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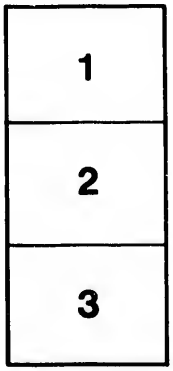

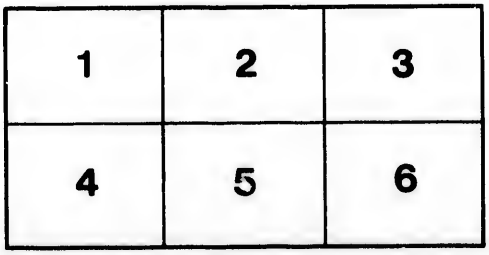

44. *On the* Superficial Geology *of the* Central Region *of* North America. By George M. Dawson, Esq., Assoc. R.S.M., Geologist H.M. North-American Boundary Commission. (Read June 23, 1875.)

(Communicated by Dr. Bigsby, F.R.S., F.G.S.)

[Plate XXXII.]

Physical Geography of the Region.

Where the great region of plain and prairie which occupies the whole central part of Mexico and of the United States crosses the forty-ninth parallel of latitude, which constitutes the political boundary between the last-named country and British North America, it is included in longitude between the 96th and 114th meridians. It narrows pretty rapidly northwards, chiefly by the encroachment on it of its eastern border, but continues as a great physical feature even to the shore of the Arctic ocean, where it appears to have a breadth of between 300 and 400 miles. North of the North Saskatchewan river, however, it loses to a great extent its *prairie* character, and, with the increasing moisture of the climate, becomes thickly covered with coniferous forest.

The eastern boundary of this interior continental plateau, north of latitude forty-nine, is formed by the western slope of that old crystalline nucleus of the continent, which extends north of the St. Lawrence and the great Lakes from Labrador to the Lake of the Woods, with a general east and west course, and then, turning suddenly at an angle of about 60° to its former general direction, runs with a north-north-west course to the Arctic sea. This boundary, though formed, wherever it has been carefully studied, in part of less-metamorphosed rocks generally attributed to the Huronian, may be called the Laurentian axis (see map, Pl. XXXII.) In this part of its course it is not of the nature of a mountain-range. It probably does not attain a height of over 1500 to 2000 feet, and has an average breadth of about 250 miles. It may rather be considered a great rocky plateau; and though it forms the division between the streams running directly into Hudson's Bay and those flowing westward and southward, the actual line of watershed has no determinate direction on it, but follows a devious curve, which in one place (to the east of the region now under consideration) approaches within twenty miles of Lake Superior. Neither is it always a continuous barrier; for near the north end of Lake Winnipeg it is broken through by the Nelson and Churchill rivers, the former of which carries across into Hudson's Bay a great part of the drainage of the plains.

To the west the plateau is bounded by the Rocky Mountains, which rise abruptly from the elevated plain at their base, presenting often to the east almost perpendicular walls of rock. They are

composed, not of a single upheaved ridge, but of a number of more or less nearly parallel ranges, which have a general direction a little west of north, and a breadth of over 60 miles, extending from the margin of the great plains to the valleys of the Kootanie and Columbia rivers. In the vicinity of the forty-ninth parallel, the geological continuity of the country is as sharply broken by the line of their eastern base as its physical character, and we pass suddenly from the little-altered or disturbed strata of Cretaceous and Tertiary age to scarped mountain-sides of palæozoic rocks, metamorphosed and crumpled. The higher peaks of the mountains north of the boundary do not seem often to surpass 10,000 feet. The plains may therefore be considered broadly as a trough intervening between the two great longitudinal watersheds of the northern part of the continent. The lowest portion of this trough, however, is several hundred feet above the sea-level; and much of its western part is actually higher than its eastern Laurentian rim (see Section, Pl. XXXII. fig. 2).

Besides the main longitudinal watersheds, there are also two very important transverse ones (see map), which are not marked by any grand physical features, but appear to be merely caused by low gentle rolls in the strata. Of these, one in a general way follows the political boundary of the forty-ninth parallel. It separates the waters of the Red, the Assineboin and Saskatchewan rivers (which find their way through Winnipeg Lake to Hudson's Bay) from those of the Mississippi and Missouri and their various tributaries. Beginning in that region of swamp and lake in Northern Minnesota which feeds the variously destined head-waters of the Winnipeg, St. Lawrence, Mississippi, and Red rivers, it dips southward between the tributaries of the latter two streams, and passes between Lake Traverse and Big-Stone Lake, with an altitude of only 970 feet, about 200 miles south of the boundary-line. Thence it pursues a general north-westerly course along the high lands formed by the southern extensions of Pembina Escarpment and the Missouri Coteau, and, becoming identified with the latter, crosses the boundary-line near the 104th meridian, 300 miles west of Red River. Then falling south of the drift ridge of the Missouri Coteau, it follows the summit of the plateau of the Lignite Tertiary for about 300 miles to the Cyprés Hills, where it is only 40 miles north of the line, in longitude 110° 30′. Thence it trends southward and crosses the forty-ninth parallel for the last time about 30 miles east of the base of the Rocky Mountains. The average altitude of this watershed region east of the Red River is 1400 feet. In Northern Dakota it may be estimated at 2000 feet; and from this it rises till near the mountains it has attained an elevation of about 4000 feet.

The second transverse watershed crosses from the Rocky Mountains to the Laurentian region, near the fifty-fourth parallel; and not much is known about it. It separates the rivers which reach the Arctic Sea directly, from those of the Saskatchewan system, which flow into Hudson's Bay. Where crossed by the canoe-route to Mackenzie River at Methay Portage, near its eastern extremity, it

height, according to Sir J. Richardson, is 1566 feet. Near its western extremity it would appear (according to Dr. Hector's observations) to be about 2400 feet. It is probable that this watershed is lower than either of these measurements in the intervening region.

Between the two transverse watersheds thus defined, the three prairie *steppes* or plateaus of different elevation now to be described are embraced.

