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GLACIAL DEPOSITS OF SOUTHWESTERN ALBERTA IN THE VICINITY OF THE ROCKY MOUNTAINS

BY

GEORGE M. DAWSON

WITH THE COLLABORATION OF R. G. MCCONNELL

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(*Presented before the Society August 28, 1895*)

CONTENTS

INTRODUCTION.

The western plains and the Rocky Mountain region of Canada undoubtedly constitute one of the most important fields of investigation in connection with the glacial period in North America. The area there characterized by glacial deposits is an enormous one, but the facts derived from it have so far been accorded comparatively little weight in the construction of hypotheses for the continent. Of these hypotheses those in best standing have grown up chiefly during the detailed study of the southern portion of the glaciated region of the east. Distance, and a general unfamiliarity with the somewhat complex physical features of this western region, have undoubtedly prevented a ready appreciation of its phenomena, but these also must in the end be fully reckoned with before satisfactory conclusions of a general kind can be definitely reached. In former papers* the writer has endeavored to combine the observations made by himself and others in the Cordillera and adjacent parts of the Great plains in a common scheme, although one admittedly of a char-

*Am. Geologist, Sept., 1890, p. 153. On the Physiographical Geology of the Rocky Mountain region in Canada. Trans. Roy. Soc. Can., vol. viii, sec. 4, 1890, p. 4.

acter entirely tentative. In the following notes his purpose is merely to amplify previous observations on a particularly interesting part of this western region by the addition of new facts, given, as far as possible, apart from any theoretical considerations whatever. In the concluding pages, however, an attempt is made to indicate the more obvious deductions which appear to flow directly from the examination of the particular district in question.

In a report by the writer on the southern portion of the district of Alberta,* the principal facts then ascertained of the "superficial geology" are given, but the work upon which that report was based was directed chiefly to the "solid geology" of the country, and details respecting the superficial geology were as far as possible eliminated in the interests of brevity. Since the publication of that report great advances have been made in our knowledge of the glacial phenomena of the northern part of the continent, some of which seemed to render the region particularly referred to in this paper one of especial importance as the meeting place of the deposits (whether immediately or proximately derived) of the Cordilleran and Laurentide ice-sheets. Thus it became desirable that an attempt should be made to further investigate this region and to test the previous observations and conclusions. With this object in view, a couple of weeks in the early part of the summer of 1894 were devoted chiefly to a critical examination of the superficial deposits of that part of southwestern Alberta adjacent to the eastern slopes of the Rocky mountains. The writer was accompanied by Mr R. G. McConnell, who had previously acted as his assistant in the same field, and, while he assumes the responsibility for the statements made in the sequel, those observations made by Mr McConnell will be given under his own name and in his own words. He would further take this opportunity of acknowledging the value of Mr McConnell's coöperation, and of stating that in regard to the observations of fact, at least, there is complete unanimity between himself and that gentleman.

Physical Features of the Region.

The region treated of may be described as extending from the international boundary northward to Bow river, or in latitude from 49° to 51° 20′. The eastern edge of the Rocky mountains proper (Laramide range) is defined by the line separating the Paleozoic rocks from those of the Cretaceous and Laramie, and, although this line is not a perfectly definite one, it corresponds closely with the orographic features, and the eastern front of the mountains is often particularly abrupt and striking. The want of definiteness referred to arises from the fact that embayments

* Report on the Geology of the Bow and Belly Rivers region. Geol. Survey of Canada, 1882–'84.

and infolds of Cretaceous rocks occur in this part of the mountains, while at least one isolated area of Paleozoic rocks is found to the east of the main margin of the range. Both the mountains and the adjacent foothills have been subjected to similar parallel folding and disturbance at the same post-Cretaceous orogenic period.*

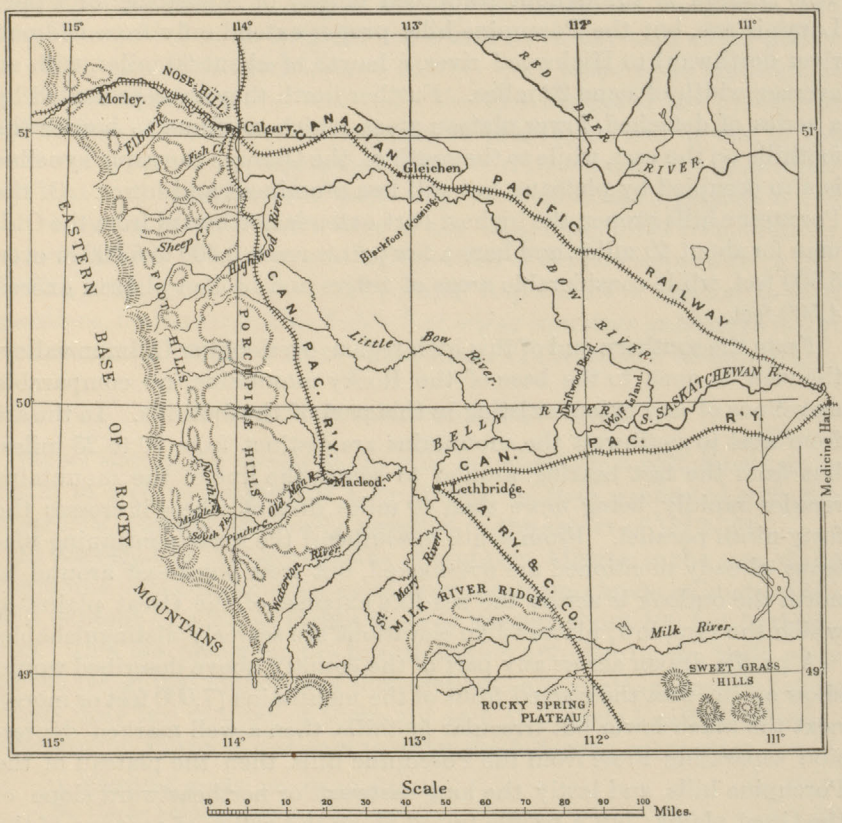

FIGURE 1.—*Southwestern Part of the District of Alberta.*

The foothill belt varies in width from 10 or 12 miles in its southern part to about 20 miles at the north, in the vicinity of Bow river. Fundamentally, the foothills represent a bordering zone of folded and contorted Cretaceous rocks, reduced by denudation to series of more or less nearly parallel ridges and valleys. The rivers and larger streams from the mountains generally cut across nearly at right angles in wide and relatively low transverse valleys, while the higher ridges and hills occasionally surpass 5,000 feet in elevation.

* For some notes on this and on the Pliocene history of the region, see Am. Jour. Sci., June, 1895, p. 463.

On the east the boundary of the foothills proper coincides with that of the flexed strata, and is nearly always quite definite, the corrugations ceasing abruptly and being succeeded by a wide, low syncline, which is continuous between the latitudes above referred to, and is occupied by the remnants of a long elevated plateau—that of the Porcupine hills. This plateau is throughout composed chiefly of sandstones of Upper Laramie age, but the Porcupine hills proper extend only from Oldman river northward to Highwood river, a length of about 60 miles, with an average width of some 20 miles. Further north they are represented by a series of detached, lower plateau areas, which continue to border the foothills on the east, while to the south of the Oldman the same syncline is also occupied by plateaus, but still less prominent and lower. Of the Porcupine hills proper, the highest part extends northward from the Oldman for about 40 miles, and here a few points reach 5,300 to 5,400 or even 5,500 feet, while considerable areas of ridges and broken plateau exceed 4,500 feet.

From the southern end of this high region, overlooking Oldman valley, the view is open to the base of the Rocky mountains, no comparable elevations of any extent existing in this part of the foothills. In the arc from west to southwest the mountains are distinct from 20 to 25 miles, but from the last bearing, around to south, the line of the mountains recedes rapidly, being more than 40 miles distant where it crosses the forty-ninth parallel. From south to southeast the lower continuing plateaus already mentioned are overlooked, but from southeast around to north the outlook is across the sea-like expanse of the Great plains, of which the rare, low, plateau-like elevations are scarcely distinguishable.

A profile drawn across any part of the country above described would show on the west the rugged front of the mountains (7,000 feet or more), next the much lower but irregular foothills, then a well marked depression separating these from the Porcupine hills, then the plateau of the Porcupine hills, and lastly the long eastward or northeastward slope of the Great plains; but a profile traced along the valley of any one of the larger streams, and thus following the actual drainage level of the country, would show a nearly uniform descent from the base of the mountains, only slightly increased in slope while crossing the foothill belt. These streams leave the mountains at an average elevation of about 4,350 feet. Along the eastern edge of the Porcupine syncline the plains have a nearly uniform height of about 3,300 feet, with which the general level of the rivers may be considered as practically coincident, although these often occupy postglacial valleys of from 100 to 200 feet in depth below the adjacent plain; thence to the northeastward the surface of the plain (with its rivers) gradually descends some 1,000 feet in a distance of about 120 miles.

The two most notable breaks in the continuity of the foothill belt and the Porcupine Hills plateau are those of the Bow valley and the valley occupied by the Oldman and its tributaries. The latter especially, which is not merely a wide river valley, but occurs in conjunction with the breaking off to the south of the highlands of the Porcupine hills, is an important and wide opening in the approaches to the mountains, and may be regarded as an irregular southwestern embayment of the plains, in which Laurentian erratics had already been found at an elevation of 5,280 feet above sealevel and upon the very margin of the mountains themselves. It was therefore chiefly in this region and in that of the Bow valley, taken in conjunction with the elevated tracts in their vicinity, that further information respecting the conditions of glaciation and the character of the western edge of the Laurentian drift seemed likely to be obtained. The southern high portion of the Porcupine hills in particular, it appeared, might be of peculiar importance in relation to such questions, for here it was probable that either moraines or terraces might characterize the farthest and highest limits of the drift of eastern origin.

Summary of previous Observations.

Before stating the results of the late investigation it will, however, be useful to give, in the form of a summary, the facts connected with the superficial deposits previously recorded in the report of 1882–'84.

In the region of the Great plains of southern Alberta, to the east of the Porcupine hills and their representatives, an approximate estimate of the drift deposits as a whole makes these to average about 100 feet in thickness. In a few places on the line of section afforded by the Belly river all the recognized members of these deposits are together present, but in others only two or three of them are seen at a single locality. A complete section shows in descending order the following succession:

1. Stratified sands, gravels or silts.
2. Upper boulder-clay.
3. Stratified interglacial deposits, sometimes including lignite.
4. Lower boulder-clay.
5. Quartzite shingle, sometimes with stratified sands and silts.

