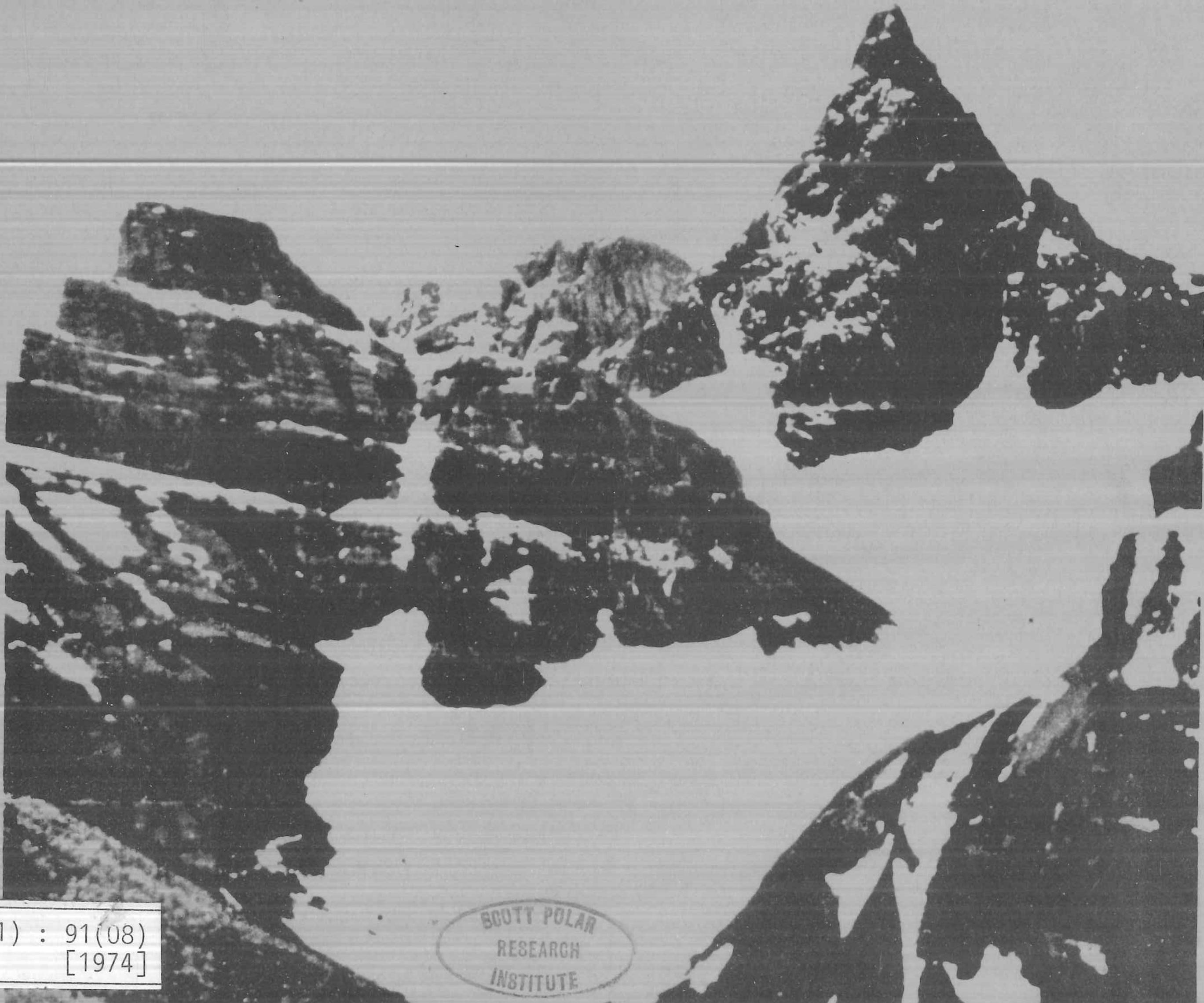
NEWCASTLE UNIVERSITY EXPLORATION SOCIETY

BRITISH COLUMBIA EXPEDITION, 1974



UNIVERSITY OF NEWCASTLE-UPON-TYNE

EXPLORATION SOCIETY

British Columbia Expedition 1974

R E P O R T

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

There's a land where the mountains are nameless,
And the rivers all run God knows where,
There are lives that are erring and aimless,
And there's death that just hangs by the hair.
There are hardships that nobody reckons,
There are valleys unpeopled and still,
There's a land, Oh it beckons and beckons
And I want to go back and I will.

from 'Spell of the Yukon'
by Robert Service

Mid-July and an overnight snowstorm for the advanced Base Camp party.

Far too heavy 'first day' loads: an exhausted rest from back-packing.

Mid-July and an overnight snowstorm for the advanced Base Camp party.

Far too heavy 'first day' loads: an exhausted rest from back-packing.

CONTENTS

EXPEDITION MEMBERSHIP

The Expedition comprised six members as follows:-

Graham D. Withers	Leader
Peter G. Rogers	Vice Leader; Equipment Officer
Robert G. Pearce	Secretary; Medical
Peter D. Brettell	Treasurer; Climbing Expedition Leader
Teresa Jack	Food Committee Representative
Stella Whateley	

EXPEDITION MEMBERS

Graham Withers:
Leader

Pete Rogers:
Vice Leader & Equipment

Bob Pearce:
Secretary & Medical

Pete Brettell:
Treasurer

Terry Jack:
Food

Stella Whateley

INTRODUCTION

The British Columbia Expedition 1974 was to the wild and relatively unexplored Racing River valley in the Northern Rockies of Canada. The area is approached from the Alaska Highway, the largely gravel highway which winds its tortuous and dusty way northwards from Dawson Creek in central British Columbia, through largely uninhabited and endless forested plains and mountain wilderness, to Fairbanks, Alaska. One hundred and fifty miles west of Fort Nelson, at Mile 401, is a track leading southwards to the Consolidated Churchill Copper Corporation's Yedhe Mine, from which the expedition set out into the bush.

Travel in Canada.

The expedition members flew to Eastern Canada by Charter flight from Gatwick, arriving at Toronto Airport on July 3rd. From there we travelled three thousand eight hundred miles across Canada to Fort Nelson, largely following the Trans-Canada Highway, joining the Alaska Highway in British Columbia. Economy in transport was essential, achieved through flexibility and frugality, so that our modes of travel included: 'driveaway' car for a car sales firm; public transport, largely by Greyhound bus; and some hitch hiking. Our food and equipment were freighted in advance by sea to Montreal, thence by rail to Fort Nelson. In Fort Nelson 'Churchill Mines' took us into thier care, under the managership of Mr. George Dvorak, who generously transported us to the Yedhe Mine, where we were boarded and fed.

Establishing Base Camp.

The evening of our arrival at the mine we were flown in George's light plane over our proposed route into the bush. The upper Racing River valley had only been penetrated by a few mineral explorers and hunters, despite the unique advantage of the mine's presence and because of the relatively poor landing opportunities for small aircraft and helicopters, which are more easily found in other valleys, such as the neighbouring Tuchodi Lake.

Air reconnaisance enabled us to pick a site for the most daunting river crossing, of the wide and heavily braided Churchill Creek and assess the opportunities and difficulties of route finding and the establishment of a base camp. It also gave us our first taste of the true vast scale of the Northern Rockies in British Columbia, a mountainscape of harsh beauty and isolation where each deep and enclosed mountain valley is a mighty world of its own. The incredible vast wilderness can only be recaptured from the mountain tops, where hundreds of snow-capped and glaciated rock peaks stretch into every distance around you.

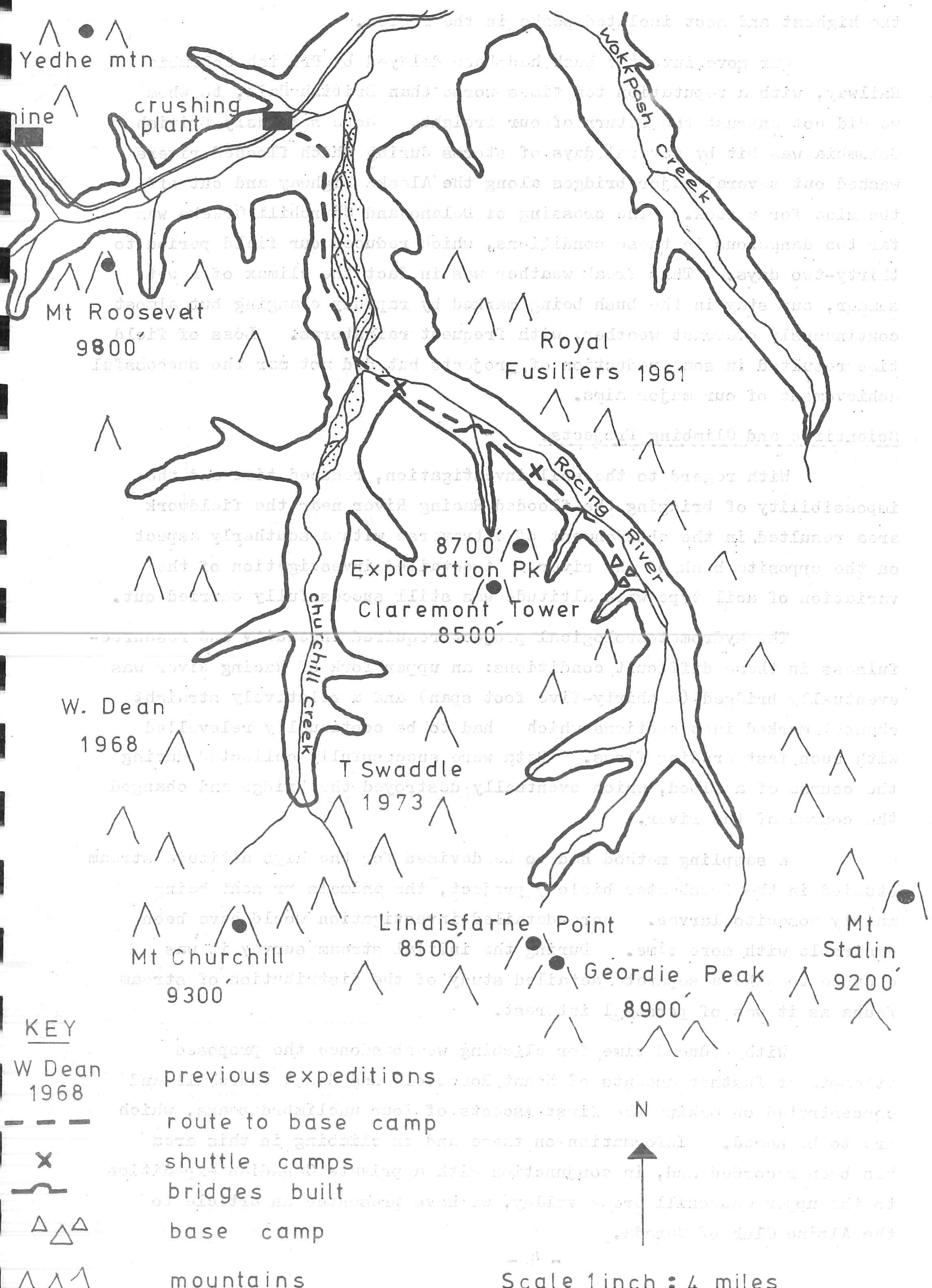
The eroded remnants of a prospectors' trail along the gravel flats encouraged George to help transport us by powerful caterpillar loader in the crossing of Delano Creek and seven miles up to Churchill Creek, from where we carried about eight hundred pounds of gear a further eleven miles up the Racing River fork.

Back-packing in the Canadian bush is made tenable by game trails forged alongside every river and stream by the abundant and sizeable wildlife: moose, caribou, bears, wolves, mountain sheep and goats. With familiarity and experience we were able to switch into 'automatic pilot' by which one kept almost instinctively to the winding and broken trails. Splitting into three groups we carried loads of over forty-five pounds in a shuttle system between three camps. The terrain varied from easier gravel flats to more arduous, thick spruce forest, with many fallen trees and grasping scrub birch and occasional precarious steep gravel banks and fast-flowing sidestreams, two of which we bridged for safety. Our base camp was finally established eighteen miles from the mine, an event heralded by over one foot of snow - in mid-July.

The splendour of our campsite has been well captured by Bob[1]:-

"By the time we left, the corners would be worn off the grandeur of this mountain setting. We were in a valley bottom at three thousand eight hundred feet and heights towered up all around us. Across the river lay a wall of dense spruce forest which curved its way upwards until it could climb no higher. Above this was a blanket of scrub birch, stretching up to the base of a limestone crag, that extended like a giant wall along the upper reaches of the valley side. On top of this stood mountains, perched like pyramids with caps of snow, above what appeared to be a great bank of loose scree reaching down to the cliff top, but so foreshortened in our upward gaze that realistic impressions of the great heights were still kept from us. Behind us rose more forest beneath more crags. Massive cornices of snow peered over the skyline and large scars of unweathered cliff told the warning tales of many recent rockfalls, while between these peaks lay the glistening hint of a snowfield. But our eyes soon gazed towards the head of our valley where grey billowing clouds

EXPEDITION FIELD AREA



hung over a horizon of snow. This was towards Mount Stalin, one of the highest and most isolated peaks in the region."

Our move into the bush had been delayed by British Columbia Railway, with a reputation ten times worse than British Rail, to whom we did not entrust the return of our freight. More seriously British Columbia was hit by several days of storms during which flooded rivers washed out several major bridges along the Alaska Highway and cut off the mine for a week. The crossing of Delano and Churchill Creeks was far too dangerous in these conditions, which reduced our field period to thirty-two days. This freak weather was in fact the climax of a wet summer, our stay in the bush being marked by rapidly changing but almost continuously overcast weather, with frequent rainstorms. Loss of field time resulted in some reduction of projects but did not mar the successful achievement of our major aims.

Scientific and Climbing Projects.

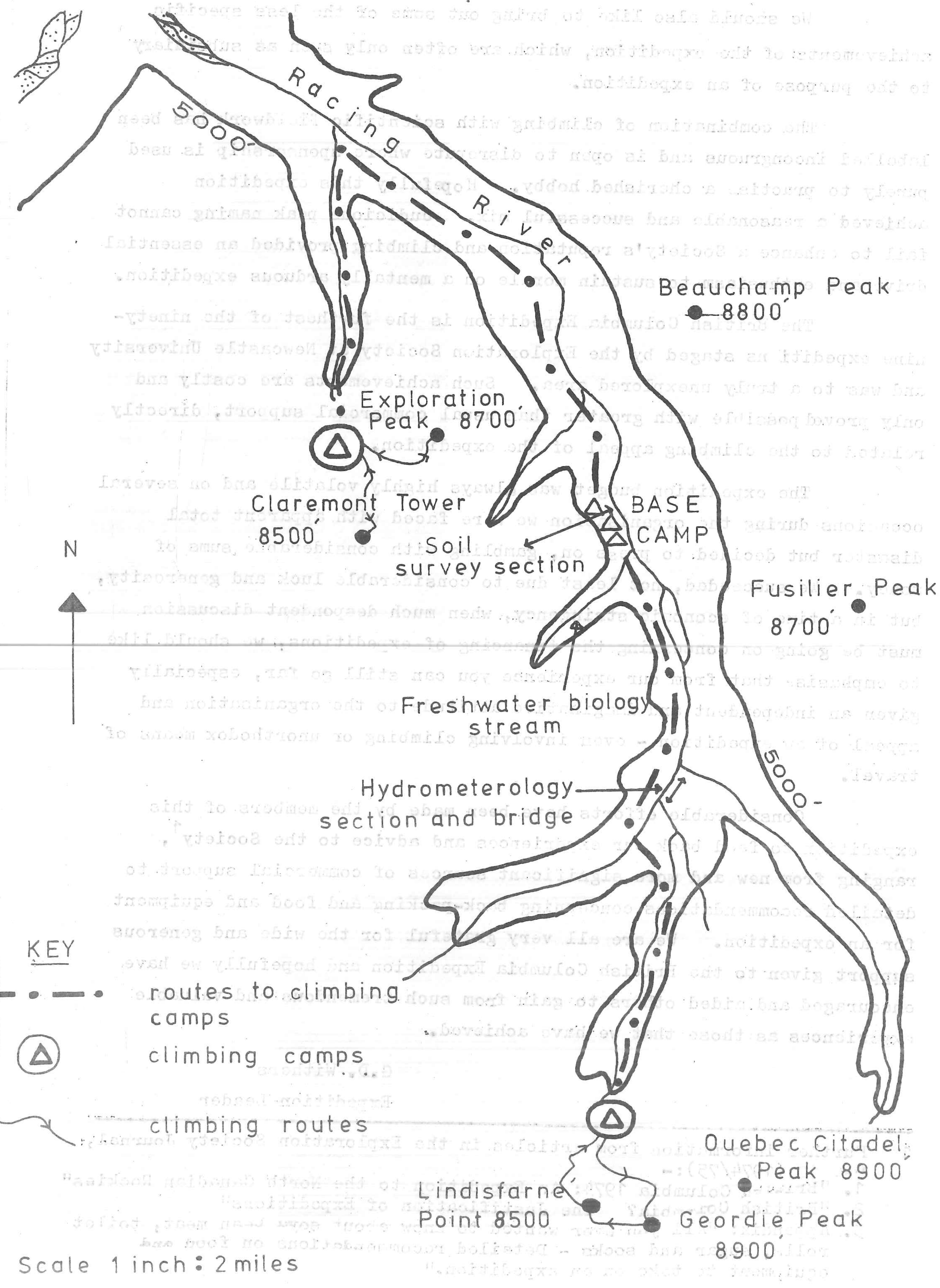
With regard to the soil investigation, reduced time and the impossibility of bridging the flooded Racing River near the fieldwork area resulted in the abandonment of a traverse with a southerly aspect on the opposite bank of the river. A detailed investigation of the variation of aoil type with altitude was still successfully carried out.

The hydrometeorological project required ingenuity and resourcefulness in these difficult conditions: an upper fork of Racing River was eventually bridged (a thirty-five foot span) and a relatively straight channel marked into sections which had to be continually relevelled with such fast eroding flows. Data were successfully collected during the course of a flood, which eventually destroyed the bridge and changed the course of the river.

A sampling method had to be devised for the high altitude stream studied in the freshwater biology project, the animals present being mainly mosquito larvae. More detailed investigation would have been desirable with more time. During the initial stream survey it was decided to make a separate detailed study of the distribution of stream fauna as it was of personal interest.

With reduced time for climbing we abandoned the proposed attempts at further ascents of Mount Roosevelt and Mount Churchill and concentrated on making the first ascents of four unclimbrd peaks, which are to be named. Information on these and on climbing in this area has been recorded and, in conjunction with a private Canadian expedition to the upper Churchill Creek valley, we have presented an article to the Alpine Club of Canada.

PROJECT LOCATIONS



Achievements.

We should also like to bring out some of the less specific achievements of the expedition, which are often only seen as subsidiary to the purpose of an expedition.

The combination of climbing with scientific fieldwork has been labelled incongruous and is open to disrepute where sponsorship is used purely to practise a cherished hobby. Hopefully this expedition achieved a reasonable and successful mix. Judicious peak naming cannot fail to enhance a Society's reputation and climbing provided an essential drive and enthusiasm to sustain morale on a mentally arduous expedition.

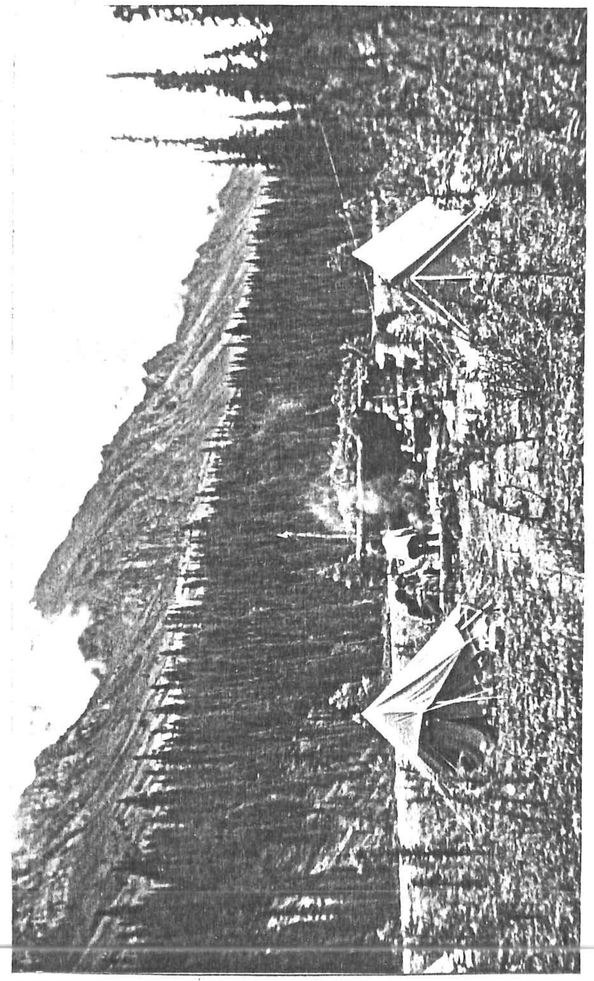
The British Columbia Expedition is the furthest of the ninety-nine expediti ns staged by the Exploration Society at Newcastle University and was to a truly unexplored area. Such achievements are costly and only proved possible with greater than usual commercial support, directly related to the climbing appeal of the expedition.

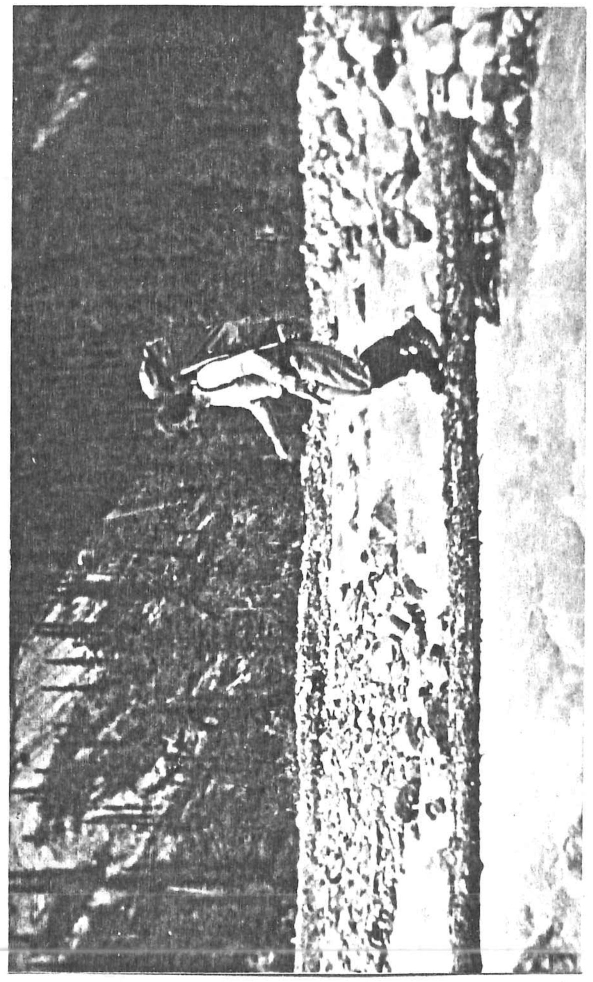
The expedition budget was always highly volatile and on several occasions during the organisation we were faced with apparent total disaster but decided to press on, gambling with considerable sums of money. We succeedad, not least due to considerable luck and generosity, but in a time of economic stringency, when much despondent discussion must be going on concerning the financing of expeditions, we should like to emphasise that from our experience you can still go far, especially given an independent and imaginative attitude to the organisation and appeal of an expedition - even involving climbing or unorthodox means of travel.

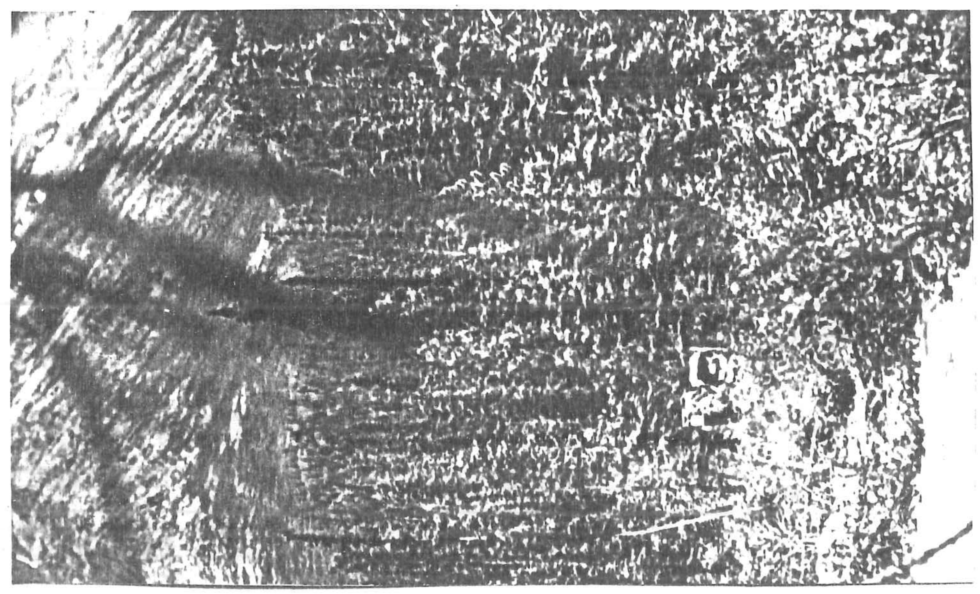
Considerable efforts have been made by the members of this expedition to feed back our experiences and advice to the Society[1], ranging from new and more significant sources of commercial support to detailed recommendations concerning back-packing and food and equipment for an expedition. We are all very grateful for the wide and generous support given to the British Columbia Expedition and hopefully we have encouraged and aided others to gain from such tremendous and valuable experiences as those that we have achieved.

