Mass Balance Measurements on Baby Glacier
Axel Heiberg Island, NWT, Canada
1959–Present, For the Record

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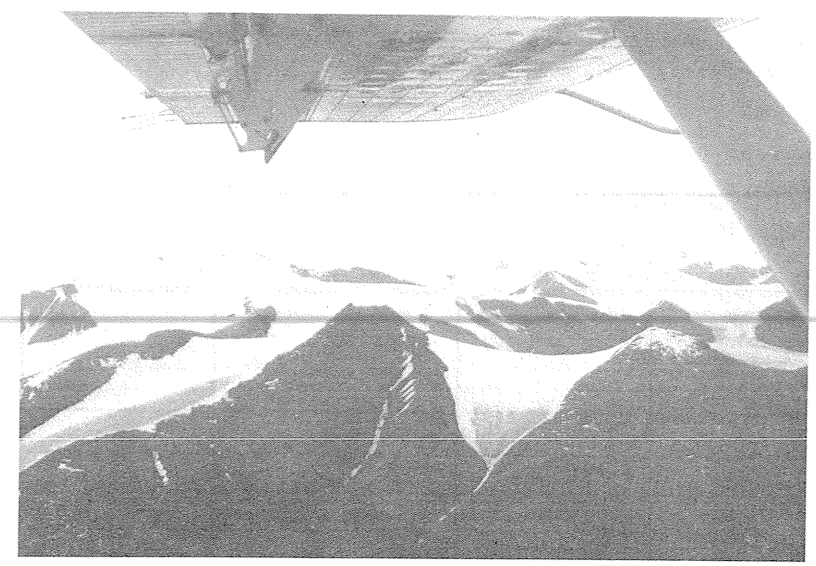
Introduction

The Baby Glacier is a triangular piece of ice which partially fills a steep V-shaped valley on the northern side of Expedition Fiord, Axel Heiberg Island, NWT, Canada (Fig. 1). It is a niche glacier flowing down from a saddle between Black Crown and Wolf Mountain and is linked to a small glacier on the northern side of those two peaks. Basic location and descriptive characteristics of Baby Glacier, obtained from remote sensing observations for August 1959, are summarized in Table 1. The purposes of the paper are to draw together and document the valuable but dispersed mass balance record of this glacier, and to solicit information about it.

Figure 1. Aerial view of Baby Glacier, 1969-70



The photo (late August, 1970, courtesy, A. Ohmura, ETH, Zurich, Switzerland) shows the situation of Baby Glacier on the SW side of Wolf and Black Crown Mountains, adjacent to a non-glacierized valley and east of Trent Glacier. The characteristic lower melt zone of a positive mass balance year is apparent.

Table 1. Specifications of Baby Glacier.

TYPE: Mountain niche glacier	LATITUDE: 79° 26′ North
SIZE: 0.613 km²	LONGITUDE: 90° 40′ West
ELEVATION: 750-1150m a.s.l.	ORIENTATION: Southwest

Mass balance measurements using techniques outlined in Ostrem and Stanley (1969) were made on Baby Glacier from 1959 to 1976 with sporadic measurements since. Because of its size, it is responsive to short-term climate changes and, because of its altitude, it is representative of equilibrium zone conditions in the high arctic. In 1989 we decided to restart the study of this small glacier so we could compare mass balance trends with the nearby White Glacier for which there is an almost complete record since 1959 (Adams, 1991).

Mass Balance Observations

Ommanney (1969) suggests that the major form of nourishment of Baby Glacier is snowfall and/or drift snow, but superimposed ice is also important (e.g. Adams, 1966, 53f and Muller, 1962, 16 and Alean and Muller, 1977).

For 1958-59, measurements are only available for the period 4-22 August, 1959. However, the magnitude of melt which occurred during that period, the extension of supraglacial streams up into the saddle area and the retreat of firn up to the higher parts of the saddle all suggested that most of the glacier was below the equilibrium line at the end of that mass balance year.

