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THE MEIGHEN ICE CAP, ARCTIC CANADA: ACCUMULATION, ABLATION AND FLOW

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ABSTRACT. Accumulation on the Meighen Ice Cap appears to be about normal for the region, but ablation seems abnormally low. Statistical analyses of several years' data reveal the following trends: accumulation increases towards the north; ablation decreases with increase of elevation, decreases towards the north and west, and is greater on south-facing slopes than elsewhere. Because ice movement is very small, these trends explain the surface topography of the ice cap quite well. Other topics discussed are the significance of changes in the margins of a stagnant ice cap, and the rate at which net mass balance changes with elevation.

RÉSUMÉ. *La Meighen Ice Cap dans l'arctique canadien: accumulation, ablation et fluage.* L'accumulation sur la calotte glaciaire de Meighen semble être normale pour la région, mais l'ablation paraît exceptionnellement réduite. Des analyses statistiques des données rassemblées pendant plusieurs années rélèvent les tendances suivantes: l'accumulation augmente vers l'extrémité septentrionale; l'ablation diminue en proportion inverse à l'élévation, se réduit vers le nord et vers l'ouest, et paraît augmenter aux versants sud. Parce que le mouvement de la glace est très faible, ces tendences expliquent assez bien la topographie superficielle de la calotte. En outre, les sujets suivants sont traités: la signification des variations de la périphérie d'une calotte glaciaire immobile, et la variation du bilan de masse par rapport à l'élévation.

ZUSAMMENFASSUNG. *Das Meighen Ice Cap, Arktisches Kanada: Akkumulation, Ablation und Fliessbewegung.* Die Akkumulation auf dem Meighen Ice Cap erweist sich als annähernd normal für diese Region, die Ablation jedoch erscheint abnorm niedrig. Statistische Analysen von Beobachtungen einiger Jahre ergeben folgende Tendenzen: Die Akkumulation nimmt nach Norden hin zu; die Ablation nimmt ab mit zunehmender Höhe, nach Norden und Westen, und ist an Südhängen grösser als anderswo. Weil die Eisbewegung sehr gering ist, lässt sich die Oberflächentopographie des Eisschildes aus diesen Daten sehr gut erklären. Weiter wird behandelt: Die Bedeutung der Randschwankungen eines stagnierenden Eisschildes und die Änderung der Nettomassenbilanz mit der Höhe.

INTRODUCTION

There is a type of Arctic ice cap that shows no obvious sign of past or present movement. Such ice caps, some of which have areas of several hundred square kilometers, are without crevasses. At most places their edges are thin and gently sloping. The surrounding area shows no evidence either of erosion or of deposition by moving ice, and recession of the ice may reveal patterned ground and patches of dead vegetation. These ice caps thus seem to protect the underlying land surface. Falconer (1966) has described such an ice cap and pointed out some general features; but few detailed studies have been made. In Canada, ice caps of this type are found in Ellesmere Island, Axel Heiberg Island, Devon Island, Baffin Island (Roots, 1963), Melville Island (Tozer and Thorsteinsson, 1964), and one or two smaller islands in the Arctic Archipelago. Savile (1961) has suggested that, during the Wisconsin glaciation, the islands in the north-western part of the archipelago also carried extensive ice caps of this type. The islands are marked "unglaciated" on the Glacial map of Canada* because no convincing signs of glaciation have been discovered on them.

In 1959, the Polar Continental Shelf Project began an investigation of one such ice cap, the Meighen Ice Cap. Arnold (1965) made meteorological observations and measurements of mass balance and flow from 1959 to 1962. The mass-balance and flow measurements have been continued; they form the subject of this paper.