G.D. Withers
Expedition Leader

1 Further information from articles in the Exploration Society Journal, No. 10 (1974/75):-
1. "British Columbia 1974: An Expedition to the North Canadian Rockies"
2. "British Columbia? The Justification of Expeditions"
3. Appendix: "All you ever wanted to know about soya bean meat, toilet rolls, sugar and socks - Detailed recommendations on food and equipment to take on an expedition."







BELOW: Back-packing through spruce forest and scrub birch.
BOTTOM RIGHT: Fast sidestreams were bridged for safety.
TOP RIGHT: Base camp, with self-built log cabin, eighteen miles from Yedhe Mine.

HYDROMETEOROLOGY PROJECT

PREPARED BY: P.D. Brettell
ASSISTED BY:- G.D. Withers

Introduction

The object of this project was to study the discharge variation of a mountain river, in order to compare two methods of measurement and to hence obtain a value for Manning's coefficient, which could be applied to other rivers in a similar environmental condition.

The methods of discharge measurement used were current metering and using the method of floats. To carry out the current meter work a section of river was chosen which could be bridged, so that the measurements could be taken at the same place each day and to make the job of taking measurements easier. In order to use the method of floats as straight a section as possible was needed, although the final section chosen had a slight curve in it.

In order to calculate Manning's coefficient the water surface slope needed to be calculated at each day's discharge measurement and was carried out by levelling at intervals along the river bank.

Procedure

A portion of the river about 10m wide was finally chosen as the site for the project and was bridged using two logs cut from nearby trees. Having established the reach a series of large rocks were placed at 20m intervals along the left bank, and at 24m along the right bank (in order to allow for the curve in the river) and were levelled relative to each other. These rocks could then be used to determine the level of the water surface at each cross section on each day of measurement, so that the water surface slope could be ascertained.

The log bridge was was measured off in ½m intervals so that the current meter readings could be taken in precisely the same position, relative to the right hand bank, each day.

Float Measurements

This method of discharge measurement requires measuring the cross sectional area at a number of stations along the river and then timing the passage of a float between the sections. Thus the velocity can be determined and knowing the average cross section the discharge is found from the equation

$$Q = V A$$

where Q = discharge in the river;
V = velocity of flow;
A = cross sectional area.

Floats were manufactured each day using a piece of dead wood to which was attached a small stone, so that the float would travel, down the river vertically and hence a true velocity of flow would be obtained. This proved to be difficult to achieve as the floats either travelled too low in the water and tended to knock against rock on the bottom of the river or else floated lying on the surface, and therefore in both cases gave a false velocity measurement. This problem was only overcome by practice but even so a large error can be attributed to it.

In order to measure the cross sectional areas the river had to be waded and readings were taken on a staff. This proved a most trying experience since the water was exceptionally cold, being glacier melt, and due to the fast flow dragging at our legs on an uneven and precarious rocky bed. As a result the river was only waded once for each cross section and this was considered a source of error since it was apparent that the river bed was changing shape due to the movement of bed material by the water. The result of these problems was to make the readings obtained using the floats rather dubious, and this was borne out when the results were compared with the current meter work.

Current Metering

The current meter readings were taken from the bridge since it required at least a couple of minutes for each reading and the water was too cold for wading. The method used was for one person to hold the current meter on its staff at the correct depth and to count revolutions of the buckets, using the 'beep' of a broken electrical contact, and for the second person to take timings.

A series of readings at ½m intervals across the bridge were taken with the current meter placed at a distance of 0.4 x depth of water from the bed of the river. At this point the average velocity of flow should be obtained. Knowing the depth at each point of measurement and also the velocity, the total discharge in the river can be calculated from equation (1).

These readings proved to be exceptionally easy to carry out and gave most consistent results and were therefore used in the calculation of Manning's coefficient in preference to the float readings which varied too greatly to be considered to be reliable.

Manning's Coefficient

Manning's coefficient occurs in the following equation:-

$$Q = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad - \qquad (2)$$

where Q is the discharge;
n is Manning's coefficient;
R is the hydraulic mean depth,
= A/P where A is the cross sectional area
and P is the wetted perimeter;
S is the water slope.

The advantage of knowing Manning's coefficient, n, is that the discharge can be calculated without having to calculate the velocity of flow. Therefore, if the slope of the water surface can be measured and the cross sectional area and wetted perimeter ascertained, then a discharge can be calculated. This will only apply for a river of similar dimensions and of similar bed material since n varies with discharge and with different environmental conditions.

The river conditions at our location consisted of a bed material which ranged foom silt, through sand and pebbles up to rocks of a maximum of $0.125m^3$ volume or about 0.5m x 0.5m x 0.5m and could be described as well graded in an engineering sense. There was no vegetation growing in the river probably due to the cold and the velocity at which the water was flowing. A maximum velocity of $2.401 ms^{-1}$ was recorded using the current meter and $3.667 ms^{-1}$ using the method of floats. The water was silt laden from the glaciers and always appeared cloudy.

Rain Gauging

During the length of our stay at the site a rain gauge was used to record readings twice per day at 10.00hrs and at 22.00hrs, and it was hoped that a correlation between rainfall and discharge could be obtained. It was observed however that often when it was not raining at our camp site precipitation could be seen falling on the mountains and glaciers at the head of the valleys. It was also noted that during our entire stay of one month in the area there were only four days when there were clear skies and it did not rain. It was observed that on the days of fine weather the discharge in the rivers rose rapidly and significantly, indicating that the main effect on high discharge was glacier melt and not precipitation. The glaciers were snow covered and it was the melting of the snow which caused increased discharge.

Results

(a) Float method

The results are given in tabular form beginning with the float work.

There were four cross sections chosen along the reach of river used for measurements and these were numbered A_b (bridge section), A_1, A_2 and A_3. In order to calculate the discharge an average was taken of the three discharge values obtained by considering the flow between A_b and A_1, A_1 and A_2, and A_2 and A_3.

The area at each section was calculated by plotting on graph paper each cross section and then using the method of counting squares to determine the area. Each area was divided into three portions known as Right Hand (RH), Left Hand (LH) and Middle (M) and the distance travelled by each float depended on which side of the river it passed down. Knowing the time of travel the velocity could be calculated and knowing the average area between each section the discharge could be calculated.

A summary of the results, giving the calculated discharges for each section on each day, is given in Table 1. An example of the table of results compiled for each day as explained above, is presented in Hydrometeorology Appendix A. This shows variations typical of the readings taken by this method.

Date	Total discharge in each section m^3s^{-1}			Average total discharge m^3s^{-1}
	A_b to A_1	A_1 to A_2	A_2 to A_3	
30/7/74	5.09	6.14	6.17	5.80
31/7/74	10.44	8.98	8.86	9.43
2/8/74	9.77	9.62	10.06	9.82
3/8/74	10.27	9.47	9.95	9.90
4/8/74	8.99	8.06	6.76	7.93

Table 1 Calculated discharges each day by float measurement. (Readings were unobtainable on 1/8/74)

(b) Current Meter method

A summary of the results, giving the total cross sectional area and total discharge for each day, appears in Table 2. An example of one day's detailed table of results is given in Hydrometeorology Appendix B, and shows the computation of the discharge as being an addition of a number of subsidiary discharges found from each point velocity.

Date	Total cross sectional area m^2	Total discharge m^3s^{-1}
30/7/74	2.48	3.78
31/7/74	3.40	4.83
1/8/74	3.32	3.34
2/8/74	4.06	6.46
3/8/74	4.40	6.87
4/8/74	4.21	6.43

Table 2 Calculated discharges each day by current meter measurement.

Date	Wetted perimeter P m	Water slope S	Manning's coefficient $n = \frac{1}{x}$
30/7/74	7.22	0.0087	x = 92.06
31/7/74	7.40	0.0117	75.25
1/8/74	7.39	0.0101	56.56
2/8/74	7.52	0.0145	81.01
3/8/74	7.60	0.0155	79.50
4/8/74	7.52	0.0154	75.95

Table 3 Values of Manning's coefficient obtained for each day.

Calculation of Manning's Coefficient

Due to the large difference between the results obtained from the float method and those obtained using the current meter it was decided to use the current meter readings to obtain values of n at each each of the discharges measured. Values of P, the wetted perimeter, were calculated and the water slope S was computed from the levels which were recorded each day at each cross section. In order to find an average slope, the slope was measured from the bridge section to each of the other sections and the final six results (three for each bank of the river) were averaged.

Table 3 shows the values of P, S and Manning's coefficient n, obtained for each day, and an example of the detailed measurements taken is given in Hydrometeorology Appendix C.

Comparison of results obtained by the float method and the current meter

Values for the discharge obtained using the two methods are shown in the right hand column of Tables 1 and 2 respectively. The current metering was felt to be the more accurate of the two methods due to the ease of measurement and the fact that many measurements could be taken across the section at known positions. The float method suffered from not having a section of river absolutely straight and the bed of the river varied in depth. This meant that the the floats had to be made for each part of the river and often drifted onto the wrong side. These difficulties we tried to overcome but were not very successful since the variation between the two methods was too great for a sensible comparison to be made.

Stage/Discharge rating curve for River

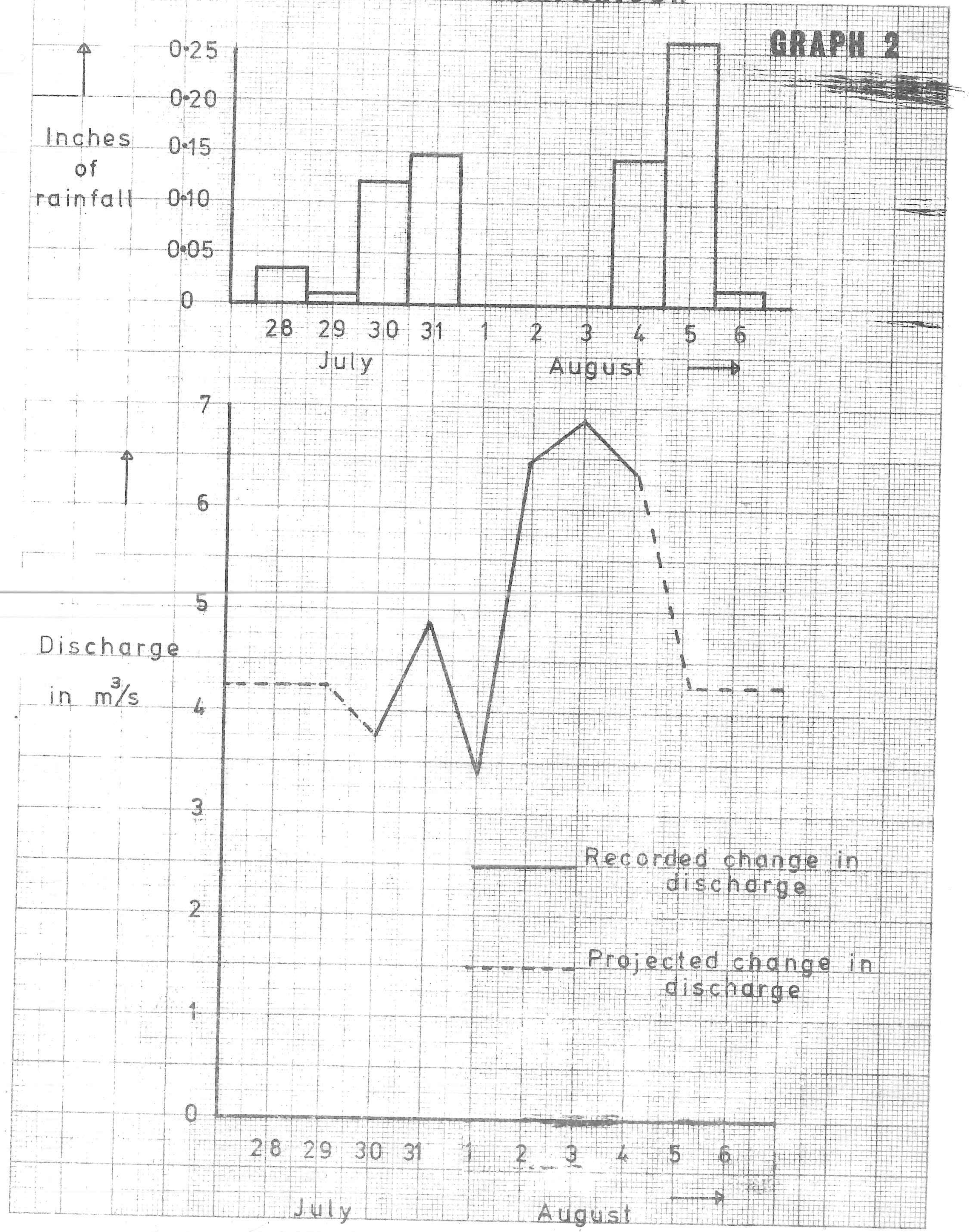
On each day of discharge measurement the stage was recorded relative to an arbitrary level so that a change of stage from day to day could be observed. The result of this was to produce a rating curve for the river, shown in Graph 1. These results are tabulated in Table 4.

Rainfall/Discharge comparison

Graph 2 shows the distribution of rainfall over the period 28/7/74 to 6/8/74 and the six discharge recordings. The dotted line on the discharge graph is a projection of the curve it was observed to follow, although not actually measured. The graph does indicate that

RAINFALL / DISCHARGE COMPARISON

GRAPH 2



on days of no rainfall and clear skies (1st, 2nd and 3rd of August) the discharge rose rapidly and significantly due to glacier snow melt.

Rainfall recordings were taken at 22.00 hrs. between 22/7/74 and 7/8/74 and the results are shown in Table 5. The third column shows a total for 24 hour period which was plotted on Graph 2.

Discharge $m^3 s^{-1}$	Stage m
3.34	0.668
3.78	0.618
4.83	0.733
6.43	0.780
6.46	0.788
6.87	0.788

Table 4 Observed relation between discharge and stage.

Date	Rainfall up to 10.00 hrs. (ins.)	Rainfall up to 22.00 hrs.(ins.)	Total in 24 hrs(in.) plotted on Graph 2
22/7/74	Trace	0.040	
23	C.007	0.013	
24	0.020	0.160	
25	Trace	0.0	
26	0.080	0.0	
27	0.0	0.0	
28	0.0	0.036	0.036
29	0.009	0.0	0.009
30	0.0	0.122	0.122
31	0.148	0.0	0.148
1/8/74	0.0	0.0	
2	0.0	0.0	
3	Trace	0.0	
4	0.114	0.030	0.144
5	0.169	0.089	0.258
6	0.002	0.012	0.014
7	0.168	0.0	

Table 5 Rain gauge recordings during the Expedition.

Results obtained for Manning's coefficient

Manning's coefficient, n, was found to vary widely at low discharges and to be relatively constant at higher discharges. Table 6 shows the variation in the coefficient over the range of discharges measures.

Discharge m^3s^{-1}	Manning's coefficient (n = 1/x)
3.34	x = 56.56
3.78	92.06
4.82	75.25
6.42	75.95
6.45	81.01
6.87	79.49
Average =	76.72

Table 6 Values obtained for Manning's coefficient.

Conclusions

Float method of discharge measurement

This method needs to be handled very carefully and with much attention paid to using a stretch of river where the bed slope and shape is constant and which is as straight as possible. Floats are difficult to make so that they will float vertically, and therefore at the correct depth, and they are also not easy to retrieve in fast rivers.

Current metering

This is a most successful method of measurement and is made much easier by having a bridge to work from. In high mountain rivers the water is too cold for wading and, since they tend to be fast flowing, maintaining one's balance is also not easy.

Manning's coefficient

It was found that a value of Manning's coefficient of $\frac{1}{77}$ could be taken as reasonable for the river conditions encountered and that at high discharges the variation about this figure was not large. The variation at lower discharges was significant but due to the lack of large numbers of readings no conclusion can definitely be made.

Acknowledgements

We should like to thank the following for their help and advice with this project:-

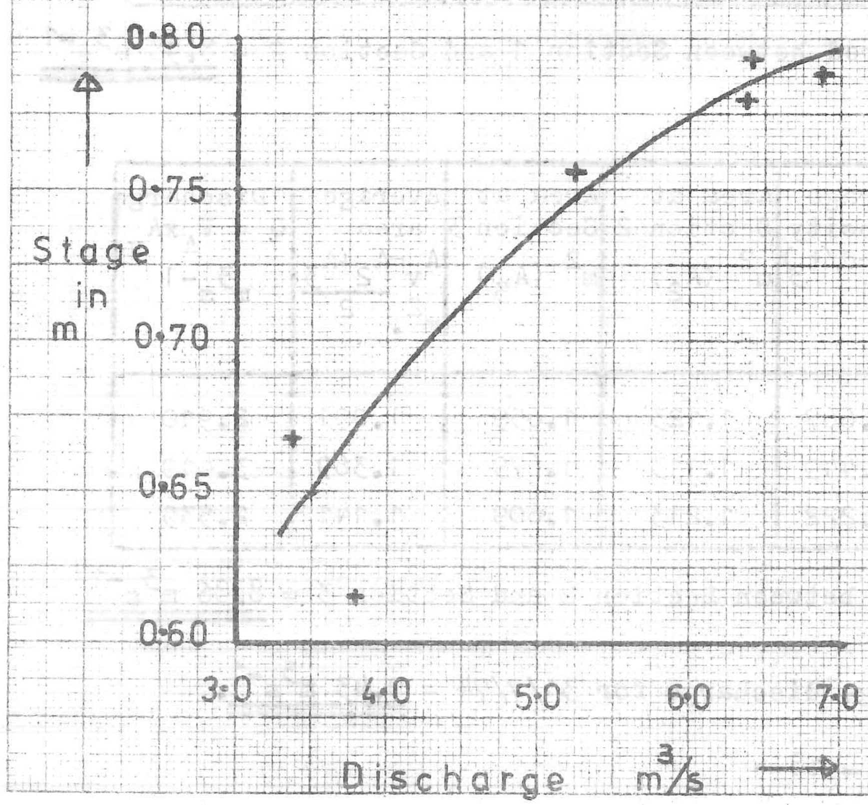
Professor P. Novak, Professor of Hydraulics and Hydrology, Department of Civil Engineering, University of Newcastle-upon-Tyne;

Mr. P. Johnson, Lecturer in Hydrology and Water Resources, Department of Civil Engineering, University of Newcastle-upon-Tyne;

E.G. Tallman Esq., Senior Planning Engineer, British Columbia Hydro and Power Authority, Vancouver.

DISCHARGE RATING CURVE FOR RIVER

GRAPH 1



Hydrometeorology Appendix A

Below is given an example of the detailed measurements compiled for one day, using the float method:-

Date:- 31/7/74

Float position (P) (RH,M,LH)	Time of travel - Bridge to Section 1 sec. (t_1)	Distance travelled Bridge to Section 1 m. (d)	Average velocity ($V_A=d/t_1$) ms^{-1}	Area at Bridge m^2 (A_B)	Area at Section 1 m^2 (A_1)	Average area $A_v=\frac{A_B+A_1}{2}$ m^2	Discharge $Q = V_A x A_v$ m^3s^{-1}
RH	9.0	24	2.667	1.554	1.403	1.478	3.936
M	6.5	22	3.385	1.142	1.323	1.231	4.172
LH	7.0	20	2.857	0.699	0.933	0.816	2.331

Total discharge, as measured between Bridge and Section 1 = 10.44 m^3s^{-1}

Float position (P) (RH,M,LH)	Time of travel - Section 1-Section 2 sec. (t_2)	Distance travelled Section 1-Section 2 m. (d)	Average velocity ($V_A=d/t_2$) ms^{-1}	Area at Section 1 m^2 (A_1)	Area at Section 2 m^2 (A_2)	Average area $A_v=\frac{A_1+A_2}{2}$ m^2.	Discharge $Q = V_A x A_v$ m^3s^{-1}
RH	9.0	24	2.667	1.403	1.123	1.263	3.368
M	8.0	22	2.750	1.323	1.113	1.218	3.349
LH	9.5	20	2.105	0.933	1.213	1.073	2.259

Total discharge, as measured between Section 1 and Section 2 = 8.98 m^3s^{-1}

Float position (P) (RH,M,LH)	Time of travel - Section 2-Section 3 sec. (t_3)	Distance travelled Section 2-Section 3 m. (d)	Average velocity ($V_A=d/t_3$) ms^{-1}	Area at Section 2 m^2 (A_2)	Area at Section 3 m^2 (A_3)	Average area $A_v=\frac{A_2+A_3}{2}$ m^2.	Discharge $Q = V_A x A_v$ m^3s^{-1}
RH	9.0	24	2.667	1.123	1.059	1.091	2.910
M	9.0	22	2.449	1.113	1.679	1.369	3.419
LH	9.0	20	2.222	1.213	1.609	1.141	2.535

Total discharge, as measured between Section 2 and Section 3 = 8.86 m^3s^{-1}

Average discharge for 31/7/74 = 9.43 m^3s^{-1}.

Hydrometeorology Appendix B

Below is given an example of the detailed measurements compiled for one day, using the current meter method:-

Date:- 31/7/74

Distance from RH bank m.(L)	Depth of section m. (h)	C.S.A. about section m^2	Measurement time s. (t)	No. of revs.	Velocity average ms^{-1}(v)	Discharge Q=vxC.S.A. m^3s^{-1}
0.25	0.432	0.216	40	49	0.837	0.180
0.75	0.457	0.228	45	67	1.020	0.233
1.25	0.609	0.304	40	120	2.059	0.626
1.75	0.660	0.330	50	155	2.125	0.701
2.25	0.635	0.476	54	150	1.904	0.906
3.25	0.609	0.609	63	150	1.632	0.995
4.25	0.533	0.533	68	100	1.010	0.538
5.25	0.381	0.381	41	60	1.008	0.384
6.25	0.254	0.191	40	60	1.028	0.195
6.75	0.250	0.127	51	40	0.543	0.069

Total cross sectional area (C.S.A.)=3.395 m^2. Total discharge=4.827 m^3s^{-1}.

Hydrometeorology Appendix C

Below is given an example of the calculation of the wetted perimeter P and the Manning's coefficient n for one day.

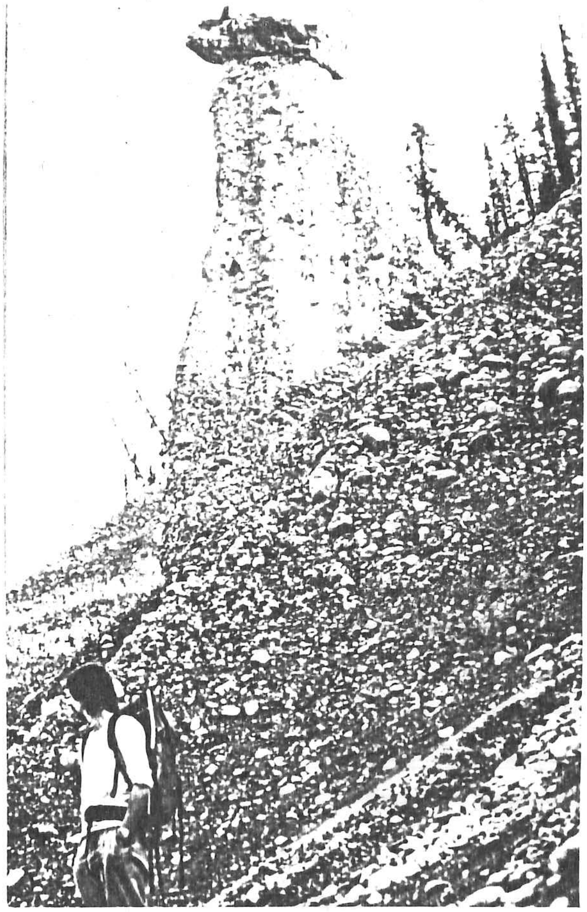
Date:- 31/7/74

Distance from previous point of measurement m.(L)	Depth of water m. (h_n)	$H = h_n - h_{n-1}$	Contribution to wetted perimeter $P_n=\sqrt{L^2+H^2}$
0.25	0.432	0.432	0.498
0.5	0.457	0.025	0.501
0.5	0.609	0.152	0.524
0.5	0.660	0.051	0.502
0.5	0.635	0.025	0.501
1.0	0.609	0.026	1.0
1.0	0.533	0.076	1.003
1.0	0.381	0.152	1.011
1.0	0.254	0.127	1.008
0.5	0.254	0.0	0.500
0.25	0.0	0.254	0.354

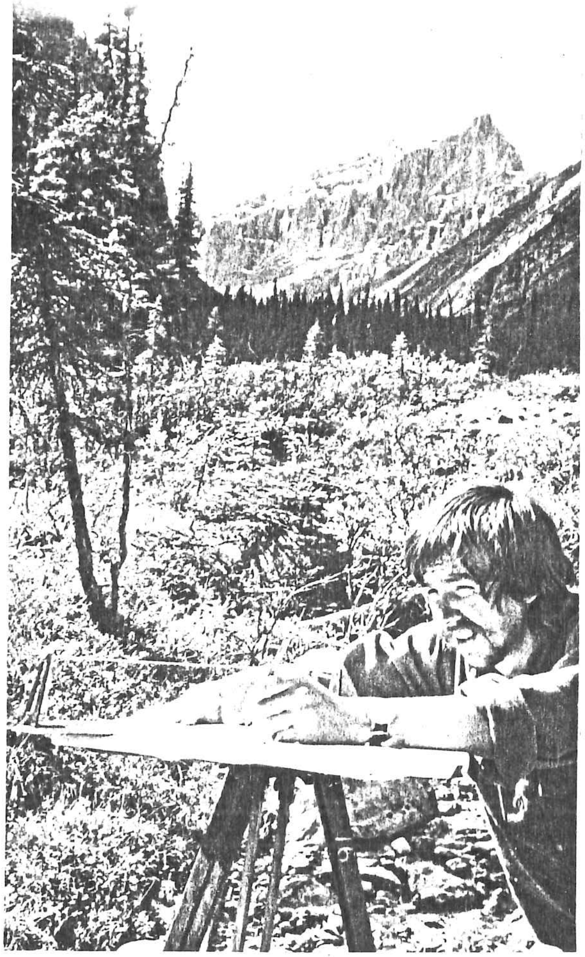
Total wetted perimeter $P = \sum P_n$ = 7.402 m

Water slope S (average of 6 readings) = 0.01167

Manning's coefficient $\frac{1}{n} = \frac{Q}{R^{\frac{2}{3}}S^{\frac{1}{2}}}$ = 75.25.



