GLACIER MOVEMENT IN NORTH-EAST GREENLAND, 1949

WITH A NOTE ON SOME SUBGLACIAL OBSERVATIONS

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ABSTRACT. Work on the Fröya Gletscher, N.E. Greenland, appears to substantiate the evidence already brought forward for the irregular flow of glaciers over short periods. It appears possible to correlate the daily temperature regime with the flow of some "polar glaciers." The distribution of thrust planes seems to have no noticeable effect on the flow. It is suggested that *Block-Schollen* movement may underlie the jerky motion of some of even the slower moving glaciers. A subglacial stream bed on the Skille Gletscher was explored from the snout for a distance of 500 m. It is estimated that at the farthest point the ice was 76 m. thick. There appears to be good observational evidence for de Martonne's theory of medial moraines extending to the bed of the glacier.

ZUSAMMENFASSUNG. Arbeiten am Fröya Gletscher, Nord Ost Grönland, scheinen den bereits hervorgebrachten Beweis, dass Gletscher in kurzen Zeiträumen unregelmässig fliessen, zu bestätigen. Es scheint möglich zu sein, die tägliche Temperatur-Haushalt mit der Strömung einiger „Polar-Gletscher" in Zusammenhang bringen zu können. Die Verteilung von Schubflächen scheint keinen merklichen Einfluss auf die Strömung zu haben. Es wird darauf hingewiesen, dass die Block-Schollen-Bewegung der stossweisen Bewegung einiger, selbst langsam fliessenden Gletscher, zu Grunde liegen mag. Ein subglaziales Strombett am Skille Gletscher wurde von der Spitze ausgehend eine 500 m Strecke weit untersucht. Es wurde geschätzt, dass das Eis an der entferntesten Stelle 76 m dick war. Die Martonnesche Theorie, dass mittlere Moränen sich bis zum Bett des Gletschers erstrecken, scheint durch Beobachtungen bestätigt zu werden.

THE work described below was carried out as a subsidiary part of a glaciological programme the main work of which was to continue observations made the previous year by the Leeds University Greenland Expedition 1948. In 1949 the aim was to study the movement, over as long a period as possible, of the Fröya Gletscher. Plans were made to observe the movement every half-hour for a period of twenty-four hours, in order to gain more information on the short period variation of glacier flow in polar regions. Washburn and Goldthwait [1] working in Alaska had found that glaciers do not flow at a constant speed even over short periods. Similar results had been obtained about the same time by R. Finsterwalder [2a, b] in the Himalaya. It was also hoped to find out whether there were any slight differences in surface flow which might be correlated with the thrust planes. The Fröya Gletscher was considered most suitable for velocity observations as Ahlmann [3] had already studied the regime of this glacier in 1939–40.

A Wild theodolite was used to measure the linear movement of the glacier. In order to measure the velocity over a cross section of the glacier stakes were set out across it and their angular movement from a fixed point was observed. The distance moved by each point was then computed. The stakes were driven into holes in the glacier bored to a depth of 80 cm. Over twenty-four- and forty-eight-hour periods the stakes remained quite firm, but sights were always taken on the junction between the stake and the ice. When observations over longer periods were required, the holes were bored to 120 cm. and deepened every third or fourth day.

This work was only a part of the glaciological programme and the two observers were not able to devote more than two twenty-four-hour periods to continuous readings. These were confined to two stations. Station 1 lay at an altitude of 518 m., 2·4 km. from the snout. Station 2 was at an altitude of 396 m., 1·2 km. from the snout, see sketch-map in Fig. 5 (p. 561).

Adverse weather conditions made the twenty-four-hour readings at Station 1 too discontinuous to be included, but the observations from this station over three weeks are presented. The only short-term readings to be discussed are those from Station 2. Although such observations can only be really valuable when extended over at least a month (a year would be ideal), they correspond sufficiently with those of Goldthwait to be worth recording. Also, so far as is known, they are the first hourly records of movement ever attempted in Greenland.

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Observations at Station 1 (Fig. 1, p. 561) taken at irregular intervals over a period of three weeks show:

1. That the Fröya Gletscher does not, like most glaciers, flow fastest in the centre. Instead, if the movement of the line of stakes is plotted, one finds that the glacier has two zones of greatest speed separated by a zone of slower moving ice. The zone of greatest speed was 600 m. across the 760 m. broad glacier, and in three weeks the stake here moved 209 cm. down-stream. Between this and the other zone of faster moving ice was a slow zone at 470 m. where the stake only moved 80 cm. The second zone of fast moving ice moved 203 cm., its position being approximately half-way across the glacier. It is not easy to explain these zones of differing velocities. They would be understandable if the Fröya Glacier were fed by two accumulation areas separated by a rock ridge, but this is not the case. However, there may be a rock ridge running up the glacier which, though causing thinning, is still invisible.

