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KENNECOTT GLACIER OF ALASKA [1]

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(Read before the Society December 29, 1920)

CONTENTS

INTRODUCTION

A few observations and measurements of Kennecott [2] Glacier were made by the writer,[3] incidental to other geological work in Alaska. The data are here presented as "scientific by-products." The field observations were necessarily disconnected, but no apology is offered for the sketchiness of this paper, for the data may possibly be of use to others.

The Kennecott Glacier is situated in Alaska, on the south slope of the Wrangell Mountains. The town of Kennecott is near the foot of the glacier, some 200 miles from the coast by the route of the Copper

[1] Manuscript received by the Secretary of the Society May 11, 1921.

[2] The U. S. Geological Survey orthography correctly gives the spelling of this name as "Kennicott," but the post-office, town, and mining company name are spelled as "Kennecott." As the latter is common usage throughout the country, it is followed in this paper.

[3] Extending over the field seasons of 1915 to 1920.

River and Northwestern Railroad. (See figure 1.) It is reached from the railroad terminal and port of Cordova, which lies on the east side of Prince William Sound.

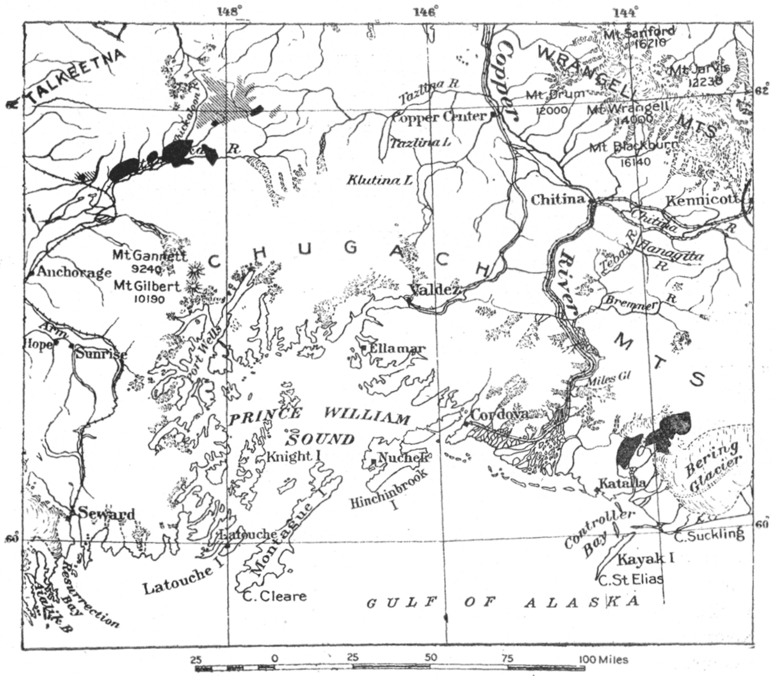

FIGURE 1.—*Index Map of Part of Alaska*

Showing location of Wrangell Mountains and Kennecott Glacier (after U. S. Geological Survey)

TOPOGRAPHIC SETTING

The gathering grounds of Kennecott Glacier are in the lofty Wrangell Mountains. These form an irregular mountain group, with a northwesterly-southeasterly trend, and have been and still are the seat of intense glaciation. They support extensive snowfields and innumerable large and small valley glaciers. The range lies north of the Gulf of Alaska and is separated from it by the high, rugged, snow-covered Chugach Range, and is thus an interior range of mountains. The higher peaks of the Wrangell Mountains rise to 16,140 feet and many are over 12,000 feet.

Kennecott Glacier emanates from Mount Blackburn, which rises to an elevation of 16,140 feet, and its largest tributary extends from

Regal Mountain, another lofty peak of the Wrangell Mountains. The glacier flows down Kennecott Valley (figure 2) the sides of which rise steeply to over 6,000 feet above the top of the glacier. The glacier is a

