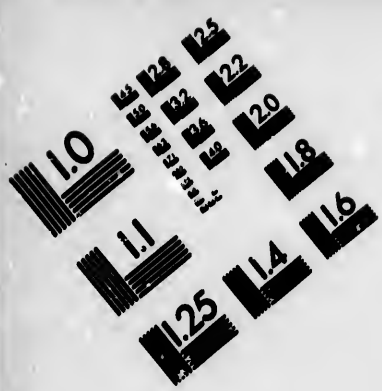

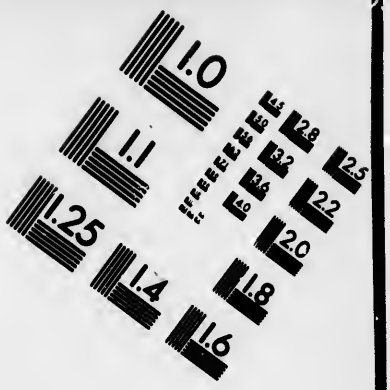

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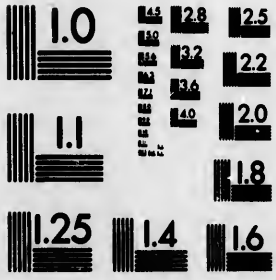

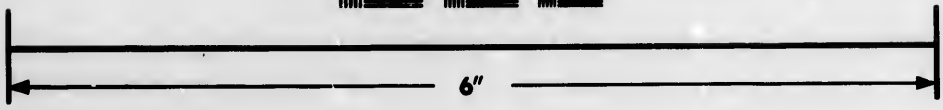

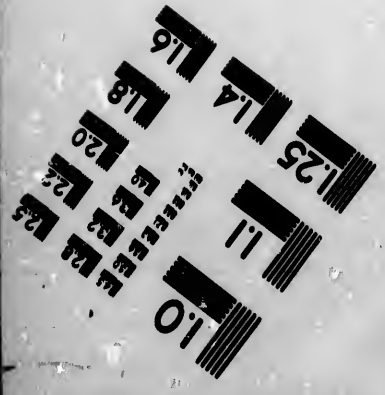

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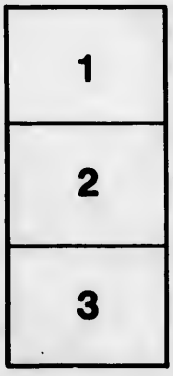

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 1, PP. 395-410

POST-TERTIARY DEPOSITS OF MANITOBA AND THE ADJOINING TERRITORIES OF NORTHWESTERN CANADA

BY

J. B. TYRRELL
OF THE GEOLOGICAL SURVEY OF CANADA

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(*Read before the Society December* 27, 1889.)

CONTENTS.

THE REGION AND ITS GENERAL GEOLOGICAL FEATURES.

Southwest of the margin of what has long been known as the Archean continental nucleus lies a great drift-covered area, including in it most of the plains and prairies of northwestern Canada. It extends on the international boundary line from the western side of the Lake of the Woods to near the eastern base of the Rocky Mountains, through between sixteen and seventeen degrees of longitude, or a distance of more than 750 miles. Towards the northwest it stretches along the face of the Archean area to beyond the arctic circle in the valley of the Mackenzie river.

Lying on an irregular floor of old gneisses and schists, rocks of Silurian and Devonian age are known to occur over the whole eastern and northeastern portion of this district, while further westward these disappear under others of upper Mesozoic age; and thence westward to the foot of the Rocky

Mountains, Cretaceous or Tertiary beds everywhere underlie the post-Tertiary or recent deposits. The character of most of these beds, which consist of sandstones, marls, and clay-shales, is perfectly well known, but I wish to draw your attention for a moment to the occurrence of conglomerates of Miocene and Pliocene age, the existence of which has been pointed out of late years, since they furnish sources of supply for a large amount of drift which was formerly supposed to have been derived directly from the Rocky Mountains at the same time that the other associated portions of the drift were derived from the Archean and Paleozoic rocks to the east.

The Miocene is at present known as a fresh-water formation of sands, silts, and gravel, or conglomerate, lying on the eroded surface of the Cretaceous and Laramie rocks on the more elevated portions of the Hand and Cypress hills, and on the higher plateaus stretching east from these as far as long. 107° 15′. The pebbles in this conglomerate are all well rounded and waterworn, and consist of a white quartzite similar to that in the Rocky Mountains described by Mr. McConnell as belonging to his "Bow River group," or lower portion of the Cambrian system. This material has been carried eastward by rapid streams during Miocene times, and deposited either in lakes or on the flood-plains of rivers. The gravel has in many places been indurated by the infiltration of a calcareous cement into a hard conglomerate, much harder than the underlying shales and sandstones, and has preserved the hills that it now covers from degradation by atmospheric and fluviatile agencies to the same extent as the surrounding country, and at the same time has furnished a scale by which to measure the thickness of the rocks washed away since Miocene times.