THE MEIGHEN ICE CAP

Meighen Island (lat. 80° N., long. 99° W.) is in the northern part of the Canadian Arctic Archipelago. An ice cap, about 85 km² in area, lies on relatively high ground in the interior

* Glacial map of Canada. *Canada. Geological Survey. Map* 1253A, 1968. 1 : 5 000 000.

of the island. Figure 1 shows the form of the ice cap. A publication by Arnold (1966) includes a map at scale 1 : 25 000. A bore hole, 121 m deep, has been drilled through the thickest part of the ice cap. Ice temperature ranged from −17.5°C at a depth of 10 m to −15.9°C at the base (Paterson, 1968). From a petrofabric analysis of the core, Koerner (1968) reached the following conclusions:

1. Formation of superimposed ice has always been the normal mode of accumulation, although a thin firn layer may remain at the end of exceptional summers.
2. There is no evidence that the ice cap, at the bore hole, has ever been more than about 15 m thicker than it is now.
3. There is no evidence of past or present ice movement.
4. The ice cap has probably developed since the end of the Climatic Optimum (i.e. in the past 3 000 years or less).

However, Benson (personal communication) has questioned the second and fourth conclusions.

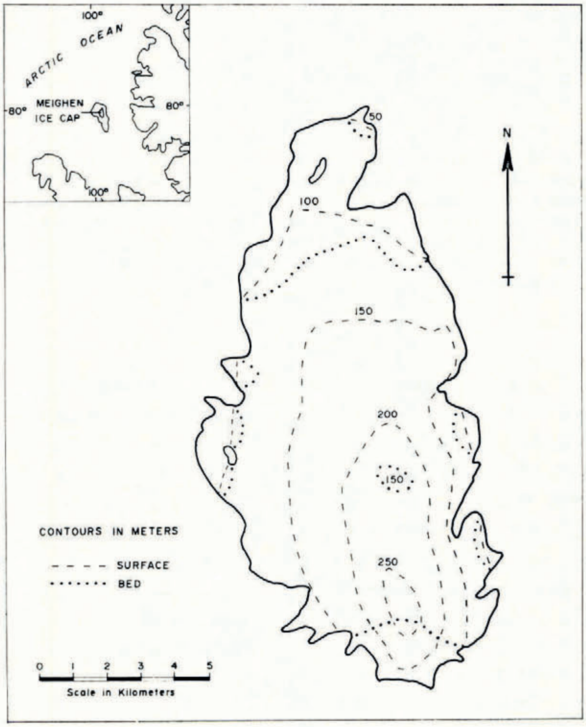

Fig. 1. The Meighen Ice Cap.

Methods

Figure 2 shows the network of stakes used in both movement survey and mass-balance measurements. The survey requirement that each stake had to be visible from the adjacent ones controlled their spacing. The position of each was determined by traversing, with theodolite and tellurometer, from fixed points on land around the perimeter. Surveys were made in 1959, 1960, 1961 and 1964.

We use the mass balance terminology recently proposed (Anonymous, 1969). Measurements made at the end of the winter season, which usually occurs in June, determined the

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winter balance for the current year and the net balance for the previous year. Winter ablation is negligible in most Arctic regions. Moreover, Arnold (1965) who made observations throughout three summers found that summer accumulation was less than 10 mm. In these circumstances, the winter balance should be approximately equal to the total accumulation; we shall call it "total accumulation" in what follows. What we call "total ablation" is, strictly speaking, the summer balance. This was not measured directly; it was calculated as winter balance minus net balance. The standard error of a value of accumulation is estimated to be 15%; of net balance, 20%. Accumulation and ablation, averaged over the years of record, were analysed by multiple regression to separate the effects of the factors: north–south and east–west coordinates, elevation, and surface slope. The *t*-test showed which regression coefficients

