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THE SUPERFICIAL GEOLOGY OF BRITISH COLUMBIA AND ADJACENT REGIONS.

Additional Observations *on the* Superficial Geology *of* British Columbia *and* adjacent Regions.

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Contents.

In two papers previously communicated to the Geological Society, the results of observations on the glaciation of the northern portion of the American continent from Lake Superior to the Pacific have been given *. The geological work of which these observations formed a part was carried on first in connexion with the North-American Boundary-Commission Expedition, and subsquently on the Geological Survey of Canada. In continuing the exploration of British Columbia on the Survey last named, during the seasons of 1877, 1878, and 1879, many additional facts of interest have been gathered, which it is proposed here briefly to summarize and discuss with special reference to the second of the two papers above mentioned, in which a description of the salient physical features of the province of British Columbia has been given, and a map published; to these, which it is unnecessary here to repeat, reference should be made in considering the points now brought forward.

Observations on the Southern part of the Interior of British Columbia.

In the more detailed examination of that part of the southern portion of the province extending from the Fraser eastward to the Gold ranges, and including the whole breadth of the region formerly called the interior plateau, traces of a general north-to-south glaciation have been found in a number of additional localities at high levels; and it would appear that the ice, whether that of a great glacier or water-borne, pressed forward to, or even beyond, the line of the 49th parallel, notwithstanding the generally mountainous character of that part of the country. With the facts previously recorded, these now extend the known area of north-to-south glaciation to a portion of the plateau over 400 miles in length.

The most striking instance of this general glaciation, and that which carries it up to a height greater than elsewhere observed, is met with in the case of Iron Mountain at the junction of the Nicola and Coldwater rivers. This mountain is one of the more prominent points of that portion of the plateau, which, toward the eastern or inland borders of the coast-range, becomes rough and broken. It rises in a broad dome-like form to a height of 3500

* Quart. Journ. Geol. Soc. vol. xxxi. p. 603, and vol. xxxiv. p. 89.

feet above the neighbouring river-valleys, or 5280 feet above the level of the sea. Its summit has been heavily glaciated, the projecting rocky masses being worn into ridges parallel to the direction of ice-movement, the indicated direction of which is nearly parallel to a bearing N. 29° W. to S. 29° E. If not due to the general glaciation, these markings can have been caused only by ice from the coast-ranges; and though ice has flowed from these as from the other mountain masses of the province during the later portion of the glacial epoch, I believe the situation of Iron Mountain to be such as to preclude altogether this mode of explanation. The mountains of the coast-ranges are neither high enough nor so near as to supply a body of ice capable of overriding it.

On the plateau south of Kamloops glaciated surfaces have been found in several places at an elevation of about 3200 feet above the sea. The locality is far removed from any mountain-ranges capable of giving rise to extensive glaciers, being situated in the very centre of the interior plateau. The rocks are broadly ice-shaped and not unfrequently polished, more rarely distinctly striated. The direction of movement varies from S. 6° E. to S. 27° E. On another part of the plateau, north of the course of the upper part of the Nicola River between Stump and Douglas Lakes, at an elevation of about 3622 feet, are glacial traces similar to the last, consisting of polishing and striation without fluting, having a general direction of S. 9° E. Still another instance of this general glaciation is found on the granite rocks near Chain Lake, between Lake Okanagan and the Similkameen River, in latitude 49° 40′ N. Here, as in the cases before mentioned, the circumstances seem entirely to preclude any explanation by local glaciers, as the portion of the plateau on which it occurs is fully up to the general level, and surpassed only by a few insignificant hills at a considerable distance. The rock-surfaces are beautifully polished, and show striation varying in direction between S. 20° E. and S. 28° E., but no deep grooving. The elevation is 4075 feet.

