THE CAMBRIDGE EXPEDITION TO BRITISH COLUMBIA 1984

REPORT

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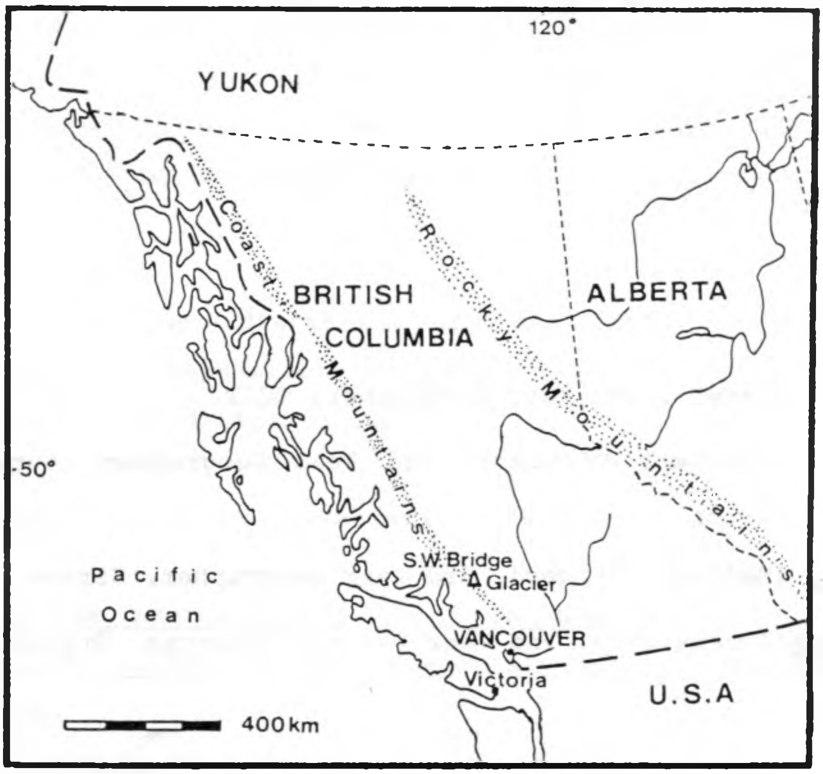
INTRODUCTION



MAP 1 - Location of the Expedition

LOCATION : South-West Bridge Glacier, Lillooet Ice-cap, British Columbia.

DURATION : 26th June - 23rd August 1984.

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REFEREES

The Lady Adrian, MA, PhD. Newnham College, Cambridge.

Sir Charles Evans, MA, BM (Oxon), Hon. DSc (Wales), FRCS Principal, UCNW, Bangor, Gwynedd.

MEMBERS

Peggy Allcott (Leader), 2nd Year Geographer, CCAT.

David Norris (Equipment Officer), 2nd Year Geographer, Luton College of Further Education.

Rosemary Riley (Medical Officer), 3rd Year Geographer, Girton College.

William Wilcock (Treasurer), 2nd Year Natural Sciences, Trinity College.

ADMINISTRATIVE AND LOGISTICAL REPORT

"We were not pioneers ourselves, but we journeyed over old trails that were new to us, and with hearts open. Who shall distinguish?"
J. Monroe Thorington (The Glittering Mountains of Canada).

The Cambridge Expedition to British Columbia grew out of an idea the leader had to go to Canada, a place she had visited in 1979 and longed to return to. At first armed with only the Continent as her destination, a vague aim of a glaciological project and a belief that there must be other people willing to launch themselves into the wilds, she set about reading, asking and listening to anything Canadian.

Her visits to Scott Polar Research Institute in Cambridge yielded valuable sources of information. A PhD student Neil McIntyre gave much assistance, and directed her to Denise Reed who had undertaken a glaciological project on an expedition in 1979 to British Columbia of which they were both members. Whilst deciding upon projects, Peggy began to hunt for other members. She was quickly joined by Helen Bird from Newnham College. They realised that if they were to visit a glacier, then mountaineers were needed. Notices were placed in the University Departments but few replied to the "two females seek mountaineers," advertisement. Eventually William Wilcock from Trinity College and his friend David Norris from Luton College of Further Education joined the two girls. William, a second year natural scientist was going to undertake a study of the moraines associated with the chosen glacier.

After much deliberation, discussion and our first expedition argument, the location for the expedition was decided as the Bridge Glacier, near the Lillooet ice-cap in British Columbia.

The area was believed to be suitable for the aims of the expedition, these were:

1. A study of the internal hydrology of the glacier.
2. The relative dating of Late Quaternary glacial moraines associated with the glacier.
3. Mountaineering in the vicinity of the glacier.

Sir Charles Evans and Lady Adrian were asked to be referees, and not only did they agree but they also provided many ideas and assistance with the initial planning.

The Coastal Mountains of British Columbia had been chosen because they were on the very doorstep of Vancouver. Despite the close proximity to the city, access to the Lillooet ice-cap is notoriously difficult. The first recorded expedition to the area was led by Walker was in 1932. Since then the area has been visited relatively infrequently, by a few scientists looking at the Geology, or the outflow from glacial streams, and mountaineers and skiers who love the challenge and appeal of this remote area.

Our initial plans to gain a foothold in the mountains were to travel along a logging track to the north of the Lillooet valley for twenty four kilometres to the furthest point to which a truck could travel. From here a helicopter would collect us and place the members at the proposed campsite near the tree line below the Bridge Glacier. We would spend four weeks at this location with no contact with the outside world. All our food and equipment had to be taken in with us. By December 1983 we had gained the approval of the Cambridge Expeditions Committee and our prospectus was printed.

Unfortunately in March 1984 we learned that the Bridge Glacier was not suitable for the study of its internal hydrology, a lake had developed at the snout, making it impossible to carry out the chosen technique of investigating its network of channels. The alternatives were to look at the Bridge Glacier's moraines and select another nearby glacier for the hydrology project or to choose a completely new glacier suitable for both projects. Faced with these two options, eventually it was decided to select a new glacier because of the time involved in travelling between two glaciers. We decided to make the final selection of a glacier in Canada after consultation with the Geography Department at the University of British Columbia.

In April we gained approval from the Royal Geographical Society, and several large donations arrived from charities, college funds and industries. Unfortunately, in May Helen Bird had to drop out of the Expedition. This was a sad loss and finding a replacement member was not easy. Eventually when our optimism had been stretched to its limit, Rosemary Riley, a third year Geographer from Girton College arrived on the doorstep of the leader. She asked if there was a place left on the Expedition, and after an explanation of what she was letting herself in for she was hastily despatched armed with a list of addresses to write to for sponsorship.