The 1959-60 mass balance year was one of considerable net loss (Fig 2a,b). The entire glacier was below the equilibrium line. Winter accumulation was relatively small (Table 2) and soon melted. Superimposed ice was not observed. Supraglacial stream channels again extended up into the saddle area (Fig 2b).

Winter accumulation was more substantial in 1960-61 (Table 3). The melting of this and summer snowfall and formation of superimposed ice within the snowpack of higher parts of the glacier (Figure 3a,b) reduced the melt of reserve ice and delayed mass losses. Even at peak ablation, melt and runoff were only observed on the steep, central lower portion of the glacier which is often snow-free, even in winter. This was a year of net gain and most of the glacier was at or above the equilibrium line.

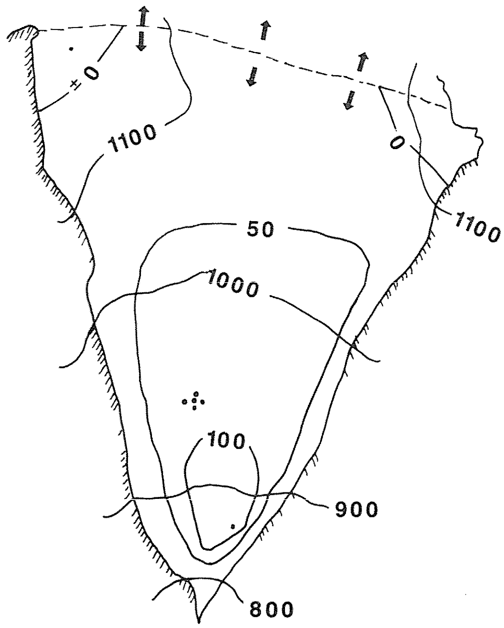
The 1961-62 year (Figs. 4a, 4b, Table 4) was again one of considerable net loss with another winter of low snowfall. However, there was some superimposed ice development.

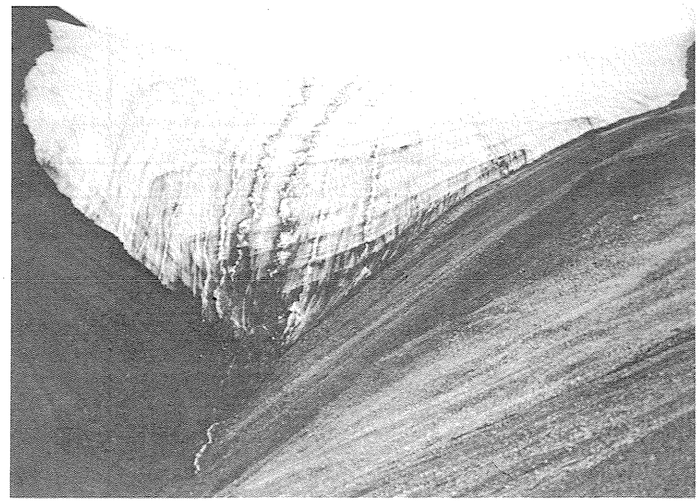
The spatial and chronological patterns for those early years, shown in Figs. 2-4 and Tables 2-4, are of considerable interest to those concerned with mass balance of arctic glaciers.

Table 2. Baby Glacier, cumulative mass changes, 1959-60 (m^3 w.e.)

Date	1. Reserve loss	2. Accumulation present	3. Net budget total	4. "Total melting" ((1) plus change in (2))	5. Superimposed ice present
End, 1959 ablation	Zero	Zero	Zero	Zero	Zero
17 June, 1960	Zero	58 754	+58 754	Zero	Zero
1 August, 1960	270 981	9 219	-261 763	320 516	Zero
24 August, 1960	551 589	Zero	-551 589	610 343	Zero

Figure 2a,b. Net mass changes 1959-60: A year of net loss





Glacier entirely below the equilibrium line. Melt streams derive from the highest areas. Peak melt in low central area, not terminus.

