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THE FRESHFIELD GLACIER, CANADIAN ROCKIES

(With 9 Plates)

BY
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To the student of the phenomena of active glaciers the Canadian Rockies offer an advantageous and almost untouched field. Three of the most accessible ice tongues along the Canadian Pacific Railway have been made the subject of detailed investigation, but on the remoter and larger ice systems almost no work has yet been done. During recent years, the Alberta-British Columbia Boundary Survey has produced a series of admirable contour maps (scale 1:62500) which delineate the continental divide, together with its adjacent mountains and glaciers. Thus there is now available to the glacialist an excellent groundwork for the prosecution of his particular researches.

Of the newly mapped glaciers, the Freshfield is the most attractive. Size, ease of access, and majesty of scenery all commend it. Lying in a direct line 40 miles northwest of Lake Louise, five days of comfortable traveling will take one to its tongue. The trail distance is about 65 miles, all the way through wild mountain valleys with peaks, glaciers, torrents and lakes in plenty to beguile the march. A good camp ground is to be had not far from the tongue and there is ample feed for the horses.

The Freshfield massif is a well-defined group of peaks about 12 miles square situated in a semicircular loop of the continental divide between tributaries of the North Saskatchewan and Columbia rivers. Its drainage is principally to the former. It is separated from the Yoho-Waputik group on the southeast by Howse Pass (5,010 feet) of historic fame, and from the Forbes-Lyell group on the north by Bush Pass (7,860 feet). There are 25 peaks in the group surpassing 10,000 feet in elevation, Mt. Barnard (10,955 feet) being the loftiest. Eleven of them exceed 10,500 feet.

The Freshfield glacier and tributaries occupy an elliptical basin in the midst of the group, nine miles long from southeast to northwest, and four miles wide. Around the periphery the peaks stand in

[1] A summary of glacier measurements and observations in the Canadian Alps, with references will be found at the end of this paper, page 13.

line, forming a retaining wall which almost completely incloses it. The ice discharges through a gorge-like valley to the northeast in a single tongue three-quarters of a mile wide and three miles long, buttressed on both sides by mountain masses over 10,000 feet high. Excepting this valley, there is no real break below 9,000 feet in the entire sweep of the rim. The area of the ice and névé in the Freshfield system proper is approximately 22 square miles, but adjacent connected, or nearly connected, glaciers on the outer slopes of the basin bring the total area of ice in the group up to about 40 square miles. The trunk glacier from its most distant source to the tongue is almost exactly nine miles long.

In the summer of 1922, the writer in company with Dr. J. Monroe Thorington and Edward Feuz, Swiss guide, visited the Freshfield group mainly for the purpose of ascending some of the unclimbed peaks. At the same time, however, it was felt that advantage should be taken of the opportunity to make such observations on the glacier itself as conditions might permit. Accordingly the writer brought along a small light telescopic level reading to 5′ of arc on both vertical and horizontal circles, a prismatic compass, a clinometer, a 100-foot steel tape for base-line measurements, white paint for marking stations, white cotton cloth and wire for erecting signals, etc., in addition to the usual aneroids and thermometers employed in mountaineering. As it turned out, we were able to spend only eleven days at the glacier, and of these only three were exclusively devoted to observations on it, so that the results presented herewith cannot claim to be more than of a preliminary and tentative nature. We did, however, familiarize ourselves with nearly every part, for in the course of our five ascents (Mts. Gilgit, Nanga Parbat, Trutch, Barnard, and Freshfield) we travelled, on the ice itself, some forty miles besides obtaining excellent views from the summits.

The work attempted falls under the following headings: (1) measurement of the rate of surface velocity of the ice; (2) instrumental triangulation for the location and measurement of a line of stones and for effecting connection with the government map; (3) observations on the tongue and its retreat; (4) observations on general features of the glacier.

