THE CAMBRIDGE

STAUNINGS EXPEDITION 1970

VOL II

"OTHER PROJECTS"

CUED/Special Project Report, 2 (1972)

Summary

Vol. I was primarily concerned with reporting the glaciological projects including (a) the radio echo-sounding work which was satisfactorily completed using a modified radar altimeter, and (b) ice temperature profiles.

Vol. II is concerned with the survey projects, oxygen-isotope analysis of ice samples, snout recession studies, meteorological reports and computer programmes.

Vol. III will compile statistics on Food, Equipment, Finance, Medical Supplies, etc. and will conclude with impressions of the expedition by some of its members.

Editor
K.J. Miller
Trinity College
December 1971

FIG.20 The Roslin Glacier from the north west seen right of centre
Reproduced by kind permission of the Geodetic Institute, Copenhagen.

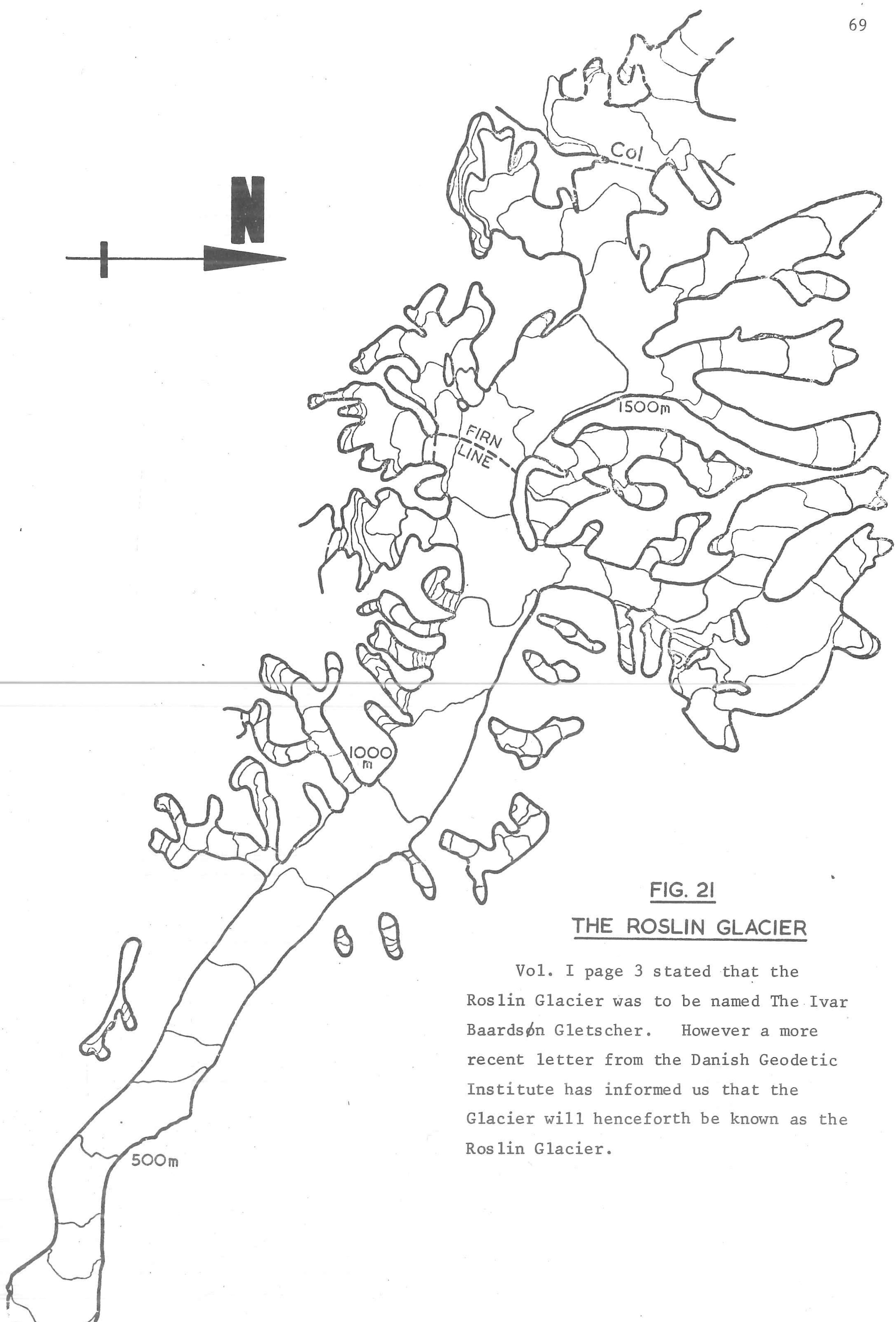

FIG. 21

THE ROSLIN GLACIER

Vol. I page 3 stated that the Roslin Glacier was to be named The Ivar Baardsøn Gletscher. However a more recent letter from the Danish Geodetic Institute has informed us that the Glacier will henceforth be known as the Roslin Glacier.

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APPENDIX

FIGURES

TABLES

THE AIR DROP AND THE RECOVERY OF PARACHUTES

The air drop of expedition food and equipment was successfully carried out by a Hercules of the Royal Air Force on Sunday, 12th July, after being forced to return to Keflavik the previous day because of unsuitable weather conditions.

The drop required a total of 29 parachutes, 27 of them near to the proposed base camp, whilst the remaining two were to be dropped near the snout, see Fig. 22, page 73. Fortunately Dundee University provided a party of four men, led by Bob Heywood, to look after both the parachutes and equipment until our party arrived on Wednesday, 15th July. A few items of food and equipment for the Dundee party were included in the drop. No difficulty was experienced in finding the base camp drop since a message was left by Heywood at a marker boulder in the middle of the Roslin Glacier informing us of its location. On the way up the Roslin Glacier there was no sign of the snout drop. On the day the helicopter dropped the party on the Tundra, the pilot and Miller spent some ten minutes hovering above the snout zone but no parachutes could be spotted, although they did see the lower markers that Heywood had left on the glacier. Several days later, as Davis and Miller were relaying stores to Tundra camp and scientific equipment to base, they stopped for a few seconds and in that short period saw the flash of red over by the far (true right) moraines. It was the second drop. This sighting was quite fortuitous since latter observations were not possible due to glacier surface profile fluctuations in the vicinity of the drop. On the initial march up the glacier the party had walked within one hundred yards of the second drop without spotting it. The supplies were later established at Fly Dump, see Fig. 22, and were later to prove invaluable.

Of the total loads dropped, only two suffered any damage. A parachute failed to open on one load of food supplies, the contents bursting and spilling on impact. The second load possibly rolled on impact; the damage caused however was negligible. Approximately 60% of the first load was recovered. The perishable items were rapidly consumed in situ while the non-perishable items were repacked. Contained in the air drop was a message requesting that the party recover as many chutes as possible and in consequence many man-days were used in relaying chutes from the drop zone to base camp and thence to either the Fly Camp (Roslin left bank), see Fig. 3, Vol. I, or the Fly Dump (Roslin right bank). The chutes were then transported to the snout and relayed over the moraine to Tundra Camp, a total carry of twenty miles. The number of man-days consumed in this task involved more time than the party could afford, causing a reduction of time for field work and yet the R.A.F. had rendered such magnificent service there was never any question but to accede to their request.

Five parachutes were used in the construction of teepees in order to protect equipment and supplies until such time as all stores could be ferried over to base camp, a distance of 2 km. Three parachutes however served as teepees for the complete period of the expedition. One teepee was used by the radar sledging party as a workshop while the other served as a store for surveying and allied sundry equipment. The remaining parachutes were ferried over a period of several days to base camp where they were dried and packed.

Two members travelled downstream on 23rd July to deploy fuel and to unpack the contents of the lower air drop. A dump was laid to assist the eventual return to Tundra Camp.

Throughout the whole period of the expedition parachutes were ferried down glacier as and when practicable. By the 14th August, 18 parachutes were stored at Fly Dump Right which was approximately six miles from Tundra Camp. The 15th and 16th August were taken over entirely with ferrying the parachutes from Fly Camp Left to Tundra Camp, including all clips, buckles and steel links from the ripped chutes so that possibly they could be used again in the manufacture of new parachute harnesses. The transportation of parachutes was not without its lighter moments, for example, one member dropped a chute into a melt stream and, having carried it some twelve miles that day, was most loathe to lose it. He therefore jumped into the stream and chased the wanderer downriver until it was caught on the end of his ice axe. It must be admitted however that the stream was not very wide but ice cold water is still ice cold!

On Thursday, 27th August, 22 parachutes were airlifted from the Roslin tundra to Mesters Vig by helicopter followed by DC6 aircraft to Iceland and M.V. Gullfoss to the U.K.

Finally, the expedition would like to extend a most sincere thank-you to the R.A.F. and all the personnel who assisted in this aspect of the project. The expedition are more than grateful and it is hoped that the recovery of 22 chutes plus an assortment of steel links is in some small way an indication of the effort made to show the expedition's gratitude. Drop day conditions were far from ideal and so the party are doubly indebted for the excellent service given.

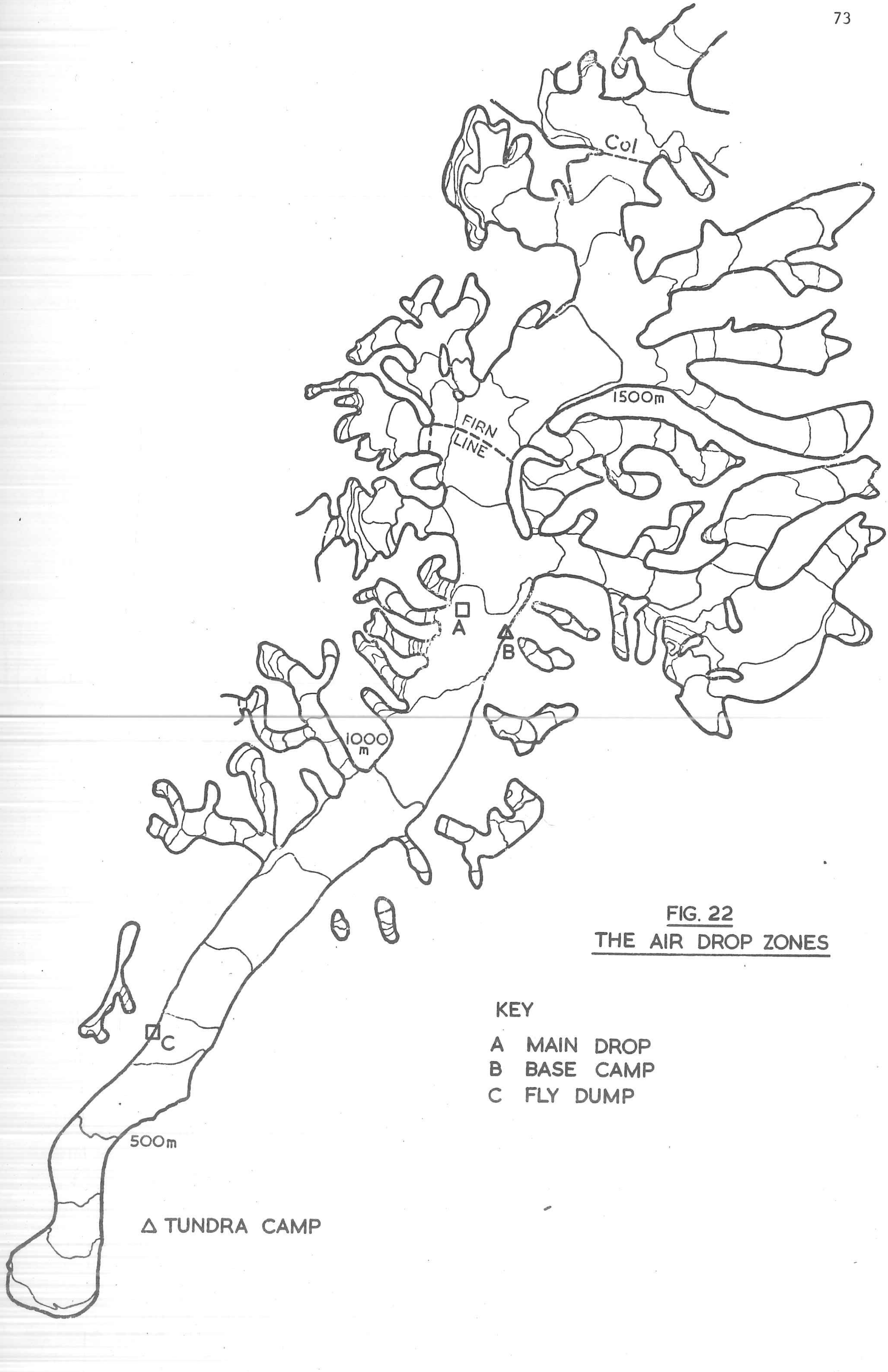


FIG. 22
THE AIR DROP ZONES

KEY

A MAIN DROP
B BASE CAMP
C FLY DUMP

METEOROLOGY - GENERAL REPORT

The weather generally remained fine and predictable up to the end of July. The prevailing wind at surface level (base camp - glacier surface - altitude 1100 metres) was constantly down-glacier. This also applied to wind at altitude although there were occasions when it would veer but by no more than 90^{o}, and usually for a period not exceeding 24 hours. Cloud in the main was cirrus with the occasional covering of strato-cumulus. The barometer however was falling steadily for the period 21st-31st July, i.e. from 26.6 ins Hg to 26.0 ins Hg in ten days.

The beginning of August brought about a marked change, with rain, sleet and snow for two days. This was followed by a period of settled conditions (4 days) after which it further deteriorated. Winds were more variable both in direction and strength; increasing cumulus cloud cover and lower temperatures with decreased diurnal variation. This became the pattern for the remainder of the expedition with the exception of the period 17th-24th August which again was fine and settled. In conclusion therefore it can be stated that down-glacier winds, (Arctic continental), give rise to good stable conditions- whilst up-glacier winds, (Arctic marimetime), give rise to unstable conditions.

METEOROLOGY - EQUIPMENT AND INSTRUMENTS

2 off	Maximum thermometers	Met. Office
2 off	Minimum thermometers	" "
2 off	Soil thermometers	" "
1 off	Rain Gauge	Great Ouse River Authority
3 off	Psychrometric thermometers	Expedition Member
1 off	Hand anemometer	" "
2 off	Thermographs	Williamson Manufacturing Co. Ltd.
1 set	Psychrometric tables	Expedition Member
2 off	Barometers	Royal Geographical Society

All meteorological equipment functioned correctly with the exception of the minimum thermometers where trouble was experienced due to the breaking up of the alcohol columns which probably occurred during the air drop.

The data exhibited in the following figures were collected at the base camp meteorological station.

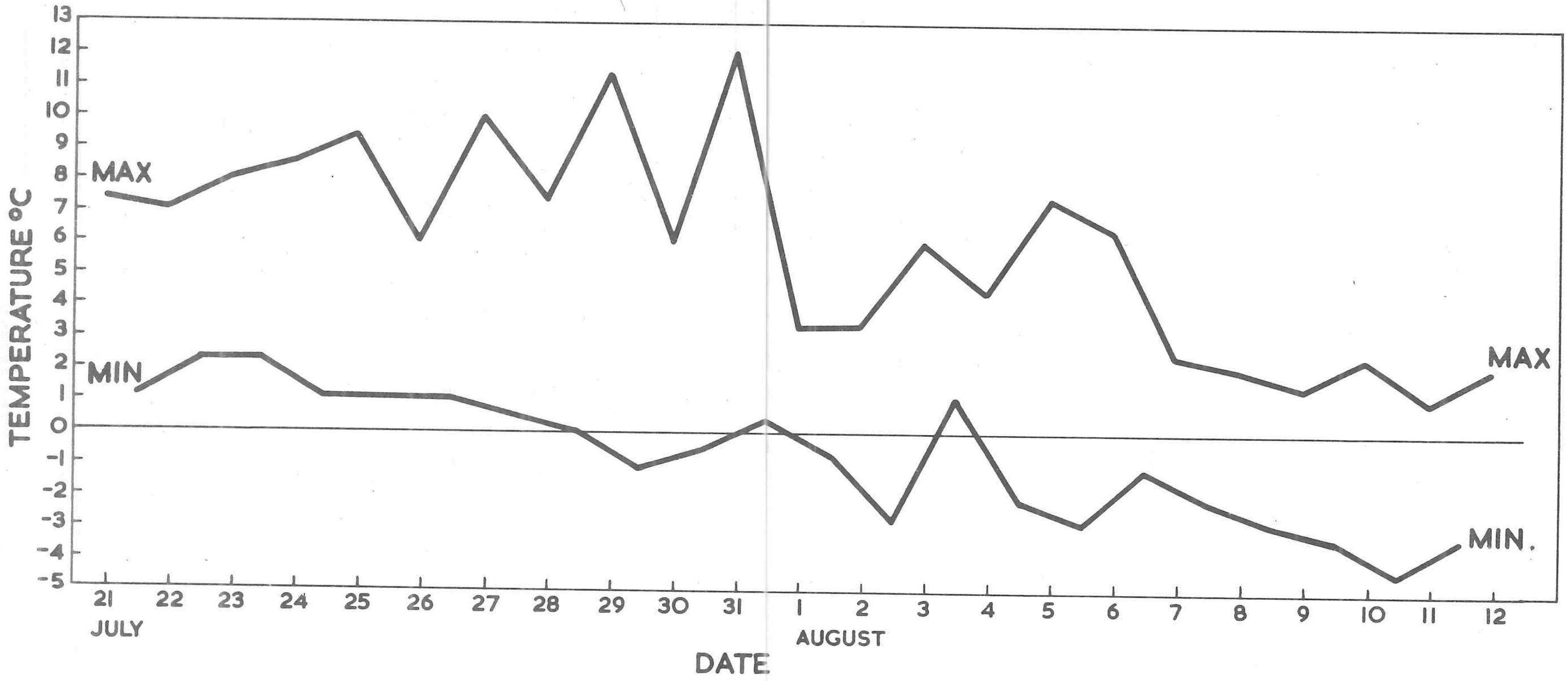


FIG.23 MAXIMUM AND MINIMUM TEMPERATURES (Roslin Glacier 21st July-12th August 1970)

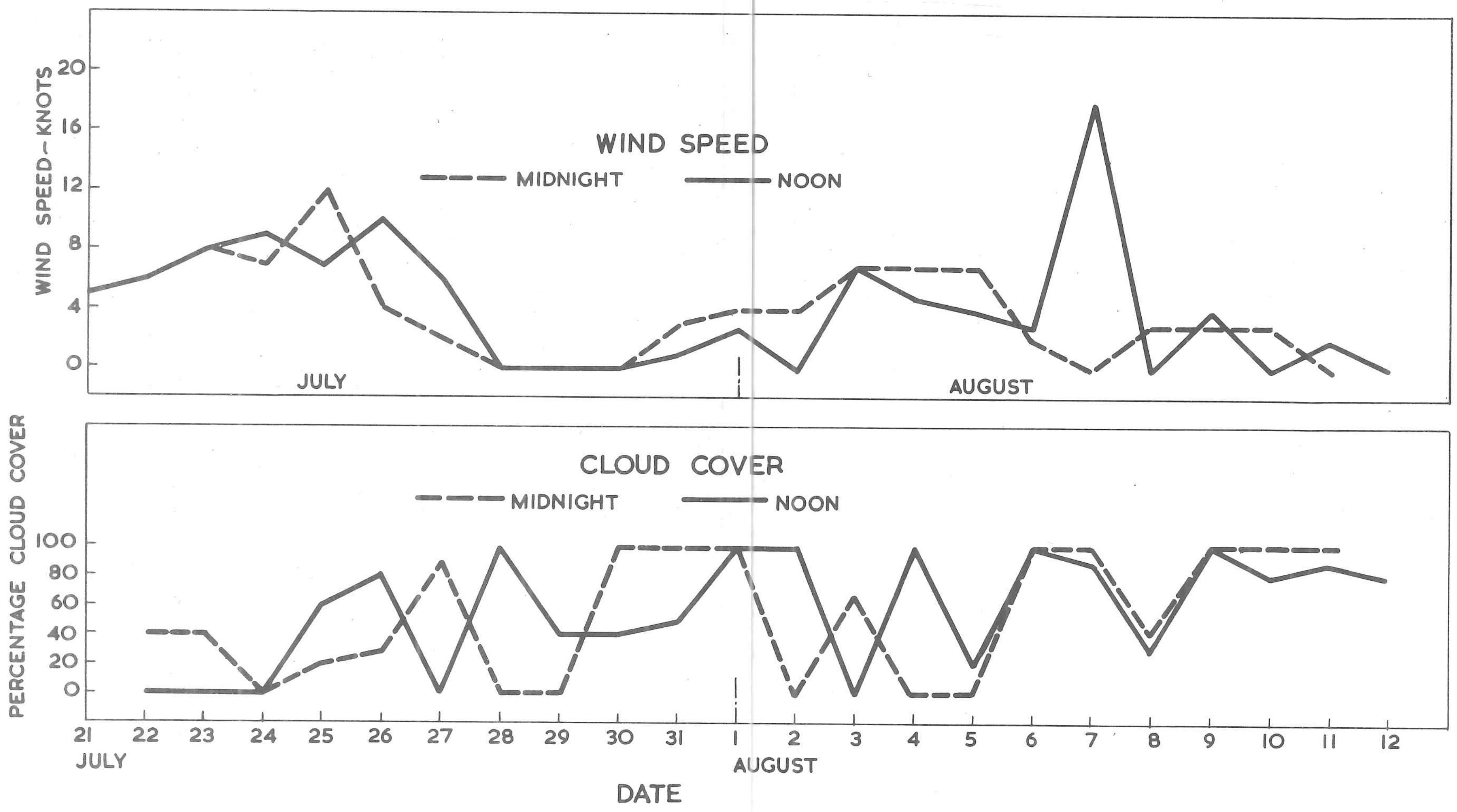


FIG.24 WIND SPEED & CLOUD COVER DATA. (Roslin Glacier 21st July - 12th August 1970)

