UNIVERSITY OF NEWCASTLE UPON TYNE EXPLORATION SOCIETY

N.U.E.S.

EXPEDITION TO THORISJOKULL

ICELAND

1970

CONTENTS

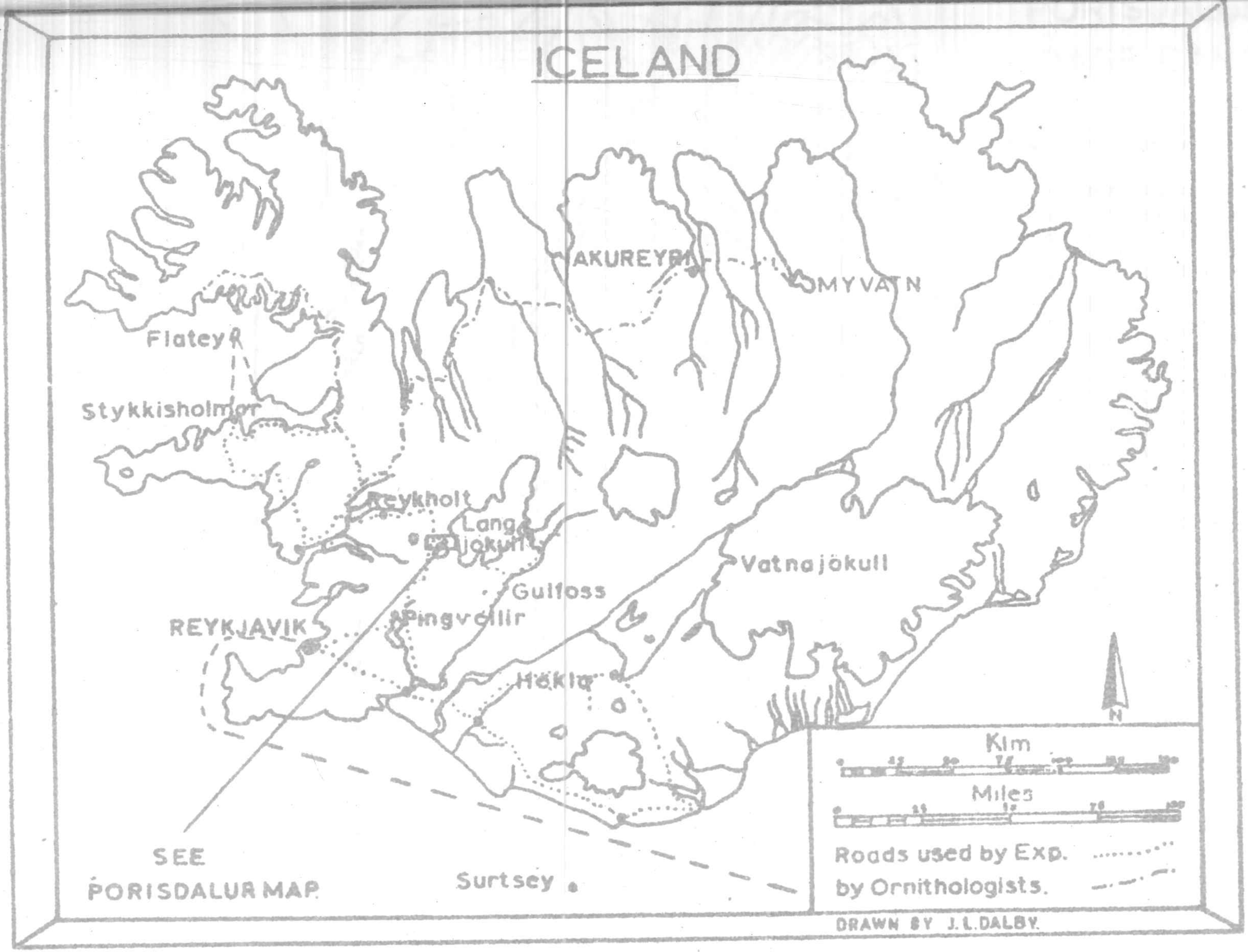
1:4000 map of study area inside back cover.

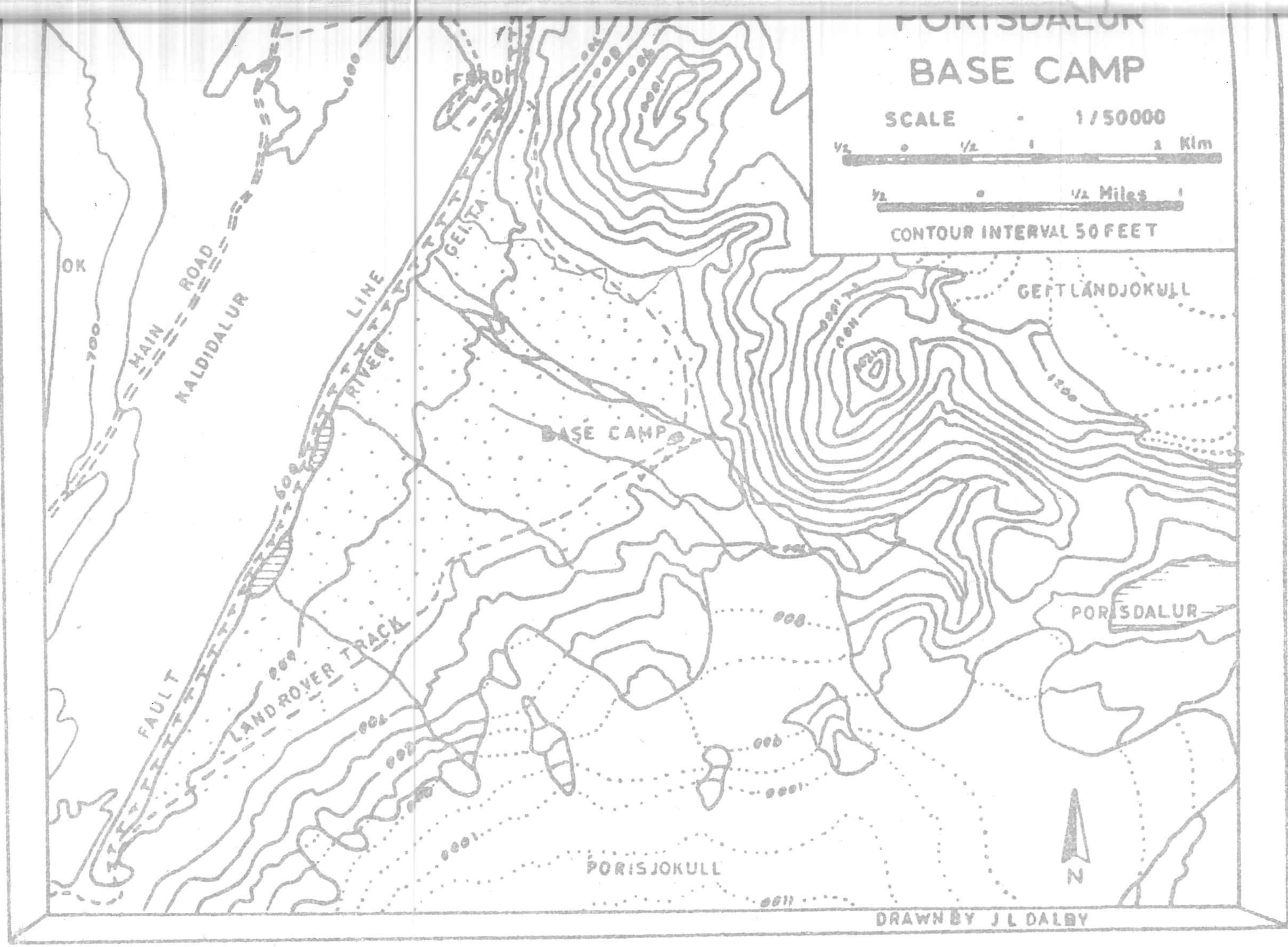
Diagrams are inserted in the relevant sections.

For further copies apply to the Society.

Produced at and by the :

Exploration Society,
Daysh Building,
University of Newcastle-upon-Tyne,
Newcastle-upon-Tyne,
NE1 7RU
England.


ICELAND
AKUREYRI
MYVATN
Flatey
Stykkisholmur
Reykholt
Lang
Jökull
Vatnajökull
Gulfoss
REYKJAVIK
Þingvellir
Hekla
SEE
ÞORISDALUR MAP
Surtsey
N
Kim
Miles
Roads used by Exp.
by Ornithologists.
DRAWN BY J.L.DALBY.


BASE CAMP
SCALE - 1/50000
½ 0 ½ 1 2 Klm
½ 0 ½ Miles 1
CONTOUR INTERVAL 50 FEET
GEITLANDJOKULL
1200
FORDI
GEITA
LINE
RIVER
MAIN ROAD
KALDIDALUR
OK
700
600
BASE CAMP
FAULT
LAND ROVER TRACK
PORISDALUR
800
900
1000
PORISJOKULL
1100
N
DRAWN BY J L DALBY

MEMBERS OF THE EXPEDITION

Michael Burnford, Mechanical Engineering, Leader.

John Dalby, Surveying/Geography.

Mike Forbes, Surveying/Geography.

Andy Lowe, Zoology, Ornithology.

Jane Wobey, Geography/Botany.

Janet Moody, Geography.

All the above were undergraduates at the University of Newcastle upon Tyne.

The following were also members of the Expedition:

Margaret Banks, Geography at Nottingham University.

Bob Eden, Lecturer in Civil Engineering at Southampton University.

Both are graduates of Newcastle University.

Tikki Forbes, graduate of Rhodes University, South Africa.

SUMMARY

The Expedition was in Iceland from 6th July to 16th September 1970, and studied Hydrology, Botany, Glaciology, and Topography of the Northern-most glacier of the ice-cap Thórisjökull, in West Central Iceland. The two Ornithologists made behavioural studies of birds in North and West areas.

An area of 2 sq.km. was mapped on a scale 1:4000 using Theodolite triangulation and air-photographs.

Water discharge, cross-sections, sediment loads, and bed composition, were measured at 9 stations along outflowing streams. Detailed measurements were made hourly over 48 hours to accompany detailed meteorological and glaciological observations. These last two were otherwise made daily; the glaciological observations more detailed at specific forms on the glacier.

Transects were drawn across the valley at 100m intervals from the glacier, and vegetation in a metre wide band at each transect recorded. This method, although unorthodox, was necessary because of the scarcity of vegetation.

The diving and preening behaviour of three species: Scaup (Aythya marila), Great Northern Diver (Gavier immer), and Barrow's Goldeneye (Bucephala islendica) was studied, the first under continuous daylight. Species seen were recorded and notes of diving behaviour taken of: Red Throated Diver (Gavier stellata), Slavonian Grebe (Podiceps auritus), Cormorant (Phalacrocorax carbo), Shag (Phalacrocorax aristotelis), Eider (Somateria mollissima), Long Tailed Duck (Clangula hyemalis), Red Breasted Merganser (Mergus serrator).

GENERAL REPORT

On the morning of 3rd July the Expedition left Newcastle with all ts equipment crammed into a 1955 Land Rover and a 1954 Volkswagen Microbus. ost of the previous night had been spent loading, and so we were looking orward to the three day rest the sea voyage from Leith would give us.

At Leith there was some considerable doubt as to whether the .V. Gullfoss would said on time, because of the strikes, but we were ssured that all was back to normal. The only worrying moment was when e overload bell on the crane rang as our Land Rover was being hoisted board. We managed, however, to persuade the crane operator that there as a fault with his crane and that the Land Rover was, in fact, below the aximum load!

In spite of being a very well-appointed vessel below, the M.V.Gullfoss as a none too comfortable motion in a sea; and so we were glad to step hore in Reykjavik on the cold morning of the 6th July. Then ensued a hectic ay of chasing customs officials and insurance brokers in a finally successful ttempt to legally use our vehicles. In this, and indeed throughout our tay, we would have been hopelessly lost without the help of Ingvar Karlsson.

We spent a few days in Reykjavik and then headed towards Thórisjökull. n the way we camped at Thingvellir, the site of the old open-air Parliament, here there was the annual horse festival in progress, with much joviality mongst those present!

On the 5th May 1970 there had been an eruption near the volcano ekla, and as it was still active we went to see. Unfortunately the fireworks' had ceased a few days earlier, and we only saw the immense ava-flow which oozed and 'tinkled' from the crater. However not to be ut out, we boiled water on the lava-flow and made coffee. Unhappily the ettle has never been the same since! The lava-flow was a few kilometres ong, about 15 - 20 metres high and several hundred metres broad.

On our return to Thingvellir it was snowing, and it then took us four ays to reach a suitable area to set up base-camp only 30 kilometres away. e had to dig through snow-drifts on the road, and once it took two of us everal hours to extricate the Land Rover from quick-mud; luckily on a hot, till, sunny day.

By this time the ornithologists had gone to the West, but ran into rouble when a rear wheel and hub came off the Volkswagen. In order not to aste more time they continued their studies using the Land Rover. However heir troubles were not over: on a lonely mountain track in the North-West he rear differential broke and seized. They made it to Akureyri where the and Rover agents, Baugur H/F, helped them repair it.

We are greatly indebted to Baugur H/F for their generosity in giving us parts we could not possibly afford, and for their help and advice.

At the base-camp the work was proceeding well in spite of the exceptionally bad weather, which made many trips up the glacier impossible as well as making living conditions difficult. We had several gales; the final one lasting six days with 25,0mms of rain a day. After this we retreated to Reykjavik, wet, bedraggled, but cheerful!

We had two weeks to wait for our boat, so after sorting stores in Reykjavik, we went to Hagavatn, the area we had originally intended to work. Landmannalaugar, the impressive waterfall Gullfoss, and the thermal area Geysir, were also visited. Landmannalaugur is a thermal area of exceptional beauty in the mountains. A hot river flows through the valley and it is wonderfully relaxing to soak in this river even when the air temperature is below freezing. We approached Landmannalaugar from the East along a torturous track through magnificent mountains and lava-fields. This was a drive which, even at that late stage in our stay in Iceland, none of us will forget.

On the 16th September the Expedition sailed on the M.V. Gullfoss to Leith with mixed feelings - eager to return home, yet sad that such a wonderful time had to end.

Michael Burnford

7th February, 1971

TRAVEL

We took two vehicles with us to Iceland - a LandRover and a Volkswagen Microbus. The shipping tariff for accompanied vehicles on the M.V. Gullfoss is low, and insurance is fairlycheap, although the AA now provide 5-Star cover for Iceland.

Our vehicles were very old - 1955 and 1954 - and we had some troubles with the Volkswagen, the elder, which would not have occurred in a newer model because of modifications. It is not necessary to use new vehicles as it is much cheaper to use well-maintained old ones, although if they can be afforded newer vehicles than ours are advised. We found that we needed one LandRover but it would have been excessively expensive to have had two, and unnecessary.

There are very few tarmaced roads outside the major towns, most roads being a loose gravel surface. They are very rough, often with many potholes. The South-West has, on the whole, roads wide enough for two-way traffic without any difficulty, but in much of the country they are single track, though wide enough usually for two cars. The cross-country routes are not always passable and one must expect steep slopes and unbridged rivers. The Kaldidalur mountain road, which we used many times, is usually passable in an ordinary car in the summer and has only one unbridged river. It was blocked with snow when we first tried it in early July, but this is not typical. With care an ordinary car will be able to cover much of the country.

The suspension, tyres, and exhaust systems take a tremendous beating, and we saw several cars with broken suspension. The heavy vibration tends to shake nuts loose and we found that the bodywork began to fall apart. Dust is another problem and finds its way everywhere. Most vehicles are, where possible, diesel, as it is cheaper than petrol. There is no problem in obtaining fuel and it is only necessary to carry spare cans on long cross-country trips. On many of the roads fuel consumption can be very heavy. Information on roads can be had from the F.I.B. (Icelandic Automobile Association), Tourist Offices, or the Road Authorities.

There is a good public bus service but space for expedition equipment is limited; some firms have cross-country buses for charter but this is costly: a 12 seat bus would cost £0.10per km. in the summer of 1970. There are firms which hire out self-drive LandRovers and Volkswagens, but this is also very expensive.

Importation of equipment to Iceland is not difficult as long as it is well packed and organised; with detailed forms of boxes and contents available for the Customs. All must be for use by the Expedition of course.

VEHICLES

LandRover

1955 long wheel-base truck cab pick-up. Petrol. Maximum permitted load 800kg. (1800 lb.) plus 3 persons. Maximum overload was 40%. (In England driving to Leith). Weight of vehicle is 1500kg. (3300lb.) Trouble encountered: broken exhaust manifold, bent rear axle and broken differential, brake master cylinder seals, burst brake pipe, dirt in fuel, loose nuts in suspension and steering, water in ignition, lights, bodywork shaking loose.

Volkswagen

1954 Microbus van. Petrol. 1132cc. Maximum permitted load 800kg. (1800lb.) plus driver. Maximum overload was 100%. (In England driving to Leith.) Weight of vehicle is 800kg. (1800lb.). Trouble encountered: Rear hub splines shearing, clutch slipping, dirt in fuel.

The Volkswagen was driven off the road and overturned once but sustained no obvious damage.

The LandRover covered 8,000km. (5,000 miles.), and the Volkswagen 3,000km. (2,000miles.)

Item	Income	Expenditure.
Income		
rsonal Contributions (£60.00 per person)......	£540.00	
versity of Newcastle upon Tyne..........	£500.00	
al Geographic Society..................	£ 50.00	
o Watkins Memorial Fund.................	£ 40.00	
ll International Petroleum Co. Ltd.........	£ 75.00	
d (Dagenham) Foundation.................	£ 75.00	
christ Educational Trust................	£ 50.00	
er Donations..........................	£ 20.00	
e of Mini Bus On Return................	£ 12.00	
e of Landrover On Return...............	£ 45.00	
Expenditure.		
avel..................................		£592.50
od....................................		£171.50
ndRover...............................		£150.00
surance...............................		£186.85
icle Spares And Running Costs...........		£136.30
scellaneous equipment..................		£ 30.00
ationery..............................		£ 10.75
oking Fuels............................		£ 15.50
lm....................................		£ 7.52
r Photographs..........................		£ 9.25
lance Returned to Exploration Council.......		£ 96.83
st of Report to be deducted from this balance		
Totals.	£1,407.00	£1,407.00

BREAKDOWN OF EXPENDITURE.

avel

at Passage Fares (inc. vehicles)	£334.95
r Fares.	£151.55
st of Petrol.	£ 95.00
at Trip to Flatey.	£ 11.00
	£592.50

od.

nount Spent in England.	£136.50
nount Spent in Iceland.	£ 35.00
	£171.50

nsurance Cover.

ersonal.	£ 47.25
ehicles (Iceland)	£ 39.60
" (England)	£ 35.00
quipment.	£ 65.00
	£186.85

ehical Running Costs.

pares and Tyres bought in England.	£ 58.15
pares required in Iceland.	£ 40.50
unning Costs in England.	£ 19.35
oad Fund Licences.	£ 18.35
	£136.35

EQUIPMENT REPORT

INTRODUCTION

For any venture of this nature, accurate planning for stores and equipment is necessarily limited by inexperience and lack of knowledge of conditions likely to be experienced. In fact, little of major importance was omitted and little taken which was not of some use, albeit for some purpose wholly different from that originally intended.

Full stores and equipment lists are not included in this report, because choice of items taken was severely curtailed by availability, compromise being the order of the day. It was necessary to do without anything which could not be begged, borrowed or cheaply and quickly homemade, which produced interesting variety, especially in tentage and cooking utensils. However, this did allow for useful comparison of a wide range of items under similar conditions of usage.

A. Tentage

Arctic Guinea (Protex) and Flysheet	1970	1.
New Mountain "	1970	1.
Icelandic (13ft.) and Flysheet	c.1965	1.
New Guinea and Flysheet	old	2.
Meade (3 man model)	1967	2.
Itisa Senior and Flysheet	1960	1.
Ridge tent (8' x 6')	Very old	1.
Bivouac (ex-Army)	old	2.

It must be remembered that the vintage of the tents differed widely. Several tents were too old for the rough usage received, while being adequate for ordinary use in Iceland. Indeed, five tents and three old flysheets were irreparably damaged by the severe gales, from which no tent escaped undamaged.

The Icelandic proved its reputation as a lifesaver, withstanding the worst conditions. However, the poles chafed through the flysheet three times and and tent once, through the severity of the gusty gales playing on sodden canvas, although the pitching conditions in Thorisdalur were far from ideal. The weight of wet canvas was sufficient to buckle the steel spike of the flysheet extension pices, letting the flysheet sag onto the tent producing leakage. For such extreme conditions, a flysheet ridge pole is desirable, though a long rope over the poles, lashed to pegs at either end of the tent provided an adequate substitute when it could be kept taught.

The New Mountain and the Meade have the best design for these conditions and withstood gusty storms well. The Meades, having already seen rough usage in Greenland, holed easily, but their groundsheets remained completely waterproof, despite the sharp, rocky ground beneath. They therefore tended to turn into bathing pools, the groundsheets carefully retaining a 3" depth of water, leaving the unfortunate occupants floating on their lilos! The New Mountain flysheet is an excellent development, but need it have a metal zip? Inevitably this broke within the first month of use.

The Arctic Guinea, reputedly ideal for such conditions, did not so prove. It was impossible to prevent the flysheet from touching the side of the tent during anything above moderate windspeeds. A modification to pull out the sides of the tent and flysheet similar to the New Mountain would give much improvement, as would a flysheet reaching to ground level. For the existing design, the addition of yet more guys to the flysheet is the only practicable answer to the problem. The doorway leaked a surprising amount. Once the outer panel becomes wet it flaps against the inner and sprays the incumbents. Some modification is desirable here if the tent must be used in exposed positions.

The Itisa and the New Guineas, designed for lightweight camping, performed well for the touring ornithologists, but could not withstand the worst conditions at Base. Flysheets reaching the ground would be essential to weather the storms, for the wind gusted underneath and easily lifted and ripped the saturated canvas. It was this combination of wind and rain which proved so difficult. Most tents could survive these elements separately.

The remaining tents were too old for accurate assessment of performance.

An invaluable addition to the tentage was a large supply of spare poles, pegs, rope, canvas and guycord. The former have innumerable uses in any long standing camp. The canvas, of various thicknesses, was used for patching. Almost every tent had each guy renewed once, excluding the New Mountain and the Icelandic, for each gale took extensive toll in chafted or snapped guys.

B. Cooking Gear

The main party at Base used large calor gas cylinders, filled with Dutch Kosengas procured from the Kosengas-salan, Sjavarbraut 2, on the Reykjavik dockside. 'Primus' and 'Optimus' paraffin stoves, 'Bluet Gaz' and a meths. stove were used for smaller parties or when the gas ran out. The 'Gaz' stove performed well for the ornithologists, but in cold temperatures and on ice the gas pressure is lowered to inefficient levels. Gas will not function much below 4°C. The paraffin stoves, although messy, give a strong flame, but even the new 'Primus' stoves needed repair after only short use. More spare parts would have been useful. The single meths. stove was the most reliable and, being low to the ground, the least dangerous for use in blustery weather. Meths. a prohibited import, is difficult for the uninitiated foreigner to obtain in Iceland, however, as it must be bought as spiritus denaturatus from the Goverment Afengis og Tobaksverzlun Rikisins in Reykjavik.

There was some minor excess of cooking utensils, especially after the departure of the ornithological party, but this compensated for the occasions when articles were blown away down the sandur! Two teatowels in Base were insufficient. Even after four more were purchased in Reykjavik these were in short supply, owing to the drying difficulties and the tendency for the hydraulic jack to spew forth oil.

C. Personal Kit

There was great variety within the suggested personal kit and equipment, depending on what members already possessed. Certain items proved desirable or best for the conditions:-

The terrain was very hard on mittens, boots and trousers. Water resistant, strong breeches would have been desirable, for, despite supposedly waterproof overtrousers, members spent too long in wet trousers. Strong, waterproof over-mittens would have been similarly helpful, as well as saving much darning time.

Waterproofing varied from Black's nylon cagoules, anoraks and overtrousers, which were no longer waterproof after two months' use, to Helly Hansens and P.V.C. sailing gear. The "Hellies' were most water resistant, but the nylon gear provided light, necessary windproofing on the drier days.

Sleeping bags ranged from Black's 'Icelandic' to a Fairy Down The latter was obviously the best. The 'Icelandics' were rarely sufficient in Base or at Ice Camp. Some form of lilo was essential for a lengthy stay on rocky terrain but prone to puncture. Lilos had the advantage of drying easily and floating above pools in leaky tents! Foam mats, idal in dry conditions,

D. Ice Equipment

Ice Axes were taken and the old ones proved to have some thirty uses apart from the obvious. However, an ice axe is an expensive item best not used for such purposes. Future expeditions please note! For icework the long handled variety (30" - 32") were most suited. Crampons would have been useful, but the climbing rope, was necessary for safety, was rarely utilised.

CONCLUSION:

The expedition was as well equipped as circumstance permitted, but future expeditions to this area should have new tents, preferably "New Mountain" variety. Compromise between the best equipment available and the least expensive can be a false economy. A minimum of superfluous items was taken, although some could well be omitted by future expeditions with weight difficulties.

Our thanks are due to the P.E. Department of this University for the loan of cooking utensils, to the Claremont Tower Porters for constant help, to our long suffering friends and indeed to all those who were cajoled into donating us the small items which proved so invaluable, ranging from can-openers and frying pans to garden canes and string.

J.N. MOODY

April, 1971

MEDICAL REPORT

Medical Stores

Lack of knowledge of conditions likely to be experienced again affected the choice of items for the First Aid kits. This was the one instance where gross excess was taken, but this was somewhat inevitable. Detailed lists are not included, but can be obtained from the Society's Stores Manager upon request. Brief comments upon individual items only are given:-

Surprisingly, as this was included on the personal equipment list, although apparently overlooked by the majority of expedition members, elastoplast and similar dressings were in rather short supply by September. Future expemditions should recall that lava is tougher than skin when estimating quantities.

The dozen or so tubes of insect repellent and "Waspese" were unnecessary. The advent of any insect in Base Camp was a major event. The ornithologists encountered few troublesome insects, even at Myvatn.

Some tablet or powder form of treatment to replace the traditional kaolin mixture for diarrhoea would prove a considerable saving in weight and bulk, as would a reduction in the number of glass containers for tablets, where plastic would safely suffice.

2. Water Supply

Water supplies were first drawn direct from the glacial outwash streams. However, these carry a high and variable proportion of sediment. At time of turbulent flow this was readily seen to be excessive, but at other times this was less obvious. Deeming the cumulative amount of sediment absorbed to be injurious to health, supplies of drinking water were taken from a small spring issuing from the base of a scree fan on Prestahnukur. This was somewhat inconvenient when the rivers became too deep and fast flowing during storm periods, just when the sediment content was consistently high. One day in late August the stream developed a fine crop of larvae, so purification was necessary, until tablets ran out, when the river was resorted to once more. No untoward effects were experienced. Possibly the sediment absorbed may account for the lack of bowel complaints.

3. Illness

The general health of the party remained good until the last fortnight in Base Camp, when continuous inclement weather and the effects of nine weeks' restricted diet began to show. Fresh food and milk purchased during the last week produced considerable improvement.

The type of sanitation used was primitive, but low temperatures and the absence of insects remove the main dangers this would cause elsewhere. Surprisingly, only one case of diarrhoea of brief duration was encountered.

One accident occurred when the botanist deeply cut her wrist, just missing the artery. This necessitated a visit to the nearest doctor for stitching, at a time when there was no vehicle in camp. Most fortunately a Horse Festival was in progress at Hussafell, which obviated the need for a trip to Reykjavik, for the Doctor at the First Aid Post of the Hjalparsveit Skata (Reykjavik Rescue and First Aid Group of the Icelandic Scout Association) kindly performed the necessary surgery. Dr. A. Lister arrived at Base Camp in time to remove the stitches.

The main illness contracted on the expedition highlighted a major omission from the medical supplies: penicillin or its equivalent. Again Dr. Lister came to the rescue, for the patient succumbed to tonsalitis during her stay. This omission illustrates one of the great difficulties for expedition medical officers who are not qualified doctors. Should an expedition carry supplies to deal with cases of this nature?

Apart from these instances, any wound not quickly healed or upset not of short duration was rare.

ACKNOWLEDGEMENTS

The Expedition extends its grateful thanks to Messrs. Mawson and Proctor for providing the medical supplies, Dr. Norbury of the University Health Service for advice and the members of the Reykjavikur Hjalparsveit Skata for their great help in Husafell.

J.N. MOODY

May 1970

UNIVERSITY OF NEWCASTLE UPON TYNE EXPEDITION TO ICELAND 1970.
SURVEYING REPORT

J.L. DALBY. M.G. FORBES.

The object of the surveying project was to produce a large scale map of e valley and glacier to act as a base map on which the results of the other rojects could be plotted, and to assist these projects by providing stream ofiles and laying out transects etc.

A third order triangulation network was observed, using a Kern DKM2 one econd Theodolite, and a 240 metre base line measured by steel tape. Diagram (1) llustrates the network used, in which 3A4B and 1235 are quadrilaterals and 345 triangle. Point 6 was resected and points D and F intersected.

As it was planned to plot the detail by plane table, using a Kern Self educing Alidade and a metric levelling staff, the triangulation beacons were set p on prominent features so as to be visible from anywhere in the valley or on the lacier. The beacons were made of bamboo canes with small brightly coloured flags ailed to them and held vertical by stone cairns such that the cane could be emoved without disturbing it and the alloy centering rod of the theodolite inserted n its place. With light coloured rock as a background, these were sometimes ifficult to find and the observations would have been quicker and easier had the lags been larger (say one foot square) and the canes painted red and white. f the red, mauve and green materials used, bright green was found to show up the est against the reddish background of palagonite tuffs. Stations D and F were ountain peaks with very distinctive cairn shaped lumps on top. These made very ood targets.

All the horizontal and vertical angles were observed on two zeros and in the ase of the latter, to the tops of the flags and from both ends of the line hough not simultaneously. A slope correction was applied to the measured base and after adjusting the figures by the 'approximate method', the lengths of the sides were computed. There being only one Icelandic Triangulation Pillar visible, namely on the extinct volcano OK, we were unable to connect our survey to the national system and it had to be independant. Arbitary co-ordinates were given to station 1, 10,000 metres in both Eastings and Northings, and the geographic bearing of B3 found by observing a sun azimuth at B. Working from 1, the co-ordinates of all the other stations were computed. Self checking methods were used and the use of a Curta hand calculating machine speeded up the process considerably and helped prevent mistakes. The co-ordinates were then plotted on the plane table ready for use in the field. A scale of 1/4,000 was chosen as being the largest scale that would allow all the points to be plotted on one table and contain the area to be mapped.

A suitable height datum for the survey was found from a spot height on a 1/50,000 US Army map (loaned to us by Brathay Exploration Group) which gave the peak of the mountain on the southern edge of the valley as having a height of 856 metres. From this peak the altitude of a bench mark stone in base camp was derived by altimeter and thence the altitude of station 5 by the same means. The bench mark stone is an unmistakeable armchair shaped stone near the foot of the terminal moraine, the seat of which has an altitude of 620 metres above Icelandic Datum. Using the observed vertical angles the altitudes of all the other trig. beacons were computed using simple trigonometry. As in computing the co-ordinates the height of any one point was calculated from any two others so that the network was self checking and no large errors were found. Initially the beacon tops were heighted but these were later reduced to the level of the ground beneath the cairn.

SURVEYING REPORT.

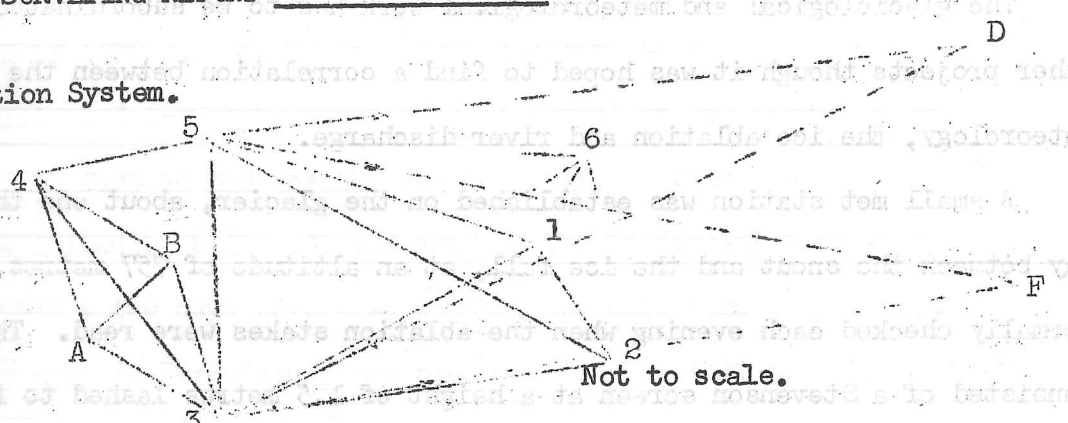
The good weather that had lasted during the triangulation broke when we began to fill in the detail and rather than let the rain showers repeatedly stop the plane tabling, we resorted to theodolite tacheometry. The Kern theodolite is well suited to this work as its centering and levelling system is very quick and efficient and its powerful telescope enables a metric staff to be read quite accurately for distances up to 200 metres. Some twenty-six instrument set-ups were required adequately to cover the area and at each horizontal and vertical angles wer observed to three trig. beacons, thus enabling their co-ordinates and altitudes to b computed at a later date. By this method the time spent in the field was cut to a minimum, there being no drawing or calculating to do, and observations could continu in driving rain or drizzle that would have made plane tabling totally impossible. I these conditions a small umbrella was found most useful in keeping the instrument and field book reasonably dry.

All the position and height resections and the tachy data were computed back in Newcastle, using the Geography and Surveying department's Hewlet Packard desk computer. Programmes were either borrowed from the surveying library or specially written, with the help of the Surveying Dept. Staff and the use of this machine greatly speeded up the work and generally eliminated arithmotic errors. The valley detail was then plotted.

Other work done whilst in the field included the cross profiling of certain river valleys for the hydrology project. This was done by tacheometry and the profiling of the stream beds by Abney levelling. An attempt was also made to measure any movement of the glacier by two sets of observations to the ablation stakes which had been drilled into the ice surface. The first set was completed shortly after our arrival but bad weather and poor visibility prevented us from observing the second set.

SURVEYING REPORT ——————— TECHNICAL INFORMATION

1). Triangulation System.



2). Co-ordinates of the Triangulation Stations.

	Eastings.	Northings.	Altitude.
1.	10 000.00	10 000.00	701.5 (base of cairn).
2.	9 683.13	9 746.03	856.0 (top of beacon).
3.	9 311.01	10 601.61	642.5 (base of cairn).
4.	9 565.85	11 276.93	616.5 (" ").
5.	10 032.98	11 032.97	713.5 (" ").
6.	10 418.37	10 033.06	694.5 (" ").
A.	9 313.51	10 983.15	
B.	9 539.86	10 903.59	
D.	11 475.42	9 313.41	1017.5 (mountain peak).
F.	10 935.18	8 384.52	1061.0 (" ").

Co-ordinates and altitudes in metres. Altitudes rounded off to nearest half metre.

(3) Geographical bearing of Bto3, found from the mean of two Sun Azimuth observations is 217 06' 27". Magnetic north, found with a Prismatic Compass is about 16 degrees west of true north. This is smaller than it should be for the area and is probably due to local anomalies.

(4) List of equipment taken.

Kern DKM2 Theodolite & Tripod.
Kern Plane Table. *
Kern Self Reducing Alidade. *
Metric Levelling Staff.
Steel Band.
Linen Tapes (2).
Spare Plane Table and Alidade. *
Chain.
Binoculars.
Abney Levels (2)
Prismatic Compasses (2)
Altimeters (2)

Steel Rule.
Curta Calculating Machine.
Arrows. *
Station Pointers. *
Box Sextant. *
Protractor. *
Ranging Poles.
Seven Fig Trig Tables.

* These items not needed.

