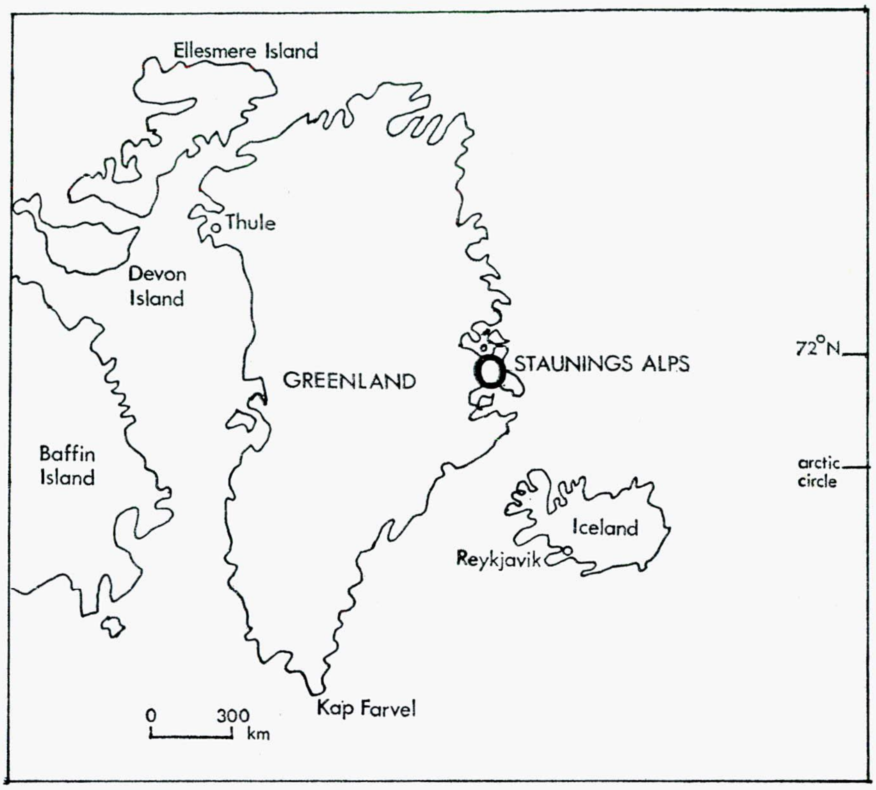
CAMBRIDGE SCHUCHERT EXPEDITION 1972 REPORT

with compliments.

REPORT OF THE CAMBRIDGE SCHUCHERT EXPEDITION, 1972

Staunings Alps, N.E. Greenland

July 7th — September 9th



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This report is an excellent opportunity to say 'Thank you' to all the people in Britain, Iceland and Greenland, who have helped the expedition in so many ways. It tells the story of the expedition, as well as publishing our scientific findings, and so we hope that it will be of assistance to those planning future expeditions. We would like to apologise for the delay in producing this report.

We would especially like to thank all those bodies whose financial aid made the expedition possible, and the firms who so kindly donated food and equipment for our use. Our directors of studies, the Hon. Mrs. Lucy Adrian and Dr. Jean Grove, deserve special mention for their unfailing support during the planning stages of the expedition.

We are indebted to the staff of R.A.F. Lyneham and the crew of the Hercules for our airdrop, the Atlantic Richfield Company for helicopter assistance, Nordisk Mineselskab, the station manager, and his staff at Mesters Vig for many kindnesses.

Our thanks are also due to our parents for putting up with so much, and to Dr. Keith Miller for giving us this chance of proving that we are just as good as men!

S.C.W. (Editor), Michaelmas 1973

"A Long Line of Everybody" at Mesters Vig on September 2nd. Kate, Christa, Sheila, Alayne (and Smokey Bear), Sue, Clare.

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MAIN REPORT

In the summer of 1972, an expedition of six Cambridge women geographers carried out a series of studies in the Staunings Alps region of North-East Greenland. Most of the proposed scientific work was successfully completed, despite the late snow melt and unusually high meltwater conditions, which made some modification to the projects necessary. Some days of fieldwork were lost due to bad weather in the six weeks which we spent based in Schuchert Dal, but the achievements of this women's expedition have shown just how successful such a venture can be.

We were most fortunate in having the general support of the Cambridge Staunings Expedition, whose leader, Dr. Keith Miller, had first given us the opportunity of taking part in such an Arctic expedition, and who gave us valuable assistance in the planning of our expedition.

From its first conception in the autumn of 1971, the organisation of the expedition proceeded in fits and starts. It was officially approved by the University Expeditions Committee early in 1972. Most of the planning took place over numerous cups of coffee in Cambridge; punctuated by airmail letters to Alayne, who was studying in America, and telephone calls to Clare, who was spending part of her year before coming up to Cambridge on Holy Island. Christa, Kate, Sue and Sheila spent a very wet week in the Lake District in the Easter vacation, where new boots were walked in, sleeping bags tested and the discovery made that Sue talked in her sleep!

Our friends never ceased to be amazed at the boxes of food and equipment which accumulated in our rooms over the year. Sheila, as food officer, had many amusing experiences, when gifts of food intended for use in Greenland, appeared in the college kitchen by mistake! However, everything was carefully packed and documented in the week following the end of term, and taken down to Lyneham in preparation for the airdrop which the R.A.F. were so kindly organising for us.

Five of us embarked at Leith, on m.v. 'Gullfoss' on July 7th, and sailed for Iceland. We arrived in Reykjavik early on July 10th, and most of the day was spent waiting for the scientific equipment of the two Cambridge expeditions to be unloaded, obtaining customs clearance, and transporting it to the airport just outside Reykjavik. Alayne joined us on July 11th, having flown from Boulder. On July 12th, we flew to Mesters Vig airstrip in Greenland, in a chartered DC-6, together with the Cambridge Staunings Expedition and the Dundee North-East Greenland Expedition. The flight had been delayed by bad visibility at Mesters Vig, but we eventually left Iceland on a damp grey evening, arriving in Mesters Vig in brilliant sunshine.

At about noon the following day, the Cambridge Expeditions started the 100km. walk-in to our proposed base-camp at the snout of the Roslin Glacier. We were given an excellent start by the staff of the Danish station at Mesters Vig, who gave us all a lift in the station truck to the far side of the braided river immediately to the west of the air strip. Our route then lay across rolling tundra to the low summit of Hesters Pass, and then along the shores of Mesters Vig fjord to the Expeditionshus, where we spent the night. On July 14th, our plans to cross the Mellem Col were thwarted by bad visibility, and so we bivouaced in the moraines of the Mellem Glacier. The rivers this year were exceptionally full, and one river in particular, near Sortjehorn, was very difficult to cross. We eventually managed a safe crossing with the aid of a rope slung across the icy torrent, and an ingenious pulley system using karabiners, by which we sent our packs, cameras and dry clothes to the far side of the river before attempting this crossing ourselves.

Exceptionally bad snow conditions on the Mellem and Arcturus glaciers made the ascent of the Mellem Col, on July 15th, very hard work, and so we were delighted to see the huts of the Malmberg mine, which we reached late that evening. From the crest of the col, we could see the icebergs in Scoresby Sund, some 100kms. away, and could also see the snout of the Roslin, but it was another two days of 'moraine-bopping' and a bivouac in the Lang moraines before we arrived at 'Tundra Camp' late on July 17th. The Cambridge Staunings Expedition moved on to their base camp, some 17 miles up the Roslin glacier, on the morning of July 18th. Later that afternoon, we heard the low drone of the R.A.F. Hercules reverberating among the mountains, as it flew southwards

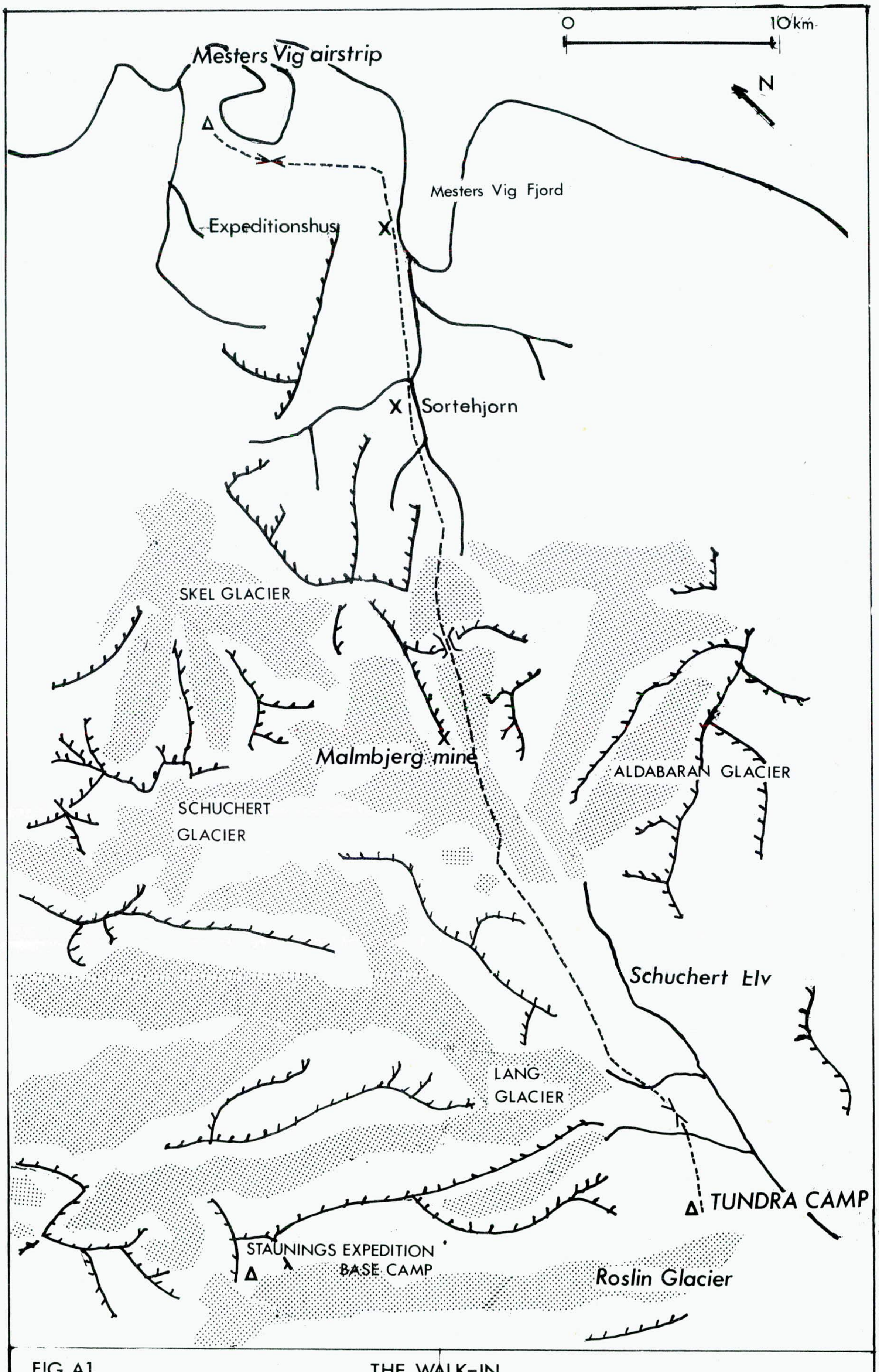


FIG. A1. THE WALK-IN

down the Schuchert valley. The plane turned in a wide arc over our parachute markers on the ground, and then flew up the Roslin to carry out the men's airdrop. After several runs up the glacier, the plane then passed low over us and made two drops, one weighing over a ton, containing all our food and equipment, and a smaller separate drop of fuel, both of which were remarkably well on target. When we recovered the drops, we found 'Smokey Bear' and a plaque to wish us luck from the R.A.F., both strapped on the outside of one of the 'chutes. Smokey Bear became the only male member of the expedition as our mascot!

The next few days were spent pitching our tents, and organising our stores and work, although serious fieldwork was not begun until July 23rd, after the arrival of the helicopter with our scientific and surveying equipment.

On July 26th, helicopter assistance was obtained from Atlantic Richfield to take Alayne and Sue across the treacherous Schuchert river to Pingodal. The fieldwork over this side of the valley was unfortunately limited by bad weather, including snow on July 28th, which contrasted greatly with the warm sunny weather which we had enjoyed in the first few days at Tundra Camp. Although the flight to Pingodal took only a few minutes, the return journey was a three day trek around the north end of Schuchert Dal, over the Aldebaran, Sirius, Schuchert and Lang glaciers, arriving back in camp at midnight on August 4th.

During the six weeks in which we were based in Schuchert Dal, all members of the expedition were able to spend a few days as guests of the Cambridge Staunings Expedition in their camp at the junction of the Dalmore and Roslin glaciers. Marvellous views over the whole of the Staunings Alps were obtained, and it was most interesting to see their projects and sample different menus! On August 7th, we were able to return some of this hospitality, when Keith Miller and Dave Drewry spent a night at Tundra Camp before starting the long walk back to Masters Vig, as they unfortunately had to return early.

On August 15th, a Nordisk Mineselskab helicopter arrived with a message concerning the date of the proposed helicopter assistance at the end of the season, which was to take all the scientific equipment and samples back to Mesters Vig. It was decided that Sue and Sheila should take this message to the men's expedition, so that arrangements could be made for the equipment to be brought down to Tundra Camp by the earliest date mentioned by Nordmine. Their departure was delayed until August 17th by bad weather, but the message safely delivered and the return journey made almost immediately.

By August 25th, all members of the two expeditions were assembled in our base camp, and one group started their walk-out to the coast the next day. The party had to be split in this way as there had been no further news of the helicopter, and we were beginning to become anxious about the time-factor and the weather. This first party experienced a very snowy and unpleasant bivouac in the Lang moraines that night. The helicopter made a flying visit in the middle of breakfast on August 28th, but was unable to take any of the equipment on that occasion. Because of the exceptionally bad weather, the company were finding it very difficult to finish all their own work before the end of the season, when the helicopters are dismantled and then freighted from Greenland. As the equipment had still not been collected by late on August 29th, the second walk-out party began. We managed to carry all our results in our rucksacks, but a great deal of equipment, and all our samples, were left in the protected dump on the tundra, awaiting the helicopter lift which we still hoped would be forthcoming. Unfortunately the weather conditions of the next few days made this impossible, and so arrangements were then made for the collection of all the equipment in the summer of 1973.

All members of the expedition arrived safely in Mesters Vig by September 2nd. Our air charter was delayed by bad weather in Iceland for two days, but this was more than compensated for by the superb views of the Northern Lights, which we were so lucky to see. On arriving in Reykjavik, 'civilisation' was rather over-powering. We departed on the m.v. 'Gullfoss' on September 6th, and enjoyed the sea journey back to Leith, celebrating the end of the expedition with a visit to the Edinburgh Tattoo.

In the summer of 1973, a small party, led by Keith Miller, returned to Greenland to retrieve the equipment which had been left behind. Other efforts to recover it at the very end of the 1972 season, or during the long winter, with the aid of sledges, had not been practically or financially viable. Despite many difficulties in organising this expedition, especially the uncertainty about the availability of landing facilities at the airstrip, the equipment arrived back in Cambridge in mid-September. It was in excellent condition, and all the samples were also intact, after the rigours of the Arctic winter. We owe many thanks to Keith and his expedition members for this gallant rescue!

THOUGHTS ON A BOULDER . . . A PERSONAL REPORT

For some reason, someone wanted six women. To go to Greenland. Why not, I thought?

Having been born in the fens, the first sight of Greenland's icy mountains from the chartered 'plane were absolutely breathtaking. Dark jagged rocks emerging from untouched fields of snow and ice, rising above the levels of icy fjords. An area devoid of people and pollution and possessions. Soon we were down amongst the mountains, on our five-day walk-in to our base-camp. The austere beauty of the unclimbed mountain and the tundra tended to be forgotten in the concentration required in putting one foot in front of the other safely with a fifty pound sack upsetting the equilibrium. But on stopping for rests, the magnitude of the scenery all around was devastating. To lie in one's sleeping bag on the tundra and watch the colours over the mountains change as sleep comes; to awake with the warm sun thawing the hoar frost on the nylon; a good strong brew. The satisfaction, relief and exhilaration on reaching the summit of the Mellem Col in deep snow after considerable physical effort, and the challenge of proving to the engineers that we were better than they were. Exhausting. Long live women's lib!

Excitement as our pink parachutes debauched from the belly of the Hercules, heralding the arrival of our Mars bars, tents and loo rolls. Six weeks of field work. A routine of porridge, work, lunch from a nose-bag of nuts and cheese, more work, lemonade powder mixed in glacial water to quench our thirst after sampling in waterless moraines, supper. Cards, writing our epic diaries, map-drawing, playing the harmonica, reading Tolkein or Tolstoy.

The foxes stealing our mugs and our sugar. Confronting a shaggy muck ox in his wallow hole where you are having a long over-due wash. Sitting on a boulder overlooking the braided channels of the Schuchert Flod and thinking. . . Arctic hares at play, standing on their hind legs and not knowing enough about humans to be frightened by our presence, their white coats very visible against the dark green of the tundra and dark grey of the boulder fields—camouflage for nine months of winter.

Perfectly formed snowflakes, melting, and the unending white of limitless snow. Glacial streams plunging into cavernous cork-screw moulins.

Attempts at sorrel pancakes, with local-grown sorrel and dried egg, to relieve the monotony of cuboid curried farmhouse stew. A flaring primus and the wind catching the flysheet, blowing from the ice-cap to the coast. The clank of crampons and ice-axes, and the red vitamin pills in their container. Lapping of icy water against the ice floes.

Continual daylight; then the half-lights of August nights with magnificent sunsets staining the snow crimson and catching the autumnal tints of the tundra flora. A harvest moon and the aurora borealis in wintry September, an ever-changing shimmering curtain of green and silver against a blue dim sky. A king-sized dose of Arctic fever.

Agony of return to the noise and the dirt of the people. Fading memories of an almost perfect summer. The lure of a land that is seldom green.

GENERAL INFORMATION FOR PLANNING GREENLAND EXPEDITIONS

Greenland is a colony administered for the Danish Government by the Ministry for Greenland. It is necessary to formally apply for permission to take an expedition to Greenland, and the applications are studied by the Commission for Scientific Investigations in Greenland. This application may be made to the Foreign and Commonwealth Office (Western European Department), or the Danish Embassy, and is forwarded to Copenhagen from London. There are stringent regulations about climbing expeditions, and they insist on adequate insurance. Special approval is required for the collection of specimens of any kind, and for mapping, and any work intended for publishing may have to be submitted to the Ministry first. A plant permit is required for the export and import of botanical specimens.

It is most advisable to apply for this permission in plenty of time; our permission, although applied for in December, was not received until the day after we sailed from Leith! Permission to land at Mesters Vig is usually obtained by the charter firm used, Icelandair in most cases. The cheapest charter flight is from Reykjavik to Mesters Vig, and our costs were much reduced by sharing the aircraft, a DC6, with two other expeditions.

We were most fortunate in having the R.A.F. airdrop; the expedition in this particular area would have been almost impossible without it. The weather is normally very stable during July and August, with very fine visibility, although we were unlucky, with early snowfalls and heavy cloud from mid-August.

Maps and aerial photographs may be obtained from the Geodetic Institute, Copenhagen. We found the aerial photographs to be particularly useful, but, when travelling, we rarely used either, using well-known landmarks in the very clear air, for navigation purposes, and the experience of members of the Staunings Expedition members who had visited the area before.

Bibliography

Much useful basic information may be obtained from 'the little green book' — the book by Donald Bennet entitled 'Staunings Alps' in the Expedition Library Series. This is rather expensive, particularly as the maps are rather dubious in parts, but contains much of value. It has doubtless been a contributory factor to the recent flood of applications to visit the Staunings.

Many good articles about the Staunings have appeared in the monthly climbing and mountain magazines, and articles of more specific scientific interest appear in 'Meddelelser om Grönland' (Copenhagen). Past expedition reports are always very valuable. We in Cambridge are fortunate in that a large number of British expeditions to the area have been from Cambridge, and there is a great deal of specialist knowledge to draw upon. Past expeditions to the Staunings have included such eminent personalities as Graham Tiso, Alan Blackshaw, Lord Hunt and Keith Miller!

An excellent book of general interest is 'The Sledge Patrol' by David Howarth, a vivid story of sledge chases and survival in this part of Greenland during the Second World War. We were thrilled to meet some of the Sledge Patrol members on our last night in Mesters Vig.

SPECIAL REPORTS

These are more detailed reports concerning various aspects of the expedition organisation.

FINANCIAL REPORT — (K.S.T.)

The following is an account of the financial affairs of the expedition up to October 1st, 1973. The financial account cannot be submitted at this stage because of continued insurance premiums throughout the year on the equipment left at Tundra camp for the winter of 1972-73, and also the cost of its retrieval.

INCOME	£ p
The Mount Everest Foundation	250.00
The Royal Geographical Society	200.00
Worts Travelling Scholars Fund	100.00
John Spedan Lewis Fund for the Advancement of Natural Science	100.00
The Drapers Company	85.00
The Gilchrist Educational Trust	50.00
The Ford Foundation	100.00
British Petroleum	25.00
Gino Watkins Memorial Fund	60.00
Douglas January Ltd., Cambridge	25.00
The Geological Society of America	125.00
Arthur Reckitt Trust	100.00
B.D.A. Group	10.00
Personal contributions and grants to individuals	1,062.00
	£2,346.00

EXPENDITURE	
Travel: England to Iceland, return	406.51
Iceland to Greenland, „	696.00
Equipment (general and scientific)	116.52
Food in field and in transit	106.69
Insurance (personal & equipment, for duration of expedition only)	80.75
Administration and miscellaneous expenses	69.51
	£1,475.98
Balance in Bank	870.02
	£2,346.00

Estimated cost of Report, Post, Expedition Expenses, etc. £200.00 PLUS continued insurance on equipment in Greenland, cost of airlifting it back to England, and a contribution towards the overheads of the rescue expedition.

The expedition sincerely thanks all the organisations and bodies shown above, who by their generous financial support made the expedition possible.

(ii) EQUIPMENT REPORT (C.H.S.)

We hope that the following lists of equipment taken on the expedition will assist other expeditions in their planning. No attempt has been made to specify how much of the equipment was airdropped and how much was carried in, as this must vary for each expedition. The comments on various items of equipment are by no means an exhaustive survey, but do point out the good and bad points of some essential items. We did not omit anything essential which could not be improvised by the alternative use of other equipment available. Clothing was, of course, an individual matter, but the personal list given is a rough guide to the most important items.

When only the name of a firm is given, this indicates that they provided the article free.

Discounts included:—		
	I. & M. Steiner	40%
	Blacks of Greenock Ltd.	20%
	Y.H.A.	10%

£ denotes that the article was purchased at full price.

(a) EQUIPMENT LISTS

1. TENTS.
   - 1 André-Jamais and flysheet .... (loan — Kate)
   - 1 YHA Endeavour and flysheet .... (loan — Christa)
   - 1 Black's Good Companion and flysheet .... Blacks — discount
   - 1 Millett's Clifton .... £

Maintenance—

Polythene (for groundsheets) .... Excelsior Plastics
Sailmaker's twine .... YHA — discount
Runwell thread .... „ „
2 sailmaker's needles .... British Needle Company
1 Awl-U-Need .... loan — Kate
Nylon line .... I.C.I.
Tent fabric .... Mr. Stock
Spare tent pegs — 3 dozen .... YHA — discount

2. COOKING.

3 x 1 pint Optimus paraffin stoves .... loan — Army
1 pressure cooker .... Prestige
Primus spares and prickers .... YHA — discount
1 set 3 billies .... I. & M. Steiner — discount
1 x 2 pint billy .... Loan
1 mess kit set .... I. & M. Steiner — discount
2 plastic funnels .... „ „ „
1 sharp knife .... £
1 large spoon .... £
1 ladle .... £
1 sieve .... £

3. FUEL.

Paraffin ($\frac{1}{3}$ pint per man-day) .... £
Polythene jerricans .... Blewis & Shaw, and Fibrenyle Ltd.
Polythene paraffin bottles .... „ „ „ „ „
Solid Meta fuel .... £

4. CARRYING.

3 Canvas buckets .... YHA — discount

5. CLEANING.

Brillo pads .... Brillo Co. Ltd.
Rags .... Members
Kitchen rolls .... £
Toilet rolls .... £
Nylon scourers .... Rustless Curtain Co.
Washing-up liquid .... Procter & Gamble
J-cloths .... £
Kiwi wetproof and polish .... Kiwi Ltd.
Boot brushes .... „ „
Toilet soap .... Procter & Gamble/Colgate-Palmolive
Toothpaste .... Unilever
Toothbrushes .... Halex

6. MEDICAL.

First aid box and medical supplies .... See Medical Report

7. CLIMBING.

1 x 150′ 11mm kernmantel rope .... British Ropes Ltd. — discount
1 x 120′ 11mm No. 3 Nylon Viking rope „ „ „ „
1 x 150′ 11mm No. 3 Nylon Viking rope „ „ „ „
6 karabiners .... Graham Tiso — discount
6 prussick loops .... „ „ „

8. SUNDRIES

Bootlaces .... Kiwi Ltd.
Sherry — 1 bottle .... J. Harvey & Sons Ltd.
Nivea .... Gala Cosmetics
Camera film .... Kodak Ltd. — discount
Mosquito netting .... YHA — discount
Folding spade .... I. & M. Steiner — discount
Matches .... Morelands/Bryant & May
Spring balance (50 kg x 200gm/110lbs. x $\frac{1}{2}$lb.) .... Geo. Salter Ltd.
Uhu glue .... Liberta-Imex Ltd.