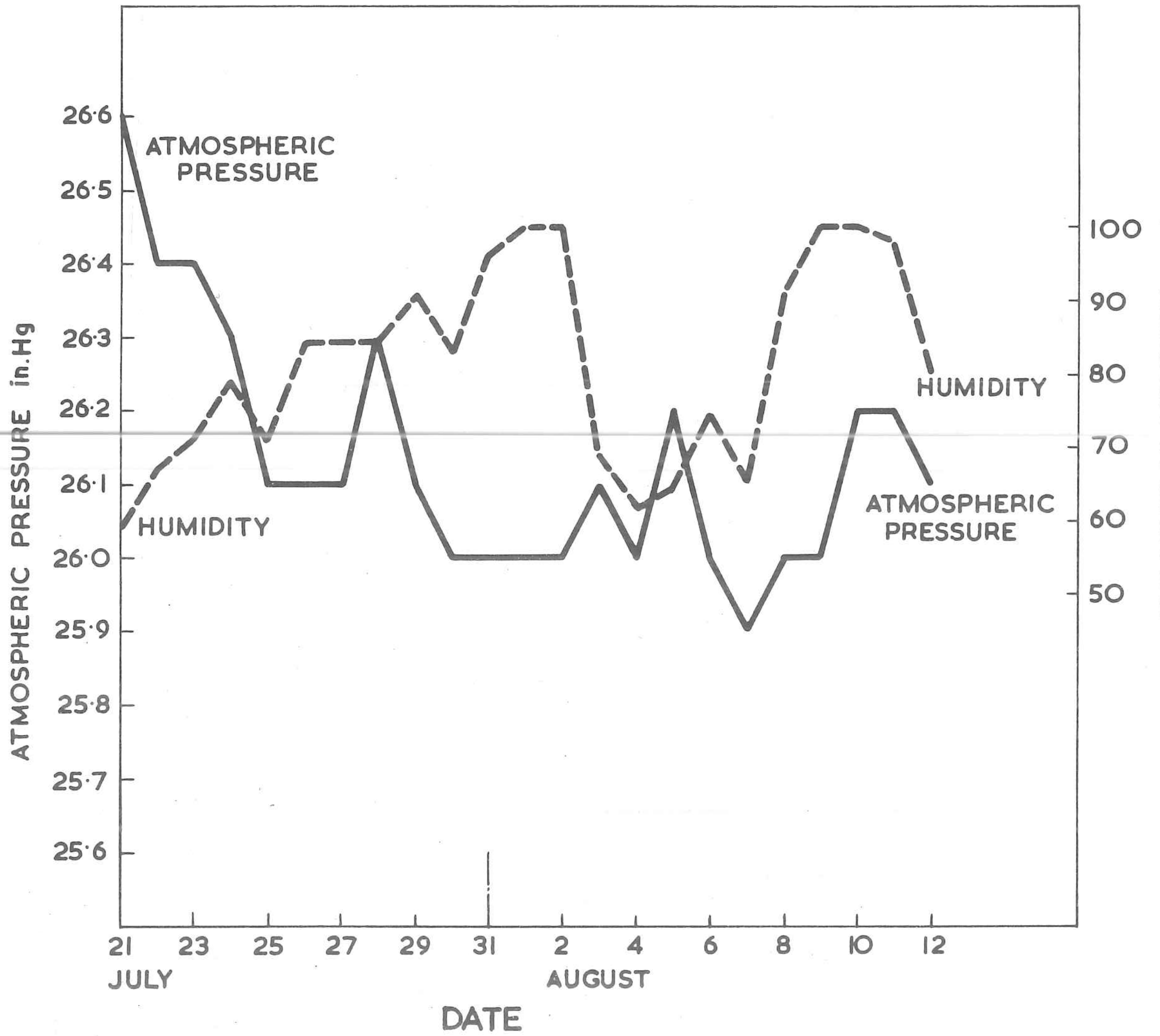


FIG. 25 ATMOSPHERIC PRESSURE AND HUMIDITY
(Roslin Glacier 21st July - 12th August 1970)

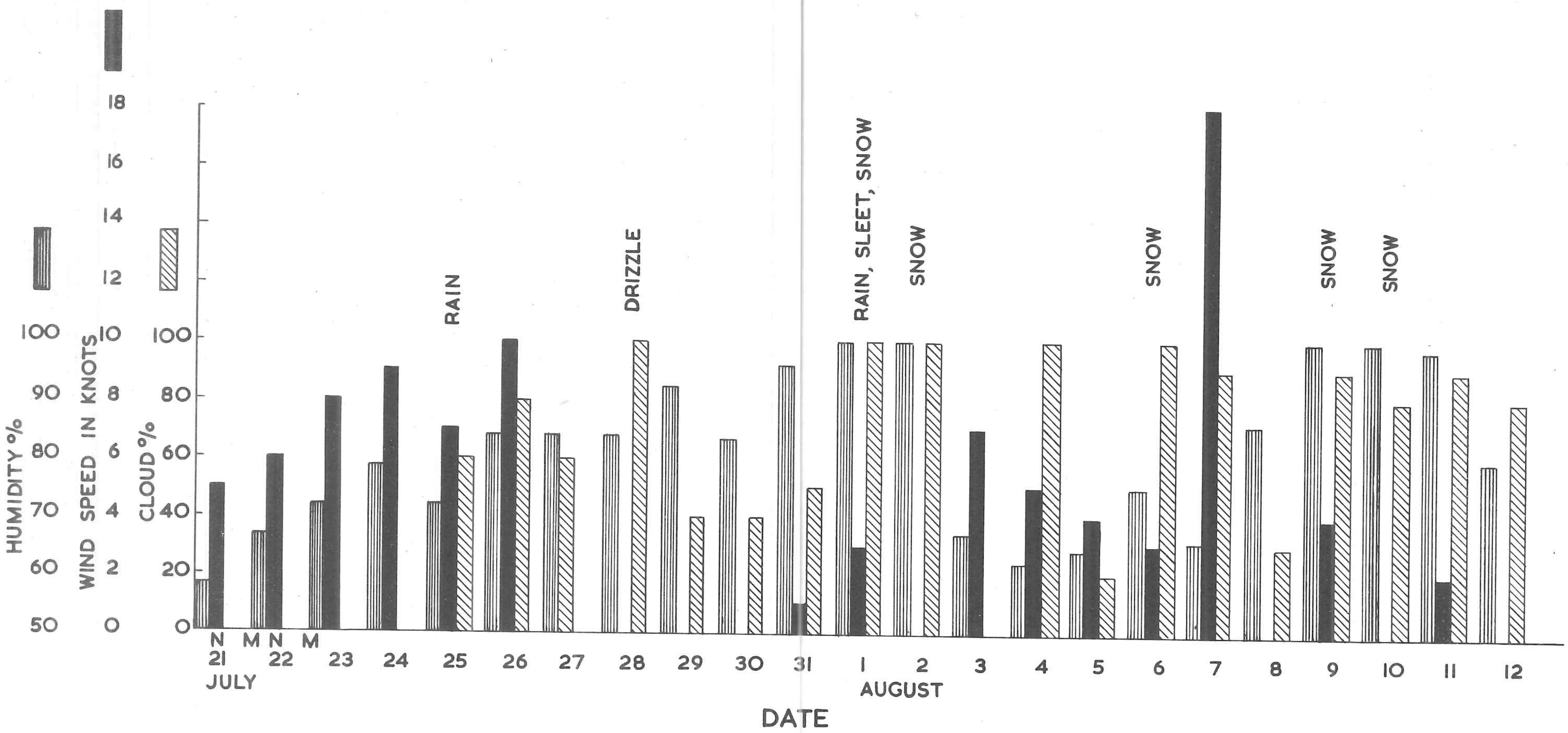


FIG. 26 COLLECTED WEATHER DATA (Roslin Glacier 21st July - 12th August 1970)

Mapping of Glacier Recession by Age Determination of Woody Willow Plants

On the 19th of August all members were reunited at Tundra Camp. Whilst waiting for the helicopter to transport equipment and scientific results to the airstrip at Mesters Vig it was decided to test a method of determining glacier recession rates by examining woody willow plants in terminal moraines. Because of shortage of time and some apparently anomalous results the field studies were not satisfactorily concluded. However the subsequent analysis of results has produced an unexpected solution to the anomalous results and provides further evidence to validate the usefulness of the method.

METHOD

The age of recently uncovered moraines may be determined by taking sectional samples of the woody willow plant main stem and counting the annual rings. This method is time consuming, destructive, and involves carrying samples from the field. A more convenient and non-destructive method is to count the number of annual terminal bud scars along the stem from root to tip. In the longitudinal direction growth recommences each year only at the tip of each branch. The terminal bud loses its scales in spring and leaves a circular scar, quite distinct from the crescent shaped leaf scars which do not encompass the entire circumference. This method is limited to a maximum of 25 years; above this age the bark becomes too horny to allow reliable measurements to be taken.

Studies of flora development in freshly uncovered Arctic soil have shown that willows can root within a couple of years of the first exposure of the soil. Thus woody willow age measurements should give more reliable data over a short period than the often measured lichen clumps which may not develop for twelve years or so. Willow ages should give good age contours for fairly rapidly receding glaciers or ice sheets. The techniques should also prove useful when analysing the time scales of other transient phenomena such as floods, landslips or dried-up lakes.

RESULTS AND DISCUSSION

Willows in the Staunings Alps of East Greenland were easily recognised, being the only plants with woody stems.

The area of the Roslin terminal moraine to be mapped was divided by a series of judiciously spaced rays which were plotted on a topographical map, see Fig.(27). Age determinations were then made at intervals along the line and plotted on the map. From these data, contour lines of maximum age of willow plants could be drawn. At a particular sampling point, the age of several willow plants was measured and the oldest recorded.

A brief survey of willow ages along the two rays on the Roslin Terminal Moraine shows that the Roslin glacier is retreating very slowly, if at all, but the measurements taken revealed one important feature. As shown in Fig.(27), there is an inconsistency in the ages of certain zones, i.e. stations $^{4}/5$, 5, 12, $\frac{12}{13}$, 14. The willows in these areas were never older than eight years and those immediately outside this area were 12 or more years old. However, the suggestion that this anomaly represented an old lake was eventually supported by an old map and 1950 aerial photographs.

The positions of lakes were then rather different from those of 1970 and the old lake location agrees well with the 8 year old willow contour. The lake must have dried up a little over eight years ago.

The work done on this project was sufficient to prove the validity of the technique. The method is applicable to a short time span where there is no other simple alternative.

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

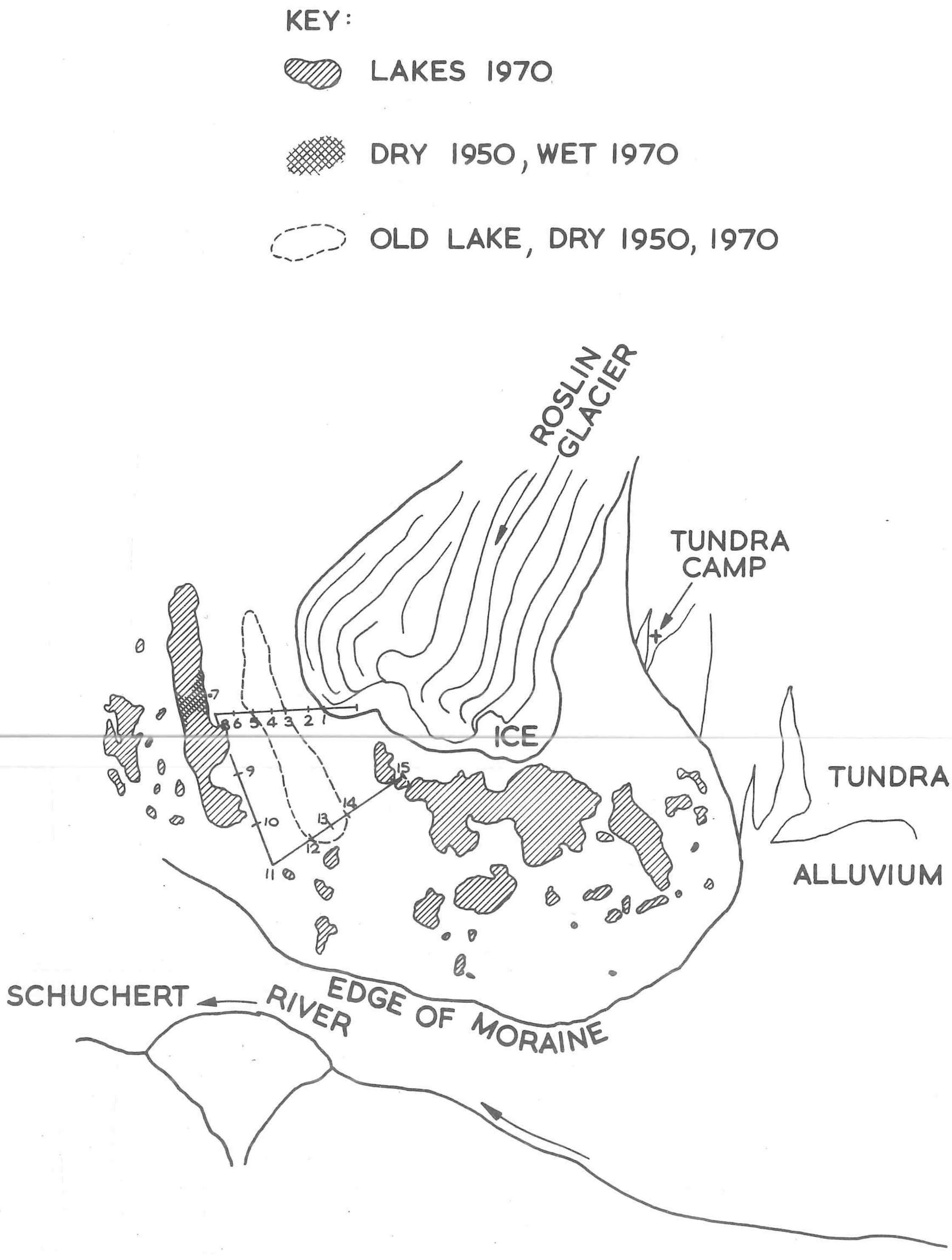


FIG. 27 PLAN OF ROSLIN SNOUT MORAINE, SHOWING SAMPLING LINES FOR 'WOODY WILLOW' SURVEY, AUGUST 1970

The Mountaineering Report

Future expeditions to this area should note that mountaineering skills are a prerequisite ability of intending participants since many glaciers have to be traversed, cols ascended, moraines crossed and streams forded. Thus, although this expedition was a scientific one, its members included several mountaineers.

It is to the credit of the young mountaineers that they subjugated their desires to climb all peaks in view and concentrated their efforts on the scientific programme. However, three opportunities permitted three peaks to be climbed and these are now reported

For location of peaks see

Fig. 28, page 84.

For photographs of peaks see

Figs. 29 and 30, pages 85 and 86.

Ascent of Dalmore Junior (2140 m)

This striking peak lay 4 km to the North-West of base camp, see Figs 28/29. Visible from a short distance above the snout of the Roslin, it rose to 2140 m in one long snow ramp from a snowfield 300 m above the glacier.

On 27th July it was ascended by Bishop and Young via the Dalmore Glacier. The route lay up a moderate 150 m ice couloir, 400 m north of the small icefall, which lies almost at the junction of the Roslin and Dalmore Glaciers. From the couloir they followed the edge of the snowfield to the bottom of the ramp. Little difficulty was encountered from a few, narrow, equi-spaced crevasses which are concentric about the top of the icefall.

The ramp was largely deep soft snow on ice. At 15.00 hours almost two and a half hours from the Dalmore Glacier, Bishop and Young reached the summit. Much of the glacier from snout to col was visible with the firn line clearly visible at about 1400 m. After an hour on the top, the descent by the same route took an hour and twenty minutes.

The Ascent of Hird Star (2250 m)

Directly opposite base camp and to the South of Diamond Peak, rises "Hird Star", see Fig. 30 This was the first peak which the expedition decided would provide a worthwhile ascent. Keith Miller and Peter Mackeith planned a route during the early days of the expedition but unfortunately the pressure of scientific work did not allow them the time to make the ascent. Luckily, however, Chris Padfield and John Danby had a day to spare after completing the final survey of the stake lines and with the weather apparently settled they began their attempt around midnight on the 15th August.

The initial aim was to gain the north rock ridge. Unfortunately the party made the mistake of climbing the retaining wall too far to the north, and much time was lost traversing the top of the ridge which was deeply indented with gullies and covered in loose rock. The next part of the route was up crevassed snow onto a snow dome summit. By this time a low cloud ceiling had formed and fearing a snowfall they descended to base camp. Very soon, however, the sky cleared and they were bitterly disappointed at not having made the summit.

Determined to shake off the sickening feeling of failure they left base camp at 11.30 p.m. the next evening and quickly gained the snow dome summit and then set off across the central snowfield of the mountain in a line between two major crevasses. The route led up to a triangular snowface which was climbed to the right of a bergschrund. They then ascended the line of ridges and arrived on the summit at 3.30 a.m. on the 17th August.

On the summit they discovered an apologetic note addressed to Keith Miller, which had been left by Bob Heywood (Dundee University) a few weeks earlier, after his party had ascended the Bjonboss face to the South.

The latter route had also been used when the mountain was climbed, probably for the first time, by a German party in 1966.

The Ascent of Junction Peak (2180 m)

Junction Peak stands on the right bank of the Roslin glacier approximately six miles above base camp, see Fig. 29. The peak commands a view both of the upper Roslin basin, and the base camp area and therefore it appeared as though the summit would be an excellent point from which to establish a survey station. With this purpose in mind John Halliday, Chris Padfield and John Danby set out to climb the peak in the early hours of the 1st August. The only problems were the crossing of the central melt stream on the Roslin and the traversing of a heavily crevassed minor glacier which flows round the base of Junction Peak into the Roslin. The climb itself was entirely on scree and boulders. The summit was attained at 7.30 a.m. by which time clouds were gathering around the neighbouring mountains. Very soon Junction Peak summit was also shrouded in cloud.

Hoping for the cloud to clear the survey party waited several hours on the summit. However the cloud gradually thickened, and when it started to snow the party decided to descend. They followed their previous tracks home and eventually emerged from the clouds only a few hundred feet from base camp. It is believed that this was the first ascent of Junction Peak.

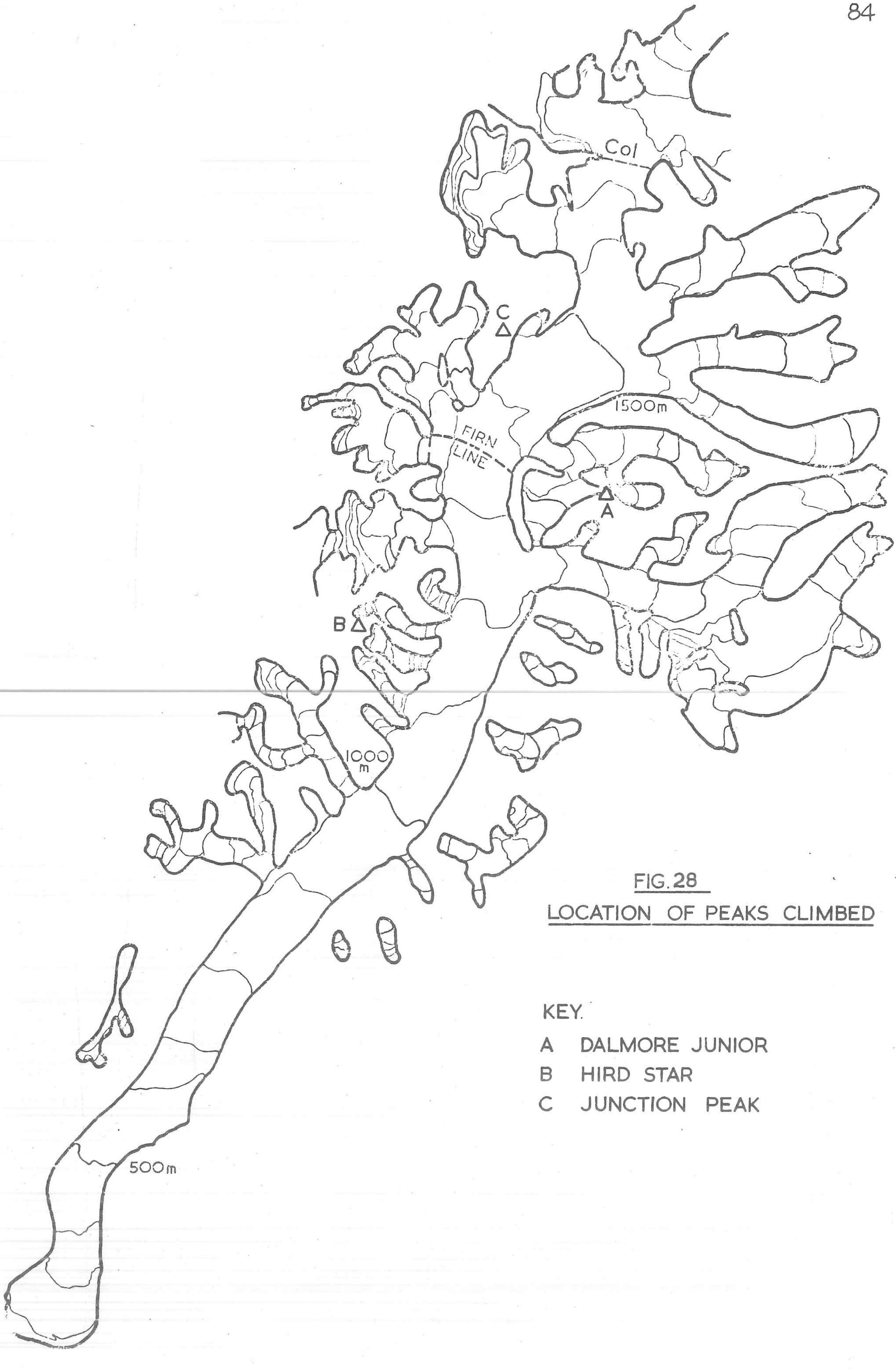


FIG. 28

LOCATION OF PEAKS CLIMBED

KEY.