1. MEASUREMENT OF THE RATE OF SURFACE VELOCITY

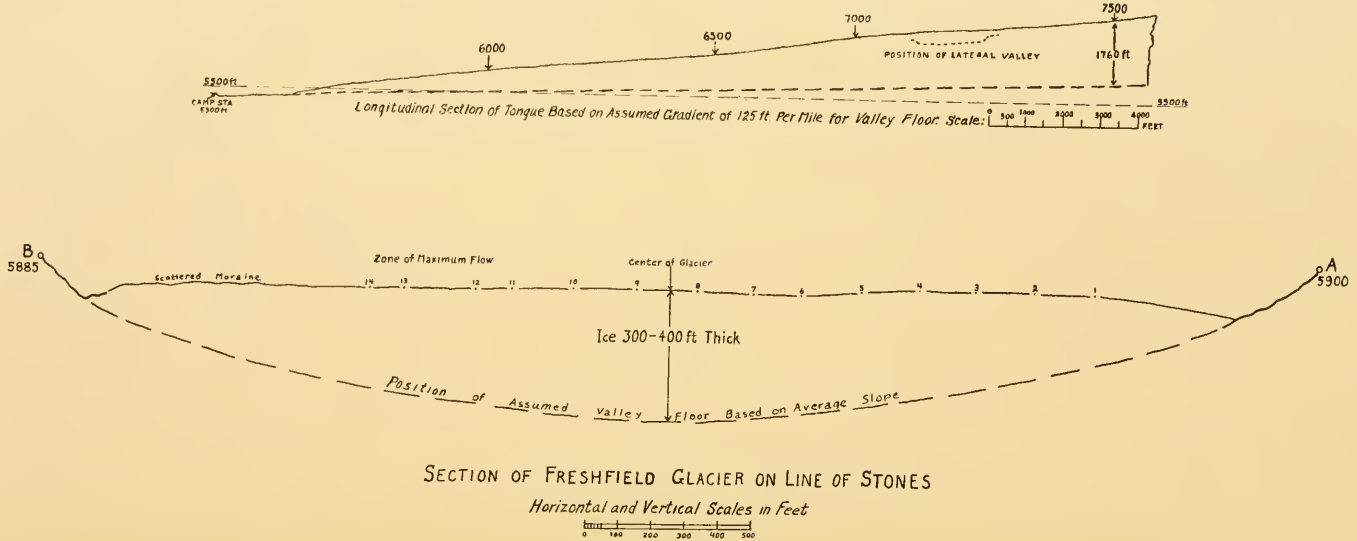
We established our base camp 683 yards from the forefoot on July 10, altitude 5,300 feet. The site, on the top of a high bank, commands an excellent view of the broad flat tongue completely fill-

ing the valley bottom, and of the sharp peak of Mt. Freshfield (10,945 feet) rising over it in the background five miles away. Around the trunk of an evergreen tree on the edge of the bank a white band was painted to serve as a station in the instrumental triangulation. A stream of clear water lies at the foot of the bank.

After a trip up the three-mile tongue, a suitable location, 1,250 yards above the end of the glacier, was chosen for establishing a line across the surface of the ice. The mark for the northern end was a rectangular slab of rock a rod square, perched on the inner slope of the north lateral moraine 50 yards above the glacier. It is one of the most prominent boulders anywhere on that side of the valley and is visible from nearly all parts of the northern half of the lower glacier. It is also visible from Camp Station, being about one and one-quarter miles distant therefrom. It is tilted towards the glacier and is the largest stone to be seen near the top of the lateral moraine from that standpoint. It is designated Station A. Owing to lack of time it was not painted. The mark for the southern end of the line was a much smaller boulder 125 feet above the edge of the ice on the crest of the south lateral moraine near the base of a prominent gully that scars the valley wall. A vertical reference line was painted on the side towards the glacier. It is designated Station B.

On July 13, Station A was occupied with the instrument. Fourteen numbered flat stones were carried out on the glacier and set in flat-bottomed niches chipped in the ice, 50 paces apart, on the line indicated by the vertical hair of the telescope, in accordance with signals from the observer. Such stones, particularly if dark in color, have a tendency to become fixed in the ice through melting. The writer has set out three of these lines, and has never had reason to suspect that any stone slipped from its original position. If one side of the stone is straight, it gives a good fiducial edge upon which to sight with the instrument. The azimuth and angle of depression of each stone were determined from a second station on the north moraine, later ascertained to be 320 feet distant. On line A-B the ice was 1,133 yards wide.

The positions of the stones are shown on the accompanying cross-section of the glacier (fig. 1). The estimated thickness of the ice is based upon the assumption that the gradient of the valley floor obtaining below the forefoot continues uniformly back under the ice. According to the configuration of the valley hereabouts, this does not seem unwarranted. The slope is about 125 feet to the mile and the maximum thickness of the glacier at the line of stones works



SECTION OF FRESHFIELD GLACIER ON LINE OF STONES

Horizontal and Vertical Scales in Feet

0 100 200 300 400 500

FIG. 1.

out at 400 feet. The longitudinal section is also constructed on the assumption that the valley bottom continues back at the same gradient of 125 feet per mile, the surface slope being plotted from the contours of the government map. Although this basal gradient is purely hypothetical, it probably is fairly approximate to the truth on this particular tongue, where the evenness of the surface and its comparative freedom from crevasses are strong indications of a smooth, regular valley floor beneath. The average slope of the similarly situated Forbes Brook valley adjacent, is 160 feet per mile.

Six days later (July 19) Station A was occupied again and the line re-determined on the ice which had meanwhile moved downward. The amount each stone had advanced was measured directly with a tape. The results are given in the following table:

OBSERVATIONS ON A LINE OF STONES SET ACROSS THE FRESHFIELD GLACIER JULY 13, 1922

Stations	Distance from north margin of glacier	Motion from July 13 to July 19	Average daily motion for six days	Remarks
On north lateral moraine	*Ft.*	*In.*	*In.*	
A.	255	0	0	Superficial moraine
1	420	24	4.00	extends from ice
2	610	18	3.00	margin out on
3	775	25	4.17	glacier about 400
4	950	26	4.33	feet.
5	1125	18	3.00	
6	1305	26	4.33	
7	1450	22	3.67	
8	1620	27	4.50	
		CENTER OF GLACIER		
9	1800	26.5	4.42	
10	1990	24	4.00	
11	2175	28.5	4.75	
12	2285	28.5	4.75	
13	2500	29	4.83	Maximum motion.
Superficial moraine begins and extends 850 ft. to margin of glacier.				
14	2600	23	3.83	
On south lateral moraine				
B.	3600			200 feet from ice margin.

