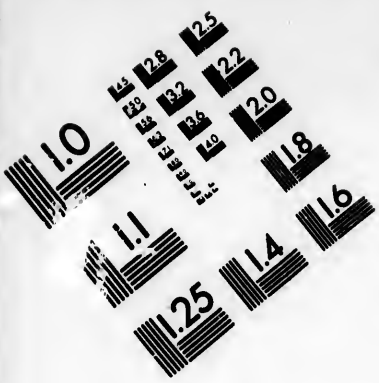

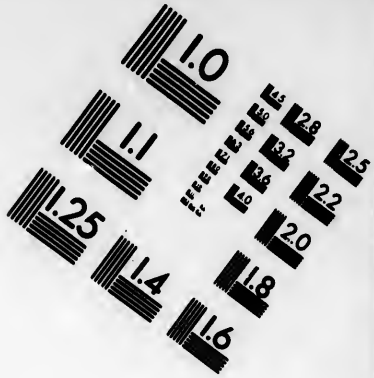

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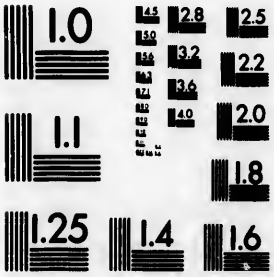

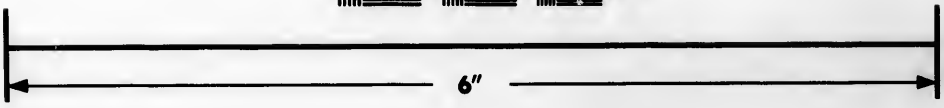

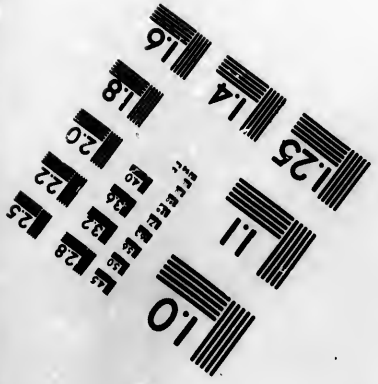

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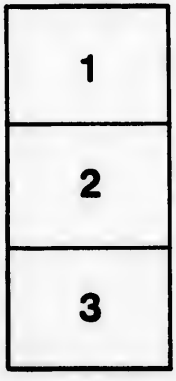

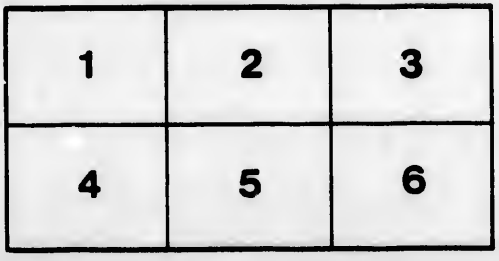

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ADDITIONAL OBSERVATIONS ON GLACIERS IN BRITISH COLUMBIA

FROM THE PROCEEDINGS
OF THE
ACADEMY OF NATURAL SCIENCES
OF PHILADELPHIA
DEC. 1899

Additional Observations on Glaciers IN British Columbia.

BY
GEORGE AND WILLIAM S. VAUX, JR.

From the Proceedings of
The Academy of Natural Sciences of Philadelphia,
December, 1899.

ADDITIONAL OBSERVATIONS ON GLACIERS IN BRITISH COLUMBIA.

BY GEORGE AND WILLIAM S. VAUX, JR.

Excluding the territory which lies to the north of the Arctic Circle, all the principal glaciers of North America lie within the great ranges of the Rocky Mountain system. These ranges stretching along the Pacific Coast are peculiarly well situated for the formation of glaciers, which are found in places, probably not inferior to the better known ice streams of Switzerland.