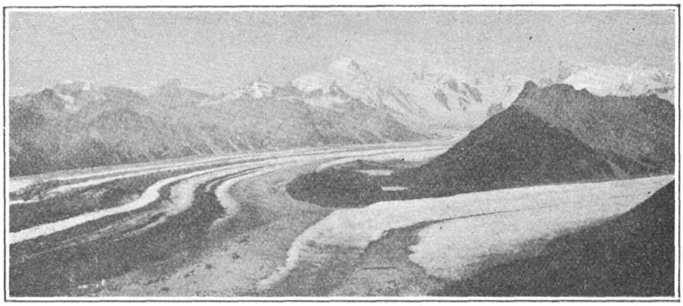

FIGURE 2.—*Kennecott Glacier, showing Moraines, Mount Blackburn in Distance*

remnant of a greater ice-tongue whose surface at the time of maximum glaciation, stood at a level about 3,000 feet higher than the present terminus.[4] The latitude at this point is 61° 30′ north.

Climatic Setting

The coastal region of this section of Alaska is characterized by exceptionally heavy precipitation and much overcast weather. The summer temperatures are moderate and in winter the thermometer rarely reaches 0° Fahrenheit. Snowfall is abundant and the mountains near the coast contain extensive snowfields and are the seat of the greatest glacier development in Alaska. They are the gathering grounds for the great Malaspina and Bering River piedmont glaciers, in addition to numerous valley glaciers.

Inland from the mountains that border the coast the climate is different. The prevailing winds from the ocean lose much of their moisture in crossing the coastal mountains; the precipitation is lighter; the summers are short, sunshiny, and warm; the winters are long and cold and temperatures down to 65° below zero are not uncommon. Glaciers are abundant and of the valley type.

Unfortunately, climatological records for Kennecott are incomplete. From 1910 to 1920 there are only two years during which complete monthly temperatures are recorded and one year of complete monthly

[4] See Plate III accompanying U. S. Geol. Survey Bull. 448, 1911, by F. H. Moffitt and S. R. Capps.

precipitation. These data at the town of Kennecott (elevation, 2,003 feet), are:[5]

Mean Temperature

1917	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1917	7.6	12.6	21.8	28.4	42.3	51.8	51.4	52.8	46.0	28.3	6.4	21.4	27.3
1918	5.2	6.0	9.4	28.2	40.0	51.4	56.8	51.0	47.8	30.9	19.2	9.5	29.6

Precipitation (Inches)

1919	1.03	0.15	0.18	tr.	1.44	tr.	2.30	0.20	2.00	1.07	1.04	1.55	10.96

The elevation above sealevel of the recording station is approximately the same as the top of the glacier near this point. Some climatological records have been kept at the mines, about 4,000 feet above the town of Kennecott, but are too scattered to be of value.

This is the climatic setting of Kennecott Glacier, in the Wrangell Mountains.

Still farther inland beyond the Wrangell Mountains the precipitation becomes less and equals that of the semiarid and arid regions of southwestern United States. An annual precipitation as low as 7.76 inches has been recorded at Fairbanks.[6] The summers are short and warm and the winters extremely cold. Glaciers do not exist and the region never has been glaciated, except for local small ice-tongues.

In comparing various Alaskan glaciers, particularly with respect to their rate of movement, this climatic difference must be taken into consideration. Differences of precipitation and temperature, and relative durations of summer and winter seasons would be expected to affect the rate of movement of glaciers. In comparing Alaskan glaciers with those of other regions, such as the Alps, other climatic factors also enter. Kennecott Glacier is situated in a latitude where sunlight in early summer persists for more than twenty hours of the day; but the sun's rays are more slanting and consequently less warm. The summer season is shorter and the mean annual temperature much lower; the duration of time when the air temperature is above 32° Fahrenheit is, therefore, much less.

Description of Glacier

TYPE

Kennecott Glacier is of the valley type (see figure 3). Two large branches, an eastern one, from Mount Regal, and a western one, from Mount Blackburn, coalesce about 6 miles above its terminal and con-

[6] U. S. Geol. Survey Bull. 525, 1913, p. 27.
[5] Records supplied by U. S. Weather Bureau.

stitute the main glacier. The Blackburn branch is fed by numerous large tributaries, all of which contribute their lateral moraines to form the medial moraines of the master glacier, imparting to it a pronouncedly ribboned appearance.

