REFERENCES

1. Olsson, Hilding. Radiation measurements on Isachsen's Plateau. *Geografiska Annaler*, Årg. 18, 1936, p. 225–44.
2. Wallén, Carl Christian. Glacial-meteorological investigations on the Kårsa Glacier in Swedish Lappland, 1942–1948. *Geografiska Annaler*, Årg. 30, 1948, p. 451–672.
3. Eckel, O., *and* Thams, Chr. Untersuchungen über Dichte-, Temperatur- und Strahlungsverhältnisse der Schneedecke in Davos. *Der Schnee und seine Metamorphose, Beiträge zur Geologie der Schweiz*—Geotechnische Serie; Hydrologie; Lief. 3, Zürich, 1939, p. 273–340.
4. Prohaska, F., *and* Thams, Chr. Neue Untersuchungen über die Strahlungseigenschaften der Schneedecke. *Helvetica Physica Acta*, Vol. 13, 1940, p. 21–44.
5. Cooperative Snow Investigations, Corps of Engineers Analysis Units. Albedo of the snow surface as related to weathering factors and stage of the season. *Research Note, South Pacific Division, Corps of Engineers, U.S. Army*, San Francisco, Calif., 11 Dec., 1950 (mimeographed).
6. Sauberer, Franz, *and* Dirmhirn, Inge. Der Strahlungshaushalt horizontaler Gletscherflächen auf dem Hohen Sonnblick. *Geografiska Annaler*, Årg. 34, Ht. 3–4, 1952, p. 261–90.

GLACIOLOGICAL OBSERVATIONS ON SOME OF THE OUTLET GLACIERS OF SOUTH-WEST VATNAJÖKULL, ICELAND, 1954

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Part I: GLACIER REGIME

ABSTRACT. Accumulation and ablation measurements on Morsárjökull are described and a tentative glacier budget for the three seasons 1951–52, 1952–53 and 1953–54 is presented. Observations of glacier flow on Morsárjökull, Svínafellsjökull and Skaftafellsjökull are considered. The recent fluctuations of the snouts of Skaftafellsjökull and Svínafellsjökull are discussed and related to variations in the height of the accumulation zones of the glaciers; recent glacier thinning is also mentioned.

ZUSAMMENFASSUNG. Anhäufungs- und Ablationsmessungen auf dem Morsárjökull werden beschrieben, und ein vorläufiges Gletscher-Budget für die drei Saisons 1951–52, 1952–53 und 1953–54 ist aufgestellt.

Beobachtungen der Gletscherströmung auf dem Morsárjökull, dem Svínafellsjökull und dem Skaftafellsjökull werden in Betracht gezogen. Die jüngsten Schwankungen der Stromenden des Skaftafellsjökull und des Svínafellsjökull werden besprochen und auf Unterschiede in der Höhe der Anhäufungszonen der Gletscher bezogen; jüngster Gletscherschwund wird auch erwähnt.

A. ACCUMULATION

The observations begun in 1953 on the south-west margin of Vatnajökull, in the accumulation area of Morsárjökull, were continued in the summer of 1954. A pit, about 1½ km. north of the Midfellstindur ridge, at 1200 m. elevation was dug in the same area as the 1953 accumulation pit[2] to measure the firn accumulation during the winter of 1953–54 and to check the estimate for 1952–53 which was based on the measurements in the 1953 pit (see Fig. 1, p. 564). On 12 August 1954 the profile showed 3·65 m. of firn overlying the 1953 summer horizon. The layer between the 1952 and 1953 summer surfaces was 1·33 m., which is rather in excess of the estimate made on the 1953 measurements. It appears that ablation after 16 August 1953 only amounted to 0·4 m. instead of the 0·91 m. estimated. This observation shows that the ablation period in 1953 must have ended sooner than is generally anticipated and earlier than suggested by Ahlmann's observations on south Vatnajökull between 1935 and 1938[1]. However, the observations do show that the amount of firn varies very much from year to year. The 1953–54 season was particularly snowy; at the beginning of the ablation season the depth of snow at 1200 m. must have been at least 5–6 m.