The whole of the region slopes gradually eastward from the most elevated plains at the base of the Rocky Mountains to the lowest, at the foot of the Laurentian plateau to the east. The inclination becomes more abrupt on approaching the mountains, but not so much as to attract special attention; but along two lines which are in a general way parallel and hold a north-west and south-east course across the plains, a very marked step-like rise occurs. These escarpments form the eastern boundaries of the two higher prairie plateaus. The lowest and most eastern prairie-level is that which includes the valley of the Red River in its southern portion, and northwards embraces Lake Winnipeg and associated lakes and the flat land surrounding them. Its average altitude may be estimated at about 800 feet; its area at 55,600 square miles, of which the great system of lakes in its northern part occupies 13,900 miles; its average width is over 100 miles; its eastern boundary is in part conterminous with the shore of Lake Winnipeg and the Laurentian axis, in part formed by the great drift plateau south of the Lake of the Woods. Its western limit is

Fig. 1.—*View of Pembina Mountain, part of the Escarpment of the Second Prairie-Plateau.* (From the Alluvial Prairie of the Red River.)

found at the foot of the lowest of the great escarpments already mentioned, which in the vicinity of the boundary-line is known as Pembina Mountain (fig. 1), and, though broken through by the Assineboin river, is continued northward in the Riding, Duck, and Porcupine Mountains.

Rising to the summit of the second prairie-steppe, we find ourselves on the margin of the "Great Plains," properly so called. This plateau has an average elevation of about 1600 feet, and is bounded to the west by the Missouri Coteau and foot of the third prairie-steppe. On the forty-ninth parallel it has a width of 230 miles, on the fifty-fourth of about 200 miles, though it cannot there be so strictly defined. To the south the boundaries of this region appear to become more indefinite, and in the southern part of Dakota the three primary levels of the country, so well marked north of the line, are probably scarcely distinguishable. The elevated region lying south and west of the Lake of the Woods, and forming in one place the eastern boundary of the lowest prairie, also assumes the form of a plateau; and though having an elevation of from 1000 to 1600 feet only, it corresponds with the height which the second plateau above described might be expected to have, had it continued thus far eastward. It is covered to a great depth with drift materials, and may be called the drift plateau of Northern Minnesota.

The third or highest prairie-steppe has an altitude of about 2500 feet where it is first met with; its surface, however, is much less uniform and more weathered than that of the lower plains; and toward the base of the mountains it rises on the boundary-line to a height of 4200 feet, and in the latitude of the North Saskatchewan to about 3000 feet. Southward, as is well known, the plains along the base of the mountains continue to increase in elevation, the level of the passes through the range being equally affected.

The eastern escarpment of this highest steppe (fig. 2) crosses the boundary-line about longitude 103° 30′, and runs thence with a general west-north-west course to the elbow of the South Saskatchewan in longitude 108°. Here it bends abruptly, and, passing due north, crosses the North Saskatchewan river.

Disregarding the two escarpments (which in reality account for but a small part of the westward increase of elevation) and drawing a line in the direction of the greatest general slope of the prairie-surface, from the intersection of the eastern base of the Rocky Mountains and the forty-ninth parallel to a point on the first prairie-level near the northern end of Lake Winnipeg, we find that it crosses the escarpments nearly at right angles, and has an average fall of 5·38 feet per mile. A second line starting at the same point, and terminating eastward in the lowest part of the Red-River valley, on the forty-ninth parallel, shows an inclination of 4·48 feet.

In the foregoing brief summary of the physical features of the region, I have been guided not only by the facts obtained by the Boundary-Commission Surveys, but by the observations of previous explorers, among whom Dr. Hector deserves special mention. To this geologist (who accompanied Capt. Palliser's expedition) is due

the first clear definition of the three steppes into which the interior region of British North America is naturally divided.

The region which has come under my own observation is for the most part pretty closely confined to the forty-ninth parallel, and forms a line about 900 miles in length, extending completely across the interior plateau of the continent.

Glacial Phenomena of the Laurentian Axis.

Beginning, then, with the glacial phenomena of the Laurentian axis, I shall describe the appearances presented in the neighbourhood of the Lake of the Woods only, where this axis is intersected by the forty-ninth parallel; but, from the similarity of the traces of glacial action even in very distant parts of the Laurentian region, this will serve in some sense as a representation of its general features.

The Lake of the Woods, as a whole, occupies a depression in the south-western slope of the Laurentian region (see Map, Pl. XXXII.). It is over 70 miles in extreme length, and has a coast-line of between 300 and 400 miles. Its northern part is comparatively deep, reaching in some places a depth of over 80 feet. Its general form has been determined by that of an area of less highly altered rocks, which are probably Huronian; and the details of its outline even follow very closely the changing character of the rock, spreading out over the schistose and thinly cleavable varieties, and becoming narrow and tortuous where compact dioritic rocks, greenstone conglomerate, and gneiss prevail. Its shores are almost invariably composed of solid rock with the rounded forms characteristic of ice-action, and dip rapidly below the surface of the water, forming a bold coast, sandy or gravelly beaches being comparatively rare. It is studded with innumerable islands, few of which are laid down on the imperfect maps yet made of the region, but which vary from those several miles in length to mere water-wasted rocks. The islands, like the mainland, are seen, where not covered with luxuriant vegetation, to be composed of round-backed rocks. Only where the rocks are of a specially soft or schistose character has the action of the waters of the lake had sufficient effect on them to form cliffs. The southern part of the lake is very different: there are few islands; the water is not deep; and the whole southern shore is formed by low-lying deposits of sand and detrital matter, Where rock-surfaces appear, however, they are like those of the northern part of the lake, heavily glaciated.

All the harder rocks of the region still show with the utmost perfection the scratching and grooving of the glacial period; and some of the more compact granites and intrusive diorites retain a surface still perfectly bright and polished. On a small scale even the hardest and most homogeneous of the rocks show a tendency in the longer axis of their elevations to parallelism with the glacial markings. Though the general direction of the northern part of the lake

also follows that of the ice-action, it is at the same time that of the belt of Huronian rocks already mentioned. The course of the glacial striæ is extremely uniform, and, from a great number of observations in different parts of the lake, is found to vary through a few points only, lying between north-north-east and south-south-west and north-east and south-west. Slight deflexions, sometimes observed, are generally traceable to deviation of the ice by masses of resistent rock running athwart its course, the striæ always showing a tendency to bend towards the more level regions, and away from the more elevated and rugged parts.