The Okanagan valley has been alluded to in the paper already referred to as the most important southern gateway of the interior plateau. The bottom of this valley, where it crosses the 49th parallel, is about 860 feet above the sea-level. It is wide, and must at one time have been much deeper, as its rocky floor is not now seen. It occupies the axis of a general depression of some magnitude, and appears to have carried the drainage of a great part of the interior of British Columbia at a former period. This valley has probably been subject to heavy ice-action during the time of general glaciation; but to what extent the features now found may be due to this, and in how far to a subsequent period when, as a narrow arm of the sea or of a great lake, it carried southward ice produced by glaciers nearer the mountains, it is now difficult to ascertain. Glacial striation was observed descending obliquely from the sides toward the centre of the valley, and also in several places in the valley itself, but in both cases without distinct grooving. The rocks of the sides of the valley are often distinctly *moutonnées*; and, as seen

from a distance, those on the lower part of the slopes show flattened outlines, while those higher up are more abruptly rounded and have not been so thoroughly ground down.

The general statements made in a former communication, in reference to the covering of Boulder-clay or unmodified drift spread over the entire area of the interior plateau, are borne out in the region now more particularly in question. From the rearrangement of this material the great systems of terraces subsequently mentioned have been formed.

Details need not be given of the evidence in striation and rock-polishing of the existence of glaciers radiating from the various mountain-systems, though it may be mentioned that some of these seem to have had a very great extension down the lower valleys.

In this southern portion of the interior plateau, terraces are exhibited on a scale scarcely equalled elsewhere. They border the river-valleys, and at greater elevations are found expanding beyond these and attached to the higher parts of the plateau and mountains. None has yet been found here, however, equal in height to that previously described on Il-ga-chuz Mountain in the north at 5270 feet above the sea. Many of the terraces and "benches" of the valleys may be the result of the gradual cutting-down of the river-course in the hollow previously filled with glacial débris; but for others, including more particularly those of the higher levels, no explanation short of the complete flooding of the plateau-region will suffice. Knowing therefore that the water must have stood successively at every lower level, it is of comparatively little importance that in the case of some of the lower terraces it becomes impossible to determine whether they belong to this period of the retreating waters or to a subsequent river-erosion.

In this region the terraces frequently surpass 3000 feet in elevation above the sea-level. The more prominent of those seen on the southward slope of Iron Mountain may be taken as an example of the arrangement of these old water-marks. These terraces are as follows, the approximate heights being given in feet—2386, 3063, 3392, 3611, 3715. It is frequently observed, however, that the occurrence of a terrace at any particular level is merely a matter of local circumstance, probably dependent on the supply of material and other such causes; and in different places not very remote the the scale of terraces often differs. This is illustrated on Okanagan Mountain, situated east of the lake of the same name. On the south side of this elevation the principal terraces were barometrically determined as follows—1862, 2042, 2141, 2645, 2800, 2839 feet; on the northern slope six principal terraces were again observed, as follows—1451, 1579, 1962, 2452, 2553, 2879 feet.

The wide trough-like valleys which traverse the plateau are, over a considerable portion of its extent in the southern part of the province, partly filled with a deposit of white silt or loess-like material comparable with that described under the same name in the Nechacco basin to the north*. It is, however, unconnected with the latter,

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 105.

and at a considerably lower elevation, reaching a maximum height of about 1700 feet above the sea. In the vicinity of Kamloops Lake and in the South Thompson and Okanagan valleys, it is well shown, generally forming the first terraces above the rivers. In origin it is probably, like that of the Nechacco region, a deposit from the turbid waters flowing from glaciers at a time when these had a considerable extension from the various mountain-ranges. At this time, either from general depression of the land, or the damming of the valleys by ice or moraines, a system of winding water-ways, lakes or fiords, must have occupied the main valleys. The heads of these valleys in the Gold ranges still hold long and deep lakes, on the banks of which, where they have been examined (more particularly in the Shuswap region), drift deposits are comparatively unimportant, and the white silts are not found. The fine silty material must have been deposited in somewhat tranquil waters; but it appears difficult to explain its absence from the valleys on the flanks of the Gold ranges. It may be suggested that the currents in the upper parts of the valleys were so strong as to prevent the deposition of the silt; but, apart from the difficulty found in supposing such great bodies of water as the valleys must have held at this time to be in rapid motion, there is no such sudden widening in the valleys at the points at which the silt commences as might account for the slackening of the current.