A pedestal rock left by differential erosion.



Pete R. plane-tabling for the Freshwater Biology study.

Terry identifying larvae from a high altitude stream.

Bob digging a soil profile pit.

SOIL INVESTIGATION REPORT

R.G. Pearce

Abstract

The results of a soil investigation in the Northern Rockies of British Columbia are presented. The investigation is based upon a field transect across the upper Racing River Valley (Lat. 58°21'N, Long. 124°57'W) covering an altitude range from 3,800ft. to 5,400ft. Documentation from twelve primary soil sites is supported by a brief review of existing geological and other related research in the region. Soils formed on parent materials of recent alluvial terraces, glacial till and modern sedimentary scree are represented. Forest podsol soils are found at a range of sites on glacial till. Results show that alluvial terraces are generally too much subject to erosion to allow development of consolidated soil horizons, while the scree parent materials, found at higher altitudes above the tree line, support only young montane soils. The tree line is observed to follow the upper bound of glacial morainic deposits, rather than to follow a fixed altitude.

Introduction

We believe that no soil investigation has previously been attempted within one hundred miles of the present work. The British Columbia Soil Survey have published a report[1] on a survey of soils in a thirty-five mile square area centred on Fort Nelson, a small town one hundred and twenty miles east of the present study, and lying at the eastern foot of the Rocky Mountain chain. Thus although a small western section of the Fort Nelson study area was forested plateau land rising to 2,200 feet, the bulk of that study centred on the flatter, lower muskeg terrain, derived from a post-glacial lake basin, and covered largely with lacustrine clays - a soil environment which may be expected to contrast strongly with that of the mountain valleys to the west, where fine, glacial till, alluvial deposits and a variety of exposed sedimentary bedrocks provide a great variation of parent material from mile to mile.

Consideration of the extreme local climatic[2] and topographic variations in our area prohibited any any assimilation of general soil patterns without recourse to a survey far outside our scope, so it was decided to attempt a soil transect across the Racing River valley, where the Expedition was based, with an emphasis on detailed documentation rather than interpretation, although some interesting conclusions will be drawn from this study in isolation.

Geological and Physiographical Background

Until recently, the extent of geological survey in northern British Columbia was limited to a corridor a few miles either side of the Alaska Highway, and to isolated work in a few other accessible areas. This resulted in a geological Memoir and incomplete map being published by the Canadian Geological Survey in 1950 (reference 3). But with the improvement of communications (in particular in the use of helicopters for fieldwork) and the urge to exploit mineral resources, The Survey undertook to map the geology of the whole of map area 94K (124-126°W, 58-59°N). Thus after extensive aerial and field studies collectively referred to as Operation Liard, the latest Memoir was published in 1973 (reference 4) accompanied by a 2 miles to 1 inch complete geological map. This is, at present, the definitive work on the geology of the area.

Surface geology of the Racing River valley upstream of Delano Creek is dominated by dolomites, quartzites and sandstones of the Tuchodi formation[4], which outcrops throughout this section of the valley below an altitude averaging 5,000 feet. This formation, identified in several parts of the map area, lies in the Helkinian (an uppermost Precambrian period.) A thick layer of dolomitic limestone at the top of this formation has formed a band of steep cliffs along both sides of the valley. Glacial morainic deposits, observed to overlay the bedrock nearer the valley bottom, appear to be derived from the

Wisconsin Cordilleran ice sheet of the last major glaciation period.[5]

Physiographically, the area is typified by high peaks, many above 8,000 feet in height, dissected by deep valleys, with valley bo tom altitudes between 2,000,and 4,000 feet. The principal valley systems, notably the Gataga and Finlay valleys of the Rocky Mountain rench, follow SSE - NNW trends, reflecting the large scale tectonic blundary of the Circum-Pacific belt. However, in most of the Tuchodi Lakes map area this trend is not immediately apparent from the topography alone, as the major rivers such as the Liard, Toad and Tuchodi Rivers flow in a northerly or north-easterly direction towards outflows in the Arctic Ocean. The river valleys have been heavily glaciated, and have typical 'U' shaped profiles, and widths of up to three miles. Glacial morainic deposits consequently cover the lower slopes of these valleys, except on the valley floors, where river erosion has denuded large flat areas. In many places this has resulted in the development of extensive braided river beds, gravel covered and devoid of vegetation. In such cases, the swift undercutting of the glacial material by the river has formed an abrupt bank, often twenty to thirty feet high, at the sides of the bed. The weakening of tree roots by this process has led to a heavy litter of driftwood bing scattered on the valley floors. The deposition of large glacial erratics (or rockfall boulders in some cases) and consequent compression of the underlying glacial till has resulted in the formation of erosion pillars, left standing after water erosion of the glacial material. Although these were reported by Taylor and Stott[4], in the neighbouring Wokkpash valley, this expedition found a group of such pillars on the south bank of Racing River, six miles upstream of its confluence with Churchill Creek. The largest was over twenty feet high, and was the only one still to be capped by a pedestal rock (see plate).

Climate is continental, with extreme seasonal variations. During the short summers temperatures rarely rise above 65°F, and winter temperatures fall bwlow -30°F. Day to day climatic conditions are extremely varied and unpredictable during summer, when most precititation occurs. Rainfll figures recorded at the base camp during the Expedition are given elsewhere[9] but it must be emphasised that altitude and aspect were observed to have a profound effect on all weather variables, particularly rainfall. For example, from observations of changing river level, and of changing snow cover and cloud formations towards the Mount Stalin area, it was clear that the temperatures and sunshine hours were consistently and significantly lower. It must be concluded that local climatic variations are likely to exert a major influence on soils.

Choice of Soil Transect

Owing to lack of time and resources it was not possible to study the variation of soil type with a large number of parameters, such as aspect, valley gradient and parent material along a section ofmthe Racing River valley. Instead it was planned to study the variation of soil type with altitude using one soil transect. Therefore the first aim was to choose a transect line across the valley which would, as far as possible, yield results typical of that section of the valley. With this in mind, a transect was sought which accommodated the following considerations:-

1) It should not be crossed or approached by sidestreams, which would be likely to provide abnormal drainage conditions.

2) Areas with an atypical vegetation type should be avoided.

3) Similarly, the transect should not cut isolated corries or other topographical irregularities which, by their particular conditions of exposure and drainage, might foster a soil and vegetation type not representative of that altitude.

4) It should cover as wide a range of altitudes as is feasible.

5) The transect must be accessible, and free from falling rock.

These requirements were taken into account, together with the requirements of other projects, when deciding on the final location of the base camp in the field. The insert in Figure 1 shows the location, aspect and length of the transect chosen.

Choice of Primary Soil Sites

It was decided to study first the transect south of the river, where the base camp was situated. Though it was planned to include a study of the whole transect, the difficulty of crossing Racir g River and the shortage of time resulting from bad weather precluded extending the study to the northern half.

A preliminary examination of the transect was made in order to establish a minimum number of primary soil sites which would illustrate the variations of soil type along the transect. Variations in vegetation,

topography, drainage and slope were used as a basis for digging preliminary soil pits, for a comparison of the soil types found, and to establish a guide as to the degree of variation within an apparently uniform environment.

Primary soil sites at different altitudes were then fixed, and assigned numbers 1a, 2a, etc. Where additional sites were studied at a given altitude, to sample different conditions away fromthe transect, these were postscripted b, c etc. Below is given an outline of this preliminary investigation, leading to the choice of the twelve primary sites, which are shown on the map in Figure 1:-

Beginning at the valley floor, it was observed that near the transect, a flat zone, 2m to 8m wide, bordered the denuded river channel, which was 1m lower. As has been mentioned, this was not typical, as usually an eroded bank rose from the channel. Here the bank had been free from river action for a considerable time, and three distinct environments were sampled. Site 1a lay on the transect, where the flat area was 2m wide, and appeared to be well drained. Site 1b sampled an area where it was 8m wide, and apparently poorly drained. Pools, averaging a few m^2 were interspersed with hummocks, and a few spruce, mostly leaning owing to weak root anchorages. Site 1c was on the alluvial plain of the base camp, and proved to have an entirely separate genesis (see discussion).

Moving upwards, a number of discrete terminal moraines were identifiable on the steep slope (see Figure 1), and Site 2a and Site 2b sampled soils on the crest and trough of such a moraine, at the same position along the length of the transect. It was apparent that different drainage conditions prevailed, and that soil differences were significant.

Site 3a was placed at a flatter section, which began immediately above the region dissected by terminal moraines. Although no obvious vegetation differences were apparent, it was thought that this area comprised mainly side moraine material, and might provide a different parent material composition.

Above this, smooth changes in slope provided slight topographic evidence of several successive side moraines, presumably corresponding to different glacial advances. Though the gradient never became flat, the flatter ground associated with the 'troughs' was noticeably poorer drained, and a typical site exhibiting this was chosen for Site 4a.

The next observed change came near the tree line, where a flatter gradient was accompanied by an increase in grass species at the expense of moss, and areas of sparser tree density. There were notably pockets of sparse tree density interspersed with areas typical of Sites 3a and 4a, and after preliminary investigation, Site 5a was chosen as being typical of the soil associated with the sparser tree cover.

Site 6a was located only a few metres above the abrupt tree line, and was marked by a thick undergrowth of labrador tea and scrub birch. This site appeared to mark the transition between forested and alpine environment.

Above this level was a region coverdd with boulder scree, with some blocks larger than $2m^3$. The scree was generally covered with moss, and was composed of smaller blocks towards higher altitude, where moss cover was thin and soil structure was younger. Site 7a was an attempt to typify this very irregular section of the transect.

Between here and the crag base ground cover was similar, with an even slope and consistent surface of gravel scree, with very young alpine soils, supporting scrub birch and alpine flowers. Site 8a is typical of this environment, whereas Site 8b was located near it, but samples a sheltered spot at the base of a gulley in the crag, where gravel scree had hardly been cultivated into a recognisable soil structure, though many alpine species flourished.

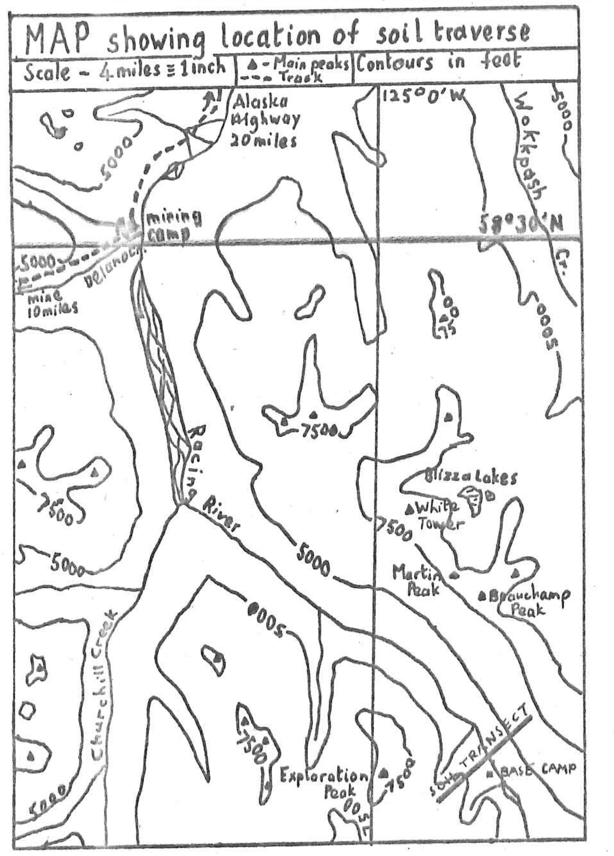
Above the crag, at an altitude of 6,000 feet, a small region of similar young soils was in evidence, though this was not accessible for detailed examination.

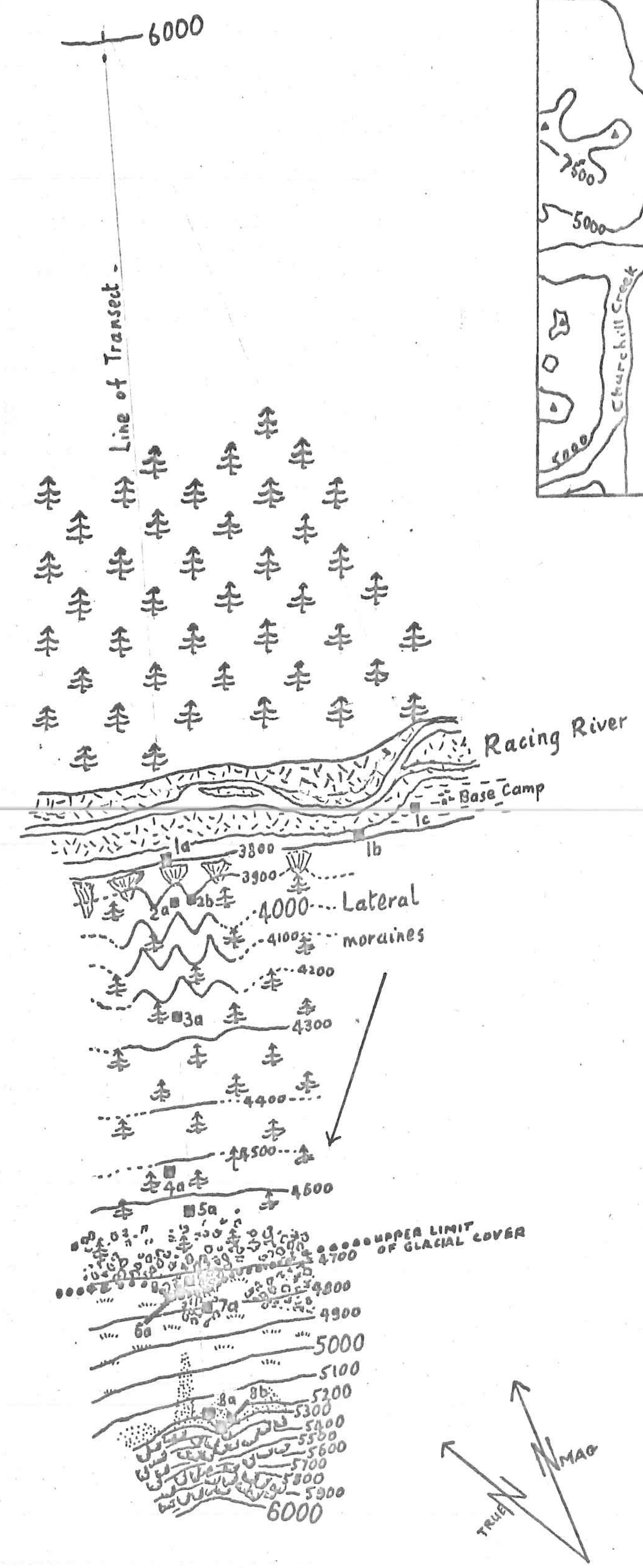
Soil Site Evaluations - Fieldwork Method

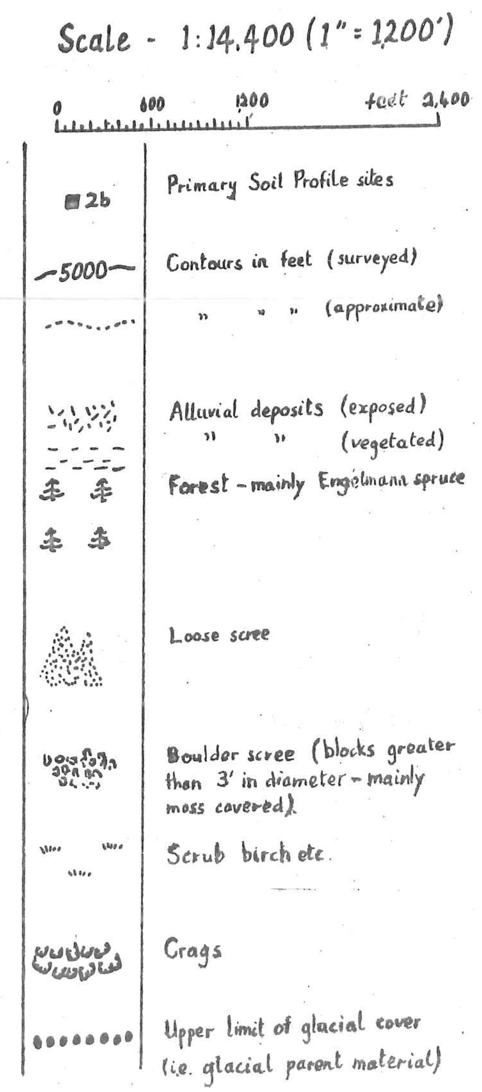
Having established the location of a soil site, it was visited for the recording of soil site details, and for the digging, facing up and documentation of a soil profile. Weather conditions were a severe hindrance to the latter task, as although soil pits could be dug in adverse weather conditions, documentation in such conditions was difficult. At the same time it was necessary to record a faced profile on the same day as facing, before the disturbance changed its 'live' characteristics. In such cases it was always refaced, by removing at least six inches of soil from the faced side. In all cases the faced side ran along the line of dip. In profile 5a the south-east side of the pit was used. In all other profiles the north-west side was used,

Figure 1

Map of soil traverse showing primary soil sites (location map inset at right)







with the exception of the flat sites 1a and 1b, where the south side was used.

The terrain was, in general, easily negotiated on foot. Contrary to expectations, tree density or ground cover did not prove a significant hindrance in themselves, unlike in southern British Columbia, where such difficulties are well known. For the benefit of anyone contemplating similar work, the following additional points are worth noting. First, though forests can easily be negotiated in this region, rivers generally have a large discharge, are fast-flowing, and are often freezing (if they contain glacial melt). Further, it is seldom possible to bridge rivers with trees, owing to the wide braiding characteristic of even most small streams. Thus rivers are the greatest barrier to mobility on the lower slopes of valleys, and as a rough guide for the interpretation of river sizes from the map, Racing river at this transect is the largest that could be crossed, and only in favourable conditions, with a group of people. Often it was impassable.

Wildlife never presented any danger, but harassing from bears, moose or other animals is always a possibility, particularly where such animals are used to man. Near the transect, a route pushed through a thick clump of trees, felling three of them, was thought to be caused by a bear.

The greatest problem of all was forest navigation, and in particular, the relocation of soil sites. As an aid to this, a large wooden tripod was erected from driftwood on the valley floor, to which bearings of sites were taken where possible. For the higher profiles, bearings to neighbouring peaks had to be relied upon. In addition, tree-slashing was sometimes used, though to be effective, this was time-consuming to prepare. Memorization of tree formations along the transect proved extremely useful.

Documentation for each soil site was collected following a standard procedure as explained in Appendix A. Where possible pits were dug to reach the uniform parent material. Where this was not possible, reasons are given in the corresponding profile record in Appendix A. In addition, soil samples were collected, usually of every identifiable horizon at the soil site. These samples averaged a few hundred grammes when collected, and were immediately air dried at base camp (conditions permitting) and stored in sealed polythene bags.

Though the samples have been retained, the only laboratory analysis conducted was that of determining pH values. Measurements were made using a Pye Unicam 292 pH meter on the < 2mm fraction, sieved after crushing. 20g of soil were stirred into 50ml water, and left for one hour, before measuring the pH in the supernatant liquid.

Soil Site Evaluations - Results

reports compiled at each of the twelve primary soil sites are presented in Soil Investigation Appendix A, which comprises the twelve soil profile records, prededed by a detailed explanation of the presentation and significance of the data.

Discussion

From the profile records in Appendix A the soil sites can be divided into three categories depending on parent material. It will be seen that, within the limits of this transect, parent material is a major factor in determining soil type.

Beginning at the valley floor, it is clear that Site 1c is alone in being formed on recent alluvial deposit. River activity has caused deposition of grit to gravel sized particles to form many alluvial terraces along the length of the valley. Observation showed that the material remains structureless, and in most cases only supports isolated plant life, with no soil profile developing. In general this is a result of such terraces only having a short life before being re-eroded by the changing course of the river. (Significant differences between observed river braidings and those shown on the topographic map, based on 1948 aerial cover, were noted. These included the observed absence of a one mile long split in the river immediately upstream of the base camp, as marked on the map.)

The base camp alluvial terrace (Site 1c) is an exception to the above as it has survived long enough for the growth of spruce up to four feet high. The age of this terrace is estimated to be between fifty and a hundred years, during which time the observed young structureless soil has evolved.

Soils formed on glacial till constitute the second category. These include Sites 1a and 1b, up to Site 5a, and in a less pure form, Site 6a. The parent materials of Sites 2a to 5a are seen to have similar composition, while that at Site 6a has been contaminated by a

dolomitic limestone fraction from scree deposition. On the valley floor the bank between alluvial terrace and glacial till was generally well marked (the terrace of Site 1c terminated at a typical bank, which rose two metres, and marked the beginning of mature tree cover, and thick blanket moss.) However, Sites 1a and 1b, themselves on a flat terrace, were not characteristic of this, and from topographic examination, were first thought to belong to the alluvial zone. However, their parent materials are seen to be glacial, although they contrast strongly with the other glacial parent materials, by being composed of the pure clay fraction. It is clear that these sites represent a glacial outwash terrace, which has been allowed to form during a considerable period of freedom from river erosion, presumably after previous river erosion had removed the original glacial material. Evidence of similar characteristics was seldom seen elsewhere along this valley.

At Site 1a only a preliminary stage of gleying was observed (some rusty coloured patches around the more readily oxidised root channels and rock surfaces). The buried humus layer found at this site is of interest. It did not exhibit characteristics of an illuvial humus accumulation though this remains a possibility. There was no evidence of gross slumping having buried a soil profile.

By contrast, Site 1b was heavily gleyed, at least to a depth of one metre, and was the least well drained site studied.

Sites 2a and 2b to 6a all exhibit typical characteristics of forest podsol soils, with slight evidence of gleying in some cases. Within this group there are no noticeable trends related to altitude alone, though several differences are observed, mainly related to drainage conditions. For example, some evidence of gleying in the intermediate horizons of Sites 3a and 6a are seen, and possibly in those of Sites 4a and 5a, though only 6a showed the presence of a water table, and evidence of waterlogging, at the time of study. In this connection it must be remembered that although the present study was conducted during the season of heaviest rainfall, it is expected that drainage conditions are much freer during the summer than at other times, causing a more oxidising environment within the profile. During the winter the complete profile is always frozen, while during the spring thaw a constant waterlogging, with associated reducing conditions, will be prevalent, probably for at least two months.

An interesting observation is the conspicuous yellow eluvial horizon, unique to Site 2a, on a recessional moraine crest. Here the eluvial horizons are marked by extreme leaching of the clay fraction, and consequently exhibit characteristics of a more highly oxidising environment. This more efficient leaching is to be expected in areas of freer drainage such as this, and contrasts strongly with the equivalent Site 2b, where typical reducing characteristics indicate impeded drainage during some seasons.

The third category of soils are those of Sites 7a, 8a and 8b, which have young montane characteristics and are formed mainly on scree derived from the dolomitic limestone cliff referred to earlier. The true bedrock here was not established - parent material was exclusively scree. At Site 7a, development of a soil structure between scree boulders is progressing by means of a moss blanket which, allied with erosive processes, is breaking down the rock boundaries into mineral soil.

At Site 8a the only evidence of particle consolidation is by root fibres, whereas at Site 8b no particle consolidation was evident.

It is important to consider to what extent the above appraisal is typical of this section of the Racing River valley. For observations along the valley, it is claimed that, within the limits outlined under 'Choice of Transect', the transect is typical. No gross variation in floral cover or microtopography were observed between the confluence of Racing River with Churchill Creek, and the headwaters of the river, fifteen miles upstream. Though tree cover extended to the bank of most sidestreams, a sidestream one mile upstream of the base camp on the north side was associated with a corridor some 200m wide, and throughout its length, which was devoid of trees. This stream was not examined owing to difficult approach from the south side if the river.

Above the confluence of Churchill Creek and Racing River the tree line was observed to follow the upper bound of the glacial cover, rather than to follow a constant altitude. On the opposite (northerly) valley side, the tree line behaved similarly, but a significant number of isolated trees were consistently observed above the main tree line.

Basic differences in physiography and altitude mean that forest soils of this type are not generally represented in the Fort Nelson area[1], which, being east of the main cordilleran topography, is typified by flat, poorly drained plateau land between 1,000 and 2,000 feet with only sparse glacial deposits. Soils therefore tend to be formed directly on bedrock, and thick deposits of sphagnum peat develop in the

anaerobic conditions. Areas of permafrost also occur.

In a study of soils in the area of Nevis Mountain, in the Rocky Mountain foothills 30km west of Mile 175 of the Alaska Highway, Lord and Luckhurst[10] find forest podsolic soils in similar environments to those at Sites 2a to 6a in the present study (the 'Unit G' soils in their notation). It is interesting to note that these soils are mainly formed on glacial till below the tree line at a similar altitude, and on moderately to steeply sloping areas.

Conclusion

The study of this single transect has revealed three main soil types. On the valley floor, young and generally short-lived alluvial terraces support poorly developed unconsolidated mineral soils, with isolated plant species. Exceptionally, as sampled here, these terraces survive re-erosion long enough to allow colonisation by trees, notably spruce, but soils remain poorly developed.

