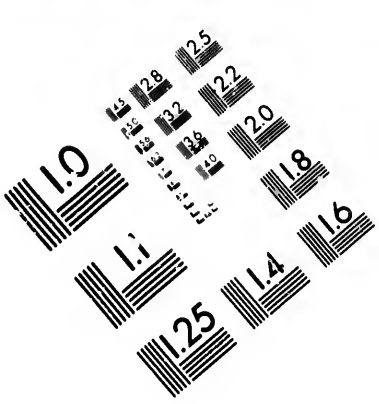

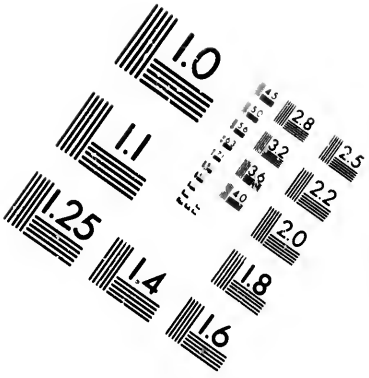

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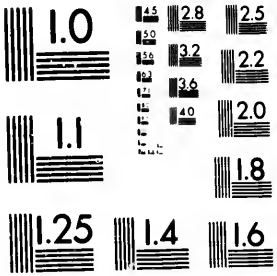

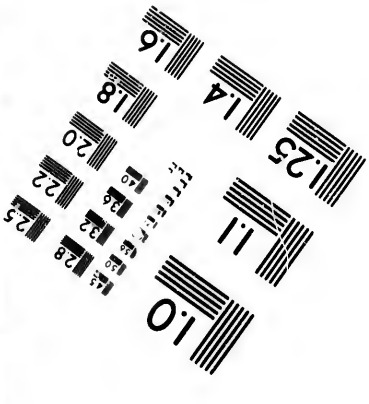

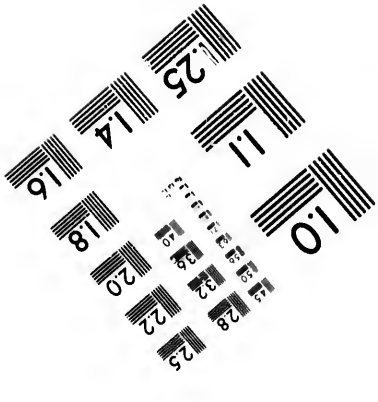

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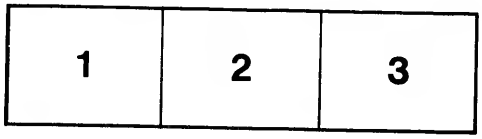

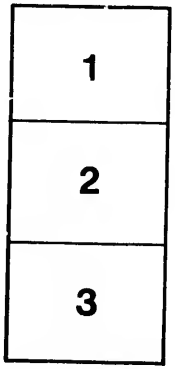

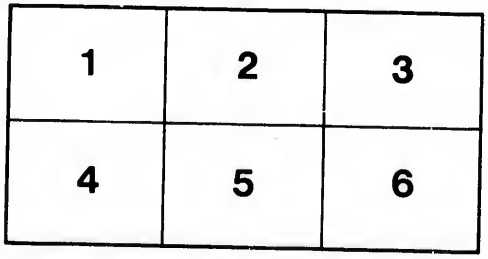

12.

(*From the Canadian Naturalist, Vol IX. No. 1.*)

NOTES ON THE GLACIATION OF BRITISH COLUMBIA.

By George M. Dawson, D.S., Assoc. R.S.M., F.G.S.,
of the Geological Survey of Canada.

While engaged in geological work in British Columbia during the seasons of 1875 and 1876 many points bearing on the glacial period, or epoch of extreme cold and great accumulation of ice which immediately preceded the present condition of affairs, came under notice. The regions more particularly examined during these years were in the interior of the province south of the 54th parallel of latitude, and about the Strait of Georgia on on the coast. Journeys of a more hurried character in other parts of the country enabled me, however, to extend the general conclusions arrived at so as to embrace the greater part of the area of the province. These proved to be of considerable interest, and important particularly in doing away with the apparently anomalous absence of traces of general glaciation on the Pacific slope, a hypothesis based on certain statements rather loosely made, which were afterwards extended to an area greater than they were at any time intended to cover. My observations above referred to, were embodied in a communication presented to the Geological Society, forming an extension to the coast of the Pacific of investigations formerly carried, in the vicinity of the 49th parallel, across the width of the great plains from the Laurentian axis to the Rocky Mountains.* This paper has been printed with a map and illustrations in the Quarterly Journal of the Society.†

In a country with such pronounced physical features as British Columbia, the solution of the problems offered by the traces remaining to us of the glacial period, is by no means so simple as in less rugged districts, and it becomes necessary to keep clearly in view the chief outlines of its geography, and to endeavour in the field and at the time of observation to bring before the mind the various possible causes of each particular phenomenon.