Our grateful thanks go to the following for all the help and assistance given to us:
Mr. P.J. Carmody and Mr. E. Fripp of Newcastle University Surveying Dept.
Mr. W. Jenkins of Brathay Exploration Group.

METEOROLOGICAL REPORT

J.L. DAIBY AND M.G. FORBES

The glaciological and meteorological work had to be subordinated to the other projects though it was hoped to find a correlation between the meteorology, the ice ablation and river discharge.

A small met station was established on the glacier, about one third of the way between the snout and the ice fall, at an altitude of 757 metres. This was normally checked each evening when the ablation stakes were read. The station consisted of a Stevenson screen at a height of 1.5 metres lashed to four poles drilled into the ice containing a recording Thermohygrograph and a wet and dry bulb thermometer. A rain gauge was fixed on the ice surface and an anemometer mounted at 2m.

Some problems were encountered in running the station, mainly due to the frequent gales and rapid ablation, (around 4 cm per day), that loosened guys and poles that had to be re-drilled every week. It was similarly difficult to keep the rain gauge vertical. For the last three weeks the screen was set directly on the ice and lashed to a pole drilled well in. This had the effect of lowering the recorded temperatures by one to two degrees and rather spoilt the overall trace.

For two days at this glacier station, air temperature and humidity, wind speed and radiation were recorded hourly to compare with ice melt and river discharge. See last section of this met. report.

At Base Camp 1 km from the glacier snout and at an altitude of 620 m, periodic measurements of rainfall, pressure and temperature were taken and during certain gales, the wind velocities were measured with a second anemometer. These observations would have been more valuable had they been better organised and a Max and Min thermometer or even a second thermohygrograph should have been taken.

THE WEATHER.

The Kaldidalur area in which we were camping has by reason of its surrounding mountains and ice caps, a very complex microclimate. Kaldidalur itself (meaning 'the cold valley'), is open to airstreams from both the north and south and also from the east, coming through Porisdalur between Porisdjokull

and Geitlandjokull. Cold air from these ice caps further add to the complexity and the local sandur forms a meeting ground for all these airstreams.

The summer of 1970 was one of the worst recorded this century and so the weather we experienced cannot be considered as normal unless corroborated by future visits. In fact so bad was the weather that our first attempts to reach Porisdalur were foiled by blizzards and snow in the Kaldidalur pass which had been blocked until a few days before we established base camp on July 13th.

During our stay in Porisdalur, the predominating weather pattern consisted of periods of dry calm weather with high pressure alternating with short but vi cious easterly gales. Five distinct gales were experienced, normally lasting about three days with a marked peak of severity but towards the end of our stay, in the second half of August, the bad weather was almost continuous and one storm ran into another.

Under these conditions the cloud base was about 800 m and the wind, funneling down the valley often at 14 metres per second (30 miles per hour), drove the rain horizontally in blinding sheets. A shift of wind to the east normally indicated unsettled weather, with strong winds and rain. A northwesterly airstream brought more settled conditions, especially in July when we experienced a prolonged spell of sunny weather.

Cloud layers, fog banks formed over the sandur and towards evening it was common for long streamers of cloud to creep up the valley at about 800 to 900 m obliterating the sky. The temperature inversions that caused these effects, (and sometimes two inversions were visible), were purely local and clear blue sky could often be seen to the north and south of Kaldidalur. Indeed, some very beautiful sunsets were observed through the window between the cloud and land. A second example of how local were the conditions was the occurence of clear sky to the east of Porisdalur when the western end was blanketed in low cloud and rain. So often was this observed that it was easy to believe the old legend of Porisdalur being a lush oasis of green vegetation in a barren desert of rock and ice.

TEMPERATURE.

Daily max, min and mean temperatures from the hygrograph (after correction from wet and dry bulb readings) are shown in graphical form at the end of this report.

From the graph it can be seen that mean daily temperatures on the glacier at this altitude (757 metres) never rose above 5.5. C and only once fell below freezing point. This was in part the consequence of lowering the screen onto the ice on August 9th which had the effect of lowering the recorded temperatures by about two degrees. However dips in the trace also coincide with a cold stormy period which no doubt exaggerates the actual drop. A definite rise in temperature was recorded between the 18th and 26th of July immediately following an abnormally cold spell, and the clear skies during this period account for the large diurnal range, between 5 and 8 degrees. As the summer advanced, cloudy skies and unsettled weather were the norm and the diurnal range was less than 4 degrees.

The frequent temperature observations at base camp are compared with those read off from the thermohygrograph trace on the glacier, diagram 2. It is interesting to see the difference decreased from between two and three degrees during fine weather to one to two degrees during unsettled weather. This despite the lowering of the screen, which would have been expected to increase the difference. As with the mean temperatures graph, a definite fall can be detected during the period of records and this is especially marked after the 8th August when a prolonged spell of bad weather occured.

RELATIVE HUMIDITY

The Relative Humidity was consistently in the 80s and 90s and only dropped into the 70s on a few occasions. However it was extremely erratic and could change by as much as 30% in the space of half an hour. The second graph on Diagram 1 shows the mean daily R.H., abstracted from the Thermohydrograph trace, and the minimum recorded value for each day. The maximum for any day was very nearly 100%. When compared with the mean daily temperatures, a fairly good negative correlation can be seen, though the correlation with rainfall is zero.

RAINFALL

Rainfall was recorded daily both at base camp and met. station with a 13 cm. plastic funnel and a measuring cylinder. The records are not all that reliable because the gauge on the glacier kept tilting over as the ice melted and eddies round the funnel would have carried some of the rain over the top. The gauge at base camp, though flush with the ground, was partially sheltered by the terminal moraine.

Bearing this in mind, several points may be seen from the graph. The rainfall at base camp shows a marked peak, with one day having two or three times as much rain as the others during each storm. On the other days of a storm, the rain though no less prolonged was much less intense. In comparison, up on the glacier the pattern is different with less of a distinct peak and a more equally distributed rainfall. Also the total amount recorded during each storm is less at the met.station, on average 68% less than at base camp. This indicates a less intense form of rain, which was what in fact was experienced, and is probably due to its proximity to the cloud base.

WINDS

The prevailing winds at the western end of Porisdalur tend to be from either the north west or south east quadrants, being channeled into these by the orientation of the valley. Diagrams le and lf. show the wind directions recorded each day, at the base camp and met. station, with an indication of the strength.

From them several points arise, the most noticeable of which is the tendency for an easterly airstream to produce gales and a northerly airstream calm weather. A prolonged spell of such winds between the 16th and 30th of July brought fine dry weather with very little rain, and again on August 12th to 15th north westerly winds brought calm conditions but accompanied by heavy rain and snow.

When winds blew from the south east quadrant, they were nearly always strong and gales were common. Five such gales were experienced, one before records were begun, and they occurred in two periods separated by a short spell of northerly winds. Wind speeds at the peak of a gale could and often did reach 14 metres/sec. with gusts much stronger, though in the lea of the terminal moraine the velocities were about 30% of this.

It was thought that Katabatic winds might have been experienced at base camp but there is little evidence for this except for the period July 24th to 27th when winds at the met. station were southerly whilst those at base camp were from the north west. This may be due to the influence of cold air over Porisjokull.

PRESSURE

This was recorded with a pocket aneroid altimeter, mainly in the hope of foreseeing bad weather. The instrument was not very sensitive though the readings are shown to demonstrate any correlation with the other records. The most obvious correlation is with the rainfall, where on two occasions low pressure coincides with heavy rainfall but any correspondence between low pressure and easterly gales is not apparent.

CONCLUSIONS

Although the met. observations were not particularly efficiently organised or carried out, a sufficient picture of the late summer weather in the upper Kaldidalur can be obtained from the results for the following conclusions and recommendations to be made.

(a). Easterly gales are common and can be severe. They can blow up at very short notice and good shelter from the east is essential if camping is contemplated.

(b). Northerly winds usually mean more settled weather, but may bring thick mists and at times heavy rain.

(c). Atmospheric pressure does not seem to bear any relation to the type of weather experienced.

The weather in this area is extremely unpredictable and can change from a fine dry state to gale force winds and driving rain in a matter of hours. Thus anyone contemplating entering the area on foot must be adequately prepared for such conditions.

ACKNOWLEDGEMENTS

Our grateful thanks go to The University of Newcastle upon Tyne Geography Department for the loan of all the Met. equipment used on the expedition and our special thanks go to Dr. Lister for his advice and to Mr. R. Hope for all the work he did in preparing the equipment and advising us how to use it.

eat responsible for evaporation and melting at the ice surface.

Glacier melting attracts many young explorers so the problem is summarised here as a guide to future expeditions.

To find the relative importance of the meteorological elements responsible for melting and evaporation of the glacier, requires a series of precise measuring probes, carefully read and maintained almost continually. Approximate values of the source and sink of heat at the ice surface can be found from more simple equipment mounted within the first 2 m of height and read frequently in each hour of the sampling period, chosen to cover a range of weather conditions. The expedition programme rated the ablation and meteorological work as very secondary to the ornithological work of Mr. A. Lowe and the hydrological observations for Miss M. Banks. Hence severe simplification was necessary.

Incoming and reflected radiation were measured by potentiometer and Eppley Pile on three or four occasions in each hour observed. Run of wind was measured at 1 and 2 m by cup counter anemometers but only those at 1 m seemed valid. Dry and wet bulb temperatures were read by whirling psychrometer, used hourly at 1 m as a check on a thermohygrograph, mounted in a small met. screen. The data is summarised in figure 1.

Glaciers in Iceland are the most reliably temperate (0°C) and in August the wet ice could be assumed to be at 0°C for considerable depth and hence there was no heat transfer through the ice, to or from the surface.

The approximations made to use these elementary observations in a heat budget calculation may be summarised:
Evaporation, heat and momentum can be found from the product of the coefficient (of each) and the respective gradient.
Since turbulent transfer is the dominant mechanism it is often assumed that the coefficients are identical, though similarity of the profiles (after necessary change of scales) at least should be checked. If the form of the vertical profile of wind speed can be expressed mathematically, the coefficient of momentum transfer can be found and applied to the gradients of humidity and temperature to derive the vertical flux of water vapour and of sensible heat. (See R.S. Sutton 1953 "Micrometeorology")

The logarithmic low of wind speed variation with height may be theoretically proved and has been found to give good agreement with observations, though sometimes with small modifications. Over many melting ice surfaces the log low has given the best fit

With Prandtls boundary condition that velocity should be zero at distance Zo from the surface, the wind low is written

$$U_Z = \frac{1}{K}\sqrt{\frac{\tau}{p}}\ \log_e \frac{Z}{Zo} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where U_Z = wind speed at height Z

K = von Karman's constant 0.4

τ = surface horizontal shear stress, assumed constant in the first few m of height.

p = fluid density (here 11×10^{-4} gm cm^{-3})

If Km = coefficient of eddy viscosity.

$$\tau = pKm \frac{dU}{dZ} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and hence with (1)

$$Km = \frac{U_Z K^2 Z}{\log \frac{Z}{Z_o}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The basic equations of the vertical flux of heat H and of water vapour E are

$$E = K_e \frac{dq}{dZ} \;\ldots\ldots\ldots (4) \quad \text{and} \quad H = p\, C_p\, K_h \left(\frac{dT}{dZ} + \Gamma\right) \;\ldots\ldots\ldots\ldots (5)$$

where K_e = Coefficient of eddy diffusivity and K_H of eddy conductivity

q = specific humidity gm m^{-3} and T = air temperature ^oC

Cp = specific heat of air at constant pressure (= 0.2396)

Γ = adiabatic lapse rate = 1×10^{-4} $^oV\ vm^{-1}$ which can be neglected since so small compared with observed temperature gradients

Inserting Km (3) in place of Ke in (4) and Kh in £5) and putting in the log profiles for gradients of humidity and of temperature, the vertical flux of water vapour E and of heat H can now be expressed.

$$E = \frac{U_2\, K^2\, (q_1 - q_2)}{\log \frac{Z2}{Zo} \text{ by } \frac{Z2}{Z1}} \;\ldots\ldots\ldots (6) \quad \text{and} \quad H = \frac{p\, Cp\, U_2\, K^2\, (T2 - T1)}{\log \frac{Z2}{Zo}\ \log \frac{Z2}{Z1}}$$

It is clumsy and not desirable to use the three heights Z_2, Z_1 and Zo in this manner. Wind speed 13 zero at height Zo (by definition) but it is not true to say that temperature and humidity retain surface values at a height of Zo above the surface. This surface roughness coefficient is not more than a few m.m. over snow and ice (4 m.m. is the mean of many values over ice surfaces), the melting surface of which must be at 0^oC and saturated (0.46 cm Hg vapour pressure or 4.9 gm moisture per m^3 and fair) Gradients of wind speed, temperature and humidity can be very steep in the first few cm of height but with only one height at which these values were observed, the surface values have been assumed to apply at the height Zo. It would have been preferable to observe at three or more heights, checking the form of the variable changing with height and avoiding the use of values in the boundary region.

Accepting surface values and observations at one height, compels the expressions for evaporation (4) and (6) with sensible heat (5) and (7) to be re written in a yet more approximate form. Separating the constants, for convenience, these expressions become:

$$E = -\,BU_2\,(qo - q2) \;\ldots\ldots\ldots (8) \quad \text{and} \quad H = C\, U_2\, T_2 \;\ldots\ldots\ldots\ldots (9)$$

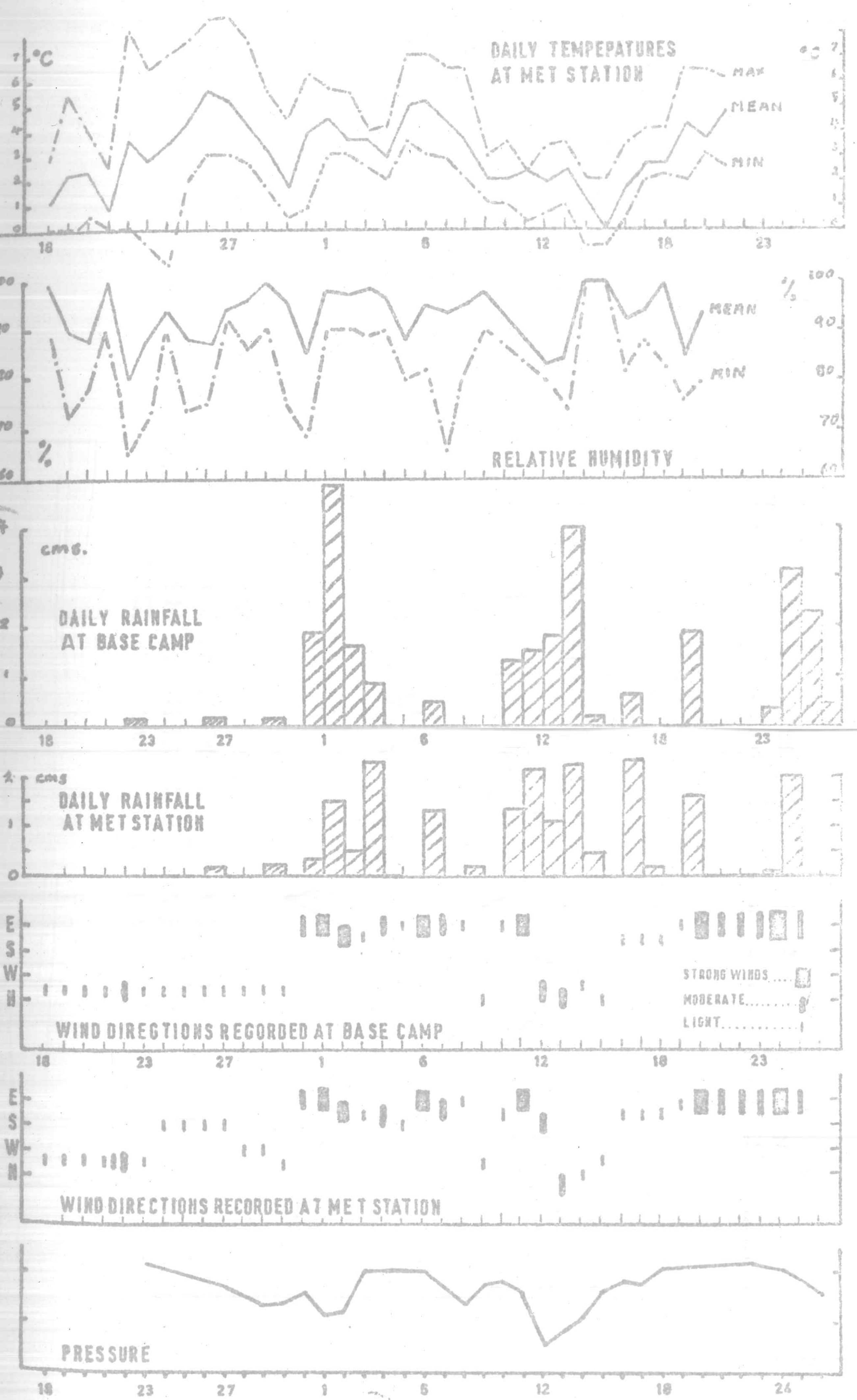
where $B = \dfrac{K^2}{(\log \frac{Z2}{Zo})^2}$ where $C = \dfrac{p\, C_p\, K}{(\log \frac{Z2}{Zo})\, 2}$

Inserting values given above but modifying the constants to permit use of humidity tables in gm m^{-3} with wind in m sec^{-1} and final values in gm cm^{-2} hr^{-1} for E and cals cm^{-2} hr^{-1} for H the constants become $B = 1.8 \times 10^{-3}$ and $C = 0.54$.
Values of E were thus very small indeed, negligible in the mass budget but when multiplied by the latent heat of vapourisation (600 cal gm^{-1}) become only a little less than half the values of sensible heat, as shown in figure 1.

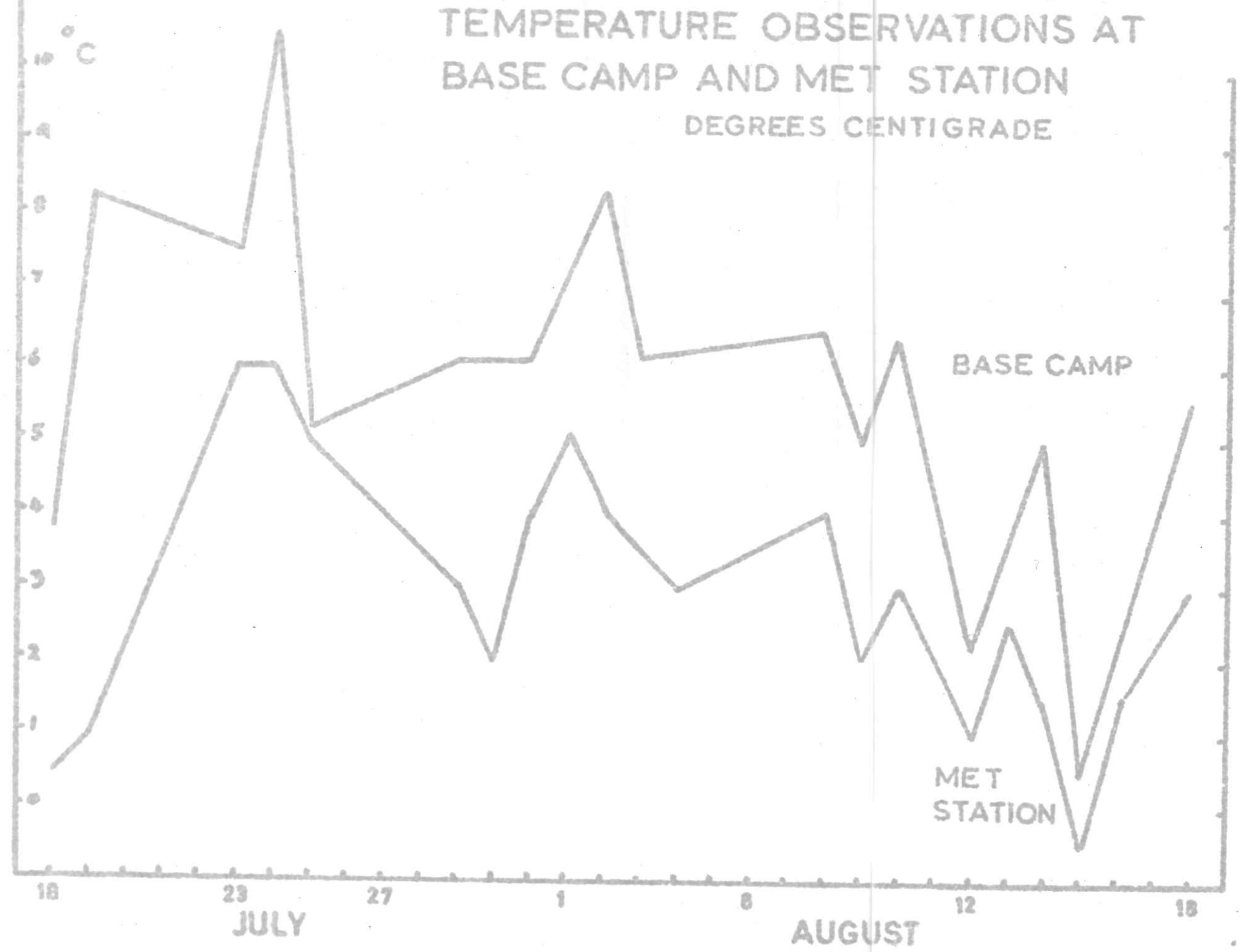
Incoming short wave radiation varied considerably in the changing sky conditions and similarly there is a wide range of albedo (the ratio of reflected to incoming radiation). The albedo is lower than expected for an ice surface, probably because of the darkening of the ice by volcanic ash and dust. The albedo is seen generally to increase with decrease in incoming radiation, which implies selection by the ice of parts of the incoming spectrum.

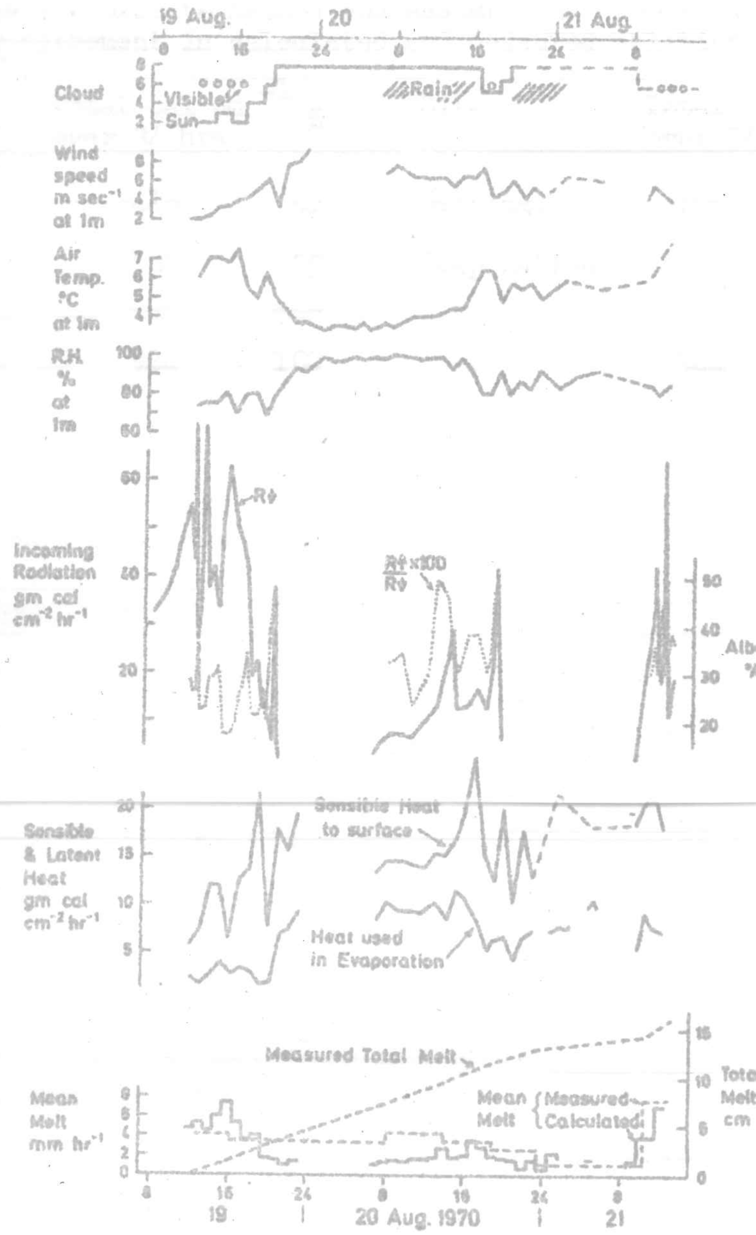
After subtracting the heat used in evaporation, the remainder, divided by the latent heat of fusion (80 cal gm^{-1}) gave the approximate hourly melting. This, compared with the ablation necessarily measured over longer time intervals,

MET RECORDS



2.


COMPARISON OF SIMULTANEOUS
TEMPERATURE OBSERVATIONS AT
BASE CAMP AND MET STATION
DEGREES CENTIGRADE
°C
BASE CAMP
MET
STATION
18
23
27
1
8
12
18
JULY
AUGUST



Meteorology and Ablation on Lower Þorisjökull s shown in figure 1. The assumption of surface values persisting near and not ly at the surface, steepened the gradients of temperature and humidity and hence alues of the vertical flux will be too high. Certainly heat cannot be stored ; the surface, though it is interesting to note that many workers, after lmann and Sverdrup began this glacial meteorology in the 1930's, have alculated more heat available than seems to be used at the glacier surface. onsidering the approximate method and assumptions compelled by the paucity of ata, the near agreement in calculated and measured ablation is remarkable.

Source	Total cal cm^{-1} over 34 hrs	%	Sink	Total cal cm^{-1} over 34 hrs	%
ot Radiation	418	45	Melting.	702	76
ensible Heat	506	55	Evaporation.	222	24
	924	100		924	100

HYDROLOGY. M.H. BANKS

Numbers given to the streams refer to the number of the gauge (see map)

Pattern of drainage from the glacier

The glacier had five main outlet streams as may be seen on the map. Of these the westernmost (stream 1) and easternmost (stream 8) were the largest, and between them they accounted for more than eighty per cent of the total discharge from the glacier. The easternmost stream had a slightly higher discharge than stream 1, and it was on this stream and its tributaries that the majority of the work was carried out. Measurements of discharge and stream profiles were, however, made on the four western streams.

The tributaries of the eastern stream were interesting in that they drained from different parts of the glacier and consequently showed varying discharge and sediment load patterns. Stream 5, which was the smallest of the gauged tributaries, was more or less marginal, draining from the névé on the eastern edge of the glacier. Its discharge was practically constant, and it carried very little material in suspension, probably because it was much less turbulent in character than the other streams. The other three major tributaries (6, 7 and X) showed far greater variations in discharge and suspended sediment load both diurnally and throughout the summer. Stream 6 had quite a high proportion of drainage from the glacier surface, but it also carried subglacial meltwaters. The drainage of stream 7 was virtually all subglacial as the main part of the stream issued from quite a considerable ice cave. Stream X, which on first reconnaissance and during the early part of the summer appeared to play an insignificant part in the drainage of the glacier and was at first ungauged, in fact showed the greatest variations both in discharge and suspended sediment load. Its water was derived both from the glacier surface and from beneath the glacier, and it drained from the central part of the glacier front. In the latter part of the summer it changed its course considerably.

Aims of the study

This study was carried out in order to learn something of the hydrological characteristics of the streams draining from the glacier. It was also carried out with a view to comparing these characteristics with those of streams draining from other glaciers, and those of "fossil" glacial drainage features in order to learn more of the relationships such features bore former glaciers in Britain.

Techniques employed in the field and laboratory

For the purposes of measuring stream discharge staff gauges were set up in all the main outlet streams (gauges 1-4 and 8) and in some of the tributaries to the easternmost outlet stream. The gauges were set close to the reach used for the discharge measurement so that stage/discharge relationships (rating curves) could be established. These staff gauges were graduated at 0.005 metre intervals as it was estimated that this was the greatest accuracy to which they could be read under the prevailing conditions.

A recording gauge set in a stilling well would have been an advantage in the major streams where a difference in stage of 0.005 m caused a considerable difference in discharge.

For the larger streams (at gauges 6, 7, X and 8) velocity was measured using a Watts bucket-wheel type current meter. Measurements were taken at 0.5 metre intervals across the streams (starting from the true right bank) at a predetermined cross-section and at 0.6 of the depth of the stream. Measurements of velocity at this depth have been shown to be approximately equal to the mean velocity in any one vertical (see Corbett 1943 and B.S.I. 1964).

Discharge at a given stage was calculated using the mean section method (see B.S.I. 1964 p. 24). Discharge by current meter technique is fallible in turbulent streams (Adams 1961 p.76)

The surface velocity of the streams whose discharge was determined by current meter was also determined by timing wooden floats over a ten metre reach where cross profiles had been sounded at two metre intervals. This enabled the calculation of a bottom correction factor.

In the smaller streams (2,3,4, and 5) and in stream 1, where there was no suitable section in which to use the current meter, discharge measurements were made using surface floats. These wooden floats were timed over marked ten metre sections in a straight reach of the stream. Depths were measured at 0.5 metre (in the case of stream 1 one metre) intervals across the stream (working from the true right bank). The floats were set free at similar intervals across the stream in such a way that they had taken up the velocity of the stream by the time they reached the upper end of the measuring reach. Discharge per unit width was calculated by the formula:

$$q = \frac{0.85 L d_n}{t_n}$$

where: q is the discharge per unit width (m^3/sec)

0.85 is a correction factor to give mean velocity in the vertical rather than surface velocity

L is the distance over which the floats were timed (metres)

d_n is the average depth (metres) at the two sections at corresponding distances from one bank.

t_n is the time of the floats over the given distance (secs) at the same distance from the bank as d_n.

By plotting the values for discharge per unit width against the width of the stream, the total discharge of the stream was represented by the area under the curve.

Related to the measurement of stream discharge was the determination of suspended sediment concentration in streams 5, 6, 7, X and 8 at varying stage. Two completely different techniques were applied for these measurements, one relying on sampling the sediment laden stream water, the other on a photo-electric device. Some comparison was made between the two methods (see results section).

Sampling to obtain suspended sediment concentration was carried out over a forty eight hour period at regular intervals, using an integrating sampler made to a design used by the Trent River Authority. Samples were taken from streams 6, 7, X and 8 at a point that had been determined by the photo-electric method to show approximately the mean concentration for that particular stream. These 500ml samples of sediment laden water were then filtered through papers whose individual weights had been determined in the laboratory after drying in an oven at 105°C overnight. Drying and weighing was repeated on return to Britain to give the weight of the sediment. Filtering took approximately one hour per sample and it was difficult to avoid 'poisoning' the sample during this tedious process. The clay content of the samples clogged the filter papers. This meant that great care had to be taken in the use of the evacuating pump so that the filter papers remained intact. The sample bottles were of such a design that any sediment that had settled out tended to stick in the neck of the bottle and a considerable time had to be spent in clearing it. This was quite an important source of possible error in the measurements so taken.

Of the disadvantages inherrent in the technique as a whole an important one is the size of the intake nozzle of the sampler, which limits the size o particles that will pass through it. In these streams, because of the high degree of turbulence, particles of such a size as would normally be carried as bed load are carried in suspension.

The photo-electric device employed was a Partech/W.R.P.L. suspended solids monitor, with many advantages over the sampling and filtering techniqu It operated from two 12 volt dry batteries, was portable and could be used by one person. The probe containing the photo-electric device was submerged to required depth in the stream and the meter read. The instrument is amenable continuous recording, a feature that is of great value in glacial outwash streams where sediment concentration can vary by large amounts over a few minutes. One of the main disadvantages experienced in the work in Iceland wa the fact that the monitor would only record a limited range of sediment concentration. Our monitor had been calibrated for a range of 0-1,000 parts per million (mg/l) using a clay suspension. This range at first appeared to be more than adequate, but later, on several occasions an indicated value of 1,000 mg/l was exceeded; great fluctuations in sediment concentration are characteristic of glacial outwash streams. By calibrating the monitor for su a wide range it could only be read to an accuracy of 5mg/l indicated concentr which meant that large proportionate changes at low concentrations could not determined with great accuracy. From this point of view it would be an advantage to be able to calibrate the instrument on a logarithmic scale.

The instrument is sensitive to variations in particle size, so had to be recalibrated on return to Britain for the precise type of sediment found in th streams under study. All the results obtained then had to be corrected on the basis of this recalibration. The fact that the glacial outwash streams were v turbulent and consequently carried material in suspension with a great range i particle size and colour presents a problem in use of a turbidity instrument. One sample (made up of the total collected) was analysed for particle size composition for each of the four streams (6, 7, X and 8) from which samples we taken. The material was taken to Britain for dry sieving of the coarser particles, and then the material which passed through the 240 mesh sieve (i.e. the clay fraction) was analysed using a Gallenkamp sedimentation balance which uses only a very small sample (of the order of 0.5 gm).

Particle size analysis was also carried out on samples taken from the beds of streams 5, 6, 7, X and 8 at various distances from the glacier snout (see figure 8 for sampling plan). All the samples were taken in the following manner. Three shovels of material were scooped from the bed working from the left bank to the centre of the stream. This method of collection meant that both the coarsest and the finest material were lost, the fine material being washed off the shovel as it was lifted from the stream. The samples were taken at fairly low water to reduce this loss. The samples were then "wet" sieved to separate the coarsest material (greater than one inch and greater than two inches) from the rest of the sample, and the weights recorded. The long, short and intermediate axes and the minimum radius of curvature in the principal plane measured on all stones retained in these two sieves. In some cases the coarse material was retained so that comparisons between wet and dry weights could be made on return to Britain. All material finer than one inch was "dry" sieved in the laboratory. In addition the three axes and minimum radius of curvature in the principal plane of all stones retained by the half-inch sieve were measured. Further analysis of the clay fraction was not carried out on these samples since it formed a small part of the whole, and this was where one of the greatest errors was likely to occur due to the sampling technique.

Profiles of the stream beds were measured at each gauging station: for streams 1-4 by Abney level and levelling staff; for the other streams, profiles were sounded by metre rule. In all cases the profiles were at two metre intervals in the reach used to measure surface velocity by floats.

Profile measurement was also carried out on a valley scale, cross rofiles of the stream valleys being measured in several places in the icinity of gauges 1-5 and 8. These profiles were measured tacheometrically sing the theodolite and levelling staff. The advantage of this technique as that several profiles could be measured from one instrument position, he results being plotted on a map and the profiles drawn from the map. lso readings were only necessary where marked changes in slope occurred. ong profiles of all streams from the terminal moraine to the glacier snout ere also measured tacheometrically in the course of mapping the area.

Results

tream discharge.

Rating curves are shown in figure 1. From the gauge readings the total discharge from the glacier was seen to vary between about $0.8m^3/sec$ and .6m³/sec. This discharge was generally at its lowest for any one day in the early morning and at its maximum in the late afternoon. Of the total discharge streams 1 and 8 accounted for over eighty per cent, stream 8 carrying a slightly higher proportion than stream 1. The discharge values for stream ranged from 0.27 to $1.1m^3/sec$, while those for stream 8 had a range from 0.46 to $1.4m^3/sec$. The rest of the discharge was contributed by streams 2, 3 and 4, whose individual discharge values rarely exceeded $0.1m^3/sec$. Of these last three streams, stream 4 was marginally the largest.

Streams 6 and 7 were nearly always the biggest of the streams making up stream 8, giving approximately equal contributions to the main stream. Much of the time they accounted for eighty per cent or more of the drainage from this part of the glacier. Stream X, however, with its great variations in discharge, on a few occasions carried nearly as much water as streams 6 and 7, so that on these occasions each of the three streams carried about one third of the drainage. Stream 5, which entered stream 6 above its gauge, carried only a very small amount of water (approximately $0.026m^3/sec$) and showed only very slight variations in discharge throughout the summer. Of the three larger streams making up stream 8, stream 7, which carried subglacial water almost exclusively, was the one to show the smallest variation in discharge.