Silva compasses .... B. J. Ward Ltd. — discount
Vacuum flasks .... Thermos Ltd.
Gas lighters .... Ronson Products Ltd.
Tin openers .... Black's Ltd. — discount
Araldite .... Cambridge Block Order Scheme
Alarm clock .... (loan — Christa)
Novels .... Cambridge Market — £
Polythene bags .... I.C.I./Excelsior Plastics
Plastic containers ... Blewis & Shaw, Fibrenyle Ltd. and Tupperware
Tea towels — 2 .... £
Scissors .... £
Sewing/darning kit .... British Needle Company
Screwdriver .... £
Pliers .... £
Wire-cutters .... £
Sandpaper .... £
Clothes pegs .... £
Washing-up bowl .... £
Plastic bucket .... £
Soap powder .... Procter & Gamble
Sanitary towels .... Lilia White Sales
Rubber bands .... Isola Manufacturing Co. Ltd
Metal boxes for packaging .... Metal Box Co.
Assorted safety pins .... Whitecroft Ltd.
2 packs of cards .... (loan — Kate and Christa)
Cardboard packaging boxes .... Tillotsons Ltd.
(6 tea chest size, 1 ½-tea chest size, 12 22″ x 18″ x 17″)
Adhesive tape, etc. .... Tennex Ltd.

9. PERSONAL.

Pack-frame
Rucksack
Crampons .... Graham Tiso — discount
Ice-axe .... £ and loans
Walking/climbing boots — 1 pair
1 cagoule
1 pair overtrousers
1 duvet (optional)
3 sweaters (2 thick, 1 thin)
1 pair climbing breeches
1 pair plimsoles
1 pair jeans/lightweight trousers
3 pairs thick socks, 2 pairs thin
Underwear and long johns
Paper pants .... £ — local chemist — discount for quantity
Vests or equivalent .... Damart Thermawear
Shirts
Balaclava .... Black's — discount
Wide-brimmed hat
1 pair inner/1 pair outer gloves .... Miller-Lauder Ltd.
Stoptouts/gaiters
Camera
Log-book .... McNiven & Cameron Ltd.
Sleeping-bag (high level/Arctic)
Bivy-bag 8′ x 4′ .... Excelsior Plastics Ltd.
Foam mattress .... British Vita Co. Ltd.
Polaroids/snowgoggles
Whistle .... I. & M. Steiner Ltd. — discount
Pocket knife
Shampoo
Flannel
Towel .... Ashton Bros. Ltd.
Knife, spoon, mug, bowl .... I. & M. Steiner Ltd. — discount
Pens, biros, markers, pencils ...... Venus Easterbook/Liberta Imex/
Bic Biro Ltd.
Cigarettes and tobacco (optional)

10. SCIENTIFIC.

1 theodolite and tripod	Royal Geographical Society — loan
1 altimeter	,, ,, ,, ,,
2 ranging poles	,, ,, ,, ,,
1 200′ steel band	,, ,, ,, ,,
1 prismatic compass	Cambridge Geography Dept. — loan
1 plane table and tripod	,, ,, ,, ,,
1 abney level	,, ,, ,, ,,
1 alidade	,, ,, ,, ,,
1 Indian Clinometer	,, ,, ,, ,,
1 thermometer (max. and min.)	£
Nylon string	I.C.I. Fibres Ltd.
Bulldog clips	Whitecroft Ltd.
Paint and brush	Day-Glo Ltd.
Geological hammers	Sue and Alayne — loan
Log tables	£
Cartridge paper for surveying	Cambridge Geography Dept.
2 pocket stereoscopes	Cambridge Geography Dept. — loan
File and graph paper	£
Notebooks	McNiven & Cameron Ltd.
Adhesive tape	Tennex Ltd.
Scllotapc	,, ,,
Masking tape	,, ,,
Aerial photographs	£
Alcan foil	Alcan Polyfoil Ltd.
Plant press	Royal Horticultural Society — loan
1,200 corks	Benito Remus
1 ruler	£
1 pencil sharpener	£
1 rubber	£
Plastic bag ties	John Dale Ltd., H. A. Coombes Ltd.
Clipboard	Sue
Thigh waders	Avon Footwear Division, Uniroyal Ltd.
2 stopwatches	Heuer Time Ltd., Smiths Industries Ltd.

(b) EQUIPMENT COMMENTS.

1. Tents.

Clifton. Remarkably good value for money. Used as a general equipment/storage tent.

Essential to have the small tents fitted with mosquito netting, which we did ourselves, to cover the door openings.

20 man Army mess tent. It was useful to have such a large tent for general living space, food storage, cooking, and accommodating extra bods at the end of the expedition.

The ground was nice and bouncy, on the tundra, and so extra polythene groundsheets were unnecessary, and were used to help cover the food dumps instead.

The tents stood up very well to the strong winds, and hardly any repairs were needed.

2. Cooking.

The pressure cooker was damaged in the air-drop, so was not used as intended, but became a very useful large billy. The ladle and large spoon were indispensable, as was the strainer.

3. Fuel.

Solid meta fuel is not essential, but using it makes less need to clean the primuses, a difficult and fiddly job. It also helps to conserve fuel.

4. Carrying.

The canvas gallon buckets were not really large enough, and tended to tip over easily. They also began to leak.

5. Cleaning.

Kitchen rolls were very useful for many purposes.

6. Climbing.

Ropes. As many rivers were uncrossable this year, even with a rope, the 120′ rope taken for this purpose was superflous. Only one 150′ was really used, for the crossing of the Mellem Col, and as the crossing was made with the Staunings crowd, the other 150′ was not used. When in the field, a rope was used for local boulder problems, when mountaineering, and a 120′ rope carried as a safety measure on the Roslin glacier.

7. Sundries.

Camera film. Always take more than you think you will need!

Folding spade. Standard kind. This broke at the bottom of the handle, which was not due to rough treatment.

Spring balance. Very useul to weigh equipment for the helicopter. Otherwise used to boost ego on weighing sacks on arrival at Mesters Vig.

Tin openers. It is useful for everyone to have their own 'baby' tin opener, as they are always being mislaid.

Metal boxes. These were buckled in the airdrop, and then were a hazard around camp because of the sharp corners.

Packaging boxes. Strong enough and survived the airdrop well. Good in camp for continued storage. Some were possibly too large for easy movement.

Polythene bags. Exceptionally useful.

(i) Large dustbin size were very useful for storing personal belongings, packing food inside boxes, doing up the dump, and keeping things dry when being pulled on plastic sledges.

(ii) Medium-sized. Mainly superfluous.

(iii) Small. Useful for packing food, lunches, samples, etc.

(iv) Bivy bags. Too large (could sleep two comfortably). Very necessary for the walk-out.

ICI Ltd.	16 x 10" x $17\frac{1}{2}$"	thin gauge bags
	150 x 17" x 28"	medium gauge bags
	500 x 16" x 23"	sheets thin gauge
	40 x 15" x 24"	bags thin gauge
	300 x 20" x 39"	bags, medium gauge
Excelsior Plastics	1600 x 12" x 12"	bags 250 gauge
	150 x 17" x 28"	bags 250 gauge
	500 x 8" x 9"	bags 250 gauge
	500 x 20" x 30"	bags 250 gauge
	12 x 12" x 15"	bags 1000 gauge (maps)
	12 x 8" x 15"	bags 1000 gauge (aerial photos)
	6 x 30" x 30"	sheet 500 gauge (plane table)
	2 x 54" x 25'	sheet 1000 gauge (tent groundsheets and dump covers)
	2 x 7' x 7'	sheet 1000 gauge (tent groundsheets and dump covers)

Plastic containers. All useful, though many small ones were not used.

Blewis & Shaw — 4 plastic jerrycans — $\frac{1}{2}$ gallon

Tupperware — £3 assortment

Fibrenyle Ltd.	6 plastic jerricans	1 gallon
	4 plastic jerricans	$\frac{1}{2}$ gallon
	1 10 litre container	
	Screwtop containers	20 x 4 oz.
		12 x 10oz.
		12 x 14oz.
		6 x 2 oz.

8. Personal.

Rucksacks. Useful for some of the party to have smaller daysacks, as well as the large framed ones for load-carrying, which are useful for field-work.

Bergen. Extremely uncomfortable, carrying over 30lbs. Otherwise frames are a very individual choice.

Paper pants. Advocated as essential by some, especially on the walk-in/out. Others not so keen.

Foam matresses. Useful, as long as they can be airdropped. Two fit into a Good Companion, but only one in the smaller tents. Karrimats just as good, and very useful on the walk-in, although we did not have them.

9. Scientific.

Nylon string. Largely superfluous for scientific and general camp purposes, because of the ample local supply of parachute cord; this covered most contingencies, especially bootlaces.

Rulers. Should have had at least two.

(iii) FOOD REPORT (S.M.B.)

(a) The catering was done on the basis of providing 70 days food for the six expedition members, divided between Tundra Camp, Mesters Vig, the walk-in and the walk-out. This meant that there was some surplus at Tundra Camp and Mesters Vig to allow for the flexibility in timing of the walk-out. The total weight of food taken, including packaging, was between 1,050 and 1,100 lbs., but not all was needed, and some was carefully packed and left for the use of future expeditions.

Apart from the containers and wrapping mentioned in List 1, the food for the air-drop at Tundra Camp was packed in small (usually 12″ x 12″) polythene bags, and then in nine strong cardboard boxes (22″ x 18″ x 18″), lined with a double layer of large polythene bags. In general, it all survived the air-drop very well, the only mishaps being a few packets of crushed crispbread. No tins burst, though some of the biscuit tins used to protect fragile items were badly dented and their sharp corners had pierced the polythene bags.

A variety of rigid plastic containers with screw tops were extremely valuable for storing everything from coffee to jam and from sugar to milk powder in camp. They are definitely recommended. The 250 gauge polythene bags used to pack and store the food were found to be thick enough.

An unexpected problem was 'fox-proofing' all the food, after a family of Arctic foxes 'adopted' the camp! In the past, no trouble from them had been reported, but future expeditions to Schuchert Dal should bear this in mind when planning how to pack and store food.

In the following remarks, comments and criticisms arising mainly from personal preferences have been excluded as far as possible. In the course of the expedition, several suggestions were made for additional items. Even though an expedition does not need an elaborate menu, variety has its merits. It does allow different preferences to be catered for, and firms are more likely to be willing to supply small quantities of their products free or at discount.

Comments and Ideas:—

1. The quantity of dried milk taken was gauged from the experience of previous expeditions — only just over half was actually used.
2. The amount of sugar needed varies greatly from person to person, and the expedition members were consulted when deciding how much to take. In this case the majority used very little.
3. The pre-packed servings of muesli tended to be too small, and often two were eaten together.
4. Cocoa, drinking chocolate and lemonade crystals were all popular: the latter were especially appreciated.
5. Complan was taken, not to use as a milk substitute, but only to feed invalids incapable of eating ordinary food. On the few occasions it was used, it was found to be quite palatable if flavoured with coffee or cocoa.
6. Altogether, four types of crispbread were taken — some are far more easily broken than others.
7. Biscuits were regarded as something of a luxury, and more would certainly have been eaten if they had been there.
8. Some flavours of soup were found much more satisfying than others: mushroom, in particular, was rather tasteless and unpopular. All needed extra salt, although above-average amounts were not being added to other food. Extra quantities could be allowed for small parties working away from base and travelling as light as possible, to replace other items, for example, at breakfast. Soup would seem a good place to introduce variety into the diet, without additional complications, but difficulties may arise if each flavour must be bought in bulk.
9. The estimates of servings given in List 1 for soup and dried vegetables were those suggested on the packets — these were found to be inadequate. The same was true of the dried meats.
10. Dried apple was popular. The variety needing hot rather than boiling water is preferable.
11. More variety in the way of puddings was a unanimous suggestion. Ideas included dried apricots as well as prunes and apple, and tinned fruit (only feasible if weight is not a major consideration). However, a highly successful crumble was improvised!

12. Cheese was definitely a great success, especially for lunch-time snacks, though occasionally macaroni cheese was cooked for supper.
13. Marmite, cheese and fish and meat pastes were all popular. Other ideas for savoury items were pickle and peanut butter. Savoury spreads were appreciated just as much as sweet ones, even by those fond of sugar.
14. Jam, honey and syrup were ali worth taking. In future, marmalade could perhaps provide a change.
15. Custard was liked and considercd worth taking.
16. Fudge proved to be one of the star successes of the expedition.
17. Fruit sweets were definitely the most popular, as they seemed more satisfying when the going was tough.
18. Despite its weight, the Dynamo glucose drink (containing salts besides glucose) proved invaluable for giving an extra boost during strenuous exercise, especially on the walk-in and walk-out. The idea of taking ordinary glucose could be considered by future groups.
19. Herbs and spices are invaluable for making dried food more appetizing.
20. Dried egg could be a good addition to the menu.

We would like to thank all those firms who so generously donated food both to the Expedition, and to the Explorers and Travellers Club Block Order Scheme. A special mention must be made of Chris Rowley's competence in administering this scheme for the Club, for an expedition really does march on its stomach!

b) LIST 1. FOOD TAKEN ON EXPEDITION.

KEY

T = Tin

P = Paper wrap or bag

C = Cardboard packet

G = Glass jar

PB = Polythene bag

PLB = Polythene-lined bag

PC = Plastic container

CP = Cellophane packet

FW = Foil wrap

* = Comment included in report.

ITEM		Weight in oz. of one serving or per man-day, where appropriate	Total weight in lb.	Packaging material	Unit of packaging, where appropriate
1. Margarine		1.5	40	T, P	8 oz.
2. Dried milk	*	2.1	56	PB	7 lb.
3. Sugar	*	2.1	55	PB	5 lb.
4. Porridge oats		2.0	30	C	1 lb. 8 oz.
5. Muesli	*	2.0	24	C, CP	13 oz., 1 serving
6. Coffee		0.2	6	T, PLB	1½ lb.,1 oz.
7. Teabags		2-3 bags	1070 bags	C + CP	20, 250 bags
8. Drinking chocolate		-	4	T	1 lb.
9. Cocoa		-	8	PB	-
10. Lemonade crystals	*	0.5	14	PB	-
11. Complan	*	-	14	P + C	1 lb.
12. Crispbread	*	2.3	58	T, P	14 oz.,7 oz.
13. Biscuits (Digestives, shortcake, ginger nuts)	*	-	20	CP	1 lb.
14. Soup powder	*	0.6	20	P+C,PLB	1 lb.
15. Dried potato		2.0	48	T	6 lb.
16. Rice		2.3	37	PB	-
17. Macaroni		2.5	26	C, CP	8 oz.,1 lb.
18. Spaghetti		2.5	2	C	1 lb.
19. Dried peas	*	0.6	3.5	PLB	1 lb.
20. Dried beans	*	0.3	3.75	PLB	1 lb.
21. Dried carrots	*	0.4	3.8	PLB	1 lb.,13 oz.
22. Dried swede	*	0.3	4.5	PLB	1 lb. 8 oz.
23. Dried onion	*	0.4	5	PLB	1 lb.
24. Dried farmhouse stew		1.3	6	P + C	1 lb.
25. Dried savoury mince		1.5	7	P + C	1 lb. 2 oz.
26. Dried chicken supreme		1.3	6	P + C	1 lb.
27. Dried chicken and potato dumpling		-	6 servings	P + C	2 servings
28. Dried beef curry		1.6	2	PLB	1 lb.
29. Dried chicken curry		1.6	2	PLB	1 lb.
30. Dried Bolognese sauce		1.6	2	PLB	1 lb.
31. Corned beef		4	26.25	T	12 oz.
32. Chicken supreme		7	5.25	T	7 oz.
33. Chicken mince		7	7.5	T	10 oz.
34. Steak & kidney pudding		8	6	T	1 lb.

LIST 1. FOOD TAKEN ON EXPEDITION continued.

ITEM		Weight in oz. of one serving or per man-day, where appropriate	Total weight in lb.	Packaging material	Unit of packaging, where appropriate
35. Rice pudding		5	11.25	T	15 oz.
36. Semolina pudding		5	11.25	T	15 oz.
37. Tapioca pudding		5	11.25	T	15 oz.
38. Macaroni pudding		5	11.25	T	15 oz.
39. Dried apple	*	0.6	10	PLB	1 lb.,2 lb.
40. Prunes	*	4	12	CP	12 oz.
41. Raisins / sultanas		1.9	50	CP	12 oz.
42. Peanuts		2.4	63	PB	-
43. Cheese	*	2.2	48	Vacuum-packed in plastic	8 oz.
44. Cheese spreads	*	-	9	PC	3 oz.
45. Meat / fish paste	*	-	4.7	G	$1\frac{1}{4}$ oz.
46. Marmite	*	-	1.5	G	8 oz.
47. Honey	*	-	14	T	7 lb.
48. Jam	*	-	7	T	7 lb.
49. Syrup	*	-	12	T	2 lb.
50. Chocolate		-	7	PB	-
51. Fruit bars		-	6.5	P	$1\frac{3}{4}$ oz.
52. Mint cake		-	13.5	P	3 oz.
53. Mint crisp chocolate		-	9	FW	3 oz.
54. Butterscotch		-	2	FW	4 oz.
55. Cake (home made)		-	3	CP	12 oz.
56. Custard powder	*	-	1	T	-
57. Salt		-	12	PC	$1\frac{1}{2}$ lb.
58. Flour		-	6	PB	-

Miscellaneous items:-	
59. 100 packets of chewing gum	
60. 288 Mars Bars	
61. Fudge in cellophane packets	*
62. Assorted sweets - fruit drops, mints and barley sugar	*
63. Dynamo glucose drink in polythene jerricans	*
64. Pepper in screw top tin	
65. Mustard in tube	*
66. Tomato paste in tube	*
67. 36 Gravy cubes in foil wrap	*
68. Curry powder in screw top tin	*
69. Bouquet garni in screw top tin	*
70. Cayenne pepper in screw top tin	*
71. Vitamin tablets.	

LIST 2. FIRMS WHICH SUPPLIED PRODUCTS FREE OR AT DISCOUNT.

KEY * = Supplied free + = Supplied at discount

FIRM		PRODUCT
A. A. Supply Co. Ltd.	*	Muesli
Allied Services Ltd.	*	Dried fruit
Allinson Ltd.	*	Porridge oats, cakes
Barker & Dobson Ltd.	*	Sweets, chocolate
Batchelors Catering Supplies Ltd.	+	Soup powder, dried meat, vegetables and apple
Beecham Group Ltd.	*	Dynamo glucose drink, vitamin tablets
Bibby Food Products Ltd.	*	Margarine
Briess & Co. Ltd.	*	Potato powder
British Sugar Corporation Ltd.	*	Sugar
Brooke Bond, Oxo Ltd.	*	Coffee, teabags, Oxo cubes
Buitoni Foods Ltd.	*	Macaroni, spaghetti
Bush Boake Allen Ltd.	*	Herbs & spices
Callard & Bowser Ltd.	*	Butterscotch
Carr's Flour Mills Ltd.	*	Flour
Cerebos Foods Ltd.	*	Salt
Crome & Mitchell Ltd.	*	Peanuts
General Foods Ltd.	*	Coffee
Gill & Duffus Ltd.	*	Corned beef
Glaxo Group Ltd.	*	Complan
Heinz-Erin Ltd.	*	Dried Complete Meals
P. J. Hunter & Co. Ltd.	*	Muesli
Lesme Ltd.	*	Chocolate
Lipton Ltd.	*	Teabags
Mapleton's Foods Ltd.	+	Fruit Bars
Mars Ltd.	*	Mars Bars
Nabisco Foods	*	Crispbread
George Payne & Co. Ltd.	*	Drinking chocolate
Pearce Duff & Co. Ltd.	*	Dried onion, custard powder, curry powder
Quaker Oats Ltd.	*	Porridge oats, macaroni
RHM Foods Ltd.	*	Macaroni
Reckitt & Colman	*	Honey
Ryvita Co. Ltd.	+	Crispbread
J. A. Sharwood & Co. Ltd.	*	Curry powder
C. Shippam Ltd.	*	Fish & meat pastes, tinned meat
Smith Kendon Ltd.	*	Glucose sweets
Smiths Food Group	*	Mixed nuts & raisins
Swel Foods Ltd.	+	Soup powder, dried meat, vegetables and apple
Tate & Lyle Refineries Ltd.	*	Sugar, syrup
Thames Rice Milling Co. Ltd.	*	Rice
J. W. Thornton Ltd.	*	Fudge
Unigate Foods Ltd.	*	Cheese, cheese spread, milk powder, tinned milk pudding
Unilever Ltd.	*	Margarine
Whitworth's Holdings Ltd.	*	Raisins
J. E. Wilson & Sons Ltd.	+	Mint cake
Wrigley Co. Ltd.	*	Chewing gum

List 3 — FOOD LEFT AT TUNDRA CAMP DUMP.

Large Wooden Chest

12 x 1lb. pkts. rice
6 x 12oz. pkts. currants
1 x 12oz. pkt. raisins
3 x 1lb. pkts. raisins
4 x 1lb. pkts. sultanas
2 x 12oz. pkts. prunes
1 x 11¼oz. custard powder
½-tin custard powder
1 x 1lb. tin curry powder
1 x 1lb. tin drinking chocolate
1 x 1oz. tube mustard
Opened tube tomato paste
14 Oxo cubes
1oz. chilli powder
1oz. cayenne pepper
4oz. white pepper
5oz. curry powder
4lb. table salt
1 x 2lb. tin golden syrup
c120 vitamin tablets
4oz. flour

Compo: 1 x 14oz. tin sugar
1 x 5oz. tin tea
1 x 7½oz. tin margarine
2 x 2½oz. tins milk

Also contains **pink poly bag** with:

4 x 5lb. pkts. sugar
3 x 1½lb. pkts. oats
3 x 13oz. pkts. muesli
7 single-serving pkts. muesli, + oddments
3lb. margarine (pkts.)
2lb. margarine (tins)
4oz. dried egg powder
400 tea-bags

And **pink poly bag** with: 1 tube honey
12 x 7oz. pkts. Ryking
4 tins (each 2 x 7oz. pkts.) Ryvita

Box 8

Pink poly bag : 2 x6lb. tins potato
2 x 2½lb. complete potato mix
11 x 3½oz. sachets instant mashed potato
6 x 1lb. cut macaroni
8 x 8oz. quick macaroni
c15lbs. rice

Pink poly bags : 5 x 15oz. tins Irish stew
2 x 10oz. tins chicken-mince pie filling
4 x 12oz. tins corned beef
2 servings chicken casserole + potato dumplings
3 x 15½oz. pkts. farmhouse stew
7 assorted meat bars

In poly bag : 1 x 11½oz. pkt. carrots
3oz. carrots
1lb. carrots
1½lb. golden swede
13½oz. mixed veg.
3oz. cabbage
6oz. mixed veg.

In poly bag : 14oz. tomato soup
14oz. chicken soup
2 x 13oz. chicken soup
3 x 3oz. pkts. assorted soup
8oz. coffee

Box 2 (in pink poly bag)
22lb. miracle milk
10lb. complan (Jan. 1973)
4 x 7oz. tins marvel milk

Any future expeditions to Schuchert Dal are more than welcome to make use of these supplies, but would they please ask one of us first, and then submit a list of food used so that an up-to-date inventory of the contents of the dump may be kept at all times. The dump also contains some general items of equipment which may be of some use, and some rather dirty clothes!

MEDICAL REPORT (S.C.W.)

My job as medical officer started at the University Health Centre in Cambridge, where, under the expert guidance of Dr. Hawtrey May, the medical requirements of the expedition were discussed and the various items assembled and packed. The supplies were divided into two parts; a small light first-aid kit to be used on the walk-in to our base-camp, and the main kit, which contained the more bulky and sophisticated items, was included in the air-drop. All members had thorough medical and dental examinations before leaving Britain.

The main complaint on the walk-in was that of sore feet and blisters, which were easily treated and soon healed in camp. Many of the grimey, horny feet presented to me for treatment proved, on closer inspection, to belong to members of the other expedition! This would perhaps account for the vast consumption of plasters in the first five days. Feet also suffered from the prolonged damp and cold incurred after wading through numerous streams and boggy ground. Some stomach cramps were experienced whilst marching, which were attributable to low, narrow waist-straps on some makes of rucksack. Apart from general colds and sore throats, which were quite common, no serious accidents or illnesses occurred throughout the expedition.

The arrival of six new sources of flesh on the tundra was a great attraction to the mosquito population of Schuchert Dal, who feasted until the middle of August, some being spotted until our departure. A welcome respite from their attentions was gained on the glacier. The repellent taken was quite successful, but the army-issue type was found to be more effective and remained active for longer. Mosquito netting in the mountain tents allowed mozzie-free sleep, but the tropical bee-keepers' hats were worn only for photographs!

I would like to take this opportunity of thanking Dr. Hawtrey May and his staff at Fenners, and also all those firms who so generously sent gifts of medical equipment to the expedition and to the Health Centre.

MEDICAL KIT

(a) WALK-IN (in polythene bag)

- 1 Triangular bandage
- 2 Plain wound dressings (No. 15)
- Elastoplast: 2 x 2½″ packs (inadequate quantity)
  1 x 1½″ packs
- Zinc oxide strip 1 x ½″ x 5yds.
- Butterfly sutures
- 6yds. absorbent gauze
- Elastic sock dressing
- 1 White open wove bandage (3″)
- 1 3″ crepe bandage
- 1 tin 'Solfratulle' (paraffin gauze dressings)
- 1 tube 'cicatrin' powder (antiseptic dusting powder)
- 2 tubes insect repellent cream (inadequate amount)
- 50 Aspirin
- 2 x 100 water sterilising tablets (not required)
- 10 Travel sickness pills (for Gullfoss and 'plane)
- 2 tubes ultraviolet screen for lips (also used as ordinary lip-salve)
- 2 tubes ultraviolet cream (used according to individual preferences —not necessary all the time)
- 1 pair surgical scissors
- safety pins
- first-aid pamphlet

(b) MAIN MEDICAL KIT (in Boots Medical Box and key)

(i) CREAMS, OINTMENTS & POWDERS.

2 tubes Hibitane cream
1 bottle Savlon (8oz.) (not used)
Embrocation (Nasciodine
1 tube Golden eye ointment
4 tubes insect repellent cream
6 tubes sting-relief
1 tube lanolin cream (very useful)
1 tin foot powder (fungicidal)
1 small bottle tooth tincture
Kaolin, Thalazone 100 (for diarrhoea)
Nivea cream (very useful)

(ii) TABLETS.

