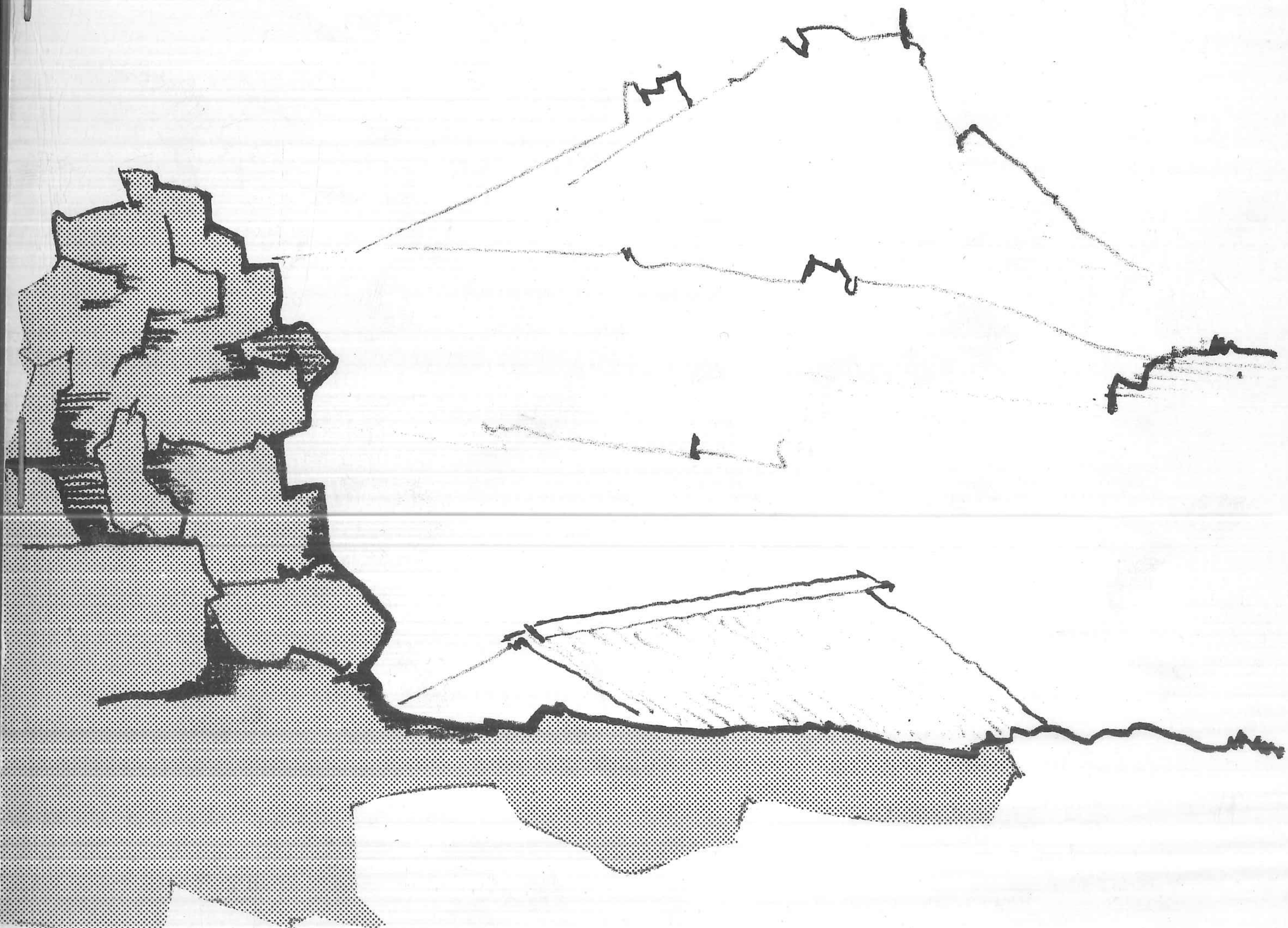
ICELAND EXPEDITION 1971



university of newcastle upon tyne exploration society

UNIVERSITY OF NEWCASTLE UPON TYNE

EXPLORATION SOCIETY

REPORT OF THE EXPEDITION TO THORISJÖKULL, CENTRAL ICELAND 1971.

edited by

Wendy and David Huddart

MEMBERS OF THE EXPEDITION

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Wendy Huddart (Newcastle Education Committee) was a visiting member of the expedition for four weeks and was based at Thorisjökull for one week and Hagavatn for three. Robert Eden (Department of Civil Engineering, Southampton University) was a visiting member of the expedition for ten days, based at Thorisjökull.

CONTENTS

INTRODUCTION

Jane Drummond

On the morning of Friday, 25th June eight members of our party sailed down the Forth from Leith on our way to Iceland and the Thorisjökull ice-cap. The final two weeks of term had been spent in a strenuous combination of packing equipment and food crates, obtaining insurance policies, ensuring that the Landrover was suitably roadworthy, and general end-of-term plus expedition preparation activities including seeking out examination results!

Without the help and advice of members of the University Exploration Society, the University Exploration Council, Hodgson's Garage of Wearhead, Mr. Fripp (Surveying Dept.), Mr. Hope (Geography Dept.), Mr. Calvert (P.E. Dept.), the L.D. Mountain Centre, Helly Hansen Ltd., Miss Brynn Evans, Miss Kathy Rorison, Miss Jane Hooper, Mr. Andrew Hargreaves, parents and other patient friends we would undoubtedly have been fortunate to arrive in Leith on time! To relax on the 'Gullfoss' enjoying the Icelandic Steamship Company's superb food was a welcome 'calm between the storms'.

We docked at Reykjavik early on Monday, June 28th to be greeted by Mr. Eric Kinchin as we emerged from the usual customs formalities. Mr. Kinchin is a friend of one of the team members and since he lives in Iceland was of very valuable help to us during our stay particularly when one member contracted shingles. Navigating through the Icelandic Health Service would have been most difficult without a guide.

The ninth member of our team arrived that evening on a flight from Glasgow and, despite the luxuries of flying, was even more dismayed than the earlier arrivals. The 'lunar landscape' across which runs the road between the airport and Reykajavik is a dismal introduction to the unsuspecting visitor to Iceland. Perhaps it is this forbidding landscape which makes the most immediate impact on a visitor.

Since our Landrover could not accommodate nine people plus luggage and stores on a journey to Thorisdalur, the transfer from Reykjavik Municipal Campsite to our Thorisdalur Base Camp took place in three stages. As each stage arrived new team members were overwhelmed by the unexpected 'greyness' of the valley. The backdrop to Base Camp was a glacier streaked with crevasses and coloured by the reflection of a grey overcast sky. Black ash mountains loomed around us. The grey sandur stretched into the distance where it was cut by the Geita Fault. A chain of small lakes at the base of the fault reflected more greyness. All these combined to present a dismal first impression.

When we finally left the area this monochromatic devastation had assumed a beauty of its own and much film had been exposed in an attempt to capture the interplay of greys and browns beneath the weak Icelandic sunlight. Thingvellir and Myvatn, Icelandic beauty spots displaying verdant areas of grass, trees and flowers, were a trifle gaudy to us. British vegetation when we returned in September was positively vulgar.

By July 2nd, the end of our first week in Iceland, Base Camp was smoothly operational. Depth gauges had been set up in nine meltwater streams; two meteorological stations were functioning; the constant depth recorder in one of the main meltwater streams was revolving satisfactorily; Carole Dickinson's physiology with its iniquitous pink polythene bags was underway; the sedimentologists had started their interminable collection of sand and stones and sample sites were marked by cairns built at hundred metre intervals along the sandur; and the botanists were happily occupied in their 'Green Valley'.

Thorisdalur, reputedly one of the bleakest valleys in Iceland, had at times during our stay a population of thirty-five. As well as the Newcastle University group there was an Icelandic-American mining camp and the British Schools Exploring Society's ice-training camp all within a mile of each other.

During the earlier weeks at Thorisdalur there was some remarkably good weather. On one notable day the temperature soared to 71^{o} Fahrenheit and watchful pilots over the area might well have spotted two tiny figures on the glacier clad in an unorthodox combination of swimming costume and climbing boots. In all we had about sixteen of these clear, sunny days which were occasionally welcomed as tent-repairing days, although it should be added that the tents withstood the vagaries of the weather admirably. Sun on Thorisdalur endowed it with a more companionable character. Braided streams wove silver through the stony sandur, Prestahnukur (a rhyolitic mountain overshadowing the camp) softened with a golden glow, even the black ash mountains persuaded us that they supported some vegetation. Most of all the glaciers responded magnificently becoming a brilliant blue-white as they reflected the azure sky.

Not all members of the team spent the full ten weeks in Thorisdalur. The two botanists (Hugh McAllister and Jo Hardaker) returned to Reykjavik

to visit the Botany Department at Reykjavik University and it was then that Jo contracted shingles. This necessitated a decision to remain in Reykjavik and during these two weeks they took the opportunity to work on the vegetation in the city area. A second misfortune at this time was a malfunction of the cine camera so our photographer, Chris North, spent some time having it repaired in Reykjavik. Since misfortunes come in threes, an Icelander possibly felt obliged to collide with our Landrover. (Credit is due to Icelandic officials who helped us cope with this situation with a minimum amount of difficulty. One rear wheel was replaced and a payment was made to cover the cost of replacing a side panel).

During these first few weeks two more members arrived, namely Dr. Huddart's wife Wendy and Mr. Bob Eden. Dr. and Mrs. Huddart spent one week in Thorisdalur and then left to set up a camp in Hagavatn where Dr. Huddart planned a section of his work. Bob Eden participated in the Hydrology project in Thorisdalur.

The penultimate week saw the departure of the first of our 'Grand Tours' - a break from work projects and an opportunity to see more of the country. The first party travelled a route along Kaldvegur to Akureyri in the north and then via Myvatn to the Eastern fiords. The second party travelled through the south-west and on to Isafjordur, Akureyri and Myvatn. Roar Jacobsen's energy and skill in driving for long hours over difficult terrain deserves special mention.

On these tours we usually spent the night in tourist huts which are to be found dotted around Iceland. Arriving late at night we were indebted to Rob Riley who systematically organised us in the preparation of substantial meals. Mention should be made of his personal management and culinary expertise! Sitting in these huts eating our curry which had been cooked on 'black-monster' cast iron stoves, Newcastle seemed to be removed in time as well as space.

The last four days were spent in Reykjavik packing, shopping and washing.

On September 1st we sailed from Reykjavik for Leith. When it arrived it was a day of mixed feelings. After spending ten weeks in a country absorbing its moods and customs one inevitably develops a deep attachment to it. We left, a little sad to say farewell, a little relieved to be returning home, and very grateful to the innumerable people and organisations who had enabled us to spend a memorable time in Iceland.

THE SANDUR DEPOSITIONAL ENVIRONMENT, KALDIDALUR, ICELAND

David Huddart

1. INTRODUCTION

The purpose of this report is to present geomorphological and sedimentological data from a modern proglacial outwash plain, or sandur. Such data will be of use in interpreting relationships between bedforms, sedimentary facies and depositional environments in Pleistocene, proglacial, braided river, sedimentary sequences which are being studied in north-west England. This was attempted by making a detailed study of the sedimentary textures, the facies distribution and the relationships between bedforms and sedimentary structure on the Kaldidalur valley sandur. This sandur is confined between the Thorisjökull ice cap (1350 m), Prestanukur (1223 m), Hadegishnukur (1076 m) and the 15 m high north-east to south-west trending fault scarp below the Ok shield volcano (see figures 1 and 2). The sandur, a well defined morphological unit approximately 5.5 km long and 4.0 km wide, forms the headwaters of the river Geita which becomes a single river after the sandur streams pass through the 20 m high rock gorge between Hadegishnukur and the fault scarp. The Geita is fed by meltwater from the northern and western tributary glaciers of Thorisjökull, which are at present in active retreat, and in the recent past also received meltwater from Geitlandsjökull (1400 m).

The solid geology is dominated by the Pleistocene Palagonite, or Moberg formation, composed chiefly of brown tuffs, breccias and grey basalts. These rocks form Hadegishnukur and the solid beneath Thorisjökull whilst Prestanukur is an acid intrusion composed of perlite, obsidian and rhyolite. This Moberg landscape is considered to have been formed by volcanic eruptions beneath the Pleistocene ice sheet (Kjartansson 1960, Jones 1969, 1970). The Ok shield volcano is formed of Young Grey Basalts laid down on an ice free land surface and is considered probably to be 'last interglacial' in age by Kjartansson (1960). The fault scarp, which controls the western margin of the sandur, is part of a series of tectonic fractures, with downthrows to the east, which delimit the western margin of the Neovolcanic zone (Bodvarsson 1960).

The northwesterly outlet glaciers of Thorisjökull have been retreating since their maximum historical advance, which either took place in 1740-50, or between 1850-90. Thorarinsson (1943) suggests that most Icelandic glaciers reached their maximum extension in 1750, but that some of the Vatnajökull glaciers reached their maximum in the 1850 advance. However,

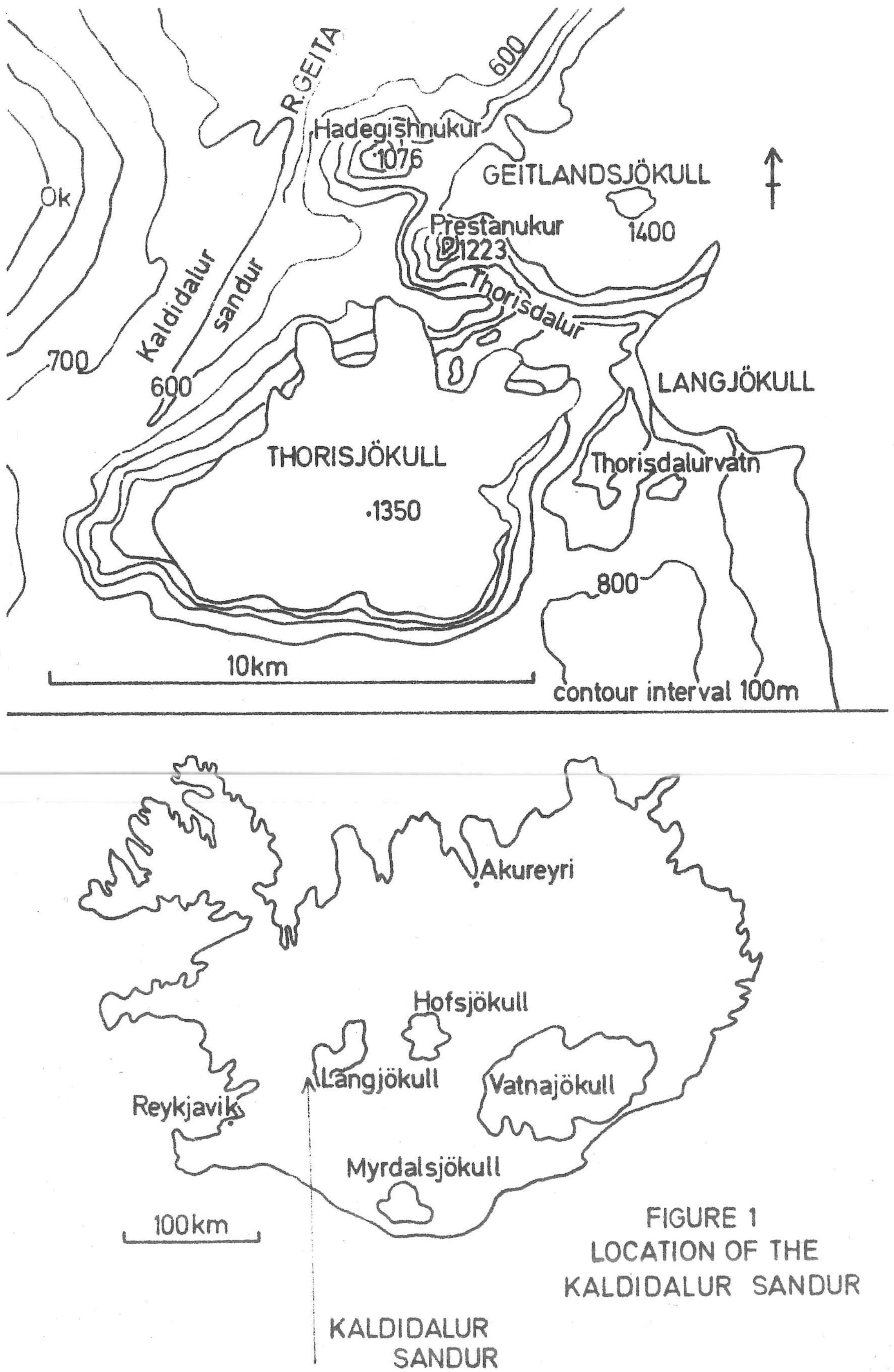


FIGURE 1
LOCATION OF THE
KALDIDALUR SANDUR

in the Thorisjökull region the main western glacier has a much smaller series of moraines marking its maximum advance, whereas the massive, ice-cored moraines are several hundred metres closer to the ice. This can be clearly seen on figure 2. These large moraines probably mark the advance in the second half of the nineteenth century, whereas the smaller moraines indicated the 1750 advance. The most northerly Thorisjökull glacier has no series of smaller moraines outside the large ice-cored moraine which probably indicates the 1890 advance. Since about 1930 there has been a very strong general recession of the Icelandic glaciers and the approximate ice frontal positions for the most northerly Thorisjökull glacier in 1850-90, 1948, 1960 and 1970 are shown in figure 3. Since 1968 the ice has retreated at approximately 25 m/year. The most acceptable explanation for the presence of the large area of ice-cored moraine close to the present day ice front is that the basal ice rising to counteract Prestanukur has brought debris along shear planes into an englacial position. Ablation has concentrated this debris and it eventually appears supraglacially covering a wide expanse of glacier ice indicated on figure 3. The position of the sandur behind the maximum advance moraines is controlled by the topography and is situated between areas of hummocky moraine. The main stream in this sandur system breaks under the southern, ice-cored, outer moraine in an ice cave which is indicated by the displaced position of the stream exit on the aerial photograph.

2. TOPOGRAPHY OF THE SANDUR

Detailed observations were limited to the sandur streams and sediment which emanated from the most northerly Thorisjökull glacier. These streams are the main streams on figure 3, which unite to form the most active present day sandur system. The sandur is characterised by three main topographic subsections:

(a) the section situated between the ice-cored, hummocky moraine and the terminal moraine. In the hummocky moraine area the meltwater streams flow in deep gullies which pass into a sandur area laterally confined by further areas of hummocky moraine.

(b) the section outside the '1890' moraine which forms the main sandur. There are no lateral constraints on the stream system and a wide outwash plain has developed between the 585 m and 625 m contours.

(c) the section near the fault scarp where the sandur streams are limited by the scarp and turn to flow to the north-east through a gorge into the river Geita. In this region the bed material is finer, better sorted and the bedforms differ from the main sandur.

The latter two subsections will be called the proximal and distal sandurs respectively. The longitudinal slope of the sandur from near the fault scarp to the terminal moraine is shown in figure 4 where it can be seen that there is a change in profile about 1.6 km from the moraine. Here there is a discontinuity which joins two straight line segments of the profile. This has also been noted by McDonald and Banerjee (1971) from Peyto sandur in the Rocky Mountains (Alberta) and they suggest that the change marks a downstream shift from a degrading to an aggrading system. The main result of the probable discharge increase, which would be consequent on the rapid ice frontal retreat since the 1930's, would be erosion leading to a decrease in channel slope across the sandur. This hypothesis relies on the fact that there has been no change in the volume or size of sediment supplied to the sandur and suggests that the sandur downstream from the break of slope is an actively aggrading one whereas the surface upstream from the discontinuity is being incised and abandoned. The longitudinal slope on the Kaldidalur sandur decreases from 16.5 m/km near the moraine to 1.1 m/km near the fault scarp. A similar decrease has been noted by Boothroyd (1970) along the 12 km Scott glacier sandur in Alaska, where the slope decreased from a maximum of 15.5 m/km to 2.0 m/km.

In the proximal and distal sandur sections channel cross profiles were measured as illustrated in figure 4. The Bed Relief Index, as calculated by Smith (1970), gives an indication of the amount of relief across a stream cross section at right angles to the main channel trend. The index (B.R.I.) is calculated according to the formula:-

$$B.R.I. = \frac{(T_1 + \ldots T_n) - (t_1 + \ldots t_n) \pm Te_1 \pm Te_2}{L} \times 100$$

where $T_1 + \ldots T_n$ is the sum total elevation of all relative highs between adjacent lows

$t_1 + \ldots t_n$ is the sum total elevation of lows between adjacent highs

L is the traverse length

Te_1, Te_2 are the heights of the extreme ends of the traverse.

FIGURE3 ICE FRONTAL POSITIONS AND GEOMORPHOLOGICAL UNITS NORTH THORISJÖKULL VALLEY

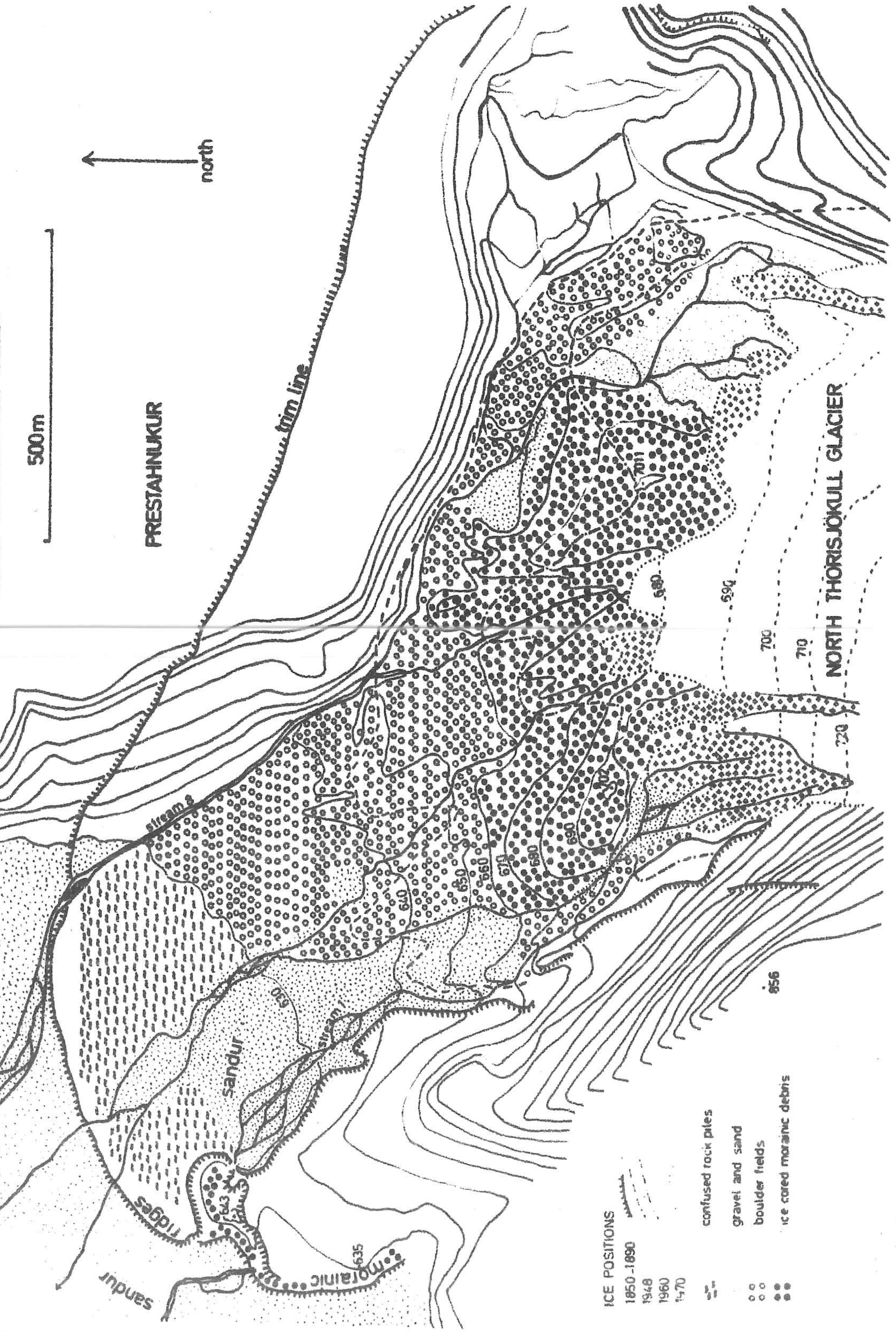


FIGURE 4 SANDUR TOPOGRAPHY: CROSS PROFILES, LONG PROFILE AND CHANGES IN BED RELIEF INDEX

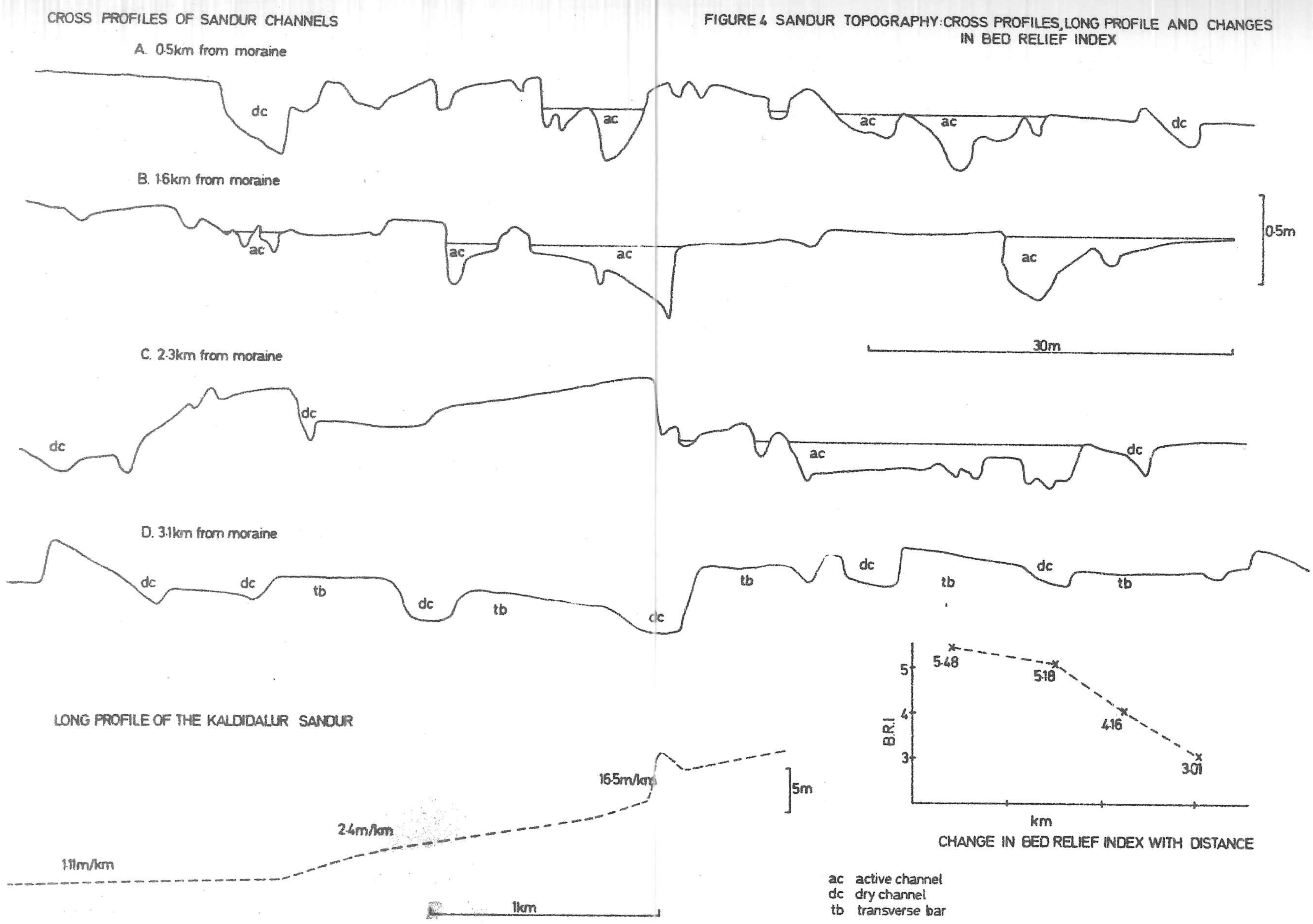


Table 1

Channel index values for fossil and modern sandur environments

Locality	n	mean W/D	σ	range
Kaldidalur				
(a) sandur behind the terminal moraine	30	19.3	7.6	6.9-38.3
(b) proximal sandur	55	25.8	9.7	9.8-92.0
(c) distal sandur	25	25.7	11.5	9.0-49.2
White River, Washington				
(Fahnestock 1963)	112	23.1	9.9	10.0-71.0
Peyto Outwash Plain, Alberta				
(McDonald & Banerjee 1971)	9	13.0	-	8.0-21.0
Donjek River, Yukon				
(Williams & Rust 1969) 3 levels: (i)	43	21.8	11.5	4.7-51.4
(ii)	38	22.8	11.5	6.0-49.0
(iii)	48	40.8	22.8	6.5-129.0
Mousecroft Lane, Shrewsbury				
Pleistocene braided river (Shaw 1969)	21	13.5	6.2	4.2-30.0
Harrington, Cumberland				
(Huddart 1970)	13	13.3	10.1	5.0-38.5

If either extreme end adjoins a low the value is added, if it is a low adjoining a high it is subtracted. A plot of B.R.I. with distance down the sandur shows a decrease which means that the amount of relief across the bed is less in the distal sandur. The same kind of change was found by Smith (1970), although over a far greater distance, from the Platte river in Nebraska. He attributed this decrease to the concurrent increase in the relative proportions of transverse to longitudinal bars. This topic will be returned to in a later section on sandur bedforms.

Channel index (the ratio of top width to mean depth) is a measure of the cross sectional shape of a river channel and was computed for 110 channels in the three subsections. The frequency of the index is shown in figure 5 and the values for both modern and Pleistocene braided rivers are given in table 1. These values suggest that there is a significant difference between the sandur channels from behind the moraine and those in the proximal and distal sections of the main sandur. The reason is probably that whereas there are no lateral constraints to change in stream course on the main sandur, behind the terminal moraine there are constraints caused by areas of hummocky moraine.

3. SANDUR BEDFORMS AND ASSOCIATED SEDIMENTARY ASSOCIATIONS

The sandur consists of two general morphological units:

(a) active and inactive channels and

(b) the bars or interchannel areas.

The typical channel pattern is braided, with anastomosing channels and intervening bars. In poorly sorted, gravel bed streams this braiding is caused by the construction during high discharge periods of low, linear, mid-channel, longitudinal bars (Fahnestock 1963, Krigstrom 1962, Ore 1964, Williams and Rust 1969, Smith 1970). According to Leopold and Wolman (1957) the formation of these longitudinal bars needs a stream which at some point is unable to transport part of its coarsest load. The coarsest load is deposited and additional sediment is trapped enabling the bar to build both vertically and downstream. During the periods of lower discharge these longitudinal bars divide the channel into a number of branches and become dissected as shown by Krigstrom (1962).

Where the sediment is composed mainly of well sorted sand, bars are more typically transverse, with wide, flat surfaced, tabular sand bodies

being defined by sinuous to lobate depositional margins (Ore 1964, Smith 1970, Williams 1971). The terminology of these transverse bars has been discussed by Smith (1971) who suggests a definition which is accepted in this paper. He states that transverse bars are a varied group of tabular, essentially flat topped, periodic or solitary sand bodies which grow by down current additions of sediment to slip faces. This definition includes the linguoid bars of Allen (1968) and Collinson (1970) and the tributary and alternating bars of Brush, Einstein, Simons, Vanoni and Kennedy (1966). When the transverse bars appear above the water level during periods of lower discharge they are eroded by streams flowing over their surface and this dissection results in a braided channel pattern.

On the Kalčidalur sandur both types of braiding occur in a distance of under 4 km: the proximal sandur is dominated by the build up of longitudinal bars, whereas in the distal sandur the braiding process is effected by the dissection of transverse bars. Apart from these large scale bedforms, small scale bedforms are formed chiefly in abandoned channels during periods of waning and low discharge but also on the surface of larger forms and on the flanks of active channels. Trenches were dug to try and elaborate the relationships between the geometry of the surface bedforms and their three-dimensional, internal stratification. Problems encountered in this work were that, especially in the distal sandur, the water table was usually within 30 cm of the surface and that the sand/gravel bank material was liable to rapid collapse.

(a) Distal Sandur

(i) Characteristics of the transverse bars

This section of the sandur is dominated by transverse sand bars between 9.5 cm and 23.0 cm in height and tens of metres in width and length. These bars usually have lobed and sinuous frontal margins (figure 6a & c), although occasionally straight margins are formed, as in figure 6b. The bar surfaces are covered by small scale, parasitic ripple trains, by flat beds in coarse sand and by granule gravel. There is a tendency for a coarsening grain size from the outer margins of the bars upstream as reported by Smith (1971). Internally the transverse bars are formed of tabular, planar sets of large scale, cross stratification which have a concentration of coarser particles at the foreset base. This can be seen in figure 7 where grain size curves 25b and 2.12 and 25b and 2.11 show samples taken from the base and upper part of the foreset.

These foresets dip between 20° and 35° and occasionally have thin (2.5-3.0 cm) topsets composed of coarse sand and granule gravel or up to 2.5 cm of parallel laminated, fine sand or silt. However, it is more usual for the transverse bars to be covered by 3.0-4.5 cm small scale, trough, cross stratification. The large scale, cross stratified sets usually rest on parallel laminated or small scale, cross stratified fine sand or silt but occasionally on horizontally stratified sand with pebble gravel. Only one case was observed where the large scale, cross stratified set overlay an earlier cross stratified set, divided only by 1.5 cm parallel laminated silt which followed the frontal trace of the lower, cross stratified unit. The basal contacts of the large scale, cross stratified sets vary from horizontal to highly irregular, depending upon the original condition of the bed. Grain size distribution curves for examples of transverse bars are illustrated in figure 7 and relationships between sorting and mean grain size are shown in figure 8 for both longitudinal and transverse bars. In general the transverse bars are better sorted, with values between 0.899 and 1.495, indicating moderately sorted to poorly sorted sediments on Folk & Ward's (1957) scale (Appendix A), although if the full range of grain sizes were used for the longitudinal bar analysis this distinction would be more obvious. Most of the samples were positively skewed indicating an excess of fine material. In front of the transverse bar margins there are usually ponded water bodies infilling abandoned channels as in figure 6a & d. These abandoned channels are filled either with parallel laminated fine sand or silt, or small scale ripple trains.