By June the Expedition had raised just over £3,700, and with the injection of personal contributions we had enough money to go. The flights were booked, William and Dave left first to meet our contacts in the University of British Columbia, arrange transport and contact the Canadian Salt Company. Peggy and Rosemary undertook the last minute preparations and packed all the donated goods. On the 3rd of July they left for Vancouver, the leader causing a stir at Heathrow as she carried the conductivity meter through the security checks as hand luggage.

Once in Canada our plans became more definite and we selected a small glacier to the south-west of the Bridge Glacier for the location of the

Expedition. The glacier was unvisited and unnamed, lacking imagination we called it the South-West Bridge Glacier. Our chosen campsite was at the confluence of three valleys, one of which contained the glacier we were studying. The area was sheltered, and even provided four convenient smooth boulders for seats. Day to day work involved Peggy and David carrying out saline injections and William and Rosemary surveying the glacier. William and David also undertook several mountaineering excursions, to the nearby ice-cap.

The four weeks flew by, in that time we had all grown a little thinner, were a lot fitter, and were all tanned, except one extremely red and sunburnt leader. The weather had been particularly kind with only three days when it rained during the four week stay. In fact upon our return to Pemberton we learnt that the Canadian Mounted Police were desperately trying to control forest fires throughout the district.

Considering the difficulties involved in working in the environment and our lack of experience in organising such ventures, the Expedition was a great success, and not just because we all returned. The time spent in the glacial wilderness was not always easy, but we all feel priviledged to have lived in such dramatic surroundings. The expedition provided us with a unique opportunity, and we are grateful to everyone who enabled the original idea to become reality.

Peggy Allcott

EXPEDITION DIARY

The two mountaineers, Will and Dave left Cambridge for Heathrow on the 26 June. Taking most of the money with them, their farewell call to the leader was 'we will send you a postcard from Rio!' Despite this threat they were eventually joined one week later (in Vancouver) by Peggy and Rosemary whose departures were delayed by exam commitments and graduation ceremonies. With no time to recover from jet lag the two girls were taken shopping for essentials, tents, skis and, the strongest mosquito repellant known to man!.

We were staying with students at the University of British Columbia and the Geography Department had loaned us their map room. The Geography students took the invasion in good heart and helped us to pack the food into day rations. Each box was sealed in plastic and labelled with the number of man/woman days of food.

The Expedition suffered a major setback as it proved extremely difficult to hire a truck to transport all our gear to the helicopter pick up point. The fact that we were taking it into the 'outback' and worse along logging tracks, not surprisingly increased the reluctance of the hire car operators. Eventually a van was obtained from 'Rent A Wreck', which it certainly resembled upon our return.

On Friday 6 July, everything was assembled for our departure. Dave and Peggy took the van to collect 180kg of salt, an essential ingredient in the hydrology project, which had been donated by the Canadian Salt Company. After being given the wrong address they eventually turned up at the correct warehouse and loaded the salt on board.

On their return the remainder of the equipment was loaded and with additional transport provided by Tony Webb, an ex Cambridge student, we set off for the wilds; right into the middle of the Friday afternoon rush hour. (Remember expeditions stand or fall by their good planning!).

Eventually we made it to the other side of town and drove out along Howe Sound and up into the ski resorts of Whistler and Squamish, finally arriving at Pemberton, a logging and farming centre. Here we stopped at 'Phils Drive In', (an old haunt for a previous Cambridge expedition), and had our last real food for four weeks. It qualified as real, but I am not so sure as to food.

At Pemberton we spoke to Eldon Talbot, the helicopter pilot, and arranged for him to collect us at 10am the next day from the pick up point, twenty five kilometres further up the logging track. After leaving the relative comforts of Pemberton the first kilometre of track was excruciating. One kilometre of being shaken, battered, bounced and deafened inside the van as the suspension worked overtime trying (unsuccessfully) to cope with the potholes was enough, we thought, but we still had to endure twenty four more. Finally, we arrived at the pick up point where we stored the equipment overnight in a disused 'A' frame building owned by British

Columbia Hydrological Survey. The old camp had a certain erieness about it and with fairly large paw marks visible in the dust, it was a relief that we did not have to camp here for the night, but instead turned off the logging track and camped at some hot springs. Thus we spent the last night if not in civilisation, then at least near it, wallowing in the hot spring water.

Next morning we cooked what was to become the standard expedition breakfast of tea and porridge. The leader, who detested the stuff, was later caught trying to encourage the local wildlife to develop a taste for it.

Soon the throb of an approaching helicopter was heard and a tiny orange dot appeared in the sky to the south. Eldon landed and gave us a lecture on 'How to approach a helicopter'; they have a nasty bite when cornered. Transportation of the team and equipment required three return flights. Will and Peggy left first with the tents and some food, just in case the weather prevented Eldon returning. The flight in took us up the Lillooet valley. Here the river was choked with glacial debris and below us the water flowed menacingly around huge boulders and gravel islands at high speed. As the Lillooet Glacier came in sight Eldon turned westward and flew along a side valley. At the head of the valley was 'our' glacier. Our first view showed that its lower reaches were still covered in snow.

Will and Peggy located a suitable base camp from the air, on an area of glacier moraine near a stream and the river. Eldon set his cargo on the ground and set off to collect more equipment and food. He returned with this slung under the helicopter in a large cargo net, the boxes of food wrapped in plastic and sealed in brightly coloured tape resembled something out of Santa's Grotto. Finally, the helicopter collected Rosemary and Dave. At last all was assembled. We paid Eldon for the flights in, and with much sadness watched him leave. He had said that if he was in the district he might 'drop in' to say hello, or bury the bodies!

The rest of the day was spent setting up camp. Will and Dave, in true pioneering spirit, went off into the nearby forest to cut down suitable trees, which were to form the poles for our stores tent. Eventually with the tents in position and all the food and equipment stored, we cooked the first of many 'interesting' meals.

As temperatures dropped we made our way to our tents and soon all of us were lost in various dreams. Well, all except Dave. In the morning he arose from the tent and informed us that he had remained awake the whole night. This was repeated the next morning as the insomniac stood forlornly over the boiling porridge, explaining that he had not 'slept a wink'. Our fears were allayed when Will informed us that Dave must be dreaming that he had not 'slept a wink', as Will had been disturbed from slumber by Dave's rather loud and persistent snoring.