The absolute and relative thickness of each of these deposits varies much, and along Bow river, somewhat farther to the north, the interglacial beds were not noted, and no line of separation as between an upper and lower boulder-clay was in consequence determined.* The under-

*This may, however, in part result from the fact that the importance of such a separation was not recognized at the time these sections were examined, but it is certain that there is here no such striking plane of division as on Belly river. Still further north, on Rosebud creek, Mr J. B. Tyrrell again found two boulder-clays separated by a thin layer of lignite. Geol. Survey of Canada' vol. ii, new series, p. 143 E.

lying "quartzite shingle," subsequently named by Mr McConnell the "Saskatchewan gravels,"* was, however, seen in a number of places along the Bow, the evidence here, as elsewhere, being such as to show that this deposit, although widespread, is generally characteristic of the relatively lower tracts of the plains.

It is thus not often possible to determine, where boulder-clay is met with in isolated exposures, whether the lower or upper boulder-clay is represented, but it is probable that the upper or newest boulder-clay is that generally seen in all the more superficial excavations.

"Overlying the boulder-clay are widespread stratified deposits, the distribution of which assists materially in giving uniformity to the tracts of level plain. It is, indeed, quite exceptional to find the surface soil consisting of boulder-clay disintegrated in place, and this occurs only on the slopes of plateaus, or in hollows formed by denudation. That the beds overlying the boulder-clay have not been merely formed by its rearrangement in water without the addition of new material, is indicated by the fact that in many places erratics much larger than those characterizing the boulder-clay of the locality are found strewn over the surface of the country.† The beds observed in river sections and elsewhere to overlie the boulder-clay are generally gravels or sands below and sandy or clayey loams above. The latter form the subsoil over most of the region, and are generally rather pale brownish- or yellowish-gray in color."

Further study has served to verify and in some directions to amplify the statements summarized in the foregoing paragraphs.

On the subject of terraces and water-leveled tracts it is said in the same report:

"Terraces are prominent features in some parts of the river valleys in this district, but are generally clearly due to the action of the river itself at a former period. The extensive tracts of almost perfectly level prairie which occur, afford evidence of water action of some duration and may be regarded as wide terraces."

The conditions of the drift deposits in the region of the Porcupine Hills were not fully examined at this time and it is merely stated in the report that—

"The eastern face of the Porcupine hills appears from a distance to be very distinctly terraced, but this aspect was found to be due to the outcrop of the nearly horizontal sandstone beds."

Further and more extended investigation in 1894 shows that while the existence of these sandstone outcrops has contributed to the form assumed by the Porcupine hills, true water-formed terraces also exist and are actually found to extend to very great elevations, as more fully noticed in the sequel.

Respecting the general aspect of the drift deposits in the foothill re-

† Or "South Saskatchewan gravels." Ann. Rep. Geol. Survey of Canada, vol. i, new series, p. 70 C.
‡ Compare McConnell. Op. cit., p. 74 C.

gion between the Porcupine hills and the base of the mountains, little change can be made in the following statement given in the report of 1882-'84:

"Terraces in the entrance to the South Kootanie pass, at a height of 4,400 feet, have already been described in my Boundary Commission Report (1875). In the valleys of Mill and Pincher creeks, and those of the forks of the Oldman, east of the actual base of the mountains, wide terraces and terrace-flats are found, stretching out from the ridges of the foothills, and running up the valleys of the various streams. Actual gravelly beaches occasionally mark the junction of the terraces with the bounding slopes, and they have no connection with the present streams, which cut through them. The level varies in different localities, but the highest observed as well characterized attains an elevation of about 4,200 feet. In the Bow valley near Morley, and thence to the foot of the mountains, similar terraces are found, which are quite independent of the modern river; and in the wide valley of the Kananaskis pass a series of terraces was seen from a distance which must rise to an elevation of at least 4,500 feet."

It is important to note that in all this region there can be no doubt as to the origin of the crystalline erratics attributed to the Laurentian plateau of the east. Neither the Cretaceous nor Laramie rocks of the plains nor the Paleozoic strata of the mountains yield any such material, while the eastern derivation of the granitic and gneissic drift is further evidenced by its connected spread across the plains to the region of its supply. Thus the western limit of such characteristic erratics clearly indicates the extent of the drift from the Laurentian plateau. In regard to this western limit, it then was observed that it practically reaches the base of the Rocky mountains near the forty-ninth parallel, where Laurentian boulders were found at a height of 4,200 feet. Some 30 miles to the northwest and within a few miles of the mountains similar erratics were found at the mill on Mill creek (3,800 feet), and one was seen near Garnett's ranch (4,200 feet). It was added:

"I did not, however, observe any Laurentian drift on the North fork of the Oldman, and it is probable that it is absent or nearly so in the district sheltered by the higher parts of the Porcupine hills. On the Bow river no Laurentian or Huronian erratics were seen west of Calgary, and even after their first appearance they were very scarce for some distance" (to the eastward). The elevation of the Bow at Calgary is 3,393.6 feet,* and in comparing this with that of the more southern localities the conclusion was drawn that "the western limit of the Laurentian drift cannot conform strictly to any contour line of the present surface of the country."

The later investigations tend somewhat to modify the above statements in showing that Laurentian drift does occur in a scanty and

*This and some other elevations given here are derived from the results of the irrigation survey or from railway surveys. Most of the heights are less precise, depending on barometric observations reduced by comparison with Calgary. All may, however, be accepted within maximum limits of error (±) of 20 feet, and are sufficiently exact for all purposes of the present paper.

sporadic manner behind the Porcupine hills, and also by the discovery of such erratics on hills of some height above the Bow river at Calgary, although that place still remains the western limit in so far as the valley of the Bow is concerned.

The elevations just mentioned were not, however, the highest at which Laurentian erratics were found previous to the publication of the report of 1882–'84, for—

"In 1883 several indubitable Laurentian boulders, representing three varieties of granitic and gneissic rocks, were found about 20 miles north of the forty-ninth parallel, at an elevation of 5,280 feet."

These boulders occur stranded upon a morainic ridge, due to local glaciers of the adjacent mountains. On a plateau to the south of the Porcupine hills Laurentian stones were found, though not abundantly, at a height of 4,390 feet, while similar erratics were observed to be scattered over the high country near Milk river at a distance of from 30 to 40 miles from the mountains and at an elevation of 4,200 feet. The observations since made in the Porcupine hills enable considerable additions to be made to our previous knowledge of the maximum height attained by such eastern drift near the Rocky mountains.

Digressing for a moment to places farther from the eastern base of the mountains, it will be useful to remember that on West butte of the Sweet Grass hills, 90 miles east of the mountains,* Laurentian fragments were found to a height of 4,660 feet, while according to Mr McConnell the drift of this origin finds its limiting height on the Cypress hills 200 miles from the mountains, at 4,400 feet.† Both the places last mentioned are not far from the forty-ninth parallel; but much farther to the north, in the Hand hills (latitude 51° 25′, longitude 112° 20′), Mr J. B. Tyrrell has found a similar upper limit for Laurentian boulders at 3,400 feet.‡ These observations are cited here for purposes of comparison.

In the report of 1882–'84 it was stated that a similar limit occurred on the Rocky Spring ridge of northern Montana, 10 miles south of the boundary line and 66 miles from the mountains, at 4,100 feet. The plateau only slightly exceeds this height, and, while convinced of the accuracy of the observation at the time, its wide discrepancy from other results may perhaps be regarded as leaving it open to suspicion. I have not had an opportunity since of verifying it.

Before dealing with the facts ascertained in 1894, it should be noted that Mr McConnell had in 1890 carefully examined the sections of the glacial deposits along Bow river between the mountains and Gleichen (about 80

* In this and other cases, unless otherwise noted, distances from the mountains are measured at right angles from the nearest part of the base of the range.

† Op. cit., p. 75 C.

‡ Annual Report, Geol. Survey of Canada, vol. ii (n. s.), p. 145 E.

miles eastward), and there found reason to believe that the Saskatchewan gravels of the plains represent and gradually pass into a "western boulder-clay" in approaching the mountains. This observation has remained unpublished, but now appears to be well established, and it follows from it, taken in connection with the facts already summarized, that there are no less than three distinct boulder-clays in the region here treated of, the oldest or "western" boulder-clay being followed in time by that previously named the "lower" boulder-clay, which is in turn distinctly separated from the "upper" boulder-clay over a considerable part of the district, at least, by interglacial deposits. The western boulder-clay, as its name implies, contains no Laurentian or Huronian material, while such material, as well as limestone derived from the Winnipeg basin, is present in both the others. This general statement will serve as a clue to many of the observations subsequently detailed.

In further presenting the results of recent observations attention will first be given to the sections found on the Belly and Oldman rivers, to the surface of the plains in their vicinity, and to the wide low area which is occupied by the tributaries of the Oldman in the neighborhood of the mountains.

Sections in the Valleys of Oldman and Belly Rivers.

Although in the report of 1882–'84 the occurrence of two boulder-clays with an interglacial deposit was noted at Coal Banks (now Lethbridge) and a photograph was reproduced showing these deposits there running for miles along the bluffs of the river valley, no detailed section was recorded for this place. A careful examination was made of this section in 1894, at a place about four miles north of Lethbridge, with the following result: The valley of the river at this place is cut down about 300 feet into the prairie. From 50 to 80 feet above the water level is occupied by dark shales of the Pierre formation of the Cretaceous, resting upon which, along a perfectly even line, are the Saskatchewan gravels or "quartzite drift," with a thickness from 10 to 15 feet. The upper part of the shales, to a depth of two feet, is weathered and brownish in color. The gravels are coarse, often containing stones up to six inches in diameter, all well smoothed and water-worn, but often not perfectly rounded. They are generally arranged in a rather tumultuous manner; that is, not in regular layers graded according to size, and with the pebbles sometimes standing on end. The interspaces are filled with a coarse gray sand, and a similar material forms occasional discontinuous layers a few inches or feet in thickness on the upper surface of the gravels. The stones are chiefly characteristic Rocky Mountain quartzites, but a considerable number of pebbles of limestone from the same source are included, as well as a few examples of the peculiar Rocky Mountain

"greenstone," about which some remarks are made subsequently. One or two pebbles of peculiar crystalline rocks, not Laurentian, and probably from intrusive masses in the mountains, were also found.