Secondly, liberal glacial till deposits to an altitude of 4,700 feet support a type of forest podsol profile, under a cover of spruceyto a height averaging eight metres. Although drainage in the upper horizons was generally observed to be free, some water tables were found, and anaerobic profile characteristics suggested that drainage is impeded for much of the year (as expected during the winter freeze and the spring thaw). Variations in these characteristics, in particular the degree of leaching, was significantly dependent upon the moraine topography, with crestal sites exhibiting evidence of freer drainage, and hence greater leaching.

Thirdly, above this, young montane soils have been formed on modern scree, mainly derived from crags higher on the valley sides.

Within fifteen miles of this point along the valley the tree line was observed to follow the upper bound of glacial moraine as it rose in altitude upstream, and did not remain at a constant altitude.

Acknowledgements

I wish to thank Mr. G.P. Askew of the Department of Soil Science, University of Newcastle-upon-Tyne, for his advice, and for the use of equipment. I also thank Dr. T.M. Ballard of the Soil Science Department, University of British Columbia, for some useful references. Lastly I should like to thank Stella Whateley for identifications of all flora specimens, and Pete Rogers for his survey of the transect, upon which Figures 1 and 2 are based, and also for his help with the manual work so prevalent in soil studies.

Soil Investigation Appendix A - Soil Profile Records

The records presented here are based on the original summaries compiled in the field. Information of general applicability to the whole transect has been omitted in the original records, as has location data only of relevance to fieldwork. Each profile record is arranged in sections as explained below:-

Explanation of the soil profile records reproduced in the following pages.

Soil Site Details

1. Date Date of facing up and documentation of soil, profile.
2. Prevailing weather conditions A brief summary for the preceding few days is given because of its possible bearing on the interpretation of soil properties and on direct evidence of profile drainage conditions.
3. Site location Magnetic bearings and clinometer dip values to neighbouring peaks were noted on the field records. In addition, bearings to a fixed wooden tripod on the valley floor (see Figure 1) were also noted where possible. This was necessary in order to relocate soil sites in the lower forested section of the traverse. The data have been retained, but they are omitted here.
4. Factors influencing choice of site A summary of the considerations leading to the choice of this particular primary soil site is given. This is discussed further in the main text.
5. Aerial photography Details of aerial photography cover for this area may be obtained from the British Columbia Department of Lands, Forests and Water Resources, Parliament Building, Victoria, B.C. At the time of this study no aerial photography on a scale useful for soil interpretation was available.
6. Ground photography Reference numbers and descriptions of photographic material recorded at each site is given. This consists primarily of soil profile photographs taken on Kodachrome II using ambient light. Copies may be obtained from the author through the Exploration Society, though it must be emphasised that, owing to difficult field conditions, some slides are of inferior quality. All profile photographs include a depth measure.

7. Soil samples Soil samples, air dried at base camp, were in general collected from each identifiable horizon of each profile. Samples averaged a few hundred grammes, and have been retained. Identifying numbers are given.
8. Mapping References for surveying only - not included here.

Soil site characteristics

9. Locality - general A general appraisal of the environment of the site.
10. Map reference For field purposes only.
11. Altitude Altitude in feet is deduced from the contour surveying of this expedition, which was related to a datum at the base camp. Relative accuracy is about ± 10 feet (standard error). The absolute datum height was calculated by interpolation of contours on the 1:250,000 topographic map, and is estimated to have an error of ± 50 feet. (It must be remembered that a horizontal uncertainty for soil site location must also be taken into account when measuring their altitudes. It is thought that this error might reach 40 feet below the tree line, where surveying conditions were more difficult.)
12. Macrotopography As for the description of the transect in the text.
13. Microtopography Topographic trends in the immediate area of the site are included, as well as features such as hummocks in the vicinity of the site. Dip values and direction of dip of the profile site are given where meaningful.
14. Climatic data. Discussed in the text.
15. Parent material Field notes only are included here. Parent materials are discussed more fully in the text.
16. Flora An analysis of species and number of flora occuring within five metres of the site is given, as well as a general comment on the type of vegetation cover. Identifications are included, and are cross-referenced to other profiles where appropriate, to avoid repetition.
17. Fauna No gross influence of soil fauna on the physical properties of soils was found at any of the sites studied. In particular, no earthworm population was found at any site. Above ground, small animals such as mice and voles were prevalent near the river (a

dead mouse was found in pit 2b on one occasion.) Game was sparse, though evidence of mountain goat and sheep, moose and black bear were found below the tree line. No evidence of game was found above the tree line.

18. Drainage conditions Standard descriptions of soil site and soil profile drainage conditions follow reference 8.

19. Accelerated erosion/saline conditions Inapplicable.

20. Special problems encountered Problems with possible influence on profile documentation or interpretation are included, such as slumping or a highly irregular profile structure.

Soil profile characteristics

Each discrete identifiable horizon in the profile is then described. Depth details include the form of boundaries between horizons, e.g. regular, gradual, undulating. Horizons are labelled according to the scheme of the Soil Survey of England and Wales[7]. A systematic description of each horizon is given, under the following subheadings, which are abbreviated for convenience. The terminology and classification used follow standard soil study proceedure, as summarised in reference 8. For each horizon the following is given:-

M- Soil colour, according to the standardised Munsell system[6], with standard descriptions of mottling and other colour characteristics. All colour measurements were taken at the site, and represent values in the ambient moisture environment.

H- Humus content, i.e. all dead organic content.

R- Root content, i.e. living organic content.

C- Consistency, including detail of soil structure.

T- Texture.

D- Drainage conditions.

S- Stone distribution, (includes soil structure details in some cases).

pH- Acidity. See text for method of measurement.

Where the bedrock or parent material was not reached within the depth of the profile, details are given, and the reason for being unable to investigate deeper is included.

SOIL PROFILE RECORD No. 1a

1. Date 25th July 1974

2. Prevailing weather conditions
Cloudy, heavy showers for previous week.

4. Factors influencing choice of site
One of three profiles sampling different characteristic sites along river bank.

6. Ground photography
BC4/26 & BC4/27 - profile; BC4/25 - looking upstream from site; BC4/28 - general view of site looking south.

7. Soil samples
1a/1 - C horizon sample; 1a/2 - buried humus layer at 68cm deep.

Soil site characteristics

9. Locality - general
2 m from river bank, on flattish bank before sharp rise to moraine. 1m above mean river level.

11. Altitude 3,800 ft.

13. topographical detail
Slope dipping 11° to 040 True at pit, being at the base of 22° rise to moraine. Evidence of slumping, though mature profile at chosen site. 1m drop to alluvial sand and gravel 2m from pit.

15. Parent material Soil formed on glacial material; at edge of extensive moraine deposits.

16. Flora Edge of evergreen woodland; young Engleman spruce up to 4m high along river edge. Abundance of flora at this site: alpine buttercup (ranunculus adoneus), huckleberry, Labrador tea (all common), silverberry (several shrubs), scrub birch (several bushes), and at least one each of: American bistort (polygonum), milk vetch (astragalus agrestis), grouseberry, wild strawberry, various grasses.

18. Drainage conditions Normal site, freely drained profile, with no evidence of gleying.

20. Special problems encountered Water table stablised at 53cm. before spill trench was dug into river. Consequently much slumping of C horizon material in pit.

Soil profile characteristics

Horizon	Depth(cm)	Description
H (granular /fibrous MOR)	0 - 9 (regular)	M-very dusky red (10R 2/2); H-dedomposed vegetation with some root fibres identifiable; R-few, fine.
C	9 - 66 (regular)	M-olive (5Y 5/3), no mottling but some rusty patches around stones; H-none; R-common, decreasing to rare by 50cm, fibrous/woody, generally fine; C-friable, stickier with depth; T-sandy clay loam; D-upper profile freely drained to water table (see below); S-full distribution of size up to 30cm diameter, rounded; pH 8.45.
Hb	66 - 69 (regular)	Similar to horizon H, but more consolidated. M-very dusky red (2.5YR 2/2); pH 7.7.
C	69 - ?	Continuation C as above to at least 80cm (maximum depth possible owing to waterlogging and slumping).

SOIL PROFILE RECORD No. 1b

1. Date 8th August 1974

2. Prevailing weather conditions

Heavy showers for previous week.

4. Factors influencing choice of site

For comparison of soil types along river bank - this site in flatter, poorly drained area, and apparently not formed on glacial material.

6. Ground photography

BC8/32 & BC8/33 - profile

7. Soil samples

1b/1 - gleyed region, grey at 30cm
1b/2 - gleyed region, yellowat 10cm.

Soil site characteristics

9. Locality - general

Bank of river (2m from river bed) in flat, waterlogged area.

11. Altitude 3,800 ft.

13. Microtopography

Hummocks about 2m x 1m with pools 1m to 3m diameter. On a much broader (4 to 6m) flat bank than at 1a, with a consequently poorer drainage environment to be expected.

15. Parent material

Soil formed on alluvial deposit apparently condisting predominantly of fine fraction of glacial material, washed down from neighbouring moraine (see text).

16. Flora

As for 1a with greater abundance of grass species, generally clumped. Some taller spruce, up to 8m, but many trees dead of fallen due to poor ground strength.

18. Drainage conditions

Receiving site, with some runoff. Profile poorly drained - ground water gley characteristics.

20. Special problems encountered

Unlike 1a no tendency to slump when digging below the water table. Soil was well consolidated when wet, owing to fine consistency and smooth texture (see profile details).

continued....

Soil profile characteristics

Horizon	Depth(cm)	Description
Bg	0 - 16	M-dark grey (2.5Y 4/0) with mottles of light olive brown (2.5Y 5/6) below 5cm, patchy, common, faint, medium size (about 1cm diameter). Also spots (≃ 0.5cm diameter); H-none; R-common, fleshy, mainly thin; C-sticky to friable; T-silt loam; D-many fine pores, poor drainage, but evidence that this horizon is seldom below water table; S-none; pH 7.45.
Bh	16 - 20 (sharp, regular)	M-black(2.5YR 3/0); H-consolidatad, unrecognisable as to origin; R-common, thin to med um, fleshy to woody; C-friable to fibrous; T-silt loam; D-many fine pores, well drained; S-none. A very well defined horizon.
Bg	20 - 25 (sharp, regular)	Gleyed layer, as 0 - 16cm.
Bg	25 - 37 (sharp)	M-dark grey (5Y 5/1), slight yellow mottling at base; otherwise light grey mottling. Other characteristics as 0 - 16cm.
Bh	37 - 38 (sharp)	Humus layer as 16 - 20cm, but with more mineral material. M-light grey; H&R-some dead humus and root fibres - medium, common, generally black and woody.
Bg	38 - 42	Gleyed layer as 25 - 37cm.
Bh	42 - 43 (sharp)	Humus layer as 37 - 38cm.
Bg	43 - 48	M-olive (5Y 5/4) to yellowish brown (10YR 5/8) (patchy mottles); H-none; R-none; T-silt with small gravel particles.
Bg	48 - ?	Repeat of alternate light grey and yellow mottled horizons as above, to >1m.

Summary of structure:- Generally yellow mottles to 25cm, then predominantly grey to 35cm. More illuvial humus to 45cm, then alternate yellow and grey mottled layers to at least 1m (deeper inspection impossible owing to water infill, though no slumping in pit.

SOIL PROFILE RECORD No. 1c

1. Date 9th August 1974

2. Prevailing weather conditions

For last five days raining nights and mornings, sunshine afternoons and evenings.

4. Factors influencing choice of site

Comparison of various valley floor profiles - this site on young alluvial plain, not waterlogged.

6. Ground photography

BC8/30 - profile.

7. Soil samples

1c/1 - parent material (small particles).

Soil site characteristics

9. Locality - general Situated on young alluvial plain (100 x 300m) on inside of river meander. (The much older bank, of 1a and 1b, is seen rising behind this younger deposit.)

11. Altitude 3,800 ft.

13. Microtopography Flat, 1.5m above mean river level.

15. Parent material Soil formed on alluvial material - mainly sandstone and limestone pebbles, with gravel and sand infill.

16. Flora Young Engleman spruce up to 2.5m high, at 2 to 5m spacing. Mostly bare earth between, with several of the following interspersed:- alpine buttercup (ranunculus adoneus), yellow mountain avens (dryas drummondii), milk vetch (astragalus agrestis), northern asphodel, grass of parnassus (unfringed), fire weed (epilobium angustifolium).

18. Drainage conditions Freely drained profile, normal site.

20. Special problems encountered Completely unconsolidated material.

Soil profile characteristics

Horizon	Depth(cm)	Description
L	Surface	Thin distribution of litter (dead leaves and twigs);
A_1	0 - ½/2½ (very poor definition of lower limit)	Mixture of humus particles in mineral soil. M-reddish black (10R 2/1) to black (2.5YR 2/0); H-well decomposed fibrous particles; R-abundant, thin, fibrous to woody; C-soft to loose; T-silt loam; D-freely drained horizon; S-gravel to medium pebbles, stony.
A_3	½/2 - 30/35 (poorly defined)	Unconsolidated alluvium - gritty with pebbles up to 10cm abundant. M-very dark grey (2.5YR 3/0); H-none except for root distribution; R-common, fibrous to woody, thin, decreasing with depth; C-single grain structureless, loose; T-sand; D-freely drained to at least 50cm; S-stone dominant, gravel to large stones (mainly rounded pebbles); pH 8.3.
C	30/35 - ?	As above, but without root distribution - boundary of bio-zone, larger pebbles becoming more dominant with increasing depth.

SOIL PROFILE RECORD No. 2a

1. Date 27th July 1974

2. Prevailing weather conditions

Cloudy, sunny periods. No rain for two days - river level getting steadily lower for previous week.

4. Factors influencing choice of site

This site to sample the top of the river slump slope; i.e. this site is on the crest of a lateral (recessional) moraine truncated by river action. (2b will sample a corresponding trough in a neighbouring position.)

6. Ground photography

BC8/34 - profile; BC4/35 - view of site looking west, and showing crest of lateral moraine.

7. Soil samples

2a/1 - humus layer at 5cm; 2a/2 - sand horizon at 10cm; 2a/3 - illuvial humus layer at 15cm.

Soil site characteristics

9. Locality - general See 4. - crest of lateral moraine truncated by river.

11. Altitude ~~3,850~~ 3930 ft.

13. Microtopography See 4. Crest smooth and rounded, 6m wide.

14. Parent material Soil formed on glacial material, as profile 1a.

16. Flora In forest of predominantly Engleman spruce up to 12m high, spaced at 4 to 8m, with blanket moss and lichen ground cover throughout, 4 to 10cm deep, with birch bushes and wild lupins.

18. Drainage conditions Normal site, freely drained profile.

20. Special problems encountered -

Soil profile characteristics

Horizon	Depth(cm)	Description
H	0 - 5 / 10 (undulating)	M-black (5YR 2/1) with patches of yellowish red (5YR 4/8) corresponding to decaying wood chunks; H-exclusively humus layer, partially decomposed, generally unrecognisable as to origin except for larger twigs and other wood; R-common, depending on neighbouring flora, fibrous, woody; C-friable; T-no mineral content; D-freely drained; S-none; pH 5.65.
A_2	5 / 10 - 9 / 13 (undulating)	Yellow sandy layer almost devoid of humus content. M-yellowish brown (10YR 5/6); H-very few black humus grains; R-common, predominantly thin, fibrous, some woody; C-soft to friable; T-loam; D-freely drained; S-structureless, abundant fine pores; pH 6.55.
B_2	9 / 13 (undulating) down to 20 (very gradual)	Slight humus illuvial deposition in parent material (just identifiable as a B horizon). M-olive (5Y 5/3) with black specks 1mm diameter (humus); H-granular black deposit of illuvial humus; R-few, becoming rare by 20cm depth, thin, fibrous; C-soft to loose (the many large particles break soil up when worked); T-loamy sand; D-freely drained; S-stony, mainly small stones with a few up to 20cm diameter, structureless, abundant fine pores. pH 7.75.
C	20 - at least 75	M-olive (5Y 5/3); H-none; otherwise as for B_2 except S-more large stones (25cm diameter).

SOIL PROFILE RECORD No. 2b

1. Date 28th July 1974

2. Prevailing weather conditions

Cloudy after clear, cold night. Trace of rain in last few days.

4. Factors affecting choice of site

Lateral moraine trough corresponding to 2a.

6. Ground photography

BC8/35 - profile. Also assorted b&w photography.

7. Soil samples

2b/1 - F horizon; 2b/2 - H horizon; 2b/3 - H horizon (wood samples); 2b/4 - A_2 horizon; 2b/5 - B_2 horizon; 2b/6 - C horizon.

Soil site characteristics

9. Locality - general See 4. Approximately 100m from site 2a.

11. Altitude 3,930 ft.

13. Microtopography At base of trough between lateral moraines, with crests each 100m distant and 25m higher. Generally smooth topography; profile dipping 8° to 040 True, along axis of trough. Average dip of trough axis 20°.

15. Parent material Soil formed on glacial material (lateral moraine).

16. Flora As for site 2a - no differences observed.

18. Drainage conditions Normal site, but with signs of water table at 60cm. Freely drained profile.

20. Special problems encountered -

Soil profile characteristics

Horizon	Depth(cm)	Description
F	0 - 5-7 (sharp, undulating)	M-yellow to red (2.5YR to 5YR, variable); H-humus layer, mainly dead moss, with some twigs and leaves; R-no live roots identifiable; C-soft and springy, leaves hands clean; T-fewmineral particles; D-well drained; S-slight stone 'litter', fine gravel only; pH 5.25.
H	5-7 - 12-15 (sharp, undulating)	M-reddish black (10R 2/1) with large patches (~20x5cm) of dark reddish brown (2.5YR 3/4) corresponding to decaying wood(pH 6.2); H-felty, springy and fibrous; R-common, fine to medium, mainly woody; C-friable; T-few mineral particles; S-slightly stony, fine gravel only, D-well drained.
A_2	12-15 - 17-21 (lower bound gradual, undulating)	M-gradual darkening from dark greyish brown (10YR 4/2) with increasing depth to reddish black (10R 2/1); H-almost no humus content, distribution of black humus particles (less than 1mm diameter) increasing downwards towards B horizon; R-rare, fine and fibrous; C-plastic; T-silt, very soapy between fingers; D-well drained, abundant fine pores; S-slightly stony, gravel; pH 6.65.

profile continued ...

Soil Profile Record No. 2b continued

Soil profile characteristics continued

Horizon	Depth(cm)	Description
Bh	17-21 - 28-29 (lower bound sharp, flat)	M-reddish black (10R 2/1); H-consists of well decomposed black humus particles in humus fraction, very fine (individual particles not visible); R-rare, fine and fibrous; C-more friable; T-silty clay loam; D-well drained, extremely fine pores; S-slightly stony, fine gravel only, pH 6.35.
C	28-29 - ? (upper bound sharp, flat)	M-very dark greyish brown (2.5Y 3/2) to light yellowish brown (2.5Y 6/4) in wetter, deeper parts, some gravel patches more yellow; H-none; R-few, rare, extending down to 35cm; C-slightly sticky, especially deeper; T-sand, but tending to finer particles below 60cm; D-well drained but wetter lower, abundant fine pores less than 1mm diameter; S-very stony, distribution up to 50cm diameter, mixture of rounded (water eroded) and erratic stones, pH 7.7.

SOIL PROFILE RECORD No. 3a

1. Date 12th August 1974

2. Prevailing weather conditions

Cloudy, sunny periods, unsettled.

4. Factors influencing choice of site

Profile characteristic of regular, well drained valley side site, above region dissected by ~~lateral~~ recessional moraine topography.

6. Ground photography

BC9/23 - profile

7. Soil samples

3a/1 - A_1 horizon (light region); 3a/2 - A_1 horizon (dark region); 3a/3 - A_2 horizon at 20cm; 3a/4 - parent material at 40cm.

Soil site characteristics

9. Locality - general See 4.

11. Altitude 4,370 ft.

13. Microtopography Site with average slope on this section of valley side (dip = 5°). Dip of surface at pit = 0°.

15. Parent material Glacial - as sample 3a/4.

16. Flora Engleman spruce forest, spacing of trees 3 - 6m, height to 12m. Ground cover of blanket moss, otherwise distribution of spieces as for 4a.

18. Drainage conditions Freely drained profile, normal site.

20. Special problems encountered -

continued...

Soil Profile Record No. 3a continued

Soil profile characteristics

Horizon	Depth(cm)	Description
F (O_1)	0-3 (regular)	M-red (2.5YR 4/8) to black (2.5YR 2/0), predominantly dusky red (2.5YR 2/0); H-mainly undecomposed moss.
H (O_2)	3-7 (regular)	M-reddish black (10R 2/1) to dark reddish grey (10R 3/1); H-decomposed humus, peat type; R-many roots, fine to medium, fibrous and woody; C-friable; T-silt loam; D-freely drained; S-slightly stony, gravel to small stones.
B(g?)	7 - 15	M-dark reddish brown (5Y 3/2) with horizontal strips (1x6cm) of yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/4), also black patches (of decomposed humus); H-patches of black decomposed humus; R-common, fine, fibrous; C-friable; T-silty clay loam, except strips of lighter coloured material (1x6cm) - clay; D-freely drained; S-slightly stony, few stones noticeable; pH 6.35, pH of lighter coloured materal in horizontal strips 6.05.
B_3	15 - 37	M-dark brown (10YR 3/3); H-few small particles of decomposed humus; R-rare, decreasing to zero by 35cm depth; C-plastic to friable; S-rounded, gravel to medium (up to 6cm diameter) fairly stony; pH 6.8.
C	37 - ?	M-olive brown (2.5Y 4/4); H&R-none; C-friable to loose; T-sand; D-freely drained; S-abundant, gravel to large stones (10cm. diameter maximum); pH 7.55.

SOIL PROFILE RECORD No. 4a

1. Date 11th August 1974
2. Prevailing weather conditions
   Subsequent to heavy shower, wet nights and mornings for previous week.
4. Factors influencing choice of site
   Flat, wetter strip on valley side.
6. Ground photography
   BC9/2 - profile.
7. Soil samples
   4a/1 - decomposed humus layer; 4a/2 - illuvial A horizon; 4a/3 - parent material.

continued...

Soil Profile Record No. 4a continued

Soil site characteristics

9. Locality - general See 4. Probably situated on old side moraine.
11. Altitude 4,520 ft.
13. Microtopography Almost flat for 4m along line of transect (dip = 3°) on general slope of 8°. Hummocks up to 0.5m diameter, 0.3m high.
15. Parent material Glacial material.
16. Flora Engleman spruce only to about 6m high, at about 5m intervals. Blanket moss ground cover. Also several of : dwarf huckleberry (vaccinium caespitosum), alpine buttercup (ranunculus adoneus), American bistort (polygonium bistortoides), scrub birch (betula glandulosa).
18. Drainage conditions Receiving site, heavily waterlogged.
20. Special problems encountered Water table at 35cm.

Soil profile characteristics

Horizon	Depth(cm)	Description
H (O_2)	0-8 (irregular surface - ± 5cm)	M-black (2.5YR 2/0); H-well consolidated humus fibre, peaty humus; R-common, fine, fibrous to woody; C-sticky to plastic; T-silty clay loam; D-freely drained to this depth; S-slightly stony, gravel, mainly glacial sandstone fragments littering organic material; pH 7.4.
A_1	8-21 (lower bound undulating, fairly sharp)	Transitional horizon between humus layer and parent material. M-black (2.5YR 2/0) with horizontal stripes about 2cm thick of dark grey (2.5YR 4/0), thickness and extent of stripes variable; H-humus particle mixture with mineral soil; R-few, fine, fibrous to woody, decreasing rapidly with depth; C-plastic to sticky; T-sandy clay; D-freely drained to this depth; S-slightly stony as above, but also a few large angular blocks up to 20cm diameter, structureless, single particle soil; pH 7.8.
C	21 -	M-greyish brown (2.5Y 5/2); H&R-none; C-plastic to friable; T-sandy clay; D-poorly drained, top of horizon just above water table; S-stony, rounded and angular, gravel to large stones, structureless single particle soil; pH 8.0.

SOIL PROFILE RECORD No. 5a

1. Date 11th August 1974

2. Prevailing weather conditions

4. Factors influencing choice of site

Flatter average dip than at 4a in arae of much less dense forest, with more grassy than moss ground cover.

6. Ground photography

BC8/37 & BC9/1 - profile.

7. Soil samples

5a/1 - humus layer; 5a/2 - transitional horizon; 5a/3 - parent material.

Soil site characteristics

9. Locality - general See 4. 300m field distance below tree line.

11. Altitude 4,600 ft.

13. Microtopography Generally flat, regular surface.

15. Parent material Glacial till.

16. Flora Engleman spruce much sparser than at 4a: in clumps, about 6-12m high, 20-30m spacing between clumps. Ground cover dominated by spieces of grass rather than moss. Also even distribution of the following; labrador tea (ledum groenlaridicum), mountain bluebell (wertensia ciliata), scrub birch (betula glandulosa), trailing azalea (loiseleuria procumbens), bunchberry (bomus canadensis), grouseberry (vaccinium scoparium), pyrola (wintergreen), crowberry (empetrum nigrum).

18. Drainage conditions Freely drained profile, normal site.

20. Special problems encountered -

Soil profile characteristics

Horizon	Depth(cm)	Description
F	0-1 (variable)	Unconsolidated litter. Leaves, grass, some twigs. M-grey to dark grey (2.5YR 5/1 to 2.5YR 4/1).
H	1-14	M-black (2.5YR 2/0) with areas of rotting wood yellowish red (5YR 4/8); H-decayed; R-common, fibrous, woody; C-sticky to plastic; T-silty clay loam; D-freely drained; S-none, structureless single particle soil throughout profile; pH7.2
A_1	14-20 (lower bound fairly well defined)	M-black (2.5YR 2/0) with horizontal banding of dark grey (2.5YR 4/1), 2cm wide, 20-30cm long; H-some humus particles, decomposed; R-few, generally fine, fibrous to woody; C-plastic to sticky; T-sandy clay; D-freely drained; S-none; pH 7.2.
C	20 -	M-light olive brown (2.5YR 5/4); H-none; R-few, fine, fibrous to about 40cm; C-friable, with some medium pores (much drier and lighter than 4a); T-sandy loam; D-freely drained; S-stony, gravel to large stones, angular; pH 6.8.