Berkmycen 100 tetracycline
Cascara (constipation)
Gastrils (for indigestion)
50 throat lozenges (very useful)
50 Paracetemol
40 Penbritin (2 courses) (ampicillin)
112 Penavlon (penicillin 112) (2 courses)

(iii) DRESSINGS.

1 x 2″ white open wove bandage
3yds. x 3″ Elastic adhesive bandages
2 Shell dressings
3 x 2½″ x 1yd. porous strip dressings
3 Wound dressings (No. 15)
2oz. Cotton wool

(iv) MISCELLANEOUS.

1 Eye bath
1 tin fly spray aerosol (only used in small tents)
safety pins
1 pr. Splinter forceps
clinical thermometer
surgical scissors
chewing gum (temporary tooth stopping)
First Aid pamphlets

Some of these have been left in the Tundra Camp Dump. I will be pleased to give a full list of these supplies to any future expeditions who may wish to make use of them.

The following contributed medical supplies: Allen and Hanbury, Beecham Group, Bencard, Boyers, British Drug Houses, Burroughs Wellcome Co., Ciba, Glaxo, I.C.I., Johnson & Johnson, Lloyds' Research, May & Baker, Merck, Sharp & Dohme, Napp Laboratories, Pfizer, Smith & Nephew, W.B. Pharmaceuticals.

SCIENTIFIC REPORTS.

Three main projects were carried out by the expedition. The main project, Alayne's responsibility, was aimed at assessing the changes in rock weathering and the properties of soil and fines related to surface age and glacial history. Christa's study focussed on the valley side fans, and, in particular, on the correlation of factors affecting their morphology. Kate was interested in the colonisation of vascular plants on the Roslin moraines. A brief study was also made by Sue and Sheila of patterned ground in west Schuchert Dal.

The work carried out by Christa and Kate formed the basis for their B.A. degree dissertations at Cambridge.

Shortened accounts of these studies follow, and we would all be pleased to answer any further questions and to provide fuller references, if required.

GENERAL DESCRIPTION OF THE EXPEDITION FIELD AREA (F.A.S.)

Schuchert Dal is an impressive outwash plain about 70 kms in length, stretching southwards from the snout of the 30 km-long Schuchert Glacier to Scoresby Sund, East Greenland. The major features of its landscape have all been sculpted by Quaternary ice. In the north and west the rugged summits of the Werner Bjerge and Staunings Alps tower up to 2,000 metres above the Schuchert River. On the east side rises the disserted plateau of Jameson Land. Numerous alpine tributary glaciers terminate on, or near, the main valley floor.

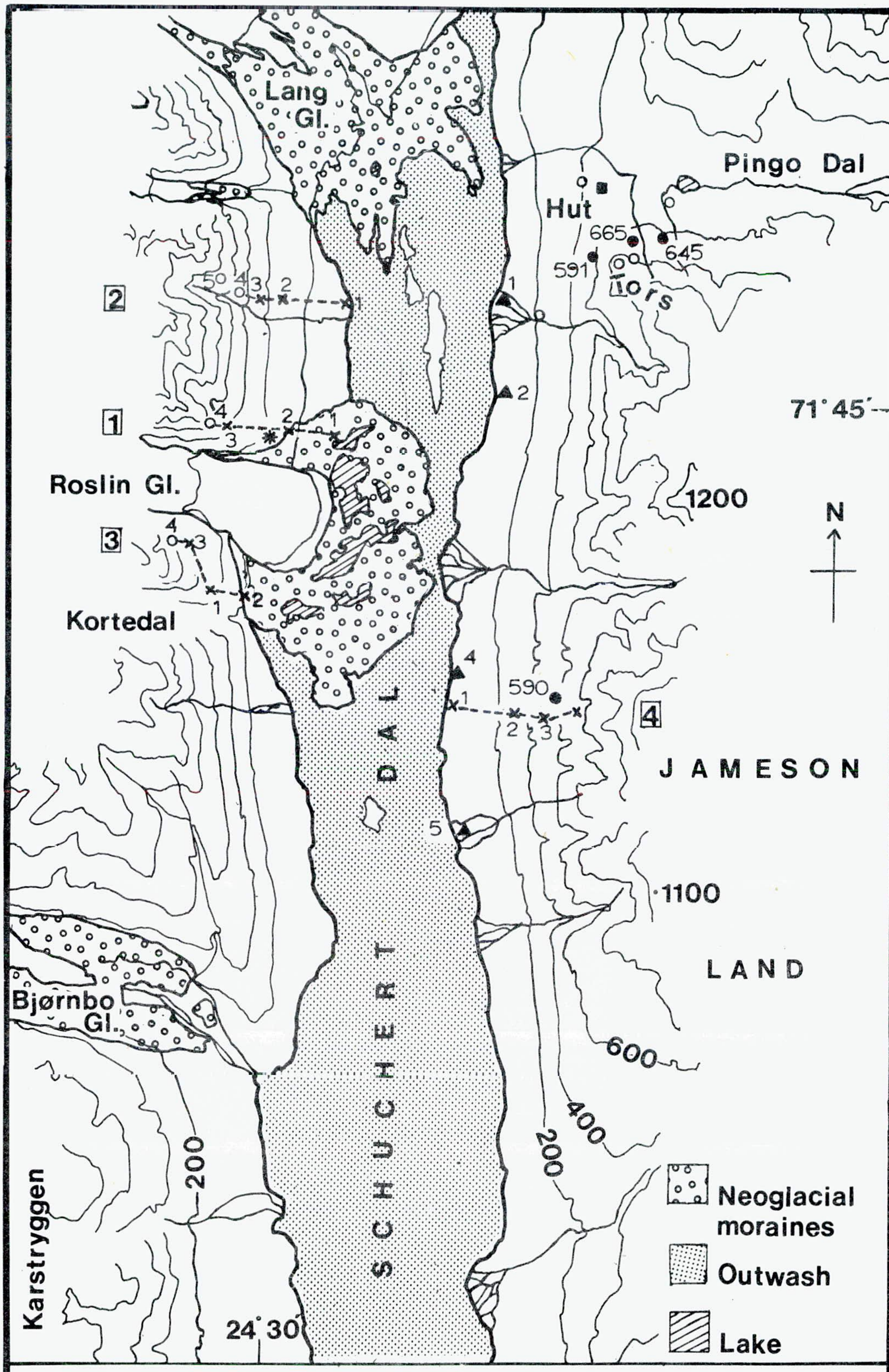
The Staunings Alps are a mass of Caledonian marble-bearing migmatites and migmatite-granites, interrupted by large granitic and syenitic bodies. (Henriksen and Higgins 1970). Processes of fluvial and glacial erosion have etched out Schuchert Dal along the main boundary fault zone separating the Caledonian crystallines from the sedimentary basin of Jameson Land to the east. The valley floor and the east wall, together with a horst and graben area on the west side south of the Roslin glacier, are underlain by beds of Carboniferous (?) to Triassic age, dominantly arkose and conglomerate (Kempter 1961, Bromley et al. 1970). However, Upper Permian reef limestones are locally present. They cap the Karstryggen plateau, south of the Bjrnbos Glacier. In the Werner Bjerge, the Upper Palaeozoic clastic sediments have been disturbed and indurated by a Tertiary intrusive complex (Bearth 1959). This is commonly represented in glacial deposits by a light grey nepheline and nepheline sodalite syenite. Basic dikes and sills of Tertiary age also intrude the sediments.

Scoresby Sund is the world's largest fjord system. It drains both the Inland Ice and many mountain glaciers and ice caps. Its intricate network of glacial troughs and fjord basins, interconnected at high levels by glacially smoothed cols, shows that the terrain has been extensively modified by ice to levels well above the present glaciers. The chronology and extent of glaciation are discussed further by Alayne.

Major glaciations have occurred at least twice prior to 40,000 BP (Funder 1972 a, b). The earliest known advance overwhelmed the entire area, leaving only traces in the form of scattered summit deposits in Jameson Land. (Funder 1972a, Callomon 1970). Much later, Scoresby Sund carried an enormous calving outlet of the Inland Ice. It was fed, through Schuchert Dal, from the Staunings Alps and Werner Bjerge. This advance probably deposited the subdued blanket of till covering the lower slopes of Schuchert Dal and Pingo Dal. It is now thought to represent the Weichsel/Wisconsin maximum in the area (S. Funder 1972a).

Younger tills in many major valleys date from a Late-glacial readvance or stillstand of the retreating Weichsel ice. This left sequences of hummocky moraines a few kilmetres from present glacial snouts. Cut into these moraines are beaches, formed as the sea followed the retreating glaciers over land still depressed by the weight of ice. Hence, about 9900 BP, Schuchert Dal was occupied by an enlarged Schuchert Glacier whose moraines were built into a sea ca. 107m above its present level (Sugden and John 1965, Funder 1972 a, b). They can be seen to flank the lower Schuchert. By 7900 BP, the ice had retreated behind the

FIG A2



Map of upper Schuchert Dal showing sampling sites

▲3 Pingo ✱ Base camp All heights in metres

x1 Soil pit [2] Soil profile traverse 2km

• Highest erratic (metres) ○ Other sites

Neoglacial Schuchert moraines. Schuchert Dal was a shallow fjord. Raised strandlines and shelly marine silts of this age occur up to 50m on both sides of the valley. By this time, tundra plant communities were probably becoming established on the newly deglaciated land.

Sea level continued to fall. 5000-6000 years ago, it approached its present position (Washburn and Stuiver 1962, Lasca 1966), providing a minimum estimate of the time available for mass movement and fluvial processes on the lower slopes and valley floor. Alluvial fans (studied by Christa) and talus accumulations developed below glacially over-steepened rock walls. On the older parts of these deposits, lichen thalli of Rhizocarpon geographicum have grown to maximum size. This suggests that their accumulation began 4000-7000 years ago. In better-turfed areas, periglacial flow and creep processes have produced turf- or stone-banked terraces and lobes. Not surprisingly, since the mean annual temperature at Mesters Vig is ca.—9.7°C, the ground is perennially frozen to depths of 150-220m in northern Schuchert Dal. (Kirchner 1963, Hintsteiner pers. comm. 1972). The active layer is believed to be about 0.6-1.5m thick (Bondam 1965). Networks of ice-wedge polygons cover the silty areas at the base of the alluvial fans (see Sheila and Sue's report).

Groundwater, welling up through the permafrost under pressure, has formed numerous pingos since deglaciation. In fact, Pingo Dal is a classic pingo locality (Müller 1959). Seven occur in Schuchert Dal (Cruikshank and Colhoun 1965, O'Brien 1971). Maximum ages for two pingos, in Schuchert Dal and Mesters Vig Bay, are ca. 8500 and 5500 years (O'Brien 1971, Trautman 1963). Resampling of pingo waters for R. O'Brien was carried out by Alayne and Sue.

The alpine glaciers readvanced, probably from just behind their present termini, to form the massive system of fresh moraines which now rise like ramparts around their snouts. The Roslin moraines (Plate 5) postdate 1490 BP. (Lepin et al. 1965). They have been colonized by a number of plant species which were studied by Kate. The form and lichen cover of the moraines suggest that all the glaciers advanced more or less simultaneously, during the world-wide Neoglacial climatic deterioration. They retreated again after the 1930's. But several glaciers in the Staunings Alps are known to surge (Rutishauser 1971). Although spectacular advances of the Roslin, Lang or Schuchert Glaciers have not yet been observed, the size and form of their complex moraine loops suggest that they do indeed surge. Perhaps secular trends in mass balance can trigger surges. As yet, nobody knows.

Further information on climate, vegetation, geomorphic processes and soils around Mesters Vig is available in the publications by Washburn, Lasca, Raup and Ugolini in Meddelelser om Gronland.

For the references cited here, please see Alayne's report.

QUATERNARY GEOLOGY OF SCHUCHERT DAL—F.A.S.

(a) Introduction

The purpose of this study was to gather data on the extent and chronology of late Quaternary glaciation in the Schuchert Dal area. Particular emphasis was placed on gathering evidence to help resolve the controversy as to whether unglaciated summit areas existed in the Greenland coastal mountains at the Weichsel/Wisconsin glacial maximum. Botanists in Scandinavia, Greenland the eastern Canadian Arctic have maintained that the survival of the arctic-alpine flora depended on these refugia. The consensus of geological opinion has, until very recently, always rejected the 'nunatak hypothesis' and favoured total glaciation. (See Ives, 1974, in press). The summary presented in the "General Description of the Field Area" is a personal view, based on new evidence and on the fieldwork described here.

This report can only be a preliminary one, since it was impossible to carry out laboratory analyses until the samples collected had been brought back from Greenland. Full descriptions and analyses of soil and other samples, including the soil profiles studied, can be obtained from me, c/o Dept. of Geography, Cambridge University, as soon as they are completed.

Schuchert Dal possessed several advantages for this study. It lies about 100 kms from the inland ice and 200-300 kms from the continental shelf margin. Measured ice sheet profiles suggest that the mountain tops might still protrude as nunataks even if the ice sheet advanced right to the shelf edge. Existing information from the valleys east of the Staunings Alps themselves argues strongly that they were occupied at the Weichsel maximum only by expanded alpine glaciers (Washburn 1965 p.29, Pessl 1962 p.75, Lasca 1969 p.39, Funder 1972a, Cruikshank and Colboun 1965 pp.227-29). There is excellent background information on vegetation, soils, periglacial processes and weathering compared with other parts of Greenland. In addition, studies by Washburn and his co-workers around Mesters Vig, by Christian Hjort of the University of Lund, and by Svend Funder of the G.G.U., all of whom have been very helpful to me, have considerably clarified the glacial geology and history of isostatic uplift.

Around Mesters Vig, the upper limits of the oldest glaciation of which extensive traces remain, mainly in the form of very subdued lateral moraines, an upper limit of abundant erratics, and ice-smoothed cols, indicate an inundation of the valleys by local ice up to 500-600m. As already stated, this is now believed to be the true Weichsel glacial maximum, which occurred during the early Weichsel/Wisconsin.

In Schuchert Dal, Cruikshank and Colhoun (1965) observed that "the lateral limits of the last major glacial advance were within the valleys. There is neither landform indication, nor evidence from glacial erratics, that glaciation extended above the slopes of the main valleys in . . . . Karstryggen and in Jameson Land." They based this view on the sharp upper limit of erratics, and the highest lateral moraines, which occurred at about 600m in both the Karstryggen and Pingo Dal. The existence of "periglacial tors and buttresses" above the 600m level (Fig. A.1) in East Schuchert Dal was also cited in support of a Weichsel refugium in Jameson Land.

The main emphasis of the summer's field-work was on the systematic collection of data on traverses up the valley sides in West and East Schuchert Dal, and also in Pingo Dal, a col which is believed to have carried ice from East Schuchert Dal through the mountains towards the Greenland Sea. The aim was to assess the changes in rock weathering and the properties of soil and fines related to surface age and glacial history. It was anticipated that the glacial deposits of the Wisconsin maximum would occur in the highest positions on the valley sides, with possible non-glaciated areas above. I hoped to map erratics on the sedimentary mountains of Jameson Land (East Schuchert Dal) and the Lower West Schuchert Dal. This is impossible on the very complex igneous and metamorphic terrain of the Staunings Alps.

(b) **West Schuchert Dal**

Measurements carried out on dry and stable sites on three altitudinal transects, largely on igneous and metamorphic bedrock, were as follows:—

Soil description and sampling.

Lithological counts on parent material.

In situ impregnation of B horizon samples with resins, to observe age-related changes in thin-section (Brewer & Sleeman, Soil Science 1969).

Measurements of surface weathering, Cailleux roundness and angularity on a sample of surface stones (discounting easily weathered sedimentaries).

Macroweathering was noted e.g. pits.

Soil samples were taken for textural analysis, heavy mineral etching studies, clay mineral analysis, scanning electron microscope studies of quartz grains, and chemical analysis, e.g. for free iron. It was found that the lithologic mix was too great for weathering rinds to be of much assistance. Macroweathering was very slight on surface boulders. Very few showed micropits and projecting inclusions. None showed macropits. Even the boulders in till believed to be of Early Wisconsin age had only weathered surfaces. Interior grussification was limited to basic sills and to the nepheline- and nepheline-sodalite syenite which occurs in the till of East Schuchert Dal, derived from the Werner Bjerge.

Scanning Electron Microscopy

Additional samples were taken up to about 970m in West Schuchert Dal, from till and fines. Six samples were also taken for comparison from the recent ablation moraine, ice-cored moraine and subglacial moraine of the Roslin Glacier. These are to be examined by me and by W. B. Whalley, of Reading University.

Dating

A record was kept of the maximum sizes of three lichens, the geomorphic situation of each site, and the vegetation cover. The available chronological information was disappointingly limited. Owing to the unusual weather conditions during the previous winter, all the melt streams were very high, and it was impossible to reach the lower west side of the Schuchert Dal over the dangerously swollen meltstream from Kortedal. This prevented any work on the postglacial marine terraces, or the Late-glacial (?) terminal and lateral moraines which cross the Lower Schuchert and border its tributary valleys on the west. These moraines appear on the aerial photos to be much fresher than the featureless till which plasters the valley sides.

A chainsaw was taken for sampling peat deposits, but no peat accumulations have as yet been found. The very extensive and fresh moraines in front of the glaciers have no lichens on, apart from the outermost margins. The maximum size observed for Alectoria minuscula (35mm) indicates either instability or very recent deposition—probably both. There was a general absence of other glacial deposits within the timescale covered by lichenometry.

Samples of the buried 'turf' horizon below the northern margin of the Roslin moraines, believed to be a soil profile buried by the Neoglacial readvance, were taken to check the age (1490 BP) obtained for it through C14 dating by Hartshorn and Schafer (Levin et al. 1965). It is likely that this date is too old, including a factor due to the mean residence time of C14 in the soil at the time of burial. Although the very outermost moraines are definitely somewhat older than the main ridges, the lichen cover and plant growth indicate that a recent date is more likely.

(c) East Schuchert Dal.

Original plans to visit the ancient high level deposits of supposed glacial origin in Jameson Land were deferred because of their inaccessibility. On July 26th, helicopter assistance was obtained from Atlantic-Richfield to take Sue and I across the impassable Schuchert River to Pingo Dal and East Schuchert Dal. The aims were:—

To reach the Late-glacial (?) terminal moraine of the 'Schuchert Glacier' on the east side of the Schuchert River.

To collect data and map erratics, on transects up the valley sides.

To study the post-glacial marine deposits.

To take ice and lake-water samples from the pingos for Rob O'Brien, Dundee University.

Due to bad weather — snow, bitter winds and low cloud — only two whole days of fieldwork were possible. One transect (4 sites up to 733m) was completed. Samples of marine shells were collected from the 58m marine terrace and from the upthrust silt of one pingo. These should date the maximum invasion of Schuchert Dal after the Late-glacial (?) ice advance and give a maximum age for the pingos and valley train. It was impossible to reach the 'Late-glacial' moraine and contemporary shore deposits. Water samples were collected from three pingos, numbers 2, 4 and 5.

Mapping of erratics (Plates 2, 3) was carried out on the transect and on the south side of Pingo Dal. This confirmed that the featureless Early Winconsin (?) till appears to die out suddenly above 600m. The highest indubitable erratic was a block of Werner Bjerge syenite at 665m in Pingo Dal. The syenite and the metamorphosed conglomerates from the Werner Berje were the only reliable erratics, since granite pebbles are today weathering out of the local sandstones (Plate 2). Pingo Dal was confirmed as a route by which local ice, flowing south down Schuchert Dal, carrying erratics from the Werner Bjerge, crossed into Orsted Dal to the east. The col is at present just above 525m. No erratics from the Staunings Alper to the west, such as the distinctive calcsilicates, were present. This supports the view that the Inland Ice did not overrun these mountains in the Wisconsin. Sufficient time has elapsed since this stage for syenite boulders near 500m at the lip of Pingo Dal to weather into pedestals (Plate 4). The basic sills show similar weathering. Samples of grus and fresh rock were taken for a petrographic study of the mechanism of grussification. Further samples of till were taken for SEM work.

It is hoped to prepare a detailed report, including the laboratory data, as soon as this becomes available.

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This is a report on the computerised data bank of all published C14 dates on Greenlandic raised marine deposits, which was compiled as a follow-up to the 1972 expedition work.

Plate 2. — Large granite 'pseudo-erratics' weathering out of a block of Permo-Triassic conglomerate. When they are detached from their matrix, these can easily be mistaken for true glacial erratics.

Plate 3. — A large glacial erratic at 590m. in East Schuchert Dal. This is a Werner Bjerge metamorphosed conglomerate, resting on much older Permo-Triassic sandstones.

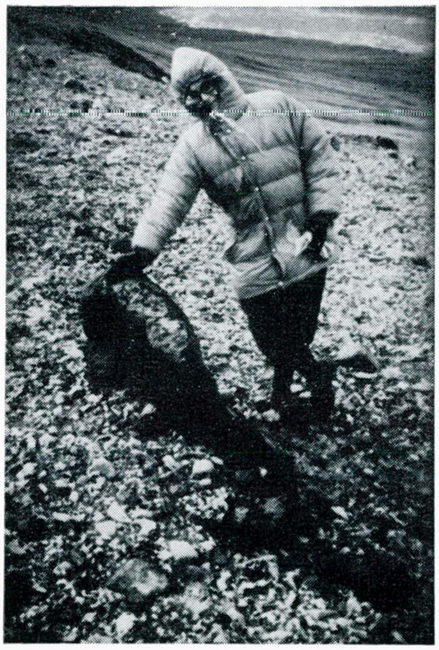


Plate 4. — Granular disintegration of a Tertiary basic dike rock, at about 500m near the Pingo Dal hut.

PREFACE

THE DEVELOPMENT OF DEBRIS FANS IN SCHUCHERT DAL (C.H.S.)

Accumulation of various sized material on the debris fans common on the lower slopes of Schuchert Dal is supplied from denudation in the corries at the snowline. Between the corries of the upper slopes and the lower depositional areas, streams have developed deep gorges. The way these streams, all tributaries of the main glacial meltwater streams in Schuchert Flod, flow around or down through the debris fans was investigated.

I looked generally at debris fans in crystalline, sedimentary and limestone areas, and observations were also made on smaller alluvial fans at the edge of the terminal moraines of the Roslin glacier. More specifically, all instances of debris fans were studied in a five-mile length of valley-side. After basic surveying, quadrat analysis was undertaken along random traverses on each debris fan, with three sizes of quadrat (0.3, 0.6 and 1.2 m square) for statistical comparison of the results. Ten samples were taken consistently from the upper left-hand corner of each quadrat for measurements of the geology of the particles, and of their curvature and a, b and c axes, to allow calculation of roundness and sphericity indices. Also note was made of the type and percentage of vegetation, providing an indication of the age since the deposits were last modified by the streams.

By a study of the relationship between such factors, and a consideration of fan gradient, the various processes leading to fan formation may be postulated. Field measurements of fan gradients were made by abney level, along the radial profile of the median line of the fan over the upper quarter of the surface, since it is here that the fan gradient should be most closely controlled by the upstream basin character, and errors were held to be minimal. Some relationships were immediately apparent, such as the differing sizes of boulders in an area on interfluves and in stream channels, connected with different types and quantities of vegetation. Possible links also arise from the occurrence of different types of boulders on different sides of a fan, for example the abundance of arkose on the north and sandstone on the south of Desolation Fan. Generally the stream channels flow discontinuously on the fans during the summer, with deeper channels towards the sides. More than one age of deposition is often apparent, shown distinctly on Desolation Fan with various levels being superimposed, leaving a large, upstanding, triangular area of debris near the apex. Also obvious is the characteristic decrease in fan gradient about two-thirds of the way down. By comparison with mid-valley-side slopes in Schuchert Dal, it seems that on the more elongated features of Octopus, Squid and Battersea Fans, rockfall is of more importance than on the cone-shaped features of Tundra-Camp and Desolation Fans, where the action of streams is certainly the dominant process.

1. INTRODUCTION

When considering specific features of scree slopes in the last twenty years, much attention has been concentrated on the alluvial fans of the arid and semi-arid south-western United States. Little attention has been given to debris fans in areas that were glaciated in the Pleistocene. Ryder (1971a), though, has recently pointed out that the fans she studied in south-central British Columbia are products of an environment in the process of transition from predominantly glacial to dominantly fluvial conditions. The characteristics, and therefore the formation, of these paraglacial fans are distinct from those of arid alluvial fans, but are in some respects fairly similar to the debris fans in north-east Greenland, where the periglacial climate also approaches aridity. By the use of morphometric and statistical techniques that have previously been applied to samples of arid fans, I have attempted to make a comparison with fans in three environments, truly arid, paraglacial and periglacial. Debris fans were examined in detail along the west side of Schuchert Dal between the Roslin and Lang glaciers. Certain properties of others in different geological situations nearby were examined by a study of the available maps and aerial photographs. Unfortunately, these two areas, on the east side of Schuchert Dal to the south of Pingo Dal, and on the west side of Schuchert Dal immediately south of the Bjornbos glacier, could not be visited in the field because of the abnormally high meltwater streams, due to the unusual weather conditions in summer 1972.

Frost-weathering

To judge from the cold climate, much of the denudation of the valley sides would seem to have occurred through frost-weathering. The effect of this is probably dependent on the resistance of the bedrock, the number of freezing-point changes, and the water supply. It seems reasonable to follow Rapp's conclusion for Spitzbergen (1960), that large rock-fall chutes with talus slopes imply rapid postglacial and recent denudation. This depends on the fact that frost-weathering is extensive on account of a severe climate and not very resistant bedrock, a situation that is true in Schuchert Dal.

Climate

The climate of Schuchert Dal is periglacial. Rainfall records for short periods at the coast (Mesters Vig and Scoresby Sund), suggest an annual precipitation in the valley of 25-40 cm, mostly in October and November. Thus the thaw, making water available for fluvial erosion and mass movement, occurs in the dry spring months of May and June. From records taken at Tundra Camp from 26th July - 21st August, 1972, the following was found:—

Mean maximum temperature	15.1°C
Mean minimum temperature	5.2°C
Mean daily amplitude	7°C

which ties in well with data from the coast. The north-east Greenland daily freeze-thaw cycles are rare, and few occur when the surface is snow-free, so seasonal freeze-thaw is more significant. Schuchert Dal is also in the zone of continuous permafrost, to possible depths of 200 m (Washburn, 1965).