A DALMORE JUNIOR

B HIRD STAR

C JUNCTION PEAK

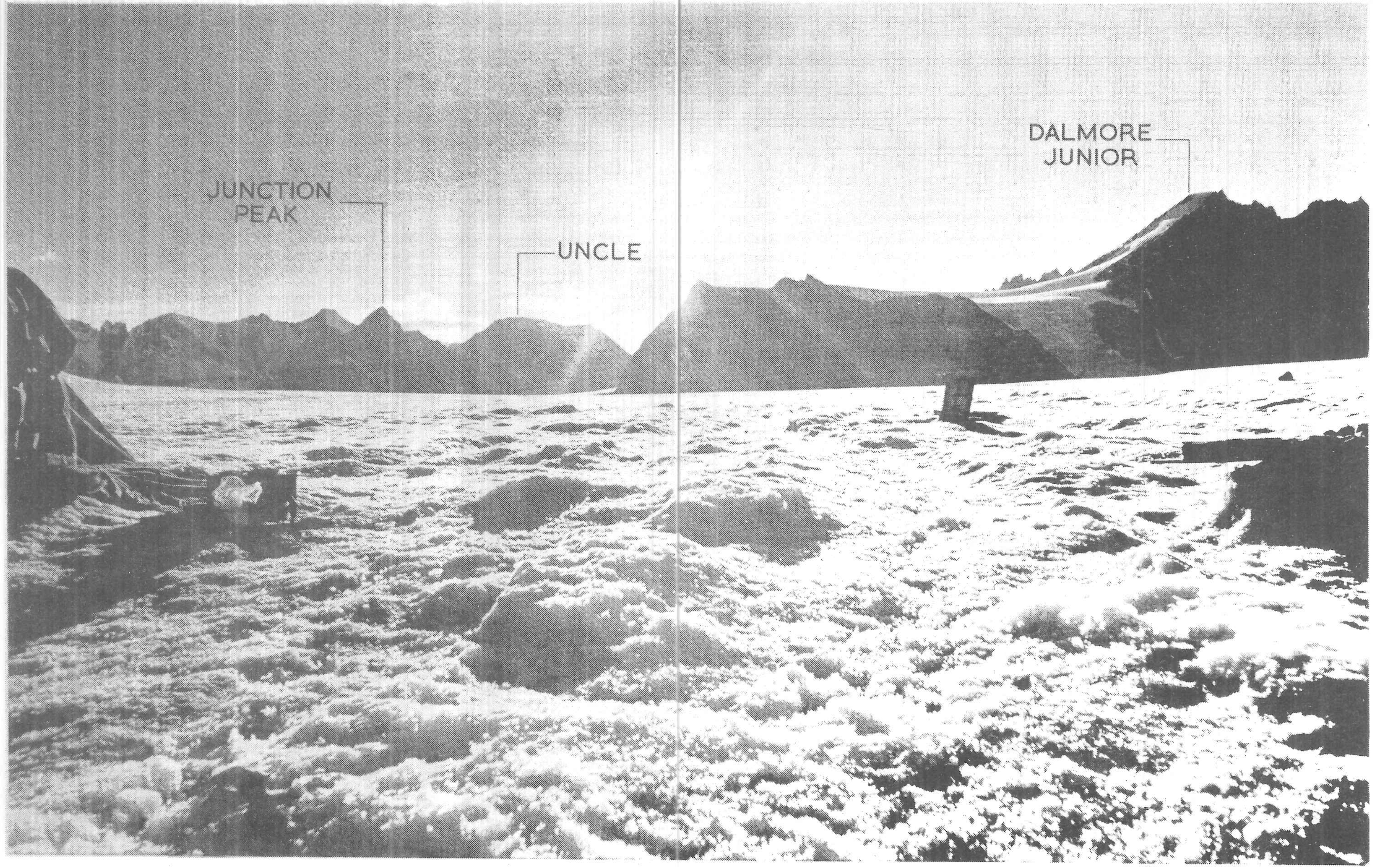


FIG. 29. LOOKING UP THE ROSLIN GLACIER LATE EVENING

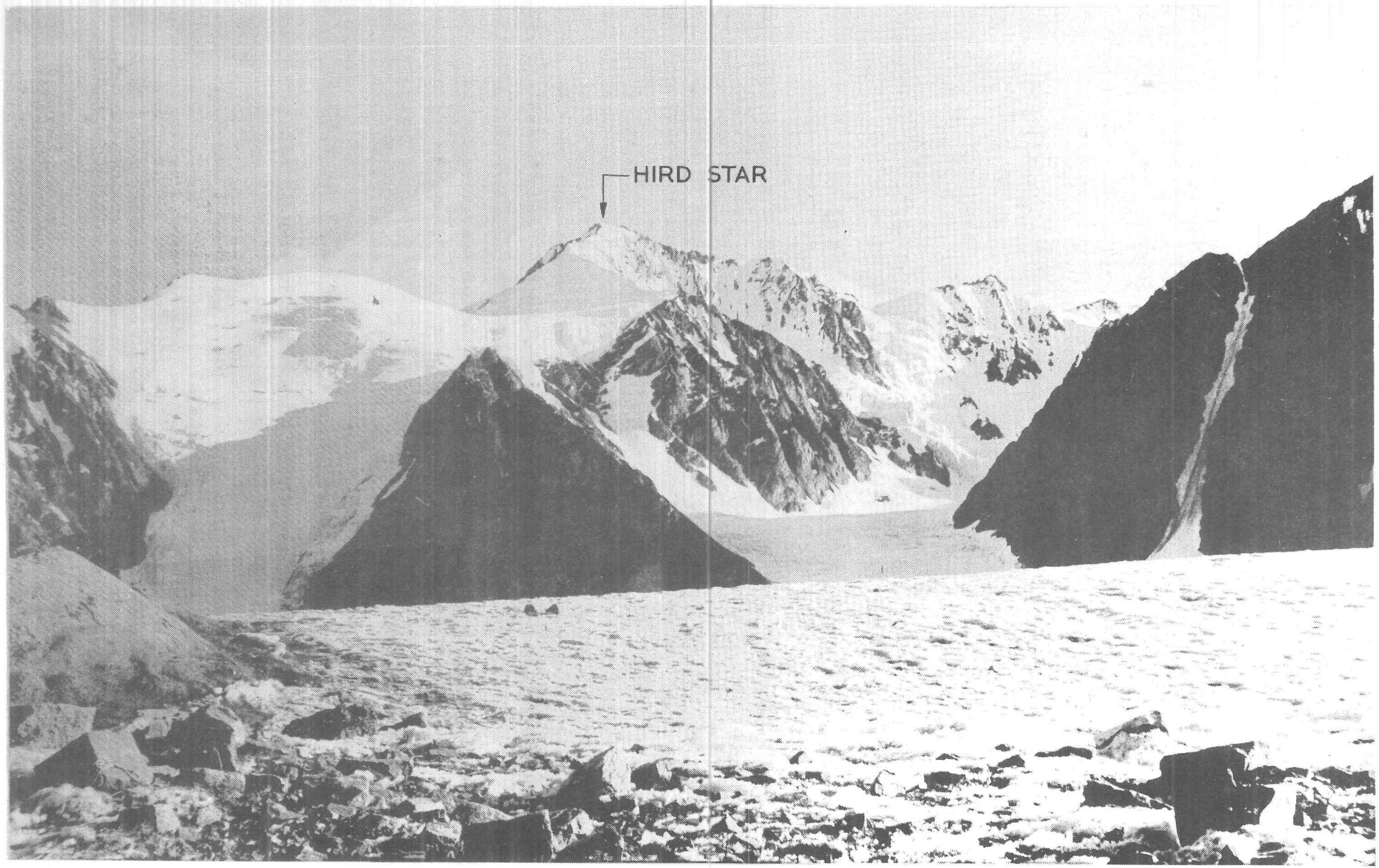


FIG. 30: LOOKING SOUTH ACROSS THE ROSLIN GLACIER FROM BASE CAMP.

The Survey Projects

INTRODUCTION

Although this section of the expedition report involves many separate issues, the major aim of the survey was to set up a triangulation system as quickly as possible and from which it would be possible to

(i) plot the exact path taken by the radio-echo sounding sledge,

(ii) chart the ridges, peaks and side glaciers of the Roslin valley, and

(iii) locate exactly the three stake line systems, one being placed on the Dalmore glacier whilst the other two being placed above and below that glaciers confluence with the Roslin glacier.

It would be impossible to describe the amount of labour, especially post-expedition work, that has gone into producing the maps exhibited in the following sections but future expeditions may wish to note the following statistics. During the course of the expedition some 13 maps were drawn and over 36 tracings made to facilitate resectioning of stage points on the sledge run. After the expedition another 12 maps were drawn involving a further 32 tracings. This report will concern itself only with describing a little of this work and presenting some of the end products.

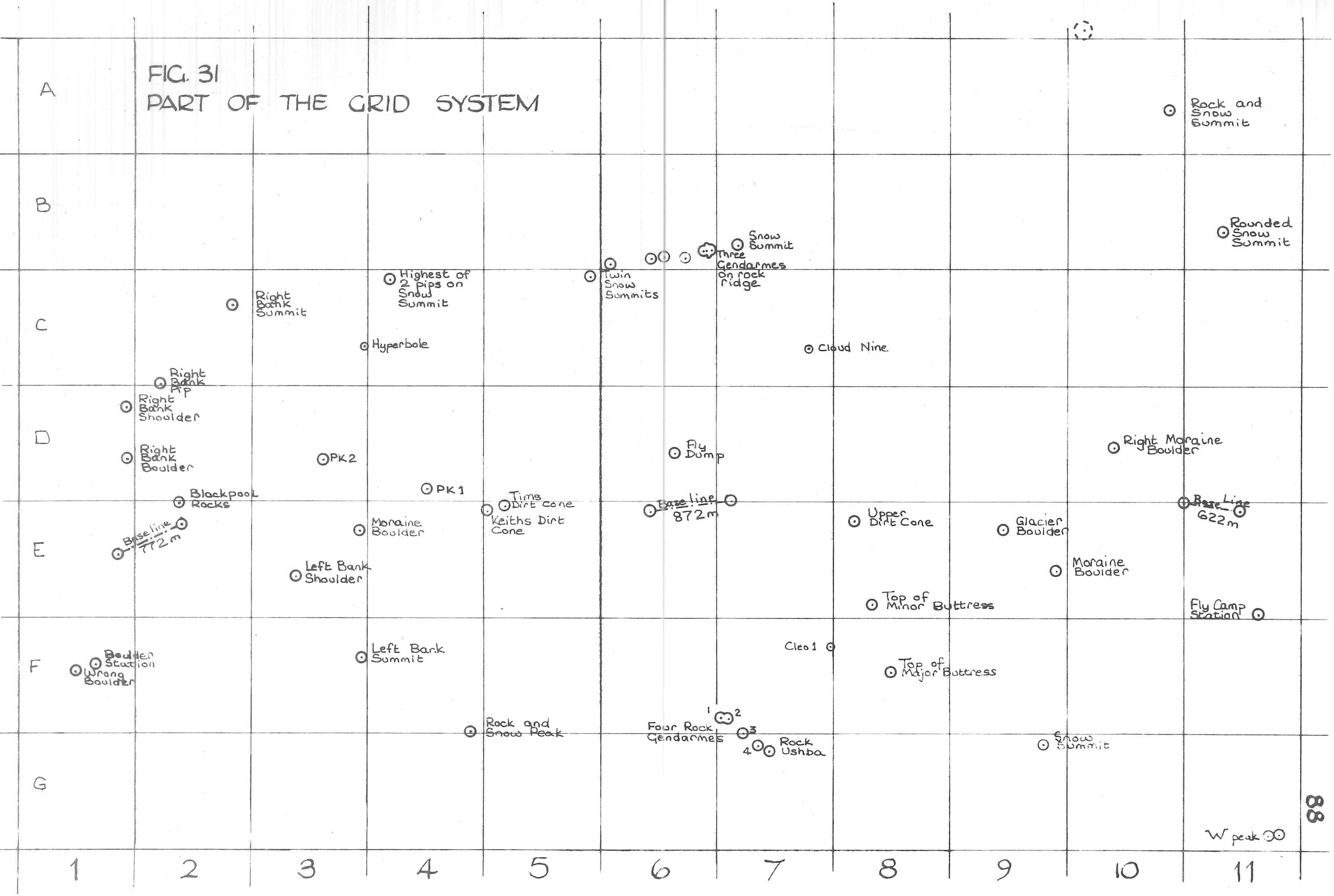
The grid

The initial grid was established at a scale of 1:25,000 in the vicinity of base camp approx. 16 miles above the Roslin snout. This network was completed within 4 days and permitted the mapping of early trial runs of the radio echo sounding sledge. An example of such a grid is shown in Fig.31 Eventually several grids were drawn and assembled to cover the entire area of activity. A master grid was eventually drawn to a scale of 1:20,000 on return to the U.K. There was insufficient time in the field however to fix the relative position of the expedition grid with the trig point details kindly supplied by the Geodetic Institute, Copenhagen. This data is reproduced below.

Established Trig Points: Roslin Glacier Snout Vicinity

The details of the 11 trig points are presented in Table III . Fig. 32 shows the relative location of these points.

FIG. 31
PART OF THE GRID SYSTEM



TECHNICAL NOTE NO.

DETAILS OF TRIG. POINTS IN THE ROSLIN SNOUT VICINITY

Nr.	LATITUDE	LONGITUDE	ELEVATION	DESCRIPTION
51003	71 41 19	24 14 56	1315.38	Highest point of mountain. Bronze-sheet bolted to boulder. 1.5 m centered cairn.
51832	71 46 35	24 14 42	1086.13	Highest point of rounded mountain. Bronze-sheet bolted to boulder. 2 m centered cairn.
51833	71 46 08	24 33 54	1706.33	Eastern spur of high mountain with snowcrest. Bronze-sheet bolted to boulder. 1.5 m c. cairn.
51834	71 41 37	24 34 15	1298.76	Ledge east of snowdome. Bronze-sheet bolted to boulder. 1.5 m c. cairn.
51933	71 46 10	24 33 26	102.63	Low N-S going ridge in riverbed. Bored hole in small loose stone. 0.5 m centered cairn.
51934	71 44 47	24 15 28	1180.83	Top of flat mountain. Wooden peg in topsoil. Small centered cairn.
51935	71 45 05	24 36 30	138.72	Top of hillock in northern part of snout of moraine. Loose bolted bronze-sheet on small stone. Small cairn. Probably not extant.

TABLE III

Continued overleaf.

CONTINUATION OF TABLE GIVING DETAILS OF TRIG. POINTS IN THE ROSLIN SNOUT VICINITY

51936	71 44 05	24 24 41	133.63	Top of hillock in eastern part of snout of moraine. Small cairn. Probably not extant.
51937	71 43 28	24 16 07	1070.32	Local maximum (means local bump on ridge). Bronze-sheet bolted to loose rock.
51938	71 42 19	24 22 18	78.13	10 m elevated over riverbed on sandy hill. Wooden peg in topsoil. 0.6 m c. cairn.
51939	71 42 10	24 27 56	153.14	Top of hillock of stone and rubble in southern part of snout of moraine. Small cairn. Probably not extant.

NOTES

1. All low and most high stations are provided with 2-4 sheets of plastic foil on the ground, each about 0.6 x 3 m, as markers for air-photography.
2. All stations are provided with plastic poles usually 2 m in height with 1 or 2 red fluoresceing wings.
3. All stations were visited in July 1968.

TABLE III Continued

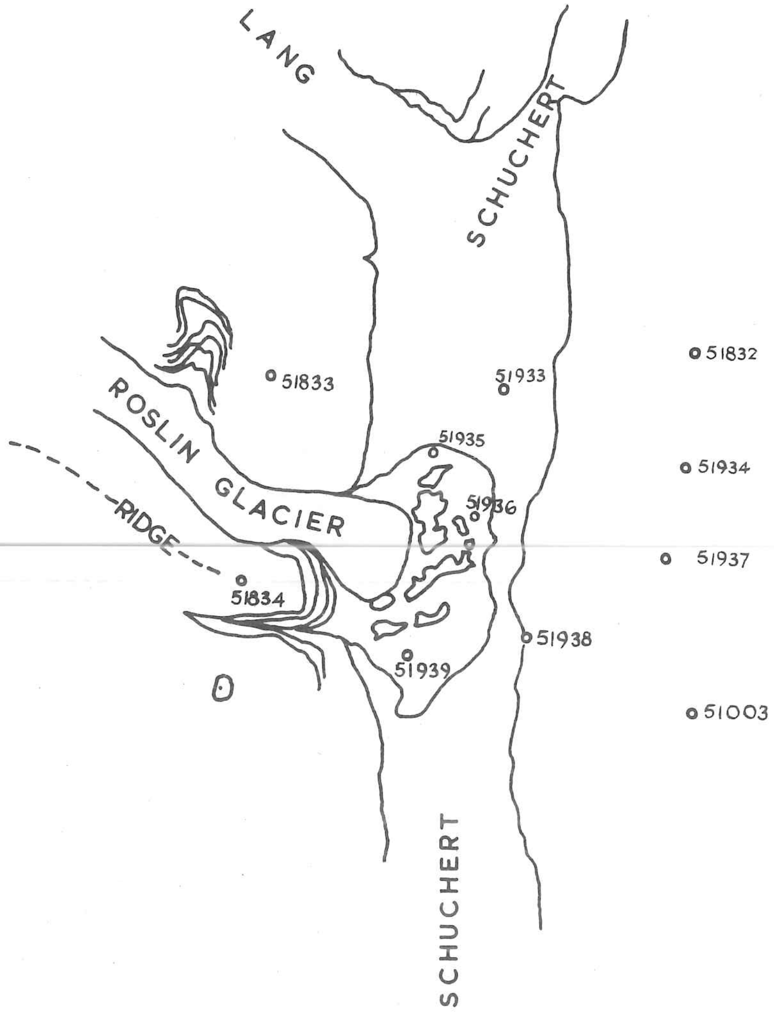


FIG. 32

LOCATION OF TRIG POINTS IN ROSLIN SNOUT VICINITY

(details in table III)

SCIENTIFIC EQUIPMENT

Used by the Survey Group

Item	Source	Terms
1 Watts microptic theodolite	Royal Geographic Society	Loan
1 Watts microptic photo theodolite	" " "	"
1 Ross Ensign Theodolite Camera	" " "	"
2 Theodolite tripods	" " "	"
2 Altimeters	" " "	"
2 Measuring tapes	" " "	"
1 Levelling staff	Cambridge Univ. Eng. Lab.	"
3 Telescopic Alidades	Imperial College	"
3 Plane tables and tripods	Cambridge Univ. Eng. Lab.	"
3 Spirit levels	(Local purchase)	Cash
20 off 18" x 18" x 0.005" sheets Astrofoil	Deep Etch Processes Ltd.	"
15 yards red nylon fabric	Samuel Courtauld & Co. Ltd.	Given
40 off 10' x 1" diameter PVC pipe	Chemidus Plastics Ltd.	"
8 pints tangerine paint	Wall Paper Manufacturers Ltd.	"
2 off 2½" paint brushes	" " " "	"
8 x 1 lb. tins Day-Glo paint	Dane & Co. Ltd.	"
1 gallon white spirit	(Local purchase)	Cash
28 lbs. freezing salt	Cambridge Univ. Chem. Dept.	"
2 Power drill (Teles "Earthworm")	E. H. Bentall & Co. Ltd.	"
1 Drill brace	L. Farnell & Co. Ltd.	"
6 off 3' Flight shaft extension rods	" " " " "	"
1 Ice drill bit 1¼" diameter	" " " " "	"
1 Ice drill bit 1¾" diameter	Scott Polar Research Institute	Loan
1 Tube silicone grease	Hopkins & Williams Ltd.	Cash
Set of spares for Power drill	E. H. Bentall & Co. Ltd.	"
1 Small stereo viewer	Cambridge Univ. Eng. Dept.	Loan
Sets of oblique and vertical aerial photos	Danish Geodetic Institute	Cash
1 Diaso copy of a 1:200,000 map	" " "	"
1 set of log tables	(Local purchase)	"
1 Slide rule	(J. F. Bishop)	Loan

Plane-Table Work

Introduction

Plane-tabling is undoubtedly the best method of producing a rapid grid system in the field for use by other members working on other projects. Furthermore, once experience in the technique has been gained, maps can be prepared with a minimum of delay and calculations are reduced to a minimum. It should be noted that active field work may be reduced to as little as four weeks in the Arctic and so speed in obtaining results is essential.

In order to acquire skills in plane table techniques a short course was held at Brathay Hall, Ambleside, and the expedition would like to take this opportunity to thank Brian Ware and Tony for the facilities they placed at our disposal. The experience gained in plotting old moraine mounds on Loughrigg Fell was most invaluable albeit if the distance between the Gasometer of Ambleside and the Barn on the island in the middle of Grasmere Lake was found to be 20 m in error. For the sake of aspirants who have troubled to read so far into this document this section will conclude with a few 'tips' to assist future plane tablers on expeditions.