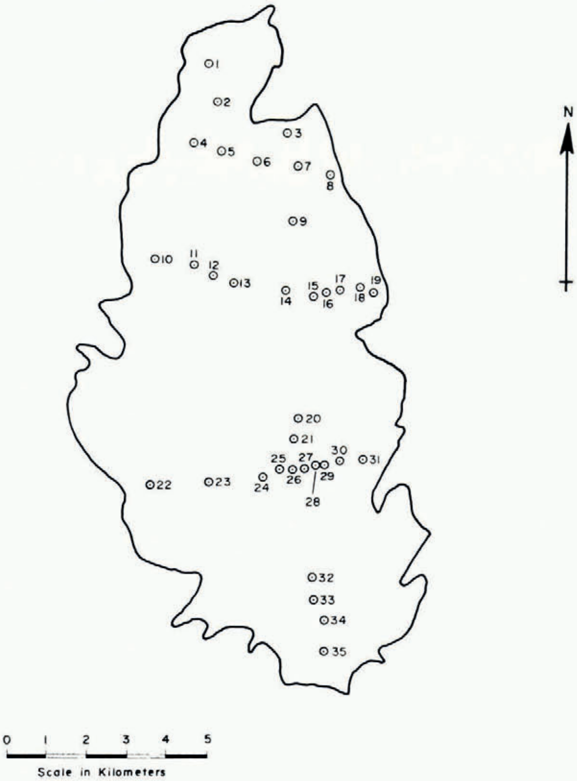

Fig. 2. Position and number of each stake on the Meighen Ice Cap.

differed significantly from zero and hence were worth retaining in the analysis. The multiple correlation coefficient then showed how well accumulation (or ablation) could be predicted from the regression equation. Analysis of covariance (Kendall, 1948, p. 237) was used to determine whether the effects of the important factors differed significantly from year to year. A 5% level of significance was used throughout. Data from four stakes (numbers 1, 8, 26 and 33) were omitted from the analysis. For the first two, several years' data are missing. The other two lie near buildings which make the measurements unrepresentative. Data for one year, in which about a third of the stakes were lost, have also been omitted. In 1964, the measured winter balance was appreciably less than the total accumulation, as a result of heavy summer snowfalls. Data for this year were omitted from the analysis of accumulation, but not from the net balance analysis.

Results and Discussion

Accumulation

Table I lists the accumulation data. Values for 1959–62, already published by Arnold (1965), are repeated for completeness. Statistical analyses gave the following results. Accumulation increases with increase of distance from the south end of the ice cap at an average rate of about 7 mm km^{-1}. This is the major trend in accumulation, but it is not very marked: in two years it was not significant. However, Arnold (personal communication) thinks that the trend merely results from two local effects: accumulation of drifting snow on the low-lying

Table I. Total Accumulation in mm of Water

Stake	*1959–60*	*1960–61*	*1961–62*	*1962–63*	*1963–64*	*1964–65*	*1965–66*
1	160	200	120	150			190
2	140		220	240		190	130
3	120	210	160			240	190
4	140	260	120	300		220	200
5	110	200	180	200		270	140
6	180	220	250	270		210	150
7	80	120	130	260		220	160
8	50	150	150	220		260	
9	150	170	130			210	180
10	120	220	160			210	150
11	140	170	120			140	110
12	140	130	120	110	300	160	160
13	160	180	90			200	140
14	140	200	190	100	320	140	150
15	150	210	140	240	390	140	130
16	160	190	160	220	350	170	130
17	130	180	160	200	250	170	170
18	50	140	160	170	250	160	110
19	50	140	150	200	170	150	100
20	170	180	110	200	310	150	150
21	200	170	130	190	350	140	180
22	130	240	80	160	290	140	170
23	130	190	130	210	380	110	170
24	120	180	200	210	260	140	150
25	140	230	160			140	160
26	110	240	150				
27	120	190	160	190	280	150	170
28	210	180	190	220	330	160	130
29	130	200	150	210	340	150	150
30	140	180	310	260	300	160	130
31	150	150	130	240	270	160	190
32	70	110	160	240	240	90	140
33	70	170	140	190	280		
34	70	150	120	170	290	60	150
35	60	110	150	130	310	40	110

northern part of the ice cap, and removal of snow from the relatively steep southern slope by katabatic winds. Over the ice cap as a whole, accumulation shows no consistent relation to elevation. It appears to increase with elevation on the central transverse line of stakes and on the northern part of the north–south line; but the trend is not quite significant. Accumulation shows no significant east–west variation and is not related to distance from the edge of the ice cap or to the magnitude or direction of surface slope.