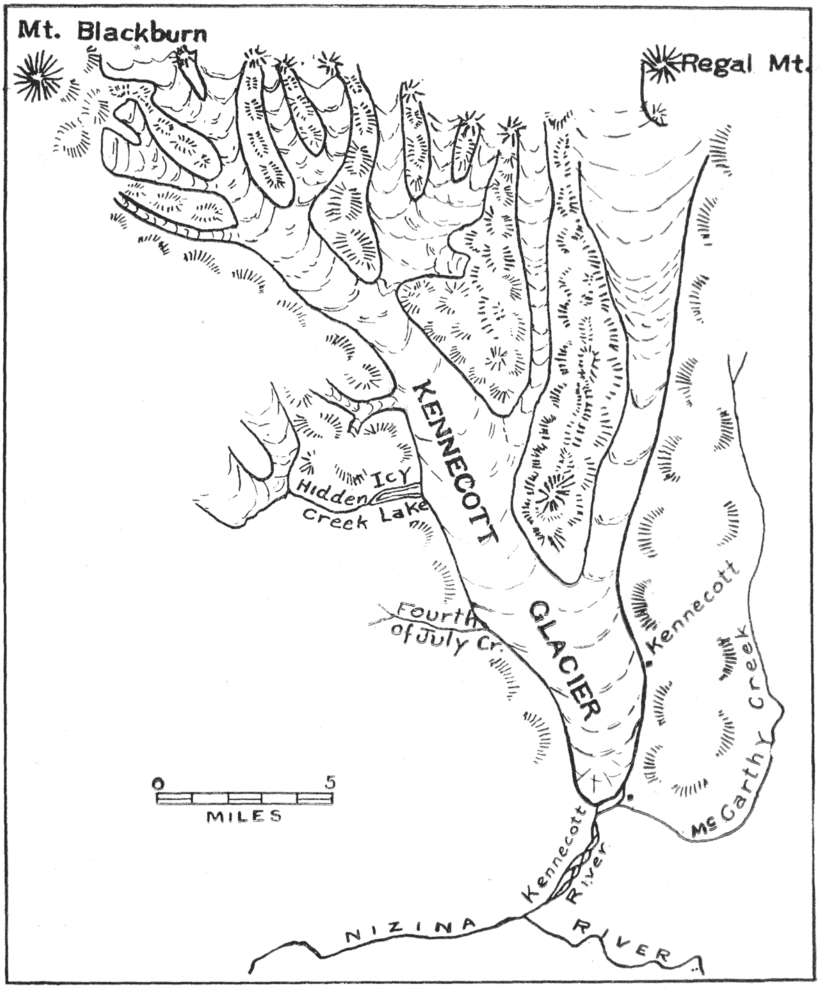

FIGURE 3.—*Map of Kennecott Glacier, its Tributaries and gathering Grounds*

Drawn from map accompanying Bulletin 374, U. S. Geological Survey.

LOCATION

The gathering grounds lie on the southern and eastern flanks of Mount Blackburn, on the southern slopes of Mount Regal, and along the 25 miles of high divide connecting these mountains (figure 3). The adjacent gathering grounds on the northern slope of the Wrangell range supply the great Nabesna Glacier and its numerous tributaries. Kennecott Glacier thus emanates from a high and extensive névé field which is the mother of a number of large glaciers.

DIMENSIONS

The glacier proper starts high up on the flanks of Mount Blackburn (16,140 feet), at an elevation of about 13,000 feet, and descends to an elevation of 1,380 feet at its terminal. The total drop is thus about 11,600 feet, most of which occurs in the upper reaches. The lower part has a relatively gentle gradient, rising from an altitude of 1,380 feet at the terminal to about 4,000 feet, 15 miles upstream, or approximately 175 feet to the mile. The gradient steepens at this point, and the remaining difference in elevation, about 9,000 feet, occurs in about 10 miles. Part of this steep descent is marked by many prominent ice falls, which, from an inspection by the eye, appear to extend over a vertical range of about 5,000 feet. The total length of the glacier is thus about 22 miles. Its maximum width below the junction with the Regal branch is about 4 miles; above and below this point it is about 2 miles wide [7] (figure 3). The whole glacier may be seen from certain vantage points on the surrounding peaks.