(ii) <u>Origin of the transverse bars</u>

The origin of this type of transverse bar has been discussed by Smith (1969, 1971). At low and intermediate discharges the bars form in a way similar to that described by Jopling (1966) for laboratory deltas. As sand moves along the stream bed it encounters depressions which cause changes in the local hydraulic conditions. The stream's bedload will be deposited if the depression is deep enough to lower the velocity below the value needed for traction transport. If this is the case the sediment is deposited like a delta into the depression, with the coarsest grains avalanching to the base of the foresets. The bar enlarges by lateral and downstream extension of slip faces, which define the bar perimeter. Once a critical depth and velocity are reached again so that traction transport can take place, the bar top becomes the new channel floor and sediment is transported along its surface. This bar surface is covered by small

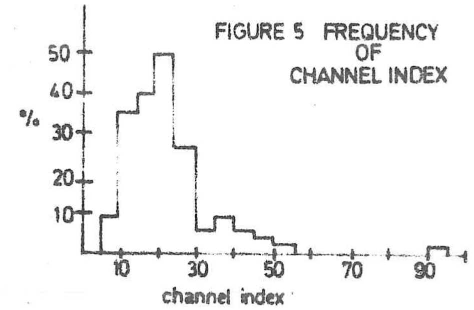


FIGURE 5 FREQUENCY OF CHANNEL INDEX

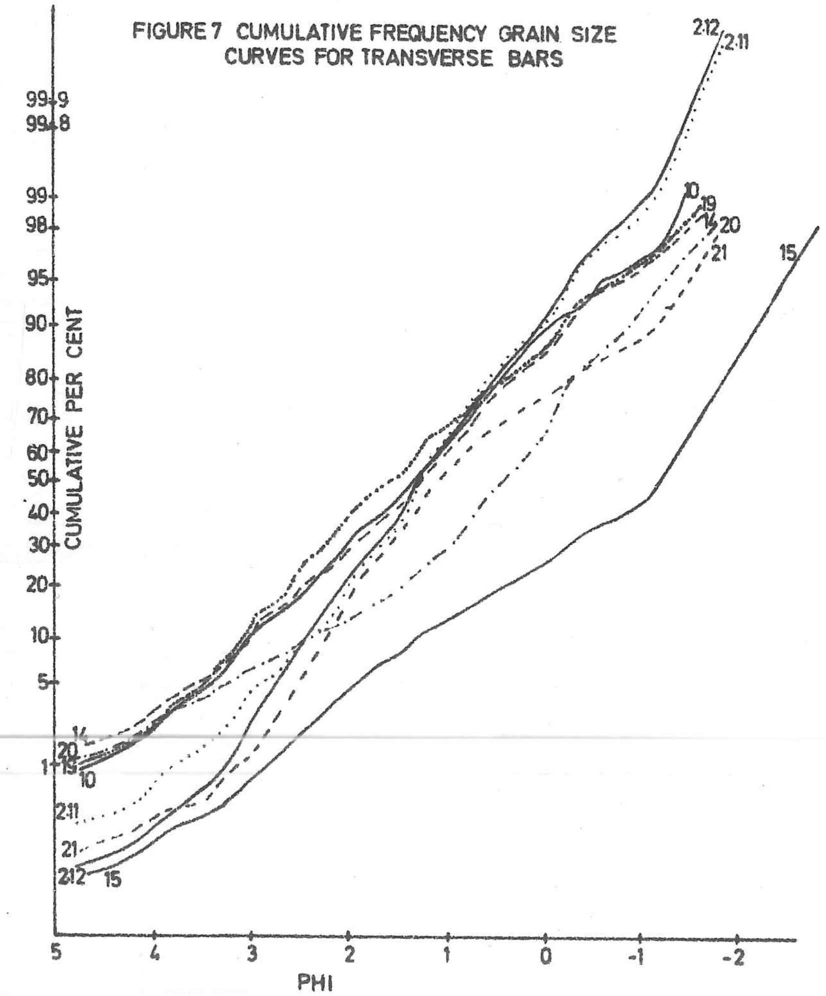


FIGURE 7 CUMULATIVE FREQUENCY GRAIN SIZE CURVES FOR TRANSVERSE BARS

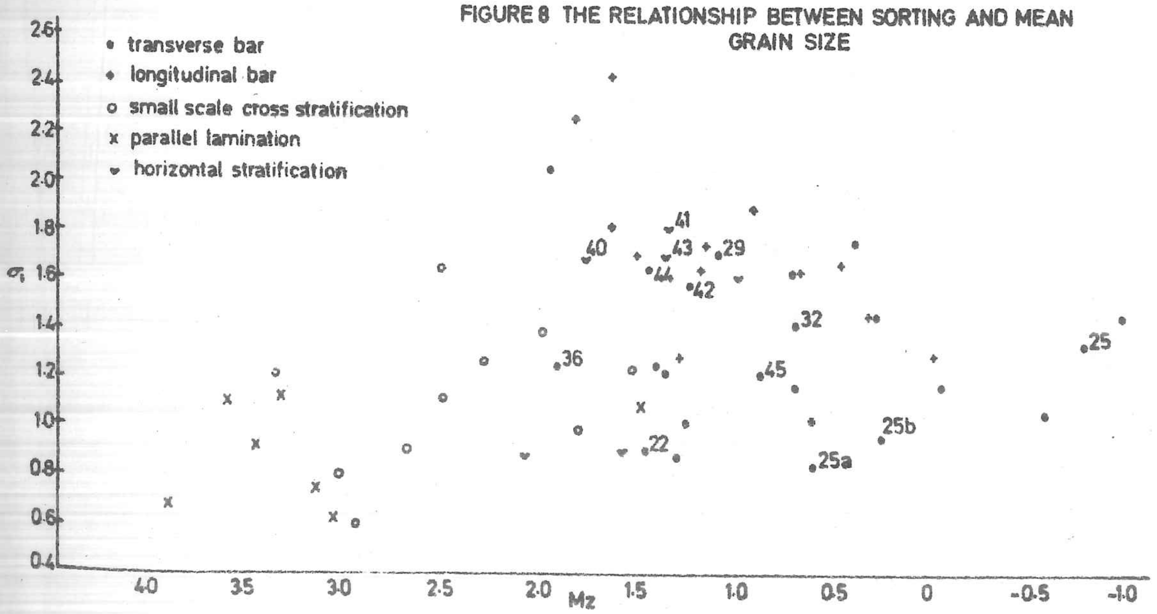


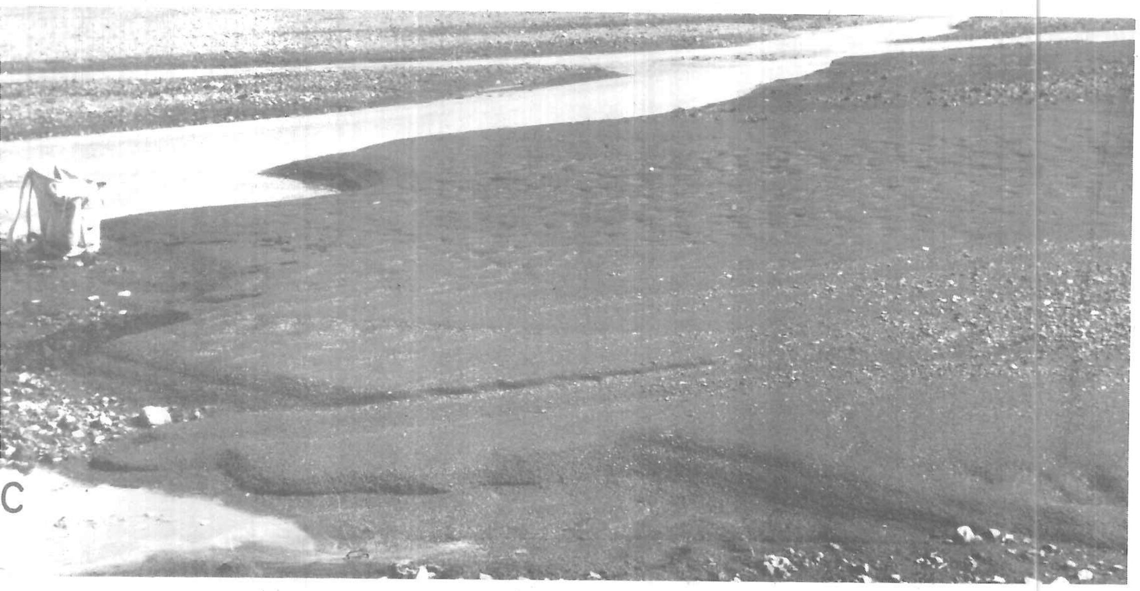
FIGURE 8 THE RELATIONSHIP BETWEEN SORTING AND MEAN GRAIN SIZE

A

with sinuous and lobed frontal margins

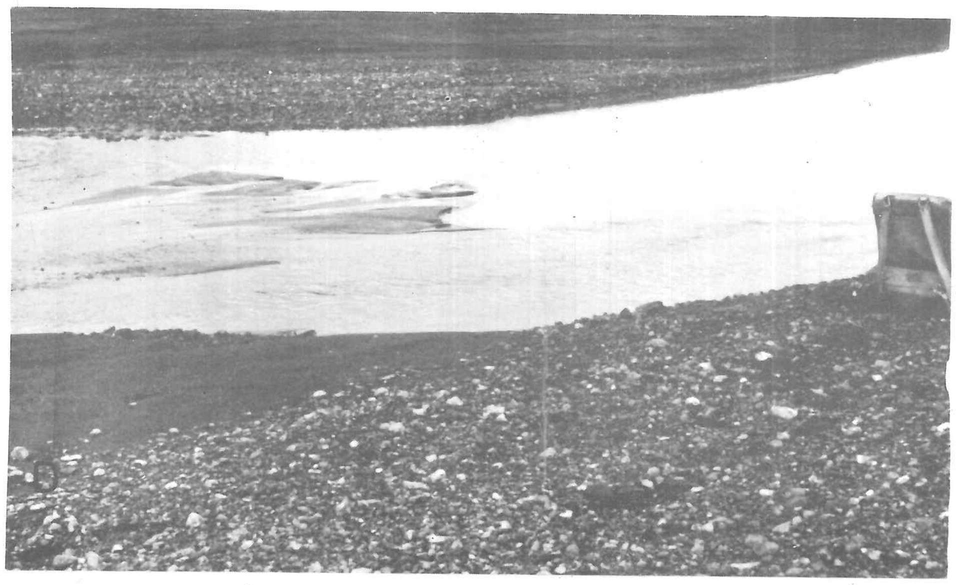
B

with a straight frontal margin



C

building into an abandoned channel



D

FIGURE 6 TRANSVERSE BARS IN THE DISTAL SANDUR scale bedforms which transport sediment to the bar margins. At high stream discharges some bars are thought to form as diffuse dune fields with vaguely defined frontal margins (Culbertson and Scott 1970, Smith 1971). As discharge diminishes the dunes at the downstream margins of the field coalesce and form straight, sinuous or lobate avalanche faces.

When the flow over the sand bar is sufficiently reduced parts of the bar become inactive and the stream flow is confined to one or more small channels which continue to transport sand to the bar margins and form new lobes as the sediment avalanches over the bar margin. This is illustrated in figure 6c and in figure 6d where the bar is being built out as a solitary transverse bar into a lagoon in an abandoned channel. This takes the form of a tributary bar of Brush et al (1966). Part of the bar is above water level and is being eroded, whereas sediment transport is still taking place on both sides of this section. Water depth in the lagoon is about 20 cm whereas the depth over the transverse bar is 2.5-3.0 cm.

(iii) Complex stratigraphy in the distal sandur region

After several cycles of transverse bar development in a river section there is produced a complex of bars and smaller bedforms which overlap, extend and merge from the margins of the original transverse bar. Whereas single transverse bars produce a simple stratigraphy with tabular sets of large scale, cross stratification overlain by thin units of small scale, cross stratification, granule gravel or parallel lamination, the bedform complex described above produces a complicated stratigraphy. An example of the stratigraphy is shown in figure 9 from a region with a surface topography composed of an abandoned, sand filled channel, flanked by higher granule gravel and sand bars. The lowest units observed were parallel laminated sands which represent suspension sedimentation in an abandoned channel or depression. This was followed by the deposition of a thin, pebble gravel unit and two cycles of transverse bars with foresets building out from opposing directions. Between the two large scale, cross stratified sets was a thin ripple unit. The final filling up stage was by small scale, ripple trains. Grain size curves and the associated mean grain size and sorting values for abandoned channel sediments in the distal sandur area are illustrated in figures 10 and 8.

(iv) Bedforms and stratigraphy in the southern sandur region

Near the lakes which have been dammed up by the fault scarp in the southern part of the sandur there are no major active streams at present.

On the aerial photograph of July 1960 (see figure 2) there is a well marked shoreline, whilst on the topographic, 1:100,000 Hlödufell sheet, surveyed in 1938, all three lakes are marked as one. During the summer of 1971 no streams were observed on this part of the sandur except after periods of high rainfall, for example in the period 13-15th July when 480 cc fell and a thin trickle of water, about 2 cm deep, extended from the stream source in the few major channels. Most of the southern distal sandur area is a flat plain with little topography and the major active process seems to be erosion by deflation. This is illustrated in figure 11 where two dunes are being rapidly eroded in figure 11a and in figure 11b a pebble gravel lag is the remanée deposit from deflation. The stratigraphy 25 m from the present lake shore showed alternations of rippled sands and silts and horizontally stratified, medium and coarse sands. Small, dry channels up to 2 m wide show small scale ripples and dunes, as in figure 11a where the dunes are 6 and 8 cm high, with foreset dips between 24 and 26°. In another part of this channel the stratigraphy was from the top down:

0.5 cm parallel laminated silt
12.0 cm large scale, cross stratification
0.5 cm parallel laminated silt
13.0 cm horizontally stratified medium sand

Grain size curves and parameters for these sediments in the southern distal sandur are illustrated in figure 10. At least in the recent past this part of the sandur seems to have been dominated by occasional heavy rainstorms which produced sheet floods. These deposited the horizontally stratified sands and large scale, cross stratification. During the decay of these sheet floods rippled and parallel laminated sand units were deposited.

(b) Proximal Sandur and the Sandur Behind the Moraine

These two sandur areas are characterised by the development of longitudinal gravel bars and several genetic types of small scale sand bar. The latter are of little importance in the total sandur landscape and are ephemeral bedforms but they can be preserved in the sedimentary record. Detailed observations suggest that several processes operate to form these sand bars and the resulting stratigraphy developed can be complex.

(i) Characteristics of the longitudinal bars

The initial form of the longitudinal bar seems to be a vaguely defined triangular to delta-shaped gravel bedform which has poorly defined margins,

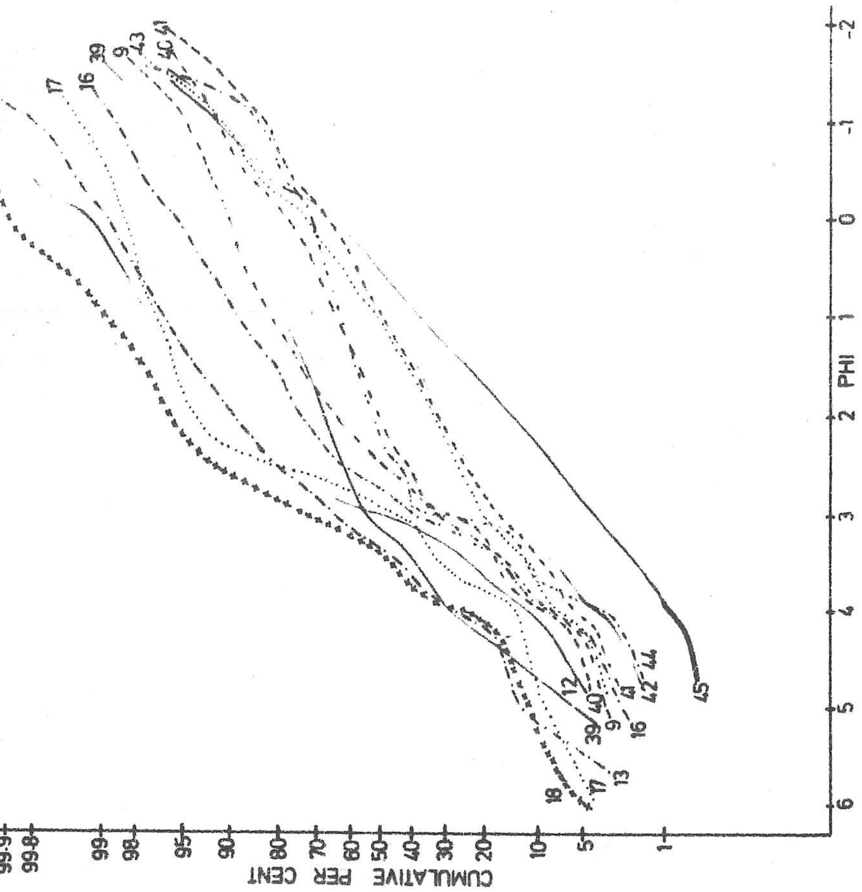


FIGURE 10 CUMULATIVE FREQUENCY GRAIN SIZE CURVES FOR SEDIMENTS IN ABANDONED CHANNELS AND NEAR THE DISTAL SANDUR LAKES

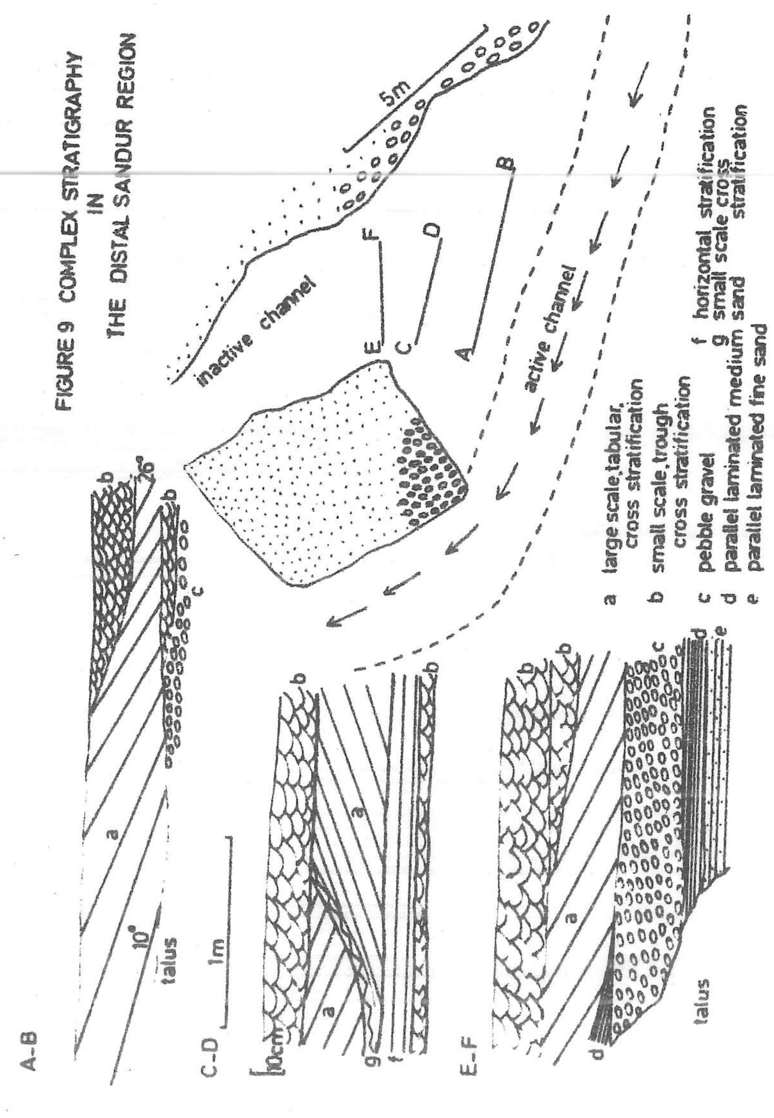


FIGURE 9 COMPLEX STRATIGRAPHY IN THE DISTAL SANDUR REGION

On the aerial photograph of July 1960 (see figure 2) there is a well marked shoreline, whilst on the topographic, 1:100,000 Hlödufell sheet, surveyed in 1938, all three lakes are marked as one. During the summer of 1971 no streams were observed on this part of the sandur except after periods of high rainfall, for example in the period 13-15th July when 480 cc fell and a thin trickle of water, about 2 cm deep, extended from the stream source in the few major channels. Most of the southern distal sandur area is a flat plain with little topography and the major active process seems to be erosion by deflation. This is illustrated in figure 11 where two dunes are being rapidly eroded in figure 11a and in figure 11b a pebble gravel lag is the remanée deposit from deflation. The stratigraphy 25 m from the present lake shore showed alternations of rippled sands and silts and horizontally stratified, medium and coarse sands. Small, dry channels up to 2 m wide show small scale ripples and dunes, as in figure 11a where the dunes are 6 and 8 cm high, with foreset dips between 24 and 26°. In another part of this channel the stratigraphy was from the top down:

0.5 cm parallel laminated silt
12.0 cm large scale, cross stratification
0.5 cm parallel laminated silt
13.0 cm horizontally stratified medium sand

Grain size curves and parameters for these sediments in the southern distal sandur are illustrated in figure 10. At least in the recent past this part of the sandur seems to have been dominated by occasional heavy rainstorms which produced sheet floods. These deposited the horizontally stratified sands and large scale, cross stratification. During the decay of these sheet floods rippled and parallel laminated sand units were deposited.

(b) Proximal Sandur and the Sandur Behind the Moraine

These two sandur areas are characterised by the development of longitudinal gravel bars and several genetic types of small scale sand bar. The latter are of little importance in the total sandur landscape and are ephemeral bedforms but they can be preserved in the sedimentary record. Detailed observations suggest that several processes operate to form these sand bars and the resulting stratigraphy developed can be complex.

(i) Characteristics of the longitudinal bars

The initial form of the longitudinal bar seems to be a vaguely defined triangular to delta-shaped gravel bedform which has poorly defined margins,

FIGURE 10 CUMULATIVE FREQUENCY GRAIN SIZE CURVES FOR SEDIMENTS IN ABANDONED CHANNELS AND NEAR THE DISTAL SANDUR LAKES

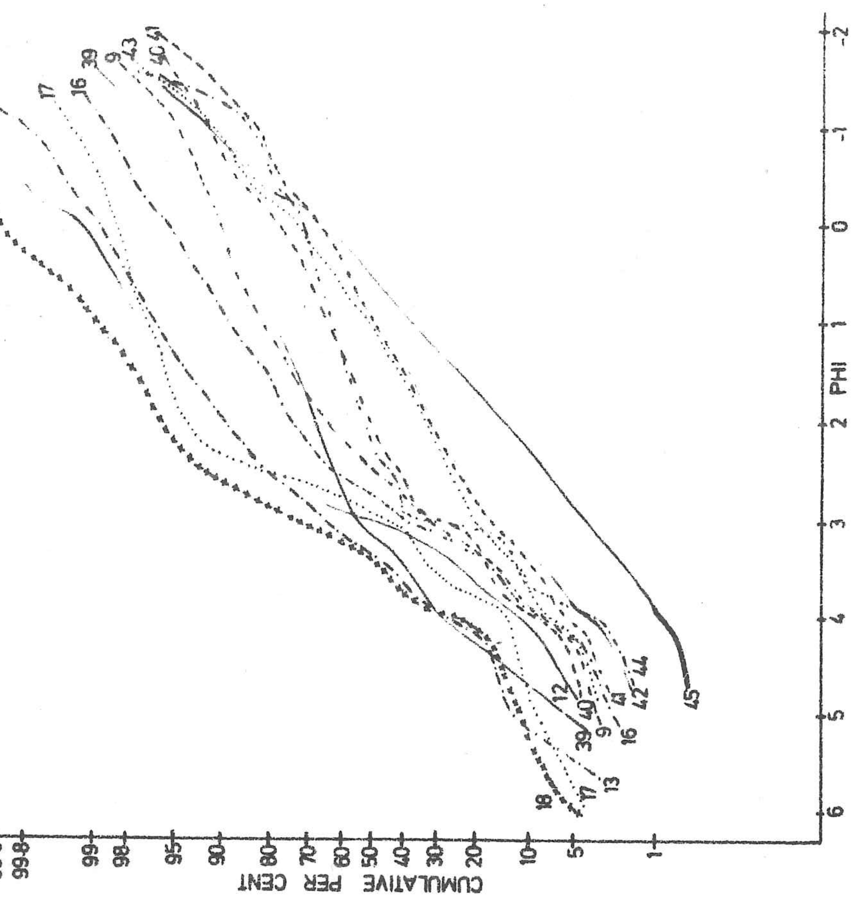
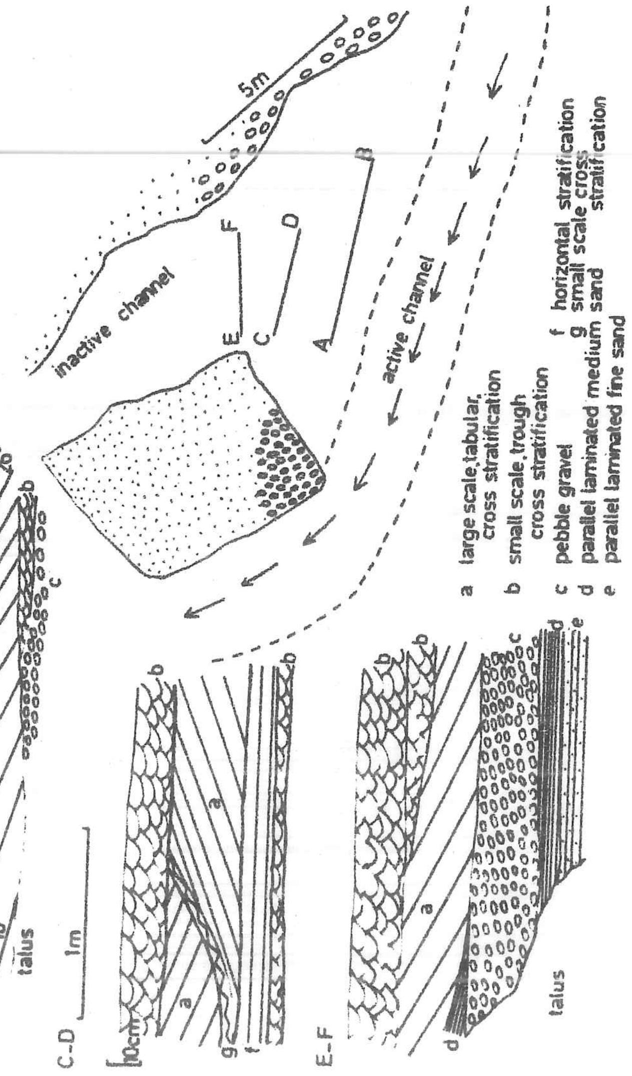
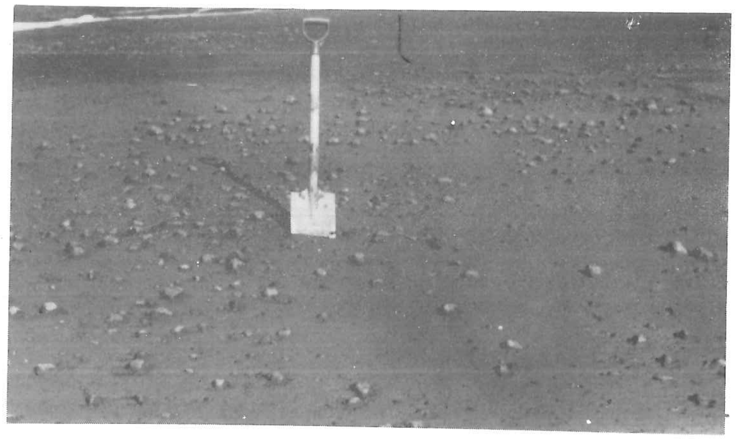


FIGURE 9 COMPLEX STRATIGRAPHY IN THE DISTAL SANDUR REGION

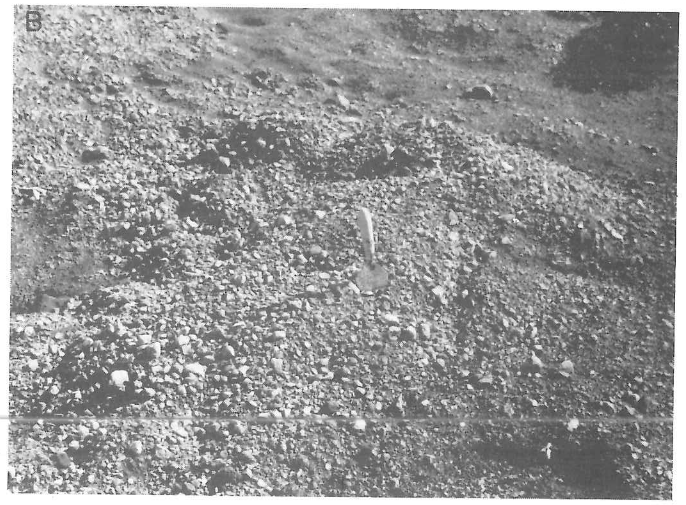


on of dune bedforms



pebble gravel lag deposit after deflation

11 EFFECTS OF DEFLATION IN THE SANDUR SECTION NEAR THE LAKES



2 LONGITUDINAL GRAVEL BARS AND THEIR MODIFICATION DUE TO THE FORMATION OF GROUND ICE DOMES

as illustrated in figure 12c. This initial form is built up both in a vertical and a downstream direction until the typical, elongate, longitudinal bar is produced, as in figure 12d. These bars are formed mainly during high discharge whilst during waning and low discharge periods erosion modifies the original depositional form. This topic has been dealt with by Krigstrom (1962). The longitudinal bars are poorly to very poorly sorted and are composed of mainly pebble and cobble gravel by weight but the range of grain size can be up to ten ø (over 1000 mm). The longitudinal bars fine downstream as is shown in figure 12, where 12d is a coarse, proximal bar, whilst 12e is a more distal bar, approximately 2 km downstream from the former. The bars are horizontally stratified parallel to the bar surface, or massive with no obvious stratification. Both these structures are probably indicative of a plane bed during deposition and no examples of the migratory bar avalanche face on the bar downstream margins were noted (cf. Williams and Rust 1969).

There was no pronounced downstream fining on individual bars and no small scale, parasitic bedforms as reported by Williams and Rust (1969). During waning discharge the upstream and downstream ends of the bar are sharpened by the marginal streams and the bar developed resembles the spool-like or rhomboidal shaped islands of Krigstrom (1962). During low flow rills continue to modify the bar, as shown in figure 12e and a braided channel pattern develops as the original bar is dissected into smaller forms.

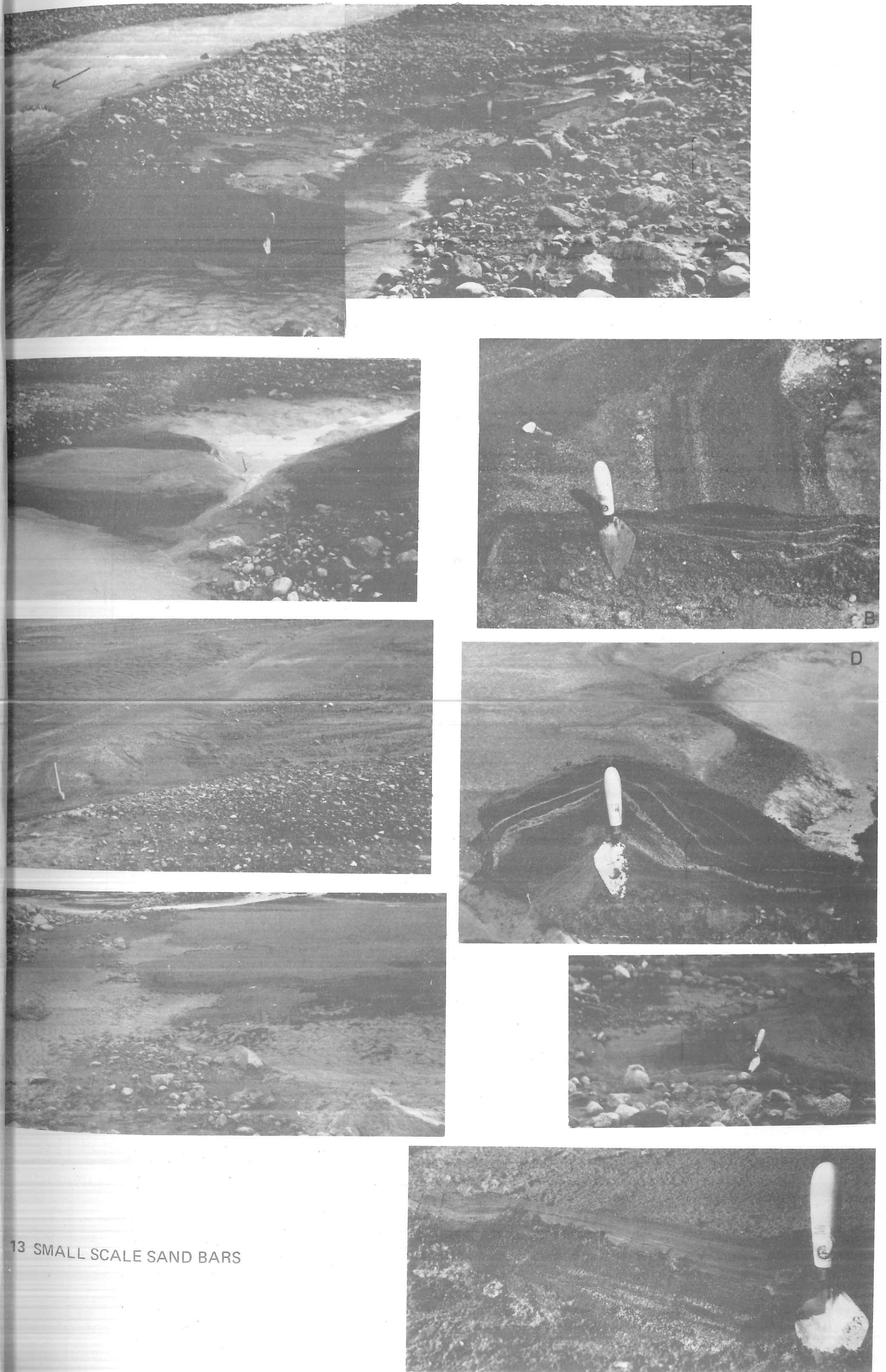
Further modification of the original depositional forms may take place by the development of ground ice domes, illustrated in figure 12a. In this example an ice lens, 2 m wide and 40 cm thick, has domed the bar surface to produce a 20° dip away from the centre of the dome in coarse sand and pebble gravel. When this ice melts, hummocky, disorganised gravel areas are formed as in figure 12b.

(ii) <u>Characteristics of the small scale sand bars</u>

The scale of these sand bars seldom reaches over 5 sq.m except in cases where part of the sandur is protected to a certain extent from erosion. This happens in the sandur region behind the moraine where sand bar/lagoonal complexes of over 20 sq.m develop because they are protected by areas of hummocky, boulder moraine. These hummocky areas inhibit the lateral extension of the braided stream system and parts of the braided river complex are relatively fixed over long time periods, especially towards the margins of the sandur. Most of the sand bars are built out from the main channel into an abandoned channel and no examples were noted of the reverse situation where bars were built into subsidiary channels as described by Krigstrom (1962).

The bars observed seem to be of two main types relating to different stages of discharge. At high stage sand bars are formed in abandoned channels or lagoons by streams overtopping the main channel. In this type of bar cross stratified sands are formed which have many of the characteristics of transverse bars in the distal sandur. The second main type of sand bar is that developed during waning stage where parallel laminated sands are deposited in abandoned channels away from the turbulent flow in the channel centre by shallow water flows, usually at right angles to the main flow. The sequences developed in this type of bar normally fine upwards in grain size.

Figure 13a,b,e and f illustrates the second type of bar which is developed during waning discharge and the typical stratigraphy developed. In figure 13e the sand barrier is 85 cm wide, 1.56 m long, 17.5 cm thick and rests on pebble gravel. The stratigraphy is composed of a lower unit of 11.5 cm parallel laminated medium sand and a 6 cm thick upper unit of parallel laminated fine sand and silt. The lower unit's basal contact is uneven and there is a definite fining upwards in grain size. This type of bar is also forming in figure 13a where at the downstream end of a longitudinal, gravel bar a sand barrier complex is being deposited into an abandoned channel. The bar has gradually extended across the mouth of the old channel as a sand barrier which has been built up by waves moving at right angles to the main turbulent flow in the shallower, marginal water. Small shoreline ridges can be seen in figure 13a & b where from the highest part of the complex there is a series of lower shorelines indicating a progressive emergence. The stratigraphy reveals horizontally stratified, medium and coarse sand, with occasional thin, silt laminae. Oscillation ripples were noted moving parallel with the flow direction across the barrier in a water depth of 5-7 cm. At an earlier stage to the development of the main section of the sand barrier small scale (up to 5 cm thick) deltas were deposited in the abandoned channel. This brings us to the first type of sand bar which is developed at high water stage. This type of small scale sand bar is the most common form although there are examples of complex bars which develop initially during high water stage and were added to during the waning stage. Three examples



13 SMALL SCALE SAND BARS

of this type of sand bar will be given to illustrate the morphology and stratigraphic sequences developed.

In figure 14a is illustrated a lagoonal/sand bar complex common in the sandur section behind the moraine. Four stages of development at successively lower levels can be recognised from the surface bedforms, which are composed of four sand bars, in varying stages of dissection and one in process of formation. Each bar has formed during a high water period when the flow overtopped the main channel and deposited the sand bars as typical transverse bars in a lagoon. The stratigraphy in this bar/lagoonal complex revealed a series of large scale, cross stratified sets, between 8 and 16 cm thick, which thin laterally into parallel laminated, fine sand and silt, or horizontally stratified, medium or coarse sand. Between the sets of cross strata are small scale rippled and parallel laminated sequences. The bars have crenelate frontal avalanche faces, a concentration of coarser particles at the foreset base and their surfaces show no parasitic, ripple trains but do show plane sand beds. The lagoonal stratigraphy shows 30 cm of parallel laminated silt and fine sand, with occasional thin (up to 1.5 cm thick), rippled fine sand units. The whole complex rests on pebble and cobble gravel. Thus, the stratigraphy reveals that this lagoonal/bar complex has remained a permanent landform assemblage for a relatively long time period and has probably developed in a topographic low protected from incorporation into the sandur system by the hummocky boulder moraine on either side. Similar morphological bedforms are illustrated in figure 13e, g and h where transverse bars have been deposited in abandoned channels.

The stratigraphy and morphology of a bar/lagoonal complex developed in a proximal sandur abandoned channel is shown in figure 14b and figure 13c and d. This bar developed in three stages. During (A) a high stage flow overtopped the main channel and cross stratified sets were deposited as deltas into a lagoon, with the contemporaneous deposition of rippled and parallel laminated units in the lagoon. This transportation of sand across the bar was interspersed by periods of purely suspension sedimentation as can be seen from the silt laminae in figure 13d. During (B) a waning discharge resulted in the deposition of parallel laminated and rippled silts on the cross stratification as in a type 2 sand bar. In stage (C) water level fell below the bar level and water from the lagoon broke through the bar into the main channel.

In figure 14c an example of large scale, cross stratification exposed in an abandoned channel sequence probably formed as a type 1 sand bar. The channel stratigraphic sequence showed alternations of horizontally stratified, medium and coarse sands, parallel laminated, fine sands and small scale, cross stratification. In the upper part of the sequence a period of scouring, followed by suspension sedimentation, preceded the deposition of a large scale, cross stratified unit at right angles to the main flow in the channel. The unit exhibits similar characteristics to the bar in the last paragraph. Channel filling was completed by suspension sedimentation and small scale, ripple trains.

(iii) Stratigraphic sequence developed between the ice-cored moraine and Prestanukur.

This sedimentary sequence, illustrated in figure 15, is developed in a flat terrace unit between the high area of ice-cored moraine and Prestanukur. The succession was thought by Eden (1971) to have developed in a proglacial lake dammed up between the ice front and Prestanukur. The lake was considered to have lasted for at least 150 years as that number of 'varves' was counted. However, the sequence shows a typical fluvial succession, with large and small scale, cross stratification, horizontally stratified medium and coarse sand and granule gravel and thin parallel laminated, silt units. There is a definite coarsening upwards succession which is typical of proximal, deltaic, lacustrine sequences but the angle of dip of the beds is not steep enough for this grade of material. The angle should be around 18-30°, whereas it is around 4-5°, with a steepest dip of 10°. Moreover, the ice front position in 1948 was in approximately this area and so the sequence probably represents an outwash stage from the early 1950's.