It is perhaps on the whole most probable that the basins now occupied by the Shuswap lakes and others in a like position were filled with glacier-ice, from which the water flowed down the long valleys, while the abrasion of the rocky beds of the glaciers supplied in large quantity the material of the silt deposits. From the height at which the silts occur, their greater coarseness in the lower part of the Okanagan valley, and the evidence of current-action in that valley near Osoyoos Lake, it is probable that this depression has served as the main outflow of the white-silt lake or sound. At the last it would appear that the glaciers retreated with considerable rapidity, becoming extinct or dwindling to nearly their present size, and leaving the upper portions of the valleys which penetrate the Gold ranges almost free from débris and ready to form the basins of the lakes which now generally occupy them.

The explanation here adopted to account for the existence of these lakes will, I believe, be found applicable to many in other parts of British Columbia, and is again referred to on a subsequent page. It is the same advanced by A. Helland for Norwegian lakes *. Whether any of the lakes in the region now in question lie in rock basins of glacial formation has not been determined, as the valleys below their outlets are generally filled to an unknown depth with detrital materials.

Observations north of the 54th parallel in British Columbia.

An exploratory survey of the remote region lying between the 54th and 56th parallels in British Columbia and of part of the

* Quart. Journ. Geol. Soc. xxxiii. p. 165.

Peace and Athabasca river-basins to the east of the Rocky Mountains, enables the characters of glacial evidence to be defined further north, and has aided in the decision of some theoretical points referred to in the sequel. Most of the facts observed to the west of the Rocky Mountains resemble so closely those previously described for the regions south and east of this that they do not require lengthened notice. The southward or south-eastward passage of glacier-ice in the valley of Babine Lake is indicated by glacial grooving, while the valley of the Skeena has formed a main channel of discharge of glacier-ice toward the coast. In the mountains between the valley of this river and Babine Lake a somewhat irregular, but still, I believe, distinct terrace-flat was observed on the watershed at an elevation of 4300 feet. Its surface is strewn with water-rounded stones differing from those of the mountains of the vicinity. The region north-east of Stuart Lake, extending to McLeod's Lake and the Parsnip River at the base of the foot hills of the Rocky Mountains, is deeply drift-covered, the surface consisting either of Boulder-clay charged with erratics of varied origin, or terrace-flats formed by its rearrangement. This region lies to the north of and somewhat higher than the Nechaco basin, which is characterized by the white silts of a former paper *. The highest part of its surface crossed by the trail has an elevation of 2900 feet.

In the valley of the Misinchinca, flowing westward from the summit of the Pine pass of the Rocky Mountains, glaciation was observed in a few places parallel to the direction of the main depression. In the Pine-River valley, draining eastward and joining the Peace, no glaciated surfaces were seen—a circumstance which may arise from the comparatively soft character of the rocks.

Peace and Athabasca Basins.

In the comparatively level country drained by the Peace and Athabasca rivers, to the north-east of the mountains, underlain by unaltered rocks of Mesozoic and Tertiary age, the chief evidences of the glacial period are found in the distribution of erratics, and the existence of extensive "drift" deposits. In travelling eastward from the mountains by the Pine-River valley, a remarkable absence of such deposits is noted in that part of the valley which traverses the eastern foot hills; but at the Middle Forks the plateau, with an elevation of 1000 feet above the river, or 3000 feet above the sea, and at a distance of thirty miles from the indurated rocks of the mountains, is strewn with rounded pebbles of quartzite &c. from these rocks, though material of local origin preponderates. Eighteen miles further east, at the Lower Forks, the superficial deposits are much more important, covering the surface of the plateau to a considerable depth, and consisting of gravelly beds passing upwards into finer silty materials; the elevation of the plateau is here 2350 feet. In continuing eastward after passing over a summit of 3300 feet on the line followed, Laurentian boulders which must have come

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 105.

from the axis of these rocks to the east or north-east were first observed, and appear in abundance, at a height of from 2300 to 2500 feet, near the D'Echafaud River, in latitude 55° 45′, longitude 120°.