Legend for Figures 2 -4

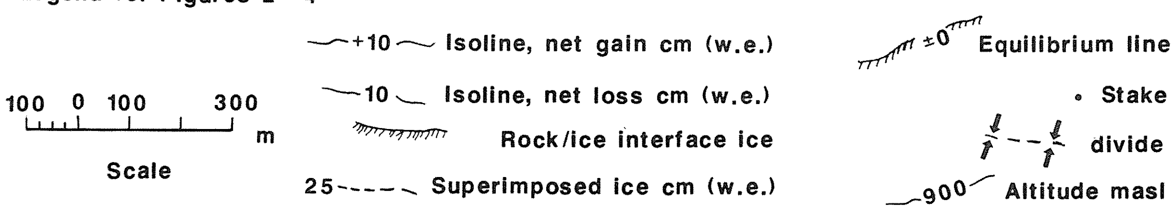
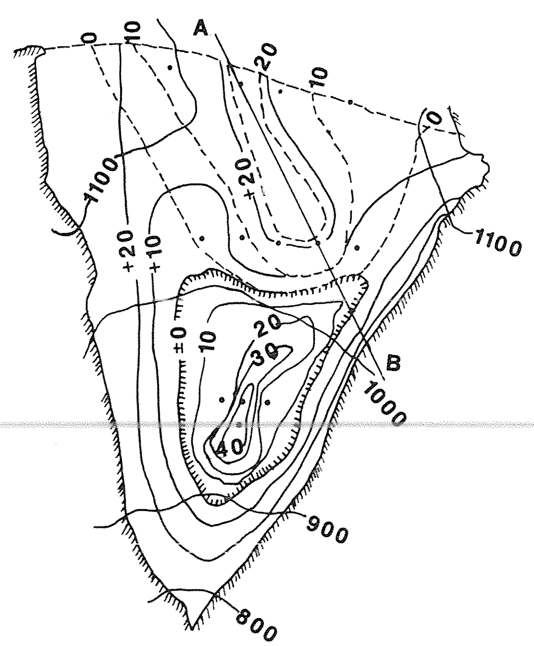
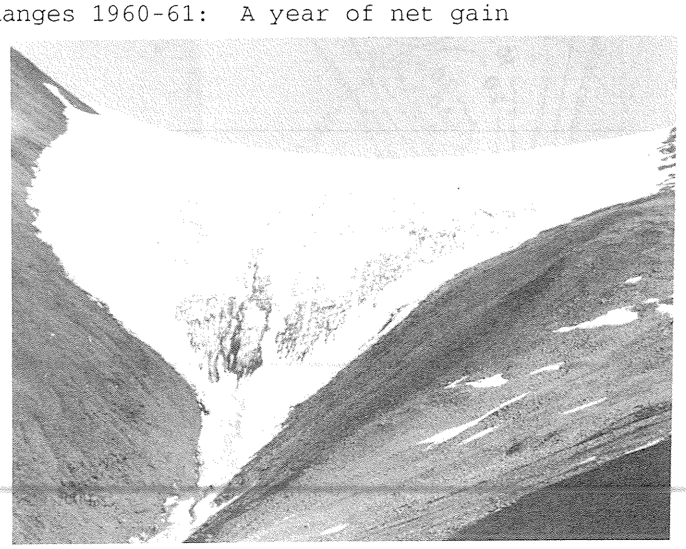


Figure 3a,b. Net mass changes 1960-61: A year of net gain





Areas of both net gain and net loss are apparent producing a positive annual balance. Peak melt is again in low central area. The terminus accumulates snow and is shaded by valley sides so that melt there is reduced. Note that part of the accumulation is superimposed ice, typical of the equilibrium zone of arctic glaciers.