SURFACE

Viewed from a distance, the most striking feature of the glacier is its ribboned character, due to the distribution of white ice and debris (figure 2). For a mile or so up from the terminal, all of the glacier is of a somber color, due to distributed debris of the terminal moraine. Then white ice appears in the center, with bands of lateral moraine, approximately a half mile in width, at the sides. Still farther up, the irregularly distributed debris differentiates into two lateral moraines and seven medial moraines. These are narrow bands separated by white ice and extend upward with sinuous courses, becoming fewer and fewer in number until they give way to white ice at the ice falls. The lateral moraines persist as diminishing ribbons of debris well up toward the gathering grounds. Smaller transverse bands of debris, bowlike in plan, impart to the glacier the appearance of flowing and recall the conventional lines used to designate glaciers on maps. The distant view also

[7] The elevations and distances here given are only approximate, based on rough triangulation and checked by U. S. Geol. Survey top. map accompanying Bulletin 374.

discloses a furrowed character, due to the numerous crevasses on its surface.

Closer inspection reveals a pronouncedly hummocky appearance, with broad depressions surrounded by steep ridges, above which rise many conical or irregularly shaped peaks (figure 4). Again, broad domes may characterize the surface. Some of these surface irregularities have a difference in elevation of as much as one hundred feet. White ice alternates with deep opaline blue ice and with dark patches of debris. Rivulets of water traverse the surface; some reach the margins of the glacier, others disappear in cascades down pipelike holes or in deep

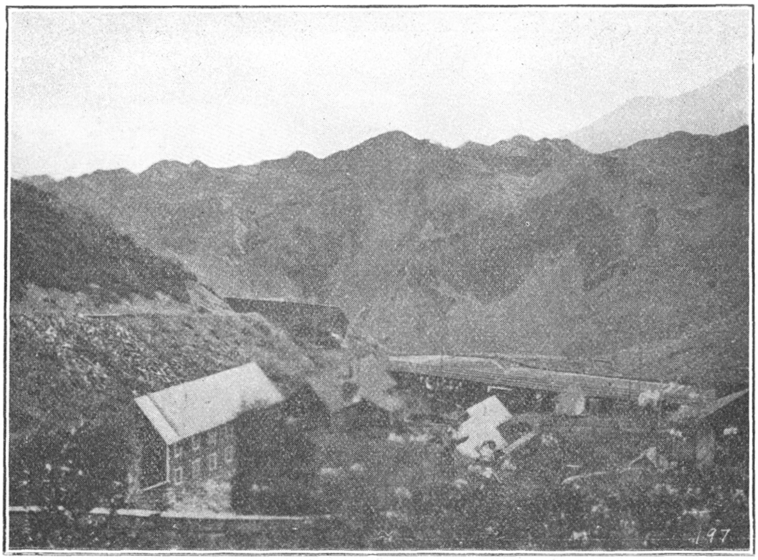

FIGURE 4.—*View of Edge of Glacier opposite Kennecott*

Gray is debris; black is melting ice.

crevasses. Underneath is a continuous dull gurgle or roar of running water, somewhat more noticeable near openings. The furrows which mark the crevasses are found to be deep, elongated depressions formed by the more rapid melting of the sides of the crevasses. Steep, elongated ridges of ice separate them, and the relief is from 10 to 100 feet; so that travel across them is in most places impossible.

Both central and marginal crevasses were noted. The lower six miles are relatively free from crevasses, but above this point, where the width of the glacier is less, crevasses are the rule rather than the exception. Crevasses are most abundant, of course, where changes in direction or grade occur. Where the grade steepens, marginal crevasses are prevalent and appear to extend across about one-quarter the width of the glacier. Some fourteen measurements of direction made on these marginal crevasses show that they point upstream and form an angle of 50 degrees with the edge of the glacier. This figure is a mean of all the measurements, but individual readings did not vary more than six degrees from the mean.