East of this point the wide Peace-River plateau extends, and the general character of the country in regard to its superficial deposits is so uniform that it is unnecessary to particularize localities in describing it. Its surface is so thickly covered that exposures of the underlying rocks are, as a rule, found only in the larger river-valleys. The lower layers of the drift appear to represent the Boulder-clay of the great plains to the south and east and the northern part of British Columbia to the west; they are sandy clays with boulders and stones in abundance, and their upper surface is somewhat irregular, rising in some places in ridges or broad gentle elevations, which stand out above the newer silty deposits in which a great part of the surface is enveloped. The silt is generally pale grey or fawn-colour, and while in places passing almost into clay, becomes occasionally a fine sand. This sandy covering of the surface is found especially at the southern rim of the Peace basin, near the Athabasca, where the plateau attains an elevation of about 3300 feet (long. 117°). The ridges at this elevation are still thickly strewn with Laurentian boulders.

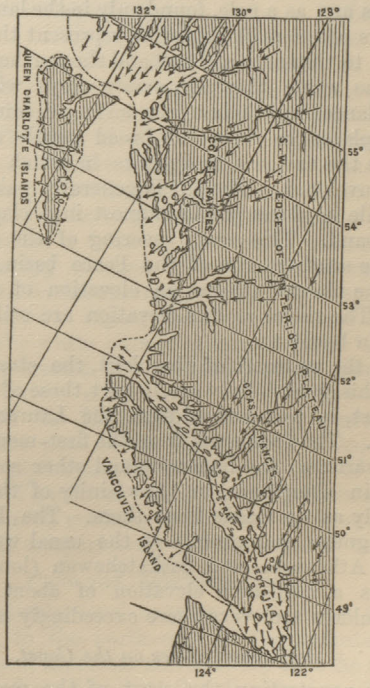
In regard to the material of the drift, the stones and boulders scattered over this great district are, in part, those of the Rocky Mountains to the west, in part derived from the Laurentian axis to the north and east. The fragments from the first-mentioned source are generally of quartzite; the limestone and other softer rocks accompanying these in abundance in the vicinity of the mountains, decreasing rapidly as we recede from them. The Laurentian material is chiefly gneiss and granite of the usual well-marked types. Between the Athabasca and Saskatchewan (long. 113° 30′) the plateau attains a maximum elevation of about 2300 feet, and Laurentian boulders are everywhere exceedingly numerous.

Additional Notes on the Coast.

In the fiords penetrating the coast of the mainland of British Columbia, and channels intervening between the numerous islands lying off it, from the southern extremity of Alaska to the north end of Vancouver Island, marks of the passage of glacier-ice are to be found wherever the rocks are unweathered (see Map, p. 278). These marks are generally in strict conformity with the directions of the passages, which it is evident must have been filled with ice moving in the main seaward from the coast-ranges, in which many smaller glaciers are still found. Whether at any time the supply of ice has been so great as to form a confluent mass flowing toward the sea, at right angles to the general direction of the coast mountains, and without regard to the smaller features of the surface, has not been definitely ascertained; but it is highly probable that this has happened. The outer islands of the Shore archipelago have scarcely been examined; but the little group called the Gnarled Islands (lat. 54° 39′), on the south side of the strait, thirteen miles wide, which lies between

Dundas Island and Cape Fox at the southern extremity of Alaska, shows heavy grooving from N. 50° E. to S. 50° W., proving that this strait must have been filled with ice.

Sketch Map of part of British Columbia, showing the supposed extension and general direction of flow of the glacier-ice when near its maximum limit.



The arrows indicate the direction of flow of the ice.
The dotted line shows the seaward margin of the confluent glacier.

The scarcity of examples of well-marked terraces on the coast, and the comparatively small elevations at which they are found, has been remarked previously. At Fort Simpson, however, in lat. 54° 34′, the surface bears a considerable thickness of detrital matter, and from a distance this appears to form an ill-defined terrace at a height of somewhat over 100 feet. A few miles further southward, at Metlakatla, there is a well-marked terrace, flat, with an elevation, barometrically determined, of 95 feet above high-water mark.