Approximate width of glacier on line of stones, 3400 ft.
Distance between stations marking the line, 3855 ft.

The increased average velocity of the southeasterly portion of the glacier as compared with the northwesterly portion is doubtless

due to the fact that on the former side the ice is sweeping through a broad arc, which normally has the effect of deflecting the zone of most rapid motion away from the middle. When, as here, the curve is associated with a reversed curve further upstream, the deflection, following the analogy of running water, naturally would be more pronounced. And so, in fact, we find it here, the zone of maximum velocity being thrown far over towards the southeasterly margin. Actually it occurs about half-way between the center and the side instead of at the center.

The weather during the period of our stay was generally warm and pleasant, although windy and smoky, the smoke at times settling down in a dense pall almost obscuring the sun and hindering both mountaineering and photography.

2. INSTRUMENTAL TRIANGULATION FOR LOCATION AND MEASUREMENT OF A LINE OF STONES AND FOR EFFECTING CONNECTION WITH THE GOVERNMENT MAP

Conditions for the laying off of a base-line on the surface of the ice were not very favorable in the neighborhood of the line of stones, but after some search a location was finally chosen, 400 yards upstream, and a level line 270 feet long was measured with a steel tape. Observations from this gave the distance (3,855 feet) between Stations A and B at the ends of the line.

From these the position of the great boulder (pl. 1, fig. 1) on the surface of the ice near the center of the glacier was determined. On July 19 the downstream edge of the boulder was 2,440 feet distant from Station A, and 2,510 feet distant from Station B, the elevation of its base being 6,000 feet. The azimuths between the boulder and the ends of the line were: from A, 39° 10′, and from B, 38° 10′. It is visible from Camp Station, and distinctly appears in plate 3, figure 2, $1\frac{5}{16}$ inches from the left edge on the ice profile.

This boulder is the largest of many sizable erratics that are scattered over different quarters of the tongue. They occur singly and sometimes in pairs, surrounded by clean white ice. This gives them good visibility from a distance and will render them valuable markers for studies of the ice motion. The stone in question was doubtless noticed by Dr. Collie in 1897, for it appears to be shown in the illustration opposite page 62 in his "Climbs and Explorations in the Canadian Rockies." He writes (page 55), "We noticed them within a mile of the snout of the glacier and in 1902 they did not seem to have moved much." The rock is now exactly a mile from the end

1. Great boulder on surface of Freshfield Glacier looking north. Photograph by J. M. Thorington.

2. Glacial erratic marked "1922." Photograph by J. M. Thorington.

Test view of tongue from rock "C," showing rock "H," July 20, 1922. Glacier is 1,000 feet distant. Photograph by H. Palmer.

FIG. 2.

Reproduced from Sheet No. 18 of the Interprovincial Boundary Commission.

of the glacier. Its dimensions are estimated to be 36 feet long, 18 feet wide, and 16 feet high. The cubic contents would be about 10,000 cubic feet. With some difficulty, it was climbed by Feuz, who erected a little cairn on the downstream point out of loose fragments found on the top. It was not otherwise marked.

Another of these stones was utilized as a marker for one end of the base line (pl. 1, fig. 2). It was painted "1922" with white paint, and lay 350 feet distant from the block just mentioned. The distance to Station A was computed to be 2,080 feet, and to B, 2,580 feet, the elevation being 5,960 feet. The azimuths between this boulder and the ends of the line were: at A, 38°45′, and at B, 30°25′.