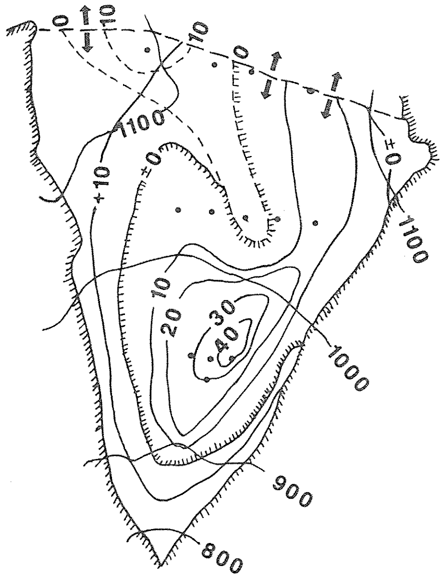
Table 3. Baby Glacier, cumulative mass changes, 1960-61 (m^3 w.e.)

Date	1. Reserve loss	2. Accumulation present	3. Net budget total	4. "Total melting" ((1) plus change in (2))	5. Superimposed ice present
End, 1960 ablation	Zero	Zero	Zero	Zero	Zero
5 July, 1961	Zero	173 295	+173 295	Zero	Zero
1 August, 1961	1 215	146 795	+145 580	27 715	30 603
28 August, 1961	14 545	81 531	+66 986	106 309	23 876

Table 4. Baby Glacier, cumulative mass changes, 1961-62 (m^3 w.e.)

Date	1. Reserve loss	2. Accumulation present	3. Net budget total	4. "Total melting" ((1) plus change in (2))	5. Superimposed ice present
End, 1961 ablation	Zero	Zero	Zero	Zero	Zero
5 July, 1962	30 149	32 103	+1 954	?	4 919
22 July, 1962	2 306 609	Zero	-306 609	338 711+	Zero
25 August, 1961	616 070	Zero	-616 070	648 173+	Zero

Figure 4a,b. Net mass changes 1961-62: A year of net loss.



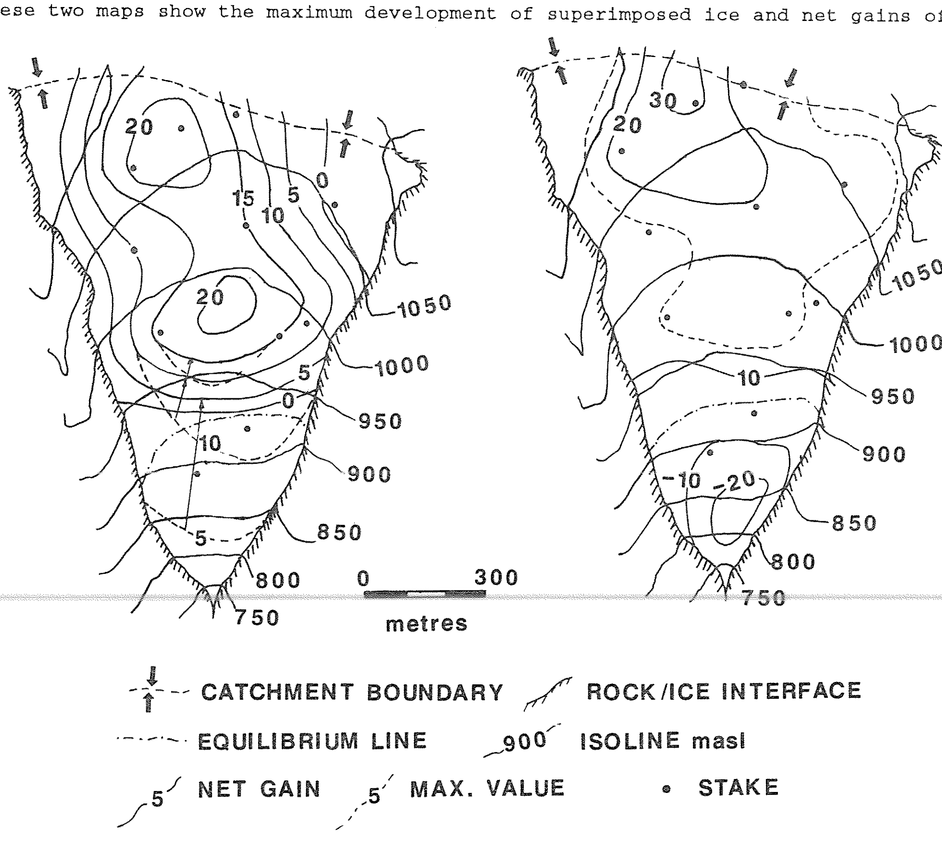
Again Glacier almost entirely below equilibrium line. Note superimposed ice in saddle at upper elevations of glacier.