At a few places in the southern part of the lake, glaciation in the ordinary direction which gives form to the rock masses, was observed to be superinscribed with coarser scratches nearly east and west in direction. Some of these may be due to the packing of the ice of the lake itself in the spring; but instances occur which cannot be accounted for in this way. Some rock-surfaces on a low promontory in the southern part of the lake afford interesting examples. The most important direction and that with which the forms of the surface coincide is here S. 13° W., superimposed on which at one place are scratches S. 45° W. or N. 45° E. Near this a direction of S. 50° W. or N. 50° E. occurs, on which is superimposed striation S. 15° W., a direction closely agreeing with the general one, and probably indicating a brief resumption of the original force after a short interval.

Many interesting special cases showing the character and effect of the glacial action, came under observation; but with these I do not wish to burden this paper. The nature of the present outfall of the lake, however, deserves mention. There are two channels now in use, and evidence of at least one other now disused. They cross a narrow ridge which separates the waters of the lake from those of the basin-like head of the Winnipeg River, and are comprised within a distance of about two miles. The hard ridge marks the junction by fault of the Laurentian and Huronian rocks, the line nearly following its crest. The gaps through which the water flows do not depend on any evident peculiarity of geological structure, but probably owe their origin to smaller transverse faults or joints, as a fissure filled with a large greenstone dyke was observed not many miles distant with a direction parallel to theirs. The gorge-like gap through which the northern stream flows is the most interesting, and was most carefully examined. It is occupied by a very picturesque cascade, the first leap of the Winnipeg River. It is certainly preglacial in date, and has probably arisen from subaerial weathering along some line of weakness. The glacial striæ cross over it obliquely at an angle of about 30° with its direction; and the ice has had wonderfully little effect on its shape, having only succeeded in rounding off somewhat the exposed angles of the cliffs. Since the glacial period the river has done little, as the rocks retain their rounded aspects and show ice-striation almost everywhere.

Drift Plateau of Northern Minnesota and Eastern Manitoba.

The great plateau of Northern Minnesota, which stretches southward from the Lake of the Woods, shows only drift materials, and is composed of them to a great depth (see Map and Section Pl. XXXII., *a*). Its general surface is remarkably uniform, and its slopes almost imperceptibly slight. It is, however, diversified on a small scale, being thickly strewn with shallow hollows, which are filled by little lakes or the almost impassable "muskegs" of the region. There are also low flat-topped ridges of sand and gravel of the nature of kames or eskers, and in many localities traces of larger lakes than those now existing, which have been drained by the gradual wearing down of the beds of their outfall streams.

The drift-deposits of this region rest on the gently sloping foot of the Laurentian axis, and are, where I have seen them, composed to a depth of 60 feet or more of fine sands and arenaceous clays, with occasional beds of gravel and small boulders. The finer deposits are generally very evidently false-bedded, and sometimes quite hard. The gravelly layers, as a rule, are found resting on the finer material between it and its surface-soil, and sometimes lie on the denuded edges of the curved sand-beds below. In one place only did I find any trace of organic remains. On the Roseau River, about 30 feet from the top of the bank, a piece of wood protruded from a cliff of hard sandy clay, and, on microscopic examination, appeared to be a fragment of the common cedar (*Thuja occidentalis*). I have no doubt that these distinctly-bedded deposits of the plateau repose throughout on boulder-clay. I have observed them to do so in the southern part of the Lake of the Woods; and, on the Roseau River, also, indications of the underlying boulder-clay are found. In general, however, the few sections which exist do not penetrate sufficiently deep to show this deposit.

An interesting confirmation of the general direction already stated for the glacial action, is found in the composition of the materials of this plateau. Its eastern side, fronting on Lake Superior, is very abrupt, and seems to be held up by a ridge of hard old rocks, which here and there appears from beneath it. Ascending to the plateau-level from the extreme western point of Lake Superior by the Northern Pacific Railway, the drift is seen to have a reddish-purple colour, which continues, though gradually becoming less marked, for some distance after attaining the summit. The colour then changes to the pale yellowish grey which is generally characteristic of the drift of this plateau. The red drift is derived from the red rocks of the border of the lake, and is found along its whole southern side. It is here bounded by a line lying a short distance back from the north-western shore and nearly parallel to it. This western edge of the red drift has been already noticed by Whittlesey in his paper in the Smithsonian Contributions. The surface of the plateau is very generally strewn with erratics; and some of them are of great size. They are chiefly derived from the Laurentian and Huronian to the north; but there are also many of white limestone. Dr. Bigsby

has given an account of the geology of the Lake of the Woods and of the distribution and origin of the erratics there, in former volumes of the Journal of this Society (Quart. Journ. Geol. Soc. 1851 and 1852.) Its shores and islands are covered with boulders, most of which can be traced to outcrops of similar rocks not far to the north-east; but here too a considerable quantity of limestone is found. It is not generally in such large fragments as the metamorphic rocks, and is often seen in small pebbles only, but occurs in some places in great profusion. The limestone drift is entirely confined to the southern and western shores of the lake; and its origin is a question of some difficulty. No similar rock is known to exist to the north-east, unless the limestones of the shores of Hudson's Bay are of this character. Limestone is known to occur on the western side of the Laurentian axis 50 miles further north-west, and beyond that point in great abundance. The limestone there found, however, is of Lower Silurian and Devonian age, while the fossils in some, at least, of the erratics prove them to be Upper Silurian. A south-eastern drift of floating ice may account for some of the specimens; but I am inclined to believe, with Dr. Bigsby, that an outcrop of Upper Silurian is concealed by the drift-deposits along the base of the Laurentian in the Lake-of-the-Woods region.

Lowest Prairie-Level and Valley of the Red River.