The first visit to the glacier proved somewhat uninviting, as snow obscured much of the surface drainage, (as well as the crevasses) required for the hydrology project. It was necessary to postpone this project until the snow melted. The next few days were spent with Will and Dave doing some mountaineering, whilst Peggy and Rosemary began a study of the vegetation. Problems were again encountered here as little of the vegetation was in flower due to the lateness of the summer melt.

The weather proved hot and sunny and ominously on Friday 13th July it was decided that enough snow had melted to start on the hydrology project. Dave terkked forlongly up the glacier to the desired moulin, (a natural pipe draining water downwards through the glacier), carrying 3 kg of salt and a large bucket, (but no spade). At a predetermined time Dave threw the saline solution into the moulin and Peggy plus conductivity meter began taking readings at one of the outflow streams. A positive reading was obtained, proving that the chosen technique worked.

The following days were filled with moulin tests, surveying the glacier and anything else that resembled ice, and completing a study of the moraines. In the evening we would return to camp to cook. The clear dark skies proved the most spectacular sights to behold and made our remoteness seem even more acute. We could understand what it must have been like for the true pioneers who tamed such areas. Yet in the midst of these thoughts, the occasional satellite would drift across the darkened zenith, reminding us that these are the 20th century pioneers.

Life at camp became disrupted by the mysterious disappearance of our daily ration of peanuts. Blame was laid at the chipmunk's door, but eventually their innocence was proved when a mouse was discovered in the tent. Despite our valiant attempts to defend supplies, we had to admit defeat and retreat to an island in the middle of the river. Here we left the food boxes and covered them with tarpaulin held down by stones. This now meant that any meal was fraught with adventure, as to get the food involved crossing the river. To aid this process we had stepping stones but we could have done with Brunel's experience as some of these disappeared when the level of water was particularly high. Many a portion of milk powder met its fate in the icy water as someone lost their balance and fell in.

By the end of the second week, the mosquito bites had also become part of the routine. Peggy, Rosemary and Dave all suffered, despite the repellant, but Will did not. A mosquito was once observed to land on his leg, its proboscis went out, but instead of biting him, it immediately took to wing. Various scientific reasons were put forward for this reaction, but none were proven!

Eldon and helicopter paid us a social call on 21st July, and after having discovered that we were still in various stages of survival, he arranged to collect us some time near the 4th August, weather permitting.

Eventually in the last week the two projects were completed. Will and Dave left for a few days mountaineering on the 28th July, whilst Peggy and Rosemary extended the surveying to include the braid plain. They also undertook a 24 hour study of discharge from the glacier. This proved to be difficult as both had a nasty habit of sleeping through the alarm clock as it went off with monotonous regularity every hour. However the feat was completed with interesting results. Bleary eyed they emerged to discover that at 2am the braid plain was completely submerged and resembled a lake, luckily for them their tent was on the only dry piece of land.

On the 1st August Will and Dave arrived back, both sunburnt but jubilant having completed their aims. The last few days were spend consolidating our projects and making plans for the remaining fortnight before we returned to England. The plan was, if space allowed, the girls would fly out, if not they had to bushwack out with Will and Dave. It was about this time that the leader discovered that the only way to eat porridge was to bury it under piles of brown sugar, or drown it in golden syrup. (Can anyone recommend a good dentist?)

On the final night the competition for worst cooks of the year was held, when Will and Dave created a brew whose recipe must have originated from Macbeth. Those of nervous disposition please read no further. Its ingredients ranged from noodles and spaghetti sauce mix, to marmalade and curry powder.

We spent a lot of time clearing camp as we wished to leave the area unspoilt as this was the way in which it was found. On the 4th August, a familar hum was heard, Eldon arrived just in time to save us from the interminable breakfast of porridge. After several packing attempts the load was eventually fitted into the helicopter with some room for Peggy and Rosemary. We made our farewells to Will and Dave who after their bushwack out were heading for the Bugaboos and yet more mountains to climb. We were to head north into the Canadian Rockies.

Peggy Allcott

A STUDY OF THE INTERNAL HYDROLOGY OF THE SOUTH WEST BRIDGE GLACIER

The only accessable parts of a glacier drainage system are the supraglacial (surface) streams and the outflow streams. Connecting these streams is an englacial and subglacial drainage network, which by its very nature, proves difficult to investigate.

The aim of the project was to assess the internal hydrology of the glacier using a saline injection to trace the water through the ice. Saline solutions were injected into moulins (vertical shafts in the ice channelling surface water down into the glacier), at predetermined times. The outflow was monitored at the snout of the glacier, by means of a conductivity meter.

Theories of Glacier Hydrology

There are two principle sources of meltwater within a glacier:
a) Surface drainage (snow and ice melt, rainwater)
b) Basal and internal drainage (friction melting and geothermal heat)
Surface streams flowing across the ice often descend down moulins, water is then channelled to the base of the glacier.

Various theories have been put forward for the flow of water within a glacier. Weertman, 1972 believes that water flows at the base of the glacier in a thin sheet. Rothlisberger proposed that the flow of water is concentrated into channels cut into the ice. These are termed 'R' channels. Conversely, Nye believes that channels may exist cut down into the bedrock (Nye Channels). Nye suggests that there is a 3 dimensional network of streams within the ice, flowing into one central channel in a dendritic pattern.

If no channels existed under a glacier then water would flow in a thin sheet, as long as water pressure at an arbitary point on the bed is equal to ice overburden pressure.

When these slopes of surface and bed are comparable, the pressure gradient and therefore direction of flow will be determined by the surface slope. It will not always be possible for sheet flow to run parallel to the axis of the valley. Figure 1a shows a hyperthetical glacier with a surface slope in the 'X' direction, and a bed slope in the 'Y' direction. Water moves down and towards the centre of the valley under the pressure gradient (Figure 1b).

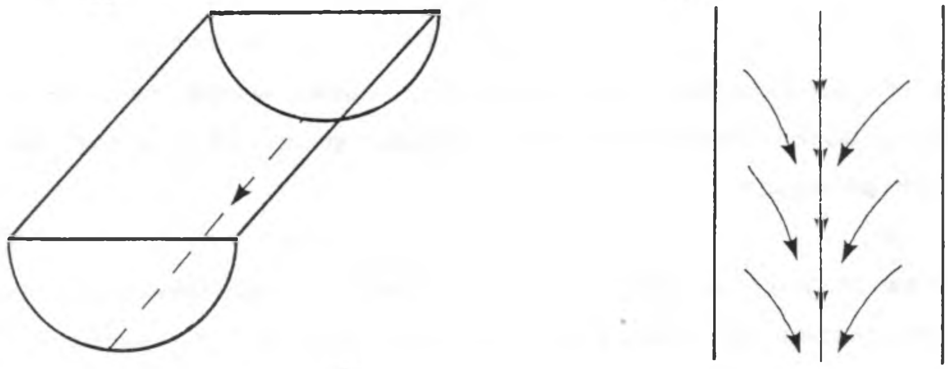
The upper ice surface will in general have a slope in the 'Y' direction. This tends to be concave in accumulation areas, and convex in ablation areas. Where the upper ice surface of a glacier is concave, water underneath and within the glacier is forced under hydrostatic pressure towards the centre of the valley. Conversely where the surface is convex water is forced to the sides of the glacier (see Figure 2). The South West Bridge Glacier shows strong convexity.