In the previous paper, already several times referred to, evidence was brought forward in favour of a belief that during a part of the glacial period a vast glacier filled the entire Strait of Georgia, which separates the south-eastern part of Vancouver Island from the mainland, and that the ice swept across the south-eastern extremity of the

island, and may even have passed some distance southward to Puget Sound, and westward by the Strait of Fuca. It still remained, however, to determine whether the ice supply of this glacier was wholly derived from the neighbouring mountainous country, or whether (as might be supposed in accordance with some theories of glaciation) a great ice-sheet entered at Queen-Charlotte Sound, and passed continuously southward between it and the mainland. It is now found that the last-mentioned idea must be abandoned. In several places about the northern end of Vancouver Island, but more particularly on the little islands of the Masterman group near Hardy Bay, and on those in Beaver Harbour, are marks of very heavy glaciation from south-east to north-west, in bearings varying from N. 49° W. to N. 62° W. This not only passes over the islands, but has grooved, polished, and undercut vertical, or nearly vertical, faces on their south-eastern parts, while the north-western slopes are comparatively rough. These traces precisely resemble those found in the track of the Strait-of-Georgia glacier near Victoria*, and show that here, as there, the ice rode over the low extremity of Vancouver Island. The seaward margin of the continental shore is here also low, and the width of the glacier of Queen-Charlotte Sound can scarcely have been less than twenty or twenty-five miles, and may have been much greater.

Some additional evidence of the movement of the upper parts of the Strait-of-Georgia glacier has been found at Nanaimo, on the inner coast of Vancouver Island, sixty miles north-west of Victoria. Hard sandstone rocks which have been bared on the colliery railway show heavy glacial grooving running parallel to the general trend of the coast and Strait of Georgia in such a way as to prove that the entire strait must here also have been filled with ice. No local glaciation, which would radiate from the mountains of the district, can account for the facts. In clays resting on these glaciated rocks, shells like those formerly observed at Victoria were found, a small collection comprising *Saxicava rugosa*, *Mya truncata*, and *Leda fossa*. The height of the locality is about 70 feet above the sea.

Between Vancouver Island and the mainland, on both sides of the central region from which the ice spread in two directions to form the Queen-Charlotte-Sound and Strait-of-Georgia glaciers, well-stratified deposits of clays and sands occur, in some places forming cliffs 200 feet in height. In the course of the Queen-Charlotte-Sound glacier, Cormorant Island may be cited as an example of these deposits; and in that of the Strait of Georgia, Harwood, Mary, Hernando, and Savary Islands. These deposits resemble those of Victoria, New Westminster, and the islands in the southern part of the Strait of Georgia previously described, but imply for the period of their formation a decreased length in the glacier, from its point of maximum extension, of at least 100 miles. Harwood, Mary, Hernando, and Savary Islands lie about the entrance of Bute and

* Quart. Journ. Geol. Soc. vol. xxxiv. pp. 94, 96, 99.

neighbouring inlets in such a position as to suggest that they may in part represent a moraine marking a stage in retreat of the ice. They form the projecting points of a comparatively shoal bank off these inlets, which, in their upper parts, are very deep. Boulders here occur in great abundance on the beaches, and are probably derived from a Boulder-clay or morainic material underlying the well-bedded deposits.

Glaciation of the Queen-Charlotte Islands.

These islands were the subject of geological examination in 1878. They form a compact archipelago widely separated from the southern extremity of Alaska to the north, and the western coast of British Columbia to the east, and may be regarded as a partly submerged mountain system, the axis of which lies in a N.N.W.–S.S.E. bearing. In its central part summits surpassing 4000 feet, and still bearing patches of perennial snow, are frequent, but it falls at both ends. On the north-east side of the mountain axis, at its north end, is a wide triangular attachment of flat land forming the greater part of Graham Island.