SOIL PROFILE RECORD No. 6a

1. Date 30th July 1974

2. Prevailing weather conditions

Warm, humid, but cloudy.

4. Factors influencing choice of site

At tree line. Highest point on traverse covered by glacial material, according to topography of moraines.

6. Ground photography

BC8/25 & BC8/26 - profile; BC8/27 - general area looking down valley, approx. west, and showing tree line.

7. Soil samples

6a/1 - 3-12cm horizon; 6a/2 - 12-17cm horizon; 6a/3 - parent material.

Soil site characteristics

9. Locality - general Tree line, less than average slope, just below base of loose scree dump from crags above.

11. Altitude 4,720 ft.

13. Microtopography Almost flat at soil site; average dip in this area towards 043True.

15. Parent material Soil formed on glacial till, but with loose buried limestone rocks above 20cm depth.

16. Flora Distribution of: bunchberry (cornus canadensis); dwarf huckleberry (vaccinium caespitosum); crowberry (empetrum nigrum); scrub birch (betula glandulosa); labrador tea (ledum groenlandium).

18. Drainage conditions Normal site; freely drained profile.

20. Special problems encountered -

Soil profile characteristics

Horizon	Depth(cm)	Description
F	0 - 4 (gradual)	M-very dusky red (2.5YR 2/2); H-well matted, fibrous, mainly moss.
H	4 - 12 (lower bound undulating)	M-reddish black (10R 2/1); H-well decomposed; R-common, fine to medium (some large), fibrous to woody, very variable; C-friable; T-loam; D-well drained; S-none; pH 5.8.
A_1	12 - 17-20 (lower bound gradual)	M-very dark grey (2.5YR 3/0); H-some well-decomposed humus particles; R-few, thin, fibrous to woody, very variable; C-plastic; T-silty clay loam; D-freely drained; S-slightly stony to none, small, angular; pH 6.1.
Bg	17-20 - 35 (gradual)	M-dark grey brown (10YR 4/2) with patches of black (10YR 2/10) to very dark greyish brown (2.5Y 4/2), patches horizontal (about 30 x 3 cm); H-illuvial dark humus particles only; R-few, thin, fibrous; C-plastic to friable; T-silty clay loam; D-freely drained, moist at present; S-few, medium, angular to subangular,
B_3 - C	35 - (gradual) (water table at about 50 cm - variable)	M-dark greyish brown (2.5YR 4/2), several mottles (1x4cm) down to 40cm of dark reddish brown (2.5 YR 2/4); H-none; R-none (but an undefined possible C_1 horizon contains few fine fibrous roots down to 40cm depth); C-structureless, single grain, sticky, very wet below 50cm; T-silt loam; D-very wet, poorly drained below this level; S-very stony, gravel to large stones, angular to rounded, some large angular (scree), rest rounded (glacial); pH6.4.

SOIL PROFILE RECORD No. 7a

1. Date 10th August 1974

2. Prevailing weather conditions

For last week rain during night and morning with generally cloud and sunny periods during afternoon and evening.

4. Factors influencing choice of site

Sample of young soil developing on the boulder scree above the tree line. Dominant rock size ranged from 0.1m diameter at 4,850ft to 3m diameter at the tree line, and was accompanied by a decrease in soil maturity.

6. Ground photography

BC8/28 & BC8/29 - profile.

7. Soil samples

7a/1 - eluviated mineral material from rock pockets.

Soil site characteristics

9. Locality - general See 4. 200m field distance above tree line.

11. Altitude 4,800 ft.

13. Microtopography Average dip 15° but profile area consisting of loose rocks averaging ½m diameter.

15. Parent material Dolomite (scree) above consolidated bedrock of same (depth unknown for scree).

16. Flora Many young alpine fir (abies lasciocarpa) (up to 1½m high, spaced at intervals of about 2m). Large interspersed patches of scrub birch (betula glandulosa) with the fir giving way to scrub birch by 4.900 ft altitude). Also some crowberry (empetrum nigrum) and thimbleberry (rubus parviflorus).

18. Drainage conditions Freely drained profile, shedding site.

20. Special problems encountered The large scree with its large open cavitied made the constructing of a representative profile difficult.

Soil profile characteristics

Horizon	Depth(cm)	Description
F	0 - 8 (variable depth, highly irregular)	M-very dusky red (10R 2/2); H-bedded moss; R-common, fibrous, woody, thin to medium; C-friable to loose, fairly dry; T-fibrous to silt loam; D-freely drained; S-common, angular, but generally not consolidated with moss.
H		Irregular pockets between F and A horizons according to distribution of rocks.
A Highly eluviated rock particles and silt (no deeper horizons could be identified owing to nature of scree.)		Lying in low pockets between rocks below about 10cm, variable. M-reddish grey (10R 5/1) to weak red (2.5YR 5/2) with humus patches to black; H-some humus patches present, fibrous, apparently illuviated from F horizon; R-none in most of horizon, very few roots reaching to this depth; C-friable to sticky, loose, many small pores, also holes up to 30cm diameter between rocks, bound by root fibres near rock boundaries; T-silt loam; D-freely drained; S-rock fragments, angular to shaly, up to 5mm, large scree rocks as above; pH 4.1.

SOIL PROFILE RECORD No. 8a

1. Date 12th August 1974

2. Prevailing weather conditions

Dry, cloudless, some rain during previous day, rain showers and sunny periods for preceding week.

4. Factors influencing choice of site

At base of crag at top of traverse. With site 8b, the highest soil sampled.

6. Ground photography

BC9/22 - profile; BC9/12 - general view of site looking approx. N across valley.

7. Soil samples

8a/1 - H horizon; 8a/2 - transitional;horizon; 8a/3 - parent material.

Soil site characteristics

9. Locality - general See 4. This site near the snout of an outcrop of the crag, being on more consolidated material than site 8b, situated at crag inlet, in which was a 'delta' of fine recentlt fallen material.

11. Altitude 5,170 ft.

13. Microtopography Dip 40°, 1m from base of bare crag.

15. Parent material Loose scree from crag above.

16. Flora In an early stage of development on this soil. Some bare mineral material, with distribution of: arctic raspberry (rubus arcticus); trailing azalea (loisileuria procumbens); crowberry (empetrum nigrum); mountain avens (dryas drummondii); gentian (gentiana acuta); alpine buttercup (ranunculus adorneus); death camas (zigadenus elegans); tansy (tanacetum vulgare); milk vetch (astragalus agrestis); mountain bluebell (wertensia ciliata); moss campion (silene acaulis); dwarf mountain fleabane (erigeron compositus).

18. Drainage conditions

Freely drained profile, shedding site.

20. Special problems encountered. -

Soil profile characteristics

Horizon	Depth(cm)	Description
H	0 - 5-10 (variable)	M-dark red (2.5YR 3/6) to very dusky red (2.5YR 2/2); H-fibrous; R-common, fibrous, thin; C-friable; T-loam, fibrous, coherent; D-freely drained; S-common, angular, stony, up to 10cm diameter; pH 5.5.
A_1 - C	5-10 - 27 (upper bound variable - lower bound gradual but even)	M-very dusky red (2.5YR 2/2) to black (2.5YR 2/0);H-none; R-common, thin, fibrous; C-plastic to sticky; T-sandy clay loam; D-freely drained, few pores, rather more moist than other horizons; S-slightly stony, mainly gravel (between particles of sandy clay loam, root fibre consolidated soil; pH 5.7.
C	27 - (gradual but even)	As for above horizon e cept: M-very dark grey (7.5 YR 3/0);R-none; C-loose, slightly sticky below 33cm depth; T-sand; S-stone dominant, gravel to stony; pH 5.9.

SOIL PROFILE RECORD No. 8b

1. Date 12th August 1974

2. Prevailing weather conditions

Dry, cloudless, some rain during previous day, rain showers and sunny periods for preceding week.

4. Factors influencing choice of site

For comparison with 8a; similar site but at the base of crag gulley rather than outcrop, consequently on young fan of fine mineral material from above (see 8a).

6. Ground photography

BC9/21 - profile.

7. Soil samples

8b/1 - biologically active horizon; 8b/2 - parent material.

Soil site characteristics

9. Locality - general As for 8a, except as explained in 4 above.

11. Altitude 5,190 ft.

13. Microtopography Dip 40°, 5m from base of crag, about 25ft field distancefrom site 8a.

15. Parent material Loose scree from crag above.

16. Flora Fine loose scree only sparsely covered by a distribution of the following: gentian (gentiana spieces); death camas (zigadenus elegans); tansy (tanacetum vulgare); milk vetch (astragalus agrestis); mountain bluebell (wertensia ciliata); moss campion (silene acaulis); white dryas (dryas hookeriana); scrub birch (betula glandulosa) (less than ½m in size); northern bedstraw (galium boreali); barren strawberry (waldstunia edohaensis); parrot's beak (pedicuoaris bractiosa); columbine (aquiligia formosa); grouseberry (vaccinium scoparium); red heather (phyllodoa empetriforinis).

18. Drainage conditions Freely drained profile, shedding site.

20. Special problems encountered -

Soil profile characteristics

Horizon	Depth(cm)	Description
A	0 - 33 (lower bound gradual)	Biologically active horizon - no soil formation above this horizon, or any identifiable humus horizons; M-grey (7.5YR 6/0) in dry region (above 5cm), very dark grey (7.5YR 5/0) below this depth; H-none; R-abundant, thin, fibrous, decreasing to common by 20cm depth, and to none at 33cm; C-loose in top 3cm (dry) to friable below this depth; T-sand, single particle structureless; D-freely drained horizon, excessively drained above about 5cm depth; S-stone dominant, angular to subangular, gravel to large stones (up to about 20cm diameter) with stone outcrops (loose scree litter) up to 1m in diameter (sparse); pH 5.95.
C	33 - (gradual)	As above, but with upper limit on stone size 10cm diameter, and: C-slightly sticky below 33cm; T-tending to silty cleyey sand below this depth; pH 5.95.

Bedrock not reached at 50cm - estimated vertical depth to consolidated bedrock 2-3m.

References

1. VALENTINE K.W.G. Soils of the Fort Nelson Area of British Columbia. Report No. 12 of the British Columbia Soil Survey, Research Branch, Canada Department of Agriculture (1971).

2. KERR D. and KENDREW Climate of British Columbia and the Yukon, Ottawa (1955).

3. McLEARN F.H. and KINDLE E.D. Geology of Northeastern British Columbia, Geological Survey of Canada Memoir 259 (1950).

4. TAYLOR C.G. and STOTT D.F. Tuchodi Lakes Map Area, British Columbia. Geological Survey of Canada Memoir 373, Department of Energy, Mines and Resources, Ottawa.(1973).

5. PREST V.K., GRANT D.R. and RAMPTON V.N. Glacial Map of Canada. Map 1253A, Geological Survey of Canada, Department of Energy, Mines and Resources, Ottawa (1968).

6. Munsell Soil Colour Chart.

7. Soil Survey of Great Britain, Field Handbook. Soil Survey Staff, Rothhampstead Experimental Station, Harpenden (1960).

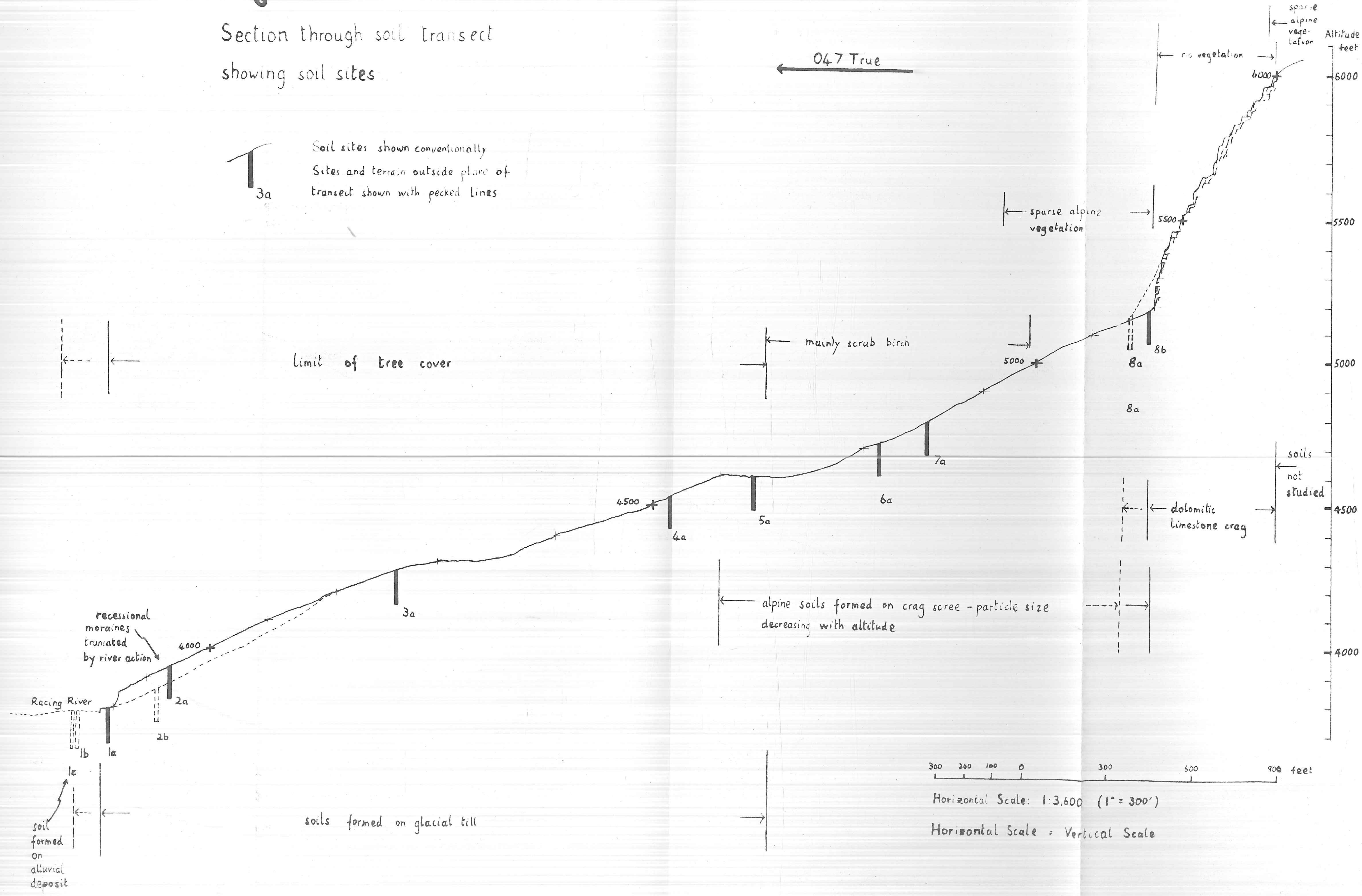
8. Soil Morphology and Profile Description. Department of Soil Science, School of Agriculture, University of Newcastle-upon-Tyne (unpublished).

9. BRETTELL P.D. and WITHERS G.D. Hydrometeorology Report of this Expedition (preceding report).

10. LORD T.M. and LUCKHURST A.J. Alpine Soils and Plant Communities of a Stone Sheep Habitat in Northeastern British Columbia. Northwest Science Vol. 48 pp. 38-51 (1974).

Figure 2

Section through soil transect showing soil sites



FRESHWATER BIOLOGY PROJECT

by Terry Jack

and

BOTANY PROJECT

by Stella Whateley

The main aim of this project was to make a general survey of stream fauna, and if time allowed to do further work, such as looking at the effects of altitude, the effect of water speed, and so on. In the prospectus it was stated that no definite plans for this further work could be given until the area had been visited.

Observations of maps before departure showed that our base camp would probably be sited at an altitude of about 3,900 feet, in a north-west - south-east valley. There were streams flowing from glaciers to the main river indicating that a stream study could be made.

Investigation of the literature before departure revealed very little. No references to work of this natere in this area of Canada could be found, although there were papers looking at feeding in aquatic invertebrates and various distributional studies in other parts of Canada.

Invaluable advice and information on available keys for flora and fauna was received from Professor G.E.G. Scudder at the University of British Columbia, Vancouver, Dr. Mc Lachlan of the Zoology Department, University of Newcastle-upon-Tyne, and Dr. Richards of the Plant Biology Department there.

Method

As can be seen from the map (Figure 1) the stream studied met the main river close to the base camp. It was of moderate size, shallow and fast flowing. Its width ranged from two to fifteen feet, approximately, although in a number of regions it was extensively braided. It had ots source at the snout of a small glacier (approximate altitude 4,900 feet) and flowed down the corrie for a mile and a half, before reaching Racing River.

Sampling stations were set up along the level of the stream at roughly 100ft. intervals. This was done crudely using a clinometer. The stations were the same for both the botany and zoology project, except at the head of the corrie where different sites were used. This area was studied at different times and the markers were lost in the intervening time. An accurate map was later made by Mr. P.G. Rogers (Figure 1).

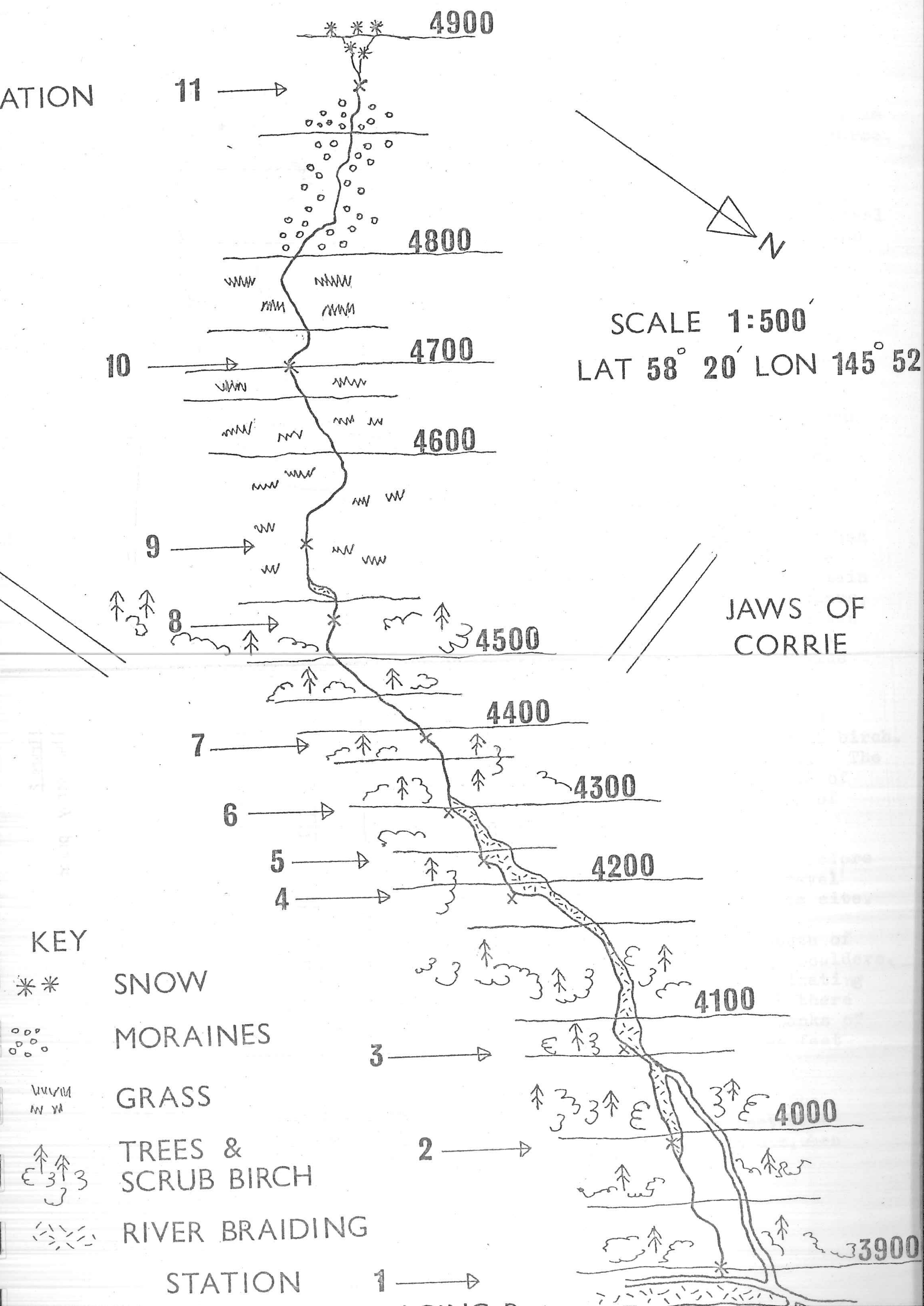
Botany Project

At each sampling site a line transect was taken at right angles to the stream, and on both sides. A stick marked in ten intervals, 4cm apart was moved along the transect line. The plants at each point were identified and the percentage occurance at that site calculated. This gave the approximate distribution of plants at each site (Figure 2).

Zoology Project

Kick sampling was initially used as the collecting technique, however it was found to be almost completely fruitless. No animals were collected in this way. The method adopted was to mark off a half metre square on the stream bed. A net was held downstream, and a single layer of stones from within the layer removed to a collecting tray. These were individually checked. The number of animals attached to the stone was counted, a subjective assessment of colour was made, and the mass of the stone was measured. This was done by displacement of water - this was collected in a rain gauge and hence a measurement obtained. A count of numbers of animals caught in the net was also made.

FIG.I SAMPLING STATIONS



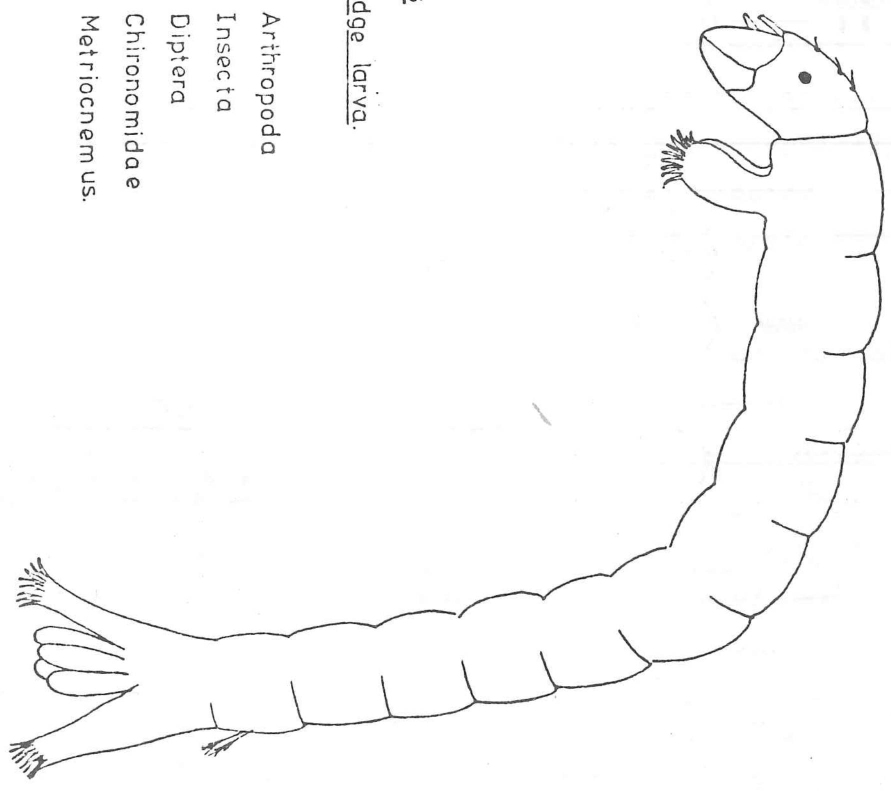


Figure 3
The midge larva.

Phyla: Arthropoda
Class: Insecta
Order: Diptera
Family: Chironomidae
Genus: Metriocnemus.

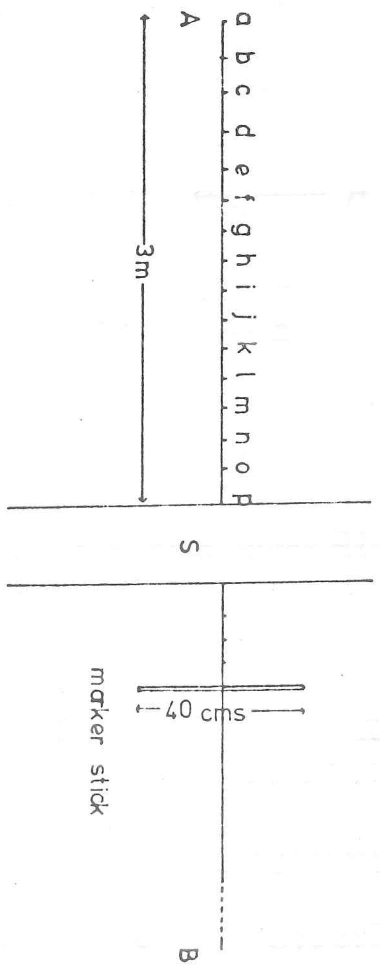


Figure 2
The botany project

distance ab,cd etc = 20 cms.

At each 20cm interval a stick [40cms] was placed across the main line. Plants were identified along the stick at 4cm intervals.

Sampling Site Descriptions

Site 1 Almost flat, level with main valley floor, well drained. A thin humus layer overlaying a sandy-gravelly base. Stream substrate gravel and small stones. Vegetation fairly sparse, a few shrubs growing beteeen Engelmann spruce.

Site 2 A well sheltered, gently sloping site, with good drainage. Humus layer thicker than in Site 1. Stream substrate gravel and small stones. Fairly heavily vegetated with Engelmann spruce and shrubs such as silverberry, scrub birch and soopolallii.