The Pliocene, here called by Mr. McConnell the "South Saskatchewan group," is also composed of rounded quartzite gravel; but it now occupies the bottoms of valleys or other depressions, and has been derived in part from the pre-existing Miocene deposits, and also in part directly from the quartzite areas of the mountains.

The district under consideration, extending from the boundary between the United States and Canada northward to the North-Saskatchewan river, is largely overlain by a series of heterogeneous deposits which are commonly embraced under the term "drift." This consists of bowlder clay or till, morainic detritus including erratics, drumlins, kames, alluvial sands, clays, and silts, beach-ridges, terraces, etc.

The Glacial Deposits.

Till.—The bowlder clay or till rests irregularly on all the pre-glacial formations down to the fundamental gneisses and schists, and in the Archean area itself fills many protected depressions and recesses. It does not, however, reach the base of the Rocky Mountains, but extends westward to within

forty miles of them, as far as Calgary, on the Canadian Pacific railway, and from there southward to the international boundary it keeps at about the same distance from the mountains. North of Calgary the western edge of the great sheet of till crosses the Red Deer and North-Saskatchewan rivers at approximate elevations of 3,000 feet above the sea, the latter in long. 115° W. Further north it is stated by Dr. Dawson to cross the Peace river in lat. 56° N., long. 119° W. To the south its boundary everywhere lies on the United States side of the Forty-ninth parallel of latitude. North of or near this geodetic line it covers all the country of the plains without regard to elevation, with four exceptions, viz., the upper portions of the Sweet Grass hills above 4,660 feet, the Cypress hills above 4,400 feet, the Hand hills above 3,400 feet, and Rocky Spring plateau above 4,100 feet.

The general character of this great sheet of drift is remarkably uniform throughout, being essentially composed of a gray, more or less sandy clay, massive in character, and holding numerous pebbles and bowlders. It is largely composed of the débris of the Cretaceous and Tertiary rocks that surround or immediately underlie it, consisting probably of the parts of these strata that were rotten from long exposure to the weather during the ages that intervened between the close of the Laramie period and the commencement of that of glaciation. By this latter agency the rotten rock was kneaded up, with the bowlders and pebbles transported from a distance, into a homogeneous mass. That the till is local is clearly seen where the underlying rock has any very marked characteristic by which it can be recognized—as, for instance, the rocks of the Edmonton series of the Laramie, which are associated with numerous beds of lignite. Overlying these rocks, and especially for some distance south of a lignite outcrop, the drift is filled with pieces of lignite sometimes as large as a hen's egg, and the whole mass becomes dark in color from its presence in minute fragments. Another instance is recorded by Dr. Dawson where the drift has a distinctly reddish tint, derived from some neighboring reddish clays of the Laramie formation. The bowlders are, however, largely of eastern origin, being composed of granitoid gneiss, mica-schist, quartzite, diabase-trap, gneiss-conglomerate, and stratified Paleozoic limestone, those of limestone, as well as an occasional one of the other rocks, being usually irregular in shape, with smooth, polished surfaces and sharply marked glacial striæ. The pebbles included in the till throughout the western portion of the district, where they consist largely of white quartzite, the same as that composing the Miocene gravels on the Cypress and Hand hills, are doubtless partly of local origin, having been derived from the gravel on these hills, or from other areas that have been entirely denuded away. Some are also probably derived from the parent beds of Cambrian quartzites in the Rocky Mountains. A few of gneiss are almost everywhere met with, and while the western quartzites

gradually disappear on proceeding eastward those of gneiss become more numerous, and pebbles of Paleozoic limestone also become very common.

In thickness the till varies greatly in different places, ranging down from 500 feet or more to a very thin covering; but, generally speaking, throwing out of account deposits clearly referable to terminal moraines, it becomes slightly thinner from east to west, the outcrops seen along the 3,000-foot contour line above mentioned being as a rule not more than a few feet in thickness.

Throughout the greater portion of the area under consideration the till falls naturally into two major subdivisions, a lower very compact bluish-gray unstratified deposit, and an upper softer and sometimes thickly lamellated clay usually of a light brownish color. These two subdivisions have been chiefly recognized in the extreme western portion of the area, from the international boundary north to the North-Saskatchewan river, where they are often separated by stratified waterlaid deposits, in which, on the Belly river, Dr. Dawson records the occurrence of a bed of lignite eight inches in thickness. The till in this latter locality is also of extraordinary thickness as compared with the average found farther north between the Bow and North-Saskatchewan rivers. Farther east these two subdivisions have not been so generally recognized, probably on account of the great thickness of the whole deposit and the comparative paucity of good sections.