* Quarterly Journal Geological Society, Vol. XXXI, p. 603.
† Ibid, Vol. XXXIV, p. 89.

British Columbia may be described as including the whole width of a certain portion of the Cordillera region of the continent. The Rocky Mountains, properly so called, form the boundary between the belt of the Cordilleras and the great plains to the east. The south-eastern flank of this system is defined by a remarkably deep and straight valley, in which lie considerable portions of the courses of the largest rivers of the country. Beyond this valley to the south-west, is a second and broader mountain region, called by various names in different parts of its length, but which may be designated as the Selkirk or Gold Range. Many of the summits of these mountains are scarcely less in altitude than these of the Rocky Mountains, which frequently surpass 9000 feet. Nearly parallel to these two great ranges is the Coast or Cascade Range, in which the average altitude of the higher peaks may be stated as between 6000 and 7000 feet. A fourth range may be traced in a partially submerged condition, in the mountains of Vancouver and the Queen Charlotte Islands. Between the Coast Range and the Selkirk or Gold Range lies the great Interior Plateau of British Columbia. This represents the interior basin included between the Sierra Nevada and Rocky Mountain ranges in better known regions to the south. It has an average width of 100 miles, and a mean elevation of about 3500 feet. Its height on the whole increases to the south, while northward it falls gradually towards the cluster of great lakes, and the low country of the Peace River Valley. It is now dissected by deep and trough-like river valleys, into most of which water standing at 3000 feet above the present sea-level would penetrate; and though in some places pretty level and uniform, it is generally when broadly viewed only that its true character is apparent. The north-western end of this plateau appears to be blocked by a high mountainous country formed by the coalescence of the three great ranges about latitude 55° 30′; while nearly coincident with the 49th parallel, is a second irregularly transverse mountainous zone, which is however traversed by several great river valleys, of which that of the Okanagan in longitude 119° 30′ is the most important.

The general conclusions arrived at as to the glacial phenomena of the country as quoted from the paper above referred to are as follows :—

1. The character of the rock-striation and fluting on the south-eastern peninsula of Vancouver Island shows that at one time a great glacier swept over it from north to south. The glacier must have filled the Strait of Georgia, with a breadth, in some places, of over 50 miles, and a thickness of ice near Victoria of considerably over 600 feet. Traces of the glacier are also found on San Juan Island and the coast of the mainland.

2. The deposits immediately overlying the glaciated rocks, besides hard material locally developed, and probably representing *moraine profonde*, consist of sandy clays and sands, which have been arranged in water, and in some places contain marine shells. These, or at least their lower beds, were probably formed at the foot of the glacier when retreating, the sea standing considerably higher than at present.

3. Observations in the northern part of the Strait of Georgia, and the fjords opening into it—where the sources of the great glacier must have been—show ice-action to a height of over 3000 feet on the mountain-sides. The fjords north of the Strait of Georgia show similar traces. Terraces along the coast of the mainland are very seldom seen, and have never been observed at great elevations.

4. In the interior plateau of British Columbia, there is a system of glaciation from north to south, of which traces have been observed at several localities above 3000 feet. Subsequent glaciation, radiant from the mountain-ranges, is also found.

5. The superficial deposits of the interior may be classified as unmodified and modified. The former, representing the boulder-clay, hold many water-rounded stones, with some glacier-marked, and occurs at all heights up to over 5000 feet. The latter characterize nearly all localities below 3000 feet, and are most extensively developed in the northern low country, where they appear as a fine white silt or loess.

6. The interior is marked with shore-lines and terraces from the present sea-level up to 5270 feet, at which height a well-marked beach of rolled stones occurs on Il-ga-chuz Mountain.

7. Moraines occur in great numbers. Some of the moraine-like accumulations may have been formed in connexion with the north-to-south glaciation. Most of those now seen, however, mark stages in the retreat of glaciers towards the various mountain-ranges. The material of the moraines resembles that of the boulder-clay, but with water-rounded stones even more abundant.

8. The sequence of events in the interior region has been :— glaciation from north to south, with deposit of boulder-clay; formation of terraces by lowering of water-surface, accompanied or followed by a warm period; short advance of glaciers from the mountains contemporaneously with formation of lower terraces; retreat of glaciers to their present limits. Glaciation of Vancouver Island may have occured during both the first and second cold periods, or during the second only.