B. ABLATION

The ablation was measured in the accumulation zone of Morsárjökull in July and August 1953. In 1954 it was measured in the ablation zone of Morsárjökull and of Skaftafellsjökull and Svínafellsjökull, where the flow observations were made (see Fig. 4, p. 565). The ablation stakes on Morsárjökull were situated between the edge of the pro-glacial lake at 180 m. and close to the back-wall at 560 m. Another set of observations were made across the glacier where the flow was measured. The results are shown in Fig. 2 (p. 565). There appears to be little change in the rate of ablation down the glacier; possibly this is because the valley is narrow with steep rock walls.

The daily ablation for the glacier averaged 6·5 cm./day in July and early August. The ablation was greatest when the temperature was highest as would be expected. The ablation measurements on Skaftafellsjökull and Svínafellsjökull, for a shorter period, gave an average of 5·6 and 5·85 cm./day respectively. The lower ablation rates may be explained by the greater width of these glaciers and the cleaner ice of their surface.

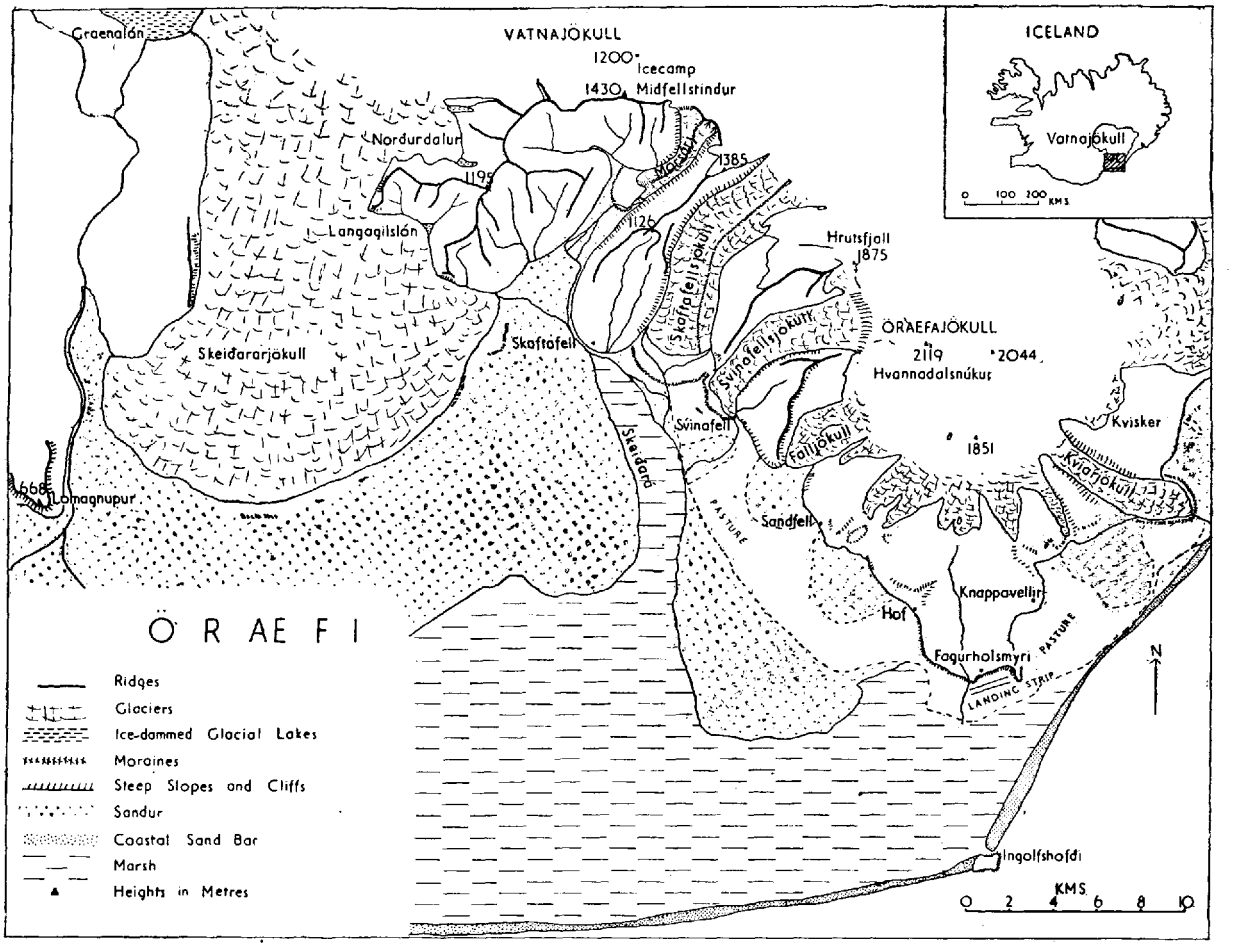
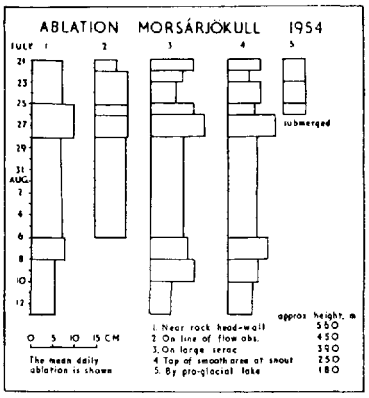
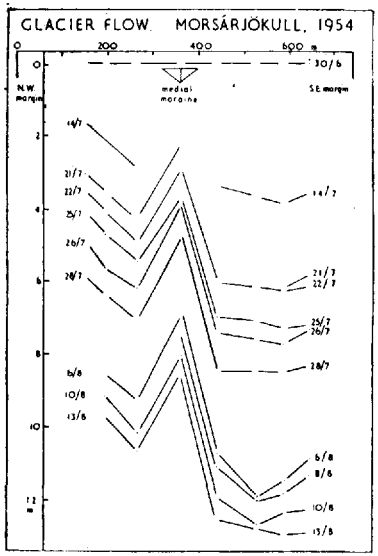