First, this glacier, although quite simple topographically, does not exhibit the regular altitudinal zonation of ablation and accumulation that one expects from textbook accounts. Second, Baby Glacier only partially fills the steep-sided, V-shaped valley in which it is located. This and the steep surface slope of its lower section affects the accumulation of snow and melt. For example, deep snow accumulates upon and around its terminus and along its lower sides. This relatively shaded, deep snow tends to persist, reducing net ablation in what would "normally" be a high ablation zone. The snow in the channel immediately below the ice is an important source of runoff. The steepness of the lower section of the glacier has at least two other important mass balance effects. One is that, when the ice surface is in the sun, it is nearer to being perpendicular to the incoming solar radiation. The other is that the steep slope limits accumulation of superimposed ice which is a normal feature near the equilibrium line of polar glaciers (Adams, 1966; Muller, 1962; Koerner, 1970, 1979). On this glacier, superimposed ice, is concentrated on the less steep areas. For example, the 1960-61 accumulation/ablation pattern (Fig. 3a), shows a central area on the lower part of the glacier (steep and relatively exposed to wind and sun) which accumulated little snow and experienced all the measurable ablation. At the end of the ablation season, this area of net loss was surrounded, on all sides, by net gain, including the lowest part of the glacier.

This pattern can be discerned in the distributions shown for the other years. Alean and Muller (1977) include excellent portrayals of the annual net mass balance and evolution of superimposed ice for 1969-70, a net gain year. Fig. 5a,b again show the concentration of melt in the lower tongue area and the importance of superimposed ice in the accumulation pattern. Fig. 5a shows the peak extent and volume of superimposed ice and Fig. 5b, the net gain of it at the end of the summer. Fig. 1, for August 1970, shows the glacier as it must often have been seen in the 1960's and 1970's (see Fig. 6). With a positive net balance, ablation is focussed on the steeper snout zone.

Figure 5a,b. Superimposed ice development (a) and net mass changes (b) 1969-70 (from Alean and Muller, 1977)

These two maps show the maximum development of superimposed ice and net gains of it.