In connection with the discharge measurements, bottom correction factors were calculated for streams 6, 7 and 8 as the ratio of the surface velocity to the mean velocity of the stream in question. The results obtained were in all cases lower than the value used in the computation of discharge from float measurements (0.85) and they ranged from 0.68 to 0.74. However, the number of measurements made to calculate a bottom correction factor was too few for the values obtained to give a true average, so the discharge values have not been recomputed on the basis of these results. Despite this it should be borne in mind that the actual discharges of the streams measured by the float method may be slightly less than the computed results.

Suspended sediment load

The work was limited to stream 8 and its component streams, to compare the load characteristics of streams draining from different parts of the glacier and to see if there was any relationship between sediment concentration and discharge.

Readings were taken on the turbidity monitor at 0.5m intervals (at two points in each vertical) across each stream in the section used for discharge measurement. From these readings, which gave a clear indication of the high degree of turbulence in these streams in that readings near the surface differed only slightly from those near the bed, a mean concentration could be determined. A point at which to take samples with the integrating sampler was determined, such that samples were taken at a position giving approximately

FIG 2 CROSS PROFILES OF SUSPENDED SEDIMENT CONCENTRATION

Station 6

Distance from right bank (metres)		0.5	1.0	1.5	2.0	2.5	3.0	3.5
Depth of measurement (i)	Top	-	510	520	510	525	520	535
	Bottom	510	550	550	535	550	540	
(ii)	Top	200	200	200	210	185	200	-
	Bottom		210	225	210	200	200	-

Sediment concentration mg/l

(i) gauge: 0.185m, discharge: 0.550m^3/sec (ii) gauge: 0.150, discharge: 0.320

Station 7

Distance from right bank		0.0	0.5	1.0	1.5	2.0	2.5	3.0
(i)	Top	250	165	150	150	155	165	175
	Bottom		175	155	155	175	175	
(ii)	Top	-	25	50	60	85	100	85
	Bottom	-	35	60	75	85		

(i) gauge: 0.210m discharge: 0.355m^3/sec

(ii) gauge: 0.205m discharge: 0.340m^3/sec

Station X – no gauge at this time

Distance from right bank	0.0	0.5	1.0	1.5	0.0	0.5	1.0	1.5	2.0
Top	200	185	185	175	775	1270	1415	1270	1215
Bottom		200	200	175		1270	1435	1325	

Station 8

Distance from right bank		0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
(i)	Top	385	385	385	370	350	360	345	325	300	300	310	325
	Bottom		410	395	385	370	370	345	325	320	305	325	
(ii)	Top	285	270	260	260	260	325	295	300	310	300	270	270
	Bottom		335	270	385	285	360	300	310	325	320	300	

(i) gauge: 0.185m, discharge: 1.030m^3/sec (ii) gauge: 0.180m, discharge: 0.930m^3/

of figure 2.

From the monitor readings it was shown that stream 5 carried little or no material in suspension. This stream, which had a very small discharge, was also less turbulent than all the others that were gauged. It was because of this and also its near marginal position that suspended solids concentration was so low (0-10mg/l).

The other three tributaries forming stream 8 all showed fairly high suspended sediment concentrations (100mg/l or more). They all showed wide variations in suspended sediment concentration. Correlation coefficients between suspended sediment concentration and discharge were determined using the monitor readings for stations 6, 7 and 8. For stations 6 and 7 it was very low (0.06 and 0.08). See figure 3, which gives the result for stream 7. For station 8 the correlation was 0.59, so it was impossible to establish a sediment concentration/discharge relationship.

The total samples of sediment obtained from each stream during the forty eight hour survey were analysed for their particle size composition. Results are shown in figure 4. From this analysis it can be seen that all the samples showed a very wide range in particle size, and that the clay fraction only accounted for 40% or less of the total sample (in the case of stream 7 less than 20%). From the analysis of the clay fraction it was shown that 30% or more of that fraction was of a colloidal nature as it failed to settle out during the analysis.

An attempt was made to compare the results obtained at station 8 during the forty eight hour survey using the two different methods of determining sediment concentration. Figure 5 shows the results obtained and gives the correlation coefficient of 0.71. Ratios between readings obtained by the two methods were also calculated, the mean ratio of integrating sampler concentration to suspended solids monitor concentration being 2.20 with standard deviation 1.71 which indicates the wide scatter of the 27 points.

Forty eight hour survey

A forty eight hour survey of the hydrological characteristics of stream 8 and its tributaries was carried out in conjunction with a similar survey of meteorological and ablation conditions on the glacier. The purpose of this study was to gain a picture of the diurnal cycle of discharge and suspended sediment load conditions in these glacial outwash streams.

Readings for this survey were taken in the following manner:-

Every 15 minutes: suspended sediment reading at station 8 by suspended (on the ½ hour) solids monitor
Every hour: readings of gauge heights at stations 6, 7, X and 8 (on the hour)
Every two hours; a suspended sediment sample was taken from stream 8 by (even hours) integrating sampler
Every four hours; suspended sediment samples were taken from streams 6, 7 (4,8, 12, 16, 20, 24) and X by integrating sampler.

The results obtained are shown in figures 6 and 7. From these graphs it is shown that sediment concentration and stream discharge and hence sediment discharge tended to reach a peak at 15.00 - 16.00 hours (all times are G.M.T.) This is shown particularly well in figure 7. From figure 6 it can be seen that certain anomalies occur in the sediment results presumably because of the inaccuracies inherent in the sampling technique. However, apart from an anomalous peak for station 8 at 08.00 hours on August 20th, The general pattern of sediment characteristics is similar to the more detailed picture produced by the suspended solids monitor and shown in figure 7.

The stream discharge characteristics show a pattern which tends to be representative of the whole season. Streams 8 and 6 both fluctuated quite widely giving early afternoon peaks, whereas stream 7 showed only small changes over the whole period. It was unfortunate that it was not possible to obtain a complete record of the discharge of stream X. However, this stream changed so much that by mid afternoon on 19th August it had overflowe its banks and the character of the stream bed at the measuring section was completely altered. By 17.00 hours on August 20th the course of this stream had changed completely leaving the gauge high and dry. By visual observatio however, it was possible to note that this stream also reached its peak discharge in mid afternoon.

Stream bed characteristics

The plan used in taking stream bed samples is shown in figure 8, and the results gained from the particle size analysis are shown in figure 9. The curves in figure 9 indicate that the samples are generally coarse grained, the clay fraction in all cases accounting for less than 10% of the sample. Some tendency for the particle size to increase with increasing distance from the glacier front is shown (note right-hand graph), and it is very obvious that sample A which was taken closer to the snout than all the rest was much the finest in particle size composition.

From the measurements of the four parameters on the stones larger than half an inch in diameter, various pebble shape measures were computed (see P.M. Mather and M.J. McCullagh 1969). The measures calculated for each stone were the pebble shape, volume, maximum projection area, sphericity, flatness and roundness. The most dominant shapes were compact bladed, compact elongated and bladed. Roundness values were quite low, lying between 130 and 185, but tended to increase with increasing distance from the glacier.

Profiles.

From the stream bed profiles it was clear that the beds of streams of this type are very irregular. The mean depths, which could be related to gauge height, for streams 5, 6, 7 and 8 were:-

Stream	Gauge height (m)	Depth (m)
5	0.170	0.064
6	0.120	0.090
7	0.175	0.196
8	0.150	0.129

Using the correction factors given here discharge could be related directly to depth in these streams.

The measurement of valley profiles showed the streams on the whole have steep sided valleys which opened out above to the main valley level. From the long profiles, which for streams 1 - 4 are shown in figure 10, it was shown that there was a steepening towards the glacier snout. The lower end of the steeper section tended to occur where there was a definite rise in the altitude of the main valley floor. It is hoped that it will be possible to compare the profiles obtained from these streams with those of other glacial meltwater streams and with "fossil" channel profiles.

Acknowledgements.

I would like to thank Dr. J. Grindley of the Hydraulics Research Station, Wallingford, for checking over and rerating the current meter and for advice concerning techniques of discharge measurement and Mr. H. Potter of the Trent River Authority for supplying the design of the integrating sediment sampler and also his advice on stream gauging and sediment sampling

FIG 1 RATING CURVES FOR ALL STREAMS

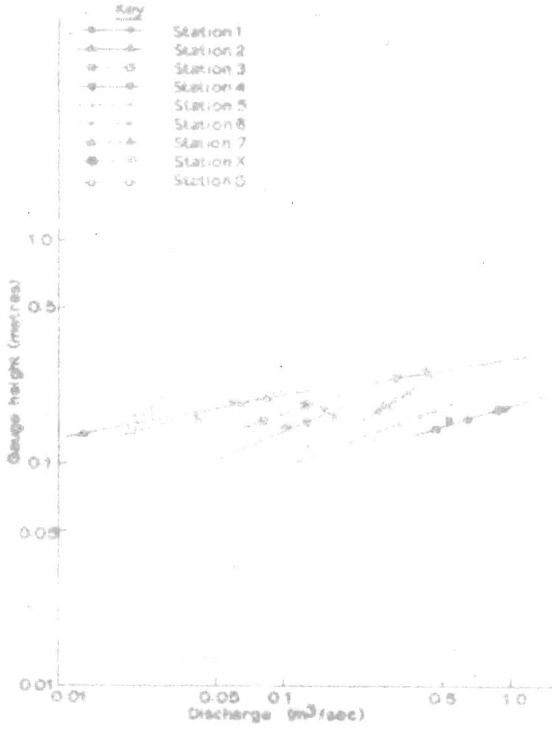


FIG 3 RELATIONSHIP BETWEEN DISCHARGE AND SUSPENDED SEDIMENT CONCENTRATION (S.S. MONITOR) STREAM 7

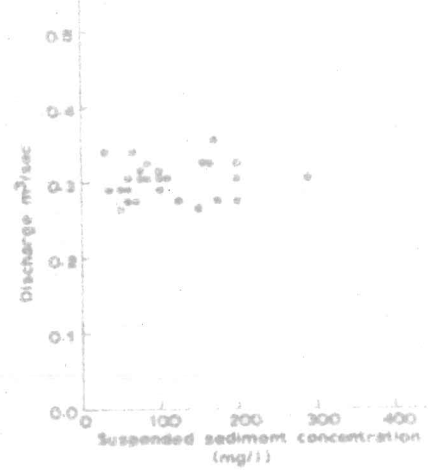


FIG.4 PARTICLE SIZE ANALYSIS OF SUSPENDED SEDIMENT SAMPLES TAKEN BY INTEGRATING SAMPLER 19-21.8.70

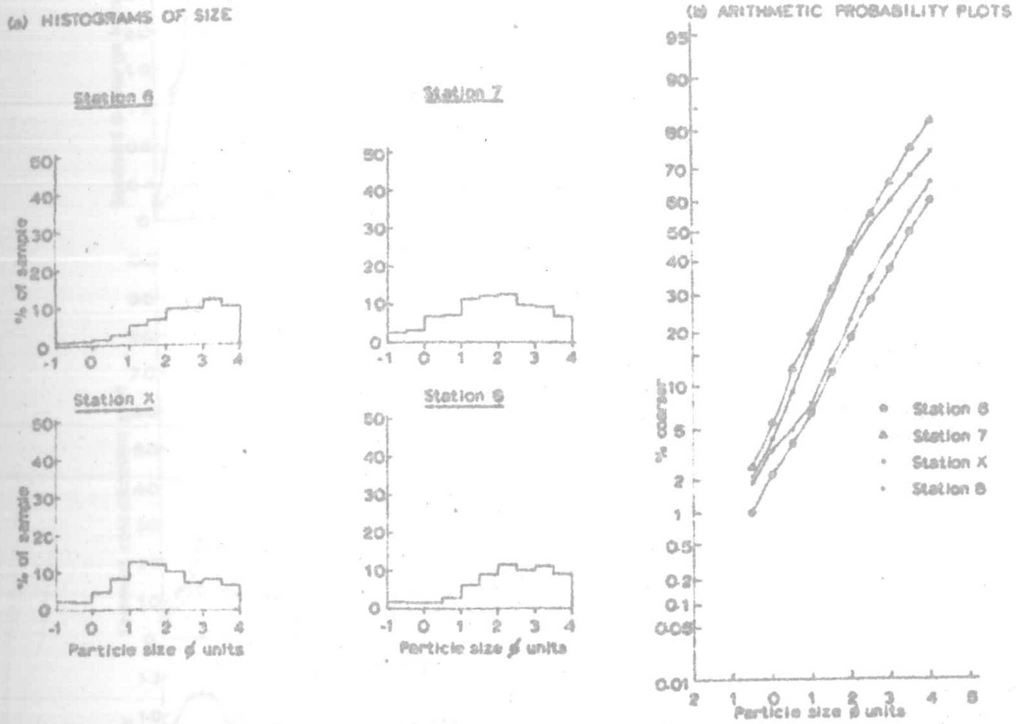


FIG.5 COMPARISON OF METHODS OF MEASUREMENT OF SUSPENDED SEDIMENT CONCENTRATION

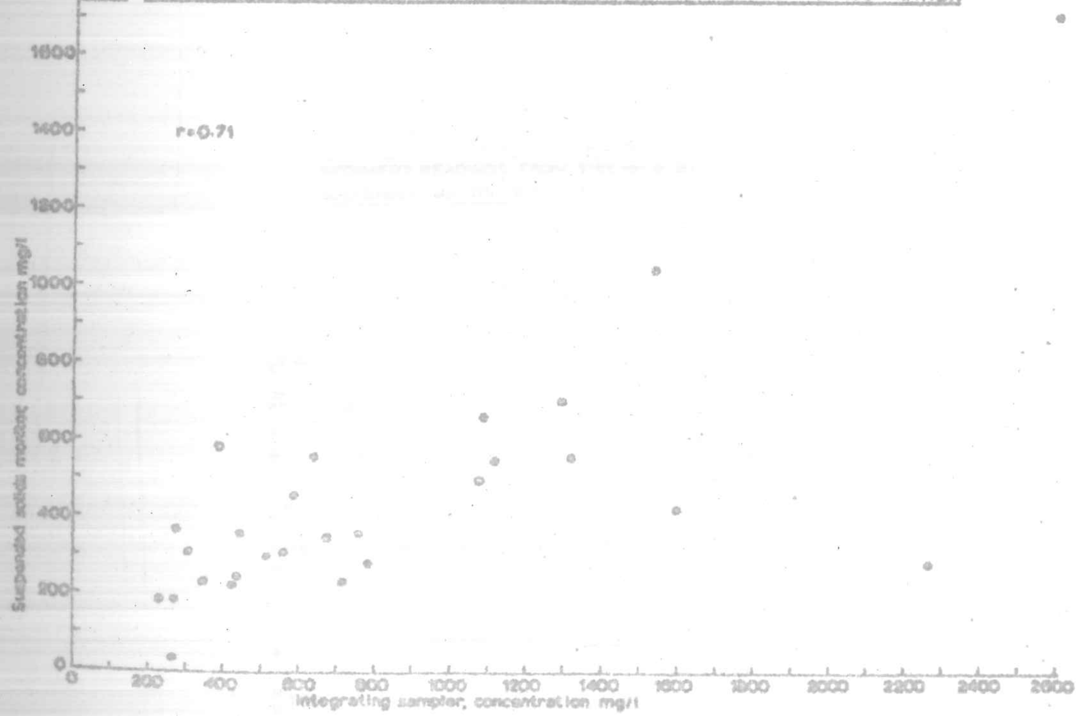


FIG 6 FORTY EIGHT HOUR SURVEY 19.8.70 - 21.8.70

(All sediment readings are from the integrating sampler)

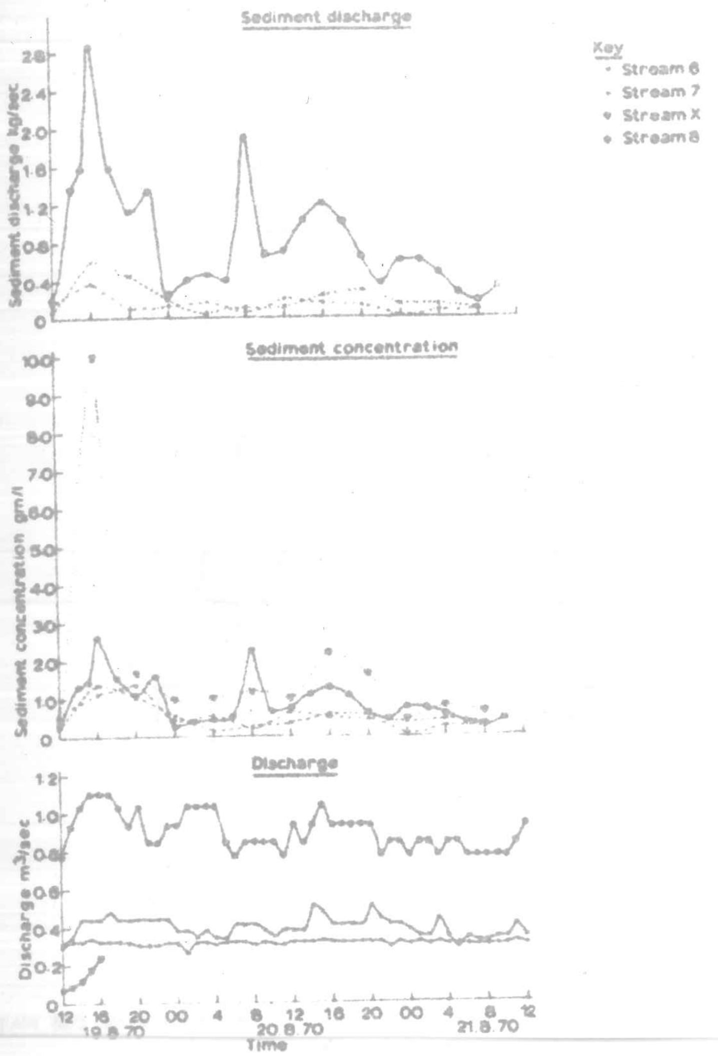


FIG 7 FORTY EIGHT HOUR SURVEY 19.8.70 - 21.8.70
SEDIMENT READINGS FROM STREAM 8 BY
SUSPENDED SOLIDS MONITOR

(Breaks in the curve occur where the indicated
reading was too great for the range of the monitor)

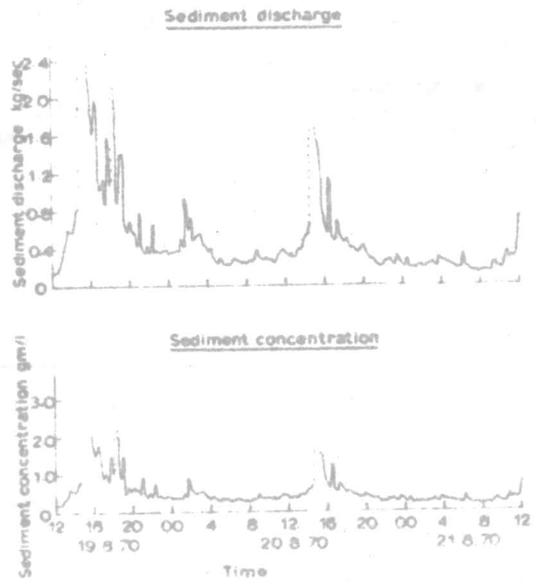


FIG.8 MAP TO SHOW SAMPLING PLAN FOR STREAM BED SAMPLES

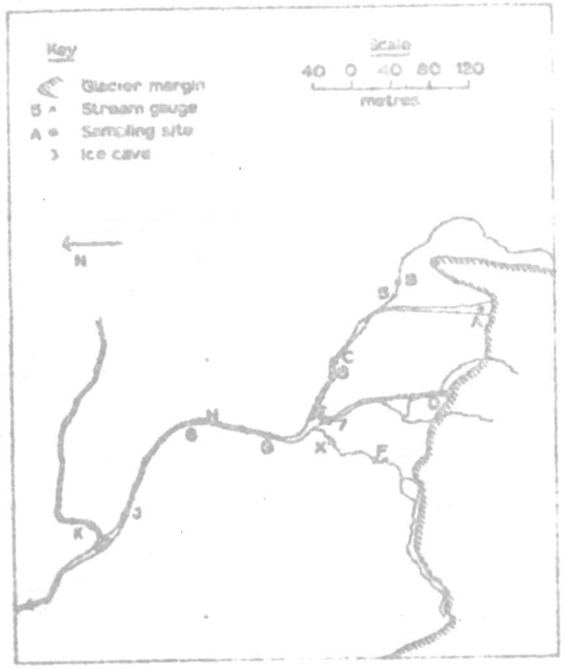


FIG.9 STREAM BED CHARACTERISTICS

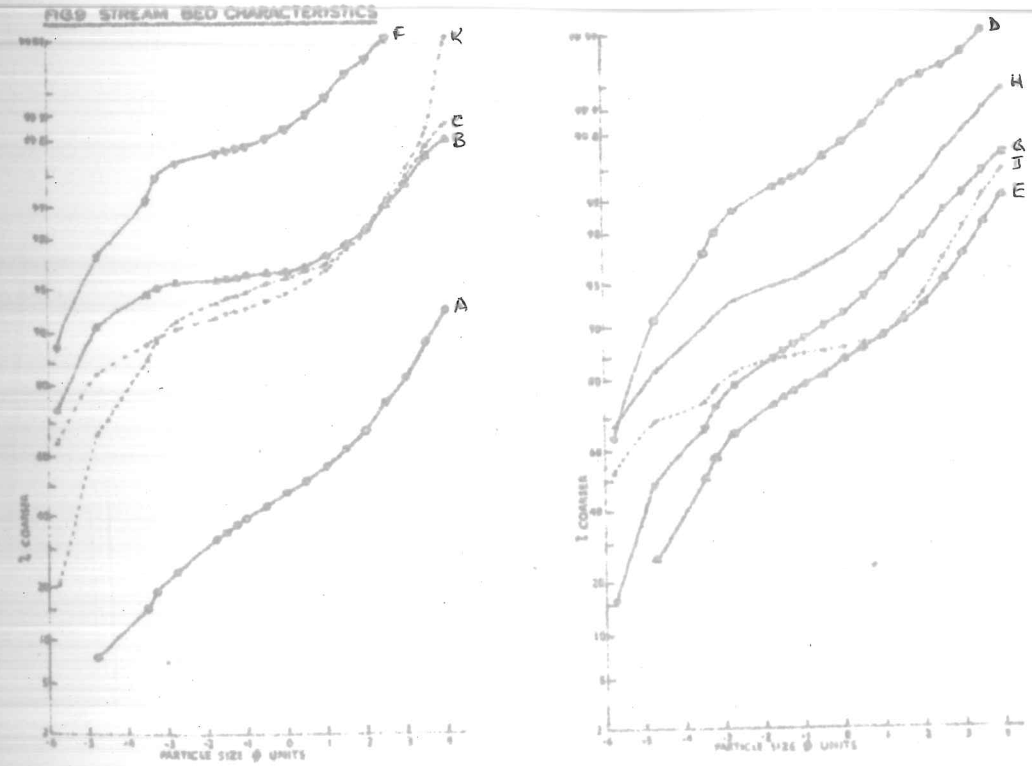
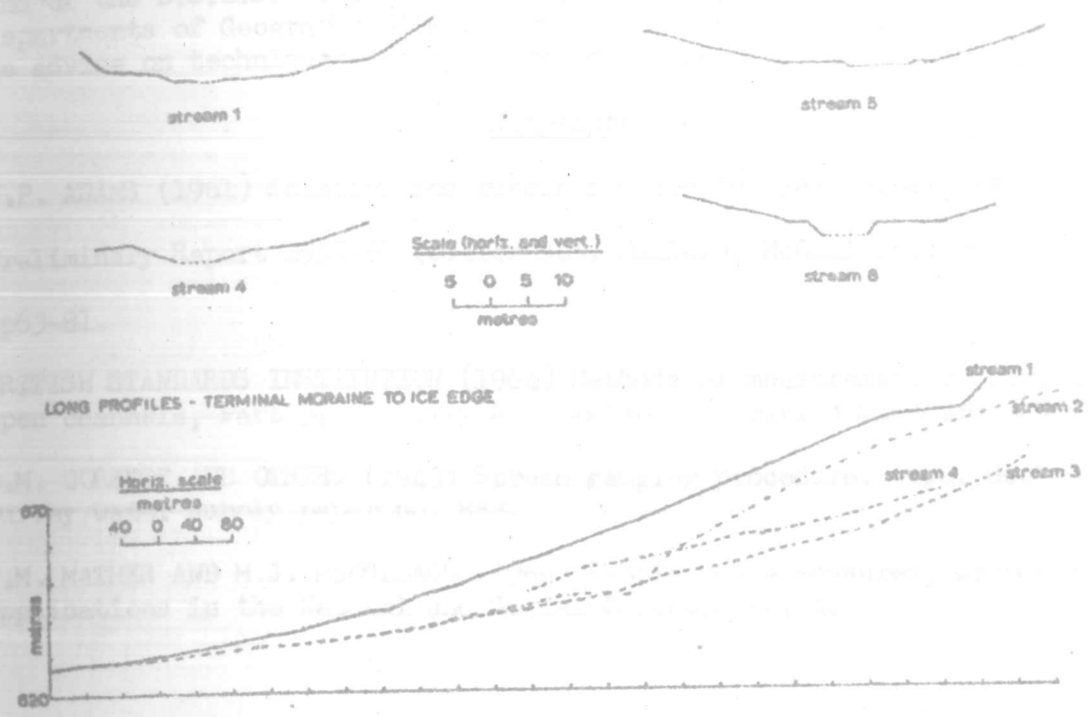


FIG.10 STREAM VALLEY PROFILES

SELECTED CROSS PROFILES



procedures. I would also like to thank the other members of the expedition and of the B.S.E.S. Iceland Expedition for help in the field, and the departments of Geography of Nottingham and Newcastle Universities for giving me advice on techniques and also providing the necessary equipment.

References

W.P. ADAMS (1961) Ablation and runoff studies in Axel Heiberg Island Preliminary Report 1959-60 (editor B.S. Muller), McGill University, Montreal pp63-81.

BRITISH STANDARDS INSTITUTION (1964) Methods of measurement of liquid flow in open channels, Part 3, Velocity area methods. British Standard 3680.

D.M. CORBETT AND OTHERS (1943) Stream gauging procedure. U.S. Geological Survey water supply paper no. 888.

P.M. MATHER AND M.J. McCULLAGH (1969) Pebble shape measures, Computer Applications in the Natural and Social Sciences no. 4.

APPENDIX 1

Hydrology Report. R.E. Eden.

THE SUSPENDED SOLIDS MONITOR.

Use was made of a Laboratory Portable Suspended solids monitor to determine the suspended solids content of the rivers under investigation. The type used was a Partech (WPRL) monitor type FP/PH using a standard head having a range of 0 - 1000 mg/l. In the field two Ever Ready type HP1 batteries were used for the 24v supply needed for operation. In the instrument design it was intended that these batteries should be external to the monitor and the supply fed via cables to a socket on the instrument panel. It was soon found that, by a simple modification, these two batter could be mounted internally in the monitor, greatly facilitating its portability. A voltmeter was taken with the spares equipment - its being recommended that the batteries be charged when the voltage dropped to 22v.

Partech Ltd. were of help in preparing a list and advice on field repair. It is to the credit of the instrument that, despite the arduous conditions it was called on to operate, it performed faultlessly throughout the working period on the glacier.

Being a semiconductor device the 'warm up' time is small and the instrument was only switched on briefly before use. Power consumption is small (2 watts) and over the 4 weeks in use two batteries coped without replacement.

Information from the recorder is in the form of a meter scaled 0 - 10 Facilities are also provided for fitting a recorder (output 1 mA into 100 although this was not used. Its use is however recommended if a similar project is undertaken in the future.

The meter was calibrated in the laboratory prior to departure. As particle size and specific gravity affect the monitor indication, the instru was calibrated against a glacial clay suspension and then a similar standard turbidity solution made up. In this instance a suspension of 900 mg/l was produced with the clay and a standard giving an indicated valu of 915 made up to nearly correspond with this. This standard was taken into the field for checking and any necessary resetting of the range. The standard appeared to be unchanged when checked upon return. Samples of the river material was brought back and against the original standard a gravimetric check made and the meter recalibrated against this. A calibration curve was produced relating the meter indication to the true suspended solids. This curve as expected is only linear in its lower values, becoming progressively more non-linear at high values. Although it was discovered upon return that the monitor head was used for material outside its optimum design range (0 - 1000 mg/l) the non-linearity of the curve was not great. Heads in the range 0 - 5000 mg/l are available and may be better suited to some glacial stream discharge/sediment measurements

On the relatively few periods when the solids in the rivers exceeded the meter range a sample was taken from the river and diluted with clean water until within the range. This method appeared to agree well with samp brought back and gravimetrically determined in the U.K.

The monitor operates on the principle of the interruption of a steady light source by the particles in suspension. This interruption is amplifie and recorded as an out of balance current. To balance the effects of day-light on a photocell two photocells are employed set at different distances from the light source. A 'set zero' control on the instrument takes care of this. The probe head is simply inserted in suspension free water and adjusted to a zero meter reading. The only field operation necessary is to clean the optical windows (approximately weekly) to prevent a 'zero' drift and to check/adjust using the probe in clear water.

The probe head is mounted on a steel shaft handle and the whole assembly very robust. However care was taken to reduce knocks and impacts by rolling stones on the river beds to a minimum.

The advantages of the instrument became fully apparent when it was found that the gravimetric methods were taking up to 1 hour to filter. In the often rapidly changing conditions that prevailed one was able to follow closely the patterns of sediment flow.

In Appendix 2 a method of stream gauging using suspended solids is suggested.

APPENDIX 2

POSSIBILITIES OF STREAM GAUGING BY SUSPENDED SOLIDS FLOW.

One of the basic difficulties of stream flow measurement in glacial areas is the general variation in course and flow that occurs over one season of melt. Often the smaller tributories have a very variable course and the establishment of anything resembling a permanent gauge is difficult or out of the question. At the beginning of the melt season the streams may be apparently insignificant but grow to sizeable proportions within a few weeks. In certain types of glacial work it is required to measure each of the smaller streams flowing from the glacier.

One possible solution is to use a sedimentation flow net. In the simplest case consider two streams meeting. Suspended solids (S_1, S_2, S_3) are measured on the three limbs. (Fig. i) If the flow in each section is taken as Q_1, Q_2, Q_3 respectively then the two basic equations are:-

$$Q_1 + Q_2 = Q_3$$

$$Q_1 S_1 + Q_2 S_2 = Q_3 S_3$$

from which the ratios $Q_1 : Q_2 : Q_3$ can be derived.

If a gauge is placed in the stream to measure Q_3 then

$$\frac{Q_1}{Q_3} = \frac{S_3 - S_1}{S_1 - S_2} \quad \text{and} \quad \frac{Q_2}{Q_3} = \frac{S_2 - S_1}{S_3 - S_1}$$

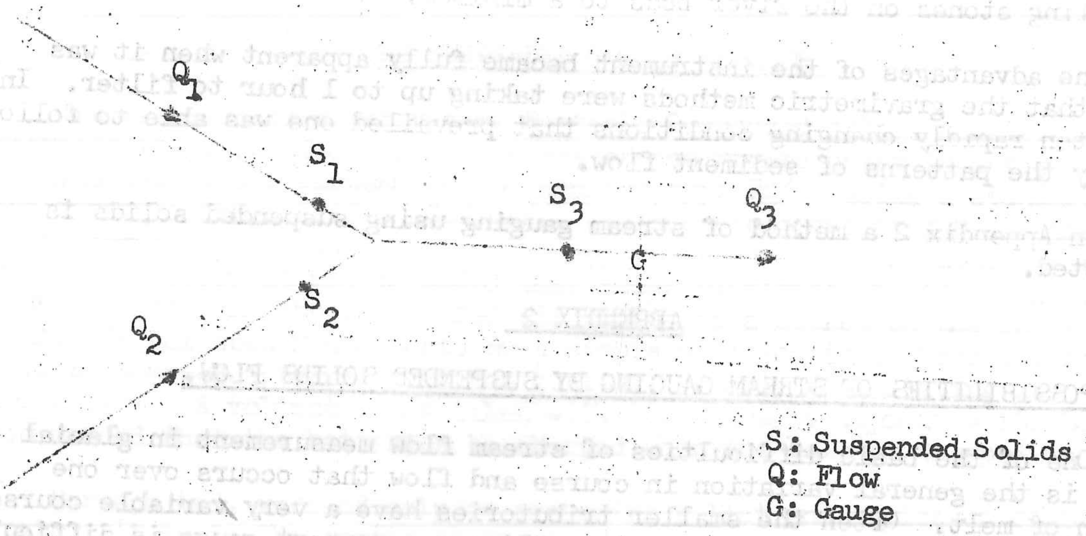


Fig. i

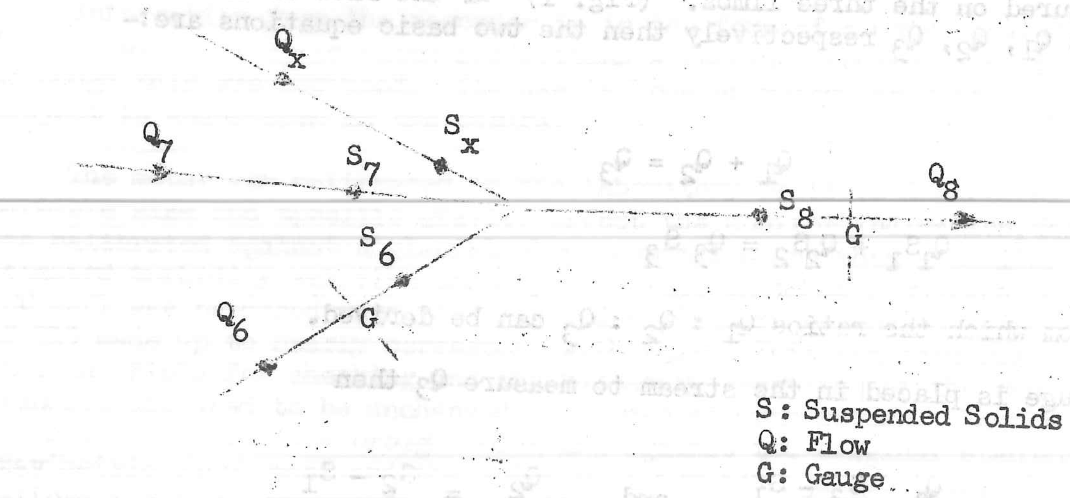
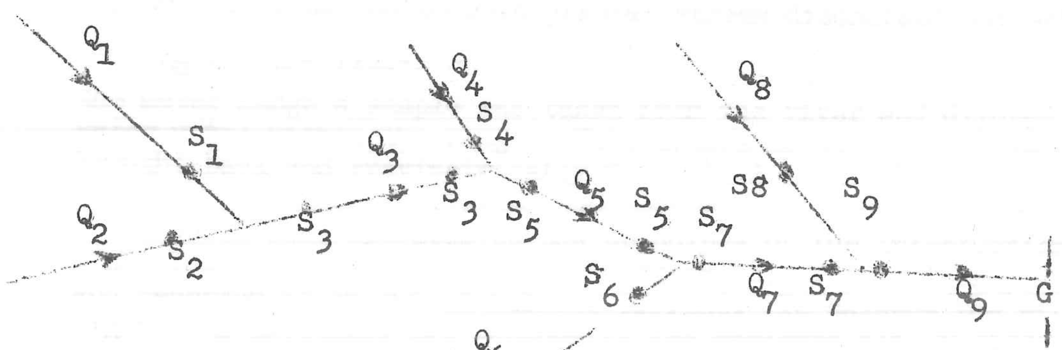


Fig ii



APPENDIX 3

Hydrology Report. R.E. Eden.

ANALYSIS OF SUSPENDED SOLIDS PULSES

One of the noticeable features of continuous observation of monitor output over four separate days was that the general shape of all the suspended solids pulses was very similar. Each solids pulse could be analogous to an electric pulse-circuit having a fast rise-time and slow decay. Fig. (iv).