4. CHANGES IN CLAST GRAIN SIZE AND SHAPE ALONG THE KALDIDALUR SANDUR

It was thought that changes in clast grain size and shape along a modern sandur would provide data which would be of use in interpreting palaeo-braided river sediments. Clast size, roundness, and sphericity measurements were made every 100 m along stream 8 (figure 2) on the sandur from the terminal moraine to the gorge.

(a) Clast Size

The method used to observe changes in clast size along the sandur was that of Wolman (1954). In this method the determination of grain size is based on an analysis of the relative area covered by given sizes

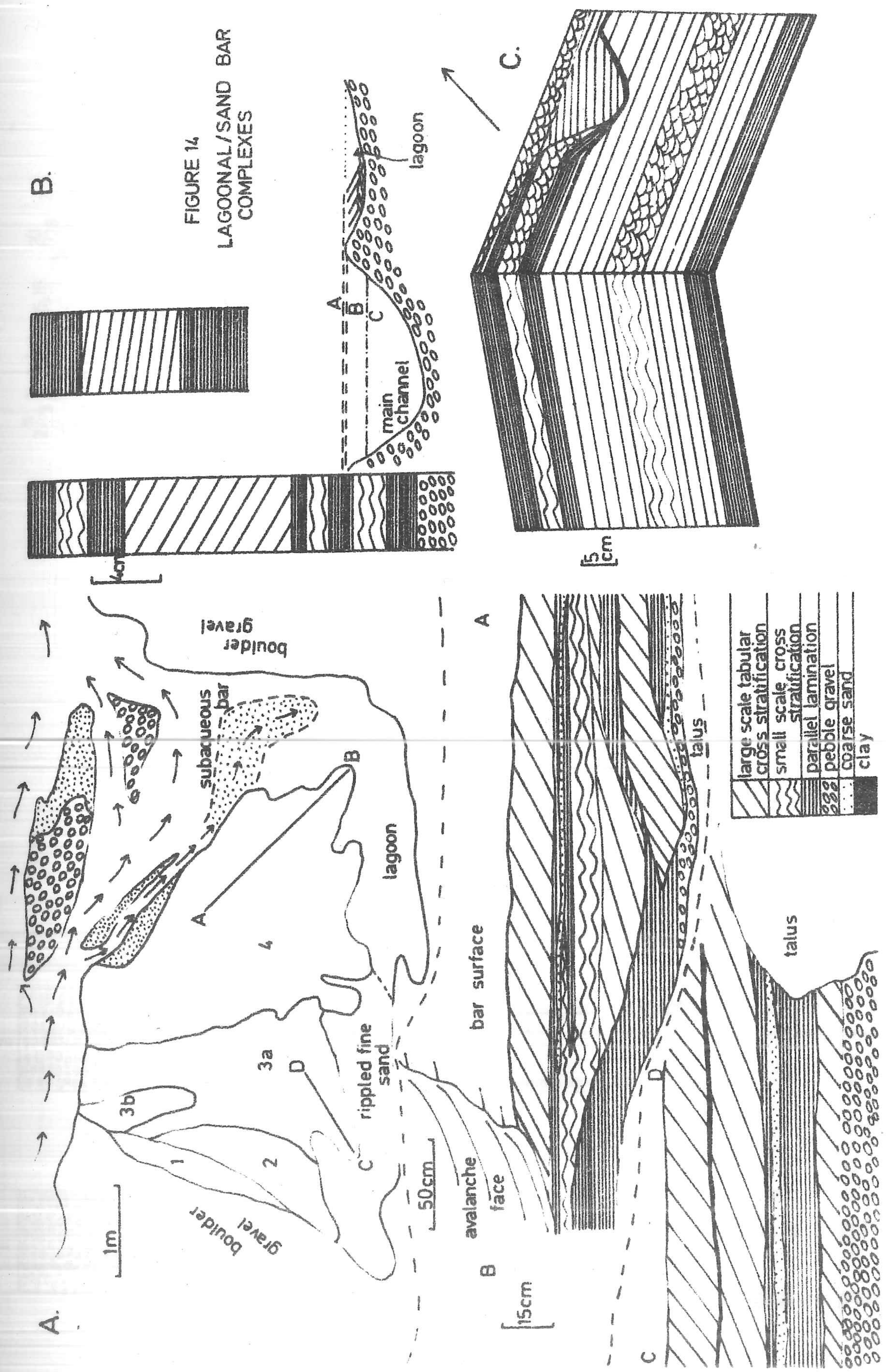


FIGURE 14
LAGOONAL/SAND BAR COMPLEXES

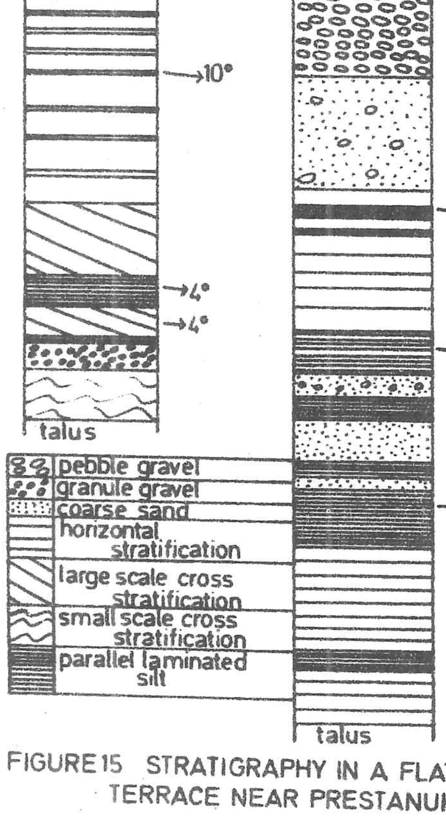


FIGURE 15 STRATIGRAPHY IN A FLAT TERRACE NEAR PRESTANUKUR

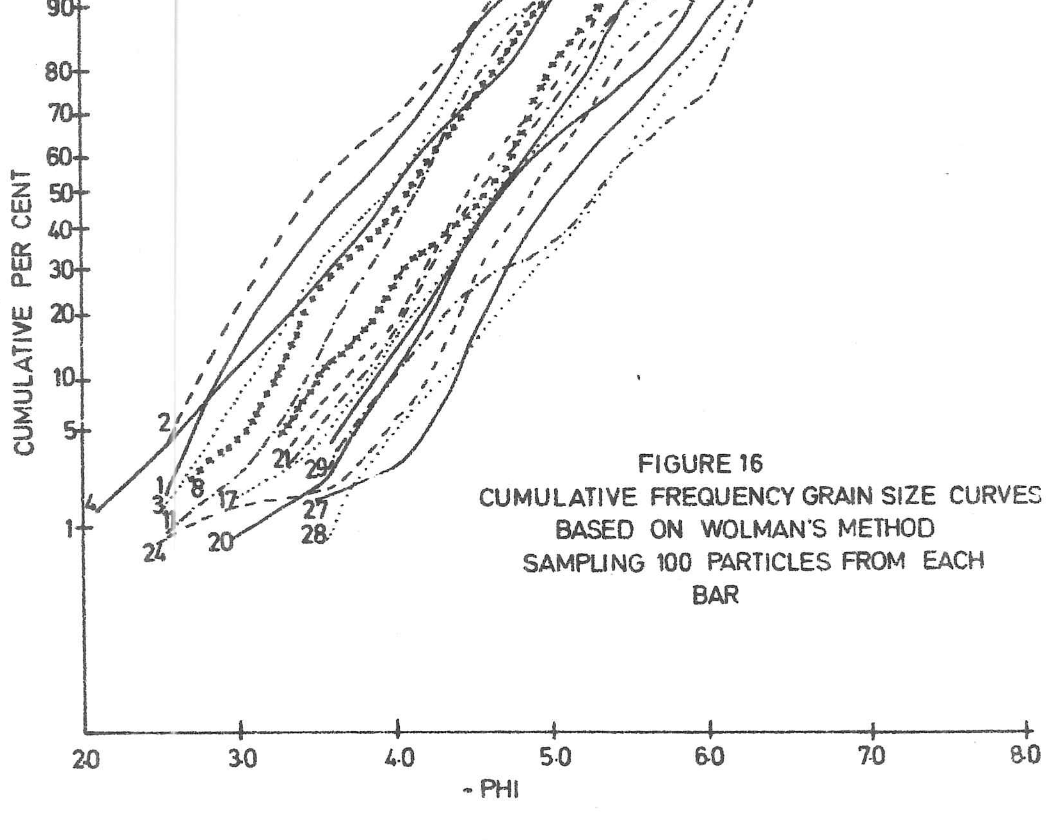


FIGURE 16
CUMULATIVE FREQUENCY GRAIN SIZE CURVES BASED ON WOLMAN'S METHOD SAMPLING 100 PARTICLES FROM EACH BAR

rather than on their relative weights. At every sampling point the nearest longitudinal bar was divided into three sections (upstream, midstream and downstream) and 100 individual clasts sampled from the bar surface at random without looking at the surface. The intermediate axis was measured (defined as the longest dimension at right angles to the maximum projection plane) and cumulative frequency curves drawn which are illustrated in figure 16. The main limitation to the method is that clasts under 4 mm could not be measured. The results in figure 17a indicate that the mean 'b' axis decreases with distance of transport (r = 0.879) from -5.2 phi (18.281 mm) around 0.7 km from the moraine to -3.5 phi (11.31 mm) near the gorge. There is a distinct possibility that in the first 0.5 km from the moraine a different population is being sampled which is related to older outwash associated with the terminal moraine ice front position. This is because the clasts in this area are much finer (see figure 16) whereas because of the proximal position they should be coarser than the rest of the sandur.

Sorting (Inclusive Graphic Standard Deviation of Folk & Ward 1957) improves with distance down sandur from over 4 around 0.5 km from the moraine to 2.914 at 3.4 km from the moraine. Figure 18 illustrates the fact that in general the greater the mean diameter the poorer the sorting.

The mean 'b' axis measurements were divided into three lithological groups which also showed the same change down sandur (figure 17a). The maximum 'b' axis value for each clast sample position was plotted on figure 17b and this illustrates the same down sandur change (r = 0.898). These changes in clast size with distance down sandur reflect clast abrasion due to the decreasing power of the fluvial system from the proximal to the distal part of the sandur. Similar observations have been made by Fahnestock (1963), Boothroyd (1970) and Miall (1970) who found that there was a systematic decrease in median diameter with distance from the source.

Miall (1970) also suggested that clast lithology counts would show little variation on a given fan surface if all the clasts had a similar density and resistance to erosion and tended to produce similar shapes when fractured. Transport would not then be selective and abrasion would reduce all clasts to sand size at a similar rate. However, the bedrock in Kaldidalur varies from the volcanic ash and basaltic clasts of the Moberg Formation to the intrusive, acidic obsidian, perlite and rhyolite.

It was felt that these different lithologies would produce changes in clast populations along the sandur. This was proved by lithology counts down sandur which are illustrated in figure 17 where it is shown that the vesicular basalt from the Moberg Formation is relatively non-resistant to fluvial erosion and decreases from over 50% of the population near to the moraine to 10% near the gorge. Obsidian on the other hand is more resistant and whereas it only forms 5% of the population near the moraine it increases to 20% 0.3 km from the gorge.

The grain sizes of the longitudinal bars were also sampled by bulk methods which deal with a different population because of the gravel paving effects evident on exposed bar surfaces. The results of grain size analyses in figure 19 indicate that there is no systematic decrease in grain size down sandur.

(b) Clast Shape

The morphology of any given clast depends on several factors including its shape when eroded from the bedrock, internal characteristics of that bedrock, clast size, effectiveness and distance of transport and the type of transporting medium. In this study the lithologies observed were vesicular basalt, rhyolite and obsidian and the changes in roundness, sphericity and form which took place down sandur from the moraine were noted.

(i) Roundness and flatness ratio

Roundness values of 100 clasts at 100 m intervals along the sandur were obtained by a visual comparison of the silhouette of the maximum projection face with the set of clast images developed by Krumbein (1941b). Blissenbach (1954) had found an approximately linear downstream decrease in roundness with distance along alluvial fans and Sneed and Folk (1958) suggested that in the fluvial environment roundness decreases rapidly at first and then slows down to approach some asymptotic limit. In the present case, illustrated in figure 20a, there is a marked decrease in mean roundness with distance and also similar changes in the three different lithologies.

The flatness ratio ($\frac{a+b+c}{3}$) developed by Wentworth (1919) shows a systematic decrease, illustrated in all three lithologies in figure 20b.

(ii) Sphericity

The sphericity of 100 clasts was sampled down sandur every 100 m. The three axes of each clast were measured with vernier calipers and the

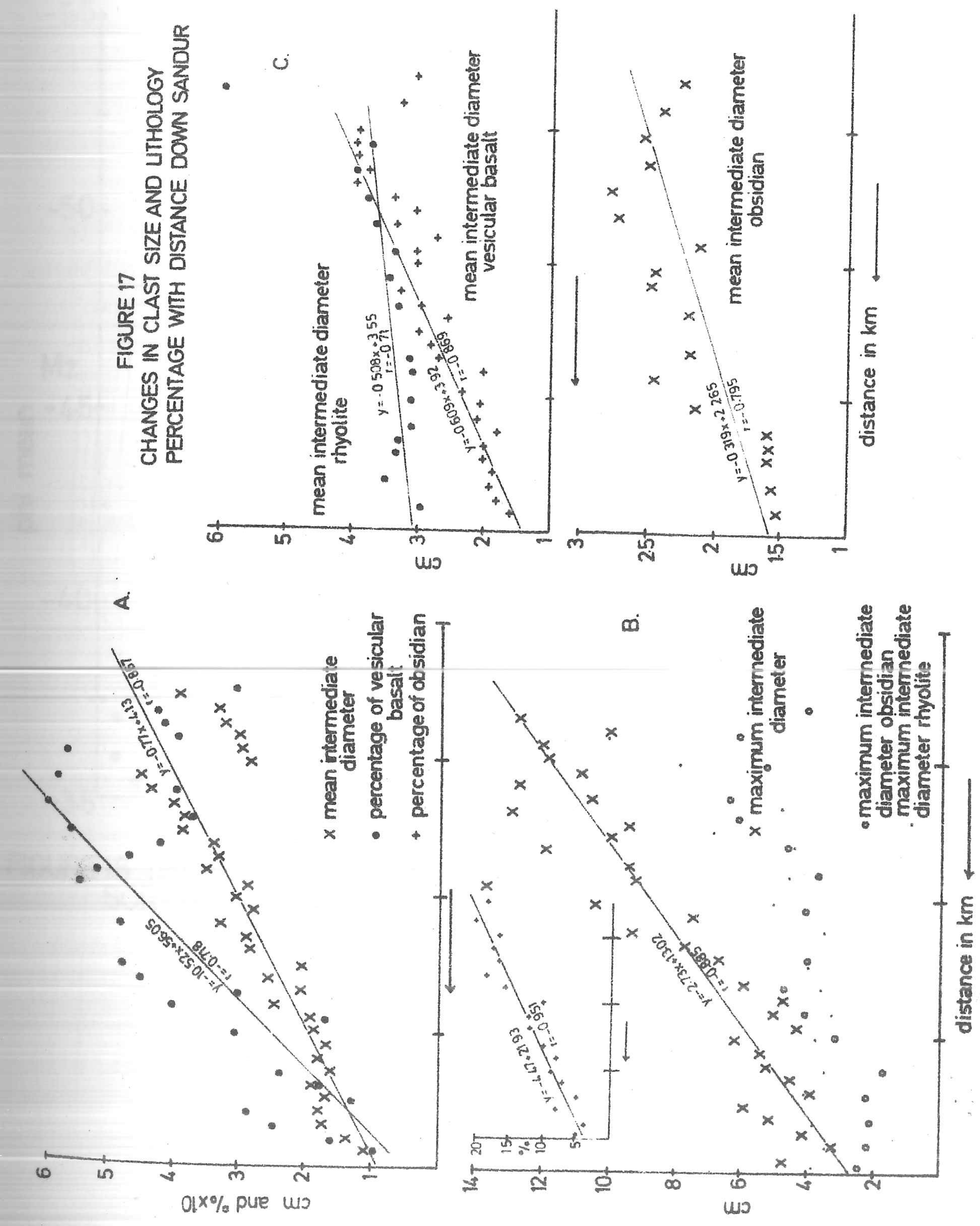


FIGURE 17
CHANGES IN CLAST SIZE AND LITHOLOGY PERCENTAGE WITH DISTANCE DOWN SANDUR

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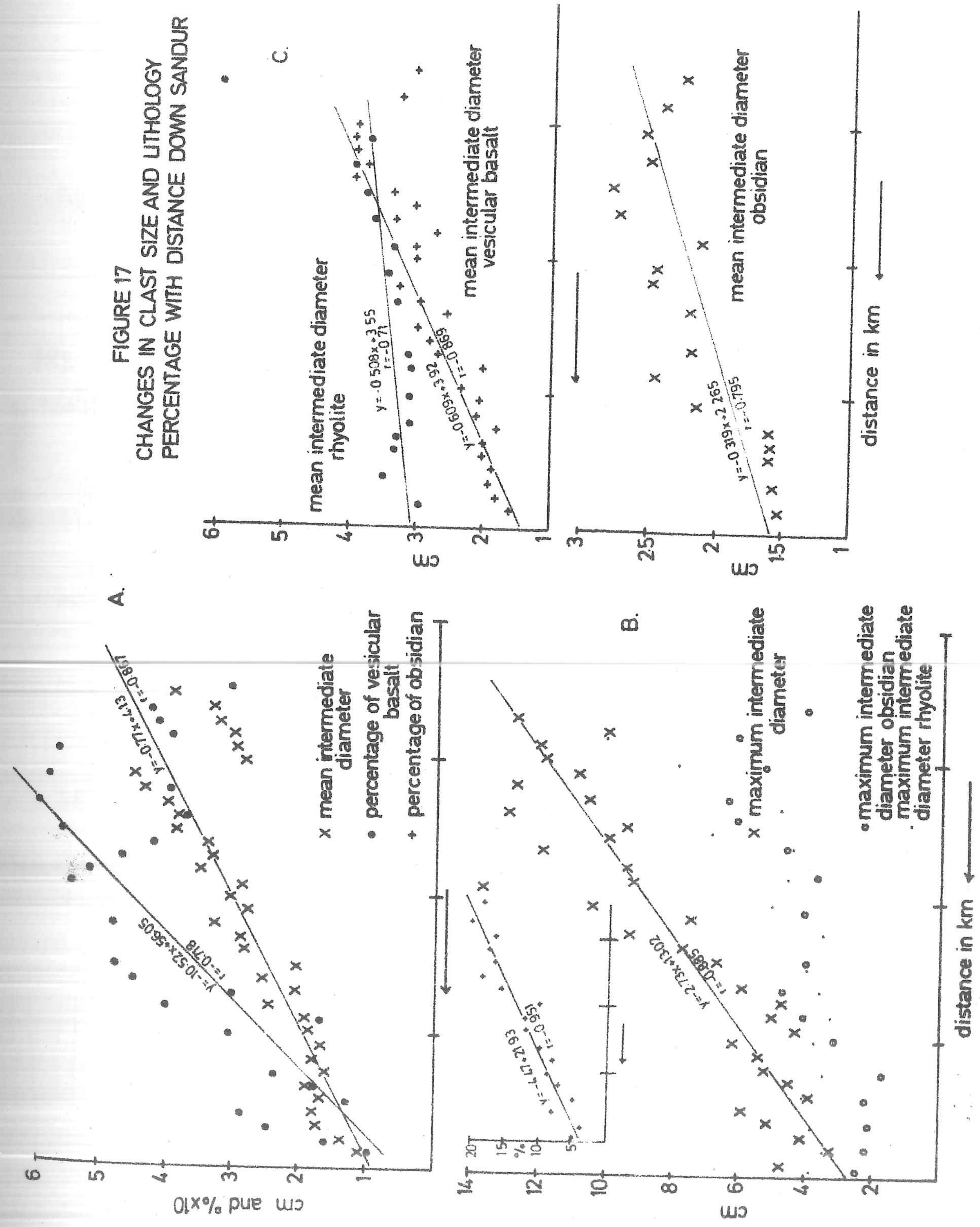


FIGURE 17
CHANGES IN CLAST SIZE AND LITHOLOGY PERCENTAGE WITH DISTANCE DOWN SANDUR

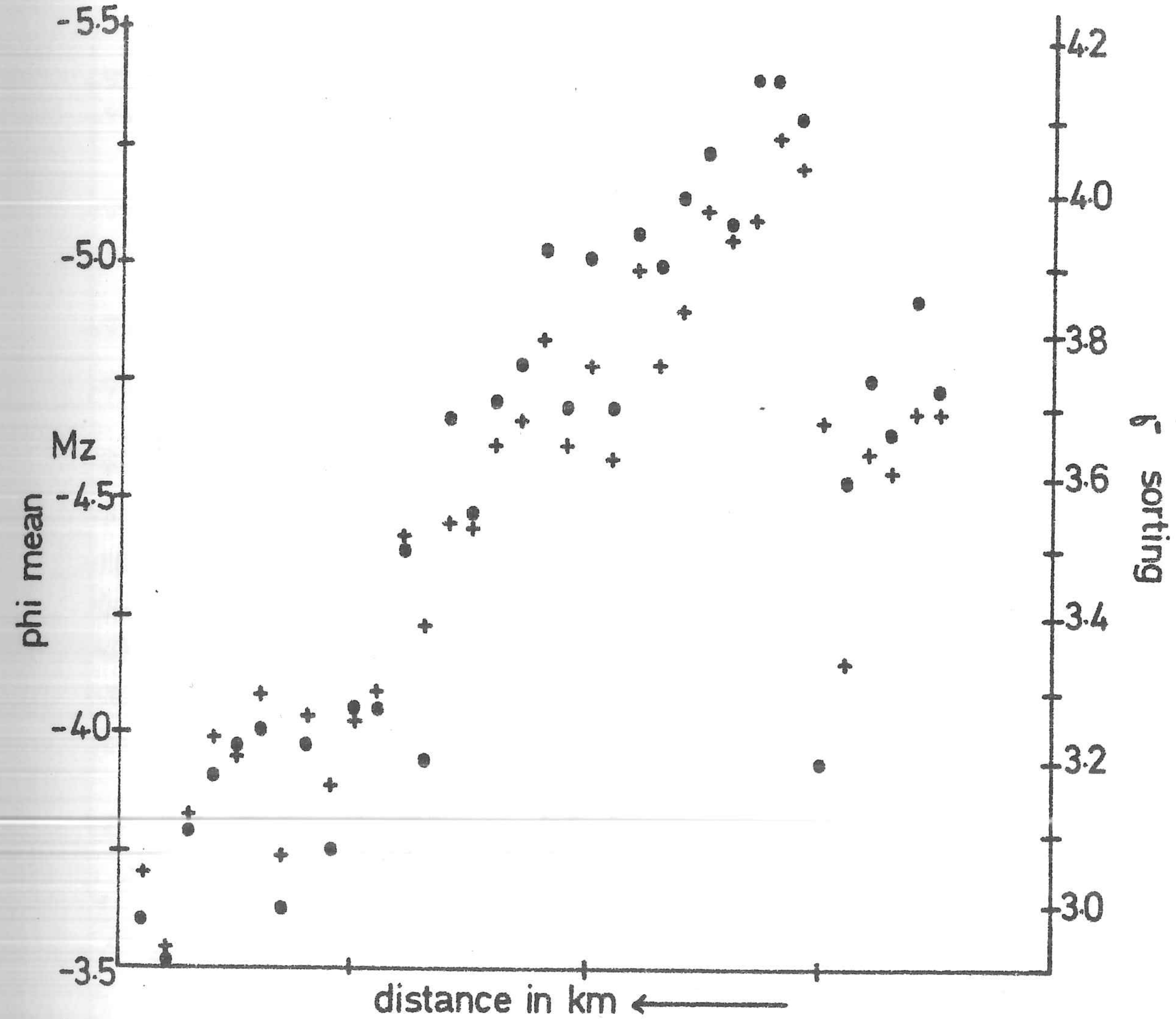


FIGURE 18 THE RELATIONSHIP BETWEEN MEAN GRAIN SIZE, SORTING AND DISTANCE ALONG THE KALDIDALUR SANDUR

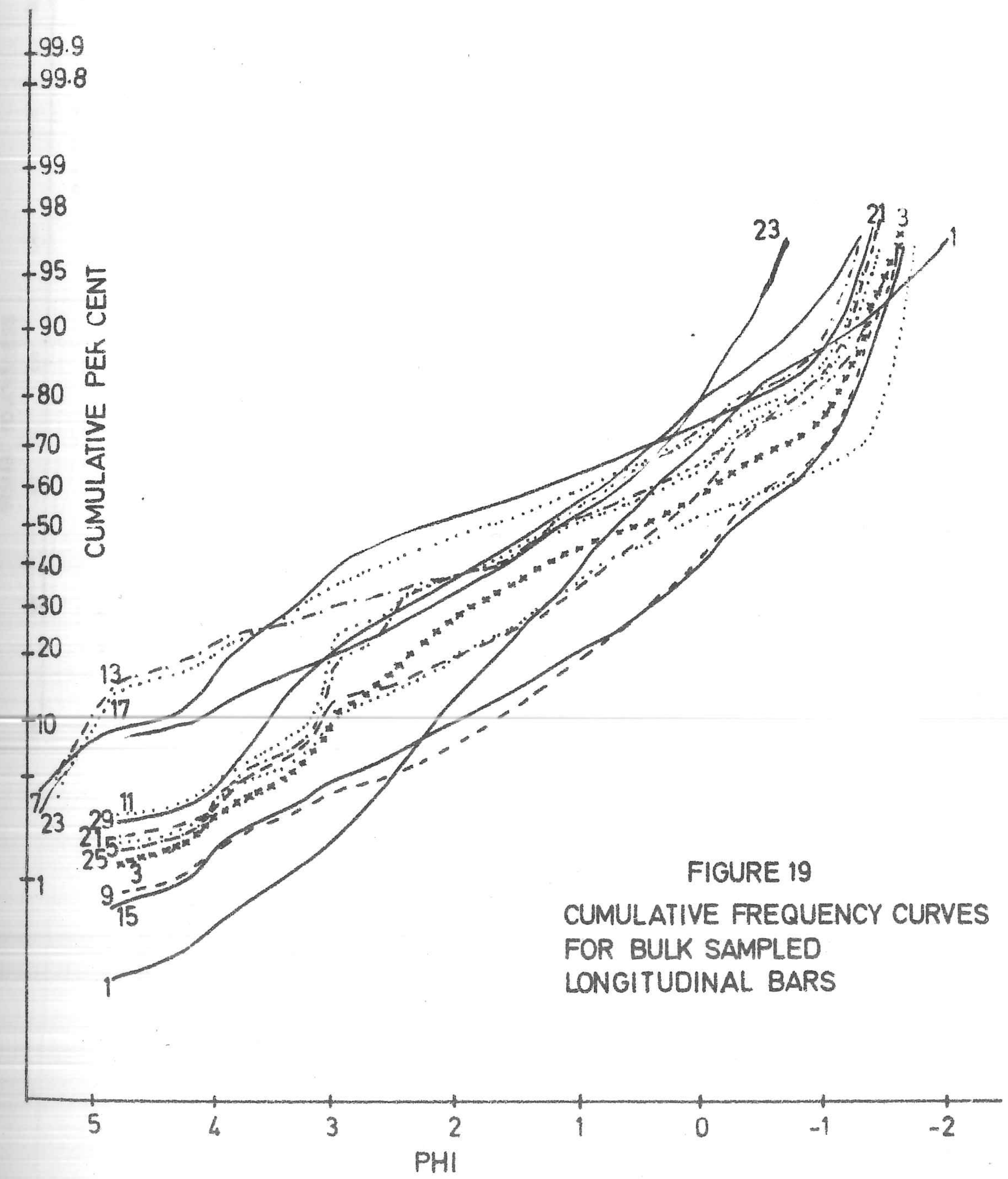
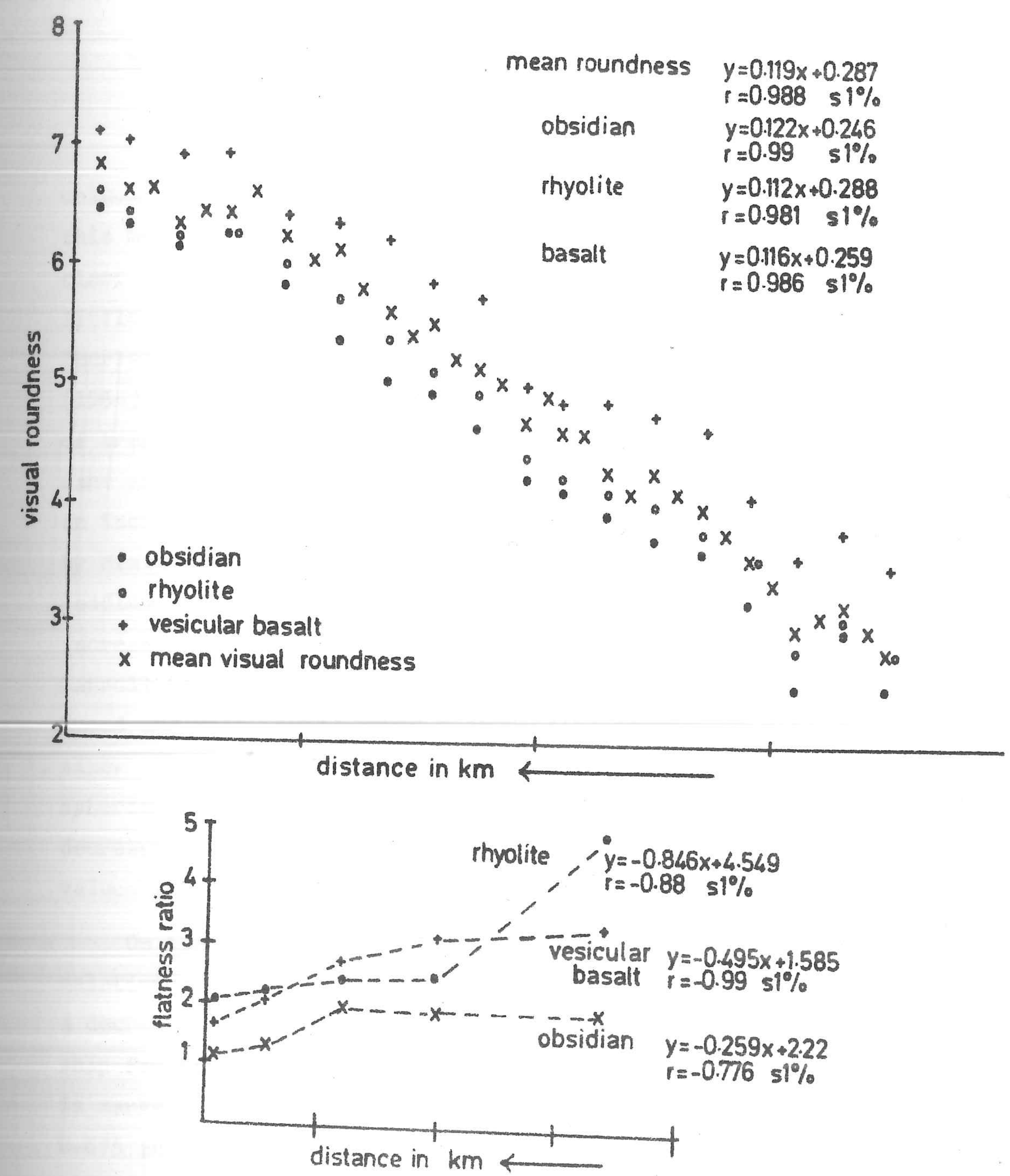


FIGURE 19

CUMULATIVE FREQUENCY CURVES FOR BULK SAMPLED LONGITUDINAL BARS

FIGURE 20 CHANGES IN ROUNDNESS AND FLATNESS RATIO WITH DISTANCE ALONG THE SANDUR



maximum projection sphericity,

$$\sqrt[3]{\frac{s^2}{l.i}}$$

where s - short axis

l - longest axis

i - intermediate axis

calculated (Sneed and Folk 1958). There are many factors which affect this measure of clast morphology, such as jointing controlling the initial clast shape, lithology and clast grain size. In the literature there is little agreement as to the changes to be expected in sphericity with increasing transport. Krumbein (1941a), Blissenbach (1954) and Bluck (1964) found no significant relationship between sphericity and distance of transport. However, Bluck (1965) on a Triassic fanglomerate and the same author (1967) on a Devonian fanglomerate claimed that there was an increase in sphericity with distance. This relationship was doubted by Miall (1970) who suggested that Bluck's graphs were based on too few readings. Bluck (1965) also reported an increase in sphericity with increasing size and Allen (1948) found the same relationship. However, Carroll (1951) found no correlation between size and sphericity and Sneed and Folk (1958) found a decreasing sphericity with increasing size. Particles of their larger size groups, 65-125 mm, increased in sphericity downstream but smaller sizes showed a marked downstream decrease. Nearer the source grain size had less influence on sphericity values than downstream.

On the Kaldidalur sandur the sphericity versus transport distance relationships which are illustrated on figure 21a suggest that there is a decrease in sphericity downstream for rhyolite and an inverse relationship for obsidian. The importance of lithology in controlling sphericity is marked with mean values for each site between 0.725 and 0.8 for basalt, 0.675 and 0.75 for obsidian and 0.53 and 0.7 for rhyolite. All three curves show a marked decrease in sphericity between 1.0 and 1.5 km from the gorge. The cause of this change is not understood but it correlates with the change from the longitudinal to transverse bar section of the sandur and the region where there is a mixing of source areas. In this region the distal sandur receives material from western as well as northern Thorisjökull.

Table 2 shows the importance of clast size in affecting the sphericity. As a generalisation there is a decreasing sphericity with increasing clast size. In figure 21b there is a definite decrease in rhyolite sphericity with distance downstream (r = 0.996 and 0.929). In the case of basalt the relationship is weaker and for obsidian there is no relationship.

Table 2

Sphericity and Size

		0.8-1.6cm -3 to -4 phi	1.6-3.2cm -4 to -5 phi	3.2-6.4cm -5 to -6 phi	6.4-12.8cm -6 to -7 phi
Obsidian	n	93	233	107	9
	sphericity	0.691	0.707	0.724	0.657
Rhyolite	n	5	135	248	33
	sphericity	0.684	0.669	0.612	0.642
Vesicular basalt	n	52	364	545	151
	sphericity	0.775	0.767	0.776	0.764

These sphericity results indicate that selective sorting by shape is unimportant and clasts of a given shape are not carried further than clasts of another shape. If selective sorting was important then one would expect all lithologies to have a similar sphericity pattern with fluvial transport. This is not the case. Rhyolite decreases, obsidian increases and there is not much change in the sphericity of basalt with transport distance. It seems that sphericity patterns are almost entirely the result of the different physical properties of the parent rock.