In these islands we find everywhere evidence of the descent of glacier-ice from the mountains toward the sea, but (with one important exception subsequently noticed) none of the passage across the group of any more ponderous ice-mass. The channels and fiords penetrating the southern portion of the islands show in general distinct and heavy glaciation which has evidently been local in character, the scoring and grooving being parallel to the main directions of the valleys, and changing with their course. In Houston-Stewart Channel, separating Prevost and Moresby Islands, the ice has evidently flowed from the axial mountains both eastward and toward the open Pacific to the west. Many of the boulders of the beaches are distinctly glaciated, and, as they lie in some places rudely packed together, seem to have been little disturbed since they were deposited by the ice. Sands, clays, and other detrital deposits referable to the period of glaciation are here almost entirely wanting, and the water round the coast is deep.

Further north, near Laskeek, where the width of the islands becomes greater, there is evidence, in the comparatively slight degree in which the rocks at the outer ends of the inlets are glaciated, that the glaciers did not long stretch much further out than the present coast-line. At Cumshewa Inlet (lat. 53°), and further north at Skidegate Inlet, the character of the coast changes, becoming low; but both these inlets still head in the high axial mountains of the group. Traces of the glaciers of these inlets are found nearly to their mouths; but while the upper parts are still deep and fiord-like, they are partly blocked at their seaward extremities by transverse bars, and shallow water extends far off shore.

Further north a series of fiord-like valleys are still found penetrating the eastern side of the mountainous axis of Graham Island, and the shoal-water found off Cumshewa and Skidegate is repre-

sented by the wide stretch of flat land before alluded to. Several of the fiords here open together into a large sheet of water forming the upper part of Masset Inlet, which communicates with the sea to the north by the long narrow passage known as the Masset Sound. The fiords are heavily glaciated, bordered in most places by steep rocky shores, deep and free from drift deposits, and contrast in these respects markedly with the low-shoal eastern shores of the Masset expansion into which they open.

The composition of the low land to the east and north-east is best shown in the cliffs forming its eastward-facing margin. A few miles north of Skidegate a low cliff or bank shows deposits which are evidently of glacial age, cut off above by a gently undulating surface of denudation, above which is 10 or 15 feet of material which shows no sign of blending with that below. The upper deposit consists of sand and well-rounded gravel in regular and often nearly horizontal layers. It has here become in many places quite hard, being apparently cemented by ferruginous matter. Its lower layers hold small boulders, a few of which are from 18 inches to 2 feet in diameter. The lower deposit in one place is a typical Boulder-clay, with many half-rounded or subangular stones and occasional boulders of some size. The matrix is bluish grey, hard, and somewhat arenaceous, the whole being irregularly mingled, and having no distinct bedding. At a short distance this Boulder-clay begins to show bedding, and to become interleaved with hard clayey gravels composed of well-rounded pebbles. The stratification of these is undulating and rather irregular, and there is some local unconformity by erosion between the different layers. A few paces still further on these become interbedded with, and are eventually replaced by, hard, bluish-grey, arenaceous clays, which hold some pebbly layers and an abundance of broken specimens of mollusks, among which *Leda fossa* is the most common. A small *Cardium*-like shell and fragments of a *Balanus* were also observed.

Further north on this coast the clays, with the overlying sandy deposit in greater or less thickness, form long ranges of cliffs ; and though locally irregular, their general character continues the same. The clays are, in some places, very hard, and were observed to hold fragments of trees quite brown in colour, but not mineralized. These deposits, as a whole, very closely resemble those previously described as occurring at Victoria, on the south-eastern extremity of Vancouver Island.

Lying like Masset Inlet near the junction of the hilly and low countries is Naden Harbour, and between this and Masset Inlet are two large freshwater lakes, which doubtless occupy an analogous position, but have so far not been visited by any but Indians. Southward there is reason to believe that there are one or more basins in a similar relation between Masset Inlet and Skidegate.

Boulders are very numerous on the coast of some parts of the northern portion of Graham Island ; and these and the beach-gravel are in many cases formed of rocks which must have been transported from the mainland to the north or east, and quite unlike

those of the Queen-Charlotte Islands. Similar erratics appear to characterize in greater or less abundance the whole of the low country above described, but are not found about the heads of the south-western extremities of Masset Inlet.