Terminal Moraines.—Intimately associated with the till are a number of irregular ridges of rounded hills severed by deep depressions, in the bottoms of which are often lakelets of clear, sweet water without visible outlets. The rim of the basin of one of these lakes is frequently fifty or sixty feet above the surface of the water, and surrounding knolls in many cases rise to a height of from a hundred to a hundred and fifty feet higher. Sections of these hills show them to be masses of transported material, consisting of unstratified sand, clay, and bowlders, and their sides and summits are almost always thickly strewn with large northern or eastern erratics.

As to the mode of formation of these hilly tracts, there is now little room for doubt that they were the terminal moraines of one or more extensive glaciers that moved outwards from the central Archean nucleus, planing off the higher points of the surface and shoving before them the accumulated mass of mixed material. Much of this fell back under the moving ice in the depressions of the preglacial surface, while the rest, consisting chiefly of the coarser material, continued at the ice-foot, and was left as an irregular ridge on the final retreat of the glacier. Very few of these morainic belts have as yet been definitely located, but the following may be mentioned as some that have been examined in late years and whose character is pretty certainly known.

On the western margin of the Winnipeg basin, a rugged morainic ridge

runs along the face of the northern continuation of the Pembina escarpment, with a mean elevation of 1,600 feet. In the great depression drained by the Valley river its width is from a quarter to half a mile. It is composed chiefly of sand, but it also contains very many large bowlders of dark-gray and reddish gneiss, mingled with others of Paleozoic limestone.

Proceeding a little further to the west, the whole surface of Duck mountain is found to consist of irregular ridges and knolls of gneissic débris rising in some parts to a height of 2,000 feet above Lake Winnipeg, or 2,700 feet above the sea. This rugged tract extends southward over the summit of the Riding mountain, and it is not improbable that the Brandon hills (which have been described to me as having somewhat similar characters to those already mentioned) may be a southern continuation of the same extensive ridge.

Proceeding still farther westward along the Forty-ninth parallel of north latitude to the westward margin of what has been known as the second prairie steppe, a wide belt of rounded morainic hills is reached, lying on a sloping preglacial surface rising gradually from east to west. This hilly country, which has been known since the time of the early voyageurs as the Missouri Coteau, was well described by Dr. Dawson in his report on the geology and resources of the Forty-ninth parallel. It has also been identified by Professor T. C. Chamberlin as the continuation of the great terminal moraine of the second glacial period, which has been traced by himself and others from Dakota eastward to the Atlantic Ocean. From the northern boundaries of Dakota it has been traced by Mr. McConnell northwestward in Canada for two hundred miles to a point on the South-Saskatchewan river, twenty-five mile above the elbow, crossing the line of the Canadian Pacific railway in the vicinity of Secretan station. North of this point its course is not at present known, and it must be borne in mind that north of the Fifty-first parallel of north latitude the plains lose to a great extent their eastern slope, the summits of the Duck mountain, in long. 101° W., being equal in height to the general surface of the country due west of them in long. 113° W., or more than five hundred miles distant. Since, then, the slope on which the moraine constituting the Missouri Coteau was deposited becomes very indefinite or dies out a little north of the South-Saskatchewan river, it is not improbable that the course of the moraine itself is much changed, so that it may curve around and join others that are now known to the east or west of it. It is, however, more probable that it is here an interlobate moraine, and that as a definite entity it does not extend much further north than its present known limit.

West of the Coteau the till is of essentially the same character as that to the east of it, and numerous detached ridges of "rolling hills" or terminal moraines are known to occur. In describing the vicinity of the Cypress hills Mr. R. S. McConnell classes with the Coteau, as being "covered with

steep-sided drift-built hills," the "ridge extending northwest from Pintohorse butte" (near the head of the middle branch of Old Wives creek and in approximate lat. 49° 45′ N., long. 107° 45′ W.) in a general direction parallel to the Coteau and about fifty miles southwest from it, and the "spur south of the west end of the Cypress hills" a hundred miles still farther west.