While one or two glaciers exist in the central part of California, on the sides of Mt. Lyell, and further to the north in Oregon and Washington on Mts. Hood and Ranier, it is not till the international boundary is crossed that the scenery becomes truly Alpine and glaciers are found of great size and striking characteristics. As the ranges stretch northward they converge till at the narrowest portion they exceed but little a breadth of 400 miles. At this point they are composed of parallel ranges, the outer ones being nearly continuous, while the inner are more broken and cut by deep valleys through which, in several instances, noble rivers find their way. Beginning at the west, the most important of these ranges are the Cascade, the Gold, the Selkirk and the Rocky; the last two being the highest, the most Alpine and broken and the most covered with glaciers. The reason for the greater glacier activity in these eastern ranges is in part as follows:

If a map of the Pacific Ocean be examined on which the currents have been marked, it will be seen that the Japan current, after flowing past the islands of Japan, divides into two unequal parts. The smaller of these takes a northeast direction through Bering Sea and Strait into the Arctic Ocean, while the larger portion assumes an eastern and then a southeastern course, bathing the west coast of British North America, and finally, being deflected to the south by the continent, and cooled, forms the North Equatorial current, which is a feeder to the Japan current. The evaporation from this stream of warm water is very rapid, and

the moist winds, the prevailing direction of which is eastward, soon reach the coast line and the ranges of mountains beyond. Nearly at right angles to the path of these moist winds lie the parallel ranges of the Rocky Mountains. The Cascade and Gold Ranges, not being high, the clouds pass over them with a comparatively small precipitation on the western slopes, but on reaching the higher and more rugged ranges of the Selkirks and Rockies, cooling takes place more quickly, and the precipitation is very rapid. It is for this reason that on the western slopes of the mountains the snow is always deeper than on the eastern. The clouds as they rise to cross the individual ranges are cooled, and give up their moisture, which is precipitated before the summits are reached.

While the annual snowfall in the Rocky Mountains is always heavy, the winter of 1898–99 was one of the most severe since the construction of the Canadian Pacific Railway during the late seventies and early eighties. The record of snowfall, which is kept with more or less regularity at Glacier House, shows an excess of 108 inches over the average of the three previous years, while the rain, which unfortunately was not measured, must have added materially to the total. At Field, in the Rocky Mountain range, on the Kicking Horse river, the winter was no less rigorous than the preceding ones, but the snowfall was much lighter than the average of previous years, being twenty-three feet, as observed by the watchman on the pass just above Field. The precipitation from the winds as they blew eastward from the Pacific Ocean took place earlier than usual, and while probably about the same amount of rain and snow fell in both localities, the local fall in the west was more and in the east less than the average. The spring being late and the early summer cool, melting took place without much damage from freshets, and resulted in the mountains retaining more snow during the summer months than for several years.

In addition to this the summer was unusually cool. Snow was noted frequently on the higher mountains and even down to the lower levels. On August 15th a heavy snowstorm broke over the mountains, which lasted for several hours. Snow lay thick on the ground at Glacier House, at an elevation of 4000 feet; at Field it measured four inches on the platforms, while at Hector, the summit of the Kicking Horse Pass, there was a full foot. Clearing

weather soon melted this at the lower levels, but on the mountains the fall was heavier and lasted for a longer period. It will be interesting to watch the effect, if any, which this unusual season will have on the glaciers of the locality. Of the glaciers observed, both last summer and this, a much smaller recession took place during the twelve months than in previous years.

VICTORIA GLACIER.

The Victoria Glacier, at the head of Lake Louise, Alberta, was visited on the 26th of July, 1899. Although seldom seen by travelers, it is almost as accessible, and probably more interesting, than the Illecillewaet Glacier, in British Columbia. A row across the beautiful Lake Louise, followed by a walk of about two miles over a fairly good trail, brings one to the tongue, which is deeply buried in a large and high moraine. Following the northwest side of the valley, which has evidently been quite recently abandoned by the ice, the surface of the glacier is reached with ease. Over the lower part crevasses are almost entirely wanting, the drainage, to a very large extent, taking place on the surface.

For a distance of nearly one and one-quarter miles from the tongue the surface is thickly covered with moraine composed of shales, sandstones of several colors and limestones. These fall with the avalanches from the hanging glaciers above, and many of them are of large size.

From indications which seem to be borne out by the observations of others,[1] the glacier is receding and contracting. The slope of the surface is small, the lower part being nearly flat, and the motion is accordingly likely to be insignificant, though no observations have been made for its determination. For future reference, a very large block of limestone, near the centre of the glacier, and about one mile from the tongue, was located by range lines and marked "VX, '99." The movement next year can easily be determined from this rock. The position of the ice on the northwest side was also located, being twenty feet distant from the nearest of three very prominent and nearly cubical blocks of red sandstone, which recently had been released from the ice.