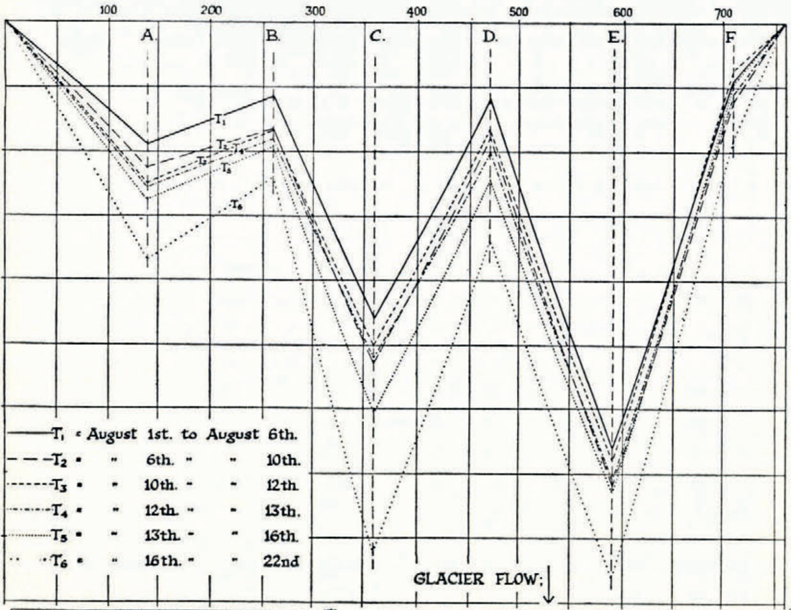
2. The variation of speed over the three-week period is shown in the other two graphs of flow at Station 1 (Figs. 2 and 3, p. 561). In Fig. 2 the distance travelled by each stake is plotted against the time, and the minimum overnight temperatures at the camp are also shown. The steep drop in velocity from 1 to 10 August is more readily distinguished in Fig. 3, where the average daily velocity has been plotted against time. The curve of maximum night temperatures in Figs. 2 and 3 gives some indication of changing conditions over the period. The steady drop in temperature was also noticed in 1948, and it may account for the diminution in glacier speed, if allowance is made for a slight time lag. Forbes,[4] Goldthwait, Finsterwalder and others correlate temperature changes with glacier movement over short periods, although Carlson [5] working in West Greenland, could not find any such relationship.

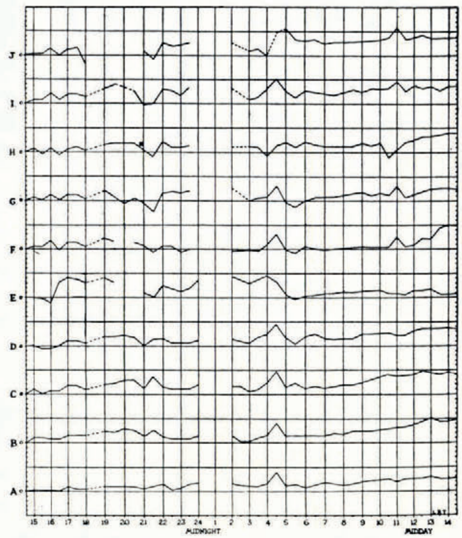
The negative movement of the farthest stakes so clearly marked in Fig. 3 is difficult to explain. Pfaff [6] obtained somewhat similar results in 1875 on the Great Aletsch Glacier, where he found a backward movement in the firn area.

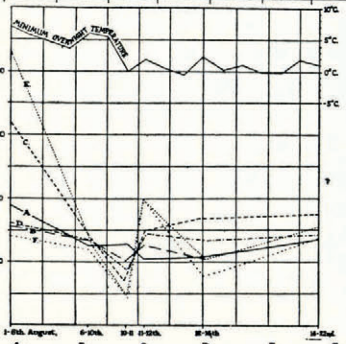
Observations at Station 2 (Figs. 4 and 5, p. 561) show that the surface movement of the ice downstream seems to be unaffected by the position of thrust planes. In Fig. 5 (left) the positions of the major thrust planes are marked as dotted lines. The distance between the stakes was only one metre, and it was hoped that there might be some detectable difference in movement between either side of the thrust planes. This was not so and over the three-week period it seems that the speed of flow throughout the glacier was not materially affected by any discontinuities resulting from the position of thrust planes. There was some slight differential movement between the group of stakes F, G, H, I and the others. These differences will be noticed on Fig. 4 in the readings just before noon. The whole of this group was situated on one side of a thrust plane and the movement may be significant on this account.