The Maps

The major aims of the plane table work were to produce (a) a map of the area and (b) an accurate location of the sledge run. The results are shown on pages 94 and 95 respectively. These maps will now be discussed.

Map of the Upper Roslin Glacier

An initial base line of 1245 m was taped out on the surface of the Roslin.

From each end of the line, station 1, 2 and 3 and major summits, in the vicinity of Base Camp, were located. Subsequent visits to stations 1, 2, 3 and other stations showed excellent intersections had been obtained and so the distance between stations 2 and 3 was calculated and this distance became the base line for all future maps since neither of these two points could be affected by ice flow. Station 2 is located on a small horizontal portion of a ridge some 300 m above and to the north of Base Camp. Station 3 is on the opposite bank of the Roslin and is perched on the only ledge of an otherwise vertical cliff that terminates the northern ridge of Hird Peak. This ledge is reached by a climb up the loose boulders of the ridge west flank.

Map of the Sledge Run (Fig. 34, page 95)

As indicated in Figs. 31 and 33, several base lines were established to facilitate the plotting of the sledge run. A technical note is provided on page 97 to indicate the problems and solutions of laying down a suitable track.

To appreciate the glacier system the map shown in Fig. 34 should be studied in conjunction with Figs. 10 and 11 of Vol. I. (pages 57 and 58) which details the depth profiles.

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Map of the Upper Roslin Glacier

An initial base line of 1245 m was taped out on the surface of the Roslin.

From each end of the line, station 1, 2 and 3 and major summits, in the vicinity of Base Camp, were located. Subsequent visits to stations 1, 2, 3 and other stations showed excellent intersections had been obtained and so the distance between stations 2 and 3 was calculated and this distance became the base line for all future maps since neither of these two points could be affected by ice flow. Station 2 is located on a small horizontal portion of a ridge some 300 m above and to the north of Base Camp. Station 3 is on the opposite bank of the Roslin and is perched on the only ledge of an otherwise vertical cliff that terminates the northern ridge of Hird Peak. This ledge is reached by a climb up the loose boulders of the ridge west flank.

Map of the Sledge Run (Fig. 34, page 95)

As indicated in Figs. 31 and 33, several base lines were established to facilitate the plotting of the sledge run. A technical note is provided on page 97 to indicate the problems and solutions of laying down a suitable track.

To appreciate the glacier system the map shown in Fig. 34 should be studied in conjunction with Figs. 10 and 11 of Vol. I. (pages 57 and 58) which details the depth profiles.

Hints to Plane Tablers

1. It is essential to obtain as much pre-expedition practice as possible.

2. Base lines should not exceed 1000 m if easy recognition of terminal base line poles and flags is required by plane tablers.

3. RECORD ALL STATIONS VISITED AND RAYS TAKEN IN A NOTE BOOK.

4. Tripods must always have rigidity and stability; in many cases it is best to bury the tripod feet some 10 cm into the glacier ice with the aid of an ice axe.

5. The tape binding the edge of the paper to the table must not interfere with the alidade position when taking readings. The alidade must always be level.

6. Errors may be expected when using the alidade to read summits almost directly overhead and the telescope has a high elevation.

7. Before survey work begins walk over the entire area of the system, sketching features and agreeing with each group the names or numbers to be given certain topographical features. Take Polaroid shots if possible; see pages 116 and 117.

8. Make certain the paper you are using is the one you desire to work on. Unknowingly your desired sheet may be covered by yet another thin sheet of Astrofoil.

9. Never have more than three sheets on your plane table otherwise the level of the working surface may be lost.

10. Carry small tools and sandpaper in order to effect repairs on equipment.

11. Carry a Note Book, HB, H, 2H and 3H pencils, soft rubbers, sandpaper blocks, sharpners, tape, scale rulers, bubble level, protractors and dividers. Some items can be stored in the Alidade box but also carry a separate satchel.

Technical Note No. 6.

The siting of sledge paths

When selecting sledge path routes three conditions had to be considered.

1. The paths had to be meaningful for the echo-sounding project. It was hoped that two longitudinal profiles would be possible,each at discrete distances on either side of the centre line of the glacier and not too close to the valley sides. The longitudinal profiles were to be supplemented where possible by transverse profiles at appropriate zones.

2. The path,suitably marked, had to be as easy a track as possible for the hauling of the sledge. Obstacles such as moraines and melt streams, both of which could produce spurious echoes, were to be avoided wherever possible. Where such obstacles had to be traversed a pre-survey was essential in order to locate optimum traverse points.

3. Wherever possible the path had to be fairly straight in order to facilitate the survey of the routes.

ROUTE MARKERS

Suitably isolated boulders, where frequently used in the lower reaches of the Roslin Glacier but when these became sparse, especially in the upper reaches, Ryvita tins, painted with "Day-Glo" were employed. The latter were positioned at 300-500 m intervals. A route card of the path, detailing paced distances and compass bearings, was written in order to aid navigation by the sledge party in bad weather conditions.

Details

1. 1.5 pints of paint were sufficient to provide two coats of colour for 50 Ryvita tins.

2. Two types of orange paint were taken. Day-Glo was preferred for marking rock walls in the vicinity of survey stations while Tangerine was used for boulders on the glacier.

3. The use of Ryvita tins permitted a rapid laying of a "track." In one day it was possible to site a 12 km route, (24 tins) in the upper Roslin. Unfortunately several days elapsed before the survey party mapped this route and they had difficulty in locating several tins.

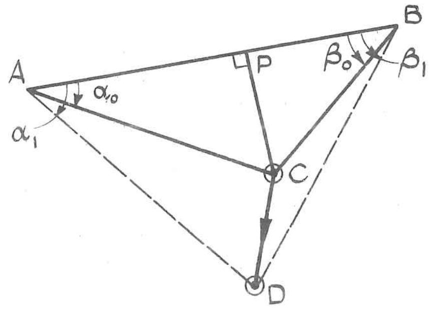
Glacier Flow Rates

As part of the general study of the Roslin Glacier and to complement the longitudinal and transverse profiling work of the sledge party, three stake lines were set out on the glacier surface. One system was established on the Dalmore Glacier and two on the Roslin, one above and one below the Roslin/Dalmore junction, Fig.(35). The stake lines, each of nine equi-distantly spaced poles, were initially set out using a theodolite. The holes were drilled four feet deep with a Telles Earthworm drill and auger. Poles were sunk into the holes and red nylon flags attached to facilitate the location of the poles from survey stations. The flags also proved an aid to navigation in bad visibility. The stakes were surveyed at the earliest and latest opportunities from situations above and below each line; the measured displacements being interpreted as glacier movement.

The locations chosen for the two higher stake lines, i.e. the upper Roslin and Dalmore Glacier lines, caused difficulty in respect of finding suitable survey sites. The ideal station must overlook the entire stake line and be visible from a sufficient number of accurately known points for its precise location to be determined with respect to the triangulation grid. The two stake lines mentioned above were close to the Roslin/Dalmore junction, which indicated the central buttress spur as one obvious choice. Stations P_1 and P_2 were set up here on rock ledges without much difficulty, see Fig.(36). The second station on the Dalmore Glacier should ideally have been on the rock face on the opposite bank, but the fragmented nature of the soft rock there and the curvature of the wall ruled this impossible. The only other solution was to find a station upstream of the stake line, on the same side of the glacier as the first station. Since the flags were relatively close to the ground level, and the surface of the glacier at this point convex, it was necessary to climb a steep buttress to reach station Q, see Fig.(36).

When working from the stake survey stations named above it was found that good repeatability could be obtained if the theodolite was set up each time with the feet in identical positions on the rock and the zero sighting marker clearly identified. For this latter purpose a large area of the rock wall behind each theodolite station was painted with an orange dayglow symbol. When sighting over a distance of a few miles, a spot, one metre in diameter proved sufficient, provided the operator knew roughly where to start looking. The theodolite tripod was usually set up with the instrument close to the ground so that the operator could sit to take the long rounds of readings, which sometimes exceeded three hours' duration.

Calculations of flow rates are simplified by using a computer program, see page 126. The program determines with reference to the sketch below, distances AP and PC for individual stakes. AB represents the base line of the system which, in the present work, was determined from plane table maps. The angles α_o and β_o represent the original horizontal sightings onto individual poles from stations A and B respectively.



C is the initial position of the pole and D the final position, hence CD, the flow, may be calculated.

Details of the three systems are presented on the following pages.

MAP SHOWING POSITIONS
OF STAKE LINES

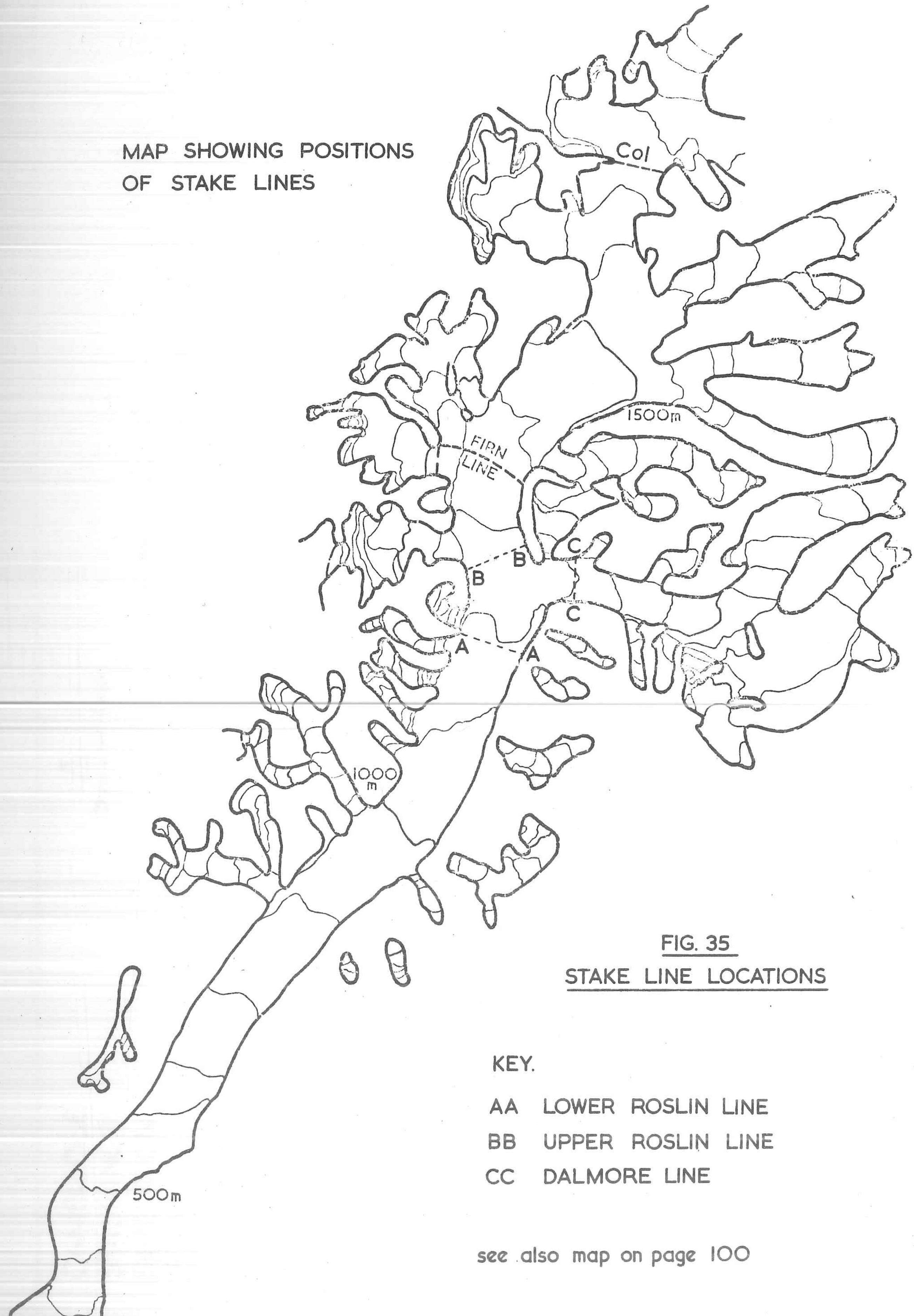


FIG. 35
STAKE LINE LOCATIONS

KEY.

AA LOWER ROSLIN LINE
BB UPPER ROSLIN LINE
CC DALMORE LINE

see also map on page 100

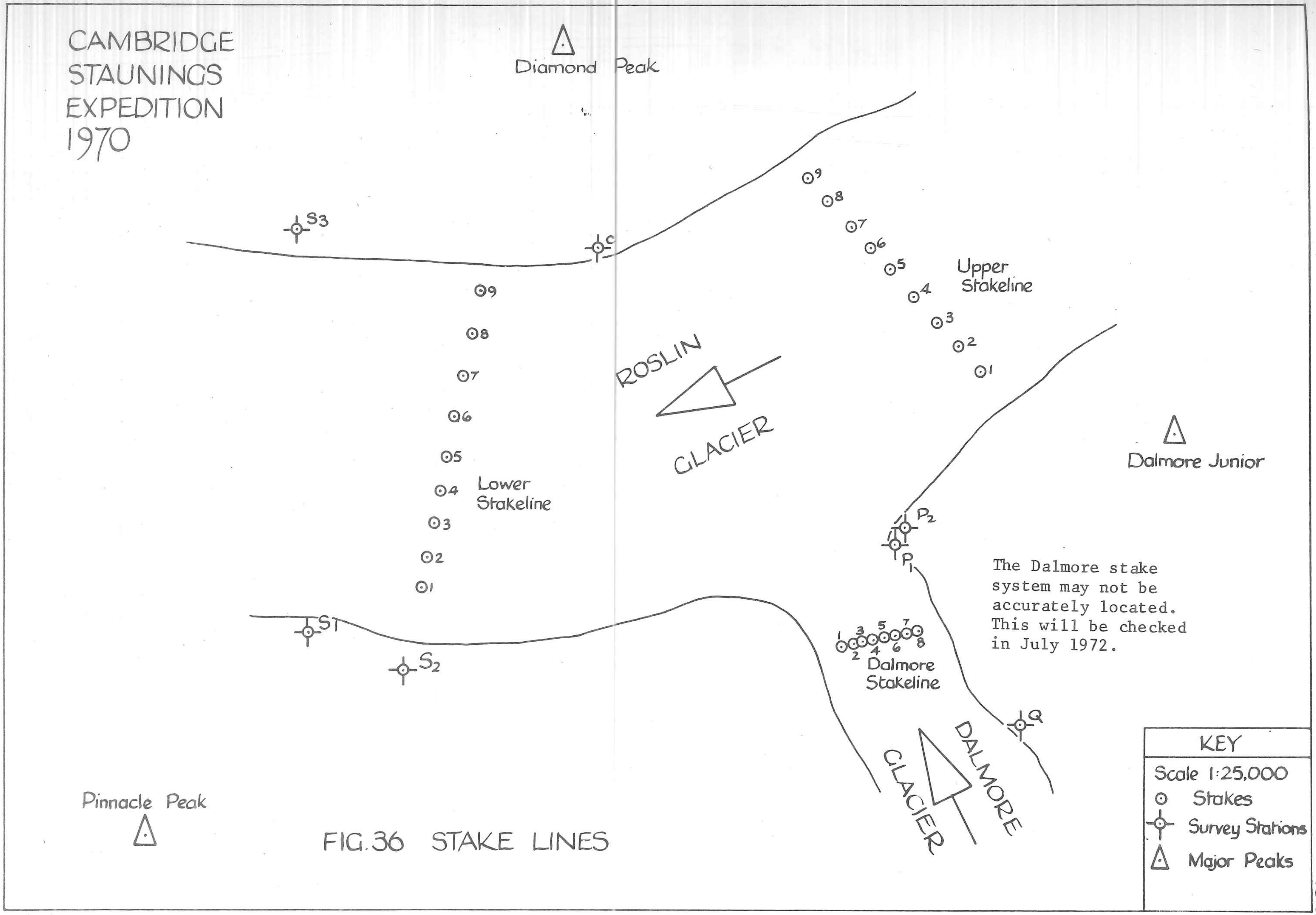
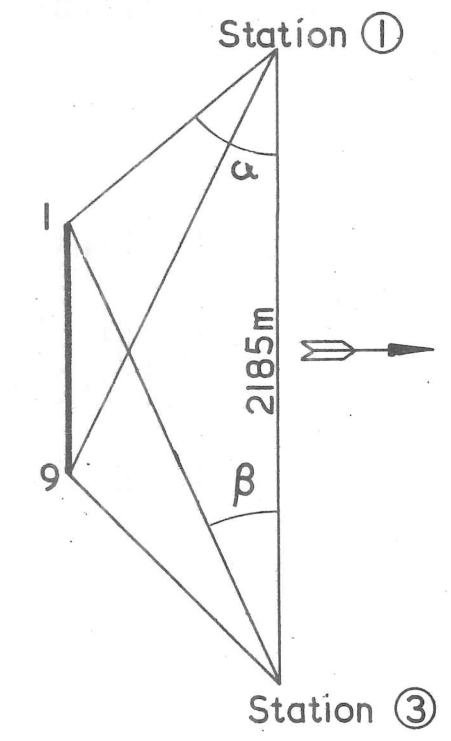


FIG.36 STAKE LINES

STAKE LINE MOVEMENTS.

SYSTEM:- LOWER ROSLIN

SKETCH OF SYSTEM



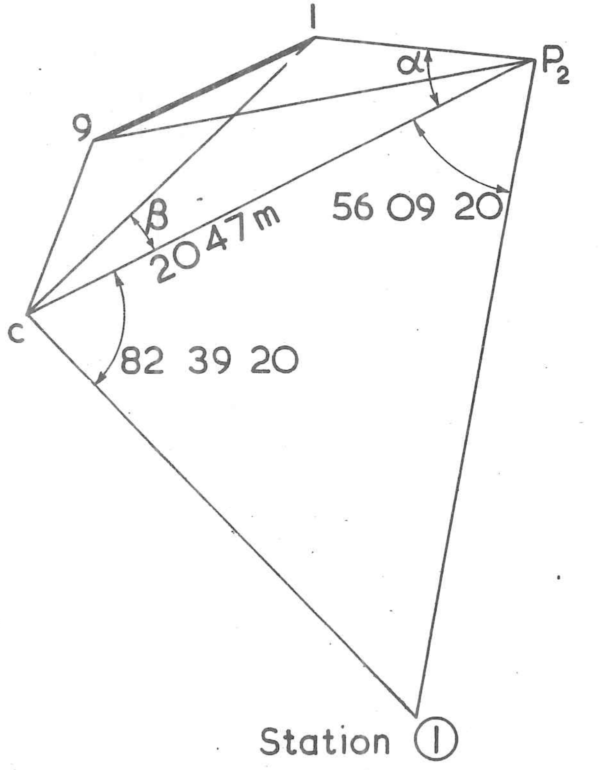
STAKE No.	DATE											
	27 JULY 1970			14 AUG. 1970			27 JULY 1970			14 AUG. 1970		
	α_0			α_1			β_0			β_1		
	°	′	″	°	′	″	°	′	″	°	′	″
1	70	12	57	70	13	40	18	20	47	18	19	55
2	60	55	40	60	55	45	20	29	30	20	28	40
3	51	23	55	51	23	20	23	56	57	23	55	53
4	44	59	12	44	58	42	27	45	57	27	45	00
5	39	55	50	39	55	10	32	39	07	32	38	02
6	36	22	42	36	22	10	38	03	15	38	02	13
7	33	10	40	33	10	07	45	38	15	45	36	50
8	30	45	32	30	45	07	54	25	05	54	24	18
9	28	48	35	28	48	22	64	38	00	64	37	43

TABLE IV a

STAKE LINE MOVEMENTS.

SYSTEM:- UPPER ROSLIN.

SKETCH OF SYSTEM



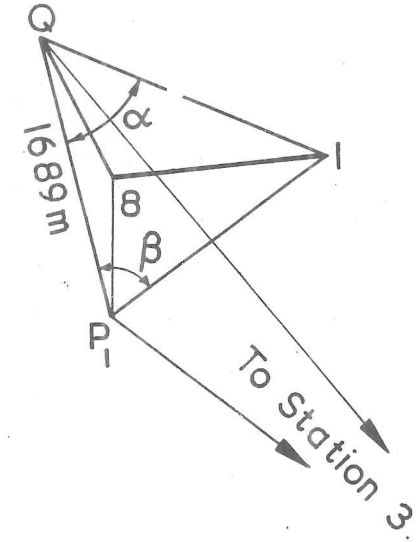
STAKE No.	DATE											
	26 JULY 1970			15 AUG 1970			26 JULY 1970			15 AUG 1970		
	α_0			α_1			β_0			β_1		
	°	′	″	°	′	″	°	′	″	°	′	″
1	77	46	00	77	45	40	23	11	30	23	10	28
2	69	02	15	69	01	10	25	07	43	25	06	35
3	60	49	37	60	48	15	27	30	15	27	28	58
4	53	20	37	53	18	55	30	29	55	30	28	18
5	47	16	17	47	14	32	34	03	58	34	02	18
6	43	03	27	43	01	50	37	32	23	37	30	43
7	39	42	05	39	40	40	41	16	20	41	14	40
8	35	57	40	35	56	20	47	06	33	47	04	30
9	33	29	07	33	27	48	52	29	58	52	27	50

TABLE IV b

STAKE LINE MOVEMENTS.

SYSTEM:- DALMORE.