Site 3 A steeper site positioned at the braiding of the river. Drainage was poor, and the layer of humus was very thick. The vegetation was rather stunted being mainly Engelmann spruce and scrub birch.

Site 4 A fairly exposed site on flat ground, where there had been much braiding of the stream. This ground was obviously prone to flooding, and had only a very thin humus layer. No trees were found on the flat area, but their number dramatically increased as the ground rose.

Site 5 This site was different from all other sites in that it had a high organic content in the water. A few yards above the sampling site a small run-off stream joined to the main stream. This passed through the thick moss-covered humus, and was quite brown. Stones on the stream bed were often covered with a film of shine. The site was flay with a heavy moss vegetation on one side and gravel flood plains on the other.

Site 7 The stream at this site was not braided. One bank had little vegetation except for Engelmann spruce and scrub birch. The other bank had a greater variety of plant species. The land sloped steeply, and at this site the maximum rate of water flow was recorded. The substrate was composed of large boulders.

Site 6 Site once again where the stream braided, and was therefore bounded on both sides by almost completely barren gravel and small stones. No plants were recorded from this site.

Site 8 The ground was still rising sharply, towards the mouth of the corrie, the stream substrate being mainly large boulders. The site was just above the tree line, thus the dominating vegetation was densely packed scrub birch, although there was an increasing number of alpine flowers. The banks of the stream were poorly drained and boggy, about ten feet from the stream the ground rose sharply.

Site 9 This site was placed at the mouth of the corrie. The ground was flat, and the stream now about ten feet wide flowed smoothly over the gravel substrate. Shrubs, when present, were small and stunted.

Site 10 As one moved up the stream towards the glacier two waterfalls of about 20ft. were passed. Site 10 was situated between these two waterfalls in a gorge. The stream at this point flowed quite rapidly over stones. The banks of the stream were quite steep and well covered with vegetation, although there were no shrubs present.

Site 11 This site was situated at the snout of the glacier. There was no vegetation present, on the stony moraine and in fact no animals were recorded at this site.

Results

The stream was found to be fast-flowing with a temperature ranging from 4.0°C at the snout of the glacier to 4.8°C at the point where it joined the main river. The height of the banks above the stream varied between a few inches and fifteen feet in some parts of the gorge.

There were very few species of animals present in the steram. The most common one by far was the midge larva Chironomidae, Metriocnemus (Figure 3). They were found in large numbers at every sampling site.

Animals found in the stream

True flies:	Dipteran larvae	: form:	Chironomidae
		genus	Metriocnemus
		: form:	Simulidae
		: form:	Cyclorhapha (two different forms)
Stone flies:	Plecopteran larvae		
Mayflies:	Ephemeropteran larvae		Polymitarcys
Caddis flies:	Tricopteran larvae		Odontoceridae

The identification of the animals collected was taken as far as the keys[1,2] allowed, but North American insect larval forms are not sufficiently known to allow the construction of comprehensive keys.

A far greater number of plant species was found, some showing an occurance throughout the whole altitude range - others being more or less restricted.

Plant Species found

Moss spp.
Dryas hookeriana
Dryas drumondii
Vaccinium caespitosum
Vaccinium scoparium
Ledum groenlandicum

continued over

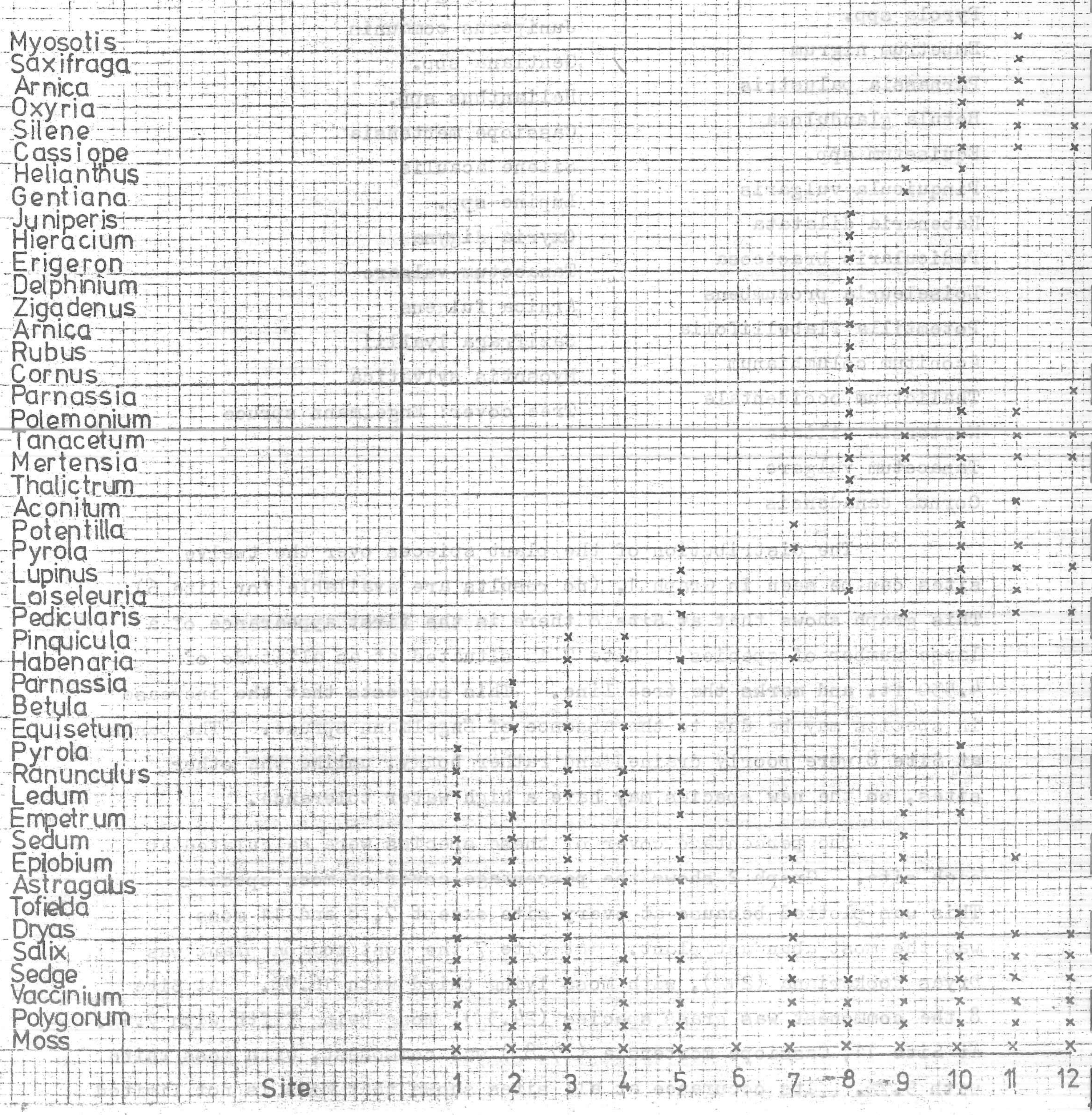
Ranunculus adoneus
Astragalus agrestris
Grass spp.
Salix nivalis
Sedum stonepetalum
Polygonum bistortoides
Tofielda palustris
Epilobium angustifolium
Pyrola spp.
Empetrum nigrum
Parnassia palustris
Betula glandulosa
Equisetum spp.
Pinquicula vulgaris
Habenaria dilatata
Pedicularis bracteosa
Loiseleuria procumbens
Potemtilla flabellifolia
Aconitum columbianum
Thalictrum occidentale
Mertensia ciliata
Tanacetum vulgare
Cornus canadensis
Rubus arcticus
Polemonium humile
Parnassia fimbriata
Parnassia palustris
Zigadenus venenosus
Delphinium menziesii
Erigeron aureus
Hieracium glacile
Juniperus communis
Gentiana spp.
Helianthus spp.
Cassiope mertensia
Silene acaulis
Lupine spp.
Oxyria digyna
Tanacetum vulgare
Arnica fulgens
Saxifraga lyallii
Myosotis sylvatica
Tree cover: Engelmann spruce

The distribution of the plant spieces over the twelve sites can be seen in Graph 1, (no results are available for Site 6). This graph shows that at Site 8 there is the first appearance of a large number of species. Site 7 is situated at an altitude of 4.530 ft. and marks the tree line. This suggests that the increase in species may be due to the absence of Engelmann spruce. The banks at Site 8 were poorly drained and rather boggy, unlike the other sites, so the new species may have a high water tolerance.

The percentage cover of these species were calculated at each site. Graph 2 shows the percentage cover of moss species This was plotted because at every site except 7, 8 and 11 moss was the most abundant plant. At Site 7 the most common plant was Dryas hookeriana (24%), with moss lying third with 16.9%. At Site 8 the commonest was grass species (24.3%), moss being fifth with 7.1%. At Site 11, Cassiope mertensia (27.8%) was commonest, with moss third with 9.7%. Its occurance at all sites shows that moss is not limited

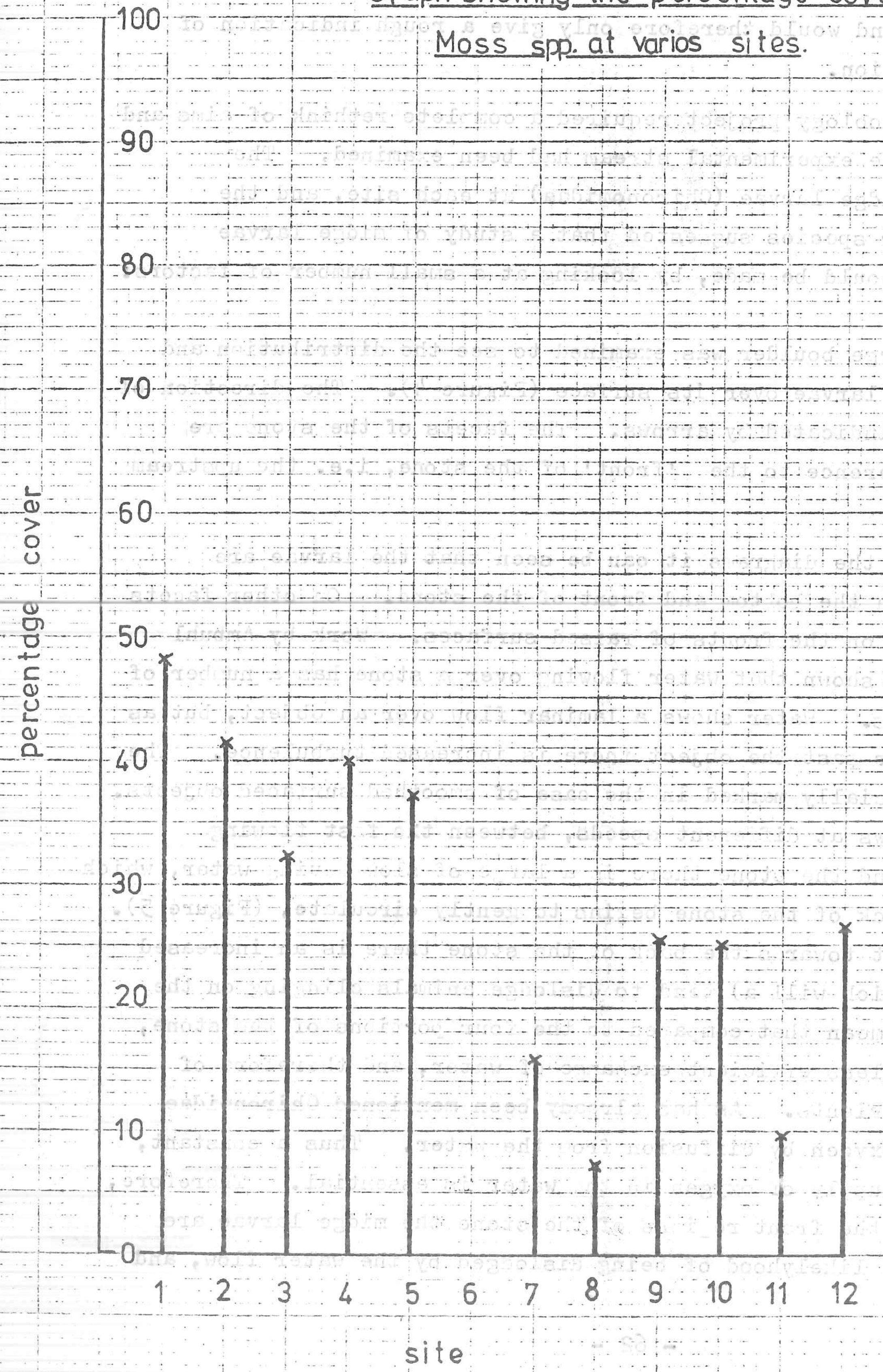
Graph 1

Diagram showing the occurrence of plants at different sites.



Graph 2

Graph showing the percentage cover of Moss spp. at varios sites.



by altitude effects, until about 4,825 feet, where all vegetation was absent. However, some plants show a restricted distribution either keeping to lower altitudes, such as Ranunculus, Ledum, Equisetum, Betula, Habenaria, Pinquiculae; or higher altitudes, such as those plants making their first appearance at the higher sites. It must be remembered that the sampling method used was rather crude, and would therefore only give a rough indication of plant distribution.

The zoology project required a complete rethink of aims and methods once the experimental stream had been examined. The abundance of midge larvae (Chironomidaa) at each site, and the dearth of other species suggested that a study of midge larvae distribution should be made, by looking at a small number of factors:

A large boulder was examined to see the distribution and orientation of larvae over its surface (Figure 4). The direction of water flow is indicated by arrows. The facets of the stone are named with reference to the 'front' of the stone, i.e. the upstream face.

From the diagrams it can be seen that the lafvae are concentrated on the bottom and front of the stone. On other facets they are found on the fronts of raised surfaces. Work by Ambuhl and others has shown that water flowing over a stone has a number of characteristics. Water shows a laminar flow over an object, but as it gets further past the object there is increased turbulence. The effect is especially marked in the case of smoothed surfaced objects. Also water flows at different speeds, between the fast flowing stream water and the stone there is a large of slow moving water, which towards the back of the stone begins to gently circulate, (Figure 5). This means that towards the back of the stone there is an increased turbulence, which will a) tend to dislodge animals clinging on the stone, and b) mean that compared to the four portions of the stone, there will be less efficient exchange of water, and therefore of oxygen and nutrients. As has already been mentioned Chironmidae obtain their oxygen by diffusion from the water. Thus a constant, and adequate supply of oxygen in the water is essential. Therefore, by keeping to the front regions of the stone the midge larvae are minimising the likelyhood of being dislodged by the water flow, and

The distribution and orientation of *midge* larvae on a stone.

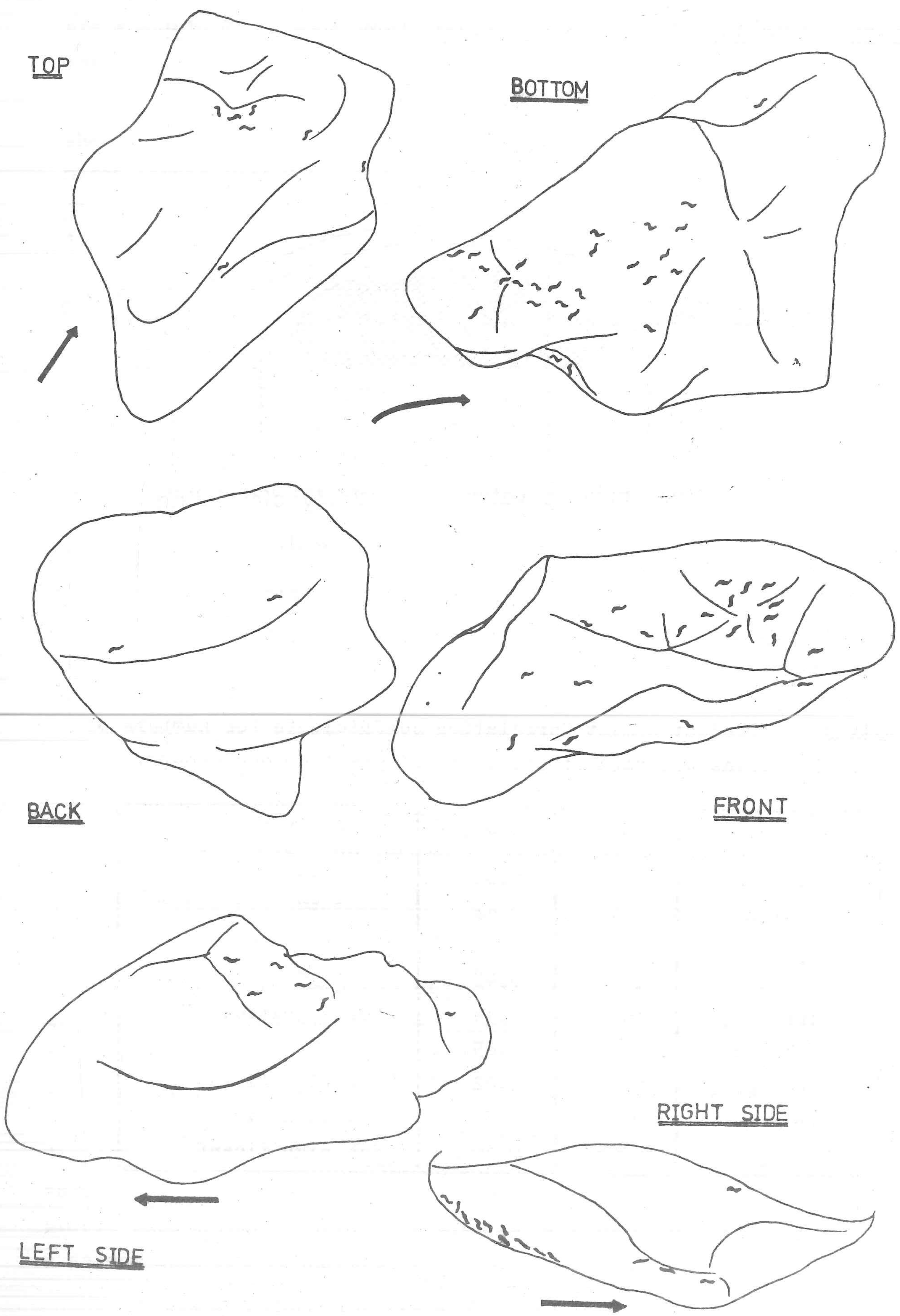


Figure 5

Diagram showing the nature of water flow over a stone.

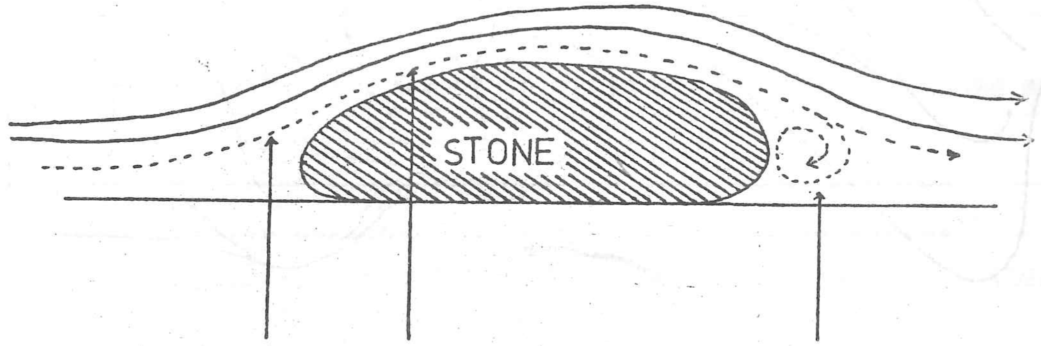


Table 1 Product Moment Correlation coefficients for numbers of midge larvae and mass of stone in different colour groups.

Colour	Abbr.	R value	Probability level
White	W	0.69	1%
Grey-white	GrW	0.42	1%
Cream	Cr	0.19	Not significant
Yellow	Y	0.48	5%
Pink-grey	PGr	0.14	Not significant
Yellow-grey	YGr	0.65	5%
Green-grey	GGr	0.22	Not significant
Brown	B	0.39	Not significant
Dark grey	DkGr	0.10	Not significant

are ensuring a good supply of oxygen and particulate organic matter as food.

Having looked at the distribution of larvae on one stone, what other factors are important? Graph 3 shows the number of midge larvae from Sites 2 to 11, (results for Site 1 are not available). It can be seen that there is a curiously regular pattern of peaks and depressions. Why this has occured is unclear, as there appear to be no common factors between Sites 5, 8 and 10 and Sites 3, 6 and 9. - The sites at which maximum and minimum peaks were recorded.

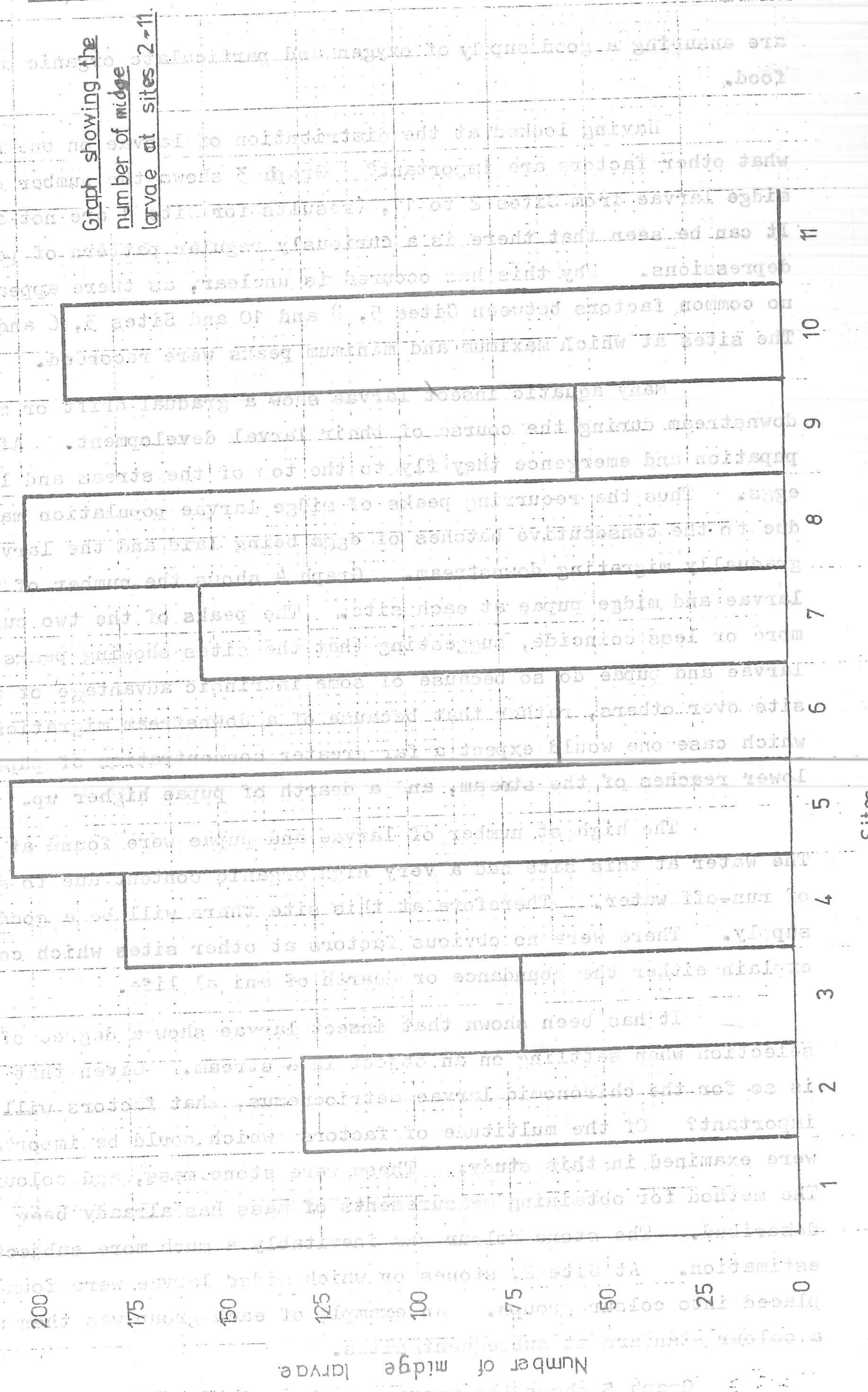
Many aquatic insect larvae show a gradual drift or migration downstream during the course of their larval development. After pupation and emergence they fly to the top of the stream and lay eggs. Thus the recurring peaks of midge larvae population may be due to the consecutive batches of eggs being laid and the larvae gradually migrating downstream. Graph 4 shows the number of midge larvae and midge pupae at each site. The peaks of the two curves more or less coincide, suggesting that the sites showing peaks of larvae and pupae do so because of some intrinsic advantage of that site over others, rather that because of a downstream migration, in which case one would expect a far greater concentration of pupae in the lower reaches of the stream, and a dearth of pupae higher up.

The highest number of larvae and pupae were found at Site 5. The water at this site had a very high organic content due to an inflow of run-off water. Therefore at this site there will be a good food supply. There were no obvious factors at other sites which could explain either the abundance or dearth of ani al life.

It has been shown that insect larvae show a degree of selection when settling on an object in a stream. Given that this is so for the chironomid larvae Metriocnemus, what factors will be important? Of the multitude of factors which could be important, two were examined in this study. These were stone mass, and colour. The method for obtaining measurements of mass has alraady been described. The stone colour was inevitably a much more subjectine estimation. At Site 2, stones on which midge larvae were found were placed into colour groups. An example of each group was then used as a colour standard at subsequent sites.