West of this ridge and south of lat. 51° N. no terminal moraines have been recognized, except such as have been formed by glaciers flowing from the valleys in the mountains, these being characterized by the angularity of the included pieces of rock and the absence of eastern erratics. North of lat. 51° N. there are a number of ridges of distinctly morainic character. One of the most typical of these surrounds the southern and eastern sides of the Hand hills. These latter hills form a high table-land rising twelve hundred feet above the surrounding plains, and are surmounted by two hundred and seventy feet of sands, silts, and gravel of Miocene age. Towards the northwest, west, and southwest they rise in an abrupt escarpment five hundred feet to their summit; towards the east and southeast they decline gradually and regularly for a short distance, and then the slope is covered with a ridge of rounded knob-like hills separated by deep kettle holes, in the bottoms of which often nestle small isolated lakes. Their summits are thickly overstrewn with bowlders.

From fifty to sixty miles further north, near the southerly bend of the Red Deer river, another similar ridge is met with, the knolls rising in many places to more than two hundred feet above the bottoms of the depressions.

Turning directly eastward a rough, irregular tract, known as the Neutral hills, is seen, the higher points of which are thickly covered with gneissic and limestone erratics, lying on a base of unmodified morainic material. The hills themselves lie on an elevated plateau of Cretaceous shale, which has been very irregularly eroded, so that it is often difficult to say without sections whether an individual hill is a product of denudation or is one of the irregularities of the moraine.

North of the Battle river the Blackfoot hills form another area of deep, unconnected depressions and high, rounded knolls, sprinkled over with bowlders of eastern gneiss.

Other morainic belts doubtless occur in this area south of the North-Saskatchewan river, but as yet they have not been traced out. Enough has been done, however, to show the former existence of a great glacier, or "mer de glace," which spread over the plains from a source or sources of supply on or north of the Archean rocks to the east, and which flowed in a southerly and southwesterly direction almost to the foot of the Rocky Mountains, from whose valleys numerous small glaciers flowed eastward to join the mighty advancing ice-sheet, leaving intervening areas along the foot of the mountains, and roughly west of the 3,000-foot contour line, unglaciated.

Absence of Terminal Moraines near the Rocky Mountains.—The absence of a terminal moraine at the extreme western limit of the till, near the foot of the mountains, is a fact worthy of notice, especially in view of the fact that the till of both the earlier and later glacial periods is found to extend approximately the same distance westward, and that there is a narrow belt from thirty to one hundred miles in width that would appear never to have been covered by the ice-sheet.

The most efficient reason that suggests itself to me to account for this state of affairs is that the glacier terminated in one or more lakes, hemmed in between the continental glacier and the mountains and cut off towards the north and south by lateral glaciers flowing eastward in such valleys as those of the Bow and North-Saskatchewan rivers. The morainic accumulation would in that case be carried off either by icebergs or waves and currents and spread out some distance beyond the limit of the till. This would account for the presence of eastern erratics along the very foot of the mountains, and may also account for the high terraces on the sides of such valleys as that of the North Kootanie river. This condition could not, however, have lasted for any great length of time, as no considerable amount of stratified deposits are found in this unglaciated area.

Western Pebbles.—The presence of western pebbles in the drift far out on the plains was for a long time an almost insuperable barrier to the general acceptance of the belief in its essentially eastern origin; but the discovery of large areas of Miocene conglomerates, holding these same pebbles, as far east as long. 107° W., has almost entirely overcome this objection in furnishing new centres of distribution from which these pebbles have been carried. Still it is not improbable that some of the drift in the extreme western part of the drift-covered country is derived from the mountains, having been carried down by the local glaciers mentioned above.

Direction of Ice Flow.—In speaking of the general direction of flow of the western portion of the great continental mer de glace it has been customary to regard it as having advanced southwestward from the Archean area—and certainly this was the direction of glacial motion when the ice first reached the Winnipeg basin,—but recent investigations have shown that in two cases, at all events, this direction was not sustained, viz., in the great Winnipeg valley, and in the valley of the upper Assiniboine, west of the Duck and Riding mountains. In both these cases the direction of flow was southward or southeastward in the direction of the trend of the valleys, and parallel to the main axis of the Rocky Mountains. This direction was in all probability sustained by the glacier all the way across the Canadian plains, and we have thus one reason for its great extent, as the ice was moving from a wide area of distribution to a much narrower area of dissipation, and there would be a constant tendency to make up for the loss from the surface by a crowding in from the sides.

Deposits of Isolated Glaciers.—After the final retreat of the general continental glacier, relatively small névés remained on the tops of some of the higher elevations that had previously been overridden, and small glaciers flowed outwards from them down valleys of various depths. The Duck mountain shows many evidences of having passed this intermediate stage of local glaciation. It is a high table-land, the summit of which rises 2,700 feet above the sea, or 2,000 feet above Lake Winnipeg, and consists entirely of Cretaceous clays overlain by a great thickness of unstratified till and transported bowlders, most of the latter being Archean gneisses and schists. From the summit of the mountains several large valleys carry the superfluous drainage outwards to the various surrounding waterways. The stratified deposits in these valleys are in many cases overlain by unstratified till. The valleys are also blocked by small local moraines, behind which in some cases the valleys are terraced as high as the tops of the moraines, while in others the rivers that formerly occupied them have been permanently diverted into other channels.