The multiple regression equation reduces to an ordinary regression equation:

$$Z = 87.6 + 0.68x_2. \qquad (1)$$

Here Z is predicted accumulation in millimeters of water and x_2 is a north–south coordinate in units of 100 m, increasing towards the north. The correlation coefficient between measured accumulation and x_2 is 0.55, which means that the observed dependence on x_2 accounts for

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only about 30% of the total variation in accumulation. Adding a term proportional to the square of x_2 to the regression equation does not produce any significant improvement. Much of the discrepancy between prediction and observation appears to result from values at only a few stakes. For instance, if we omit from the analysis the five points with the largest differences between observed and predicted values, the correlation coefficient is increased to 0.79. The anomalous values may be due to local peculiarities of topography. To get an adequate picture of the pattern of accumulation, more stakes would be needed.

Figure 3 shows the mean annual accumulation measured at each stake and lines of equal accumulation derived from Equation (1).

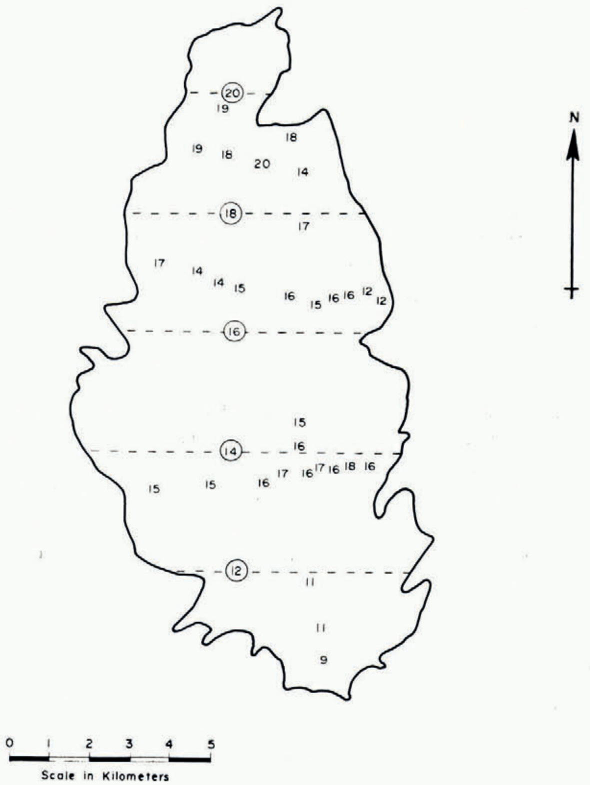

Fig. 3. Mean annual accumulation: measured values and lines of constant accumulation derived from regression equation. Units are tens of mm of water.

Ablation

Total ablation was determined as measured accumulation (Table I) minus measured net balance (Table VI). Statistical analyses gave the following results. Ablation decreases with increase of elevation at an average rate of 2.9 mm m^{-1}. The rate varies widely (from 1.6 to 6.1 mm m^{-1}) between different parts of the ice cap however. The rate of decrease is greater on the eastern side than on the western. The rate does not vary a great deal from year to year. Ablation is greater on the eastern side of the ice cap than on the western. The average rate of change is 12 mm km^{-1}. However, as the eastern side has the steeper slope, this variation may reflect a dependence of ablation on slope. We might expect this because, the steeper the slope, the greater the proportion of melt water that may drain off the ice cap instead of collecting and

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eventually refreezing to form superimposed ice. On the other hand, an east–west variation of ablation, independent of surface slope, could arise if, for example, clear skies are more frequent in the morning than in the evening, or if warm winds tend to come from the east. To separate these two effects does not seem possible with the present data.

Ablation decreases with increasing distance from the south end of the ice cap, at an average rate of 16 mm km^{-1}. Also, ablation is greater on south-facing slopes than on slopes with other aspects.