The pulse had the general shape as follows:

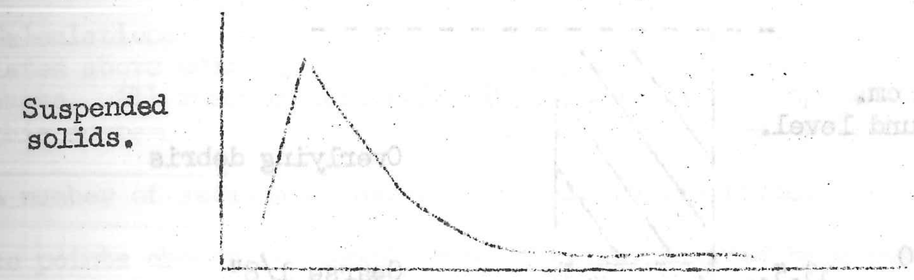


Fig. iv

The rise-time in each case was of the order of 120-150 seconds followed by an exponential decay.

In a number of instances the monitor was "off scale" but if a continuous record of suspended solids with time was maintained the decay part of the curve could be extrapolated backwards and a fair indication of the peak load determined. The decay will be some function of the river bed roughness (assuming a fully turbulent stream). The longer the delay the 'rougher' the bed. (Analogous to the discharge of a capacitor through a resistor). From continuous analysis of a glacial stream the general characteristics may be determined such as the frequency of small crevases opening up or slumping into a stream.

A change in course of a stream will be indicated by a plateau after the initial rise-time. Under favourable circumstances this may well be within the range of the instrument and thus the duration of a route change may be determined.

A 'history' of a stream may therefore be recorded during the period of observation. Unless simultaneous changes occur, each change will appear, even though it is superimposed on another decay curve.

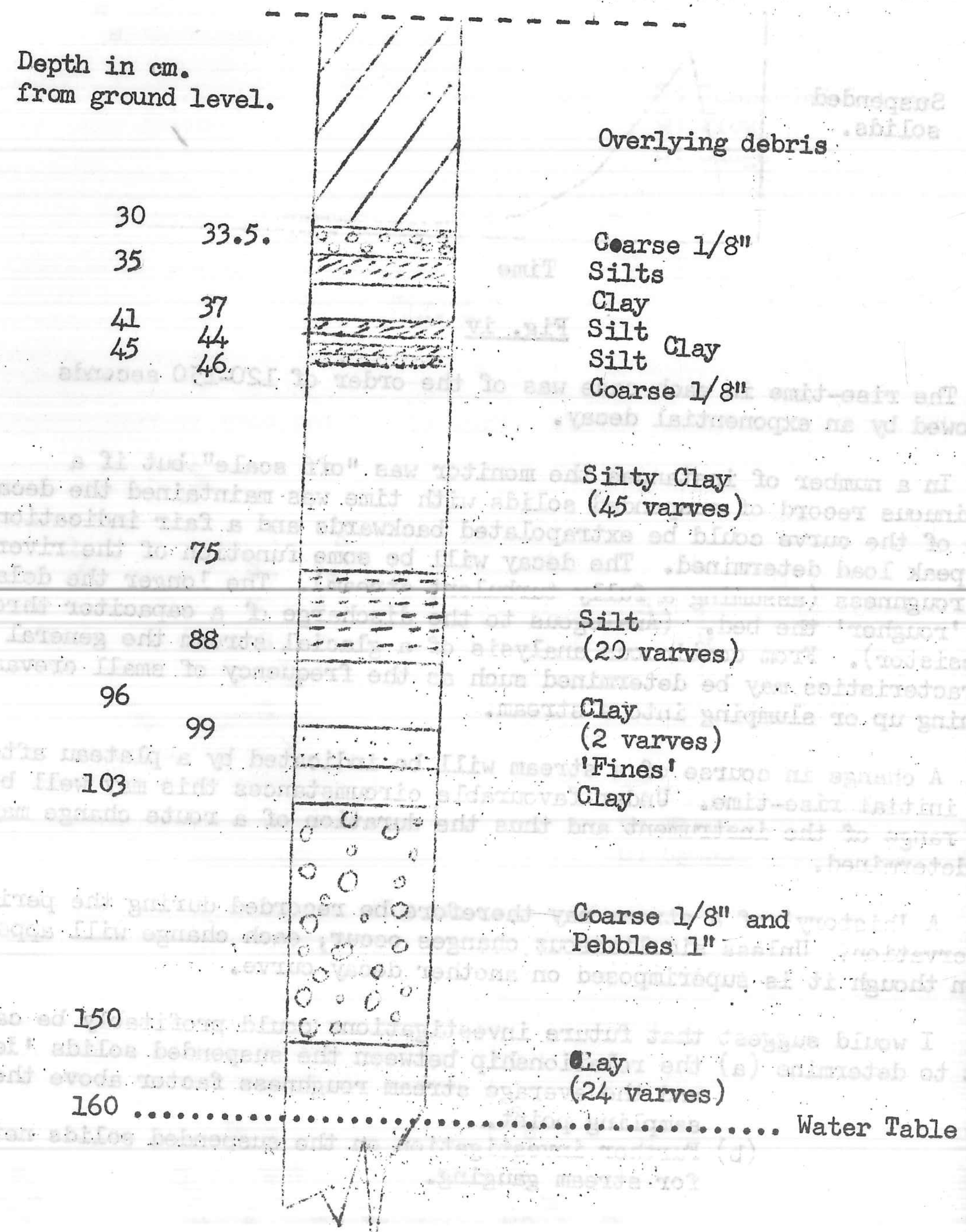
I would suggest that future investigations could profitably be carried out to determine (a) the relationship between the suspended solids 'decay' and the average stream roughness factor above the sampling point.
(b) Further investigation on the suspended solids network for stream gauging.

APPENDIX 4.

Hydrology Report. R.E. Eden.

Age Determination of former Glacial Lake in Þorisdalur.

An excavation of the lakebed of the former lake in Þorisdalur in the region of the junction of streams 8 and 9 ('Freshwater') and on the left side of stream 8. was made. Approximately 150 layers were counted in the bed indicating the age of the lake.



In general if there are n limbs (n 2) in a network meeting at a single point then to determine actual flows (n-2) gauges will be required. (See Fig ii). It should be noted however that for a stream containing a number of tributaries that providing sufficient distance exists between tributory entry points to ensure complete mixing of the suspended solids only one gauging station would be needed. (A quick check with the monitor probe across the stream will ascertain whether this is in fact the case). Fig. iii demonstrates.

For a period of time gauges were available on all streams (6, 7, X, and 8) and from these figures the sum of flows in 6, 7 and X were within 11% of the flow determined in 8.

Calculations were made on flow using the suspended solids network analysis postulated above using gauges 8 and 6 as possibly the most reliable of the gauges. All results were well within the 11% envelope which suggests that this suspended solids net analysis may have a real potential.

A number of safeguard checks were made in the field.

(1) The points chosen for sampling were first examined by plotting suspended solids profiles across the streams at different flow rates. Whilst at times variation did exist in the turbulent waters, points were selected to represent a fair mean.

(2) It was assumed that solids material was neither deposited nor gained within the network. As the gradients were reasonably similar this assumption could be considered valid.

(3) As a check the suspended solids at one point were checked again after the other streams had been measured to ensure that over the period of measurement (usually seven minutes) there had been little or no change. The actual procedure adopted was to measure at 8 then go to X, 7, 6 and then check back to 8.

(4) For the network to be operative the suspended solids in each stream must be different. This was always found to be the case.

The specific gravity of the solids did vary during the course of the investigation. Initially it was 2.35 but rose fairly rapidly to 2.79 when the more normal glacial deposits were transported. This was probably due to the Hekla ash from the Spring 1970 eruption being removed in the early season melt. According to Sigurdur Thorarinsson (1) the area under study received 0.1 cm tephra.

Reference

1. Thorarinsson S. (1970) Hekla, A Notorious Volcano. Almenna Bokafelagid Reykjavik.

The area studied by the expedition was the valley and small outlet glacier of Thorisjokull, which lies immediately to the west of Thorisdalur. The glacier was approximately 2km. in length from the icefall, by which it drained Thorisjokull, to the snout, and the valley was a further kilometre long from the glacier snout to the terminal moraine. Beyond this there wa an extensive sandur plain lying in the triangle between Thorisjokull, Geitlandsjokull and Ok.

The terminal moraine was a considerable feature, being about 2m. in height at its eastern end and somewhat higher in the west, and it stretched across the entire width of the valley. In the east it was conti into a further morainic feature which was visible on Prestahnukur, and on slope probably represented a lateral moraine. The feature on Prestahnukur showed two distinct levels which are probably indicative of two halts in th retreat of the glacier. By determining the difference in height between th top of this feature and the valley floor it should be possible to estimate the thickness of the glacier snout when it extended down the valley to the terminal moraine. It should also be possible to gain an estimate of the gradient of the glacier snout at this time.

The terminal moraine probably represents the most recent maximum exten of the glacier since there were no obvious recent signs of glaciation below this point. If this glacier has behaved in a manner similar to that of oth glaciers in Iceland, this maximum would have occurred in the latter part of the nineteenth century and would probably represent its maximum extent in historical time (see for example, Thorarinsson 1939 and Price 1969). For example it is thought (Thorarinsson 1939, fig. 9 and 1949) that Hagafellsjo Eystri, which is an outlet of the southern end of Langjokull, reached its maximum extent in post-glacial time in about 1850.

In this respect it is worth noting that the western end of the termina moraine is still ice-cored. This was shown since stream 1 disappears underneath the moraine to reappear on the downstream side in a displaced position from an ice cave. From this it would appear that this ice has remained in situ since the glacier retreated from the moraine about one hundred years ago.

From evidence shown by the morainic features on Prestahnukur it seems that Thorisdalur was ice free at the time of maximum extent or at least whilst the glacier still blocked the outlet from this valley. There is evidence that there was a lake in Thorisdalur at this time. In fact there indications of several small former lake basins in various parts of the valley, the largest of these being just downstream of the point where the river draining from Thorisdalur joins the drainage from the eastern part of the glacier. Varves were found and examined in this basin.

Behind the terminal moraine the valley exhibited many features of glacial retreat, and there was also some evidence of sorting of material by frost action. The lower part of the valley lying to the west of stream 3 consisted in the main of a sandur plain crossed by braided streams constituting the drainage from streams 1, 2 and 3. To the east of stream 3 the lower part of the valley was covered by hummocky morainic material which showed some evidence of sorting by frost.

Approximately where the valley widened out to the south of Prestahnukur the morainic features increased in size and there was a marked increase in altitude. There were in fact three distinct moraine steps (see map) in this part of the valley. In the upper part of the valley (south of Prestahnukur) the stream valleys also had river terraces (especially stream 4). There wer also kettle holes and other features typical of dead ice topography, some obviously still in process of formation. The exact position of the glacier snout was difficult to determine in many places particularly to the west of stream 4, where ice-cored moraines extended for a considerable distance

wn the valley (see map). To the east of stream 4 the moraine close to the acier appeared to be older than that in a similar position to the west, dicating that retreat in the west, where the forward development of the acier was not impeded by Prestahnukur, has been occurring more rapidly in cent years than in the east, where Prestahnukur prevents much forward evelopment.

The lower part of the glacier itself had a considerable debris cover n the form of moraines and dirt cones. The dirt cones appeared to be of two pes. Those of the first type, which constituted the majority, were covered th fine grained material, and their positions were possibly related to old crevasse lines. The lower part of the glacier had very few open crevasses. e dirt cone, sited near the outlet to stream 3, showed definite evidence indicate that the material causing its formation had originally collected the bottom of a crevasse. The ice at the tope of the cone had a groove in t along the length of the cone, and the material on the top, which stood up bove the cone surface, showed some evidence of stratification (see diagram). his cone probably evolved in a similar manner to those described by Lewis nd Swithinbank (Lewis 1940, Swithinbank 1950). A few of the cones were of the econd type and were covered with much coarser material which may indicate a ifferent origin of the dirt left on these cones.

The glacier as a whole showed a considerable amount of surface drainage elow the firn line in the form of very small streams, and in some places oulins were to be found. The glacier sloped gently up towards the ice cap of horisjokull from which it was fed by an ice-fall.

The landscape of the valley as a whole was one showing fairly recent lacial retreat, and features on the glacier such as the dirt cones gave ome idea of the amount of ablation taking place. Two dated stones were ound quite close to the eastern margin of the glacier; the distance of these rom the glacier snout was measured.

Note Numbers given to the streams refer to the number of the water level gauge (see map).

References.

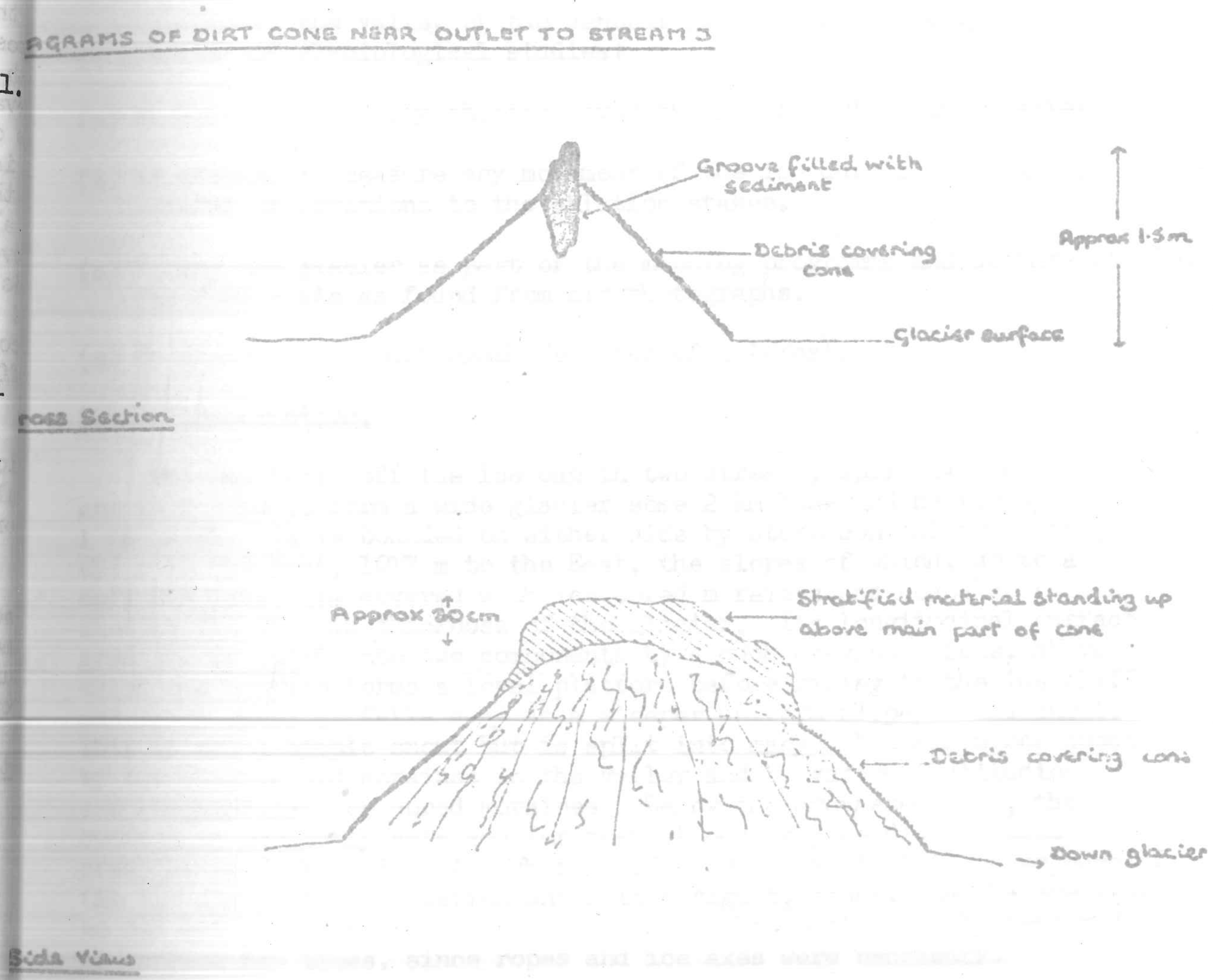
W.V. LEWIS (1940) Dirt cones on the northern margins of Vatnajokull, Iceland. Journal of Geomorphology vol III, No 1, pp 16-26.

R.J. PRICE (1969) Moraines, Sandar, kames and eskers near Breidamerkurjokull, Iceland. Trans. Inst. Br. Geogrs. 46, pp. 17-37.

C. SWITHINBANK (1950) The origin of dirt cones on glaciers. J. Glaciol. vol 1. no. 8 pp 461-465.

S. THORARINSSON (1939) The ice-dammed lakes of Iceland with particular reference to their values as indicators of glacier oscillations. Geog. Annaler, vol 21. pp 216-242.

S. THORARINSSON (1949) on the age of the terminal moraines of Hagafellsjokull Eystri in "Some tephrochronological contributions to the vulcanology and glaciology of Iceland". Geog. Annaler, vol 31, pp. 239-256.



Glaciology.

J.L. Dalby.

Porisjokull is a small ice cap lying to the SW of Langjokull, once joined to it but now separated by Porisdalur. It forms an almost perfect dome on top of a basalt plateau and its summit reaches a height of 1350 metres. Its edges are bounded by near vertical cliffs with no outlet glaciers except to the North where the ice tumbles over the cliffs and flows away as three glaciers.

It was in the valley of the central glacier that we camped and on it carried out glaciological studies:

(a) To measure the daily ablation over the lower part of the Glacier.

(b) To attempt to measure any movement of the ice during our stay by two sets of observations to the ablation stakes.

(c) To map the glacier as part of the mapping programme and compare it with its 1960 state as found from air photographs.

(d) To describe and photograph features of interest.

General Description.

The ice falls off the ice cap in two streams, split by a nunatack and then join to form a wide glacier some 2 km long and narrowing to 1 km width. It is bounded on either side by steep conical mountains, 856 m to the West, 1017 m to the East, the slopes of which, up to a definite line, are covered with ice cored morainss and heaps of rubble, showing the maximum thickness of the glacier. Its longitudinal surface gradient is split into two components by a much crevassed zone, above which the surface forms a level platform before rising to the ice cliff, and below which it falls away as a steeper uniform slope to the snout. This is not a simple snout but is split into many lobes and minor snouts by two massive old moraines in the valley and by various latitudinal and longitudinal ice cored moraines. Below the crevassed area, the surface is perfectly safe and for most of our stay we did not need crampons to walk on it. As ash covered snow was still lying over much of the ice above the met station until late August, concealing the crevasses, we did not do any ablation measurements on this part and only ventured up there a few times, since ropes and ice axes were necessary.

At the Western end of the snout, the ice disappears beneath longitudinal ice cored moraines of considerable size, and in July, the valleys between these were almost filled with hard packed snow and ice crystals, forming a hard flat surface leading up to the glacier ice proper. They gave the illusion of the glacier extending much farther than it did, and in mid July, such snow bridges extended down the valleys as far as stream gauges 1 and 2. However by mid August they had melted away leaving the actual glacier ice exposed. Ablation stake 1 was drilled into this snow so that a comparison of the ablation on the two surfaces could be made.

On the surface of the snow there was a great deal of black ash, from the May Hekla eruptions, forming long wind blown lines orientated East-West rather like the ripples in sand, and by protecting the snow from insolation may well have preserved it longer than usual. That lying on the glacier below the met station had been washed off long before we arrived.

Ablation Measurements.

The ablation was measured at eight points roughly 100 m apart in a line running straight up the glacier from the snout. It was accomplished by drilling bamboo canes deep into the ice surface and daily measuring th length of cane exposed. Initially the ice surface was flat and this presented no difficulty but as the surface melted it became uneven and several readings could be possible at the same stake. The technique used overcome this was to place the head of an ice axe across the hole and measure up from the surface of the metal next to the shaft. It was always held in the same position to give a representative mean value.

The ablation stakes were normally read daily, but for one 48 hour per they were read every four hours for comparison with theoretical melt (calculated from met observations), and river discharge.

Results.

Diagram 1 shows graphically the daily ablation for each stake, along with its altitude. As the maximum difference in height is only 90 metres, marked differences in gradient occur, though those for stakes 1 and 2 are slightly steeper. The apparent rise in the surface on August 15th occurre after snowfalls and low temperatures.

This is shown more clearly in diagram 3, which represents the ablatio measured for 18 days in the case of stake 1 and 34 days for all the others It is clear that the snow under stake 1 melted at a significantly higher r than the glacier ice (6 cm per day), and consequently disappeared by mid August.

Both stakes 1 and 2 show a higher rate of melt than 3 and 4 but stake 5, 6, 7, 8 show a slightly higher rate of melt than 3 and 4 as well, despi their greater altitude. This may be accounted for by the gradient of slop and the aspect, for stakes 3 and 4 were on the steepest part of the ice, f North, whereas the others were on much gentler slopes. This, combined wit the small height differences and observational errors may account for the correlation of melt with height (coeff of corr.^{n} = -0.502).

Diagram 2 shows the mean daily ablation for the period for which readi were made (34 days). There is some correlation with mean temperatures and the correlation coefficient for daily melt and mean daily temperature is 0.640.

It was noticed that towards late evening, melt water on the surface began to freeze again, though not entirely, and this was confirmed by strea gauge readings. However during the period of the 48 hours micro study abla occurred all through the night, and the ice surface was continually streami with water and very treacherous to walk on without crampons.

Diagram 4 shows the hourly melt (cm) derived from the 4 hourly readings for all the stakes. Definite peaks occur around mid day, with o minor reduction in ablation during the first night, but during the second day, a different cycle occurs, with a large reduction in the night time mel and a very much greater peak at mid day.

With only one such survey period, it is difficult to determine which o the two cycles is the normal one. However the area beneath the graph for t two 12.0 noon to 12.0 noon cycles give a good estimate. The first cycle during August 19-20th gives a daily melt of 9.0 cm which is about twice that actually recorded, whereas the second cycle during August 20-21st, wou result in a daily melt of 6.2 cm. This is of the same magnitude as that normally recorded.

It would appear that the 48 hour survey was conducted during a period exceptional ablation and more such surveys would be needed for a good diurn picture of the glacier regime. See the Met. Report for detailed analysis o met. and ablation records.

DIAGRAM 1

DAILY LOWERING OF THE ICE SURFACE AT THE EIGHT ABLATION STAKES. HEIGHTS IN METRES

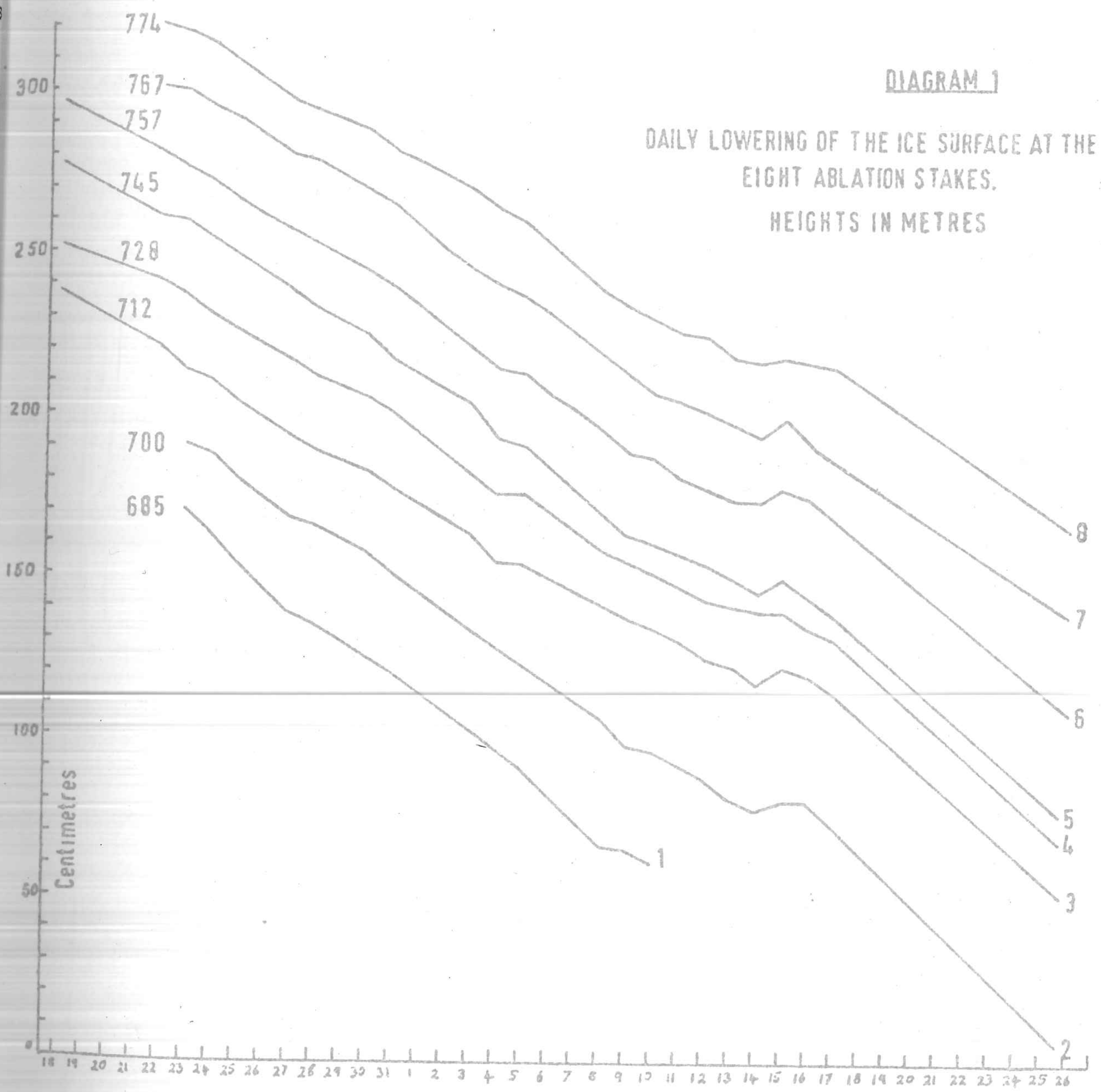


DIAGRAM 2

AVERAGE DAILY ABLATION FOR PERIOD OF OBSERVATIONS.

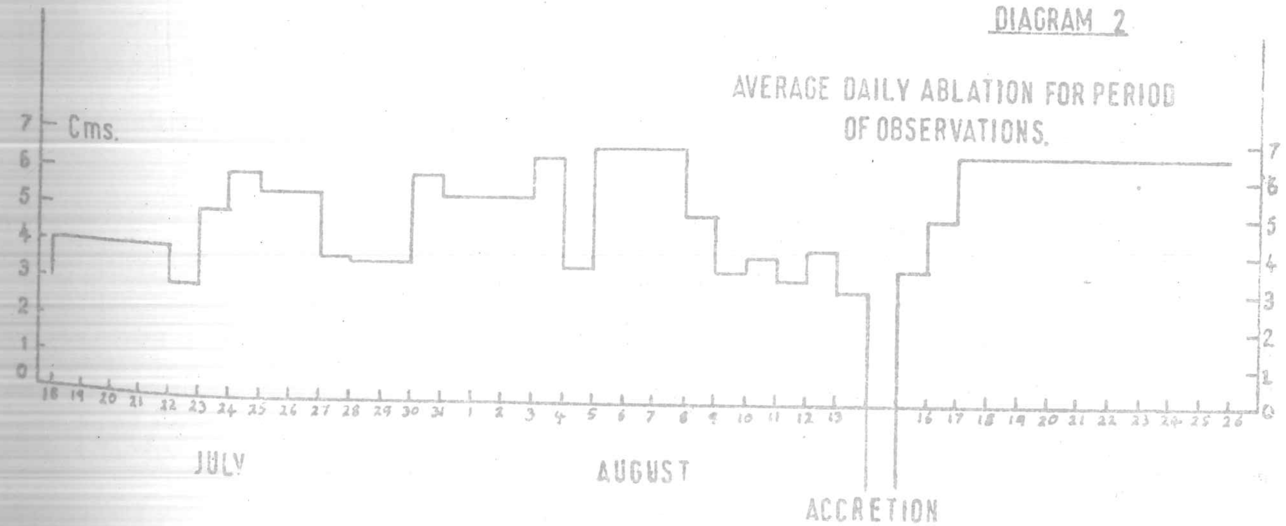


DIAGRAM 3.

MEANS FOR EACH STAKE OF 34 DAYS ABLATION READINGS.

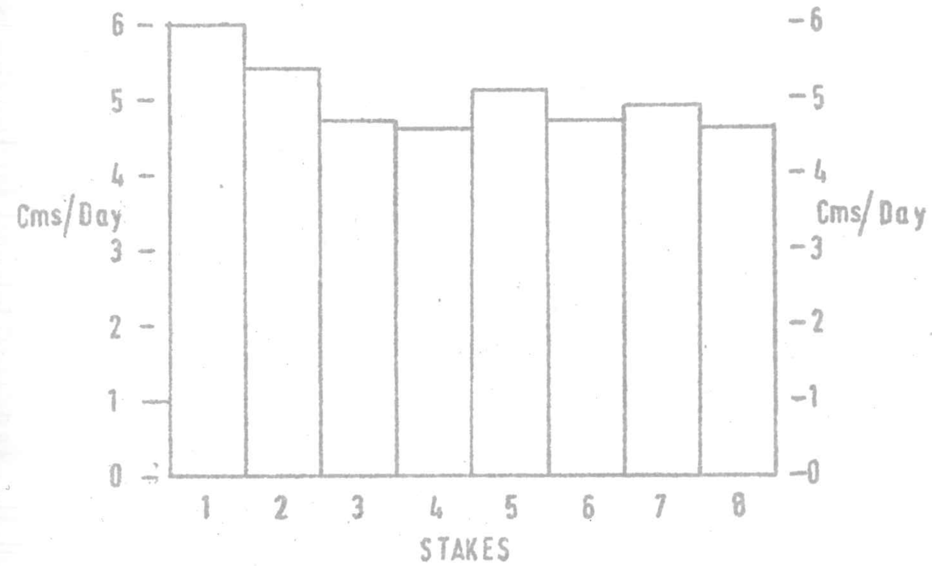


DIAGRAM 4.

HOURLY MELT RATES DURING 48 HOUR SURVEY.

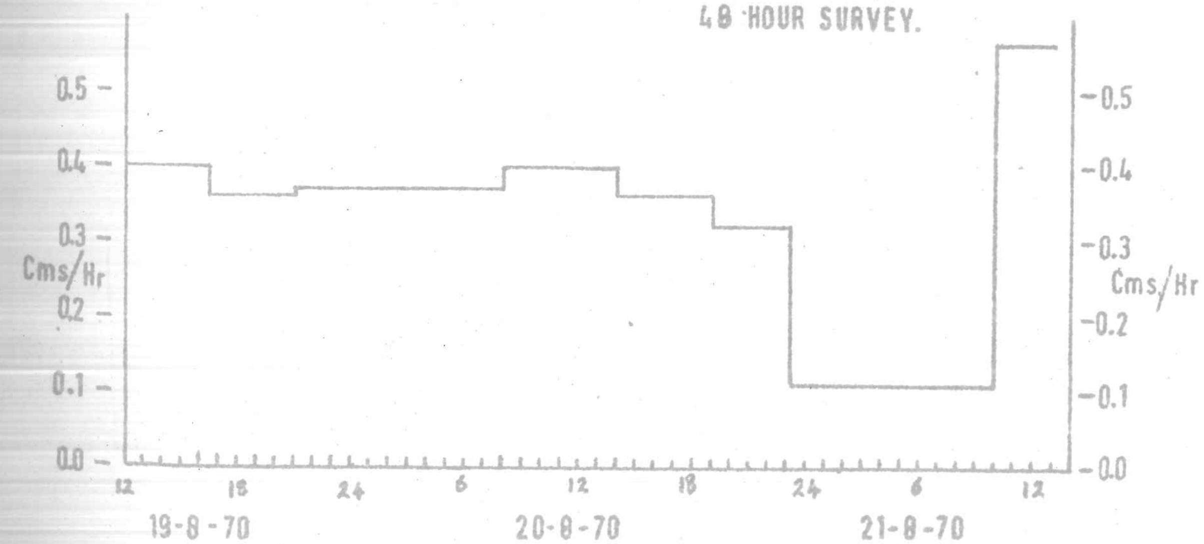


DIAGRAM 5.

ICE LIMITS IN 1850, 1958 and 1970.

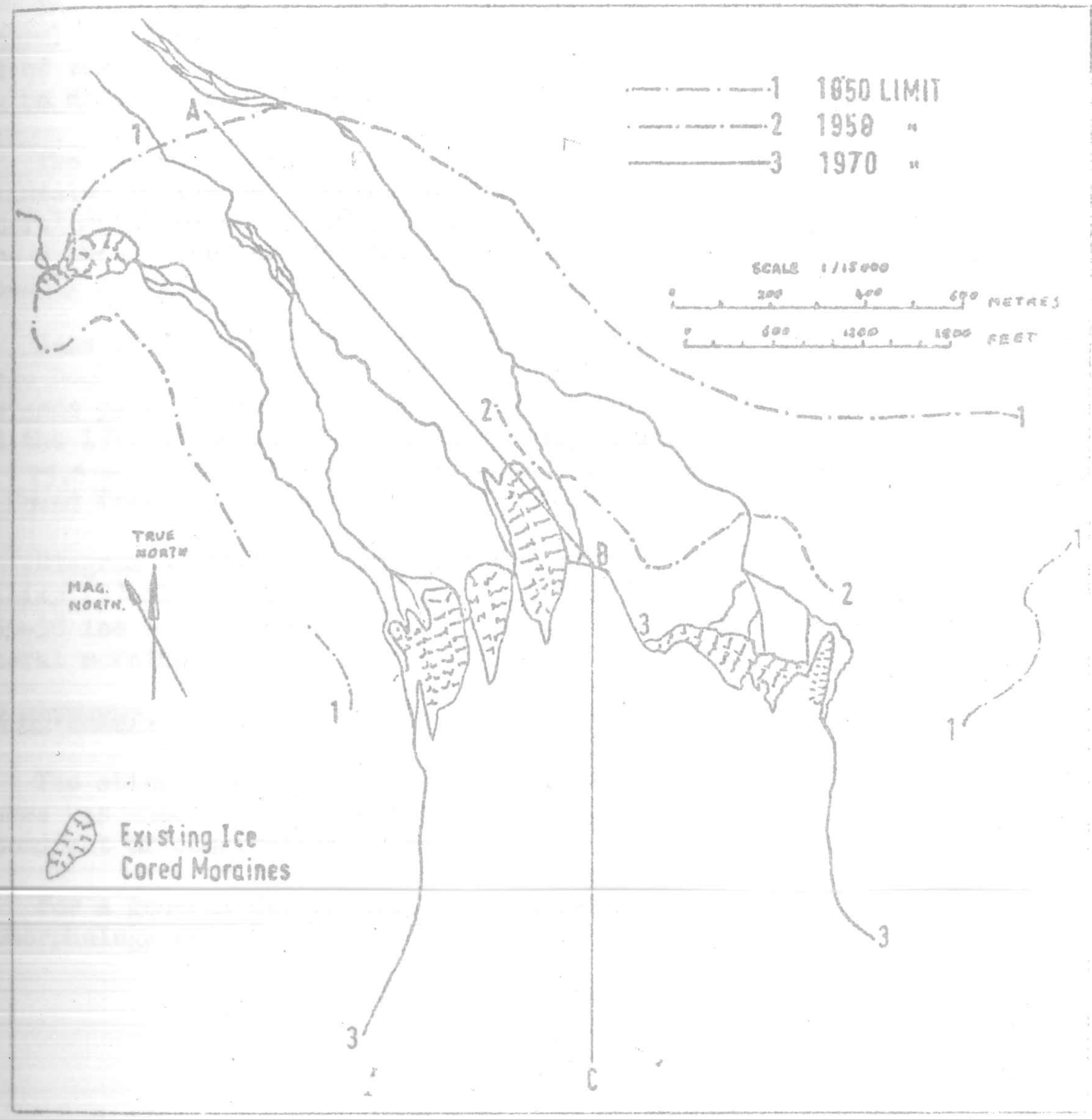
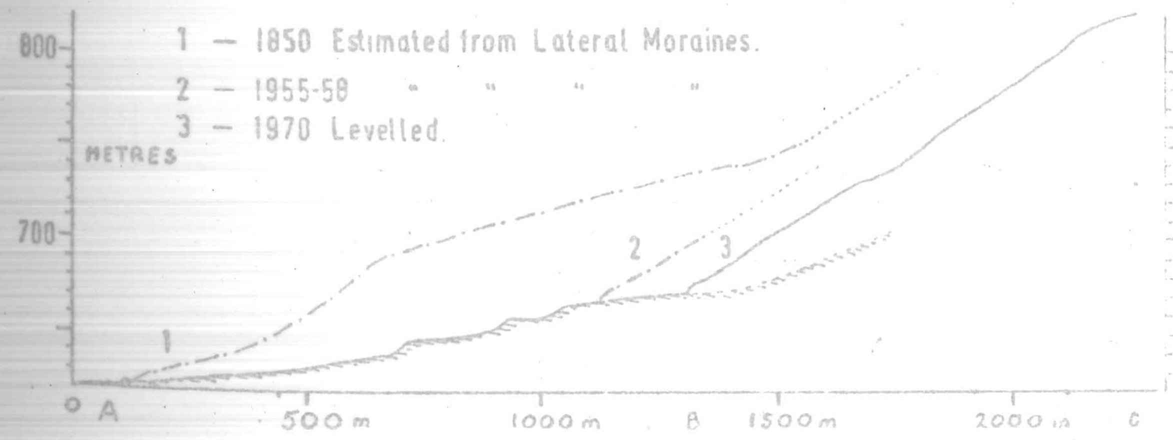


DIAGRAM 6.