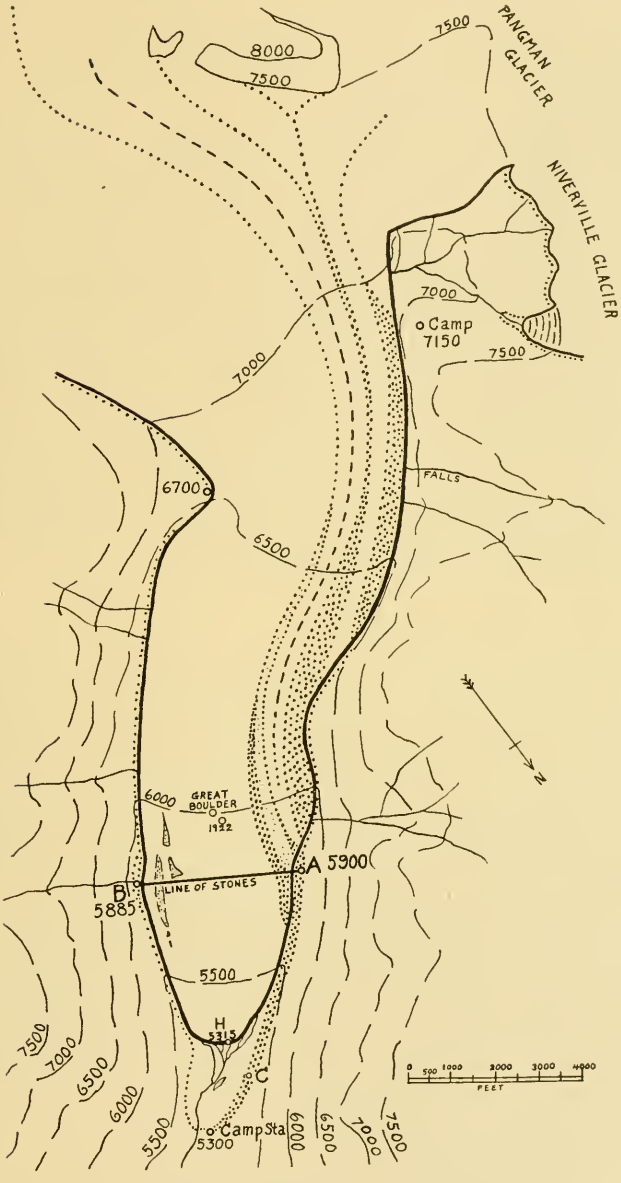
From Stations A and B, Mt. Freshfield, Mt. David, and other points on sheet 18 of the Boundary map were observed as controls.

3. OBSERVATIONS ON THE TONGUE AND ITS RETREAT

It was originally intended to make a detailed photographic survey of the terminal ice tongue and the area adjacent, but this had to be abandoned on account of the density of the smoke. A local secondary triangulation, however, was carried out by the writer from a 305-foot base, measured on the out-wash plain near camp. By this means a boulder at the ice lip (H in pl. 2) was located, together with several other features of importance, including a large stone on the north lateral moraine to serve as a station for test views of the tongue.

This rock is designated Station C. It was marked on the side towards Camp Station, from which it is distant 505 yards, with a three-foot cross (X) in white paint. The cross is visible from Camp Station, but only upon careful scrutiny and with glasses. The stone rests on the only sizable exposure of bed-rock on the north side of the valley, about 45 feet above the flat ground moraine. It lies just to the left of and above an oval-topped reddish stone plainly to be seen from Camp Station. It was occupied with the camera July 20, and the accompanying view secured (pl. 2).

There is no question but that the glacier is retreating. The actual end is a thin, semicircular, concave lip, furrowed with the typical longitudinal depressions almost universally associated with this condition. The frontal slope varies between 20° and 30°. As regards the rate of retreat, there seem to be no precise data available. However, the writer is fortunate in being able to present a view (pl. 3, fig. 1) of the tongue secured by the late Hermann Woolley on the occasion of his visit in 1902. Almost certainly this was taken very close to Camp Station, and when compared with a similar photo-



THE TONGUE OF FRESHFIELD GLACIER

Showing Moraines, Stations and other Details from a Local Survey by
HOWARD PALMER 1922
Adjusted to Sheet 18 of the Alberta-British Columbia Boundary Commission

FIG. 3.

graph of 1922 (pl. 3, fig. 2), exhibits a marked shrinkage and recession. The view of 1902, taken in connection with another of that year (not reproduced) leaves little doubt but that a certain pile of moraine (marked M in the 1922 picture) was then in process of formation at the ice lip.[1] Assuming this to be true, this pile of moraine being 925 feet distant from the most advanced ice in 1922 allows an estimate to be made of an average retreat of 46 feet per year for the 20 years intervening. A distant photograph by the Boundary Survey (pl. 4, fig. 1) taken in 1918 plainly shows the presence of this same moraine pile, although the exact position of the ice front in relation to it cannot be satisfactorily fixed.

The inner slopes of moraine and gravel bounding the open space below the tongue have not had sufficient time, since the ice was near, to develop any forest. A scattering of trees and bushes is growing up, but none have reached large size and there is far from being a continuous mat of vegetation. The 1902 picture above referred to indicates that there has been only a slight increase in the amount of vegetation on these slopes in the score of years intervening. One is probably safe therefore in estimating a lapse of at least half a century since the ice abutted against the banks in question. It was regretted that opportunity was wanting for a detailed study of this question by the cutting of trees. No growth whatever was noticed on the ground moraine of the valley floor below the tongue. The rapid cutting of the migratory glacial streams would perhaps account for this.

In the test photograph (pl. 2) taken from Station C, three fair-sized stones may be noted near the edge of the ice. These should constitute helpful markers for the future. The one most advanced (H in pl. 2) lies exactly at the ice margin and is located on the accompanying map of the glacier tongue. It is distant 683 yards from Camp Station and is marked H on the map (fig. 3).