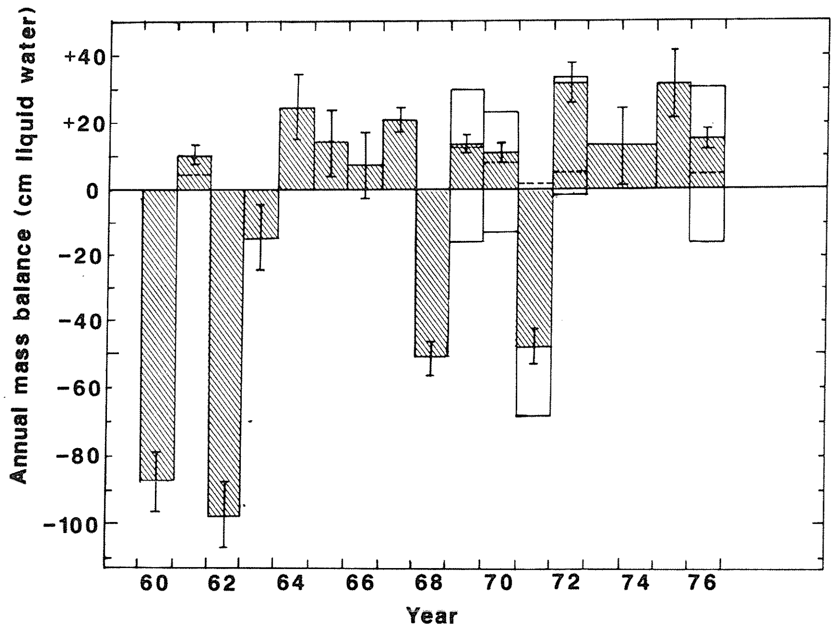


Indications of Climate Change

The Baby Glacier, in addition to being a distinctive piece of ice affected by particular local circumstances is located in the zone of equilibrium mass balance conditions for the region (see Glenday, 1988). The series of sections in Fig. 7 illustrates features of equilibrium zone development common to arctic glaciers. Melt occurs at the surface of accumulated snow, percolates to refreeze lower down in the pack; if all the snow melts, the exposed superimposed ice begins to melt. In some situations there is a net gain of superimposed ice, in others it all melts and a net loss of original glacier ice occurs.

In this altitudinal zone, even small changes in accumulation/ablation-controlling factors can change the net balance from negative to positive or vice versa. Such changes can, in effect, move the glacier above or below the equilibrium line. A persistent, relatively slight cooling , for example, might result in the complete absence of zones with net ablation. As it appears that the equilibrium zone was generally relatively high during the 1959-62 period (Adams, 1991), "normal" lower equilibrium zones could quite easily have the effect of producing positive mass balances in place of large net losses of 1959-62. There is some evidence of this in the record (Fig. 6), however we believe that there was a net loss in the 1980's.

Figure 6. The mass balance record of Baby Glacier, 1959-76 (Alean and Miller, 1977)



The early years appear to have been unusually warm however, more recent measurements on a nearby glacier suggest that three or four years like 1959-60 are present in the thirty year record. The shaded area is the net balance with error bars; the white areas upwards show winter balance, downwards they show summer balance. The annual specific net values are in cm, liquid water. For some years, net gain as superimposed ice is shown by a dashed line.

Future Research

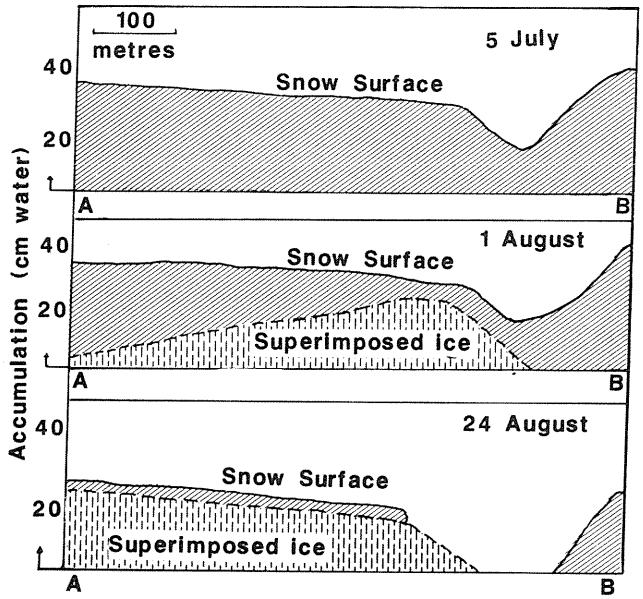
Small glaciers tend to be sensitive to climate changes (Muller, 1962; Grudd, 1989) so in considering the response of Baby Glacier it is important to remember that it is an outflow of a north-facing icefield. Its relationship with this icefield merits study.