(c) Clast Form

Clast form can be represented on a form triangular diagram as in figure 22 or the percentages of clasts in each of the ten form classes can be tabulated. However, it is difficult to make quantitative comparisons this way. The form ratio (Sneed and Folk 1958) is a numerical measure of platiness or elongateness and is a quantitative expression of the tendency of clasts to fall more to the left or right hand side of the triang-

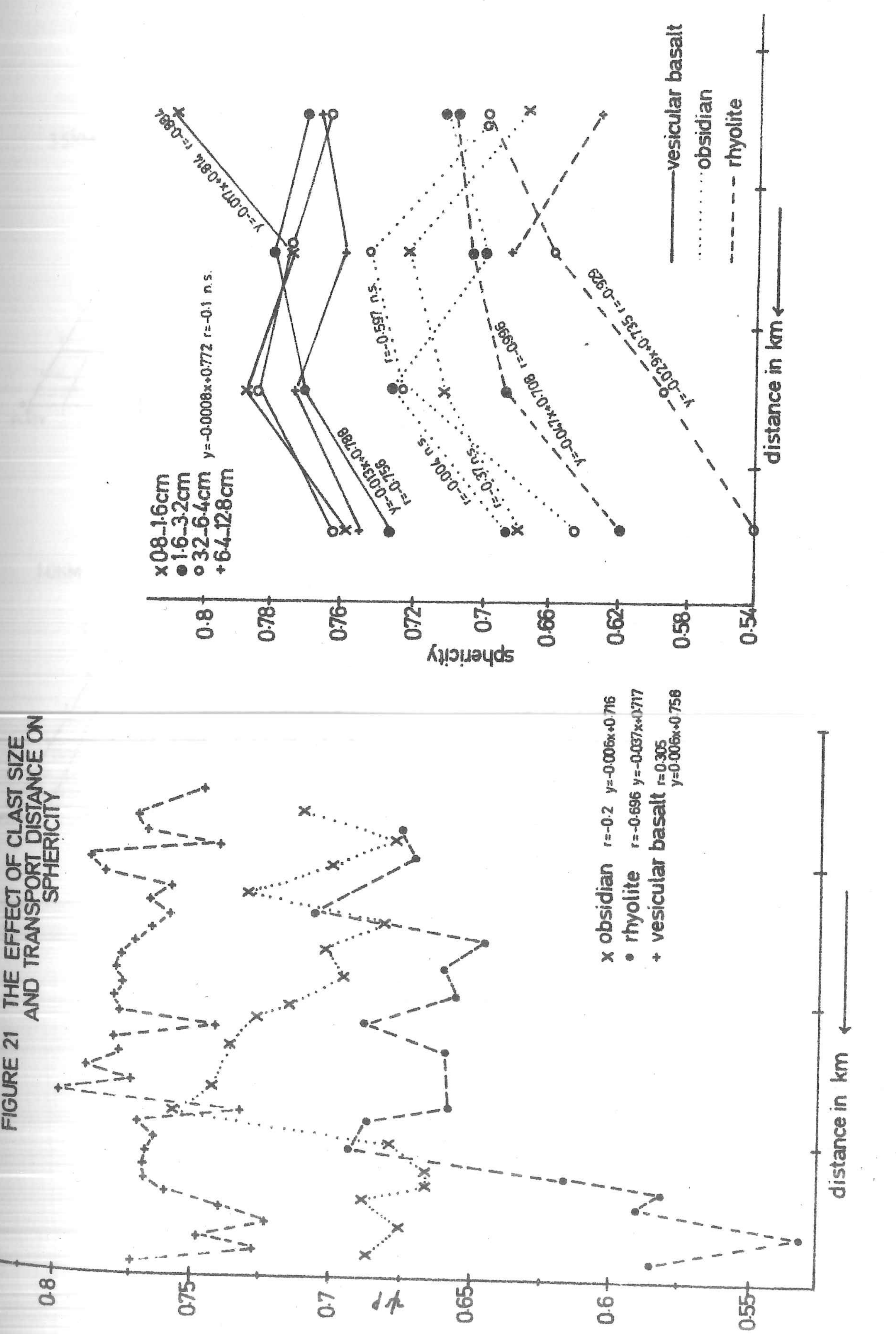


FIGURE 21 THE EFFECT OF CLAST SIZE AND TRANSPORT DISTANCE ON SPHERICITY

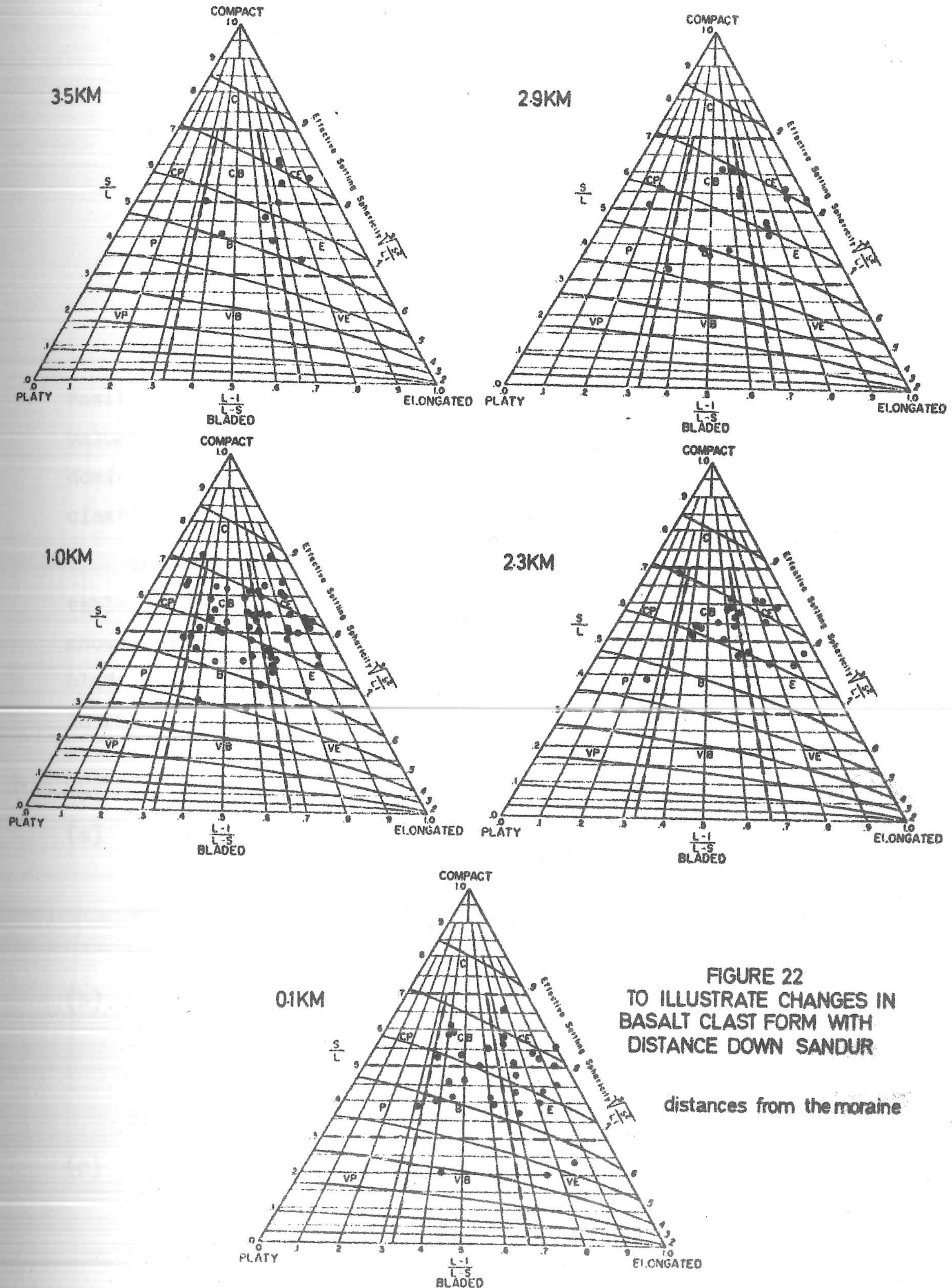


FIGURE 22
TO ILLUSTRATE CHANGES IN BASALT CLAST FORM WITH DISTANCE DOWN SANDUR

distances from the moraine

ular diagram or whether there is an equal scatter throughout. This ratio is found by:

$$\frac{(CP - CE + 2(PE) + 4(VP - VE)}{2N}$$

where N - sample number
CP - compact platy
CE - compact elongate
P - platy
E - elongate
VP - very platy
VE - very elongate

Positive values indicate a prevalence of disc/platy clasts; negative values indicate rod or elongate clasts and values near 0 indicate a dominance of bladed clasts or subequal quantities of platy and elongate clasts.

The form ratio values for the Kaldidalur sediments are given in table 3 and the changes in clast form with distance down sandur are shown. These indicate that there is a dominance of rod/elongate and blade shaped clasts and that there is no overall trend for an increase in rods downstream as was found by Bluck (1965).

5. CHARACTERISTICS USEFUL IN THE INTERPRETATION OF FOSSIL SANDUR SEDIMENTS

(a) calculations of bed relief index could indicate proximal or distal sandur environments and in a stratigraphic sequence would be of use in deciding whether an associated ice front was advancing or retreating.

(b) there are probably characteristic values of channel index and its standard deviation for sandur streams which would be of use in interpreting fossil sandur deposits. However, more data are needed for braided and non-braided streams.

(c) the change in bedform down sandur from longitudinal to transverse bars should be a diagnostic feature. The sedimentary characteristics of these bedforms and their resultant stratification types, together with the change in sedimentary facies should be recognisable in fossil sediments.

Table 3

To show the changes in clast form and form ratio with distance down sandur from the terminal moraine
(3 km from the Gcita gorge)

Sampling position	n	elongate n	elongate %	bladed n	bladed %	platy n	platy %	compact n	compact %	CE	E	VE	CB	B	VB	CP	P	VP	C
Rhyolite 3.45 km	25	7	28	16	64	2	8	-	-	1	5	1	-	2	14	-	-	2	-
2.95	25	4	16	15	60	6	24	-	-	1	1	2	1	7	7	-	1	5	-
2.25	25	9	36	13	52	3	12	-	-	2	4	3	1	6	6	-	1	-	-
1.45	25	8	32	16	64	1	4	-	-	1	5	2	2	7	7	-	1	-	-
0.25	24	3	12	17	68	3	12	1	4	-	2	1	1	12	4	2	1	-	1
Basalt 3.4 km	10	6	60.0	4	40.0	-	-	-	-	5	1	-	1	3	-	—	-	-	-
2.9	18	7	38.9	9	50.0	2	11.1	-	-	4	3	-	4	4	1	2	-	-	-
2.2	22	9	40.9	11	50.0	2	9.1	-	-	5	4	-	10	1	-	1	1	-	-
1.5	55	25	45.5	24	43.6	4	7.3	2	3.6	16	9	-	16	7	1	2	2	-	2
0.1	31	16	51.6	14	45.2	1	3.2	-	-	8	6	2	7	6	1	-	1	-	-
Obsidian 3.4 km	25	14	56.0	11	44.0	-	-	-	-	2	6	6	3	8	-	-	-	-	-
2.95	25	14	56.0	9	36.0	2	8.0	-	11	1	8	5	3	5	1	-	2	-	-
2.15	25	9	36.0	13	52.0	2	8.0	1	4.0	-	9	-	5	8	-	-	2	-	1
1.4	25	10	40.0	11	44.0	4	16.0	-	-	3	7	-	5	5	1	-	1	3	0
0.15	25	13	52.0	10	40.0	1	4.0	1	4.0	3	8	2	1	6	3	1	-	-	1

cont'd/

Table 3
cont'd

Form Ratio

	Sampling Position	Form Ratio
Obsidian	3.45 km	-0.72
	2.9	-0.66
	2.15	-0.28
	1.4	-0.06
	0.15	-0.52
Rhyolite	3.45	-0.14
	2.95	+0.22
	2.25	-0.24
	1.45	-0.26
	0.25	-0.083
Vesicular basalt	3.4	-0.419
	2.9	-0.255
	2.2	-0.227
	1.5	-0.222
	0.1	-0.35

(d) clast mean and maximum 'b' axes should decrease in the direction of sedimentary transport in any one sedimentary unit and roundness values should follow suit. Sorting values should improve with transport distance in any one unit. Thus, changes in gravel unit thickness, clast size, sorting and roundness values should be of use in interpreting the condition of the associated ice mass. Changes of sphericity and form are more difficult to interpret as these depend very much on the characteristics of the parent rock.

ACKNOWLEDGEMENTS

I should like to thank members of the University of Newcastle upon Tyne expedition to Thorisjökull 1971 for their invaluable help. Financial support came from the University of Newcastle upon Tyne and the Arthur Haydock Bequest (British Association). Thanks are due to Dr. Hal Lister who commented on an earlier version of the manuscript. Agust Bödvarsson of Landmaelingar Islands gave permission for the publication of figure 2.

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APPENDIX A

Folk and Ward's (1957) sorting scale:

under 0.35	very well sorted
0.35 - 0.5	well sorted
0.5 - 0.71	moderately well sorted
0.71 - 1.0	moderately sorted
1.0 - 2.0	poorly sorted
2.0 - 4.0	very poorly sorted
over 4.0	extremely poorly sorted

APPENDIX B

Grain Size Parameters : samples sieved at $\frac{1}{4}$ phi intervals.

Number	Stratification Type	Mz phi	Sorting	Skewness (Folk & Ward 1957)
2	horizontal stratif.	2.083	0.911	0.131
2.10	parallel lamination	3.233	0.794	0.004
37	parallel lamination	4.233	0.692	-0.14
2.12	large scale x stratif.	1.292	0.899	-0.667
2.11	large scale x stratif.	1.25	1.048	0.113
9	small scale x stratif.	2.3	1.282	-0.236
3	small scale x stratif.	2.717	0.925	-0.551
6	parallel lamination	3.33	0.642	0.419
18	parallel lamination	3.458	0.926	0.28
12	small scale x stratif.	3.233	0.971	-0.096
15	large scale x stratif.	-0.6	1.117	0.73
23	large scale x stratif.	0.167	0.723	0.095
21	large scale x stratif.	-0.992	1.495	0.018
20	large scale x stratif.	0.6	1.064	0.432
2.13	large scale x stratif.	0.283	1.5	0.072
14	large scale x stratif.	1.35	1.254	0.044
19	small scale x stratif.	1.52	1.275	-0.165
16	small scale x stratif.	2.5	1.171	0.246
17	small scale x stratif.	3.375	1.244	0.551
2.7	parallel lamination	3.325	1.186	0.305
31	parallel lamination	3.625	1.166	-0.314

cont'd/

APPENDIX B cont'd

Number	Stratification Type	Mz phi	Sorting	Skewness (Folk & Ward 1957)
34	parallel lamination	3.792	0.772	0.628
26	small scale x stratif.	3.283	0.633	0.138
2.9	large scale x stratif.	1.808	1.027	-0.005
28	small scale x stratif.	2.017	1.426	-0.134
12	small scale x stratif.	3.05	0.83	0.568
36	large scale x stratif.	1.933	1.275	-0.053
7	parallel lamination	1.592	0.936	0.163
32	large scale x stratif.	0.7	1.459	0.126
29	large scale x stratif.	1.208	1.754	-0.004
25b	large scale x stratif.	0.25	1.052	0.081
25a	large scale x stratif.	0.6	0.87	0.016
27	parallel lamination	4.4	0.875	-0.078
4	parallel lamination	4.233	0.805	0.143
5	parallel lamination	4.4	0.905	0.8
25	large scale x stratif.	-0.083	1.392	0.055
23b	large scale x stratif.	0.458	1.385	0.071
22	large scale x stratif.	1.467	0.875	-0.062
21b	horizontal stratif.	0.917	1.25	-0.325
24	parallel lamination	1.458	1.15	-0.224
39	small scale x stratif.	2.608	1.687	-0.416
42	large scale x stratif.	1.242	1.623	0.367
45	large scale x stratif.	0.875	1.262	0.109
44	large scale x stratif.	1.45	1.683	0.051
43	horizontal stratif.	1.375	1.72	0.087
41	horizontal stratif.	1.35	1.867	0.032
40	horizontal stratif.	1.783	1.771	0.369
35	horizontal stratif.	1.0	1.65	0.149
22	large scale x stratif.	0.342	1.404	0.189
10	large scale x stratif.	1.4	1.17	0.094
bar 1		0.7	1.196	-0.063
bar 3		0.733	1.688	0.069
bar 5		0.4	1.801	0.18
bar 7		1.975	2.127	-0.336
bar 9		-0.05	1.219	0.054

cont'd/

APPENDIX B cont'd

Number	Stratification Type	Mz phi	Sorting	Skewness (Folk & Ward 1957)
bar 11		1.167	1.793	0.016
bar 13		1.65	2.483	0.204
bar 15		-0.008	1.322	0.104
bar 17		1.842	2.316	0.023
bar 19		0.933	1.939	0.073
bar 21		0.658	1.658	0.303
bar 23		1.517	1.754	0.295
bar 25		1.183	1.68	0.085
bar 27		1.258	1.294	-0.064
bar 29		1.65	1.839	-0.61
bar 31		0.33	1.47	0.08
bar 34		0.467	1.688	0.181

THE FORMATION OF DIRT CONES ON NORTH THORISJŐKULL

J. Drummond and R. Riley

Dirt cones have been studied since Agassiz first described this 'strange phenomenon' which he found on the lower part of the Aar and Lernatt glaciers. The object of our study was to record the position and dimensions of such dirt cones on north Thorisjőkull; to collect measurements of eight dirt cones as they 'waxed and waned' throughout our stay in Thorisdalur, and to compare their behaviour with that of ice covered with varying depths of debris (i.e. 'artificial dirt cones'). In addition accumulation for the last three years was measured, ablation rates and dirt cone positions on a second glacier were determined. Apart from giving some verification to our results on the first glacier this data was not used.

We found that dirt cone formation was initiated by debris blown onto the glacier from moraines or washed out from the previous year's surface debris in the glacier (in our case this was identified as 1970 Hekla eruption ash). This was carried by surface meltwater streams to a point where stream velocity was too low to transport debris (i.e. at a bend in the stream or at a level point). Finally the debris accumulations developed into dirt cones.

'ARTIFICIAL' DIRT CONE SITES

Records were made of ablation at ten stakes on north Thorisjőkull. These stakes were surrounded by varying depths of debris from 0.0 cm to 1.2 cm thick and covering 4 square metres. The debris consisted of dark-coloured morainic material with grain sizes of between 0.03 cm and 0.10 cm, and was derived from the rhyolite outcrops in the area and from Hekla ash of the 1970 eruption. Initially we found debris depths of 0.0 cm to 0.9 cm, but after a month of readings it became obvious that ablation on all the squares was greater than on clean ice. The dark morainic debris was absorbing heat and not acting as an insulator. Therefore readings were taken for a few days with depths of 0.8 cm to 1.2 cm which at some depths did act as insulators. The 1.0 cm debris depths gave ablation of 59% more than that over 'clean ice'. We therefore concluded that dirt cone formation on the glacier studied would be initiated at debris depths of at at least 1.0 cm.

NATURAL DIRT CONE SITES

Eight dirt cones of varying sizes and at varying positions on the glacier were measured twice a week and recordings were made of the following:

(i) height of dirt cones

(ii) debris depths at different points on the cone

(iii) slope length of the dirt cone.

The growth and decay of dirt cones has been described by several workers. Swithinbank's and Krenek's descriptions will be outlined here. Our observations validated these descriptions but the remnant crevasses at E in figure 1 were found only twice.

Wind-blown or water-carried debris collects in a hollow (if in a water-filled hollow stratified dirt cones will be formed) and its insulating properties set up an ablation differential. Subsequent downmelting of the surrounding ice and/or continued accretion of debris results in B, and the growth process outlined in figure 1 is followed until the cone reaches maturity at E.

The dimensions of all eight dirt cones at maturity are listed in table 1. At maturity the x/y ratio approximated 1.11 and this slight elongation is attributable to deposition in former stream channels. Also at maturity the average debris depths on each cone were greater than 1.0 cm as would be expected from the results on the artificial cones. Decay of the dirt cones was initiated when debris depths became too small to insulate the core, and generally depths were less than 1.0 cm at this point.

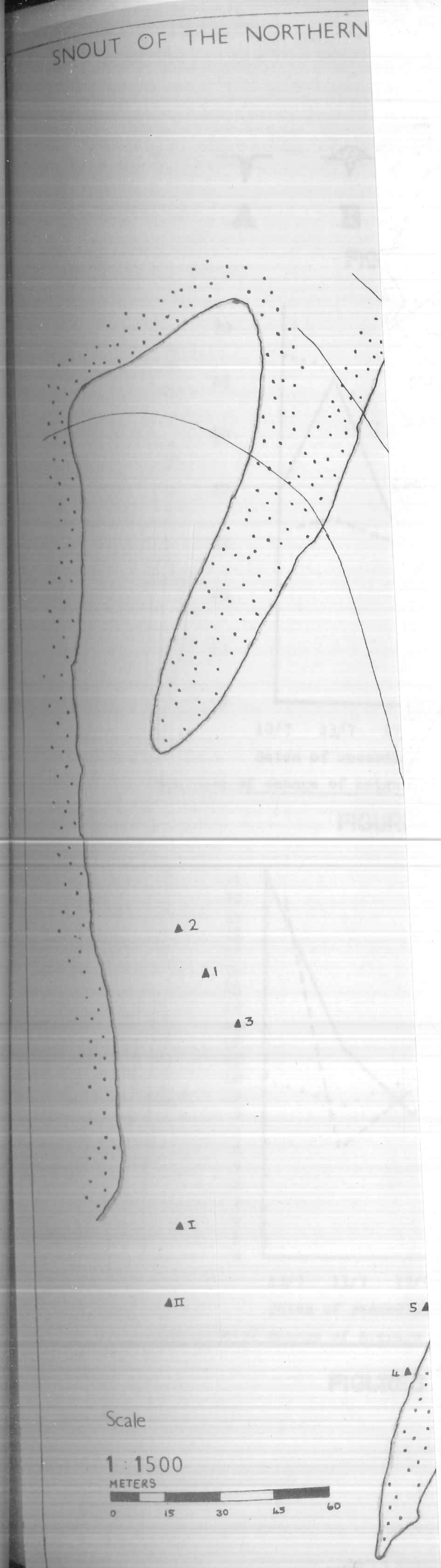
Figure 1 gives the rate of change of height for four cones and figure 2 gives the rate of change of average debris depths for four cones.

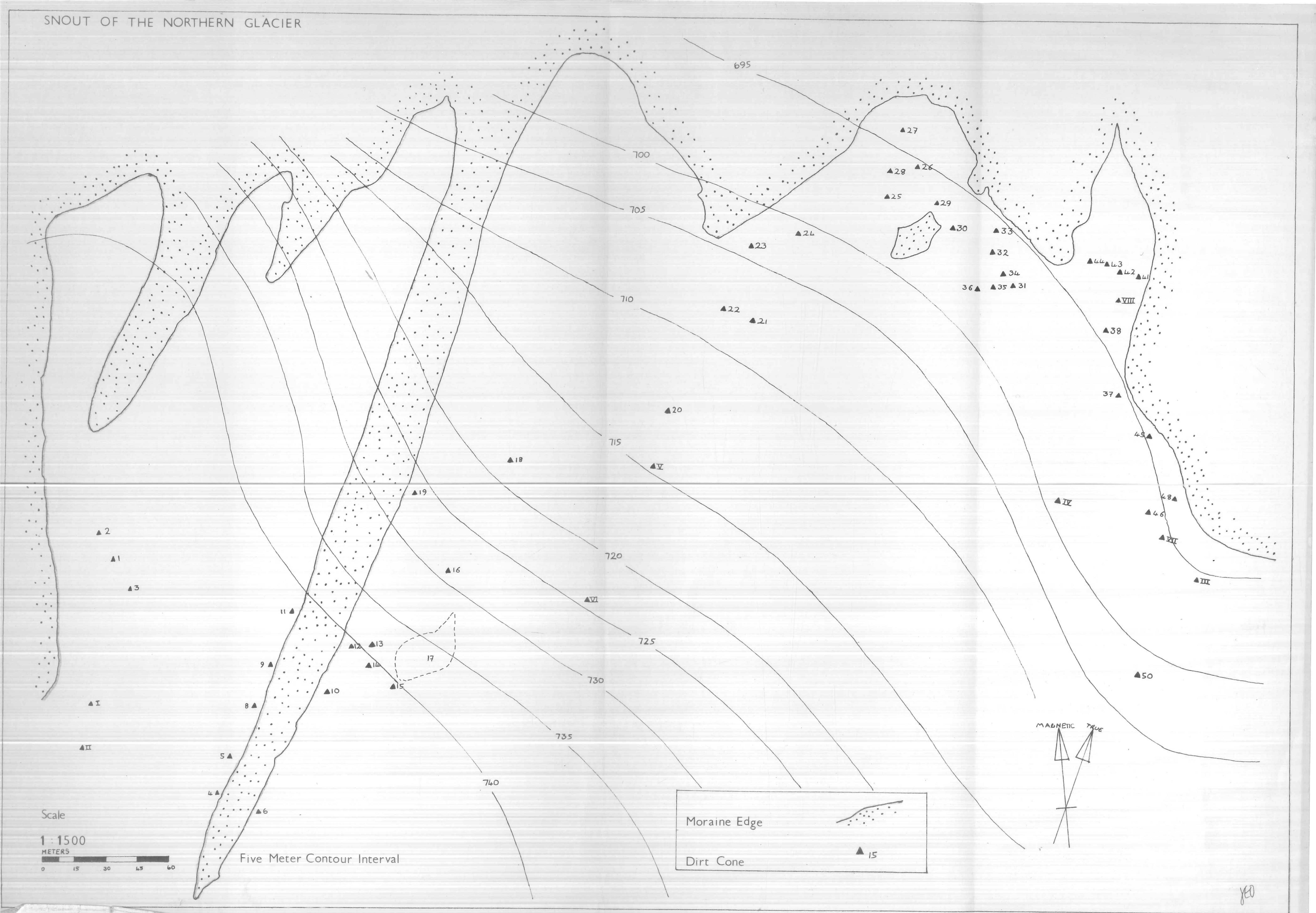
From figures 2 and 3 it can be seen that all four cones were decaying. Until July 26th there is an apparent positive correlation between cone height and debris depth indicating that as the debris was washed away or was blown away the cone melted. The correlation coefficient between height and debris depth was +0.29. After that date in all four cases there was an increase in debris depth. Height and debris depth showed a correlation coefficient of -0.89, indicating that in the 'dying' stages of a dirt cone the residual debris covering the smaller surface areas accelerated melting of the ice.

Table 2 lists all the dirt cones on the area of the glacier studied with their heights, debris depths and the nature of their debris. Their positions on the glacier are plotted on the accompanying map of the glacier snout.

Table 1

Cone	Height (z cm)	Length (x cm)	Breadth (y cm)	x/y	Sediment thickness (cm) top	Sediment thickness (cm) bottom	Side Length (cm)
1	195	740	655	1.13	10.0	5.0	240
2	88	403	367	1.11	12.0	3.0	92
3	45	155	140	1.11	1.3	0.8	88
4	35	75	67	1.12	1.5	2.0	57
5	33	63	55	1.14	0.7	5.0	50
6	65	153	150	1.02	1.9	1.0	108
7	35	98	85	1.15	0.4	1.0	65
8	25	95	85	1.12	3.5	0.7	52




SNOUT OF THE NORTHERN GLACIER
695
700
705
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720
725
730
735
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Scale
1 : 1500
METERS
0 15 30 45 60
Five Meter Contour Interval
Moraine Edge
Dirt Cone
15
MAGNETIC
TRUE

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6	65	153	150	1.02	1.9	1.0	108
7	35	98	85	1.15	0.4	1.0	65
8	25	95	85	1.12	3.5	0.7	52

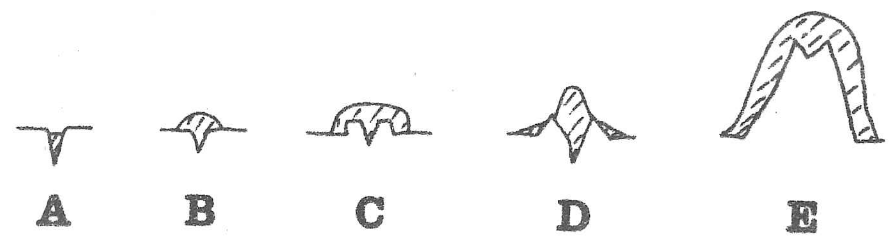
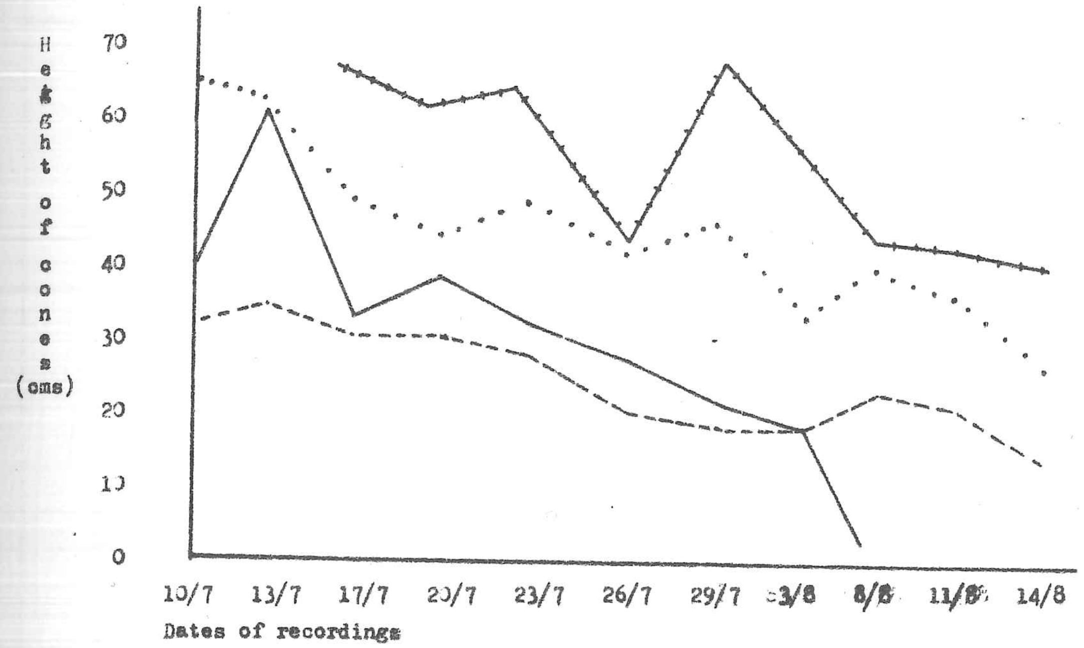
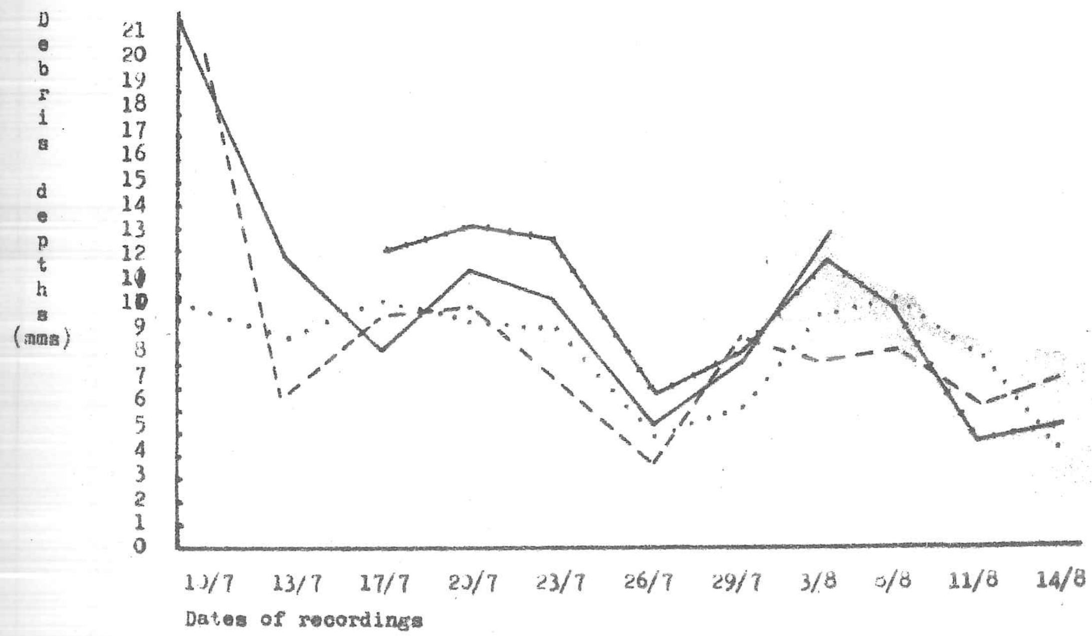


FIGURE 1



The rate of change of heights of four cones (natural sites).

FIGURE 2



The rate of change of average debris depths for four cones

FIGURE 3

Table 2

Dimensions of all Dirt Cones on the Glacier

Cone	Height (cm)	Debris Depth (cm)	Grain Grade	Observations
1	20	3	c	layered summit
2	50	2	f	" "
3	40	4	c	" "
4	50	2	c	
5	40	2	f	
6	50	1	f	
7				
8	40	1.5	f	
9	60	2	f	
10	40	2	f	
11	100	7	c	
12	40	1	f	
13	20	3		layered summit
14	170	2	f	
15	300	4	f	layered summit
16	300	4	f	
17	100	0.5	f	
18	120	1.5	f	
19	100	1	f	
20	110	1	f	
21	40	1	f	
22	120	2	f	layered summit
23	10	0.7		
24	30	0.5	f	
25	60	0.5	f	
26	160	2	f	
27	25	0.5	f	
28	60	0.5	f	
29	60	1	f	
30	100	2	f	
31	20	1	f	
32	40	1	f	
33	40	1	f	
34	100	1	f	
36	50	1	f	
37				
38				
39			c	
41	65	1	f	
42			c	
44			c	
45	100	3	f	
46	40	1	f	
48	100	1	f	
50	100	2	f	

* c = coarse grains (more than 0.1 cm diam.)
f = fine grains (less than 0.1 cm diam.)

POSSIBLE EFFECTS OF CONSTANT DAYLIGHT ON CIRCADIAN RHYTHMS

Carole Dickinson

INTRODUCTION

"For everything there is a season, and a time for every matter under heaven", says Solomon the wise king of old. Circadian Rhythm may be taken to be part of this. It is the fluctuation of biological rhythms about the day. In normal daily living this results in one cycle every 24 hours to fit in with the person's social convenience as well as his sleeping, eating habits, etcetera.

There is evidence that this rhythm is endogenous: it may retain its old phase when the day is changed, e.g. travelling east to west; it may retain its old cycle length when the cycle length of the habit is changed, e.g. imposing a 28 hour day; under approximately constant conditions, the human rhythm may depart from its exact 24 hour period. In animals light/dark alternation has been shown to be important as a Zeitgeber - the duration of light, rather than its intensity imposing the length of the cycle in the rhythm.

AIM

The project consisted of examining the effect of the constant daylight in Iceland on some of the circadian rhythms of the team members. Control observations in Newcastle in June 1971 and March 1972 were made for comparison. The following tables give a comparison of the conditions for the control period in Newcastle and the experimental period in Iceland.

Table 1

	DAYLIGHT		
	Date		Hours of Darkness
Reykjavik	July 1971	2	Nil
		16	Nil
		30	23.14-01.47
	August 1971	13	21.59-03.02
		27	20.59-03.57
Newcastle	June 1971	10	22.18-02.56
		30	22.16-03.00
	March 1972	20	18.47-05.37
		30	19.04-05.14

Table 2

	Date		TEMPERATURES (°C) Max.	Min.
Newcastle	June 1971	18	12	9
		20	11	9
		21	15	9
		22	18	9
	March 1972	23	12	1
		24	14	2
Base Camp	July 1971	4	12	5
		5	17	6.5
		6	18	2.5
		7	14	7
		8	11	3
		9	12	4.5
		21	11	8
		22	14	7
		23	15	8
		24	19.5	4
	August 1971	5	14	4
		6	14	4
		7	12	3
		8	8	7
		9	10.0	0.8
		10		7.5
		11		9.5
		12		6.5

Daylight was constant on arrival in Iceland, with two or three hours of twilight. It began to get dark from the end of July. Observation periods in Iceland were at the beginning of the expedition - 4th-9th July, then on certain subjects 21-24th July, 5-14th August, 28-31st August. The following table shows the team members, who are given a letter for reference, their sex and the times they were observed.

Table 3

Subject	Sex	June 19-21	July 4&7	July 5&9	July 21-24	August 5-14	August 11-14	August 28-31	March 24-27
A	m			x	x		x		x
B	f	x	x		x	x		x	x
C	f	x		x	x		x		
D	f	x	x						
E	m			x	x				
F	m			x					
G	m		x						
H	m		x						
I	m	x		x	x		x		

FINDINGS AND DISCUSSION

Sleep

Sleep charts were begun on arrival in Iceland and kept for varying lengths of time by different people. The duration of sleep was recorded in hours, for each day.

It is said that the states of sleepiness and wakefulness oscillate circadianly, but that the actual occurrence of sleep is influenced by other factors.

At Base Camp a routine for going to bed and rising at hours like those in England was adopted by the team, without regard to the light conditions. Since the tents had flysheets, difficulty in going to sleep because of external light was not experienced.

In figure 1 the lateness of the times of sleep kept by 'H' were due to cold at night. 'E' was working isolated from the rest of us after the end of July for three weeks. The two tend to show retiring times becoming progressively earlier as the onset of darkness became earlier. It cannot be concluded whether this is due to choice or to a difference in the times of actually feeling sleepy. There is no noticeable effect on rising times.

Temperature

In the control period and at the beginning of July, temperatures were taken using sensitive fertility thermometers placed in the stream of urine. Temperatures were also taken by four members during a continuous 24 hour working period.

This method of taking temperatures in the field was found to be quick and consistently precise when compared with the oral method. A few seconds was required to give the reading as opposed to four minutes. A more accurate measurement of deep body temperature is obtained. This was highlighted when 'I' was ill and his raised temperature taken both orally and in urine could be compared to the normal values previously obtained. Referring to figure 2c, it seems to be confirmed that body temperature is inversely proportional to oral temperature.

The control readings and those obtained in Iceland for each person tended to show a similar shaped biphasic curve, the shape characteristic to the person. This is demonstrated in figure 2a&b for two subjects.