EDGES

The edges of the glacier are marked by numerous embayments and projections. The embayments appear to be formed by more rapid melt-

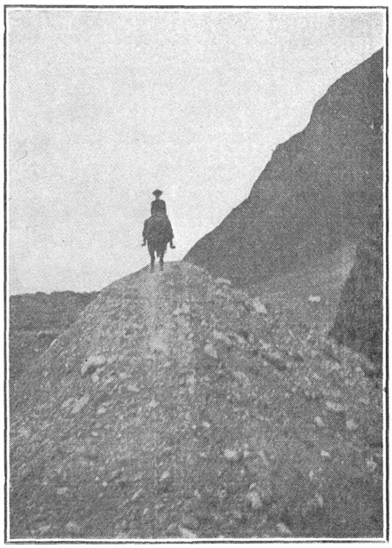

FIGURE 5.—*Narrow A-shaped Moraine parallel to Edge of Glacier and higher than Top of Glacier*

ing at certain places. They are usually half-moon shaped and may reach three hundred yards in diameter. The smaller ones are often filled by ponds of dirty glacier water. Small streamlets wind in and out along the edges, but their length is not great, for they all disappear, sooner or later, down into the glacier.

Till is present everywhere along the edges (figure 4). In some places it occurs in irregularly outlined hummocks or sporadic bunches or mantles; in others it is in the form of long moraines, A-shaped in cross-section, resembling eskers in shape, and parallel to the edge of the glacier (figure 5). These moraines are conspicuous topographic features. They form almost straight lines, and individual ones may be four miles in length. They rise symmetrically to a height of more than 50 feet, with tops barely wide enough to support a footpath. The steep slopes are determined by the angle of repose of the gravel and boulders composing them. The base of the landward slope usually rests on the solid rock or talus slopes of the valley wall, while the glacier slope rests on ice or on other glacial debris, a hundred yards or so from the ice. Their tops are in many places several feet above the level of the glacier, so that a longitudinal valley separates them from the ice. The origin of these long, symmetrical, A-shaped moraines at first seemed puzzling; later they were observed in the making. At a high, steep-sloping edge of the glacier, debris was sliding down from the melting top. Accumulation had proceeded until it spread along the base of the glacier and lapped up on its side, like a talus slope at the base of a cliff, for a height of about 45 feet. The continuation of this process would result in a flanking mantle of debris parallel to the edge of the glacier and lapping well up on the side of the ice. Eventually, as melting of the side of the glacier continued, the ice would recede from the glacial talus slope, which then would fall over toward the glacier side and rest at the angle of repose, forming a symmetrical A-shaped moraine separated from the glacier. Further melting of the top of the glacier would result in the top of the moraine standing above the level of the top of the ice.

OVERRIDING

On the west side of Kennecott Glacier is a large embayment into the ice, which obviously at one time was occupied by a pond into which mud-laden water was discharged. Later the pond was drained. At the time of observation the material within the embayment was distinctly stratified with unsorted, coarse material at the bottom, overlain by about four inches of fine gravel, and with about two feet of stratified glacial silt on top. Subsequent movement of the glacier from north to south brought the north wall of the embayment over a part of the stratified silt, and when observed by the writer large boulders and till were sliding from the melting wall of ice down on top of the stratified silt. The boulders and till had accumulated to an average thickness of about five feet over an acre of the stratified silt, thereby producing a local unconformity. In a tunnel, driven for the purpose of drainage, through the ice of a projecting lobe separating two such embayments, at Kennecott, a similar condition was observed. In several other embayments, at present occupied by ponds of thick muddy water, the deposition of silt is now taking place and is unquestionably forming stratified layers.

The stratified silt, overlain by boulders and till, was shown to the satisfaction of the writer to have been brought about under present glacial conditions clearly in the one glacial period, and in all probability within a few years. Such an occurrence, if remote from the present glacier, might hastily be interpreted as representing a glacial recession and advance or else a second glacial period.

MELTING AND DISCHARGE

Melting proceeds over all parts of the glacier, but is most rapid along the edges. No exact data are available as to the wastage on the top, though it appears to be little more than the annual accretion. Guide stakes stuck in shallow cracks to a depth of a foot were observed to stand up over the summer seasons.