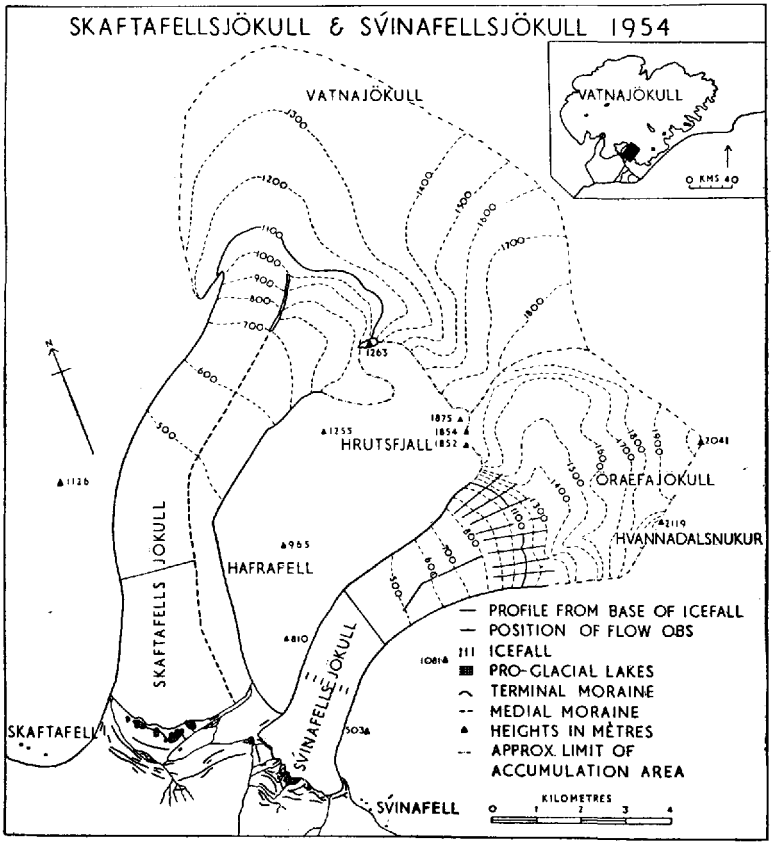
Fig. 1. Map of Öræfi to show position of the glaciers mentioned in relation to south-west Vatnajökull and Öræfajökull

C. Glacier Budget

From the amount of accumulation and ablation measured it is possible to arrive at a tentative estimate of the budget of Morsárjökull for three seasons. The estimates were made with reference to Ahlmann's methods[1]. The accumulation was calculated from the specific gravity readings made in the firn pit and the measured accumulation for three seasons. The 1953–54 figure used was the amount of firn measured in mid-August less 0·4 m. (the amount lost after mid-August 1953). The accumulation area of Morsárjökull extends from about 1100 m. to between 1300 and 1400 m., so that the accumulation measured at 1200 m. would give a reasonable average. Some uncertainty arises from lack of precise evidence of the height of the firn line for the three seasons, but it was