FIG 1 Times of sleeping and waking compared to dark

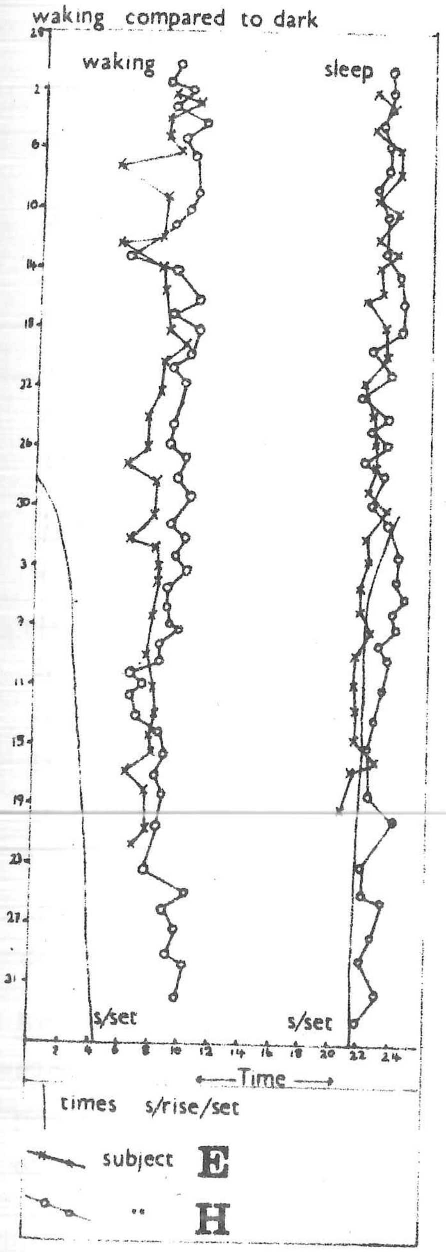
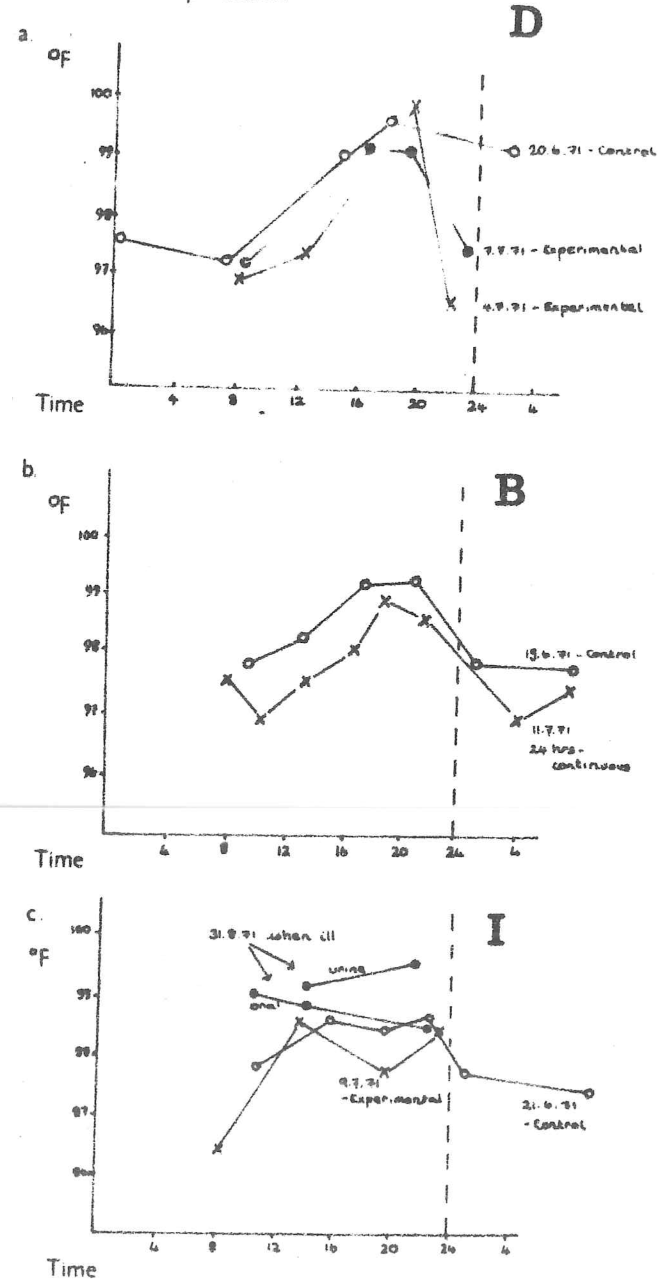


FIG 2 Temperatures



For 'B' it is seen that the 24 hour working period did not affect the normal daily temperature fluctuation. From the results it is concluded that there was no departure from the 24 hour circadian rhythm for temperature in the team members in Iceland.

There is a suggested connection between temperature and sleep rhythm. Since a normal sleep pattern was assumed by the subjects no variation in temperature rhythm would be expected.

Urine Production

Measurements were made of: volume, from which the rate of flow in millilitres per hour could be calculated; of specific gravity with a urine hygrometer; of acidity with close range pH papers. Glucose and protein which were tested for by using clinistix and Albustix were never detected.

Controls: Normally with 4 hour sampling, nocturnal oliguria is shown with the peak flow in the late afternoon, and the urine excreted at night is more acid than that in the day. This was found to be true in all control observations in all subjects. An example of this is in figure 3a. The specific gravity is dependent on the rate of flow. It is seen to be higher with a small volume of more concentrated urine at night. The rate of flow of urine is mainly due to the rate of liberation of Anti-Diuretic Hormone and total solute excretion. The pH is seen to rise proportionately to rate of flow. 'pH' is thought to depend inversely on potassium excretion, and so is a secondary rhythm.

Experimental: Light has been thought to be important in controlling urine flow as distinct from the effect of individual solutes. On an occasion, persistence of pH rhythm with loss of rhythm in urine production was observed when crossing north to continuous light.

Refer to Table 3 for times of observation for each subject. The results presented in figures 3 and 4 are selected from those during the whole experiment as being representative and relevant.

In early July urine was collected from all team members for two days. All showed a disturbance of the circadian rhythm, with the exception of subject 'F' - the Norwegian of the party. The complaint of others was a noticeably high production of urine on some nights. Some subjects gave further samples later in July and in mid-August. All showed an irregular rhythm. Figure 3b shows one subject's results for three days in August compared with his control. Note that the overnight flow rates vary considerably, the peak flow for each day are anomalously lower than night values with a corresponding higher specific gravity, and the pH line, though irregular, has clearly departed from its normal rhythm.

Comparison of flow rates: Figure 4a gives the rates obtained for each subject for several separate nights' urine collection (from 23.00–08.00) through the course of the experiment. The control rates are low. The overnight flow while in Iceland is irregular for all subjects expect 'F'. The flow rates during the night and then day in both control and experimental conditions was compared.

Table 4

	CONTROL		EXPERIMENTAL	
	Day	Night	Day	Night
Mean	65.1	33	71.3	60
No.	6	11	40	59
S.D.	13.9	5.15	20.4	29.8

Student's 't' test gave the following probabilities of two respective groups being from the same population.

Day:	Control/experimental	$p = 0.1$
Night:	Control/experimental	$p = 0.001$
Control:	Day/night	$p = 0.001$
Experimental:	Day/night	$p = 0.05$

This draws emphasis to the distinct day/night variation in a normal (control) circadian rhythm; and to a difference between overnight values obtained in control and experimental periods. The difference in day-time rates is not so significant since drinking is during this time in both sets of observations.

The form of the rhythm: One reason for the overnight difference is that the circadian rhythm is breaking down. Polyuria results when the normal

FIG 3

Comparison of Control and Experimental rythms in urine production in I

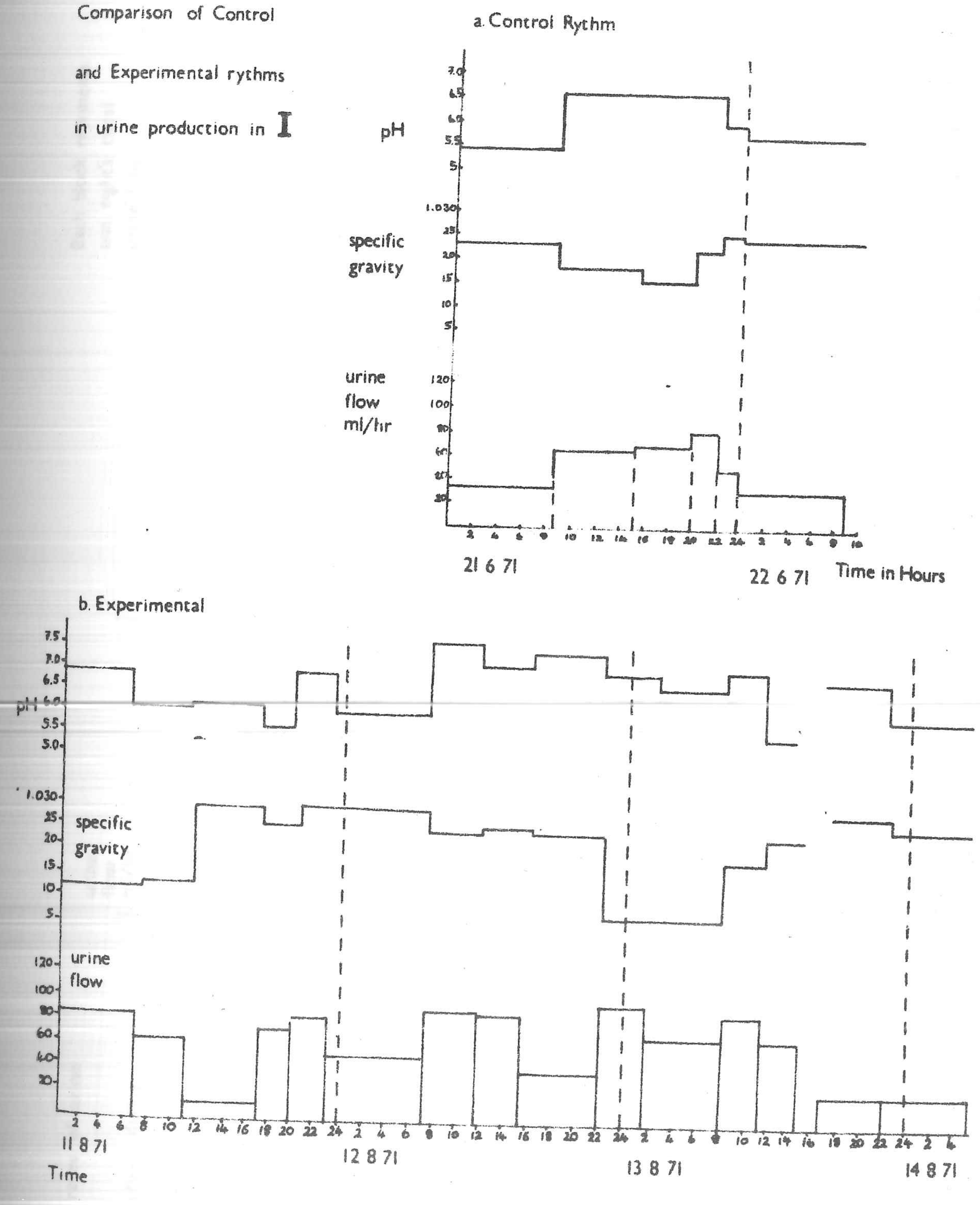


FIG.4

a Overnight rates of urine flow per subject during the experiment

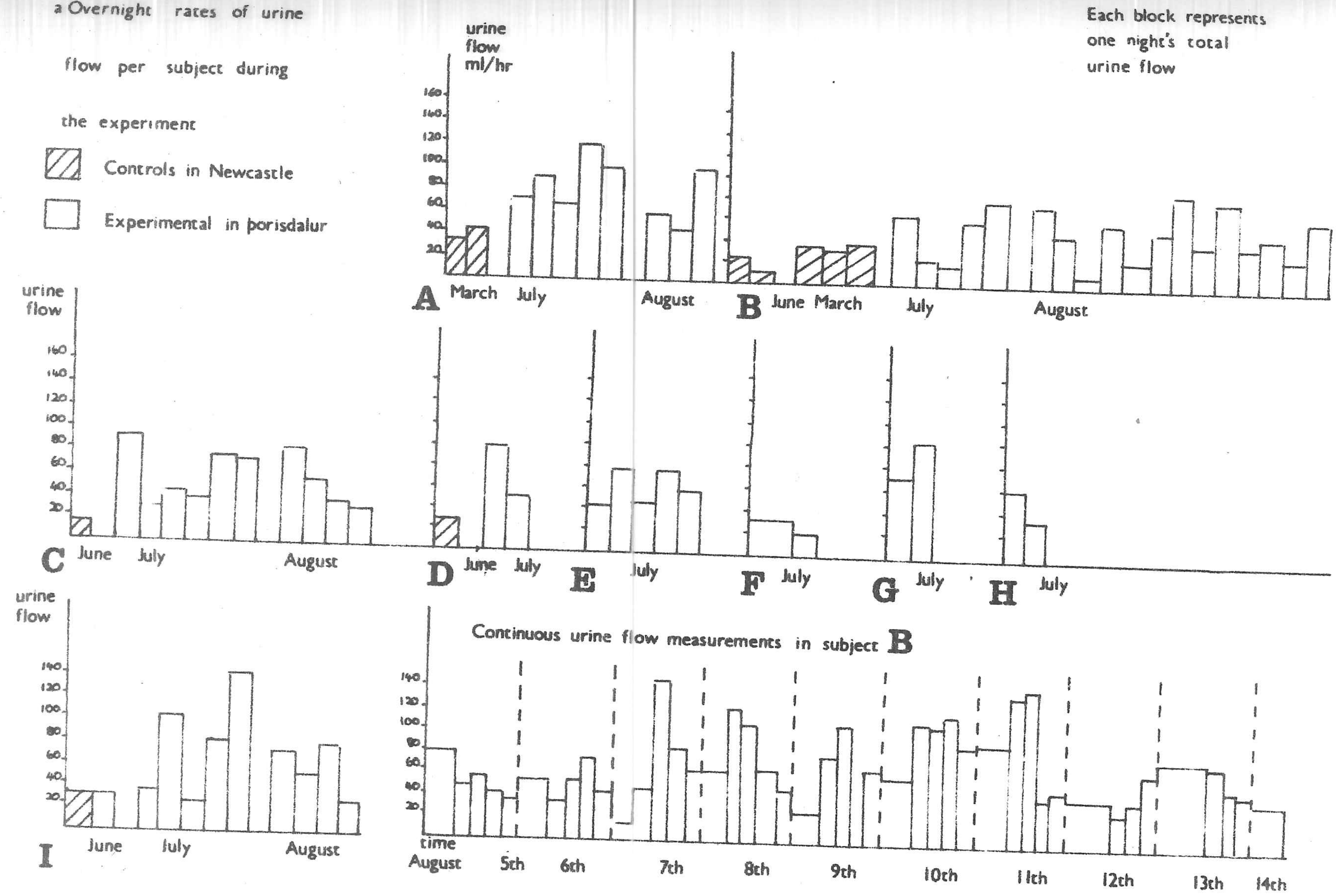
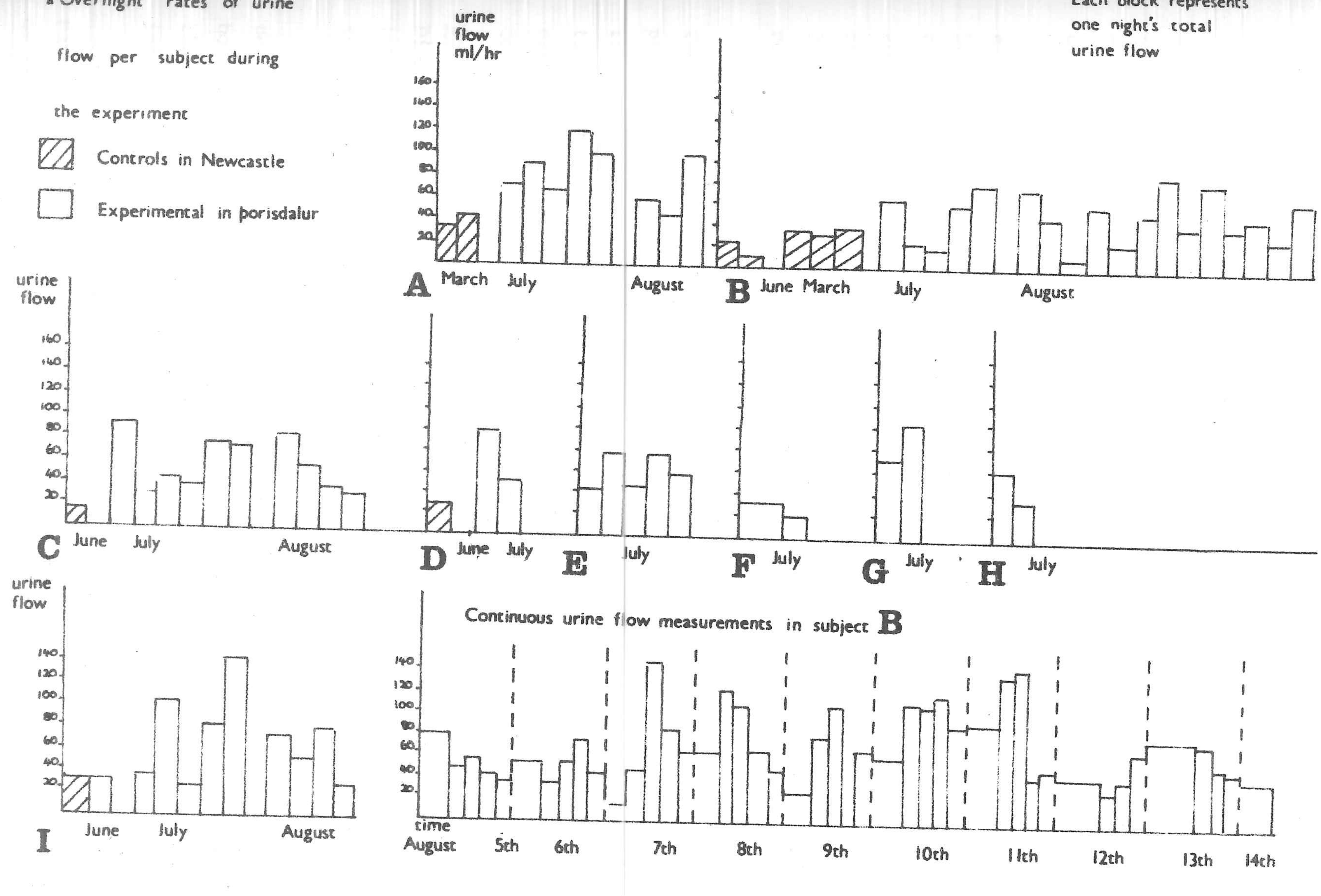


FIG.4

a Overnight rates of urine flow per subject during the experiment



concentrating mechanism is not working. However, both day and night values show some production of urine at a high concentration as well as a high production of less concentrated urine. This can be seen in figure 4b. It was borne out by observations from the subjects themselves.

The difficulty in analysing the results in figure 4b is that drinking followed by diuresis was only during the day, and so some 24 hour rhythm is still imposed. Normally the concentrating-nonconcentrating rhythm fits in with this. It is the irregular production rates overnight, when there was no drinking, which could give some clue to a change in concentrating rhythm. The conflict of the normal 24 hour eating/drinking rhythm with the new concentrating rhythm would give beats typical of interference between two waves of slightly different frequency. In figure 4b something of this might be indicated in the very low rates in the daytime on 6th and 12th, and the high rates overnight on the 7th and 10th. An extended rhythm is suggested by figure 3b with a corresponding rhythm in specific gravity. The rest of the results were similar.

Plotting overnight urine rates against frequency occurrence revealed two distinct peaks, which gives a pointer to the existence of two populations as in a non-24 hour rhythm. It is concluded, though, that the observations were not conducted over a sufficiently long period of time to detect the length of any new rhythm. To investigate this, the effect of the drinking rhythm would have to be negated by having a controlled intake at regular intervals through the day and night.

Conclusion: What caused the disturbance in circadian rhythm? Anti-Diuretic Hormone release is increased by cold. However, reference to table 2 shows that the temperatures in Iceland were similar to those in Newcastle for the control period.

Since in Iceland the pH rhythm changed in all subjects as well as that of urine flow, the rates of excretion of solutes might have caused both. Meals during the expedition were quite standard, and though the taste varied day to day the actual content varied very little. Therefore intake was the same each day.

It cannot be assumed that light directly controlled the urine flow rate. One could conjecture a connection by light controlling the release of the adrenal mineralocorticoids (aldosterone) to affect solute excretion and also A.D.H. to affect concentrating the urine.

The daylight was continuous for the July observations. The disturbance was apparent then, just one week after arrival in Iceland. By mid-August darkness was falling at about 22.30, and at 21.00 at the end of August. Observations in August continued to show a disturbance. It was remarked by the author that for herself, at least, this continued for a week after leaving Iceland. Therefore the normal rhythm in urine flow, concentration, and acidity was quickly disturbed on going to Iceland, passing to continuous light, in all team members except 'F', and this disturbance continued for up to four weeks after it could be seen to begin to get dark in the evenings.

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Thanks to:

Dr. Reed of the Physiology Department at Newcastle Medical School, for his help in preparation and in reading the results; and to the technical staff there for providing the equipment. To Professor Harper and Professor Newell who both completed forms for grants. To Boots Pure Drug Company for the supply of thermometers. Not least, to the team members for their willing co-operation.

MEDICAL REPORT

Carole Dickinson

1. EQUIPMENT

Advice was taken from last year's expedition report. Few anti-insect preparations were taken but a large number of plaster dressings were packed - not many were used. The previous report suggested including anti-biotics and acting on this advice a supply was purchased on a sale or return basis using a prescription written by a doctor at the University Health Centre. Penicillin was rarely used as throat lozenges were adequate for placating sore throats. Ampicillin was not needed. Lomotil was useful for one acute case of diarrhoea. Antibiotics are to be recommended for future expeditions.

The following equipment was found be be most useful:

Plaster dressings and cotton wool
Bandages
Savlon for dry hands
Paraffin gauze for burns
Calamine for sunburn
Analgesic tablets
Throat lozenges
Antiseptic creams
Senocot
Lomctil

Other preparations packed were as follows:

Water-purifying tablets
Dettol
Epsom salts
Milk of Magnesia
Aspirin
Splints

Aerosol anaesthetic would have been a useful addition and is to be recommended to future expeditions.

Supplies were obtained from the Exploration Society stores and were also ordered from Boots.

2. WATER

The base camp drew its water from a stream on the western slope of Prestanukur. This stream was meltwater from the snow and was sufficiently clean to drink without treatment. Fresh water was also available during journeys around the island and consequently water-purifying tablets were little used.

3. FOOD AND GENERAL HEALTH

Since fairly frequent trips were made to Reykjavik, fresh food, especially bread and milk, was readily available. A welcome variation of the menu was provided by Roar Jacobsen who caught some trout. Vitamin pills were taken regularly. With the exception of one member who was run-down and who developed a fever in the last week, there was no detectable difference in the physical well-being of members of the team. The general morale at Base Camp owed much to the proximity of the B.S.E.S. Ice Camp with the consequent frequency and variety of visitors.

4. OTHER PROBLEMS

While in Reykjavik at the end of July one member contracted shingles. She was seen by doctors in the city. The source of the infection is uncertain but she had been a passenger in the Landrover when it was involved in a collision and had suffered a blow on the forehead. It was on this part of the forehead that the lesions appeared and it is possible that they may have been precipitated by trauma. Her pain and malaise necessitated a fortnight's stay in Reykjavik. In retrospect the patient should probably have spent some time in hospital or should have returned home but the isolation of Base Camp made communications difficult and the severity of the illness was not fully appreciated at the time. Mention should be made of Hugh McAllister for his nursing of the patient.

During the second tour of the island another member was quite badly scalded on her right ankle. In the Myvatn area driving snow, steam and an overcast sky contrived to conceal hot sulphur springs. The casualty was taken directly to the hospital in Akureyri where dressings were applied for a charge of 300 kr. On the return journey to Reykjavik we called at the B.S.E.S. Base Camp and were able to see their doctor. He cut away the blistered tissue which relieved some of the pain. He kindly supplied further dressings which were needed.

ORNITHOLOGICAL REPORT

C. J. North

It is not intended that this report should be scientific but rather one of pure ornithological interest to whet the appetite of intending visitors to Iceland.

Iceland is a mixing ground for many North American and European birds and is consequently ideal for ornithological observation. Altogether there are 83 different types of birds either resident in or visitors to Iceland. Of these, 43 types were seen and identified. Unfortunately these are too many to describe in this report but a list of the places of observation is presented.

I have divided the areas visited into the North and where indicated Akureyri, the Eastern fjords and the forest on the edge of Lagarfljot, the Western inland route, Lake Myvatn, our Base Camp at Thorisdalur and the area nearby, Reykjavik and, where indicated, the South West peninsula, the Vestmann Islands and the sea journeys to and from Iceland.

It is notable that very few birds were observed in the Myvatn area despite the Icelandic claims of birds in their thousands every summer. This is possibly the result of mining at one end of the lake.

A rare sighting was that of a Long Tailed Skua in Reykjavik harbour. This bird is a native of Scandinavia. The reason for its appearance in Iceland is uncertain although it is not completely unknown. There is no doubt about the validity of this sighting on August 26th 1971.

Birds were observed on only two days for any considerable period of time. Both periods of observation took place in the Thorisdalur area where our Base Camp was situated.

In July 31st, the following birds were observed in the area known as the Green Valley about ½ kilometre east of Base Camp. This area is the only area of vegetation within a radius of 15 kilometres and consequently serves as a resting place for migratory birds.

Snow Buntings	-	Male adults
		Female adults
		Male young
		Female young
Wheatear	-	Female adult

Name	North	East	West	Myvatn	Base Camp	Reykjavik
DIVERS						
S. Gt.Northern Diver	Infrequent on lakes		1 single on lake		1 at Thingvellir	
S. Red throated Diver					1 pair on lake nr B.C.	
WATERFOWL						
R. Whooper Swan	1 pair on lake, Akure-yri		2 individuals on lakes		Family on lake. 6 flew over glacier in formation	
S. Greylag Goose	1 on lake, Akureyri		Flock of 15			
S. Pink Footed Goose	Flock of 20					
R. Mallard			Frequent			Common on lake
S. Wigeon						2 pairs on lake
S. Tufted Duck						1 male on lake
S. Scaup		Female & young				Females comm-on on lake
R. Eider	Frequent	Frequent		Several		Common on lake & harbour
S. Common Scoter	1 pair at coast					

S = Summer Visitor R = Resident W = Winter Visitor

cont'd/

Name	North	East	West	Myvatn	Base Camp	Reykjavik
WATERFOWL cont'd						
R. Harlequin		Female & 7 young	Female & 4 young	Female & 4 young		
R. Barrow's Golden Eye					Group of 5 passing : lake	1 male on lake
S. Red Breasted Merganser				Male with young		
GULLS						
R. Common Gull						Common in harbour
R. Herring Gull		Frequent at coast	Frequent at coast			Common in harbour
S. Lesser Black-backed Gull						Common in harbour
R. Great Black-backed Gull		Common at coast				Common in harbour
R. Black-backed Gull	Infrequent	1 single winter plumage				Very common in harbour
SEA BIRDS						
S. Kittiwake						Nesting colony Vestmann Isle.
R. Gannet						Fishing in flocks at sea

S = Summer Visitor R = Resident W = Winter Visitor

cont'd/

Name	North	East	West	Myvatn	Base Camp	Reykjavik
SEA BIRDS cont'd						
R. Fulmar		Frequent at coast				Frequent in Harbour
S. Razorbill						Nesting colony Vestmann Isle
R. Cormorant						1 in harbour
S. Arctic Tern		Frequent at coast				Breeding on lake
S. Puffin						Nesting colony Vestmann Isle
SHORE BIRDS						
R. Oystercatcher						1 pair in harbour
R. Ringed Plover		Several at coast			1 pair resident at lake	
S. Whimbrel	Common		Common		1 passing	Common at S.W. Peninsula
S. Redshank	Frequent at coast				2 at lake	Frequent in harbour
R. Snipe				1 at edge of lake		
R. Purple Sandpiper						14 on harbour edge

S = Summer Visitor R = Resident W = Winter Visitor

Name	North	East	West	Myvatn	Base Camp	Reykjavik
SHORE BIRDS cont'd						
W. Turnstone						6 in harbour August
S. Red-necked Phalarope						1 solitary, harbour edge
PERCHING BIRDS						
S. White Wagtail	Frequent	Frequent		Several : hot springs		
S. Wheatear		Common	1 male		1 female passing through	
W. Fieldfare	Several flocks					
R. Redwing	Infrequent	Several in Forest		Infrequent		
R. Snow Bunting			Nest with 4 young in lava flow			2 families resident
R. Redpoll		Several in Forest				
S. House Sparrow	Frequent in Akureyri					Common
R. Starling						Many flocks

S = Summer Visitor R = Resident W = Winter Visitor

cont'd

Name	North	East	West	Myvatn	Base Camp	Reykjavik
OPEN BIRDS						
R. Raven	Several	Frequent	Several		Pair in Kaldidalur	
S. Golden Plover					Flew over lake Frequent at Husafell	
S. Meadow Pipit	Infrequent		Infrequent		Frequent at Husafell	
R. Ptarmigan	Frequently heard, rarely seen					Top of Esja
BIRDS OF PREY						
R. Merlin	1 catching prey			Pair at edge of lake		
S. Great Skua						Several following ship
S. Arctic Skua	Several					1 pair, S.W. Peninsula

S = Summer Visitor R = Resident W = Winter Visitor

The second period of observation took place on the shores of a lake 16 kilometres south of Thorisdalur by road. The observations were made on August 3rd. Here a pair of Whooper Swans had reared their four young. Observations began at 1 a.m. when it was dusk. At 7.45 in daylight it could be seen that the swans were not alone. Two Red Throated Divers accounted for a call which had been heard for some time.

During this period of observation several passing birds were seen. A Whimbrel, several Snow Buntings, a Golden Plover, a Ringed Plover and two Red Shanks were observed.

ICELANDIC TURF FARMS

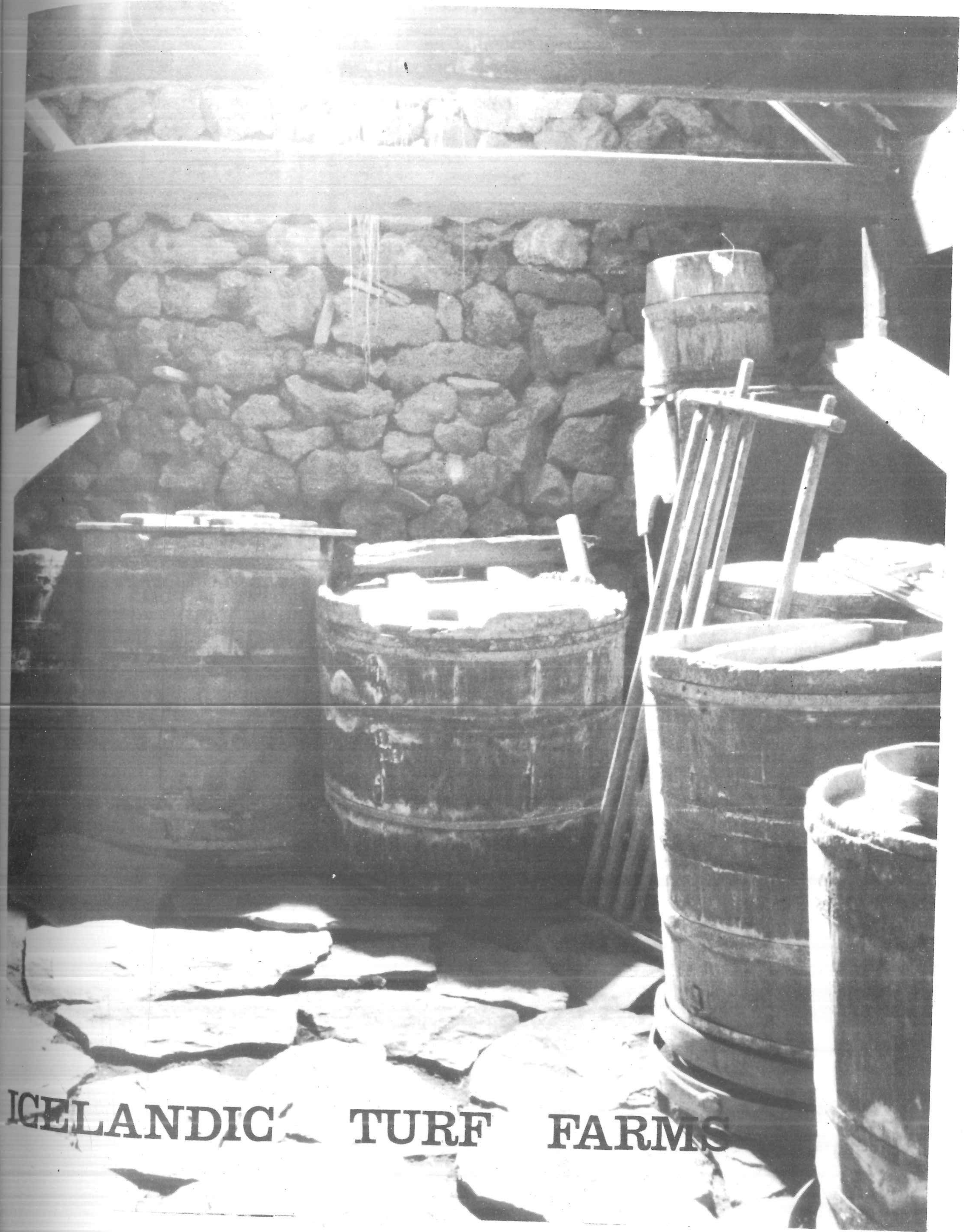
Roar Jacobsen

In countries where distances are great and opportunities for exchanging experiences and ideas are rare, people are forced to build with materials found in their own locality. Constructional methods also develop to suit locally available materials. In this way there grows up an architecture which is 'right' for the local climate and for the particular functions which buildings are given in the society concerned. The Eskimo igloo, the bamboo huts of the tropics and the pueblos built by the North American Indians are examples of excellent traditional and functional ways of building. The Icelandic method of using turf is also an example of this kind of building development. It was dictated by the lack of wood and the ease with which grass turf could be used as a building material.

However, this type of building is not very durable and the oldest existing turf house in Iceland today is probably not more than one hundred and fifty years old. Nevertheless, this type of building provided warm and weatherproof housing, a factor which was of considerable importance in the harsh Icelandic climate.

As communications improved, Icelandic architecture started to be influenced by other countries' building materials and construction. This development won wide renown so quickly that local architectural techniques were more or less abandoned. This phase started in the latter part of the nineteenth century when import of sufficient quantities of timber was possible. Timber construction became increasingly the first mood of 'modern' architecture in Iceland. However, as weatherboarding was expensive and did not fully resist the climatic conditions, corrugated iron cladding became a special, highly developed Icelandic style. From a distance it is often difficult to tell if a building is constructed of painted corrugated iron or painted weatherboarding.

The main change in architecture was brought about by the introduction of concrete in the 1920's. For the first time since the days of turf construction Iceland had a building material which was easily available throughout the country. It is not surprising that nearly all modern architecture is now constructed in concrete.



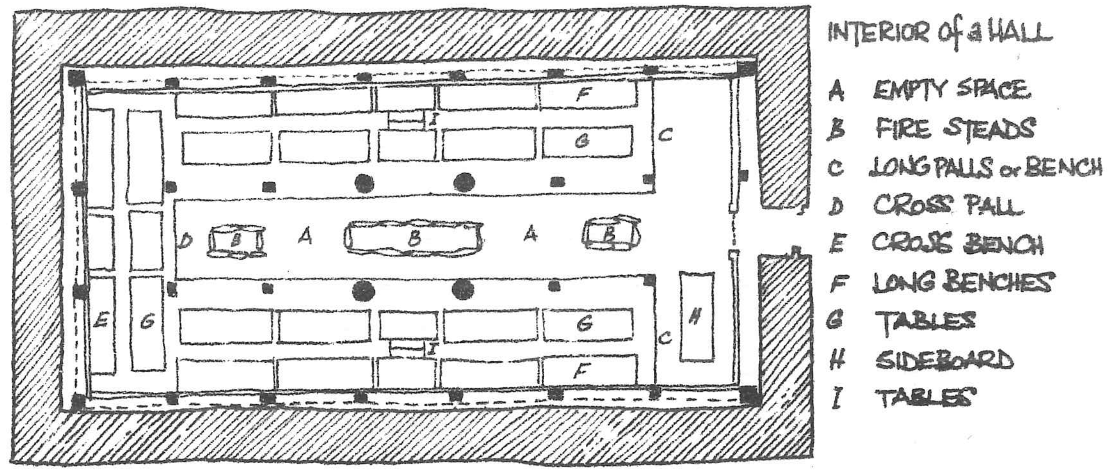
After this short review of Icelandic building materials we can discuss some of the ways in which turf houses were constructed. The materials used were primarily turf and soil with the addition of stone and wood. Stone was introduced to help stabilise the turf walls which otherwise would have tended to fall down or slip. On the other hand, by using more stonework in the construction, less thermal insulation was provided by the wall. However, since the insulation capacity of the wall was of the greatest importance the use of stone was kept to a minimum. It was confined to foundations and the inner leaf of the wall as in Aslakstunga form in figure 1.

It was found that the strongest part of the turf for use as a building material was the 50 mm top layer. This can be cut out in large sheets and placed horizontally on top of each other. This method of using turf is called 'strengur lag' or 'strengur construction'. Since it was often difficult to find a sufficient amount of this type of turf the top layer with additional soil to a total depth of 130 mm was used. Later, a combination of 50 mm and 130 mm layers was introduced and this was called 'klømbrunaus construction or lag'. These two types of construction are illustrated in figure 2 and were designed to prevent water penetration as water was unable to flow in a straight line. In the early development of turf houses 'strengur lag' was used for the living areas as well. The use of timber in these houses was limited to the roof construction and internal panels in the main living rooms and also as the front elevation in the later stages of development. This is shown in figure 3 from Laufas farm.

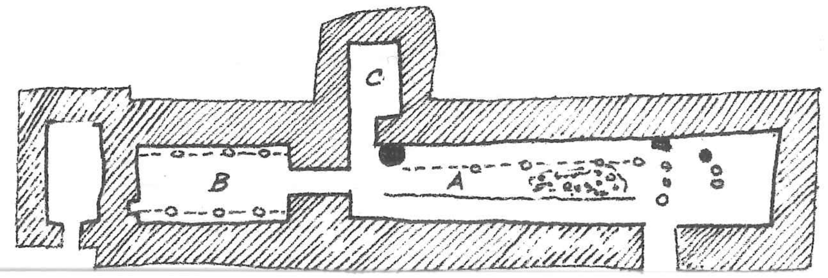
Even if the function of some of the farm houses changed through history it is found that the general layout of the houses remains unchanged. A farm was usually surrounded by a fence built of earth and stones. Many roofless sheep folds were similarly constructed but were used only for milking ewes during the summer. These are shown in figures 4 and 5, where the farm could consist of a winter farm and a summer farm. The summer farm was in the mountains where the animals could be moved in summer time. The winter farm could be divided into domestic houses and animal quarters. The domestic houses consisted of 'indhus' or 'inhouse' and 'udhusene' or 'outbuildings'. The 'indhus' was composed of living rooms which were connected to each other, for example dining and living room (stofa), sleeping room (skali), kitchen (eldhus), larder (bur), woman's working room (dyngja) and a room for winter storage, goods, cloth and saddles (skemma). The outbuildings comprised the smithy (smidja), sheep pens (fjarhus), stable (hesthus), byre (fjos) and barn (hlada). The latter two buildings were sometimes connected to the 'indhus' as illustrated in figure 2.