SKETCH OF SYSTEM



STAKE No.	DATE											
	25 JULY 1970			15 AUG. 1970			25 JULY 1970			15 AUG 1970		
	α_0			α_1			β_0			β_1		
	°	′	″	°	′	″	°	′	″	°	′	″
1		—			—		54	48	55	54	53	45
2	35	58	01	35	56	36	48	43	19	48	49	20
3	33	51	05	33	49	23	44	37	09	44	43	00
4	31	11	31	31	09	53	39	45	17	39	51	10
5	27	20	33	27	18	36	33	05	32	33	11	05
6	23	46	43	23	44	53	27	24	37	27	29	23
7	19	36	36	19	34	25	21	19	04	21	22	33
8	15	36	36	15	35	01	16	04	47	16	07	30

TABLE IV c

DISTANCE	STAKE NUMBER IN THE DALMORE GLACIER SYSTEM.								
	1	2	3	4	5	6	7	8	9
A P		1031·755 1033·520	1005·526 1007·345	977·528 979·402	941·770 943·818	913·149 915·177	882·918 885·024	857·679 859·682	
P C		748·704 749·334	674·447 674·945	591·824 592·322	486·968 487·349	402·339 402·650	314·566 314·683	239·630 239·762	
TRAVEL		1·87	1·89	1·94	2·08	2·05	2·11	2·01	

DISTANCE	STAKE NUMBER IN THE LOWER ROSLIN GLACIER SYSTEM.								
	1	2	3	4	5	6	7	8	9
A P	232·863 232·551	375·884 375·636	571·967 571 761	753·831 753·643	947·435 947·274	1125·666 1125·506	1332·774 1332·527	1532·472 1532·378	1733·087 1733·064
P C	647·361 646·918	676·100 675·693	716·454 715·946	753·479 753·072	793·037 792·590	829·255 828·867	871·404 870·938	912·046 911·739	953·155 953·000
TRAVEL	0·54	0·48	0·55	0·45	0·48	0·42	0·53	0·32	0·16

DISTANCE	STAKE NUMBER IN THE UPPER ROSLIN GLACIER SYSTEM.								
	1	2	3	4	5	6	7	8	9
A P	173·986 173·928	311·809 311·831	460·997 461·005	623·831 623·812	786·993 786·982	923·746 923·715	1051·909 1051·837	1222·845 1222·658	1357·779 1357·572
P C	802·452 801·810	813·879 813·171	825·767 825·010	838·263 837·373	852·001 851·119	863·140 862·298	873·354 872·562	887·180 886·321	898·191 897·307
TRAVEL	0·64	0·71	0·76	0·89	0·88	0·84	0·79	0·88	0·91

FIG. 36 DATA FROM COMPUTER PROGRAMME TO DETERMINE GLACIER SURFACE FLOW RATES.

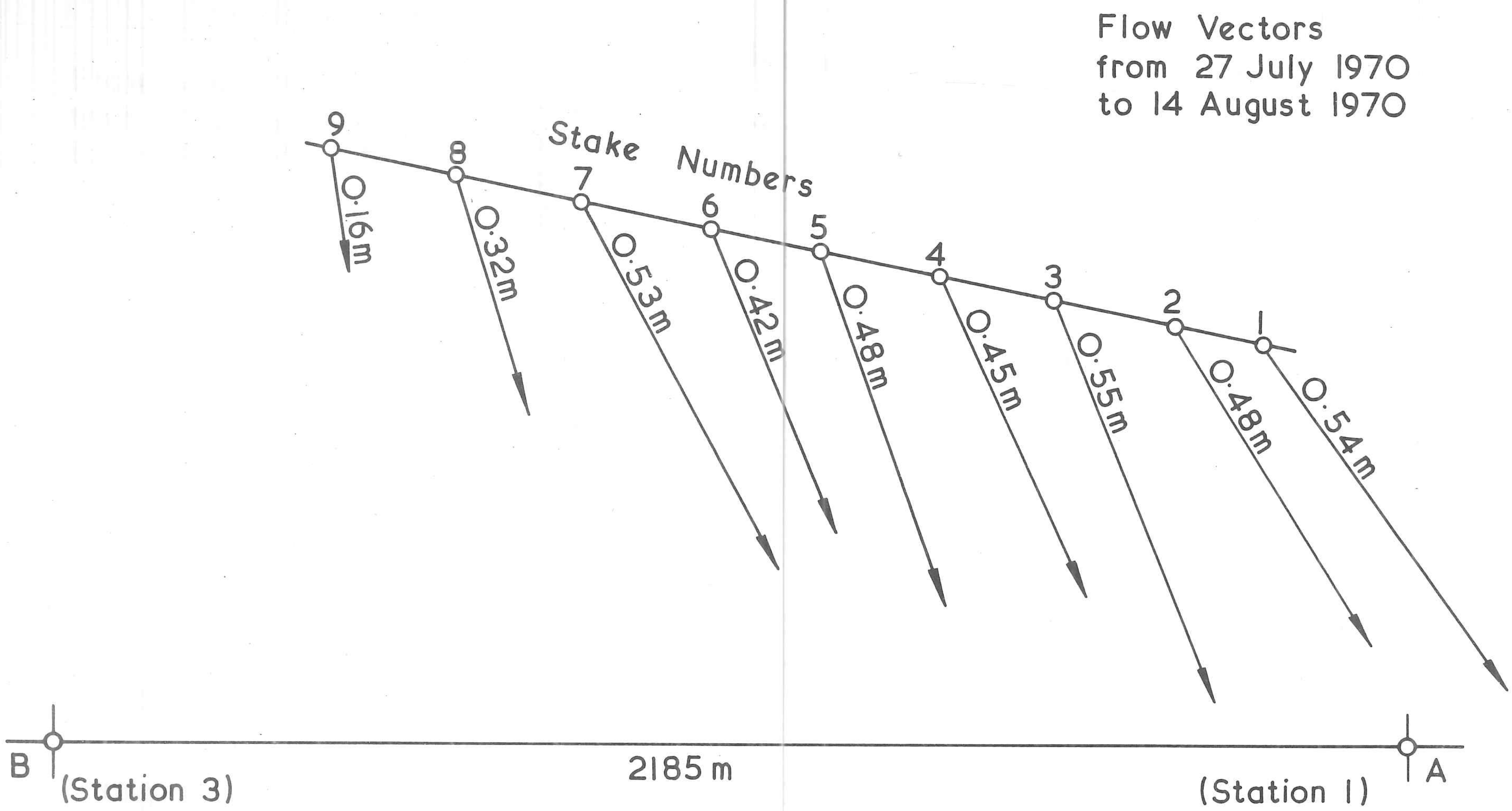


FIG.37 STAKE POSITIONS AND FLOW : LOWER ROSLIN SYSTEM.

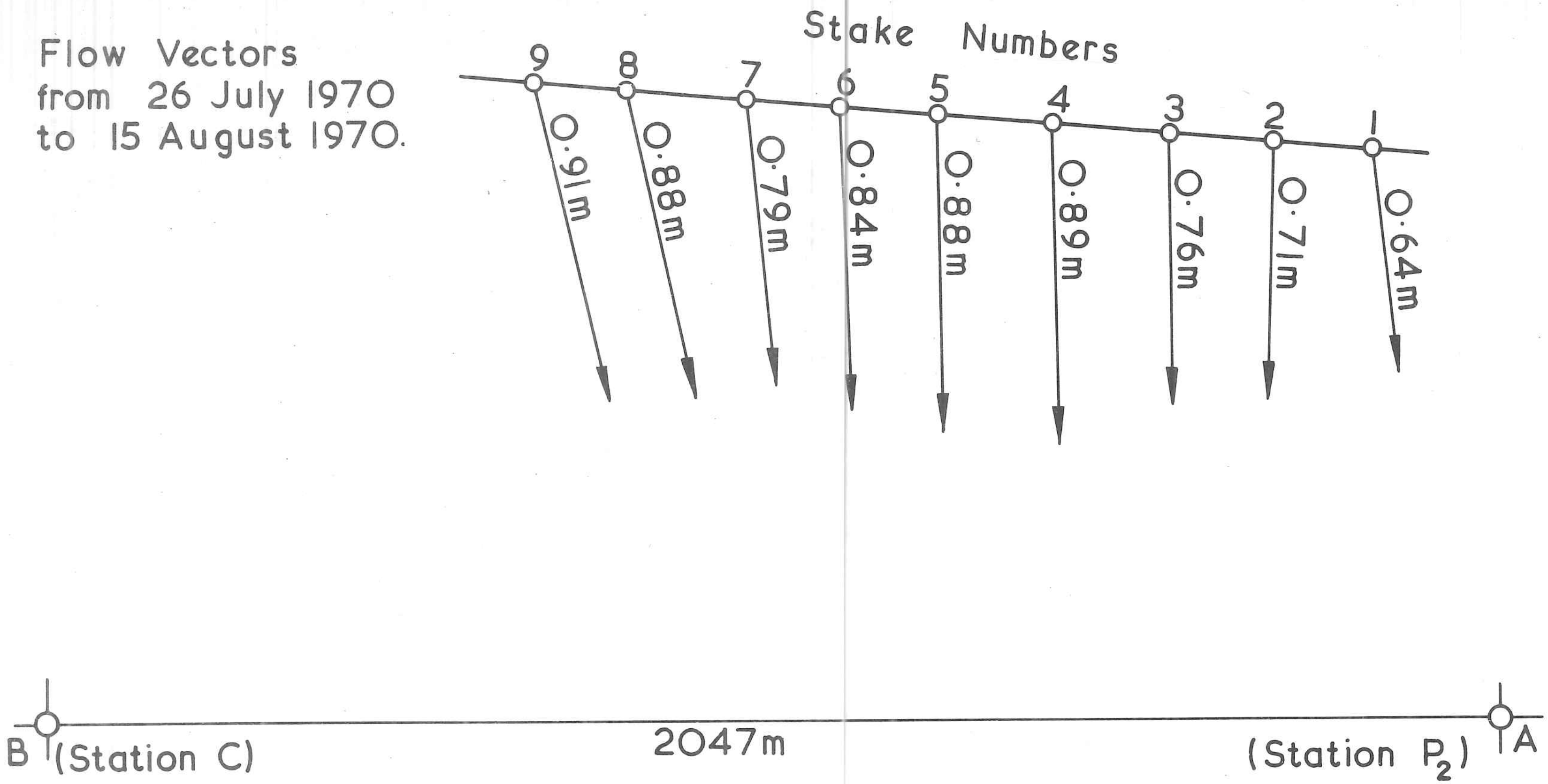


FIG. 38 STAKE POSITIONS AND FLOW: UPPER ROSLIN SYSTEM.

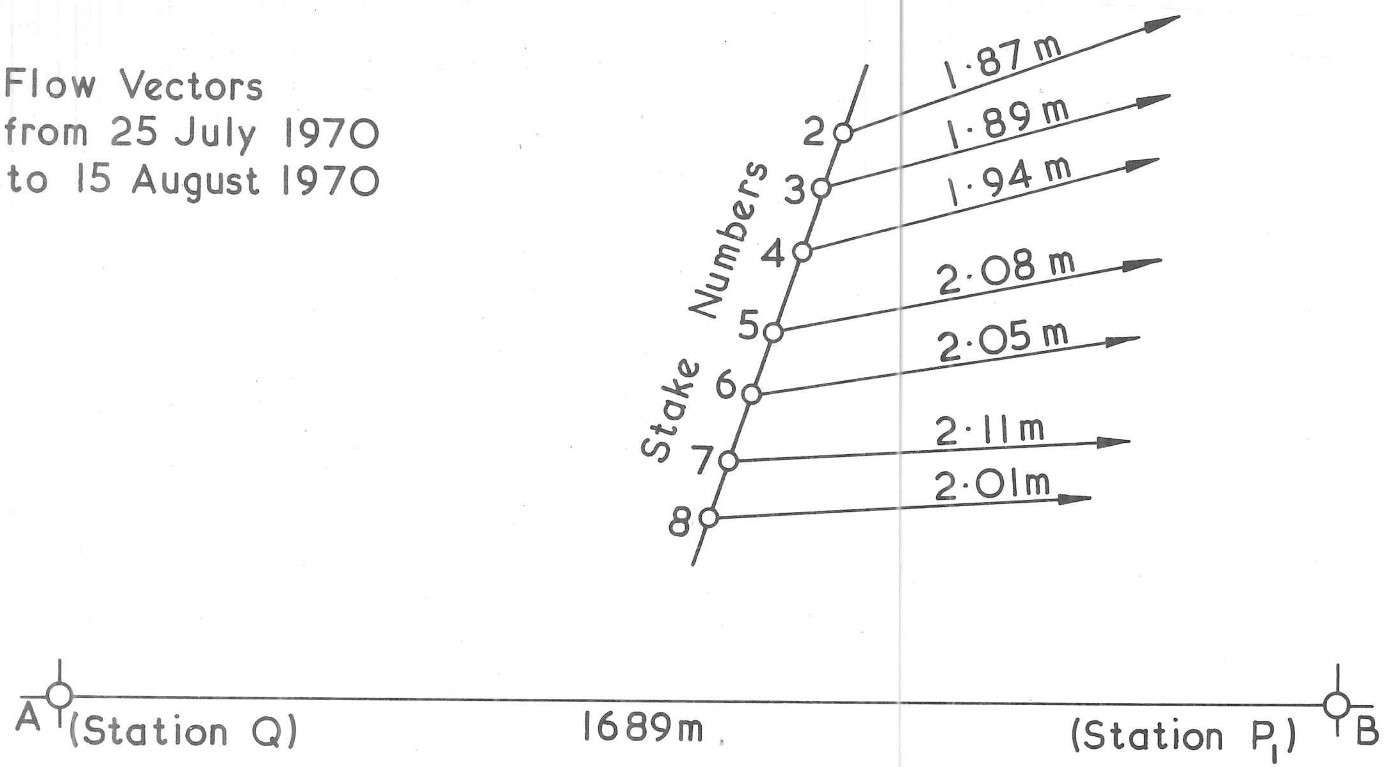


FIG. 39 STAKE POSITIONS AND FLOW : DALMORE SYSTEM.

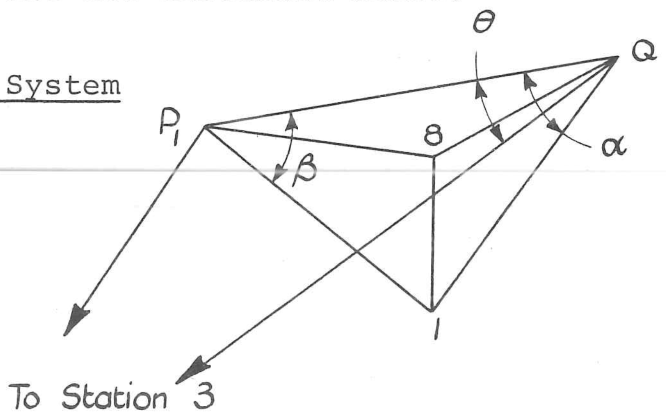
MISTAKES MADE BY SURVEYORS

As stated previously, the method of determining ice flow rates by measuring stake movements is exceedingly simple. However it is essential to check results and carry out a few basic calculations in the field to make absolutely certain all data collected is both correct and sufficient. Several mistakes were made in 1970 and when these were discovered there was insufficient time to return from Tundra to Base Camp in order to effect a remedy. The mistakes were largely due to the over-confidence of young members who were perhaps bemused by their undoubted ability to take angular readings from the theodolite with an exceedingly high degree of accuracy and repeatability. Furthermore there was perhaps too much haste by two members of the expedition who wished to squeeze a few free days away from the scientific programme in order to climb a major peak before we left Greenland.

Let future expeditions note that the delivery of several lectures on various expedition techniques before leaving the U.K. and the learning of these techniques prior to the expedition - can be wasted effort if insufficient care is taken during the course of the expedition.

The mistakes made are now discussed below.

The Dalmore Stake Line System



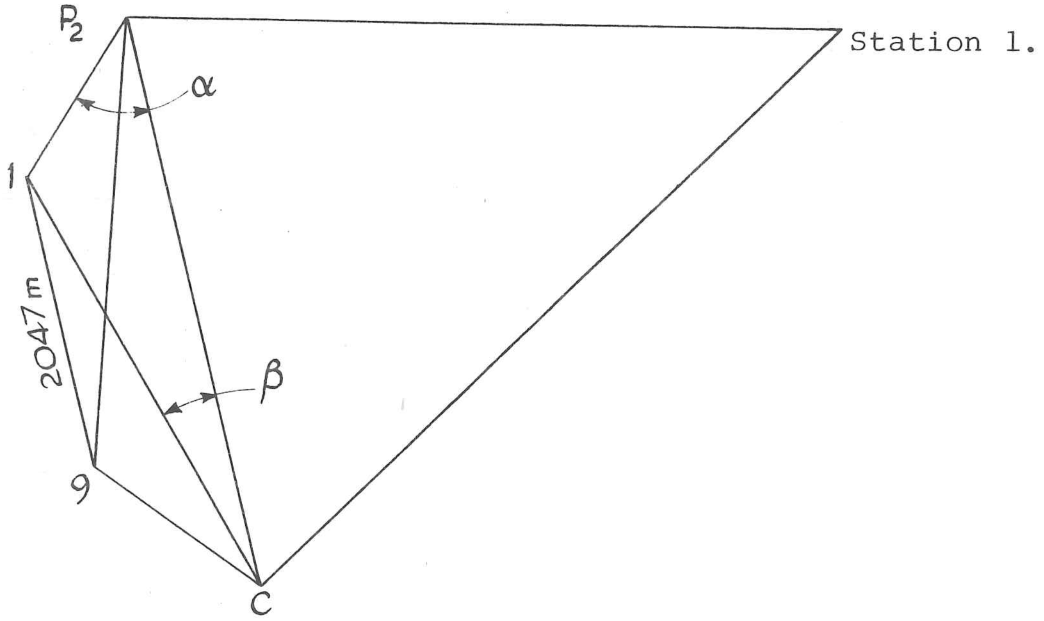
Mistake 1

From Q it was not possible to see the painted marker on the wall a few feet behind P_1 and so reference was made to station 3. (25 July 1970). However Q could be sighted from P_1. In order to compute α and β angles to stake 1, and other stakes, it is therefore necessary to determine θ via angle $P_1 3Q$. This latter angle was not determined by theodolite. From 1970 plane table results and from 1971 data it was assessed to be 27° 05' 33".

Mistake 2

The distance P_1Q must be known when computing stake movements. On 31 July a base line of 600 ft was chained out somewhere between stakes 4 and 6 in order to determine this distance. The subsequent calculation gave a result of 1689 m but on the plane table the distance is 1190 m. The error is most probably due to incorrect location of Q by the plane tabler.

The Upper Roslin Stake Line



Mistake 3

The initial survey was conducted from C with the theodolite zeroed on station 1, P_2 not then being established. To determine angle β therefore, it is necessary to know angle P_2 C 1, this was not subsequently determined directly by theodolite.

Mistake 4

FR and FL readings of the theodolite for horizontal bearings on stake 5 from P_2 read 284° 25' 25" and 103° 25' 50". This error of 1 deg should have been spotted by the recorder. Fortunately the incorrect result was determined by correlations from later readings.

Mistake 5

A similar error to Mistake No. 2 above. The distance P_2C is at variance with the plane table result of 2260 m being only 2047 m. The error is probably due to incorrect location of C.

Mistake 6

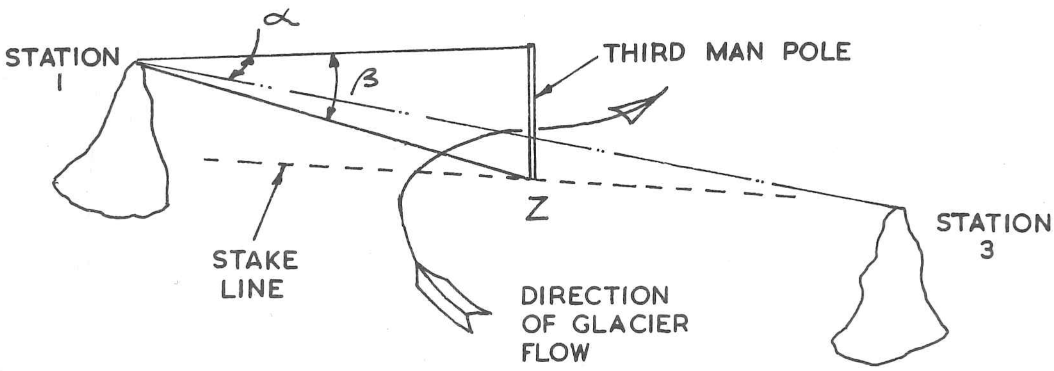
From one end of the base line set up on the ice to facilitate the determination of length P_2C a sighting was made to Station 1. This bearing was not repeated from the other end of the temporary base line. If this bearing had been taken computation of results would have eliminated Mistakes 3 and 5 above.

The above mistakes have been minimised by extensive computer analysis of results. However checks will be carried out in 1972. The maximum error in flow rates shown in Figs. 36, 37 and 38 are expected to be less than 2%.

As part of the survey programme it was decided to take transverse and longitudinal profiles of the glacier. This project would assist the radio-echo sounding work and provide a reference for further studies on the glacier. Lack of time and other difficulties led to a curtailment of this project, but one transverse profile was taken in an afternoon by three expedition members.

The undulating cross-section of the glacier at the stake line made levelling with staff and theodolite very slow and tedious. It was therefore decided to employ the following method:

A surveyor and an observer set up a theodolite at Station 1, which overlooked the whole of the lower stake line. A third man took a ten foot survey pole with flag atop to the edge of the glacier. The surveyor took both horizontal, α, and vertical, β, angles to the top of the pole, held upright at 90 points across the glacier along the line of stakes. Sketches of the profiles of streams were made by the third man as he traversed the stake line.



The stake line had initially been positioned with a theodolite and was straight and fixed by observations from Stations 1 and 3.

A computer program was written to determine the positions of each point The computer produced the co-ordinates of all points using the initial point as origin. The vertical distance of this origin below station 1 was 41 m.