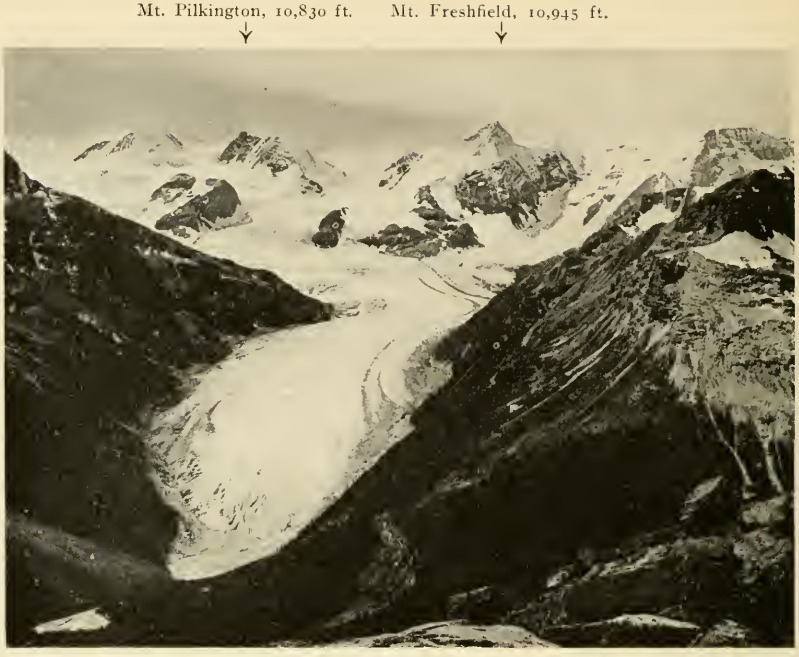
Drainage streams emerging at several points along the forefoot soon unite in a powerful torrent which cuts off the southeasterly side of the valley and prevents access to the surface of the ice except at

[1] It is possible that the moraine may have been formed in 1897 with almost no retreat between 1897 and 1902, for Professor Collie, at page 56, in his book already cited, states (referring to his visit in 1897), "The snout of the glacier was advancing and plowing up the debris before it." The weakest point in the deduction is the difficulty of identifying the moraine so plainly seen in figure 1 of plate 3 with that marked in figure 2, but it is the writer's opinion, after examining the place, that they are the same.

1. Photograph of the tongue taken from near Camp Station by Hermann Woolley in 1902. Mt. Freshfield in distance.

2. Tongue of glacier from nearly the same point as figure 1. Photograph by J. M. Thorington, 1922.

Both photographs cover exactly the same field and are reproduced on exactly the same scale. The greater apparent massiveness of the glacier in figure 1 is largely due to the fact that it is upwards of 300 yards nearer to the camera. Its skyline therefore conceals more of the distant mountains than does that of figure 2. The difference in the aspect of the two is probably due as much to perspective as to the actual shrinkage of the ice in the 20 years intervening.



1. General view of tongue from Mt. David. Photograph by Alberta—British Columbia Boundary Commission, 1918.

2. The northerly portion of the glacial basin from about 8,000 feet. Lateral depression in central distance, with tongue of Niverville Glacier behind. Pangman Glacier to the left. Compare plate 7, figure 1. Photograph by H. Palmer.

the extreme right. Apparently the tongue does not produce a terminal ice arch or cavern.

The vertical shrinkage of the three mile tongue has been enormous, according to the indications of the most recent lateral moraines. In the lower portions of the valley these moraines rise more than 100 feet above the ice. There is no terminal moraine, properly speaking. The tongue, as well as the upper plateau of the glacier, is singularly free from superficial moraines. The medial moraines of the trunk mingle with the northwesterly lateral and do not extend within a mile of the forefoot.

4. GENERAL FEATURES OF THE GLACIER

The main reservoir or collecting area of the glacier is a broad, fan-shaped basin with a flat floor that occupies a distorted synclinal fold on the axis of the main range of the Rockies. The dissipator tongue discharges at right angles in the position of the handle of the fan. The dip and direction of the northeasterly limb of the syncline are remarkably constant, so that the ice flows along a nearly straight line on this side. The inner slopes of the basin here are practically snowless, affording little, if any, nourishment to the trunk stream. The southwesterly limb is a loftier and more abrupt folding, with a greater shattering of the strata and a greater irregularity of sculpture. Here are the culminating summits of the group, and from them descend in broken ice falls many smaller tributary glaciers.