During Icelandic history the use and function of the outbuildings did not change very much. However, the 'indhus' went through an architectural development from a dwelling not unknown to the Vikings to a typical Icelandic building complex. The dwelling used by the first settlers (early 900 A.D.) was a one room house where all the family activities such as sleeping, eating and working took place. One of the best preserved ruins of this type of farm is at Hofstadir, near Myvatn in northern Iceland, illustrated in figure 2. The ruins are of particular interest because the word 'Hof' means a temple and is found in a lot of farm names from this period. Recently research has been carried out to determine whether a 'hof place' was a temple or simply a dwelling. The latter is thought to be the case. Excavations have shown that Hofstadir consisted of a hall, 36.3 m long and 8.25 m wide at the middle. This tapered to 6 m at both ends. The pitched roof was supported on 1.75 m thick walls and two rows of columns in the middle. In this main hall a great number of guests could be intertained for it is mentioned in 'Laxdaela Saga' that two hundred took part in a wedding feast in the year 1010. Rows of stones, line 'aa', mark the support for the columns and indicate the division of the hall into three parts so that a wooden, raised floor ran along the two side walls, 0.3 to 0.4 m higher than the middle section. This was conveniently arranged to keep the places where people slept and worked cleaner than the lower part of the floor which was generally covered with ashes from the fires. The smoke escaped through holes in the roof which also served to let light into the hall. The walls could be decorated with tapestry, skins and woollen and silken, woven work. The columns and wainscot were often carved or painted with the deeds of Scandinavian mythology.

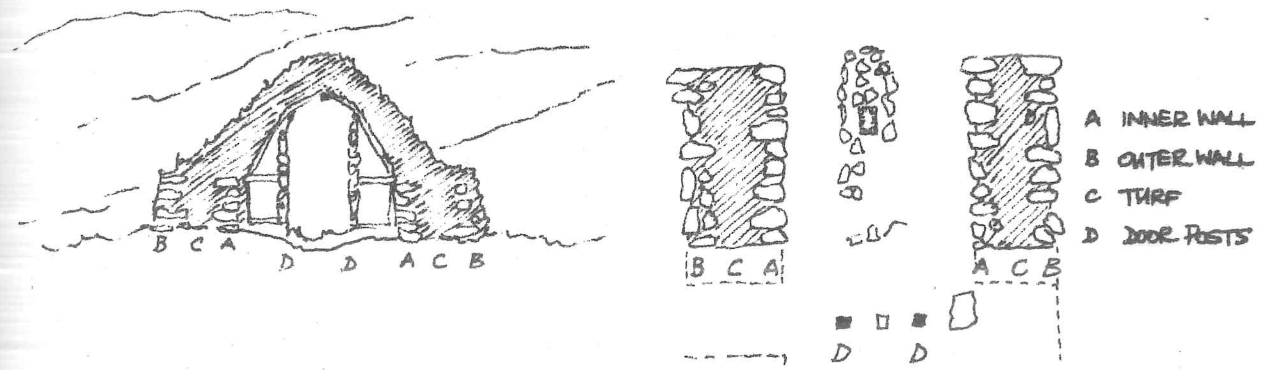
The Hofstadir type farm plan is called a long house (langhus). However, it was unsatisfactory to concentrate all the activities in one room and the growth in the number of supplementary rooms which followed is assumed to mark the progressive stages of architectural development. Thus, the 'langhus' became even longer by the addition of other rooms



(from THE RUINS OF SAGA TIME)

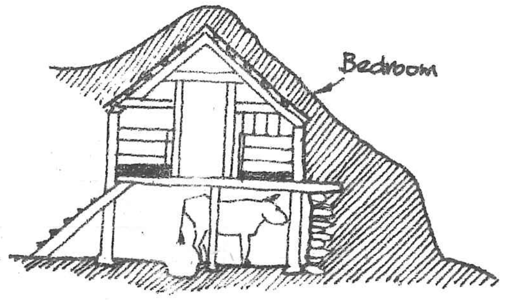


ASLAKSTUNGA
A MAIN HALL
B WORK/LIVE Room
C LARDER
(from 'NORISK BYGNINGSSKIKK' by D. BRUUN)

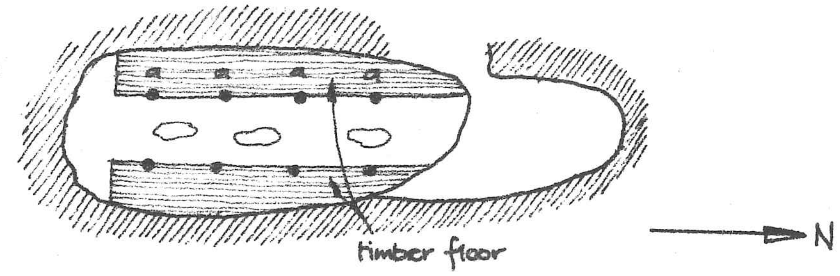


VERTICAL & HORIZONTAL SECTIONS OF ASLAKSTUNGA

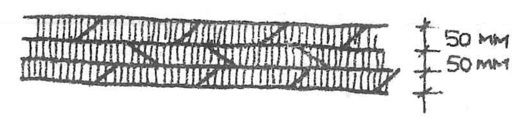
FIG 1



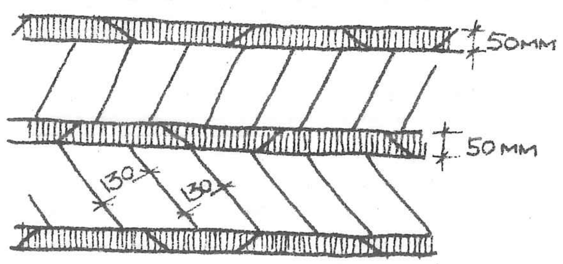
Farm and domestic quarters in the same building



PLAN OF "HOFSTAÐIR"



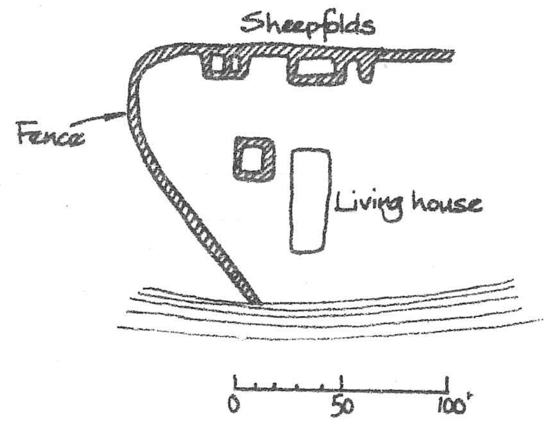
"STRENGUR CONSTRUCTION" or "LAG"



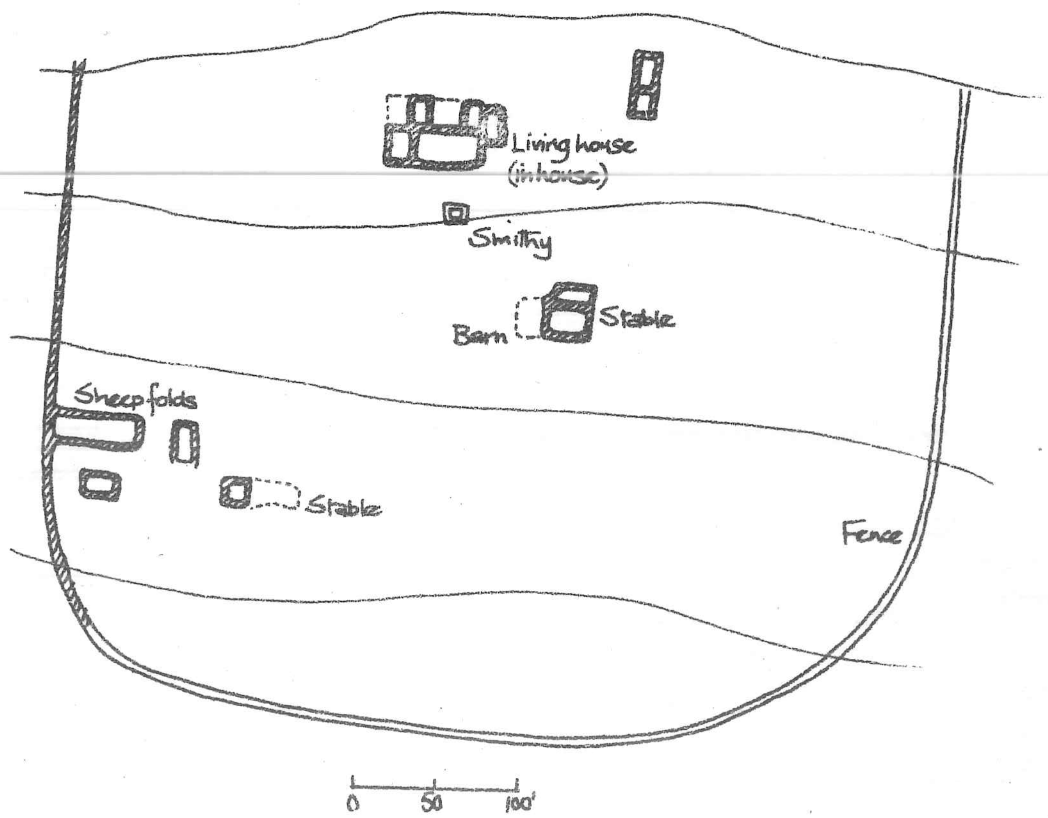
"KLØMBRUNAUS CONSTRUCTION" or "LAG"

FIG 2

FIGURE 3 LAUFAS : KLØMBRUNAUS LAG



THE SUMMERFARM "HOLAKOT"



THE WINTERFARM "LITLA VIJIKER"

FIG 4

FIGURE 2 THE KALDIDALUR SANDUR July 1960

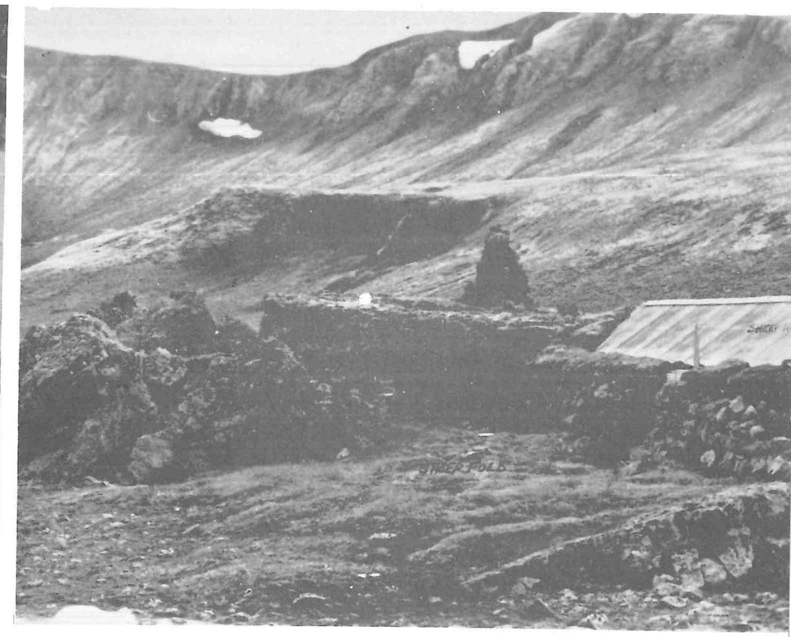


FIGURE 5 PART OF A SUMMER FARM

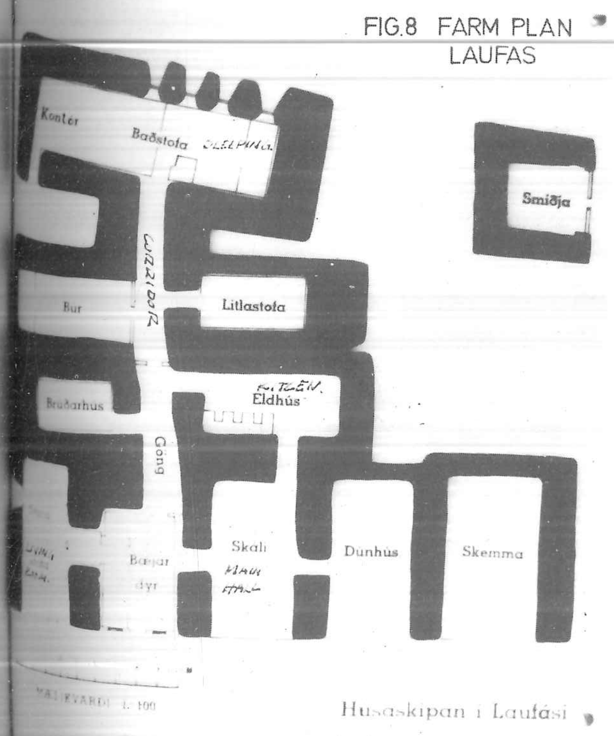
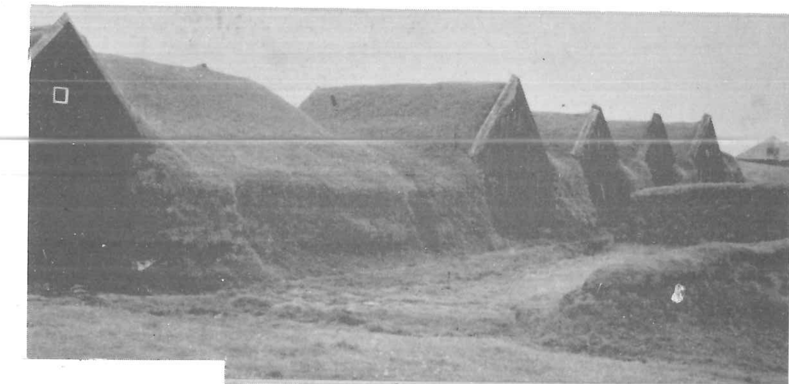


FIGURE 8 FARM PLAN LAUFAS



KELDUR

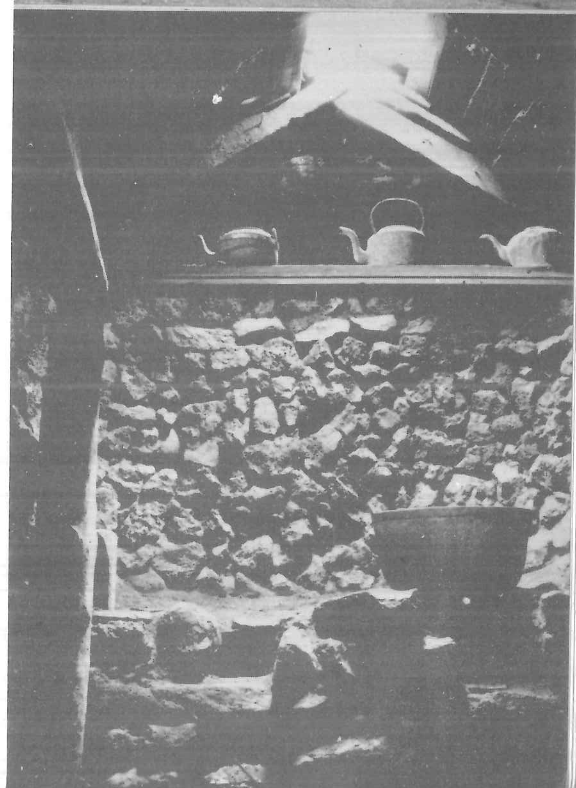
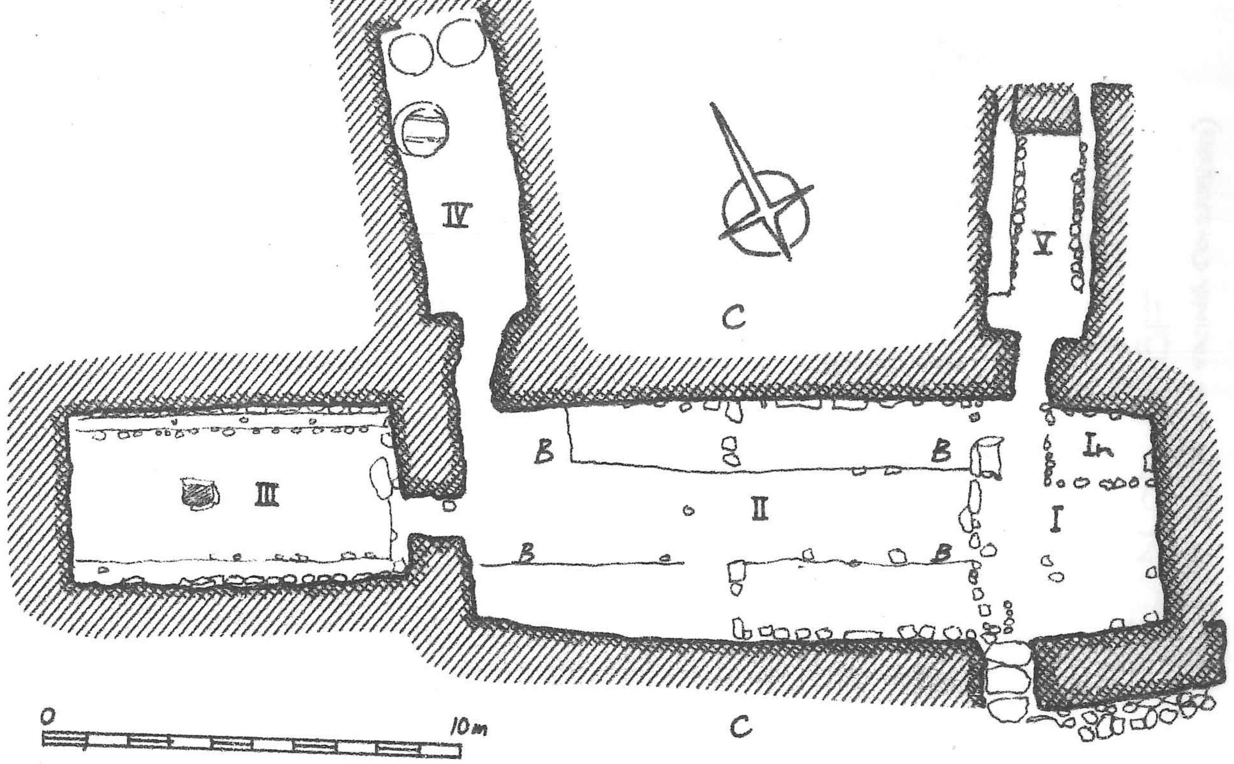
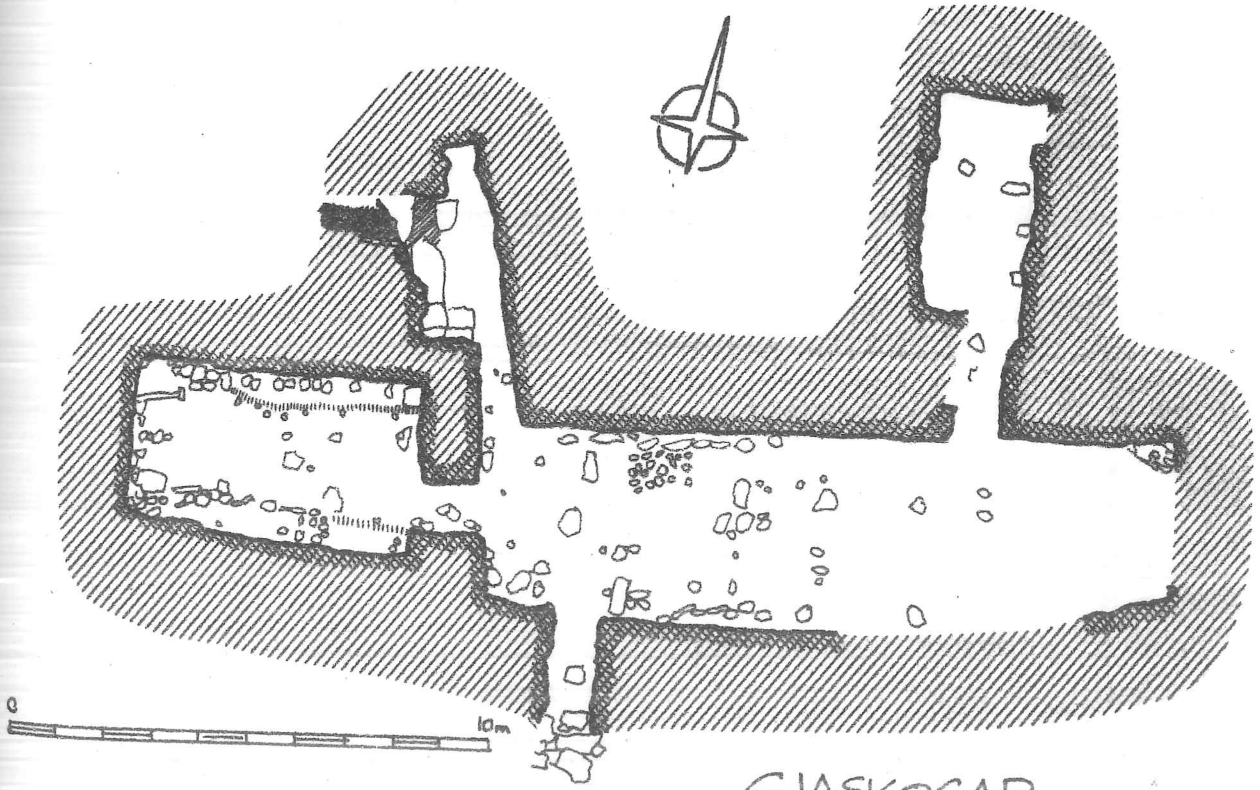


FIGURE 10
KITCHEN
INTERIOR
KELDUR



STÖNG

(from "NORISK BYGNINGSSKIKK"
by D. BRUUN)



GJASKOGAR

(from THE FOURTH VIKING CONGRESS)

FIG 6

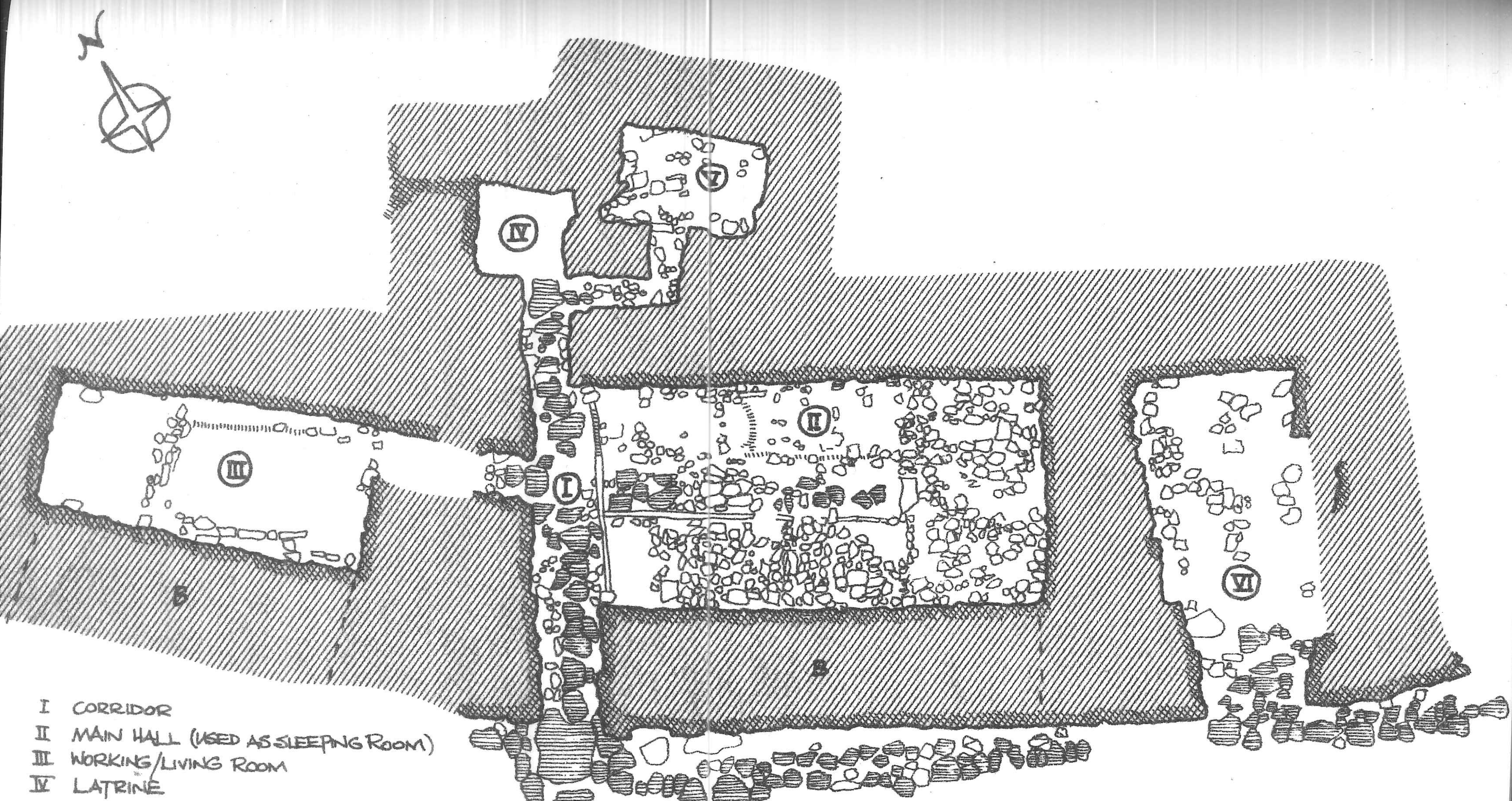


FIG. 7

PLAN OF GRÖF
(FROM THE FOURTH VIKING CONGRESS)

to the main hall. These rooms were first of all a dining room which was later also used as a living room when the main hall changed to a sleeping room. A good example of a later 'langhus' is at the Aslakstunga farm in the Thjorsar valley which is illustrated in figure 1. By the position of the larder (C) the next stage of development can be traced. Rooms no longer were added to the length but were extended backwards from the main hall.

In 1939 a joint Scandinavian expedition excavated many farms in southern Iceland. Amongst these farms were Stöng, and Gjaskogar which were both destroyed by Hekla volcanic eruptions in the eleventh century. They are both of the long house with extensions type and Stöng is said to be the best preserved house from the Middle Ages in Nordic countries. The interior of Stöng, illustrated in figure 6 was composed of lava stones which were probably covered with tapestry in the main hall (II). At the only external door the lava stones are also extended to the external wall, a feature which is not unknown in modern design. On entering this house a part of the hall (I) would be enclosed by a wall, a-a, with a room situated in the south corner (Ia). This would serve as a sleeping compartment for the farmer and his wife. The main hall is divided into three by the wooden, raised floor along each wall, b-b. Looking at the plan it seems that the hall has been divided into two, c-c. It might be that this is an example of a separate man/woman hall which is mentioned several times in the sagas. At the end of the hall was a door to the living/working room (III), which had benches along the walls and a fireplace in the middle. Rooms I, II and III are typical long house type but in addition there is a dairy (IV) with three large milk containers. The function of the other room (V) is not known but it might have been used as a meat storeroom.

The farm Gjaskogar, illustrated in figure 6, was situated 100 m higher than Stöng, two kilometres to the north-east. In Iceland a change of 100 m in altitude means a considerable climatic difference and it is interesting that the turf walls at Gjaskogar are much thicker than at Stöng. This farm was deserted before Stöng even though they both were destroyed during the same Hekla eruption. Probably the reason was that the place did not prove suitable for agriculture. Habitation at this site can be interpreted as an unsuccessful attempt to sustain life by farming beyond the habitable frontier.

The next stage of farm development is the corridor house. An early type is the farm at Gröf where different rooms lead off from a middle corridor. By cutting out the walls, B.B., shown in figure 7, and replacing the turf with a wooden wall, the stage of the fully developed corridor house was reached. This is illustrated in figure 8 from Laufas and in the next section on the farm at Glaumbaer. Remains of this farm type exist throughout Iceland today and after further work in 1972 this type will be described in an undergraduate thesis.

GLAUMBAER TURF FARM (SKAGAFJÖRDUR)

Wendy Huddart

The buildings in this farm group, illustrated in figure 9, date from slightly different periods in the eighteenth and nineteenth centuries, but all are built in the style of turf construction which was universal in rural areas of Iceland until about 1900. Extensive turf construction in Iceland evolved as a result of the shortage of large trees. Consequently the buildings at Glaumbaer are constructed from thin shells of imported wood separated from one another and insulated by thick walls of turf. They are also roofed with a layer of the same material.

Since it is difficult to build large structures of turf, the old Icelandic farm was a complex of small separate buildings. The most frequently used of these were united by a central passageway but storerooms could only be reached from outside.

Glaumbaer consists of sixteen separate areas and a brief description and plan of these follow.

Room 1. Entrance passageway

The passageway in Glaumbaer is unusually long (69 feet). It provides access to nine of the thirteen rooms, and has two intermediate doors to prevent the cold air penetrating to the living areas.

Room 2. Guest room

This room was built in 1841 and in August of that year one of Iceland's most loved poets, Jonas Hallgrimmson, slept in it. Several lines from one of his love-poems are to be found embroidered on the bed-curtains.

Room 3. The kitchen

This is the oldest part of the Glaumbaer complex, dating from about the middle of the 18th century. These kitchens were often the

1 entrance passageway
2 and 11 guest rooms
3 kitchen
4 main pantry
5,6,7 badstofa
8 south door
9 long pantry
10 dairy
12 and 13 storerooms
14 smithy
15 fuel storeroom

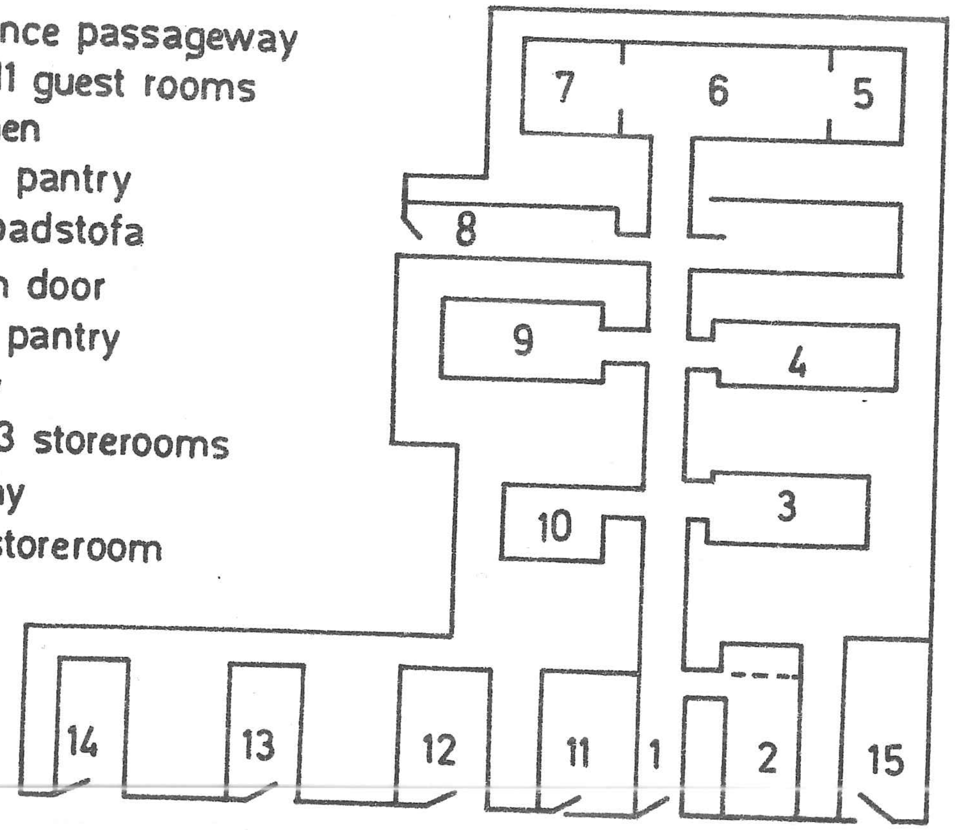


FIGURE 9 GLAUMBAER FARM PLAN

longest surviving parts of these buildings since an encrustation of soot on the woodwork and the draught and dry air acted as preservatives. This one was in continuous use until about 1900. In it were prepared meals for more than 20 people. The most common fuel was peat or dried, and consequently odourless, sheep dung.

Room 4. <u>The main pantry</u>

Here food was assembled and divided into portions by the farmer's wife. Poor trading conditions with other countries resulted in an extensive production of home-made utensils some of which are displayed.

Rooms 5-7. <u>The Baðstofa</u>

The baðstofa in the Icelandic farm was the living room in the truest sense of the word. Here the farmer, his family and the hired hands ate, slept and worked.

The baðstofa at Glaumbaer has 11 beds and since often two people would sleep in a bed, the baðstofa could accommodate 22 people. Each man worked and ate sitting on his own bed. Above the bed is a shelf on which he kept his 'askur' - a cylindrical wooden dish or bowl with a lid often intricately carved. In this his food was brought from the pantry.

The women's side was by the window since their work was usually more intricate than the men's, e.g. spinning and sewing. The men combed wool, made ropes from horsehair and carved. During the long winter evenings as people worked, a member of the household might recite or read passages from saga writing or poetry. Sometimes a semi-professional reciter would tour the farms in the neighbourhood.

On retiring, still partially clad, people would pull over themselves woollen blankets and warm featherbeds which they themselves had made. They would then tuck these in using a carved wooden board known as a 'rúmfjöl'. Putting the 'rúmfjöl' into position at night was equivalent to uttering the prayer which would be carved on it. The women slept beside the window, the men on the other side of the aisle.

Living in such confined circumstances meant that a high degree of mutual respect and tact must be practised in order to sustain harmony. What a man kept beneath his pillow was as safe from prying eyes as if it had been in a locked box.

The baðstofa was heated by the body heat of its inhabitants. This was possible because of the excellent insulating properties of the

Icelandic turf. The relatively bacteria-free Iceland air discouraged body odours. The baðstofa was partitioned into three rooms. The northernmost (No.5) contains two beds with a 'high bed' for children above them. In the central part (No.6) can be seen the various implements which were used by the inhabitants in their daily work. Clothes made from Icelandic wool have been exported for centuries and this home wool industry was the chief labour of the women throughout the long winters. In the southernmost chamber (No.7) slept the farmer and his wife.

Room 8. The 'south door'

The door itself was used to bring in water and to take out ashes. It would also be used as an emergency exit in the event of fire in the front part of the building.

Room 9. The 'long pantry'

Here would be stored 'slatur' (innards, pressed meat from the heads of sheep, feet of sheep pickled in sour whey, etc.) and sour 'skyr' which is rather like yogurt. The coolness of the rooms is ideal for food storage.

Room 10. The Dairy

Fresh milk was separated in this room to obtain several products, e.g. cream, butter, skimmed milk and 'skyr'.

Room 11. Guest room

This room and the loft above it date from 1878 and replaced the room across the corridor as the principal guest room.

Rooms 12 & 13. Storerooms

These rooms can only be entered from outside. The turf saddle to be found on display indicates the strength and durability of Icelandic turf.

Room 14. Smithy

Most Icelandic farms had their own smithy. In this one an eagle's claw carved on the bellows is a charm against fire.

KELDUR ā RANGALORUM

C. J. North

Keldur is a turf farm with a long history. It is situated south-west of Hekla in the richest farming area of Iceland 96 km from Reykjavik. Its name means 'Spring Vale' which describes its character even today.

The lava covering Iceland is porous leaving a great amount of water underground. Keldur is the place where water comes to the surface at three points. This is a spring-line settlement with fertile land to the south and infertile land to the north.

Each occupant since its first settler in 970 A.D. is known including Ingjald of Keldur who refused to support Flosi in Njal's Saga. The building there today, illustrated in figure 10, is of unknown exact date but is one of the later designs from the 16th or 17th centuries. However the kitchen is known to date from the 11th century and the original 'skali' or fire-hall has been divided into two rooms and an entrance. Rooms have also been added above for sleeping. There is also a recently discovered escape tunnel dating from the 12th century which leads from a corner of the 'skali' towards the stream and emerges only 20 metres away but already out of sight of the farm house and any attacking force. There are four outhouses of a later date.

A 19th century addition was built in corrugated iron. This is also two storeys high but in great contrast to the thick walls and turf covering on the roof of the earlier part. The present owners who still work the farm (with fewer livestock than some of the 13th century farmers who had nearly 300 head of cattle), occupy a more recent building. Keldur, like many Icelandic farms, also has a family church. This was built in 1891 on the site of an earlier church and is used every three weeks for services led by a Lutheran Minister who is responsible for three such family-farm churches.