Table II. Average Annual Ablation (mm) at Two Elevations in Different Parts of the Ice Cap

Stake line	*At 170 m above sea-level*	*At 210 m above sea-level*
North–south, north part	470	360
North–south, south part		600
Central transverse, east half	520	
Central transverse, west half	430	
South transverse, east half	600	480
South transverse, west half	510	460

To illustrate these trends, Table II lists the ablation at the same elevation on the different lines of stakes. These figures were obtained by linear interpolation between values measured at the two nearest stakes. Some places have been left blank because, on the line in question, the chosen elevation does not correspond to a point on the ice cap.

The multiple regression equation is

$$Y = 1108 + 1.16x_1 - 1.62x_2 - 2.93x_3. \qquad (2)$$

Here Y is the predicted mean annual ablation in mm of water, x_1 is an east–west coordinate in units of 100 m increasing towards the east, x_2 is a north–south coordinate in units of 100 m increasing towards the north, and x_3 is elevation in meters. The multiple correlation coefficient is 0.91. This means that the regression equation accounts for over 80% of the total variation of ablation: in contrast to the case of accumulation, the regression equation predicts ablation quite well. Figure 4 shows the mean annual ablation measured at each stake and curves of equal ablation derived from Equation (2).

Existence of the ice cap

The elevation of the Meighen Ice Cap (40 m to 270 m above sea-level) is anomalously low for ice caps in the area. Ellef Ringnes Island, some 120 km south-west of Meighen Island, rises to elevations slightly higher than any point on Meighen Island; but there is no ice cap. And on Axel Heiberg Island, some 50 km east of Meighen Island, only a few large outlet glaciers, draining the ice caps in the mountainous interior, extend to elevations as low as 50 m. This suggests that accumulation on the Meighen Ice Cap must be abnormally high, or ablation abnormally low, or both. In Table III, annual accumulation on the Meighen Ice Cap

Table III. Comparison of Annual Accumulation or Precipitation in Different Areas

	mm	*Number of years of record*	*Reference*
Meighen Ice Cap	170	7	
Isachsen, Ellef Rignes Island	90	14	
"Beaver Camp", Axel Heiberg Island	115	49	Müller and others (1961, p. 57)
"Upper Ice I", Axel Heiberg Island	100	24	Müller and others (1961, p. 57)
"Upper Ice II", Axel Heiberg Island	370	41	Müller and others (1963, p. 33)
Ice cap, north Ellesmere Island	160	46	Hattersley-Smith (1963)

is compared with values from neighbouring islands. These limited data suggest that precipitation on the Meighen Ice Cap, though greater than on Ellef Ringnes Island, is not abnormally high compared with that on other ice caps in the region. In Table IV, ablation on the Meighen Ice Cap is compared with that at the same elevations on White Glacier, a large valley glacier on the west coast of Axel Heiberg Island (Müller and others, 1963, p. 40). (Müller measured net mass balance, so his figures will be slightly less than the total ablation.) Ablation on the Meighen Ice Cap is only about 30% of that at similar elevations on White Glacier.

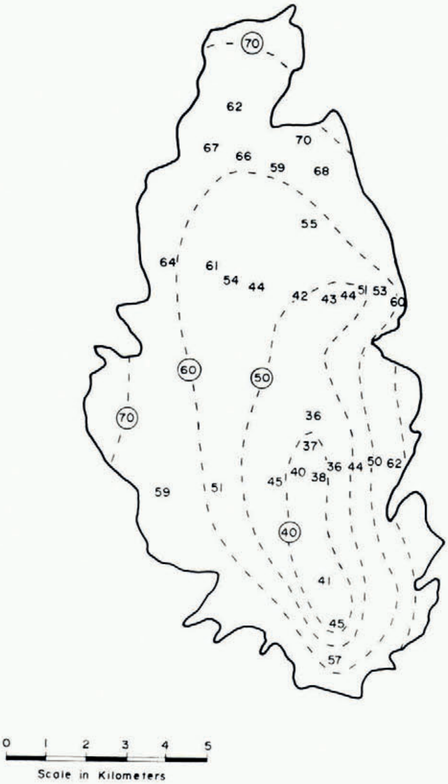

Fig. 4. Mean annual ablation: measured values and curves of constant ablation derived from regression equation. Units are tens of mm of water.