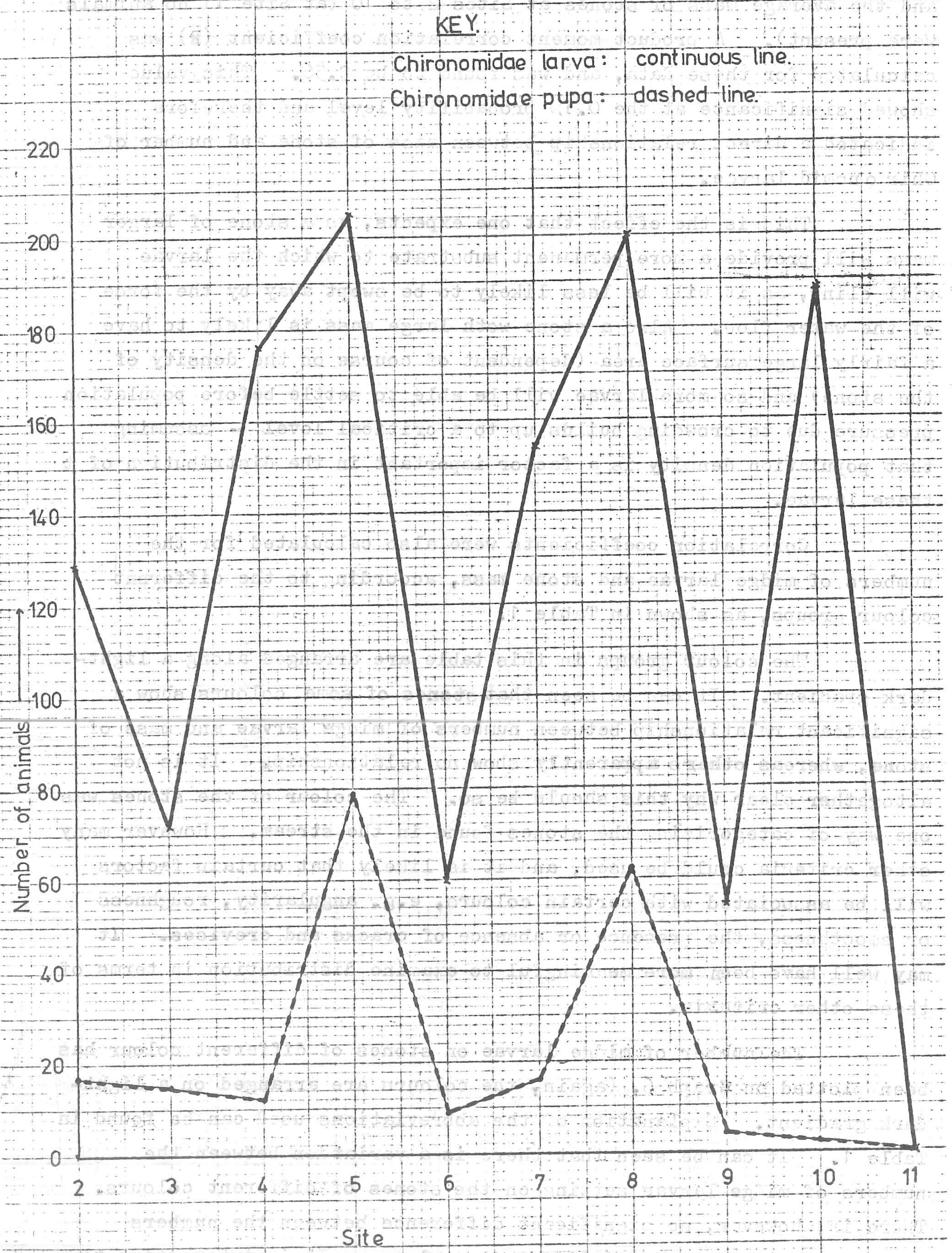
Graph 5 shows the average number of midge larvae per stone,

Graph 3



Graph 4

Graph showing the number of midge larvae and midge pupae at different sites.



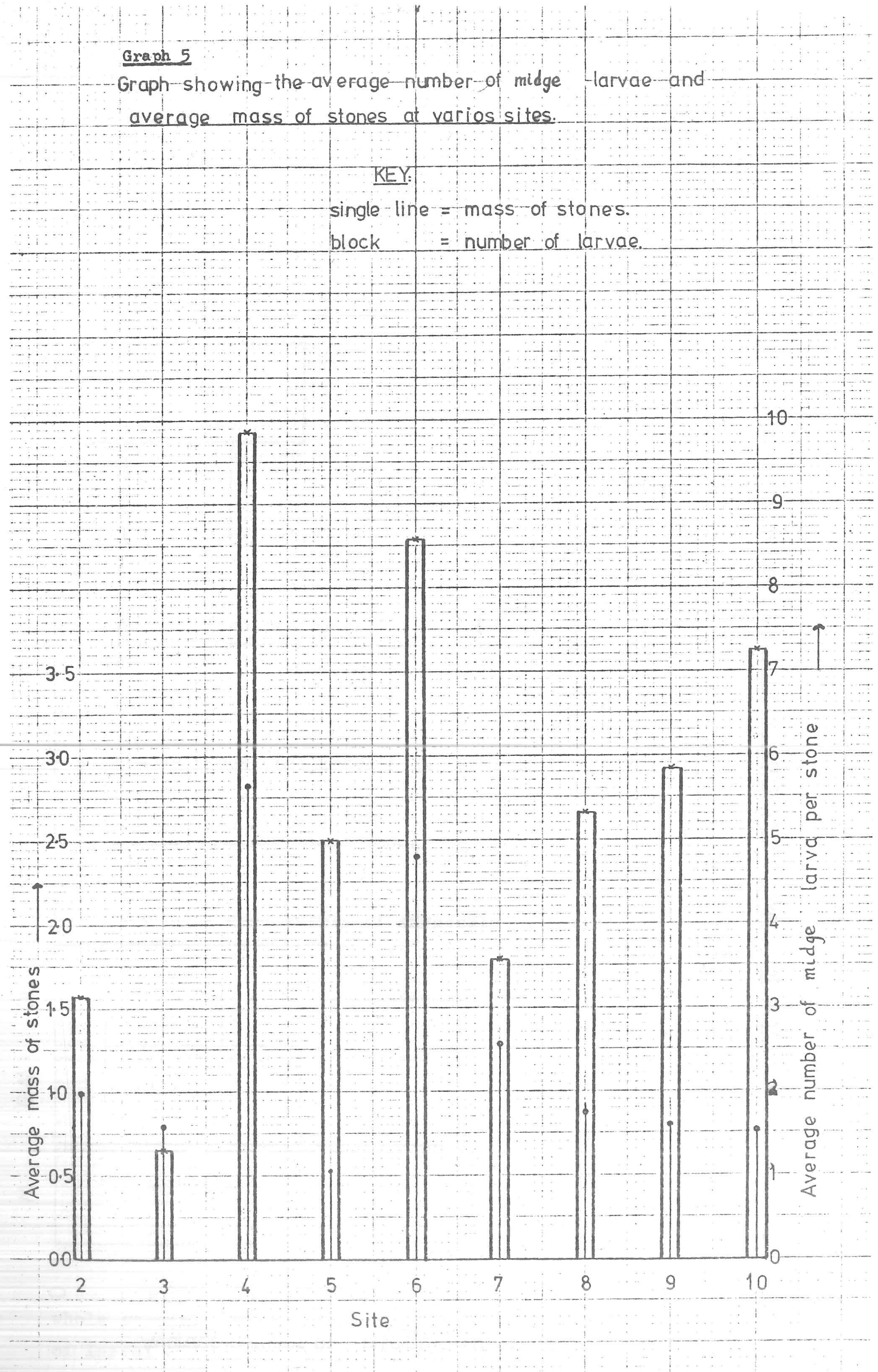
and the average mass of stones at Sites 2 to 10 (at Site 11 no animals were present). A product moment correlation coefficient (R) was calculated for these data, and was found to be 0.56. This value showed significance at the 0.1% probability level and therefore indicated a direct relationship between mass of stone and number of Chironomid larvae.

This is the effect that one expects, as a stone of larger mass will provide a more permanent substrate to which the larvae will cling, as it will be less likely to be swept away by the force of the water flow. Also a stone woth large mass is likely to have a fairly large surface area (dependent of course on the density of the stone) and so more larvae will be able to settle before population pressure due to crowding builds up to a critical level - assuming that population density is a factor important in the distribution of t these larvae.

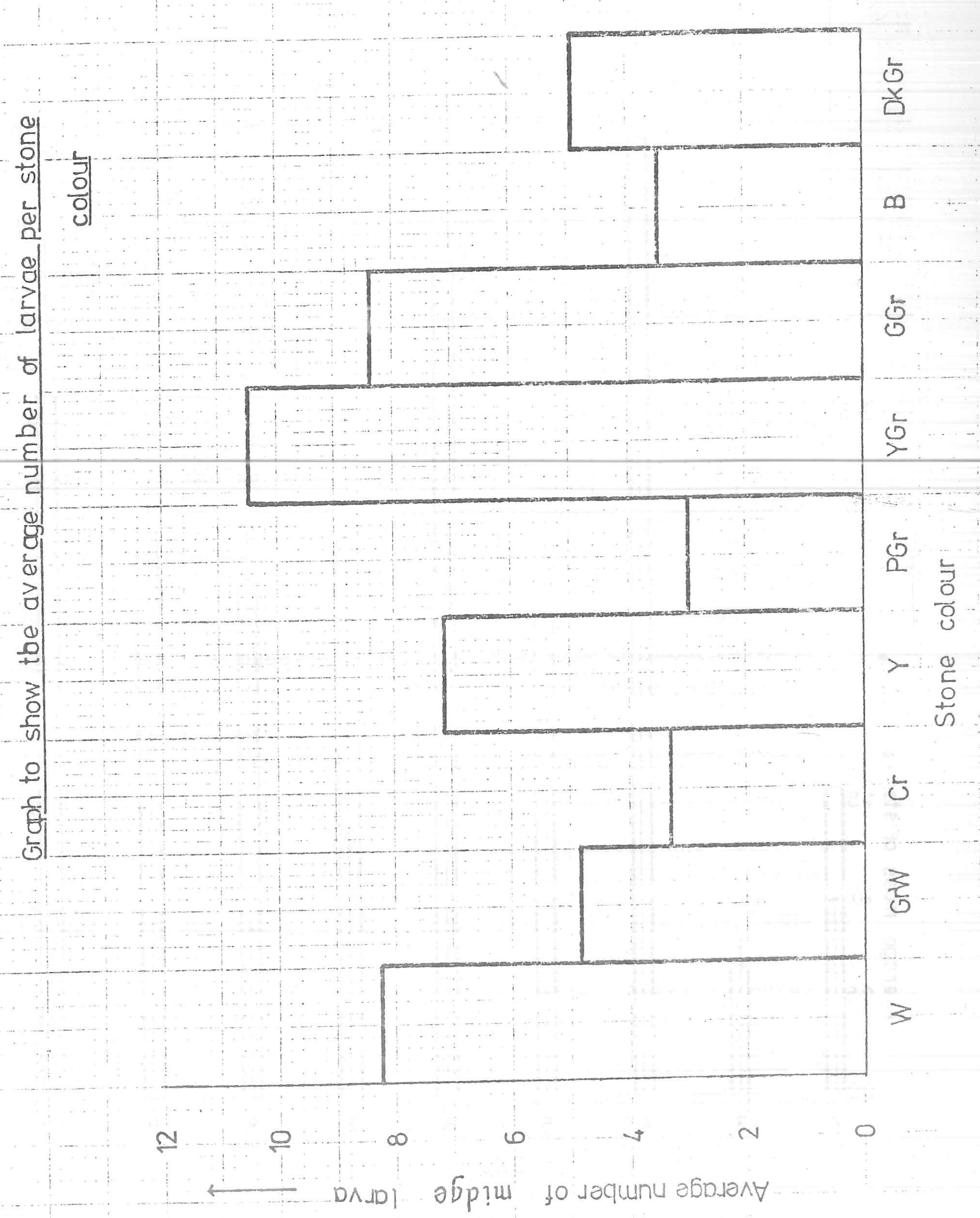
Correlation coefficients were also calculated for the numbers of midge larvae and stone mass, according to the differnnt colour groups, as shown in Table 1.

The colour groups in this table are arranged along a light-dark gradient. It can be seen that stones of some colours show a significant relationship between numbers of midge larvae and mass of stone, whereas others apparently show no relationship. It is not altogether clear why this should be so. The colour of the stones was one way of categorizing the stones found in the stream. However many other criteria could be used, and it is likely that certain factors will be associated with certain colours, e.g. angularity, roughness or smoothness, the presence or absence of cracks and crevices. It may well have been more meaningful to examine distribution in terms of these other criteria.

The number of midge larvae on stones of different colour has been plotted on Graph 6, (again, the colours are arranged on a light-dark gradient. Explanation of the abbreviations used can be found in Table 1. It can be seen that there is a variation between the numbers of midge larvae setting on the stones of different colours. There is, however, no significant difference between the numbers of larvae on the stones of different colour. It is interesting to note that stone colours which have a high average number of Chironomid larvae, are also those coloured stones which show a significant



Graph 6



correlation between stone size and number of larvae (see Table 1). That is, white, grey-white, yellow-grey and yellow. The major exception to this are the green-grey stones which have a high average larval count, but which do not show a significant correlation. However, stones in this colour group occurred relatively infrequently, thus a larger sample of stones may give a significant correlation, or alternatively a lower average larvae count.

Conclusion and Discussion

The study of the flora and fauna has shown a number of points perhaps the most obvious being the large variety of plant species and the very small variety of animal species.

The distribution of plants was examined and it was suggested that the first appearance of a large number of plant species at Site 8 may be due in part to the boggy nature of the ground at this site, or to the absence of tree cover. There appeared to be a tendency for some plants to be restricted to higher or lower altitudes, although whether this is a real effect or not is unclear because of the crude sampling method used.

A study was made of the distribution of midge larvae. On a micro-distributional level individual stones were examined, and it was found that larvae were concentrated om the front and bottom of srones. It was suggested that the reason for this is that in these areas there is a slow moving water without turbulence. These areas would be favoured because there would be less likelyhood of dislodgement, yet ensuring a good supply of oxygenated water and organic food material.

On the next distributional level some factors involved in the 'selection' of stones for setting by larvae were considered. It was shown that larvae settle in greater numbers on stones with a larger mass. Also, larger numbers of larvae were found on white, grey-white, yellow, yellow-grey and green-grey stones. These colour groups, with the exception of green-grey stones, show a positive and significant correlation between numbers of larvae and stone mass. However, whether these effects are due to the colour of the stones or, as is perhaps more likely, to some associated characteristic is not known.

Finally, there is the macrodistributional level, that of the whole stream. There was an interesting and almost regular pattern of larval and pupal distribution along the stream. Numbers of larvae showed a distinct trimodal curve, with peaks at Sites 5, 8 and 10. Pupal numbers showed a bimodal distribution, peaking at Sites 5 and 8. No logicl, explanation can be put forward to explain this pattern, although the high organic content of the water at Site 5 may be in part responsible for the faunal peak recorded there.

Before commencing this project warnings were given as to the complexity and inherent difficulties of carrying out and in particular interpreting freshwater invertebrate studies of this nature. With hind sight it is easy to agree with these sentiments. But, given the crude improvised sampling techniques and the lack of time which dogged the whole expedition, a number of interesting observations have come out of this study - a study which can only be described as preliminary. As a preliminary study it has performed its function well; it has illuminated a number of tantalising questions, which could well be studied and ultimately perhaps explained and interpreted.

References

Ward H.B. and Whipple G.C. - Freshwater Biology, Ed. W.T. Edmondson 2nd edition J. Wiley & Sons Inc. New York, (1959).

Hickin N.E. - Caddis larvae, Hutchinson & Co Ltd. London (1967).

Lyons C.P. - Trees, Shrubs and Flowers in British Columbia, Dent & Sons, Toronto & Vancouver (1965).

Mundie J,H, - Sampling Benthos and substrate materials down to microns in size in shallow streams. Journal of the Fisheries Board of Canada Vol. 28 No.6 pp 849-860.

Monakov. - Review of feeding in aquatic inverebrates. Journal of the Fisheries Research Board of Canada, Vol. 29 pp 363-383.

CLIMBING REPORT

One of the principal attractions of visiting northern British Columbia was the exciting prospect of being able to make the first ascent of a mountain. Although the number of unclimbed peaks is rapidly diminishing, we were fortunate in having many peaks to choose from due to the remoteness of the area.

The heights of the mountains vary from 7,000 to 9,500 feet, with a summer snowline at around 5,000 feet. There are many extensive snowfields in the area and summer snow conditions are usually soft. The rock is predominantly a young sandstone which shatters easily under the widely varying temperatures. The cumulative effect of these conditions has deterred many of the more energetic climbers in the past. The two main peaks in the area, Mount Churchill and Mount Roosevelt (both 9,600 feet), are the highest mountains in the north Canadian Rockies. The mountain scenery proved much better than we had expected, offering challenging routes on both rock and snow.

Three previous climbing expeditions have visited the surrounding mountains (see map), two with the aid of existing log cabins, helicopters and air supply drops. We attacked these mountains without such aids, and had the rewarding and exhausting experience of transporting 1,000 lb. of freight on our backs and getting fit in the process.

Unfortunately we encountered the worst summer weather for many years, including twenty-five days out of thirty-two on which rainfall was recorded. This necessitated a reduction in the time available for climbing, and so two four day climbing trips were arranged from base camp. Each climbing group consisted of four members, with Pete Brettell and Terry going on both trips to provide the necessary skill and experience for a successful and safe trip.

This left two members at the base camp to continue collecting data for the scientific projects and to provide assistance in the event of a climbing accident. The nearest rescue facilities were 150 miles away.

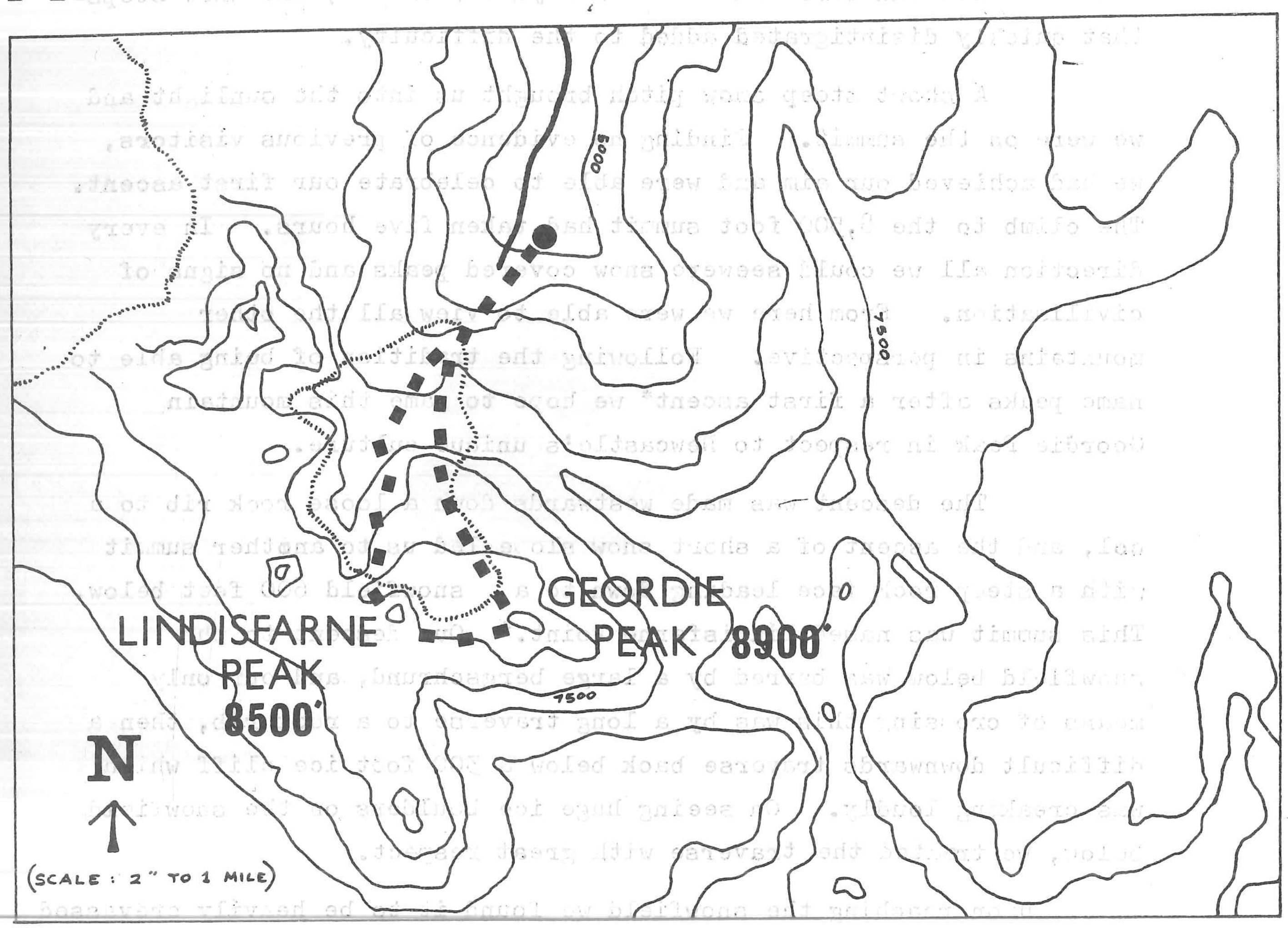
First Climbing Party

The first climbing party of Pete B., Pete R., Terry and Bob went south to explore the peaks above the headwaters of the Racing and Gataga Rivers. We set off with 50lb. packs for the confluence of two glacial streams, at 5,000 feet, where our climbing camp was to be established. The first four miles from the base camp proved to be relatively easy, following the flood plain of Racing River. Soon after the river entered a short gorge, where the crossing of a fast flowing and icy cold river was necessary. The warm, sunny weather increases snow melt - the river levels rise and consequently river crossings become much tougher propositions. While crossing the river Pete R. was swept over, as well as Pete B. on coming to give assistance. Amazingly, pith helmet and sunglasses remained in tact and we were washed onto a sandbank, only suffering from bruises and a good soaking.

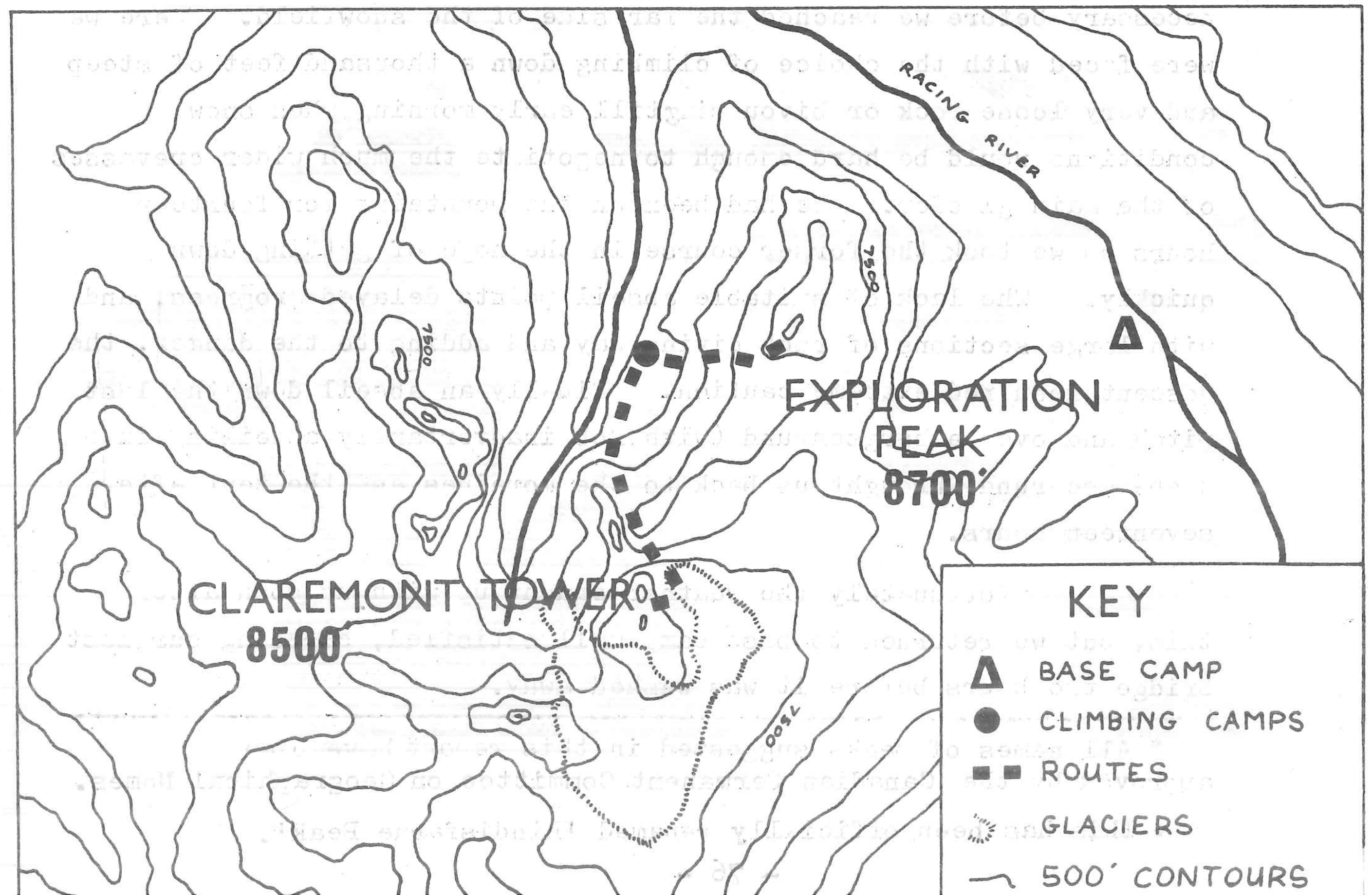
We followed the river up another thousand feet, having to battle through a dense, head high scrub birch, which often covered loose rocks and scree. Balance proved extremely difficult, and this terrain quickly sapped our energy and slowed the pace (a similar growth could occur in highland Britain if hill farming ceased - a daunting prospect for climbers and fell walkers.) Steep detours were often necessary to pass river gorges where the speed and the extent of the river made a passage impossible. On reaching the confluence of the two streams we were fortunate in finding a perfect flat campsite surrounded by giant erratics.