Descending the western side of the drift plateau of Northern Minnesota, we enter the valley of the Red River (Pl. XXXII., *b*); by which term I mean to express not the whole drainage-area of the stream in a strict geographical sense, but the well-defined and comparatively narrow trough holding the main stream, and here constituting the first prairie-level, which is bounded westward by the front of the second prairie-steppe. This trough runs nearly due north and south, and, from the south shore of Lake Winnipeg to the source of the Red River in Lake Traverse, is 315 miles in length. It does not end here, however, but passes by a continuous gap, never more than 690 feet above the sea-level, to the source of the Minnesota River, a tributary of the Mississippi. On the boundary-line the valley is 46 miles wide, and it narrows very gradually southwards. The floor of the valley, though it slopes upwards towards the sides, does so at so small an angle as to be quite imperceptible to the eye. It presents an appearance of perfect horizontality, and is perhaps the most absolutely level prairie-region of America. Looking down, towards evening, through one of the breaches in the edge of the western escarpment, it requires little imagination to suppose that the bluish level expanse is that of the sea; and, indeed, the whole of this valley must, at a time geologically modern, have been occupied by a great lake, the fine silty deposits of which now form its level floor. On examining these deposits they are found to be arranged in thin horizontal beds, which together constitute a great thickness, and rest upon till or boulder-clay. Some of the layers immediately overlying the till may correspond with those already described in the

same relative position on the drift plateau; but I believe that nearly the whole thickness of the horizontal deposit belongs to the great lake of a later period. Stones of any kind are very seldom found on this prairie; they are so rare, indeed, that those which I have seen during all my excursions over it probably do not exceed twenty in number. They have no doubt been brought to their present position by the shore-ice of the lake itself, and are similar to those associated with the drift-deposits of its bounding escarpments.

Ascending the front of the western escarpment, it is found, as might almost have been foreseen, to be terraced; and on leaving the alluvial flat, boulders are again found abundantly, both strewing the terraces and the summit of the "mountain" or second prairie-steppe. The terraces not only occur on the front of this escarpment, but extend westward along the banks of the great valley of Pembina River, which at the time of their formation must have been an inlet of the lake, and is therefore probably of preglacial age.

Second Prairie-Plateau.

The surface of the second plateau or steppe of the plain (Pl. XXXII., c) appears to be almost everywhere very thickly covered with drift deposits; and the undulations and slight irregularities of its contour seem in the main due to the arrangement of these surface-materials, which, though no doubt somewhat modified by subsequent denudation, do not seem to have suffered much. Over large areas no systems of "coulées" or stream-valleys are to be found; and the generally undulated surface must be due to original inequality of deposition, though a certain quantity of material has no doubt been removed from the rounded hillocks into the intervening basin-like swamps and hollows. Such an arrangement not only implies the porous nature of the subsoil, but is in accordance with the comparatively very small rainfall of the region, and would tend to show that at no time since its emergence has the precipitation been great. It was observed that in many places boulders and gravel are equally abundant on the crests of the gentle ridges and hillocks and in the hollows, while they are comparatively seldom seen on the intervening slopes. A similar observation has been made by Prof. Bell in a part of the second steppe considerably further north, and would tend to show slight erosion of the surface by marine currents subsequent to the deposition of the heavier materials.

The drift material is found generally to consist in great part of local débris derived from the immediately underlying soft formations; but this is always mixed with a considerable quantity of far-transported material, which is generally most abundant in the upper layers. Large erratics are in some localities very plentifully strewn over the plains, but they seem to be almost always superficial. They are generally of Laurentian rocks; but whitish and yellowish limestone, derived from the Silurian flanking the western base of the Laurentian region, is abundant. A bank in Long-River Valley shows in an interesting section, about 30 feet of drift, resting on

Cretaceous clay or shale. Of the drift the lower portion is composed of stratified sands and gravels, which are evidently false-bedded. The pebbles are chiefly of the underlying rock, which, though soon splitting up under subaerial influences, has been hard enough to bear rounding under water. There are also a few samples of rocks of foreign origin, and the whole arranged in a manner implying a very strong flow of currents in different directions. About 11 feet from the top of the bank the false-bedded layers end abruptly, being cut off by a well-marked horizontal plane. Above this the bedding is near horizontal, and the drift includes many travelled boulders of Laurentian and white limestone, some of them large, together with much small Cretaceous stuff. Large boulders are also abundant, protruding from the surface of the prairie above.

In other places similar hard yellowish sandy clays are met with, but with little sign of stratification, holding many well glaciated stones, and thus resembling true till or boulder-clay. I do not think that the boulder-clay and more perfectly stratified materials are here essentially distinct; but, as they were never seen in the same section, I cannot speak positively on this point. In order to ascertain as far as possible the origin of the foreign material of the drift and the relative proportions of the different constituents, I adopted the following method:—An average collection of pebbles taken at random from the gravel of any locality was made, stones above or below a certain size being rejected for convenience, and care being taken, where possible, to combine gatherings from two or three spots for each locality, and to make the collection a large one. The pebbles so obtained were then carefully enumerated and divided lithologically into groups, which were referred as far as possible to their formations. From the numbers thus obtained percentage ratios have been calculated. The comparative simplicity of the geological features of the interior of the continent, the similarity of the lithological characters of the formations over great areas, and the absence of harder metamorphic rocks in the strata of the plains are specially favourable to such an investigation; and the results serve to show the general course of the drift in a region where rock-surfaces capable of preserving glacial striæ are entirely absent. It was at first intended to enumerate the boulders and larger erratics in this way; but the criterion of smaller pebbles was found more frequently applicable; and wherever comparison was possible, the result obtained from them appeared to agree closely with the proportional importance of the larger masses. I shall present here only the general average deduced from the second prairie-steppe as a whole, which is as follows:—

Laurentian	28·49
Huronian	9·71
Limestone	54·01
Quartzite Drift	1·14

The Laurentian material, consisting of granites and gneisses, is easily distinguishable. Those classed as Huronian are chiefly hard,

greenish, epidotic, and hornblendic altered rocks. It is interesting to observe that the proportional importance of the Laurentian and Huronian, thus ascertained for the drift, is nearly that of their areas where they have been mapped. The proportions in the drift are respectively three to one. Prof. Bell, of the Geological Survey, has stated the proportion by area of Laurentian and Huronian in the region north-west of Lake Superior as two to one, leaving a slight preponderance of the former over the latter in the drift, as compared with the areas in the metamorphic axis, which arises no doubt from the greater prominence of the harder Laurentian rocks. The limestone is that of the flanks of the Laurentian axis; and its great abundance is an interesting feature, and one tending to prove that this rock must in preglacial times have lapped far up on the Laurentian. These three classes are derived from the north-east or east. The fourth or *Quartzite drift* is a general name which I have applied to that coming from the Rocky Mountains, which, although not entirely composed of quartzite, is characterized by the great abundance of that material, and has a peculiar and distinctive appearance. This drift was met with abundantly in many places further west; but it was only in August last that I was able to trace it to its origin in the mountains. It occurs, as will be noticed, very sparingly on this second prairie-level, and is not found over its whole area. The first clearly recognizable fragments were met with near the 101st meridian, 580 miles from the Rocky Mountains, and over 200 from the nearest part of the Laurentian region.