Stenborg (1968) suggested that the pattern of the internal drainage is closely related to the surface ice structure. There appears to be a relationship between the distribution of moulins and glacier crevasses. From Stenborg's observations of the Mikkarglaciaren, Norway he proposed a model for glacier internal hydrology.

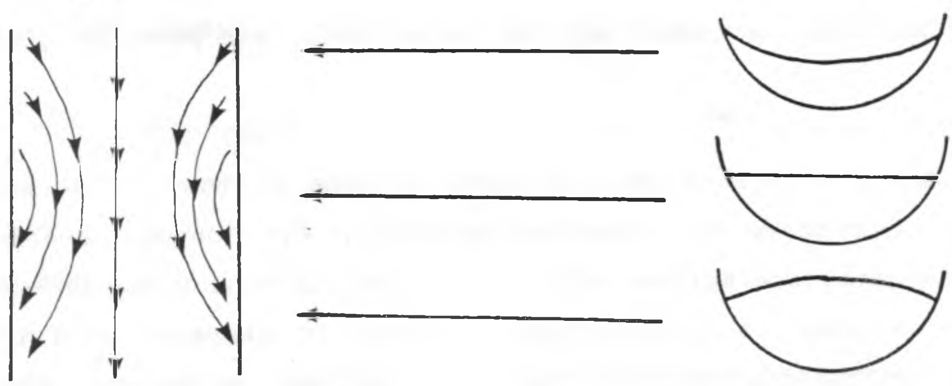
"This does not necessarily consist of the gathering together of different drainage channels towards one centrally situated bottom stream. It can, on the contrary, be supposed to occur as semi-lateral systems, which primarily follow oblique, lateral crevasses from the different points where the water leaves the glacier surface."

Figures 1 and 2

1a. 1b.



2.



Techniques

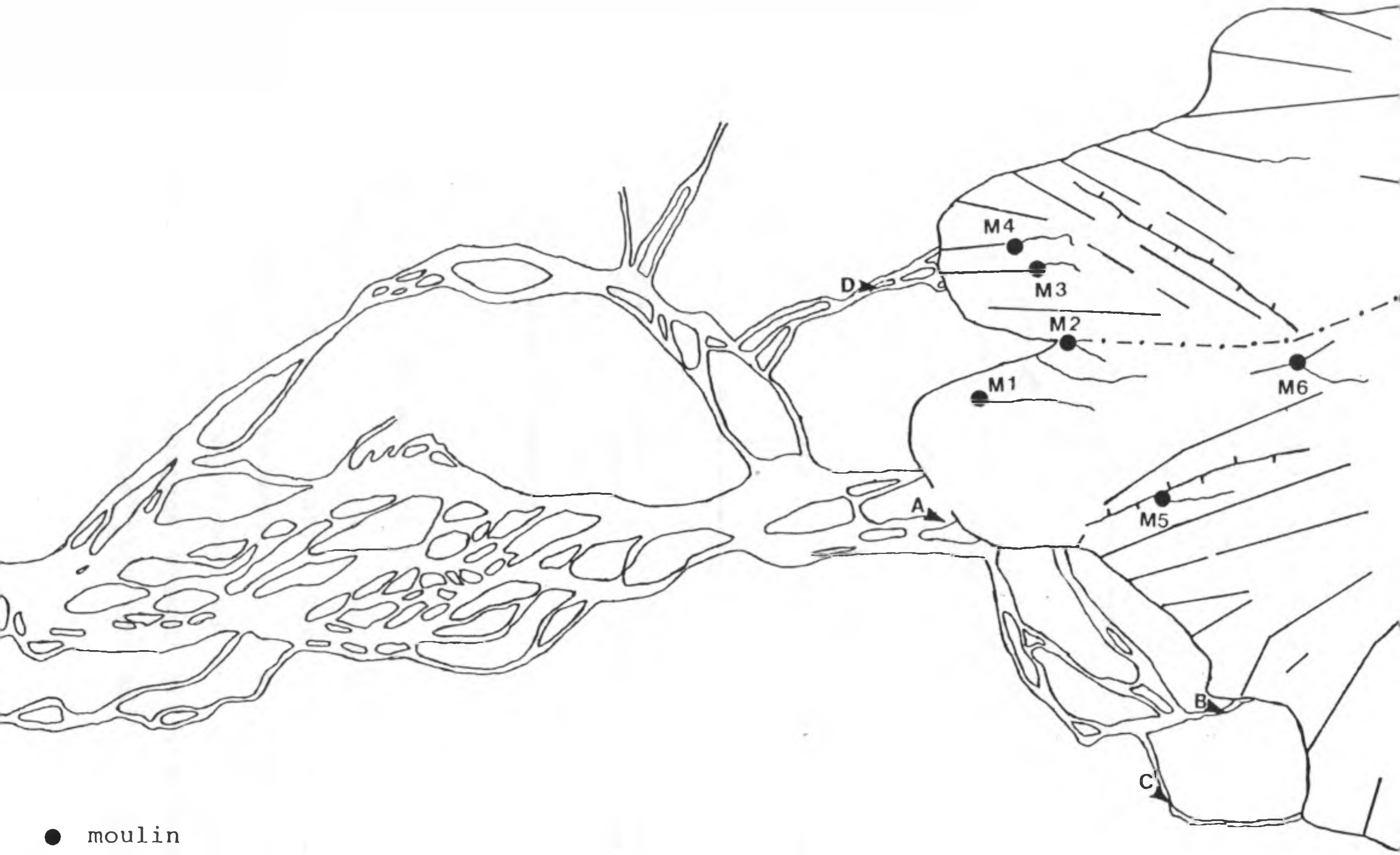
To measure conductivity a Kent Electronic Instruments Portable Conductivity Meter, Model 5003, with a dip type flow cell, was used. The meter had a conductivity range of 0.01-10^6 micromhos per cm and was powered by a long life dry cell battery.