All of the discharge takes place from the front of the glacier; no continuous marginal streams exist. Probably 75 per cent of the discharge emanates from the "pot-hole." This is a circular hole immediately in front of the glacier, which emits a column of water that is the source of Kennecott River. The depth of the hole is unknown. Usually the column of water rises a few feet above the level of the surrounding ground, but at times a giant column of water spouts up to a height of 15 to 20 feet. This "playing" of the "pot-hole" is interestingly coincident with the disappearance of Icy Lake, some 11 miles up the glacier (see figure 3). This lake lies on the west side of the glacier, where the wall of ice forms a dam directly across the right-angled tributary valley of Hidden Creek. The water of the creek impounds against the ice-dam and forms a lake, one-half mile wide and one and one-half miles long, the surface of which is covered by innumerable icebergs. Every autumn, and often in the spring, the lake suddenly disappears, and repeated observations show that almost simultaneously the pot-hole begins to "play." This establishes a direct subglacial connection between the lake and the pot-hole for a distance of 11 miles. The connection is also capable of transmitting a part of the pressure under which the water rises.

The volume of water in this subglacial stream is large. It also carries an abundance of glacial sand and gravel and is thus highly competent to produce corrasion. An interesting question arises as to whether such streams may produce an appreciable subglacial incision of the valley floor, and also if in large glacial valleys some of the cutting attributed to post-glacial processes may not have been formed in part during the later glacial stages of such subglacial streams.

Movement of the Glacier

METHOD OF ATTAINING DATA

For the purpose of obtaining data relating to the movement of the Kennecott Glacier, a number of stakes containing flags were set firmly in the ice (see figure 6). The stakes were not placed in line, owing to the

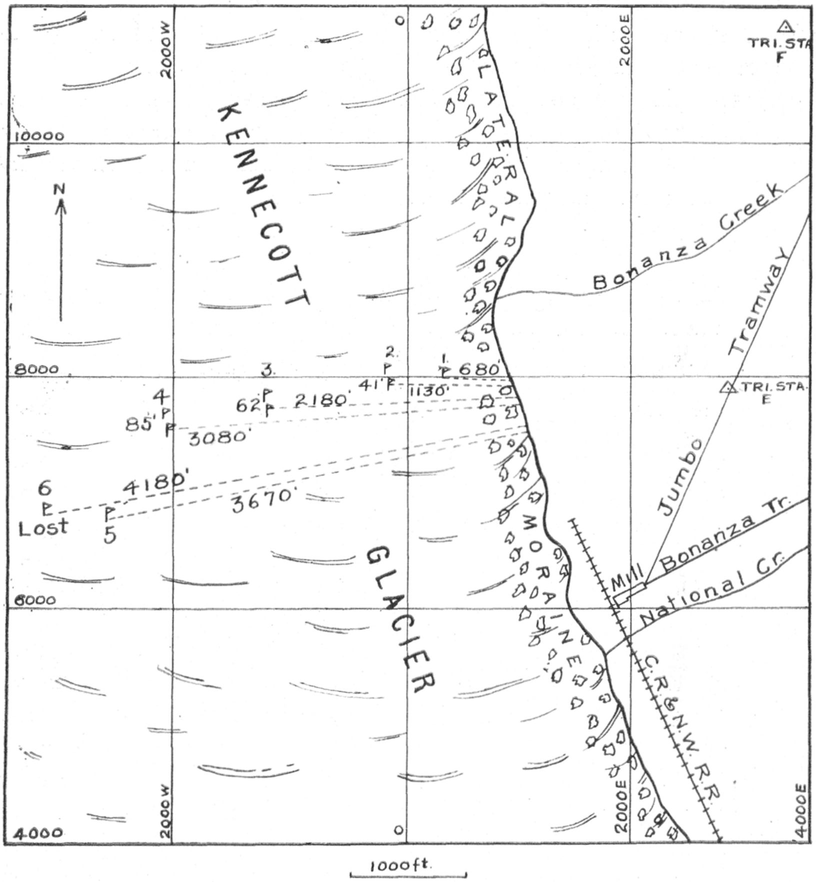

FIGURE 6.—*Map showing Position of Stakes and Movement of Kennecott Glacier*
After original drawing and plotting by D. C. Hoyt, Kennecott, Alaska.

exigencies of travel over the glacier and because the method of recording did not require it. The distances of the stakes from the edge of the glacier ranged from 680 to 4,180 feet. The total width at this point is approximately 17,000 feet. Some of the flags unfortunately disappeared, probably due to the formation of crevasses. A base line and triangulation stations were established on the adjacent land, and by means of a surveyor's transit the positions of the flags were accurately measured from the triangulation stations. The readings were recorded and plotted by means of coordinates.[8]

The positions were first measured on September 28, 1918. The same triangulation stations were again occupied on September 21, 1919, 358 days later, but unfavorable weather prevented the completion of the measurement. Sixteen days later (October 7, 1919) triangulation stations were again occupied and the final measurements taken. All of the readings were then plotted by coordinates on the accompanying map (figure 6). An attempt was made to obtain further measurements the following year, but the stakes had disappeared.