THE DISTRIBUTION OF THE ICELANDIC HAREBELL

Hugh McAllister

In Iceland the distribution of the native harebell (identified either as Campanula rotundifolia or Campanula gieseckiana) presents a problem. It is common on the east coast, from Skeithara, south of Vatnajökull to Vopnafjördur in the north east, and also in the area around Eyjafjördur in the north (Gröntved 1942). It only occupies the narrow coastal strip of fjords and glaciated valleys and becomes very sparse as one moves inland towards the drier central highland desert. It is not found in the highlands themselves, and is very rare with a scattered distribution throughout the rest of lowland Iceland.

The peculiar feature about the distribution of the harebell in Iceland is its rarity throughout most of the country while being so common in the east. If it were present only in the east the distribution could perhaps be interpreted as the result of an inability to spread across geographical barriers. However, it does occur in widely scattered localities throughout the country from which it seems to be incapable of spreading.

Climatically the east and the Eyjafjördur areas are not unique. The growing season is relatively long (an important attribute in considering a late flowering species such as the harebell), but shorter than in the south and south-west. Also the harebell grows and seeds very successfully in cultivation in Reykjavik in the south-west, and there is no obvious reason why it should not spread from its isolated localities in this area.

The east and the Eyjafjördur areas are, however, geologically comparatively old, being composed of Tertiary basalts. Both areas have high mountains rising steeply from fjords. This has been described by Dahl (1946) as the ideal situation for periglacial survival because the coastal slopes of the mountains are protected from the inland ice. The south and south-west are, in contrast, very young geologically, and relatively flat.

Only a very few species (e.g. Trientalis europea and Saxifraga aizoides) are common in the east and almost totally absent elsewhere. On the other hand there are several species (e.g. Carex glacialis) confined to the mountains round Eyjafjördur and the eastern fjords.

Yet others (e.g. Primula stricta, and Phyllodoce caerulea) are wholly confined to the Eyjafjördur area. Thus a considerable number of species have been able to survive in Iceland only in these two areas. Here, not only are geomorphological conditions favourable for periglacial survival, but also the steep, stepped (as they are composed of successive lava flows) mountains rising directly from the sea to ice capped summits provide a wide range of habitats very close to one another. Extensive populations of harebells have therefore probably been able to survive in these two areas since at least the last (Eem) interglacial.

If the harebell were native only in east and north Iceland, it could be a relatively recent newcomer from Scandinavia or the British Isles. In this it might be similar to Trientalis europea and Alchemilla faeroense, which are confined to east Iceland and only otherwise occur in Europe. They are absent from Greenland and North America.

I consider it very unlikely that the Icelandic harebell has come from the British Isles as the north-western areas of the British Isles nearest to Iceland are inhabited by hexaploids (2n = 102), while the Icelandic plants are tetraploid (2n = 68). They could however have come from Scandinavia, perhaps via the Faeroes, as both these areas are inhabited by tetraploids, (Böcher 1960). If this interpretation were correct, the scattered localities outside east and north Iceland could not be considered as relic populations. Instead they would be seen as introductions, brought about either through the agency of man, or such seed-eating birds as the snow bunting which migrate over long distances. However, the introduction of a single, self-sterile genotype (most tetraploids are totally self-sterile) would not allow any spread by seed from an original introduction site - and introductions by man or birds would most frequently be of single individuals.

The existence at Gilsbakki (an isolated locality in west Iceland) of three populations separated by several hundred metres therefore argues against this above interpretation and in favour of at least this population being relic.

Outside east and north Iceland the harebell only occurs in scattered localities in the lowlands. Einarsson (pers. comm.) has suggested that many of such occurrences are probably introductions, and it is true that the harebell is frequently cultivated in gardens in Reykjavik. Jonsson (Director, Botanical Gardens, Reykjavik, pers.

comm.) reports that many people moving from the east to other parts of Iceland frequently take with them native plants of the harebell for their new gardens. However, Jonsson considers a plant growing in the Reykjavik Botanical Gardens originating from Dyrafjördur in the north-west Peninsula to be from a native locality.

As mentioned above, I also consider a specimen collected at Gilsbakki, near Husafell, to be native. It grew on a stream-bank in native vegetation in an improved pasture in which the improvement had probably been confined to fertilisation. In the same area the harebell was reported (Magnusson - farmer of Gilsbakki, pers. comm.) to have been seen within the last ten years in a river gorge and in an area of birch woodland. The birch wood locality was not visited, but in the gorge site no harebell plants were found. No harebell was seen in cultivation on any of the farms in the area. Indeed, the only introduced plants grown were usually shelter belt trees and imported grass seed for pasture improvement. Although it is true that such imported seed might include harebell as a contaminant, the three sites in which the species had been seen were not in pasture. This suggests that they were native occurrences.

Most of the scattered localities are represented by flowering specimens in the Reykjavik Herbarium. However, if the Gilsbakki locality is at all typical, many of these populations may be very small. At Gilsbakki flowering has not been noticed in any of the three sites for several years, and the only plant found was growing rather poorly on a stream-side, rock ledge. It bore several flowering stems with very small buds, which are unlikely to have had time to develop to flowers, let alone seed, in 1971. As 1971 was the best summer in Iceland for ten years, it is probable that the harebell has not flowered in this locality for many years. Thus, these very small scattered populations may often be in unfavourable habitats, and rarely produce seed. They are also likely to be inbred and genetically weak, and thus be incapable of spreading even though the climate is suitable. If such a population were reduced to a single genotype, as may have happened at Gilsbakki, subsequent spread by seed is likely to be impossible as the tetraploid cytotype is usually self-sterile.

Löve and Löve (1965) have concluded that Iceland was joined by land bridges to Europe (Britain and Scandinavia) and Greenland in the last (Eem or Ipswichian) interglacial, but has been isolated ever since.

They suggest that some species have survived in coastal nunataks since the Pliocene, and that virtually all the native flora has survived in such situations since the last interglacial.

If this interpretation is correct, I consider it most likely that the Icelandic harebell arrived from Scandinavia or Greenland no later than the last interglacial. It must have survived the most recent (Weichselian) glaciation in refugia, primarily in the east and north, from where it has since spread to a limited extent. According to this interpretation the scattered localities throughout all parts of Iceland, except the east and north, could be the result of both periglacial survival and recent introduction. It does not seem reasonable to postulate a post-glacial expansion over the whole country followed by massive extinction.

MORPHOLOGY

Morphologically the Icelandic harebells are very similar to British mountain tetraploids. They have few large flowers borne on relatively stout stems. All specimens seen have their leaves and the lower parts of their stems covered in the minute pilose hairs typical of most harebells. No glabrous individuals were found.

Many plants had the very distinct hemispherical ovaries typical of Campanula gieseckiana. No population consisted entirely of such individuals. Some plants in every population had the conical ovaries which taper into the pedicel, typical of Campanula rotundifolia. This suggests that ovary shape may be under fairly simple genetic control, and is therefore a poor diagnostic character. The plans from Dyrafjördur in the north-west and Gilsbakki in the south-west had conical ovaries.

All the Icelandic plants examined were tetraploid.

TAXONOMY

The above discussion still leaves unsettled the question of whether Icelandic plants should be referred to C. gieseckiana ssp. groenlandica or C. rotundifolia. If, as suggested above, Icelandic harebells are derived from east Greenland or northern Scandinavian populations, the answer should perhaps be C. gieseckiana ssp. groenlandica. This would be presuming that, before the Postglacial (Holozän or Flandrian), northern Scandinavia was occupied by C. gieseckiana. Only this species occurs in Greenland today.

From other data it has been concluded that up to the end of the last (Weichselian) glaciation arctic areas were occupied by diploid and tetraploid cytotypes of C. gieseckiana. The extent of such populations is indicated by the presence of diploids today on Mount Washington in Greenland, Svalbard, and in arctic Norway. At that time C. rotundifolia is believed to have been confined to continental areas of central Europe.

As the diploid ssp. gieseckiana is so widely distributed in arctic areas today, it is almost certain that ssp. gieseckiana, and probably the tetraploid ssp. groenlandica as well, were continously distributed over the North Atlantic land bridge. It is therefore perhaps rather surprising that the diploid ssp. gieseckiana has not been found in Iceland, which has plenty of fell-field habitats suitable for such an arctic species. On the other hand, Iceland lacks the high arctic refugia such as are present in Greenland and Svalbard, and so the diploid may have become extinct in Iceland during a mild period in the post-glacial or the last interglacial. It is, however, possible that diploids may yet be found in Iceland, and they are most likely to occur in the hills surrounding Eyjafjördur. This area is the refuge of most of Iceland's high arctic species.

Evidence which suggests that the Icelandic harebells came from Scandinavia rather than Greenland is the fact that many Icelandic plants have deep mauve pollen similar to that of many European plants. Böcher (1960) describes all Greenland plants as having cream coloured pollen.

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THE VEGETATION OF THE THORISDALUR AREA

Hugh McAllister

The area and individual sites to be discussed are indicated in figure 1. Species lists were made for each of 11 sites and table 1 constructed to demonstrate the distribution of each species. Before discussing the species distribution some comment on the environmental conditions within each site will be given.

Sites M and T

In the centre of the region is the moraine (Site M), with the terminal moraine (Site T) at its westerly end. These two areas were covered by the North Thorisjökull glacier until about 1890, since when the ice has been retreating. Thus, any species growing on either of these two sites has colonised it in the last 80 years and has presumably spread from the surrounding vegetation.

Sites K,H,O, F and S

These sites are situated west of the moraine and mostly at a lower altitude. Most of this area consists of a sandur, much of which is colonised by Rhacomitrium canescens which has brought about the formation of a peaty ranker soil between the stones. The most frequent vascular plant is Salix herbacea. This is accompanied by Polygonum viviparum, tussocks of Silene acaulis and Armeria maritima, and an occasional prostrate shrub of Salix glauca and Salix lanata.

North of the sandur are the south-facing slopes of Hadegishnukur (H) and part of Prestanukur (F). Since they are south-facing and at a relatively low altitude, these are probably the warmest habitats in the region. As the slopes are steep and broken by cliffs, the duration of the snow-cover will vary enormously giving a wide range of habitats including those with the largest growing season of any in the area. Hadegishnukur is largely composed of tuffs (volcanic ashes) which readily weather to yield a dark, easily warmed, friable soil eminently suitable for plant growth. However, long unbroken slopes are subject to rapid erosion. Prestanukur on the other hand consists of perlite (a glassy rhyolite), with bands of obsidian. On weathering the perlite gives rise to a clay which normally forms a cold, wet soil. The part of Prestanukur in area L also contains a hot spring with a temperature of about 35°C. These two mountains therefore yield a wide range of habitats and are much richer in species (52) than the sandur (18). The vegetation, however, is very sparse, and when viewed from a distance appears as small green patches which mark the flushes. With respect to the whole region these mountains contain the habitats with the warmest and longest growing seasons and the greatest degree of soil development.

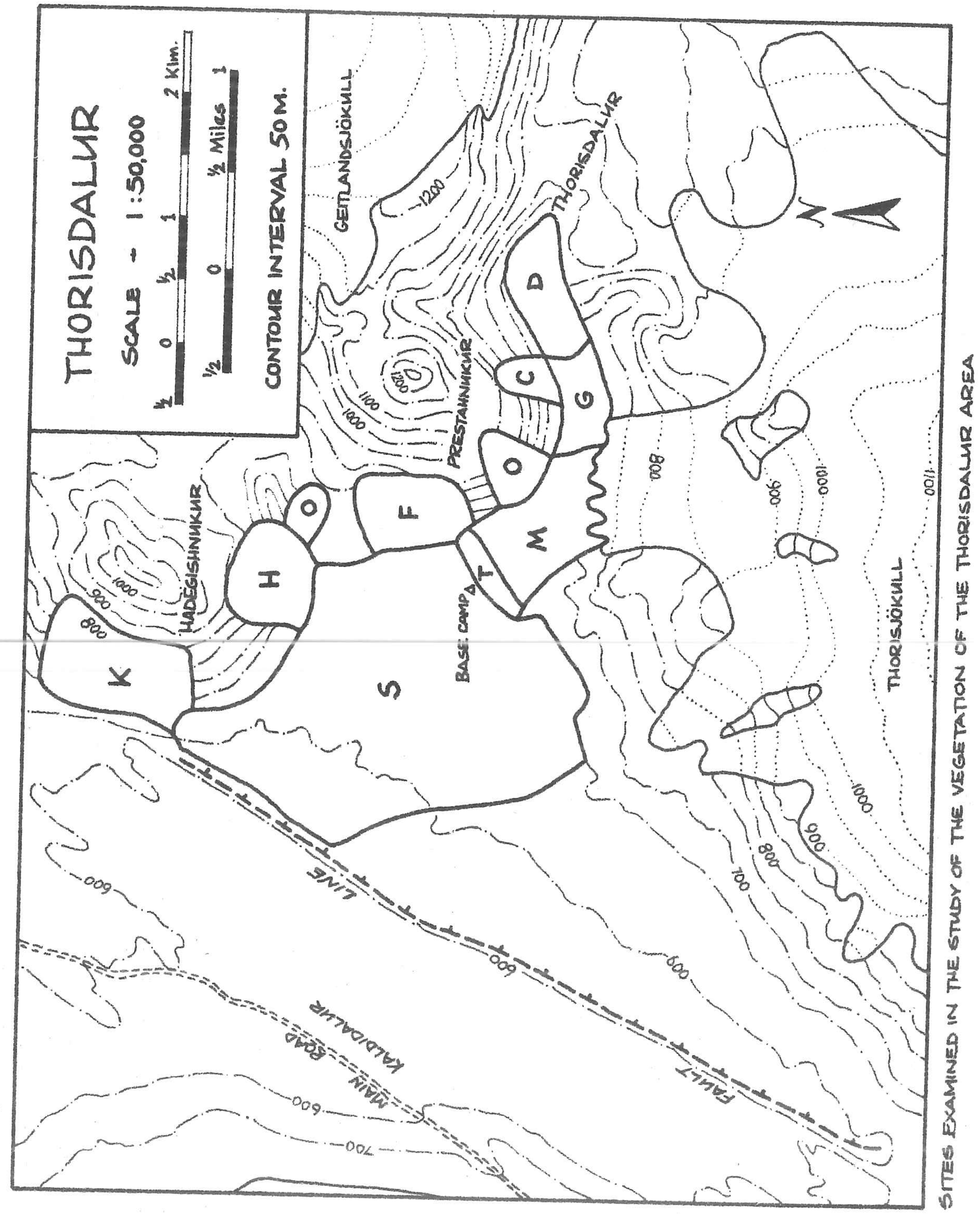
Sites G,R,C and D

These are situated at a higher altitude than the moraine and include most of Prestanukur, with two cold flushes (R and C) which are reputed to have been hot about ten years ago. Also in this area are Thorisdalur proper, a tuff mountain (D) and an area of bryophyte flushes (G). All these sites must until recently have been isolated by North Thorisjökull. This area must have been very cold, with long snow lie and a short growing season. However, some vascular plant species were confined to the bryophyte flushes or the former hot springs and many bryophytes were only found on the tuff mountain.

Table 1 gives the distribution of the sixty-two vascular plants, together with information on seed production and germination and the occurrence of seedlings. The seed collections were made on August 28th after the end of the growing season when most species had been frosted and new snow was beginning to lie. It was considered that no further development or ripening of seeds could occur. The year in which this study was carried out (1971) had a longer and warmer summer than any recorded in Iceland in the previous ten years. The non-production of seed, therefore, suggests that that species rarely, if ever, produces seed in this region. It must be a relic which has survived vegetatively for perhaps hundreds of years from a time when the climate was more favourable. The previous summer (1970) had been one of the worst recorded recently and so the occurrence of first year seedlings can be taken to indicate that seed will be produced almost every year.

Of the sixty-two species which occur in the area only twenty have spread to sites T and M which have been avilable for colonisation for about eighty years. Of the nineteen species occurring on the sandur, sixteen occur on the terminal moraine (T), with Sagina procumbens the only additional species. Of these sixteen, thirteen occur on the moraine (M) with the addition of Cerastium alpinum, Sagina procumbens, Saxifraga cespitosa and Saxifraga nivalis.

FIG. 1



SITES EXAMINED IN THE STUDY OF THE VEGETATION OF THE THORISDALUR AREA

Table 1

	K	H	O	F	S	T	M	G	R	C	D	Fruit	Viable Seed	Dehisced Fruit	1st Year Seedlings	Young Plants	Percentage Germ.
Agrostis stolonifera	–	–	O	–	–	–	–	–	–	–	–	0	0	0	0	0	0
Alchemilla alpina	–	H	–	–	–	–	–	–	–	–	–	+	+	0	0	0	c5
Arabis alpina	–	–	–	–	–	–	–	G	–	–	–	+	+	0	0	0	65
Armeria maritima	K	H	–	–	S	T	–	–	–	–	–	+	+	0	(+)	+	50
Bartsia alpina	–	H	–	–	–	–	–	–	–	–	–	+	+	0	0	0	96
Botrychium lunaria	–	H	–	–	–	–	–	–	–	–	–	+	?	?	?	?	?
Cardamine pratenis	–	–	–	–	–	–	–	G	–	–	–	0	0	0	0	0	0
Cardaminopsis petraea	K	H	O	F	S	T	M	G	R	C	–	+	++	+	+	+	?
Cassiope hypnoides	K	H	–	–	S	–	–	–	–	C	–	+	+	0	0	0	?
Cerastium alpinum	–	H	–	–	–	–	M	–	–	–	–	+	+	+	?	0	?
Cerastium arcticum	K	H	O	F	S	T	M	G	R	C	D	+	++	+	+	+	?
Cerastium cerastioides	–	–	O	F	S	T	M	G	R	C	D	+	++	+	+	+	?
Carex bigelowi	–	H	–	–	–	–	–	–	–	–	–	+	0	0	0	0	0
Deschampsia alpina	K	H	O	F	S	T	M	G	R	C	D	+	++	+	++	+	–
Draba rupestris	–	H	–	–	–	–	–	G	–	–	D	+	?	?	?	?	?
Dryas octopetala	K	H	–	–	–	–	–	–	–	–	–	+	+	0	0	+	?
Empetrum hermaphroditum	–	–	–	F	S	T	(M)	–	–	–	–	0	0	0	+	0	0
Epilobium anagaladifolium	–	–	O	–	–	–	–	G	–	–	–	+	+	0	0	?	16
Epilobium hornemannii	–	–	–	–	–	–	–	G	–	–	–	+	++	0	0	0	48
Equisetum arvense	–	–	O	–	–	–	–	G	R	–	–	?	?	?	?	?	?
Equisetum variegatum	K	H	–	–	–	–	–	–	–	–	–	?	?	?	?	?	?
Erigeron borealis	–	H	–	–	–	–	–	–	–	–	–	+	0	0	0	0	0
Eriophorum angustifolium	–	–	–	–	–	–	–	–	–	C	–	+	0	0	0	0	0
Eriophorum scheuchzeri	–	–	–	–	–	–	–	G	–	C	–	+	0	0	0	0	0

See page 68 for key.

Table 1
cont'd

	K	H	O	F	S	T	M	G	R	C	D	Fruit	Viable Seed	Dehisced Fruit	1st Year Seedlings	Young Plants	Percentage Germ.
Festuca rubra	K	H	–	F	–	–	–	–	–	–	–	0	0	0	0	0	0
Festuca vivipara	K	H	O	–	–	–	–	–	–	–	–	+	+	0	?	?	–
Galium sternmeri	–	H	–	–	–	–	–	–	–	–	–	+	0	0	0	0	0
Gnaphalium supinum	–	–	–	F	–	–	–	–	–	–	–	?	?	?	?	?	?
Hieracium (subsect.) alpinum	–	H	–	–	–	–	–	–	–	–	–	+	+	+	0	0	?
Hieracium (subsect.) vulgatum	–	H	–	–	–	–	–	–	–	–	–	+	+	+	0	0	59
Juncus trifidus	–	H	–	–	–	–	–	–	–	–	–	+	0	0	0	0	0
Luzula arcuata	–	H	O	F	S	T	M	G	R	C	–	+	++	+	0	0	100
Luzula spicata	K	H	O	F	S	T	–	G	–	C	–	+	++	0	0	0	100
Minuartia rubella	K	H	–	–	–	–	–	–	–	–	–	+	+	+	0	0	?
Oxyria digyna	K	H	O	F	S	T	M	G	R	C	D	+	++	0	+	+	?
Poa alpina (viv.)	K	H	O	F	S	T	M	G	R	C	D	+	++	0	++	+	–
Poa alpina (non-viv.)	–	H	–	–	–	–	–	–	–	–	–	+	+	+	0	0	63
Poa flexuosa	–	–	–	–	S	T	M	G	R	C	–	+	++	0	++	+	88
Poa glauca	K	H	–	–	–	–	–	–	–	–	–	+	+	0	+	+	92
Polygonum viviparum	K	H	O	F	S	–	–	–	–	–	–	+	++	+	++	+	–
Sagina procumbens	–	H	–	–	–	T	M	G	–	–	–	+	++	+	++	+	70
Salix herbacea	K	H	O	F	S	T	M	G	R	C	D	+	++	+	+	+	100
Salix glauca	K	H	O	F	S	T	M	G	R	C	–	+	++	+	0	+	100
Salix lanata	–	H	–	–	S	T	M	G	–	–	–	+	?	?	0	0	?
Salix phylicifolia	–	–	–	–	–	–	–	G	–	C	–	+	?	?	?	0	?
Saxifraga cespitosa	–	–	–	–	–	–	M	G	–	–	D	+	++	+	++	+	?
Saxifraga hypnoides	–	H	–	–	–	–	–	–	–	–	–	0	0	0	0	0	0
Saxifraga nivalis	–	H	–	–	–	–	(M)	G	–	–	D	+	++	+	++	+	?

See page 68 for key.

Table 1
cont'd

	K	H	O	F	S	T	M	G	R	C	D	Fruit	Viable Seed	Dehisced Fruit	1st Year Seedlings	Young Plants	Percentage Germ.
Saxifraga oppositifolia	K	–	–	–	S	–	–	–	–	–	–	+	?	?	?	?	?
Saxifraga hyperborea	–	–	–	–	–	–	–	G	–	–	–	+	++	+	+	+	100
Saxifraga stellaris	K	H	O	F	S	T	M	G	R	C	–	+	+	+	0	+	?
Sibbaldia procumbens	–	H	–	F	–	–	–	–	–	–	–	?	?	?	?	?	?
Silene acaulis	K	H	–	F	S	T	–	–	–	–	–	+	+	+	+	+	100
Silene maritima	–	H	O	–	–	–	–	–	–	–	–	+	+	0	0	0	36
Taraxacum (sect.) crocea	–	H	O	F	–	–	–	G	–	–	–	+	++	+	?	+	?
Taraxacum (sect.) crocea	–	–	–	–	–	–	–	G	–	–	–	+	+	+	?	?	?
Taraxacum faeroensiforme	–	–	–	–	–	–	–	–	–	C	–	+	+	+	?	?	?
Thymus drucei	–	H	–	–	–	–	–	–	–	–	–	+	+	0	0	0	?
Tofielda pusilla	–	H	–	–	–	–	–	–	–	–	–	+	?	?	?	?	?
Trisetum spicatum	–	H	–	–	–	–	–	–	–	–	–	+	+	+	0	0	32
Veronica alpina	–	H	–	–	–	–	–	–	–	–	–	+	+	+	?	?	?
Veronica fruticans	–	H	–	–	–	–	–	–	–	–	–	+	+	0	0	0	2
Viscaria alpina	–	H	–	–	–	–	–	–	–	–	–	+	++	0	0	+	100
TOTALS: 63 species	20	45	18	18	19	17	17	26	12	17	9	54	42	23	17	21	
Number of species exclusive to one site	–	17	1	1	–	–	–	5	–	2	–						

See page 68 for key.

KEY TO TABLE 1

K - Part of Hådegishnukar facing fault in Kaldidalur.

H - South facing slopes of Hådegishnukar facing Thorisdalur.

O - Hot spring (c 35°C) on Prestahnukur

F - Flushes of Prestahnukur

S - Sandur

T - 1890 terminal moraine

M - Moraine, uncovered since 1890.

G - "Green valley" flushes in Thorisdalur

R - Former hot spring on Prestahnukur above moraine

C - Former hot spring on Prestahnukur above "Green valley"

D - Porisdalur above "Green valley".

Fruit	-	Presence or absence of fruit - ripe or unripe.
Viable Seed	-	Presence of seed which will germinate. ++ denotes large quantities.
Dehisced Fruit	-	Presence of dehisced fruit after end of growing season (28.8.71).
1st Year Seedlings	-	Presence of seedlings which had germinated this growing season.
Young Plants	-	Presence of young plants obviously derived from seed.
Percentage Germ.	-	Maximum percentage germination obtained with 25 seeds.

Looking at the species in site M from the other direction, of the twenty-six species in the 'Green valley' (G), fifteen occur on the moraine, with *Cerastium alpinum* and *Empetrum hermaphroditum* being the only additional species.

Cerastium alpinum is therefore the only species found on the moraine or terminal moraine and not in either of the neighbouring habitats (S and G). This could be a case of longer distance dispersal. However, *Cerastium alpinum* is difficult to distinguish from *Cerastium arcticum* and so could easily have been missed, especially as it is very rare.

The above information is summarised in the table below.

Table 2

Diagrammatic representation of the possible directions of spread of species onto the areas deglaciated in the last 80 years.

Sandur (S)	Terminal Moraine (T)	Moraine (M)		'Green Valley' (G)
19	16	13		
	+	+		
	Sagina procumbens	*Cerastium alpinum* *Sagina procumbens* *Saxifraga cespitosa* *Saxifraga nivalis*		
	17	17		
		15		
		+	←	26
		Cerastium alpinum *Empetrum hermaphroditum*		
		17		

Of the sixty angiosperms in the area all but two (*Saxifraga hypnoides* and *Empetrum hermaphroditum*) flowered in 1971, although only forty-two produced viable seed. These included nineteen of the twenty species in areas T and M. The one exception was *Empetrum hermaphroditum* which will be discussed later.

Of the forty-two species producing seed only twenty-three had ripened and dispersed their seed or propagules by August 28th. In the other species the fruits were still green and in many species these had been frosted. These twenty-three species included sixteen of the twenty species which occur in areas T and M. Of the four species not ripening seed, Poa flexuosa occurs in both areas whilst the other three, Armeria maritima, Empetrum hermaphroditum and Luzula spicata are absent from the area M. The eight species ripening seed but not occurring in areas T or M are the three Taraxaca, the two Hieracia, Minuartia rubella, non-viviparous Poa alpina and Saxifraga hyperborea.

First year seedlings were found from only seventeen species. Fifteen of these occurred in sites T and M. In these two sites there were only six species where no seedlings were found (Cerastium alpinum, Luzula arcuata, Luzula spicata, Salix glauca, Salix lanata and Silene acaulis). Seedlings of Poa glauca and Saxifraga hyperborea were found but the species do not occur in these two areas.

The above information can be summarised as follows:- in 1971 of the twenty species in areas T and M nineteen (59) flowered, nineteen (42) set seed, sixteen (23) ripened and dispersed seed before the end of the growing season and fifteen (17) had first year seedlings present (the figures in brackets are the totals in each category for the whole area). Thus, compared to the flora of the whole area, a very high proportion of the species in sites T and M set and ripened seed which was able to germinate successfully. This was despite such a short, cold summer as in 1970. This suggests that the species occurring in these two sites have spread from the surrounding localities and that only these species which regularly produce large amounts of fully ripened seed have been able to colonise the new ground made available by deglaciation. The apparent exceptions to this hypothesis will now be examined.

By far the most striking exception is the occurrence of Empetrum hermaphroditum which was not seen to flower in the area. However, a cluster of five first year seedlings was found on the moraine by Wobey (1971). This would seem to be a clear case of the introduction into the region by birds of a species which can barely survive in the harsh climate. The few plants which occurred on the terminal moraine and the slopes of Prestanukur were growing poorly and had long, bare, straggling stems which only bore leaves towards the ends.

Of the three other species not ripening and dispersing seed before the end of the growing season, Poa flexuosa was the most surprising. This species achieved its best development on the moraine and was perhaps the commonest and most successful species in the areas nearest the glacier. By August 28th all the seed was fully formed but the panicles were still tinged with green and red and none of the seed seemed to have been shed. However, some of the previous year's dry panicles were still standing erect, devoid of seed so presumably the seed is dispersed in the autumn and/or spring. Unlike all the other species present, isolated young plants were frequently found some distance from a mature specimen.

The other two species, Armeria maritima and Luzula spicata seem to have spread to the terminal moraine from the sandur where both are quite frequent. However, on the terminal moraine they flower later than on the sandur and they produce fewer, lighter seeds. Thus, they seem to have reached a tolerance limit imposed by the short growing season. Luzula spicata, however, grows successfully above the moraine in the 'Green valley' and on Prestanukur.

The absence of seedlings of six species which occur at sites T and M might be taken to suggest that they failed to produce seed in the previous, harsh summer. This could certainly be true of Luzula spicata and Silene acaulis and perhaps also of Salix glauca and Salix lanata which ripen seed noticeably later than Salix herbacea. However, the willows are very long lived and the occasional survival of a seedling may be adequate to maintain the population. At least six young plants of Salix glauca were seen in the area. Cerastium alpinum was very rare so that the fact that no seedlings were found is of little significance and probably due to chance. Luzula arcuata, however, was one of the commonest plants in the area and it is rather surprising that no seedlings were found. Considering the large quantities of ripe, viable seed collected from several sites throughout the region, the absence of seedling and young plants is unexpected. It could be that seed is only ripened in the occasional good season but this would mean postulating that Luzula arcuata behaves differently from all the other species in the area. It is common and able to colonise new areas but only occasionally ripens seed.

The nine species ripening seed or having seedlings present but not occurring in sites T or M are all rare and confined to small areas. It is probable that they have special habitat requirements not met in these two areas. For example, Saxifraga hyperborea requires the stable, wet flush conditions provided by the 'Green valley' springs and not provided by hot springs or snow melt torrents.

The sixty-two species can be divided into groups according to their distribution within the region. The first group consists of the ten very common species which occur throughout the region. These are:-

Cardaminopsis petraea	Luzula spicata
Cerastium arcticum	Salix herbacea
Cerastium cerastioides	Salix glauca
Deschampsia alpina	Saxifraga stellaris
Luzula arcuata	

The other most striking group of species is that which is restricted to a small (about 50 sq.m) area of south-facing slope on Hadegishnukur. The uppermost part of this slope is probably the most favourable habitat in the region as judged from its physical features and the numbers and advanced seasonal state of development of the species present. It is situated under a cliff which provides some shelter and is a shoulder rather than a hollow so does not harbour a late snow patch. The tuff rocks provide a light, warm soil while the broken nature of the ground prevents rapid erosion which is seen on neighbouring unbroken soil slopes. Common species of the region such as Cardaminopsis petraea, Poa alpina and Salix glauca were at a more advanced developmental state than elsewhere in the region.

Forty-three of the sixty-two species occurred in this small area. Seventeen of these species were found nowhere else in the region. These were:-

Alchemilla alpina	*Juncus trifidus
Bartsia alpina	Poa alpina (non viv.)
Botrychium lunaria	*Saxifraga hypnoides
*Carex bigelowi	Thymus drucei
*Erigeron borealis	Tofieldia pusilla
*Galium	Trisetum spicatum
Hieracium subsect. alpinum	Veronica alpina
Hieracium subsect. vulgatum	Veronica fruticans
	Viscaria alpina

Of these seventeen species only three, the Hieracia and Poa alpina (non viv.) ripened and dispersed seed. Even then it was only the plants in the ten sq.m. area at the top of the slope which did so. It is perhaps significant that in Hieracium only fully ripened seed is said to germinate (West, pers.comm.). In addition to these three species the only other species which produced seed in large numbers was Viscaria alpina. In the species asterisked no seed was produced.

Another group of species, presumably thermophilous, is confined to the warm or formerly warm springs. These are:-

*Agrostis stolonifera
Equisetum arvense
*Eriophorum angustifolium
*Eriophorum scheuchzeri
Taraxacum sect crocea

Only Taraxacum produced viable seed.

Of the eleven species proven to have produced no viable seed in 1971, eight are confined to one of the above two favourable habitats. The three other species are Festuca rubra which grows on a flush on Prestanukur and on Hadegishnukur, Cardamine pratensis which is confined to the 'Green valley' flushes and Empetrum hermaphroditum. These non-seed producing species are isolated from the nearest population of the same species by several kilometres. In the case of Carex bigelowi and Festuca rubra this is probably only 3.3-4.8 km as they are found on the lower slopes of Ok, but for the Eriophorum species and the Agrostis it is probably about 16 km. Thus it would seem most probable that these species have survived by vegetative reproduction alone in these favourable habitats for a very long time, perhaps hundreds of years.

The final group contains the two species, Poa flexuosa and Saxifraga cespitosa, which attain their highest degree of development and are most frequent on that part of site M most recently covered by the glacier. These two species therefore seem to grow most successfully in the harshest and most open habitats.

The distribution of vascular plants in the area studied suggests that around 1890 when the moraine (T and M) was covered by North Thorisjökull, the vegetation in the surrounding areas was not very different from that found today. This implies that at least part of the flush area here called the 'Green valley' (G) and probably Thorisdalur proper (D) above the flush area were ice free. It is difficult otherwise to account for the presence of five species which occur nowhere else in the area. A flush on the hillside (C) a short distance above the 'Green valley' carried two exclusive species and another two which were exclusive to that flush and the 'Green valley'. Of the nine species which were exclusive to sites G and C, four (Cardamine pratensis, Eriophorum angustifolium, Eriophorum scheuchzeri and Salix phylicifolia) were not seen to produce seed in 1971. It is thus very unlikely that these four species could have reached these habitats since 1890.

Long distance dispersal, as is being suggested to explain the distribution of Empetrum hermaphroditum, could explain such isolated occurrences and the Eriophorum species and the Salix do have light, wind-borne seeds. However, there are many other suitable habitats for the nine exclusive species in the area, including some in the moraine (M). It is much more probable that these species have survived in situ for a long time and are not there as a result of long distance dispersal.

Further evidence about the extent of recent glaciation comes from the degree of humus development in the soil and the degree of moss cover in areas away from the flushes. It has already been mentioned that parts of the sandur (S), including those adjacent to the terminal moraine, are fairly extensively covered by Rhacomitrium canescens. The surface layers of the soil contain a relatively large proportion of humus and pieces of decaying moss. In contrast the moraine (M) shows very little development of such a moss cover, except for small tussocks on patches of sand and gravel. The species present are Rhacomitrium canescens, Sphereldus minutus and in colder sites near the glacier are found Rhacomitrium heterostichum, Dicranum blytii and Dicranum starkei.

In Thorisdalur proper (D) the latter three species are again the most important, together with Polytrichum norwegicum. However, the moss produces an almost continuous ground cover, with much humus and decaying moss in the soil. In many ways therefore this area resembles the sandur (S). In both the ground appears black due to the covering of moss. On the sandur (S) it is a springy carpet of Rhacomitrium, whilst in Thorisdalur (D) it is the shorter, firmer mat of Dicranum. In both cases the moss mat is interwoven by the roots and rhizomes of

Salix herbacea, although in the degree of seasonal development those on the sandur were far ahead of those in Thorisdalur. In contrast to the sandur and Thorisdalur the soil surface on the moraine appears lighter coloured, with only occasional tussocks of moss or vascular plant. In this area Salix herbacea grew not in a continuous mat but in small round patches.

It is concluded that Thorisdalur has been ice free and capable of bearing vegetation for much the same length of time as the sandur.

SEEDLING OCCURRENCE AND DEVELOPMENT IN THE THORISDALUR AREA

Hugh McAllister

For seven species a study was made of seedling occurrence, the spatial relationship to possible parents and the habitats in which these seedlings were found.

Cerastium arcticum

Within 20 cm of an isolated, mature plant were counted one hundred and two seedlings which bore only cotyledons on July 10th,1971. In this same area there were twenty-nine older, young plants and it was assessed that flowering occurred in the fourth or fifth year. The seedlings were growing on bare gravel.

Oxyria digyna

Within 20 cm downslope of a mature plant were nine seedlings which were bearing cotyledons and 0-1 post-cotyledonary leaves on July 10th, 1971. The seedlings were growing on bare gravel. In August fruiting spikes of this species carried few intact fruits due to predation by snow buntings.

Poa flexuosa

This is the only species where the seedlings were found far from the potential parents. Plants with upright panicles from the previous year had no seedlings in their immediate vicinity while those with fallen panicles often had many seedlirgs. These often grew from seeds still attached to the panicles. Ungerminated seed could be obtained from such fallen panicles. Seedlings occurred only on well drained gravels.

In this species a special study was made ofthe time required for a seedling to attain maturity and bear panicles. To do this a large number of plants had to be aged and a reliable method found of doing this. Fortunately, first year plants could always be distinguished because the coleoptiles were white. With older plants the number, aggregation and decomposition state of the leaves were used. Each year, usually three, but between two and five leaves are produced and each year the first leaf's lamina tends to be rather short. All the leaves of one year tend to have the lamina-sheath junction at about the same level, above that of the previous year and below that of the following year. Using these observations it was possible to count the number of leaves produced each year since germination on a large number of plants. As the plants were collected about mid-August and growth stopped at the end of August it was assumed that only in rare cases would further leaves be produced in the 1971 growing season.

The final conclusion was that it takes the remarkably long time of at least eight years for a seedling to reach maturity and flower. Some of the data collected and used in evidence is given in tables 1-4.