It has previously been shown that at the time when the Strait-of-Georgia glacier began to diminish the sea must have stood considerably higher in relation to the land than at present, and the glaciated rock surfaces about Victoria and Nanaimo no sooner appeared from beneath the glaciers than they were covered by deposits holding marine shells. Such must have been the state of affairs also in the Queen-Charlotte Islands; and to this time are doubtless to be referred the clay and sand deposits of the low north-eastern part of Graham Island above described. The material of these must have been supplied from the glaciers of the islands themselves, but added to also (as the nature of the boulders proves) by the débris borne on floating ice from the larger glaciers of the mainland, the sea levelling and spreading abroad the material, and preventing the formation of any well-marked terminal moraines by the island glaciers. The rocky beds of the fiords and Masset-Inlet expansions must have been shaped to some extent by the ice; but the absence of drift material from their areas, and especially of the erratics derived from the mainland, are, with their situation, good reasons for supposing that they mark the regions last covered by glacier-ice, and from which it eventually retreated with some rapidity, leaving the hollows formerly occupied by it to become first inlets, and then, with increasing elevation, in some instances lakes.

The exceptional case which seems to show the impingement on the Queen-Charlotte Islands of ice not produced on them was found on the north coast on the little islands lying outside the entrance to Masset Inlet; but it is probable that similar traces might be found by search in additional localities in this vicinity. Wider exposures of basalt a few feet above high-water mark here show very heavy though somewhat worn glaciation in a direction S. 10° E., or N. 10° W., but probably the former. The depth and parallelism of the grooving would appear to show that it is glacier work. The mountainous axis of the islands in this their northern part does not exceed in height about 1300 feet, and where nearest is about 15 miles from the locality, while the direction of the marking is not that which would be followed by ice descending from the mountains under any circumstances, being more nearly parallel to than radiant from them. It is, however, just that which ice-masses floating up or down the strait separating the islands from the mainland must have taken, or glacier-ice pushing southward from the long fiords of the Prince of Wales group in Southern Alaska, sixty miles distant. It may, I believe, be attributed with greatest probability to the last-named agent; and in view of the great extension which the glaciers of other parts of the coast must at one time have had, that required for the Prince of Wales group and adjacent channels does not appear excessive.

General Remarks and Conclusions.

It is somewhat difficult to connect the various observed facts of the glaciation of British Columbia in a general theory of glaciation, owing to the complexity of its physical features and their marked character. Several conjectural schemes were advanced in a former communication; but, abandoning the seemingly untenable theory of a great polar ice-cap, two probable hypotheses appear to remain. A general north-to-south movement of ice is indicated by striation in a number of places in the central-plateau zone, extending now for a length of over 400 miles. This region, from elevations exceeding 5000 feet downward, is also covered thickly with drift-deposits requiring, by their character and mode of arrangement, the action of water. To account for these facts it was thought that either the flow of strong arctic currents bearing heavy ice during a period of great submergence might be supposed, or that the whole region may have been buried under a massive confluent glacier, the drift-deposits being laid down as it retreated in the water of the sea during a period of subsidence, or in that of a great lake held in by glacier-dams in the valleys of the several mountain-ranges.

It was presumed that the gaps of the Peace and Pine rivers in the Rocky-Mountain range might have sufficed for the entrance from the north-east of such currents and masses of ice as would be required by the first theory; but the examination of the region, with this supposition in view, has convinced me that, notwithstanding the general decrease in elevation and width of the Rocky Mountains, the valleys of the rivers are too narrow and indirect, and the surrounding mountains too high, to allow the inflow of sufficient currents with the degree of subsidence which would be required by most of the localities of glaciation and by the superficial deposits. Neither is there any evidence of the passage of drift-material in this region across the mountains either from east to west or in the opposite direction.