Geomorphology

The area is highly suitable for the investigation of the form of debris fans because there are many large, well-formed features of this type in the area, that can be presumed to be of fairly rapid, recent development. The debris fans lie below or across various marine terraces, implying recent evolution, and that they have not been subjected to appreciable removal of material since their initiation. The valley is characterized by steep-sided mountains to over 1700 m, the mountain walls being strongly weathered, and regularly dissected by rockfall funnels with snow-filled cirques above, and at the bottom surrounded by talus belts and debris fans. Even the low tundra vegetation is generally absent on the upper talus slopes.

The long profiles of slopes representative of the three areas studied in Schuchert Dal are characteristically gently concave. At altitudes from 100 - 500 m, on slopes from 7 - 25°, the debris fans are found, below the gorges where streams emerge from the upper corries. In between the debris fans, the slopes are covered with solifluction lobes and terraces at angles of 12 - 25°, and with terrace and creep features on slopes of 7 - 15°, with frequent mudflows rupturing the surface vegetation. Modification of the valley slopes by post-glacial processes has meant that the present morphology of small-scale landforms, including the debris fans, has been imposed on an inherited glacial landscape.

Tundra-Camp fan consists of a small fan superimposed on an older, gentler and more stable fan, with streams and mudflows only at present re-working the upper material, the bottom area being highly vegetated. Desolation Fan similarly has an upper central area. It is about ten feet above the height of the surrounding fan, but in contrast to Tundra-Camp Fan, this seems to be the area most recently abandoned, with streams re-working the fan to both sides. On Desolation Fan the main stream, from the gully above, comes down the north side, which is probably the reason for the present greater widening of the fan on that side, with much material being newly deposited. The gorge itself on Desolation Fan is much wider than that on Tundra-Camp Fan and contains at present much material already available for future deposition, unlike Tundra-Camp Fan, where new erosion would be required to provide the supply to extend the fan area. On both these cone-shaped debris fans there appears to be a break-of-slope about two-thirds of the way down the fan, which seems to indicate the end of the region of active deposition and re-working of the material.

On Battersea Fan the stream seems to have become more competent recently, and has increasingly cut down the centre of the fan. The newly eroded material is now being redistributed around the base, extending the fan area. Octopus and Squid Fans are both of the more elongated type of Battersea Fan, but on them the main stream is at the side rather than in the centre. The asymmetry of Octopus Fan seems due to recent re-working of deposits, being steeper on the south side where the stream channel is most actively eroding at present. Bedrock occurs in the stream bed (showing a depth of thirty feet of deposits), and angular boulders are of various sizes. The lack of vegetation also occurs on Squid Fans (Photo 9).

It is hard to delimit the exact margin of the five fans studied in detail. Either lateral coalescence is forming compound features, as between Desolation and Battersea Fans, or at the bottoms of the fans the edge is uneven with tundra ridges between streams.

The fans on the east side of Schuchert Dal are of a similar conical shape to Desolation Fan, with streams over the whole surfaces. The Karstrüggen debris fans are made of unstable limestone screes, prone to rapid debris sliding and large-scale slumping at the plateau margins from the limestone cap, and of conglomerate/arkose screes that are more stable and maintained at steeper slopes. The alluvial fans at the periphery of the Roslin moraines have profiles of 3 - 10°, and 40 - 80 m long. Almost unvegetated, they usually have fairly deeply waterworn distributory channels on the surface. All become increasingly sandy away from the apex, where boulders accumulate. Most of the material appears to originate in small moraine basins, moved as much by mudflows as fluvial action.

2. NATURE OF THE MATERIAL.

(a) Morphology of the fan surfaces in north-west Schuchert Dal.

Particle size on the debris fans ranges from silt matrixes to pebbles and large boulders. Particle shape ranges from angular to rounded, seeming to depend on the mode of transportation of the material. It appears that the composition of the debris fans is dependent on the type of sediment supplied from the parent basin, and possibly partly on the character of the stream. Variations in the character of the bedrock do not seem to be reflected by changes in fan type. The differing, more elongated, nature of Octopus, Squid and Battersea Fans is more likely to be related to a shorter period of formation than to differing lithology, as the parent basins are lithologically similar to those of Tundra-Camp and Desolation Fans. The length of time since the initiation of the fans is probably important with respect to the availability of silt-sized particles, which are related to minor mudflow features on the fans. Either these fines have been washed down from the parent basins, or, as seems more likely where they occur more frequently on the older Tundra and Desolation Fans, they have been formed in situ. Possibly the relative amounts of bedrock particles of differing resistances would be important for the production of silt, and could be reflected by the vertical gradations in the calibre of fan material (as noted particularly on Desolation Fan) and could also have implications regarding the duration of fan construction. The detailed morphology of the fan surfaces gives some indication of the depositional processes, but it is of greatest value where considered together with the scree slope characteristics.

(b) Size, roundness and sphericity of particles on the fan surfaces.

Table 1 shows the size, roundness and sphericity measured on the five debris fans between the Roslin and Lang glaciers, for the three sizes of quadrats considered. More detailed information was available for Tundra-Camp, Desolation and Battersea Fans, so Figure 3b shows the variation of particle size with distance from the fan apex for the three fans separately, and Figure 3a for different sizes of quadrats. The mean particle size values are greater on the upper than the lower fan surfaces for all sizes of quadrat considered. The low values for 0.3m quadrats on Tundra-Camp fan are probably related to the abundance of fines on the lower interfluves, which closely resemble adjacent solifluced slopes. The greatest decrease in particle size down a fan occurs on Desolation Fan, possibly because over its greatest surface area there has been more scope for streams to wash smaller particles lower down.

The variation of particle roundness with distance from the fan apex is shown for different sizes of quadrats in Figure 4a, and for the separate fans in Figure 4b. Generally, the roundness seems to increase slightly lower down the fans, although this is not statistically significant. For Tundra-Camp and Desolation Fans the roundness seems greater for particles in the smaller two quadrats, but this trend is reversed on Battersea Fan where roundness increases with quadrat size. This can probably be explained because more of the particles sampled in the 0.3 m quadrats would be expected to be smaller, and so over the same distance of transportation to have become more rounded than some of the larger particles sampled in the 1.2 m quadrats. More marked is the differing roundness of particles on the three separate fans, which is important when considering the processes operating. The lesser rounding on Battersea Fan can probably be explained by the limited re-working by fluvial processes of the material. The great roundness of much of the material on Tundra-Camp Fan seems odd, but could indicate a considerably greater age than for Desolation Fan.

Figure 5a shows the variation of particle sphericity with distance from the fan apex for different quadrat sizes, and Figure 5b for the three separate fans. Ignoring some anomalous values for Tundra-Camp Fan (maybe due to errors of measurement), the sphericity seems to increase slightly lower down on the fans, although this is only just significant. Comparing the three fans, there seems to be no real difference in sphericity measured.

Although the Karstrüggen could not be visited, data from Cruickshank and Colhoun (1965) seems to suggest that the limestone is shattered to small blocks, of about 15 - 25 cms cubes. The adjacent conglomerate group (including arkose and other coarse sediments) is, in contrast, frost-shattered to generally large, flaggy blocks, of approximately 75 x 60 x 30 cm. Smaller blocks are uncommon, as they would usually have completely disintegrated into single coarse grains. Thus although the limestone material may resemble that studied in detail further north, the other debris on these fans is of a much coarser nature.

(c) Comparison of the nature of the material with previous studies.

Best comparison of the size of the material is by the use of mean log (long axis of the particle), a method adopted by Thomas (1971). Overall differences between the fans are more likely to result from differences of material supplied to the slope, rather than differences of environmental condition. The difference in size according to position within a slope presumably arises from the operation of variables producing size grading between positions on the slopes. None of the slopes considered in detail can be called " typical " scree slopes, in that they do not have the increase in particle size towards the foot of the slope, that results in Rapp's (1960) " boulder tongues ". Thornes considers that the reverse trend, with an increase in particle size with height, occurs in cases of free debris supply, or possibly of impeded supply and free basal removal. Such criteria are not directly applicable to Schuchert Dal, but do suggest that the decrease in particle size downslope is directly related to the type and method of supply from the parent basin.

Sorting of the deposits is rare on steeper talus slopes (Rapp, 1960; Thornes, 1971), but is apparent to a certain degree on the periglacial debris fans in Schuchert Dal. Although this could not be examined quantitatively, a good indication of the degree of sorting is given by the percentage of vegetation in a quadrat. For example, it is common on gentle interfluves by stream channels low down on Tundra-Camp Fan to find a quadrat 80% vegetated, mainly dryas, carex, sax. aizoides and polygonum viviaparum, associated with material about 2.5 x 1.5 x 1.0 cm. Such sandy interfluves are also common on lower Desolation Fan, with dryas, carex, arabis aranicula, lesquerella arctica and potentilla. Tundra ridges and valleys are also found at low levels (mainly betula nana, tolfieldia pulsillia, dyas, cassiope teragona, and vaccinium uliginosum), indicating fan areas no longer actively being accumulated, although periglacial processes are modifying the surface in places into hummocks. Similarly, at the more active, upper parts of the fans, a distinction can sometimes be made between the size of the material in the present (or recently abandoned) stream channels, and that on the bouldery interfluves and in old mudflows. The largest material generally occurs on the stony interfluves, and the smallest in the mudflows, although statistically there seems little difference in the mean particle sizes for the three situations, as measured on Tundra-Camp and Desolation Fans.

This differential distribution of the material has often been cited as a means to deduce the method of evolution of the slope. In Schuchert Dal, it is mainly the frequent channel changes during floods (caused by snow-belt), that account for the corrugated nature of the upper surface of the fans, which are not typical of those studied in Spitzbergen (Rapp, 1960).

Where a large range of size of particles is supplied, as in Schuchert Dal. because of their greater momentum and ease of rolling, the larger ones should travel further towards the base of a fan, so that the fragments become sorted by size, progressively finer towards the apex. Such a situation seems to require a greater slope than that existing on the Schuchert Dal debris fans. Looking at talus slopes in New Zealand, Caine (1969) observed particle sizes of 5 - 10 cm range, with a lack of fines of less than 2 mm. This is similar to Schu chert Dal, and his conclusion that the wide variation in size did not seem to conform to simple patterns is also of interest. However, where he found an increase in boulder size down-slope, his measured accumlation rates indicated dominant free-fall. Since the reverse exists in Schuchert Dal, it can be implied that rockfall is unimportant. Andrews (1961) observed similar processes on the Wasdale screes, showing that the rock there weathers to sub-angular fragments of various sizes, with roundness about 300. This roundness value is similar to mean roundness at many places on Schuchert Dal debris fans, and implies that, even although rockfall is not a dominant process there, there can be relatively little reworking of the material, probably because of the ephemeral nature of the snow-melt streams.

It seems that the complexity of the effect of debris calibre on fan gradient applies as much to periglacial fans in Schuchert Dal as to alluvial fans in the United States, where most of the studies, to date, have been carried out.

3. DEBRIS FAN SLOPE CHARACTERISTICS.

(a) Morphology of periglacial talus slopes.

Once released by frost-weathering, material tends to follow definite paths; the angle of accumulation depending on rock-type, and the size of the constituent particles, rather than friction or climate. Eventually an equilibrium is reached for the supply and removal of material (Machatschek, 1969). With the change in gradient of streams from steep gorges onto the gentler slopes of the main valley, initial discontinuities are adjusted by the deposition of a debris fan, which later becomes dissected again. Along Schuchert Dal, stream valleys develop from simple channels on the slopes, the intervals between them determining the slope gradient, depending on the nature of the rock and the magnitude of the erosive and transportable agents. The eventual shape of the debris fan is the result of deposition as the stream swings back and forth over the accumulating material about a fixed apex (Pitty, 1971). Deposition results from a decrease in slope, or is related to decreasing velocity as the stream spreads out over the fan (Bull, 1963). Initial fan growth is therefore a powerful self-enhancing factor.

On the west side of the Mackenzie delta (twenty-five freeze-thaw cycles annually, i.e. similar to Schuchert Dal), fans with gradients about 3° also show a marked decrease in particle size down-slope (Legger, Brown and Johnson, 1966). These fans are also like those of Schuchert Dal in that the top part is steeper than the base, which they attribute to differential rock resistances, something especially imporant in sub-arctic regions where the greatest disintegration occurs in the short period of snow-melt. Coarse particles, easily eroded by the runoff, are generally disintegrated before being transported far by streams. Work on sediments at the end of the Mendenhall Glacier, Alaska (Ehrlich and Davies, 1968), shows how only rocks of intermediate resistance to disintegration reflect down-valley degradation. Differences of resistance result in patterns of relative abundance of rock-types that are functions of distance from the source of the depositional history (see example in preface). Differing rock susceptibilities is possibly the inherent distinction between different forms of fans in Schuchert Dal.

The phenomen of contemporary deposition in periglacial areas such as Schuchert Dal is best explained as the substitution of a periglacial system of erosion for a glacial system (Birot, 1968). Birot considers talus to be an abnormal feature of the periglacial cycle, and this ephemeral nature of debris fans is well seen in fan super-imposition (Desolation and Tundra-Camp Fans).

In different climates the importance of various processes on a fan differ considerably. In the formation of a complex debris fan, the slope is generally determined by load-discharge relationships of the stream responsible for sediment deposition. A low discharge stream with a load of coarse detritus will produce the highest gradient fan. I measured stream velocity on fans to give an indication of discharge, but, being done in summer, this is no real indication of the potential of the streams. On Tundra-Camp Fan an average of 0.5 m/sec (compared with Schuchert River 3 m/sec) was found by timing corks over a certain distance, it being uneconomic to use more complicated dilution methods (Ferguson, 1967). Reasonable accuracy was provided for such turbulent streams. Debris fan streams, with a constantly altering braiding pattern, also meander lower down, depending on the gradient (Leopold and Wolman, 1957). Deposition of the coarser load that cannot locally be transported produces many "cul-de-sacs" on the fan surfaces, usually in the narrower channels on the upper fan surface. The channel pattern is ultimately determined by the discharge, though, and the load received from the drainage basins.

Permeability of the material in debris fans is generally great, with great loss of water by infiltration, especially in the summer. Snowmelt causes surges in the discharge, that at times are sufficient to produce mudflows, which help to transport coarse material onto the fans. With regard to permeability, where debris fans are associated with pingos, on the east side of Schuchert Dal, some indication of the general hydrologic conditions comes from the knowledge of the association of pingos with local secondary faults (O'Brien, 1971). The "freshness" of the pingos that break off the surfaces of the debris fans also indicates the recent lack of growth of the fans, suggesting that the response of the slope form to the erosional environment is not changing at present.

(b) Debris fan slope profiles.

From the long profiles of the three groups of fans studied (Figure 2), the overall concavity is immediately apparent. That this concavity begins almost at the fan apex is probably a special characteristic of periglacial debris fans. Scree slopes have usually been associated with slopes of constant inclination, related to the angle of scree stability, depending on its composition. It is in this respect that the debris fans of Schuchert Dal are so interesting, the material resting at far gentler angles than the maximum for stability.

(c) Morphometric relationships between fan and basin parameters.

Various models and statistical methods have been developed to elucidate the processes acting in the formation of debris fans (King, 1967; Scheidegger, 1970). Bull (1963) found that slopes decreased on fans with an increase in the size of the parent basin, so that for comparable basins, fans developed from mudstone with a steeper slope than those from sandstone basins. Taken from data in Table 2, Figure 6 shows that areas A (north-west Schuchert Dal) and C (east Schuchert Dal) have a similar, close relationship between debris fan area and drainage basin area, no real relationship existing for area B (Karstrüggen). There is such little difference between the coefficients for areas A and C, which implies that (excluding one extreme measurement for basin area in area C) both mean fan and basin area for the two geological situations are remarkably similar. For an increase in drainage basin area of 1000 sq m, there is a resulting increase in debris fan area of about 200 sq m. With respect to fan gradient and drainage basin area, Figure 7 shows that a relationship exists for all three regions. Areas A and C show a relationship similar to Bull's, with a decrease in fan slopes with an increase in size of the drainage basin.

Figure 8 shows the relation of fan gradient to relative relief, following Melton's (1965) work in this field, although a definite discrepancy can be observed. Melton found fan gradient to increase with increasing relative relief, but for the periglacial fans in Schuchert Dal only the steeper fans in area A agree with this finding, which is strange since they are the ones with least similar mean gradients to those in Arizona. Yet the negative relationships observed in areas B and C are equally meaningful. Most probably this is connected with the differing geological situations of the three areas, as aspect and elevation do not seem to be related to the situation.

I have taken fan gradient as the parameter best describing fan morphometry, so that a comparison may be made between Schuchert Dal fans. Product-moment correlation coefficients between fan gradient and the morphometric basin variables measured (relative relief, basin height, basin area and mean basic slope) and fan area, are given in Table 3. Apart from fan area, which had not previously been used for comparison, the basin characteristic that is most consistentlly related to fan gradients is the relative relief. The other characteristics also show several significant correlations with the fan gradient, which would be expected anyway from the close relationship of the basin characteristics used. The correlation analyses seem to indicate that the association between fan gradient and basin morphometry for periglacial fans is similar to that previously described for both arid and paraglacial fans, as studied by Ryder (1961b) and Metton, although if individual debris fans are considered, rather than using geological groupings, a far wider range of variability is found.

Fan gradient is related through discharge to basin area, and the source area lithology can influence fan slope through debris size, and its effect on depositional processes. Relative relief and mean basin slope are related to sediment yield, and thus ruggedness is also related to debris calibre. The links between the fan gradients and the morphological properties of their related drainage basins are shown in Figures 7, 8 and 9. Observations that mudflows produce steeper fans than otherwise similar fluvial fans indicates the possibility of a greater importance of debris flows on fans in area A. As the basin ruggedness (i.e. mean basin slope and relative relief) increases, then the proportion of debris flow relative to fluvial deposition may be expected to increase. Values of S and $HT/\sqrt{A}$ are greater for area A, and this seems to agree with the supposition. Yet, most of the surface forms seem to be controlled to a greater extent by fluvial processes, producing gradients that are related through the discontinuous stream flow to basin characteristics. Regional differences occur in the strength of the correlations. For example, basin height is not significantly correlated with fan gradient in area B, which suggests, in combination with morphological evidence, that deposition there has been less recently than in the other areas, where a more accurate expression of drainage basin characteristics exists in the form of the fans. A general lack of significant results for area B (except for fan area) may reflect the lithological variation of limestone/conglomerate there. Lithological control appears to be the only factor that really masks the effects of basin morphometry on fan gradient.

(d) The distinctiveness of periglacial debris fans.

Although data was limited, an attempt has been made to compare periglacial with arid and paraglacial fans on the basis of these statistical measures. For the relationship between the relative relief and fan gradient, from product-moment correlation coefficients, the arid Arizona fans (0.94) (Melton, 1965) are more significantly similar to those in Schuchert Dal than are the paraglacial fans. This might be partly due to the fact that paraglacial fans are claimed to be in transition between glacial and fluvial processes, whereas arid and periglacial fans have for longer had the same processes acting on them. Contrasting gradients between groups of periglacial fans may reflect either lower discharges with coarse debris or higher sediment concentration in flows on area A from glaciated basins. Greater sediment concentration seems likelier for area A, and is probably enough, with spring snow-melt, to cause such differences observed in the product-moment correlation coefficients. For arid fans, Melton suggested that increased debris supply from frost-shattering produced steeper fans. Such an effect, with the higher basins, may be additive to produce the steeper gradients in area A.

Paraglacial fans were distinguished by Ryder from arid fans by the relatively greater interregional variations in the morphometric relationships. Periglacial debris fans probably lie between the two. The strength of correlation between fan gradient and basin parameters is mainly greater for periglacial and arid fans than for paraglacial fans (Table 3). Possibly the lack of time available for the effects of the basin characteristics to be transmitted to the fans accounts for this, and for the same effect in area B. This is an interesting conclusion, since in both the paraglacial and periglacial environments fluvial activity has been re-established in the landscape after deglaciation.

(e) Processes acting on debris fans in Schuchert Dal.

Debris fans, of the kind found in Schuchert Dal with gradients 7 - 20°, are still widely ignored in the literature on talus forms (Rapp and Fairbridge, 1968). Of course, a full gradation exists of features between talus cones and alluvial fans, but the periglacial situation of these debris fans means that a unique combination of processes is acting on them (Jahn, 1968).

Rapp (1957, 1960) discusses individual movements of particles (rolling and sliding), talus slides, creep, snow avalanches, mud-flows and running water on slopes. He describes development from a simple talus slope below a free-face, that is retreating uniformly, to mountain walls dissected into rockfall chutes, with talus cones in front of these, growing laterally to produce compound talus slopes. Most observed rockfalls occur in May and June, in the latest phase of snow-melting. Such direct free-fall from cliffs produces accumulation decreasing in amount with distance down-slope from the cliff foot. Although rockfall may be important above the gorges in Schuchert Dal, it is of negligible importance on the debris fans, as shown by the decrease in the calibre of the material down-slope, and by the increase in accumulation spreading out with distance from the cliff foot.

Besides rockfall, Caine (1969) distinguished slush avalanching, as having importance in the redistribution of material, and producing an increase in the thickness of deposits down-slope. Such coincidence as he found between model and surveyed slopes should not imply, however, that all taluses with basal concavities have developed in response to accumulation processes used in his model. Yet, slush avalanches are likely to be important on the Schuchert Dal debris fans, where minor surface characteristics are similar to those observed by Washburn and Goldthwait (1958) at Mesters Vig, nearby. There, slush-flow is a normal process in the break-up period, with mud-like flowage of water-saturated snow along stream courses. Annual spring outbursts occur after intense thawing has produced more meltwater than can drain through the snow. Such "slushers" are probably important in Schuchert Dal as a process of erosion and deposition, and a characteristic mode of stream break-up. Some may carry much rock debris, and contribute to (or be highly responsible for) the extensive boulderstream fans. Slushers are especially important in years of rapid snow-melt, and probably of particular local importance on the Schuchert Dal fans because they can be released on gentler slopes than can normal avalanches.

Elsewhere, snow avalanches have a major role in the development of talus slopes (Luckman, 1971; White, 1968). However, the related flat cross-profiles do not exist in Schuchert Dal, although some avalanche tongues are of fan form (Rapp, 1959). Only on parts of Octopus or Squid Fans could the typical boulder tongues, with concave long profiles, be said to exist. Even there, there is none of the usual tendency for larger boulders to lie near the edge of the fan, and fluvial activity, eroding a single main channel, is obviously far more important.

Fluvial activity is probably most dominant in connection with the construction of the massive debris fans in Schuchert Dal, the streams being most effective in late spring. Fluvial erosion is necessarily limited by the small quantity of runoff, but the concentration of this implies a possible great capacity for transport. The considerable amplitude of seasonal discharges is favourable for lateral erosion (Birot, 1968), because initially much water flows over a frozen bed, and so can attack the banks. Thus, the capacity ouf late-spring floods can be considerable, as is their competence, and there seems no reason to deny the erosional potential of periglacial streams, at least at certain months. With winter winds, drifting snow in the parent basins can produce local storage of water, despite the low precipitation in the region. Relatively slow melting of the snow drifts, especially on north-facing slopes provides a moderate regulation of the runoff. With the obvious importance of fluvial activity on the debris fans, from observations of the channels and the nature of the material, and its possible capacity for erosion and deposition in a periglacial environment, there appears little reason to doubt its importance as the major fan-constructing process.

Solifluction is unimportant on the active parts of the debris fans, although wash and creep modify the surface on the vegetated, inactive parts at the end of the spring when the soil is saturated to such an extent that surface flow is possible. At the same time of year, many small mudflows and debris flows probably occur on the fan surfaces. This is suggested by the irregular distribution of large boulders on the fans, and the general lack of sorting of material, especially on the steeper sections near the fan apexes.

CONCLUSION

(a) Debris fans, like most geomorphological features, are produced and modified by several interacting processes. Although fluvial activity seems most significant for the Schuchert Dal fans, slush avalanches and minor debris flows may also affect the development of debris fans in a periglacial environment. The relative importance of these processes varies between fans and during a year (but any one may become locally dominant), giving debris fans their distinctive characteristics of the nature of the material and the morphology.

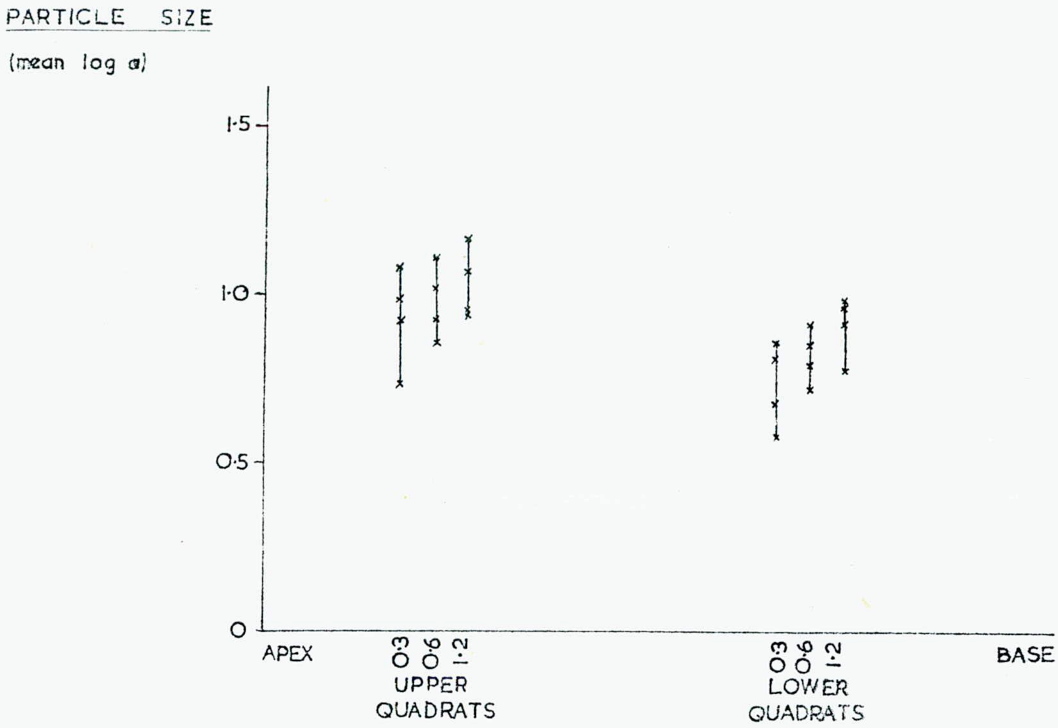
(b) The morphometric parameters of the parent basin above a fan apex impose a certain control on the processes of deposition that are operative, through the hydrologic character of the fan-building stream. On the more active parts of the fans, the main streams are often directed to the edges, and are extending the fans laterally. On the more elongated features, the main stream channel usually lies down the centre, and any extension of the fan occurs at the base.