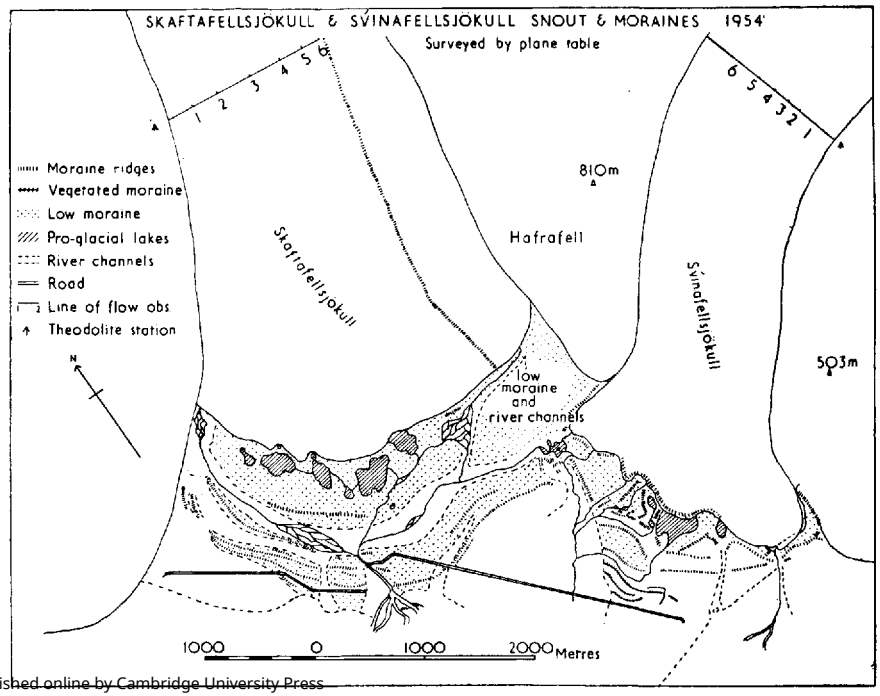


Fig. 2 (top left). Ablation observations on Morsárjökull in July and August, 1954. The average daily ablation between observations is shown

Fig. 3 (bottom). Map of the snouts and pro-glacial features of Skaftafellsjökull and Svínafellsjökull plane-tabled in August 1954. The position of stakes for measuring glacier flow is shown

Fig. 4 (top right). Map of Skaftafellsjökull and Svínafellsjökull to show the height and extent of the accumulation areas. Contours are taken from the 1 : 50,000 Danish Map

Fig. 5 (left centre). Flow observations on Morsárjökull from 30 June to 13 August, 1954

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observed to lie between 1000 and 1100 m. This zone covers the upper part of the ice-fall and only amounts to 4·5 per cent of the whole glacier surface area so that the variations of the annual accumulation and ablation due to the changing firn line would also be small. The annual total of the ablation was calculated using the percentage value of the July figure in relation to the whole year, for different height ranges, as given by Ahlmann[1] and based on the measurements made in 1954.

SEASON 1951–52

Firn line about 1025 m.

Accumulation	34	million	cu.	m.	of water
Ablation	40	,,	,,	,,	,,
Total loss	6	,,	,,	,,	,,

SEASON 1952–53

Firn line about 1100 m.

Accumulation	18	,,	,,	,,	,,
Ablation	44	,,	,,	,,	,,
Total loss	26	,,	,,	,,	,,

SEASON 1953–54

Firn line about 1050 m.

Accumulation	43	,,	,,	,,	,,
Ablation	41	,,	,,	,,	,,
Total gain	2	,,	,,	,,	,,

The figures show that Morsárjökull has, in general, a negative budget, but the snowy conditions of 1953–54 probably caused a slightly positive balance, under the present climatic conditions. The morphology of Morsárjökull is such that the area of the accumulation zone is much larger than that of the ablation zone. With the firn line at 1100 m. it is 3·44 : 1 and with it at 1000 m. it is 4·55 : 1. As a result the regime of the glacier is more sensitive to variations in the accumulation zone than in the ablation zone, particularly as the critical area covering the variations of the firn line is steep and therefore of small area. This applies also to Skaftafellsjökull and very strongly to Svínafellsjökull, where the 1100 m. contour is in the centre of the ice-fall (see Fig. 4). This means that the winter snowfall is probably the dominant factor in the budget. This conclusion must, however, be very tentative in the light of the evidence used.