On the surface of this prairie-level there occur some remarkable elevated regions, which seem to be entirely composed of accumulated drift materials (see Map, Pl. XXXII.). The most prominent of these are included under the names of Turtle Mountain, Moose Mountain, and the Touchwood Hills. Though quite unconnected, these elevations follow in a general way a contour-line of the surface, and form a range roughly parallel to the Coteau, to which in their appearance and material they also bear the closest likeness. Of these elevations the only one which I have personally examined is that known as Turtle Mountain, which is bisected by the forty-ninth parallel and forms the most southern of the series. It is a region of broken hilly ground, which may be about 20 miles square, and is for the most part thickly wooded—a circumstance which renders it a specially prominent feature when viewed across the prairie. Its extreme height is not more than 500 feet above the prairie at its base; and its general elevation is a little more than 2000 feet above the sea, or nearly the same as that of the surface of the Coteau. On approaching it from the east the already gently-swelling plain becomes more markedly undulating, small basin-like swamps and ponds are more frequent, and its junction with the region of the "Mountain" would be undefinable but for the limiting border of the woods. The western end of the mountain is more abrupt towards the plain, and is much diversified with ridges, between which lie swamps and lakes, which show a general tendency to arrangement in north-and-south lines. Towards the eastern end there are somewhat extensive

areas of gently undulating land, though always characterized by the abundance of pools and swamps. Notwithstanding the apparent abundance of water, there are few brooks or drainage-valleys, and the streams which do occur are quite small. The surface seems very nearly that of the drift as originally deposited, though sufficient fine material has been washed from the ridges to render the intervening hollows flat-bottomed.

Edge of the Third Prairie-Plateau.

One hundred and twenty miles west of Turtle Mountain the second prairie-plateau comes to an end against the foot of the great belt of drift deposits known as the Missouri Coteau. Beyond this point three diverse zones of country cross the forty-ninth parallel obliquely with a west-north-west course, in the order subjoined:—

1. Tumultuously hilly country based on a great thickness of drift, and forming the Coteau de Missouri properly so called.

2. Flat-topped *watershed plateau*, formed of rocks of the Lignite Tertiary, and constituting a part of the first transverse watershed already described.

3. Lower, broken-down region, south of the plateau, partly based on the Lignite Tertiary, and characterized by gorges and large valleys draining towards the Missouri.

The second region can perhaps hardly be said to cross the line, but appears immediately north of it. On the line and southward the streams flowing to the Missouri rise near the southern edge of the first division, the greater part of the plateau having succumbed to denuding agencies.

The Missouri Coteau (fig. 2, and Map and section Pl. XXXII., *z*) is one of the most important features of the western plains, and is certainly the most remarkable monument of the Glacial period now existing there. I have had the opportunity of examining more or less carefully that portion of it which crosses the forty-ninth parallel, north-westward for a length of about 100 miles. On the parallel, the breadth of the Coteau, measured at right angles to its general course, is about 30 miles; and it widens somewhat northward.

On approaching its base, which is always well defined at a distance, a gradual ascent is made, amounting in a distance of 25 miles to over 150 feet. The surface at the same time becomes more markedly undulating, as on nearing Turtle Mountain from the east, till, almost before one is aware of the change, the trail is winding among a confusion of abruptly rounded and tumultuous hills. They consist entirely of drift material; and many of them seem to be formed almost altogether of boulders and gravel, the finer matter having been to a great extent washed down into the hollows and basin-like valleys without outlets with which this district abounds. The ridges and valleys have in general no very determined direction; but a slight tendency to arrangement in north-and-south lines was observable in some places.

The boulders and gravel of the Coteau are chiefly of Laurentian

origin, with, however, a good deal of the usual white limestone and a slight admixture of the quartzite drift. The whole of the Coteau-belt is characterized by the absence of drainage-valleys; and in consequence its pools and lakes are often charged with salts, of which sulphates of soda and magnesia are the most abundant. The saline lakes frequently dry up completely towards the end of the summer, and present wide expanses of white efflorescent crystals, which contrast in colour with the crimson *Salicornia* with which they are often fringed.

Taking the difference of level between the last Tertiary rocks seen near the eastern base of the Coteau, and those first found on its western side, a distance of about 70 miles, we find a rise of 600 feet. The slope of the surface of the underlying rocks is therefore, assuming it to be uniform, a little less than 100 feet per mile. On and against this gently inclined plane the immense drift deposits of the Coteau hills are piled.

The average elevation of the Coteau above the sea, near the forty-ninth parallel, is about 2000 feet; and few of the hills rise more than 100 feet above the general level.

Between the south-western side of the Coteau belt and the Tertiary plateau is a very interesting region with characters of its own. Wide and deep valleys with systems of tributary coulées have been cut in the soft rocks of the northern foot of the plateau, some of which have small streams still flowing in them fed by its drainage; but for the most part they are dry, or occupied by chains of small saline lakes which dry up early in the summer. Some large and deep saline lakes also exist which do not disappear even late in the autumn. They have a winding, river-like form, and fill steep-sided valleys. These great old valleys have now no outlet; they are evidently of preglacial age, and have formed a part of the former sculpture of the country. The heaping of the great mass of débris of the Coteau against the

Fig. 2.—*The Missouri Coteau, forming the edge of the Third Prairie.* Long. 104° W. (From the north-east, distant about 4 miles.)

foot of the Tertiary plateau has blocked them up and prevented the waters finding their way northward as before; and since glacial times the rainfall of the district has never been sufficiently great in proportion to the evaporation to enable the streams to cut through the barrier thus formed. The existence of these old valleys, and the arrangement of the drift-deposits with regard to them, throw important light on the former history of the plains.