TABLE IV. ABLATION ON MEIGHEN ICE CAP AND WHITE GLACIER. (THE FIRST FIGURE IN EACH PAIR REFERS TO WHITE GLACIER, THE SECOND TO MEIGHEN ICE CAP)

Elevation range m	Ablation m of water 1959–60		1960–61		1961–62	
0–100	3.01	0.96	2.03	0.32	3.78	1.24
100–200	2.30	0.73	1.30	0.14	2.86	1.05
200–300	2.14	0.51	1.11	0	2.30	0.80

Low ablation, perhaps resulting from the high frequency of fog during summer, is probably the main reason for the existence of the Meighen Ice Cap. Present values of ablation are, however, still too high to maintain it. If the net mass balance were to remain at the value it has averaged since 1959, the ice cap would disappear in a few hundred years.

Flow

We now discuss whether ice flow has any appreciable effect on the topography of the ice cap. Flow is expected to be small because the ice is cold (−16°C to −18°C) and nowhere more than 125 m thick. The 1959, 1960 and 1961 surveys gave no definite evidence of movement (Arnold, 1965).

Let b denote net mass balance, h ice thickness, t time, x distance measured horizontally in the direction of a flow line, y distance measured horizontally and perpendicular to x, and q flow, that is the volume of ice per unit distance y flowing in unit time. The axes are fixed in space. If we assume, as is justifiable for the Meighen Ice Cap, that the density of the ice cap is uniform, the equation of conservation of volume can be written:

$$\partial h/\partial t = b - \partial q/\partial x. \tag{3}$$

This equation expresses the fact that, at any point fixed in space, the change in surface elevation in one year is determined by (a) the net balance and (b) the difference between the inflow and outflow of ice in a small vertical column below the point. We wish to determine $\partial q/\partial x$. Because $q = uh$ where u is ice velocity averaged over the ice thickness,

$$\partial q/\partial x = u(\partial h/\partial x) + h(\partial u/\partial x). \tag{4}$$

If u is replaced by the surface velocity, which is a good approximation, all the quantities on the right-hand side are known.

The longitudinal strain-rate $\partial u/\partial x$ at each stake can be calculated from the survey data because the line of the traverse was always within about 10° of the direction of maximum surface slope. Table V shows the results obtained over the interval 1960–64 for the stakes in the southern part of the ice cap. The 1964 survey was restricted to this region, the most likely area in which to detect movement. The value for each stake is the mean of the values measured on each side of it. It is difficult to assign a standard error to these figures and so test whether the strain-rates differ significantly from zero. The tellurometer is capable of measuring strain-rates as small as these. But there are other sources of inaccuracy such as errors in centering the instrument over the stake, possible tilting of the stake, and the fact that some stakes had to be reset between the two surveys.

Table V. Longitudinal Strain-rates in Units of 10^{-5} a^{-1}

Stake	*Strain-rate*
23	18
24	−13
25	−13
26	2
27	12
28	45
29	−2
30	−33
33	−3
34	−2

The velocity u at each stake was also determined from the survey data. The maximum value, at stake 29, was 0.25 m a^{-1}. It is doubtful whether this differs significantly from zero. The value of $\partial q/\partial x$ was calculated for each stake in the southern part of the ice cap, on the assumption that the measured strain-rates and velocities are genuine and not merely a result of survey inaccuracies. The greatest value of $\partial q/\partial x$, 40 mm a^{-1}, was obtained at stake 28. The net balance there is −80 mm a^{-1}. Thus we conclude from Equation (3) that, at stake 28, the ice cap is thinning by 120 mm a^{-1}; about two-thirds of this results from ablation, the remainder from flow. At all the other stakes, including stakes 27 and 29 which are within 300 m of stake 28, flow was found to contribute less than 10% to the total thinning. Thus, changes in surface elevation of the Meighen Ice Cap from year to year are determined largely by the mass balance: the effect of flow is small. In the terminology of Lliboutry (1964–65, Tom. 2, p. 458–60) the ice cap is a *glacier réservoir*.