LONG PROFILES.



GLACIAL RECESSION.

The history of ice recession is indicated by the terminal and lateral moraines left in the valley. Some are shown on the map at the end of the report and Diagram 5 shows the three stages of retreat that can be dated with some certainty.

The maximum advance, thought to have occurred around 1850 is delineated by the main terminal moraine (1) and the highest of the lateral moraines on the slopes of Prestahnukur and Mts 1017 and 856. Line 2 shows a series of minor moraines from which the ice had only recently retreated in 1960, (as shown on air photographs taken then).

Some evidence of measurements to the ice front were found, notably a large boulder near gauge 6 with the inscription RSG. MM. 1968 and a distance painted on it. The distance to the snout in 1968 was 21.8m and the 1970 value was 72 metres, giving an average annual rate of retreat of 25.6 m. No information as to who had made these measurements could be found from the Iceland Research Council.

Diagram 6 shows the long profiles of the valley floor and existing glacier (3) along section ABC on diag. 5. The profiles of the 1850 and 1955-58 ice surfaces are shown (1 and 2), estimated from the levels of the lateral moraines.

ICE MOVEMENT.

The attempt to measure any ice movement by theodolite observations to stakes was unsuccessful due to prolonged bad weather and low cloud when the second set of observations were due.

For a general description of features found on the glacier, see the geomorphology report.

THE VEGETATION OF WESTERN THORISDALUR, ICELAND :

JULY AND AUGUST 1970 by JANE WOBEY

SUMMARY

This paper is a description of the vegetation of Western Thorisdalur, a valley to the North of Thorisjokull in South West Iceland.

This area is 600 metres above sea level, on the periphery of the Central Icelandic Desert, and has recently been glaciated. Due to these factors and the severe weather, the vegetation is very sparse.

Using both subjective and objective techniques the valley vegetation has been mapped and to some extent quantified. Four main plant communities are recognised:-

(1) A Morainic community which varies with distance from the glacial snout.

(2) A Terminal Moraine community dominated by Rhacomitria and Lichens.

(3) A Sandur community - consocies of Rhacomitria - Salix heath.

(4) A Mire-Flush community, Philonotis-Bryum consocies.

Some notes on factors influencing these plants are included.

VEGETATION OF THE WESTERN THORISDALUR

I C E L A N D

troduction

JECTIVES AND METHODS USED IN ASSESSING THE VEGETATION

The main object of this study was to make an inventory of the plant ecies of the area and map the recognisable plant communities using the base p provided by other members of the Expedition. Also quantitative ecological udies were carried out.

Two methods were used. Where the vegetation formed a fairly continuous ver over the ground, standard Braun-Blanquet quadrats were used. However, in e Morainic Community the vegetation was so sparse that this method would have en meaningless, so a continuous metre strip was taken across the valley, first : 50 metre intervals from the snout, then 100 metre intervals, to assess the creasing cover with distance from the glacier. However, because of difficulty th instruments, due to magnetic influence, the distances from the snout are only proximate, and may vary by as much as two metres.

Any soil fungi that may have been present were not collected and certain the smaller crustose lichens may have been missed. Bad weather conditions also revented collectior of species from the mountain sides. It is to be hoped that his can be remedied by future expeditions. Soil samples were collected and nvestigated.

otanical Studies that have been conducted

To the knowledge of the author (based on information from the Icelandic esearch Council) no detailed Botanical work has been done on this particular rea before.

NOMENCLATURE

The nomenclature of the plant species in this report generally adheres to the following sources:-

Vascular plants	-	Clapham, A.R., Tutin, T.G. and Warburg, E.F.: Flora Europaea; London, 19
Mosses and Liverworts	-	Paton, J.A.: Census Catalogue of British Hepatics, 1965.
		Warburg, E.F. : Census Catalogue of Britis Mosses, 1963.
Lichens	-	James, P.W. : A new check-list of British Lichens : Lichenol. 3, pp 95 - 153, 1965.

Mosses collected are in the possession of the author, while many, especially the lesser known species, are deposited in the Herbarium of the University of Newcastle upon Tyne. Live species of Poa alpina collected are also being grown there.

ACKNOWLEDGMENTS

My thanks to all members of the University of Newcastle upon Tyne Botany Department who helped and encouraged me in this work, DR. DAVIDSON who gave help with general ecological ideas and soils, Mr. T. BINES for general help and especially to Mr. McALLISTER who helped with identification. Dr. O.L. GILBERT for identifying the Lichens, and to Mrs. Hilda Wobey for her assistance in preparation of the manuscript. Also to those members Expedition who helped with Mapping etc.

DESCRIPTION OF THE AREA AND ITS VEGETATION

The Western Thorisdalur valley contains four recognisable plant communit the extent of which (see Map) seem to be largely controlled by topography, while large areas of the Valley contain no vegetation at all. However, the actual floristic composition of the valley and the morphology of the plants seems to be largely climatically controlled.

FACTORS INFLUENCING THE VEGETATION OF WESTERN THORISDALUR :-

Observed features as suggestions for further ecological work.

1. BIOTIC AND ANTHROPOGENIC

Human interference in this area is negligible, the nearest settlement being at least 20 kilometres away. Placed between two icecaps and so recentl covered by glacial ice, this area can be considered as the natural community undisturbed by man, although lack of knowledge of the history of the area makes it impossible to rule out human interference altogether as a factor. However, once in high summer, three sheep were seen grazing on the Mire commun

1. Biotic and Anthropogenic (continued)

These were so few as to be probably not highly significant.

Few species of birds were seen, only Ravens, Ringed Plovers and female Harlequin ducks. The Plovers lived on the numerous insects of the area and probably had little effect on the vegetation. The Harlequin ducks might have grazed on Philonotis fontana - Pohlia wahlenbergii communities besides the rivers and thus had some effect.

2. CLIMATE

The climate of the area is described in detail in the Meteorology Report, but since few detailed readings were taken actually in the Valley and the microclimate in which the plants existed was not investigated, only very general comments can be made.

a) LIGHT

Daylight is almost continues during June and July when the plants must be at their maximum rate of growth and photosynthesis. However, by September, daylight was diminished significantly, with six to eight hours of darkness. On clear sunny days there is high light intensity due to clear air and high altitude, but many days are overcast and light intensities are reduced.

b) TEMPERATURE

Summer air temperatures can be 10^{o}C, but sensible temperatures are considerably less than that. The first frost of winter arrived in late August 1970, the last snow of Summer being in mid July. Temperature falls drastically at night. The shortness of the growing season was probably a principal factor in the very small size of most of the species present. No attempt to measure growth was made as it was judged that when we reached the valley the main growing season had finished. This was confirmed by careful observation.

The climatic factor most significant to growth in the region is the occurrence of strong winds. These condition the floristic make-up of the valley, for only small, low growing species can flourish; the morphology of these species - dwarf, tight rosette plants, often with tough, cuticled leaves; and where the majority of plants occurred, i.e. in small cracks and sheltered places. In winter the whole area is snow covered. Ground temperatures are considerably lowered by the cold, strong winds.

c) PRECIPITATION

Precipitation is high but spasmodic. Over 25 mm. can fall in one day. The amount and severity of these storms is probably due to the position of this area between two icecaps, which creates a highly specialised microclimate. However, due to the short duration and intensity of the rainfall and the porous nature of the ground, most of this precipitation must be lost to the plants, so that some areas might experience drought conditions.

d) WIND

This is persistent and strong in this valley, and comes mainly from the North-west or the South-east. Very few days are without wind, which is constant and strong in dry weather, gusty and strong in wet weather. Its constant effect must increase the evapotranspirati rate of the plants considerably, thus the rosette form is common and non grow more than an inch or so above ground except in the most sheltered positions. Vegetation trends to occur only in the most sheltered spots away from the wind. Wind is thus an important factor in the morphology of the plants and their occurrence in communities. Wind has another important effect in that it causes a great deal of instability of the area. The loose silt brought down by glacial outwash streams with that the ice-cored moraine, which is unvegetated and therefore not held togeth is whipped by the fierce winds into dust storms. This fine wind-blown dust is then deposited between the rocks and is soon colonised by grasse The wind sometimes started moving this again, and well established plant are covered with dust and become moribund.

III. PHYSIOGRAPHY AND GEOLOGY

The whole area is one of recent glacial retreat. Although the bedrock of the area is primarily Palagonite, (excepting Prestanukur, which is Rhyolite), this is everywhere masked by glacial drift.

The Western end of the valley is marked by a 15 metre high, crescent shaped, terminal moraine, part of which is still ice-cored. Historical records show that this was the limit of the glacier about 100 years ago. Between this and the snout, the morainic material varie from unordered rock heaps to fluvial outwash plains, both of fine silt and unsorted boulders. All grades of particle size are present, from clay to boulders of 2 metres or more in diameter. Some vegetation was found on the ice-cored moraine at the glacier snout.

The moraines of Western Thorisdalur cannot be considered to represent a direct time succession. The rivers flowing from the glacie change course frequently and the area is in a state of continuous movement and redeposition by wind and river action. The ice-cored moraine is subject to soil slip.

In Thorisdalur the Mire community was being encroached upon by a gravel plain brought down by the main stream from the surrounding mountains. The gravel bore no vegetation.

The Sandur to the north of Western Thorisdalur is a completely flat area of smaller stones and gravel which stretches away from the edge of Thorisjokull to the Lake trapped by a fault 4 km. away. The Sandur has been deposited by the outwash streams and is deeply dissected by these fast streams all summer. The actual flood plains of these streams bore no vegetation, being unstable. The interfluves, slightly higher, are fairly well vegetated.

The streams themselves fluctuate in volume and rate of flow. The Hydrology Report shows the great variations which occur.

This instability of the surface and substrata is one of the major factors which limits the growth of the vegetation in this area. This is illustrated by the paucity of lichen species in the valley itself, until the fairly stable Terminal Moraine is reached.

River 8, which flows along the north eastern side of the valley, is more stable in its bed and therefore it has a large moss flora around its banks, in contrast with the other rivers which have completely unvegetated flood plains (see Map). Other factors could influence this, for example the streams which flow into River 8 flow through the Mire community and may be able to carry propagules and organic particles which could be redeposited. Also its lower reaches contain some water not directly from the glacier.

The rivers themselves are fast flowing, very cold and full of sediment, thus it is not surprising that they contain no flora.

The stones which cover most of this area are subject to erosion, by frost shattering, wind erosion and fluvial erosion and also by the torrential rain storms. They thus are being constantly worn down and broken into smaller pieces which give rise to the soils.

The moraine across Thorisdalur proper is deeply dissected by rivers. The Mire Community lies where many small streams have deposited alluvium among the moraine hummocks, which harbour slightly different plant complexes.

SOILS

The soils of these communities are largely immature. The deep till left by the glacier has not had time yet to develop into recognisable horizons, except on the Sandur, the Terminal Moraine and well vegetated parts of the Morain Communities, where a shallow organic rich humus layer is present. Detailed descriptions of soils from the top of the valley, unvegetated, and from the well vegetated areas of the Morainic Community illustrate this point. However the profiles are not complete since bed rock was not reached, the Drift being very deep.

Samples of the soils were taken and tested. The pH was found and the water holding capacity measured.

pH was tested with an ordinary pH meter and thus the results cannot be more exact than in a range of 0.2. Several readings were taken and the mean obtained.

Water holding capacity was tested by simply adding water to a known weight of soil until it was saturated, thus these figures are only approxima The results are expressed as the amount of water held by 100 gms. of dry soi

UNVEGETATED SOIL - From Ice-cored Moraine (see diagram I.)

The ground is completely unvegetated with a surface of boulders, cobbles, pebbles, granules, various grades of sand, silt and clay with particles of diameter 256 mm. to under 1/256 mm., as already described.

Below this is a mineral layer of 0 to 10 cm. thick (very variable). This is a light grey colour and contains particles from clay up to pebble size, i.e. 4-64 mm. in diameter. It thus has a gritty texture but is also silky. It contains no organic matter at all. This layer is dried out and is unstable. The smaller particles tend to be blown in the wind.

Below this is a saturated layer identical in many respects to the layer above, but waterlogged by melted ice below. Thus it is a dark grey-brown in colour, 12 to 15 cm. thick, quite variable. Slight signs of greying may have been observed.

There is no bedrock as such. A layer of soil mixed with large blocks of ice lies directly on the glacier ice. There is no indication as to the nature of the actual bedrock from which the soil was derived, but the whole of Iceland is made of Basic Volcanic rocks and the moraine is a mixed collection of these. The pH of this soil is 7.2 and it can hold approximately 7.2 gm. of water per 100 gm. dry weight. It is thus very basic in composition and has little organic content. It also contains a fair amount of carbonates.

SOIL 150 METRES FROM GLACIER

Aspect: North
Drainage: Shedding. (See Diagram II)
Slope: 3.

This soil is only built up between the large boulders. Wind and wa moved silt collected between boulders has been colonised by mosses and grasses. These form an H Humus layer, approximately 5 cm. thick. This is the dark black-brown colour of dead roots of grasses and stems of mosses largely unaltered and not visibly decomposed, probably because of the sever cold.

The grey layer beneath this seems largely unaltered, such as is found on the ice-cored Moraine.

At the bottom of the valley the layer of organic remains is deeper and a very thin layer of powdery black humus can be distinguished. The underlying mineral layer of till is still largely unaltered.

The generally unaltered, skeletal nature of the valleys' soils is due mostly to the small amount of time they have had to develop in and the instability of the upper layers.

pH determination of soils down the valley are summarised in a histogram, as are the maximum waterholding capacities. (see Diagrams III and IV.)

TABLE TO SHOW THE FREQUENCIES OF INDIVIDUAL SPECIES FURTHER BACK FROM THE GLACIAL SNOUT

Since each transect was made over roughly the same area the figures are ± comparable.
But the transects 400 - 600 in their most westerly extent traverse the flood plants of Rivers 1 and 2, where there is no vegetation, therefore a drop number of species is not significant. This decrease is also due to the difficu-lty of distinguishing individuals in some species, unlike in the Angiosperms where distinguishing individuals is fairly easy. The mosses and Bryophytes occur in clumps of varying size. Individuals, however defined, cannot be counted, but the figures here refer to the number of clumps. Thus each species is not absolutely comparable with the rest but a general picture can be obtained.

Also human error must be taken into account, although the figures for the more showy flowers and grasses can be considered accurate. The tiny liverworts or the less common mosses could have been overlooked in places and their numbers therefore underestimated. However, where there is very little vegetation, on the transects near to the glacier, every individual was counted easily. In the more vegetated lower parts of the valley moss cover especially could be nearly continuous around the rocks and in patches and then the difficulty of deciding what constituted an individual clump was solved by considering the average clump 10 cm. across. In these cases especially, description is needed to supplement the figures.

Finally it is to be stressed that these figures in no way represent the cover of the species. A clump of Rhacomitrium canescens covering an area of 25 x 25 cms. is counted as one individual, as is one plant of Cardaminopsis petraea, which though a conspicuous plant in fact provides very little ground cover. These figures are of frequencies.

TABLE I — Number of incidences recorded in transects

Species	Metres from Glacial Snout: 50	100	150	200	250	300	400	500	550	600	700	80
Pohlia wahlenbergii	32	173	152	95	122	189	89	98	88	40	36	13
Philonotis fontana	1	34	15	7	32	14	0	8	0	2	4	2
Dicranum falcatum	6	0	0	2	0	5	0	3	1	0	30	7
Emptrum nigrum	1	0	0	0	1	0	0	0	0	0	0	1
Poa alpina	5	31	71	99	140	127	54	59	72	207	214	25
Lophozia spp.	1	1	2	9	5	1	2	47	24	1	7	2
Rhacomitrium Canescens	12	116	102	102	62	131	102	349	177	249	163	13
Rhacomitrium lanuginosum	0	65	28	33	36	83	76	256	121	237	250	17
Polytrichium urnigerum	21	16	5	11	29	37	44	21	11	11	22	2
Polytrichium alpinum	7	3	4	3	9	14	7	8	0	1	1	[illegible]
Saxifraga rosacea	1	0	1	0	2	0	1	0	0	0	1	0
Rhacomitrium fasciculare	1	2	6	0	2	10	3	1	1	1	2	1
Oligotrichum hercynicum	0	3	6	23	19	72	63	105	108	251	229	25
Cardaminopsis petraea	0	1	6	1	2	3	1	0	31	120	147	54
Cerastium cerastoides	0	10	21	0	2	2	0	13	9	4	133	14
Salix phylicifolia	0	0	1	0	0	2	0	0	0	5	3	5

TABLE II — Number of incidences recorded in transects

Species	Metres from Glacial Snout: 50	100	150	200	250	300	400	500	550	600	700	800
Salix herbacea					1	1	1	3	8	12	10	26
Salix glauca										3	1	1
Bryum terbinatum			1	2			2					
Cerastium arcticum				1		6				4	4	28
Sphenolobolus minutus					1		5	5	12		7	2
Saxifraga nivalis						1			1		1	
Saxifraga caespitosa						1	1				1	
Luzula arcuata						1	3	1	5	3	24	66
Arabis alpina							1	4	1	1	1	5
Saxifraga hypnoides							1	1				
Poa flexuosa								16	7	15	67	22
Dicranum glaciale										1	9	10
Anthelia julacea												44
Oxyria digyna												14
Armeria maritima												1
Silene acaulis												1
Arctoa fulvella												1

DESCRIPTION OF MORAINIC COMMUNITY

This is a dynamic community, increasing in density and number of species away from the glacial snout. (See diagram V). This general trend although important, obscures the very scattered, patchy nature of the vegetation; where a small hollow can harbour many species and nearly continuous cover of plants, while next to it, a small hummock has only one or two lichens, and this is illustrated by the very variable results from the frequency counts of individual species. Very little pattern of increase down the valley can be distinguished from any one species, see Table (I).

Types of the mosaic of vegetated and non-vegetated areas of this community are illustrated below.

HUMMOCKS HAVE LESS VEGETATION THAN ADJACENT HOLLOWS

Thus:- 550 metres from the glacier on a hummock:-

Oligotrichium hercinum) Rhacomitrium canescens)	few clumps

In hollow further east along the transect:-

Sphenolobus minutus	one clump
Salix herbacae	one clump
Pohlia wahlenbergii	one clump
Oligotrichium hercynicum	three clumps
Rhacomitrium canescens	thirteen clumps
Cardaminopsis petraea	three plants
Poa alpina	one plant
Luzula arcuata	one plant
Rhacomitrium lanuginosum	two clumps

STEEP SLOPES HAVE LESS VEGETATION THAN ADJACENT GENTLE SLOPES

300 metres from the glacier, gentle west facing slope of hummock:-

Poa alpina	sixteen plants
Rhacomitrium canescens	one clump
Cerastium arcticum	one plant

Steep east facing bank:-

No vegetation.

ALLUVIAL PLAINS CAN HAVE LESS VEGETATION THAN ADJACENT HUMMOCKS

Flat alluvial plains where alluvium builds up too quickly to allow vegetation to flourish occur next to small hummocks of stones which have quite a lot of vegetation between them.

500 metres from the glacier, flat plain of alluvium:-

No vegetation.

Hummock of stones:-

Rhacomitrium canescens	ninety six clumps
Poa alpina	four plants-
Poa flexuosa	one plant
Oligotrichium hercynicum	four clumps
Pohlia wahlenbergii	nine clumps
Luzula arcuata	one plant

This heterogeneity is also reflected in the distribution of individual species. Large clumps of the same species are the rule. This is especially noticeable in the Angiosperms, whereas the mosses tend to be rather more widespread. The Grasses, Cardaminopsis petreae and Saxifraga rosacea particularly behave in this way, occurring most commonly in deposited silt and spreading in large clumps. The viviparous habit of Poa alpina tends to this type of patchy distribution of individual mature plants surrounded by many new plantlets.

The dominant plants of this community are Rhacomitrium canescens, R. Lanuginosum and Pohlia wahlenbergii. Whereas the Rhacomitria tend to increase down the valley, Pohlia albicans is more important nearer the glacier. Oligotrichum hercynicum, another numerous plant, becomes more important down the valley.

Possibly the increasing stability of the habitat and the differing habitat niches down valley favour the Rhacomitria, the Pohlia being a primary coloniser, and declining in competition with the others.

Other points of interest in the distribution of individual species:-

(1) There is a concentration of Philonotis fontana around wetter areas, especially River 8, and the kettle hole lakes in the upper moraines.
(2) Flowering species increase with distance in the glacier and all the flowers, except at 800 m., where two pink flowered species occur.
(3) Placopsis gelida is the only lichen which can survive in the unstable conditions up to 400 feet from the glacier. This instability is probably the main factor which precludes their extensive growth, which occurs on the more stable mountain sides and terminal moraine.
(4) Very few species actually grow on the rocks themselves except the lichens, Arctoa fulvella and Rhacomitrium canescens.

In no way is this a closed community, but a subsere. It represents the earliest stages of colonisation of bare rock exposed by the receding glacier.

TERMINAL MORAINE COMMUNITY

The Moraine which is the substrate for this community, is a crescent shaped ridge approximately 15 metres high which traverses the Western Thorisjøkull Valley (See map). Its vegetation affords considerably more cover than the surrounding plant communities, and is thus distinctive. However, some parts of it could be considered as more advanced parts of the sere which the Moraine community represents the earliest stages.

In fact nearly all the species found on the Terminal Moraine are represented in the valley Morainic community. However, although Rhacomitria are still very important species, other species hardly represented in the valley become dominant. This could be just a further seral development. The case for this is quite strong, but the Terminal Moraine does not represent a homogenous set of vegetation. Three distinctly different kinds of vegetation can be found on the Moraine, indicating they are not a simple further part of the sere. These three areas are:-

(1) The south-south-east facing slope vegetation.
(2) The flattish top of Terminal Moraine vegetation.
(3) The north-west facing slope vegetation.

These can be named as to their dominant species.

(1) Rhacomitrium-Salix community.
(2) Lichen community.
(3) Rhacomitria-Lichen community.

(The dominance of these species is illustrated in Tables III-V.)

(1) The Rhacomitrium-Salix consocies appears to be a continuation of the Morainic community it faces. It has the same complex of species as the 800 metre transect, but not so many of them, possibly because the cover of the dominants is greater, or, perhaps because the whole slope is quite exposed and species which need more shelter will not be able to survive. (The area sampled on the Terminal Moraine is much smaller than the area sampled from the longest exposed parts of the Moraine community, especially since the area sampled is divided into three parts. This may account for the lack of species.)

There is a fairly even spread of the dominants and many of the more important plants, but like the Morainic community, some species occur in scattered patches, such as Poa alpina, Luzula arcuata and Anthelia julacea, which forms small patches with continuous cover. Lichens play a significant part in the community, most probably because of the relative stability of the rocks. The lichens and some mosses grow on the large boulders, while other species grow in between the rocks. In this, the Salix-Rhacomitria association is the most important.

(2) Unlike in the community previously described, most of the plants grow on the rocks of the top of the moraine. This is a very exposed habitat, the flat top of the Moraine being constantly scoured by strong winds, and there is negligible shelter for any plants. Thus the number of species is decreased considerably to fifteen, with the notable absence of Poa alpina, possibly because this is one of the tallest species in the valley. Lichens are the Dominants here, encrusting the rocks which have been stable for long enough to allow the colonies to reach quite large sizes. Salix herbacea, Rhacomitrium canescens,

Arctoa fulvella and many of the other species, occur only in small patches between the rocks, where a little shelter is afforded. The area is 70% bare rock, and lichens total 27% of the cover. Other species are relatively unimportant.

(3) The community of the north west facing side of the Terminal Moraine has a considerably reduced cover of Lichens, and Rhacomitria and Salix become important with other mosses. The pattern of vegetation is patchy - only Rhacomitrium canescens, Salix herbacea and Arctoa fulvella occur in all the sample quadrats. A noticeable feature of this community is the decrease of bare soil and rocks to only 43%. The cover has increased because this slope is sheltered from the cold influence of the glacier and is stable. The seven soecies which provide over 50% of the cover could exclude many other species thus accounting for the small number of species.

The decline of number of species in the latter two communities is largely because of the decrease in number of angiosperms. This could be due to the scattered nature of the occurrence of the plants, so that they could have been missed from the small area sampled.

VEGETATION OF THE ICE-CORED MORAINE

Part of the Terminal Moraine in the extreme east is much higher and consists of a number of deep hollows and large hummocks. Seven of the species of the ice-cored moraine near the glacier are represented in the vegetation of this area. However, it also contains many other species which occur only in the lower parts of the valley. The vegetation is very sparse. No quantitative studies were made in this area, but species found on this moraine include:-

Poa flexuosa
Poa alpina
Salix herbacea
Salix glauca
Salix phylicifolia
Cerastium alpinum - Cerastium cerastoids
Arabis alpina
Cardaminopsis petraea
Saxifraga rosacea
Pohlia wahlenbergii
Rhacomitrium canescens
Rhacomitrium fasciculare
Rhacomitrium lanugunosum
Oligotrichum hercynicum
Polytrichium alpinum
Polytrichium urnigenum

These species, especially when occurring in the deep cracks, can grow to larger than average size. One example of this is Polytrichium alpinum, which grows to 10 cm. high. Lichens do not have a particularly extensive growth here. Vegetation is well developed here because of the considerable shelter afforded by the deep hollows. The grasses are the most frequent species here, the Rhacomitria and Pohlia wahlenbergii also being important. The Salix species occur in small scattered bushes and do not afford much ground cover.

TABLE III - SOUTH FACING SLOPE OF TERMINAL MORAINE

Rhacomitrium canescens	Mean 25% in all quadrats	
Salix herbacea	10% in all quadrats	
Arctoa fulvella	3% in all quadrats	
Lecidea macrocarpa	5% in all quadrats	
Poa alpina	14 individuals in clumps .6	
Luzula arcuata	Mean 5.5 individuals in clumps of nearly 30.	
Anthelia julacea	Mean 3% mostly in clumps.	
Oligotrochium hercinum	4 occurrences .2	
Orange Lichen spp.	9 "	
Rhacomitrium fasciculare	5 " .25	
Cerastium cerastoides	2 " .1	
Cardaminopsis petrea	2 " .1	
Silene acaulis	2 " .1	22 species in total
Armeria maritima	2 2 .1	10 Angiosperms 7 Bryophytes 3 Lichens
Dicranum glaciale	1 .05	
Oxyringa dyniga	1 .05	
Emptrum nigrum	1 .05 % Bare 60	
Salix glauca	1 .05	
Polytrichum urnigerum	1 .05	

TABLE IV - TOP OF TERMINAL MORAINE

Lichen. 4 Foliose	20% Mean Cover all quadrats.	
Salix herbacea	5% " " patchy	
Rhacomitrium canescens	2.5% " " "	
Orange lichen spp.	3% " " all quadrats	
Lecidea macrocarpa	.6% " " patchy occurrence	
Arctoa fulvella	1% " " " "	
Cerastium cerastoides	10.5% individuals in patches.	
Lichen spp.	8 " " "	
Luzula arcuata	9.45 " " "	
Placopsis geldia	7.35 " " "	
Green lichen spp.	4.2 "	15 spp.
Oligotrichium hercinium	5.25 "	5 angiosperms
Cardaminopsis petrea	3.15	6 lichens
Dicranum falcatum	2.1 "	4 Bryophytes
Empetrum nigrum	1.05 "	70% Bare.

15 species in total.

TABLE V - NORTH WEST FACING SLOPE OF TERMINAL MORAINE

Rhacomitrium canescens	17% Mean cover all quadrats	
Lecidea macrocarpa	12% " patchy	
Salix herbacea	8% " " all quadrats	
Dicranum falcatam	7.5% " " patchy	
Anthelia julacea	2.3% " " patchy cover	
Luzula arcuata	5 plants per metre.	Very patchy cover.
Poa alpina	2.5 " " "	Very patchy occurrence.
Lichen spp.	1% " " "	"
Polytrichum unigerum	1% patch " "	
Silene acaulis	1% " " "	
Empetrum nigrum	7 plants in all	
Pohlia albicans	7 " "	
Lichen spp.	4.2 patches in all	
Cerastium cerastoides	2.1 plants in all	
Oligtrochium hercynium	2.1 " "	
Polygoneum viviperum	1.05 plants in all	
17 species.	7 Angiosperms 6 Bryophytes 3 Lichens	
	% Bare. 43.	

VEGETATION OF THE KALDIDALUR SANDUR BEYOND THE WESTERN THORISDALUR VALLEY

Ten 4 metre quadrat samples were taken from an area approximately 100 square metres immediately to the south of the Terminal Moraine. The actual Sandur stretches right along the foot of the eastern side of Thorisjokull to the lake bordered by a fault cliff about four kilometres away. Therefore this small sample cannot be considered representative of the whole area. On the whole the vegetation of the Sandur does not have so much cover. Large areas of stream beds or dried up stream courses and the area which the lake has covered recently are completely unvegetated. Much of the rest of the Sandur has the sparse vegetation represented by the areas between the Rhacomitrium-Salix heath of my sample.

The greater cover of the area studied is due partly to the shelter from the winds coming from the glacier and (probably more important) partly to the stability of the area. The main streams coming from the glacier are channelled by the Moraine to either side of this area. Therefore it is not affected by the constant rechannelling of numerous glacial outwash streams which occurs on the rest of the Sandur.

Small stretches of the channel of river 8 and of several small streams which run off Prestanukur and therefore contain non-glacial water, have dense Philonotis-Bryum patches along their banks. This is only in the extreme north of the Sandur. This short account only represents observations on the nature of this vegetation, and by no means is the whole described.

DETAILED OBSERVATIONS OF THE SANDUR NEAR THE TERMINAL MORAINE OF WESTERN THORISJOKULL

(For mean figures of Quantative observations see Table VI)

This area can be seen to be a mosaic of Rhacomitria-Salix heath broken by less vegetated areas. The boundaries are indistinct. Some quadrats record nearly 100% cover of Rhacomitrium canescens and Salix herbacea, while in others the cover is less than 5%. But there are all grades between clumps of Salix and Rhacomitrium, dense in their centres gradually become less dense outwards until very little covered is afforded. Areas of dense cover can be .5 of a metre to many metres across and of varied shape. A common growth habit, is for crescent-shaped, prostrate salix bushes to be associated with Rhacomitria. The Salix branches afford a stable substrate. Often, the main trunk of the shrub is exposed for the area around it has been wind eroded. A dune shape is then produced, for the upwind side of the colony has a sheer, eroded face.

Lichens figure as important, growing on the rocks which make up the substrate of this community with only small areas of soil between. This surface layer of stones is a periglacial phenomenon. Dicranum falcatum also grows on the rocks.

The Angiosperms seem evenly scattered about the communities, occurring equally in very densely and sparsely covered areas. In spite of their prominence they provide very little cover.

Polygonum viviperum is the only species which occurs on the Sandur and not in the moraine communities.

Mosses seem to be more abundant in the most vegetated parts, consistently occurring where the Rhacomitrium heath is dominant.

The plants of this consocies can be conveniently divided into three groups, the dominants, the frequently occurring, and those species which occur only occasionally and provide little cover.

This can be thought of as a poorly developed Rhacomitrium heath. It has a distinctly seasonal aspect, the Salix losing its leaves in autumn and the Rhacomitria definitely increasing in cover during the summer.

TABLE VI - SANDUR COMMUNITY

Species	MEAN % COVER Heath	Less vegetated	
Rhacomitrium canescens	40	7	dominant
Salix herbacea	5.3	5.3	
Lecidea macrocarpa	4.4	2.01	
Dicranum falcatum	3.2	.1	
Athelia julacea	1.75	.6	frequent
Pohlia wahlenbergii	.6	.3	
Rhacomitrium langinuosum	2	1	
Luzula arcuata	.4	.4	
Lichen spp.	.25	.5	
Orange lichen spp.	.35	.35	
Silene acaulis	.4	.55	
Placopsis geldia	.2	.65	
Polytricium urnigerum	.05	.2	
Armeria maritima	0	.2	occasional
Polygonum viviperum	.05	.05	
Salix phylisifolia	.1	.05	
Cardaminopsis petrea	.1	.3	
Poa alpina	.1	.2	
Cerastium cerasoides	0	.2	
Empetrum nigrum	.1		
	50% Bare	90% Bare	

MIRE COMMUNITY

This community occurs in Thorisdalur proper.

It is in an area of many small streams which come from the surrounding mountains and are not glacial outwash streams. This type of vegetation is best represented here, but occurs along River 4 in the Morainic Community and on the Sandur as described.

It is definitely the most conspicuous vegetation in the area, the bright green of the moss standing out amongst the barrennness. The Mire is not a continuous area of vegetation but is interrupted by large boulders, large stony hummocks and many pools and small streams. The hummocks and boulders are not unvegetated but indeed provide a substrate of many types of plants not found in the Mire proper.

The Mire with its dominant species Bryum pseudotriquetrium agg consists of a very deep layer of moss completely covering the ground. On top are the new year's growth of moss up to 10 cm. long, growing on top of successively older dead stalks which go down as much as one metre. The Bryum is accompanied by Philonotis fontana, which grows in the same manner. Dicodontium pellucidum grows in the slightly more shallow areas near rocks and does not have such long plants. Growing on top of these mosses are Poa alpina, Pohlia wahlenbergii and many brightly coloured angiosperms in which Epilobium homemanii is noticeable, growing in serispheral shapes which protrude from the moss.

On the larger boulders between the moss and the small and large heaps of stones a different kind of community occurs. Bryum is still dominant but Rhacomitrium canescens and Dicodontium pellucidum are very important, as is Philonotis fontana. Many of the angiosperm species are identical, but on these rocks three liverwort species occur. Riccardia pinguis tends to occur in small patches directly on top of the rock. Marchantia polymorpha grows with its rhizoids embedded in the rock but its actual thallus spreading over the moss, presumably to obtain better moisture. On the higher and more bare rock mounds Salix species occur, forming small prostrate bushes. Likewise lichens grow on the bare stones.

The water of the rivers which run through this moss have a $_{p}H$ of 7.4 and are thus quite calcarious. This Mire of flush grows around these streams, the alkalinity of which might explain the floristic composition.

The area was sampled, taking ten 4 metre quadrats. Owing to the large size of the area, this might not give an accurate picture of the Mire.

The Mire is not homogeneous in composition and in some areas the Philonotis or even the Dicodontum or Dicaranum falcatum assume local dominance.