Thus we would appear to have in this area three distinct bowlder clays, two formed by the continental glacier moving southward, and the third or upper formed by local glaciers existing at the same time that the great post-glacial lakes filled all the adjacent depressions.

Drumlins.—Over the great portion of the plains drumlins have not been recognized, possibly in part because in the press of other work they have not been looked for sufficiently; but in the northern portion of Lake Winnipegosis many excellent examples are to be seen. They here form groups of narrow, very much elongated elevations in the till, rising in islands a few feet above the surface of the lake, and are generally thickly covered with transported bowlders of gneiss and limestone. A very casual glance at these groups of islands will serve to show that they are structurally different from neighboring ones underlain by rock and on which the bowlders have been shoved by the ice. There is no sign of any rock in place and the stones are not all of constant lithological character, as is generally the case where the rock is close to the surface, but they are true transported bowlders, differing as widely from each other as crystalline gneiss and coralline limestone. The islands are also formed with their long axes parallel to the direction of the glacial striæ in the vicinity.

The Aqueous Deposits.

Interglacial Deposits.—As has been already shown, the evidences of a recurrence of glacial conditions and the intervening temperate era near the northwestern limit of the glaciated area leave no room for doubt that the glacier retired for a considerable time from the greater part of the western prairie region; and perhaps during this interglacial period conditions may

have been much as they are now, for near the northern end of the Duck mountains there is a deposit of stratified silt underlying a great thickness of unstratified till, and probably of inter-glacial age, holding numerous fresh-water shells, with fragments of plants and fish remains essentially the same as those living in Lake Manitoba and the surrounding lakes to-day.

Kames.—Very few kames have up to the present been definitely located in the Canadian northwest, and none that would appear to have been connected with any but the later stage of glaciation, viz., that of isolated local glacial centres. The most important of these stretch as straight ridges down the middles of deep valleys on the east side of the Duck mountain. The two most important ones recognized were covered by several feet of pebbly unstratified till, the same as that composing the surrounding hills. In some cases what have been taken for moraines may possibly be kames, but it is difficult in all cases to distinguish them in the absence of sections.

Lacustral Beds.—Resting on the bowlder clay throughout very extensive tracts in Manitoba and the North West territories are stratified sands, silts, and clays that have been deposited in the bottoms of post-glacial or recent lakes. The delineation of these lake basins is a work of the greatest economic importance, as it is evident from what we at present know—that many of the most fertile tracts in the west are underlain by rich alluvial clays deposited in the bottoms of sheets of water of greater or less extent, which have now disappeared.

The number and extent of most of these old lakes has not as yet been determined, but the positions of a few may be here generally indicated.

The country drained by the upper waters of the Bow, Red Deer, and North-Saskatchewan rivers, having at present a mean elevation of between two and three thousand feet, was largely submerged, fine clays and silts overlying the till being here very generally met with, though no shore lines have been recognized. A marked peculiarity of these deposits is the utter absence in them of any shells or other fossils that would indicate the existence of life in the lakes in which they were deposited.

Another extensive stratified deposit skirts the eastern margin of the Missouri Coteau.

The depression lying west of the Duck mountain, which is now drained southward by the Assiniboine river, was also, at the close of the glacial period, the basin of a large lake which first drained eastward through the valley of Short creek and Valley river, between the Duck and Riding mountains, and afterwards, when this valley was blocked by a local glacier from the Duck mountain (the terminal moraine of which still stretches across its western end), cut out the present valley of the Assiniboine. Southward, this lake extended down to lat. 51° N. Its northern and western boundaries have not yet been determined; but standing on the morainic

ridge that forms the western side of the Duck mountain, and which was also the eastern shore of the lake, a wide, level, alluvial plain or lake bottom may be seen stretching westward to the limits of vision.

But by far the largest and most important of these ancient post-glacial lakes is that named Lake Agassiz by Mr. Warren Upham, and which once occupied the Winnipeg basin and the valley of Red river. In its bed was deposited the rich alluvial clay that is now enabling Manitoba to take its place as one of the foremost wheat-producing areas in the world.

Ancient Beaches.—I shall not now discuss the altitude, length, and depth of these lakes; but a few words may be said of the beaches that at various times formed the shore lines for the gradually receding waters.