Each saline injection was made from 3kg of salt dissolved in 10 litres of water taken from the surface stream draining into the moulin. There were frequently problems in dissolving the salt, as the water was less than 1°C. The saline was injected at a predetermined time, conductivity was recorded at 30 second intervals. The four monitoring points are marked A - D on Map 2. The length of time for the salt waves to reach the monitoring point is shown on Table 1.

TABLE 1 **Salt Injection Results**

Moulin	Onset of Wave (Mins)	Peak (Mins)	Depth of Moulin (metres)	Positive Reading Obtained	Nagative Reading Obtained
M 1	2.3	4.0	1.0	A	-
M 2	-	-	8.0	-	A.B.
M 3	9.3	13.0	2.0	D	A
M 4	15.0	27.0	3.0	D	A
M 5	18.0	21.0	2.0	A	D
M 6	5.3	7.3	5.0	A	D
M 7	13.0	21.0	6.0	A	D
M 8	13.3	18.0	5.0	A	D
M 9	19.0	22.0	7.5	A	D
M 10	-	-	3.0	-	A.B.C.D.
M 11	4.3	5.0	5.5	A	B.C.
M 12	4.0	8.3	7.5	A	B.C.
M 13	-	-	5.0	-	A.B.C.D.
M 14	6.0	7.3	3.2	B	A.C.
M 15	1.5	8.5	2.0	C	A.B.

Please note depth of moulin does not mean depth to bedrock, the moulins were measured until an obstruction or horizontal change in direction.



- ● moulin
- —— crevasse
- ice ridge
- surface stream
- —·— boundary line between N.E. & N.W. striking crevasses

Scale 1:2,500

X● Discharge measuring location

<u>MAP 2</u> SURFACE FEATURES OF THE SOUTH-WEST BRIDGE GLACIER

Discussion

Meteorological conditions were fairly constant throughout the study period, with only three days of rain. Thus most of the surface water originated from the melting of snow and ice. The surface drainage of the glacier was composed of rills and channels which eventually entered the internal drainage system via moulins and crevasses. The direction of drainage was controlled by surface slope. The ice ridges (marked on the map) drove the water away from their flanks. Streams were also guided by structures in the ice. Shear planes were particularly important in the central area of the glacier. Both the eastern and western margins of the glacier were heavily crevassed and water drained into these crevasses. In the snout area, a crevasse had opened up to divide the snout in two. Water on one side of the crevasse flowed into moulin 1 and water on the other side into moulin 2. The bedrock acted as a watershed, so water entering via the crevasse was then deflected by the bedrock configuration.

A 24 hour study of the discharge indicated that maximum discharge was at 21.00 hours, although maximum ablation was in the early afternoon. Elliston (1973) noted that the daily maximum becomes progressively earlier during the ablation season. The daily variations and longer variations over the course of the study must therefore be taken into consideration when studying the transit times of the salt solutions.

The South West Bridge Glacier is divided into two major systems based on the north-east and north-west striking crevasses. The boundary line is shown on the map. On the western side of this divide moulins drain into streams D and on the eastern side into streams A, B and C. Drainage on the western side will be dealt with first. Moulins 3 and 4 drain into channel D. They are situated below an area of heavy crevassing. Moulin 4 had a slower transit time than moulin 3. The difference cannot be explained by variations in the conditions with time, or different meteorological conditions, as they were measured on the same day. It is possible the variation in transit times is due to the position of the moulin for water supply, its characteristics, the drainage system and subglacial topography. The slow transit time for moulin 4 may indicate an intricate system of channels from the moulin to the exit, or the slow movement of water through a reservoir in the ice.

Moulin 1 is in the snout area, draining into channel A. During the second week the supply of surface water draining into the moulin became exhausted. The snout was mostly free of striations so little surface meltwater was channelled into it. Instead the water drained off the snout via sheet flow into channel A. The moulin did not fill up with water, so its course was obviously still clear.

Moulins 5 and 6 were situated in the snout area, moulin 5 was shallow (2m) and had a low volume of water draining into it. The saline solution took 18 minutes to reach the exit point A. The length of time might be related to sub-glacial topography. The ice ridge to the west of the moulin may force water to the sides. The transit time of nearby moulin 6 shows that these moulins have separate drainage courses.

Moulins 7, 8, 9 and 10 are situated on the western edge of the glacier below the upper icefield. Although near the western edge of the glacier they drain into channel A. Their location is between two major ice ridges which cause the area to resemble a small depression despite the overall convexity of the glacier's surface. It is for this reason that surface streams drain downslope and not out to the margins to be captured by crevasses. The transit times for moulins 7 and 8 suggest they may possibly join, they also show similar salt wave curves. Moulin 9 is higher up on the glacier and has a longer transit time. The salt curve here is less distinct than the previous two, with several 'peaks'. This may suggest the influence of a reservoir of water, which slows the saline solution down, releasing it intermittantly. No drainage connection for moulin 10 was discovered, which also suggests some local subglacial topographic feature.

The moulins of 11, 12a, 12b and 13 are located to the east of moulins 7, 8 and 9. Moulin 12b was found to receive much of its water from moulin 12a. This captured its water from streams draining the ice ridge to the west. The convexity of the glacier was also forcing water to the valley sides. The water from moulin 11 and 12a emerged in stream A. No connection was discovered from moulin 13. Below moulin 13 surface drainage was confused with a stream disappearing into the ice, around grain boundaries. This area formed a 'slush pool'. It may infact be capturing water from moulin 13 at depth and dissipating the saline solution. Moulin 14 drains into stream B and proves the existence of another drainage network to the one already operating on the western margin.

Moulin 15 is located near the glacier/snow margin and water drains into channel C. The volume of water at C is far greater than that entering the moulin 15, so considerable amounts must be added from snow melt. Some may also originate from water draining the valley sides, unfortunately it proved impossible to test any streams.

Conclusion

The results give little support to Nye's theory of one central drainage channel. Generally, the drainage appears to follow Stenborg's model of semilateral streams, and water emerges from the glacier as four separate streams. Water tended to be forced towards the ice margins, under the pressure of the convex ice profile. However, topographic anomolies also control the drainage, and for moulins 7, 8 and 9 the influence of the bedrock on the ice structure and drainage had a more important effect than the overall glacier convexity in determining drainage patterns.

Equipment

Kent Industrial Measurements Ltd, Portable Conductivity Measuring Set, Model 5003 with dip type flow cell. 180kgs of salt and plastic buckets.

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Peggy Allcott

A RELATIVE DATING OF THE LATE QUATERNARY GLACIAL DEPOSITS IN THE VICINITY OF SOUTH WEST BRIDGE GLACIER.