Northward, the Coteau ceases to be identified with the Tertiary plateau, and rests on a slope of Cretaceous rocks. It can be followed by Palliser's and Hector's descriptions of the country to the elbow of the South Saskatchewan, and thence in a line nearly due north through the Eagle and Thickwood Hills; beyond the North Saskatchewan, however, it appears to become more broken and less definite. In Dr. Hector's description of certain great valleys without outlet in this northern region, I believe I can recognize there too the existence of old blocked-up river-courses similar to those just described.

South of the forty-ninth parallel the continuation of the belt of drift material can also be traced. It runs south-eastward, characterizing the high ground between the tributaries of the Missouri and the Red River, which has already been noticed in connexion with the watershed of the continent; but wanting the backing of the Lignite-Tertiary plateau, it appears to become more diffuse, and spread more widely over the country. That the drift-deposits do not *form* the high ground of the watershed, but are merely piled upon it, is evident, as Cretaceous rocks are frequently seen in its neighbourhood at no great depth. From what I can learn of the region it would appear that the so-called Coteau des Prairies and Coteau de Missouri, between which a distinction is made on the maps, are parts of the same great feature. Their elevation is similar, and nearly the same as that of the Coteau on the line; and they are equally characterized by the immense profusion of erratics with which they are strewn, and by basin-like swamps and lakes. The Coteau des Prairies, however, stretches furthest, and dies away only in the south-western corner of Minnesota.

In the Coteau, then, we have a natural feature of the first magnitude—a mass of glacial débris and travelled blocks with an average breadth of perhaps 30 to 40 miles, and extending diagonally across the central region of the continent for a distance of about 800 miles.

Third or Highest Prairie-Plateau.

Passing the Coteau and ascending the plateau of the Tertiary (Pl. XXXII., *d*), we notice at once a change in the character of the drift deposits. They are much thinner, and, area for area, perhaps do not equal one twentieth of those on the second prairie-steppe. They are also now largely composed of *quartzite drift* from the Rocky Mountains, of the nature of shingle, and seldom showing much trace of glaciation. With this western drift, however, a smaller proportion of that from

the east or north-east is mingled. South of the watershed-plateau the third region (that sloping to the Missouri, where it is well sheltered to the north) shows the *quartzite drift* in even greater purity. Where, however, gaps or lower places in the watershed-plateau occur, incursions of Laurentian rocks and of eastern limestones are also found to a greater or less extent.

The general character of the travelled drift of the third steppe may be seen from its percentage composition, derived in the same way as already shown for the second steppe.

Laurentian	27·05
Huronian	?
Limestone	15·84
Quartzite Drift	52·10

Though the percentage of Laurentian material appears nearly the same as before, the much smaller total quantity of drift on this level must be remembered. A mark of interrogation is put after Huronian, to indicate that a few specimens of this formation may be present, but, if so, are undistinguishable from some varieties of the *Quartzite drift*. The great decrease in limestone is at once seen; and even the percentage here given includes some specimens of Rocky-Mountain limestone which has travelled eastward with the *Quartzite drift*. The limestones of the flanks of the Laurentian were probably completely submerged ere the water reached the level of the third steppe. Quartzite and similar rocks now form over half of the entire travelled portion of the drift deposit.

Some of the lower parts of this steppe show thick deposits of true till or boulder-clay, which holds in a hard yellowish sandy matrix well glaciated stones, both from the mountains and from the east, and also a great quantity of débris from the softer underlying beds, among which are fragments of lignite from the Tertiary. These deposits of till, though generally massive and weathering into rudely columnar forms in perpendicular banks, often show traces of bedding and arrangement in water; and false-bedded sandy masses are found abruptly cut off above the confused bouldery clay. The shingle deposits of the higher levels may perhaps be formed partly from the rearrangement of this material; they are at least superior to it.

The width of the third steppe, on the line, is about 450 miles; but it narrows rapidly northward. Its surface is more diversified and worn than that of either of the other prairie-levels; and the occurrence and features of the drift are less constant. Following it westward, and in the main slowly rising, Laurentian and Eastern limestone boulders continue to occur to within about 25 miles of the base of the Rocky Mountains, at a height of about 4200 feet. The distance of these travelled blocks from the nearest part of the Laurentian region is over 700 miles. Beyond this point eastern and northern rocks were not found: but that the depression of the continent ceased here cannot be argued from this fact; for by this time the whole of the Laurentian highlands would be submerged.

On the higher prairie, sloping up towards the mountains, the

drift is entirely composed of material derived from them, and consists of quartzite, with softer shaly and slaty rocks, and limestone, which is generally distinguishable from that of eastern origin. No granitic or gneissic rocks occur in the vicinity of the forty-ninth parallel, or northwards in British America, in the eastern ranges, so far as is known. Southwards, in Montana, granites and gneisses are found underlying all the other formations, but they do not appear to be very extensively exposed.

The Rocky Mountains.

The brook issuing eastward from the mouth of the South Kootanie Pass has cut through a great thickness of clean gravel drift, composed of large and uniform well-rounded pebbles. Above the brook, on the flanks of the mountains on the south side, are several well-preserved terrace-levels composed of similar material. The highest of of these, though its altitude was not actually measured, was estimated from the known altitude of the Pass to be about 4400 feet above the sea. From the position of these terraces, in the open eastern throat of the pass, from which the whole surface of the country falls rapidly away, they can hardly be other than old sea-marks. The topography of the region would not allow me to explain them on any hypothesis of a former moraine blocking up the valley.

Dr. Hector has measured similar terraces at several points along the Rocky Mountains north of the region now more especially under consideration, and states that they may be said to range from 3500 to 4500 feet above the sea. He also states that in the region examined by him the ordinary Laurentian erratics were not observed above 3000 feet, but mentions a very remarkable line of boulders of red granite deposited on the plains at a height of 3700 feet, which, knowing what we now do of the country, can hardly be supposed to have other origin than the Laurentian axis. It will be observed that my measurements tally closely with Dr. Hector's for the more northern part of the region.

Among the Rocky Mountains themselves traces of the former action of glaciers are everywhere abundant, though in the part of the range near the forty-ninth parallel glaciers do not at present exist. The evidence here met with so closely resembles that found in many other mountain-regions as to render it unnecessary that it should be gone over in detail. Nearly all the valleys hold remnants of moraines, some of them still very perfect. The harder rocks show the usual rounded forms; but striation was only observed in a single locality, and there coincided exactly with the main direction of the valley.