It therefore appears to remain as the most probable hypothesis that a great glacier mass resembling the inland ice of Greenland has filled the region which may be called the Interior Plateau, between the Coast Mountains and the Gold and Rocky Mountain ranges, moving (though perhaps very slowly) southward and south-eastward from the region of great precipitation and high mountains of the northern part of the province*, and discharging by the Okanagan depression and through the transverse valleys of the coast range. It still appears to me most probable, however, that this stage of the glacial period was closed by a general submergence, during which the deposit referred to as Boulder-clay was laid down in the interior plateau, and that as the land again rose it assumed its present terraced character. Conditions may be suggested to account for the temporary existence of a great lake in the interior

* Explorations in the northern part of the province in 1879 have shown that the mountains here are even higher and more extensive than had been supposed, several ranges exceeding 8000 feet in great portions of their extent.

plateau of British Columbia; but this will not explain the great height to which water-action has extended on the east side of the Rocky Mountains*, which was probably synchronous. The last stage of the glacial period in the northern part of British Columbia appears to have given rise to the silts of the Lower Nechacco basin, while on the opposite side of the Rocky Mountains similar deposits were laid down over the Peace-River country, the elevation of the two districts being nearly alike.

The general question of the origin of the drift-deposits of the Great Plains having been fully discussed elsewhere†, it will be unnecessary here to enter into it at length. The most remarkable feature of the glacial deposits of the plains is the Missouri Coteau, which it was supposed ran northward from the region near the 49th parallel, where it was more particularly studied, nearly following the margin of the third prairie steppe. This supposition has since been in great measure confirmed; and on the journey from Edmonton to Winnipeg, in the autumn of 1879, I was able to examine cursorily the character of this feature where it touches the north Saskatchewan near the "Elbow," and to observe the great accumulation of heavy boulders of eastern and northern origin in that vicinity. Further north, the facts now advanced show that with the general lowering of the surface of the country the well-defined zone of drift-deposits known as the Coteau is more or less completely lost, the material being scattered broadcast over the upper parts of the basins of the Peace and Athabasca rivers, and approaching in considerable mass the highlands near the base of the Rocky Mountains.

Over the whole western portion of the plains, from the 49th to the 56th parallels, there is a mingling of the eastern and northern Laurentian débris with that from the Rocky Mountains to the west, the latter consisting largely of certain hard quartzite rocks, and the overlap seeming to imply the existence of a sea in which ice derived from both sources floated freely.

Discussion.

The President spoke of the care with which Dr. Dawson conducted his researches, and the value of his observations.

Mr. Bauerman stated that he was not acquainted with the district described by Dr. Dawson; but he thought, from what he had seen in Oregon and the Columbia valley, that many of the conclusions of Dr. Dawson could be established. He, however, doubted whether the ice had been quite so widely spread as Dr. Dawson supposed. He described some of the great terraces on the Barrier River; there were sixteen, one over the other, on a stupendous scale. He had traced them on the Columbia River to 2300 feet above sea-level;

* Quart. Journ. Geol. Soc. vol. xxxi. p. 618.

† Quart. Journ. Geol. Soc. vol. xxxi. p. 603. 'Geology and Resources of the 49th Parallel,' p. 6.

and they could be found still higher but for the degrading action of the climate. The rapid melting of the snow, followed by freezing, and slipping of the ice then formed, produced well-defined ice-scratches in a very short time.

Prof. Boyd Dawkins said that he had studied the glacial phenomena in America, though he had not been so far north; and, so far as he could form an opinion, that northern area appeared to have been a great area of dispersal of ice. In the Western and Pacific States, however, there was no evidence of a great ice-sheet, only a rather larger extension of local glaciers. On the eastern side the southern boundary of the confused glacial deposits, or the drift, passed from the latitude of New Brunswick in a N.W. direction towards the area of the Mississippi, forming a low range of well-marked hills. To the south of this are the "Champlain terraces" and traces of local glaciers on the higher hills. So that in North America there are two great systems of glaciation—one in the N.W., such as Dr. Dawson had described; and another in the N.E. region, apparently pointing towards Greenland and Labrador.