The 'Little Ice Age' advances of the last century were, in south-west British Columbia, generally the furthest ice advance of the Late Quaternary and hence evidence of earlier events is usually obliterated.

On reaching camp it was immediately apparent that the extensive areas of moraine were all relatively recent and fresh. The most prominent feature in the valley is a large U-shaped bank of moraine (see map 3) which reaches impressive heights of tens of metres at its North end. For the most part it is just under ten metres high and frequently splits into two parallel banks about 50m apart. On the valley floor it has been partially obliterated by fluvial action.

Methods

The techniques used in multiparameter relative dating required the selection of compact test sites where the moraine had remained undisturbed and above the water table since deposition.

Despite the large areas of glacial debris fluvial action on the valley floor and scree falls on the steep unstable valley sides severely limited the choice of suitable test sites. Using both aerial photographs and on site inspection 13 tests sites (20m x 20m) were chosen on topographic highs.

At each site 50 granitic boulders (> 50cm diameter) were used to collect information relating to a number of weathering and lichenometric parameters. The final choice of parameters was made in the field and was as follows:

1) Weathering - A weathered boulder is rough to touch and shows single grain mineral relief. For each boulder an estimate was made of the % of weathering of exposed surface.

2) Pitting - A pit is a depression produced by grain by grain disintegration. The prescence and depth of the largest pit was established.

3) Surface Oxidation - Oxidation produces a surface discolouration. The % of the exposed surface oxidised was recorded.

4) Rind - A weathering rind is a zone of darker weathered rock parallel and adjacent to the surface. Each boulder was split open (very tedious) and the prescence and thickness of the rind was noted.

5) Lichen - Quantitative dating using lichen sizes is a very controversial and difficult technique. Lichen taxonomy is notoriously difficult. No attempt was made to identify lichen for the purposes of relative dating it was only necessary to take measurements of size from a distinctive and ubiquitous lichen type. Two lichenometric measurements were taken:

i) The % of lichen cover.
ii) The maximum diameter of the chosen lichen type.

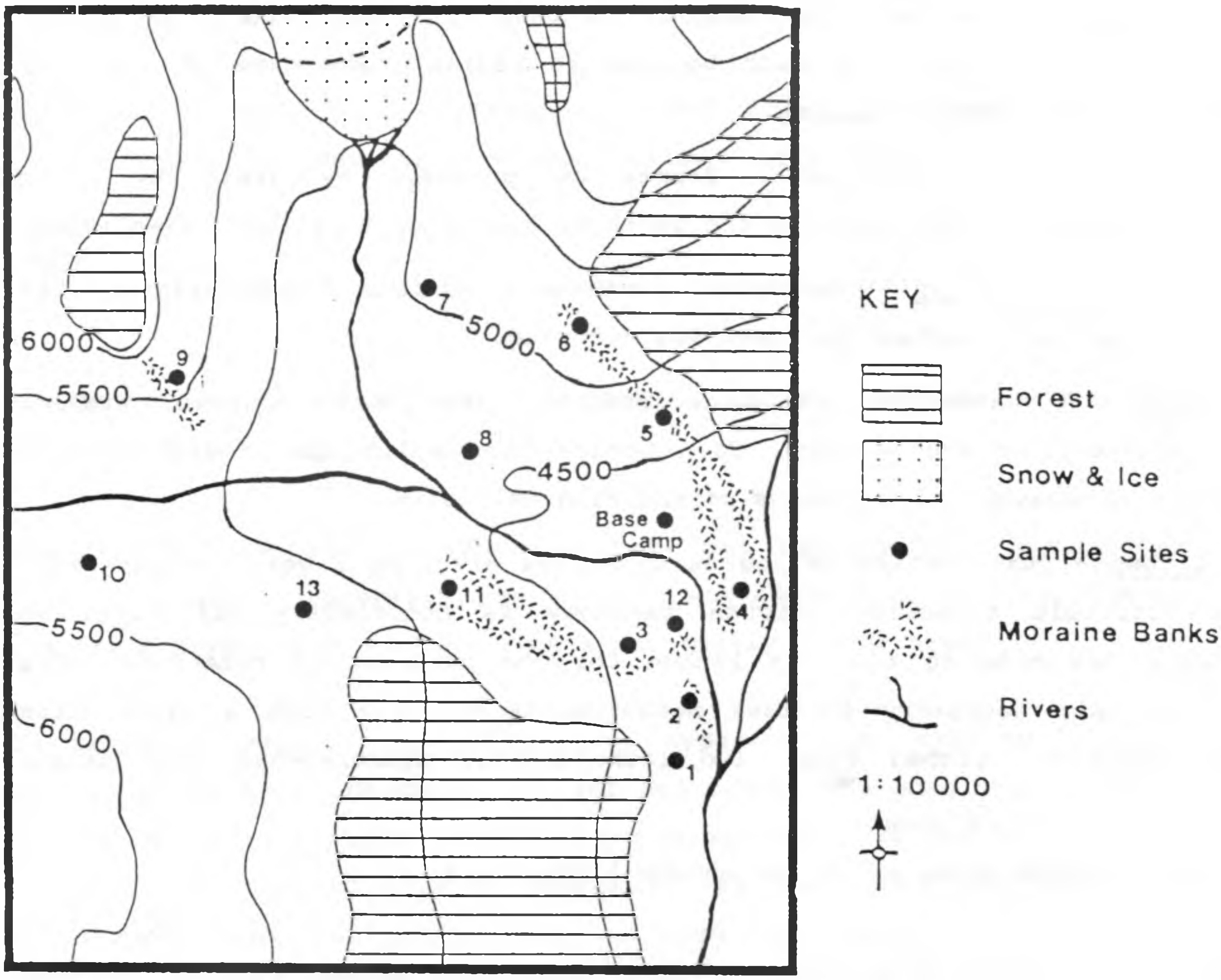
Previous studies have shown that independent field workers produce inconsistant results in terms of absolute values for the parameters. Thus all the data for this project was collected by one member of the expedition.

Results

The processed data is shown in Table 2 site numbers refer to the locations shown on the map 3.

Sites 11, 12 and 13 had insufficient granitic boulders to allow a full set of measurements to be taken within the site areas (20m x 20m).

MAP 3 Location of Sample Sites



Discussion

Inspection of the collated data and comparison with similar studies confirms that the glacial debris is indeed young. A precise comparision of absolute values would not be valid, but the values of pit depth, % surface oxidation and rind thickness are roughly an order of magnitude below the findings of East coast workers.