[1] *The First Ascent of Mount Victoria*, Prof. C. E. Fay, Appalachia, vol. ix, p. 4.

Many pretty examples of sand cones and glacier tables were to be seen, while the avalanches, which at frequent intervals thundered down the almost perpendicular cliffs of Mts. Lefroy and Victoria, lent an awfulness to the scene truly in keeping with the surroundings. The lower glacier is almost entirely fed from those hanging on the steep slopes above.

ASULKAN GLACIER.

The Asulkan Glacier was visited on the 12th of August, when a picture was taken from the test rock of 1898, and three boulders marked to determine in future the position of the tongue. A search was made for the rocks marked by Mr. H. W. Topham without result. Changes in the deposits about the glacier have evidently taken place rapidly, and it is probable the rocks marked by him have been covered up by fresh material.

The tongue of ice seems to be slowly receding from the moraine, as noted last year,[1] and it was possible to locate the limit of the ice quite accurately. In order to fix its position on the above date, a line, passing through three rocks and the tongue, was chosen, the magnetic bearing of which was 85° 35′ E. The rocks marking the two ends of this line were situated, one on the small moraine just to the left of the glacier, and the other on the high and stable moraine to the right, while the third and smallest rock lay just below and to the right of the tongue. Bearings were taken to locate these rocks with other prominent objects.

The changes which have taken place in the glacier during the year are not marked. A comparison of the test pictures of 1898 and 1899 shows a slight shrinkage in the height and a very slight increase in the breadth, while the position of the tongue has not changed to an appreciable extent. The ice fall about three-eighths of a mile above the tongue, where a series of exquisite seracs is to be seen, is visibly less than last year, and the névé line is much lower. The hanging glaciers to the west, on the sides of Mts. Castor and Pollux, are more active, and we noted a number of pretty avalanches. These seemed to be very infrequent last year.

[1] *Proc. Acad. Nat. Sci. Phila.*, 1899, p. 124. Also Plate VI.

ILLECELLEWAET GLACIER.

Owing to its accessibility, this glacier has been more carefully observed than any other in the region. It may be reached by a good trail in thirty minutes from Glacier House, and we visited it almost daily between the 29th of July and the 20th of August of the present year. During this period, partly owing to the cold and damp weather, but little melting or recession of the tongue was noted. This was in marked contrast to the rate of melting observed last year.[3]

The observations on this glacier naturally divide themselves under four principal heads, which will be taken up as follows:

1. Measurements of rate of flow.
2. Measurement of recession and other changes since 1898.
3. Photographic record from test rock "W."
4. Survey of tongue, and mapping moraines and streams.

1. Measurements of rate of flow.

These were determined at nine points on the glacier, one a few feet above the tongue, and eight on a straight line at right angles to the flow and about 1500 feet above the tongue. Rev. Wm. S. Green, in 1888,[4] made a determination of the rate of flow by driving stakes into the ice in a direct line. Owing to the rapid melting, however, these soon fell, and when he returned to remeasure, no accurate results could be obtained. Profiting by his experience, we decided to employ plates of steel, six inches square and one-eighth inch thick, in the centres of which holes were bored and threaded to receive three-quarter-inch pipes, three inches long. The original purpose of the pipes was to support small flags to facilitate observation. It was found, however, when the practical test came to be made, that if the plates were inverted, with the pipes extending on the under side, they sank into the ice, forming anchors, while the plates rested on the surface and could be easily seen. The plates were given two coats of vermilion paint, and lettered and numbered in white for identification.

The right moraine of the glacier being high and secure, and

[3] *Proc. Acad. Nat. Sci. Phila.*, 1899, p. 123.
[4] *Among the Selkirk Glaciers*, p. 218.

affording an excellent view of the surface of the ice, we determined to use its ridge as the station for the transit. Observations had been made to determine the mean direction of flow of the ice, and on the 31st of July, 1899, the transit was adjusted on the ridge. A large tree was taken as a line mark on the left side of the valley.