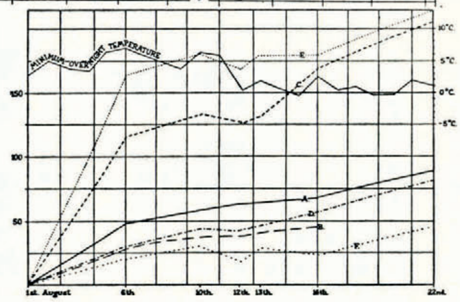
It will also be seen from Fig. 5 that at Station 2 there is a noticeable reduction in the surface speed of the Fröya Gletscher towards the end of the summer, just as at Station 1. Thus the line T_1 represents the movement of stakes between 7–10 August and varies from 40–50 cm. The line T_2 represents the additional movement between 10–16 August. This is only 20 cm. or less, even though it is over a longer period. If the number of days represented by the lines T_1 to T_5 are divided by the intervals between them, one finds a diminution from 17 cm. a day to 1 cm. a day. The decrease in velocity in Fig. 5 appears earlier in August at the upper station, Station 1. One is tempted to suggest that they mark a general slowing down of velocity as the winter advances, noticeable first in the upper part of the glacier, and later in the lower section.

3. The discontinuous movement of the glacier over a period of twenty-four hours is clear from Fig. 4, the dotted line and breaks indicating the time during which visibility was obliterated by snow. The movement of all the stakes A–J is shown, and their position relative to the glacier as a whole is given in the sketch-map, Fig. 5. This jerky movement appears similar to that recorded by Goldthwait and Washburn, although, as would be expected, the variation seems to be of greater









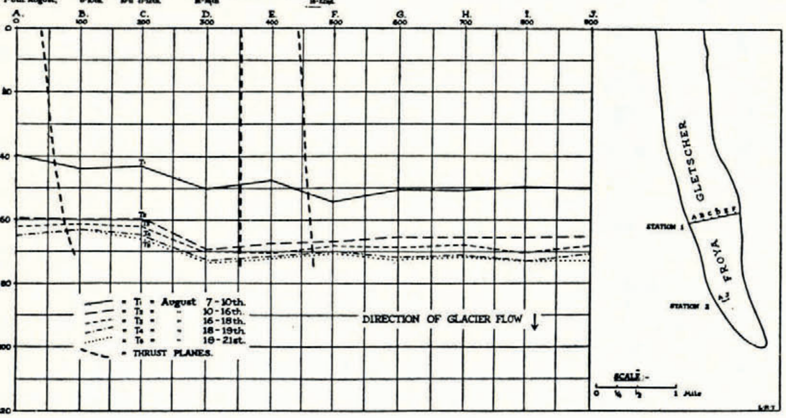


Fig. 1 (top left). Station 1. Movement in centimetres (ordinates) during the periods indicated. Abscissae show distance across glacier

Fig. 2 (centre left). Station 1. Showing (ordinates) distance moved in centimetres plotted against time in days (abscissae)

Fig. 3 (centre right). Station 1. Showing (ordinates) average velocity in centimetres per day plotted against time intervals

Fig. 4 (top right). Station 2. Showing (ordinates) movement over 24 hours of each stake against time in hours. One small marginal division = 1 cm.

Fig. 5 (bottom). Station 2. Distance moved in centimetres (ordinates) during the periods indicated. Abscissae show distance between each stake in centimetres. The sketch map gives the positions of Stations 1 and 2

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magnitude in Greenland. In the South Crillon Glacier variations of between 0 and 5 mm. were recorded in the half-hour, whilst on the Fröya Gletscher variations of up to 1–2 cm. in the same period were noted. The posts used in Greenland were probably not as accurate as the indicator used by Goldthwait, but the experimental error in measuring the distance moved by the posts was probably never more than 50 mm. and usually much less. This error is not sufficient to nullify the erratic motion observed. The Fröya Gletscher was crevassed very little, and there were no crevasses between the theodolite station and any of the posts at Station 2.

The observations show that the glacier moved about 1–2 cm. more by day than by night. Similar conclusions were reached by Goldthwait and also by Krasser,[7] although the results of the latter were questioned by Mercanton.[8] The greatest movement at all but one stake took place between 16.00 and 17.00 hr. There also appears to be a decrease followed by a slight forward surge about two hours before midnight. On the South Crillon Glacier, however, the peak periods were 08.00, 12.00 and 16.00 hr. It is noteworthy that both these series of observations show a steady forward surge of the glacier during the day, which appeared to start earlier on the Fröya Gletscher than on the South Crillon Glacier. The jerky movements also seem to coincide in the late evenings.