(c) Present disintegration in the upper corries is relatively slow, especially on the resistant crystalline rocks, but the debris fans are large in spite of this. This lack of agreement between the modern supply and the size of the fans is probably explained by a greater supply of debris in the past. Differing rock susceptibilities is possibly the inherent distinction between different forms of debris fans in Schuchertdal. Debris fans are steeper than most comparable groups of paraglacial and arid fans. There appears to be an intermediate degree of correlation between their basic parameters and fan gradients, and those of paraglacial and arid fans.

Note: For more detailed references, please refer to Christa.

FIGURE C1 VARIATION OF PARTICLE SIZE WITH DISTANCE FROM THE FAN APEX

(a) FOR DIFFERENT SIZES OF QUADRATS



(b) FOR TUNDRA-CAMP, DESOLATION AND BATTERSEA FANS

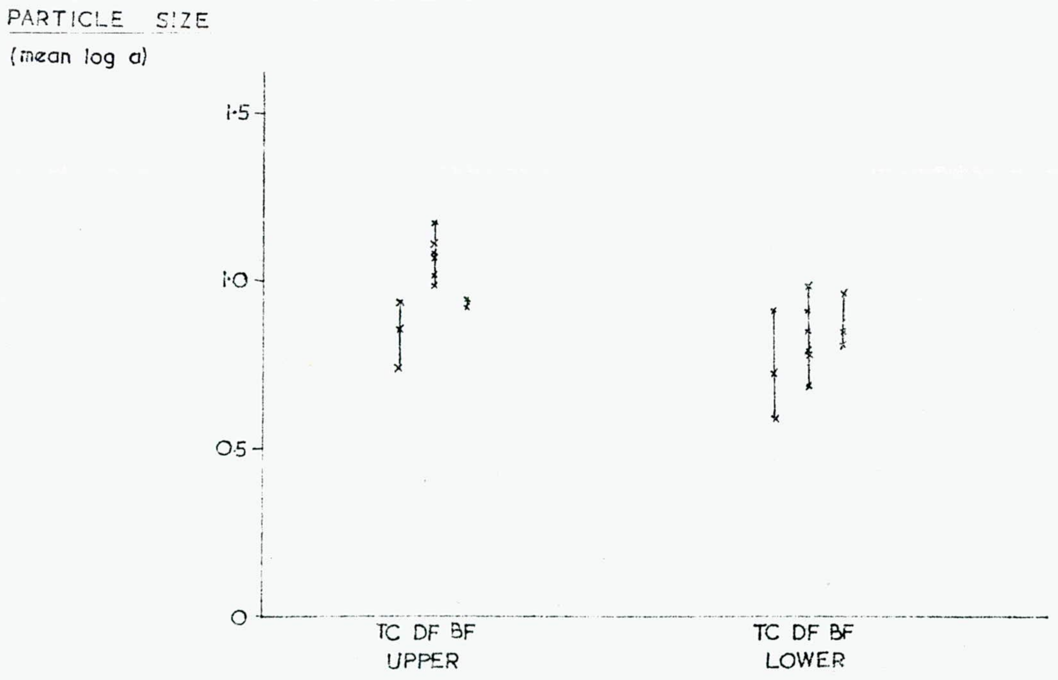
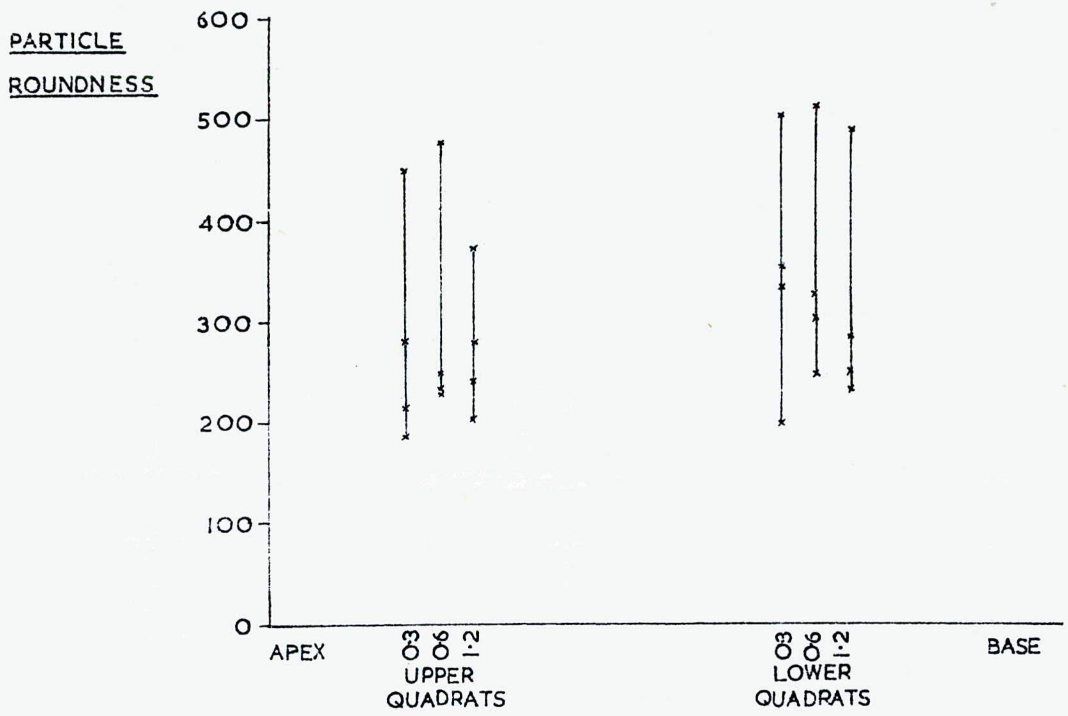


Figure C2 Variation Of Particle Roundness With Distance From The Fan Apex

(a) FOR DIFFERENT SIZES OF QUADRATS



(b) FOR TUNDRA-CAMP, DESOLATION AND BATTERSEA FANS

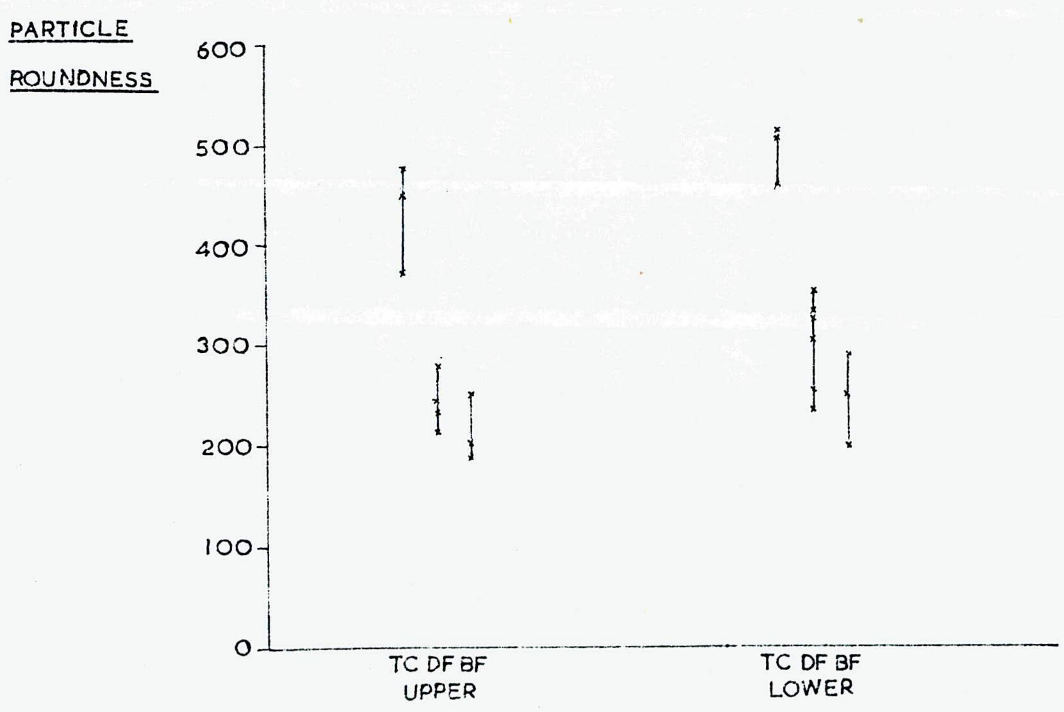
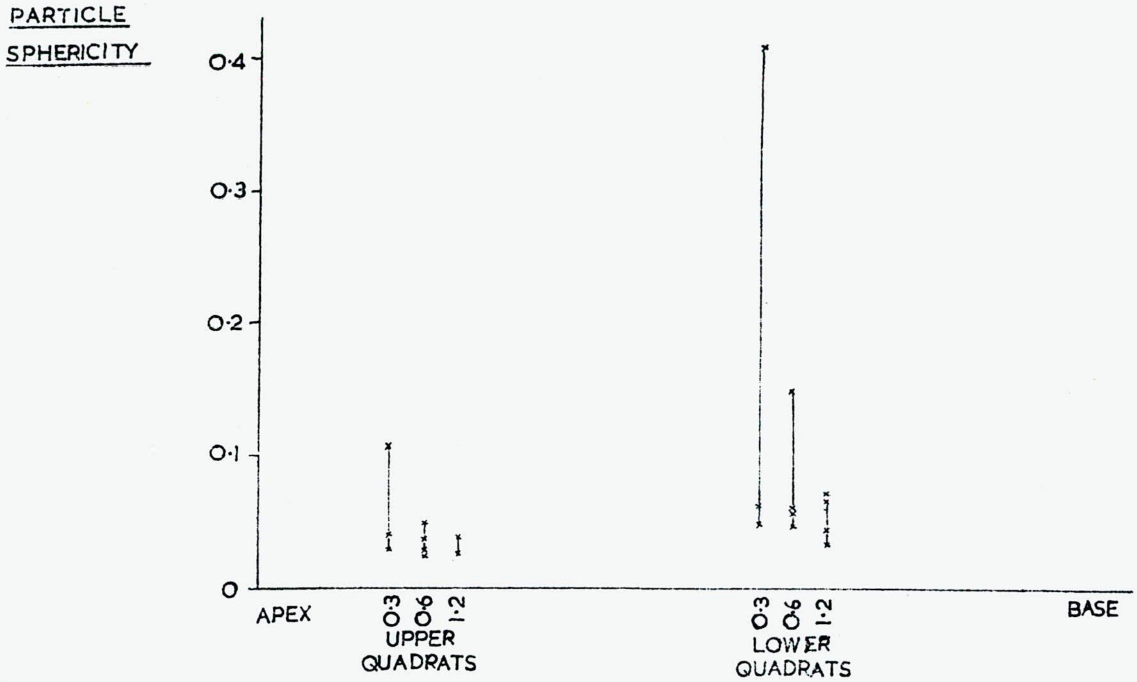


FIGURE C3 VARIATION OF PARTICLE SPHERICITY WITH DISTANCE FROM THE FAN APEX

(a) FOR DIFFERENT SIZES OF QUADRATS



(b) FOR TUNDRA-CAMP, DESOLATION AND BATTERSEA FANS

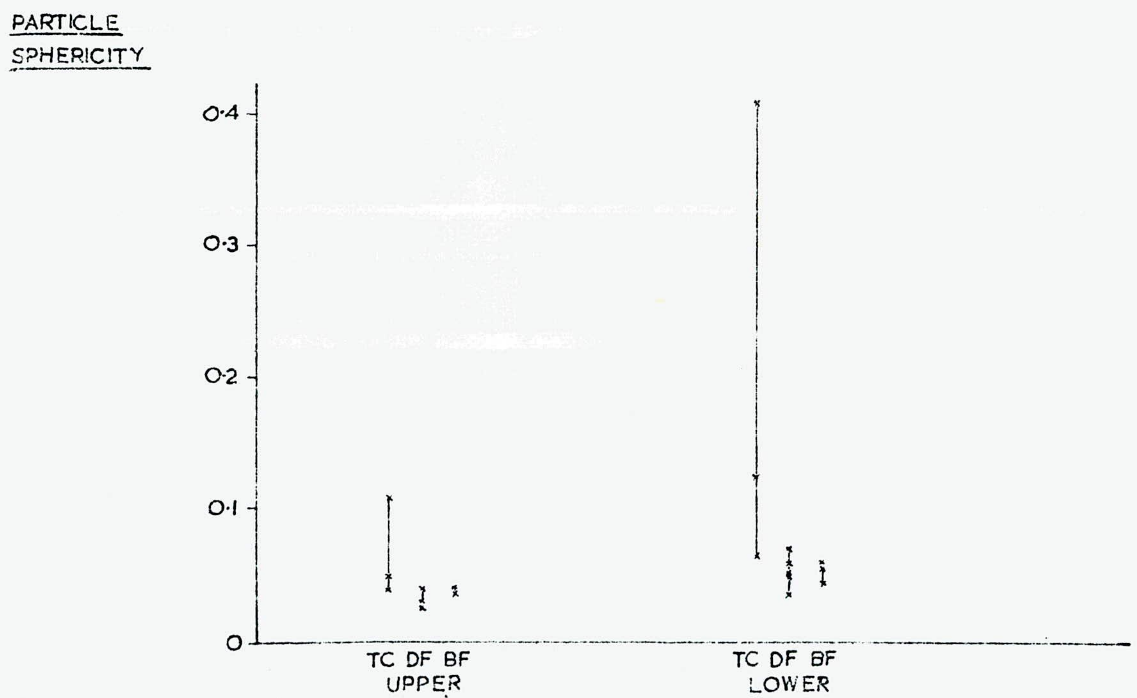


FIGURE C4 GRAPH TO SHOW THE RELATIONSHIP BETWEEN BASIN AREA AND FAN AREA

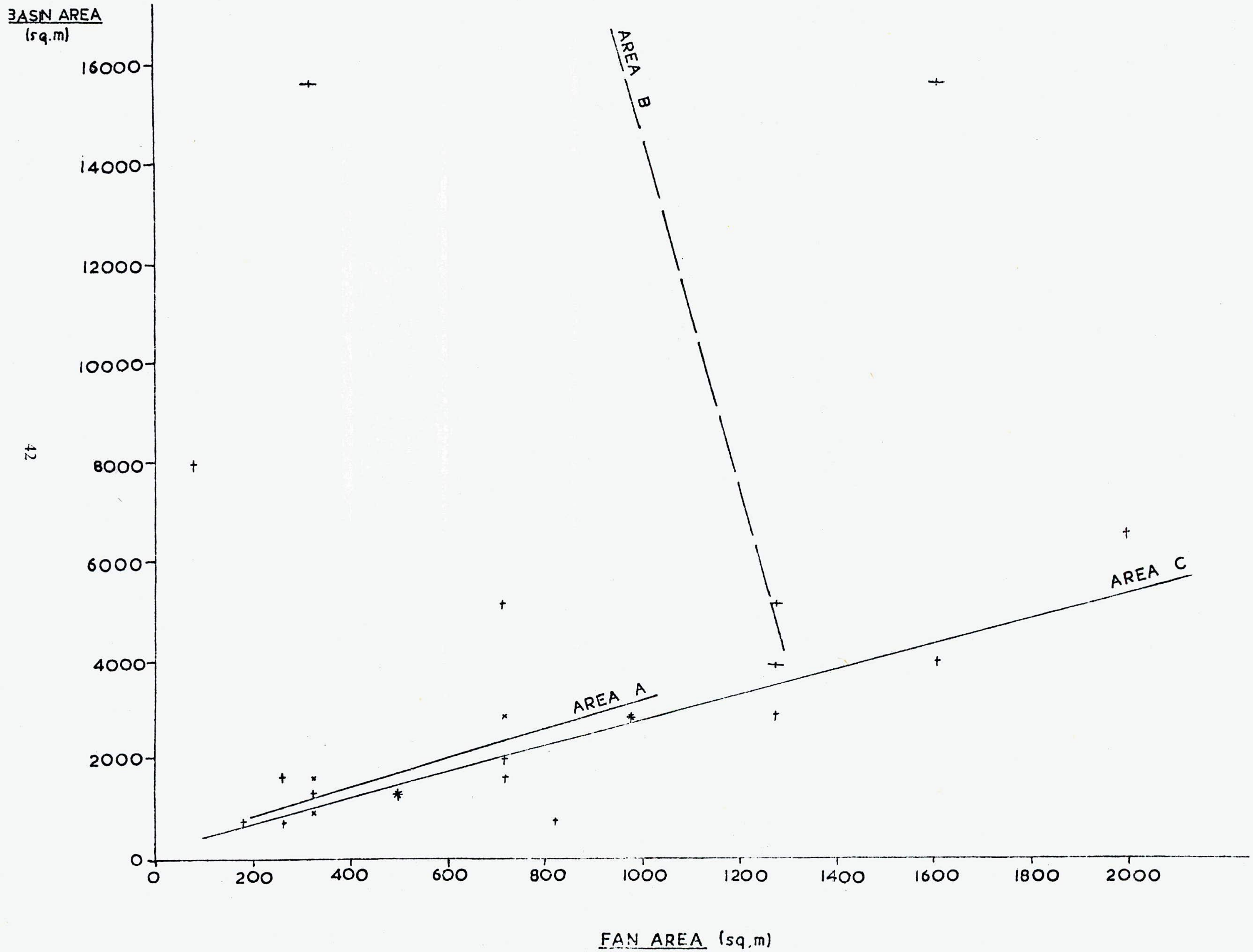


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Figure C5 Graph To Show The Relationship Between Fan Gradient And Basin Area

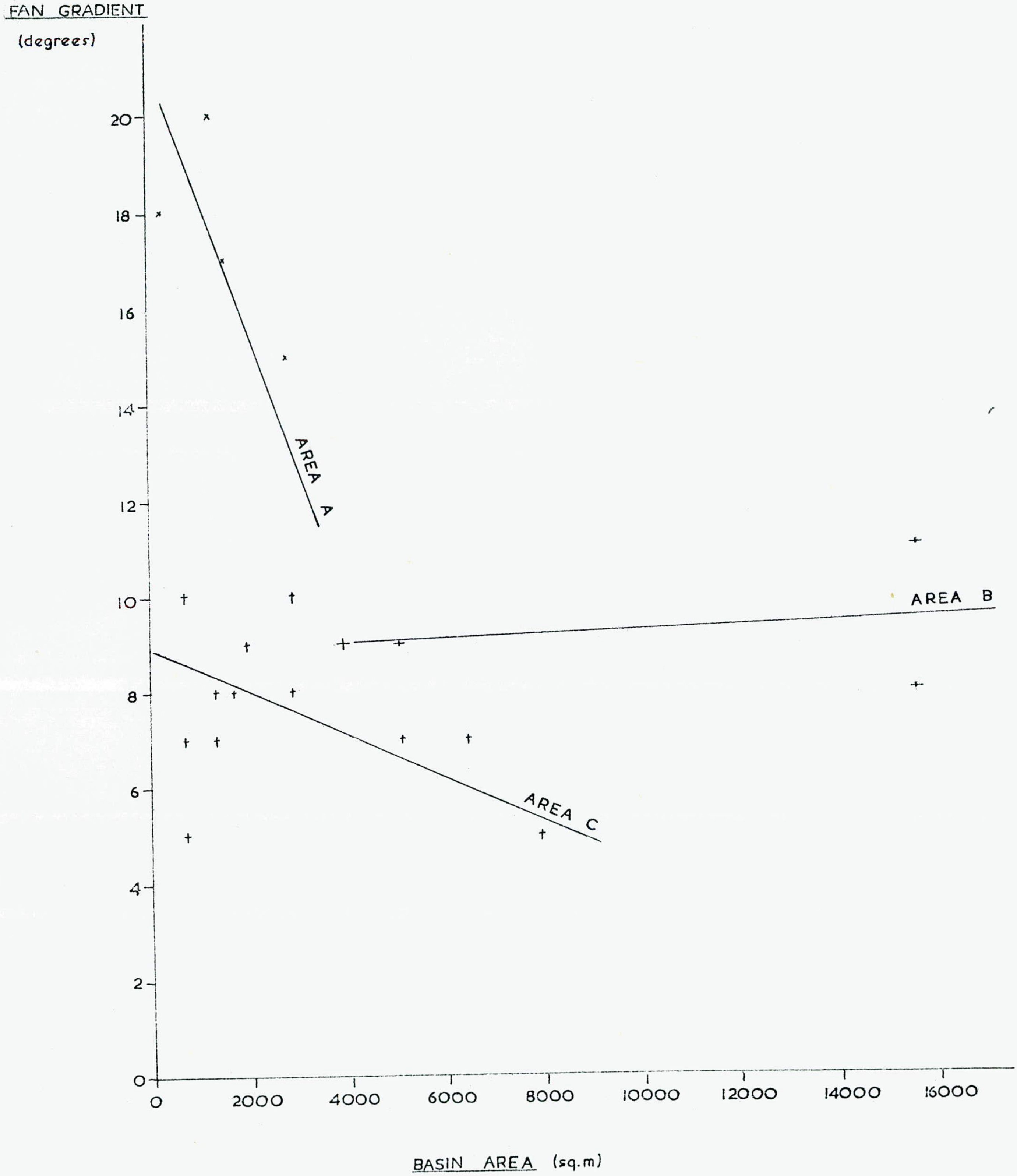


Figure C6   Graph To Show The Relationship Between Fan Gradient And Relative Relief