The last known position of measured stakes dates from 1976-77 (Weiss, Geographical Institut, Swiss Federal Inst. of Technology (ETH), Sonnegrasse 51, Zurich, Switzerland, CH-8006, pers. comm) and are shown in Fig. 8. The fact that six of these were relocated 12 years later in May, 1989 (Ecclestone, Geography, Trent

University, pers. comm.) with some showing approximately 2m of their total buried length (total ca. 4m) above solid ice, suggests that net changes have not been great.

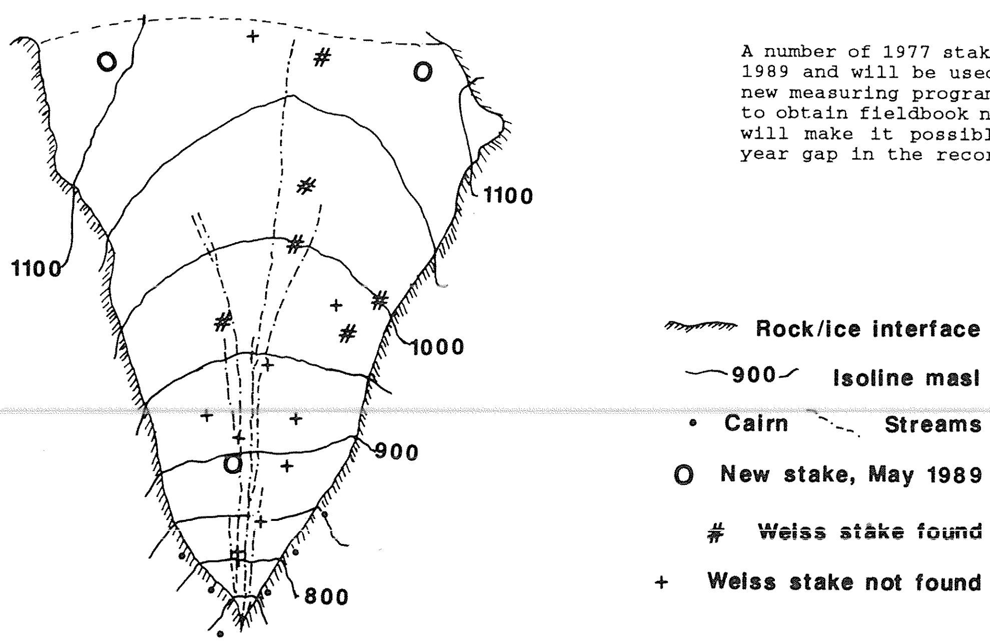
We have re-started a mass balance and run-off measurement program on the glacier with this summer (1991). We hope to obtain copies of the 1976-77 field notes to bridge the 1977-1988 gap in some fashion. The cairns shown in Fig. 8 were also established in 1976-7 as a means of measuring retreat of the glacier margins. We hope to obtain the exact, original locations of these. They will used to measure ice margin retreat in future years.

Figure 7. Superimposed ice development over time, Baby Glacier



Developments in the accumulation area of Baby Glacier along A - B in Figure 3a. To illustrate role of superimposed ice in the equilibrium zone on arctic glaciers. The snowline does not coincide with the Equilibrium line because of net gain of superimposed ice.

Figure 8. Baby Glacier, location of stakes and cairns in 1977 & 1989



A number of 1977 stakes were relocated in 1989 and will be used as the basis for a new measuring program. The authors hope to obtain fieldbook notes from 1977 which will make it possible to bridge the 12 year gap in the record.

Concluding Remarks

Series of mass balance records are a useful indicator of climate trends in any part of the world. Current models of climate change suggests that global warming will be greatest and felt first at high latitudes. Baby Glacier, at close to 80 deg. North, just east of the Arctic Ocean, is well located to sense such changes, should they occur. The global models also suggest appreciable warming within decades. Baby Glacier, because of its size and location in the equilibrium zone, is also well suited to sense changes in such a short time period.

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