The trunk glacier takes its source on the inner slopes of the southerly wall of the basin, a ridge 9,500-10,000 feet high, stretching for six miles between Mts. Barnard and Low. Here, broad, unbroken, gently tilted inclines afford ideal conditions for glacier alimentation. In the first three miles the snow fields descend to 8,000 feet, where, as nearly as may be judged, the snow-line occurs. The next three miles are a wide icy plain, flat and level to the eye, but really descending a thousand feet, designated on the map the "Freshfield Icefield[1]" (pl. 4, fig. 2, and pl. 5, figs. 1 and 2). Hereabouts the medial moraines, so prominent half-way down the tongue, begin to appear along the westerly side. On the diagram, figure 3, they have

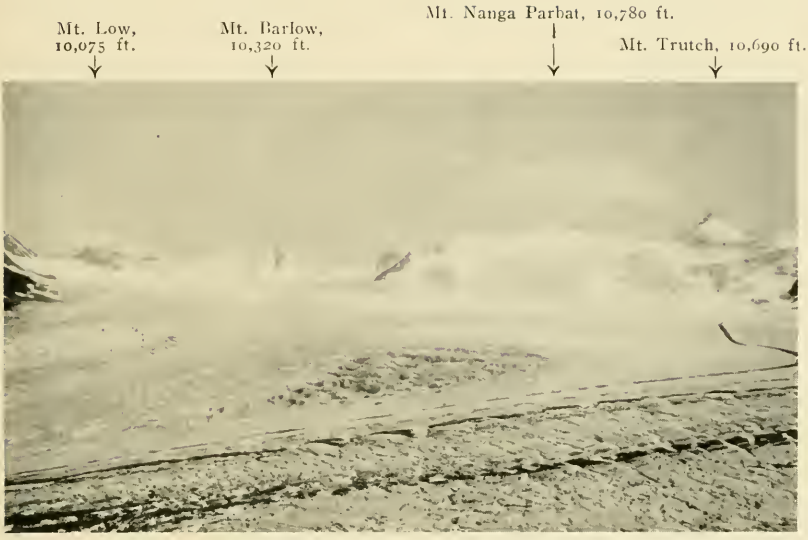
[1] The writer deprecates the use of "icefield" as commonly employed in connection with valley glaciers. It tends to obscure the fact that the "icefield" is only a portion of an advancing body of ice. Emphasis needs to be laid on the fact that a glacier is a distinct entity, with a definite locality of origin and a definite place of termination, between which the ice mass moves in an orderly progression. We do not so easily or so harmfully call the slack water of a river, "lake."

been sketched in from photographs, giving a graphic picture of the relative importance of the tributaries as sources of ice supply. Compared to the size of the ice system, they are small and scanty (pl. 6, figs. 1 and 2). They do not anywhere pile themselves up into lofty continuous ridges. Their prominence is due chiefly to their lineal distinctness and lack of wide dispersion over the surface of the ice.

The northerly segment of the basin, beyond the discharge tongue, contributes scantily to it (pl. 7, fig. 1). Owing to various causes, but chiefly to a more direct exposure to the sun, melting has exceeded the snow supply and the ice is in an essentially stagnant condition. Three commensal streams occur here: the Niverville and Pangman glaciers, and another without a name which issues from a deep precipitously walled cirque on the north side of Mt. Freshfield. Judging from its position and length, this is the most vigorous of the trio. At the corner where the main tongue issues from the basin, the Niverville and Pangman glaciers, in receding to the higher slopes, have uncovered a portion of the trough floor and a little upland valley filled with rushing streams and bordered with ice tongues. (See pl. 7, fig. 2 and pl. 4, fig. 2.) Thus there has been produced a lateral U-shaped alcove, across the open end of which the main body of ice flows, exposing a section about 75 feet thick and 500 yards wide. Its position has been indicated on the map (fig. 2).

Such depressions are not uncommon features of valley glaciers. They often give rise to marginal lakelets, as the Marjelen See on the Aletsch Glacier. But this particular one possesses the peculiarity of occasionally being filled by an offshoot from the main ice field in the shape of a secondary tongue. Although at the time of our visit in 1922, it was entirely bare of ice, in July, 1918, the Boundary Survey photographs show that it was filled to the brim with shattered ice fragments in the nature of icebergs or seracs. (Note even line of vegetation at level of main glacier in pl. 7, fig. 1. This would seem to be an "ice-line" corresponding to the waterline in the case of a lake.) The accompanying photograph, taken in August, 1913 (pl. 8, fig. 1), indicates that not long before an ice invasion had also occurred here, as many wasting pillars of glacier ice were scattered about on the floor of the alcove. Thus, the place appears to serve as a kind of safety valve, which relieves pressure on the constricted dissipator whenever the snow-fall on the mountains to the south and west has accumulated beyond the dissipator's capacity for prompt discharge.

The writer spent an afternoon visiting the locality and in photographing the ice wall at close quarters. Another secondary tongue seemed to be forming, for the wall had thrown forward several



1. Gathering basin of Freshfield Glacier looking southeasterly. Sky line is Continental Divide. Photograph by E. Feuz.

2 Gathering basin of Freshfield Glacier as seen from promontory below advanced camp. Ice at right slopes down into lateral depression. Compare plate 7, figure 2, which is an approximate continuation. Photograph by H. Palmer.