The weathering parameters show a remarkable consistency and no significant variation between sites. However, the lichenmetric parameters show a significant reduction in area of the moraine at sites above the bank (7-

	SITES	1	2	3	4	5	6
	>15% Weathered	48	44	44	50	42	46
WEATHERING	>50% Weathered	16	14	16	16	10	8
	mean % Weathered	23±4	20±3	20±3	22±3	21±4	18±3
	% of boulders pitted	42	48	40	50	52	46
PITTING	mean pit depth (mm)	5.±1.4	3.2±.8	4±1	4±1	3.9±.9	3.1±.8
	Deepest pit (mm)	20	15	19	15	16	13
SURFACE	% of boulders with oxidation	38	28	28	30	32	22
OXIDATION	mean oxidation	3.4±1.2	2.8±1.0	3.6±2.0	2.8±1.2	3.4±1.4	3.2±1.5
	% of boulders with rind	40	52	60	54	54	62
RIND	mean rind depth (mm)	.9±.3	.9±.2	1.2±0.4	.7±0.2	.9±0.3	1.2±0.3
	Greatest rind (mm)	3	3	3	2	3	3
	Largest lichen found	52	47	37	33	36	36
	mean maximum lichen size (mm)	32±3	31±2	27±4	21±2	23±3	26±2
LICHEN	mean % lichen cover	19±3	24±4	13±3	7±1	17±3	22±3
	% of boulders with 30% of exposed surface covered	28	34	28	0	32	26

Table 2

10) compared with those on and below it. They also suggest less convincingly a slightly older age for moraines below the bank (sites 1, 2).

There are two basic interpretations of these facts, which depend on ones faith in the technique.

The optimist would suggest that the lichenometric results show a significant reduction in the age of the moraine above the bank. This would imply that the bank marked a temporary reversal in the retreat of the ice mass. It could be interpreted that the lack of variation in the weathering data is due to the insensitivity of these parameters when applied to young moraines which are probably less than 200 years old. Weathering parameters are usually applied when ages vary by up to thousands of years.

The pessimist, (with whom I must admit to having some sympathy) would dismiss these arguements as simplistic, as no account was taken of the differences in location, aspect, altitude and proximity to the cold ice mass will all affect weathering and lichen growth in an unquantifiable way. Sites above the bank are at higher altiudes and are closer to the ice mass. The resulting cooler temperatures are likely to affect lichen growth more than weathering. It might also suggest that since sites were examined roughly in sequence up the valley that observed trends might be a result of trends in the workers estimating technique and not actually in the parameters. However, the most damaging criticism would undoubtably involve the time effectiveness of the project. Days of very tedious work are required to collect the multi parameter data and the results of this project and indeed many others only serve to 'confirm' simple time relationships that any competent physical geographer would very quickly regard as obvious or at least very likely.

William Wilcock

MOUNTAINEERING REPORT

The remoteness of the Lillooet Ice-cap, means that it is infrequently visited. Most activity is confined to May when access through the forests on skis is still possible and the weather is relatively good. By using air-drops, long visits become possible. All the peaks in the area have been ascended, but only by the route most convenient to skiiers. There has been very little pure mountaineering in the area.

A few days after reaching camp, we made what turned out to be a ridiculously optimistic attempt on Bridge Peak. The route to the north-west of base camp, consisted of a steep snow plod, followed by a long bumpy snow ridge. Initially our progress was quick but our lack of fitness and the deep wet snow on the ridge rapidly slowed our progress. Our enthusiasm was sapped by several false summits, and we finally settled for a lesser (unnamed) peak, about 1000 feet below and 2 kilometres from the main peak.

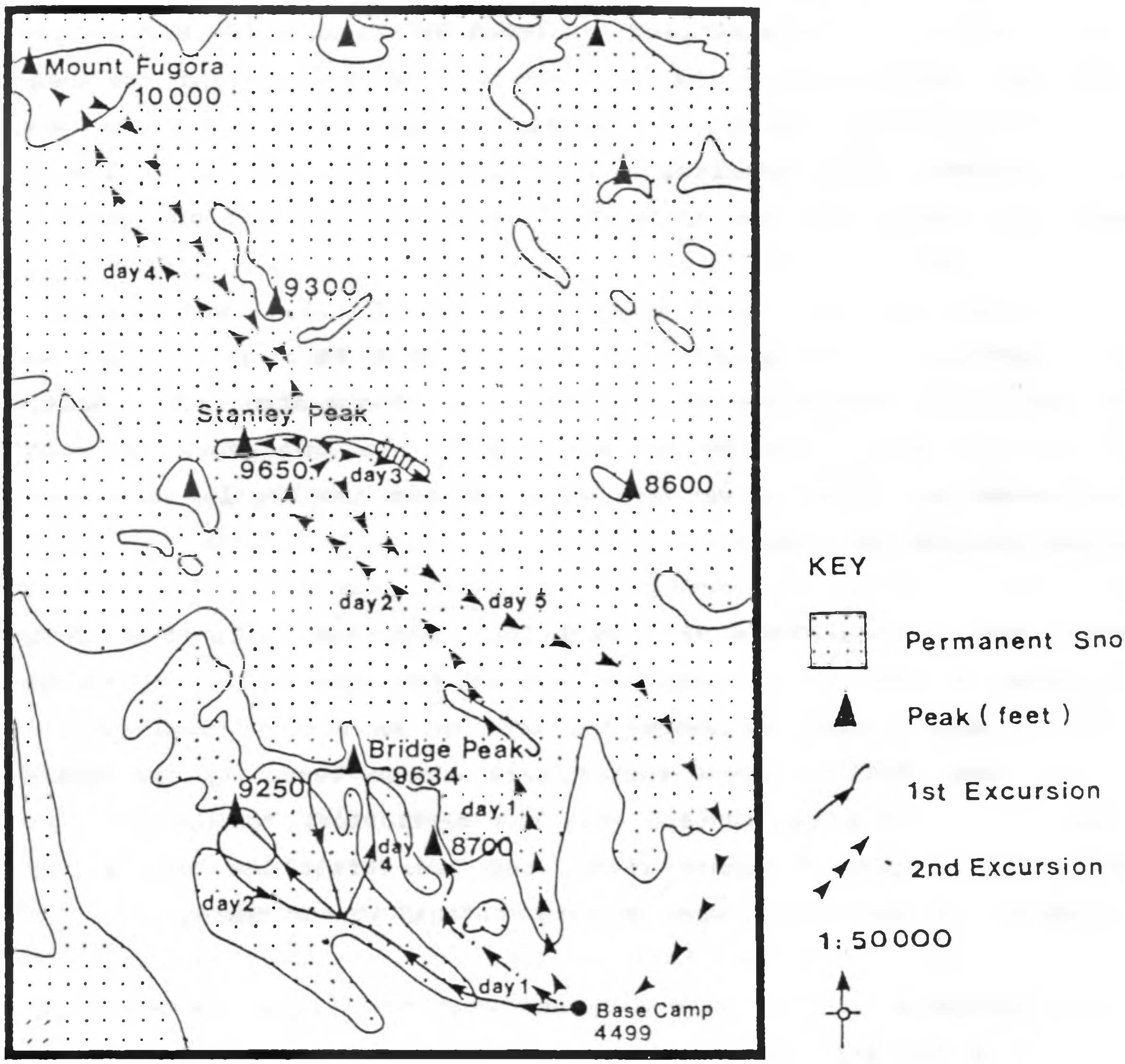
The first attempt was not wasted since it showed us that it was essential to either use skis on the less steep snow, or stick to rock. Even on the summits the nights were rarely cold enough to produce a strong crust which would last more than a few hours. Armed with this knowledge, and much improved levels of fitness, we were able to amke two highly successful excursions later in the expedition.