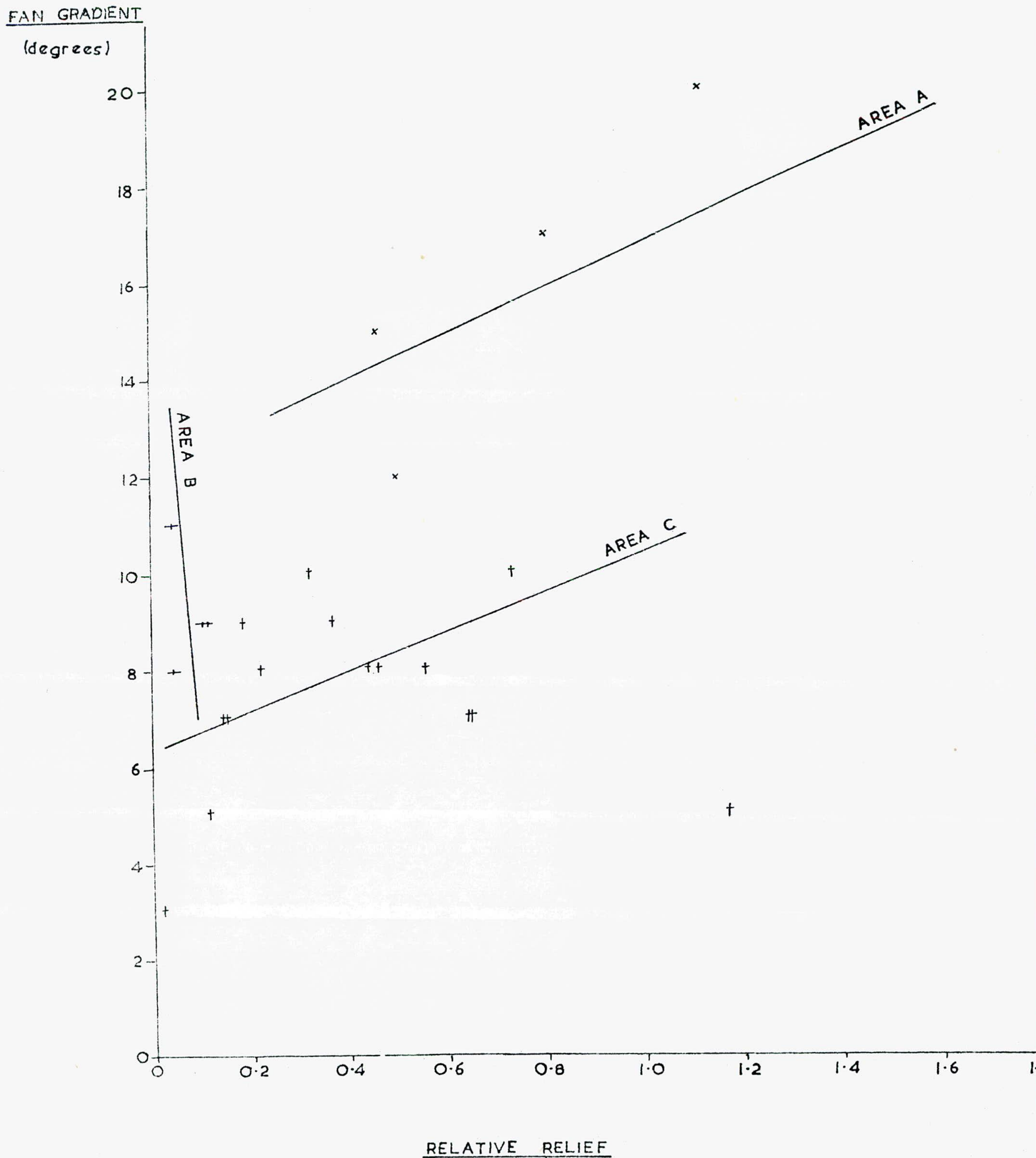


FIGURE C7 GRAPH TO SHOW THE RELATIONSHIP BETWEEN FAN GRADIENT AND MEAN BASIN SLOPE

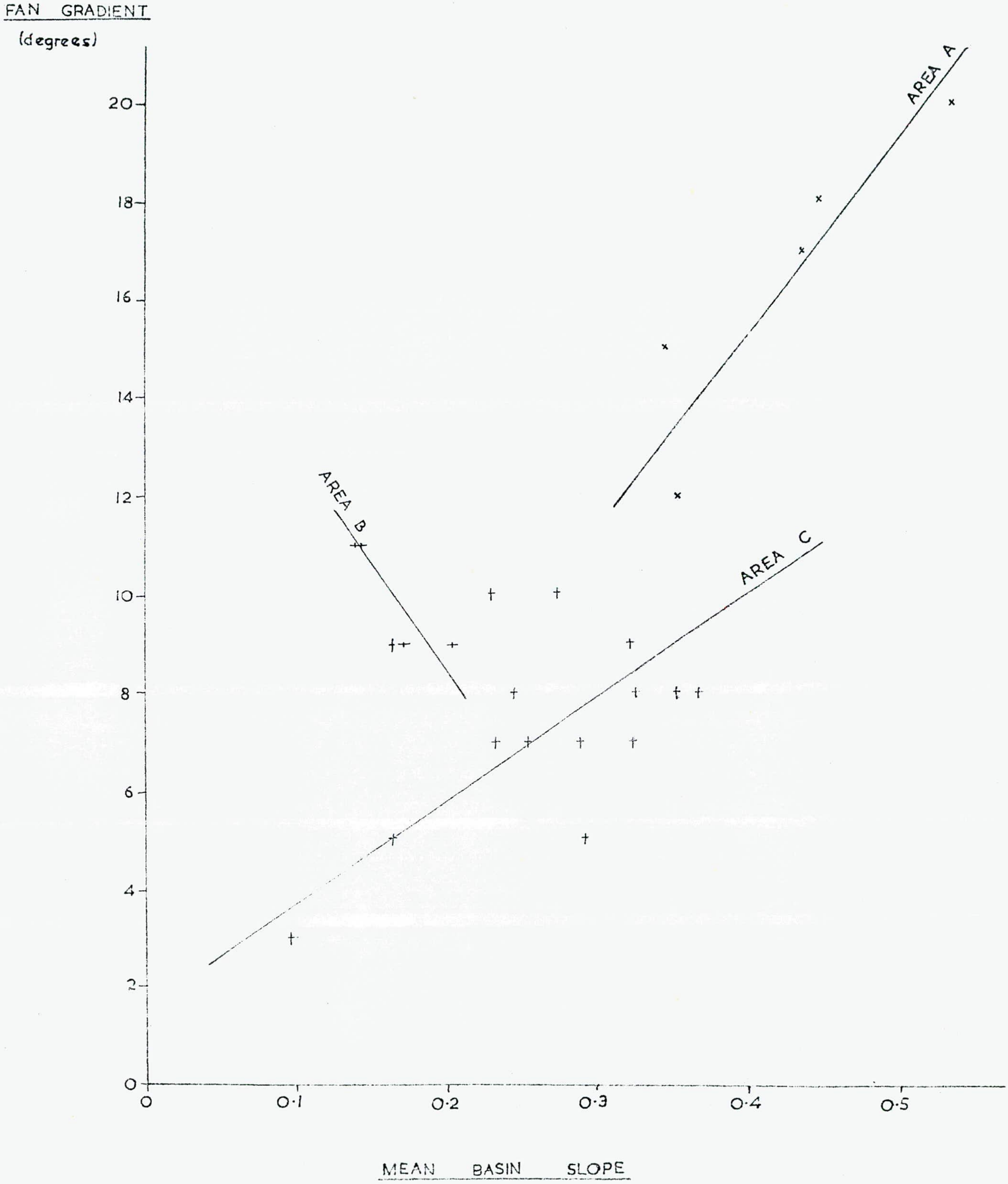
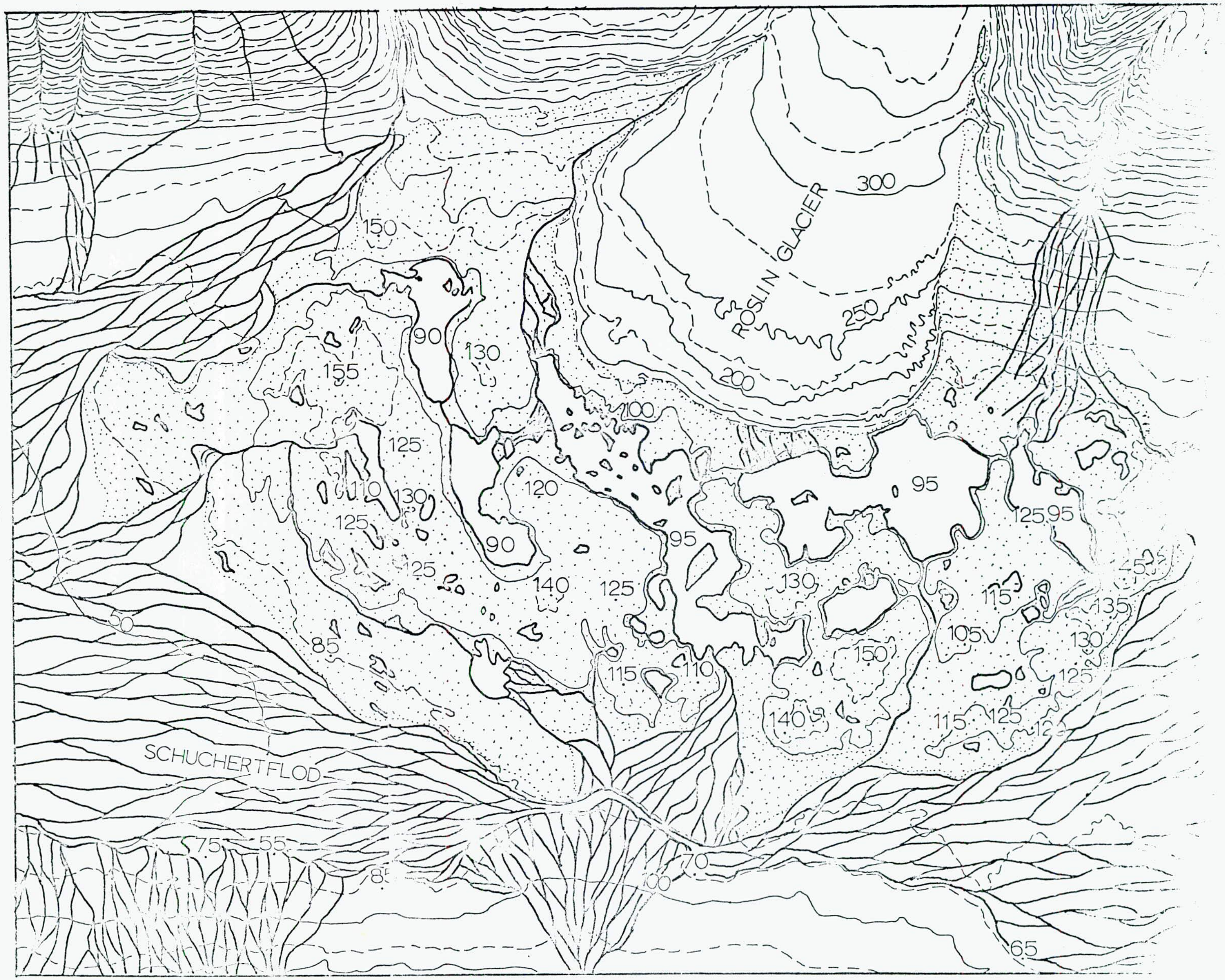


Figure K1



TERMINAL MORAINE OF THE ROSLIN GLACIER (shown stippled)

Scale 1:25,000 Contour interval 25m

THE COLONISATION AND SUCCESSION OF VASCULAR PLANTS ON THE TERMINAL MORAINES OF THE ROSLIN GLACIER K.S.T.

The Flora of Greenland

Greenland as a whole possesses about 500 native plant species, of which roughly half are found in the circumpolar region. 30-40 of these species are endemic to Greenland, while the rest are also found in North America and Europe. About eighty species have their main area in East Greenland — these include a few endemic species, e.g., Saxifraga nathorstii, found around Mestersvig; most of the other species are north European in origin, although a few come from North America.

Three vegetation belts can be distinguished in Greenland: a sub-arctic belt, in inland parts of the warmest valleys of the south and south-west; a low arctic belt, northwards to about latitude 72°N, but restricted to inland areas in its northern extent; and a high arctic belt, including northernmost Greenland and the cold outer coastal areas, southwards to about latitude 69°N. Schuchert Dal lies just within this last belt where willow scrub gives way to Cassiope heaths and extensive boggy tundra areas.

A record card made for the W. Schuchert area by Dr. G. Halliday in 1972, which is unfortunately very incomplete having been made late in the season, includes:—

Arctagrostis borealis
Antennaria canescens
Arctagrostis latifolia
Armeria scabra
Arnica alpina
Betula nana
Braya humilis
Calamagrostis purpuras
Campanula rotundifolia
Carex bigelowii
C. capillaris
C. misandra
C. nardina
C. norvegica
C. saxatilis
Cassiope tetragona
Cerastium alpinum
Chamaenerion latifolium
Cystopteris fragilis
Draba alpina
Draba hirta
Dryas octopetala
D. integrifolia
Empetrum nigrum
Equisetum arvense
E. variegatum
Erigeron eriocephalus
Eriophorum triste
Festuca rubra
Festuca vivpara
Hippuris vulgaris
Hierochloe alpina
Juncus arcticus
J. triglumis
Kobresia mysuroides
K. simpliciuscula
Lesquerella arctica
Luzula arctica
L. confusa
Lycopodium selago
Melandrium affine
Minuartia rubella
Oxyria digna
Papaver radicatum
Pedicularis lapponica
Poa arctica
P. pratensis
Polygonum viviparum
Potentilla hyparctica
Pyrola grandiflora
Rananculus hyperborealis
Rhododendron lapponicum
Salix arctica
Saxifraga aizoides
S. caespitosa
S. cernua
S. nivalis
S. oppositifolia
Sedum roseum
Silene acaulis
Tolfieldia coccinea
T. pusilla
Triglochin palustre
Vaccinium uliginosum
Woodsia glabella

The species found on the moraines in 1972 were as follows:—

Arctagrostis borealis	Juncus triglumis
Arctostaphylos alpina	Lesquerella arctica
Arabis alpina	Minuartia rubella
Betula nana	Oxyria digna
Carex bigelowii	Pedicularis lapponica
C. misandra	Polygonum viviparum
C. microglochin	Pyrola grandiflora
C. saxatilis	Salix arctica
Cerastium alpinum	Saxifraga aizoides
Chamaenerion latifolium	S. cernua
Dryas octopetala	S. oppositifolia
Eriophorum scheutzeri	Silene acaulis
Equisetum arvense	Tolfieldia pusilla
Juncus arcticus	

The Area of Study

The moraines (see Figure 1) consist of unconsolidated material ranging from very fine silty sand, through pebbles and angular cobbles, to large erratics up to 20m in length. The slopes within the moraines can attain steep angles, being almost vertical in some places, but they are very unstable and subject to slumping to a high degree. Cracks up to 20 cms wide can be seen running parallel to the slope contours near the crest, indicative of the tensions produced by slumping. In some places incrustations of carbonates indicate dry, highly alkaline conditions. These effectively preclude plant growth and are quite common, although not extensive.

Many lakes exist in the moraines, some of them quite large (see figure 2), and at many different heights. The levels of water in these lakes fluctuate by different amounts; those lakes with definite stream inflows or outflows are subject to more pronounced changes of level than those which appear isolated. The sediment content of the different lakes varies; those near the glacier are fed by direct run off from the snout and in consequence appear cloudier than the others. (Some indication of the difference in colour of the lakes can be gained from Plate K1). Comparisons of the levels of various lakes in the northern half of the moraines indicate that lake levels were higher in the summer of 1972 than at the same season in 1970. It seems likely that the fluctuations of lake levels do not conform to any one general trend. On old air-photographs various lakes are shown which no longer exist. The permanent height differences between the lakes seem to imply that the moraines are not permeable at depth, although the general surface aridity in other areas indicates that the constituent materials are highly permeable. The possible effect of ice cores in the moraines should not be overlooked, and, in this case, differential melting of the ice cores could well cause differential fluctuations in lake levels.

During a preliminary survey of the area it was found to be impossible to cross the central braided melt stream which runs through the moraines, and it proved impracticable to cross the glacier snout and surrounding quicksands to find a route onto the southern half of the moraines. Therefore only the northern half of the moraines was studied. (See figure 3.)

The concept of climax vegetation in arctic ecosystems.

The use of the concept is often the subject of dispute even in temperate zones, and in consideration of arctic and alpine plant communities its validity is even more doubtful. The concept of climax vegetation implies a development through time towards a steady state in the floristic structure of an area. In arctic regions the apparent instability of habitat and vegetation, and the constant effect of such disruptive forces as frost heaving and solifluction, makes the attainment of such a steady state extremely unlikely.

In many cases the vegetation of arctic areas is apparently controlled by the degree of local geomorphic activity; this gives rise to serious doubts as to whether the resultant vegetation is more than a heterogeneous assemblage of pioneer species. In areas such as this, instability of the

Plate 5 — The Roslin Moraines

surface material is a perfectly normal manifestation of an ecosystem, and can prevent either long occupancy by individual communities, or changes in the communities leading to greater uniformity of vegetation.

"The tundra, as vegetation, is a great many things and its climates will, no doubt, prove equally diverse. Time, surface, materials, topography—all factors controlling landscape—are variable in the extreme: different regions, different complexes, different results. No widespread uniformity should be expected and none is found." Max E. Briton.

Sampling

A preliminary survey was carried out and it was quickly established that the vegetation of the area was extremely diverse both in density of cover and in variety of species. One significant variable appeared to be the degree of stability of the moraine. Thus, in the centre, where little surface moisture was available at the time of study, many signs of sporadic chaotic slumping were apparent, including deep cracks on the steeper slopes; also boulders and cobbles on the slopes were very unstable, and small landslips of sand and gravel could be initiated with very little difficulty. In these areas the plant cover was extremely thin, consisting of very sparsely scattered grasses, and isolated prostrate plants often growing in the lee of large boulders where the likelihood of disturbance was locally diminished. Where stream action or past mudflows had created environments where less catastrophic instability might be expected at more regular intervals the plant cover was much greater and the number of species present greatly increased. A system of stratified sampling was therefore adopted, based upon the type of sorting affecting the surface material, and hence the characteristics of its instability.

In the more densely vegetated communities strip and line sampling was employed, using square quadrats of side dimensions 0.5m. This quadrat size was selected after consideration of the small size of the individual plants and the extreme variability of plant cover. These were arranged in a line plot strip at right angles to the main axis of sorting, each alternate quadrat was examined. A number of such strips was investigated for each community until an adequate sample was obtained. Where a significant change in vegetation occurred in a direction parallel to the main axis of sorting a number of transverse strips, as described above, were sampled to explore the nature of the change and to see whether a new vegetation type had been encountered. If the main axis of sorting is considered as a topographic continuum, then this system is similar to Castro's technique for correlating vegetation changes with topographic changes.

In the very thinly vegetated communities the overall spatial distribution of plants appeared random and the difficulties in applying any sampling system at all were enormous. In the time period available for field survey the chance of any random sampling system, whether using quadrat or line samples, actually including an adequate number of plants, was so small that this line of research was considered unfruitful, and a general description of these areas was employed instead.

The habitats finally selected for study were as follows (see figure K2):

A. Stream deltas within the moraines, subject to fluctuations in water level; sorting by the action of a permanent stream.

B. Permanent stream flowing within the moraines, subject to fluctuations in water level; sorting by stream action.

C. Small fans at the periphery of the moraines descending to the plain of the Schuchertflod; sorting by ephemeral streams and by mudflows.

D. Similar small fans, but steeper; sorting mainly by viscous mudflows and some slumping.

E. Ephemeral lake beds; sorting by water action and mud cracking.

F. Flat sandy fans on E. side of moraines; sorting by stream action and widely effective wind action.

G. General internal moraine topography; occasional sorting by chaotic slumping controlled by a number of factors.

For each sample quadrat the occurrence of any species was noted and an abundance index applied. This index ranged from 1 to 5 as follows:—

1. Very sparse.
2. Sparse.
3. Not numerous.
4. Numerous.
5. Very numerous.

In order to overcome bias due to different growth habits the index number was estimated with reference to the number of plants of a species, the amount of ground cover they provided, their maturity, and vigour. Since this can only be a subjective valuation, it was estimated by the same operator in all quadrats to increase the internal consistency of the measure.

Habitat A

Only two stream deltas exist within the study area. The first, where the small streams from the glacier snout flow into a large lake nearby, is an area of very unstable quicksand where the glacier is melting and actively shedding its moraine, and there are no vascular plants at all in this area. The second delta (marked A on figure K2) is found where the braided stream to the north of the glacier which flows into the terminal moraines enters one of the moraine lakes. Here a single strip transect was taken across the delta at its central point. The delta was approximately 74m. across at this point, with several minor channels and one main stream channel. Some of the minor streams were dry and some contained flowing water at the time of sampling, but the main channel was wide and, although fluctuating in discharge, seemed permanent. The regime of this stream varies with the amount of melting taking place in the snow-filled cirque which is its source, and therefore discharge varies both annually and diurnally. On either side of the delta the moraines rise fairly abruptly to a height of 3 to 4 metres above the delta floor and these moraines are dry and poorly sorted like the rest of the internal moraines. In general the surface material of this area is very fine sand with occasional cobbles and boulders; the consistency is loose, although very slightly sticky when wet, and the material is non-plastic.

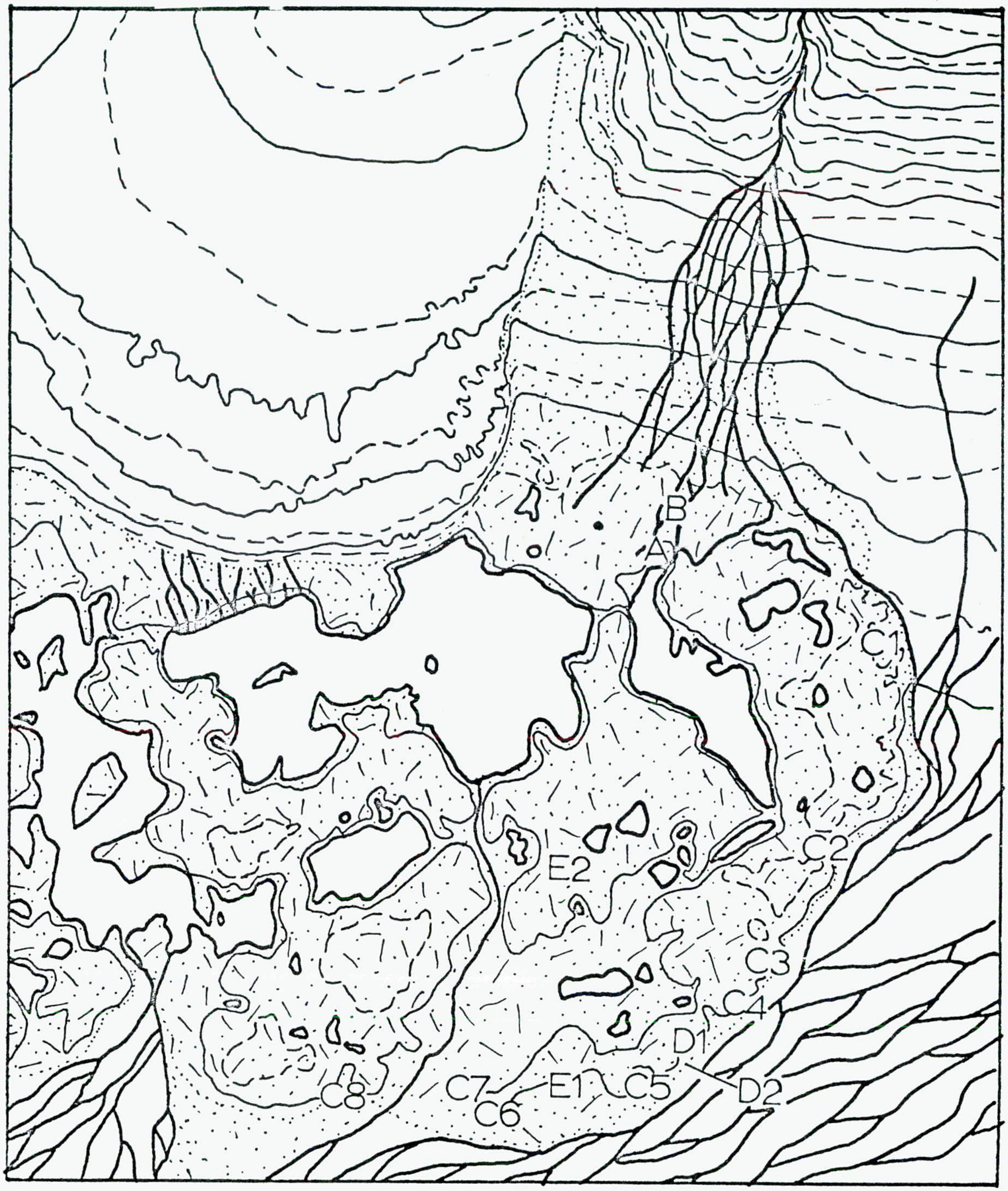
The most abundant genus in this habitat proved to be **Juncus,** with two species **J. arcticus** and **J. triglumis** occurring with almost equal frequency although seldom found together in the same quadrat. **J. triglumis** occurs exclusively in the wettest areas only about 5 cms. above the level of the main stream channel where ephemeral streams had obviously been flowing quite recently. **J. arcticus** occurs on slightly drier interfluves and is most abundant 5-10 cms. above the stream channel, although it is found sporadically up to 20 cms. above that level.

The genus **Carex** is slightly less abundant but more widespread in distribution, avoiding only the very wet, sandy area near the main stream channel. These plants are most abundant at the borders of the delta, 20 - 40 cms. above the level of the stream channel, where the surface soil is dry. **C. misandra** was by far the most common species, although individuals of **C. bigelowii** and **C. saxatilis** were also found. These two genera combined to give the delta a green grassy aspect which, although sparse and patchy, was not found anywhere else in the moraines.

Saxifrages are moderately abundant, all, except one plant of **S. oppositifolia,** being the yellow **S. aizoides** (see plate 3). These prefer slightly drier more stony conditions than the Juncas and generally seem to surround the green patches of those plants mingling sparsely with the outer individuals of **J. arcticus. Salix arctica** is also moderately abundant and generally prefers the drier areas. Most of these plants are small, the majority showing only one to four years' growth. This may indicate that in this unconsolidated soil spring flooding is sufficient to uproot and carry away any dwarf willow plants sufficiently large to impede the flow of water.

Eriophorum scheutzeri was found in a few of the wettest places where it was locally more abundant than **Juncas triglumis.** One or two plants of **Saxifraga oppositfolia**, **Silene acaulis** and **Chamaenerion latifolium** grow at the drier, stony borders of the delta, but in general the habitat was unsuitable for these species to flourish.

Figure K2



LOCATION OF SAMPLE SITES

Scale 1:25,000 Contour interval 25m

A rough correlation between topography and vegetation of this habitat can be established from the samples taken, although it must be emphasised that the ranges of the various species overlap to a great extent and that no clear cut zones can be defined. The driest areas are **Chamaenerion latifolium,** while small plants of **Salix arctica,** also **Saxifraga aizoides** and **Carex misandra** are found in slightly moist pebbly areas. **Juncus arcticus** gradually takes over in the moist sandy areas, and is in turn superseded first by **J. triglumis** and then by **Eriophorum scheutzeri** as the surface sand becomes progressively more saturated by water from the permanent and ephemeral streams of the delta.

Habitat B

Of the streams flowing within the study area only those flowing into the moraines from the braided stream to the north provided suitable communities for study under this section. The streams from the glacier snout flow through quicksand and no vegetation exists in this area. The outflow stream from the long central moraine lake is very fast flowing and carries a quantity of suspended sediment; it flows over a large sandy alluvial fan which is subject to permanent sorting by wind action and the vegetation of this area is therefore treated under section F. The outflow stream from the large lake in the northern part of the moraines is ephemeral and although a large valley in pebbles and cobbles exists in the moraines no water was ever seen in it during the study period and it is assumed that this stream only exists during the spring snowmelt when the amount of water available is much greater. No especial plant communities are associated with this stream and the surrounding vegetation is treated under section G.

The vegetation of this habitat was sampled in the area marked B on figure K3. The soil is similar to that described under habitat A although the surface was often covered in pebbles, cobbles and boulders. Four sample areas were selected at intervals upstream, and in each sample area two to four strip transects were taken at right angles to the long profile of the stream bed, the distance between the transects being approximately equal to the average distance between the interfluve and the stream channel.

Sample area I is at the break of slope where the stream channel flattens out into the delta. Here a single wide stream flows between cobbles and pebbles embedded in very fine sand in a valley about 30m. wide. The steep valley sides have very little vegetation, are extremely dry and show signs of slumping. The boundaries of the strip transects are determined by the limits of evidence of sorting by stream action. Four transects were taken in this area working upstream from transect (a).

Salix arctica proved to be the most abundant species occurring in 82% of all the quadrats investigated. Many of the plants were well established, showing 6 to 9 years' growth, and one plant was at least 13 years old. This part of the stream must be subject to annual flooding in the same way as in habitat A, but here the surface of cobbles and boulders allows the individuals to become more firmly anchored by their roots, and therefore these willows are not so easily washed away.

Carex misandra is abundant and occurs in 90% of the quadrats investigated in the two lower transects, but in the upper transects it is less widely distributed and occurs in only 33% of the quadrats, generally where a sandy surface locally replaces the pebbles and cobbles. **Saxifraga aizoides** occurs in about 90% of the quadrats of the lowest transects, but this high level of constancy decreases upstream to only 25% in the highest. This plant grows most abundantly in moist areas, especially in ephemeral or abandoned stream channels, and seems to prefer a sandy surface, although it is found growing among cobbles.