The valleys radiating from the summits of greatest elevation hold long lakes, many of which appear to be deep, and are filled with the most pellucid water. Whether they are in all cases dammed in by moraine matter I was unable to determine. These longer valleys very generally terminate in *cirques*, or amphitheatres, with almost perpendicular back and sides, which overlook small but deep terminal lakelets, held in by moraine-matter and shattered rock.

In these sheltered hollows, and on the shady sides of the higher peaks, are masses of perennial snow, which have no doubt kept up the direct succession from the time when great *névés* filled the heads of the valleys and the mountains around them were completely snow-clad, and are only waiting some change in the climatic conditions, to advance again down the old valleys and occupy the places they formerly filled.

State of the Interior Region of the Continent previous to the Glacial Period.

Having briefly stated the main phenomena of the Glacial period in the central region of North America, it may be well to recapitulate and to give some of the conclusions to which I have been led by their study.

Before the onset of glacial conditions we find the continent standing at least at its present elevation, with its complete system of drainage from the larger river-valleys to many of their less important tributaries already outlined. Subaerial action must before this time have been in operation for a vast period, all the great features of the western plains having been already marked out, and the removal of a truly enormous mass of the soft and nearly horizontal Tertiary and Cretaceous rocks effected. That some very considerable changes in the direction of the drainage of the country in preglacial and in modern times took place, however, is probable. An examination of the Lake-of-the-Woods region and a comparison of levels render it almost certain that the waters of the area now drained by its tributary streams then found their outlet southward and westward, towards the present valley of the Red River, and that only after the blocking up of the southern region with the deposits of the drift did the waters flow over the preexisting breach in the northern rim of the lake, and descend over the surface of the Laurentian to Lake Winnipeg. The Winnipeg River does not show any of the characters of a true river-valley, but consists of eroded and glaciated rock-hollows, from one to another of which the stream falls. There is also some evidence to show that the Red River itself, agreeing with the general structure of the country, flowed southwards; and if so, the Saskatchewan, too, would probably with it join the former representative of the Mississippi.

This subject, however, requires a more detailed discussion than can be granted it in this place.

Mode of Glaciation and Formation of the Drift Deposits.

To the precise manner in which the Glacial period was initiated, the area now in question gives no clue; but I have not found, either in the Laurentian region, or over the area of the plains, or in the Rocky Mountains, any evidence necessitating the supposition of a great northern ice-cap or its southward progress.

The great drift ridge of the Missouri Coteau at first sight resem-

bles a gigantic glacier-moraine; and, marking its course in the map, it might be argued that the nearly parallel line of elevations, of which Turtle Mountain forms one, are remnants of a second line of moraine produced as a feebler effort by the retiring ice-sheet.

Such a glacier must either have been the southern extension of a polar ice-cap, or derived from the elevated Laurentian region to the east and north: but I think, in view of the physical features of the country, neither of these theories can be sustained.

To reach the country in the vicinity of the forty-ninth parallel a northern ice-sheet would have to move up the long slope from the Arctic Ocean and cross the second transverse watershed, then, after descending to the level of the Saskatchewan valley, again to ascend the slope (amounting, as has been shown, to over 4 feet per mile) to the first transverse watershed and plateau of the Lignite Tertiary. Such an ice-sheet, moving throughout on broad plains of soft, unconsolidated Cretaceous and Tertiary rocks, would be expected to mark the surface with broad flutings parallel to its direction, and to obliterate the transverse watersheds and valleys.

If it be supposed that a huge glacier resting on the Laurentian axis spread westward across the plains, the physical difficulties are even more serious. The ice moving southward, after having descended into the Red-River trough, would have had to ascend the eastern escarpment of soft Cretaceous rocks forming its western side, which in one place rises over 900 feet above it. Having gained the second prairie-steppe, it would have had to pass westward up its sloping surface, surmount the soft edge of the third steppe without much altering its form, and finally terminate over 700 miles from its source, and at a height exceeding the present elevation of the Laurentian axis by over 2000 feet. The distribution of the drift equally negatives either of these theories, which would suppose the passage of an immense glacier across the plains.

In attributing the glacial phenomena of the great plain to the action of floating ice, I find myself in accord with Dr. Hector, who has studied a great part of the basin of the Saskatchewan—and also, so far as I can judge from his reports, with Dr. Hayden, who, more than any other geologist, has had the opportunity of becoming familiar with all parts of the Western States.

The glaciating agent of the Laurentian plateau in the Lake-of-the-Woods region, however, cannot have been other than glacier-ice. The rounding, striation, and polishing of the rocks there, are glacier-work; and icebergs floating, with however steady a current, cannot be supposed to have passed over the higher region of the watershed to the north, and then, following the direction of the striæ and gaining ever deeper water, to have borne down on the subjacent rocks. The slope of the axis, however, is too small to account for the spontaneous descent of ordinary glaciers. In a distance of about 30 miles, in the vicinity of the Lake of the Woods, the fall of the general surface of the country is only about 3½ feet to the mile. The height of the watershed-region north-east of the lake has not been actually measured: but near Lac Seul, which closely corresponds

with the direction required by glaciation, according to Mr. Selwyn's measurements it cannot be over 1400 feet. The height of land in other parts of the Laurentian region is very uniformly between about 1600 and 1200 feet. Allowing, then, 1600 feet as a maximum for the region north-east of the Lake of the Woods, and taking into account the height of that lake and the distance, the general slope is not greater than about 3 feet per mile—an estimate agreeing closely with the last, which is for a smaller area and obtained in a different way. This slope cannot be considered sufficient to impel a glacier over a rocky surface which Sir William Logan has well characterized as "mamillated," unless the glacier be a confluent one pressed outwards mainly by its own weight and mass.

Such a glacier, I conceive, must have occupied the Laurentian highlands; and from its wall-like front were detached the icebergs which strewed the débris over the then submerged plains, and gave rise to the various monuments of its action now found there.