The existence of the old shores of Lake Agassiz was clearly pointed out by Professor H. Y. Hind in 1859, but their relative heights were not at all understood by him. Of late years Mr. Warren Upham has carefully studied these beaches from Lake Traverse, at the south end of the Red river valley, to a short distance north of the 50th parallel of north latitude. In the wooded district further north, and one hundred and fifty miles north-northwest from where the old lake beaches cross the international boundary at the foot of the Pembina escarpment, several gravel ridges were located by the writer on the northern face of the Riding mountain, close to the banks of Ochre river, a small stream flowing into Lake Dauphin. The heights of these ridges are respectively 1,215, 1,115, and 1,025 feet above sea level. From Ochre river they were followed for eighteen miles in a northwesterly direction, at the end of which distance the highest one runs along the summit of a steep escarpment one hundred feet in height, while the one below it is continuous with the line of the base of the cliff. The face of the cliff is now overgrown with trees, but a gulley that cuts back into it shows it to be composed of the white limestones and chalk-marls of the Niobrara subdivision of the Cretaceous.

The sequence of events is here very beautifully shown: For a considerable time the lake stood at the level of the highest of these beaches, and the land sloped gradually beneath the surface of the water. The lake then fell more or less rapidly a hundred feet to the next lower shore line, and must have stood at this level for a long time, sufficiently long at all events to allow the waves to cut a cliff of limestone one hundred feet in height from what was before a gradually declining surface.

From this chalk cliff, which formerly must have stood out boldly as a conspicuous landmark on the shore of Lake Agassiz, coast ridges were again followed and crossed at intervals in travelling northward to Valley river. This stream flows in a wide depression separating Duck from Riding mountains. The highest beach ridge seen on its banks has an elevation of 1,280 feet above the sea, but above this is an extensive sandy plain covered with

stunted grass and dotted with a few scrubby oak trees. This plain is a delta deposit of a river that flowed into Lake Agassiz when this lake was at its highest stage; and on the sides of the channel which the present river has since cut through the plains a number of very interesting and instructive sections can be seen, including both the superficial deposits and the underlying Cretaceous.

Beyond the Valley river the ridges continue in a direction 15° west of north for sixty miles, to the northeast angle of the Duck mountain, when they turn abruptly westward into the valley of Swan river. Crossing this valley they are well marked on the eastern face of the Porcupine mountains, north of which they turn westward for a long distance into the vallay of Red Deer river, ending in a wide, flat, sandy delta plain.

Whether they extend along the face of the Pasquia mountain has not yet been determined; but the Pas ridge on the Saskatchewan river would appear, from descriptions we have of it, to be one of these ancient beach ridges, though its elevation is not nearly so great as most of the well defined ridges along the face of the Duck and Porcupine mountains.

These beaches as a rule are in the form of slightly rounded ridges from fifty to two hundred feet wide, raised from three to twenty-five feet above the surrounding country. They are composed of sand and small waterworn pebbles, a few of which are granitic or quartzitic, while a great majority are of the white Paleozoic limestone at present outcropping around the adjoining lakes. The gravel must, however, have been derived entirely from the till that had previously been carried by the glacier from the bedded rock at a distance, for there is now no known outcrop of these limestones with a greater elevation than about nine hundred and thirty feet, or more than five hundred feet below the summit of the highest of the gravel ridges. Cliffs of till that might furnish sources of supply for the pebbles are also often separated by very long intervals; so that it is probable that most of the gravel was brought down by rapid streams flowing from the adjoining mountains, and was distributed by currents along the shore.

The beaches would appear essentially to have been formed by waves and currents, as there are very few signs of ice action such as are seen around the shores of Lakes Winnipegosis and Manitoba to-day.

Where most conspicuously developed the beaches are covered, as a rule, with only a meagre growth of short grass, which in some of the more northern parts is varied with a few stunted trees of Banksian pine. They thus often form beautiful dry roads through country that would otherwise be an impenetrable forest.

So far as the eye can detect, the line of the crest of the ridge is quite horizontal, but careful measurements show it to rise gradually and regularly towards the north, just as the crests do in Minnesota and Dakota. At

the boundary line the ridges range in altitude from 995 to 1,230 feet above the sea,* while on the eastern face of the Duck and Riding mountains they were found to ascend as high as 1,460 feet above the sea, showing a rise in the upper boundary beach, supposing it to continue this far north, of about one foot to the mile from the point of crossing latitude 40° north to the Duck river, where the highest beach was seen. If the highest beach at the boundary does not extend so far north, the rise per mile will be somewhat greater.