The plan of measuring a distance of 250 feet between the plates by means of a tape measure was proved to be impracticable on going on the ice. While the surface was comparatively smooth, it was rolling and broken by valleys running at right angles to the direction in which the measurements were to be made. In nearly every case it was not possible to see from one plate to the next. We accordingly decided to abandon the actual measurement, and after adjusting the plates, to lay out a base line and take the angles to the plates from each end. The results could then be plotted on the map and the distances obtained. This plan worked well, and on the second visit we were able to place a transit at each end of the base line, and make readings of both angles at the same time.

Eight steel plates were laid out on the line shown on the map. At this point the total breadth of the glacier is 1720 feet. Owing to the rounded surface of the glacier the position for the ninth plate was not visible from the ends of the base line, and as it was quite close to the left border it was omitted altogether.

On the 11th of August, or eleven days later, transits were set up at each end of the base line and the bearings to each of the plates taken. At the same time the exact movement of the plates was accurately measured from the direct line in which they had originally been placed. This will be found noted in the fourth column of the table.

Table showing Motion of Line of Plates, across Illecillewaet Glacier, British Columbia, July 31st to September 5th, 1899.

Number of Plate.	Feet from N. Border.	Dates of Observation.	Motion since last Obs. (ins.).	Average daily motion (ins.).
1	265	July 31	On line.	2.56
		August 11	42.5	
		September 5	31.5	
2	500	July 31	On line.	3.90
		August 11	40	
		September 5	104	
3	605	July 31	On line.	5.51
		August 11	75	
		September 5	105	
4	750	July 31	On line.	6.77
		August 11	74.5	
		September 5	Lost.	
5	845	July 31	On line.	6.06
		August 11	71.5	
		September 5	140.5	
6	980	July 31	On line.	6.79
		August 11	76.5	
		September 5	165.5	
7	1040	July 31	On line.	6.16
		August 11	60	
		September 5	172	
8	1310	July 31	On line.	6.00
		August 11	66	
		September 5	Lost.	

Again, on September 5, through the kindness of Mr. E. J. Duchesnay, of Revelstoke, B. C., another measurement was made by Messrs. H. B. Muckleston and C. E. Cartwright. The positions of the plates on July 31st and September 5th only are shown on the map, as the motion which had taken place up to August 11th was so small as to be hardly noticeable on that scale.

These determinations show a marked decrease in the rate of flow as compared with the observations of Rev. William S. Green in 1888. They demonstrate the more rapid motion of the central portion of the glacier, and also that the ice on the convex side of the line of flow moves faster than on the concave side.

Two of the plates, Nos. 4 and 8, could not be found on September 5th. All the plates were left on the ice, and it will be interesting to determine the amount of flow during an entire year if they can be found again next summer.

Besides the row of eight plates across the glacier, an additional plate (No. 9) was placed a few feet above the tongue and measured at frequent intervals. The slope of the ice at this point

was about 40°, and as the reference point was located at the level of the ground moraine below, the vertical height of the plate and the diagonal distance were noted, from which the horizontal motion was calculated. The vertical distance from the ground moraine was obtained through a crevasse near by, while the direct distance from the marked boulder was readily measured with the tape line. Unfortunately, after these measurements had been made for several days, and very satisfactory results obtained, a great mass of the tongue on which the plate had been located broke away from the main glacier. Immediately the daily rate of flow changed from a little over five inches to a fraction under three, and remained almost constant. Whether this apparent motion was due to the melting of the plate in the ice, or to the reduced flow of the smaller mass when not urged on by the parent glacier, was not determined. The crevasses seemed to widen from day to day in spite of the fact that the motion of the ice alone would cause them to become narrower.

Table of Motion of Plate No. 9, on Tongue of Illecillewaet Glacier, British Columbia, August 1st to 20th, 1899.

a. Number of Observation.....	1	2	3	4	5
b. Date of Observation.....	8/1	8/2	8/6	8/15	8/20
c. Interval since last measurement (days).		1.24	3.75	9.25	5.1
d. Actual horizontal motion of plate (ins.)		7.3	18.5	26.1	13.5
e. Motion of plate per day (inches).....		5.9	5.1	2.8	2.7

2. Measurement of recession and other changes since 1898.

After the rapid changes of the last few years we were surprised that very little alteration had taken place in the form of the glacier since last summer. In the fall of 1898 the average *daily* recession was nearly eight and one-tenth inches, while the average annual recession was fifty-six feet.[5] Measurements showed that on July 29th, 1899, the tongue was seventy-one feet above the marked rock "C," (see map, Plate XX) and on August 20th, seventy-six feet. These indicate a recession of but sixteen feet

[5] *Proc. Acad. Nat. Sci. Phila.*, 1899, pp. 123, 124.

for the year as compared with fifty-six feet, the average of the past eight years; and an average daily recession of but two and three-tenths inches as compared with eight and one-tenth inches in the same month of the previous year. On the right side, where the ice has a much steeper slope, practically no change from the position noted last year could be observed.