The Saskatchewan gravels are sharply cut off above by a dark boulder-clay, the color of which is evidently due to the incorporation of a considerable proportion of the material of the Pierre shales and in which rather numerous crumbs of the coal of the vicinity are contained. The included stones are varied in origin, embracing quartzites from the mountains, Laurentian gneisses and some limestone of mountain origin, all often distinctly striated and glaciated. The thickness of this boulder-clay is about 50 feet.

Next in ascending order is a thickness, from 25 to 30 feet, of pale colored silty beds, often very finely stratified and in certain layers assuming a "leathery" character and showing layers of almost paper-like fineness. Crumbs of coal are present, but no lignite or peaty layer is here seen. This well bedded intercalation preserves its place and character for miles along the valley and is continuous with that previously described lower down the river.*

Overlying the last is the "upper" boulder-clay, yellowish gray in color, and this, so far as can be ascertained, extends nearly or quite to the top of the bank or the general level of the adjacent prairie. Stones and boulders are not notably abundant in it at this place, but those which occur came both from the mountains on the west and the Laurentian plateau on the east.

Summarizing this section and placing it in relation to others described in the report of 1882–'84, we obtain the following representation of the drift deposits of this part of the plains, the section on the right being that farthest from the base of the mountains:

Sections on Belly River.

Near Lethbridge.		Driftwood bend.		Wolf island.	
Distance from mountains, 60 miles.		Distance from mountains, 75 miles.		Distance from mountains, 85 miles.	
Height of base of section, 2,655 feet.		Height of base of section (approximate), 2,360 feet.		Height of base of section (approximate), 2,270 feet.	
	Feet.		*Feet.*		*Feet.*
Upper boulder-clay (about)..	140	.....	40	.....	100
Interglacial deposits.....	30	(Sands, ironstone, carbonaceous layers).....	33	(Sandy clay, with lignite)...	8
Lower boulder-clay.....	50	.....	80	.....	15
Saskatchewan gravels.....	15	(Below river level.)		(Gravels, sands and clay)....	40
Pierre (Cretaceous) shales..	65			(Cretaceous rocks).....	10
	300		153		173

* Report of Progress, Geol. Survey of Canada, 1882–'84, p. 144 C.

Before continuing the notes made in the deeper river sections to the westward of Lethbridge, a few words may be devoted to the character of the general surface of the plain corresponding to the sections above cited. This is well shown in numerous fresh cuttings along the line of railway between Dunmore (near Medicine Hat) and Lethbridge, a distance from east to west of 100 miles. Whether in the rolling prairie toward the east or the nearly level prairie to the west, the surface is almost uniformly composed of gray or brownish gray silty or loamy material, of which the depth may be stated to vary from two to five feet, although certainly greater in some places. On the crests of knolls and ridges and in some of the valleys which have evidently been cut out by postglacial flows of water, this deposit has been removed, leaving a grayish boulder-clay, which sometimes contains large stones at the surface. The stones are generally Laurentian, but are seldom abundant. It might be supposed that the prolonged action of rains or that even of the winds would in time produce a surface deposit of this kind, but much of the plain is so entirely flat that such explanations appear improbable. Neither are the projecting ridges notably bouldery, as should be the case if much denudation of their finer material had occurred, and the circumstances favor a belief that the silty deposits have been laid down in a body of rather shallow water, coextensive with the plain itself, in which some slight rearrangement of the exposed parts of the boulder-clay has taken place. There is some appearance of rolled gravelly deposits about the slopes of the ridges, but the cuttings are insufficient to show these fully.

Following the axis of the main depression already alluded to, no exposures have been found further to the westward in which the lower and an upper boulder-clay are clearly distinguished, and as the sections are not continuous, it becomes impossible to decide in each case which is represented. In an exposure nearly opposite Rye Grass flat, 12 miles west of Lethbridge (52 miles from the base of the mountains), locally upturned Laramie beds are overlain by 10 feet of stratified sand and silt, followed by 20 feet of boulder-clay, which again is followed by 12 feet of rolled gravels, apparently replaced in a short distance horizontally by stratified sands. The whole section is capped by some feet of the loamy superficial silts above described. The boulder-clay seen in this section includes a number of discontinuous layers of sand and gravel.

Another section of considerable length two miles and a half below Macleod (45 miles from the base of the mountains, elevation 3,024 feet) was carefully examined by Mr McConnell, and is described by him as follows:

"The boulder-clay is here 45 feet in thickness from the river level and is overlain by 20 feet of sands and silts which contain layers of finely

foliated leathery clays. The lower part of the boulder-clay is darker in color than the upper, but there is no division into upper and lower members, as dark and light layers alternate and change in color when followed along the bank. Stones both of western and eastern origin occur throughout, the former preponderating toward the bottom and the latter toward the top. The mass of the boulder-clay is in some places hard and clayey, in others soft and sandy, that of the last mentioned character passing occasionally into layers of sand and gravel."

The stratified sands, silts and leathery clays or shales of the above section much resemble the interglacial beds of Lethbridge, but, as already stated, there is here no means of certainly identifying the boulder-clay.

Farther up along Oldman river, at the mouth of Beaver creek (28 miles from the mountains, elevation about 3,260 feet), a bank examined by Mr McConnell shows, above the river level, "50 feet of compact boulder-clay overlain by 6 feet of stratified silts and sands. There is here a marked diminution in the proportion of eastern drift as compared with the last section, a rough estimate making it about two per cent of the whole."

In the same vicinity, on Oleson creek, about 400 feet above the river and to the north of it, a moderately indurated pale drab silty or sandy boulder-clay was found holding comparatively few stones, but some of them distinctly glaciated.

Still further to the westward, at the confluence of the North and Middle forks of the Oldman (about 15 miles from the line of the base of the mountains, elevation approximately 3,650 feet), a good section was found, which may be set out as follows in descending order:

	Feet
1. Well rolled and rounded gravels, with some stones as much as 8 or 10 inches in diameter, apparently all of Rocky mountain origin	10
2. Good typical boulder-clay, moderately indurated; matrix brownish yellow and earthy, containing glaciated stones and boulders of moderate size, mostly subangular, but some well rounded, derived from the mountains or from the Cretaceous rocks of the foothills, but chiefly quartzites; some limestone and a few examples of greenstone. Two or three small pieces of Laurentian rocks were found which probably came from this boulder-clay	20
3. Stratified, earthy, brownish yellow sands, containing a few glaciated stones.	10
4. Obscurely stratified gravels, containing some stones 10 inches through, all well rounded and like beach or river shingle. Traces of glaciation were suspected on a few of these, but were in no case observed to be absolutely decisive. The line between this and the overlying deposit is quite regular and definite. Although there is an appearance of blending in a thickness of a few inches, there is no sign of any intervening condition of importance	10
5. Laramie sandstones and shales to river level	40
	90

Numbers 3 and 4 of this section are believed to represent the Saskatchewan gravels, while number 2 may be either the lower or upper boulder-clay of the plains. Less than a mile to the northward the boulder-clay was observed to rest directly upon the Laramie rocks, numbers 3 and 4 having run out. Number 4 has in some places a clayey matrix, thus beginning to assume the character of the "western" boulder-clay.

About two miles further north, along the North fork and well behind the southern part of the Porcupine hills (elevation about 3,900 feet), another section was examined, of which, however, the total thickness remained indetermined because of slides in the bank. This again shows boulder-clay of a somewhat earthy and soft character, but containing many stones, derived from the mountains or adjacent foothills. The limestone pebbles are often distinctly but very lightly striated, and have apparently been well rounded by ordinary water action before the striation had been added. Two small crumbs of Laurentian material were discovered by search on the face of this exposure, but the decrease in importance of such material in the boulder-clay to the westward and where sheltered by the high ridges of the Porcupines is very apparent.

The comparatively soft and earthy character of the boulder-clay seen behind the Porcupine hills was generally observable.

Reverting to the main line of approach which we have been following toward the mountains, an exposure on the South fork of the Oldman, examined in 1883, may next be alluded to. This is distant from the mountains about 12 miles, with an approximate elevation of 3,700 feet. It again shows a boulder-clay, similar to the last, overlying a few feet of gravel derived from the mountains. Both deposits occupy a hollow, possibly that of an old river valley, as shown in the diagram annexed.

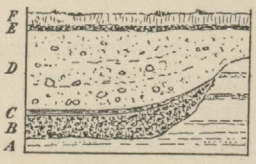

FIGURE 2.—*Section on the South Fork of Oldman River.*

A = Laramie (Willow creek) beds.
B = Saskatchewan gravels.
C = finely stratified clays.
D = boulder-clay.
E = surface gravel.
F = soil.

Base of section 25 feet above present river-level.

In 1881 another section was noted on Mill creek, still nearer to the mountains (six miles distant, elevation 3,817 feet), which showed boulder-clay of the usual character underlain by a very hard boulder-clay or till of different aspect, below which was a few feet in thickness of fine, compacted gravels. Some Laurentian stones were found on the surface in this vicinity above the level of the section, but none were seen in it. A similar instance of bouldery clay overlying thin layers of gravel was discovered in the same year high up on Pincher creek, in this neighborhood, within a couple of miles of the actual base of the mountains.

The two last mentioned localities are within the limit of the country

characterized by moraines, evidently due to local glaciers from the Rocky mountains, and the indurated boulder-clay of the Mill Creek section is believed, like the moraines, to be a deposit of these glaciers. The lower gravels in this case and in that of Pincher creek are obviously due to preglacial streams flowing from the mountains, and, although the name Saskatchewan gravels may be applied to them, they here evidently antedate the eastern gravelly representative of the Rocky mountains or earliest boulder-clay. Further to the east, where this boulder-clay gradually passes into such gravels, there is no means of distinguishing between wholly preglacial beds and those which may have been formed during the main period of the Rocky Mountain glaciers. Many exposures of the Saskatchewan gravels may include both, and this without necessitating the supposition of any great chronologic break.

Southern Part of the Porcupine Hills.

Having thus followed the main southern line of approach at low levels to the mountains, attention may next be given to the southern end of the Porcupine hills, which overlooks this avenue on the north side, at a distance from about 15 to 30 miles from the base of the mountains. Oleson and Beaver creeks flow southward from this end of the hills, and it was chiefly in the vicinity of these streams that the observations noted were made.