Plotting results produced a profile agreeing very closely with sketches made on the surface. Occasional points were obviously fallacious and found to be due to errors made in transcription of 10 seconds of arc. The whole profile is given in Fig. 40 . Sections where the profile is uncertain are marked as dotted lines. The error at the end furthest from the theodolite was estimated to be $\pm$ 0.5 m.

The ice flow emerging from the Dalmore produces the marked hump at the left of the profile shown in Fig. 40 .

Ablation

During the short arctic summer the surface of a glacier is lowered by the melting of ice and snow and the subsequent runoff of the water. This loss is termed ablation. The recording of ablation is important in calculating the gross annual budget of a glacier i.e. the net loss or gain of ice. The water runoff is also important since it may affect the dynamics of the glacier by lubricating the bed and causing basal sliding. Ablation is usually given in cubic centimetres of water equivalent, thus necessitating the measurement of ice and snow densities.

It was not possible during the expedition either to make a study of the mass balance of the glacier or to compare ablation rates with relevant meteorological conditions. However the twenty-six stakes set up on the glacier for observation of surface movements were also employed to measure ablation over a period of two weeks. The summer melt was well advanced at the beginning of this period and was practically finished at the final reading.

Ablation was determined by recording, the difference between the top of the stake and the ice surface. The difficulty lay in defining the surface. Devices such as the star ablatometer,(1) whereby the mean of 36 points around the stake is taken, can be used for more accurate short-term measurements and involves errors of only ± 0.3 cm. Without such a cumbersome piece of apparatus our results, see Fig. 41 , are considered to be accurate to ± 1 cm. Stake 7 on the Upper Roslin Line was disturbed whilst being used as a marker for the sledge run.

Ablation is affected by wind, altitude, solar radiation and surface topography. The difference in mean ablation between the two Roslin stake lines is essentially a function of altitude. However the consistent wind down the Roslin Glacier causes nearly double the ablation at the Upper Roslin Line compared to the Dalmore Line, which is at the same altitude but considerably more sheltered.

Reradiation from the steep rock walk at the sides of the Dalmore glacier produced greater ablation at the ends of the line than the centre. A more undulating surface could also cause the differences in ablation to those recorded on the Roslin lines.

Ref.

1. F. Müller and C. M. Keeler Errors in short-term ablation measurements on melting ice surfaces.

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Additional theodolite work

In addition to the survey of stake lines, the theodolite was used for triangulation and vertical angle measurement, to support and help tie in the general plane-table mapping of the valley. This function occupied a part of the theodolite crew's time after the stake lines had been set up. Rounds of horizontal and vertical angle measurements to every prominent feature visible in the Roslin system were taken from all the main triangulation points in the vicinity of base camp. Later, similar, though less detailed measurements were taken from several stations at the head of the glacier and downstream of base camp. A theodolite party climbed a peak called Junction Peak upstream of base but visibility at the summit was not good and no readings were taken. This possibly virgin mountain held a commanding view both up and down the glacier so the inclemency of the weather on this occasion prevented the group from obtaining a potentially very valuable set of readings. A later attempt to triangulate up from the snout to base camp also suffered from heavy cloud during two of the available four days and was not successful.

Of the two theodolites, both on loan from the RGS, only one was extensively used. It was a modern Watts 20" instrument and performed faultlessly for horizontal angle measurement. Unfortunately, despite careful precautions against error, the repeatability of vertical angle measurements was extremely poor. Horizontal angles were always accurate to 30" and usually much better; vertical angles showed a mean error of 2' 10" but this was variable. A Ross Ensign camera, which proved reliable in operation, was attached to the theodolite to take rounds of photographs from all important stations.

TECHNICAL NOTE NO. 7

COMPUTER PROGRAM FOR THE GLACIER TRANSVERSE PROFILE

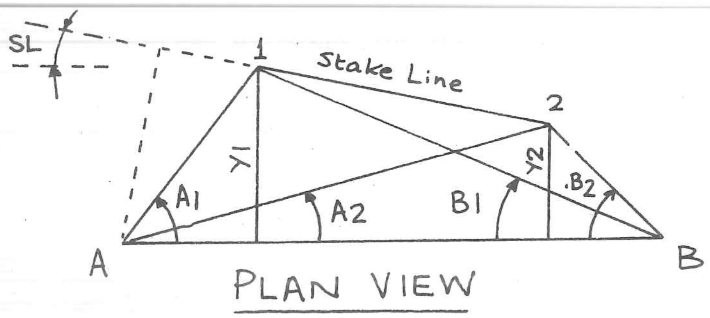
Presentation of Data

SYMBOL	DESCRIPTION
N	Number of points surveyed
AB	Distance between stations A and B (metres)
A1, A2, B1, B2	Angles from stations to two ends of stake line. See sketch.

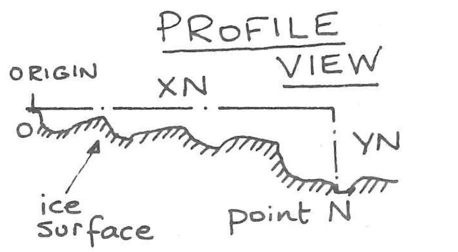
THIS IS FOLLOWED BY THE THEODOLITE READINGS PRESENTED WITH HORIZONTAL ANGLES FIRST. THEODOLITE CORRECTIONS SHOULD BE ADDED TO THE PROGRAM

Horizontal Angles (α)			Vertical Angles (β)		
73	21	05	359	15	25
72	19	30	1	00	10

1 and 2 should be the extreme ends of the stake line.



SL = inclination of stake line to AB.



XN = horizontal distance along stake line from origin to N.

YN = vertical displacement at point N.

THE PROGRAM

```
// JOB
// *GTP GLACIAL TRANSVERSE PROFILE
// FOR
*IOCS(TYPEWRITER,PAPER TAPE)

      PAUSE

      CALL IDATA(4,N)
      CALL DATA(4,AB)
      CALL DATA(4,A1)
      CALL DATA(4,A2)
      CALL DATA(4,B1)
      CALL DATA(4,B2)

      A1=RAD(A1)
      A2=RAD(A2)
      B1=RAD(B1)
      B2=RAD(B2)
```

(continued overleaf)

```
      CA1=COS(A1)/SIN(A1)
      CA2=COS(A2)/SIN(A2)
      CB1=COS(B1)/SIN(B1)
      CB2=COS(B2)/SIN(B2)

      Y1=AB/(CA1+CB1)
      Y2=AB/(CA2+CB2)

      Q=AB-Y1*CA1-Y2*CB2

      SL=ATAN((Y1-Y2)/Q)

      D=Y1*SIN(A1+SL)/SIN(A1)
C     POSITION OF STAKE LINE RELATIVE TO STATIONS A AND B IS NOW ESTABLISHED
1     FORMAT(6X,'X',8X,'Y',5X,'METRES')
      WRITE(1,1)

2     FORMAT(F8.1,2X,F8.2)
7     FORMAT('HEIGHT INITIAL POINT ABOVE DATUM')
8     FORMAT(14X,F8.2)

      DO 3 I=1,N
C     PROGRAM NOW CALLS ANGLES    AND
      CALL IDATA(4,IDEG)
      CALL IDATA(4,IMIN)
      CALL IDATA(4,ISEC)
      CALL IDATA(4,JDEG)
      CALL IDATA(4,JMIN)
      CALL IDATA(4,JSEC)

      HN=FLOAT(IDEG)+FLOAT(IMIN)/60.+FLOAT(ISEC)/3600.
      VN=FLOAT(JDEG)+FLOAT(JMIN)/60.+FLOAT(JSEC)/3600.

      HN=RAD(HN)
      VN=RAD(VN)
C     THEODOLITE READINGS ARE NOW CONVERTED TO RADIANS
      T=SIN(HN+SL)/COS(HN+SL)

      TVN=SIN(VN)/COS(VN)

      XN=D/T
      YN=D*TVN/SIN(HN+SL)

      IF(I-1)4,5,4
C     THIS DEFINES THE INITIAL POINT AS ORIGIN
5     XNA=XN
      YNA=YN
C     YNA IS THE CALCULATED HEIGHT OF THE TOP OF THE FLAG POLE BELOW THE THEODOLITE
      TELESCOPE AND MUST BE CORRECTED TO GIVE GROUND TO GROUND HEIGHTS
      GO TO 6
4     CONTINUE
6     XN=XN-XNA+0.05
      YN=YN-YNA+0.005
C     POSITIONS ARE NOW RELATED TO THE ORIGIN AND ROUNDED OFF
      WRITE(1,2) XN,YN
3     CONTINUE
      WRITE(1,7)
      WRITE(1,8) YNA

      CALL EXIT
      END
// XEQ
```

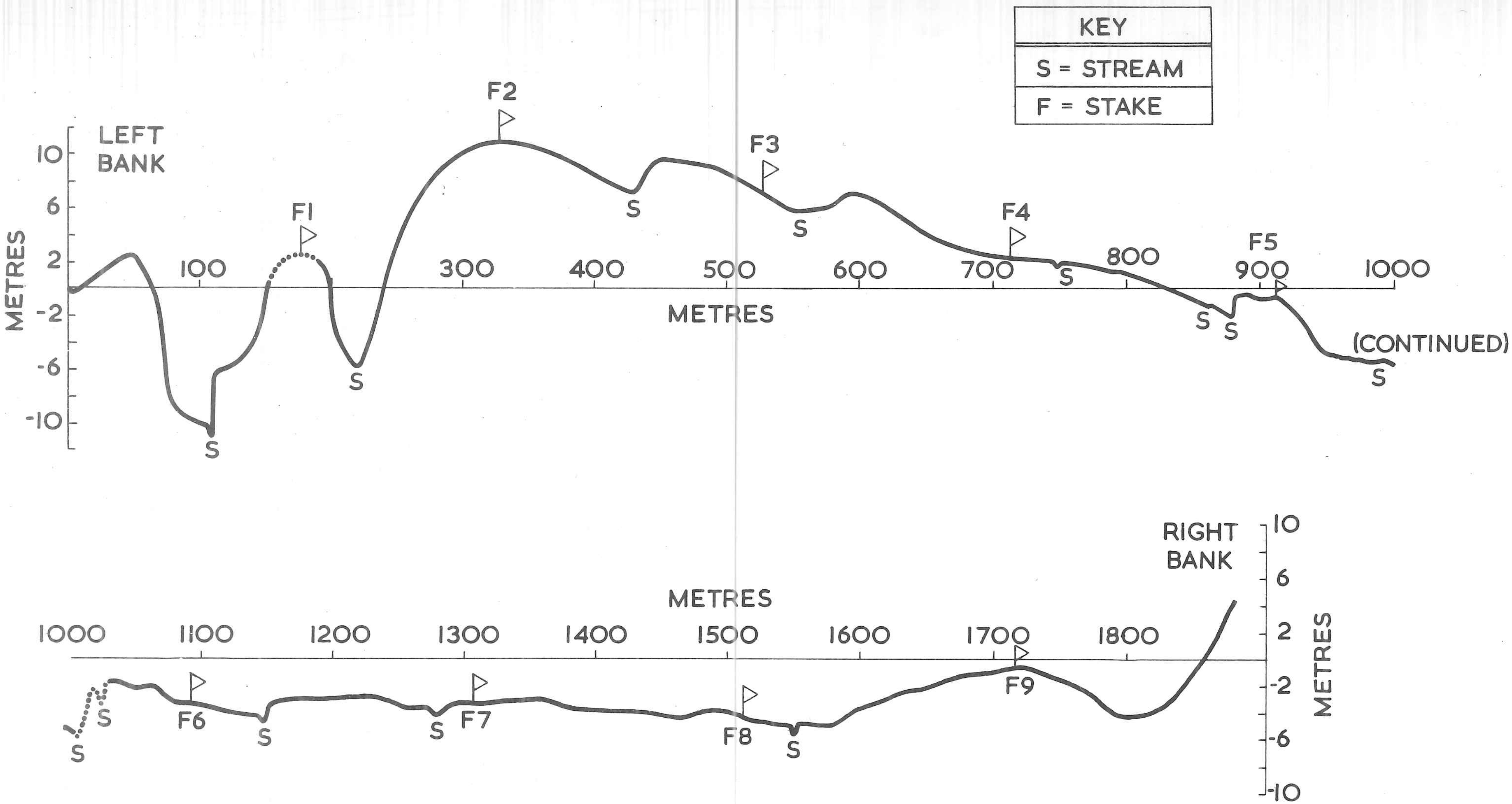


FIG. 40 TRANSVERSE PROFILE AT THE LOWER ROSLIN STAKE LINE

VERTICAL SCALE EXAGGERATION 10:1

ORIGIN IS AT THE LEFT BANK AND IS 41 METRES IN HEIGHT BELOW STATION 1

114

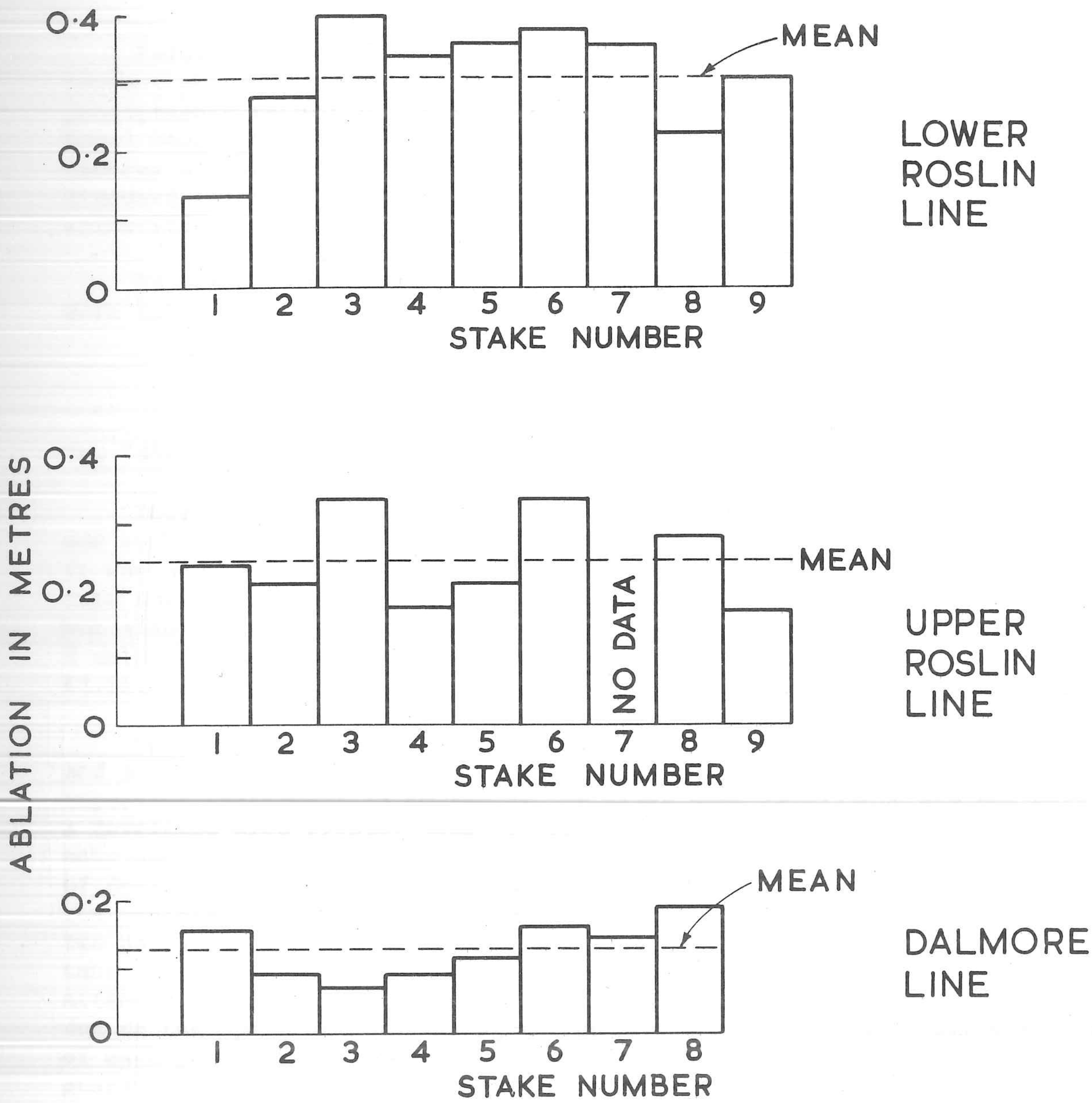


FIG. 41 TOTAL ABLATION AT STAKES ON THE ROSLIN AND DALMORE GLACIERS, DURING THE PERIOD JULY 27 TO AUGUST 11, 1970.

POLAROID CAMERAS

Polaroid cameras have the great advantage of being able to produce instant photographic prints and one, therefore, may collect an immediate photographic record of the various activities of an expedition. The Royal Geographical Society requested we analyse the function of these cameras and to recommend whether or not polaroid cameras should become standard items of equipment to be included in the essential kit of scientific expeditions.

To assist the survey work of the expedition two polaroid cameras were taken.

A "350" Land Camera cost £85
A "3000" Land Camera cost ~ £17

The "350 Land" Camera

This camera is a costly instrument and it is debatable whether or not such a camera should be subjected to the rigours of an expedition. It was used almost exclusively for colour work and expeditions should take note of not only the relative costs of the two types of camera but also the relative costs of the two types of film. In 1970 a pack of 8 colour plates cost £2.18 whilst a pack of 8 black and white plates cost £1.21.

Colour photography was only conducted in the vicinity of base camp and at the nearby survey stations. Unfortunately it was found to be an expensive instrument in so far as the first shot invariably did not have a developed area greater than 80% of the frame whilst the second shot only had a 95% developed area. This was not due to the cold conditions of developing but was probably caused by the film being tightly packed in its container. One piece of evidence to substantiate this view was that two packs of film each lost the initial two exposures due to the pull-out-tabs tearing off and hence not allowing the next film tab to be exposed. Attempts at remedial action by opening the back of the camera were clumsy due to the operator not wishing to remove his gloves. The last six shots of each pack usually presented no problems, although this could not be guaranteed. The camera has subsequently been examined by its makers who have pronounced it faultless, indeed the latest tests in the U.K. indicate this to be so and the camera has since produced good results.

Prints are not to the definition experienced by other conventional-type films and long-distance shots always produced a slight lack of definition probably due to the film grain size. The optimum conditions for use of colour polaroid cameras are for close-up work, i.e. distances of approximately 2 to 4 m. The 350 Land Camera has a built in device which facilitates coarse but adequate focusing of close-up subjects. An example of a long distance colour shot is given in Vol. III.

The "3000" Land Camera

This camera was used exclusively for black and white film and was extremely useful for the survey projects. Instead of surveyors having to sketch the views in a log book, a series of six shots could encompass the whole 360 degree panorama and it was possible to write down on the back of each film the points of interest, e.g.

"Tims Pinnacle is the highest point on the rock ridge centre background".

These films could then be handed on from the plane table crew to the theodolite crew and no one would have any doubts as to what features were of importance and had already been located.

Unfortunately the contrast on the film is not good and it is necessary to mark on the film the boundaries between cloud and snow ridges and to clearly indicate the position of snow summits. Experiments should be carried out before leaving the U.K. on how best to superimpose writings on the film itself and to gain experience in handling the camera, as well as determining the best developer times. Irrespective of the makers data on the film pack as regards speed of developing, field trials should be carried out to ascertain optimum conditions for producing the clearest possible prints. This is expensive but necessary. Few black and white films were lost due to faulty operation and then this was the sole fault of the operator. The cold clip was used throughout to facilitate the development of the film. The camera is easy to handle but it is best to carry a "waste bag" in which to put the empty cartridges, packing, strip-tabs, and the negatives, etc.

More field trials need to be run on this type of camera but under a variety of weather conditions before more sophisticated type cameras are used. Certainly summer arctic conditions did not provide a limitation to the use of this camera which was used throughout without its case.

Conclusions

The "3000" type (now superseded by the colour pack 80) camera is considered to be a most useful instrument for expeditions engaged on survey work. However further field trials are necessary before one can justify the cost expended on film.

Film prints (and cost) are the only basis on which to judge the results since the type of camera does not necessarily increase the definition or contrast of the print. As experience increases in the manner of how results can be quickly and efficiently transmitted to various parties within an expedition it would not be surprising to find that this instrument becomes an essential item of survey equipment.

The "3000" type camera has been presented to the R.G.S. with the compliments of the expedition.

The "350" land camera is considered to be too expensive an instrument for expeditions and this camera is now in use in the Engineering Laboratories, University of Cambridge.

THE OXYGEN ISOTOPE PROJECT

Introduction

This relatively modern technique of investigating glaciological phenomena depends upon the determination of the ratio of the two stable isotopes of oxygen, ^{16}O and ^{18}O, in snow and ice, and the variation of the ratio at different zones of a glacier.

Now the isotopic composition of oxygen in snow precipitation is a function of temperature which is directly influenced by the altitude and the season at which the precipitation took place. The isotope ratio may, however, undergo some modification after the snow is on the ground because of

(i) local homogenization due to melting
(ii) percolation of melt water
and (iii) refreezing

but it still retains the general characteristics related to the site of deposition. It is therefore possible to use isotopic ratios as natural tracers within a glacier to obtain the flow pattern of a glacier. Comparison has to be made therefore between the distribution of isotopic ratios in the ice above the firn line where snow accumulates and the isotopic ratios below the firn line. Above the firn line the isotopic condition is expected to vary as a simple function of altitude while at each sampling locality it will have a seasonal variation dependent on precipitation temperature.

