 1911, issued 1912.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2, 1913.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario, 1913.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa, 1913.

Guide Book No. 4. Excursions in southwestern Ontario, 1913.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island, 1913.

Guide Book No. 8. Toronto to Victoria and return via Canadian Pacific and Canadian Northern railways; parts 1, 2, and 3, 1913.

Guide Book No. 9. Toronto to Victoria and return via Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways, 1913.

Guide Book No. 10. Excursions in northern British Columbia and Yukon Territory and along the north Pacific coast, 1913.

Summary Report for the calendar year 1912, issued 1914.

Prospector's Handbook No. 1. Notes on radium-bearing minerals. 1914—by Wyatt Malcolm.

The archæological collection from the southern interior of British Columbia, 1914—by Harlan I. Smith.

Summary Report for the calendar year 1913, issued 1915.

Summary Report for the calendar year 1914, issued 1915.