In traveling westward from Macleod (situated on the plains at an elevation of 3,070 feet) to Oleson creek by the regular trail north of Oldman river, a distance of 14 miles, a gradual ascent is made which becomes greater as the flanks of the hills are reached. The following terrace-levels were noted on this route:

North of Macleod an extensive gravel plain forming the angle between Oldman and Willow rivers is reached. This rises gradually from 3,130 feet in a distance of a couple of miles to 3,220 feet. Its surface is not absolutely flat, but is diversified by low swells or ridges, which generally trend north and south.

This plain is bounded to the west by a distinct rise leading to another similar plain or wide terrace, also gravelly, of which the eastern part is at a height of 3,275 feet, and which continues to slope up gradually to the westward. The gravels of this plain and the last are composed chiefly, but not entirely, of well rolled Rocky Mountain quartzites. At 3,286 feet on this second plain is found running northward a line of remarkable large boulders,* composed of quartzite or conglomerate. These are identical

*These remarkable boulders are in size and composition unlike any observed in the boulder-clays. They have undoubtedly been water-borne and may probably have been derived from some particular region of the Laurentian plateau which became tributary at a later stage of the Glacial period.

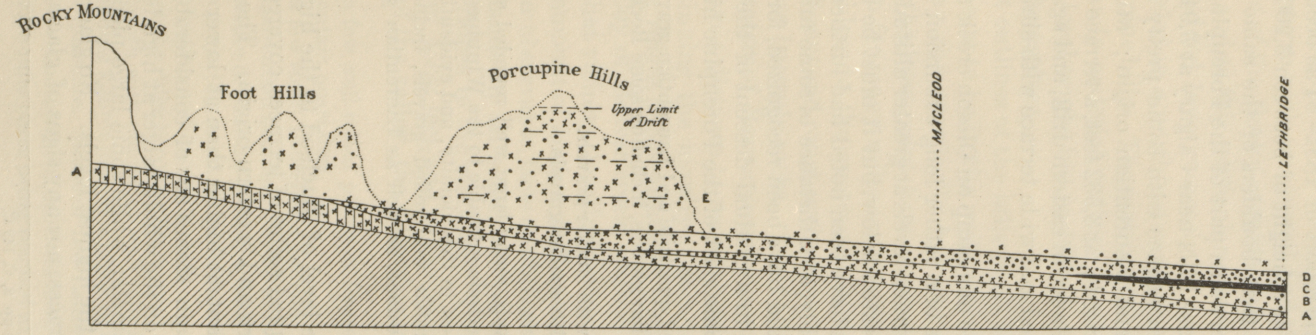

FIGURE 3.—*Diagrammatic Section from Lethbridge to Base of Rocky Mountains, along the Valley of Oldman River.*

A = (Albertan stage): Western boulder-clay passing to the eastward into Saskatchewan gravels.
B = "lower" boulder-clay.
C = interglacial deposits.
D = "upper" boulder-clay.
E = terraces and drift on the Porcupine hills.

This diagram is based on the hypothesis that the upper boulder-clay of the plains is that extending farthest to the west. Crosses indicate drift material from the mountains; dots, drift material from the Laurentian plateau. The Porcupine hills and foothills to the north of the section are shown in broken lines. The vertical scale is very greatly and not uniformly exaggerated.

in character with those noted in the report of 1882–'84 as occurring near the lower part of Waterton river at a height of between 3,200 and 3,300 feet,* and it may be added here that boulders of the same kind were found by Mr McConnell on the northern part of the Porcupine hills at a height of 3,950 feet, and on the Nose hills near Calgary at 3,940 feet.

At 3,316 feet is a boulder-strewn terrace with some pretty large boulders, both of Rocky mountain and Laurentian origin; at 3,387 feet, another terrace similarly characterized; at 3,532 feet, a terrace with rolled gravel on the surface and an abundance of eastern drift, and again at 3,643 feet occurs still another well marked and wide terrace with similar mixed drift.

From this a descent was made to our camp on Oleson creek (3,600 feet) and from this place, in the course of a rather long excursion in the hills to the northward, the following terrace-levels at greater altitudes were observed. These are briefly enumerated below, but it must be understood that many more such levels might have been noted had further time been given to the investigation. Possibly, at a distance of some miles, a quite different series of water-levels would have been recognized, for it appears probable that almost every stage in a gradual descent of the water-line may be found to be marked in some part of the Porcupine hills.

3,853 feet, a terrace-like flat with rolled quartzite and Laurentian gravel.
3,877 feet, an evident terrace with similar gravels, including some Rocky mountain limestone.
3,898 feet, a faintly impressed terrace with similar gravels.
4,182 feet, approximately, a terrace with similar gravels.
4,281 feet, a terrace with similar gravels.
4,349 feet, a terrace with similar gravels, many large well rounded stones, and a considerable proportion of limestone referable to the Winnipeg basin.
4,505 feet, a flat-topped hill, the highest in this vicinity, and evidently marking a terrace-level, covered with similar well rolled gravels, including Rocky Mountain quartzites and limestone, as well as Laurentian gneisses and Winnipeg limestones.

It is thus evident that from the level of Macleod to the highest point above noted there is an uninterrupted series of terraces, covered with well rounded pebbles of mixed eastern and western origin. The erratics of eastern origin are not less abundant at higher than at lower levels, and while some of the Rocky Mountain stones are of considerable size, the gneissic Laurentian boulders are, on the whole, larger at high levels, being often as much as three feet in diameter, while some large pieces of Winnipeg limestone were also seen at the highest levels. No glaciated stones were observed on these higher terraces, nor any signs of glaciation on the

* Op. cit. 14 pp. 8, C, 149 C.

sandstone outcrops where these occur, but the rock in place is rather too soft to preserve such traces well had they existed upon it. The peculiar greenstone of the Rocky mountains before referred to is not infrequent at all levels, and as this particular rock occurs in place in the mountains (as an interbedded layer) scarcely as far north as latitude 49° 30′, it must have traveled in a northeastward direction in order to reach this part of the Porcupine hills. The matrix of the gravels, wherever seen, is a whitish silty or sandy material, perhaps in part composed of disintegrated sandstones of local origin, but including grains of similar composition to the pebbles themselves.

The flat outlines of the hills in all this southeastern part of the Porcupines appears to be in the main plainly due to water-levelling, although assisted by the practically horizontal attitude of the sandstone beds. From the highest point here reached the terracing of the hills may be finely seen for many miles to the northward, but still higher and partly wooded ridges to the westward showed toward their summits an altogether different and rougher character, although fundamentally composed of the same Laramie rocks. The highest terrace seen on the hills, near the headwaters of Beaver creek, was very well marked, and was estimated by eye from a distance to reach about 4,900 feet above sealevel.

In continuing the inquiry it became evidently necessary to examine the higher ridges above alluded to, and this was accomplished from the upper valley of Beaver creek, whence an ascent was made to the highest point in that vicinity, locally known as Five-mile butte. In this region the total amount of foreign drift is less considerable and distinct terraces are seldom observable, facts doubtless due to the shelter afforded by adjacent highlands on all sides, but particularly to that of the wide belt of hills and ridges to the eastward. Our camp on Beaver creek was at an elevation of 4,222 feet, and in ascending from it to Five-mile butte, on the east side of the valley, the following notes were made:

4,950 feet, a few well rolled pieces of Laurentian, Winnipeg limestone and Rocky Mountain quartzites.

5,070 feet, a few small Laurentian pebbles.

5,144 feet, Laurentian boulders 2 feet 6 inches through, Rocky Mountain limestone, quartzite drift and probably a little Winnipeg limestone.

5,250 feet, a projecting point on the high ridge showing abundance of well rounded Laurentian and quartzite drift.

At 5,300 feet the ridge becomes flat-topped and probably marks a terrace-level. It is strewn with numerous well rolled pebbles of eastern and western origin, including Laurentian, Winnipeg limestone, and Rocky Mountain limestone and quartzite. Some of the Laurentian boulders are 2 feet in diameter.

Above this level nothing but debris of local sandstones was found, the highest point of Five-mile butte being reached at 5,365 feet.

It will be noted that the Laurentian drift is in this neighborhood markedly more abundant at the higher levels, the upper limit of the traveled material standing above all the hills and ridges to the eastward. A distinct terrace was observed on the opposite (west) side of Beaver Creek valley at an estimated height of about 5,130 feet. This may possibly correspond with that previously noted as seen from the hills above Oleson creek, but is not the same. The levels in both cases are necessarily somewhat uncertain.

In crossing the last ridge of the Porcupines on the west, between Beaver creek and the North fork of Oldman river, a height of 4,986 feet was reached, and here a few pebbles of Rocky mountain origin were found, although on projecting points 200 feet higher no traveled drift was observed. This evidence is, however, of a purely negative character. On the west slope, in descending toward the North fork, Laurentian drift was first recognized at 4,710 feet and continued sparingly down to about 4,060 feet. None was seen near the river itself (3,960 feet).

Plain and Valley West of the Porcupine Hills.

Between the Porcupines and the foothills proper a plain some miles in width here runs north and south. This to the eye appears almost perfectly level. It is continued southward beyond the Middle and South forks of the Oldman with increasing width and probably with a somewhat decreasing elevation. The lowest part of this plain actually traversed on our route is near the confluence of the North and Middle forks, with an elevation of 3,750 feet. In about three miles farther north it rises gradually to 4,140 feet, the surface being generally gravelly (number 1 of section on page 42). This gravel plain resembles in character that occurring near Macleod at an elevation lower by about 1,000 feet, but no eastern drift was found among the pebbles, which appear to have been entirely brought down by rivers flowing from the mountains.

In following the plain northward it becomes narrowed, but again widens about the bend of the North fork, where its average elevation is about 4,200 feet. From this vicinity (near the Upper Walrond ranch) the wide valley of North fork runs northwestward to the base of the mountains. It is floored by a regular terrace, apparently in continuation of the plain last referred to, which attaches to the bases of the neighboring hills some miles to the west at an elevation of about 4,400 feet.

From the Upper Walrond ranch a continuous valley, bounding the Porcupine hills on the west, runs northward to Highwood river, a distance of 48 miles. A very few small Laurentian boulders were seen near the ranch, and one was observed about a mile and a half to the north at a

FIGURE 1.—BLUFF ON HIGHWOOD RIVER.