The sea, or a body of water in communication with it, which may have been during the first stages of the depression partly or almost entirely fresh, crept slowly upward and spread westward across the plains, carrying with it icebergs from the east and north. During its progress most of the features of the glacial deposits were impressed. In the section described at Long River we find evidence of shallow current-deposited banks of local material, afterwards, with deepening water, planed off by heavy ice depositing travelled boulders.

The sea reaching the edge of the slope constituting the front of the highest prairie-level, the deposition of the Coteau began, and must have kept pace with the increasing depth of the water and prevented the action of heavy ice on the front of the Tertiary plateau. The water may also have been too much encumbered with ice to allow the formation of heavy waves.

The isolated drift highlands of the second plateau, including the Touchwood Hills, Moose Mountain and Turtle Mountain, must also at this time have been formed. With regard to the two former, I do not know whether there is any preglacial nucleus round which drift-bearing icebergs may have gathered. There is no reason to suppose that Turtle Mountain had any such predisposing cause; but it would appear that a shoal once formed, by currents or otherwise, must have been perpetuated and built up in an increasing ratio by the grounding of the floating ice.

The Rocky Mountains were probably also at this time covered with descending glaciers; but these would appear to have been smaller than those of the Laurentian axis, as might, indeed, be presupposed from their position and comparatively small gathering-surface. The sea, when it reached their base, received from them smaller icebergs; and by these and the shore-ice the *quartzite-drift* deposits appear to have been spread. That this material should have travelled in an opposite direction to the greater mass of the drift is not strange; for while the larger eastern and northern icebergs may have moved with the deeper currents, the smaller western ice may

have taken directions caused by surface-currents from the south and west, or even been impelled by the prevailing winds. Some of the Laurentian débris, as we have seen, reached almost to the mountains, while some of the *quartzite drift* can be distinguished far out towards the Laurentian axis.

The occurrence of Laurentian fragments at a stage in the subsidence when, making every allowance for subsequent degradation, the Laurentian axis must have been far below water, would tend to show that the weight and mass of the ice-cap was such as to enable it to remain as a glacier till submergence was very deep.

The emergence of the land would seem to have been more rapid; or at least I do not find any phenomena requiring long action at this period. The water in retreat must have rearranged to some extent a part of the surface-materials. The quartzite drift of the third steppe was probably more uniformly spread at this time, and a part of the surface-sculpture of the drift-deposits of the second plateau may have been produced. It seems certain, however, that the Rocky Mountains still held comparatively small glaciers, and that the Laurentian region on its emergence was again clad to some extent with ice, for at least a short time. The closing episode of the Glacial period in this region was the formation of the great fresh-water lake of the Red-River valley, or first prairie-level (which was only gradually drained), and the reexcavation of the river-courses.

It must not be concealed that there are difficulties yet unaccounted for by the theory of the glaciation and deposit of drift on the plains by icebergs; and chief among these is the absence, wherever I have examined the deposits and elsewhere over the West, of the remains of marine Mollusca or other forms of marine life. With a submergence as great as that necessitated by the facts it is impossible to explain the exclusion of the sea; for, besides the evidence of the higher western plains and Rocky Mountains, there are terraces between the Lake of the Woods and Lake Superior nearly to the summit of the Laurentian axis, and corresponding beach-marks on the face of the northern part of the second prairie escarpment.

Mr. Belt, in an interesting paper (Quart. Journ. Geol. Soc. Nov. 1874), deals with similar difficulties in explaining the glaciation of Siberia. The northern part of Asia appears in many ways to resemble that of America; surrounded by mountain-chains on all sides save the north, it is a sort of interior continental basin covered with "vast level sheets of sand and loam." As in the interior regions of America, marine shells are absent, or are only found along the low ground of the northern coast. To account for these facts, Mr. Belt resorts to a theory first suggested by him eight years ago, by which he supposes the existence of a polar ice-sheet capable of blocking up the entire northern front of the country, and damming back its waters to form an immense freshwater lake. The outfall of this lake, during its highest stage, he supposes to have been through the depression between the southern termination of the Ourals and the western end of the Altai to the Aral and Caspian Seas.

Prof. N. H. Winchell, in an article in the 'Popular Science Monthly' for June 1873, entitled "The Drift Deposits of the North-west," broadly accounts for the glacial phenomena on the supposition of a polar glacier. His illustrations are chiefly borrowed from a careful study of the region south of the Great Lakes of the St. Laurence; but as he includes the Valley of the Red River and the entire North-west in his deductions, a brief note may not be inappropriate. The most suggestive portion of the paper is that in which, like Mr. Belt, he traces the necessary production of a great inland lake or sea of fresh water while the foot of such an ice-sheet as that supposed gradually retreats towards the north, down the gentle inclined plane of the surface of the country. In this manner the finer stratified deposits of certain regions south of the Great Lakes are accounted for, and also those of the great valley south of Lake Winnipeg.

Ingenious as this hypothesis of a great glacial lake undoubtedly is, its inapplicability to the phenomena and physical features presented by the region under consideration is at once apparent. In addition to what has already been said, I need perhaps mention but one additional circumstance which appears discordant with it.

From the physical geography of the region it will be evident that the entire drainage of the supposed immense lake must have passed southward by the Red-River valley. There is here no range of mountains to be crossed; and no reason can be assigned why a channel once formed should not have been cut down through the gentle swell of the watershed and remained the permanent, as it appears to have been the primitive, exit of the drainage of the country.

The whole question is a very interesting one; and it would seem probable that the solution once arrived at will be found to apply equally to Northern America and Northern Asia.

EXPLANATION OF PLATE XXXII.

Fig. 1. Map of part of the interior region of North America, showing the watersheds and three primary levels of the plains, the general character of the drift, and the Missouri Coteau. *a*. The Drift plateau of Northern Minnesota, with drift chiefly of northern and north-eastern origin. *b*. Lowest prairie-level and valley of the Red River. *c*. Second prairie-plateau, drift derived chiefly from the east and north-east. *d*. Third or highest prairie-plateau, drift chiefly composed of quartzite from the Rocky Mountains, *x*. *z*. Missouri Coteau.

2. General section along the 49th parallel from the Rocky Mountains to the Laurentian axis. Vertical scale much exaggerated. *a*, *b*, *c*, *d* *x*, and *z* as in fig. 1. *y*. Turtle Mountain.