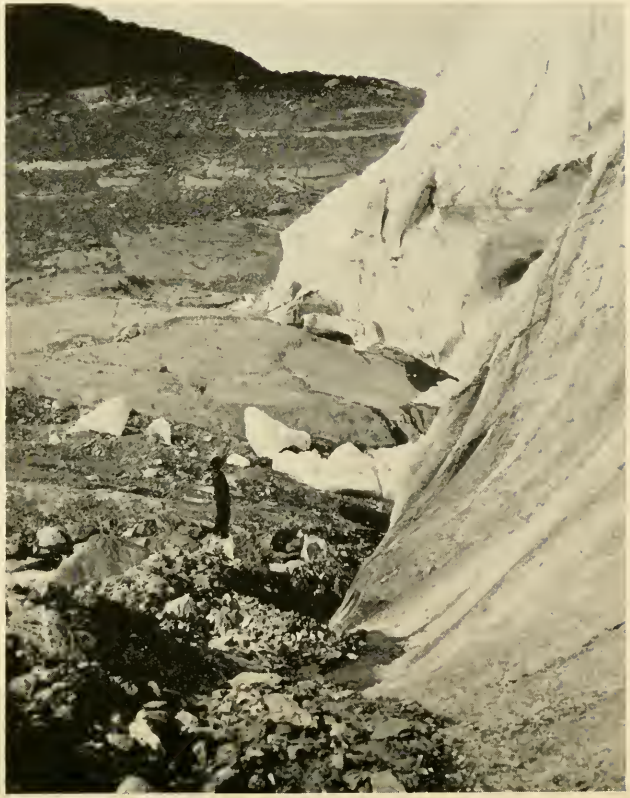
1. Surface of the glacier tongue near advanced camp. Photograph by H. Palmer.

2. Mt. Nanga Parbat and Mt. Trutch, showing upper ice plateau; snow line in distance (compare pl. 5, fig. 1). Telephotograph by H. Palmer.

1. Part of the lateral depression as seen from the main glacier adjacent, looking northwesterly. Note even line of vegetation to which alcove is filled with ice. Photograph by H. Palmer.

2. Lateral depression and secondary tongue, looking towards the reservoir of Freshfield Glacier. Photograph by H. Palmer.

1. Serac remaining in lateral depression after last advance of secondary tongue. Photograph by E. Feuz, August, 1913.



2. Ice advancing into the lateral depression, 1922. Photograph by H. Palmer.

blocks of ice, a distinct nose projected at the center, and a push moraine four feet high had been raised along the base of the wall (pl. 8, fig. 2). Another push moraine was noted 150 feet in front of the ice, apparently indicating the termination of the last advance preceding.

We thus have evidence that advances occurred here in about 1912 and 1918 and that another might soon be expected, perhaps in 1923. Can it be that this is a periodic phenomenon? It would be a very interesting matter to determine.

The floor of the alcove consists of comminuted shingle and well-broken ground moraine (see pl. 8, fig. 1). A ridge of slaty, well-scored, bed rock occurs in the center where the nose is advancing. The drainage stream from the upper glacier basin flows under the ice wall here. No signs of a lake in the alcove were to be detected.

For so great an expanse of ice, there are singularly few large crevasses and ice falls. One can wander about almost at will without serious hindrance. At the easterly corner where the tongue leaves the basin, occurs the only notable ice fall in the glacier proper. Here a 300-foot cliff breaks the floor of the basin and gives rise to a steep and interesting ice cascade of this height (pl. 9).

No considerable drainage streams were noted on the tongue or upper icefield, although small brooks of course run everywhere. The water soon finds its way beneath the ice through numerous moulins.

The rock surrounding the Freshfield glacier is mainly dark, slaty limestone, fossiliferous in places. About two miles above the foreefoot a crushed and crumpled anticlinal arch is very well displayed in the rocks of the gorge on both sides of the valley.

SUMMARY OF GLACIER MEASUREMENTS AND OBSERVATIONS IN THE CANADIAN ALPS, WITH REFERENCES

This note aims to present a brief digest of what has been done in the way of glacial measurements and study in the Canadian Alps. Not every individual report has been listed, but the titles here brought together represent the main body of the literature and will supply materials for an exhaustive study by anyone interested.

The most complete and comprehensive single publication dealing with the glaciers of the Canadian Alps is the monograph entitled, "Glaciers of the Canadian Rockies and Selkirks," by W. H. Sherzer, published by the Smithsonian Institution in 1907. (Contributions to Knowledge, Vol. XXXIV, Publ. No. 1692.) It is handsomely illustrated and contains 135 pages. The glaciers studied were the Victoria,

Wenkchemna, Yoho, in the Rockies, and the Illecillewaet and Asulkan in the Selkirks, the period covered being between 1902 and 1905. About half the space is devoted to the Victoria glacier. See also "Nature and Activity of Canadian Glaciers," by W. H. Sherzer, Canadian Alpine Journal, Vol. I, No. 2, pp. 249-263. Another general discussion of the glaciers in the Canadian Rockies and Selkirks is contained in a paper "Notes on Glaciers," by A. O. Wheeler, Canadian Alpine Journal, 1920, Vol. XI, pp. 121-146.