Showing two boulder-clays, the higher passing above into stratified silts. The base of the boulder-clay here rests directly on Laramie rocks.

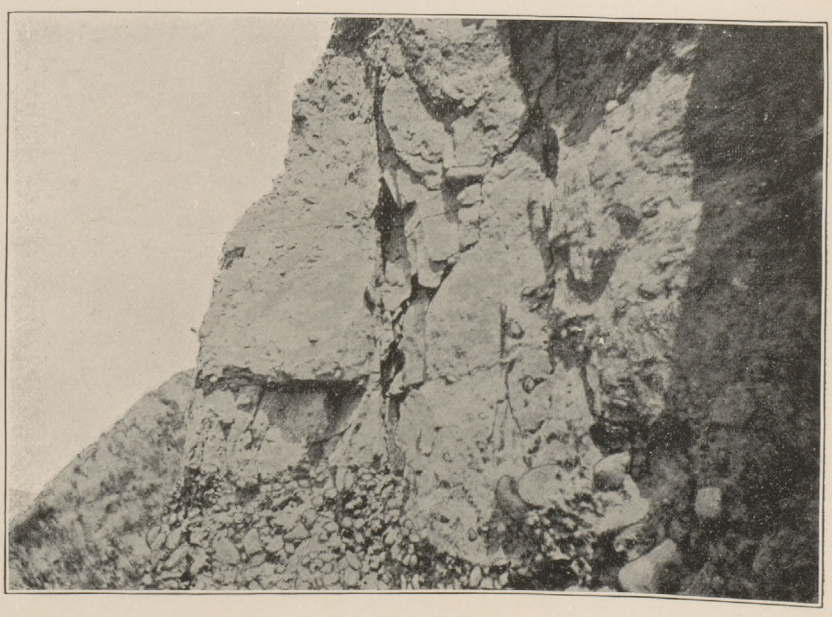

FIGURE 2.—PART OF SECTION ON BOW RIVER NEAR CALGARY.

Showing clayey Saskatchewan gravels overlain by boulder-clay.

BOULDER-CLAYS AND SASKATCHEWAN GRAVELS.

height of 4,400 feet; but no more eastern drift of any kind was found along the valley for 30 miles northward. If not entirely absent, it must here be extremely scarce.

At the distance just noted, near the chain of small lakes between the North branch of Willow creek and the South branch of the Highwood, where the wide gap of the Highwood valley begins to lay the country traversed more open to the eastward, a single Laurentian boulder was again seen. This was opposite the third or northernmost lake, at an elevation of 4,406 feet.

In this vicinity a well marked terrace was also found at 4,270 feet, with several others faintly impressed on the hillsides up to 4,500 feet, but no higher. The upward limit of terracing and of thick drift deposits appears here to be well defined. Large fragments of Rocky Mountain limestone are found here and there throughout this part of the foothills generally stranded on prominent ridges of sandstone.

At the head of the South branch of the Highwood, brownish earthy boulder-clay, with stones wholly derived from the mountains, was seen in the bank of a stream apparently resting directly on bed-rock. The surface of this boulder-clay forms a wide terrace-level in which the stream valley is cut out, with an elevation of 4,240 feet, rising to about 4,290 feet where it meets the slopes of the hills. In following the South branch northward to a point six miles from its confluence with the main Highwood, at a height of 3,960 feet, boulder-clay like the last was again seen, but here holding a few very small Laurentian fragments.

Highwood River and Vicinity.

To the eastward of the South branch Mr McConnell made a long detour among the northern ridges and plateaus of the Porcupine hills, the highest of which are there about 4,740 feet. Upon these he found abundance of Rocky Mountain limestone and quartzite, but no eastern drift above 4,150 feet and very little drift of this origin anywhere.

In the bank of the main Highwood, four miles above the mouth of the South fork (13 miles from the base of the mountains, elevation about 3,700 feet), Mr McConnell examined a section showing 35 feet of boulder-clay overlain by a considerable thickness of silts, and these in turn capped by river gravels. The boulder-clay is dark brownish below and light yellowish above, with stones seldom exceeding six inches in diameter, which, so far as observed, are wholly of western origin.

From the mouth of the South branch the Highwood was followed down to the crossing of the railway, and midway between these points some fine sections were found (see plate 1). The height of the river is here

about 3,500 feet and the distance from the mountains 19 or 20 miles. In descending order, the bluffs here show—

	Feet
1. Well stratified and current-bedded silts	5
2. Pale yellowish gray boulder-clay	15
3. Dark gray boulder-clay	20
4. Laramie sandstones and shales	15
	55

Both parts of the boulder-clay hold many and some large stones, often well glaciated and apparently all of western origin. The line between the two layers of boulder-clay is horizontal and quite distinct. Many of the larger stones occur about this level, and one of them was seen to lie about half in the lower and half in the upper division. It is not certainly known that the division between two classes of boulder-clay found in this and the preceding section corresponds with the horizon of the interglacial deposits previously described, but it is believed that numbers 1 and 2 correspond with numbers 2 and 3 of the Calgary section (see page 53).

A very few Laurentian fragments were seen in traveling from this place eastward to the town of High River, at the railway crossing (3,371 feet). They appeared to be more abundant to the east.

Highwood River to Calgary.

From the town of High River the regular road was followed northward to Calgary, 33 miles, crossing Sheep, Pine and Fish creeks and rising over eastward projections of the lower plateau, which here represents the Porcupine hills. The highest point reached between Highwood river and Sheep creek is about 3,623 feet. Here less than one-hundredth of the drift stones are Laurentian, the rest being from the mountains. At 3,495 feet, on the northern descent toward Sheep creek, perhaps one-fiftieth of the stones are Laurentian, but at a corresponding elevation on the southern slope toward the Highwood such stones are exceedingly scarce. At the crossing of Sheep creek (about 3,400 feet) a partially stratified stony deposit, resembling boulder-clay but showing no striated stones, contains a considerable proportion of Laurentian fragments.

Between Sheep and Pine creeks, beginning to the south at about 3,600 feet, rising to 3,790 feet and falling again toward Pine creek to 3,500 feet, is a lumpy, undulating country, comprising some hollows and swampy depressions without outlet, and repeating somewhat the characters of the Missouri Côteau on a much reduced scale. The surface is pretty thickly covered with soil, which is seen in places to be underlain by de-

posits of rolled gravel, but no sections of any depth occur. The extent of this country where crossed is about six miles. It is the only tract met with in this entire region which in any degree simulates the characters usually assumed as morainic. Nearly all the stones are from the west, but a very few Laurentian boulders are seen.

At the north end of the railway bridge over Fish creek a cutting has been made in pale grayish yellow boulder-clay, in which most of the stones are well rounded (though some pieces of Rocky Mountain limestone are striated) and all are of western origin. Laurentian boulders are here, however, not uncommon on the surface at elevations of 3,400 to 3,500 feet.

The higher parts of a wide plain, through the center of which the Bow valley is trenched, in the vicinity of Pine creek, have a level of about 3,500 feet.

Between Fish creek and Calgary, at heights of 3,400 to 3,500 feet, Laurentian boulders are found in increasing numbers. Some of them are several feet in diameter, and they are scattered over the surface apparently in association with deposits overlying the boulder-clay.

Sections in Bow River Valley.

At Calgary we reach Bow river, which has in the introductory pages of this paper been described as the second great avenue of approach to the mountains at low levels and the northernmost in the region here considered. Following the plan already adopted in the case of the Belly and Oldman rivers, some notice will now be given of observations made along the Bow from east to west, or in order, ascending the stream toward the mountains. These observations are chiefly those of Mr McConnell, who in 1890 descended the river in a boat from Morley to the Blackfoot crossing with the special purpose of investigating the superficial deposits, and supplemented this by a critical examination of these deposits at Medicine Hat. Medicine Hat is situated at a distance of about 155 miles from the nearest part of the mountains and about 270 miles from the mountains by a line measured along the general course of the Bow and South Saskatchewan rivers. Mr McConnell writes:

"The glacial deposits at Medicine Hat consist of light colored compact boulder-clays of the ordinary type, but showing in places faint lines of stratification, overlain by stratified sands and underlain by beds of quartzite pebbles, occasionally cemented into a conglomerate and sometimes associated with sands and silts.

"The line between the material derived from the east and that coming from the west is here drawn at the base of the boulder-clay; above that

horizon eastern gneissic and limestone boulders and pebbles, the latter often striated, are common, but no rocks of undoubted western origin were observed. The beds of well rounded quartzite pebbles below the boulder-clay, on the other hand, are derived, so far as known, entirely from the west, although they may here in part represent redistributed Miocene conglomerates like those of the Cypress hills, which were brought down from the mountains in Miocene times.

"Twenty miles above the Blackfoot crossing or 175 miles above Medicine Hat, where the next section was examined, the conditions have entirely changed. At this particular place the underlying gravels are absent and the boulder-clay holds both eastern and western drift intimately commingled throughout, pebbles of unmistakable Laurentian gneisses and well characterized Rocky Mountain limestones often lying side by side in the same hand specimen. The relative proportions of the two drifts at this point, 100 miles east of the mountains, measuring along the valley of the Bow, are nearly equal. In descending the river western drift of a recognizable character gives out in the boulder-clay before Medicine Hat is reached, and in ascending it the eastern drift gradually diminishes in relative quantity and disappears altogether above Calgary, 40 miles east of the mountains, or about 50 miles if the Bow valley be followed.

"Twenty-five miles above the Blackfoot crossing a boulder-clay section 110 feet in thickness is exposed. The boulder-clay is here separated into an upper and lower division by a band of stratified sands, the lower boulder-clay being darker colored than the upper one and differing from it also in containing a larger proportion of western drift. The junction between the two boulder-clays is not straight, but follows an irregular wavy line.

"At Pine canyon, eight miles above the last section, the Laramie sandstones are overlain by the Saskatchewan gravels 10 feet thick, above which is a peculiar morainic-looking deposit 40 feet thick, consisting of angular blocks of Laramie sandstone of local origin, gneisses and limestones from the east and limestones and quartzites from the west, all mixed confusedly together in a matrix of coarse sand and clay.