9. If the north-to-south glaciation has been produced by glacier-ice, it must have been either (*a*) by the action of a great northern ice cap (against which grave difficulties appear), or (*b*) by the accumulation of ice on the country itself, especially on the mountains to the north. In either case it is probable that the glacier filled the central plateau, and, besides passing southward, passed seaward through the gaps and fjords of the Coast Range. The boulder-clay must have been formed along the front of the glacier during its withdrawal, in water, either that of the sea, or of a great lake produced by the blocking by local glaciers of the whole of the valleys leading from the plateau, to a depth of over 5000 feet.

10. If general submergence to over 5000 feet be admitted, the Japan current would flow strongly through Behring's Strait, and over part of Alaska, while arctic ice-laden water, passing south across the region of the great plains, would also enter the central plateau of British Columbia, accounting for the north-to-south glaciation and simultaneous formation of the boulder-clay.

To these conclusions the facts met with during the continuation of the geological work in 1877 and the past summer, enable some very interesting additions to be made, all which tend to show that the opinions previously formed are in the main correct.

The region examined in 1877 embraced the southern portion of the Interior Plateau, with portions of the Coast and Gold Ranges. Evidence of the north to south glaciation above referred to, were found in a number of additional localities, on the higher parts of the southern portion of the plateau, and traced to a height, on Iron Mountain at the junction of the Rivers Nicola and Coldwater, of 5280 feet. These observations, with those of former years, cover a portion of the Interior Plateau over three hundred miles in length, and show that the ice pressed onward over the southern portion of the plateau to, or even beyond the

line of the 49th parallel, notwithstanding the generally mountainous character of that part of the region. Travelled boulders and stones rounded by water action are found at like heights with the striation, occurring even at the summit of Iron Mountain; and over the greater portion of the region, from the eastern slopes of the elevated land of the coast ranges, is spread a covering of drift material, more or less abundantly charged with erratics, and where not modified by water action subsequent to its deposition, to be referred to the boulder clay. Terraces, or "benches," are in many places in this part of the province shewn in wonderful perfection, rising tier above tier from the bottoms of the valleys, till they are found in a more or less wasted state encircling the higher portions of the plateau remote from the river-courses. These in several places exceed 3500 feet in altitude above the level of the sea, but none so high as that previously observed on Il-ga-chuz Mountain, in the northern part of the province, were found.

In the valleys connected with the Thompson, and especially about Kamloops Lake and the valley of the South Thompson above Kamloops, but also in the great Okanagan Valley, and forming small outlying patches for some distance up the Similkameen, is a remarkable horizontally-stratified deposit of white silt, in the form of terraces. These are evidently remnants of a sheet of similar material, which has at one time formed the floor of these wide trough-like valleys. In composition it resembles the white silts of the Nechacco Basin, but occurs at a different horizon, reaching a maximum height, so far as ascertained, of about 1700 feet above the sea. In origin it is probably like that of the Nechacco, a deposit from the turbid waters of glaciers at a time when the ice still had a considerable extension from the various mountain ranges, and general depression of the land, or the damming up of the valleys gave rise to a system of winding water-ways—lakes or fjords—which occupied the main depressions of the surface. The heads of these valleys, in the flanks of the Gold Range, still hold long and deep lakes, on the banks of which drift deposits appear to be scarce and the white silts are not found. I refer in this connection particularly to the system of valleys occupied by the Shuswap Lakes. It appears not improbable that at the time the white silts were laid down the portions of the valleys now held by these lakes were filled with glacier ice, and that eventually a rather rapid dissolution

tion occurring, the beds of the glaciers were left as hollows to become lakes. Whether any of these are true rock-basins can not be determined, as the material flooring the lower portions of the wide valleys is altogether detrital. A moraine appears to lie across the valley at the lower end of Little Shuswap Lake.

Explorations along the coast of British Columbia, and more especially in the Queen Charlotte Islands, during the past summer, have developed additional interesting details bearing on the glacial period. These have not yet been worked up, but the main points are as follows. The great glacier which filled the Strait of Georgia, overriding the south-eastern extremity of Vancouver Island, may be attributed with greatest probability to the earlier and more intense period of glaciation. Its motion was from north to south, but whether this indicated a general glaciation of the coast in that direction, or was due entirely to the contour of the land, was not known. It was evident that had any polar ice-cap or southward-moving glaciating ridge of ice been the agent, it must also have followed the wide sound separating the north-western end of Vancouver Island from the mainland, in a south-eastward direction. This has not occurred, but, on the contrary, a glacier equally massive with that of the Strait of Georgia has poured out of this sound north-westward, sweeping over the northern portion of Vancouver and adjacent islands. From a point nearly opposite the middle of Vancouver Island, where the channels separating it from the continental shore are most contracted, the ice has flowed south-eastward, forming the Strait of Georgia glacier, and north-westward as that of Queen Charlotte Sound.