Very few fossils that can be clearly identified have been found in these gravel ridges; but on Valley river in lat. 51° 13′ N., long. 100° 20′ W., at a distance of two feet below the surface, some roughly chipped fragments of quartzite have been discovered, lying horizontally among the disk-shaped waterworn pebbles, along with a small bone of a mammal. Precisely similar fragments are now to be found on the shores of lakes Winnipegosis and Manitoba in association with well-formed arrow-points, and the traditions of the Indians go back to the time when they were formed and used by their forefathers. As the gravel had been laid down by water action and was quite undisturbed, they clearly indicate the existence of man at the time when this lake beach was being thrown up, and it is probable that here, near the mouth of the former representative of Valley river, was one of his favorite haunts. The summit of the beach in which these "chipped flints" were found is 425 feet above lake Winnipeg or 1,135 feet above the sea.

The positions of the northern and eastern shores of Lake Agassiz have not yet been determined; but from what we know at present we can safely say that there is no land in that direction sufficiently high to form a shore line with an elevation of 1,400 or more feet, and there has been no evidence forthcoming to show that there has been any other disturbance of the country since the lake was at its highest level than the slow uplift towards the north shown by the gradual rise of the ridges in that direction. The theory has been suggested that the face of the retreating continental glacier held back the water on these two sides. It is not improbable that as the glacier retired from the face of the country, which was sloping towards it, a lake would be formed at its foot. If this be the true explanation of the cause of the formation of Lake Agassiz, it discharged its surplus water through the valley of Lake Traverse until the glacier had retired far enough or had decreased sufficiently in size to allow of a discharge for the lake over or around it. The position of this river has not been and may possibly never be determined, as all traces of it may have since been swept away.

Much has yet to be learned of the history of all of these post-glacial lake beaches, but a long array of interesting facts is now being gathered together, which it is hoped will before long solve some of the mysteries of Quaternary dynamical geology.

*The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham: Bull. 39 U. S. Geol. Survey, 1887, p. 17.

DISCUSSION.

Mr. J. E. MILLS: I should like to mention, in connection with this paper, General Warren's account of the cañon of the Mississippi. He traced the Mississippi cañon up to that of the Red river, and thence on to Lake Winnipeg. He inferred from what he saw that the cañon when first formed was higher than now, and that the waters of the Winnipeg flowed at that elevation southward. He inferred, also, that the cañon was formed by a river much larger than the present Mississippi. General Warren announced this about 1869. I had the pleasure of doing a part of the geological work of his survey. If I understand Professor Chamberlin rightly, the cañon was excavated between the two glaciations. In that intermediate period the drainage of Lake Winnipeg was southward through the Mississippi valley, and if General Warren's account is correct, the country north of Lake Winnipeg must have been drained southward. Professor Chamberlin shows that at this very time the country of the lower Mississippi was at base level—was very low. There certainly was an elevation, therefore, that caused the erosion of the Mississippi cañon about that time. This seems to confirm and strengthen General Warren's deduction that there was an elevation, and an elevation increasing northward. I should like to have Mr. Tyrrell state what bearing his observations have upon this deduction of General Warren's.

Mr. TYRRELL: The problem of the direction of the preglacial drainage of the Lake Winnipeg basin is a long and complex one. I can merely say here that much of the evidence at present in hand goes to show that it was drained by a river flowing with a more or less northerly course. I know of no evidence found in Canadian territory that will serve to indicate the direction of drainage in the interval between the first and second glacial periods. In the Winnipeg basin the tracks of the older glacier have been obliterated or greatly obscured by the severe erosion of the later glacier. Generally speaking, one must look farther south or nearer the ancient ice-front for the clearest evidence of the earlier glaciation, though it is quite probable that interglacial beds exist in Manitoba. In the postglacial period the Winnipeg basin was first drained southward through the valley of Lake Traverse and down the Minnesota river, and afterwards in a northerly or northeasterly direction, as at present.

On this latter subject, however, I beg to refer to President Chamberlin, who has given the matter a large amount of attention.

President T. C. CHAMBERLIN: The cutting of the trench from the outlet of Lake Agassiz down to the Mississippi was a work which followed the main glaciation of the second period, and was not a part of the great trenching of the Mississippi to which I referred in my paper.

I think we should be scarcely less than stolid—we of the United States—if we did not strike hands with our brethren across the border over a paper which brings into such beautiful consonance the phenomena on the two sides of the international boundary. This paper sets forth the phenomena of the great plains on the north of the boundary in precisely the same terms and under the same interpretations that we have been accustomed to use on our side of the line.