"Four miles above the last exposure the boulder-clay, here 50 feet thick, rests directly on the older rocks. The ratio of eastern to western drift in this exposure was estimated at about 1 or 2. A notable feature of the section is the presence in it of a gneissic boulder of eastern origin measuring fully three feet in diameter. The ordinary size of the eastern pebbles in the boulder-clay along this portion of the river seldom exceeds three inches in diameter.

"Two miles above the mouth of Highwood river the Saskatchewan

gravels appear again. They consist mostly of rounded quartzite pebbles and boulders, ranging in size from one to twelve inches in diameter, and have a thickness of eight feet. The pebbles increase in size toward the base of the formation. The boulder-clay above the gravel holds occasional gneissic pebbles, but they are small and scarce.

"Two miles above the last exposure the pebble bed passes into dark clays filled with stones of western origin only. Above this is 170 feet of boulder-clay, alternating in places with sandy layers. A mile below the mouth of Fish creek the gravels reappear, but are replaced a mile above Fish creek by stratified sands. Two miles farther on the sands pass into gravels again, and these continue to underlie the boulder-clay as far as Calgary. West of Highwood river the western gravels underlying the boulder-clay consist of limestone and quartzite, the proportion and size of the former increasing as the mountains are approached, but east of Highwood river they are composed almost entirely of quartzite. The gradual diminution in size of the limestone pebbles and their final disappearance to the east, while the quartzite constituents still continue, is no doubt due to their inferior hardness and consequent inability to stand the wear attendant on a lengthy journey under the conditions in which it was accomplished.

"The Saskatchewan gravels and associated sands and clays in the neighborhood of Fish creek are everywhere overlain by boulder-clays holding scratched limestone and quartzite pebbles and boulders from the west, and at rare intervals small gneissic pebbles from the east."

In my own descent of Bow river, in 1881, attention was chiefly devoted to the underlying rocks, but to the above description by Mr McConnell it may be added that the existence of the Saskatchewan gravels, though obscured by slides, was suspected at some places below the Blackfoot crossing.* Above the crossing these gravels appear sometimes at the water-level and sometimes at heights from 20 to 60 feet above it, but it is probable that if carefully looked for they might be recognized at short intervals all the way down to Medicine Hat.

At Calgary, on the north side of Bow river about a mile below the bridge, a very instructive and clear section occurs. This had been examined by Mr McConnell in 1890, and was in 1894 carefully reëxamined by that gentleman and myself. It shows in descending order: †

	Feet
1. Irregular deposits of gravel and silty soil	5
2. Stratified silts, with some lenticular layers of boulder-clay; striated stones and small boulders in both	35

* Report of Progress, Geol. Survey of Canada, 1882–'84, pp. 141 C, 142 C.

† Elevation of base of section, 3,390 feet.

	Feet
3. Boulder-clay, with some stratified silty layers and pebbles arranged in lines of stratification	20
4. Gravels	15
5. Laramie sandstones and shales, nearly horizontal	25
	100

The following details, written down at the time, further explain what is seen in this interesting section. The order followed is that of deposition, beginning with the base of the section: The surface of the Laramie rocks where composed of fairly hard sandstones is smooth and waterworn without any glacial striæ. Resting directly upon this are rather incoherent gravels with a considerable admixture of clayey or silty matter. All the stones are derived from the mountains, and most of them are quartzites (some 18 inches through), but Rocky Mountain limestone is also abundant. Nearly all are well rolled and rounded, but careful search shows traces of striation on some of the limestone pebbles. These appear to have been produced upon the already rounded stones and to have been largely obliterated afterwards by further wear. There is little or no trace of stratification in the gravels, which resemble more the deposit found in the bars or bed of some river than anything else.

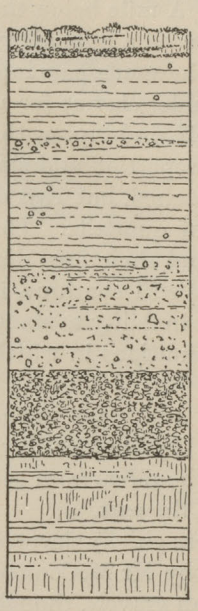

FIGURE 4.—*Section in Bank of Bow River near Calgary.*

A = Laramie rocks.
B = Saskatchewan gravels.
C = boulder-clay with silty layers.
D = stratified silts containing (D_1) a layer of boulder-clay.
E = surface gravels and soil.

The gravels are cut off above sharply on a nearly level plane, above which is a hard yellowish gray boulder-clay, often standing vertical in the face and breaking out in prismatic fragments. This contains many well striated stones and small boulders, and shows occasional lines, running for a few feet or yards horizontally of fine pebbles and sand, or of silt, which is slightly lighter in color than the rest. The vast majority of the stones are from the mountains, but a very few Laurentian stones are included. There is no marked difference between the earthy material of the gravels and that of the mass of the boulder-clay, except that the latter is more compacted, and the gravels might in fact well be regarded as a species of boulder-clay or a closely allied deposit. The boulder-clay probably varies from 10 to 20 feet in thickness within a few hundred feet.

The upper part of the boulder-clay becomes more interstratified with

silts and it thus passes up gradually into the next member of the section, which forms nearly the entire upper part of the bank. The silts overlying the boulder-clay are yellowish gray in color, well bedded and frequently show minute cross-bedding between the more prominent horizontal planes. They vary a little in tint and fineness and sometimes include layers two or three inches thick, of brownish color and leathery texture, composed of almost paper-like leaves. Glaciated stones, sometimes large, occur here and there throughout the silts, and they also include at this place one or more layers of a few feet thick which are markedly stony, not very distinctly stratified and differ in no material respect from the boulder-clay except that they are somewhat less coherent. Laurentian fragments become increasingly frequent toward the top of the silts, but are never abundant at this place.*

Above the bridge and about a mile distant another bank shows these silty deposits resting directly on the lower gravels without any boulder-clay.

It is here quite clear that the boulder-clay and silts represent a single deposit which took place under varying conditions and in which the boulder-clay forms, broadly speaking, lenticular masses, not persistent and not characteristic of any particular horizon or coextensive with the region of deposit. The section is as a whole, moreover, that of a series of stratified deposits, in which evidences of tumultuous deposit and obscure bedding occur only in the case of the boulder-clay and the underlying gravels.†

Beyond Calgary, Mr McConnell writes as follows of the sections along the river :

" Four miles above Calgary the glacial deposits consist in descending order of 3 feet of gravel and soil, 8 feet silt, 2 feet boulder-clay, 1½ feet silt and 20 feet of gravelly boulder-clay. No eastern pebbles are found in this section, nor were any found in the valley of the Bow west of Calgary, notwithstanding the fact that three miles to the northwest boulders of Laurentian origin occur on the summit of the Nose hills at an elevation of 550 feet above the river at this point (3,934 feet above sealevel).‡

*The boulder-clay in this section is evidently either the "lower" or "upper" boulder-clay of the plains. Boulder-clay holding eastern stones is here recognized for the last time in approaching the mountains by the Bow valley.

† It may here be noted that a section identical in character with that at Calgary has since been examined at Edmonton, on the Saskatchewan, abont 200 miles north, nearly in the same longitude and at an elevation of about 2,200 feet. The Saskatchewan gravels, sparingly developed, are here covered by 50 feet or more of alternating boulder-clay and well stratified silts. The boulder-clay occurs in layers of two, three or more feet in thickness. Most of the stones are included in it, and there are Laurentian and western in proportions respectively of about 1 to 2.

‡ Faintly impressed terraces, like those of the Porcupines, occur at several levels upon the eastern slope of this plateau, the best marked at a height of about 3,900 feet.

"Eight miles above Calgary a section showing the following sequence was examined:

	Feet.
1. Soil and silts	15
2. Clay with layers of silt	10
3. Gravelly sands	5
4. Stratified sands	4
5. Gravelly boulder-clay	6
6. Yellowish sands	40
	80

"The clay (number 2) underlying the upper silts is peculiar and was not observed farther east. It is destitute of stratification, light blue in color on a fresh surface, very compact and highly calcareous. It probably represents the fine material produced by glacier erosion, sorted from the coarse products, and carried eastward by glacial streams until the lessening current or a lake basin allowed its deposition. The silts overlying it have the characters of a lake deposit.

"Four miles below Cochrane (30 miles from the mountains) a section shows the same glacial clay referred to above, resting on boulder-clay and overlain by silts. The boulder-clay along this part of the river ranges in thickness from 20 to 40 feet and consists of a light drab colored sandy clay filled with striated and rounded pebbles and boulders of limestone and quartzite. It is separated in places from the overlying fine clay by sandy and gravelly beds, but in others merges gradually into it. The fine clay, like the boulder-clay, is variable in thickness, ranging from 15 to 50 feet. It holds a few scattered pebbles, which are often glaciated, and are occasionally found in an upright position and at various angles to the plane of the deposit—a fact probably due to their having been dropped from floating ice. The silts have a thickness here of about 100 feet. They exhibit curved cross-bedding, resembling the kind known as flow-and-plunge structure, except that the curved layers are short, seldom exceeding six inches in length, and the surfaces are concave upward. Pebbles, some of which are striated, occur throughout the section and lumps of clay are found at intervals.

"Opposite Cochrane the boulder-clay has a thickness of 125 feet. At the mouth of the Jumping Pound, three miles farther up, it is much thinner, and is overlain by flood-plain gravels. Half a mile below Ghost river the boulder-clay is overlain by 40 feet of coarse sands and gravels, above which is 20 feet of river wash.

"From this point to the mountains, a distance of about 20 miles, the boulder-clay has been washed away in most places and the older rocks are covered directly with river gravels. Small sections, however, occur at Morley, 15 miles east of the mountains, near the mouth of a creek

below old Bow fort, and possibly also at other places. The river here is unnavigable and was not closely examined.

"Bow river, in its passage through the foothills and for some distance beyond, is bounded by wide terraces floored with river gravels, which rise in an irregular manner to a height of about 250 feet above it. Traces of terraces exist at higher elevations, but the lines are not continuous. The accompanying illustration shows the outline of the valley a mile west of Morley.