D. EVIDENCE OF GLACIER FLUCTUATION

Evidence of the thinning and retreat of Morsárjökull was given in Part II of "Glaciological Observations on Morsárjökull"[2]. During 1954 a survey by plane-table was made of the snouts of Skaftafellsjökull and Svínafellsjökull (see Fig. 3, p. 565). The amount and character of the moraines indicate that these glaciers have reacted differently to the climatic fluctuations of the last fifty years.

Skaftafellsjökull has retreated evenly along its front by about 925 m. since the survey of the Danish map in 1904; most of this retreat has taken place since 1932, when measurements of the frontal retreat were started. Since 1932 the glacier has retreated 800 m. (778 at the north end and 810 at the south end) by 1953 [3a, b, 4a, b, c], so that it must have retreated only about 125 m. between 1904 and 1932. The rapid retreat in the last two decades, which was continuous till 1951, is reflected in the absence of high moraines near the glacier snout and the presence of large proglacial lakes (see Fig. 3). Svínafellsjökull has retreated more irregularly and on the whole much less. During the period 1904 to 1954 the maximum amount of retreat has been about 300 m. while over a considerable part of the snout the retreat has only been 100 m. The southern end of the glacier has not retreated since 1904, but it now appears to be rather stagnant. This is reflected in the moraines. The terminal moraines of Svínafellsjökull are much higher than those of Skaftafellsjökull, especially at the southern end. The heights of the moraines of Skaftafellsjökull vary from 5 m. to 14 m., while those in the centre of Svínafellsjökull are about 27 m. high and reach

50 to 60 m. at the southern end. It is possible that this greater height is partly due to an ice core in the moraine. The slow retreat of Svínafellsjökull contrasts strongly with the rapid retreat of Morsárjökull and the fairly rapid retreat of Skaftafellsjökull, which have retreated about 1000 m. and 925 m. respectively.

On the Danish map of 1904 the two glaciers are shown to join below the slopes of Hafrafell, but now they are nearly 800 m. apart. According to Thorarinsson[5] the glaciers split in 1935. At the present time the glaciers have both advanced slightly during the last two years; this is particularly noticeable on Svínafellsjökull, which has made very recent terminal moraines and whose ice front is a cliff, in places about 60 m. high above the pro-glacial lake.

Although the snout of Svínafellsjökull has not retreated very much the glacier has lost a considerable amount of ice by thinning. There is a very marked "trim-line" along the flanks of the glacier, 58 m. above its surface. This is a line above which vegetation is well established and below which it is largely absent. A very steep, unstable moraine slope lies below the trim-line on the east side of Svínafellsjökull, while above it ridges of well-vegetated lateral moraine occur. A similar feature is found on the flanks of Skaftafellsjökull at 56·5 m., but the thinning of Morsárjökull is greater, being about 90 m.[2]. Observations on the east side of Skeidarárjökull show a trim-line at 55 m. above the glacier near Nordurdalur, it is rather higher near Langagilslón.

It may be noted that between the spring of 1953 and 1954 Skeidarárjökull has thickened considerably. Calculations based on observations of the height of the ice, seen against the col north of Lómagnúpur, from Skaftafell show that the thickening is about 10 m. about 5 km. from the glacier snout. This observation and the recent advance of the two glaciers discussed may indicate that the rapid glacial retreat in this area is slowing down, in at least some of the glaciers, at the present time.

E. Retreat Related to the Height of the Accumulation Area

The variation in the retreat of the three glaciers may be related to the height of their accumulation areas, with reference to the figures given below, which have been derived from the Danish map and the plane-table surveys of the glacier snouts.