Field Work

Two pits were dug to a depth of 2 m, one pit high above the firn line at location FLP1, and the second pit just above the firn line at location FLP2, see Fig. 42. A vertical face was exposed in each pit and samples of ice and firn taken at 5 cm depth intervals. From these samples a seasonal variation is to be expected and an annual average value for each location will be obtained.

Below the firn line nine samples were taken at each of five transverse sections of the glacier, see Fig. 42 , sample zones being approximately equi-spaced. From these results variations in homogenity of ice across a section can be determined. Finally, by calculating the bulk mean isotopic composition at each section and comparing this data with the results obtained above the firn line it will be possible to determine the flow pattern of the Roslin Glacier.

Analysis of Results

The ratio is measured in a mass spectrometer by simply comparing the ratio of a sample with that of a known standard, i.e. average sea-water. The deviation of the sample ratio from the standard ratio is designated the symbol δ which may be calculated from the following formula:-

$$\delta = \left[\frac{H_2{}^{18}O \;/\; H_2{}^{16}O \text{ (sample)}}{H_2{}^{18}O \;/\; H_2{}^{16}O \text{ (standard)}} - 1 \right] \times 1000$$

Equipment is now being designed and built in the University Palaeotemperature Laboratory in order to analyse the samples returned from Greenland and results will be published at a later date.

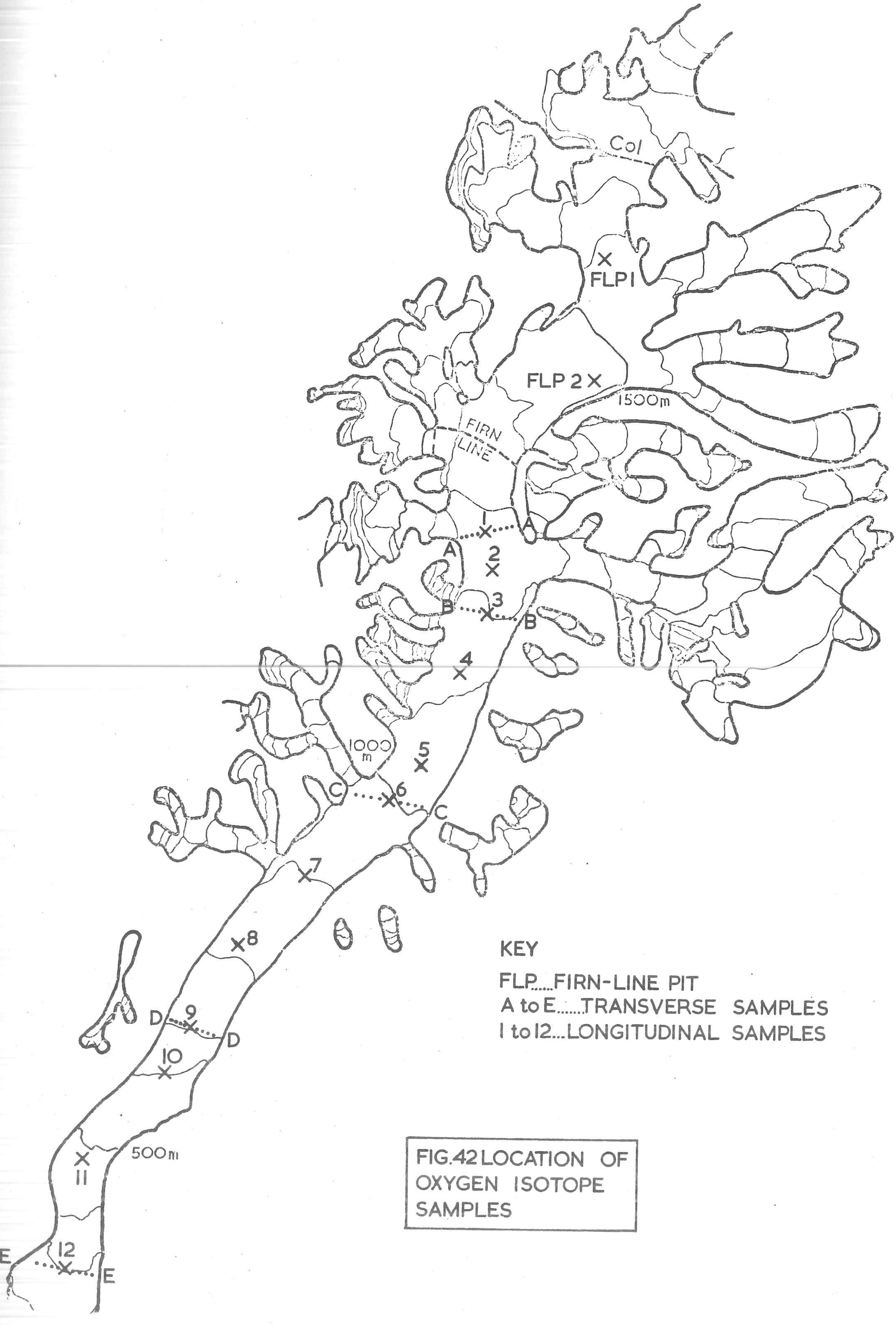


FIG.42 LOCATION OF OXYGEN ISOTOPE SAMPLES

Further reading:

Sharp, R.P. (1960) Glaciers. University of Oregon Press, Eugene, Oregon, U.S.A.

Shumskiy, P.A. Principles of Structural Glaciology. English translation by D. Kraus, Dover, New York, U.S.A.

Epstein, S. & Sharp, R.P. Oxygen - Isotope variations in the Malaspina and Saskatchewan Glaciers. J. Geolg. 1959, Vol. 67, p. 88 - 102.

Epstein, S., Sharp, R.P., & Goddard, I. Oxygen - Isotope ratios in Antarctic snow, firn and ice. Journal of Geology, Vol. 71, No.6.

Dansgard, W. Stable Isotopes in Precipitation. Tellus, Vol.16, No.4.

Epstein & Mayeda, Variation of O^{18} content of waters from Natural Sources, Vol. 4, p. 213 - 224. Geochim et Cosmochim Acta.

TECHNICAL NOTE NO. 8

SAMPLING TECHNIQUES

Sampling above the firn line

Two pits were dug, see Fig.42, with ice axes and spades. Each pit measured approximately 1 m square by 2 m deep. Distinct layers of firn were exposed, and bands of dirty and clean ice were visible.

Samples were taken consecutively in 5-10 cm lengths from one side of the pit. In order to avoid contamination from falling snow, the surface was brushed before each sample was taken. Samples were initially and individually collected in a polystyrene cup to avoid evaporation, and hence fractionation, and then quickly transferred to a 50 cc glass screw top jar which was sealed and labelled with a diamond tip scratch pen.

25 samples were taken from each pit.

Sampling below the firn line

At each of the five localities (A - E), 9 samples were taken on a transverse section, covering the whole width of the glacier. Between each of these localities single samples were also taken at one or two points at the centre of the glacier thus providing data for a longitudinal section, see sites 1 - 12, Fig.42.

The method of sampling was to sink a 1½ inch dia. auger to a depth of 20 cm. The auger was then removed and thoroughly cleaned, before being reinserted into the hole for boring a further 4 cm. The auger was then withdrawn and the ice from the bottom 3 flutes collected in a polystyrene cup and then transferred to a labelled jar. Three drillings were performed within a radius of 1 metre in order to provide an average value for each sample. Altitude readings and notes on sampling position were recorded in a field book.

Packaging

For protection during the air drop, all glass bottles were individually wrapped in tissues, sellotaped in bundles of seven and packed with straw in a cardboard box. This proved to be adequate.

List of equipment used

120 x 50 cc glass screw top bottles
Altimeter
1½ inch auger and brace
Polystyrene cups
Diamond tip scratch pen
Spade
Ice Axe
10 m tape
Boot brush

Pollen Analysis

The determination of the origin of pollen collected at various sites of deposition close to and on a glacier surface will help in the interpretation of fossil pollen spectra in Greenland.

Pollen from local vegetation will be deposited from the air on to moss polsters, lakes and snow surfaces. The pollen deposited on lakes, falls to the bottom, and becomes incorporated in the sediment, while that deposited on the glacier snow is transported by meltwater streams and eventually deposited in the lakes: the lake sediments therefore would contain both air-derived and water-derived pollen.

Field Work

Samples of pollen trapped on moss polsters were taken at various sites on the moraine, some very near to the edges of lakes in order to compare samples with those taken from the lake sediment. The surrounding vegetation was noted and photographs taken of each locality.

Sediment was collected from the bottom of a glacier lake, see Fig. 43 which was fed by meltstreams. This was simply done by sinking a tube into the lake sediments. Notes were made of locality and water depth.

Samples from snow beds on the glacier, see Fig.44, above and below the firn line, were taken and centrifuged, the centrifugate being stored in glass bottles. Location with relation to the firn line, and amount of snow that was treated to obtain the sample, were noted.

All samples were returned to Cambridge University Sub-Department of Quaternary Research for analysis. Results will be published at a later date.

Notes

Moss Collection

Samples approximately 20 cm^2 in area were dug from the moraine, and stored in 500 gauge 12" x 15" polythene bags which were secured with a metal tie and label.

Lake Sediment Collection

This was simply achieved by using a scoop on the end of piece of string and dragging it along the lake bed. The sediment was stored in sealed polythene bottles.

Snow Sediment Collection

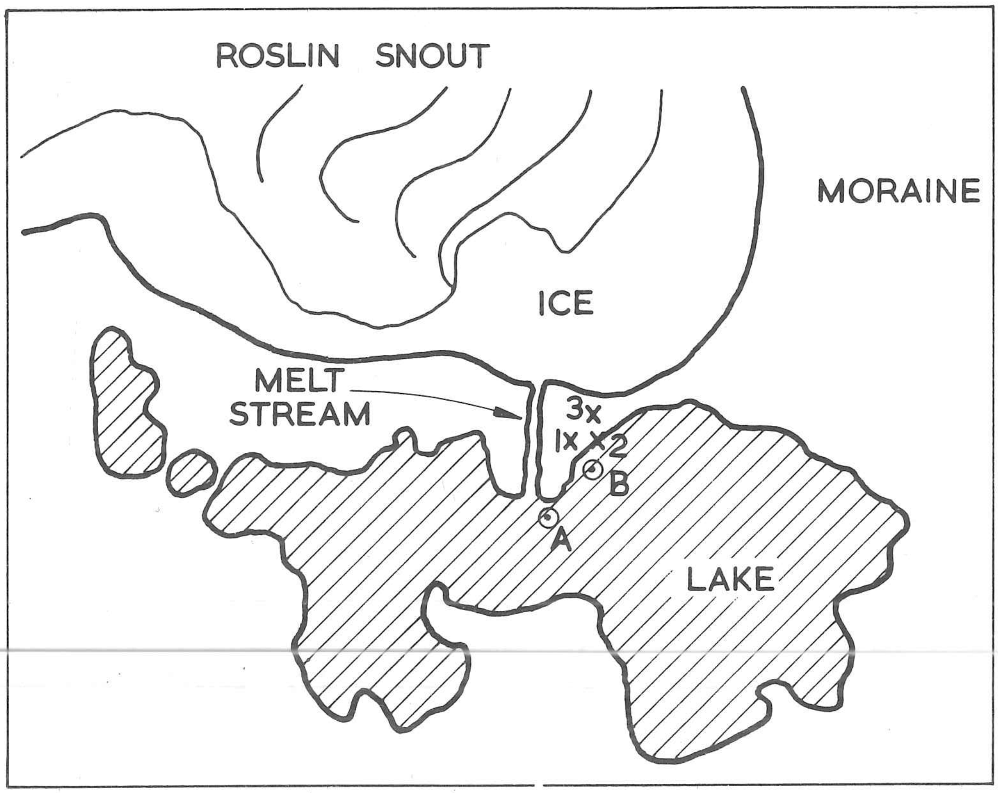
Snow was collected from the snow beds in 500 gauge polythene bags and transported to base camp. Here the snow was melted and the sediment extracted by hand centrifuge. The sample was stored in sealed glass bottles.

Because of the small buckets on the centrifuge the melted snow samples, consisting of some 600 ccs of water, had to be centrifuged in 20 cc batches.

List of equipment

- Hand centrifuge
- Polythene bottles
- Metal ties and labels
- 500 gauge polythene bags
- Polythene scoop
- Measuring cylinder

SNOUT ZONE OF ROSLIN GLACIER



KEY:-

⊙ 2 SEDIMENT SAMPLES TAKEN FROM LAKE

x 3 MOSS SAMPLES TAKEN FROM MORAINE

FIG.43 LOCATION OF POLLEN SAMPLE SITES AT SNOUT ZONE.

(see also fig 44)

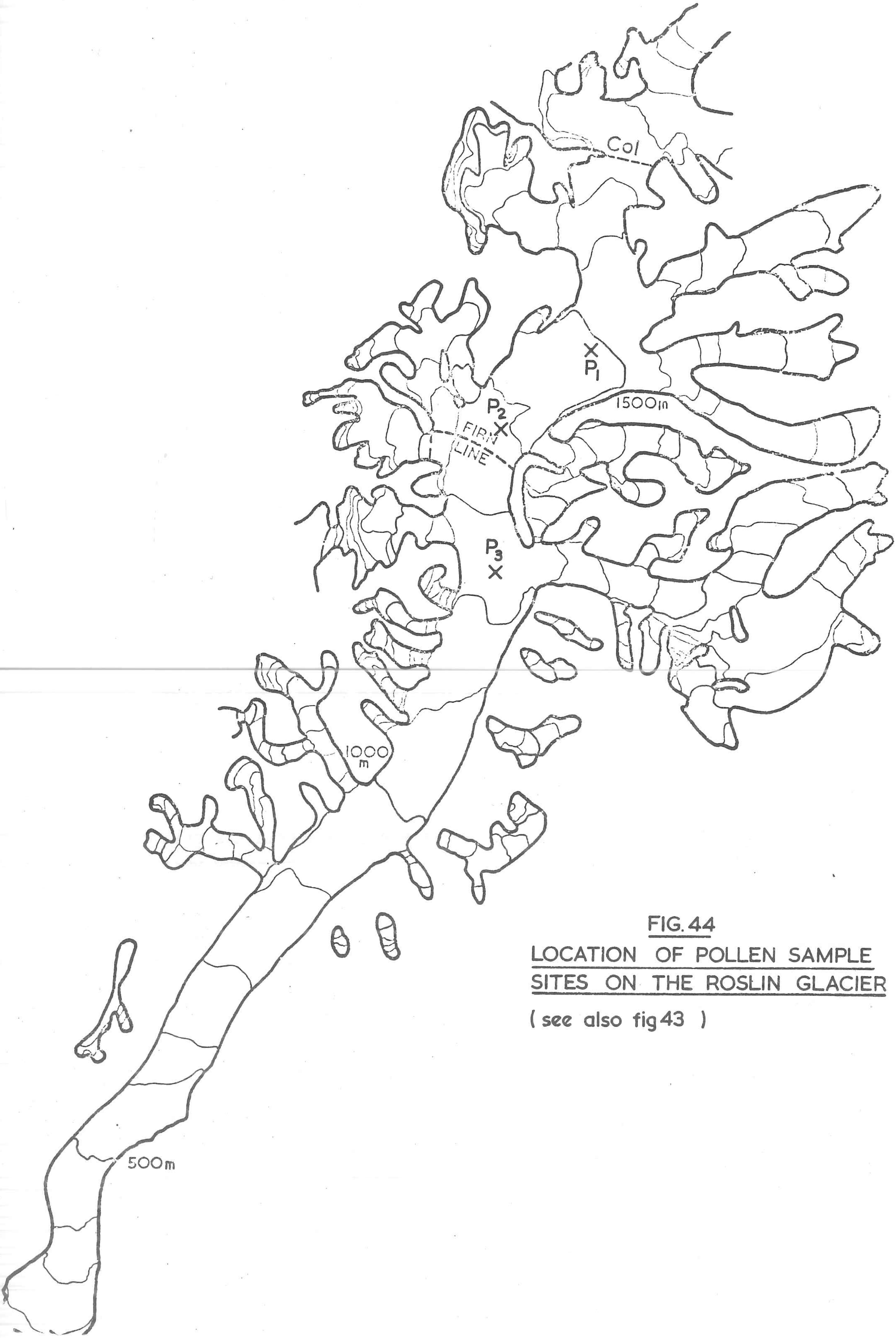


FIG. 44
LOCATION OF POLLEN SAMPLE SITES ON THE ROSLIN GLACIER
(see also fig 43)

COLLECTION OF FLOWERING PLANTS

At the request of Dr. R.G. West, of the Cambridge University Botany Dept., flowering plants were collected from various sites around the glacier and on the tundra. Photographs were first taken of each plant, and notes made on the locality and surrounding vegetation. The whole plant was then collected, dried and pressed. All specimens were returned to the Department of Botany for identification. The flowers will also be used to obtain pollen for the pollen reference collection.

Notes

A fairly comprehensive description of each site of plant collection was undertaken, including altitude, surrounding vegetation, type and slope of ground and the direction the plant was facing.

The plants we extracted from the soil by digging with a pen knife, the roots were collected wherever possible. The specimens were dried, and pressed between drying sheets in a simple plant press. This consisted of drying sheets between two pieces of thick cardboard, bound together with string; rocks provided the required mass for pressing. It was difficult to keep the press completely dry however even when it was stored in polythene bags.

List of equipment

Knife
Plant Press

Details of Wild Flowers

Site A

The col just above base camp at a height of 4,340 ft. Plants were taken from a steep rocky scree slope facing directly south.

Plant
A/19 Arenaria Pseudofrigida - small plant with white flowers.
A/18 Cerastium Arcticum - single white flower with yellow centre.
A/21 and A/22 Potentilla Rubicanlis - small yellow flowers.
A/27 and A/33 Papaur Radicatum - large yellow poppy-like flower.
A/30 Chamaenerion Latifolium - large mauve flower with long stem.

Site B

East facing cliff at a height of 4,500 ft, wet brown soil in gulley, no direct sunlight. Close to site A.

B/20 Saxifraga Oppositifolia - hanging plant with purple flowers.
B/27 Erigeson Uniflorus - thistle type flower on long stem.

Site C - By Tundra Camp.

East facing slope with moss and grasses at height of 580 ft.

C/13 Saxifraga Aizoides - hanging plant with yellow flowers.
C/14 Polygmum Viviparum - small plant with brown leaves and small white flowers.

Flowers were identified by P.D. Sell of Cambridge University Botany School.

APPENDIX

THE COMPUTER PROGRAM FOR DETERMINING GLACIER FLOW RATES

This program is given below. It provides the flow rate for each stake, distance CD illustrated in the sketch on page 98. Results for all stakes on each of the three systems are given in Figs. 37, 38 and 39.