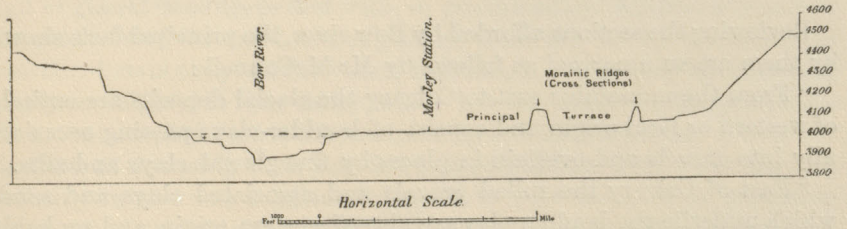

FIGURE 5.—*Section across Bow Valley at Morley.*

Showing the principal terrace, through which morainic ridges project and in which the present river-valley has been excavated since the Glacial period. At (x) a stone hammer was found in an excavation in the gravels, and it is believed to be contemporaneous with the formation of the small river-terrace indicated.

"From Cochrane west to the mountains a number of mounds and ridges, evidently of morainic origin, project through the terraces and are scattered along the slopes of the valley to a height of about 300 feet. The ridges are usually several hundred yards in length, 50 feet or more in height, and as a rule are either parallel or inclined at a small angle to the course of the valley. At Morley station such ridges and hills occupy a continuous area of fully a square mile.*

"The drift ridges are usually covered with vegetation and natural sections through them are scarce. The best sections examined were found in some railway cuttings half a mile west of Morley. The exposures here consist of hard boulder-clay of a light drab color, filled with pebbles and boulders of limestone and quartzite. The pebbles seldom exceed three inches in diameter, and while some of them are rounded and water-worn a large proportion are polished and striated. In composition the drift ridges suggest drumlins rather than ordinary moraines, but from their position there seems to be little doubt that they were deposited at the extremity and along the side of the Bow River glacier. Glacial groovings, evidently referable to the Bow Valley glacier, were found on the slopes of Bow valley south of Morley at a height of 560 feet above the river or about 260 feet above the morainic ridges just described."

Reverting to the section across the Bow valley above given by Mr

* Cf. Report of Progress, Geol. Survey of Canada, 1882–'84, p. 146 C.

McConnell,* it may be added that the same principal wide terrace there shown by him enveloping the morainic ridges was particularly observed by me in 1881 at a point about six miles farther up the valley, with an elevation of about 4,200 feet. In my note-book it is thus described:

"This (bench) is several miles wide and occurs on both sides of the river. It is sandy, gravelly or stony on the surface and is not a river-terrace, but must have been formed when water stood against the mountains at its level, the river from the pass no doubt bringing down the material. Its level at Morley is about 4,030 feet, giving a slope upward toward the west of nearly 30 feet to the mile."

Reviewing the sections afforded by Bow river, the principal facts shown by them are summarized as follows by Mr McConnell:

"From the mountains east to Calgary the glacial deposits are entirely of western or local origin and consist of boulder-clays passing occasionally into gravels and overlain in places by fine glacial clays and silts.

"East of Calgary the rolled gravels and associated clays and sands which underlie the boulder-clay are also of western origin, and probably represent, for some distance at least, the wash of streams flowing eastward from the Bow River glacier.

"From Calgary to a point between Blackfoot crossing and Medicine Hat the boulder-clay contains western, local and eastern material, the former greatly predominating at first, but gradually diminishing in relative quantity toward the east until it is entirely replaced by the latter, so far at least as it is capable of recognition.

"The third zone extends from a point above Medicine Hat eastward, and in it the boulder-clay, so far as known, is entirely of eastern or of local origin.

"The boulder-clays of the middle and eastern zones graduate into each other, but the relations between the middle and western zones are less clearly defined. At Calgary, the most westerly point at which mixed boulder-clay was found, it is underlain by a gravelly clay bed of western origin similar to certain phases of the western boulder-clay and undoubtedly a continuation of it, modified to some extent by water. The inferior position of this bed shows that part at least of the western drift was deposited before the advent of any material from the east; but whether the whole of it was laid down prior to the eastern invasion or not I was unable to ascertain."

Summary and Discussion.

In concluding this paper, which, because of a wish to present observed facts rather than any theoretical deductions, has attained considerable length, a few words may be added on the more obvious conclusions to

* Cf.; also op. cit., p. 146 C.

be derived from these facts and their interrelation. These conclusions are practically such as may directly be drawn from the region itself, not complicated by attempted correlation with distant fields, nor will I venture at the present time even to compare them with a scheme of glacial events in the west which has already been tentatively advanced by me.

As implied in Mr McConnell's summary of the Bow River section, just given, it may, I believe, now be stated with certainty that the earliest sign of glacial conditions met with in southwestern Alberta is found in the evidence of the extension of glaciers from the Rocky mountains to a certain distance beyond the base of that range. These may have reached nearly to Calgary, in Bow valley, which has the largest drainage basin in the mountains, but were much less considerable farther south. A boulder-clay was at this early time laid down in connection with these glaciers, probably in part as a subglacial deposit, in part along their retreating fronts as a fluvio-glacial deposit. The latter as it is followed eastward gradually changes into the typical Saskatchewan gravels, in places associated with silty or sandy beds. All the drift material of this stage is either local or derived from the Rocky mountain side, and it is probable that the boulder-clay of this time is actually connected with the mass of the moraine ridges and hills of Bow valley and those found fringing the mountains in places farther to the south.

Above the Saskatchewan gravels rests the lower boulder-clay of my original report, containing mixed drift from the Laurentian plateau and Winnipeg basin to the eastward and the Rocky mountains on the west. Beyond the change of conditions implied by the differing deposits, no evidence has been found to show that any long time-interval occurred between the stage of the Saskatchewan gravels and that of the lower boulder-clay; nor can it be determined to what extent mountain drift continued to be supplied from the west during the deposition of this boulder-clay, as the preëxisting Saskatchewan gravels have evidently become incorporated with it in places to an unknown degree.

Above this boulder-clay, and evidencing altogether different conditions over a tract at least 50 miles in extent from east to west where cut across by the Belly river, are well stratified interglacial deposits, including locally a thin bed of lignite.

Succeeding the interglacial deposits is the upper boulder-clay, which, like the lower, contains mingled drift of eastern and western origin. Above this and forming the surface of the plains are stratified loamy, silty, sandy and gravelly deposits, which appear to have been laid down in water and in and on which are scattered many of the larger erratics met with in the district.

As already mentioned, it is not certainly known how far the lower and upper boulder-clays of the plains or either of them extend to the west. Both are found at Lethbridge, 60 miles from the mountains, and, if the line observed in sections on Highwood river corresponds with this division, both are there present to within about 15 miles of the base of the mountains and at an actual elevation of 3,700 feet. One or the other of these boulder-clays, however, extends westward along the Oldman river beyond the longitude of the Porcupine hills, and at least as far west as Calgary, on Bow river, and there is some reason to believe that it is the upper boulder-clay which is thus most widely spread.

Respecting the conditions indicated by the various deposits, the following remarks may in the first place be made:

The Saskatchewan gravels, in their composition and because of the great distance to which they have been carried from the mountains, imply the existence at the time of their formation of a considerable eastward slope of the plains, probably greater than that by which the same region of the plains is affected today. The existence of silty deposits and sands in association with them, however, shows that areas of slack water or lacustrine conditions must in some places have occurred.

The interglacial deposits give reason to believe that at the time of their deposition, as elsewhere explained,* at least a considerable tract of the western plains had become practically horizontal.

It remains uncertain to what particular period subsequent to that of the Saskatchewan gravels, and excluding that of the interglacial deposits, the traveled gravels and boulders marking the highest levels of the drift deposits on the Porcupines and foothills are referable; but it is certain that this time was one of great relative change of level, taking the form of a depression toward the west or southwest. This is rendered evident in a broad way by the occurrence of Laurentian stones to a height of 5,300 feet, or about three times that of the present summit level of the Laurentian plateau from which they came. It is reinforced by the association of these with limestones of the still lower Winnipeg basin.

Pursuing this argument a little further into detail, we may compare some of the levels at which the highest drift is found in several places in the west. In the Porcupine hills this level is undoubtedly that of a water-line, and I believe it to be so also in other places in which it has been noted.† On this assumption a relative depression to the west at this time of 900 feet is indicated between the Cypress hills and the Porcu-

* Report of Progress, Geol. Survey of Canada, 1882–'84, p. 151 C.

† Terraces noted by Mr G. E. Culver near Saint Marys lakes, in northern Montana, may represent those here described, although no eastern drift appears to have been found upon them. Mr Culver's description appears to show that the levels are about the same. Trans. Wisconsin Acad. Sci., vol. viii, p. 202.

pines, or a slope of about 4½ feet to the mile. But if it be assumed that this level marks that of the surface of a *mer de glace*, an extension of the Laurentide glacier (as has been done by Mr Upham), a similar westward depression must likewise be admitted. In so far as such a surface might have departed from horizontality, it must have done so by sloping down toward its termination in the west. Ice standing at a level of 4,400 feet at the Cypress hills could under no conceivable conditions have been pushed up to a height of 5,300 feet at the Porcupines, 200 miles further in the general direction of its flow.* Thus, under this hypothesis, we would require to add the amount of slope of the surface to that necessary under the first mentioned assumption.†

As to the period to which this great western depression may be assigned, it is pretty clear that it must accord with one or the other of the glacial formations not already accounted for. In other words, it must have been synchronous with the lower or upper boulder-clays or with the silty deposits subordinate to them. I have elsewhere given reasons for the belief that both these boulder-clays of the western plains are attributable to the agency of floating ice,‡ but this hypothesis need not here be specially insisted on. Important bedded silty deposits are found to blend with the upper part of the upper boulder-clay, and the fact that large erratics are most abundant on the plains at the top of or overlying the upper boulder-clay, with the similarity of these to those found on and about the Porcupine hills and foothills farthest in toward the mountains, leads me to suggest that this period of greatest depression corresponded with that of the upper boulder-clay or immediately followed it.

A closer comparison of the highest levels of erratics in different parts of the field shows that the area of greatest depression, and that of greatest subsequent uplift, touches the southern part of the Porcupines and extends thence in an east-southeasterly direction, and that to this direction a series of "isobasic" lines of decreasing amount must have been roughly parallel for some distance to the northeastward. The changes in elevation seem, however, to have been accompanied by deformation of some importance, for the highest level of drift upon West butte is found to be considerably below what it should be had the difference in level been distributed uniformly in proportion to distance between the foothills and the Cypress hills, although all three of the localities are approximately in an east-and-west line. The facts are as yet too few to enable these

* The maximum depth of ice or water covering the adjacent low country must have been about 2,000 feet near the Cypress hills and 2,100 feet near the Porcupines.