Glacier	*Total area*	*Below 1100 m.*	*Above 1100 m.*	*Above 1400 m.*	*Above 1700 m.*	*Above 1900 m.*
			Area in sq. km.			
Skaftafellsjökull	75	32	43	16	6	0
Svínafellsjökull	32	13	19	16	7	2
Morsárjökull	29	6·5	22·5	0	0	0
			Area per cent			
Skaftafellsjökull	100	43	57	22	8	0
Svínafellsjökull	100	40	60	50	22	3
Morsárjökull	100	22·5	77·5	0	0	0

Ratio of area above 1100 m. to area below 1100 m. (see Fig. 4)

Skaftafellsjökull	1·34 : 1
Svínafellsjökull	1·46 : 1
Morsárjökull	3·44 : 1

From these figures the conclusion is reached that the height of the accumulation area is significant in the regime of the glacier. Morsárjökull, with its low level accumulation area, has a much greater proportion of accumulation area than the other glaciers but it is still retreating fast. Svínafellsjökull, draining the high volcano of Öræfajökull, on the other hand has a high percentage of its accumulation area at a great altitude which will help to account for the fact that this glacier has not retreated so much. This is probably explained by the fact that whereas rain falls on the ice cap at 1200 m. normally during the summer, at 1700 m. and above the proportion of precipitation falling as snow must be considerably greater, thus providing a greater accumulation in a smaller area. New snow fell on the higher ground during August while at the ice camp at 1200 m. although some

snow fell it soon melted and rain was more common. In the same way ablation will be reduced as the altitude increases, so that the net accumulation will be much greater.

F. Glacier Flow

The flow of three glaciers was measured during June, July and August, 1954. Morsárjökull was measured from 30 June to 13 August, this period including two weeks of measurements at two-day intervals. This was intended to give further data on the correlation suggested by the 1953 observations between rate of flow and rainfall[2], but during the period of observations there was not enough rain for any further conclusions to be reached; during the period 21 July till 13 August only 17·7 mm. of rain fell. The maximum flow of Morsárjökull, near the far side of the south-east ice stream, was 30 cm./day, giving an annual flow of 108·5 m. Near the position of the second stake a cairn had been built in August 1953; this was found in July 1954. During the interval the cairn had moved 92·5 m., that is between 14 August 1953 and 14 July 1954. The movement during the

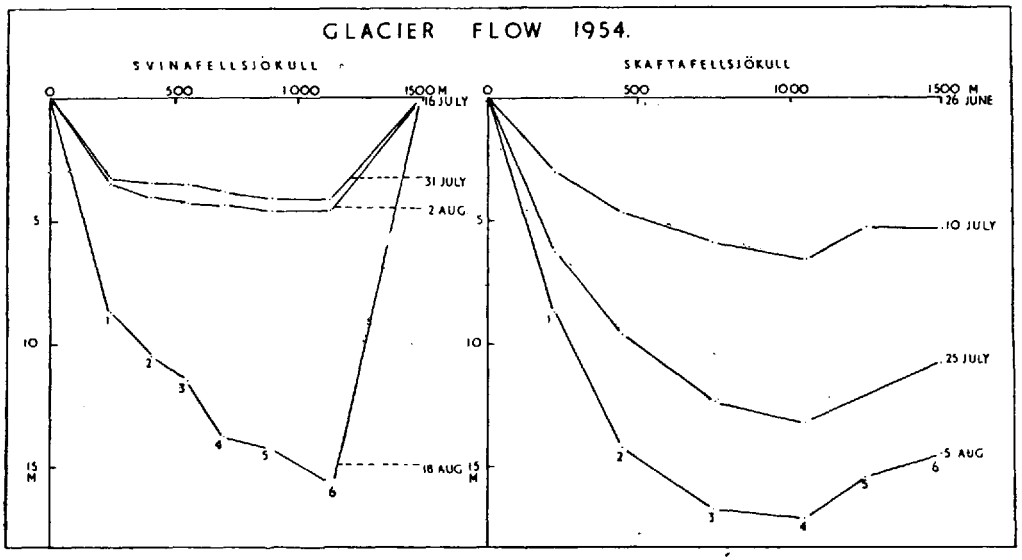

Fig. 6. Flow observations on Skaftafellsjökull from 26 June to 5 August and on Svínafellsjökull from 16 July to 18 August, 1954

remaining month would be 9·1 m., giving a total annual movement of 101·6 m. This may be compared with 105·8 m. which is the annual movement worked out from the 1954 measurements on a stake very near the position of the cairn and the value of 103 m. which is the annual movement of the cairn calculated from the 1953 measurements at the same point. This suggests that there is little seasonal variation in the flow of the glacier, although it may only be that the flow of July and August is near the average. The details of the flow observations are shown on Fig. 5, p. 565. The medial moraine moved at about $\frac{2}{3}$ the speed of the main part of the south-east ice stream, which in turn moved faster than the north-west ice stream. There appeared to be little reduction of speed near the south-east margin, but more near that to the north-west; the former lies on the outside of the bend in the valley, which may account for its greater speed as the same feature was found in the flow of Svínafellsjökull.