This irregular movement over the twenty-four-hour period on the Fröya Gletscher and noted by Goldthwait in Alaska in 1937, may perhaps be attributed to some form of *Block-Schollen* motion, if one agrees with Finsterwalder's views.[9] The speeds do not quite come within the range found by Finsterwalder in the Himalayan glaciers, 800 cm. a year, *i.e.* 7 cm. an hour, but these are not necessarily the minimum for *Block-Schollen* flow. Undoubtedly the glacier motion recorded by Carlson in West Greenland, between 18–80 cm. an hour, would come well within the suggested range. Much more work over continuous twenty-four-hour periods must be carried out before one can be certain whether all glacier motion is jerky or whether this motion only applies to glaciers moving faster than a certain minimum.

Subglacial observations

Observations in the interior of the glacier system were carried out as part of the glaciological programme in 1949. A reconnaissance on the Skille Gletscher, Clavering Island (Clavering Ø) revealed the possibility of exploring the subglacial stream bed. The Skille Gletscher (Vintergata) is a long valley glacier with a large stream emerging from two tunnels in the snout. On three occasions one of these was entered until finally a point was reached where the subglacial stream emerged from a crack in the ice, 6 m. above the stream bed. This was 500 m. from the snout of the glacier. In order to find how thick the glacier was at this point a compass traverse was made up the stream course. Later, the same traverse was followed on the glacier surface and a comparison of the aneroid readings, above and below the ice, showed that the thickness of the glacier at the farthest point penetrated was 76 m.

Whilst moving under the glacier it was noticed that the walls above and at either side of the subglacial stream often consisted of smooth and rounded boulders. But it was not until the traverse had been completed on the surface that these were seen to be part of the medial moraine, for the last half of the traverse on the glacier surface coincided exactly with the line of this medial moraine. De Martonne's [10] theory that medial moraines are not purely surface phenomena but reach glacier base is substantiated by these observations.

The Skille Gletscher may be termed a "subpolar" glacier [11] as the temperature of the ice approximates to 0° C. throughout its depth in summer. Thus in the subglacial tunnel the temperature of the ice was 0° C. as measured by a resistance thermometer. The air temperature dropped the farther one penetrated, 2° C. at 280 m. dropping to 1·4° C. at the farthest point from the snout. This probably results from the air being chilled by the englacial stream. It is not certain whether our way was finally blocked by a roof fall or whether the stream, guided by crevasses and other planes of weakness, reached the glacier bed at this point. However, it would seem that contrary to the views of some glaciologists it is possible for a tunnel to exist under 70 m. of ice.

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FLUCTUATIONS OF THE ITALIAN GLACIERS, 1950

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THE results of the annual glacier measurements of the Comitato Glaciologico Italiano for 1950 will be published in the *Bolletino Italiano Glaciologico* for 1951, but the following advance information may be useful for those interested.

The retreat continues apace; dark rocks are uncovered and the ice surface is becoming increasingly obscured by moraines. Apart from the aesthetic effect and the replacement of ice by rock for climbers the economic aspect of this retreat is serious. Thousands of streams are reduced or dried up and the large reserves of water held in the ice are shrinking. It is calculated that during the last thirty years the extent of the glaciers of the Alps has been lessened by 10 per cent and their thickness by an average of 25–30 m., representing a loss of 75 $km.^3$.

The two chief factors influencing retreat are, of course, precipitation and temperature. The winter of 1949–50 was more snowy than the previous winter. At the Cignana Observatory in Valtournanche (2100 m.) there was an average of 89·1 cm. as compared with 29 cm. the winter before. On the other hand, the average summer temperature was 9·2° C. as against 8·4° C. in the previous year. Of 95 glaciers observed in 1950, 90 were retreating, 3 were stationary, 1 was perhaps advancing and 1 uncertain.*

If, however, one examines the individual data † there appears to be a certain slowing down of the retreat in the Maritime Alps. These mountains are particularly snowy, being a part of the humid Atlantic area subject to south-west winds. The retreat is also slowing down in the glaciers in the east where the summers are, on the whole, less warm than in central and western regions.

The winter of 1950–51 was characterized by heavy snowfalls, which prompts the question whether the retreat has really been arrested. One must wait to give a reply until the summer temperatures for 1951 are known. Clearly, however, many years must elapse before our glaciers can advance again.

* *Cf.* the 1949 report: *Journal of Glaciology*, Vol. 1, No. 8, 1950, p. 421.

† The list of individual glacier fluctuations is in the possession of the Society and may be consulted by any member interested.—*Ed.*