† A similar relative change of level would, of course, be equally implied on the supposition of a great western glacier-dammed lake.

‡ On the Physiographical Geology of the Rocky Mountain Region in Canada. Trans. Roy. Soc. Can., vol. viii, sec. 4, p. 63 et seq.

local differences to be worked out in detail, but others already recorded have a similar meaning.

When the highest terraces and shingle beds were formed upon the Porcupines there is further evidence to show that in the body of water of which these formed the shores a pretty definite current must have existed. Some distance to the eastward, this probably flowed southward or southwestward, but where it reached the Rocky Springs plateau the appearances indicate that it was moving nearly parallel to the border of the glaciated region in Montana,* west or to the north of west; thence it impinged upon the base of the Rocky mountains and was deflected to a northeasterly direction, a circumstance shown by the occurrence, elsewhere referred to, of pebbles of the locally developed greenstone of the mountains in some abundance on the higher parts of the Porcupine hills. Such a current may reasonably be accounted for by the prevailing direction of the winds at the time and season of the driftage of the ice.

In the case of these high-level drifts of the Porcupines the deposit of eastern and western material must have been contemporaneous. Both find their upper level at the same plane, and there are no antecedent deposits at such a height from which either can have been derived. At this time, moreover, some deposit must have been in course of formation beneath the surrounding deeper waters across which the debris-bearing ice floated, and, because of the melting of the ice and other accidents, this could not have been otherwise than a notably stony one. As already stated, this is believed to be represented by the upper boulder-clay, the silts overlying it, or in part by both.

The terracing of the Porcupines is not so pronounced as to require the long presence of the water-margin at any of the higher levels, but the well rounded character of most of the stones, particularly those from the mountains, is such as to imply prolonged attrition. The same character is notable in the vast majority of the stones included in the boulder-clays. It seems, in fact, probable that during the winter months at this period a massive ice-foot formed along the abrupt base of the mountains, upon which, in the spring, gravels from flooded streams were often discharged, while large angular limestone blocks from cliff-falls also lodged upon it in some localities. When in summer this ice broke away it would carry with it the load thus acquired.

That the glaciers which at the period of the Saskatchewan gravels protruded from the mountains must at this time have shrunk back within the range, in the southern part of the district at least, is shown by the stranding of Laurentian boulders upon the old moraines of these glaciers close up to the foot of the mountains. It is possible that the Bow Valley

* Report of Progress, Geol. Survey of Canada, 1882–'84, p. 148 C.

glacier may still have continued to hold some importance in the foothill region, but the abundant supply of well rounded gravels, with other circumstances, renders it probable that the Rocky Mountain glaciers generally had become strictly local and relatively insignificant.

If it may thus be assumed that the higher terraces and traveled gravels of the Porcupines are approximately contemporaneous with the upper boulder-clay, all the lower and later terraces and gravel plains may be regarded as marking stages in the subsidence of this water-level from its maximum height of 5,300 feet. These, it has already been noted, are usually not strongly impressed, and there is no evidence that the subsidence was arrested long, except at one stage, which is that spoken of in the report of 1882–'84 as being at about 4,200 feet. Further examination appears to show that the terraces referable to this particular stage slope up gradually in the foothills and on approaching the mountains to a maximum height of about 4,500 feet, from which it may be argued that from the last mentioned height the water lowered its level gradually to one of about 4,200 feet, while new material was constantly being washed down by rivers from the mountains. A later and still lower, though less important, period of arrest seems to be marked by the gravel plain near Macleod at about 3,200 feet.

The first mentioned line of relative stability appears to be equally well marked in the southern portion of the region, about Waterton lake and the Oldman river, and in the northern, in the Bow valley, leading to the suggestion that the irregular uplift of the earlier stages of recovery had been succeeded along the base of the mountains by one in which further change of level occurred throughout uniformly, as compared with the actual heights of the surface found in the same region today, or with isobases changed in direction and parallel to the trend of the mountains. This later uplift may have continued, with the stranding of large boulders near the water-line from time to time, until this part of the plains reached its present condition and slope.

There is, however, some good evidence to show that in postglacial times a renewed or continued southern uplift took place. This is derived from the changes in the course of streams and slopes of their valleys, but cannot be entered into in this paper.*

In this connection I may digress so far as to mention that there is a somewhat notable correspondence between the higher levels of terraces on both sides of the Rocky mountains and continental watershed. It is found in the southern part of the interior plateau of British Columbia

* Report of Progress, Geol. Survey of Canada, 1882–'84, p. 150 C; Annual Report, Geol. Survey of Cananda, vol. i (n. s.), p. 75 C; Physiographical Geology of the Rocky Mountain region in Canada, Trans. Royal Soc. Canada, vol. viii, sec. 4, p. 63.

that the highest terraces occur at elevations of from 5,500 to 5,300 feet; that below this there is a remarkable paucity of terraces down to about 4,450 feet, between which and a height of 4,300 feet another well marked group of old water-lines appears. These facts are fully described in my forthcoming report on the Kamloops map-sheet. The circumstance may not be more than a coincidence, but it is certainly a striking one and one worthy of further investigation.

As it has already been stated that no certain evidence has been found such as to show that the lower boulder-clay may not be that extending farthest west and in toward the base of the mountains, it may be appropriate now to mention the hypotheses which present themselves on that assumption. If the lower boulder-clay holds this position and was deposited contemporaneously with the high-level erratics and gravels, the upper boulder-clay may very well have been laid down in the body of water standing later at the inferior levels of from 4,500 to 4,200 feet and indicated by the well marked terraces and gravel plains already alluded to. This hypothesis, of course, assumes that a boulder-clay may be deposited from floating ice, and to me it appears probable that a material of this nature may have been formed in any one of three ways, namely, beneath a glacier, about the edge of a glacier as a fluvio-glacial deposit, or below a body of water charged with floating ice.

According to still another possible hypothesis, it may be supposed that while the lower boulder-clay is that stretching farthest west and spreading around the base of the Porcupine hills, the high terraces may be due to a subsequent flooding about the time of the upper boulder-clay. This, however, does not appear to accord well with the facts, for in this case there is no recognizable deposit in the lower parts of the flooded district near the Porcupine hills to represent this period of submergence.

Respecting the actual western limit of eastern erratics, the investigation here reported upon seems to show that the line marked upon the map accompanying the report of 1882–'84 nearly corresponds with observed drift of this origin in the boulder-clays proper, slightly exceeding this to the south of the Porcupines and falling a little short of it to the north, but that scattered erratics occur in places considerably farther to the west. These are found upon the higher ridges and hills, and if present equally in the valleys have there been concealed by a later wash from the mountains. Behind the Porcupines, the occurrence of such erratics is in inverse proportion to the amount of shelter afforded on the east by the higher parts of these hills—a fact equally explicable under any hypothesis of their deposition; but the occurrence of such sporadic erratics renders it difficult to draw any precise western line, and it is possible that renewed investigation of the higher foothills may in some

places result in their occasional discovery even farther to the west than they have yet been observed.

Another fact of importance, and one which impressed itself on the writer in the course of the recent examination, is the following: Except in the case of the moraines evidently referable to glaciers of the Rocky mountains, which we have found reason to assign to a very early period and which save in the case of Bow valley are closely confined to the base of the mountains, the more obvious evidences of the work of glaciers are conspicuously absent in this entire region of the foothills and Porcupine hills. The highest and farthest limits of the drift are not marked by moraines, and moraines, drumlins, kames, and eskers are, with the above exceptions, entirely wanting. This is very striking when comparison is made between this region and that of British Columbia or the Laurentian plateau, both of which are known to have been overridden by vast glaciers.

Within the past year Professor T. C. Chamberlin has formulated and named a series of stages in the glacial history of North America, and although the author of the classification would probably be the first to admit its provisional character, it has undoubtedly already been of considerable service in suggesting a basis of arrangement and in fixing the direction of future work. Thus it will be appropriate briefly to note here in conclusion what appear to the writer to be the probable relations of the glacial deposits of Alberta to this general classification.

The "lower" boulder-clay may, it is believed, be regarded as representing the Kansan formation, while the interglacial deposits, best developed along the Belly river, are supposed to be contemporaneous with the post-Kansan interval. The "upper" boulder-clay of the western plains may then be identified with the Iowan formation and like it is associated with abundant silty beds. The Wisconsin formation is in all probability not met with in the extreme west, but its limit in this direction may be marked by the Missouri Côteau, which in Canadian territory extends from the forty-ninth parallel to the North Saskatchewan and indefinitely beyond in the farther north. The post-Iowan interval, in this case, appears here, as in the region farther east, to be marked by the erosion of important interglacial valleys, which find their limit at the Côteau and its systems of drift ridges and hills.* No deposits like the Côteau occur in connection with the western terminations of the "lower" or "upper" boulder-clays.

Reverting now, on the basis of the above correlation, to the Saskatchewan gravels and the "western" boulder-clay, it will be apparent that these must represent an antecedent and unnamed stage of glaciation in

* Geology and Resources of the Forty-ninth Parallel, p. 230.

North America. This, with scarcely any doubt, may, from the observations given in this paper, be regarded as that of the maximum of the Cordilleran glacier, and to it I would propose to apply the name of the Albertan stage or formation.

The Saskatchewan gravels may very possibly represent the Lafayette formation of the eastern states. This correlation has been suggested by Mr Upham, but it is prudent as yet to hold it subject to correction, for there appears to be some danger of referring to a single formation various remote gravelly deposits found below boulder-clays. It is, however, maintained by Professor C. H. Hitchcock that the Lafayette represents the earliest epoch of glaciation in eastern America, which in itself appears to give at least some force, with our present information, to the hypothesis that we find the greatest development of glacial agencies at this same time in the maximum spread of the Cordilleran ice-sheet, while only at a later date did the center of ice distribution migrate to the Laurentian plateau. Such a migration must have been in intimate connection with the vast relative changes of level, of which some striking evidence is found in the particular region now under consideration.

In these later pages of this paper it may be that conjecture has in some instances been pushed too far, but so long as it is understood to be merely a tentative discussion of the facts given, without comment, in the body of the paper, it cannot be misleading. In this southwestern part of Alberta it is at least manifest that the records exist, more or less obscured and interwoven, of a complicated series of conditions during the Glacial period, the final reading of which must add materially to our knowledge of the glacial history of the continent as a whole.