That which strikes me most, beyond this gratifying consonance, is the remarkable extension of our knowledge which this paper and the two preceding papers relating to the northwestern part of our continent* give us with respect to the delimitation of the ice sheets. The boundary line in the western portion of the plains of the Dominion has been represented as extending nearly parallel with the foot of the Rocky Mountains down to our boundary. It continues essentially parallel to the Rocky Mountains southward in our territory to the vicinity of the Sun river, then curves east and, crossing the Missouri river, swings northward on the north flank of the Lightwood mountains, and thence northeast until it strikes the Missouri again at the mouth of the Judith river; then, swinging back, it courses east to the vicinity of Bismarck, where it once more turns south and keeps near the course of the Missouri river until it strikes the Mississippi. So the delimitation in the western portion of the Dominion is brought into perfect harmony with that reported by the United States Geological Survey. Taking this in connection with the facts given in the preceding paper, it is scarcely a jump of interpretation to project this line along the foothills of the Rocky Mountains north to the border observed in the Mackenzie basin, and thence on to the delta of the Mackenzie, which practically carries the delimitation to the Arctic sea.

The limitation of this border to a line off the eastern base of the Rocky Mountains is a remarkable fact when we consider the low condition of the plains east of them; and the further fact that the glaciers of the Rocky Mountains had only a moderate extension is very remarkable. We must bear in mind that these mountains are very high and very broad, and that there sweep over them breezes bearing an unusual load of moisture, much more than the winds that sweep over the Scandinavian mountains on the other side of the Atlantic. Yet, nothwithstanding all these highly favorable conditions, they were not the source of any extensive glaciation, but, on the contrary, the great glaciation came from the far lower heights of the eastern part of the continent and spread across the vast stretches of the great plains. This, it seems to me, is a fact of profound consequence, and its colossal character ought not to be overlooked.

* By I. C. Russell and R. G. McConnell; the former printed among the memoirs (pp. 99–162), and the latter in the proceedings, in this volume.

Professor N. S. SHALER: I should like to ask whether this evidence, brought to us from north of the boundary to the United States, does not go still further and show that the last glacial period in North America was in some way connected with the conditions of the northern Atlantic ocean? The evidence now goes to show that it is a symptom of climatic conditions on the north Atlantic; and therefore it is our task to interpret the phenomena by the facts that have taken place in that ocean basin. It seems to me it is by the increased precipitation of the vapors taken from the warm waters to the sea that we may most easily explain the conditions of the last ice period.

I have recently had an opportunity to study the surface geology of Florida, and it seems to me probable that in the glacial times, or about the time of the last glacial period, the Gulf Stream flowed freely over the surface of Florida up to the northern portion of the lake district. The appearance of Florida seems to indicate that the tide at this time extended from the northern part of the lake district to the Cuban shore. It seems to me likely that we may attribute a glaciation in the eastern part of Europe and Asia and the northern part of North America to the changes in the flow of this stream dependent on modifications of the coast line topography of the region of the Caribbean and the Gulf of Mexico.

Mr. W J MCGEE: I have recently ascertained that during early Pleistocene time—during the first of the two great ice invasions which all geologists are recognizing—not only was all of Florida submerged, but two-thirds of Georgia and the greater part of South Carolina. The submergence in South Carolina reached 550 or 600 feet, and over the low-lying plains there lies a mantle of coast sands deposited during the period of submergence. These coast sands have been found continuous with the Columbia formation of the northern part of the Atlantic slope.

Dr. J. W. SPENCER: With the conclusions of Professor Shaler and Mr. McGee I concur. I have seen apparent Pleistocene deposits in Alabama at about 675 feet above the sea. Over plains and hills of the great Northwest of Canada, also, I have seen bowlders scattered upon the surface of both Paleozoic and Cretaceous rocks. In many cases these are of secondary origin, having been left upon the washing away of the finer materials from the older bowlder clay. Few or none of those erratics which I have seen have been primarily derived from their original sources, although many have been again transported by the floating ice of now shrunken or extinct lakes or seas.

From the occurrence of elevated beaches described by Mr. Tyrrell and others in the North West territories, and from the remains of still higher beaches about the Great Lakes, I am inclined to generalize and bring down the whole continent to make the beaches mark sea-level in the last stages of the Pleistocene period after the episode of the last till.

Mr. TYRRELL: I may say a word with regard to the bowlders referred to by Professor Spencer as scattered over the surface in the Northwest. It is being recognized by a number of explorers that there is probably some little difference in origin between the bowlders lying on the surface and those in the underlying bowlder clay. In many cases it is impossible that the bowlders could have been derived by denudation from the bowlder clay beneath; and I am rather inclined to suggest the explanation that those bowlders were transported in the mass of the glacier itself instead of having been beneath it, as was the till, and that as the glacier melted and retired they were dropped on the surface. I think that this explanation will fairly account for the presence of most of the solitary local bowlders on the surface of the plains, where they cannot be accounted for by erosion.