Topography of the ice cap

Because the surface elevation at each point is mainly determined by the net mass balance at that point, and because the net balance varies from point to point, the shape of the surface must change with time. As a result of minor climatic fluctuations there will be periods in which, at least in the majority of years, the ice cap gains mass, and periods in which, in most years, ablation predominates. For example, the ice cap is everywhere thinner now than in 1959 although in two years the average net balance was positive. During an ablation phase, the pattern of variation of net balance over the ice cap will largely follow the pattern of ablation variations. During an accumulation phase, the pattern of net balance variations will resemble the pattern of accumulation variations. The only trend in accumulation is an increase towards the north. Thus, during an accumulation phase, the east and west slopes of the ice cap should remain more or less unchanged, the south slope should steepen, while the angle of the north-facing slope should be reduced.

The main ablation trends are a decrease with increase of elevation, a decrease towards the north and, to a lesser extent, towards the west. The relation between ablation and elevation should cause all slopes to steepen as time goes on. However, changes in the north-facing slope should be relatively small because the decrease in ablation towards the north will counteract the elevation effect; whereas both effects will tend to steepen the southern slope. Similarly, on the western slope, the steepening caused by the decrease of ablation with increase of elevation will be counteracted by the tendency for ablation to increase towards the east; while both trends will steepen the eastern slope. Thus we expect the southern slope of the ice cap to be the steepest, the northern the most gentle, and the eastern slope to be steeper than the western. This is found to be the case (see Fig. 1).

On the other hand, certain features of the ice cap cannot be explained in terms of the accumulation and ablation trends shown by the present data. For instance, the base of the ice cap is almost horizontal along the north–south line between stakes 14 and 33. Yet the ice thickness decreases from 121 m at stake 33 in the south to 20 m at stake 14 in the north. Once the surface has developed a north-facing slope along this line, the slope may be maintained by the tendency for ablation to increase as elevation decreases. But to develop this slope in the first place the pattern of accumulation or ablation must, at some stage in the history of the ice cap, have differed from the present pattern.

Changes at the margin of the ice cap

Small stagnant ice caps such as the Meighen Ice Cap are sometimes said to be sensitive indicators of climatic changes, in the sense that small changes in climate may produce relatively large changes in the position of the margin of the ice cap. While this is true, an active glacier and a stagnant ice cap do not respond in the same way to changes in mass balance. The terminus of an active glacier responds to changes in the mass balance of the whole glacier. There is a time lag before the full effects of a mass balance change are apparent at the terminus. And the complete adjustment of a glacier to a mass balance change may require tens or even hundreds of years (Nye, 1963). On the other hand, in an ice cap in which flow is insignificant, the change in position of the margin during one year depends only on the net balance at that point on the margin for that year. If the net balance is positive, the margin will "advance"; if the net balance is negative, the margin will "retreat". In this argument we assume that the margins are wedge-shaped, not vertical. This completes the response of the ice cap to that year's mass balance. Again, the average net balance of a stagnant ice cap may be zero year after year but the margins will continue to retreat. The margins will only advance when the whole ice cap lies in the accumulation area.