Chamaenerion latifolium is found growing sparsely in a variety of situations, ranging from dry cobbles to abandoned sandy stream channels; the plants in the former conditions are more vigorous, but it is evident that this species will tolerate a wide range of conditions. **Silene acaulis, Saxifraga oppositifolia** and **Polygonum viviparum** all occur more frequently in the upstream transects of this sample area, although none of them is widespread or abundant. Isolated occurrences of **Juncus arcticus** and **J. triglumis, Equisetum arvense, Tolfieldia pusilla, Pedicularis lapponica, Dryas octopetala** and **Cerastium alpinum** are recorded in this area.

Sample area II starts 120m. upstream from the last transect of area I and consists of two strip transects 15m. apart. Here the stream is braided and flows in a valley of cobbles and boulders bedded in fine sand.

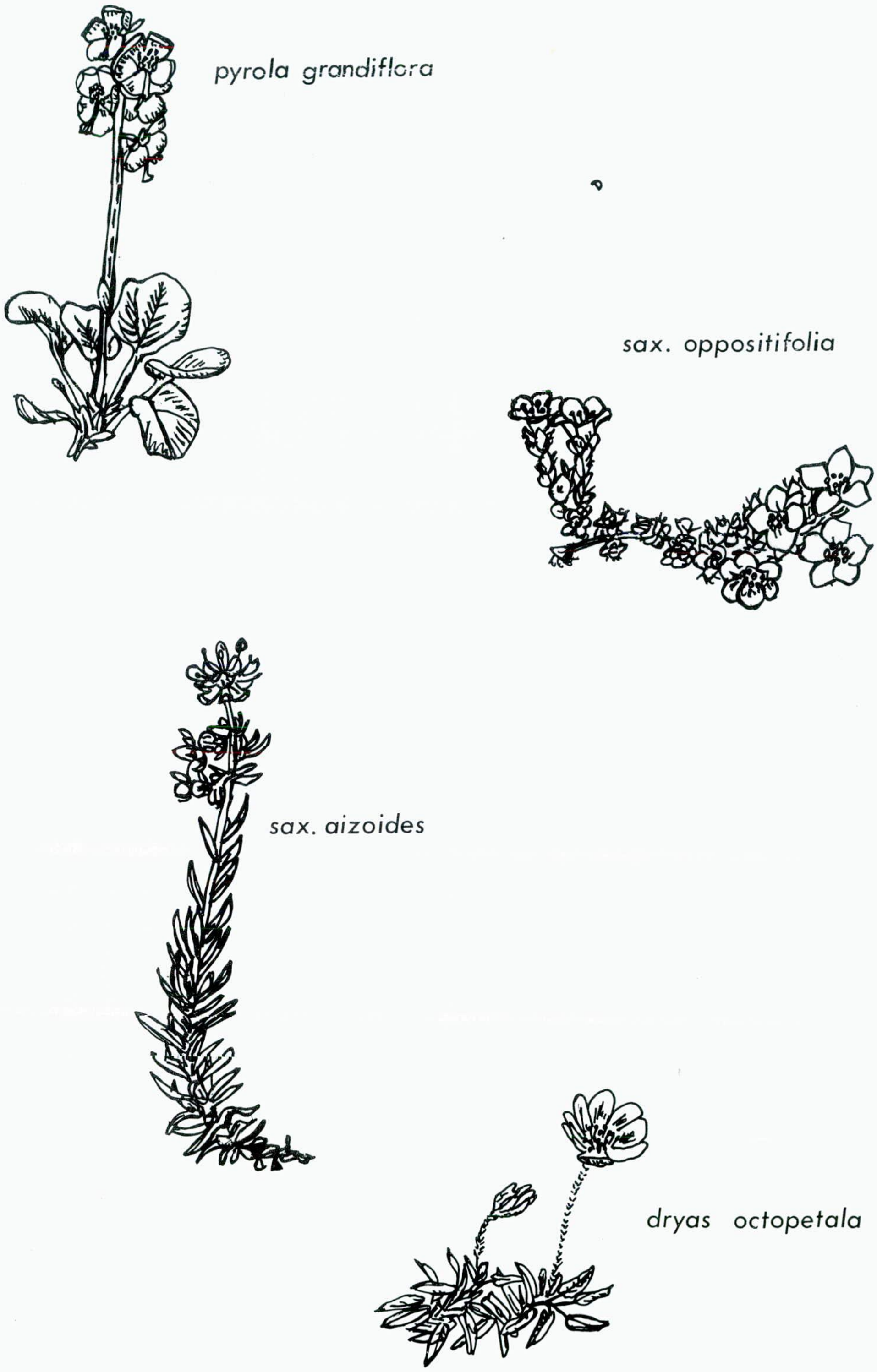
In this area **Salix arctica** and **Carex misandra** are the most abundant plants and both occur in at least 80% of all quadrats. Many of the willows have been covered by fine sand so that only 1 to 2 years' growth shows above the surface, but from the size of the plants it is obvious that many of them are at least 5 years old. **Saxifraga aizoides, Chamaenerion latifolium** and **Polygonum viviparum** are all reasonably abundant and all occur in about half the quadrats sampled. **S. aizoides** is found mainly in the wetter areas, between stream channels or in abandoned channels. The range of **C. latifolium** is slightly greater and it appears to grow best in moist stony places. **P. viviparum,** although less abundant in any one quadrat, tolerates a wider range of conditions. **Saxifraga oppositifolia** is only sparsely abundant, but occurs in about half the quadrats in a great variety of conditions. Small plants of **Silene acaulis** and **Dryas octopetala** are found in a few quadrats; **S. acaulis** tends to avoid the very damp mossy areas, while **D. octopetala** is found less abundantly at such sites. **Juncus arcticus** and **J. trigiumis** are much less abundant in this area; the former in only some of the moist quadrats and the later scarcely in any. **Tolfieldia pusilla,** although very thinly spread, appears well distributed through differing conditions. Individuals of **Pedicularis lapponica, Cerastium alpinum** and **Equisetum arvense** were also encountered.

Sample area III starts a further 42m. upstream, and consists of 3 strip transects 15m. apart. The stream is braided and flows between unsorted moraines; many of the old stream beds were dry during the period of study. The surface is of cobbles and boulders underlain by very fine sand. **Chamaenerion latifolium** and **Salix arctica** are the most abundant species in this area. Each one is found in about 60% of the quadrats sampled and they are found together in 50% of the quadrats in diverse conditions. Many of the willows are 6-8 years old, while the oldest sampled showed 14 years' growth.

Polygonum viviparum was found in 40% of the quadrats sampled, generally growing under damp, mossy conditions in the sandy crevices between cobbles. In such places it frequently attains an abundance index of 3. **Carex misandra** grows most abundantly in the wettest quadrats, **Saxifraga aizoides** in somewhat drier places, and **Dryas octopetala** in the driest quadrats of the area. These three species all occurred in about 30% of the quadrats. **Silene acaulis** and **Saxifraga oppositifolia** occur in a few of the drier quadrats growing as dense, compact cushions with high abundance values. Individuals of **Cerastium alpinum, Betula nana, Juncus arcticus, Tolfieldia pusilla, Saxifraga cernua** and **Oxyria digna** were also found.

In sample area VI, 170m. upstream, the stream is actively cutting down between bouldery interfluves. The valley is much narrower, but there is plenty of soil, which is fairly damp, and relatively thick vegetation cover, including plenty of moss, is found here. Again **Chamaenerion latifolium** and **Salix arctica** are the most abundant species, each showing a constancy of about 90% and in many of quadrats occurring numerously. Many of the willow plants are at least 7 years old, showing that the instability of surface material in this area is not of the type to disrupt willow plants while they are still small. **Polygonum viviparum,** although less abundant, has an almost equally high constancy value, indicating a wide tolerance of conditions in this area. **Carex misandra** occurs sparsely in nearly all the quadrats studied. **Dryas octopetala, Pedicularis lapponica** and **Tolfieldia pusilla** all occur in a few quadrats with abundance indices from 1 to 3. Individuals of **Silene acaulis, Saxifraga aizoides, S. oppositifolia, Pyrola grandiflora, Betula nana** and **Equisetum arvense** were included in the sample.

In this habitat the number of species in the various sample areas decreased downstream. This stream flows across the tundra over a wide talus fan before entering the moraines and nearly all the plants found in the moraine are also found on this fan. The exceptions are the plants found generally on the delta such as species of **Juncas, Eriophorum** and **Equisetum.** Such species as **Pyrola grandiflora, Pedicularis lapponica** and **Saxifraga cernua,** which are present in the upstream sample areas, but not in the lower ones, are found in greater abundance on the tundra and on the talus fan. The seeds of these plants may well have been fig K3



SOME PLANTS TYPICAL OF WEST SCHUCHERT DAL

sue

carried by the stream from the talus fans into the moraines. This would account for their numbers decreasing rapidly farther into the moraines. In the upstream transects plants capable of tolerating a wide range of conditions such as **Chamaenerion latifolium, Salix arctica** and **Polygonum viviparum** are more widespread and abundant than in the transects near the delta. The plants which thrive in moist sandy conditions, **Juncus arcticus, J. triglumis** and **Eriophorum scheutzeri,** are scarcely found at all in the upstream sample areas which are generally drier and more stony. Plants with wider tolerances but which prefer the damper, sandy regions, e.g., **Carex misandra** and **Saxifraga aizoides,** are less abundant in habitat B than on the delta, and are found less often in the upstream areas than downstream.

Habitat C

On the north and north-eastern periphery of the study area the steep descent of the moraines to the surrounding flood plain is occasionally interrupted by wide gullies. The floors of these gullies consist of moraine material which has been moved as mudflows; in some cases definite lobes can be distinguished. In general these take the form of rather steep fans, sometimes flattening and widening abruptly towards the bottom, with the channels of small braided streams etched upon the surface. These streams are ephemeral, probably existing only in spring, and during the study period no water was ever seen to flow in them, nor was the surface ever more than slightly damp. Although the surface material is generally very fine sand, sometimes forming a crust when dry, in some places cobbles occur on the surface and occasional huge boulders up to 20m. in diameter are found firmly embedded in the finer material. These boulders have induced local surface stability on their downhill sides, and in these localities vegetation cover is greater and often of a different character than in more exposed places.

Sample areas CV to CVIII (see figure K2) were of a slightly different nature. These were elongated basins within the moraines with a definite break of slope forming a back wall. The long axes of these basins are transverse to the main moraine/flood plain junction. At the lower end of such basins a slight lip can be distinguished with a small fan below. Small dried up stream channels are found on the floors of many of these basins. It is suggested that these basins are formed by the erosive action associated with more persistent snow patches which linger in the basins in spring; the meltwater from these patches allows progressive lowering of the basin floors and redeposition of some of the entrained material as the small fans below the lip.

The vegetation cover of these areas is much thinner than in habitats A and B, and is very variable from place to place. Thus the lower ends of the fans tend to have more cover, especially when markedly flatter and better sorted; also the vegetation of the gully sides is of a different nature from that of the fan itself, being either non-existent or consisting almost entirely of plants of a creeping habit such as **Salix arctica, Arctostaphylos alpina, Betula nana, Dryas octopetala, Silene acaulis** and **Saxifraga oppositifolia.**

The three most abundant plants in this habitat were **Dryas octopetala, Salix arctica** and those of the genus **Carex,** mostly **Carex misandra,** although some **C. microglochin, G. bigelowii** and **C. saxatilis** were also found. The **Dryas,** although sometimes found growing on the borders of stream channels, was most frequently found on the drier, steeper gully sides where its dense mat of roots and low clumping habit overcomes the disadvantages of the unstable soil. **Salix artica** was also most abundant in such places, but young plants could be seen growing on the central fan. Presumably this species cannot become well established on the fans because the annual flooding and mudflowing disturbs its roots when young, while on the gully sides the less frequent (although more drastic) slumping permits the development of larger plants. In the protection of the very large boulders already described both **Salix** and **Dryas** can be found in abundance. On the other hand, **Carex misandra** grows quite sparsely in a very wide range of conditions; it is found growing in dry stream channels and on the gully sides in association with **Dryas,** but it grows best in the sand rather than among cobbles. **C. microglochin** is confined almost exclusively to the wetter areas, but the other species all seem equally widespread.

Arctostaphylos alpina is very localised in its occurrence, but where found it grows abundantly. This plant, like **Salix arctica,** is prostrate with branched stems; thus one plant can completely fill a quadrat and may spread into more than one without providing more than 30% ground cover. Three individual patches were found at CI, all growing at the extreme, dry, edge of the fan, and the rest of the plants sampled were found at CVI, CVII and CVIII. These three elongate basins all run approximately west-east; thus the side walls face north and south. Without exception **Arctostaphylos alpina** grew only on the dry, sunny, south-facing wall; while **Dryas,** the other plant abundant on these basin walls, grew on both the north-facing and the south-facing slopes. **Betula nana** favoured similar localities, but was much less abundant; only a few small individuals were sampled.

Although few individuals of **Silene acaulis** were encountered, this plant was found in a wide range of conditions at sites CI to CV, but was almost entirely absent from the east facing basin CVI to CVIII. **Saxifraga oppositifolia** was found at all the sample sites. It was slightly more abundant than **Silene** and showed a slight preference for the steeper gully sides, although also found on the fans and basin floors. **S. aizoides** only occurred in abundance at site CV, where the soil was slightly damper than at any of the other sites. Here it grew quite vigorously on the basin floor, while at the other, drier sites it was scarcely found at all. **Chamaenerion latifolium** was generally widespread in distribution, but only very sparsely abundant. Comparatively few plants were sampled and those which were included were on the whole small, non-flowering specimens. **Polygonum viviparum** grows almost exclusively in the damper places, generally found thinly scattered at the lower ends of fans where water is retained longest, and found in relative profusion at site CV. Individuals of **Cerastium alpinum, Tolfieldia pusilla, Lesquerella arctica** and **Pedicularis lapponica** were found.

In this habitat it would appear that conditions are generally too dry or too sandy for **Saxifraga aizoides, Polygonum viviparum** or **Chamaenerion latifolium** to flourish, but pioneer individuals still colonise and become concentrated in the slightly more favourable areas. **Silene acaulis** and **Saxifraga oppositifolia** both occur under a wide range of conditions, but are not numerous in any; although no special advantages are available in this habitat they are sufficiently hardy to grow here. **Carex** can adapt to any of the conditions found and grows sparsely throughout these sites. **Dryas octopetala** and **Salix arctica** can colonise the fans and basins, but are hampered by the annual movement of surface material. On the gully walls and basin sides these plants flourish since there is more chance of their getting established before any slumping occurs. **Arctostaphylos alpina** is absent from most of the rest of the moraines, but is found in abundance on the dry, sunny, south-facing walls of sites CVI — CVIII.

Habitat D

The sites chosen for this habitat were similar to those of CI — IV save that the fans were steeper (c. 30° — 35°) and that signs of stream action were very poorly defined. These fans must have been formed by slumping or by very viscous mud flow, and during the study period the soil was much damper than at the sites in habitat C. Only two sites were found, and at each one three strip transects were sampled, one at the top of the fan, one at the middle, and one at the bottom. In both cases the vegetation cover was even thinner than at habitat C, and the amount of cover increased towards the base of the fan. Vegetation was largely restricted to the central long axis of the fan where faint signs of very intermittent stream action could be discerned; this area was damper than its immediate surroundings.

Salix arctica and **Carex misandra** are the most common plants, the **Carex** being marginally more widespread overall while the **Salix** appears a little more abundant in the quadrats where it was found. **Dryas octopetala** grows sparsely at the base of the fans. **Polygonum viviparum** is almost numerous in the damper quadrats. Apart from these individuals of **Silene acaulis, Saxifraga oppositifolia** (at the drier fan margins), **S. aizoides, Chamaenerion latifolium** and **Tolfieldia pusilla** were found.

These findings seem to emphasise the general adaptability of **Salix artica** and **Carex misandra** to a variety of moraine sites and to indicate that **Polygonum viviparum** can flourish at sites slightly too dry to permit the growth of Saxifraga aizoides. The only quadrat where **Chamaenerion latifolium** was found flowering was a very bouldery area of stream channel where these were the only plants growing.

Habitat E

These dried lake beds are very different from the permanent moraine lakes marked on figure K1, being merely slight depressions which are sometimes filled with water and which are generally damp. Some of the lakes studied held water and some did not during the period of field investigations. This type of lake is most common on the east side of the moraines, both towards the periphery and in the interior. The localised availability of moisture produces a very different type of vegetation from that found in habitat G. The surface generally consists of very fine sand with occasional cobbles and small boulders. One site also exhibited a very low angle mud flow, and here the vegetation was very similar to that on the mudflats of the lake bed. Four sites were chosen and each sampled with two strip transects at right angles crossing in the centre of the lake bed. Where the lake contained water the line of these transects was judged by eye.

The vegetation of the lake beds varied in several respects, and various significant features may be determined. In three of the four sites **Juncus arcticus** flourished in the wetter hollows, especially in the central areas, attaining abundance indices of up to four in some quadrats. In the fourth lake bed **Juncus arcticus** grew only very thinly in a few of the most central quadrats. This may be due to the fact that this site was drier than the others. **Salix arctica** again grew in a variety of conditions, and attained higher ages on the lake beds than in the surrounding moraines; one individual was at least 15 years old. This may be attributed to the stability of these sites. **Chamaenerion latifolium** flourished only at the drier site and was scarcely found at all in the wetter lake beds. At the drier site, however, it was numerous in many of the quadrats and was found in over 80% of the quadrats sampled. **Saxifraga aizoides** was fairly common, occurring with abundance in the quadrats surrounding the **Juncus arcticus** and also occurred, although less frequently, in the slightly drier boundary regions. **Saxifraga oppositifolia** was found towards the drier margins of the sites, although in low densities. **Carex misandra** was found growing sparsely in a large number of quadrats in these sites, but in the wetter central regions was often replaced by **C. microglochin** which grew far more abundantly there. **C. microglochin** is not found at all in the drier regions while **C. misandra** does extend, although thinly, into the central regions. **Dryas octopetala** occurred at the margins of most of these sites, but at the drier site some quadrats of the lake bed proper contained small plants of this species. Individuals of **Tolfieldia pusilla, Agrostis borealis** and **Polygonum viviparum** were found.

Habitat F

Streams, both permanent and ephemeral, from the major moraine lakes have built up large, almost flat, alluvial fans of sandy material at the eastern edge of the moraines. The dominant winds blow up the Schuchert valley from the south and are particularly strong in this area. Wind blown sand was observed in motion during the study period and this kind of sorting probably takes place throughout the year. The fan surfaces consist of dry, loose sand or of gravel and cobbles smothered in blown sand. The steeper moraine slopes surrounding this area are flanked by sand dunes. The river banks and beds consist mainly of cobbles and some parts of the outwash fans were made up of this material with any ephemeral stream channels picked out in sand on the surface.

The vegetation of this area was very sparse, consisting mainly of small scattered clumps each of one species only. The most common were **Salix arctica, Saxifraga oppositifolia** and **Dryas octopetala,** although some **Arctostaphylos alpina** was encountered, invariably in sunny places. All these plants are either prostrate with branching stems or else form dense flat cushions and thus stabilise the sand on which they grow. However, wind-blown sand is deposited on the south facing side of these clumps, and gradually a hummock of vegetation about 8 cms. high is formed; this is especially noticeable with **S. oppositifolia** and **D. octopetala.** All these clumps of vegetation are inundated by wind-blown sand although not covered. The plants of **Salix arctica** generally showed only one year's growth through the sand although the size of the plants indicated that they were considerably older. **Carex misandra** and **Chamaenerion latifolium** were also found, the latter in more stony places.

Habitat G

The character of vegetation in the dry interior moraines does not vary much, although the density does. The most common plants are **Salix arctica** growing as individuals of varying age in sandy hollows or from under large boulders, i.e., where the stability of the surface is increased and the plant can anchor its roots more securely. **Dryas octopetala** and **Chamaenerion latifolium** are also commonly found in the interior, again, growing where their roots can be well anchored. Some **Juncus arcticus** is found in the occasional damp areas, but **Saxifraga aizoides** is rarely encountered.

The extremely dry, sandy moraines of the north-east side are liberally encrusted with carbonates, and here no vegetation is found. Elsewhere the more sandy areas have a sparse vegetation of **Carex misandra** and **Chamaenerion latifolium,** while the chaotic, stony-bouldery moraines which form the higher ridges show widely isolated clumps of **Salix** and **Dryas.** These clumps are slightly more numerous and larger on the outer fans of the rim of older northern moraines.

Conclusions

The data collected and described above are, unfortunately, not suitable for quantitative treatment by such methods as ordination, due to the impossibility of developing a systematic sampling technique in the time period available for study. However, various findings may be noted, the first being that the concept of climax in its simpler forms cannot be applied to the development of vegetation on these moraines. The vegetation observed here does not develop sequentially through time towards a final steady state. Three main factors dictating the present vegetation of an area can be distinguished — stability of the surface material, since the frequency regularity and effectiveness of any surface movements will profoundly affect the vegetation of an area; the moisture content of the surface material; and the nature of the surface material, whether sand, gravel, cobbles, boulders or a chaotic mixture of all of them.

These three factors are by no means independent of each other, nor are they independent of time. The older moraines may well tend to be more stable than the younger — this may account for the slightly denser vegetation of the northern rim of older moraines — but even this simple relationship can be upset by a myriad of other factors. Older moraines may be better sorted into different types of surface material, although this is also strongly affected by the original nature of the moraine when first deposited and by the agents of sorting operating on it since deposition. The number of variables affecting the final nature of the moraines is enormous, and time is by no means the greatest of them.

Almost all the species observed on the moraine are known as good pioneers from other situations. **Salix arctica, Dryas octopetala, Eriophorum scheutzeri** and **Chamaenerion latifolium** all have light seeds with long silky hairs attached, making them easily carried by wind. Plants of the genera **Juncus** and **Carex** produce a large number of small, very light seeds. **Saxifraga aizoides** has been noted by Palmer and Miller as an extremely early pioneer (preceding **Salix**) on the moraines of the Rotmos Gletscher, Obergürgl. **Saxifraga oppositifolia** and **Silene acaulis** produce slightly heavier seeds, but still manage to colonise new areas, although somewhat more slowly than some other species.

The success of any one plant will depend upon the conditions in which it grows. **Salix arctica** can grow in a wide range of conditions and is, therefore, probably the most common plant found on the moraines. However, this plant flourishes best where it can anchor itself firmly and remain undisturbed by movements of the surface material. Many of the largest individuals of **Salix** were found in the interior moraines growing out from underneath large stable boulders. In the moister environments willows seldom attain any great size, partly because of competition from other species, and partly because the presence of moisture automatically increases the likelihood of disruptive soil movements.

Plants of the genus **Carex** are also widespread, the most common species being **C. misandra.** This species is not much affected by small frequent soil movements and seems to grow best in dry sandy areas, avoiding regions of cobbles and boulders or growing only sparsely in the sandy interstices between the stones. **C. microglochin** occurs only where very wet conditions prevail with a sandy soil and is therefore found in only a few localities. In those localities it occurs with great abundance. In wet sandy conditions where the soil is relatively stable **Juncus arcticus** and **J. triglumis** are found, the latter occurring exclusively in the wettest areas. In those wettest areas **Eriophorum scheutzeri** also occurs.

Plants confined to slightly moist areas are **Polygonum viviparum** and **Saxifraga aizoides** which both prefer a sandy or slightly gravelly surface, but can resist the effects of regular small scale solifluction or frost heaving. **Saxifraga oppositifolia** and **Silene acaulis** are found widespread over a range of conditions, but not in large numbers, possibly because these plants are slightly slower pioneers that the rest. **Dryas octopetala** is hampered by instability and prefers drier areas, but can colonise almost any surface. **Chamaenerion latifolium** seems to be largely restricted to the sunny sandy slopes of the eastern fans where it flourishes abundantly.

The vegetation of any area in the moraines will therefore depend on the relative position of that area on each of these three main ecological gradients — frequency of soil movement, moisture availability and surface material. Some species colonise a wider span of one gradient than of another, and some colonise a wider overall span and are therefore found more commonly in the moraines.

Dating by willow ages

One suggested method of determining the age of freshly uncovered moraines is by establishing the maximum age of plants growing on the moraine. With trees this may be done by counting the annual growth rings. In the case of woody willows (in this case **Salix arctica**) each year's growth leaves an annual terminal bud scar along the stem from root to tip. Each year growth recommences in a longitudinal direction only at the tip of each branch. The circular scar of the terminal bud is quite distinct from the crescent shaped leaf scars since the annual scar completely encircles the stem while the leaf scars do not. In this way the age of a given plant of **Salix arctica** may be established quickly and without damaging the plant. However, after about 25 years' growth the stem bark becomes too horny to allow reliable measurements to be taken.

Studies of floral development in freshly uncovered arctic soil have shown that willows can root within a couple of years of the first exposure of the soil after the glacier has retreated. Therefore, assuming there are no other dominant factors controlling the willow growth, willow ages should provide fairly good age contours for rapidly receding glaciers or ice sheets and should also provide information on the rate of ice retreat each year. A timelag between glacier retreat and colonisation by willow is possible, but providing the timelag is uniform, this will not invalidate the relative datings obtained.