A few local changes in the ice and moraines have occurred. The great moraine on the left being supported on the ice foot is constantly slipping down upon the glacier below. The right moraine is much more stable, and no material change can be noted in it. On the extreme left of the glacier local shrinkage and recession have taken place, uncovering a mass of bed rock, over which the principal stream issuing from the glacier tumbles in a cascade. This fall has existed for a long time, and it is probable that before another year it may be covered again by the glacier. The cascade will form an easily identified point for the limit of the ice in 1899.

After a careful examination of the test pictures of 1898 and 1899, taken from identical positions, it appears that the depth of the ice in the upper regions of the glacier just below the névé is increasing. This fact was also noted by a number of persons who have been in the region for some time.

3. Photographic record from test rock "W."

The taking of the test picture from the rock "W," from which point the others had been taken, was accomplished on the 19th day of August, 1899—the same day of the year as the 1898 picture.

4. Survey of tongue and mapping moraines and streams.

The accompanying map, Plate XX, the basis of which was a trigonometric and photographic survey, may in future years prove of interest in tracing the changes of the glacier and locating the moraines and marked rocks. The first records of the position of the glacier are in 1887, when it followed closely the narrow moraine in which rocks "E," "R" and "A" are located. One year later, on the visit of Rev. William S. Green, a marked shrinkage and recession had taken place, as shown by his photographs, and the position of his tarred rocks, still plainly visible (marked "T" "T" on map).[6] It is probable that each year since 1887 has

[6] *Among the Selkirk Glaciers*, p. 219.

witnessed some recession of the ice. Before that time there are indications that the glacier was either stationary or advancing. The alder bushes and scrub evergreens which grow in places on this moraine show, from their leaves and annual rings, an average age of from twenty-two to thirty years. Taking the smallest number noted—twenty-two years—and subtracting from it the twelve years which have elapsed since 1887, there still remains an interval of ten years, during which the glacier did not cover a greater area than it did at the time we first observed it. We have no means of knowing whether, during this period, the glacier was advancing or retreating, but there is proof that in 1887 the tongue occupied as low a position as at any time during the past twenty-two years.

This border moraine of 1887 offers several interesting features. A large part of it is composed of two distinct moraines of nearly equal size. The same characteristic is noted on the great left moraine which, at a certain point, has a marked depression in the ridge. As the amount of morainal material carried down by the glacier is insignificant, these double moraines may mark the limiting positions of two periods of advance, one of which took place not far from 1887.

The average of all the movements of the glaciers of this region has been a marked recession, which is amply proved by the lines of moraines abandoned in the valleys below. At one time, the Illecellewaet and Asulkan Glaciers, which now terminate near the heads of the valleys, extended till they joined and flowed as a common ice stream. To estimate the time at which this took place, or rather to fix a date since which the glaciers must have been separate, the rings of a number of trees in both the Illecellewaet and Asulkan Valleys were counted. In the Illecellewaet Valley, at the Second Bridge, several examples were so counted, the oldest of which showed 250 rings. In the Asulkan Valley, a tree with 296 rings was noted, while one splendid example of white spruce was thirteen feet five and one-half inches in circumference. Allowing one ring to a year, this would indicate that the recession of the two glaciers took a much longer time than has been supposed by some. It is probable many hundreds of years have elapsed since they were united and covered the ground now occupied by the railway and the Glacier House.

In closing, acknowledgment is particularly due for the thoughtful coöperation and interest of Mr. E. J. Duchesnay, Division Superintendent of the Canadian Pacific Railway, Revelstoke, B. C., and of his assistant, Mr. C. E. Cartwright, for valuable assistance in connection with the surveys. Also to Edouard Feuz, of Interlaken, whose untiring interest, and skill on ice and rock, contributed largely to the success of the results.