The first excursion (see map 4) lasted four days and followed a route up the valley to the west of camp. We climbed two spectacular, if rather loose alpine rock ridges, to reach the tops of an unnamed pead (9250') and Bridge Peak (9634'). These routes were almost certainly previously unclimbed. The loop around Bridge Peak was particularly enjoyable, with a very sharp and awkward summit ridge, and came after the only stormy day throughout the Expedition, when we were confined to our tents.

The second excursion was for five days and went north onto the main ice-cap. It took a two day trek on skis to reach the base of Stanley Peak. The impressive beauty of the seemingly endless, rolling white snow fields, broken by rock peaks and backed by vivid blue skies, filled us with a sense of freedom that will never be forgotten.

The third day was spent putting up two rock routes on the previously unclimbed granitic cliffs to the east of Stanley Peak. Here the climbing conditions were either very loose or excellent, and the situation was unbeatable. The next day we skied north to ascend a pleasant rock ridge up Mount Fugaro (10,000') before returning to the base of Stanley Peak. On the final day we ascended Stanley Peak in a swirling mist, and then skied down Bridge Glacier, hurrying back to camp as ominous cloud cover built up.

Map 4 Mountaineering Routes



Notes for climbers intending to visit the area

Anybody visiting the area would be well advised to take good skis (preferably Telemark) and to use skins. Our Nordic skis used with wax were only good for ascending gentle slopes. Descent with heavy rucksacks proved quite a challenge, as it was hard to keep control when crouched forward, with a rucksack over your head, obscuring the view.

A snow shovel is also recommended for digging in tents as this saves several hours when pitching camp.

William Wilcock & David Norris

MEDICAL REPORT

The medical kit was supplied by the Cambridge University Medical Scheme, Department of Community Medicine, at Fenners. The basic guide to the kit was the "Cambridge Expeditions Medical Handbook", which was excellent and extremely useful to such non-medical expeditionners as ourselves.

Unfortunately, the huge medical kit with which we were supplied, remained untested, as we all stayed remarkably healthy.

We would advise any expeditions to seek proper medical advice for the make-up of a kit.

FINANCES

	£
INCOME	
Miss P.C. Allen	50
Sir Baetle Frere Memorial Fund	100
W. Cadbury Charitable Trust	150
Cambridge University Explorers' & Travellers' Club	125
Consolidated Gold Fields	200
Cranfield Charitable Trust	25
Everest Double Glazing Ltd	200
Fields Ltd	5
Johnson & Bailey Ltd	25
Mr. & Mrs. J. Kirkpatrick	20
Dr. R.F. Mahler	30
Mary Euphrasia Mosley Fund	100
Mount Everest Foundation	400
Mrs. A. Mustoe	15

Podmore Fund (Trinity College)	600
Royal Geographical Society (The Augustine Courtauld Trust)	150
S.K.F. Travel Scholarship (Luton College)	50
St. Regis International	350
Sky Trust (C.C.A.T.)	100
Sale of Equipment	269
Personal Contributions	1300
Total	4293

EXPENDITURE

Air Travel	1794
Travel in Canada	233
Helicopter Hire	645
Food	519
Equipment	549
Insurance	243
Administration	210
Report	100
Total	4293

DONATIONS OF GOODS/LOAN OF EQUIPMENT

Batchelors Foods Ltd, (Dehydrated food, Cup-a-Soups, Vesta meals). The Cup-a-Soups were extremely useful especially after a cold day spent on the glacier. We used them as soups and also as sauces to flavour meals.

Canadian Salt Company (Salt for hydrology project). Although smaller bags of salt would have been preferable, the heavy duty plastic bags kept the salt dry for use over the four week period.

'In Touch' Ltd (Inflatiable splints). The splints were light and packed down, fortunately we suffered no broken limbs so they remained untested.

Jones Tent & Awning Ltd (Vancouver, Camping Equipment). A variety of items such as clothes and tents can be obtained here. The tents were light weight and good for back packing.

Kent Industrial Measurements Ltd, (Portable conductivity meter). The conductivity meter performed extremely well in very difficult conditions. The hard wood case gave extra protection which was vital when some measuring sites involved clambering across rocks.

Mountain Co-op (Vancouver). This is a useful shop for obtaining mountaineering and back packing equipment. Also advice on conditions within the Vancouver vicinity. The loan of skis by the Mountain Co-op greatly assisted the mountaineering programme.

Swiss Cutlery (London) Ltd. (Penknives). These proved invaluable and stood up to the continual use.

ACKNOWLEDGEMENTS

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We wish to thank the following, who through their help, encouragement and advise enabled the expedition to go ahead, Mrs. O. Baird, Dr. G.A. Chinner, Julian Dowdeswell, Professor J. Gittins, Dr. P. Hoare, Peter Jordan, Mrs. R. Chambers-Jones, Neil McIntrye, Denise Reed, Professor Olaf Slaymaker, Dr. R. Smith, Catherine Souch, Eldon Talbot, Tony Webb and Oleg Mokievsky-Zubok.

We are also grateful to all our sponsors, and to the following firms who donated money, goods and equipment to the expedition:
Batchelors Ltd, Canadian Salt Company, Everest Double Glazing Ltd (Mr. Bird), 'In Touch' Ltd, Jones Tent and Awning Ltd, Kent Industrial Measurements Ltd (Mr. M.C. Hall), Mountain Co-Op and Swiss Cutlery (London) Ltd.

Finally the expedition members sincerely thank their parents for support and encouragement.

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