Detailed studies of the surface velocity and frontal retreat of the Illecillewaet glacier were made over a long period by Messrs. George and William S. Vaux, and continued by Miss Mary M. Vaux. See the following articles: "Glacier Observations," by George Vaux, Jr. and William S. Vaux, Canadian Alpine Journal, Vol. I, No. 1, 1907, pp. 138-148, with map; "Observations on Glaciers, 1909," by George Vaux, Jr., Can. Alp. J., Vol. II, No. 2, pp. 126-130; "Observations on Glaciers, 1910," by Mary M. Vaux, Canadian Alpine Journal, Vol. III, p. 127; "Observations on Glaciers," by Mary M. Vaux, Canadian Alpine Journal, Vol. V, p. 59. These papers also report observations on the Asulkan glacier.

The surface velocity and retreat of the Yoho glacier were observed continuously between 1906 and 1919 by A. O. Wheeler, and reported in the pages of the Canadian Alpine Journal, Vol. I to Vol. XI. See Vol. XI (1920), p. 182, for a summary of these observations and measurements.

The only other glaciers that have been studied are the Robson, the Sir Sandford, and the Freshfield. Descriptions and measurements of the retreat of the first named are reported in the following papers: "Geology and Glacial Features of Mt. Robson," by A. P. Coleman, Can. Alp. Journal, Vol. II, No. 2, pp. 108-113; "Robson Glacier Measurements," by A. O. Wheeler, Can. Alp. Journal, Vol. IV, 1912, pp. 44-45; "Robson Glacier," by A. O. Wheeler, Can. Alp. Journal, Vol. VI, 1915, p. 139; "Motion of Robson Glacier," by A. O. Wheeler, Can. Alp. Journal, Vol. XIII, 1923, p. 158. No measurements of surface velocity have been performed on the Robson glacier.

The Sir Sandford was mapped and observed by the writer in 1910. The next year its surface velocity was measured. See "Observations on the Sir Sandford Glacier, 1911," Geographical Journal, May 1912, Vol. XXXIX, pp. 446-453. Work was continued in 1912, the surface velocity being redetermined on the same line. See "Mountaineering and Exploration in the Selkirks," by H. Palmer, Putnam, 1914, pp. 376-391.

Crest of the ice cascade at the southerly corner of the tongue. Photograph by H. Palmer.

TABULAR SUMMARY OF GLACIER OBSERVATIONS IN THE CANADIAN ALPS, 1899-1922

ROCKIES

Glacier	Frontal Recession	Surface Velocity		Remarks
		Maximum	Minimum	
		(*Inches per diem*)		
Victoria.....	1899-1912..... 14 ft. per year	2.165	.005	Period of 423 days, 1904-1905.
Yoho.....	1906-1918..... 33 ft. per year	5.03	3.09	Average, 1906-1918.
Freshfield....	1902-1922..... Estimated at 46 ft. per year	4.83	3.00	Summer motion for 6 days, 1922.
Robson.....	1911-1922..... 22.1 ft. per year	....	....	No measurements.

SELKIRKS

Illecillewaet..	1898-1906..... 33 ft. per year	5.65	3.21	1899-1903.
		11.33	7.00	Summer motion for 12 days, 1906.
	1898-1912..... 40 ft. per year	6.73	2.45	Period of 396 days, 1906-1907.
		5.13	1.34	Period of 342 days, 1909-1910.
Asulkan.....	Intermittent.....	3.13	1.13	Period of 398 days, 1906-1907.
		8.90	2.40	Summer motion for 10 days, 1906.
Sir Sandford	1909-1910..... 25 ft.	6.73	1.36	Summer motion for 15 days, 1911.
	1910-1911..... 37.3 ft. in 50 wks.	6.25	3.15	Summer motion for $11\frac{3}{4}$ days, 1912.
	1911-1912..... 54 ft. in 51 wks.	....	....	

(NOTE.—The writer estimates the total frontal recession of the Illecillewaet glacier between 1887 and 1923 as upwards of 2,000 feet.)

So far as the writer can ascertain, all the glaciers in the Canadian Alps are now in a phase of retreat. Certainly all that he has personally observed in the last 15 years are in this condition. Among them may be mentioned the following:

Swift Current	Victoria
Fraser	Sir Sandford
Columbia	Adamant
King Edward	Goldstream
Serenity	Palmer
Coronet	Illecillewaet
Unwin	Asulkan
Nameless (at S. end Maligne Lake)	Geikie
	Bishops
Conway	Deville
Freshfield	Battle

The Wenkchemna glacier has been reported to have exhibited signs of advance during this period, but the writer has not seen it. The Clemenceau, a very large glacier situated southwest of Fortress Lake, is recently reported to be essentially stagnant at an advanced stage, close up to its terminal moraine. It does not appear to have receded at all for a long period.