Geordie Peak and Lindisfarne Point - 2nd. August. To get the most favourable snow conditions on the ascent we started climbing at five a.m., making our way up lateral moraines and over snow bridges, till arriving at the base of a snowslope a half a mile long and dipping westwards 35 degrees on the first pitch. By the time we were half way up the slope the snow condition had had markedly deteriorated, each step being knee deep and a drain on our energy. The head of the snow slope led out on to the summit ridge at 7,000 feet, with a very large cornice. The ridge was followed south till two hundred feet below the summit where a traverse above a rock band was necessary. Although the exposure may have merited roping up,

FIRST ASCENTS: BY FIRST GROUP.



BY SECOND GROUP.



the soft snow and loose rock made belays impossible, and snow steps that quickly disintigrated added to the difficulty.

A short steep snow pitch brought us into the sunlight and we were on the summit. Finding no evidence of previous visitors, we had achieved our aim and were able to celebrate our first ascent. The climb to the 8,500 foot summit had taken five hours. In every direction all we could seewere snow covered peaks and no signs of civilisation. From here we were able to view all the other mountains in perspective. Following the tradition of being able to name peaks after a first ascent* we hope to name this mountain Geordie Peak in respect to Newcastle's unique culture.

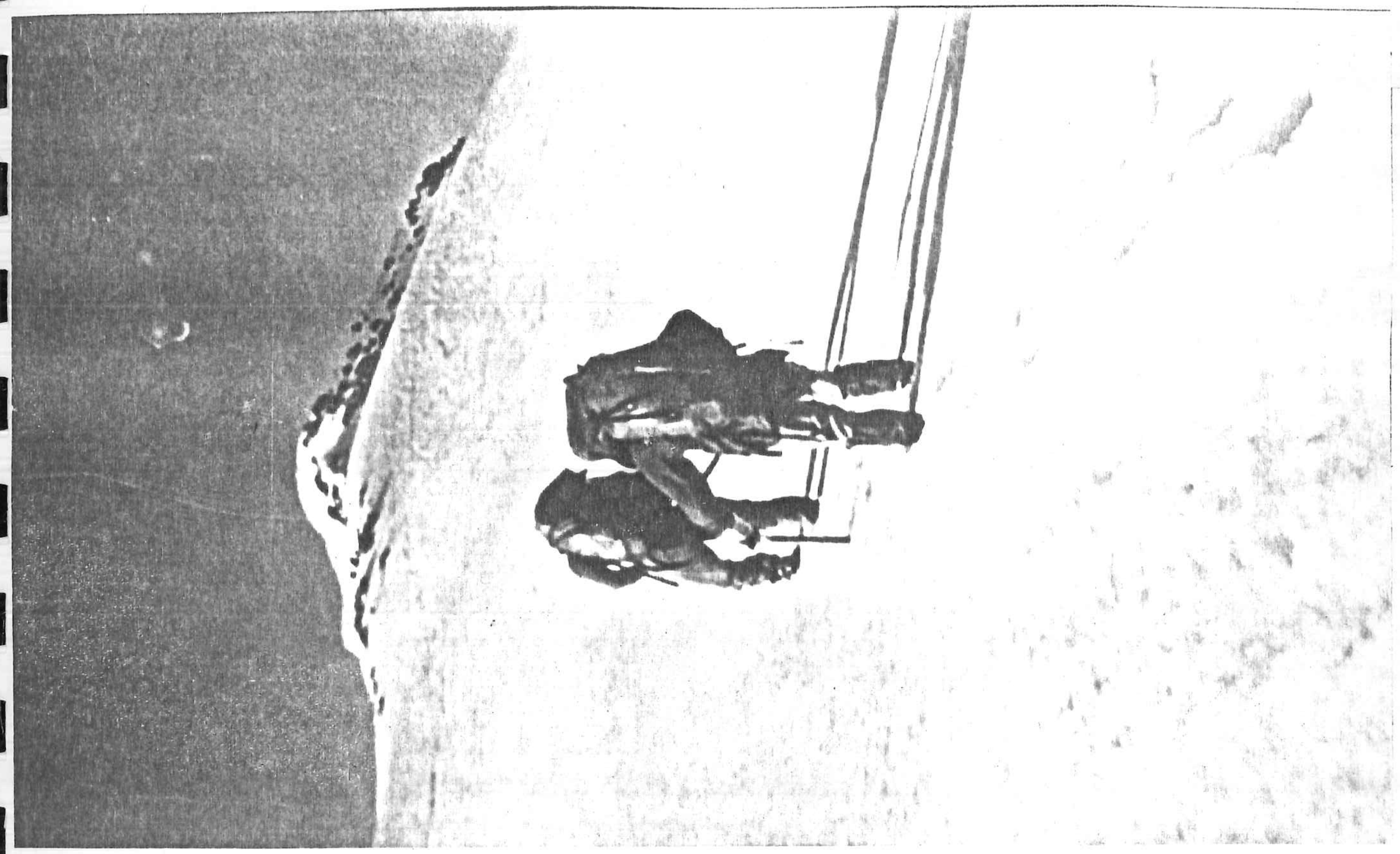
The descent was made westwards down a loose rock rib to a col, and the ascent of a short snow slope led us to another summit with a steep rock face leading down to a snowfield 600 feet below. This summit was named Lindisfarne Point.+ Our descent to the snowfield below was barred by a large bergschrund, and our only means of crossing this was by a long traverse to a rock rib, then a difficult downwards traverse back below a 300 foot ice cliff which was creaking loudly. On seeing huge ice boulders on the snowfield below, we treated the traverse with great respect.

Upon reaching the snowfield we found it to be heavily crevassed and due to the very soft snow, probing for crevasses with ice axes was not particularly effective. Three minor crevasse rescues were necessary before we reached the far side of the snowfield. Here we were faced with the choice of climbing down a thousand feet of steep and very loose rock or bivouacingtill early morning when snow conditions would be hard enough to negotiate the much wider crevasses of the main glacier. We had been on the mountains for fourteen hours so we took the former course in the hope of getting down quickly. The lack of suitable abseil points delayed progress, and with large sections of rock giving way and adding to the danger, the descent required extreme caution. Finally an abseil down the last pitch and over a bergschrund (with Bob inadvertantly abseiling into thebergschrund) brought us back to the moraines and the tent after seventeen hours.

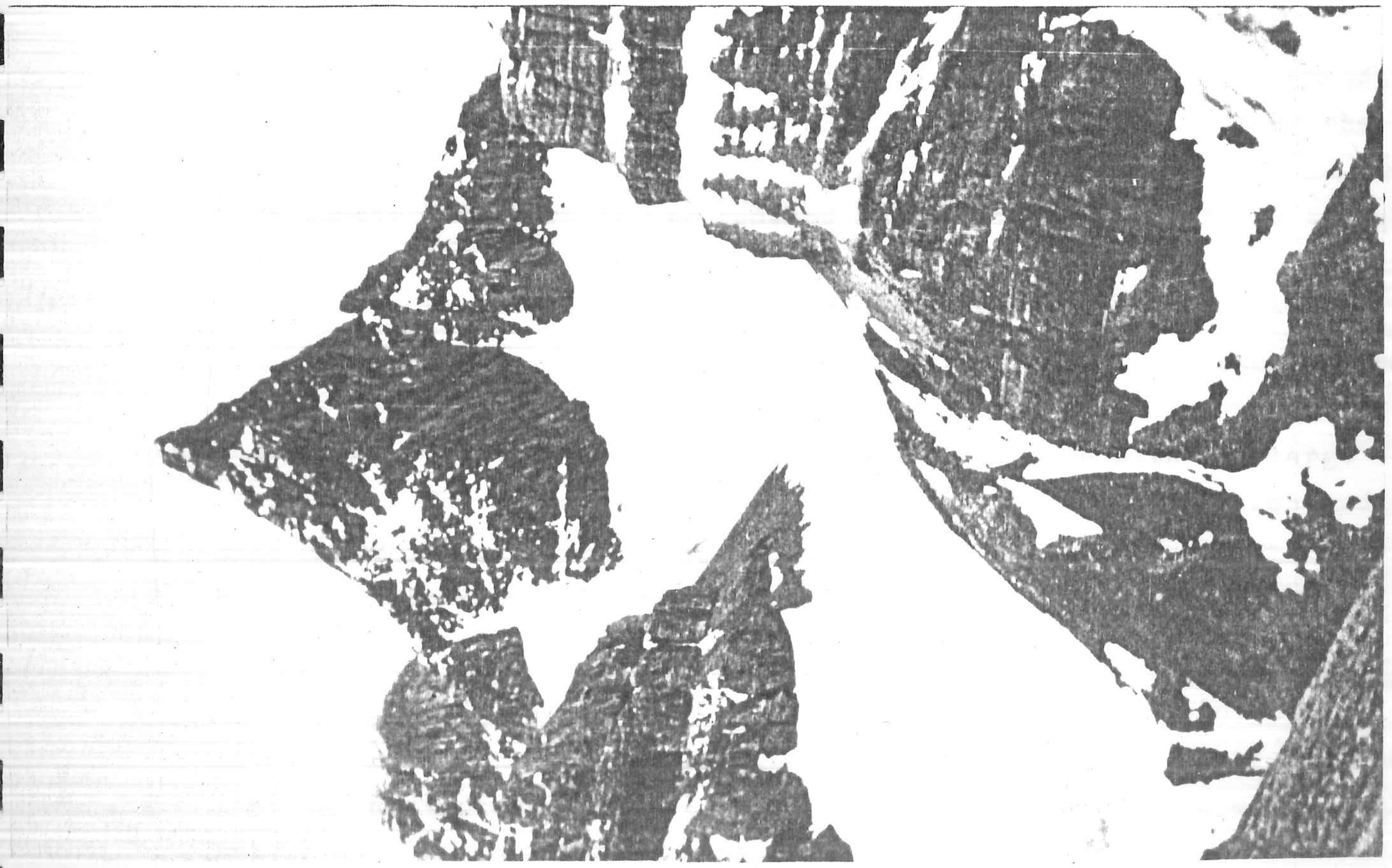
Unfortunately the weather caught up with us soon after this, but we returned to base camp well satisfied, crossing our last bridge two hours before it was washed away.

* All names of peaks suggested in this report have been approved by the Canadian Permanent Committee on Geographical Names.

\+ This has been officially renamed 'Lindisfarne Peak'.



Approaching the north east ridge of Geordie Peak.



North face of Claremont Tower.

Second Climbing Party

The second climbing trip took place during the last week of the Expedition, and it was decided to make an attempt on the group of mountains behind our base camp. This also saved time as the climbing started from half way down our walk out route. It was originally intended that Graham and Stella should join Pete B. and Terry on this trip, but a knee abcess ruled Stella out. She took this regrettable decision well and stayed at base camp to help Bob and Pete R. with their projects.

The route to the climbing camp from Racing River involved a tough walk along a steep river gorge with loose sides, and the game trail was quickly lost among the scrub birch. Despite this handicap, the walk was achieved quickly as everyone had reached a high degree of fitness. Our base camp was on the tree line at the base of a corrie, giving superb views of the surrounding peaks.

Exploration Peak - 10th. August. The next morning brought changeable weather but good enough for climbing. During a rushed breakfast the clouds began to clear and more stars became visible, so Pete B. and Graham decided to attempt the peak that also faced our base camp. Terry had remained at a lower camp after feeling ill and was to join the next day.

After following a steep grass slope, and a short scramble, the route kept to the steeper loose rock of the right hand ridge of the corrie to avoid the soft snow. The ridge led to the foot of the 300 foot summit tower, which was reached as the first light of day brought an ominous grey sky. A strong wind blew up (surprisingly, the only time on the expedition when the wind was particularly noticeable), visibility became worse and the intense cold made it necessary to wear all our spare clothing. A series of easy snow and scree gulleys up the tower led out onto the short, dramatic summit ridge with its large cornices. The ascent to the 8,700 foot summit had taken three and a half hours and the descent by the same route took two and a half hours. We decided to name this peak Exploration Peak.

On expeditions the best provisions tend to disappear very quickly and the Canadian Club whisky was no exception. An empty bottle was left on the summit with a message in it, and we are hoping that the next people that climb the peak will be presented with a full bottle as a consolation for not making the first ascent.

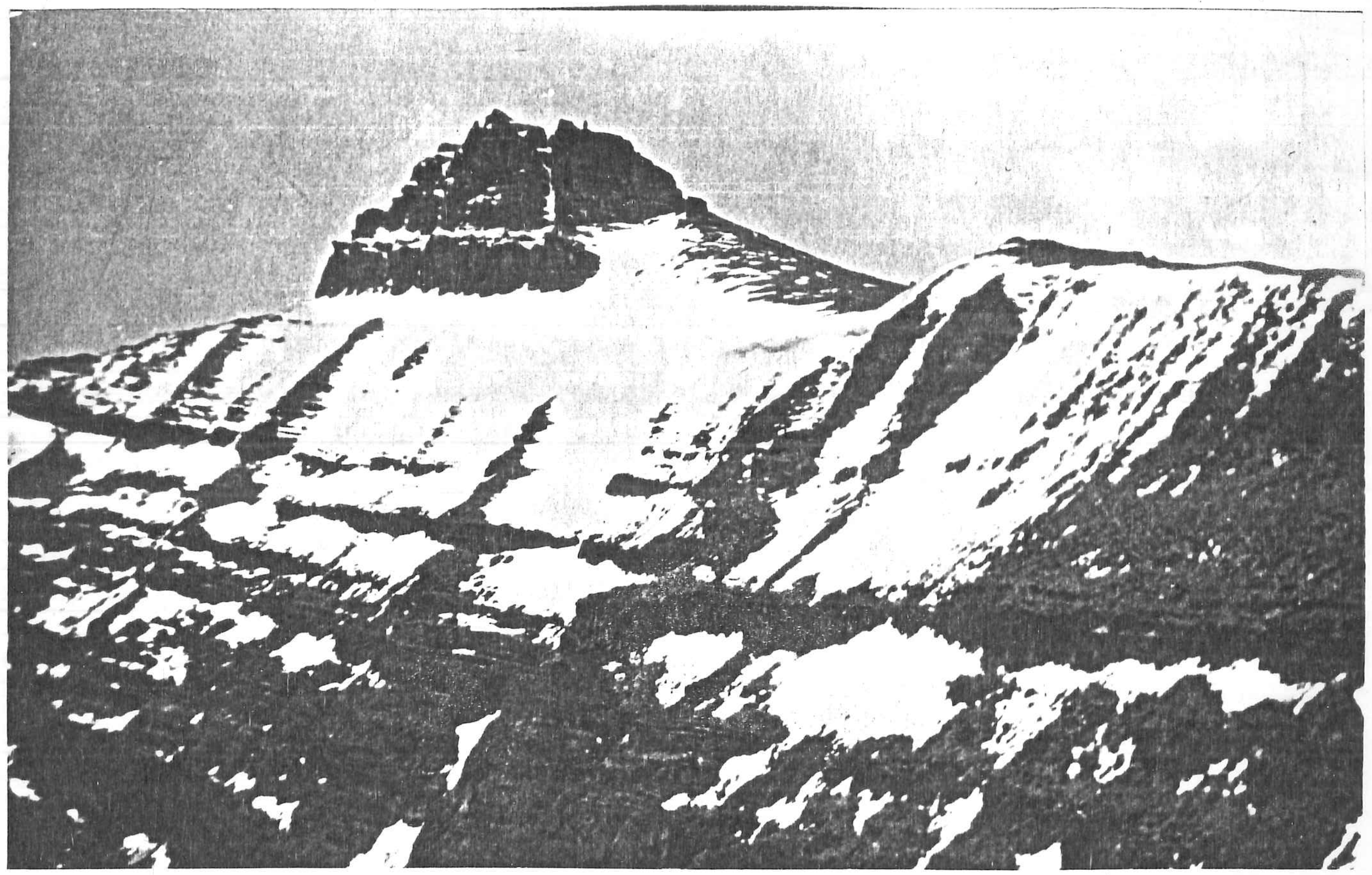
Claremont Tower - 12th. August. After a wet rest day and with Terry fully recovered, it was decided to attempt an extremely impressive rock tower, the higher of two towers with sheer rock walls rising 3,000 feet from the glacier below. The valley was followed upstream and the steep glacier snout avoided by going up a gently sloping couloir to the right of the glacier on to the snowfield and the snow col to the north east of the peak. The first 500 feet of the east ridge involved scrambling with short 'v. diff' patches on unstable rock. On reaching a difficult rock face it was decided to traverse left to join the main gulley whick appeared to offer an easier route. This was mostly 'v. diff' and sent down a constant stream of small stones. We were now at the col between the two towers with a 3,000 foot drop onto the glacier below. After securing a precarious belay here and pretending not to notice the drop, an exposed 150 foot 'mild severe' pitch with a slight overhang was ascended to a sharp summit, and Pete B's. loud yell of delight echoed down the gully.

Eight and a half hours of continuous climbing had brought its reward and a chance to view the surrounding peaks. A sheer snow and ice peak three miles to the west looked a worthy climb and appeared to have no easy line of ascent. What to call the peak was the next problem and after twenty minutes of sitting in the sun "Claremont Tower" was suggested - the namesake of that great seat of learning whose sheer brick walls rise up 150 feet above the Newcastle skyline. The descent from the 8,500 foot summit required five 150 foot abseils and took seven hours, arriving back at camp in time to see the last of the day's sun leaving the peaks.

Thus our objectives of ascending unclimbed peaks and collecting information on the mountains of the area were successfully achieved. Further ascents of Mount Churchill and Mount Roosevelt were not attempted due to lack of time resulting from adverse weather conditions and our preference for finding out more about the other mountains in the area.

However, the north face of Mount Roosevelt (probably a 14 hour 'severe') and the gully routes on the north face of Mount Churchill would make excellent routes. There exists a vast untapped climbing potential in this area and it was felt that a good balance was struck between the climbing and scientific work. The climbing added the elements of enthusiasm and personal achievement which sustained morale throughout the expedition.

The unstable rock and soft snow should not deter the keen climber and are well worth putting up with in return forthe solitude



Exploration Peak: the deep corrie wall was traversed along the west,(right hand),ridge to the summit tower.

Terry ascending the main gully of the east face of Claremont Tower.

and new challenges that these mountains present. Remote is the way that these mountains are likely to remain; when the mine closes, helicopter will be the only means of access and the proposed damming of the Liard River will isolate the area from the Alaska Highway. As the number of unclimbed peaks becomes fewer and fewer, these mountains will be climbed, but only to be re-visited by those who enjoy the hardships of this mountain wilderness.

P.G. Rogers

References for further information

1. American Alpine Club "Guide to Rocky Mountains - North" (Canada) 1st. Edition 1974, pp 264-265. (Obtainable from the American Alpine Club, 113, East 90th. Street, New York, N.Y. 10028)

2. Alpine Journal 1962 - Mount Stalin area. The Alpine Club, 74, South Audley Street, London W.1.

3. American Alpine Journal 1968 - Mount Roosevelt area (obtainable as in 1. above.)

4. Canadian Alpine Journal 1975 - Mount Churchill and Racing River area. Alpine Club of Canada, P.O. Box 1026, Banff, Alberta, Canada.

5. Tuchodi Lakes, 1:250,000 map, sheet 94K, National Topographic Series. Obtainable from Department of Lands, Forests and Water Resources, Surveys and Mapping Branch, Victoria, B.C., Canada, V8V 1X5.

6. Exploration Society Journal No. 10, 1974/75. Equipment report and account of this expedition. Obtainable from the Exploration Society, Daysh Building, The University, Newcastle-upon-Tyne, NE1 7RU.

and new challenges that these mountains present. Remote is the way that these mountains are likely to remain; when the mine closes, helicopter will be the only means of access and the proposed damming of the Liard River will isolate the area from the Alaska Highway. As the nümber of unclimbed peaks becomes fewer and fewer, these mountains will be climbed, but only to be re-visited by those who enjoy the hardships of this mountain wilderness.

P.G. Rogers

References for further information

1. American Alpine Club "Guide to Rocky Mountains - North" (Canada) 1st. Edition 1974, pp 264-265. (Obtainable from the American Alpine Club, 113, East 90th. Street, New York, N.Y. 10028)

2. Alpine Journal 1962 - Mount Stalin area. The Alpine Club, 74, South Audley Street, London W.1.

3. American Alpine Journal 1968 - Mount Roosevelt area (obtainable as in 1. above.)

4. Canadian Alpine Journal 1975 - Mount Churchill and Racing River area. Alpine Club of Canada, P.O. Box 1026, Banff, Alberta, Canada.

5. Tuchodi Lakes, 1:250,000 map, sheet 94K, National Topographic Series. Obtainable from Department of Lands, Forests and Water Resources, Surveys and Mapping Branch, Victoria, B.C., Canada, V8V 1X5.

6. Exploration Society Journal No. 10, 1974/75. Equipment report and account of this expedition. Obtainable from the Exploration Society, Daysh Building, The University, Newcastle-upon-Tyne, NE1 7RU.

EXPEDITION BUDGET

INCOME

	£
Personal Contributions	600.00
University Exploration Council	450.00*
The Drapers' Company	110.00
Ford of Britain Trust	100.00
Scott Polar Research Institute (Gino Watkins Memorial Fund)	50.00
World Expeditionary Association (WEXAS)	50.00
Raffle and Sale of donated Canadian Club whiskey	35.00
TOTAL INCOME	£1,395.00

EXPENDITURE

	£
Air flights to Canada	596.00
Travel in Canada and Great Britain	419.50**
Insurance	95.50
Food	160.00
Equipment	43.00
Organisation and Miscellaneous	46.00
Report	35.00
TOTAL EXPENDITURE	£1,395.00

Notes:-

* An additional £100 from the Exploration Council was returned after completion of the Expedition.

** For the information for anyone considering travelling in Canada it must be remembered that this item was kept to the absolute minimum by ingenuity and luck, and that two members stayed in British Columbia, thereby excluding them from the cost of returning to Toronto.

EXPEDITION ACKNOWLEDGEMENTS

The Expedition would like to express sincere thanks to the following organisations for their generous financial support:-

The Drapers' Company
Ford of Britain Trust
Scott Polar Research Institute (Gino Watkins Memorial Fund)
World Expeditionary Association
The University of Newcastle-upon-Tyne Exploration Council

We would also like to express our appreciaioon to the following organisations for their services to the Expedition:-

Consolidated Churchill Copper Corporation Ltd. - Transport and accommodation in British Columbia

I.C.B. Freight Services Ltd. - Freight operations in Great Britain and Canada

Manchester Liners - Shipping, Great Britain to Canada and return

In addition, we received help and hospitality from many individuals, too numerous to mention here (including some whose names we never discovered!) We thank them all for their varied contributions to the Expedition's success, and we would like to express our special thanks to the following:-

Mr. C.S. Brunt (Director, I.C.B. Freight Services Ltd.)
Mr. George Dvorak and staff of the Churchill Copper Corporation's Yedhe mines.
Mr. Fripp (Department of Surveying, The University)
Martin Griffiths (The Exploration Society)
Andy Kaiser (Toronto)
Mr. R.B. Mann (Lakehead Shipping Company, Thunder Bay)
Dr. Tom Swaddle (Calgary)
Mr. E.G. Tallman (B.C. Hydro and Power Authority, Vancouver)

Lastly, we would like to thank the following firms and organisations for the supply of goods, either free or at specially reduced rates, which made the Expedition possible:-

S. Behr and Matthew Ltd. - dehydrated egg
Bencard Ltd. - Juvel multivitamin tablets
Berger Paints Ltd. - assorted paints
Berghaus Ltd. - climbing equipment
Boots Company Ltd. - insect repellant, intestinal disinfectant, paracetamol, water steralising tablets

Bowater Containers Ltd. - cardboard boxes
British Columbia Lands Service - maps
British Steel Wool Co. Ltd. - steel wool, disinfectant
British Sugar Corporation Ltd. - sugar
Brooke Bond Oxo Ltd. - Fray Bentos corned beef, Oxo cubes
Bryant and May Ltd. - matches, lifeboat flamers
Copydex Ltd. - Copydex
Ever Ready Ltd. - torches and batteries
Field and Trek Ltd. - climbing equipment
General Foods Ltd. - Maxwell House coffee
George Romney Ltd. - Kendal mint cake
Glaxo Ltd. - Complan, Ostermilk
Hawkins and Timpson Ltd. - polypropylene rope
Hiram Walker & Sons Ltd. - Canadian Club whiskey
P.J. Hunter & Co. Ltd. - muesli cereal
Ilford Ltd. - black and white film
Mars Ltd. - Mars bars
Metal Box Co. Ltd. - assorted aluminium containers
Moss Brothers Ltd. - head gear
New Cheshire Salt Works Ltd. - salt
Pains Wessex Ltd. - flares
Prestige Ltd. - cooking utensils
Proctor and Gamble Ltd. - Daz and Fairy washing powders, soap
Quaker Ltd. (Sutherlands Food Div.) - assorted spreads
Rotunda Ltd. - adhesive tape
Ryvita CO. Ltd. - Ryvita
Schweppes Ltd. - Pepsi Cola
Scottish and Newcastle Breweries Ltd. - Newcastle Brown Ale
C. Shippams Ltd. - spreads
Spear and Jackson Ltd. - axes and saws
Springlow Ltd. - dehydrated foodstuffs
Tate and Lyle Ltd. - sugar, golden syrup
Thermos Ltd. - Thermos flasks
Tupperware Ltd. - plastic food containers
W.D. and H.O. Wills Ltd. - Embassy and Regal cigarettes
Whitworths Holdings Ltd. - seedless raisins

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

May 1975.