Table 1

Plants examined
(single shoot only)

(a) Number of leaves	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Number of plants Total 250 plants	3	18	31	17	49	16	39	27	6	5	3	4	2	4	2	6	1

(b) Age (years)	1	2	3	4	5	6	7	8	9
Number of plants	53	79	74	12	11	12	4	4	1

Table 2

Number of leaves on first, second and third year plants

Number of leaves	1	2	3	4	5	6	7	8	9	10
First year	3	18	31	1	-	-	-	-	-	-
Second year	-	-	-	16	49	14	-	-	-	-
Third year	-	-	-	-	-	2	39	27	5	1

Table 3

Number of leaves present in each year in four seven year old plants

Plant number	Leaves present in each year of growth						
	1st	2nd	3rd	4th	5th	6th	7th
1	3	5	8	10	13	16	19
2	3	5	8	11	14	18	21
3	3	6	8	11	13	15	17
4*	-	-	-	12	15	19	23

* this plant produced a tiller bearing four leaves in its seventh year.

Table 4

Number of leaves in each year in three eight year old plants

Plant number	Leaves present in each year of growth							
	1st	2nd	3rd	4th	5th	6th	7th	8th
1	3	6	9	12	15	18 2^t	20 0 /	24** / 2^t 2^t
2	-	-	-	11	14	18 2^t	21 4^t	/ 9^t 3^t 2^t 1^t
3	-	-	-	-	15	19 4^t	23 7^t 2^t	/ / 4^t** 3^t 2^t

** flowering stem
/ tiller died

Most of the above data is the result of a subjective assessment. However, the results given in table 4 are totally objective and taking this data alone the peaks at 3, 5 and 7-8 leaves per plant would suggest that these represent one, two and three year old seedlings respectively. The conclusions are believed to be accurate even though the method cannot be used with all species. As a demonstration of the slow rate of decomposition in such harsh habitats it is interesting to note that in the eight year old flowering plants every leaf and even the lemma and palea of the seed from which it grew was still present at the base of the plant.

Sagina procumbens

A mature plant which had borne fifteen capsules the previous year had eighty-two first year seedlings within a 20 cm radius. Within the same area were eleven older, young plants. As in the case of Poa flexuosa a large number of young plants was examined to study the length of time required to attain reproductive maturity. In this case it was discovered that young plants could produce flowers in their second year. In the first year a pair of cotyledons and two to six pairs of foliage leaves were produced. In the second year two to eight pairs of leaves were formed and the age of the plants was checked by sectioning the main root. This revealed only a single ring.

Salix herbacea

Seedlings were only found in dense mats of the leafy liverworts Gynomitrium varians and Anthelia julacea but it has not yet been determined whether these are first or second year seedlings. The habitats were continually moist, even at the surface, unlike the gravelly soil in which all the larger seeded species were capable of germinating.

Saxifraga cespitosa

A mature plant which had borne eight capsules in the previous year had forty-five seedlings (cotyledons plus up to three leaves) within a radius of 20 cm. Twelve of these seedlings were growing in a tussock of the parent plant and were mostly resting on old decaying leaves. Older, young plants were also present. As an approximate, subjective estimate it takes at least five years for a seedling to bear flowers. Young plants of this species had been very badly damaged by frost lift.

Saxifraga nivalis

A plant which had borne one flowering spike in the previous season had fourteen seedlings within 2 cm of the parent plant.

Deschampsia alpina

This viviparous grass was one of the largest, commonest and most successful species in the area. Young plantlets easily become established, especially in the flushes. This species, especially in wet habitats, usually produces a long internode towards the end of each growing season. It was therefore possible to determine the age of a young plant. It was discovered that six years, with one exceptional case of five years, are required for a plantlet to attain maturity and produce a panicle.

Comments

From the above data it can be seen that in all the species discussed, except Poa flexuosa, nearly all the seed produced is deposited in the immediate vicinity of the parent plant. The features which destroy most of young plants seem to be frost lift followed by dessication.

As certain species grow very successfully in this area it may be surprising that the vegetation is so sparse. However, the luxuriance in flushes (largely Deschampsia alpina) suggests that on the porous, gravelly, morainic soils water is limited, despite the high rainfall. It is known that nitrogen and phosphorous are limited in such soils and in addition to soil instability, slow growth rate and low seed production hinder the formation of a continuous vegetation cover.

Reference

WOBEY, J. (1971)
Vegetation of the western Thorisdalur, Iceland.
In: University of Newcastle upon Tyne Exploration Society Expedition to Iceland 1970 Report, 44-70.

Financial Report

Expenditure	£	Income	£
Transport:		Expedition members' contributions:	540.00
Personal, to and from Iceland	453.00	Mrs. Y.G. Huddart	15.00
Personal, to and from Edinburgh	23.60	Mr. R.E. Eden	12.00
Extra for equipment to Iceland	29.00	British Universities Student Travel Association	140.00
Equipment to and from Edinburgh	15.00	Ford of Britain Trust	100.00
In Iceland (incl. fuel, car-hire, etc.)	89.00	Gilchrist Educational Trust	50.00
Vehicle depreciation	150.00	Arthur Haydock Bequest	50.00
Insurance:		Shell International Petroleum Co. Ltd.	75.00
Vehicle (& tax)	50.00	Gino Watkins Memorial Fund	25.00
Personal	51.75	World Expeditionary Association	25.00
Equipment	40.00	Newcastle University Exploration Society	15.00
Food:		The University of Newcastle upon Tyne	500.00
In U.K.	227.00	Reimbursement from Icelandic Insurance Company for damage to Land Rover	66.00
In Iceland	91.00		
Medicines:			
In U.K.	14.43		
Equipment:			
In U.K.	203.08		
In Iceland	25.00		
General Expenses:			
P.O. Box Hire	1.00		
Hostel charges	5.00		
Tents repaired	18.00		
	1486.76		
Balance to be repaid to the University Exploration Council of Newcastle, and from which the cost of report will be taken	126.24		
	1613.00		1613.00

SOME OBSERVATIONS ON THE HYDROLOGY OF NORTH THORISJÖKULL

Philip Crabtree

The importance of hydrological investigations in understanding the geomorphology of proglacial environments has been emphasized by Pitty and other writers (Pitty 1971). The presented work was undertaken to provide comparison with results obtained in 1970 (University of Newcastle upon Tyne Iceland Report 1970), and was executed in conjunction with a study of the sedimentology of the proglacial sandur.

The readings were taken on all streams issuing from the northern tongue of Thorisjökull (see map) between July 2nd and August 4th, 1971. A variety of climatic conditions were experienced during this period including hot, sunny weather; rain and towards the middle of August, the onset of light falls of snow and hail. During the latter days the smaller streams issuing from the glacier edge froze during the night and consequently run off from the glacier was reduced.

Techniques

The float method of discharge measurements was used because of the nature of the proglacial streams and the ease of application of this method. The staff-gauges were marked at 0.0025 m intervals which was the greatest accuracy to which they could be read under the prevailing conditions.

Wooden floats were used to measure the surface-velocity of the streams, by timing the floats over a 25 ft reach of water. On the larger streams (Nos.1, 8 & 9) two or three separate reaches were used in order to obtain greater accuracy. The cross profiles of the streams were sounded at one foot intervals.

Discharge per unit width of the streams was calculated by using the following formula:

$$q = \frac{0.80\ Ldn}{tn}$$

where q is the discharge per unit width

0.80 is the correction factor to give mean velocity in the vertical for a rough, boulder strewn channel

L is the distance over which floats were timed

dn is the mean depth of the two cross-sections at corresponding distances from one bank

tn is the time of the floats in seconds over the distance between the two cross-sections

A number of velocity readings were taken, and stream discharge plotted against stage height to obtain rating curves.

A photo-electric device was used to measure the amount of sediment carried in suspension. This was a Partech/W.R.P.L. suspended solids monitor which recorded the amount of sediment in suspension using a photo-electric cell. The monitor had been calibrated by Mr. R.E. Eden using samples brought back by the 1970 expedition.

The size and colour of particles varies considerably in proglacial streams and consequently certain inaccuracies occur in readings. However, it is likely that the device, correctly calibrated in accordance with sediment from the proglacial streams provided a most accurate measure of suspended solids concentration.

Readings were taken, where possible, across the width of a stream both at 10 cm below the surface of the water and at the bottom of the stream, until the mean probe position was established. Care was taken to avoid the more turbid sections of the stream as turbulence and the consequent air bubbles affect the readings.

A continuous flow recorder, constructed and lent by Mr. R.E. Eden, was also used, but unfortunately its period of use was curtailed owing to storm damage which necessitated the repair of the clock mechanism.

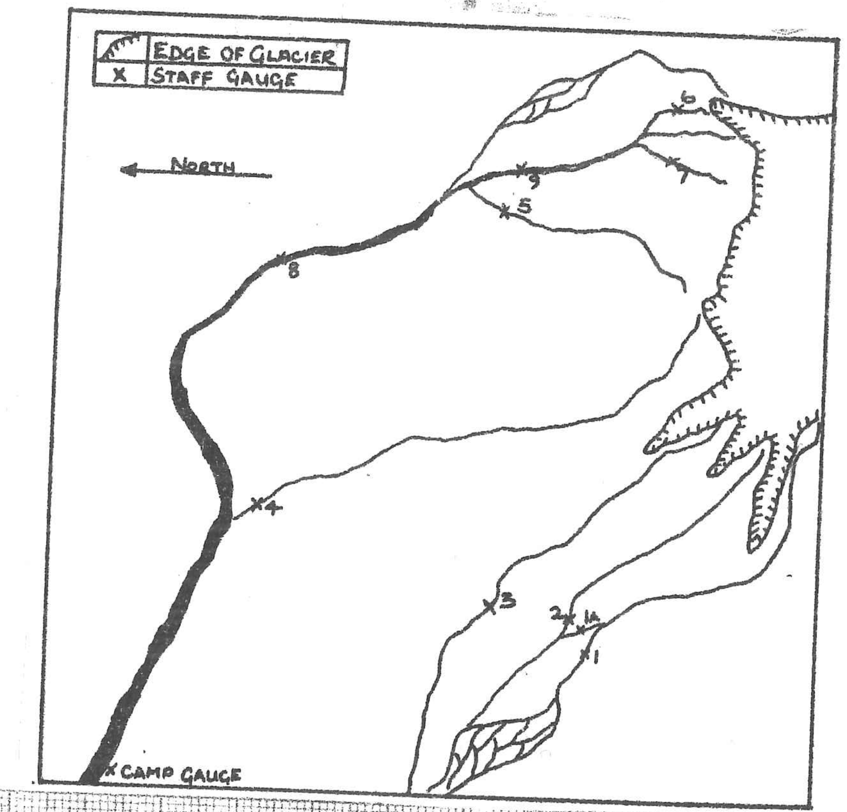
Results

1. Stream Discharge

A series of readings taken throughout the diurnal period were used to establish the rating curves, from which estimates of total surface discharge from the glacier were obtained (see Fig.3).

Total discharge varied between 0.93 m^3/sec. on July 10th, 0.88 m^3/sec on July 24th and 1.529 m^3/sec. on August 7th, when the melt period was at its height. The discharge in 1970 had varied

MAP SHOWING LOCATION OF STAFF GAUGES.



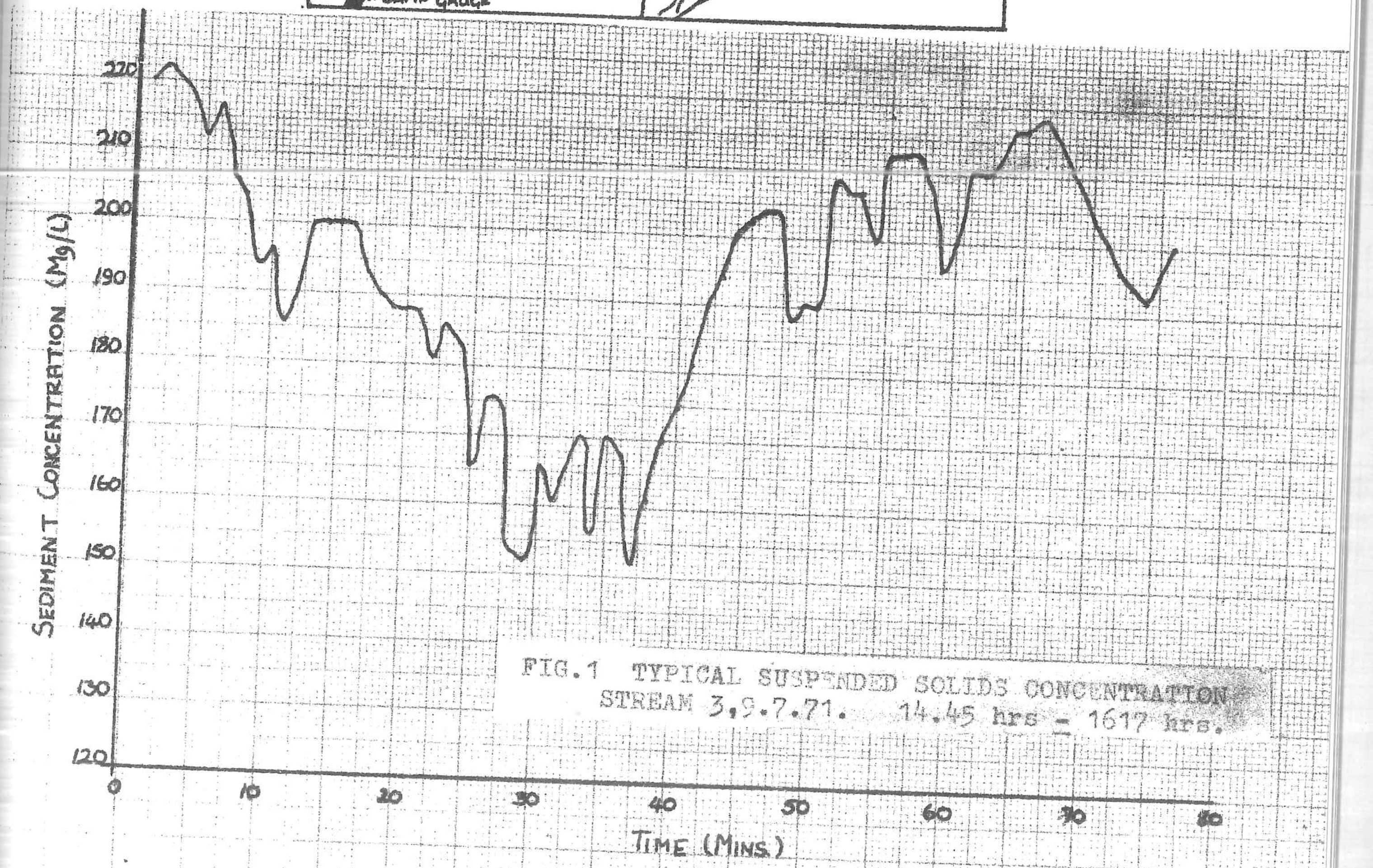


FIG.1 TYPICAL SUSPENDED SOLIDS CONCENTRATION STREAM 3, 9.7.71. 14.45 hrs - 1617 hrs.

between 0.8 m^3/sec. and 2.6 m^3/sec. The difference is explained by the lower temperatures experienced in the area during July 1970, which caused a reduction in the melting of the ice, and consequently lower run off. The higher total is probably explained by the larger rainfall experienced previously, which increases run off dramatically as can be seen by reference to Fig.5. The largest streams were Nos.1 and 9, accounting for 0.625 m^3/sec. out of a total discharge of 1.529 m^3/sec. on August 7th, greater than 40% of total discharge. Of these two streams, Stream 1 was the larger and consequently most of the sediment recordings were obtained from this stream.

The streams themselves changed their courses when large quantities of rain fell, and were apt to break their banks. These factors obviously caused inaccuracies in discharge measurement.

2. Suspended Sediment Load

All streams were sampled by use of the suspended solids monitor, but Streams 4, 5, 6, 7, 8 and 9 were found to carry relatively little sediment except when rain caused the streams to overtop their banks and increase the rate of erosion. Streams 1, 2 and 3 however, provided the fluctuations in sediment load which were mentioned in the 1970 report, and consequently the majority of our work was carried out on these streams.

Figs.1 and 2 provide examples of the nature of the sediment load carried by the streams. There is no evidence of any form of cyclical flow, but the frequent appearances of localized peaks with occasional large peaks is typical (see Fig.2). The nature of the sediment load makes the estimation of stream discharge from sediment concentration as suggested by Eden (Iceland Report 1970) extremely hazardous, for fluctuations in sediment load are apt to occur over considerable densities within a matter of minutes. There is clearly a close relationship between the discharge and sediment load carried in the stream. This could most easily be seen after rain when the colour of the water in the streams changed from being clear to a muddy, grey colour. This is more clearly indicated by the readings obtained during the 24 hour survey. Thus, during the day when discharge was at a maximum (between 1400 and 2000 hours) sediment concentration was at its highest.

3. <u>24 hour Survey</u>

Originally, it was intended to carry out three of these surveys, but illness and the work load of other projects led to only one survey being accomplished.

A survey was made of all streams, and at base camp, a record being obtained of the gauge height of all streams, the suspended sediment load of Stream 1, and rainfall at base camp. Readings were taken on the hour throughout the 24 hour period of both rainfall and stage height. The sediment load was recorded at minute intervals.

The discharge of all streams showed a slight increase during the afternoon and early evening, but then declined in the evening. Temperatures fell to 4°C, until the rain began to fall at 0300 hours, when the discharge of most streams increased, the exception being Stream 3 where discharge actually fell after 0400 hours and continued to do so until 0700 hours. After 0700 hours the discharge of Stream 3 increased considerably from 0.0017 m^3/sec. to 0.0070 m^3/sec. at 1100 hours. Discharge from most streams declined between 0800 hours and 0900 hours when rainfall began to decrease (48 cc's fell between 0300 hours and 0700 hours; 34.25 cc's between 0800 hours and 1200 hours, see Fig.5). The streams with gauges closest to the glacier were the most responsive to the decline in rainfall. Streams 1, 2, 3 and 4 showed a decline in discharge about 1 hour after the discharge decline of streams closest to the glacier.

Stream 1A only flowed when Stream 1 overtopped its banks and consequently it was only at 1100 hours when discharge was 0.19 m^3/sec. that the water began to trickle along the previously dry stream bed. The discharge of Stream 1 had, by this time, fallen from its previous maximum 0.21 m^3/sec. which was reached between 0900 and 1100 hours. This is an indication of the erosive power of proglacial streams, which rapidly change the shape of the stream bed.

Fig.5 shows how the suspended solids measured in Stream 1 gradually increased throughout the 24 hour period. The mean suspended solids readings over a period of one hour were plotted - practical reasons forbade the publishing of a complete set of readings. For a period between 0600 hours and 1020 hours all readings were at a level greater than 228 mg/l (i.e. off the scale

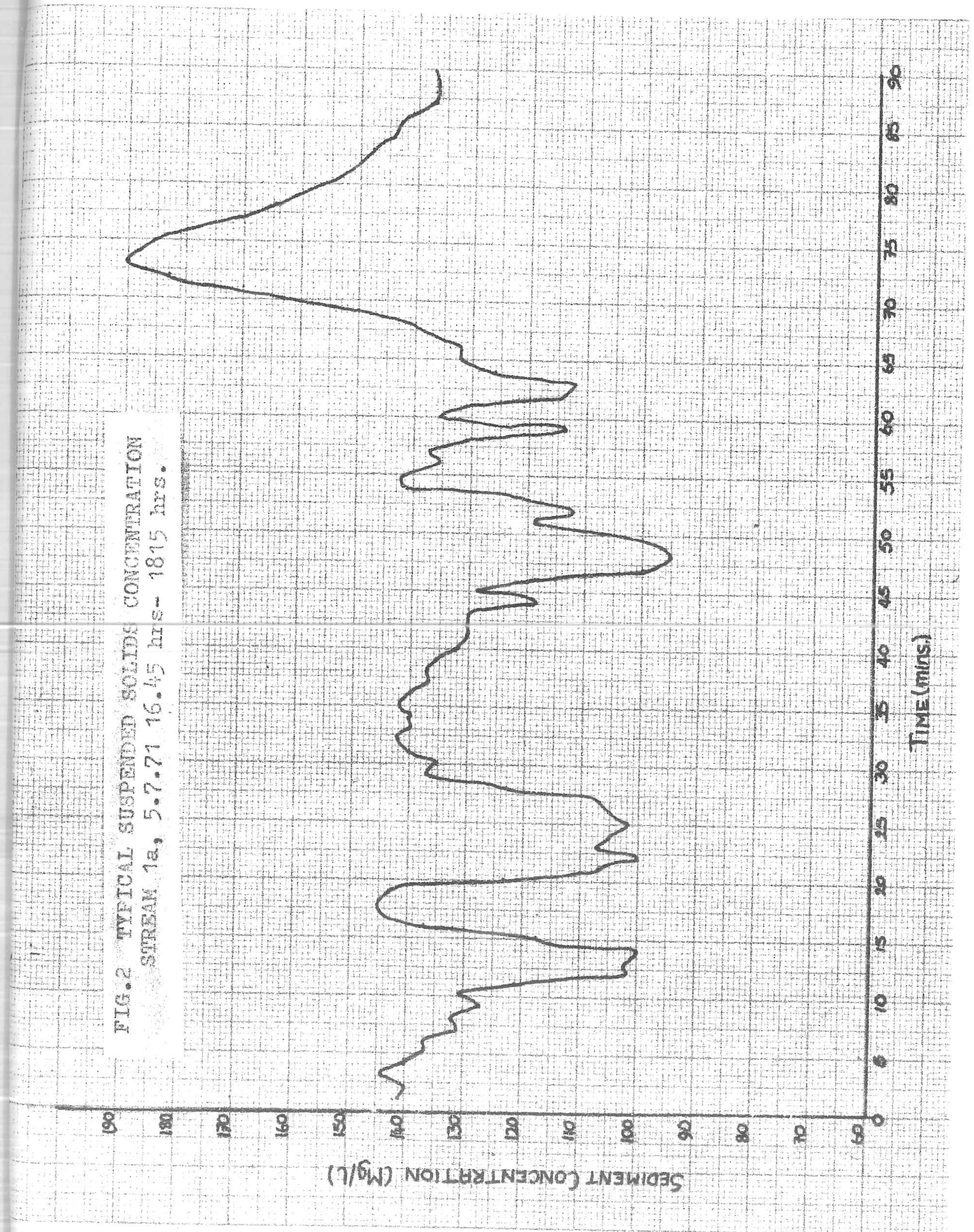


FIG.2 TYPICAL SUSPENDED SOLIDS CONCENTRATION STREAM 1a, 5.7.71 16.45 hrs- 1815 hrs.

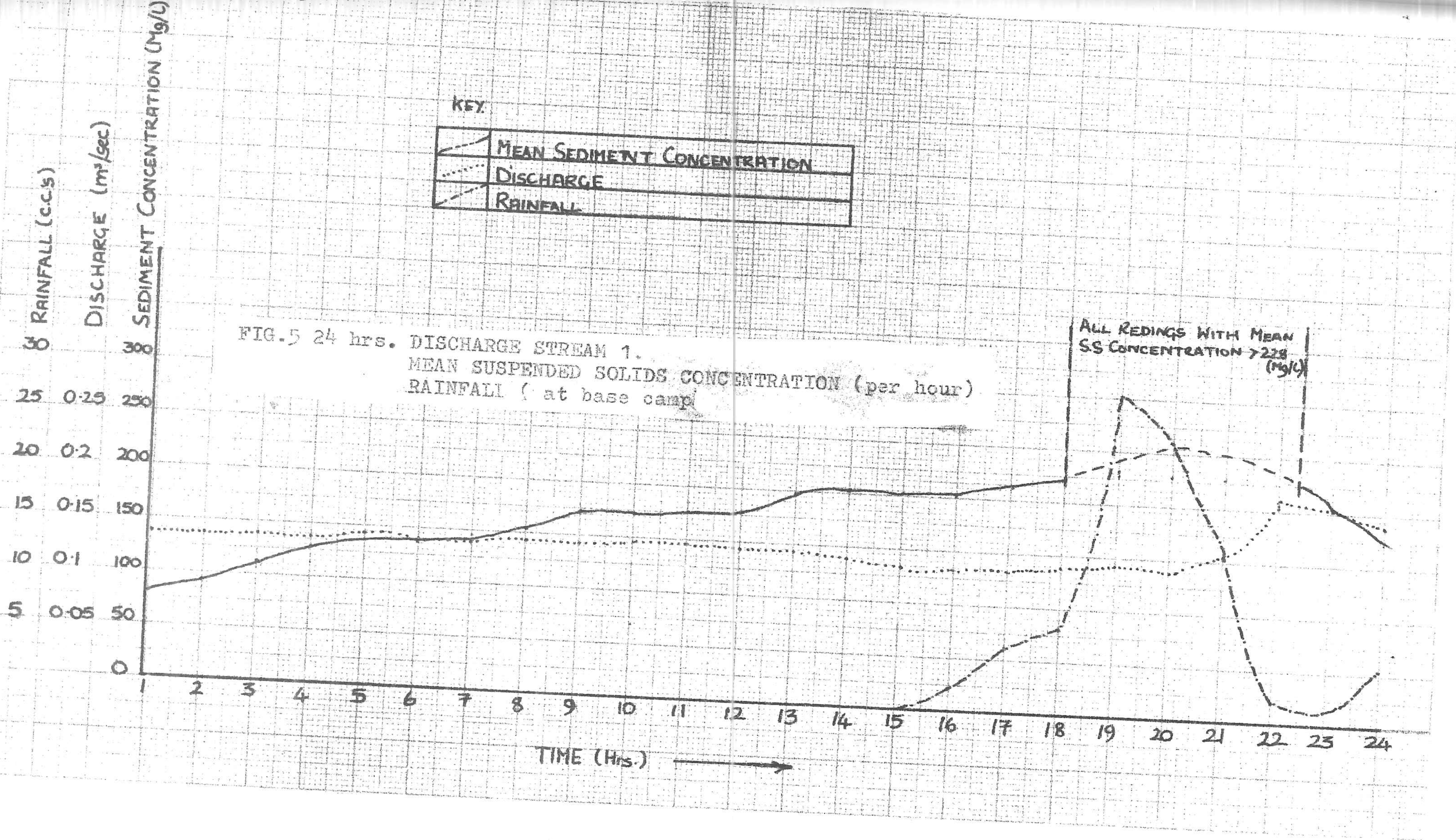


FIG.5 24 hrs. DISCHARGE STREAM 1.
MEAN SUSPENDED SOLIDS CONCENTRATION (per hour)
RAINFALL (at base camp)

FIG.6 CONTINUOUS WATER LEVEL RECORDER (at base camp stream)
(31.7.71. - 7.8.71.)

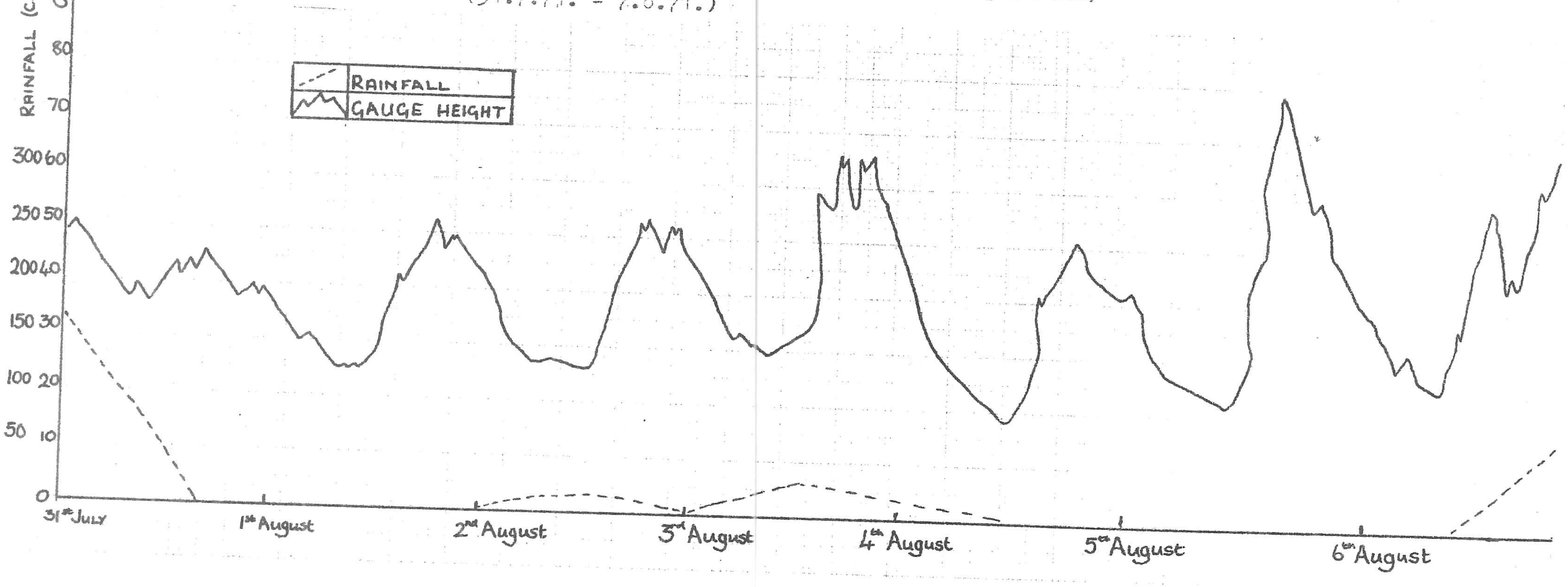
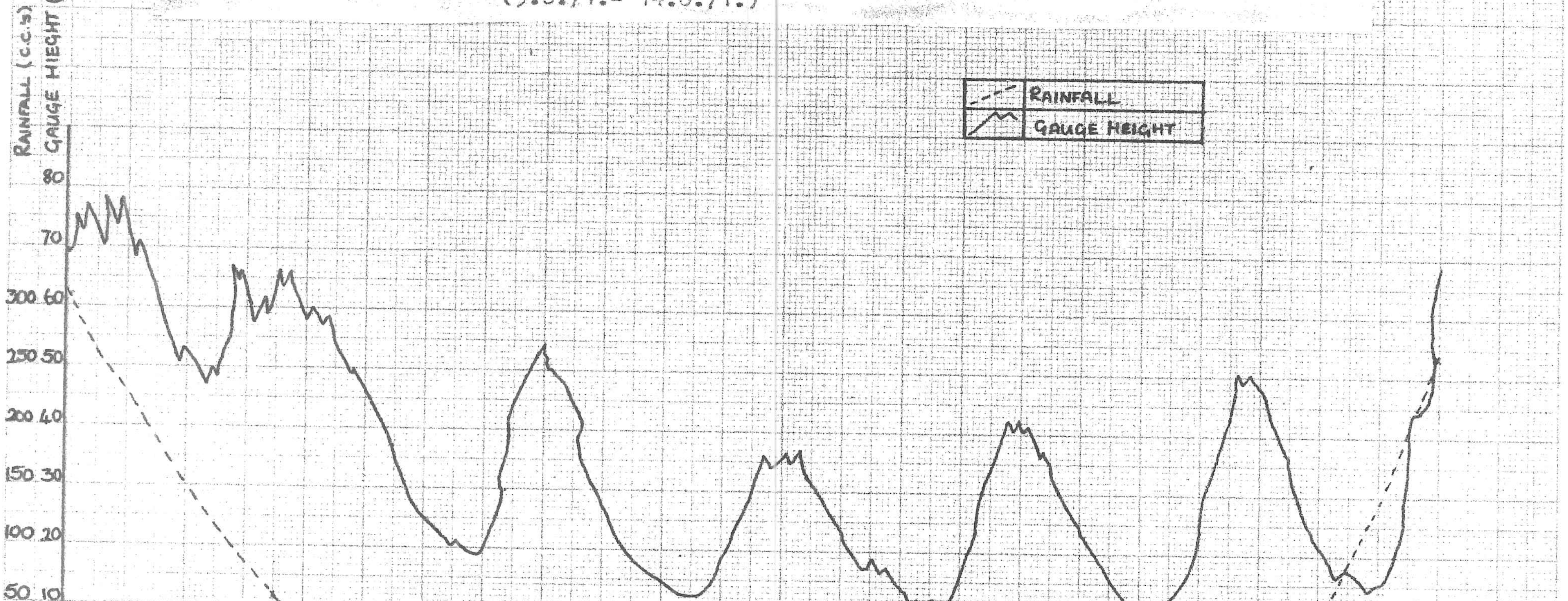


FIG.7 CONTINUOUS WATER LEVEL RECORDER (at base camp stream)
(9.8.71.- 14.8.71.)



of the suspended solids monitor). The steady increase in suspended solids concentration continued until 0200 hours when the rain began to fall. It is unfortunate that it proved impossible to obtain readings of the complete diurnal cycle in dry weather.

The discharge of Stream 1 increased steadily after 0800 hours - it taking some 6 hours before the effects of the rainfall were reflected in increased discharge. Between 0800 hours and 1000 hours the increase was quite marked, this being some two hours after the peak in rainfall occurred.

4. Continuous Flow Recorder

The continuous flow recorder was placed close to base camp in the stream which was basically Stream 8, but also contained water from Stream 4 and a freshwater stream. Thus, the recorder provided a fairly accurate indication of the nature of the diurnal range of discharge in the proglacial streams.

Both Figs.6 and 7 show the nature of the 'peaks' in discharge which usually occurred at about 1500 hours and 1900 hours, when the meltwater produced from ablation on the glacier found its way to the camp stream (some $1\frac{1}{2}$ miles from the edge of the glacier). After 1800 hours the amount of meltwater gradually declined as the sun set, and discharge reached its nadir at 0200 hours (generally about 10 cms depth compared with 35.40 cms earlier in the day).

Acknowledgements

My thanks to all the members of the expedition for assistance in taking readings, to Mr. P. Johnson of the Department of Civil Engineering (Newcastle University) for loaning hydrological equipment, and to Mr. R.E. Eden for helpful advice and his generosity in loaning the continuous flow recorder and the suspended solids monitor.

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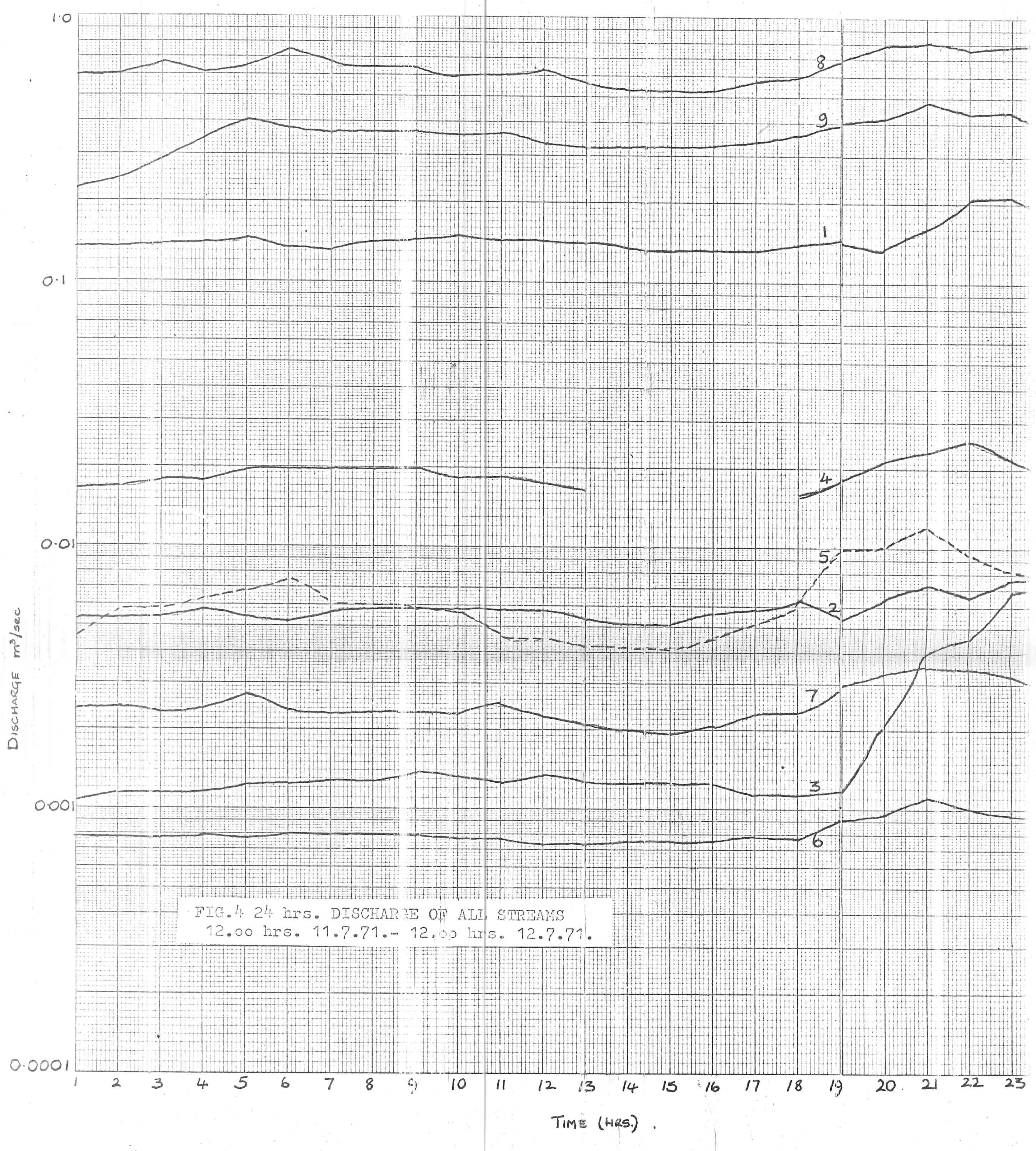

FIG.4 24 hrs. DISCHARGE OF ALL STREAMS
12.00 hrs. 11.7.71.- 12.00 hrs. 12.7.71.