MIRE COMMUNITY

Moss	Mean % Cover	
Bryum pseudotriquetrium (agg)	70	
Philonotis fontana (sl)	13	
Poa alpina	3	
Dicodontium pellucidum	2	
Pohlia wahlenbergii	1	
Saxifragastellaris	.74	
Cerastium cerastoides	.45	
Rhacomitrium casescens	.45	
Epilobium hornemanni	.5	
Saxifraga nivalis	.28	5 occurrences
Arctoa fulvella	.28	"
Rhacomitrium fasciculare	.28	"
Polytrichium urnigerum	.12	3 "
Dicranum falcatum	.12	"
Saxifraga rosacea	.04	1 occurrence
Marchantia polymorpha	.04	"
Cardaminopsis petreae	.04	"
Scapania subalpina	.04	"
Riccardia pinguis	.04	"
Salix herbaceae	.04	"
Polytricium novegicum	.04	"

Stones	Mean % Cover	
Bryum pseudotriquetium (agg)	16	
Rhacomitrium canescens	7.5	
Dicodontium pellucidium	6.3	
Poa alpina	4.3	
Saxifraga stellaris	2	
Philonotis fontana	5.4	
Epilobium hornmanii	1.0	
Polytrichium urnigerum	1.	
Sal ix herbaceae	.63	
Riccardia pinguis	.54	6 occurrences
Saxifraga nivalis	.45	5 "
Placopsis geldia	.35	4 "
Polytrichun alpinum	.27	3 "
Scapania subalpina	.27	"
Saxifraga rosacea	.27	"
Salix phylicifolia	.27	"
Dicranum falcatum	.18	2 "
Lecidea macrocarpa	.18	"
Arabis alpina	.09	1 occurrence
Luzula arcuata	.09	"
Anthelia julaceae	.09	"
Marchantia polymorpha	.09	"
Rhacomitrium fasciculare	.09	"

DISCUSSION

Partly by subjective and party by objective methods, distinct communities of plants have been distinguished, their extent mapped and their floristic constituents quantified and described.

The major divisions of Mire, Moraine and Sandur Communities are largely self evident, reflecting the physiography of the area. Objective methods have confirmed the accuracy of these divisions. Likewise the large areas with no vegetation had only to be noted.

Perhaps the greatest difficulty was distinuishing the sub-divisions within these communities. Quantification has born out the original subjective ideas of differences inside the major types. The similarities between parts of the terminal moraine vegetation and the moraine vegetation might in fact invalidate the major division the author has attributed to it. However, on the whole, the communities are distinct.

One discrepancy in the quantification is that the frequency figures for the Morainic Community cannot be directly compared with the cover figures for the other areas. This was unavoidable since cover figures for most of the moraine would have been so small as to be meaningless, perhaps a good justification for delineating this vegetation area from the others.

In no way do these communities represent closed communities but they represent subseres, from the earliest to the later stages of colonisation.

PLANT SPECIES OF WESTERN THORISDALUR

I: ANNOTATED LIST OF VASCULAR PLANTS

The nomenclature follows that of Flora Europea; Clapham, Tutin and Warbug. Actual identification by Mr. H. McALLISTER (University of Newcastle upon Tyne).

MONOCOTYLEDONAEA

GRAMINEAE

Poa alpina L. a widespread species occurring in all four communities, a primary coloniser of glacial retreat. Often in its viviparous form, in large tussocks of as many as fifty plants. Often the new plantlets can be seen growing from the turned over head of last year's spikelet. Very numerous on newly formed areas of alluvium deposited by wind or stream.

Poa flexuosa

Found in morainic community only, where it appears first at 500 metres from the glacier, not viviparous. Grows in clumps - not on such exposed habitats as Poa alpina.

JUNCACEAE

Luzula arcuata. Lindeb. Found in all communities, most commonly in the Terminal Moraine community - appears 300 metres from glacier.

DICOTYLEDONEAE

SALICACEAE

Salix herbacea L. Found in all communities. Only on drier parts of Mire, very common on Terminal Moraine and Sandur, forming a co-dominant with the Rhacomitrium spp. Appears 250 metres back from glacier. Possibly hybridises with other Salix spp. Size of plants gradually increase back from the glacier. (This is represented by number of leaves (see diagram). Creeping woody stems close to the ground, small round leaves on upright red petioles form dense ground cover. Where the wind has displaced the soil, the roots are exposed but form a small crescent-shaped barrier a few inches high which collects dust and protects the rest of the plant (see diagram).

Salix phylicifolia L. All communities, direr parts mire. Appears 150 metres from glacier. Only a few occurrences of isolated prostrate shrubs. With Salix glauca produces hybrid which was nearest Salix spp. to glacier.

Salix glauca L. Not found in Mire community, but possibly present. Isolated prostrate bushes, larger than other salix spp., can form shrubs up to .5 metres high. Deep root system, wider trunk, often colonising interfluves in Morainic community, not found until 600 metres away from glacier.

POLYGONACEAE

Oxyria digyna L. Hill. Not in mire community or on Sandur. Only found 800 metres from glacier in lower part of moraine community and on Terminal Moraine where it is locally common in hollows, beneath rocks, and where there is a fair amount of shelter.

Polygonum viviparum L. Only found on Sandur and Terminal Moraine. Small viviparous plant, its vivipary well suited to this extreme climate. Fairly uncommon, occurs where good ground cover.

CARYOPHYLLACEAE

Cerastium alpinum L. On Mire and Moraine Communities. Appears 150 metres from glacier. Uncommon in both habitats.

Cerastium cerastoides L. Britton. In all communities, most common on Moraine. Occurs only 100 metres from glacier, mostly in exposed situations, a small prostrate plant often not in flower, but flowers very conspicuous.

Silene acaulis L. Jacq. Occurs only on Terminal Moraine and in Moraine Community away from the glacier, recorded 800 metres away. Forms dense conspicuous tufts up to .3 metres across covered in pink flowers, and flowers from mid July to the first week in August.

CRUCIFERAE

Arabis alpina L. Found in all communities, except Sandur - uncommon, except locally - occurs 400 metres from glacier, often on patches of alluvium.

Cardaminopsis petraea L. Hiitonen in Hyl. Very widespread plant in all communities, drier parts of mire, occurs on terminal moraine and Sandur, most common in Moraine communities where it is found only 100 metres from the glacier. One of the main flowering plants of this community, forming prostrate clumps circular in habit with many white flowers.

SAXIFRAGACEAE

Saxifraga cespitosa L. Found in Moraine community only. Rare. Appears 300 metres from glacier, only recorded three times. A larger plant than the others of this group. Only found flowering once.

Saxifraga hypnoides L. Found in Moraine and Mire communities, Rare. Only recorded three times. Absence in other two communities might not be significant because it could have been missed, but does not prefer open habitats.

Saxifraga nivalis L. In Morainic and Mire Communities only. Rare. Recorded twice, once from each habitat. A showy spp. Grows in open habitat.

Saxifraga rosacea. Moench. Found in Morainic and Mire habitats. Frequent in Moraine hummocks. A primary coloniser on a hummock between glacial snouts, occurs singly in small tufts of many flowers. These tufts often occur in groups of approximately six flowers. Can grow on top of hummocks in open habitats.

Saxifraga stellaris L. In Mire community only. Only one plant recorded, growing on mosses of Mire community.

ONOGRACEAE

Epilobium hornemanni Rchb. In Mire community quite common, forming mound shaped colonies of plants growing out of the mosses. Mauve flowers prominent.

EMPETRACAE

Empatrum nigrum L. Found in all but Mire community. A primary coloniser, seedlings found on ice-cored Moraine, in between lobes of glacier ice. Occurs throughout Morainic community, but only becomes fairly common on Terminal Moraine where smaller bushes intermingle with the Rhacomitrium. Do not grow above .3 metres high and do not produce fruit. Overlap into Sandur community.

PLUMBAGINACEAE

Armeria maritima (Mill) Willd. This mountain variety does not grow in the Mire community. Most common on the Sandur and Terminal Moraine, it occurs first 800 metres from the glacier, but forms many tussocks in the lower part of the Morainic community. Grows in unsheltered positions.

II: ANNOTATED LIST OF BRYOPHYTA

The nomenclaure follows Dixon - The Students Handbook of British Mosses and Watson - British Mosses and Liverworts. With modifications for Modern toxonomic ideas. All identifications ratified by Mr. H. McALLISTER.

HEPATICAE

Order JUNGERMANNIALES

ANTHELIACEAE

Anthelia julacea L. Found in all communities. Only 800 metres from the glacial snout, so not a primary coloniser. Forms part of the ground layer of the lower Morainic community and Terminal Moraine and the Sandur where it often covers 5% of a metre quadrat. It occurs on drier parts of Mire but is not very common there. Characteristic blue-green colour forms very large conspicuous clumps high up on the mountain sides.

LOPHOZIACEAE

Lophozia spp. Dum. Found in Moraine community only. A primary coloniser found on morainic hummocks between ice snouts. Uncommon spp. Found in minute clumps on top of moraines on steep slopes usually in association with Rhacomitrium spp.

Sphenolobus minutus (Crantz) Steph. Moraine community only. Found 250 metres from glacier. In isolated minute clumps or in locally forming largest clumps, - in wetter hollows. Often found in association with Pohlia albicans.

SCAPANIACEAE

Scapania subalpina (Nees) Dum. Found in Mire Community, fairly common on drier hummocks, forms small clumps.

Order METZGERIALES

ANEURACEAE

Riccardia pinguis L. Gray. On hummocks in Moraine community, still in wet conditions. Quite common, forming large clumps.

Order MARCHANTIALES

MARCHANTIACEAE

Marchantia polymorpha. L. Found in Mire community either on hummocks of stones or actually on the side of the boulders, anchored to them, but growing over the Philonotis-Bryum communities. Very wet growing conditions.

EUBRYA

BARTRAMIACEAE

Philonotis fontana (Hedw) Brid. SL. Found in all four communities but widely varies in growth habit. A primary coloniser for the bare moraine hummocks, occurring as tiny individual plants, or in small colonies, each plant being not more than 5 mm. high, this increases in size down the valley, occurs commonly in large clumps mixed with Pohlia wahlenbergii, in wetter parts of moraine community. On Sandur and Terminal Moraine occurs rarely. In Mire communities an impoartant co-dominant with Bryum weigelli and Pohlia wahlenbergii, forming dense green tufts 15 cm. high.

BRYACEAE

Pohlia wehlenbergii. A very common spp. in all communities. On Moraine, it appears as tiny individual plants. It increases in size and cover down the glacier forming large clumps in between rocks and in hollows, up to 25% cover in a metre. It is also an important part of the grand cover on the Terminal Moraine and the Sandur. In the Mire it forms dense, tall tufts with Bryum pseudotriquetium (agg) and Philonotis fontana

Bryum turbinaturm. Schwgr. Found only in Moraine community, 50 metres from the glacial snout with Pohlia wahlenbergii, and rarely scattered down the valley on open sites.

Bryum pseudotriquetium (agg) Found only in Mire community. One of the co-dominant mosses with Philinotis fontana. Forms large green tufts up to 22 mm. high. Embedded in wet peat.

DICRANACEAE

Dicranum falcatum. Hedw. All four communities. Actually grows on rocks. Sporophytes noted in late July. Found 50 metres from glacier and from thence fairly commonly in Morainic community. Common on Sandur and Terminal Moraine stones. Forming large clumps, on rocks in Mire community.

Arctoa fulvella Smith. Found only in the lower parts of Morainic community 800 metres from glacier and on Terminal Moraine where it is common in between rocks and in clefts.

Dicranum glaciale. This is only found in the lower parts of the Morainic Community and is uncommon, associated with Arctoa fulvella and Rhacomitrium spp.

Dichodontium pellucidium. (Hedw) Schimp. Only in Mire community where its bright green tufts growing with Bryum-Pohlia association, form approximately 5% of the cover of the area.

GRIMMIACEAE

Rhacomitrium canescens. Brid. This is perhaps the commonest species in the area occurring in all four communities. Found 50 metres from the glacial snout it becomes progressively more common and growing in larger clumos until on the Terminal Moraine it forms on average 30-35% of the cover. On the Sandur it forms extensive carpets in association with Salix herbacea in the slightly more moist areas but only small slumps in between the stones of the interfluves. In the Mire Community it forms clumps from a few to many centimetres across on the hummocks.

Rhacomitrium fasciculare Brid. A widespread species tending to grow on the rocks themselves in small clumps. In Moraine community found 50 metres from glacier to Terminal Moraine. Not very common. Not recorded from Sandur. Occurs as small patches on rocks of Mire Community.

Rhacomitrium lanuginosum. Brid. Found in all four communities, widely spread, associated with Rhacomitrium canescens but not quite as common. Found on and in between rocks. Forms larger, more spread out clumps than Rhaconmitrium canescens.

POLYTRICHCEAE

Oligotrichum hercynicum (Hedw) Lam. Frequent on Moraine community. Occurs 100 metres from glacier to the top of the valley. On Terminal Moraine common. Not recorded from Sandur or Mire. Occurs in sheltered hollows with Philonotis fontana, in damper areas. Forms large patches in such areas often with sporophytes and male flowers recorded in early August.

Polytrichium alpinum L. In all areas except the Sandur. Frequent early coloniser. Occurs in small patches of plants up to approximately 4 cm. high, usually in very well sheltered places in deep crevices in rocks. Occurs on rocks of Mire.

Polytrichium novegium. Only found once in Mire community in association with Bryum weigelli.

Polytrichium urnigerum Hedw. Quite frequent in Moraine from 50 metres from glacier to Terminal Moraine. Forms lax patches of stems, the number of which in each colony increases down the valley. Occurs on rocks in Mire community.

LICHENS - IDENTIFIED BY DR. GILBERT

Placopsis gelida L. Linds. the most common lichen. Occurs 400 m. from the glacier and in all communities. Very common in the lower parts of the moraine.

Lecidea macrocarpa (D.C. Stend. Common species on the Terminal Moraine and Sandur, where it forms large patches.

Other lichen species, due to their poor development, were not recognisable.

REFERENCES:

Clapham, A.R., Tutin, T.G. and Warburg, E.F.: Flora Europaea, London, 1968.

Dixon, H.N. and Jameson, H.G. The Student's Handbook of British Mosses, London, 1896.

Duncan, U.K. and James, P.W. : Introduction to British Lichens, 1970

James, P.W. : A new check-list of British Lichens; Lichenol. 3, pp.95-153, 1965.

Paton, Y.A. : Census Catalogue of British Hepatics, 1965

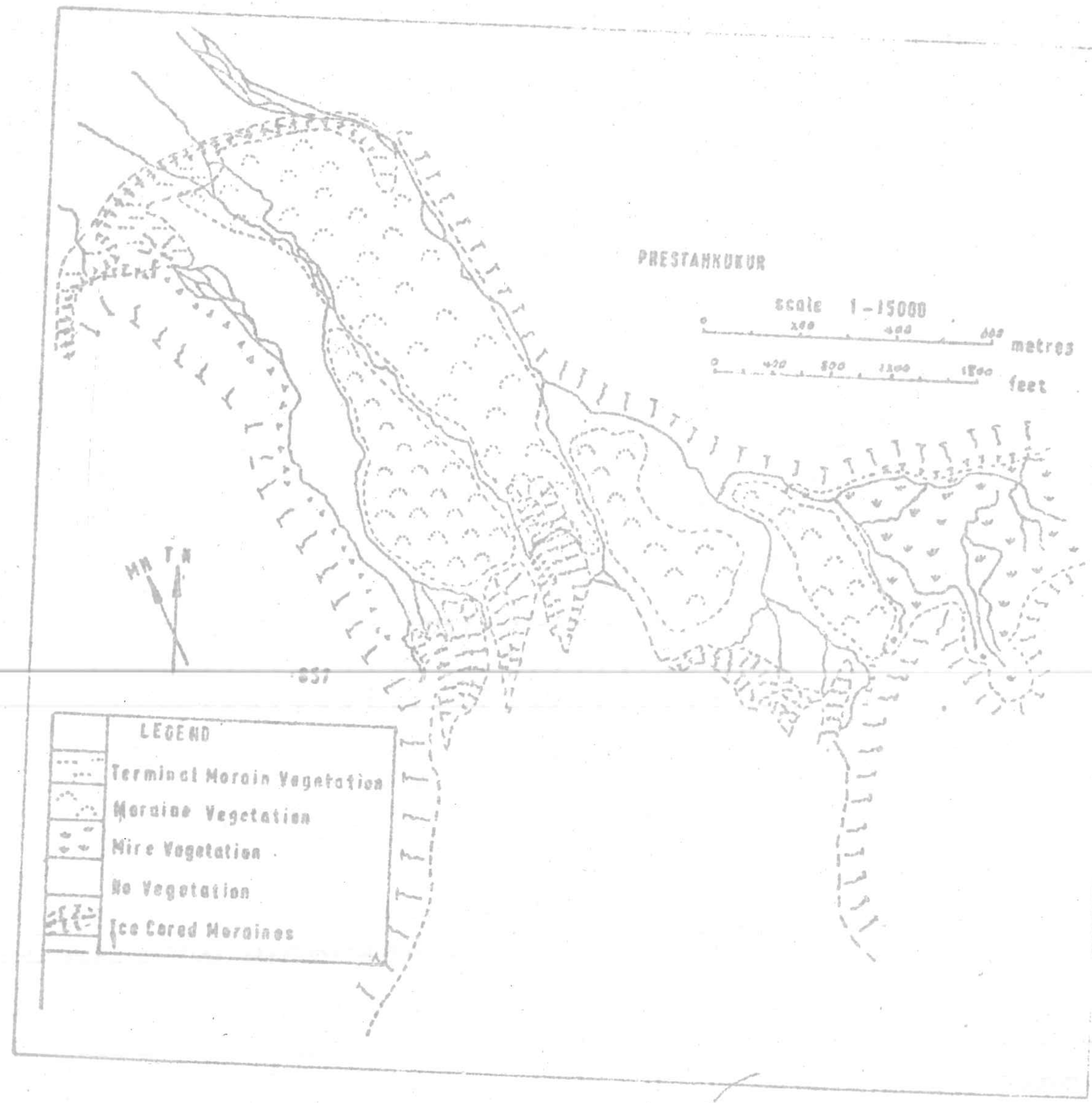
Steindorsson, S. : "Studies on the Vegetation of the Central Highlands of Iceland" in the Botany of Iceland, Reykjavik, 1945.

Warburg, E.F. : Census Catalogue of British Mosses, 1963.

Watson, E.V. : British Mosses and Liverworts, Cambridge, 1955.

BOTANY REPORT

VEGETATION ZONES IN WESTERN PORISDALUR. AUGUST 1970.



MAPPED BY J. WOBEY.

HISTOGRAM TO SHOW INCREASE IN NO. OF SPP. BACK FROM GLACIER.

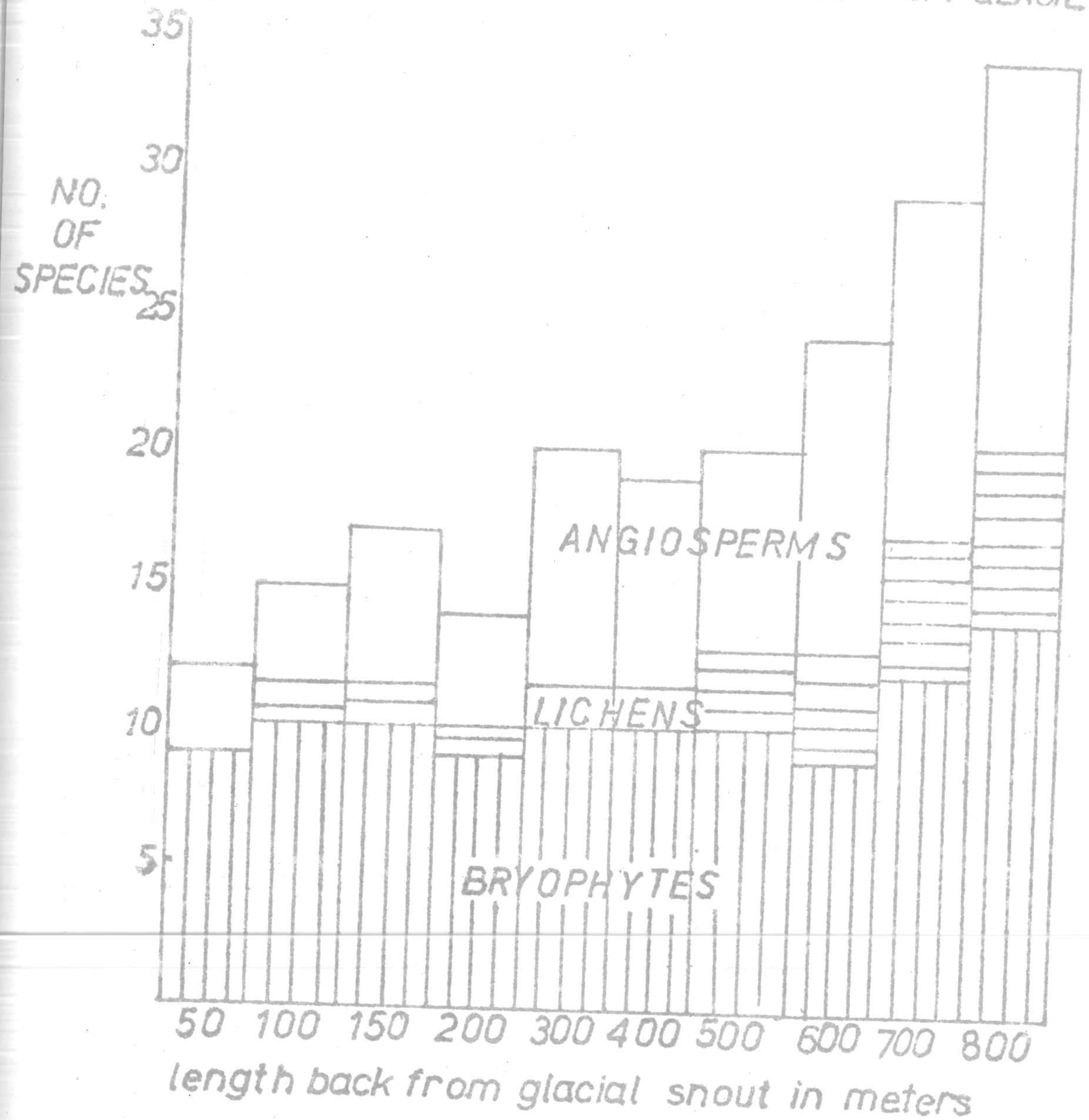
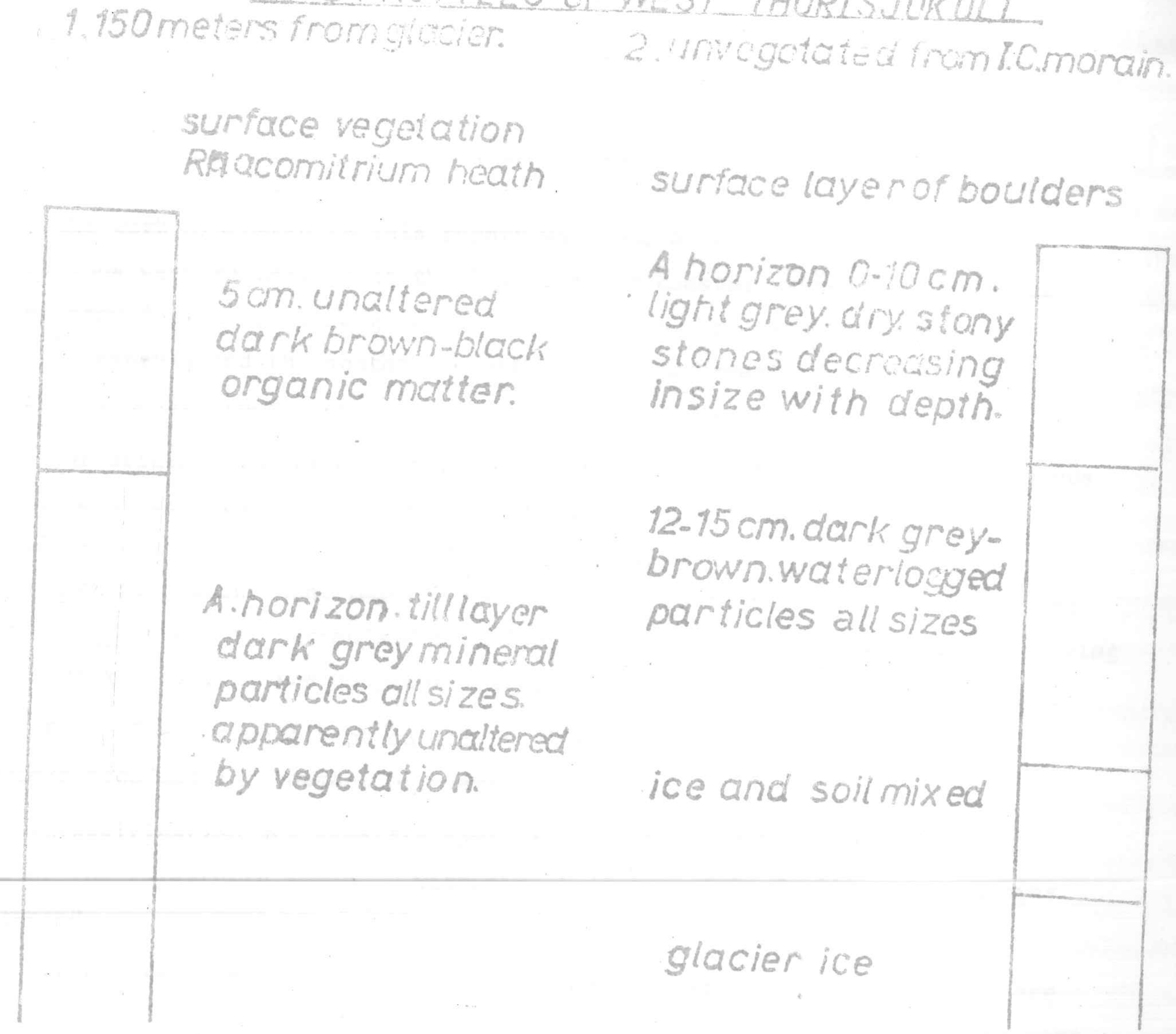


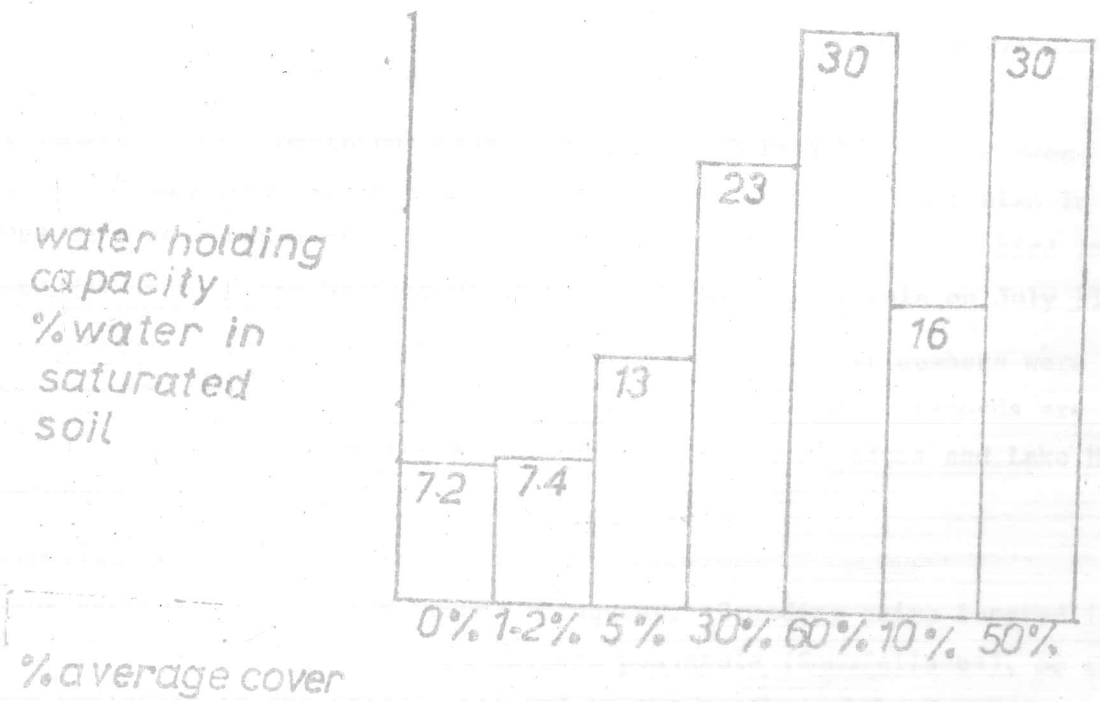
TABLE TO SHOW INCREASE IN ACIDITY OF SOILS WITH GREATER COVER.

Location of soil sample	pH	% cover
Ice cored moraine	7.4	0
50 meters from glacier	6.8	1-2
150 meters from glacier	6.8	5
south facing slope of terminal moraine	6.7	30
Sandur	6.2	50
north facing slope of terminal moraine	[illegible]	10

SOIL PROFILES OF WEST THORLSJÖKULL



THE WATER HOLDING CAPACITY OF SOIL WITH COVER INCREASE



REPORT OF ORNITHOLOGICAL SECTION OF THE 1970 UNIVERSITY OF NEWCASTLE UPON TYNE EXPEDITION TO ICELAND

INTRODUCTION

The work discussed in this report was done between 7/7/70 and 9/8/70. Observations were restricted to the lowlands and coastal areas on the west of Iceland from Reykjavik to Borgarnes and north from this area to include the western peninsula and the southern coast of the north-western peninsula. In addition to these areas Lake Myvatn in the north was visited.

Our original intentions included observations on the effect of continuous diurnal conditions on the behaviour of diving birds but our late arrival in Iceland restricted this aspect to observations on only one species, scaup, Aythya marila. Subsequent major efforts were concentrated upon Great Northern Diver, Gavia immer and Barrow's Golden Eye, where observations were made on diving and preening behaviour and on general activity at different times of the day.

General notes were kept on all species seen and diving and preening behaviour recorded in a number of species.

Classification and specific names follow those of Vaurie (1965): The Birds of the Palearctic Fauna. Witherby, London. Only families and species are listed.

It should also be noted that the numbers quoted in the species list are restricted solely to those observed by ourselves, thus Anser brachyrhynchus were infact breeding in many thousands in areas we did not visit.

Species list: Scarce (less than 10), frequent (10-100), common (100-1000) or abundant (more than 1000).

Gaviidae:

Gavia immer: Great Northern Diver. Scarce. Only 4 birds were seen; 2 adults in summer plumage from 12-14th July on Hredavatn; a third adult also in summer plumage on a sea-loch north of Borgarnes on July 18th. The only bird in winter plumage was seen on Skalmarfjordur in the north-west peninsula on July 31st.

Gavia stellata: Red Throated Driver. Frequent. Greatest numbers were found on the coastal pools in the area north of Borgarnes. Other records are from Kroksfjordur in the north-western peninsula, and near Blonduos and Lake Myvatn in the north.

Podicipedidae:

Podiceps auritus: Slavonian Grebe. Frequent. Breeding pairs located in 3 areas: pools on the south side of the mid-western peninsula (Snaefellsnes), on the north-western peninsula in the Stadur area and in the north on Lake Myvatn.

Procellariidae:

Fulmarus glacialis: Fulmar. Abundant. Continually present around ship on 2 day trip to Reykjavik from Leith. Largest concentration on sea trip was 300-400 between the Orkneys and the mainland of Scotland. High numbers were also observed in the vicinity of the Westman Islands where they are known to breed. The only breeding areas actually observed were sea-cliffs immediately south of Snaefells Jokull at Londrangar where about 60 pairs were breeding. Sea watches in all parts of areas visited yielded sightings.

Sulidae:

Sula bassana: Gannet. Frequent. Greatest numbers were observed in the vicinity of the Westman Islands which are a known breeding area.

Phalacrocoracidae:

Phalacrocorax carbo: Cormorant. Frequent. Found breeding on small coastal islands north of Borgarnes and in the Breidafjordur area.

Phalacrocorax aristotelis: Shag. Common. Distribution similar to that of cormorant.

Anatidae:

Cygnus cygnus: Whooper Swan. Common. Widely distributed breeding throughout the area visited. Largest concentrations were found in the coastal marshes where 50 pairs were estimated breeding to the north of Borgarnes, and also in the fjords on the south of the north-west peninsula where flocks of up to 40 birds were seen. The largest single flock recorded was at Myvatn where 350 were counted.

Anser anser: Greylag Goose. Scarce. A party of 6 was seen on two occasions in the Husafell area.

Anser brachyrhynchus: Pink-footed Goose. Scarce. Only one individual seen at Hredavatn on 13/7/70.

Anas platyrhynchos: Mallard. Abundant. Widely distributed, breeding in many of the localities visited. Several hundred birds live on a lake within the city of Reykjavik; the next largest concentration found was on Myvatn.

Anas crecca: Teal. Scarce. Three birds were seen at Myvatn on 6/8/70.

Anas strepera: Gadwall. Scarce. One bird seen on lake Myvatn in a bay on the east shore near Reykjahlid.

Anas penelope: Wigeon. Frequent. Recorded on the coastal marshes north of Borgarnes and at Myvatn.

Anas acuta: Pintail. Scarce. One female on the lake in Reykjavik.

Anas clypeata: Shoveller. Scarce. Recorded north of Borgarnes and at Myvatn.

Aythya ferina: Pochard. Frequent. A group of about 30 was seen on Myvatn on 6/8/70.

Aythya fuligula: Tufted Duck. Abundant. Recorded at Reykjavik, north of Borgarnes on the coastal marshes, pools on the south side of Snaefellsnes and Myvatn. No flocks of more than 100 were recorded.

Aythya marila: Scaup. Abundant. Found in all areas visited. The largest group was found on Myvatn where 1000 birds were counted in one flock. The total population was estimated at no more than 2000 birds.

Somateria mollissima: Eider. Abundant. Found with young at all parts of the coast visited. Rafts of 2000-3000 birds offshore were not uncommon.

Histrionicus histrionicus: Harlequin Duck. A river duck seen in the following localities: Leirvogsa between Reykjavik and Pingvellir (3 birds), coast west of Stykkisholmur (14 birds) and at Myvatn on the Laxa (27 birds). All these birds were females or immatures with the exception of one male in full breeding plumage included in the Stykkisholmur group.

Clangula hyemalis: Long-tailed Duck. Frequent. Seen in 3 localities: one female at Reydarvatn north of Pingvellir, 6 birds on the south side of Snaefellsnes and ca. 25 on Myvatn.

Bucephala islandica: Barrow's Golden Eye. Common. Found only on the River Laxa running from Myvatn. None were seen on the lake itself and the population was estimated at 450.

Mergus serrator: Red-breasted Merganser. Frequent. Recorded in the Snaefellsnes, Breidafjordur and Myvatn areas.

Accipitridae:

Haliaeetus albicilla: White-tailed Sea-eagle. Scarce. One adult was recorded at Hagavadall on the south coast of the north-west peninsula. (Breidafjordur).

Falconidae:

Falco rusticolus: Gyrfalcon. Scarce. A party of 3 was seen at Kroksfjordur in the north-west peninsula and 2 birds on the eastern shore of Myvatn.

Falco columbarius: Merlin. Scarce. Recorded near Pingvellir, Saudafell, Varmahlid (all single birds) and on the south coast of the north-west peninsula where 7 birds were seen including one party of 4.

Phasianidae:

Lagopus mutur: Ptarmigan. Frequent. Recorded at Pingvellir, Hredavatn, north-west peninsula and near Myvatn. Largest group of about 12 birds consistent of adults and young.

Haematopodidae:

Haematopus ostralegus: Oystercatcher. Common. Observed in most coastal areas where young were seen on several occasions.

Charadriidae:

Pluvialis apricaria: Golden Plover. Abundant. Recorded in all areas visited. Rarely seen in flocks larger than 10 birds.