North of Vancouver Island, wherever looked for in the proper situations, marks of heavy glaciation are found in all the channels and fjords, to the southern extremity of Alaska where my observations terminated, though a coast-line similar in its general features, and doubtless characterized by the same signs of a former glaciation, extends far to the north-westward. The glacier ice has not only filled the narrow fjords to a great depth, but passing westward has occupied the wider straits which separate the outer islands of the group which fringes the coast.

In the Queen Charlotte Islands, parted widely from the mainland, traces of local glaciation only, due to ice accumulating on its own mountain system, are found. The northern shore of these islands is however strewn with erratics which may have

come from the mainland. Along the eastern shore of Graham Island, a long line of cliffs displays deposits of clays and sands similar to those previously described as occurring in the southern part of Vancouver Island. Many of the beds contain boulders and some hold marine shells of the species found in the deposits just referred to, with occasional fragments of wood.

Quite recently, a great addition to our knowledge of western geology has been made by the publication by Clarence King of the volume of his series on the fortieth parallel, devoted to systematic geology. In this the quaternary period is treated at some length, and in a comprehensive manner, enabling comparisons to be drawn between the condition during the glacial period of that part of the Cordillera system included in British Columbia, and its southern continuation in the vicinity of the fortieth parallel.

King has failed to find any evidence of a great southward-moving ice-mass, or general glaciating agent, and no sheet of boulder-clay covers the region; the superficial deposits being either directly due to the descent of torrents from the mountains and high lands, or to the rearrangement of these by water action in lakes. Two great sheets of water which have been called Lakes Lahontain and Bonneville, spread widely in the high plateau region between the Sierra Nevada and the Rocky Mountains. Local glaciers were, however, extensively developed, coming down to altitudes of 2000 to 5000 feet above the sea in the Sierra Nevada, which was exposed to the moisture-bearing winds of the Pacific, but seldom reaching below a height of 7000 to 8000 feet in the dryer eastern ranges. These constitute the local expressions of the general change which further north produced great ice-fields, but at no time was more than about one-thirtieth of the area embraced in the fortieth parallel survey covered with ice.

The most interesting point established by King, however, is the existence of two periods of moisture and flooding of the lake basins, alternating with two of extreme drought, the latter of which still continues. The evidence of these is found both in the relative arrangement of the stratified and unstratified materials of the old lake bottoms, and in the chemical character of the deposit from their waters. These periods of great precipitation are correlated with great probability with the two epochs of glaciation proved in British Columbia. King, however, adopts extreme views as to the power of glaciers in eroding

valleys, attributing most of the canons of the region he has examined to their action. He draws attention to the V-shaped gorges which become U-shaped in their upper reaches, and supposes that the former were cut out by flood waters accompanying and following the first period of glaciation, while in the latter we have the unaltered work of the glaciers of the second period, stating that the work of erosion in these valleys has been absolutely trivial since the glaciers left them. It is also advanced in support of these views that many if not most of the canons of which the age can be determined, have been cut out since Pliocene times, and that in the surfaces of the Archæan masses which must have stood out as islands during long geological periods, nowhere shew the junction of newer formations with them, to follow other than broad rounded curves.

To this theory of the origin of canons and mountain-valleys, it may be objected that whatever be the case in the fortieth parallel area, vast post-glacial erosion and the formation of deep valleys and gorges since that period have elsewhere been discovered; that glaciers are never now found to exert such active erosive power, and that the idea that so sluggish and inert a portion of a glacier as its *névé* should produce the great amphitheatrical valleys or cirques of the central mountain regions, seems inconceivable. Further, the post-pliocene age of the canons, supposing it to be correctly assigned to them in all cases, may mean nothing more than that the progressive elevation of the plateau area by which the cutting down of canons may be explained, was most active about that time. Canons and fjords are in any case rather exceptional phenomena, they occur only, on any hypothesis, in regions long raised above the sea level, and the chances that such features should be preserved during a depression of the land and afterwards brought to light in the particular portions of the lines of contact of newer and older rocks exposed by denudation, are exceedingly small.