Net mass balance

Table VI lists the net mass balance data. Arnold (1965) has previously published the values for 1959–62. The main trends are an increase in net balance with elevation and with distance from the south end of the ice cap. Table VII shows the rate of change of net balance

Table VI. Net Mass Balance in mm of Water

Stakes	*1959–60*	*1960–61*	*1961–62*	*1962–63*	*1963–64*	*1964–65*	*1965–66*
1	−1090	−530	−1350				
2	−840	−140	−1160			0	0
3	−950	−290	−1220		310	−70	−60
4	−910	−200	−1220		280	40	−140
5	−950	−190	−1150		270	50	−170
6	−690	−110	−1070		250	70	−140
7	−1020	−410	−1220			30	−60
8	−1220	−370	−1220				
9	−750	−230			350	90	80
10	−900	−170	−1130		210	30	
11	−830	−190	−1130		300	−10	
12	−700	−160	−1070	−340	400	10	−80
13	−600	−90	−850		270	140	
14	−680	20	−720	−250	410	110	−10
15	−600	50	−960	−510	450	80	70
16	−630	70	−870	−20	370	130	−80
17	−700	−130	−950	−80	390	40	−10
18	−870	−150	−1000	−310	400	30	−50
19	−1010	−170	−1040	−330	330	−40	−170
20	−520	40	−770	−50	420	170	80
21	−440	70	−770		400	300	−50
22	−720	−50	−1200	−410	300	20	−230
23	−670	−140	−1020	−560	450	50	−60
24	−670	−60	−780	−90	400	0	60
25		40	−770		570	20	60
26	−650	80	−770				
27	−540	30	−770	90	390	130	60
28	−450	20	−600	−50	450	140	−30
29	−740	20	−840	380	450	150	−30
30	−770	−70	−690	120	460	60	−110
31	−740	−190	−1170	80	430	−70	−140
32	−690	50	−770	−130	400	190	−70
33	−690	50	−740	−70	430		
34	−890	10	−810	−140	400	10	−20
35	−910	−160	−1220	−390	370	50	−130

with elevation, averaged over the years of record, for the central and south transverse lines. Elevation changes by only 7 m along the north transverse line; thus estimates of the rate of change of net balance there are unreliable. On the longitudinal line, the variation of net balance with elevation is mixed with the north–south variation.

Shumskiy (1946) has called the rate of change of net balance with elevation, at the equilibrium line, the "energy of glacierization". Meier (1961) rechristened it the "activity index". The values in Table VII give an estimate of this index for the Meighen Ice Cap. The mean, 4 mm m^{-1}, can be compared with the value of 2.1 mm m^{-1} which Müller and others (1963, p. 39) derived from three seasons' measurements on White Glacier. By this index, the Meighen Ice Cap, in which movement is not more than 0.25 m a^{-1}, is more "active" than White Glacier in which velocities of about 80 m a^{-1} have been measured (Müller and others, 1963, p. 69). This suggests that, in the present context, the word "activity" should not be interpreted in terms of flow. Alternatively, the activity index should be applied only to glaciers that are not far from a steady state, that is to say, to glaciers in which the rate of change of surface elevation with time is small compared with the net mass balance. The Meighen Ice Cap would then be excluded.

Table VII. Rate of Increase of Net Balance with Elevation (mm m^{-1}) on Transverse Lines

Central, east half	7.0
Central, west half	4.1
South, east half	2.7
South, west half	1.8

In his work on South Cascade Glacier, Meier (1965) found that although the net balance varied widely from year to year, the shape of the graph of net balance versus elevation varied very little. Meier suggested that, to a sufficient approximation, the graphs for different years could be regarded as parallel to each other. If true, this result is important from both practical and theoretical aspects. Practically, it means that, once the shape of the graph of net balance versus elevation has been established for a particular glacier, the net balance of the glacier can be found either by measuring net balance at one elevation or by determining the elevation of the equilibrium line. From the theoretical aspect, the result means that the net balance for any year can be expressed as the sum of a steady state value and a perturbation from the steady state value, the perturbation being the same for all elevations. This is assumed in mathematical analyses of how a glacier responds to mass-balance changes (Nye, 1963). The test of Meier's rule for the Meighen Ice Cap is inconclusive. The rate of increase of net balance with elevation did not vary significantly from year to year on the west half of the central line of stakes or on the east half of the south line. However, there were significant variations on the other parts of these lines.

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