Charadrius hiaticula: Ringed Plover. Common. Observed breeding in various localities.

Arenaria interpres: Turnstone. Common. Recorded at coastal marshes north of Borgarnes on 17/7/70 - 4 birds - and in the Breidafjordur area on 1/8/70 when a flock of over 100 was found at Baudsdalur in the north-west peninsula.

Calidris minuta: Little Stint. Scarce. One bird was seen on 1/8/70 at Baudsdalur in the north-west peninsula.

Calidris maritima: Purple Sandpiper. Frequent. Recorded in two areas north-west of Borgarnes and on the western shore of Vatnsfjordur in the north-west peninsula.

Calidris alpina: Dunlin. Common. Recorded generally along the shore or in coastal pools.

Calidris canutus: Knot. Common. Two flocks seen in the Vatnsfjordur area of the north-west peninsula between 31/7/70 and 1/8/70. One flock contained 100 plus birds the other 60 plus.

Tringa totanus: Redshank. Common. Recorded in all areas visited, more commonly in the vicinity of water.

Limosa limosa: Black-tailed Godwit. Scarce. One breeding pair recorded south of Hekla and a single bird in the marshes north-west of Borgarnes.

Numenius arquata: Curlew. Scarce. One bird was seen on the coast north of Borgarnes when the following points were noted: larger size, slower flight, lack of facial pattern, larger bill and slower flight as compared with whimbrel combined with diagnostic call. These notes are included here as curlew is a rare species in Iceland.

Numenius phaeopus: Whimbrel. Abundant. Recorded in all areas visited and breeding birds seen in most localities. By the end of July young were fully fledged and family parties numbering up to 16 birds were seen. Departure from the breeding areas was rapidly occurring between 27/7/70 and 4/8/70.

Gallinago gallingago: Common Snipe. Common. Recorded in all areas visited. Drumming was noted in Reykjavik on 7/7/70 at 0120.

Phalaropus fulicarius: Grey Phalarope. Scarce. Four birds in winter plumage seen at Myvatn 7/8/70.

Phalaropus lobatus: Red-necked phalarope. Common. Sporadically distributed over the whole area visited often breeding on roadside pools. Largest numbers were found at Myvatn on 7/8/70 when over 80 birds were counted on the River Laxa.

Laridae:

Stercorarius skua: Great Skua. Common. Recorded pelagically with particular concentrations seen off the Westman Islands.

Stercorarius parasiticus: Arctic skua. Common. Recorded generally in all areas visited. Dark phase outnumbered light phase.

Larus ridibundus: Black-headed Gull. Abundant. Recorded in all lowland areas visited.

Larus fuscus: Lesser Black-backed Gull. Abundant. Recorded in all coastal areas visited with particularly large numbers seen in the Vatnsfjordur area of the north-west peninsula. The race concerned in all cases was L.f. graellsii.

Larus argentatus: Herring Gull. Abundant. Found in same localities and in mixed flocks with Larus f. graellsii. The race concerned was the nominate group Larus a. argentatus.

Larus glaucoides: Iceland Gull. Scarce. Single second year bird seen at Eyri on the south coast of the north-west peninsula.

Larus hyperboreus: Glaucous Gull. Abundant. Widely distributed in all coastal areas. A large breeding colony of about 400 pairs was seen in the vicinity of Eyri in the north-west peninsula. The race concerned was the nominate one Larus h.hyperboreus.

Larus canus: Common Gull. Frequent. Recorded in the Reykjavik area.

Rissa tridactyla: Black-legged Kittiwake: Abundant. Recorded breeding on the coastal islands north-west of Borgarnes and on sea-cliffs immediately south of Snaefellsjokull in the Londrangar area where over 1,000 pairs were breeding. Breeding pairs could also be seen on many islands in the Breidafjordur area.

Sterna paradisaea: Arctic tern. Abundant. Recorded in all areas visited. Breeding localities were as follows: coastal marshes north-west of Borgarnes, south coast of Snaefellsnes and at Hagavadall in the north-west peninsula.

Alcidae:

Plotus alle: Little Auk. Frequent. Flock of 18 seen in Hajourfjordur in the north-west peninsula.

Alca torda: Razorbill. Frequent. Recorded in the vicinity of the Westman Islands and 5 birds on eggs in the Londrangar area of the mid-west peninsula.

Uria aalge: Guillemot. Abundant. Large breeding colony found at Londrangar south of Snaefells jokull, consisting of over 1,000 birds. Numbers were also seen in the vicinity of the Westman Islands.

Uria lomvia: Brunnich's Guillemot. Frequent. About 60 birds were seen on the cliffs in the Londrangar area.

Cepphus grylle: Black Guillemot. Frequent. About 15 breeding pairs recorded in the Londrangar area and a single bird in the Skalmarfjordur area of the north-west peninsula.

Fratercula arctica: Puffin. Abundant. Recorded on coastal islands north-west of Borgarnes and the whole coastal area of Snaefellsnes and Breidafjordur.

Columbidae:

Columba palumbus: Wood Pigeon. Scarce. A single bird was seen on two occasions on 13/7/70 and 14/7/70 in the Hredavatn area. Because of the rarity of this bird in Iceland the following diagnostic features are described: large size, grey coloration, broad white wing-patches, white neck-patches made the bird unmistakable.

Strigidae:

Nyctea scandiaca: Snow Owl. Scarce. A brief glimpse was obtained of an adult in the vehicle headlights at 23.40 on 5/8/70 on the east side of Myvatn.

Motacillidae:

Anthus pratensis: Meadow Pipit. Abundant. A wide-spread breeding species.

Motacilla alba: White Wagtail. Common. The race concerned M.a.alba occurred generally in all areas visited as a breeding species.

Troglodytidae:

Troglodytes troglodytes: Wren. Frequent. Recorded in the Hredavatn and Myvatn areas and at Hagavadal in the north-west peninsula. In all cases the birds were living in areas of low birch (Bettula sp.)

Muscicapidae:

Oenanthe oenanthe: Wheatear. Common. A widely distributed breeding species.

Turdus iliacus: Redwing. Abundant. A very widely distributed breeding species especially in areas of low birch (Bettula sp.) One bird esas noted in full song in suburban Reykjavik at 0100 hours on 7/7/70.

Emberizidae:

Plectrophenax nivalis: Snow Bunting. Frequent. With one exception of a pair of young near Reykjavik all birds were recorded on high ground over 1000 feet.

Fringillidae:

Acanthis flammea: Redpoll. Common. A breeding bird of lowland birch scrub.

Acanthis hornemanni: Arctic Redpoll. Scarce. A single bird was seen in birch scrub at Pingvellir on 8/7/70 when very pale appearance, white unstreaked rump and underparts were noted; a double wing bar was very conspicuous in flight.

Ploceidae:

Passer domesticus: House Sparrow. Scarce. A single bird was recorded at a farm north-west of Borgarnes.

Sturnidae:

Sturnus vulgaris: Starling. Common. Noted mainly in the Reykjavik area.

Corvidae:

Corvus corax: Raven. Common. Widely distributed in all areas visited.

Diving data was collected for ten species during our stay in Iceland. These were two Divers, one Grebe, two Cormorants and six species of Duck. The results of the data collected are summarised in table 1. This gives means, standard deviations, standard errors and numbers of observations for dives and where collected recoveries of each species. In two species the D.P.R. - dive pause ratio has been collected, though closer scrutiny of the data illustrates what little value this figure has as a comparative value for diving efficiency between species.

Regression analyses were carried out on dive times versus corresponding recovery times of three species. The correlation coefficients were:

Aythya marila	0.09	
Gavia immia	-0.22	
Bucephala islandica	0.08	in broken water
	-0.23	in smooth water.

Thus clearly illustrating that there is no correlation between the time a bird spends underwater and its corresponding recovery period.

TABLE 1. DIVING DATA

				Mean	S.D.	S.E.	n	D.P.R.
1.	Gavia immer		D	46.2	26.6	1.9	200	1.93
			R	25.9	24.0	1.8	170	
2.	Gavia stellata		D	19.8	12.6	1.8	50	
			R	-	-	-	-	
3.	Podiceps Auritus		D	20.5	7.5	0.8	84	
			R	8.9	4.7	0.5	79	
4.	Phalocrocorax carbo		D	32.5	5.9	1.1	30	
			R	9.2	3.4	0.6	27	
5.	Phalocrocorax aristotelis		D	17.0	7.8	1.2	39	
			R	-	-	-	-	
6.	Aythya marila		D	15.6	4.6	0.3	318	
			R	13.8	6.3	0.6	109	
7.	Somateria mollissima		D	28.9	7.1	0.9	54	
			R	-	-	-	-	
8.	Clangula hyemalis		D	31.4	3.1	0.7	17	
			R	10.5	9.0	2.4	14	
9.	Bucephala islandica	Smooth	D	13.6	5.1	0.3	320	
			R	7.3	5.0	0.3	243	
		Broken	D	10.8	4.9	0.4	185	
			R	7.9	6.2	0.7	91	
		Overall	D	12.5	5.5	0.2	559	
			R	7.8	5.9	0.3	360	1.86
10.	Mergus Serrator		D	20.1	8.2	0.9	84	
			R	8.8	10.9	1.3	75	

The data obtained for Barrows Goldeneye has been analysed fully.

DATA OF BARROWS GOLDENEYE FROM LAKE MYVATN ICELAND, AUGUST 1970

Diving Results.

Grand mean of all dives.

Mean : 12.5 sec.
n : 559
d : 5.45
S.E. : 0.231

Dive pause ratio of the above data: 1.602.

Grand mean of all recoveries

Mean : 7.8 sec.
n : 360
d : 5.9
S.E. : 0.312

Mean of dive times in broken water.

Mean : 10.8 sec.
n : 185
d : 4.9
S.E. : 0.362

Dive pause ratio of the above data : 1.367.

Recovery times in broken water

Mean : 7.9 sec.
n : 91
d : 6.23
S.E. : 0.650

Mean dive times in smooth water.

Mean : 13.6
n : 320
d : 5.116
S.E. : 0.286

Recovery times in smooth water

Mean : 7.3
n : 243
d : 5.048
S.E. : 0.324

Dive pause ratio of above data : 1.863.

The Dive pause ratio of 1.863 i.e. simplified 1.9 exactly corresponds with the dive pause ratio quoted by Sven Axel Bengtson in his paper Field Studies on the Harlequin Duck in Iceland (Wild Fowl Trust 17th Annual Report).

Regression analysis (linear) of dive times versus recovery times

According to equation : $Y = mX + b$

r : correlation coeff. b : intercept on y axis M : slope of line.

Broken water

n : 110
r : 0.076
b : 11.169
m : 0.073

Smooth water

n : 170
r : -0.23
b : 13.642
m : -0.021

Thus neither in broken nor smooth water does correlation exist between dive times and recovery times. In both cases m approximating to zero, i.e. no correlation.

Variation in surface flow rate of the river Laxa

The surface flow rate was measured on six different stations in the main feeding areas of Bucephala islandica.

Station I.

Smooth water. Length : 8 x 204 cms.
Times : 22.8, 26.2, 24.8, 21.2
Flow rate (cms/sec.) 71.6, 62.3, 65.8, 76.9
Range : 62.3 -76.9 (4).
Mean : 69.2cms/sec.

Station 2.

Broken water. Length : 6 X 204 cms.
Times : 12.9, 6.14, 7.11, 5,12.8.
Flow rate : (cms/sec) 102.9, 126.6, 83.3, 106.1, 95.6
Range : 83.3- 126.6 (4)
Mean : 102.9 cms/sec.

Station 3.

Broken water. Length : 10 x 204 cms.
Times : 12.2, 11.8, 12.5, 11.8.
Flow rate (cms/sec) 167.2, 172.9, 163.2, 172.9.
Range : 163.2- 172.9 (4)
Mean : 169.1.

Station 4.

Smooth water. Length : 10 x 204 cms.
Times : 29.1, 29.3, 27.5, 24.4, 22.8.
Flow rate (cms/sec.) 70.1, 69.6, 74.2, 83.6, 89.5.
Range : 69.6 - 89.5 (5)
Mean : 74.4 cms/sec.

Station 5.

Broken water Length : 8 X 204 cms.
Times : 11.4, 11.5, 13.1, 11.0.
Flow rate : (cms/sec) 143.2, 141.9, 124.6, 148.4.
Range : 124.6 - 148.4 (4).
Mean : 139.5 cms/sec.

Station 6.

Smooth water. Length : 8 x 204 cms.
Times : 28.2, 27.2, 26.6, 23.0.
Flow rate (cms/sec) 72.3, 75.0, 76.7, 88.7.
Range : 72.3, - 88.7 (4)
Mean : 75.7 cms/sec.

The overall variation in surface flow rate encountered on the river Laxawas from 69.2 - 169.1 cms/sec. Smooth water having a flow rate of less than 100 cms/sec. broken water over 100 cms/sec. The mean flow rate for the two are as follows:-

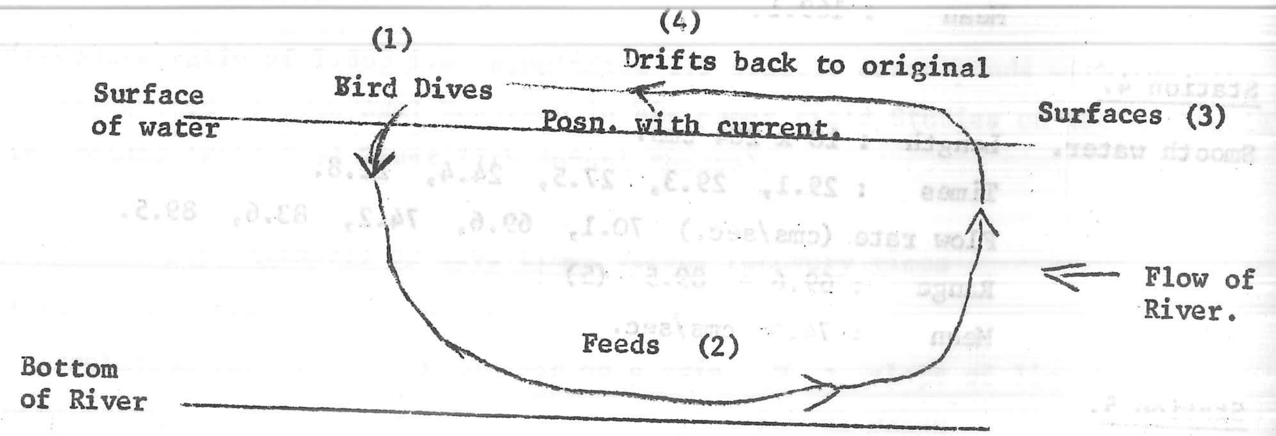
Broken water : 137.96 cms/sec.

Smooth water : 72.00 cms/sec.

SUMMARY OF DIVING DATA OF BUCEPHALA ISLANDICA FROM RIVER LAXA

	Smooth water	Broken water
Flow rate	72.00 cms/sec	137.96 cms/sec.
Mean dive times	13.6 sec.	10.8 sec.
Mean recovery times	7.3 sec.	7.9 sec.
Dive: pause ratio	1.863	1.367

While realising that the flow rate of a river varies with depth the measurement of surface flow rate goes some way towards numerically expressing the clear environmental problems the ducks were experiencing in feeding in "rough" and "smooth" water. Even though in some cases the surface flow rate was over 1 meter/sec faster than others the birds generally dived and swam up stream under the surface of the water, then surfaced to float down stream with the current to dive once again in the original position.



The diving behaviour of Barrows Goldeneye has been analysed in terms of overall dive and recovery data : mean, number of dives, standard deviation, standard error. This data has then been broken down into environmental considerations which we arbitrarily describe as rough water and smooth water. The variations in surface flow rate of the Laxa describing rough and smooth water are analysed separately. While the 559 dives of the birds analysed were often continuous from smooth water to rough and vice versa, this was by no means a continuous process thus it is necessary for completeness to analyse each individual dive session together with where the data is available the recovery data.

DIVING DATA

Session number	Mean	n	d	S.E.
1B	9.67	3	1.53	0.88
2B	6.93	14	3.60	0.96
3B	13.75	20	8.82	1.97
4B	14.17	3	7.52	4.34
5B	16.33	3	3.06	1.76
6B	11.57	23	5.36	1.12
7B	13.30	20	2.64	0.59
8S	9.77	22	5.76	1.23
9S	19.50	3	6.78	3.92
10S	14.00	4	8.37	4.18
11S	9.67	3	2.31	1.33
12S	9.00	3	3.61	2.08
13S	12.67	18	3.76	0.89
14S	11.13	16	3.32	0.83
15S	15.13	15	3.52	0.91
16S	16.00	3	8.19	4.73
17S	10.50	10	2.88	0.91
18S	16.50	4	1.91	0.96
19B	9.70	10	6.00	1.90
20B	13.25	4	6.13	3.07
21B	15.17	6	8.23	3.36
22B	5.00	5	1.22	0.55
23B	7.29	7	3.50	1.32
24B	9.87	38	4.45	0.72
25S	11.57	7	5.91	2.23
26S	15.33	3	4.89	1.47
27S	12.45	11	4.89	3.18
28S	14.13	24	2.79	0.57
29S	14.28	32	4.48	0.86
30S	13.67	39	4.60	0.74
31S	13.33	3	2.31	1.33
32S	15.00	5	7.31	3.21
33S	19.33	3	5.13	2.96
34S	16.22	46	5.39	0.79
35S	7.75	4	3.59	1.80
36S	9.63	8	3.58	1.27
37B	12.75	4	4.65	2.32
38B	11.00	5	4.00	1.79
39B	8.70	10	5.10	1.61
40B	12.54	28	5.62	1.06
41S	16.53	15	4.24	1.09
42S	15.00	6	6.78	2.77
43B	12.07	27	4.40	0.85
44B	11.29	7	4.35	1.64

/continued overleaf...

The data for the fourty four dive sessions was recorded over a period of four days from the 5/8/70 to the 8/8/70. It was unfortunately not possible to time all dive recovery periods during each diving session thus eleven sets of recovery period session data are missing from the following data.

The letter B after each session number indicates broken water, S indicates smooth water.

Session Number	Mean	n	d	S.E.	RECOVERY DATA
1B					
2B					
3B	20.00	11	23.83	7.19	
4B	7.90	2	0.71	0.50	
5B	9.40	2	0.57	0.49	
6B	11.18	22	10.37	2.21	
7B	7.32	19	3.07	0.71	
8B					
9S	10.50	2	7.78	5.50	
10S	5.50	2	2.12	1.50	
11S					
12S	4.50	2	2.12	1.50	
13S	7.27	15	2.69	0.69	
14S	6.53	15	3.87	1.00	
15S	8.00	14	1.52	0.41	
16S	12.00	2	1.41	1.00	
17S	4.22	9	1.20	0.40	
18S	7.50	4	5.74	2.87	
19B	5.89	9	2.20	0.73	
20B	5.67	3	1.53	0.88	
21B	7.40	5	1.67	0.75	
22B	3.75	4	0.50	0.25	
23B					
24B					
25S					
26S	6.00	3	1.00	0.58	
27S	11.33	9	10.34	3.45	
28S	5.74	23	3.61	0.75	
29S	8.18	28	6.22	1.18	
30S	7.72	32	6.52	1.15	
31S	9.50	2	2.12	1.50	
32S	12.33	3	6.43	3.71	
33S	4.00	2	2.83	2.00	
34S	7.36	45	4.30	0.64	
35S	3.00	3	1.00	0.58	
36S	5.63	8	3.07	1.08	
37B					
38B	11.50	4	9.88	4.94	
39B	6.88	8	2.42	0.85	
40B	7.04	28	3.68	0.69	
41S	7.86	14	3.78	1.01	
42S					
43B					
44B					

This data shows the considerable variation in mean dive and recovery times in the two arbitary environments in which the birds were diving; thus illustrating the lack of validity of the D.P.R.

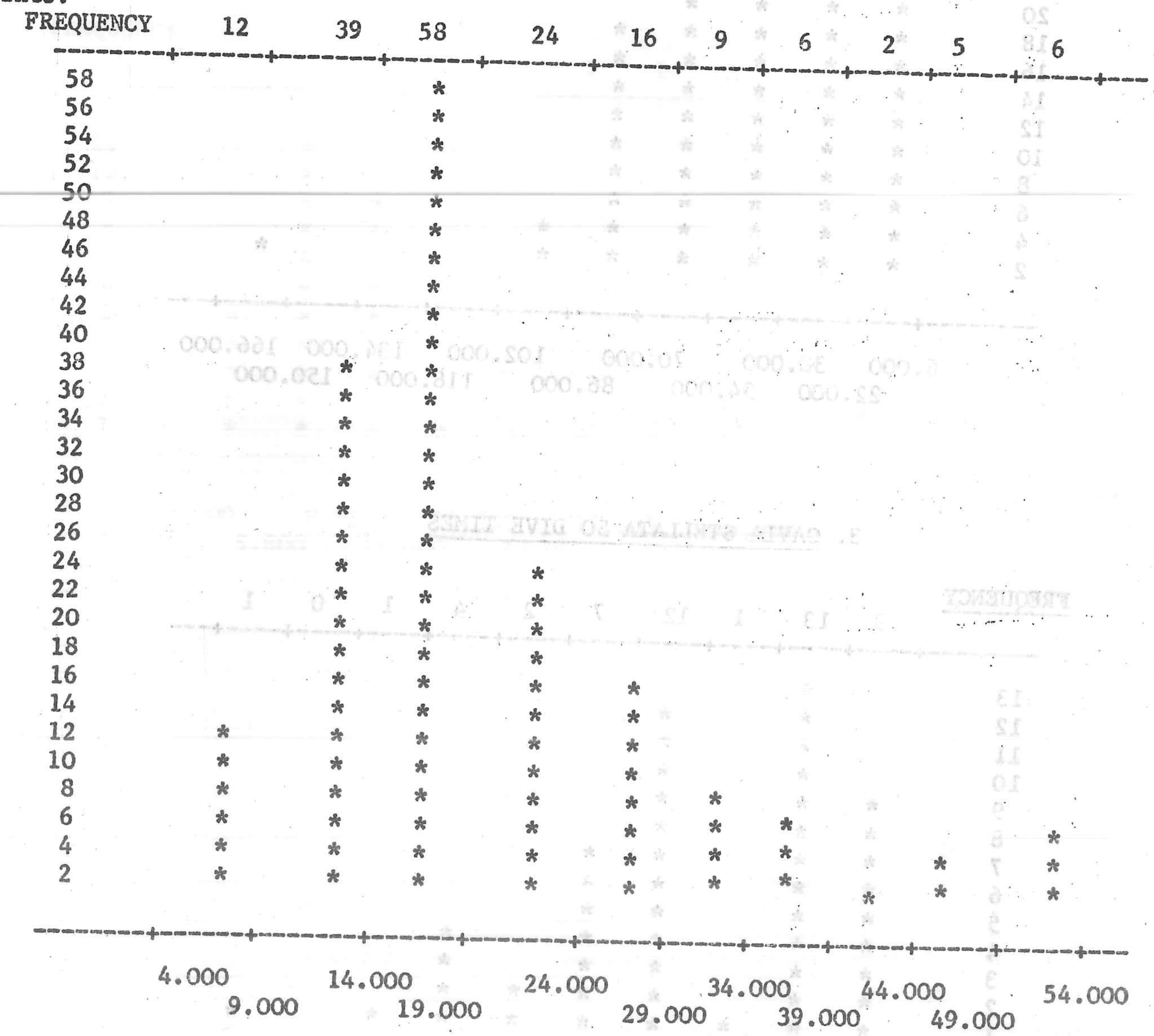
Histograms have been plotted of dive and recovery times of several of the species observed. Though several of these show bimodal peaks the significance of these may be somewhat disputed by examination of No. 6 and 7.

No. 7 is of 98 dives of Aythya marila presneted in order to compare it with No. 8 the corresponding recovery times. However the 98 dives in No. 7 are included in the overall histogram No. 6 where the bimodal peak disappears. It may be suggested in behavioural terms that the shorter time peak represents a dive in which no food was found by the bird and the longer one a dive during which food was found and consumed though there is no evidence to support this.

This data has invalidated the dive pause ratio as having no significant meaning. Any future work carried out on diving behaviour could try and investigate what goes on under the surface of the water; this may possibly give more meaning to these sets of data.

Each * equals 2 points.

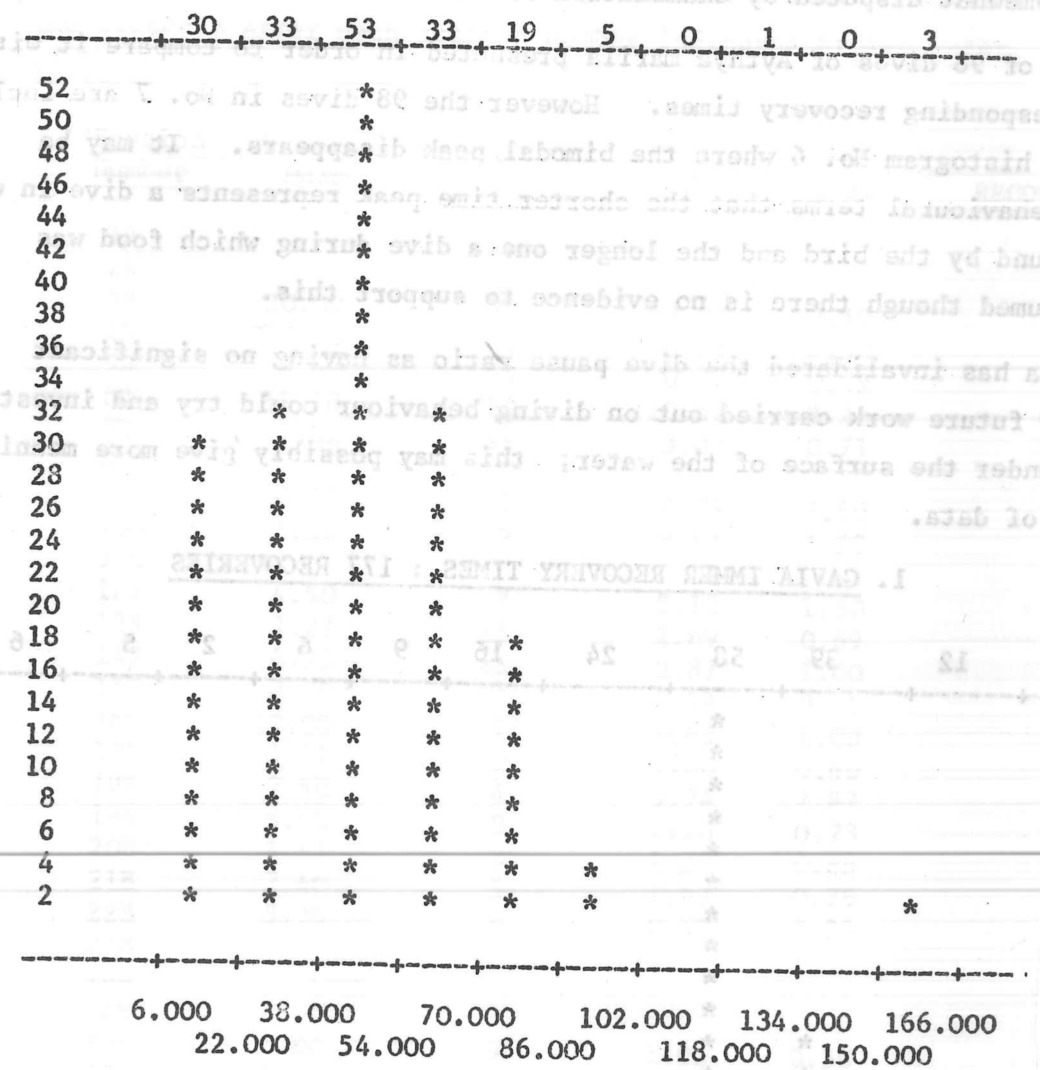
1. GAVIA IMMER RECOVERY TIMES : 177 RECOVERIES



2. GAVIA IMMER DIVE TIMES : 177 DIVES

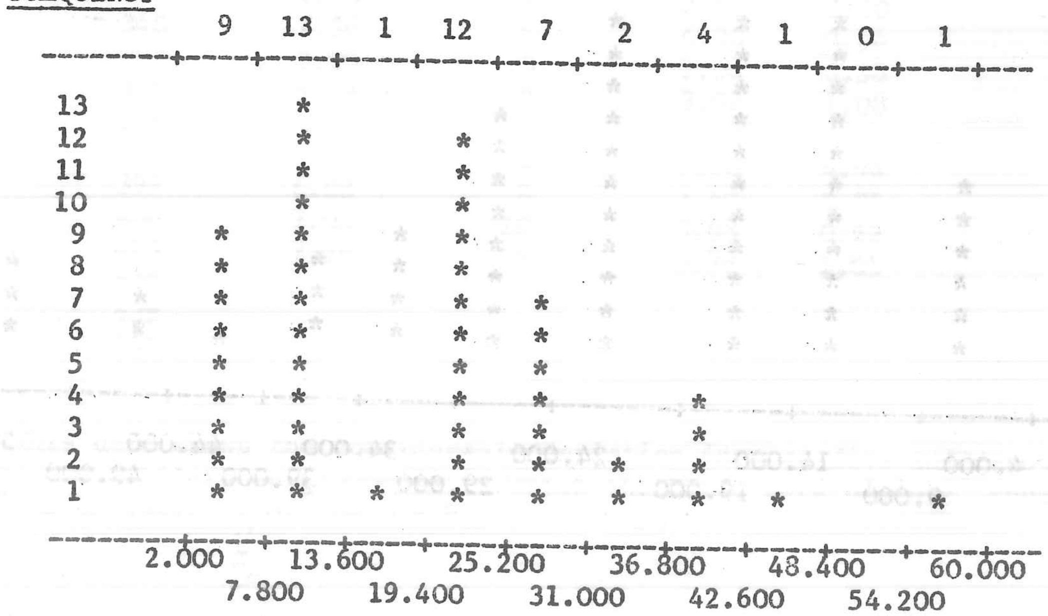
EACH * EQUALS 2 POINTS

FREQUENCY



3. GAVIA STELLATA 50 DIVE TIMES

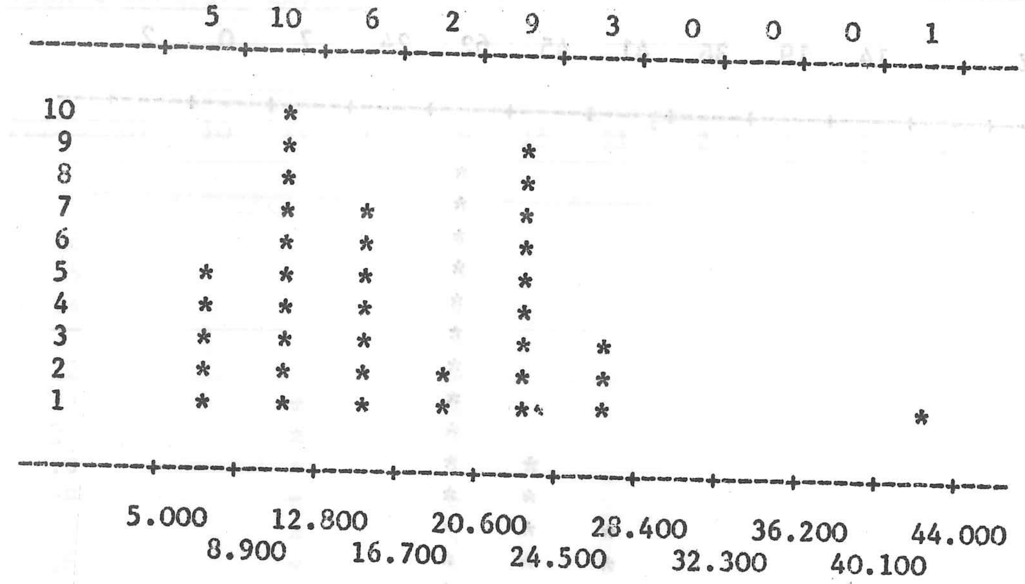
FREQUENCY



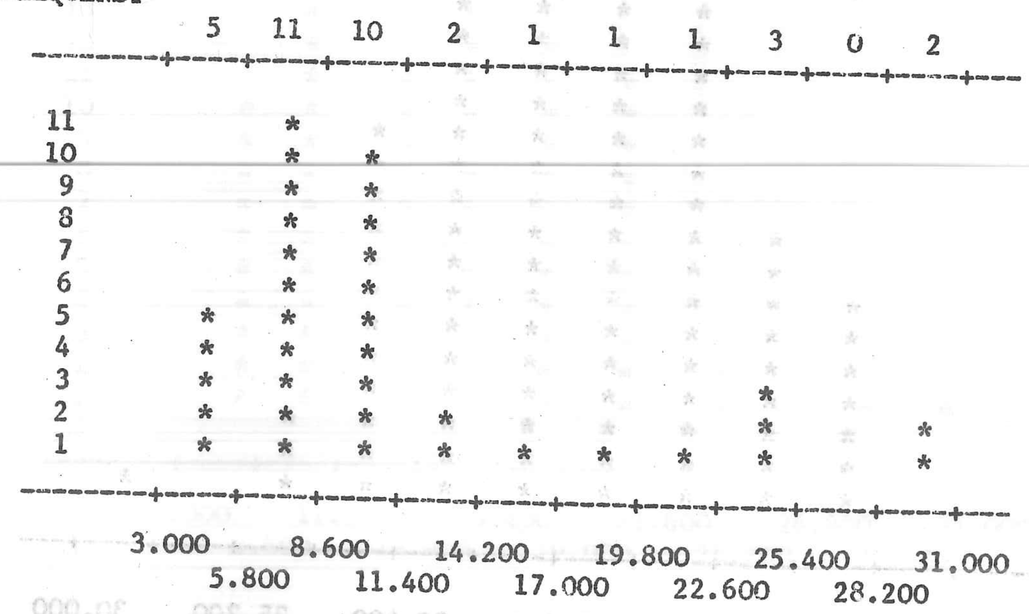
4. PHALACROCORAX ARISTOTELIS : 36 DIVES

Each * equals 2 points.