The flow of Skaftafellsjökull and Svínafellsjökull was measured along the line shown in Figures 3 and 4. The stakes on Skaftafellsjökull extended from the western edge to the medial moraine which is about three-quarters across the glacier and the same proportion of Svínafellsjökull was

measured from the south-eastern margin. The position of the stakes is indicated on the graph of flow, Fig. 6 (p. 568) and on Fig. 3. Both these glaciers moved faster than Morsárjökull as would be expected because of their greater fall and greater size. The most rapid movement on Stake 4 on Skaftafellsjökull was 43 cm./day, giving 156 m./year, while on Svínafellsjökull Stake 6, the one nearest the western side of the glacier, moved fastest at 47 cm./day, giving 172·5 m./year. Svínafellsjökull, like Morsárjökull, moves most rapidly on the outside of the bend where observations were made but Skaftafellsjökull moves most rapidly near the centre of the ice stream and the medial moraine moves more slowly than the centre. The observations were made where the glacier is flowing along a straight part of the valley. The flow observations on both these glaciers were made about 4 km. from the glacier snout, which is rather further up-glacier than the observations on the shorter Morsárjökull.

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[*Part* II *of this paper dealing with the ogive banding will be published in the next issue.*]

REFERENCES

1. Ahlmann, H. W. *Glaciological research on the North Atlantic coasts*. London, Royal Geographical Society, 1948. (R.G.S. research series, No. 1.) p. 33.
2. Ives, J. D., *and* King, C. A. M. Glaciological observations on Morsárjökull, S.W. Vatnajökull. Part II. *Journal of Glaciology*, Vol. 2. No. 17, 1955, p. 477–82.
3. (*a*) Mercanton, P.-L. Rapport sur les variations des glaciers de 1935 à 1946 [47]. *Union Géodésique et Géophysique Internationale. Association Internationale d'Hydrologie Scientifique. Assemblée générale d'Oslo 1948: Procès-verbaux des séances*. Tom. 2. Louvain, [1950], p. 258–59.
(*b*) —— Rapport sur les variations de longueur des glaciers européens de 1947 à 1950. *Union Géodésique et Géophysique Internationale. Association Internationale d'Hydrologie Scientifique. Assembleé générale de Bruxelles, 1951*. Tom. 1. Louvain, [1952], p. 117.
4. (*a*) Eythórsson, J. Jöklamælingar, 1950 og 1951. *Jökull* (Reykjavík), 1 Ár, 1951, p. 16.
(*b*) —— Jöklamælingar haustid 1952. (Glacier variations 1952.) *Jökull* (Reykjavík), 2 Ár, 1952, p. 31.
(*c*) —— Glacier variations 1952/53 in meters. (Jöklabreytingar.) *Jökull* (Reykjavík), 3 Ár, 1953, p. 49.
5. Thorarinsson, S. Vatnajökull. Scientific results of the Swedish-Icelandic investigations, 1936–37–38. *Geografiska Annaler*, Årg. 25, Ht. 1–2, 1943, p. 31–35.

INSTITUTO NACIONAL DEL HIELO CONTINENTAL PATAGÓNICO

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ITS FOUNDATIONS AND FUNCTIONS

ARGENTINA has now a special agency for the co-ordination of glaciological studies in the region of the Patagonian ice field. The Instituto Nacional del Hielo Continental Patagónico was created by Decree of 23 May 1952. It is part of the Dirección Nacional de Investigaciones Técnicas, an office for the direction of technical research under the Ministry of Technical Affairs.

The main object of the new Institute is "to guide, direct, control, co-ordinate and carry out research and scientific studies on, and in, the neighbourhood of the Patagonian ice field, including the periglacial regions and those connected with the Quaternary Ice Age". It is also responsible for a museum, information centre and library. The Decree grants "peculiar regional jurisdiction" in these respects, "without prejudice to the due co-ordination which an Institute of this nature should maintain with others concerned with research and studies of a related nature."

The first Director, Major Don Emiliano Huerta, has written to say that the new Institute is now in existence. Major Huerta is anxious to establish contact with similar institutes and societies and to keep in touch with their work; his address is c/o Presidencia de la Nación, Ministerio de Asuntos Técnicos, Buenos Aires.