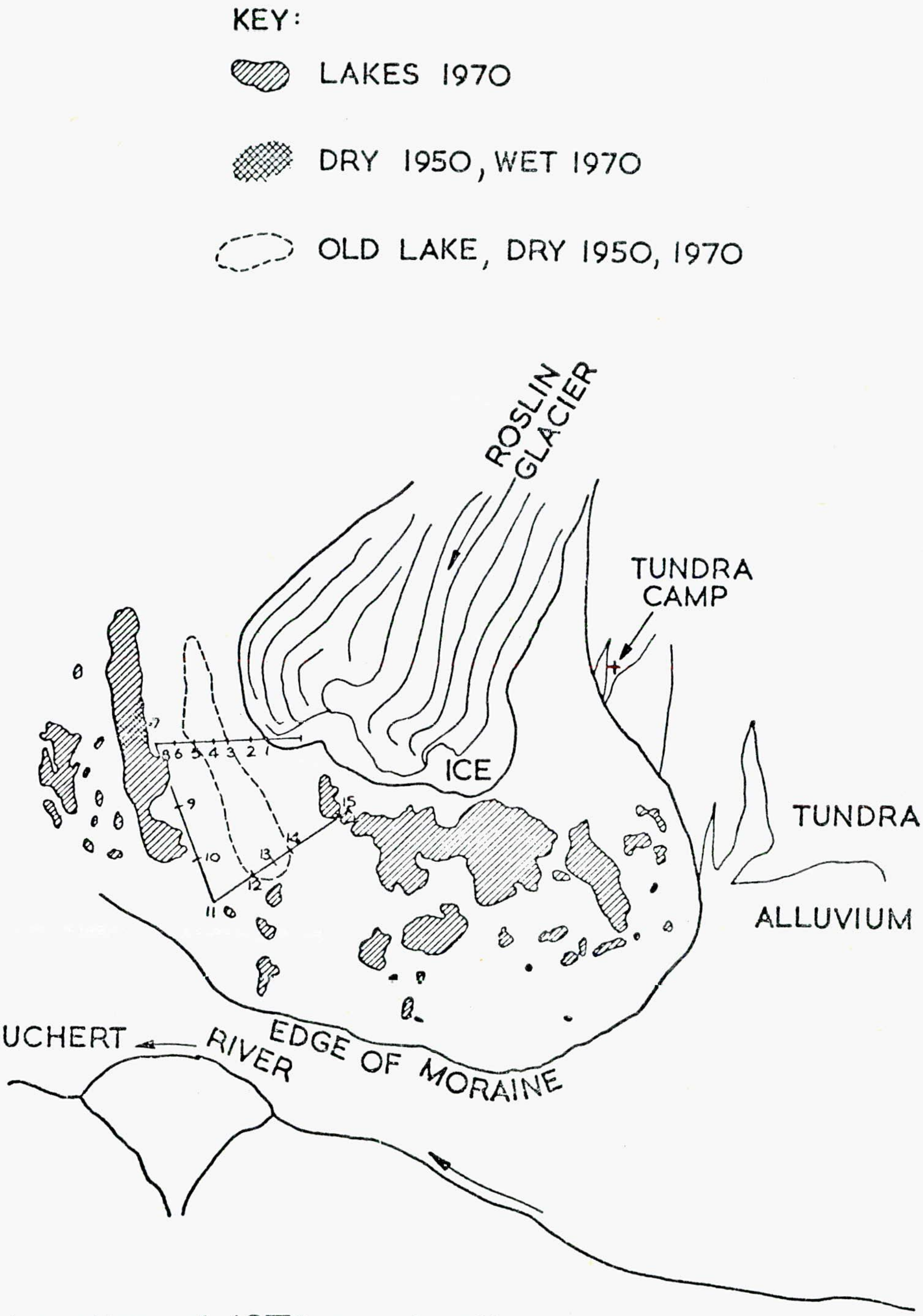
In August, 1970, some field studies were made of woody willow on the Roslin terminal moraines. A brief survey of willow ages along two rays from the glacier snout into the moraines was undertaken; willow ages were sampled at various intervals along the rays; at each sample point the maximum willow age was recorded. A total of 15 sampling points were selected, all in the southern half of the moraines. The results were as follows:—

Station	1	2	2/3	3	4	4/5	5	6	7	8	9	10	11	12	12/13	14	15
Max. age in years	2	6	8	9	—	8	8	11	18	17	16	14	18	8	8	7	14

For location of these stations see figure K4.

Plate 6 — Saxifraga Aizoides

Figure K4



Location of 1970 sample sites

In this case the apparent anomaly of willow ages was explained by the possible existence of an old lake, which is shown on the 1950 air photographs. This may explain the data for stations 3—5 and 12—14, but the remaining results, although too few to be definite, remain surprising. For example, a site as near to the glacier snout as station 15 shows willow growth has taken place for 14 years, while station 11, the most distant and therefore presumably the longest exposed of all the stations, shows only 18 years' growth.

In 1972 a further survey of willow ages was undertaken. Willows do not grow uniformly over the whole of the moraines, as the plant cover tends to be very sparse and localised. **Salix arctica** is a common moraine plant and grows in a wide variety of situations from the courses of ephemeral streams and mudflows to the moraine slopes themselves. In general these plants do not occur on very steep slopes unless in an area of localised stability such as the lee of a large rock. A general survey of the northern half of the moraines was made and 37 willow ages recorded. Each of these records refers to the maximum age in an area c. 150m square. These ages are shown in their relevant positions in figure K4. A marked lack of correlation between willow age and distance from the snout may be observed in this figure. The shortest radial distance from the glacier snout was measured from the map to the nearest 0.5cms (at a scale of 1:25,000 this represents 125m). The Spearman rank correlation coefficient with a correction factor for tied observations was used. The significance of the derived value of rs was tested and it was found that no significant correlation existed between the ranks of age and distance from the glacier for each station. See appendix I.

If it is assumed that the glacier retreated to its present position by radially contracting the extent of its snout, then present radial distance from the snout and moraine age should be positively correlated in trend, although a non-uniform rate of glacier retreat would produce a non-linear relationship. The total lack of correlation between distance from the glacier snout and age of the willow plants therefore implies that the age of such plants is not directly related to the date of exposure of the moraine in this case. Some factor or factors other than the date of exposure must be invoked to explain this major anomaly; the appearance and disappearance of lakes has already been used in interpreting the 1970 results, but the results shown in figure K4 call for a more widely applicable explanation. In this case the general instability of the surface probably precludes the long term growth of any one plant — note that only one plant older than 25 years was found whereas the moraines are known to have been in existence in more or less their present form for considerably longer than this. The number of factors tending to produce instability is probably so great as to operate overall in a random fashion; thus producing a random distribution of willow ages over the moraine surface.

The usefulness of this method depends on the assumption that willow age is mainly determined by the date of ice recession, and that the effect of other factors may be accounted for by the use of suitable statistical techniques. In this case the method is not applicable.

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APPENDIX I

Derivation of the Spearman's Rank correlation coefficient and test of its significance for Willow Age (A) and Radial Distance (D) from the Roslin Glacier Snout. For explanation see text.

Rank D	Rank A
2	19
2	30
2	15
4.5	33
4.5	11
6	19
8.5	30
8.5	30
8.5	23.5
8.5	23.5
12	26.5
12	26.5
12	2
15	11
15	11
15	19
18.5	34.5
18.5	11
18.5	23.5
18.5	6
22	34.5
22	6
22	3
24	15
26.5	30
26.5	8
26.5	11
26.5	19
31	30
31	36
31	23.5
31	6
31	4
35	19
35	15
35	1
37	37

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d^2}{2\sqrt{\Sigma x^2 \Sigma y^2}}$$

when $\Sigma x^2 = \frac{N^3 - N}{12} - \Sigma Tx$

$$\Sigma y^2 = \frac{N^3 - N}{12} - \Sigma Ty$$

$$T = \frac{t^3 - t}{12}$$

t is the number of observations tied at a given rank

$$d = R_D - R_A$$

Thus: $\Sigma d^2 = 9455.5$

$N = 37$

$\frac{N^3 - N}{12} = 50616$

$\Sigma T_x = 35.5$

$\Sigma T_y = 40.0$

$\Sigma x^2 = 4182.5$

$\Sigma y^2 = 4178$

$\therefore \; r_s = -0.1310$

H_0: This level of r_s does not show a significant correlation at the 0.1 probability level.

$$t = r_s \sqrt{\frac{N-2}{1-r_s^2}}$$

$t = -0.7818$

with N-2 degrees of freedom.

i.e. 35 df

$\therefore$ accept H_0.

(V) OBSERVATIONS ON PATTERNED GROUND IN WEST SCHUCHERT DAL. (S.C.W., S.M.B.)

Patterned ground provides one of the most distinctive elements in the landscape of periglacial regions, but beneath this all-embracing term is a wealth of different forms, shaped, in turn, by a whole range of processes. The western side of Schuchert Dal amply illustrates the potential for variety. The upper valley sides are strewn with a mass of ill-defined stone stripes and terraces. The steepness of the slopes prevents the development of sorted polygons. They were, howver, observed near the summit of a low col on the walk-in from the coast near Mesters Vig and on level ground in Pingodal. In this study, attention was concentrated on the unsorted forms at lower levels on the tundra adjoining the Roslin moraines. Here the surface of the bogs is broken up by small mounds, and similar forms are also found on drier sites. These seem to correspond to the turf hummocks described by H. M. Raup (1965) around Mesters Vig. On a much larger scale are certain polygons found characteristically on restricted patches of almost level ground bordering streams draining from the valley-side fans, immediately above where they break through bands of conglomerate to flow over the main valley floor. These were suspected to have developed in association with ice wedges: investigations confirmed this and showed that they were in an active state.

A detailed study was made of one of these sites and the adjoining area, situated about a mile to the north of the Roslin moraines. First, the ice wedge polygons and other salient features were mapped by plane-tabling (map 1), and the character of the different elements in the terrain was described. This included identifying typical plants and assessing their relative abundance and the total percentage cover of vegetation. Trenches were also dug to study the soil profiles associated with the furrows.

Even within such a small area the nature of the ice wedge polygons is far from uniform. Those to the east, stretching from E to H on map 1, are usually bounded by well-defined furrows, sometimes over 30 cm deep, in which vegetation is concentrated, taking advantage of the shelter and more favourable soil moisture regime. Salix sp. (woody willow), dryas sp., betula nana (birch) and carex sp. (grass) are the most typical plants. The polygon surface is very dry with an incomplete vegetation cover (50-80 per cent), dominated by patches of lesquerella arctica and carex sp. Where the soil is bare, the surface is whitened by a deposit of carbonate. In contrast, at the western end of the area shown on map 1 the furrows, though still distinct, are shallower and visibly much wetter, with mossy bottoms and occasional puddles of standing water. T provides the best example of this type of polygon. The vegetation cover in the polygon centre is more continuous (90-99 per cent), and salix sp. replace lesquerella arctica as one of the two main components. Intermediate between these two types in the centre of the area lies a group of less distinct polygons whose furrows are poorly developed and at times discontinuous (J—R). The surface here is generally more vegetated than at the eastern end. The reason behind this pattern of changes is not immediately apparent: the overall difference in slope in an east-west direction is only —1 degree. Using J. V. Drew and J. C. F. Tedrow's classification 1962; Embleton and King 1968 p. 492) of ice wedge polygons, according to their microrelief, in which polygons are graded from A to F with increasing depth of furrow, T would be termed type A, and C and its neighbours type B.

Drew and Tedrow are particularly interested in correlating different types of patterned ground and soils. The profiles exposed in the trenches, dug across the furrows and marked 1 to 3 on map 1, do not conform well with any of the type descriptions given by F. C. Ugolini (1966), but bear some resemblance to those for the Arctic Brown and Upland Tundra. This would fit in with Drew and Tedrow's scheme. However, the most interesting feature revealed in the trenches is the shallow depth of

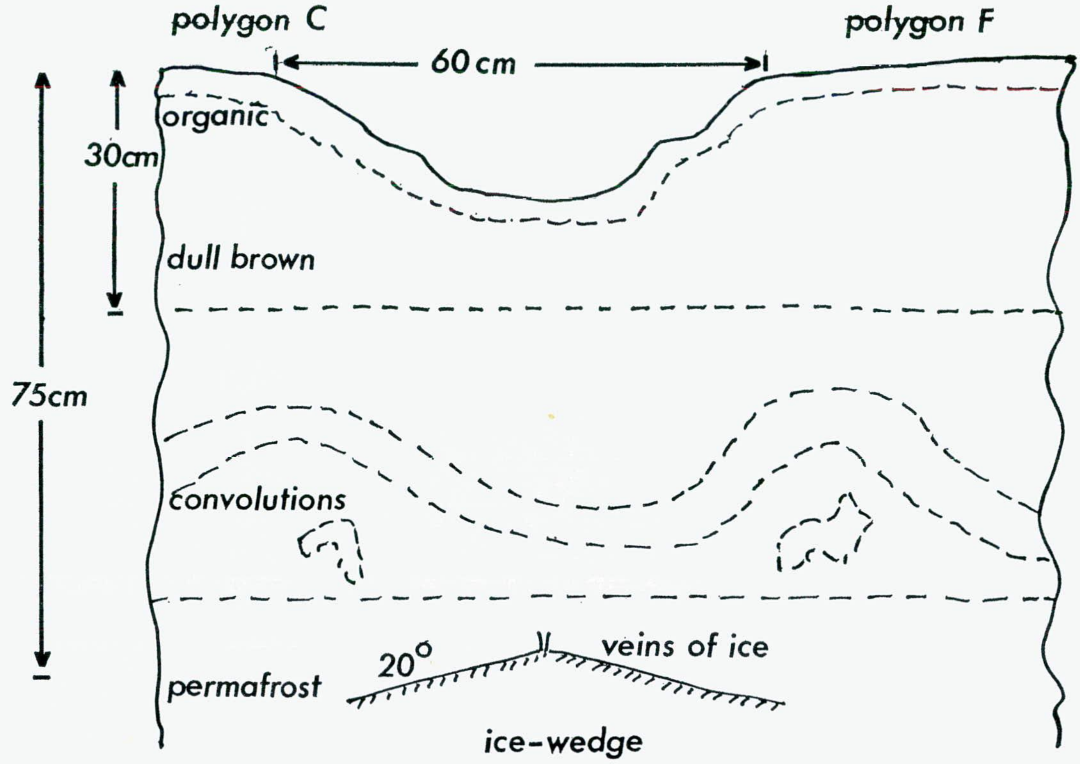

figure 1: CROSS-SECTION THROUGH TYPICAL POLYGON (soil trench 3)

the active layer (see fig 1). Previously, soil pits had been dug along transects up the valley sides over a wide range of deposits to depths exceeding those of these trenches, but in no case was permafrost reached. Presumably this is important in explaining the limited occurrence of this type of polygon in Schuchert Dal.

The nature of the material is often held to be a critical factor in the development of patterned ground. It had, therefore, been hoped to bring back samples for grain-size analysis, but, unfortunately, poor weather at the end of the season prevented the collection of all the expedition's samples by helicopter.

The perfect wedge of ice and its associated feeder veins in Trench 3 suggest that the polygons are actively forming under present conditions. Meanwhile, the ill-defined channels (the most pronounced ones are shown on the map) in the centre of some of the polygons probably mark embryo forms. In the case of H, with its present reflex angle, this is particularly feasible. Sometimes these channels peter out gradually, but occasionally the ending is abrupt (for example, in C). Apart from the more or less defined channels, the surface of every polygon tends to be uneven with hummocks, but the centre is not markedly higher or lower than its surroundings. It is interesting to speculate on what prevents the polygons developing to the south where there is no immediate change in slope. Perhaps the boulder marked on the map near L provides the clue: near the outcrop of conglomerate there may be insufficient depth of soil.

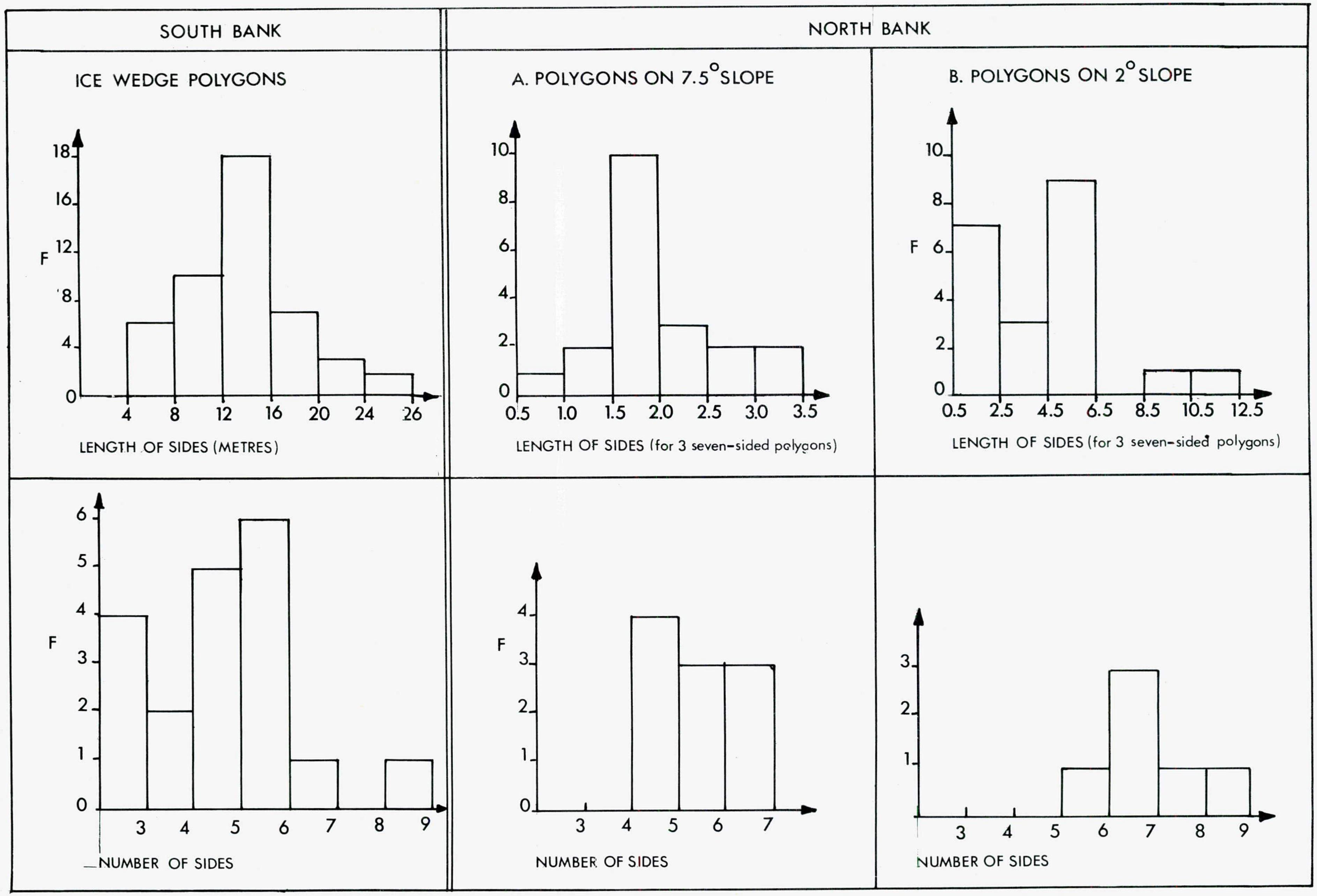
SOUTH BANK
NORTH BANK
ICE WEDGE POLYGONS
A. POLYGONS ON 7.5° SLOPE
B. POLYGONS ON 2° SLOPE
F
LENGTH OF SIDES (METRES)
LENGTH OF SIDES (for 3 seven-sided polygons)
LENGTH OF SIDES (for 3 seven-sided polygons)
NUMBER OF SIDES
NUMBER OF SIDES
NUMBER OF SIDES

figure 2

Some observations were also made on the patch of turf hummocks marked on map 1 near the ice wedge polygons on a slope of 4 to 4.5 degrees. They stand 15 to 25 cm. above the intervening channels with a maximum diameter of about 50 cm., but show no apparent ordering in rows. The dry steep sides of the hummocks are encrusted with carbonates, and there is no significant difference between the vegetation on the tops and in the channels. Two hummocks, cut into by amphitheatre-like holes of unknown origin, possess cores of light, sandy, silty soils.

Across the stream a few polygons similar to those on the south bank exist, but east of the confluence the character of the ground changes. Here the polygons are much smaller (see the frequency distributions for the length of sides in fig. 2), with furrows usually only a few centimetres deep, though a marked trench, over 30 cm. deep with a mossy bottom, was observed. As the slope steepens the sides of these smaller polygons definitely become shorter, and the change in the form of the frequency distribution is interesting. Perhaps the way that the lower mode for the length of sides on the 2 degree slope appears to coincide with the single mode on the 7.5 degree slope is significant. The graphs in fig. 2 also suggest that the number of sides decreases with increasing angle of slope, though, clearly, it is impossible to draw firm conclusions from such a small sample. The increase in slope does not seem to make the overall shape of the polygons more elongate. However, the most distinctive element of these smaller polygons is the vegetation, particularly in autumn with the reddish hues of betula nana and vaccinium uliginosum (bilberry). Salix sp. and carex sp. are the other main components. Particularly striking is the way the change in plant cover upslope coincides exactly with the disappearance of the polygons, though the angle of slope remains the same. A distinct line runs in broad zig-zags, separating in autumn the almost continuous reddish vegetation cover of the polygons from the partly bare surface beyond with patches of carex sp. and dryas sp. From the form of the boundary, it seems unlikely that the explanation could lie in a change in underlying material or moisture conditions. Here lies one of the most interesting problems revealed by this brief study of the morphology of different types of patterned ground and their relation to other elements in the physical environment on a small area of tundra in North-East Greenland.

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FURTHER INFORMATION

Members of the expedition will be pleased to answer queries and to help other expeditions in any way that they can. Please contact Sue Wrenn, "Derien", Mount Bovers Lane, Hawkwell, Hockley, Essex (Editor).

We thank Mr. Eric Kingsbury, of Kingsway Screens Ltd., Southend, for his cheerful help in producing this report.

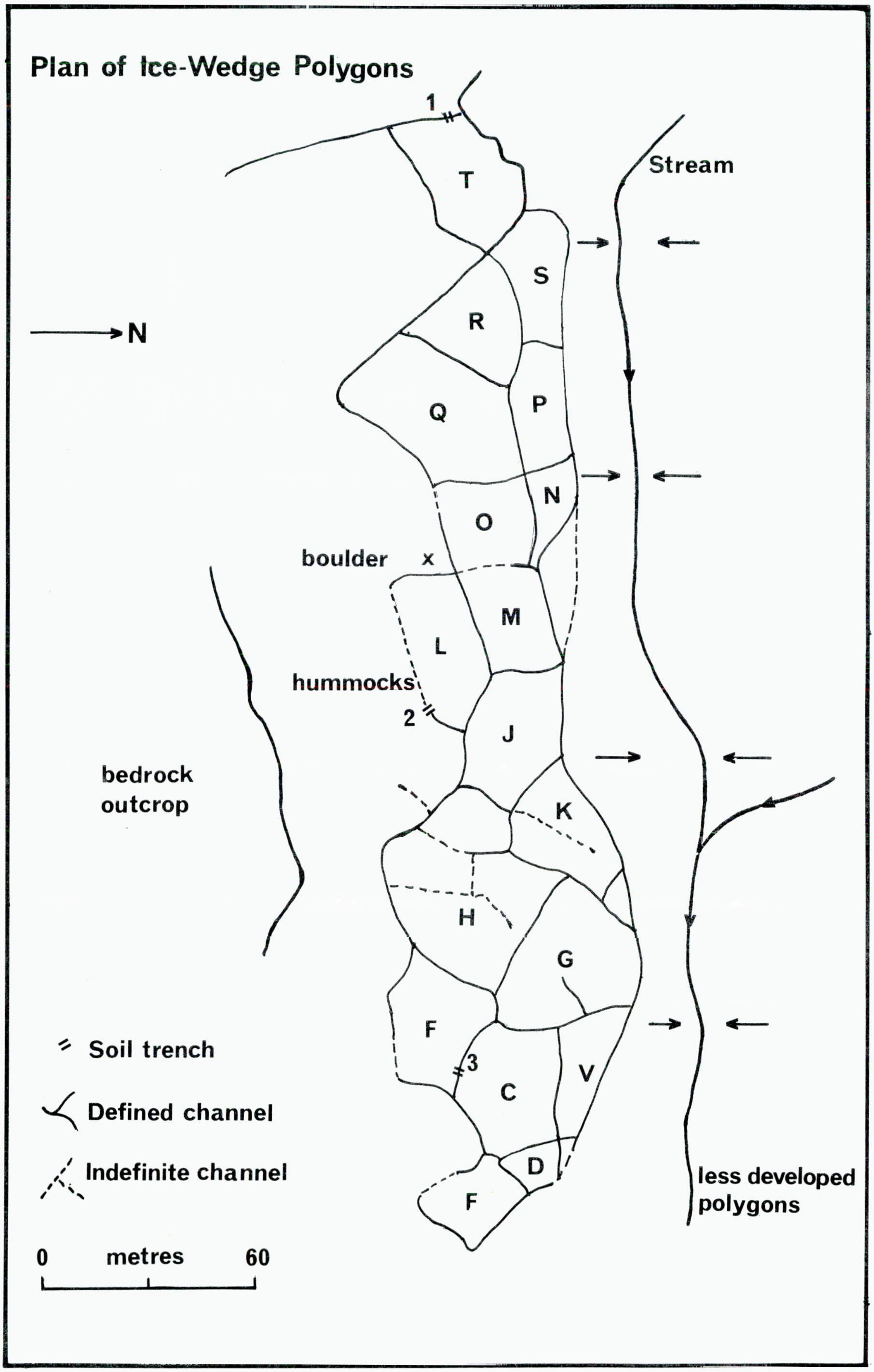
IN CONCLUSION

We hope that this report has shown how much we enjoyed this unique experience. Greenland is a fantastic place; we think that the expedition was a success, both personally, and from the point of view of the results obtained, and we hope that all those who supported us, and had much confidence in us, will think so too.

To the expeditions of the future, we say:—

"May Mars bars never land on your head,
May your tea bags never go soggy,
And may all your moraines be happy ones. . . . ."

Fig 3



Plan of Ice-Wedge Polygons
1
T
Stream
S
R
N
Q
P
N
O
boulder x
M
L
hummocks
2
J
bedrock
outcrop
K
H
G
F
3
C
V
D
F
Soil trench
Defined channel
Indefinite channel
0 metres 60
less developed
polygons

Plate 7. — "Reflections in Mesters Vig Fjord"