FREQUENCY

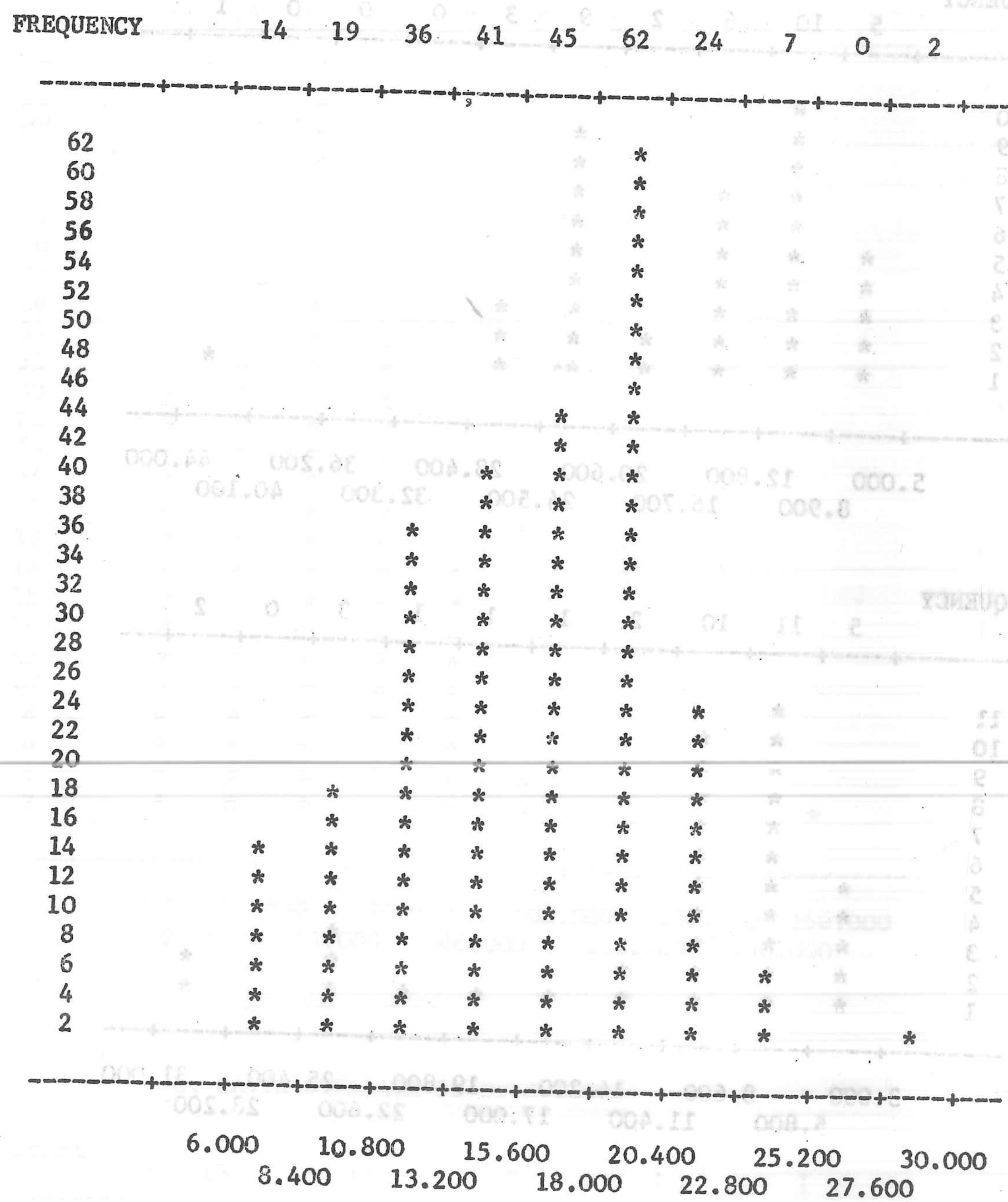


FREQUENCY



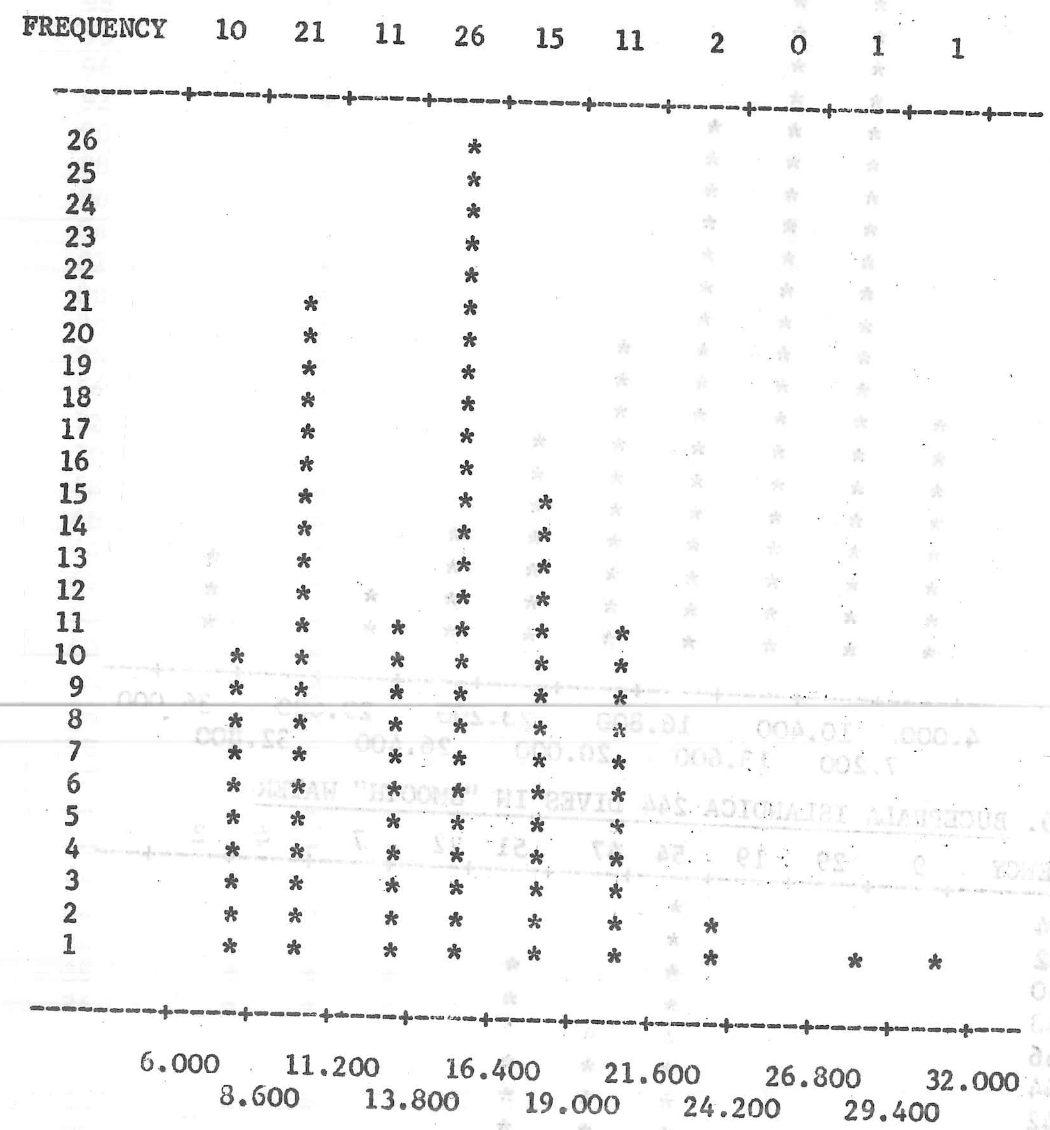
6. OVERALL DIVE TIMES OF AYTHYA MARILA: 250 DIVES

EACH * EQUALS 2 POINTS



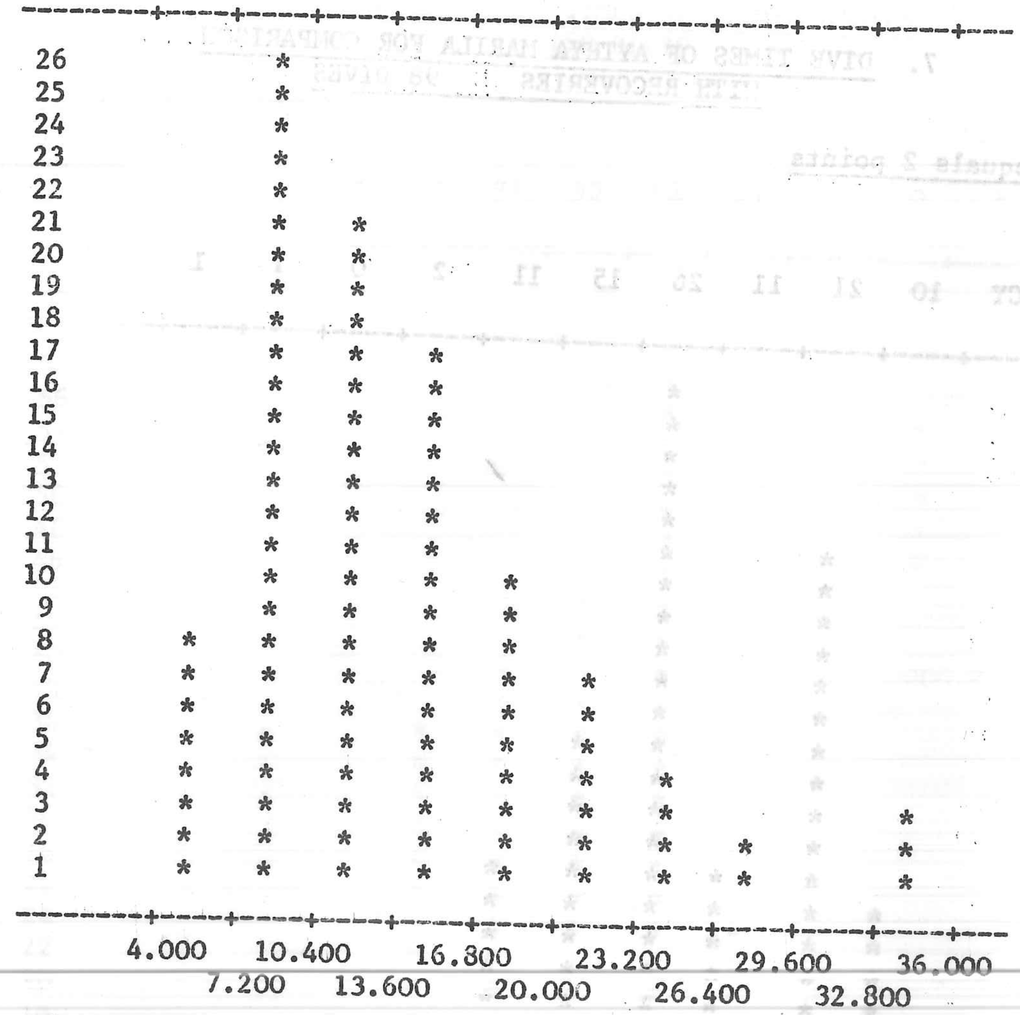
7. DIVE TIMES OF AYTHYA MARILA FOR COMPARISON WITH RECOVERIES 98 DIVES

Each * equals 2 points



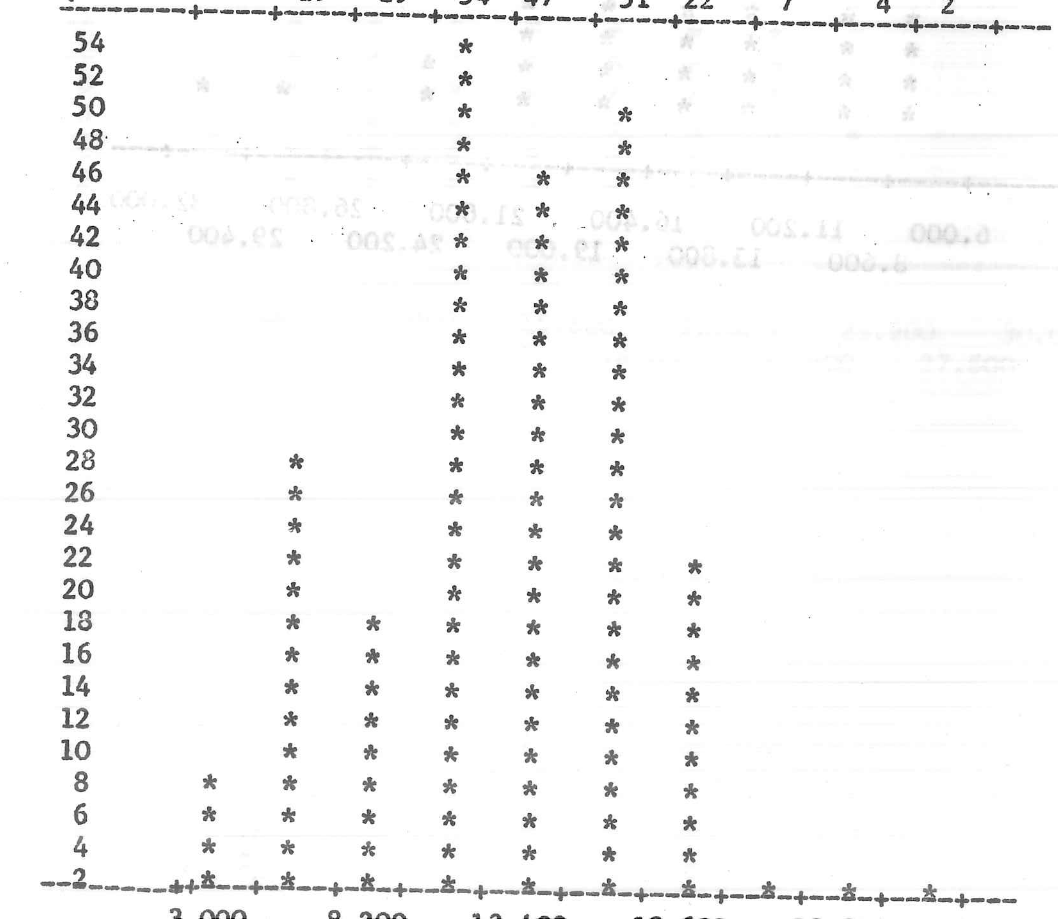
8. AYTHYA MARILA CORRESPONDING RECOVERY TIMES

FREQUENCY 8 26 21 17 10 7 4 2 0 3



9. BUCEPHALA ISLANDICA 244 DIVES IN "SMOOTH" WATER

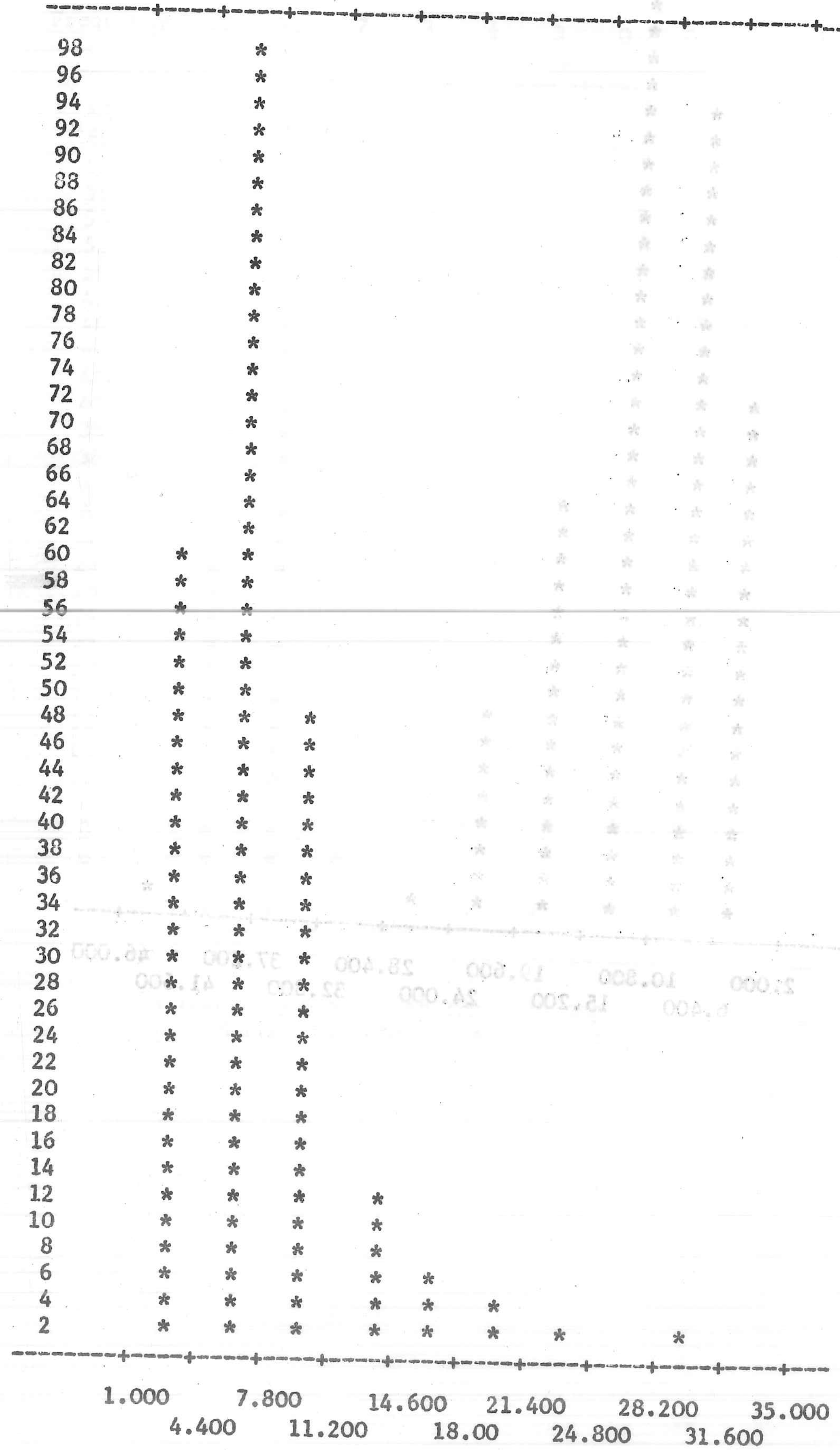
FREQUENCY 9 29 19 54 47 51 22 7 4 2



10. BUCEPHALA ISLANDICA : 244 CORRESPONDING RECOVERY TIMES IN "SMOOTH" WATER

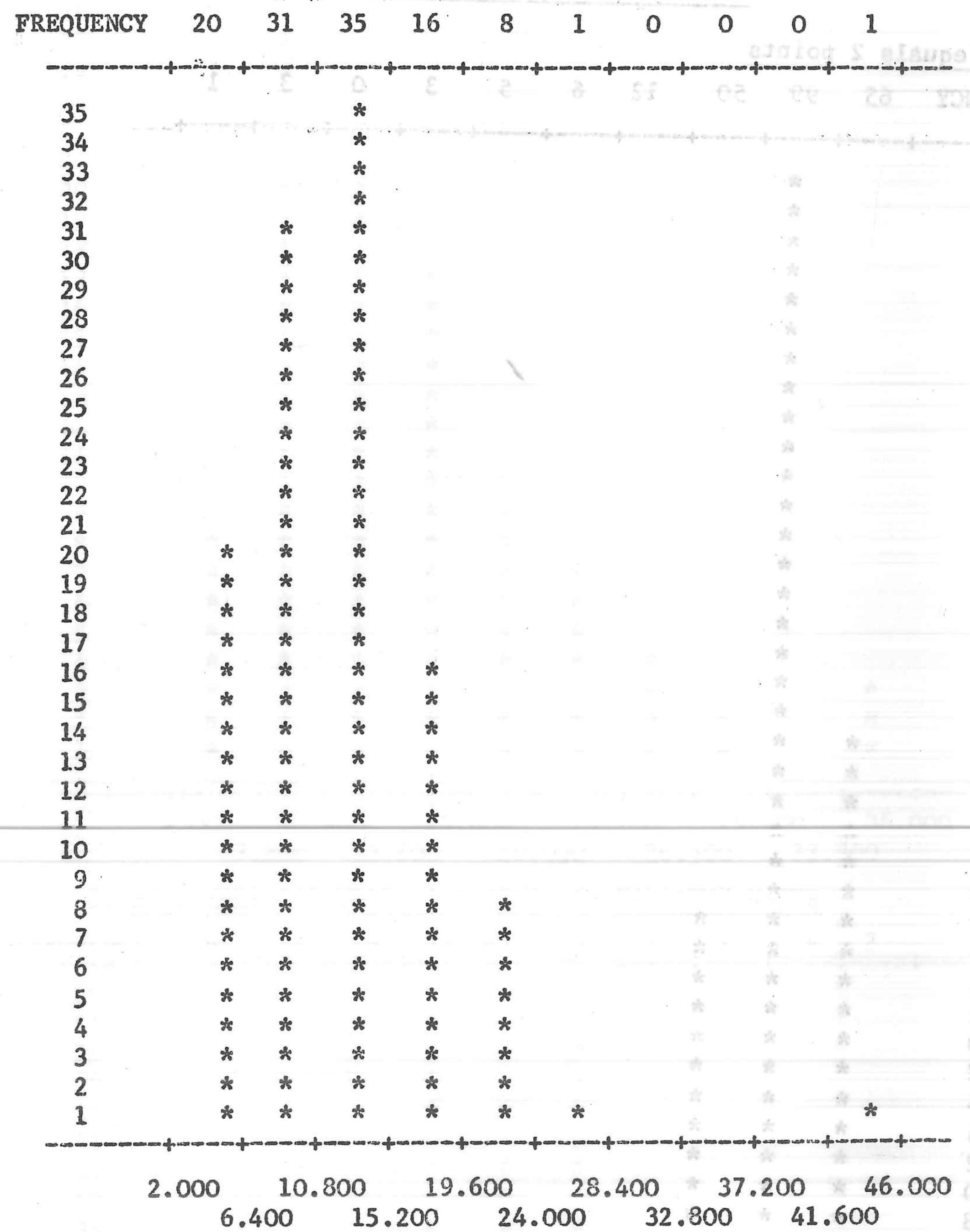
Each * equals 2 points

FREQUENCY 65 99 50 12 6 5 3 0 3 1



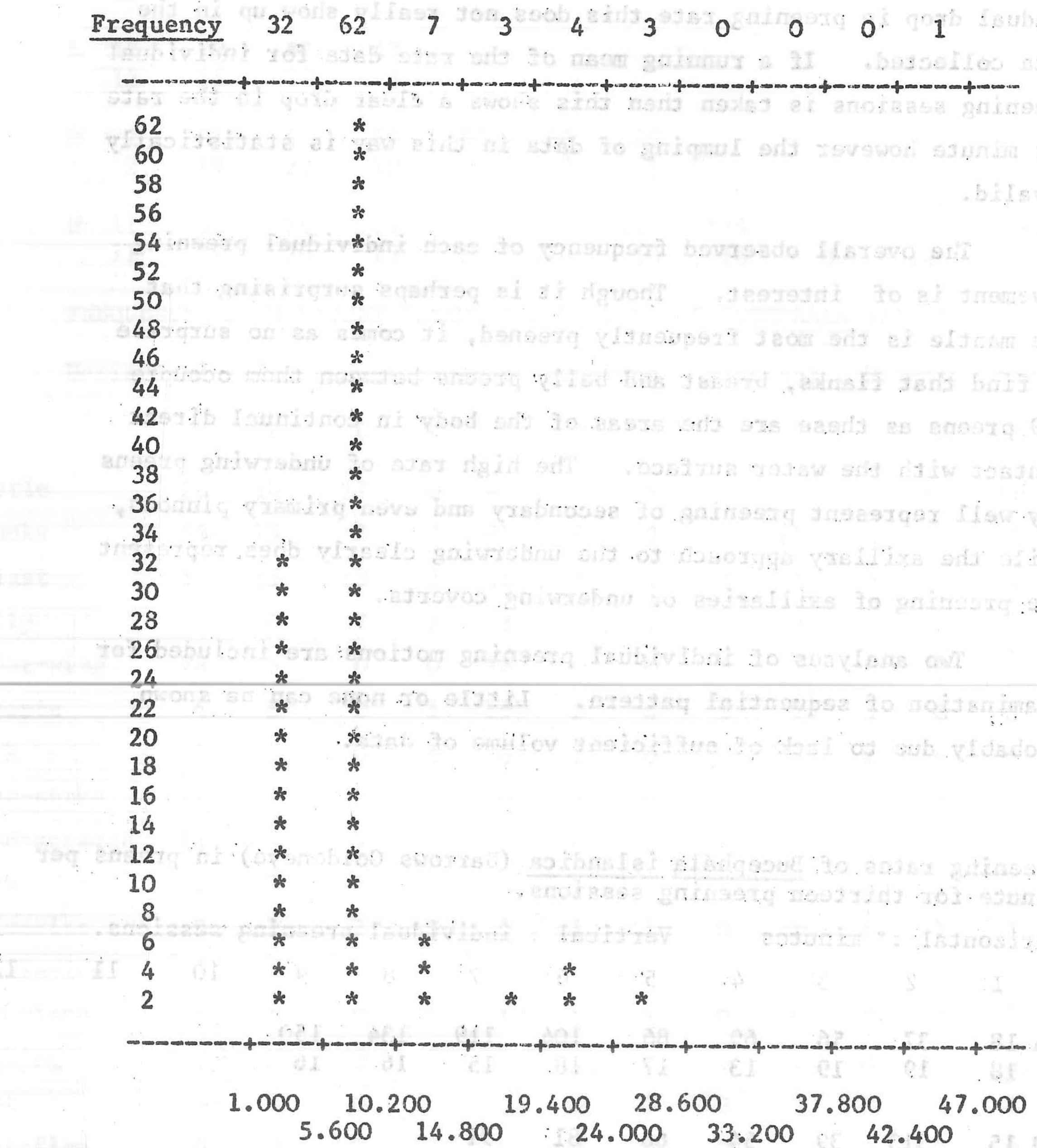
Each * equals 2 points

11. BUCEPHALA ISLANDICA : 112 DIVES IN "ROUGH" WATER



12. BUCEPHALA ISLANDICA : 112 CORRESPONDING RECOVERY TIMES IN "BROKEN" WATER

Each * equals 2 points



PREENING OF BUCEPHALA ISLANDICA

From the preening data observed for Bucephala Islandica few clear statements may be made. The rate is variable, anything up to 26 preens per minute were recorded. Though one may expect a gradual drop in preening rate this does not really show up in the data collected. If a running mean of the rate data for individual preening sessions is taken then this shows a clear drop in the rate per minute however the lumping of data in this way is statistically invalid.

The overall observed frequency of each individual preening movement is of interest. Though it is perhaps surprising that the mantle is the most frequently preened, it comes as no surprise to find that flanks, breast and belly preens between them occupie 419 preens as these are the areas of the body in continual direct contact with the water surface. The high rate of underwing preens may well represent preening of secondary and even primary pinnons, while the axillary approach to the underwing clearly does represent the preening of axillaries or underwing coverts.

Two analyses of individual preening motions are included for examination of sequential pattern. Little or none can be shown probably due to lack of sufficient volume of data.

Preening rates of <u>Bucephala islandica</u> (Barrows Goldeneye) in preens per minute for thirteen preening sessions.

Horizontal : minutes Vertical : individual preening sessions.

	I	2	3	4	5	6	7	8	9	10	11	12
A	18	37	56	69	86	104	119	134	150			
	18	19	19	13	17	18	15	16	16			
B	15	313	39	54	66	81	91					
	15	16	8	16	12	15	10					
C	13	14	16	16	23	23	40	54	59	61	68	70
	13	1	2	0	7	0	17	14	5	2	7	2
D	11	13										
	11	2										
E	18	29	39	49	58	68	76	91	101	114	124	138
	18	11	10	10	9	7	11	15	10	13	10	14
F	11	17	28	2								
	11	6	11	2								
G	9	22	31									
	9	13	9									
H	7	19	23									
	7	12	4									

Preening rates of <u>Bucephala islandica</u> (Barrows Goldeneye) in preens per minute for thirteen preening sessions.

	1	2	3	4	5	6	7	8	9	10	11	12
J	22	33	47	60	69	71						
	22	11	14	13	9	3						
K	12	14										
	12	2										
L	12	27	42	47								
	12	15	15	5								
M	2	21	40	50	60	68	69					
	2	19	21	10	10	8	1					
N	11	30	56	69	89	106	119	135	143	155	168	172
	11	19	26	19	20	17	13	16	8	12	12	4

FREQUENCY OF DIFFERENT PREENING MOVEMENTS OF <u>BUCEPHALA ISLANDICA.</u>

Horizontal : Individual preening sessions Vertical : Preening movements.

	A	B	C	D	E	F	G	H	J	K	L	M	N	Total
Mantle	26	18	27	0	44	8	5	7	13	7	11	29	21	216
Flanks	16	15	8	2	81	6	3	2	14	0	1	2	21	171
Breast	17	15	13	3	41	1	1	0	1	0	1	4	37	134
Belly	4	6	7	3	62	0	8	2	13	0	2	2	5	114
Under-wing	28	6	0	0	28	0	0	1	7	1	6	2	19	98
Coverts	4	8	0	1	19	2	4	3	5	0	0	5	8	59
Neck	2	9	0	0	8	6	0	0	8	2	4	6	7	57
Head-shake	12	1	1	2	6	1	0	4	0	1	9	1	5	43
Head-scratch	11	3	5	0	0	0	0	3	0	1	6	7	7	43
Flap	12	3	1	0	8	1	1	1	0	1	1	2	8	39
Primaries	0	1	3	0	9	1	1	0	2	1	1	1	9	29
Axillaries	6	0	1	0	12	0	3	0	2	0	1	0	1	26
Oil-gland	1	1	0	1	1	1	1	0	4	0	1	4	2	17
Bathing	4	0	0	0	2	0	0	0	0	0	0	0	7	13
Vent	0	0	0		3	0	3	0	0	0	0	1	3	10
Foot-flap	0	0	2	0	4	0	0	0	0	0	0	0	1	7
Neck-scratch	0	0	0	0	2	1	0	0	0	0	0	1	1	5
Foot-peck	4	0	0	0	0	0	0	0	0	0	0	0	0	4
Tail	1	0	2	0	0	0	0	0	0	0	0	0	0	3
Single-wing stretch	0	0	1	0	0	1	0	0	0	0	0	0	0	2
Stretch	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Drink	0	0	0	1	0	0	0	0	0	0	0	0	1	
* Shake	3	3	3	0	13	1	1	0	2	0	3	3	10	42

It is interesting to note that 10 out of the 13 sessions recorded the birds used their oil-glands. The feather settling motions i.e. head-shake, head-scratch, shake and flap occupy about the same frequency range i.e. 39-43. The relation of preen frequency to feather area could be now investigated.

SEQUENTIAL ARRANGEMENT OF INDIVIDUAL PREENING MOVEMENTS

Mantle Preens

Horizontal : minutes   Vertical : Individual preening sessions.

	1	2	3	4	5	6	7	8	9	10	11	12	Total
A	4	7	4	1	1	0	5	0	5	0			27
B	2	2	2	3	0	9							18
C	5	0	0	0	6	0	2	11	3	0	2	0	29
D	0												0
E	5	0	2	0	0	0	0	0	0	0	0	0	7
F	0	0	6	2									8
G	4	1	0										5
H	3	4											7
J	6	0	3	1	3								13
K	7												7
L	3	4	4										11
M	0	4	13	3	3	2	2						27
N	3	3	4	0	4	1	4	2	0	0	0	0	21
													180

All preening sessions lasted less than twelve minutes except E which lasted 40 minutes, however, it is convenient to analyse preening sessions up to 12 minutes duration, few lasting longer than this time. Thus only 180 preens are analysed sequentially while 216 were recorded.

Flank preens

Horizontal : minutes   Vertical : Individual

	1	2	3	4	5	6	7	8	9	10	11	12	Total
A	1	0	0	0	7	7	4	1	1	0			16
B	0	2	0	10	0	3							15
C	0	0	0	0	0	6	0	0	0	1	1	0	8
D	2	0											2
E	1	1	0	5	4	5	1	11	3	7	3	2	43 (+38 after 12 mins)
F	6	0	0	0	0	0							6
G	0	3	0										3
H	2	0											2
J	8	1	2	3									14
K	0												0
L	0	0	1										1
M	0	2											2
N	0	0	5	0	1	5	1	1	0	0	8		21
													171

ACKNOWLEDGEMENTS

Every year the business of launching expeditions gets more complicated, and consequently more people and officials are consulted during the organisation, upon whom we depend to an ever greater degree.

We would like to express our thanks to the Exploration Council for their assistance and advice, to all the other organisations and Trusts who gave us financial support, to Mr. Fripp of the Department of Surveying, Mr. Hope, Mr. Lockwood, and all who helped in the pre- and post-expedition organisation, and also in production of this report.

We are indebted to the following companies and organisations for their very generous support in supplying food or equipment either free of charge or at reduced cost:-

A.B.C.Polythene Ltd.,	Polythene sheeting and bags
Batchelors Foods Ltd.,	Dried foods
Bayer Products Ltd.,	Medical supplies
Bell, Thos. & Sons Ltd.,	Flour
Blacks of Greenock	Camping equipment
Bovril Group Marketing Ltd,.	Milk Puddings
British Egg Marketing Board	Dried Egg
British Paints Ltd,.	Paints
British Steel Wool Ltd,.	Steel wool, Scourers, Plusheen
British Sugar Corporation Ltd,.	Sugar
Brett's Oil & Grease Ltd,.	Engine Oil
Brooke Bond Oxo Ltd,.	Coffee and Corned Beef
Bryant & May Ltd,.	Safety Matches
Chambers Packaging Ltd,.	Fibreboard Boxes
Copydex Ltd,.	Copydex and Tuftape
Cottage Rusks Ltd,.	(See MacGregor, Hugh & Son Ltd.)
Danish Bacon Export Board	Danelard
Distillers Co. Ltd,.	Canned Foods
Dornay Foods Ltd,.	Potato Mix
Fewsters Ltd, Seaton Burn	LandRover Parts
Garvin Ltd.,	Wholesale Foodstuffs
General Foods Ltd.,	Coffee
Glaxo Laboratories Ltd.,	Ostermilk and Complan
Guinness, Arthur & Sons, Ltd.,	Canned Guinness
Harris, C.T. Ltd.,	Tinned Meats
Heinz, H.J. Ltd.,	Baked Beans, Sponge Puddings
Hunter, F.J.& Co. Ltd.	Swiss-style Breakfast Cereal
Jeyes Overseas Ltd.,	Toilet Rolls, Disinfectant, Fly Repellents
Kavli Ltd.,	Primula Cheese, Ryebread
Kernal Bill Products Ltd.,	A Donation
Kodak Ltd.,	Film
Knorr Anglo-Swiss Ltd.,	Soups, Beans
Landauer Co. Ltd.,	Packing Cases
Lucas, Joseph & Son Ltd.,	LandRover Battery
MacGregor, Hugh, Ltd.,	Ruskoline Crumb Dressing
Mapleton Nut Foods Ltd.,	Fruitarian Bars, Fruit Juice
Mars Ltd.,	Mars Bars, Spangles
Mawson & Procter Pharmaceuticals	Medical Supplies
Metal Box Co. Ltd.,	Tins, Tubes
Miles Eustace Ltd.,	Protein Drink
Moreland, S.J.&Sons Ltd.,	Safety Matches
Nelson Preserving Co. Ltd.,	Preserves
Nestle Co. Ltd.,	Dried and Tinned Vegetables
Pearce Duff Co. Ltd.,	Dried Onion, Lemonade Powder
Plumrose Ltd.,	Canned Meats
Pritchitt, L.E.& Co. Ltd.,	Millac

Procter & Gamble Ltd.,	Ariel, Daz, Fairy Liquid
Quaker Oats Ltd.,	Porridge Oats
Ratcliffe Bros. Ltd.,	Honey, Lemon Cheese
Reckitt & Colman Ltd.,	Shoe Polishes
Rington Ltd.,	Tea Bags
Robertson, James & Sons Ltd.,	Preserves & Fruit Juice
Romney, George Ltd.,	Kendal Mint Cake
Rotunda Tapes Ltd.,	Tapes
Ryvita Ltd.,	Crispbread
Schweppes Ltd.,	Pepsi-Cola
Scottish & Newcastle Breweries Ltd	Brown Ale
Shaws Ltd.,	Biscuits
Shippams Ltd.,	Spreads, Tinned Meats
Smiths (Crisps) Group.	Big 'D' Nuts
Snakpak Foods Ltd.,	Nuts
Spillers Ltd.,	Canned Meat
Springlow Ltd.,	Dried Vegetables
Standard Brands Ltd.,	Drinking Chocolate
Sutherlands Ltd.,	Spreads
Tate & Lyle Ltd.,	Sugar, Golden Syrup
Terry, Joseph & Sons.,	Confectionary
Thames Cases	Packing Cases
Thomas Bell & Sons Ltd.,	Flour
Thornes Student Bookshop Ltd.,	£10 of Stationary
Tickler, G.J. Ltd.,	Marmalade
Unigate Ltd.,	Tinned Cheese
Van den Berghs Ltd.,	Tinned Margerine
Wander, A. Ltd.,	Ovaltine, Nu-choc, Milk
Weetabix Ltd.,	Weetabix
Welch's & Son Ltd.,	Confectionary
Whitworth Holdings Ltd.,	Dried Raisins & Sultanas
Wills, W.D. & H.O. Ltd.,	Cigarettes & Tobacco
Joseph Steel & Sons,	)LandRover Springs
Jonas Woodhead Ltd.,	)& Shock Absorbers
Woodhead Manufacturing Co.,	)
Wrights Biscuits	Biscuits
Wrigley Co. Ltd.,	Chewing Gum
University Photographic Dept.,	Film

A list of those who helped us financially may be seen in the financial report.

We also would like to express our gratitude to the many people in Iceland who helped us and gave us advice, especially the Iceland Research Council, and the University of Iceland.