RESULTS

The data of movement for the 374-day period are shown below, as are also the data for the shorter period.

Stake.	Distance from edge.	Period.	Total movement.	Movement per day.
1	680 feet.......	374 days.......	19.0 feet.......	0.61 inches
2	1,130 feet.......	374 days.......	41.5 feet.......	1.33 inches
3	2,180 feet.......	374 days.......	61.5 feet.......	1.97 inches
4	3,080 feet.......	374 days.......	85.0 feet.......	2.73 inches
3	2,180 feet.......	16 days.......	1.2 feet.......	0.87 inches
4	3,080 feet.......	16 days.......	1.9 feet.......	1.40 inches
5	3,670 feet.......	16 days.......	5.0 feet.......	3.77 inches

DISCUSSION OF RESULTS

It is interesting to note that the daily rate of movement for the 16-day period at the end of September is much slower than for the whole year, by just about one-half. It will be observed that the rate of movement increases outward from the edge of the glacier, as would be expected. The curve (figure 7) was plotted to show the relation between the rate of movement and the distance outward. This curve is surprisingly close to a straight line, indicating a progressively uniform increase in rate with distance outward from the edge of the glacier.

The data show that the movement of Kennecott Glacier is unusually slow. It is measured in inches per day, as contrasted with movements of feet per day obtained from measurements of many glaciers. Incidental observations on other glaciers in this same section of Alaska suggests that

[8] The writer is indebted to D. C. Hoyt, chief engineer, Kennecott Copper Corp., Kennecott, Alaska, for this work and results.

this rate of movement is in keeping with the movement of other Alaskan glaciers of similar type in this same section. Some of the coastal glaciers are known to have much greater movement, but it is to be remembered that their topographic and climatic setting differs from that of Kennecott Glacier.

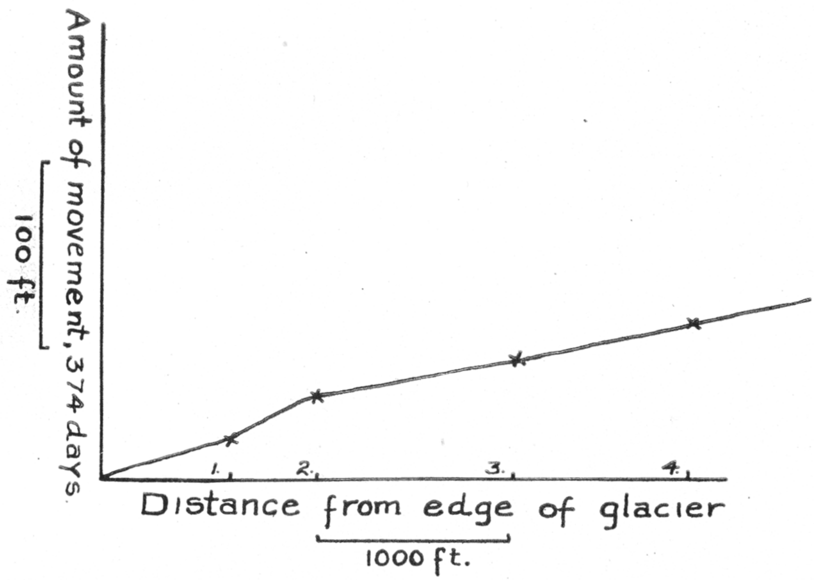

FIGURE 7.—*Curve showing Relation between the Amount of Movement of Glacier and Distance from Edge of Glacier*

The movement of Kennecott Glacier was measured at a point some 4 miles above its lower end, and is, therefore, a measurement of the body of the glacier. In this respect it differs from the measurements made on many of the Alaskan glaciers, where the advance or recession of the lower terminal only was considered.