Note:- The program written by Bishop for the transverse profile is given on pages 112/113.

```
C THIS PROGRAM DEVELOPED BY A.W.NUTBOURNE FOR DR.MILLER
C WORKS OUT GLACIER FLOW FROM OBSERVATIONS.

          DIMENSION IADEG(8),IAMIN(8),IASEC(8),A(8),IBDEG(8),IBMIN(8),
     C    IBSEC(8),B(8),AC(8),BC(8),TA(7),TRAV(7),SA(7),SPAN(7)
     C    ,AP(8),PC(8)
C SIDE ADJACENT ANGLE AND SIDE OPPOSITE ANGLE ALGORITHMS.
          SAA(P,PQ,Q)=PQ*SIN(Q)/SIN(P+Q)
          SOA(P,PQ,PR)=SQRT(PQ*PQ+PR*PR-2.*PQ*PR*COS(P))
C READ IN AND REPRINT DATA : NO. OF POINTS (UP TO 8), BASELINE
C IN METRES TO THREE DEC. PLACES, LIST OF 'A' ANGLES IN DEGREES
C FOLLOWED BY A SINGLE SPACE, MINS. FOLLOWED BY A SINGLE SPACE
C , THEN SECS. SIMILARLY LIST THE 'B' ANGLES.
          READ(2,80)N,AB,(IADEG(I),IAMIN(I),IASEC(I),I=1,N)
80        FORMAT(I1,/F10.3/(I2,1X,I2,1X,I2))
          READ(2,81)(IBDEG(I),IBMIN(I),IBSEC(I),I=1,N)
81        FORMAT(I2,1X,I2,1X,I2)
          WRITE(0,82)
82        FORMAT('INPUT DATA REPRINTED FOR CHECKING')
          WRITE(0,83)N
83        FORMAT('NO. OF OBSERVATIONS = ',I1)
          WRITE(0,84)AB
84        FORMAT('BASELINE = ',F10.3,' METRES')
          WRITE(0,85)(IADEG(J),IAMIN(J),IASEC(J),J=1,N)
85        FORMAT('ANGLES AT A ARE'/(1H ,3I3))
          WRITE(0,86)(IBDEG(J),IBMIN(J),IBSEC(J),J=1,N)
86        FORMAT('ANGLES AT B ARE'/(1H ,3I3))
C CONVERT ANGLES TO RADIANS AND CALCULATE SIDES AC AND BC.
```

continued overleaf/

```
10      DO 19 I=1,N
        ADEG=FLOAT(IADEG(I))
        AMIN=FLOAT(IAMIN(I))
        ASEC=FLOAT(IASEC(I))
        BDEG=FLOAT(IBDEG(I))
        BMIN=FLOAT(IBMIN(I))
        BSEC=FLOAT(IBSEC(I))
        A(I)=(3.14159/180.)*(ADEG+(AMIN/60.)+(ASEC/3600.))
        B(I)=(3.14159/180.)*(BDEG+(BMIN/60.)+(BSEC/3600.))
        AC(I)=SAA(A(I),AB,B(I))
        BC(I)=SAA(B(I),AB,A(I))
        AP(I)=AC(I)*COS(A(I))
        PC(I)=AC(I)*SIN(A(I))
C TYPE OUT ANGLES AND SIDES FOR INFO.
19      CONTINUE
        WRITE(0,87)
87      FORMAT(1H ,3X,1HA,5X,1HB,7X,2HAC,8X,2HBC,8X,2HAP,8X,2HPC)
        WRITE(0,88)(A(I),B(I),AC(I),BC(I),AP(I),PC(I),I=1,N)
88      FORMAT(1H ,2F6.3,4F10.3)
C CALCULATE SPANS AND TRAVELS AND TYPE OUT RESULTS.
C SPAN = MOVEMENT SINCE LAST OBSERVATION
C TRAVEL = DISTANCE AT END OF SPAN FROM THE FIRST OBSERVATION.
20      DO 29 J=1,N-1
        TA(J)=A(1)-A(J+1)
        TRAV(J)=SOA(TA(J),AC(1),AC(J+1))
        SA(J)=A(J+1)-A(J)
        SPAN(J)=SOA(SA(J),AC(J),AC(J+1))
        IF(J-1)21,21,22
21      WRITE(0,89)
89      FORMAT(1H ,6HPERIOD,2X,4HSPAN,4X,4HTRAV)
22      WRITE(0,90)J,SPAN(J),TRAV(J)
90      FORMAT(1H ,I1,2X,2F9.2)
29      CONTINUE
C SUM THE SPANS AND TYPE OUT. THIS SHOULD ALWAYS EXCEED THE
C FINAL VALUE OF TRAVEL.
        SUM=0.
30      DO 39 I=1,N-1
        SUM=SUM+SPAN(I)
39      CONTINUE
        WRITE(0,91)SUM
91      FORMAT('SUM OF SPANS=',F9.2)
        STOP
        END
```

FIG. 33
THE UPPER ROSLIN GLACIER

CAMBRIDGE STAUNINGS EXPEDITION
JULY - AUGUST 1970

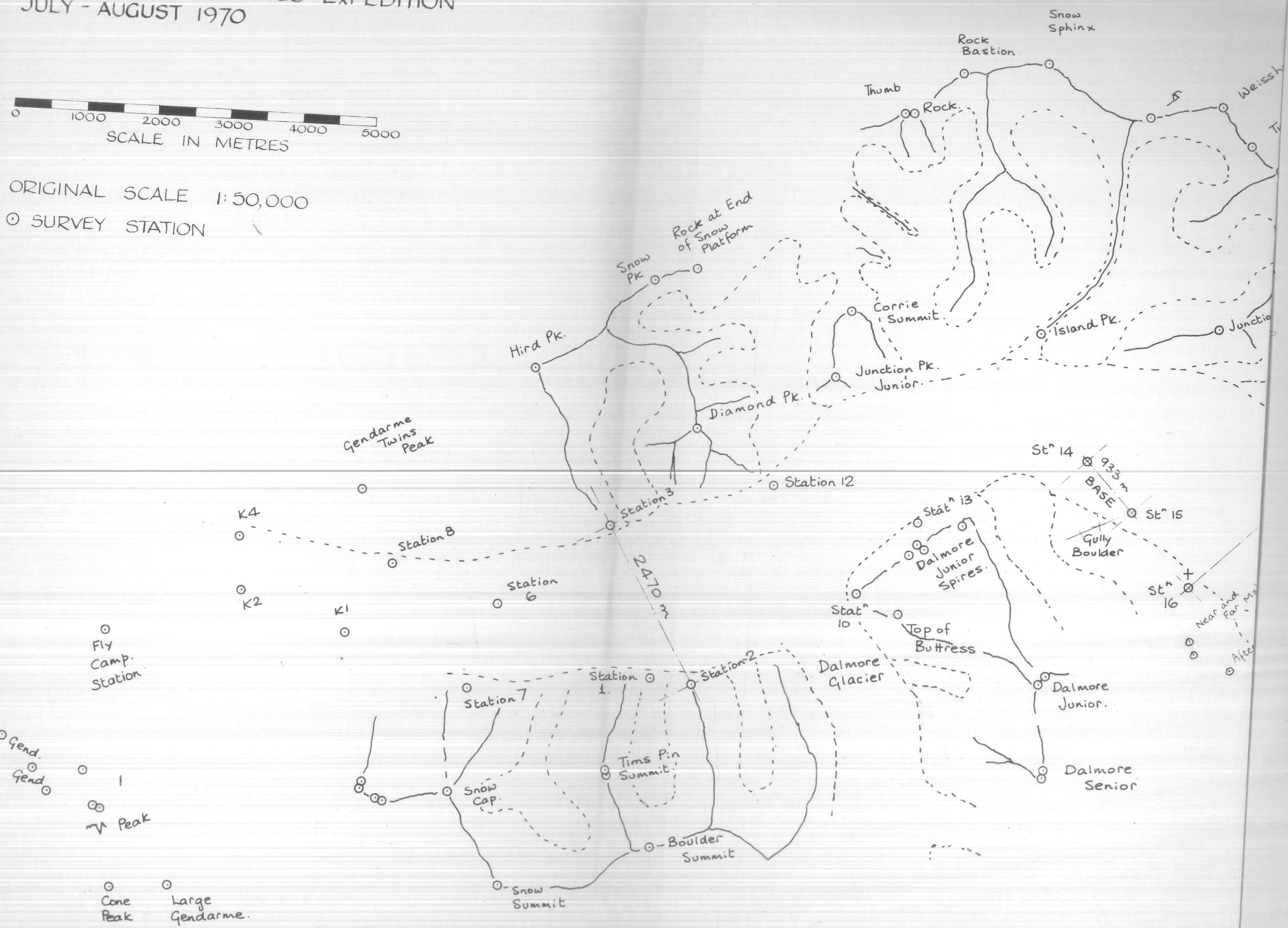
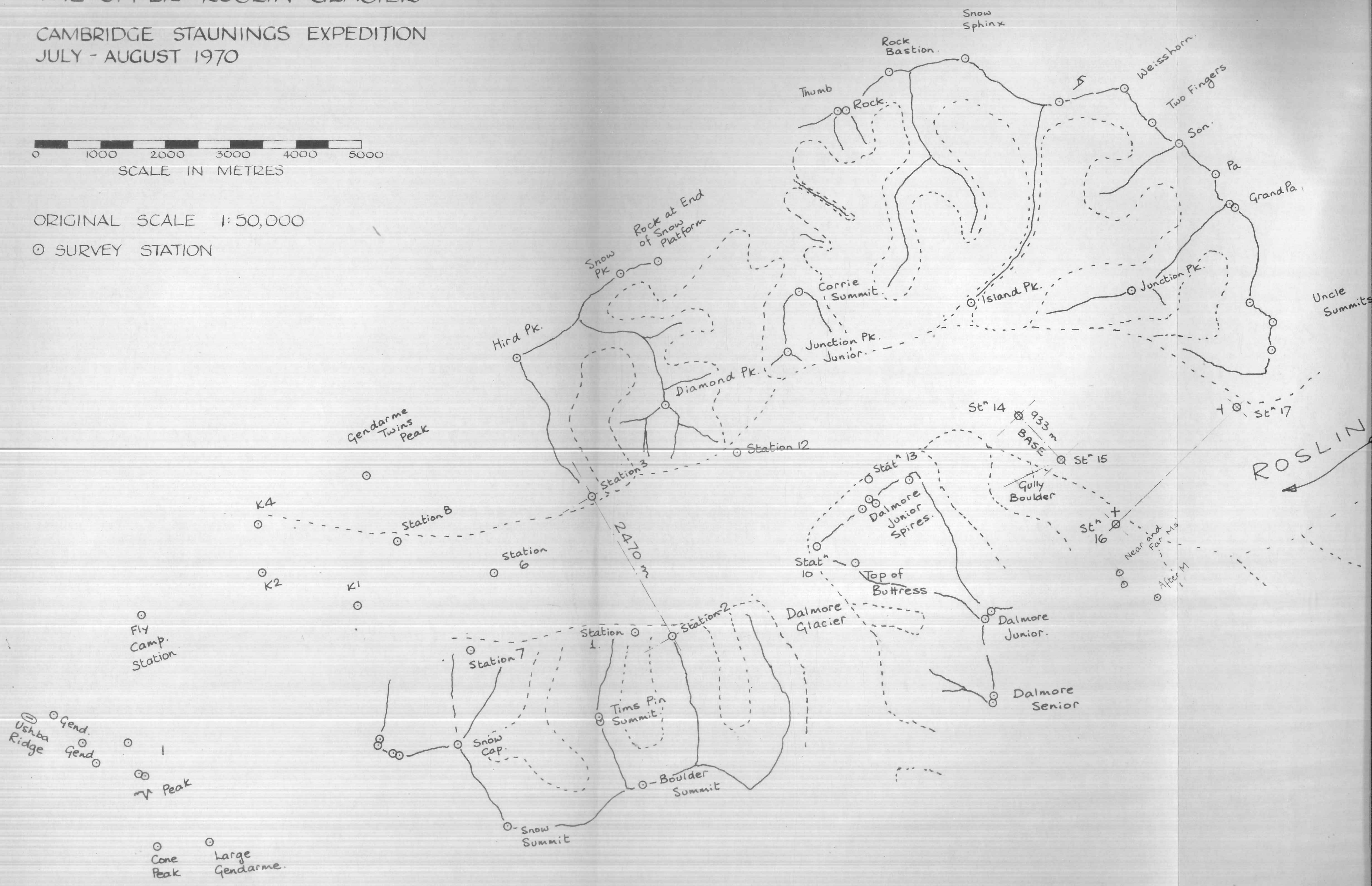


FIG. 33

THE UPPER ROSLIN GLACIER

CAMBRIDGE STAUNINGS EXPEDITION
JULY - AUGUST 1970



GLACIER

EXPEDITION

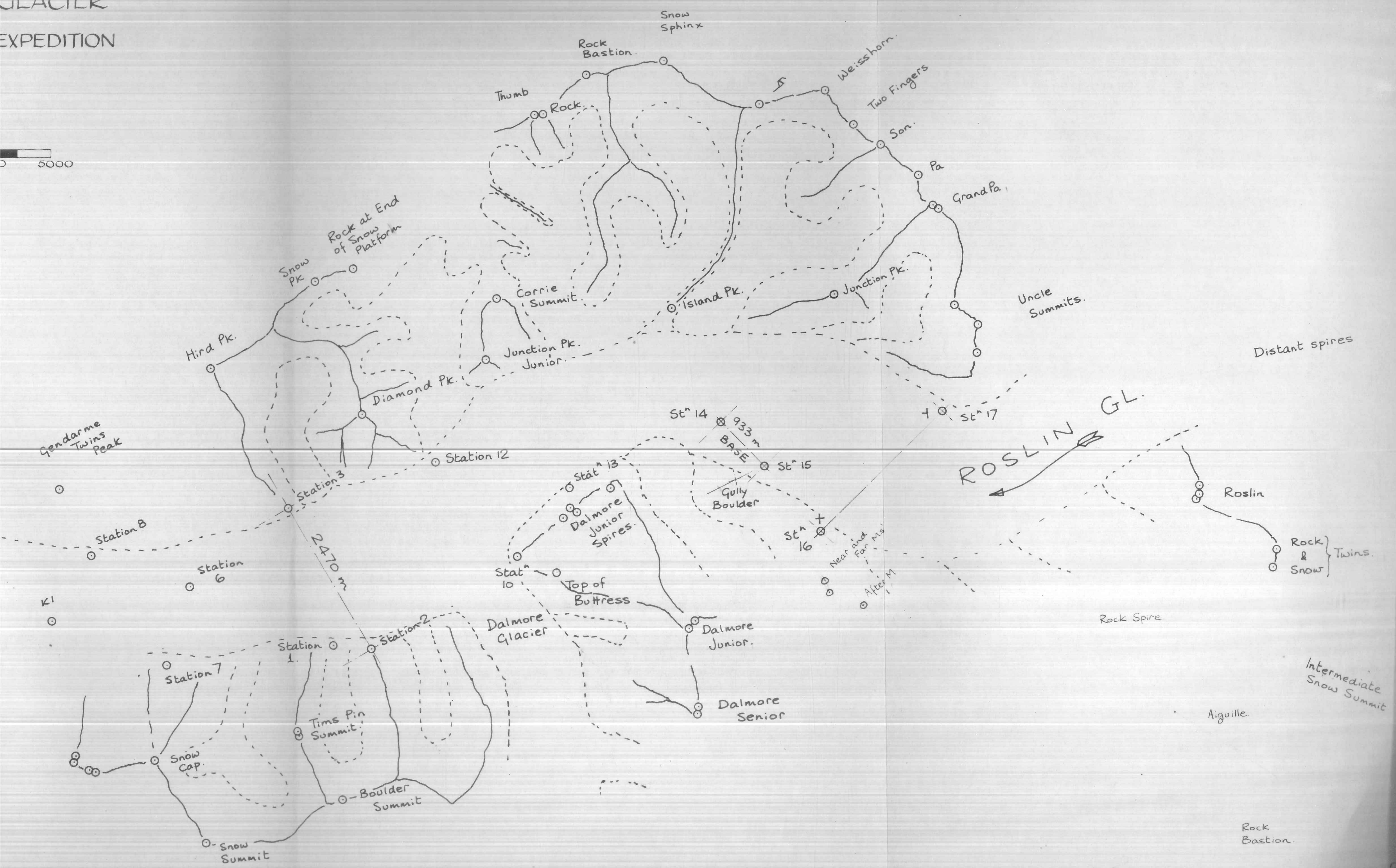
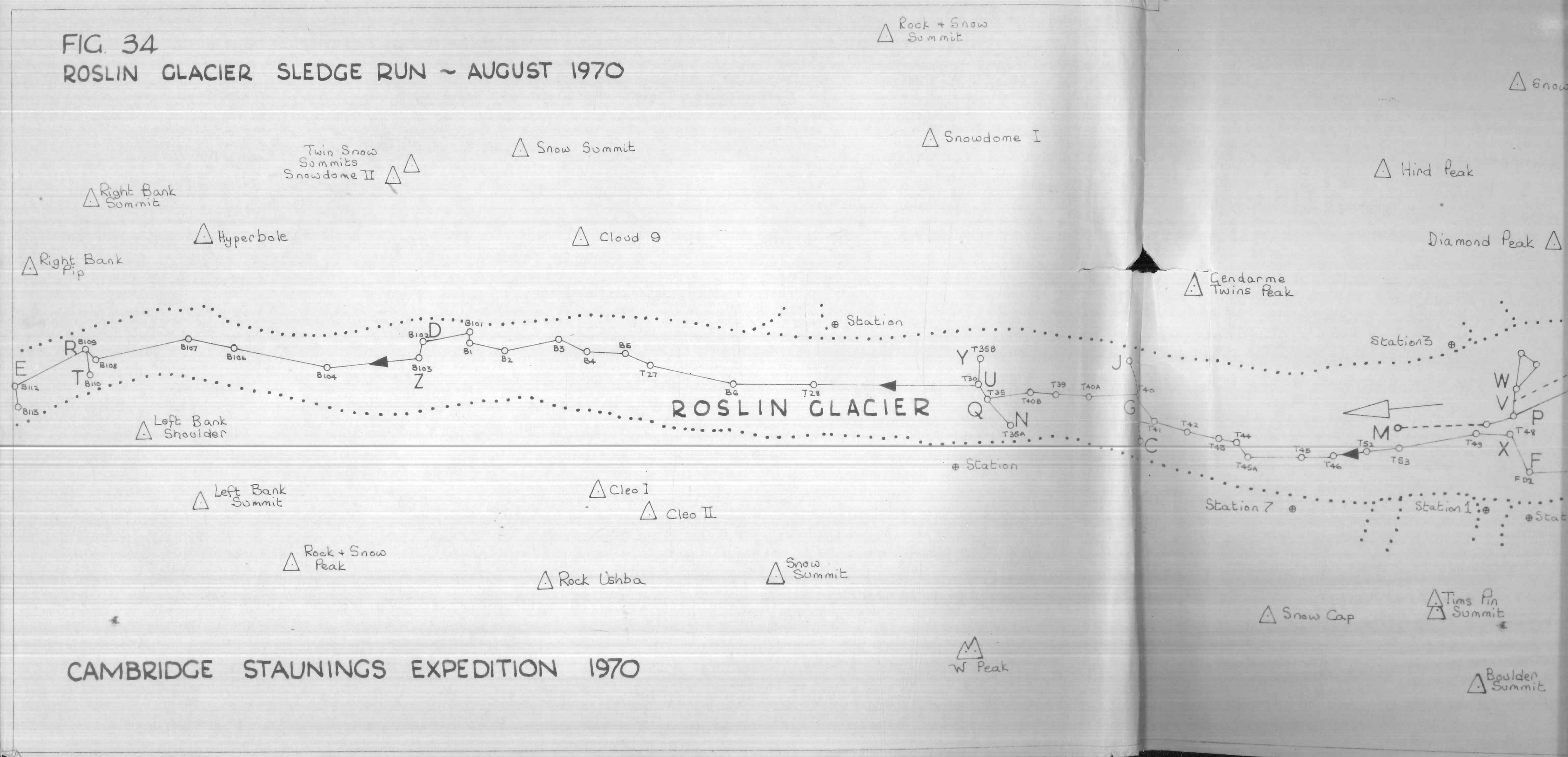
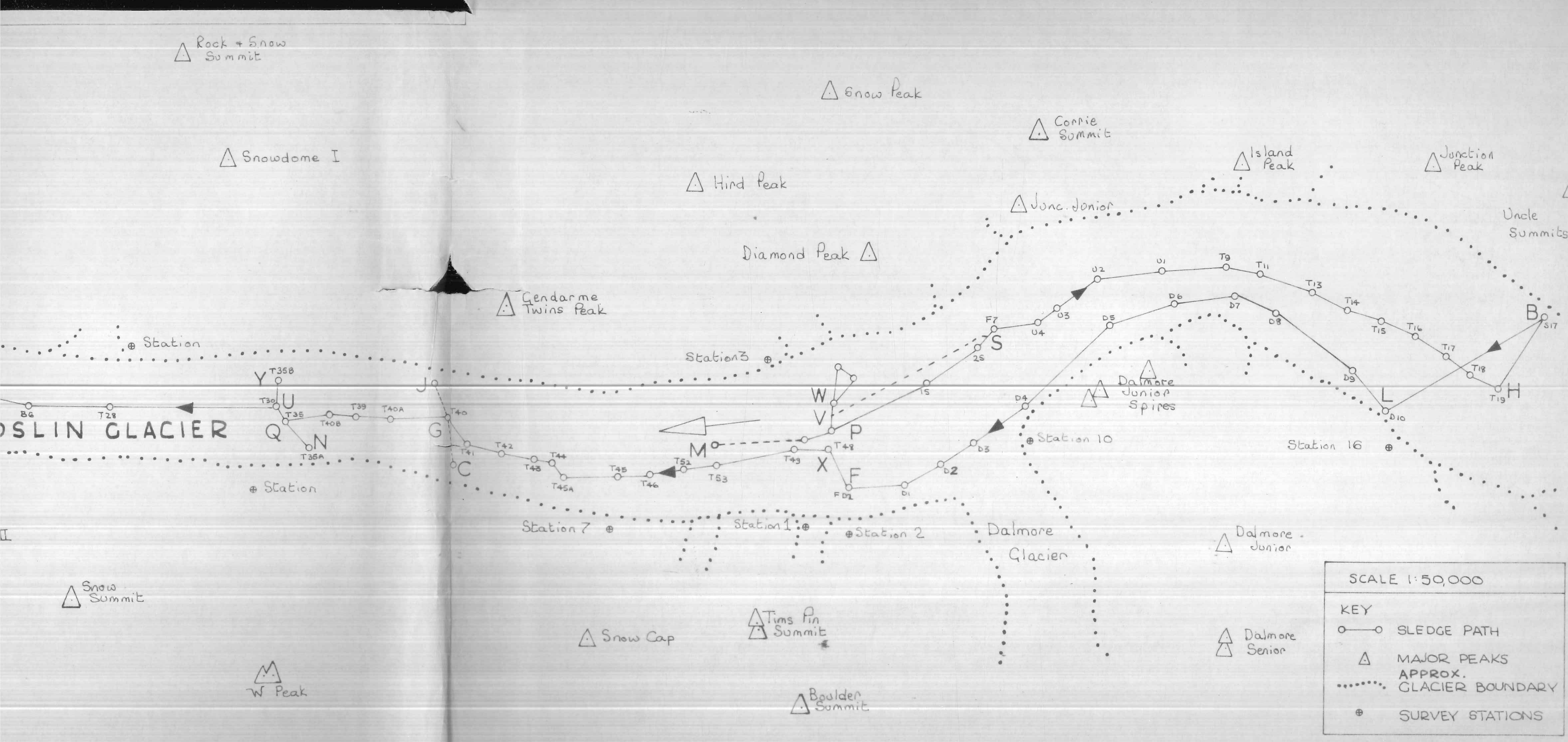


FIG. 34
ROSLIN GLACIER SLEDGE RUN ~ AUGUST 1970



CAMBRIDGE STAUNINGS EXPEDITION 1970


Rock + Snow Summit
Snow Peak
Corrie Summit
Snowdome I
Hind Peak
Island Peak
Junction Peak
Junc. Junior
Uncle Summits
Diamond Peak
Gendarme Twins Peak
Station
Station 3
OSLIN GLACIER
Dalmore Junior Spires
Station 10
Station 16
Station
Station 7
Station 1
Station 2
Dalmore Glacier
Dalmore Junior
Snow Summit
Snow Cap
Tims Pin Summit
Dalmore Senior
W Peak
Boulder Summit
SCALE 1:50,000
KEY
SLEDGE PATH
MAJOR PEAKS
APPROX. GLACIER BOUNDARY
SURVEY STATIONS